1 INTRODUCTION

Shell Canada Limited (Shell) is applying to the Alberta Energy and Utilities Board (EUB) and Alberta Environment (AENV) for the expansion of an integrated oil sands mining and bitumen extraction operation near Fort McKay, Alberta. The proposed project, named the Jackpine Mine Expansion & Pierre River Mine Project ("the Project"), will include an amendment to the Shell Jackpine Mine – Phase 1 approval for an expansion on the east side of the Athabasca River and a new approval for development of the Pierre River Mine, located on the west side of the Athabasca River.

For the purposes of this report, the Jackpine Mine Expansion is referred to as the Jackpine Expansion Mining Area (JEMA) and the Pierre River Mine is referred to as the Pierre River Mining Area (PRMA).

The JEMA will increase bitumen production at Jackpine Mine – Phase 1 by 100,000 barrels per day to a nominal bitumen production capacity of 300,000 barrels per day. This expansion will include additional mining areas and associated processing facilities, utilities and infrastructure.

The PRMA will produce up to 200,000 barrels per day of bitumen and will include additional mining areas and associated processing facilities, utilities and infrastructure.

Environmental Setting Reports (ESRs) have been prepared in support of the Environmental Impact Assessment (EIA) for the Project to provide information on existing environmental and cultural conditions in the assessment study areas. The environmental setting field studies for the Project have focused on portions of Leases 88, 89, 15, 631 and 632 for the JEMA and Leases 9, 17, 309, 310, 351 and 352 for the PRMA. Neighbouring leases and swap areas were also included in the field studies.

The Aquatics ESR consists of five sections:

- Section 1 – Introduction.
- Section 2 – Surface Water Hydrology ESR.
- Section 3 – Surface Water Quality ESR.
- Section 4 – Aquatic Health ESR.
- Section 5 – Fish and Fish Habitat ESR.

The associated appendices for each section are provided in entirety at the end of the report.

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SURFACE WATER HYDROLOGY ENVIRONMENTAL SETTING FOR THE JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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2 HYDROLOGY

2.1 INTRODUCTION

This section of the Environmental Setting Report (ESR) presents the methods and results of an environmental setting study of surface water hydrology for the Jackpine Mine Expansion & Pierre River Mine Project. The purpose of this study is to characterize the surface water hydrologic conditions of the Project study areas, including the physical setting and climatic conditions that affect hydrology. Information collected from previous surface water hydrologic studies for the region and new data collected for this study are used to characterize the surface water hydrologic conditions required to conduct an Environmental Impact Assessment (EIA).

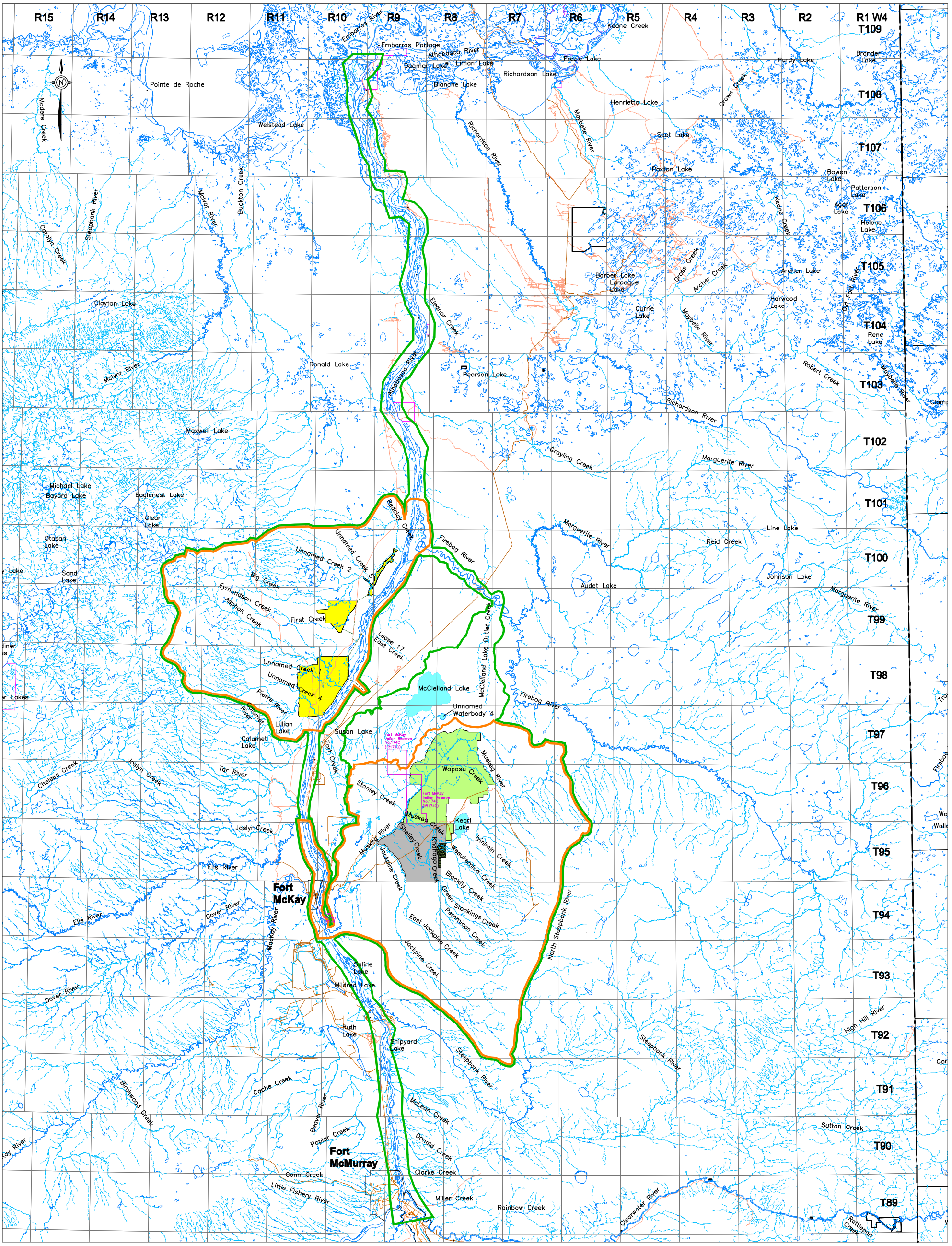
This ESR considers regional surface water hydrologic and climatic conditions for the region, as defined in the Regional Study Area (RSA) and the two Local Study Areas (LSAs) for the Jackpine Expansion Mining Area (JEMA) and the Pierre River Mining Area (PRMA), as shown in Figure 2.1-1.

Climatic variables analyzed for this ESR include air temperature, precipitation, evaporation and evapotranspiration, relative humidity, solar radiation and wind speed and direction. Sources of climatic data include historical records of the long-term monitoring stations operated by the Atmospheric Monitoring Division of Environment Canada, seasonal monitoring stations by Alberta Sustainable Resource Development (ASRD), and short-term stations by the Regional Aquatics Monitoring Program (RAMP) and oil sands mine operators, and environmental setting field work conducted for the Project.

Hydrologic variables analyzed include stream flows, basin water yields, suspended sediments in streams, basin sediment yields and stream geomorphology. Sources of hydrologic data include records of the long-term monitoring stations operated by the Water Survey Division of Environment Canada, short-term monitoring stations by RAMP and environmental setting field work conducted for the Project. Site-specific hydrologic data were acquired and analyzed in and around the Project.

Relevant annual, seasonal, monthly and daily statistics for the climatic and hydrologic variables were derived from the available data and modelling. Stream flow analysis considered flood and low flow events.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.1-1 Regional and Local Study Areas.dwg Nov 22, 2007 - 1:39pm



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

15 0 15
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

REGIONAL AND LOCAL STUDY AREAS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	RSA-LSA
DESIGN	CS	07/05/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.1-1	
CHECK	KM	17/08/07		
REVIEW	WES/TC	20/11/07		

2.1.1 Study Objectives

The surface water hydrology conditions in the Project development areas will be affected by Project activities, including muskeg drainage and overburden dewatering, mine-pit development, closed-circuit operation, stream diversion and reclamation activities. An assessment of the effects of the proposed Project activities on receiving watercourses and waterbodies and identification of mitigation measures requires a thorough understanding of the existing hydrology conditions.

The objectives of the surface water hydrologic study are to:

- identify major climatic and hydrologic variables;
- collect hydrologic and climatic data and information;
- calculate key statistical parameters for the major climatic and hydrologic variables by characterizing their spatial and temporal variations using regional and local data;
- describe and characterize the baseline climatic and hydrologic conditions for the RSA and LSAs; and
- present the results as a baseline for assessing future hydrologic changes that may be caused by the Project.

2.1.2 Study Areas

The RSA is the area selected for studying the environmental issues related to the cumulative effects of the Project and other regional developments. The Project is expected to have negligible effects beyond the RSA. The LSAs are the areas representing the spatial extent of surface water resources directly or indirectly affected by the Project. The RSA is the study area for addressing the incremental effects resulting from the Project. The RSA and LSA boundaries for the surface water hydrology, surface water quality and fish and fish habitat components are the same. Figure 2.1-1 shows the RSA and LSA boundaries and Figure 2.1-2 shows the LSAs at an enlarged scale. Specific watersheds included in the RSA and JEMA and PRMA LSAs are described in Sections 2.1.2.1, 2.1.2.2 and 2.1.2.3 respectively.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.1-2 PRM-JACKPINE MINE EXPANSION_Local Study Area.dwg Nov 22, 2007 - 2:22pm

R13 R12 R11 R10 R9 R8 R7 R6 W4

T101 T100 T99 T98 T97 T96 T95 T94 T93 T92 T91

Eaglenest Lake
Clear Lake
Redclay Creek
Marguerite River
Firebag River
Unnamed Creek 2
Unnamed Creek 5
Big Creek
Eymundson Creek
Asphalt Creek
First Creek
Audet Lake
Lease 17 East Creek
McClelland Lake Outlet Creek
Unnamed Creek 1
Unnamed Creek 4
Pierre River
McClelland Lake
Unnamed Waterbody 4
Columet River
Lillian Lake
Susan Lake
Calumet Lake
Fort Creek
Fort McKay Indian Reserve No.174C (IR174C)
Tar River
Joslyn Creek
Wapasu Creek
Muskeg River
Stanley Creek
Muskeg Creek
Kearl Lake
Shelley Creek
Khahago Creek
Iyinimin Creek
Wesukerrina Creek
Jackpine Creek
Ells River
Blackfly Creek
Green Stockings Creek
Pemmican Creek
Dover River
MacKay River
East Jackpine Creek
North Steepbank River
Fort McKay
Saline Lake
Mildred Lake
Ruth Lake
Shipyard Lake
Steepbank River

LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA

5 0 5
SCALE KM

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

LOCAL STUDY AREAS FOR THE JACKPINE EXPANSION AND PIERRE RIVER MINING AREAS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	JPMexp-PRM-LSA
DESIGN	CS	07/05/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07		
CHECK	KM	17/08/07		
REVIEW	WES/TC	20/11/07		

FIGURE: 2.1-2

2.1.2.1 Regional Study Area

As shown in Figure 2.1-1, the 357,820 ha RSA includes the JEMA and PRMA LSAs, which are described in Sections 2.1.2.2 and 2.1.2.3, respectively. The JEMA and PRMA LSAs include watersheds for watercourse and waterbody areas that may be affected by the Project. In addition, the RSA encompasses the following areas:

- Muskeg River watershed;
- McClelland Lake and McClelland Lake Outlet Creek watershed, and the downstream reach of the Firebag River below the confluence with the McClelland Lake Outlet Creek;
- Pierre River watershed, Eymundson Creek watershed, Big Creek watershed and Redclay Creek watershed; and
- the reach of the Athabasca River from Fort McMurray to Embarras Portage for the examination of potential upstream and downstream effects.

The northern limit of the RSA represents the downstream point beyond which potential changes resulting from oil sands development activities are expected to be negligible.

2.1.2.2 Local Study Area for the Jackpine Expansion Mining Area

The 104,862 ha JEMA LSA includes the Muskeg River watershed and a short reach of the Athabasca River to evaluate the changes to river flows because of potential water withdrawal for water supply. The watercourses and waterbodies that would be potentially affected directly and indirectly by the Jackpine Mine – Phase 1 and JEMA development activities include Muskeg, Jackpine, Shelley, Khahago (and tributaries) and Wesukemina creeks, Muskeg River and Kearl Lake.

2.1.2.3 Local Study Area for the Pierre River Mining Area

The 157,407 ha PRMA LSA includes a reach of the Athabasca River where potential flow changes due to water withdrawal for water supply will be evaluated, and watersheds of watercourses that may be affected directly or indirectly. These watercourses include Pierre River and Unnamed Creek 1, Asphalt, Eymundson, First and Big Creeks, Unnamed Creek 2, Unnamed Creek 5 and Redclay Creek.

2.2 METHODS

2.2.1 Previous Studies

Surface water hydrology ESRs for open pit oil sands projects from 1996 to 2007 were reviewed, including the Aurora Mine – Syncrude Canada Ltd. (BOVAR 1996), Jackpine Mine – Phase 1 – Shell Canada Ltd. (Golder 2002), Muskeg River Mine Expansion – Shell Canada Ltd. (AXYS 2005), Kearl Oil Sands Project– Imperial Oil Resources Ventures Limited (Imperial Oil). (Golder 2005), and Fort Hills – Petro-Canada Oil Sands Inc. (PC0S1) (Golder 2006).

The regional surface water hydrology presented in the recent environmental setting hydrology reports for the Muskeg River Mine Expansion EIA (Shell 2005), Suncor Voyageur Project EIA (Suncor 2005), Suncor's Voyageur South Project (Suncor 2007) and Kearl Oil Sands Project Mine Development EIA (Imperial Oil 2005) was updated for this study. The update was based mainly on recent data collected and collated by RAMP as part of the regional hydrologic monitoring program. The latest RAMP report (RAMP 2007) provides detailed information on the monitoring networks, including station locations, hydrologic data and available periods of record.

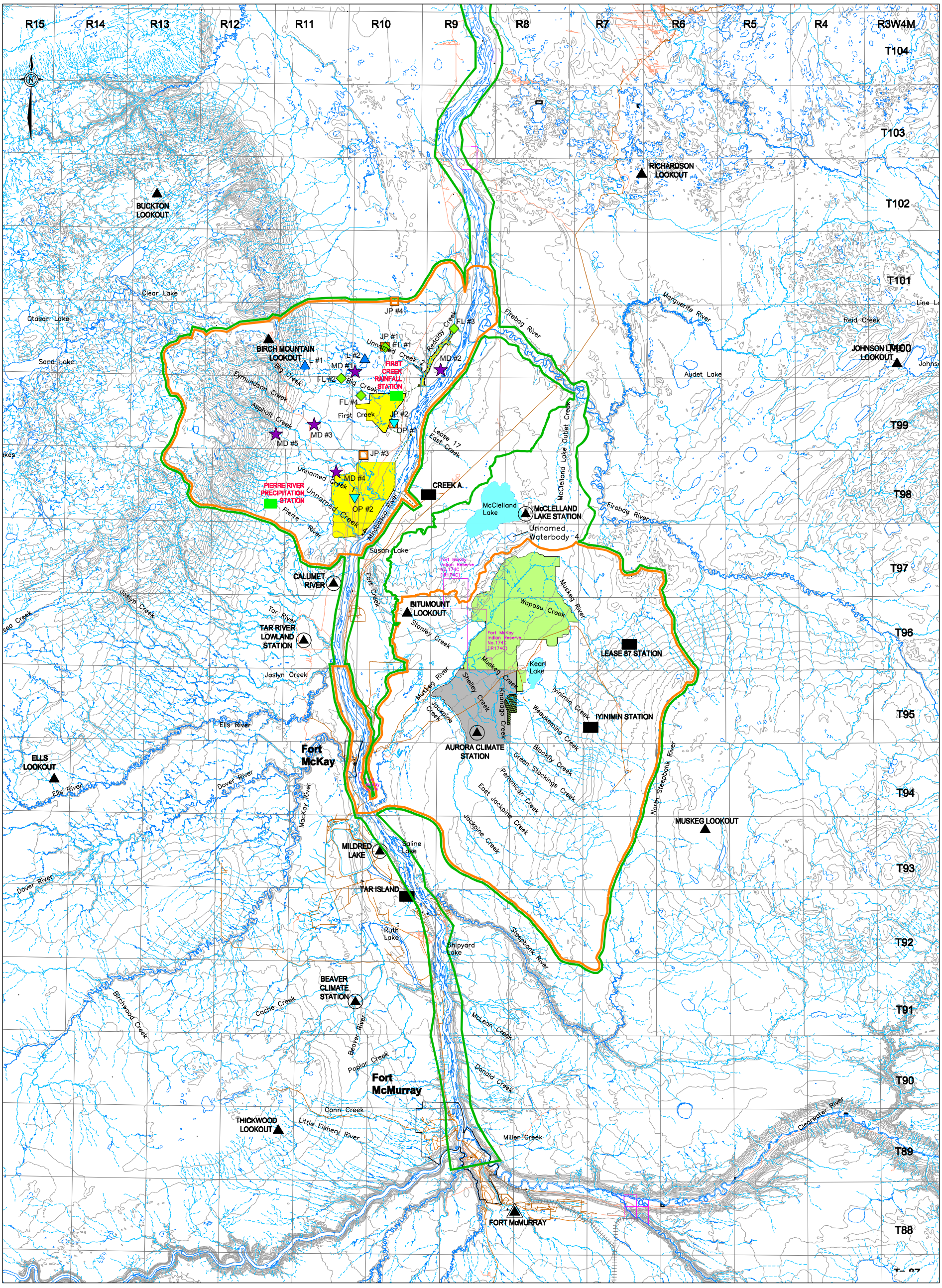
2.2.2 Climate

2.2.2.1 Data Sources

Substantial amounts of regional climatic data, with the majority obtained from RAMP (RAMP 2007), are available for the Oil Sands Region. As shown in Figure 2.2-1, the data were recorded at regional climate monitoring stations by:

- Atmospheric Monitoring Division of Environment Canada (year-round, long-term climate monitoring station) at Fort McMurray Airport;
- ASRD (regional network of seasonally operated climatic monitoring stations);
- the oil sands industry through RAMP; and
- Project monitoring stations.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.2-1 Locations of Regional and Local Climate Monitoring Stations.dwg Nov 22, 2007 - 3:00pm



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- OIL SANDS INDUSTRY YEAR-ROUND CLIMATE MONITORING STATION
- ALBERTA SUSTAINABLE RESOURCE DEVELOPMENT SEASONAL PRECIPITATION MONITORING STATION
- ENVIRONMENT CANADA ATMOSPHERIC MONITORING DIVISION YEAR-ROUND LONG-TERM PRECIPITATION MONITORING STATION
- LEASE SWAPPED TO SYNCRUDE
- OIL SANDS INDUSTRY SEASONAL PRECIPITATION MONITORING STATION
- PROJECT PRECIPITATION STATIONS
- MD #3 — MIXED DECIDUOUS SNOW COURSE SURVEY SITE
- L #1 — LAKE SNOW COURSE SURVEY SITE
- FL #4 — FLAT LOW LYING SNOW COURSE SURVEY SITE
- OP #1 — OPEN LAND SNOW COURSE SURVEY SITE
- JP #2 — JACKPINE SNOW COURSE SURVEY SITE

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

REGIONAL AND LOCAL CLIMATE MONITORING STATIONS AND PROJECT SNOW COURSE SURVEY SITES

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Reg-Snow Course
DESIGN	CS	11/05/06	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07		
CHECK	KM	15/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: 2.2-1

Data were collected from two local climate monitoring stations installed as part of the Project field program. As shown in Figure 2.2-1, data were recorded at Pierre River Precipitation Station and First Creek Rainfall Station. The period of record and elevations of the climate stations used in this study are listed in Table 2.2-1.

Table 2.2-1 Regional and Project Climate Stations

Station	Period of Record	Approximate Elevation [masl]
Fort McMurray[(a)]	1908 to 1944 year round	253
Fort McMurray Airport[(b)]	1944 to 2006 year round	369
Ells Lookout	1961 to 2006 seasonal	610
Birch Mountain Lookout	1960 to 2006 seasonal	853
Aurora climate station	1995 to 2006 year round	310
Calumet River climate station	2001 to 2006 year round	266
Stony Plain climate station	1953-1994 year round	766
Pierre River precipitation station	2005 to 2006 year round	338
First Creek rainfall station	2006 seasonal	250

(a) Although the station was established in 1908, air temperature data from 1908 to 1918 and precipitation data from 1908 to 1919 are poor in quality and were not used in this study.

(b) The Fort McMurray station was decommissioned at the end of 1944. A new station was opened in early 1944 at the Fort McMurray Airport Station.

Snow data were also collected as part of the Project field program. Snow course surveys, at locations shown in Figure 2.2-1, were conducted to measure snow depth, snow density and snow re-distribution in various terrain types in the PRMA. Sufficient snow data are available in the JEMA LSA from RAMP snow course studies conducted from 1997 to 2005 (RAMP 2006).

Environment Canada Monitoring Station

The Fort McMurray Airport station is the only existing Environment Canada climate monitoring station located close to the Project that has long-term continuous climate records. It was originally established in Fort McMurray in 1908 to record air temperature and precipitation and relocated to the Fort McMurray Airport in 1944. Wind speed and direction, dew point temperature and sunshine hours monitoring were added in later years.

The Stony Plain climate station is an Environment Canada climate monitoring station near Edmonton that was used to obtain solar radiation data to support evaporation and evapotranspiration analysis for the RSA. This is the closest station to the Project that has a long period of solar radiation data.

Alberta Sustainable Resource Development Monitoring Stations

The ASRD climate monitoring stations record summer rainfall and air temperature data. Stations used in the analysis include:

- Thickwood Lookout;
- Muskeg Lookout;
- Bitumount Lookout;
- Ells Lookout;
- Birch Mountain Lookout;
- Buckton Lookout;
- Richardson Lookout; and
- Johnson Lake Lookout.

As shown in Figure 2.2-1, many of these stations are located at high elevations. The ASRD data were only used to characterize the regional variation of rainfall as part of the Hydrological Simulation Program-Fortran (HSPF) model calibration (Golder 2003) and to confirm the presence of a rainshadow east of the Birch Mountains. A rainshadow is an area having relatively low precipitation due to the effect of a barrier, the Birch Mountains in this case, that causes the prevailing winds to lose their moisture before reaching the area.

Oil Sands Industry Monitoring

Oil sands industry monitoring includes monitoring that is conducted by RAMP and independently by oil sands mine developers.

Within and adjacent to the LSAs, the oil sands industry operates year-round climate monitoring stations: Aurora, Mildred Lake, McClelland Lake (year round beginning in 2006), Calumet River, Tar River Lowland, Beaver and Fort Hills Creek A stations. The oil sands industry also operates seasonal rainfall monitoring stations, including Lease 87, Iynimin and Tar Island stations, as shown in Figure 2.2-1.

Of these year-round climate monitoring stations, the Aurora climate station has data applicable to the JEMA LSA and the Calumet River climate station has data applicable to the PRMA LSA. The Aurora climate station, operating since 1995, is maintained by RAMP. Climate variables recorded at this station include air temperature, rainfall, snowfall, global solar radiation, relative humidity and wind speed and direction. The Calumet River climate station, operating since 2001, is also maintained by RAMP. Climate variables recorded at this station include air temperature and precipitation.

Project Monitoring Stations

The Project field program included one precipitation station and one rainfall station, as shown in Figure 2.2-1.

One precipitation station was installed in fall 2005 in the upland area of the Pierre River watershed at 450766E 6372422N (NAD 83) to monitor year-round precipitation. It was equipped with a data logger, a tipping bucket rain gauge and a snow gauge adaptor. The snow gauge adaptor was removed during the spring 2006 program, re-installed during the fall 2006 program and removed during the spring 2007 program. Data were downloaded from this station on a seasonal basis.

One rainfall station was installed on First Creek at 467137E 6386706N (NAD 83) during the spring 2006 field program for operation in the spring, summer and fall seasons only. This station was equipped with a data logger and a tipping bucket rain gauge. It was decommissioned in summer 2006 when the station was found to have been damaged beyond repair by animal activity. New equipment was installed and the station was reactivated in April 2007.

An overview of the local climate monitoring program activities and climate monitoring results is provided in Appendix A.

Rainfall and snow course survey data are available for the JEMA LSA from the RAMP program and these data were used to support HSPF model calibration (Golder 2003). For the PRMA LSA, snow course survey data were collected in winter 2007 as part of the Project field program.

Snow accumulation was surveyed for a variety of terrain types and vegetation variations, including open land and lake areas, mixed deciduous areas, flat low lying areas consisting mostly of shrubs and willows, and areas with heavy jackpine cover. For each of the four terrain types, a snow survey was performed at four sites (five sites for mixed deciduous areas), for a total of seventeen sites, as shown in Figure 2.2-1. The variables measured included snow depth, density

and water equivalent. An overview of the Project snow course survey and results is provided in Appendix A.

2.2.2.2 Methods of Analysis

Regional Data

Regional climatic conditions were characterized by analyzing historical data collected for the region. Spatial variations in climatic conditions were derived from regional data to:

- extend the short periods of local climate data; and
- extrapolate the applicable regional information to the LSAs.

Climate Variables

Climate variables that affect the surface water hydrologic characteristics were analyzed, including air temperature, precipitation, solar radiation, relative humidity, wind and evaporation and evapotranspiration. Annual, seasonal, monthly and daily statistics of the climate variables were derived to describe baseline climatic conditions. Stations, periods of record and statistical analysis conducted for each climate variable analyzed are shown in Table 2.2-2. Details of the methodology used for each climate variable are provided below.

Table 2.2-2 Climate Variables

Variable	Stations and Periods of Record	Analysis Completed
air temperature	• Fort McMurray Airport Climate Station (1944-2006); and • Fort McMurray Climate Station (1908-1944)[(a)].	daily, monthly and annual characteristics
precipitation	• Fort McMurray Airport Climate Station (1944-2006); and • Fort McMurray Climate Station (1908-1944) [(a)].	monthly and annual characteristics, Intensity-Duration-Frequency (IDF) curve
solar radiation	• Fort McMurray Airport Climate Station (1971-1996); • Aurora Climate Station (1995-2006); and • Stony Plain Climate Station (1953-1994).	daily and monthly characteristics
relative humidity	• Fort McMurray Airport Climate Station (1953-2006).	hourly, daily, monthly and annual characteristics
wind	• Fort McMurray Airport Climate Station (1959-2006).	speed characteristics
evaporation and evapotranspiration[(b)]	• Fort McMurray Airport Climate Station (1971-1996); • Aurora Climate Station (1995-2006); and • Stony Plain Climate Station (1953-1994).	monthly and annual characteristics

(a) Although the station was established in 1908, data from early years are poor in quality and were not used in this study.

(b) Stony Plain climate station solar radiation data (1953 to 1994), Aurora climate station solar radiation data (1995 to 2006) and recorded sunshine hours (1971 to 1996) from Fort McMurray Airport climate station were used to derive solar radiation for the RSA. This data were used in the Morton model to derive monthly evaporation and evapotranspiration values.

Air Temperature

Within the RSA, long-term air temperature records are available at the Fort McMurray climate station, operated from 1908 to 1944 and the Fort McMurray Airport climate station, in operation since 1944.

The air temperature record at the Fort McMurray Airport climate station is continuous. However, the record at the Fort McMurray climate station has a number of data gaps from 1908 to 1918. The differences between the recorded monthly air temperatures at the two stations in 1944 are usually less than 1°C. This slight variation allowed the records at the two stations to be combined, resulting in a continuous air temperature record for Fort McMurray from 1919 to 2006. This record was used to derive the daily and monthly air temperatures for the RSA.

Within the JEMA LSA, the Aurora climate station is the closest station having continuous records of air temperature. This station, in operation since 1995, is located east of Jackpine Creek (Figure 2.2-1). The recorded data at this station are short-term and cannot be used to obtain long-term temperature statistics representative of the conditions in the JEMA LSA. The air temperature records for a concurrent period at the two climate stations (Fort McMurray Airport and Aurora) were compared and found to be similar. Thus, the combined long-term air temperature data and statistics for Fort McMurray were adopted for the JEMA LSA.

Within the PRMA LSA, the Calumet River climate station (Figure 2.2-1), in operation since 2001, is located south of Pierre River and is the station closest to the PRMA LSA that has continuous records of air temperature. The recorded data at this station are short-term therefore they cannot be used to obtain long-term temperature statistics representative of the conditions in the PRMA LSA. The air temperature records for a concurrent period at the two climate stations (Fort McMurray Airport and Calumet River) were compared and found to be similar. Thus, the combined long-term air temperature data and statistics for Fort McMurray were adopted for the PRMA LSA.

Air Temperature Trend Analysis

The analysis of trends in air temperature in the Oil Sands Region specifically, as a result of climate change, climate variability, or both, was based on the long-term air temperature data recorded at the Fort McMurray Airport (1944 to 2006). This data were not combined with Fort McMurray Station air temperature data (1919 to 1944) to minimize errors in the trend analysis results. Air temperature trends were computed for eight statistical parameters at this station,

including monthly mean, seasonal (spring, summer, fall and winter), annual mean, annual maximum and annual minimum air temperatures.

Three methods of testing for trends in air temperature were applied to the recorded air temperature data from the Fort McMurray Airport climate station (1944 to 2006).

First, the air temperature series for eight statistical parameters were plotted to determine if either an increasing or decreasing trend was evident based on the slope of the best fit line for each time series. Secondly, both a parametric (Spearman) and a non-parametric (Mann-Kendall) test were conducted to identify trends. The Spearman and Mann-Kendall are tests that are commonly used for assessing trends in observed data. Finally, the annual and seasonal mean air temperature series were divided into two equal time periods (1944 to 1974 and 1975 to 2006). For each time series, a two-sample t-test was conducted to determine whether there is a difference between the means of the two samples. A two-sample F-test was conducted to determine whether there is a difference between the variances of the two samples.

Precipitation

Precipitation data are available at the Fort McMurray climate station from 1908 to 1944, and at the Fort McMurray Airport climate station from 1944 to 2006. The recorded data from 1908 and 1919 have many data gaps and were not used for analysis. The differences between the monthly precipitation values in 1944 at the two stations were small; therefore, the two records were combined into one continuous record (from 1920 to 2006) that was adopted for the RSA.

The mean and extreme monthly and annual precipitation for the RSA were calculated. The 10- and 100-year wet and dry monthly precipitation values were obtained by fitting theoretical probability distributions (including 3 Parameter Lognormal, Extreme Value and Log Pearson III) to the combined Fort McMurray data. The distribution was chosen based on the best fit to the data.

For the JEMA LSA, the continuous precipitation data at Fort McMurray (1920 to 2006) were adjusted for elevation to derive precipitation values for the JEMA LSA. The Fort McMurray precipitation values were multiplied by an adjustment coefficient derived from a regression equation between precipitation and elevation for the region (Golder 2003).

For the PRMA LSA, this approach was not applied because of the rainshadow effect of the Birch Mountains (Golder 2003). To account for this effect, the long-term precipitation data for the PRMA LSA were based on measured

snowfall data at Fort McMurray and elevation-adjusted Ells Lookout (610 masl) rainfall data. Elevation adjustment was also based on the method presented above.

Precipitation Trend Analysis

The analysis of trends in precipitation in the Oil Sands Region specifically, as a result of climate change, climate variability, or both, was based on precipitation recorded at the Fort McMurray Airport climate station (1944 to 2006). Precipitation trends were computed for three statistical parameters at this station, including monthly mean, seasonal and annual mean precipitation.

The three methods of testing for trends that were applied to the air temperature data (1944 to 2006) from Fort McMurray Airport climate station, as discussed above, were also applied to the recorded precipitation data from the Fort McMurray Airport climate station (1944 to 2006). For the t-test and F-test analysis the data were divided into two equal time periods (1944 to 1974 and 1975 to 2006).

Solar Radiation

Solar radiation is an important hydrologic variable that affects the rate of snowmelt. The amount of solar radiation depends on daily sunshine hours, length of daytime, latitude and solar angle. Solar radiation data for the region for the period of 1953 to 2006 were derived by combining and analyzing the following data sources:

- sunshine hour data recorded at Fort McMurray Airport climate station from 1971 to 1996;
- solar radiation data recorded at Aurora climate station from 1995 to 2006; and
- solar radiation data from Stony Plain climate station from 1953 to 1994.

A relationship to determine solar radiation for the Oil Sands Region was derived as follows:

- Daily solar radiation data at the Aurora climate station, recorded between 1995 and 1996 were used to derive the parameters of a regression equation to convert sunshine hour at the Fort McMurray Airport climate station to solar radiation. This relationship was used to estimate solar radiation at the Fort McMurray Airport climate station for the period of 1971 to 1996.

- A relationship between the solar radiation measurements at Stony Plain climate station from 1971 to 1996 and solar radiation derived for the Fort McMurray Airport climate station was developed. The solar radiation data at the Fort McMurray Airport climate station was then extrapolated to 1953 using the relationship.

The solar radiation recorded at the Aurora climate station was adopted directly for the period of 1996 to 2006. This process produced a record of solar radiation at the Fort McMurray Airport for 1953 to 2006 that is applicable to the RSA and the LSA.

Relative Humidity

Relative humidity statistics for the RSA, including hourly, daily and monthly statistics, were derived based on an empirical equation, from the long-term record of air temperatures and dew point temperatures at the Fort McMurray Airport climate station for the period of 1953 to 2006. The derived relative humidity statistics for the RSA were assumed to be applicable to the LSAs because relative humidity is expected to vary little spatially in the region.

Wind

The recorded hourly wind data at the Fort McMurray Airport climate station (1959 to 2006) and Aurora climate station (1995 to 2006) were analyzed for mean wind speeds and probabilities of occurrence. Fort McMurray long-term wind data were also analysed to determine the extreme hourly wind speeds for various return periods for each wind direction. Wind varies significantly due to local topography and the wind data and the derived wind statistics should be used with caution when applied to the LSAs.

Evaporation and Evapotranspiration

The Morton evaporation model (Morton et. al. 1985) was used to derive the potential and actual lake evaporation and evapotranspiration values for the RSA. The model requires recorded or derived monthly series of air temperature, relative humidity and solar radiation for Fort McMurray. These monthly series were obtained for the 1953 to 2006 time period based on the methods described above for climate variables. Derived monthly evaporation and evapotranspiration series were analyzed to determine monthly and annual statistics. Evaporation and evapotranspiration values for the RSA area assumed to be the same for the JEMA and PRMA LSAs because they are assumed to vary little spatially within the region.

2.2.2.3 Quality Assurance and Quality Control

Several Quality Assurance and Quality Control (QA and QC) procedures were implemented for:

- field data collection;
- historical data compilation; and
- data analysis.

Climate Field Data Collection Quality Assurance and Quality Control

The field data collection program collects site-specific information and is usually done seasonally over a short period. The field data collection QA and QC included:

- developing specific work instructions for field tasks, including testing climate monitoring instruments to verify proper calibration and functioning before field trip(s) started;
- installing climate monitoring stations according to generally accepted protocols;
- verifying continuous data logging after installation;
- regularly downloading recorded data to reduce the risk of complete data loss in case of instrument malfunction or damage to the monitoring station;
- checking for gross errors or missing data in recorded series at the end of each seasonal field program; and
- keeping detailed field notes documenting any outstanding differences in observations or possible reasoning for discrepancies in recorded data.

Historical Data Compilation Quality Assurance and Quality Control

Several government agencies and industry groups collect historical climate data that are very useful for characterizing the local and regional climate. Before analyzing historical data, a number of QA and QC procedures were followed, including:

- identification of missing data. For example, months with several days of missing data would be coded as “Missing Data” and would be removed from further analysis; and
- identification and verification of unusual deviations from, or abrupt changes in, average values or other statistical values.

Climate Data Analysis Quality Assurance and Quality Control

Historical and site-specific data were analyzed, described and summarized using statistical techniques. Each data series was checked to make sure it met the standard criteria for such analyses. The QA and QC included the following steps:

- data entry was checked and reviewed for errors;
- data transposed from distant locations to the Project RSA and LSAs were checked for similarities (such as precipitation patterns) and differences (such as precipitation variation with elevation);
- data series were tested for statistical homogeneity, trend and independence;
- the goodness-of-fit of theoretical probability distribution functions to the data series was tested using standard statistical methods;
- results were compared to results from previous work in the region; and
- results of analyses were reviewed by staff not involved in the analyses.

2.2.3 Hydrology

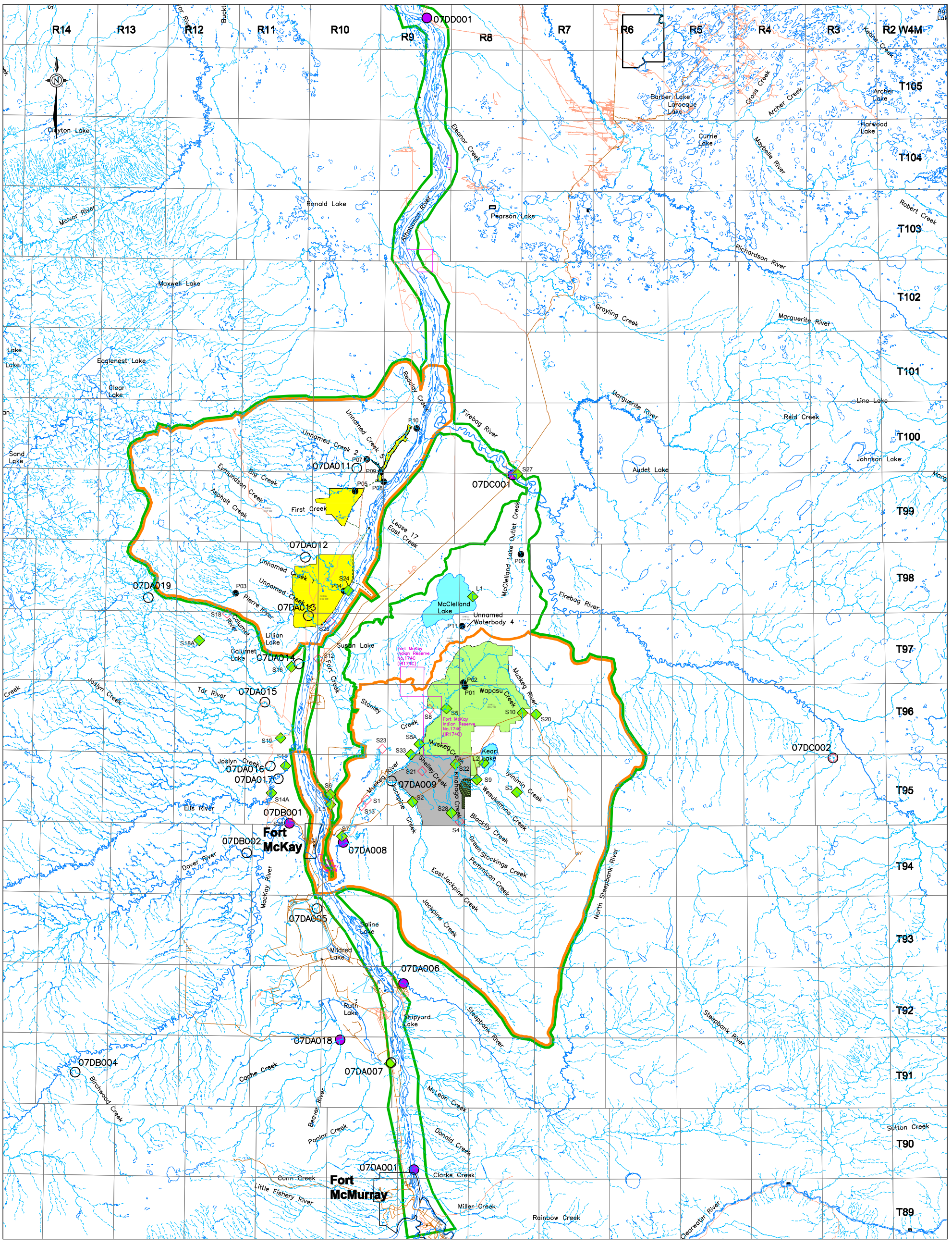
2.2.3.1 Data Sources

Environment Canada Water Survey Division Monitoring

The Water Survey Division of Environment Canada operates stations for the measurement of stream flow, water level and Total Suspended Solids (TSS) concentrations. Stream flow and water level (or lake level) are monitored at all hydrometric stations with sediment data only monitored at select stations.

There are more than 20 active or discontinued hydrometric stations in the Oil Sands Region (Figure 2.2-2). Relatively long data series are available for 14 Environment Canada stations (Table 2.2-3). The remaining stations have short-term or discontinuous periods of record and are of limited value in defining the regional hydrologic characteristics. A minimum of 10 years of hydrologic data is considered necessary for reliably characterizing hydrologic parameters.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.2-2 Regional and Local Hydrometric Stations.dwg Nov 22, 2007 - 3:24pm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07DA008
07DA009
07DA001
07DA018
07DC001
07DC002
Fort McKay
Fort McMurray
Athabasca River
Eleanor Creek
Pearson Lake
Ronald Lake
McIvor River
Clayton Lake
Maxwell Lake
Eagle Lake
Clear Lake
Sand Lake
Eymundson Creek
Big Creek
Asphalt Creek
First Creek
Unnamed Creek 2
Unnamed Creek 5
Unnamed Creek 1
Unnamed Creek 3
Pierre River
Calumet River
Lillian Lake
Calumet Lake
Susan Lake
Fort Creek
Tar River
Joslyn Creek
Stanley Creek
Muskeg River
Muskeg Creek
Shelley Creek
Jackpine Creek
Kearl Lake
Wapasu Creek
Fort McKay Indian Reserve No.174C (IR174C)
Unnamed Waterbody 4
McClelland Lake
McClelland Lake Outlet Creek
Firebag River
Lease 17 East Creek
Kinosayo Creek
Iyinimin Creek
Wesukamina Creek
Blackfly Creek
Green Stockings Creek
Pemmican Creek
East Jackpine Creek
Jackpine Creek
North Steepbank River
Steepbank River
Ells River
Dover River
Mackay River
Saline Lake
Mildred Lake
Ruth Lake
Shipyard Lake
Cache Creek
Beaver River
Poplar Creek
Birchwood Creek
McLean Creek
Donald Creek
Clarke Creek
Conn Creek
Little Fishery River
Miller Creek
Rainbow Creek
Clearwater River
Sutton Creek
Marguerite River
Grayling Creek
Audet Lake
Reid Creek
Line Lake
Johnson Lake
Harwood Lake
Archer Lake
Barber Lake
Laroque Lake
Currie Lake
Gross Creek
Archer Creek
Moybelle River
Robert Creek
Richardson River
Joslyn Creek
Tar River
Lake
Lake
Creek
Creek
Creek

Table 2.2-3 Regional Hydrometric Stations With Relatively Long Periods of Record

Station Number	Station Name	Station Location [a]		Period Of Record			Drainage Area [km^2]	Status
		Easting [m]	Northing [m]	Start Year	End Year	Years		
07DA005	Beaver River near Fort McKay	461630	6328696	1961	1975	10[b]	454	discontinued
07DB005	MacKay River above Dunkirk River	401334	6291802	1981	1991	11	1,010	discontinued
07DA017	Ells River near the mouth	456928	6347420	1975	1986	12	2,450	discontinued
07DA007	Poplar Creek near Fort McMurray	472009	6307895	1972	1986	15	151	discontinued
07DA011	Unnamed Creek near Fort McKay	468990	6391131	1975	1993	19	274	discontinued
07DA016	Joslyn Creek near Fort McKay	455278	6348149	1975	1993	19	257	discontinued
07DA009	Jackpine Creek (formerly Hartley Creek) near Fort McKay	471966	6346362	1974	1993	20	358	discontinued
07DA008	Muskeg River near Fort McKay	465670	6338865	1974	n/a	33[c]	1,432	active
07DA018	Beaver River above Syncrude	465624	6311004	1975	n/a	32[c]	165	active
07DA006	Steepbank River near Fort McMurray	474777	6318112	1972	n/a	35[c]	1,320	active
07DB001	MacKay River near Fort McKay	458120	6341037	1972	n/a	35[c]	5,570	active
07DC001	Firebag River near the mouth	487980	6389855	1970	n/a	37[c]	5,990	active
07DA001	Athabasca River below Fort McMurray	475558	6293030	1957	n/a	50[c]	133,000	active
07DD001	Athabasca River at Embarras Airport	477079	6451600	1971	1984	13	155,000	discontinued

[a] Station location shown in Universal Transverse Mercator (UTM) co-ordinates (datum NAD83).

[b] Missing period of record from 1967 to 1971.

[c] Number of years of record as of 2006.

n/a = Not applicable, station is still active.

Note: All stations listed are operated by Environment Canada.

Alberta Environment Monitoring

Concentrations of TSS in watercourses and waterbodies in the Oil Sands Region are monitored by Alberta Environment. Monitoring locations include Muskeg River, Muskeg Creek, Kearl Lake, MacKay River, Ells River, Jackpine Creek, Wapasu Creek and Athabasca River. Alberta Environment's historical TSS data are stored in its Water Data System.

Regional Aquatics Monitoring Program

The RAMP has been monitoring stream flow, water level and sediment data in the Oil Sands Region since 1997. The locations of the RAMP hydrometric stations are indicated in Figure 2.2-2, and the RAMP stations in the RSA are listed in Table 2.2-4. Some of these local, short-term hydrometric stations were active as early as 1995, before RAMP was initiated.

Table 2.2-4 Regional Aquatics Monitoring Program Hydrometric Stations in the Regional Study Area

No.	Name	Station Location[a]		Operating Season	Variables Measured
		Easting [m]	Northing [m]		
L1	McClelland Lake	483430	6371950	all year	water level, discharge
L2	Kearl Lake	484935	6349023	all year	water level
S2	Jackpine Creek at Canterra Road	475132	6343680	open-water	water level, discharge
S3	Iyinimin Creek above Kearl Lake	489491	6345029	open-water	water level, discharge
S5	Muskeg River above Stanley Creek	479820	6356551	all year	water level, discharge
S5A	Muskeg River above Muskeg Creek	476100	6351600	all year	water level, discharge
S6	Mills Creek at Highway 63	463829	6344743	all year	water level, discharge
S7	Muskeg River near Fort McKay[b]	465408	6338944	winter	water level, discharge
S8	Stanley Creek near the mouth[c]	477500	6356450	open-water	water level
S9	Kearl Lake Outlet	483980	6346750	all year	water level, discharge
S10	Wapasu Creek at Canterra Road	490272	6355942	all year	water level, discharge
S20	Muskeg River Upland	492106	6355709	open-water	water level, discharge
S21	Shelley Creek[c]	476419	6347933	open-water	water level
S22	Muskeg Creek near the mouth	480970	6349071	open-water	water level, discharge
S24	Athabasca River below Eymundson Creek	466313	6372760	all year	water level, discharge
S27	Firebag River near the mouth[b]	489553	6388830	winter	water level, discharge
S28	Khahago Creek below Blackfly Creek	480489	6342185	open-water	water level, discharge
S33	Muskeg River at the Aurora North/ Albian Boundary	474876	6350204	all year	water level, discharge

[a] Station location shown in UTM co-ordinates (datum NAD83).

[b] Environment Canada monitors water level and discharge at these stations during the open-water season.

[c] Discontinued station.

Regional Geomorphic Assessment in the Oil Sands Region

Most of the geomorphic studies in the Oil Sands Region are documented in previous hydrology ESRs. Each of these studies presented the geomorphic conditions and characteristics including basin, flow and channel characteristics in and adjacent to the proponent's Project development area. Geomorphic sites in the LSAs, as shown in Figure 2.2-3, are relevant to this Project.

Vegetated channels in the Oil Sands Region were studied by Golder in 2004 with funding from Syncrude (Golder 2004). A comprehensive geomorphic assessment of alluvial channels in the Oil Sands Region is currently being conducted by Golder with funding from the Natural Sciences and Engineering Research Council of Canada (NSERC), Canadian Oil Sands Network for Research and Development (CONRAD) and Fisheries and Oceans Canada (DFO). The main objectives of this study are to develop relationships for channel parameters and propose design concepts of designing alluvial channels at mine closure. Results from this study are expected in 2008.

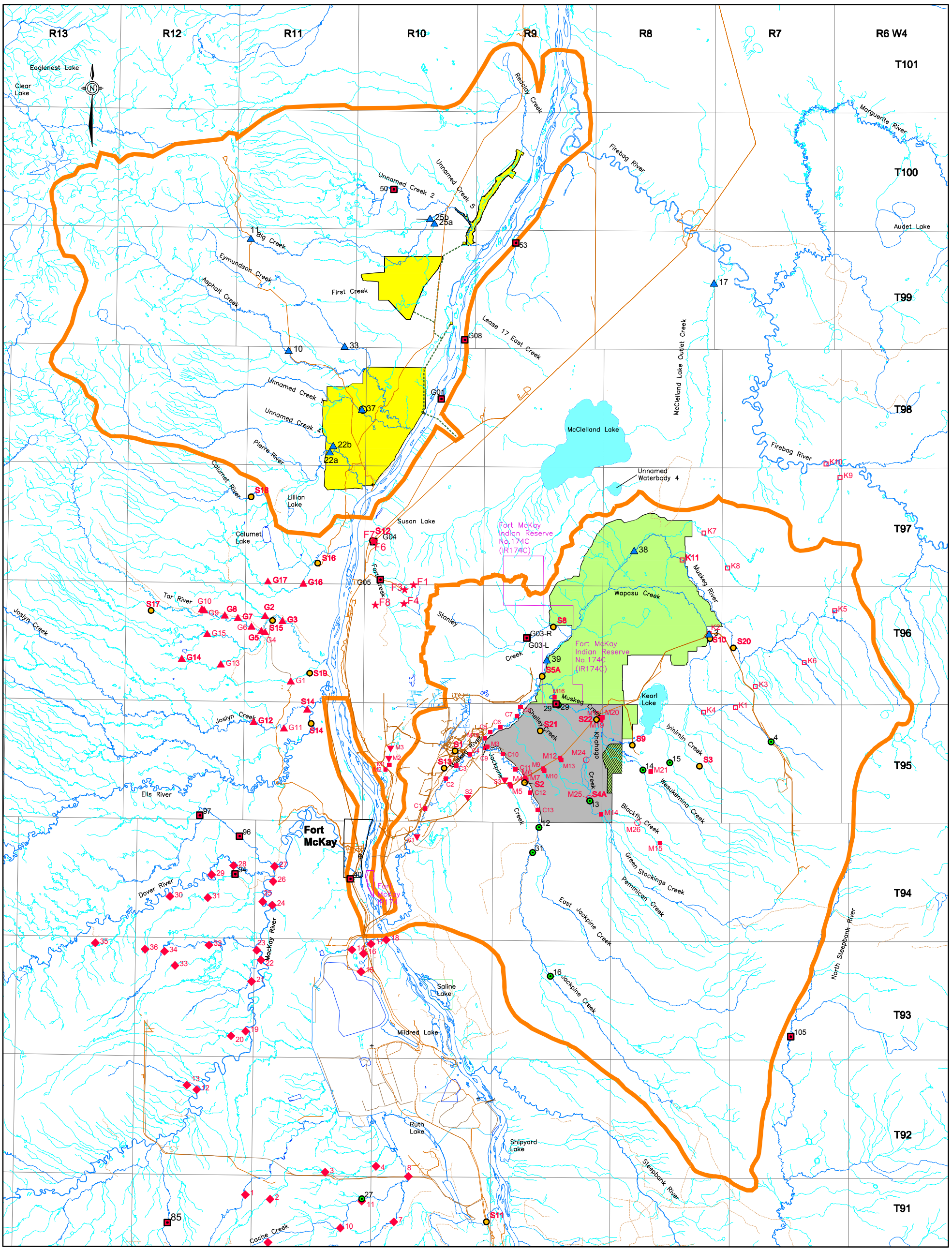
Project Hydrology Field Program

The Project hydrology field program was conducted from fall 2005 through fall 2007. This field program included hydrometric monitoring, stream geomorphic surveys and a lake level survey for McClelland Lake and Unnamed Waterbody 4 (Figure 2.2-2). TSS data were also collected at this time.

Project Hydrometric Monitoring

Shell installed 11 hydrometric monitoring stations to monitor stream flows in and near the LSAs (Figure 2.2-2). The locations, basin areas, and periods of record for all hydrometric stations visited are provided in Table 2.2-5. An overview of the hydrometric monitoring program, local hydrology program data including water level figures and derived rating curves and photos of the hydrometric monitoring stations are provided in Appendix B. Field methods used for the hydrometric monitoring program are described in Section 2.2.3.3.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.2-3_ Regional and Local Geomorphic Survey Locations Adjacent to Local Study Areas.dwg Nov 22, 2007 - 3:38pm



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- SYNCRUDE MINE SITE (MILDRED LAKE) (1994)
- PETRO-CANADA FORT HILLS OIL SANDS PROJECT
- ALBIAN SANDS MUSKEG RIVER MINE (2001)
- CANADIAN NATURAL HORIZON OIL SANDS PROJECT (2001)
- ALBIAN SANDS MUSKEG RIVER MINE EXPANSION (2003)
- IMPERIAL KEARL OIL SANDS PROJECT (2003)
- SHELL JACKPINE MINE — PHASE I (2004)
- RAMP HYDROMETRIC STATION
- 2005 CONRAD SURVEY SITES
- 2006 CONRAD SURVEY SITES
- PROJECT GEOMORPHIC SURVEY SITES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

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SCALE KM

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

REGIONAL AND LOCAL GEOMORPHIC SURVEY LOCATIONS ADJACENT TO LOCAL STUDY AREAS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Reg-Loc-Geomorphic	
DESIGN	CS	07/05/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.2-3	
CHECK	CS	05/07/07		
REVIEW	WES/TC	20/11/07		

Table 2.2-5 Project Hydrometric Monitoring

Station Number	Stream Name	Station Location[a]		Basin Area [km^2]	Period of Monitoring Activity
		Easting [m]	Northing [m]		
P01	Wapasu Creek	482352	6359575	106	Winter/Spring/Summer/Fall 2006
P02	Muskeg River	482140	6360109	290	Winter/Spring/Summer/Fall 2006
P03	Pierre River	450766	6372422	69	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P04	Eymundson Creek	465722	6372730	313	Winter/Spring/Summer/Fall 2006
P05	First Creek	467137	6386706	26	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P06	Unnamed Creek 3	490039	6377785	45	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P07	Unnamed Creek 2	468831	6390858	110	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P08	Big Creek	471162	6387771	316	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P09	Unnamed Creek 7	470778	6389112	6	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P10	Redclay Creek	475697	6395108	211	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P11[b]	Unnamed Waterbody 4	481928	6367882	6	Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007

[a] Station location shown in UTM co-ordinates (datum NAD 83).

[b] Station P11 was added in spring 2006.

Project Stream Geomorphic Survey

Shell completed a geomorphic study to supplement regional data to obtain site-specific information and data to assist in defining the geomorphic characteristics of the streams in and adjacent to the Project. Field methods used for geomorphic survey are described in Section 2.2.3.3. Stream locations included in this field program are shown in Figure 2.2-3. Detailed results of the Project geomorphic survey are provided in Appendix B.

Project Lake Level Survey

Shell conducted a water level survey of McClelland Lake and Unnamed Waterbody 4 to determine their geodetic lake water elevations. This information is required to understand the hydrology of the connection between the two lakes.

2.2.3.2 Field Program Methods

Hydrometric Monitoring Field Methods

Eleven hydrometric stations were installed on streams in the RSA. The stations were monitored from summer 2005 through fall 2007. Each hydrometric station was equipped with a pressure transducer to continuously measure water depth

and a data logger to store recorded data. Seasonal visits were made to each of the stations to manually measure stream flow rate and water level relative to a temporary benchmark. Site conditions were recorded, data loggers were downloaded and photos were taken.

The measured flow rates and water levels collected at the hydrometric stations were plotted to determine the relationship between water level and measured flow rate at each station. The resulting rating curve can be used to determine the flow rates corresponding to the continuous water depths recorded by the pressure transducer. See Appendix B for more details.

Stream Geomorphic Survey Field Method

Geomorphic sites were selected on streams within the LSAs as indicated in Figure 2.2-3. Stream geomorphic data were collected during field surveys in September 2005, and October 2007, and measured from maps. Basin areas and parameters were measured from 1:50,000 maps from the National Topographic Database (NTDB). Channel parameters were measured in the field. Bed material size was measured by collecting grab samples and performing a sieve analysis on the sample. Stream flow rate at the time of survey was measured and values of flow parameters were derived using the HSPF model. The following information was collected during the field program:

- channel flow depths and widths at the times of survey and at bankfull conditions were measured at three or four locations within a 80 to 120 m stream reach;
- detailed cross-section at three or four locations (depending on the level of detail required to delineate the reach);
- typical sample of stream bed material and a qualitative description of the spatial variation of the bed material;
- longitudinal water level profile of the survey reach;
- river mapping with detailed notes to describe the stream reach morphology; and
- photos capturing the upstream, downstream, side and aerial views of the stream reach.

Lake Level Survey Field Method

A geodetic survey of lake levels was performed on May 11, 2007 using Real Time Kinematics (RTK) survey to ensure accuracy across large distances.

2.2.3.3 Methods of Analysis

Regional Stream Flow and Trend Analysis

The long-term stream flow data from hydrometric stations within the Oil Sands Region were analyzed and the results were used to describe the regional variations in basin runoff and stream flow. A basin that has a station installed to monitor flows is termed a gauged basin. These gauged basins, excluding the Athabasca River basin, have drainage areas ranging from Poplar Creek's 151 km^2 to the Firebag River's 5,990 km^2.

Detailed flow analysis was conducted on the Athabasca River, which is the largest river in the region. The hydrologic characteristics of the Athabasca River were based on the records at the Environment Canada hydrometric gauging stations below Fort McMurray (Station 07DA001, with data from 1957 to 2006) and at the Embarras Airport (Station 07DD001, with data from 1971 to 1984).

Standard statistical methods were used in the regional analysis to derive long-term averages, extremes and probability of occurrence of extreme events, based on theoretical probability distribution. The Consolidated Frequency Analysis (CFA) program developed by Environment Canada (1993), the frequency analysis (FRQ) computer program developed by Dr. G. Kite (Kite 1999) and analysis programs developed by Golder were used to derive flow characteristics.

Mean annual discharges at the Fort McMurray and Embarras Airport stations were compared on a concurrent period basis for 1971 to 1984. This comparison was used to derive the mean annual discharge at Embarras Airport from 1957 to 2006. The low flow period for the Athabasca River is the winter months, typically between November and March. Therefore, the hydrologic year (September to August) rather than a calendar year (January to December) was used for the frequency analysis of the low flows to ensure that annual low flow events are independent of each other. An annual minimum daily discharge series and 7-day low flow series were developed. A frequency analysis was used to determine the 2-, 10- and 100-year low flow discharges at each station. Some of the flow statistics for the Athabasca River were compared to other large streams in the region.

The minimum, average and maximum water yields for the Firebag River and the Muskeg River were determined by statistical analysis. The hydrologic characteristics of the Firebag River are based on long term data recorded at Environment Canada Station 07DC001 from 1970 to 2006. The hydrologic

characteristics of the Muskeg River are based on long-term data recorded at Environment Canada Station 07DA008 from 1974 to 2006.

The recorded flow data from 1957 to 2006 at Environment Canada Station 07DA001 (Athabasca River below Fort McMurray) were analyzed using Spearman and Mann-Kendall tests to identify possible trends at the 5% level in maximum, mean, minimum, monthly mean and seasonal mean flows. The Spearman and Mann-Kendall tests are the standard tests, parametric and non-parametric respectively, used to identify trends in observed data.

Local Stream Flow Analysis

Long-term local flow series for the JEMA and PRMA LSAs were simulated using the calibrated and validated HSPF model (see below) based on the derived long-term climate data for the LSAs and watershed and stream channel parameters. The derived flow series were analyzed to obtain flow statistics for the average and extreme hydrological conditions.

Hydrologic Model Calibration and Simulation Analysis

The continuous HSPF model, developed by the U.S. Environmental Protection Agency (U.S. EPA), was used to derive simulated hydrologic data series for streams in the LSAs. Modelling is necessary because most of the streamflow monitoring stations in the LSAs have data since May 1995 only. These data series, while valuable for calibrating a hydrologic model, are insufficient for deriving reliable statistics without extending the database by modelling.

The HSPF model was calibrated previously by AGRA (1996) and Golder (1997). In 2002, the model was re-calibrated (Golder 2003) based on updated climatic and hydrologic data to 2000 and available surficial geological information. Hydrologic model parameters were derived for the Oil Sands Region using a systematic approach to calibrate the HSPF model for various surficial geologic conditions and land types. The calibration accounted for the effects of precipitation that varied spatially across the Oil Sands Region. The calibrated model has been used to characterize hydrology for approved projects in the region.

Hydrologic Model Validation

The calibrated HSPF model was validated for the Oil Sands Region using the required streamflow records at the Steepbank River Environment Canada Hydrometric Station and the Joslyn Creek Environment Canada Hydrometric Station (Golder 2003).

The HSPF model, which was calibrated and validated in 2003, was further validated for the JEMA LSA with local data from 2001 to 2005 to demonstrate that all available climatic and hydrologic data have been used in the modelling analysis, and that the calibrated and validated HSPF model was still applicable to the watersheds in the JEMA LSA. Measured stream flows from 2001 to 2005 were compared to simulated stream flows and it was found that the model is still valid. For the PRMA LSA, the HSPF model was validated by comparing simulated and measured flows at Environment Canada Stations on Asphalt Creek (07DA012), Big Creek (07DA011) (referred to as Unnamed Creek near Fort McKay by Environment Canada) and Pierre River (07DA013). For more details on the model validation, see Appendix C.

Flood Risk Analysis

Flood risk analysis involves the calculation of open water flood water surface profiles using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) program developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers. The flood aerial risk limits are then mapped out based on estimated flood levels.

The HEC-RAS model was calibrated using the rating curve from RAMP Station S24 in previous studies (Golder 2000). The computed flood levels based on the calibrated hydraulic model were used to map the flood risk limits for a study reach that included:

- the location of the planned Athabasca River bridge crossing, access road and utility corridor to supply utilities from the existing utility lines on the east side of the Athabasca River to the PRMA development area; and
- the location of the proposed PRMA water intake.

Sediment Analysis

Alberta Environment, Environment Canada and RAMP measure sediment as TSS concentrations in the streams of the LSAs. Local TSS concentration measurements were started in fall 2005 as part of the water quality environmental setting study. This historical and local data were analyzed to derive TSS concentration values for the winter, spring, summer and fall seasons. In the PRMA LSA, long-term TSS data were not available and thus, no meaningful statistics could be obtained.

The historical stream sediment measurements available for the large gauged watersheds in the study areas were analyzed to derive annual sediment yields

even though the percent of missing data is high at each of these gauged basins. For example, the mean annual sediment yield estimate for the Athabasca River is based on the analysis of 1,387 bed load measurements by Environment Canada between 1967 and 1972. The Muskeg River annual sediment yield estimate is based on analysis of 57 bed load measurements by Environment Canada between 1976 and 1983.

The mean annual basin sediment yield ranges for the JEMA LSA and PRMA LSA were obtained based on the estimated annual sediment yields of gauged basins east and west of Athabasca River, respectively.

Stream Geomorphic Assessment

Geomorphic survey data collected at local streams for the Project were compiled to develop descriptions of the stream geomorphic conditions in and near the LSAs. The resulting stream geomorphic data sheets are presented in Appendix B.

Lake Water Level Analysis

Monitoring data collected by RAMP from June 1997 through December 2006 were used to determine the average lake water level and the water level fluctuation at McClelland Lake. This data were also used to develop a relationship between lake water level and lake outflow. A geodetic survey was conducted on May 11, 2007 to determine the hydrology of the connection between McClelland Lake and Unnamed Waterbody 4 (Figure 2.2-2).

2.2.3.4 Quality Assurance and Quality Control

Several QA and QC procedures were implemented for field data collection, historical data compilation and analysis, and hydrologic model simulations. The QA and QC procedures implemented are outlined below.

Hydrology Field Data Collection

The field data collection program obtained site-specific information and was done seasonally for a short period. The field data collection QA and QC procedures included:

- developing specific work instructions to cover all activities required to conduct field tasks;
- testing flow rate and water level instruments to verify proper calibration and function prior to field trips;

- installing hydrometric stations according to commonly accepted protocols and instructions provide by the manufacturer;
- verifying continuous data logging after installation;
- downloading recorded data regularly to reduce the risk of complete data loss in case of instrument malfunction or damage to the monitoring station; and
- checking for gross errors or missing data in recorded series after data download.

Hydrology Historical Data Quality Assurance and Quality Control

A number of government agencies and industry groups collect and hold historical climate data that are very useful for characterizing the local and regional hydrology. Before analyzing historical data, QA and QC checks were made, including:

- identification of time periods with large quantities of missing data, such as months missing data for several days, and removing those time periods from further analysis; and
- identification and verification of unusual deviations from, or abrupt changes in, average values and other statistical values.

Hydrology Statistical Analysis Quality Assurance and Quality Control

Historical and site-specific data were analyzed, described and summarized using statistical techniques. The data series were checked to make sure they met the standard criteria for such analyses. The QA and QC procedures included the following steps:

- checking data entry and reviewing for errors;
- carrying out statistical tests for homogeneity, trend and independence of the data series;
- testing the goodness-of-fit of theoretical probability distribution functions to the data series using standard statistical methods;
- reviewing results against those of previous work in the region; and
- reviewing results of analyses by staff not involved in the analyses.

2.3 REGIONAL RESULTS

2.3.1 Climate

2.3.1.1 Air Temperature

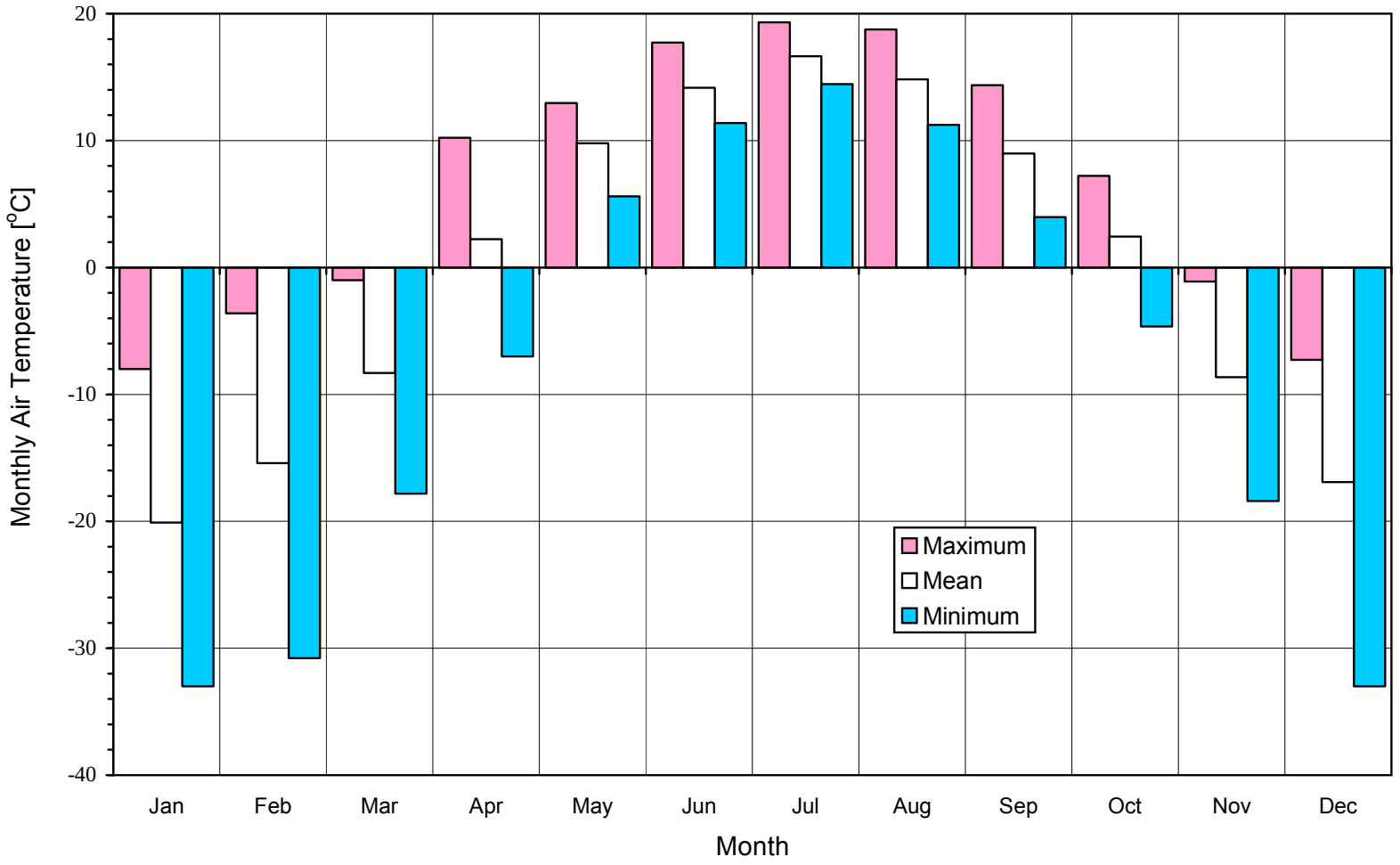
The daily and monthly air temperatures were derived for the RSA from data at Fort McMurray (Table 2.3-1). The maximum daily air temperature of 27.3°C occurred on August 5, 1998, while the minimum daily air temperature of -48.6°C occurred on December 31, 1933. The mean monthly air temperatures typically ranged from -20.1°C in January to 16.6°C in July. The annual mean air temperature is 0.0°C. For more information on the temporal distribution of monthly air temperatures derived for the regional study area, see Figure 2.3-1.

Table 2.3-1 Derived Daily Extreme and Monthly Air Temperatures at Fort McMurray

Month	Daily Extreme Temperature [°C]		Monthly Average and Extreme Temperature [°C]		
	Maximum	Minimum	Maximum	Mean	Minimum
January	9.8	-46.7	-8.0	-20.1	-33.0
February	9.2	-40.6	-3.6	-15.4	-30.8
March	9.9	-34.2	-1.0	-8.3	-17.8
April	20.9	-26.5	10.2	2.2	-7.0
May	25.3	-6.7	12.9	9.8	5.6
June	25.7	2.0	17.7	14.2	11.4
July	27.2	6.9	19.3	16.6	14.4
August	27.3	1.1	18.8	14.8	11.2
September	21.6	-5.1	14.4	9.0	4.0
October	18.1	-19.1	7.2	2.4	-4.7
November	10.9	-36.4	-1.1	-8.6	-18.4
December	6.5	-48.6	-7.3	-16.9	-33.0

Note: Based on data recorded at the Fort McMurray climate station from 1919 to 1944 (1908 to 1918 data are poor in quality and were not used for analysis) and Fort McMurray Airport climate station from 1944 to 2006.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-1 Derived Monthly Air Temp-Fort McMurray.dwg Nov 22, 2007 - 4:13pm



NOTE

BASED ON DATA RECORDED AT THE FORT McMURRAY CLIMATE STATION FROM 1919 TO 1944 (1908 TO 1918 DATA ARE POOR IN QUALITY AND WERE NOT USED FOR ANALYSIS) AND FORT McMURRAY AIRPORT CLIMATE STATION FROM 1944 TO 2006.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED MONTHLY AIR TEMPERATURES AT FORT McMURRAY

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. air temp-Fort Mac	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.3-1	
CHECK	KM	17/08/07		
REVIEW	WES/TC	20/11/07		

2.3.1.2 Precipitation

Recorded Precipitation Values

Fort McMurray has a long period of record; therefore, data from this station can be used to derive precipitation statistics for the RSA. Precipitation data from the Fort McMurray climate station and the Fort McMurray Airport Climate station provided a continuous record of precipitation from 1920 to 2006. The mean and extreme monthly and annual precipitation, as well as the 100-year dry, 10-year dry, 10-year wet and 100-year wet annual precipitation for the RSA were calculated from this record.

Average Monthly and Annual Precipitation

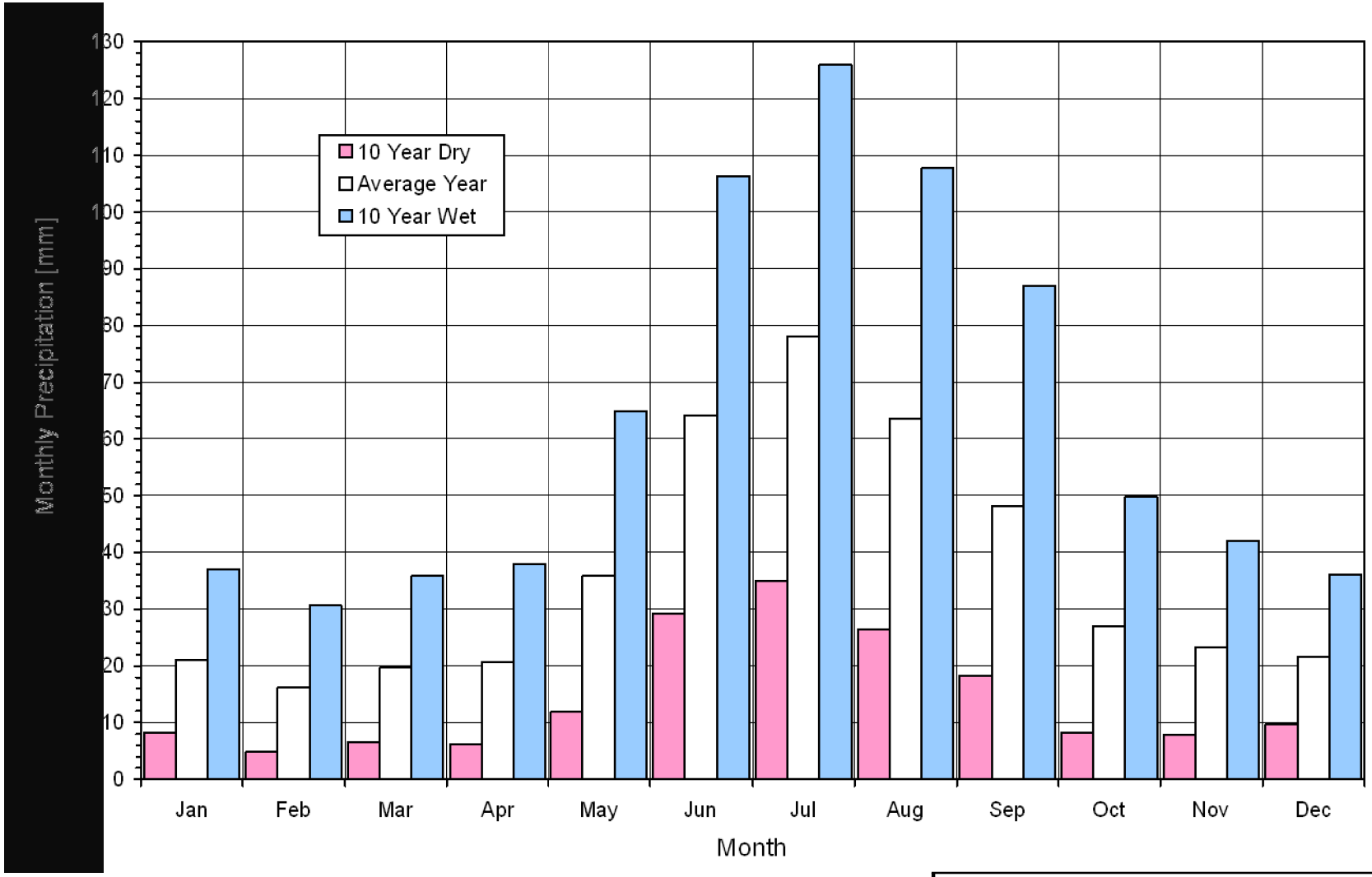
The average monthly precipitation at Fort McMurray varied from approximately 16.2 mm in February to about 78.1 mm in July as shown in Table 2.3-2 and Figure 2.3-2. Average annual precipitation is estimated to be 439 mm for the 1920 to 2006 period. The Environment Canada website on climate (Environment Canada 2004) reports that approximately 75% of the average annual precipitation at Fort McMurray Airport climate station occurs as rainfall and approximately 25% occurs as snowfall, based on recorded data from 1971 to 2000. Based on these percentages, it is estimated that average annual rainfall and average annual snowfall are 329 mm and 110 mm respectively.

The 10-year wet annual precipitation is estimated to be 565 mm and the 10-year dry annual precipitation is estimated to be 325 mm.

Table 2.3-2 Monthly and Annual Precipitation for Fort McMurray

Month	Total Precipitation [mm]						
	100-Year Dry	10-Year Dry	10-Year Wet	100-Year Wet	Minimum	Average	Maximum
January	3.1	8.2	37.0	61.8	2.1	21.0	70.0
February	1.1	4.9	30.7	56.3	0.3	16.2	56.1
March	2.3	6.6	35.8	59.6	2.7	19.6	59.5
April	0.0	6.1	37.9	57.4	0.0	20.7	52.5
May	1.9	11.9	64.9	106	2.3	35.9	105
June	14.8	29.3	106	170	16.0	64.1	188
July	9.5	35.0	126	179	5.7	78.1	204
August	9.4	26.4	108	169	7.4	63.5	174
September	8.5	18.3	87.1	149	9.1	48.1	133
October	0.7	8.2	49.9	85.2	0.5	27.0	83.7
November	1.3	7.8	42.0	69.1	0.5	23.3	55.8
December	5.1	9.8	36.1	56.8	5.8	21.5	53.0
Annual	255	325	565	698	242	439	676

Note: Based on data recorded at the Fort McMurray climate station from 1920 to 1944 (1908 to 1919 data are poor in quality and were not used for analysis) and Fort McMurray Airport climate station from 1944 to 2006.



NOTE

BASED ON DATA RECORDED AT THE FORT McMURRAY CLIMATE STATION FROM 1920 TO 1944 (1908 TO 1919 DATA ARE POOR IN QUALITY AND WERE NOT USED FOR ANALYSIS) AND FORT McMURRAY AIRPORT CLIMATE STATION FROM 1944 TO 2006.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED MONTHLY PRECIPITATION AT FORT McMURRAY

Shell Canada Limited

PROJECT 05-1344-027.6650		FILE No. Monthly preciptation
DESIGN	KM	09/07/07
CADD	TY	18/11/07
CHECK	KM	17/08/07
REVIEW	WES/TC	20/11/07
SCALE AS SHOWN		REV. 0

FIGURE: 2.3-2

Intensity – Duration – Frequency Results

The Environment Canada rainfall IDF data from the Fort McMurray Airport climate station for 1966 to 1990 are presented in Table 2.3-3. The corresponding IDF curves are provided in Figure 2.3-3.

Intensity-Duration-Frequency data for the RSA were derived from the long-term record at the Fort McMurray Airport climate station. The 24-hour rain with a 10-year return period is estimated to be 67 mm in total or 2.8 mm/h. The 24-hour rain with a 100-year return period is estimated to be 101 mm in total or 4.2 mm/h.

Relative Humidity Results

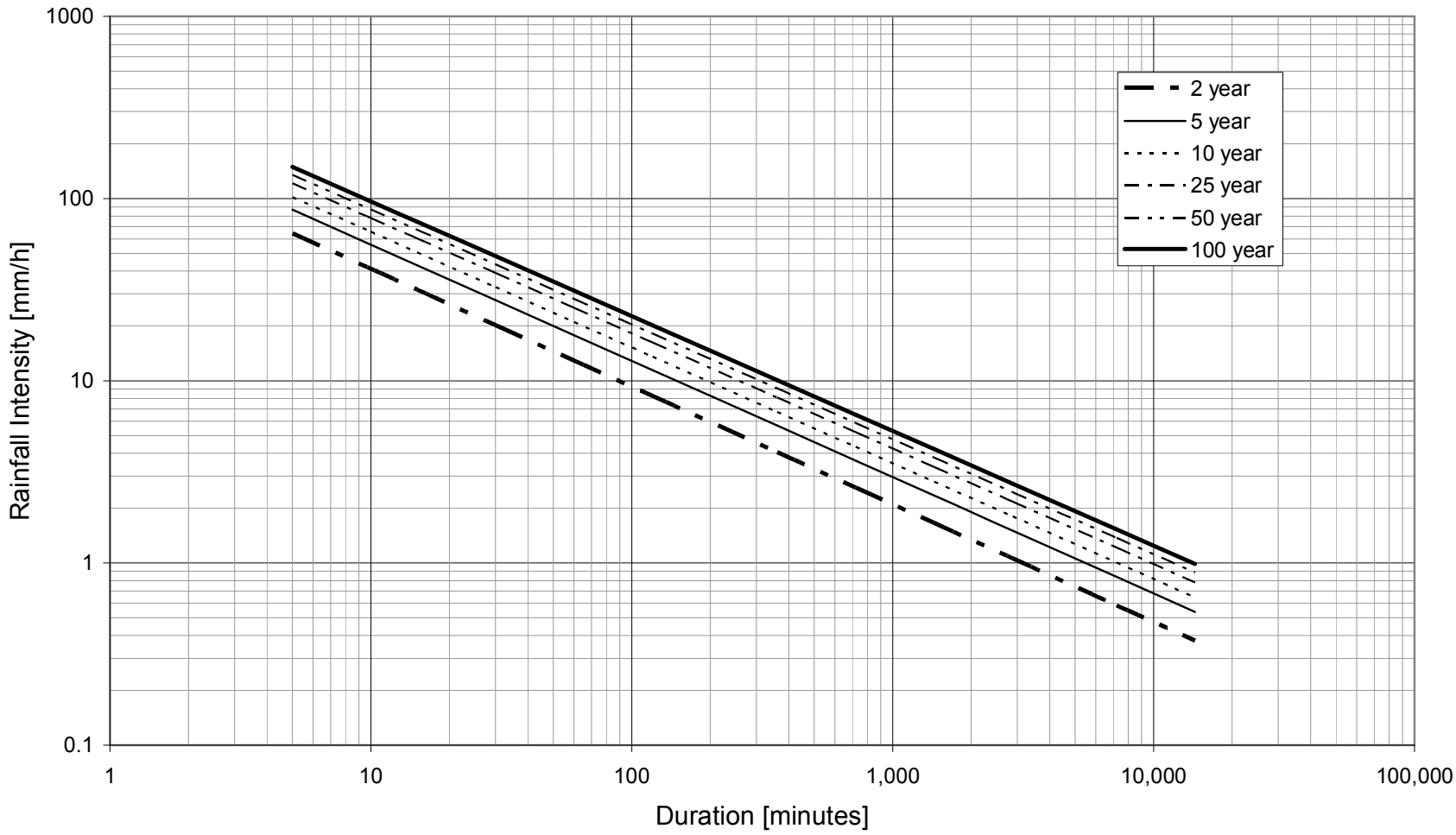
Winter months typically have higher relative humidity values than summer months (Table 2.3-4, Figure 2.3-4). The lowest relative humidity typically occurs in May and the highest relative humidity typically occurs in November and December. Mean monthly relative humidity is in the range of 57 to 79%.

Table 2.3-3 Derived Rainfall Intensity-Duration-Frequency Data for Fort McMurray

Duration	Rainfall Intensity [mm/h]					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5 minutes	64	87	102	121	135	149
10 minutes	41	56	66	78	87	97
15 minutes	32	43	51	60	67	75
30 minutes	20	28	33	39	44	48
1 hour	13	18	21	25	28	31
2 hours	8.2	11	14	16	18	20
6 hours	4.1	5.7	6.7	8.1	9.1	10
12 hours	2.6	3.6	4.3	5.2	5.9	6.5
24 hours	1.7	2.3	2.8	3.4	3.8	4.2
2 days	1.1	1.5	1.8	2.2	2.4	2.7
5 days	0.6	0.8	1.0	1.2	1.4	1.5
10 days	0.4	0.5	0.6	0.8	0.9	1.0

Note: Based on data at the Fort McMurray Airport climate station for the period of 1966 to 1990.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-3 Derived Rainfall Intensity.dwg Nov 22, 2007 - 4:31pm



NOTE

BASED ON DATA RECORDED AT THE FORT McMURRAY CLIMATE STATION FOR THE PERIOD OF 1966 TO 1990.

PROJECT

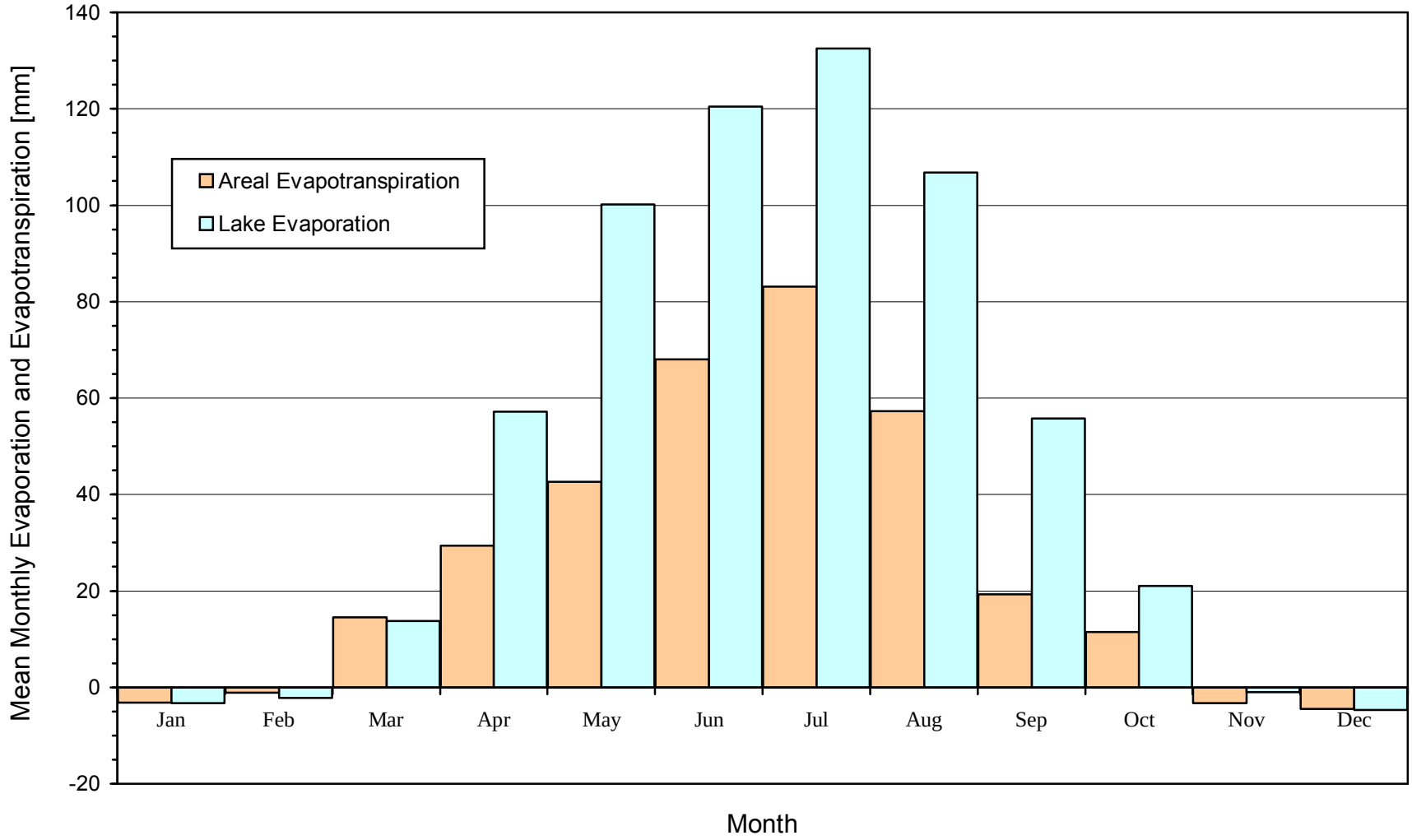
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED RAINFALL INTENSITY-DURATION-FREQUENCY CURVES FOR THE REGIONAL STUDY AREA

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Rainfall intensity	
DESIGN	KM	09/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.3-3		
CHECK	KM	17/08/07			
REVIEW	WES/TC	20/11/07			



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED MONTHLY RELATIVE HUMIDITY FOR THE REGIONAL STUDY AREA

NOTE

BASED ON DATA RECORDED AT THE FORT McMURRAY CLIMATE STATION BETWEEN 1953 AND 2006.

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Monthly humidity	
DESIGN	KM	09/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.3-4		
CHECK	KM	18/07/07			
REVIEW	WES/TC	20/11/07			

Table 2.3-4 Derived Relative Humidity for Fort McMurray

Month	Hourly Relative Humidity [%]		Daily Relative Humidity [%]		Monthly Relative Humidity [%]		
	Maximum	Minimum	Maximum	Minimum	Maximum	Mean	Minimum
January	100	18	100	44	93	75	60
February	100	20	99	34	88	73	60
March	100	9	97	34	78	68	53
April	100	11	99	25	73	59	45
May	100	10	98	23	68	57	43
June	100	15	97	31	76	64	52
July	100	16	100	32	77	69	59
August	100	20	98	37	82	72	61
September	100	17	100	39	84	74	58
October	100	15	99	35	85	74	65
November	100	24	97	31	88	79	70
December	100	9	96	43	86	77	67

Note: Based on the data recorded at the Fort McMurray Airport climate station between 1953 and 2006.

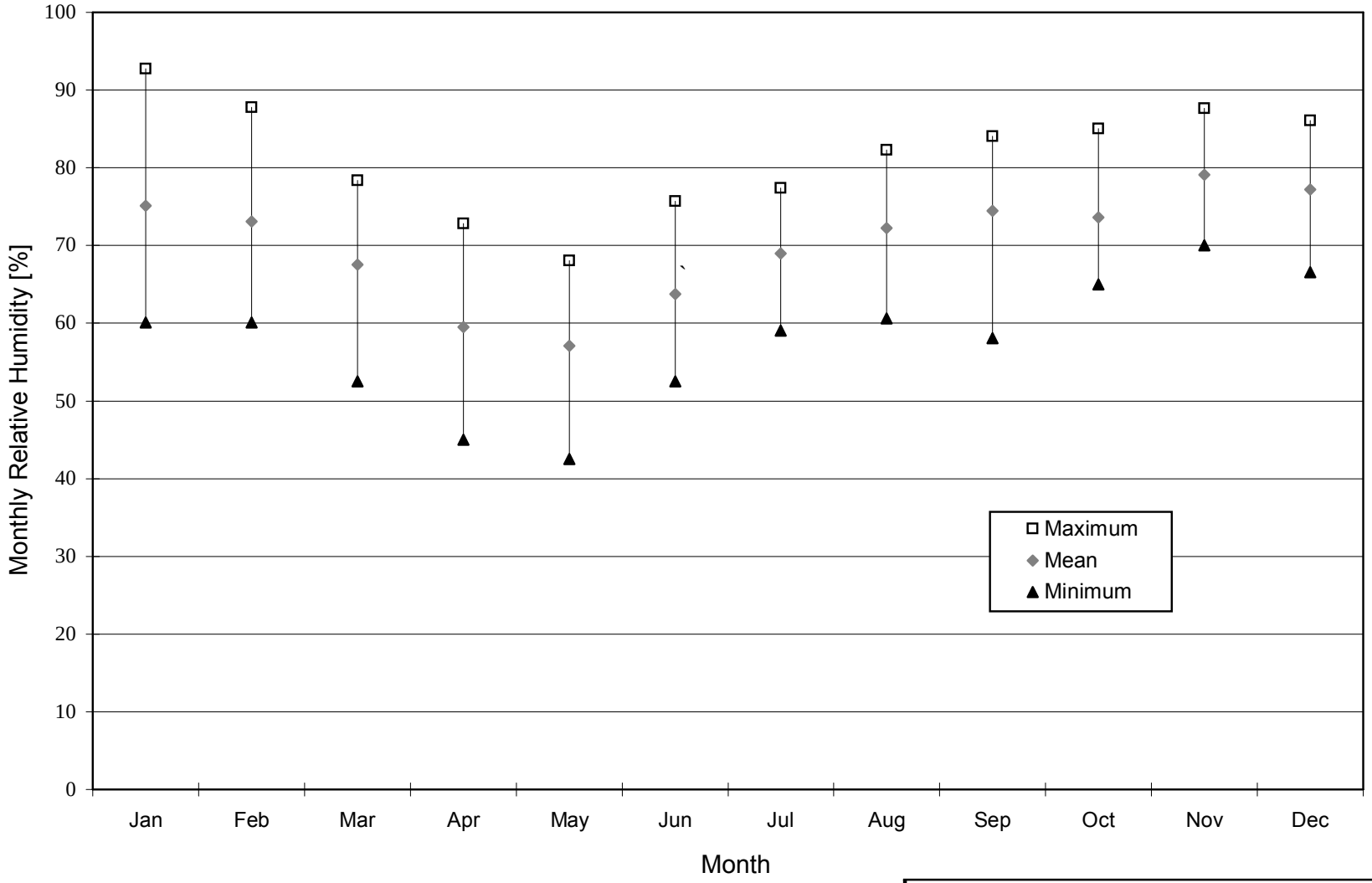
2.3.1.3 Solar Radiation

For the daily and monthly solar radiation for the RSA, see Table 2.3-5. Mean monthly solar radiation typically ranged from 16.3 W/m^2 in December to 212 W/m^2 in June. Maximum daily solar radiation varied from 41.7 W/m^2 in December to 370 W/m^2 in June. The daily solar radiation varied from a minimum of 1.13 W/m^2 in December to a maximum of 370 W/m^2 in July. The derived monthly solar radiation values for the RSA are plotted in Figure 2.3-5.

Table 2.3-5 Derived Monthly Solar Radiation for the Regional Study Area

Month	Daily Extreme [W/m^2]		Monthly Mean and Extreme [W/m^2]		
	Maximum	Minimum	Maximum	Mean	Minimum
January	65.0	1.63	36.3	23.6	6.15
February	120	9.17	73.2	54.8	37.1
March	209	10.8	135	108	75.4
April	291	23.7	198	164	126
May	364	20.6	266	200	155
June	370	22.2	272	212	141
July	358	29.6	250	207	166
August	299	15.7	209	173	114
September	225	13.0	144	106	72.3
October	139	3.96	76.5	61.2	43.9
November	77.2	2.92	40.3	27.3	16.4
December	41.7	1.13	27.7	16.3	7.03

Note: Based on sunshine hour data recorded at Fort McMurray Airport climate station from 1971 to 1996, solar radiation data recorded at Aurora climate station from 1995 to 2006 and solar radiation data from Stony Plain climate station from 1953 to 1994.



NOTE

BASED ON SUNSHINE HOUR DATA RECORDED AT FORT McMURRAY AIRPORT CLIMATE STATION FROM 1971 TO 1996, SOLAR RADIATION DATA RECORDED AT AURORA CLIMATE STATION FROM 1995 TO 2006 AND SOLAR RADIATION DATA FROM STONY PLAIN CLIMATE STATION FROM 1953 TO 1994.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED MONTHLY SOLAR RADIATION FOR THE REGIONAL STUDY AREA

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Solar radiation
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.3-5	
CHECK	AS	18/11/07		
REVIEW	WES/TC	20/11/07		

2.3.1.4 Wind

The recorded daily wind data at the Fort McMurray Airport and Aurora climate stations for May 1995 to December 2006 were analyzed to obtain mean wind speeds of 10.0 km/h at the Fort McMurray Airport and 4.3 km/h at the Aurora climate station. Standard deviations were 7.5 and 3.1 km/h, respectively, at these two stations. A comparison of the wind statistics shows that the Fort McMurray Airport and the Aurora climate stations have different wind statistics, possibly due to the influence of local topographic conditions.

Mean monthly wind speed statistics and probabilities of occurrence based on the records at the Fort McMurray Airport climate station (1959 to 2006) and Aurora climate station (1995 to 2006) are provided in Table 2.3-6 and Table 2.3-7, respectively. Wind characteristics were derived from a frequency analysis of extreme hourly wind speeds at the Fort McMurray Airport climate station. (Table 2.3-8 and Figure 2.3-6).

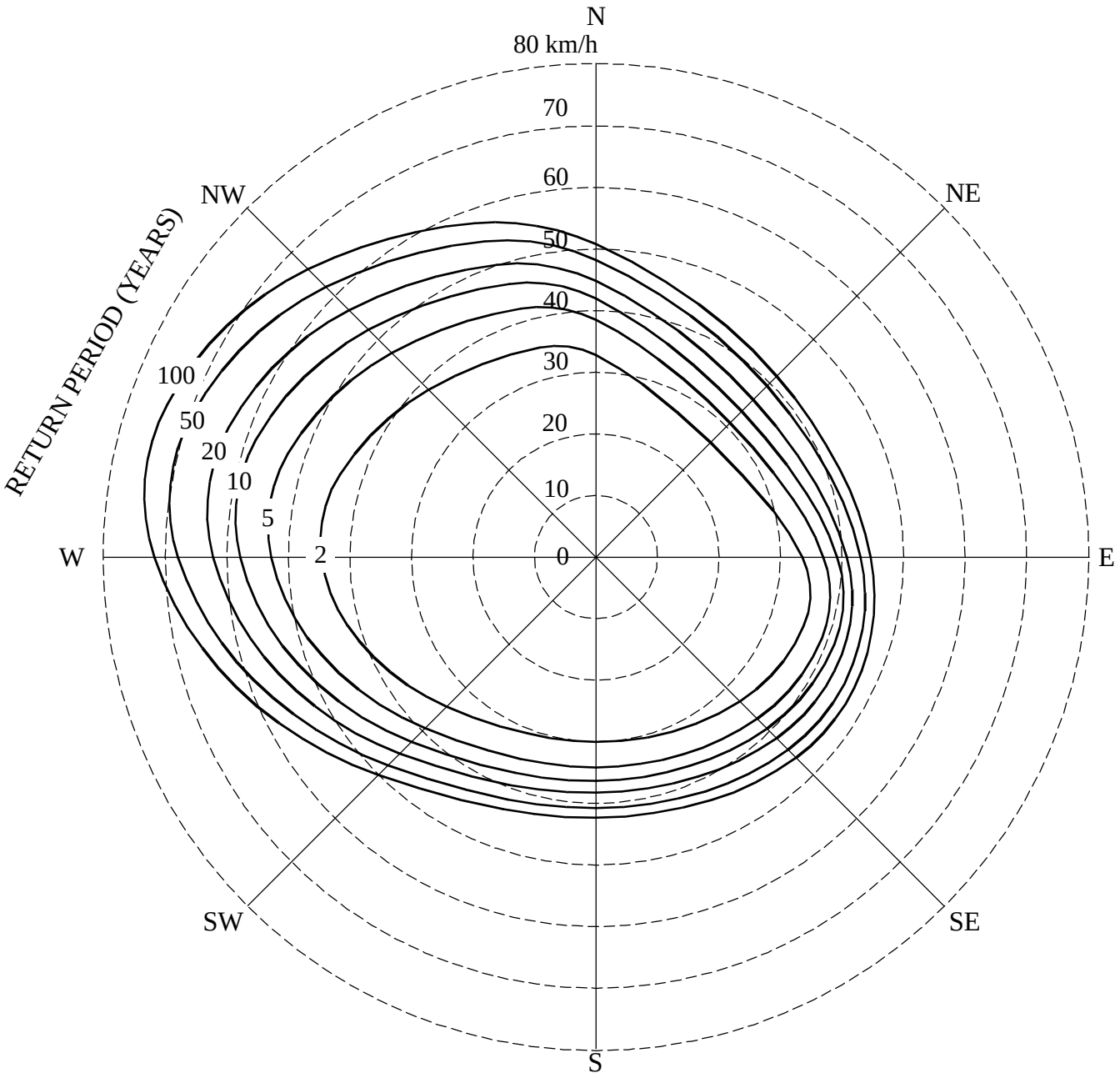
Table 2.3-6 Mean Wind Speeds and Probabilities of Occurrence at Fort McMurray Airport

Wind Direction From	Mean Speed [km/h]	Probability of Occurrence [%]
north	11.1	7.6
northeast	9.7	3.9
east	11.0	20.6
southeast	11.2	8.4
south	10.0	6.3
southwest	10.7	10.2
west	12.9	15.5
northwest	11.3	11.9
calm	0.0	15.7
all directions	9.5	100.0

Note: Based on recorded data at the Fort McMurray Airport climate station from 1959 to 2006.

The dominant wind at the Fort McMurray Airport climate station was an easterly wind, with the highest probability of occurrence (20.6%). The mean wind speed was 9.5 km/h. The westerly wind typically had the highest speed, with a mean value of 12.9 km/h. The 100-year return period of extreme hourly wind speed was 71.6 km/h (Table 2.3-8), also from the west.

The dominant wind reported at the Aurora climate station based on recorded data from 1995 to 2006 was a southerly wind, with the highest probability of occurrence (32.1%). The mean wind speed was 4.3 km/h. The northeasterly wind typically had the highest speed, with a mean value of about 5.2 km/h.



NOTES

1. BASED ON DATA AT THE FORT McMURRAY AIRPORT CLIMATE STATION FROM 1959 TO 2006.
2. ONLY INTERPOLATE ALONG MAIN DIRECTIONS.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

FREQUENCY ANALYSIS OF EXTREME HOURLY WIND SPEEDS AT FORT McMURRAY AIRPORT CLIMATE STATION

Shell Canada Limited

PRO	05-1344-027.6650		FILE No.	Wind Speeds
DESIGN	PW	10/05/07	SCALE NA	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.3-6**	
CHECK	KM	18/07/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\ Drawing file: Fig 2.3-6 Hourly Wind Speeds.dwg Nov 22, 2007 - 4:56pm

Table 2.3-7 Mean Wind Speeds and Probabilities of Occurrence at Aurora Climate Station

Wind Direction From	Mean Speed [km/h]	Probability of Occurrence [%]
north	4.4	8.9
northeast	5.2	18.1
east	3.4	4.0
southeast	3.4	7.2
south	4.2	32.1
southwest	3.6	11.4
west	3.6	7.8
northwest	5.1	10.2
calm	0.0	0.5
all directions	4.3	100.0

Note: Based on recorded data at the Aurora Climate Station from 1995 to 2006.

Table 2.3-8 Frequency Analysis of Extreme Hourly Wind Speeds at Fort McMurray Airport

Wind Direction From	Extreme Hourly Wind Speeds [km/h]		
	2-Year	10-Year	100-Year
north	32.9	41.8	50.8
northeast	26.0	33.4	41.6
east	33.4	38.9	44.6
southeast	32.6	39.5	45.7
south	30.0	36.2	42.3
southwest	34.2	42.3	49.9
west	44.6	57.6	71.6
northwest	38.2	51.8	65.7

Note: Based on recorded data at the Fort McMurray Airport climate station from 1959 to 2006.

2.3.1.5 Evaporation and Evapotranspiration

Evaporation

As shown in Table 2.3-9, average annual potential evaporation is estimated to be 820 mm for the RSA. Negative values denote condensation, when water vapour changes to liquid or solid state. Average annual lake evaporation is estimated to be about 597 mm, which is lower than the potential evaporation because blowing air has a cooling effect over a large lake surface area. Lake evaporation is affected by lake depth and varies by month, peaking in July with a monthly evaporation of approximately 132 mm. The higher heat capacity of a deep lake delays seasonal warming and cooling, resulting in higher evaporation rates at later dates.

Evapotranspiration

As shown in Table 2.3-9, average annual potential evapotranspiration is estimated to be 795 mm, which is almost as high as average annual potential evaporation. The actual areal evapotranspiration averages 314 mm per year, because of the limited water available in a basin for evaporation and the cooling effect of moving air. The peak mean monthly areal evapotranspiration occurs in July and is estimated to be 83 mm.

Temporal Variation

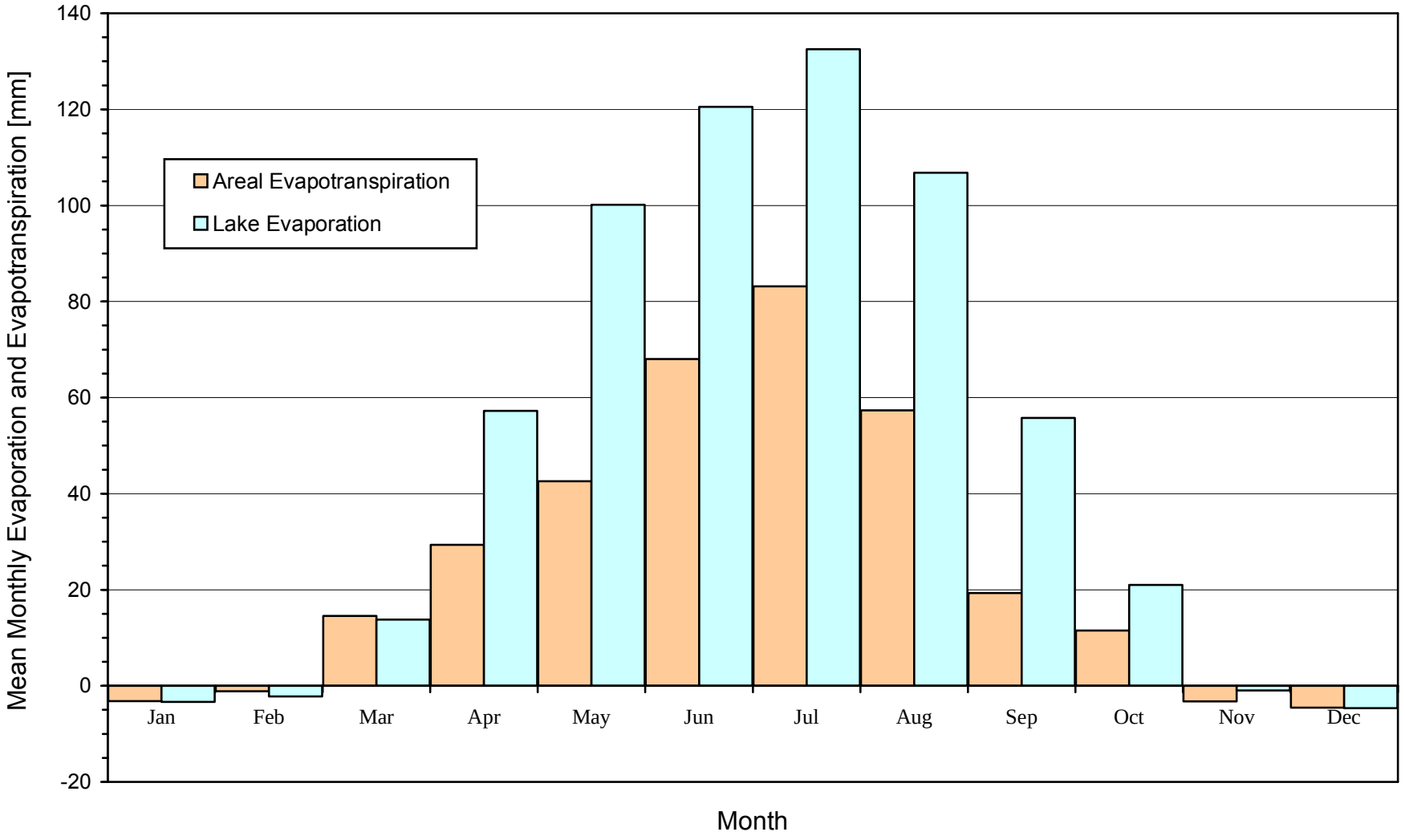
The temporal distribution of mean monthly lake evaporation for a lake depth of 1 m and areal evapotranspiration values were derived for the RSA (Figure 2.3-7). Relatively little variation occurs in lake evaporation and areal evapotranspiration from year to year, as shown by the annual values derived through frequency analysis (Table 2.3-10).

Table 2.3-9 Derived Monthly Evaporation and Evapotranspiration for the Regional Study Area

Month	Evaporation [mm]				Evapotranspiration [mm]	
	Potential (1-m Depth)	Lake			Potential	Areal
		1-m Depth	2-m Depth	5-m Depth		
January	-3	-3	-3	-3	-3	-3
February	-2	-2	-3	-3	-1	-1
March	17	14	8	1	25	15
April	88	57	47	21	94	29
May	150	100	94	66	152	43
June	165	121	119	105	163	68
July	170	132	132	128	164	83
August	138	107	113	122	128	57
September	78	56	65	87	65	19
October	26	21	27	49	18	11
November	-1	-1	2	20	-3	-3
December	-5	-5	-4	-1	-5	-5
Annual	820	597	596	592	795	314

Table 2.3-10 Derived Annual Evaporation and Evapotranspiration for the Regional Study Area

Return Period [Year]	Annual Lake Evaporation (1-m Lake Depth) [mm]	Annual Areal Evapotranspiration [mm]
2	598	311
5	633	340
10	651	357
20	665	372
50	680	389
100	690	400



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DERIVED MEAN MONTHLY LAKE EVAPORATION AND AREAL EVAPOTRANSPIRATION FOR THE REGIONAL STUDY AREA

NOTE

BASED ON RECOVERED AIR TEMPERATURE, DERIVED RELATIVE HUMIDITY AND DERIVED SOLAR RADIATION DATA FOR THE FORT McMURRAY AIRPORT STATION FOR THE 1953 TO 2006 PERIOD.

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Monthly Evaporation	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.3-7**	
CHECK	KM	18/07/07		
REVIEW	WES/TC	20/11/07		

2.3.1.6 Trend Analysis

Objective

Trend analyses of recorded air temperature and precipitation in the Oil Sands Region were conducted to determine:

- the presence of statistically significant trends in pertinent climate variables; and
- any linkages or correlations between trends in climate variables, if such trends were detected from the previous analyses.

The following sections summarize the results of the climate trend analyses, and the corresponding detailed data are presented in Appendix A. The trend analysis methods for air temperature and precipitation are explained in Section 2.2.2.2.

Air Temperature

As stated in Section 2.2.2.2, three methods for testing for trends were applied. First, the air temperature series for seven statistical parameters were plotted and the best fit lines suggest an increasing trend for all the air temperature parameters.

Secondly, both a parametric (Spearman) and a non-parametric (Mann-Kendall) test were conducted to identify trends. An analysis of mean annual, minimum and maximum daily air temperatures at the Fort McMurray Airport station indicates an increasing trend (i.e., significant at the 5% level or 95% confidence that there is a trend). Average daily air temperatures in spring, summer and winter also have increasing trends that are significant at the 5% level. However, the apparent increasing trend in average fall daily air temperature is not statistically significant at the 5% level. The results of the Spearman and Mann-Kendall tests indicate an increasing trend in air temperature at both stations for all seasons except in the month of October for data recorded at Fort McMurray Airport station, which shows a decreasing trend.

The third test was conducting two-sample t-tests and F-tests. Two-sample statistical t-tests of annual and seasonal mean air temperature corresponding to the periods 1944 to 1974 and 1975 to 2006 indicate the two samples have different mean spring, summer, winter and annual air temperatures. For the fall season, the mean air temperatures for the two samples are statistically similar based on the t-test. The results of the t-test suggest that there has been a significant change (increase) in seasonal and annual mean air temperatures during the period 1975 to 2006 compared to the period 1944 to 1974. Based on

the F-test, however, the variances in daily temperature for both periods are statistically similar, except for the winter period. The statistical t-test and F-test used here are the commonly used tests for assessing whether the means/variances from two samples are statistically different.

Precipitation

As stated in Section 2.2.2.2, three methods for testing for trends were applied. Appendix A contains details on the precipitation trend analysis.

First, the precipitation series for five statistical parameters were plotted. The best fit lines do not suggest any trend.

Secondly, both a parametric (Spearman) and a non-parametric (Mann-Kendall) test were conducted to identify trends. An analysis of monthly, seasonal and annual precipitation based on the data recorded at the Fort McMurray Airport station from 1944 to 2006 does not suggest any statistically significant trend over the last 50 to 60 years, except for the month of December. The analysis of the monthly precipitation data and seasonal total precipitation at the Fort McMurray station shows that there has been an apparent decrease in precipitation in winter (i.e., November to February) and the beginning of autumn (i.e., August and September). Monthly precipitation apparently has increased in the spring and the beginning of summer (i.e., from April to July). However, the increasing and decreasing trends in monthly precipitation are not statistically significant at the 5% level, except in the month of December that shows a statistically significant decreasing trend.

The third test was conducting two-sample t-tests and F-tests. The t-test indicates that the two samples have comparable total precipitation in spring, summer, fall and annually. For winter, the two samples have different total precipitation. The period of 1944 to 1974 had more precipitation than the period of 1974 to 2006. The variances in total precipitation in summer, fall and winter for both periods are statistically different based on the F-test.

2.3.2 Hydrology

Regional hydrology analysis has been completed for the Athabasca River and the Firebag River watershed, including McClelland Lake. The Athabasca River will be the source for raw water supply for the Project, and receives discharge from the watercourses identified within the Project. While the Project development areas do not directly impact the Firebag River watershed, other developments in the region have potential impacts on the Firebag River watershed, which includes McClelland Lake.

2.3.2.1 Athabasca River

Physical Setting and Hydrological Conditions

The head watershed of the Athabasca River is situated in the Rocky Mountains of Alberta near Mount Columbia (elevation 3,747 masl). The river generally flows in a northeastern direction through the province of Alberta, and passes by or through Jasper, Hinton, Whitecourt, Athabasca and Fort McMurray before emptying into Lake Athabasca (elevation 208 masl), which outflows through the Mackenzie River system to the Arctic Ocean.

The basin of the Athabasca River covers about 160,000 km^2, of which, 89% is in Alberta and 11% is in Saskatchewan. The Athabasca River system is comprised of 94 rivers and at least 150 named creeks and 153 lakes (Science Outreach - Athabasca 2004, website).

In the lower Athabasca River between Fort McMurray and Lake Athabasca, some of the major tributaries include the Beaver, MacKay, Ells, Muskeg, Steepbank, Firebag and Richardson rivers, and Poplar and Joslyn creeks. About 17% of the Athabasca River total drainage area drains into the lower reach below Fort McMurray to the Environment Canada station at Embarras Airport.

As shown in Figure 2.2-2, three hydrometric stations are located on the lower Athabasca River:

- Environment Canada Athabasca River below Fort McMurray;
- RAMP Station S24; and
- Environment Canada Athabasca River at Embarras Airport.

The river flows below Fort McMurray have been monitored by Environment Canada since 1957 and at Embarrass Airport from 1971 to 1984. The RAMP Station S24 has been in operation since 2001 (Table 2.3-11).

Table 2.3-11 Stream Flow Monitoring Stations on the Lower Athabasca River Reach

Station ID	Station Name	Station Location[a]		Drainage Area [km^2]	Period of Operation
		Easting [m]	Northing [m]		
07DA001	Athabasca River below Fort McMurray	475558	6293030	133,000	since 1957
S24	Athabasca River downstream of oil sands developments	466313	6372760	146,500	since 2001
07DD001	Athabasca River at Embarras Airport	477079	6451600	155,000	1971 to 1984

[a] Station location shown in UTM co-ordinates (datum NAD83).

Basin Water Yields

The results of analysis at 10 major gauged basins in the region, shown in Table 2.3-12, indicate no distinct correlation between annual water yield and basin area. Other basin characteristics, such as slope and elevation, affect water yield. The mean annual water yields of the large gauged basins in the region range from 49 to 137 mm (excluding Athabasca River below Fort McMurray and Poplar Creek).

Table 2.3-12 Recorded Mean Annual Water Yields for Large Gauged Basins in the Regional Study Area

Basin and Hydrometric Station Gauge Number	Drainage Area [km^2]	Annual Water Yield		Period of Record
		[m^3/s]	[mm]	
Poplar Creek (07DA007)[a]	151	0.96	201	1972 to 1986[b]
Beaver River (07DA018)	165	0.52	99	1975 to 2006[b]
Joslyn Creek (07DA016)	257	0.62	77	1975 to 1993[b]
Big Creek (07DA011) [c]	274	0.42	49	1975 to 1993[b]
Steepbank River (07DA006)	1,320	5.09	122	1972 to 2006[b]
Muskeg River at the Environment Canada Station (07DA008) [d]	1,432	4.04	89	1974 to 2006[b]
Ells River (07DA017)	2,450	7.00	90	1975 to 1986[b] 2001 to 2005[e]
MacKay River (07DB001)	5,570	13.8	78	1972 to 2006[b]
Firebag River (07DC001)	5,990	25.9	137	1970? to 2006[b]
Athabasca River below Fort McMurray (07DA001)	133,000	630	149	1957 to 2006[b]

[a] Recorded flows at Poplar Creek included diverted flows from the Beaver River basin. Therefore, this value does not represent the natural Poplar Creek basin water yield.

[b] Recorded by Environment Canada.

[c] Referred to as Unnamed Creek near Fort McKay (07DA011) by Environment Canada.

[d] This record includes winter and open water flows from 1974 to 1988, and open water flows from 1989-2006. It includes some of the release flows from Aurora North Mine and Albian Sands Muskeg River Mine.

[e] Recorded by RAMP.

Athabasca River mean annual discharges at the Fort McMurray and Embarras Airport stations have been calculated for the periods of 1971 to 1984 and 1957 to 2006 (Table 2.3-13). Mean annual discharges at the Fort McMurray and Embarras Airport stations can be compared on a concurrent period basis for 1971 to 1984.

Table 2.3-13 Mean Annual Discharges at the Athabasca River Hydrometric Stations

Period	Station	Mean Annual Discharge [m^3/s]
1971 to 1984	Fort McMurray Station[(a)]	699
	Embarras Airport Station[(a)]	749
	Embarras Airport Station[(b)]	755
1957 to 2006	Fort McMurray Station[(a)]	630
	Embarras Airport Station[(b)]	678

(a) Based on reported data.

(b) Based on reported and derived data.

The mean annual discharge at the Fort McMurray station is higher for the period of 1971 to 1984 (699 m^3/s) compared to the longer period of 1957 to 2006 (630 m^3/s).

The mean annual discharge at the Embarras Airport station is 749 m^3/s based on mean monthly flows as reported by Environment Canada. However, some flow data, particularly data for the winter months, are missing. The mean annual discharge estimate is increased to 755 m^3/s when the missing monthly flows are estimated based on the ratios of mean monthly flows at the Fort McMurray and Embarras Airport stations for the concurrent period.

The mean annual discharge estimate at Embarras Airport station is reduced from 755 m^3/s (1971 to 1984) to 678 m^3/s for the longer period of record (1957 to 2006). This estimate is based on the ratios of mean monthly flows at the Fort McMurray and Embarras Airport stations.

Estimated mean annual discharges and drainage areas at selected locations are provided for the lower reach of the Athabasca River (Table 2.3-14). This table is based on reported flows and drainage areas of Athabasca River tributaries and discharge estimates.

Table 2.3-14 Mean Annual Discharges and Drainage Areas on the Lower Athabasca River Reach

Locations on the Lower Athabasca River	Drainage Area [km^2]	Mean Annual Discharges (1957 to 2006) [m^3/s]
below Fort McMurray Station (07DA001)	133,000	630
below Muskeg River	136,800	638
below Eymundson Creek[(a)] (RAMP S24)	146,500	656
Embarras Airport Station (07DD001)	155,000	678

[(a)] See Figure 2.2-4 for stream locations associated with Environment Canada and RAMP stations.

Frequency analyses of the annual water yield series were conducted to determine the mean annual water yield, and the 10-year and 100-year wet and dry annual water yields (Table 2.3-15).

The Consolidated Frequency Analysis (CFA) and the Frequency Analysis (FRQ) allowed the available data sets to be analyzed using several frequency distributions. The analysis involved selecting an appropriate distribution based on the goodness-of-fit of the theoretical distribution to the data.

The distribution of monthly flows over a year was summarized for the Environment Canada hydrometric stations below Fort McMurray and at the Embarras Airport (Table 2.3-16 and Figure 2.3-8). The mean monthly river flow is typically highest in July (1,385 m^3/s near Fort McMurray) and lowest in February (161 m^3/s near Fort McMurray).

Flow Trend Analysis

Trend analyses of recorded streamflow in the Oil Sands Region were conducted to determine:

- the presence of statistically significant trends in pertinent streamflow variables; and
- any linkages or correlations between trends in streamflow variables, if such trends were detected from the previous analyses.

Table 2.3-15 Annual Water Yield Statistics for the Lower Athabasca River

Parameter	Fort McMurray Station[a]	Below Muskeg River[b]	RAMP Station S24[b]	Embarras Airport Station[c]
drainage area	133,000 km^2	136,800 km^2	146,500 km^2	155,000 km^2
mean annual discharge (water yield)	630 m^3/s (149 mm)	638 m^3/s (147 mm)	656 m^3/s (141 mm)	678 m^3/s (138 mm)
maximum annual discharge (water yield)	1,012 m^3/s (240 mm in 1997)	1,025 m^3/s (236 mm)	1,052 m^3/s (227 mm)	1,087 m^3/s (221 mm in 1997)
minimum annual discharge (water yield)	373 m^3/s (89 mm in 2002)	378 m^3/s (87 mm)	388 m^3/s (84 mm)	401 m^3/s (82 mm in 2002)
frequency distribution	3 Parameter Lognormal and Log Pearson Type III[d]	n/a	n/a	3 Parameter Lognormal and Log Pearson Type III[d]
100-year wet annual discharge (water yield)	1,019 m^3/s (242 mm)	1,032 m^3/s (238 mm)	1,059 m^3/s (228 mm)	1,092 m^3/s (222 mm)
10-year wet annual discharge (water yield)	819 m^3/s (194 mm)	830 m^3/s (191mm)	853 m^3/s (184 mm)	881 m^3/s (179 mm)
100-year dry annual discharge (water yield)	357 m^3/s (85 mm)	361 m^3/s (83 mm)	369 m^3/s (79 mm)	379 m^3/s (77 mm)
10-year dry annual discharge (water yield)	458 m^3/s (109 mm)	465 m^3/s (107 mm)	477 m^3/s (103 mm)	493 m^3/s (100 mm)

[a] Based on recorded flows for the period 1957 to 2006.

[b] Estimated based on runoff volumes from tributaries.

[c] Based on recorded and derived flow series for the period 1957 to 2006.

[d] The 3 Parameter Lognormal frequency distribution was used to determine the dry annual water yield and the Log Pearson Type III frequency distribution was used to determine the wet annual water yield.

n/a = Not applicable.

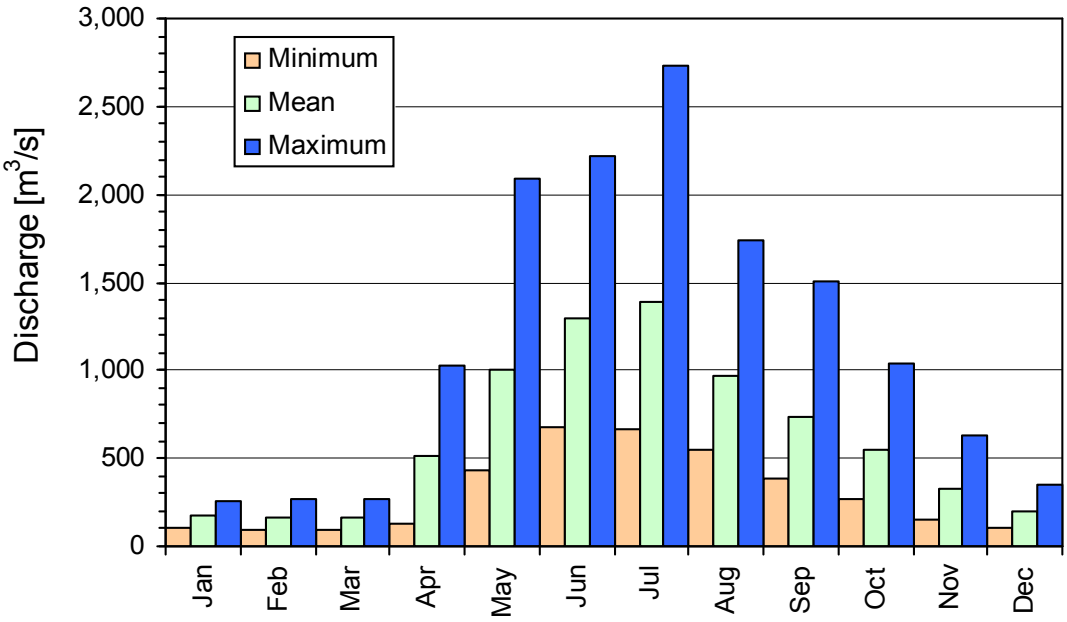
Table 2.3-16 Athabasca River Monthly Flows Near Fort McMurray and at the Embarras Airport

Month	Monthly Discharge [m^3/s]					
	Environment Canada Hydrometric Station near Fort McMurray[a]			Environment Canada Hydrometric Station at Embarras Airport[b]		
	Maximum	Mean	Minimum	Maximum	Mean	Minimum
January	261	176	101	269	179	103
February	266	161	99	274	166	102
March	271	167	97	291	179	104
April	1,029	508	128	1,059	525	131
May	2,084	1,003	432	2,325	1,123	482
June	2,214	1,298	671	2,337	1,371	709
July	2,737	1,385	663	2,789	1,479	709
August	1,744	967	547	1,893	1,049	594
September	1,508	739	382	1756	798	410
October	1,039	554	273	1212	605	296
November	635	324	155	712	364	173
December	353	202	107	375	214	114

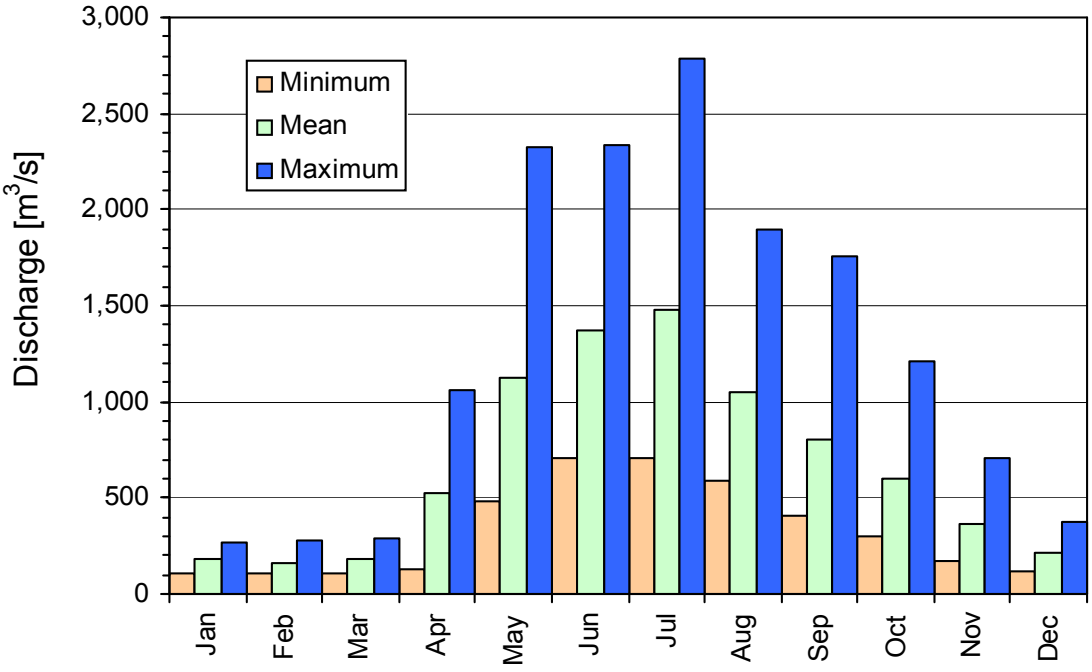
[a] Based on recorded flows for the period 1957 to 2006 at the Environment Canada hydrometric stations.

[b] Based on recorded and derived flow series for the period 1957 to 2006.

a. Athabasca River Monthly Flows below Fort McMurray (1957-2006)



b. Derived Athabasca River Monthly Flows at Embarras Airport (1957-2006)



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE **ATHABASCA RIVER MONTHLY FLOWS BELOW FORT McMURRAY (1957 TO 2006) AND DERIVED ATHABASCA RIVER MONTHLY FLOWS AT EMBARRAS AIRPORT (1957 TO 2006)**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Monthly flows
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.3-8**	
CHECK	KM	17/08/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-8 Athabasca River Monthly Flows-1957-2006.dwg Nov 22, 2007 - 5:02pm

The results of the analysis suggest a statistically significant trend at the 5% level for annual mean flow, and the mean flow in the spring, fall and winter seasons for the Athabasca River below Fort McMurray. The results also indicate a decrease in the summer, annual daily maximum and 7-day low flows; however, these trends are not statistically significant at the 5% level. The corresponding detailed data for the streamflow trend analysis are presented in Appendix B.

Flood Flows

A frequency analysis of annual maximum daily discharge series was used to determine the 2-year, 10-year and 100-year flood peak discharges at selected locations on the lower Athabasca River (Table 2.3-17). The 100-year flood peak discharge is estimated to be approximately 5,500 m³/s in the lower Athabasca River.

Table 2.3-17 Daily Flood Peak Discharges on the Lower Athabasca River

Parameter	Fort McMurray Station[(a)]	Below Muskeg River[(b)]	RAMP Station S24[(b)]	Embarras Airport Station[(c)]
drainage area [km^2]	133,000	136,800	146,500	155,000
frequency distribution	Log Pearson III	n/a	n/a	Log Pearson III
maximum daily flood peak discharge [m^3/s]	4,700 (in 1971)	4,709	4,731	4,751 (in 1986)
100-year daily flood peak discharge [m^3/s]	5,532	5,516	5,476	5,440
10-year daily flood peak discharge [m^3/s]	3,734	3,747	3,781	3,810
2-year daily flood peak discharge [m^3/s]	2,369	2,391	2,446	2,495

(a) Based on recorded flows for the period 1957 to 2006.

(b) Estimated based on drainage areas.

(c) Based on recorded and derived flow series for the period 1957 to 2006.

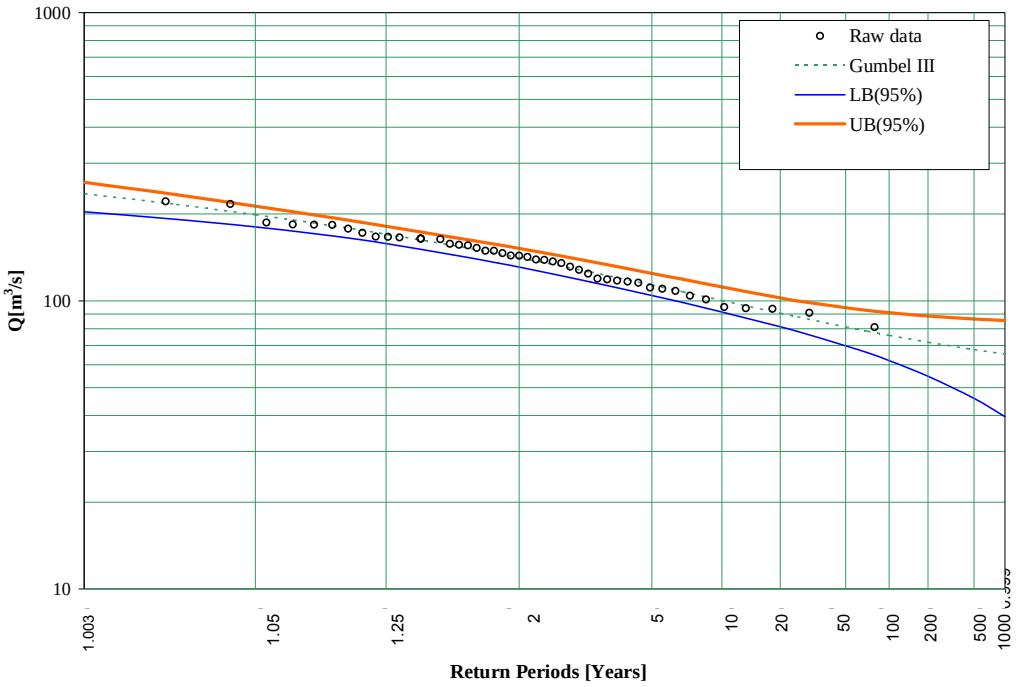
n/a = Not applicable.

Low Flows

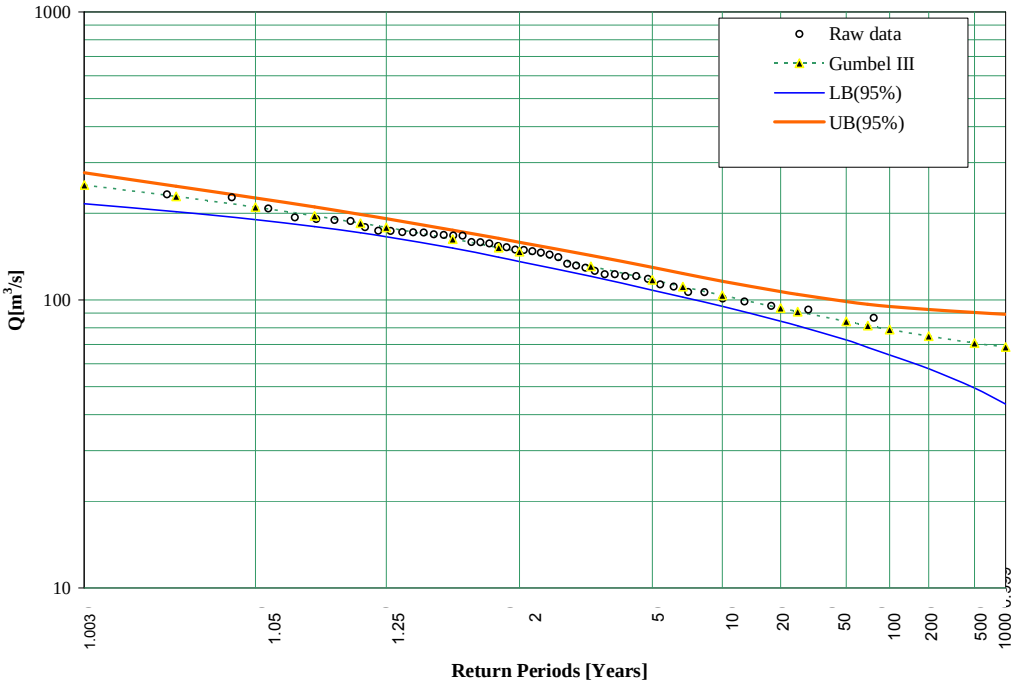
The low flow period for the Athabasca River is the winter months, typically between November and March. Therefore, the hydrologic year (September to August) rather than a calendar year (January to December) was used for the frequency analysis of the low flows to ensure that annual low flow events are independent of each other.

An annual minimum daily discharge series and 7-day low flow series were developed. A frequency analysis was used to determine the 2-year, 10-year and 100-year low flow discharges at each station (Table 2.3-18). Figure 2.3-9 shows the frequency curve for recorded 7-day low flows of the Athabasca River at Fort McMurray and at Embaras Airport Station. The lowest daily flow recorded below Fort McMurray was 75 m^3/s in 2001. The 7Q10 low flow (7 day low flow with a 10-year return period) was estimated to be 100 m^3/s near Fort McMurray and 104 m^3/s at the Embarras Airport Station.

(a) Athabasca River Below Fort McMurray



(b) Athabasca River River of Embarras Airport



NOTES
LB=LOWER BOUND
UB=UPPER BOUND

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
FREQUENCY CURVE FOR RECORDED 7-DAY LOW FLOWS OF THE ATHABASCA RIVER

Shell Canada Limited

PROJECT	05.1344.027.6600		FILE No.	Frequency Flows
DESIGN	KM	22/10/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.3-9**	
CHECK	AS	18/11/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-9 Frequency Plots.dwg Nov 22, 2007 - 5:16pm

Table 2.3-18 Low Flow Statistics of the Lower Athabasca River

Parameter	Fort McMurray Station[(a)]	Below Muskeg River[(b)]	RAMP Station S24[(b)]	Embarras Airport Station[(c)]
drainage area	133,000 km^2	136,800 km^2	146,500 km^2	155,000 km^2
Daily Low Flow				
frequency distribution	Gumbel III	n/a	n/a	Gumbel III
2-year daily low flow [m^3/s]	138	139	141	142
10-year daily low flow [m^3/s]	96	97	98	100
100-year daily low flow [m^3/s]	70	71	73	75
highest annual daily low flow on record [m^3/s]	213 (in 1997)	215	221	227 (in 1997)
lowest annual daily low flow on record [m^3/s]	75 (in 2001)	76	78	80 (in 2001)
7Q (mean flow over a duration of 7 days) Low Flow				
frequency distribution	Gumbel III	n/a	n/a	Gumbel III
highest annual 7Q low flow on record [m^3/s]	221 (in 1997)	223	228	233 (in 1997)
7Q10 [m^3/s] (7Q low flow with a 10-year return period)	100	101	102	104
lowest annual 7Q low flow on record [m^3/s]	81 (in 2001)	82	85	87 (in 2001)

(a) Based on recorded flows for the period 1957 to 2006.

(b) Estimated based on drainage areas.

(c) Based on recorded and derived flow series for the period 1957 to 2006.

n/a = Not applicable.

Flood Risk Mapping

As shown in Figure 2.3-10, the proposed west end location of the Athabasca River bridge crossing is located at the east side of the PRMA proposed development area, about 1.8 km south of the mouth of Eymundson Creek. The proposed location of the PRMA water intake, also shown in Figure 2.3-10, is on the east side of Lease 17, north of the confluence of Lease 17 East Creek with the Athabasca River.

Table 2.3-19 indicates the flood levels for the 6.3-km reach of the Athabasca River where the proposed river crossing is located. In Figure 2.3-10, the flood risk limits for the 2-, 10- and 100-year flood events have been delineated, providing information for any hydraulic structure design and for evaluation of the effects of any potential encroachment on the Athabasca River.

R.11

R.10 W4M

R.9 W4M

T.99

T.98

First Creek

Eymundson Creek

Asphalt Creek

Unnamed Creek 1

Lease 17 East Creek

RIVER INTAKE

#3

#4

#5

#6

#7

#8

#9

#10

#11

#12

BRIDGE

ACCESS ROAD AND UTILITY CORRIDOR

Athabasca River

LEGEND

PIERRE RIVER MINING AREA

2 -YEAR FLOOD LEVEL

10 -YEAR FLOOD LEVEL

100 -YEAR FLOOD LEVEL

STREAM FLOW DIRECTION

1 0 1

SCALE 1:50,000 KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**FLOOD RISK MAP
FOR 2-, 10-, AND 100-YEAR FLOOD EVENTS**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No. FloodRisk-2-10-100	
DESIGN	PW	08/05/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.3-10**	
CHECK	KM	17/08/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-10_PRM-Flood Risk Map.dwg Nov 23, 2007 - 11:41am

Table 2.3-19 Flood Levels for the Lower Athabasca River

Cross Section	Flood Water Level [masl]		
	2-Year	10-Year	100-Year
12	228.29	229.40	230.49
11	228.10	229.22	230.31
10	228.00	229.12	230.20
9	227.80	228.91	229.98
8	227.57	228.68	229.75
7	227.36	228.48	229.55
6	227.16	228.26	229.31
5	226.97	228.06	229.08
4	226.79	227.87	228.88
3	226.54	227.62	228.62

Sediment Transport

The Athabasca River below Fort McMurray, with a drainage area of 133,000 km^2, has an estimated mean annual sediment yield of 0.0316 mm (Table 2.3-20). This estimate is based on the analysis of 1,387 bed load measurements by Environment Canada between 1967 and 1972.

The mean annual sediment yields for the large gauged basins vary from 0.0005 mm per year in the Muskeg River to 0.0617 mm per year in Joslyn Creek (Table 2.3-20). The large gauged basins range in drainage area from 151 km^2 (Poplar Creek) to 133,000 km^2 in the Athabasca River. Sediment yield and drainage area do not appear to be correlated.

A summary of the recorded TSS data in the Athabasca River is presented in Table 2.3-21. The TSS concentrations in the summer period are generally higher than the rest of the year.

Table 2.3-20 Mean Annual Sediment Yields of Large Basins Gauged by Environment Canada

Basin Name and Hydrometric Station Gauge Number	Drainage Area [km^2]	Period of Record	Number of Samples	Mean Annual Sediment Yield [mm]
Poplar Creek (07DA007)[(a)]	151	1974 to 1983	829	0.0088
Beaver River (07DA018)	165	1976 to 1980	43	0.0074
Joslyn Creek (07DA016)	257	1976 to 1983	56	0.0617
Jackpine Creek (07DA009)	358	1976 to 1983	57	0.0015
Steepbank River (07DA006)	1,320	1975 to 1983	59	0.0154
Muskeg River (07DA008)	1,432	1976 to 1983	57	0.0005
Ells River (07DA017)	2,450	1976 to 1983	56	0.0204
MacKay River (07DB001)	5,570	1975 to 1983	50	0.0134
Firebag River (07DC001)	5,990	1976 to 1983	46	0.0036
Athabasca River (07DA001)	133,000	1967 to 1972	1,387	0.0316

(a) Recorded sediment yield at Poplar Creek is prior to diversion of flow from the Beaver River basin into Poplar Creek.

Table 2.3-21 Total Suspended Solids Concentrations (mg/L) in the Athabasca River Watershed

Data Source	Period of Record	Winter (November to March)				Spring (April to May)				Summer (June to August)				Fall (September to October)			
		Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count
Athabasca River between Fort McMurray and Muskeg River	1960 to 2006	3	<0.4	92	175	58	<0.4	1,090	69	145	≤0.8	2,602	196	16	<1	386	158
Athabasca River between Muskeg River and Firebag River	1968 to 2006	4	≤0.4	146	65	61	18	276	25	123	10	1,702	78	17	<1	317	63
Athabasca River between Firebag River and Embarras River	1987 to 2006	4	<0.4	76	51	52	<1	419	23	116	22	505	51	22	4	197	36

Note: Based on data collected by Alberta Environment, RAMP and the Project field program.

Geomorphic Conditions

The lower Athabasca River below Fort McMurray can be characterized as being entrenched in limestone, straight, with occasional islands, some mid-channel bars and laterally stable (Kellerhals et al. 1972). The reach is expected to become more stable over time based on low gradient and lack of evidence of abrupt avulsion events. The river transports predominantly fine to medium sand, with lesser amounts of gravel, course sand and fines. The flow velocity in the river has exceeded 2 m/s during floods. Flood events are typically of short duration and have limited geomorphic impact (Catto 1995).

2.3.2.2 Firebag River

Physical Setting and Hydrological Conditions

The Firebag River originates in Saskatchewan and flows westward through northeastern Alberta to join the Athabasca River north of Fort McMurray. The Firebag River is about 160 km long and falls from an elevation of about 550 masl in Saskatchewan to about 225 masl at the Athabasca River. The average river slope is about 0.2%. The eastern segment of the river flows through high relief terrain, the central portion through undulating moraine and the western segment through undulating glaciofluvial terrain. The channel is meandering except for a short central segment through wetlands where it is relatively straight. The incised alluvial plane increases downstream from 3 to 30 m deep, and from 0.5 to 3 km wide (Fenton and Mougeot 1983). The riverbed is armoured with cobbles and boulders; sand is present mainly at the junction with tributary streams and on point bars.

Daily flows in the Firebag River at its mouth are lowest usually between December and March, with the lowest flow on record of 4.2 m^3/s having occurred on October 25, 1981. Rising temperatures melt the snow on the ground in the spring. The resulting runoff increases flows in the river and, in most years, generates the annual flood. In some years, the annual flood can be caused by intense rain storms in late summer or early fall. The floods have occurred in May and August, with the highest flood on record of 238 m^3/s having occurred on August 10, 1973.

Flood hydrographs, whether in the spring or fall, tend to have steep rising and falling limbs. The hydrograph shape is related to the high relief in the upper portion of the basin and the incised, or sharply notched, flood plain at the mouth. River flows generally decrease from June onwards, with occasional increases due to rain events.

Basin Water Yields

Firebag River flows are currently monitored at a hydrometric station near the mouth. This station is monitored by Environment Canada (as Station 07DC001) during open-water season and by RAMP during the winter season (as Station S27). The gauge location has a drainage area of 5,990 km^2. The average flow at the gauge location is 25.9 m^3/s, which is equivalent to an annual water yield of 136 mm based on recorded flows between 1971 and 2006. The yield from the Firebag River is the highest among the large regional gauged watersheds. During a typical year (Table 2.3-22, Figure 2.3-11), the monthly discharge of the Firebag River at its mouth is highest (56.9 m^3/s) during May and lowest (8.9 m^3/s) during February.

Table 2.3-22 Monthly Flows of the Firebag River

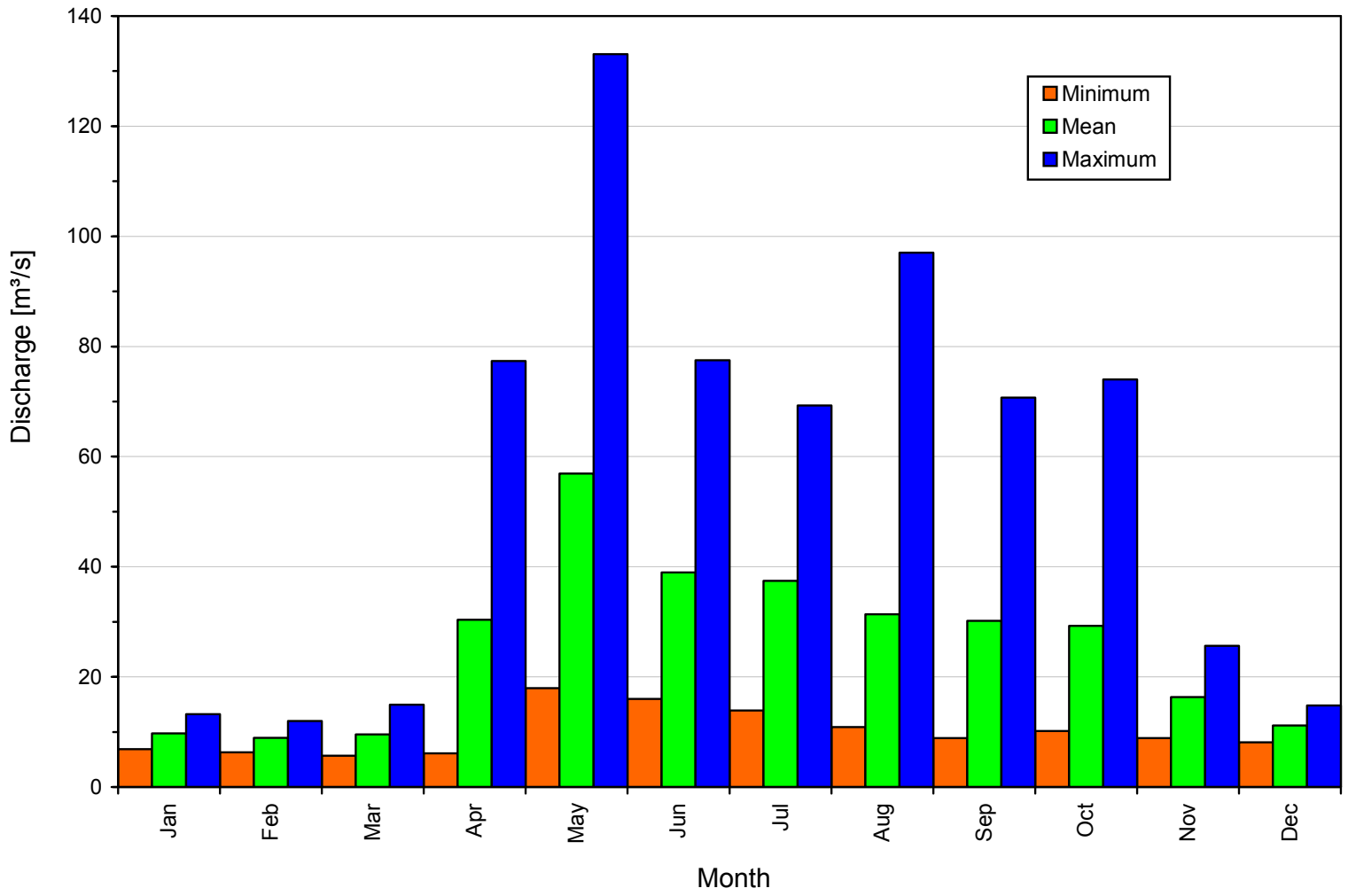
Month	Monthly Discharge [m^3/s]		
	Maximum	Mean	Minimum
January	13.2	9.8	6.9
February	12.0	8.9	6.3
March	15.0	9.5	5.7
April	77.4	30.4	6.1
May	133.1	56.9	18.0
June	77.5	39.0	16.0
July	69.3	37.4	13.9
August	97.0	31.4	10.9
September	70.7	30.2	8.9
October	74.0	29.3	10.2
November	25.6	16.3	8.9
December	14.8	11.2	8.1

Note: Based on recorded data by Environment Canada (Station 07DC001) and RAMP (Station S27) from 1971 to 2006.

Flood Flows

Annual floods in the Firebag River can be caused by either snowmelt runoff in the spring or rainstorms during late summer or early fall. Although spring floods tend to be more common, summer or fall floods can be equally high. A frequency analysis of annual floods based on data available from 1971 to 2006 indicated that for the Firebag River, the 2-year peak flood is 101 m^3/s, the 10-year is 177 m^3/s and the 100-year peak flood is 284 m^3/s (Figure 2.3-11).

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.3-11 Firebag River Monthly Flow.dwg Nov 23, 2007 - 9:41am



NOTE
BASED ON REWARDED DATA BY GOVERNMENT CANADA (STATION 07 DC 001) AND RAMP (STATION S27) FROM 1971 TO 2006.

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
FIREBAG RIVER MONTHLY FLOWS

Shell Canada Limited

PROJECT 05-1344-027.6650		FILE No. Flows of firebag river
DESIGN	KM	09/07/07
CADD	TY	18/11/07
CHECK	KM	17/08/07
REVIEW	WES/TC	20/11/07

SCALE AS SHOWN REV. 0

FIGURE: 2.3-11

Low Flows

The 2-year (8.47 m^3/s) and 10-year (661 m^3/s) monthly low flows and 7Q10 low flows (5.95 m^3/s) were derived for the Firebag River gauging station with data from 1971 to 1986.

Sediment Transport

The Firebag River, with a drainage area of 5,990 km^2 at its mouth, has an estimated mean annual sediment yield of 0.0036 mm. This estimate is based on analysis of 46 bed load measurements by Environment Canada between 1976 and 1983. A bed load is the amount of sediment that is transported along the bottom of the river bed per unit time.

A summary of the recorded TSS data in the Firebag River shows that TSS concentrations historically are greater during snowmelt (Table 2.3-23).

Geomorphic Conditions

The reach of the Firebag River within the RSA (Figure 2.1-1) is a well-defined irregular meandering stream with mainly cobble and gravel substrate. Undercut banks exposing granular and root matrix materials do not resemble the substrate material. The banks are well vegetated with grasses and shrubs near the stream and deciduous trees about 20 to 30 m back from the bankfull stage.

2.3.2.3 McClelland Lake

Physical Setting and Hydrological Conditions

McClelland Lake is located at the east side of the Athabasca River about 85 km north of Fort McMurray, Alberta. The lake has a surface area of approximately 29.9 km^2, an average depth of 1.0 m and a maximum depth of about 5.0 m. A small unnamed waterbody located southeast of McClelland Lake (Unnamed Waterbody 4, as shown in Figure 2.1-2) is linked to McClelland Lake by a 2-km-long stream.

Table 2.3-23 Total Suspended Solids Concentrations (mg/L) in the Firebag River Watershed

Data Source	Period of Record	Winter (November to March)				Spring (April to May)				Summer (June to August)				Fall (September to October)			
		Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count
Firebag River	1976 to 2006	4	≤1	13	33	11	4	70	9	7	≤1.2	18	12	5	<0.4	17	14

The geomorphic character of the McClelland Lake outflow conveyance system varies greatly from the lake outlet to the confluence with Firebag River. The upper reach of the McClelland Lake outlet channel has a total length of about 7.9 km and is characterized by small conveyance channels, some of which are ill-defined or unidentifiable for a distance of up to 2.2 km. The upper reach is situated in a large wetlands floodplain with dense vegetation and variable lateral extents. The middle reach of the McClelland Lake outlet channel has a total length of about 2.3 km and is characterized by a well-defined grassed waterway. The downstream reach of the creek, with a total length of about 10 km, has a well-defined channel and incised valley near its mouth to Firebag River.

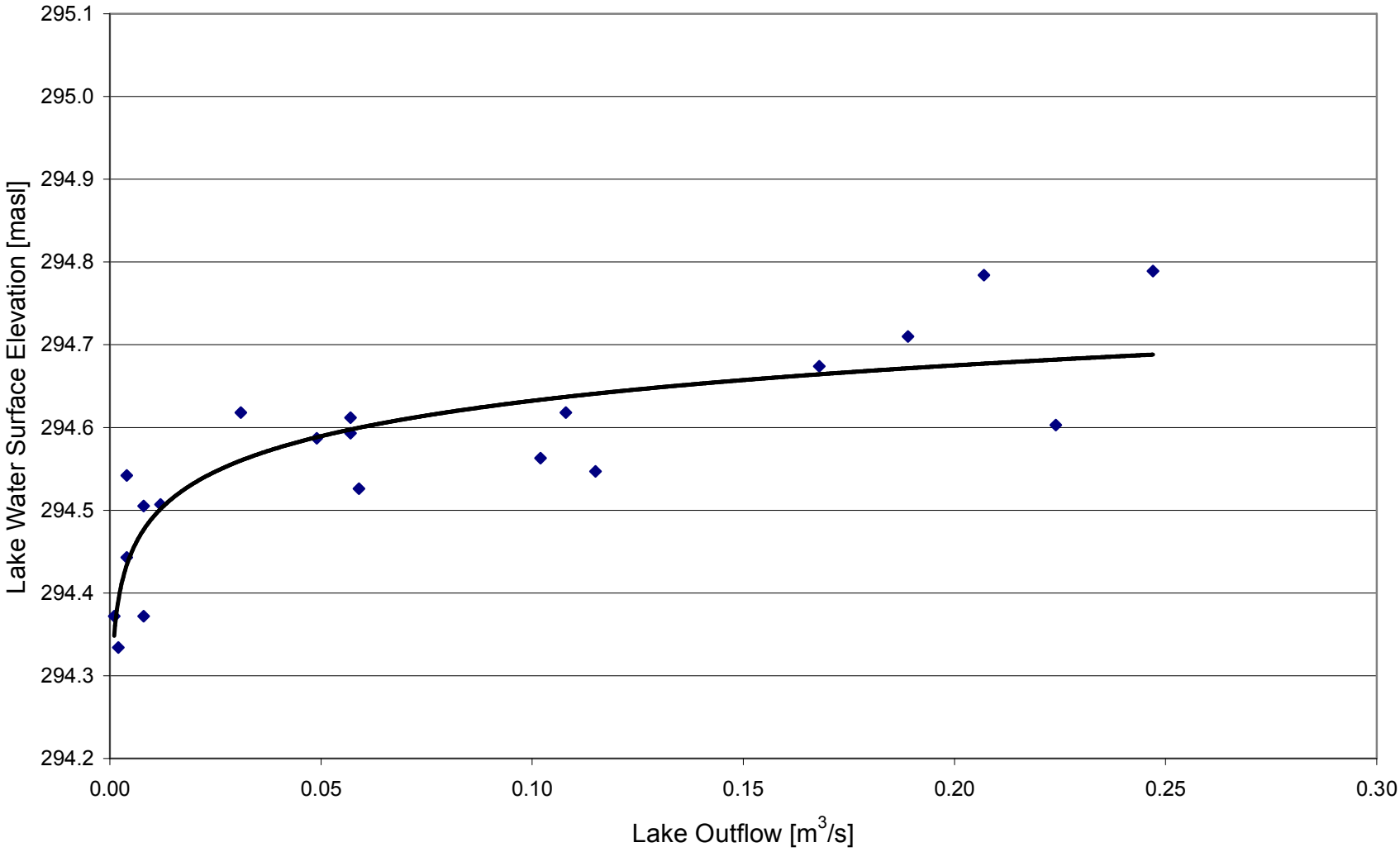
Most of the upper and middle reaches of the McClelland Lake outlet channel appear to convey water in an intermittent fashion, and only convey flows during wet periods, when McClelland Lake has significant outflows during wet cycles and floods. During dry periods, the upper and middle reaches can be completely dry with no water in the channels. The lower reach of the McClelland Lake outlet channel appears to be a permanent stream, conveying flows including surface runoff and groundwater seepage.

Lake Water Levels

Monitoring data collected by RAMP between June 1997 and December 2006 indicated that the water level of McClelland Lake fluctuated by 1.65 m between 294.78 and 293.13 masl. The average lake water level was 294.44 masl. Shell conducted a water level survey of McClelland Lake and Unnamed Waterbody 4 to determine their geodetic lake water elevation. This information was required to understand the hydrology of the connection between the two lakes.

Inflows and Outflows

A relationship between lake water level and lake outflow, referred to as an outflow rating curve (Figure 2.3-12), was needed to determine lake outflows. This relationship was developed based on the recorded flow measurements by RAMP from 1997 to 2006.



NOTE

BASED ON RAMP DATA COLLECTED FROM JUNE 1997 TO DECEMBER 2006.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

OUTFLOW RATING CURVE FOR McCLELLAND LAKE

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Rating curve	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	18/11/07	**FIGURE: 2.3-12**		
CHECK	KM	17/08/07			
REVIEW	WES/TC	20/11/07			

2.3.3 Athabasca River Water Use

2.3.3.1 Current Existing and Approved Water Allocations

Table 2.3-24 presents a summary of current Alberta *Water Act* licence allocations for surface water withdrawals from the Athabasca River and its tributary streams and the return flows. The total approved annual water allocations to the non-oil sands users is about 337 million m^3. The total annual net water allocation, which is defined as the total allocations minus return flows, is about 189 million m^3. This accounts for less than 1% of the annual river water yield of about 19.9 billion m^3 estimated for the Athabasca River at Fort McMurray.

The total net water allocation for the existing and approved oil sands developments is about 464 million m^3. The represents 76% of the total net water allocation of 611 million m^3 in the Athabasca River basin. The net annual water allocation to the existing and approved oil sands developments represents about 2.1% of the annual water yield estimated for the Athabasca River at Fort McMurray.

Table 2.3-24 Approved Water Allocations From Athabasca River and its Tributaries

Purpose	Existing Annual Licences and Licence Applications for Water Allocations[a] [dam^3]				
	Interim Licences	Licences	Total Withdrawals	Return Flows	Net Water Allocations
Non-Oil Sands Water Allocations					
agricultural	24	742	766	0	766
commercial	4,783	149,556	154,339	123,562	30,777
dewatering[b]	280	35,367	35,647	1,293	34,354
habitat enhancement	14	1,413	1,427	0	1,427
industrial	4,517	90,054	94,571	2,772	91,799
irrigation	37	3,631	3,668	1,381	2,287
municipal	7,997	34,643	42,641	34,851	7,790
water management	0	21,592	21,592	2,221	19,371
other use	2	154	155	2	154
subtotal	*17,654*	*337,152*	*354,805*	*166,081*	*188,723*
Existing and Approved Oil Sands Developments[c]					
Suncor	0	62,825	62,825	38,655	24,170
Syncrude	0	60,441	60,441	0	60,441
Albian Sands	0	55,100	55,100	0	55,100
Fort Hills	0	39,270	39,270	0	39,270
Shell	0	63,500	63,500	0	63,500
Canadian Natural	0	79,320	79,320	0	79,320
Imperial Kearl	0	104,000	104,000	0	104,000
subtotal	*0*	*464,456*	*464,456*	*38,655*	*425,801*
Grand Totals [dam^3]	**17,654**	**801,608**	**819,261**	**204,737**	**614,524**

[a] 1 dam^3 = 1,000 m^3.

[b] Except for oil sands mines.

[c] Some operators have staged water licence withdrawal amounts. The water licence withdrawal amounts stated are the higher withdrawal on their licences.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

Data Source: Golder 2005.

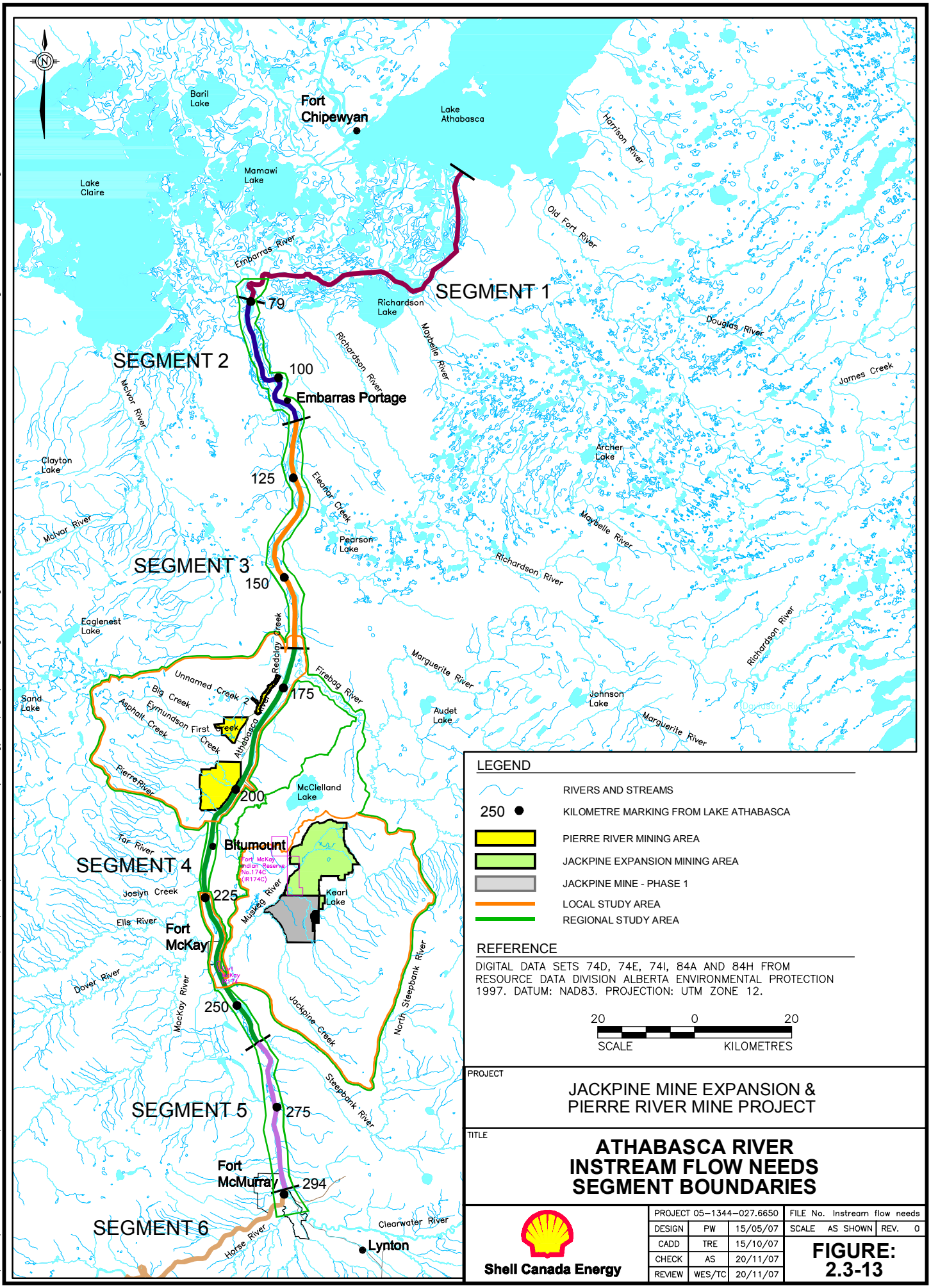
2.3.3.2 Athabasca River Water Management Framework

Under the (Alberta Environment/Fisheries and Oceans Canada Water Management Framework Phase 1), withdrawals from the Athabasca River by oil sands projects are restricted by management actions under specific river flow conditions (green, yellow and red) for each week of the year. Phase 1 is in effect until December 31, 2010. Phase 2 takes effect January 1, 2010 and will be in place when this project will be requiring water from the Athabasca. Phase 2 requirements are not known at this time and may be either more or less restrictive than Phase 1.

The oil sands water withdrawals occur in Segment 4 and any impacts could also affect the downstream reaches. As shown in Figure 2.3-13:

- Segment 5 begins slightly downstream of Fort McMurray and ends upstream of the confluence with the Steepbank River.
- Segment 4 begins upstream of the confluence with the Steepbank River and ends upstream of the confluence with the Firebag River.
- Segment 3 begins upstream of the confluence with the Firebag River and ends upstream of the confluence with the Embarras River.
- Segment 2 begins upstream of the confluence with the Embarras River and ends at Embarras Portage.
- Segment 1 begins upstream of the confluence with the Embarras River and ends at Embarras Portage.

The Project LSAs lie entirely on or adjacent to Segment 4. The RSA includes Segments 3, 4 and 5.


Baril Lake
Fort Chipewyan
Lake Athabasca
Harrison River
Lake Claire
Mamawi Lake
Old Fort River
Embarras River
SEGMENT 1
79
Richardson Lake
Douglas River
Maybelle River
Richardson River
SEGMENT 2
100
Embarras Portage
McIvor River
James Creek
Clayton Lake
Archer Lake
125
Eleanor Creek
Pearson Lake
SEGMENT 3
150
Eaglenest Lake
Redclay Creek
Unnamed Creek 2
Firebag River
175
Sand Lake
Big Creek
Asphalt Creek
Eymundson First Creek
Athabasca River
Marguerite River
Audet Lake
Johnson Lake
Pierre River
200
McClelland Lake
Tar River
Bitumount
SEGMENT 4
Fort McKay Indian Reserve No.174C (IR174C)
Joslyn Creek
225
Muskeg River
Kearl Lake
Ells River
Fort McKay
Dover River
MacKay River
250
Jackpine Creek
North Steepbank River
Steepbank River
SEGMENT 5
275
Fort McMurray
294
SEGMENT 6
Clearwater River
Horse River
Lynton
LEGEND
RIVERS AND STREAMS
250 KILOMETRE MARKING FROM LAKE ATHABASCA
PIERRE RIVER MINING AREA
JACKPINE EXPANSION MINING AREA
JACKPINE MINE - PHASE 1
LOCAL STUDY AREA
REGIONAL STUDY AREA
REFERENCE
DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.
20 0 20
SCALE KILOMETRES
PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT
TITLE
ATHABASCA RIVER INSTREAM FLOW NEEDS SEGMENT BOUNDARIES
Shell Canada Energy
PROJECT 05-1344-027.6650
FILE No. Instream flow needs
DESIGN PW 15/05/07
SCALE AS SHOWN REV. 0
CADD TRE 15/10/07
CHECK AS 20/11/07
REVIEW WES/TC 20/11/07
FIGURE: 2.3-13
L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\ Drawing file: Fig 2.3-13 Athabasca River Instream flow Needs Segment Boundaries.dwg Nov 23, 2007 - 9:59am

2.4 JACKPINE EXPANSION MINING AREA RESULTS

2.4.1 Climate

2.4.1.1 Air Temperature

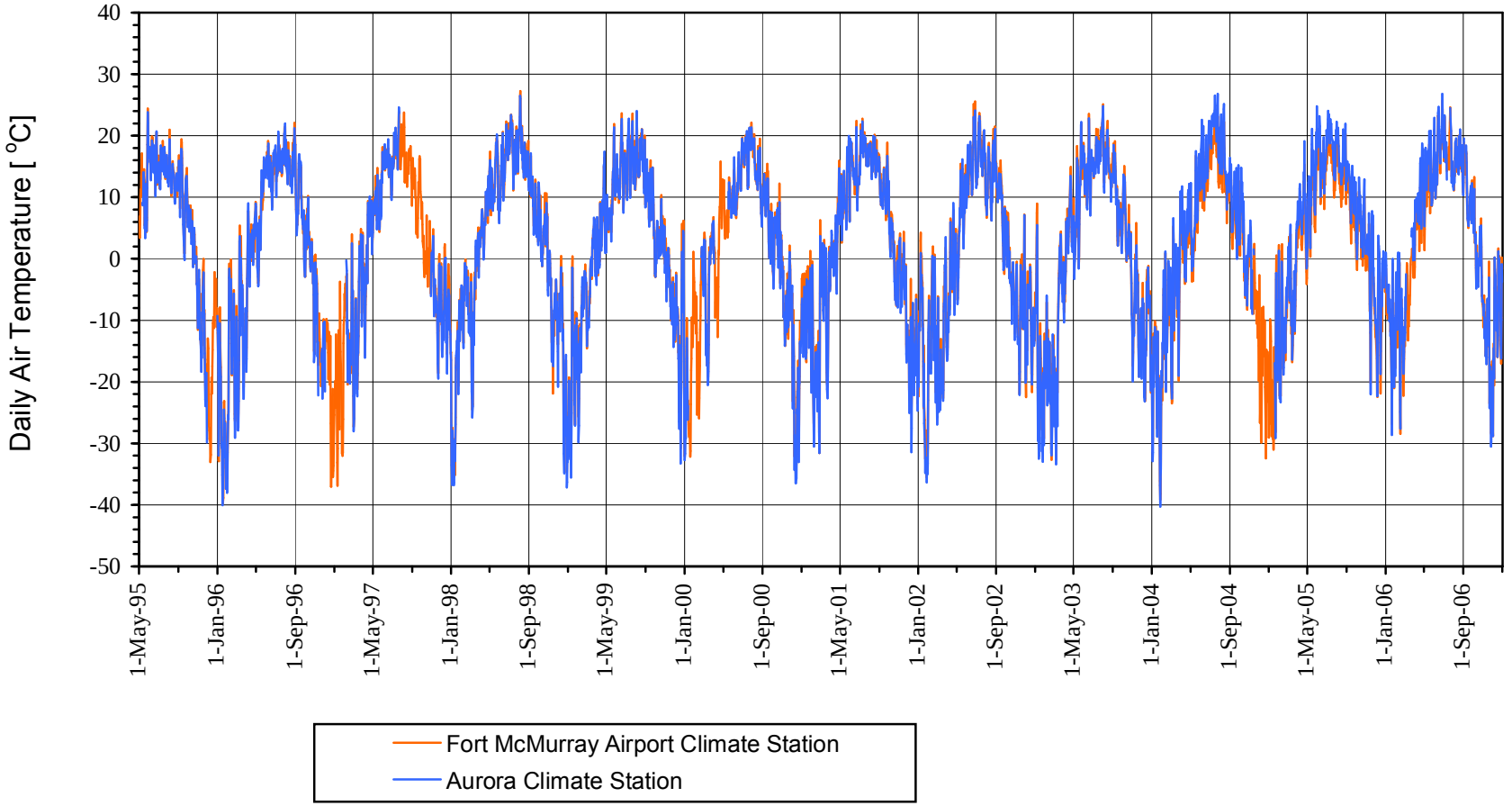
Comparing the recorded daily air temperatures at the Fort McMurray Airport and Aurora climate stations between May 1995 and December 2006 (Figure 2.4-1), a 0.7°C difference in the mean air temperatures was noted. Similar standard deviations of 13.5°C and 13.6°C, respectively, were also noted. This similarity of daily air temperature means and deviations between these two stations suggests that the long-term air temperature data and statistics at Fort McMurray (Section 2.3.1.1) are representative of conditions in the JEMA LSA.

The effects of elevation on temperature were also considered. Comparing variation of mean monthly air temperature with elevation at regional lookout stations for the summer months of June and July (Golder 2003), air temperature was found to decrease with increasing elevation at a lapse rate of about 0.5°C per 100 m. Considering this correlation, the JEMA LSA, at a mean elevation of 352 masl, would have a temperature increase of 0.1°C from that of Fort McMurray, at a mean elevation of 369 masl.

2.4.1.2 Precipitation

The regional precipitation data from Fort McMurray were adjusted for elevation to derive precipitation values for the JEMA LSA. The data were multiplied by an adjustment coefficient based on a regression equation between precipitation and elevation (Golder 2003). The adjustment coefficient of precipitation, 0.986, was estimated and applied to all the precipitation values derived for the RSA in Section 2.2.2.2 for the JEMA LSA (mean elevation of 352 masl).

The mean annual precipitation in the JEMA LSA was estimated to be 433 mm. Based upon regional precipitation data, the precipitation was estimated to be 75% rainfall (mean annual rainfall of 325 mm) and 25% snowfall (mean annual snowfall of 108 mm). The 10-year wet annual precipitation is estimated to be 557 mm and the 10-year dry annual precipitation is estimated to be 320 mm.



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DAILY AIR TEMPERATURES AT FORT McMURRAY AIRPORT AND AURORA CLIMATE STATIONS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Daily air temp
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.4-1	
CHECK	AS	18/11/07		
REVIEW	WES/TC	20/11/07		

The Environment Canada rainfall IDF data for the Fort McMurray Airport climate station were also adjusted for elevation using an adjustment coefficient of 0.986. The 24-hour rain with a 10-year return period is estimated to be 66.0 mm in total or 2.75 mm/h. The 24-hour rain with a 100-year return period is estimated to be 99.8 mm in total or 4.16 mm/h.

2.4.2 Hydrology

2.4.2.1 Muskeg River Watershed

Physical Setting and Hydrological Conditions

The Muskeg River is one of the major tributaries of the lower Athabasca River. The river originates in the western slopes of the Muskeg Mountain. It drains west into a lowland area and collects flows from several tributaries as it drains in the southwest direction toward the Athabasca River. Major tributaries of the Muskeg River in the JEMA LSA include:

- Wapasu Creek;
- Muskeg Creek and tributaries including Wesukemina, Iyinimin and Khahago creeks;
- Stanley Creek; and
- Jackpine Creek.

Kearl Lake also lies within the Muskeg River watershed. The locations of the Muskeg River and its tributaries, as well as the locations of hydrometric stations in the basin, are shown in Figure 2.2-2.

Muskeg River

The Muskeg River basin has a drainage area of 1,476 km^2 at the river mouth, which includes an upland area of 748.6 km^2 (or 51% of the total drainage area), a lowland area of 721.7 km^2 (or 49% of the total area) and a lake area of 5.5 km^2.

The Muskeg River watershed is mostly flat, except for Muskeg Mountain on the east side of the upper watershed. Ground slopes of less than 0.5% are typical of the poorly drained lowland area. Slopes of 1 to 3% are typical of the better-drained upland areas at elevations above 340 masl.

The dominant surficial soils within the JEMA are fen soils. These soils are highly absorbent, usually poorly drained and have a high groundwater table that is at or near the ground surface following the spring snowmelt. The fen soils in the

JEMA are typically 0.5 to 2 m thick and lay over relatively impervious lacustrine (lake origin) deposits.

Vegetation within the JEMA LSA is dominated by willow, shrubs, black spruce and sphagnum moss. Upland areas have a mixed forest cover of coniferous and deciduous trees. Substantial beaver activity occurs in the lowland area of the watershed. Most of the well-defined streams are blocked at numerous locations by beaver dams. Beaver lodges are also present at permanently flooded lowland areas.

Flows in the Muskeg River increase during the spring freshet, when rising temperatures melt the snow and increase runoff. The spring freshet usually peaks in May. Although runoff from rainstorms in late summer or early fall may generate secondary floods, the annual flood usually occurs during the spring freshet.

Existing and approved major oil sands developments in the Muskeg River basin include:

- Syncrude's Aurora North Mine;
- Syncrude's Aurora South Mine;
- Albian Sands' Muskeg River Mine and Expansion;
- Shell's Jackpine Mine – Phase 1;
- Petro-Canada Oil Sands Inc.'s Fort Hills Oil Sands Project; and
- Imperial Oil's Kearl Oil Sands Project.

The major tributaries of Muskeg River (Figure 2.1-2), with current oil sands activities (if any) are as follows:

- **Wapasu Creek:** Wapasu Creek has a total drainage area of 105.4 km^2 at its mouth, which includes an upland area of 56.5 km^2 (or 54% of the total drainage area) and a lowland area of 49.0 km^2 (or 46% of the total area). Currently no development has started in this watershed.
- **Muskeg Creek and tributaries including Khahago Creek and Wesukemina Creek:** Wesukemina Creek and Khahago Creek are tributaries of Muskeg Creek, and Blackfly Creek, Green Stockings Creek and Pemmican Creek are tributaries of Khahago Creek. Kearl Lake discharges into Muskeg Creek. Iynimin Creek discharges into Kearl Lake, and is also within the Muskeg Creek watershed, although it lies outside of the JEMA LSA. Muskeg Creek has a total drainage area

of 352.1 km^2 at its mouth, which includes an upland area of 252.0 km^2 (or 71% of the total drainage area), a lowland area of 94.6 km^2 (or 27% of the total drainage area), and a lake surface area of 5.5 km^2 (less than 2% of the total area). Development has started in the Muskeg Creek watershed as part of the activities associated with Jackpine Mine – Phase 1, including clearing and dewatering activities.

- **Stanley Creek:** The headwaters of Stanley Creek are situated in the sandy Fort Hills. Stanley Creek has a total drainage area of 63.2 km^2, including about 33.5 km^2 of upland area (52%) and 29.7 km^2 of lowland area (48%). Development has started in Stanley Creek watershed as part of the activities associated with Syncrude Aurora North. As of 2005, a clean water ditch (for overburden and muskeg dewatering) has been developed that intercepts Stanley Creek at the toe of the Fort Hills, where Stanley Creek disperses into the muskeg, upstream of where it enters the Muskeg River.

- **Jackpine Creek:** Jackpine Creek is one of the major tributaries of the Muskeg River and has a total drainage area of 366.7 km^2 at its mouth, which includes an upland area of 218.7 km^2 (or 60% of the total drainage area) and a lowland area of 148.0 km^2 (or 40% of the total area). The current development of Jackpine Mine – Phase 1 External Tailings Disposal Area (ETDA) extends into this watershed and has a very small effect on Jackpine Creek flows.

- **Muskeg River:** Development has started in the lower reach of Muskeg River below Muskeg Creek as part of the close-circuit, muskeg draining or overburden dewatering activities associated with Muskeg River Mine, Syncrude Aurora North and Jackpine Mine – Phase 1.

Basin Water Yields

The simulated daily flows at various locations in the Muskeg River watershed were analyzed to obtain the mean annual water yields, shown in Table 2.4-1. The annual water yield depends mainly on the drainage area and the ratio of upland area to lowland area. The upland area is generally well drained and has a higher basin water yield. The lowland area is flat, poorly drained and has a lower basin water yield.

Table 2.4-1 Simulated Mean Annual Water Yields for the Muskeg River and Major Tributaries

Name	Drainage Area [km^2]				Annual Water Yield	
	Upland Area	Lowland Area	Lake Area	Total Area	[m^3/s]	[mm]
Wapasu Creek	56.5	49.0	n/a	105.4	0.28	83.7
Stanley Creek	33.5	29.7	n/a	63.2	0.18	88.2
Iyinimin Creek	62.6	9.2	n/a	71.7	0.24	106.2
Muskeg Creek	252.0	94.6	5.5	352.1	0.98	88.1
Khahago Creek	151.8	29.7	n/a	181.5	0.56	97.1
Wesukemina Creek	37.6	11.3	n/a	48.9	0.14	92.6
Jackpine Creek	218.7	148.0	n/a	366.7	1.01	86.7
Muskeg River below Wapasu Creek	244.5	143.1	n/a	387.6	1.14	93.0
Muskeg River (S5A)	277.9	259.7	n/a	537.6	1.44	84.7
Muskeg River at Environment Canada Station	748.6	678.1	5.5	1,432	3.68	81.1
Muskeg River at the mouth	748.6	721.7	5.5	1,476	3.75	80.1

n/a = Not applicable.

The mean annual water yield at the Muskeg River mouth is estimated to be 80 mm, corresponding to a mean annual discharge of 3.75 m^3/s. The annual water yields vary from 80 to 106 mm when locations on the Muskeg River and its tributaries are compared.

The recorded and simulated monthly flows (record period: 1974 to 2006) at the Environment Canada hydrometric station on the Muskeg River are summarized in Table 2.4-2. The maximum mean recorded monthly flow is 10.26 m^3/s (May) and the minimum mean recorded monthly flow is 0.31 m^3/s (February). It is noted that the flow data since 1987 has no winter record from November to February. Recorded daily flows in the river at its mouth are lowest between January and February, with the minimum (0.04 m^3/s) occurring in January 1984. The highest recorded flood discharge was 66.1m^3/s on May 9, 1985.

The monthly flows of Wapasu Creek, Muskeg Creek, Iyinimin Creek, Jackpine Creek and Muskeg River (Node S5A) (Figure 2.2-2) have been simulated for each month of the year (Table 2.4-3).

Table 2.4-2 Monthly Flows at the Environment Canada Hydrometric Station on the Muskeg River

Month	Monthly Discharge [m^3/s]					
	Measured[(a)]			Simulated[(b)]		
	Maximum	Mean	Minimum	Maximum	Mean	Minimum
January	0.65	0.35	0.05	0.53	0.21	0.02
February	0.49	0.31	0.08	1.04	0.15	0.02
March	1.60	0.46	0.18	2.64	0.25	0.01
April	16.62	4.72	0.95	16.27	4.40	0.09
May	34.30	10.26	0.62	48.42	12.61	0.48
June	19.50	7.60	0.66	37.75	5.54	0.17
July	14.36	6.42	0.74	17.77	4.04	0.21
August	21.02	4.71	0.35	20.48	4.29	0.22
September	22.13	5.61	0.17	32.22	5.74	0.18
October	21.05	5.18	0.37	27.28	4.95	0.14
November	5.72	2.13	0.38	6.80	1.70	0.07
December	1.16	0.50	0.15	1.52	0.45	0.04

(a) Based on Environment Canada data collected for the Muskeg River near Fort McKay (1974 to 2006). This record includes winter and open water flows from 1974 to 1988, and open water flows from 1989 to 2006. It includes dewatering flows not taken into account in the simulation.

(b) Period of simulation under natural conditions is 1953 to 2006.

Table 2.4-3 Simulated Monthly Flows of Major Tributaries of the Muskeg River Watershed

Month	Monthly Discharge [m^3/s]											
	Wapasu Creek			Muskeg Creek			Jackpine Creek			Muskeg River (S5A)		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
January	0.003	0.021	0.059	0.001	0.058	0.174	0.005	0.031	0.115	0.010	0.094	0.203
February	0.002	0.010	0.035	0.001	0.046	0.122	0.004	0.021	0.192	0.008	0.055	0.570
March	0.001	0.012	0.099	0.000	0.076	0.706	0.004	0.048	0.518	0.006	0.095	1.375
April	0.006	0.294	1.290	0.043	1.334	4.648	0.019	0.830	3.252	0.022	1.902	6.887
May	0.053	1.004	3.857	0.127	3.326	13.504	0.120	3.679	13.762	0.192	4.657	17.614
June	0.016	0.426	2.926	0.017	1.514	10.232	0.011	1.741	11.217	0.116	1.988	13.347
Jully	0.016	0.302	1.285	0.028	1.129	4.839	0.016	1.110	5.075	0.158	1.683	6.677
August	0.021	0.333	1.713	0.019	1.206	6.141	0.012	1.196	5.874	0.131	1.807	7.940
September	0.008	0.430	1.882	0.011	1.528	6.341	0.009	1.505	8.820	0.109	2.333	10.212
October	0.005	0.350	1.966	0.006	1.131	6.303	0.006	1.374	6.914	0.091	1.922	10.488
November	0.006	0.134	0.491	0.004	0.379	1.604	0.007	0.495	2.043	0.037	0.625	2.669
December	0.004	0.050	0.143	0.001	0.111	0.466	0.005	0.093	0.451	0.017	0.196	0.469

Note: Period of simulation under natural conditions is 1953 to 2006.

Flood Flows

The results of frequency analyses of simulated flood peak discharges are provided for various locations in the Muskeg River watershed and for large gauged basins (Table 2.4-4). Most of the flood peak discharges in the Muskeg River watershed occurred as a result of snowmelt runoff, which typically produced higher peak flows than the rainfall events. The relatively large percentage of lowland area and relatively high storage capacity in the Muskeg River basin tend to reduce the importance of rainfall events in generating annual flood peaks. Based on recorded flows at the Environment Canada Station on the Muskeg River, the 2-, 10- and 100-year annual flood flows are 22.5, 45.9 and 78.1 m^3/s respectively.

Low Flows

Low flows usually occur in the winter from January to March. The two-year and 10-year monthly low flows and the 7-day average low flow with a 10-year return period (7Q10) at various locations in the Muskeg River watershed are based on a simulated flow series. Low flows from large gauged streams are also presented (Table 2.4-5).

The small basins in the Muskeg River watershed are expected to be dry or frozen to the river bed during the extreme low flow conditions (Table 2.4-5). The 7Q10 low flow at the Environment Canada Hydrometric Station on the Muskeg River is estimated to be 0.093 m^3/s based on recorded flows from 1974 to 1987. This compares to the Steepbank River 7Q10 low flow of 0.116 m^3/s.

Table 2.4-4 Flood Peak Discharges in the Muskeg River Watershed and Other Large Gauged Basins

Stream	Drainage Area [km^2]	Flood Peak Discharges for Various Return Periods [m^3/s]		
		2-Year	10-Year	100-Year
Muskeg River and its Tributaries				
Wapasu Creek[a]	105.4	1.92	5.34	12.1
Stanley Creek[a]	63.2	1.44	2.88	4.88
Iyinimin Creek[a]	71.7	2.67	8.08	22.9
Muskeg Creek[a]	352.1	7.33	18.6	45.3
Khahago Creek[a]	181.5	5.35	15.7	38.6
Wesukemina Creek[a]	48.9	1.40	4.38	11.5
Shelley Creek[a]	20.1	0.29	0.80	1.80
Jackpine Creek[a]	366.7	5.78	12.2	21.5
Muskeg River (Node S5A)[a]	537.6	9.84	23.2	42.3
Muskeg River below Wapasu Creek[a]	387.6	7.84	19.2	39.5
Muskeg River at Environment Canada Station	1,432	22.5[a] (22.5)[b]	50.4[a] (45.9)[b]	85.9[a] (78.1)[b]

Table 2.4-4 Flood Peak Discharges in the Muskeg River Watershed and Other Large Gauged Basins (continued)

Stream	Drainage Area [km^2]	Flood Peak Discharges for Various Return Periods [m^3/s]		
		2-Year	10-Year	100-Year
Other Large Gauged Streams				
Poplar Creek[(c)(d)]	151	8.05	17.7	33.3
Beaver River at Environment Canada station 07DA018[(c)]	165	6.73	18.7	43.0
Joslyn Creek[(c)]	257	10.5	22.6	43.3
Big Creek [(c) (e)]	274	3.53	9.61	27.5
Steepbank River[(c)]	1,320	31.5	63.6	98.5
Ells River[(c)]	2,450	34.1	159	656
MacKay River[(c)]	5,570	99.4	230	346
Firebag River[(c)]	5,990	101	177	284

(a) Peak flows were derived from simulated discharges (1954 to 2006).

(b) Peak flows were derived from recorded discharges (1974 to 2006).

(c) Peak flows were derived from recorded discharges (dates are variable).

(d) Recorded flows at Poplar Creek included diverted flows from the Beaver River basin; these values do not represent the natural Poplar Creek basin flows.

(e) Referred to as Unnamed Creek near Fort McKay (07DA011) by Environment Canada.

Table 2.4-5 Low Flow Discharges of the Muskeg River Watershed and Other Large Gauged Basins

Stream	Drainage Area [km^2]	Daily/Monthly Low Flow Discharges for Various Return Periods [m^3/s]		
		2-Year	10-Year	7Q10[(b)]
Daily Flows of Muskeg River and its Tributaries[(a)]				
Wapasu Creek	105.4	0.003	0.001	0.0016
Muskeg Creek	352.1	0.017	0.000	0.0000
Iyinimin Creek	71.7	0.000	0.000	0.0000
Stanley Creek	63.2	0.000	0.000	0.0000
Jackpine Creek	366.7	0.007	0.004	0.0044
Wesukemina Creek	48.9	0.000	0.000	0.0000
Shelley Creek	201	0.000	0.000	0.0000
Muskeg River (Node S5A)	537.6	0.013	0.006	0.0065
Muskeg River below Wapasu Creek	387.6	0.010	0.005	0.0051
Muskeg River at Environment Canada Station	1,432	0.058	0.015	0.0157

(a) Daily low flows of the Muskeg River watershed were derived from simulated discharges (1954 to 2006).

(b) Minimum of 7-day average flow with a 10-year return period.

Sediment Transport

The Muskeg River has an estimated mean annual sediment yield of 0.0005 mm. This is the lowest sediment yield in the region. The Muskeg River annual sediment yield estimate is based on analysis of 57 bed load measurements by Environment Canada between 1976 and 1983.

The TSS concentrations in the region are monitored by Environment Canada, Alberta Environment and RAMP. The recorded data are summarized in Table 2.4-6. The mean annual basin sediment yield was determined based upon data for large gauged basins, as shown in Table 2.3-18. The mean annual basin sediment yield for the JEMA LSA ranges from 0.0005 to 0.0015 mm.

Geomorphic Conditions

Streams in the upland areas convey flows at a higher velocity, because they usually have slopes greater than 0.5%. The upper tributaries of the Muskeg River are incised, or deeply cut, parallel streams that have valley slopes of about 2.5%. They also have a higher drainage density measured as total stream length per unit area. Major streams in the JEMA LSA include Muskeg River, and Jackpine, Muskeg, Khahago and Wapasu creeks (Figure 2.2-2). The upland streams have a sinuosity of 1.3 or less and a bankfull width of about 0.5 to 0.75 m. The channel bed material typically consists of clay and silt.

The upland streams become lowland streams when upland stream slopes are less than 0.5%. The lowland streams are slow-flowing, meandering streams flowing through a poorly drained area characterized by high groundwater. The lowland streams typically have a sinuosity greater than 1.3. Lowland streams frequently consist of cascades of beaver dams.

The geomorphic survey data for the Project supplemental surveys are provided in Table 2.4-7. Additional geomorphic data in the LSA are provided in Appendix C.

2.4.2.2 Kearl Lake

Physical Setting and Hydrological Conditions

Kearl Lake is an important geographical feature in the Muskeg River watershed. The lake is fed by flows from Iyinimin Creek and local runoff from surrounding area. The total drainage area at the lake outlet is 92.1 km^2, including:

- 62.6 km^2 of upland area;
- 24.0 km^2 of lowland area; and
- 5.5 km^2 of lake surface area at elevation 331.0 masl.

Table 2.4-6 Total Suspended Solids Concentrations in the Muskeg River Watershed

Data Source	Period of Record	Winter (November-March)				Spring (April-May)				Summer (June-August)				Fall (September-October)			
		Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count
Upper Muskeg River	1976 to 2006	10	≤0.4	176	31	2	≤0.8	33	32	3	≤0.8	24	41	3	≤0.4	25	49
Middle Muskeg River	1976 to 2006	7	<1	40	90	4	<1	16	49	4	<1	45	52	4	<0.4	25	37
Lower Muskeg River	1972 to 2006	4	<0.4	72	136	5	<0.4	36	66	3	<0.4	16	87	2	<0.01	70	62
Jackpine Creek	1974 to 2006	5	<0.4	459	56	5	<0.4	36	36	2	<0.4	103	54	7	<0.4	52	51
Stanley Creek	1976 to 2006	29	7	73	5	<3	<0.4	13	7	1	<0.4	4	8	<3	<3	58	9

Note: Based on data collected by Alberta Environment, RAMP and the Project field program.

Table 2.4-7 Project Geomorphic Survey

Site No.	Stream Name	Basin Area [km^2]	Channel Slope	Mean Bankfull Depth[(a)] [m]	Bankfull Width[(b)] [m]	Sinuosity[(c)]	Entrenchment Ratio[(d)]	Width/ Depth[(e)]	D_{50}[(f)] [mm]	D_{90}[(g)] [mm]
10	Asphalt Creek	101.5	0.002	0.909	7.43	1.1	1.34	8.18	0.57	1.60
11	Big Creek (Upstream)	56.7	0.0086	0.96	9.381	1.2	1.6	9.77	n/a	n/a
17	McClelland Lake Outlet Creek	323.5	0.0008	0.435	14.525	1.5	n/a	33.39	0.27	0.72
22A	Pierre River	113.1	0.0001	1.20	13.43	1.3	1.86	11.16	0.27	0.42
22B	Unnamed Creek 4	19.7	0.000002	0.701	6.657	1.7	n/a	9.50	0.24	0.66
25A	First Creek	31.23	0.0023	0.861	8.297	1.4	2.3	9.64	0.36	0.77
25B	Big Creek (Downstream)	122.1	0.0019	0.680	10.635	1.1	1.84	15.63	0.18	0.36
33	Eymundson Creek	45.7	0.0044	0.381	2.568	1.0	1.99	6.75	n/a	n/a
37	Unnamed Creek 1	64.7	0.0023	0.723	3.206	1.1	1.08	4.43	0.43	1.31
38	Muskeg River (above Wapusu Creek)	256.7	0.0007	1.319	13.00	1.3	n/a	9.86	n/a	n/a
39	Muskeg River (near S5A)	541.7	0.002	1.005	12.935	1.2	n/a	12.87	0.33	0.73

(a) Mean depth: mean bankfull depth across a stream channel.

(b) Bankfull width: width of channel measured at bankfull stage.

(c) Sinuosity: ratio of stream length to valley length.

(d) Entrenchment ratio: (width of the flood-prone area at an elevation twice the maximum bankfull depth) / (bankfull width).

(e) Width/depth ratio: bankfull width / mean bankfull depth.

(f) D_{50} = median particle size of channel bed soil.

(g) D_{100} = maximum particle size of channel bed soil.

n/a = Not available.

The lake has a maximum depth of 2.5 m and storage of about 7 million m^3. The lake surface-area-elevation and storage-elevation curves shown in Figure 2.4-2 were based on the available data collected for the Other Six Lease Owners (OSLO) Project (WER Engineering 1991).

Lake Water Levels

Monitoring data collected from May 1999 to December 2006 show that the water level of Kearl Lake fluctuated by 0.95 m between 331.54 and 332.49 masl. This compares with a maximum water level fluctuation of 1.021 m based on simulated water levels for the 1954 to 2006 period.

The percent of time that the lake water elevation is exceeded was also calculated and illustrated in Figure 2.4-3. The lake water level exceeds 331.2 masl 10% of time, the median lake water level is 331.0 masl and the lake water level exceeds 330.9 masl 90% of time.

Inflows and Outflows

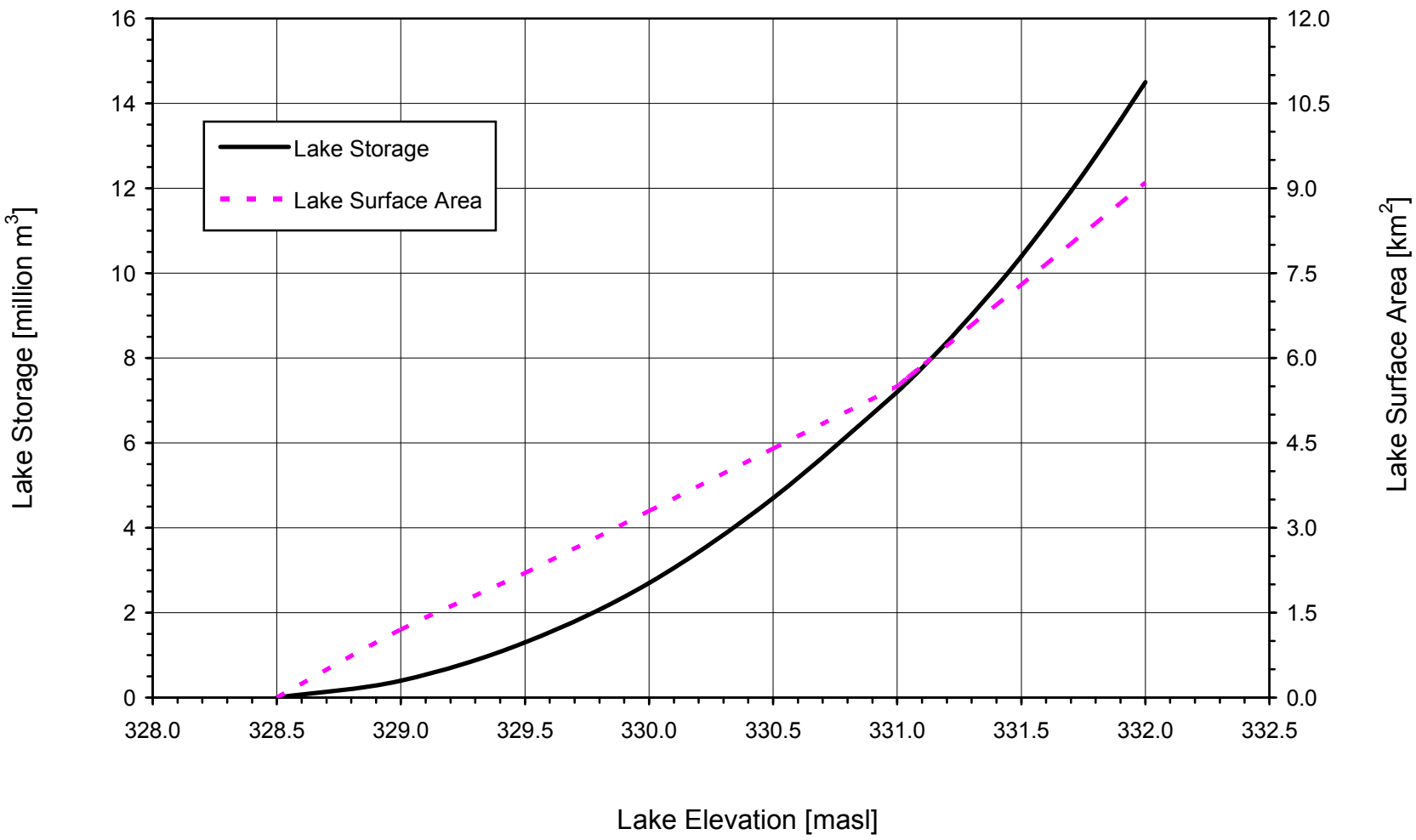
A relationship between lake water level and lake outflow, which is referred to as the outflow rating curve (Figure 2.4-4), is needed to determine lake outflows. This relationship was developed based on the recorded flow measurements at Kearl Lake outlet and the recorded water level of Kearl Lake since 1999.

Daily lake inflows and outflows for the period of 1954 to 2006 were simulated using the HSPF model. They were then analyzed to obtain flood peak discharges and low flows (Table 2.4-8).

Table 2.4-8 Statistics of Simulated Basin Inflows and Lake Outflows

Inflow or Outflow	Flood Peak Discharges [m^3/s]			7Q10 Low Flow [m^3/s]
	2-Year	10-Year	100-Year	
total basin inflow	2.87	8.58	23.3	0.000
lake outflow	1.05	2.37	4.81	0.000

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.4-2 keral lake surface area and storage curves.dwg Nov 23, 2007 - 10:39am



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

KEARL LAKE SURFACE AREA AND STORAGE CURVES

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Surface and curves	
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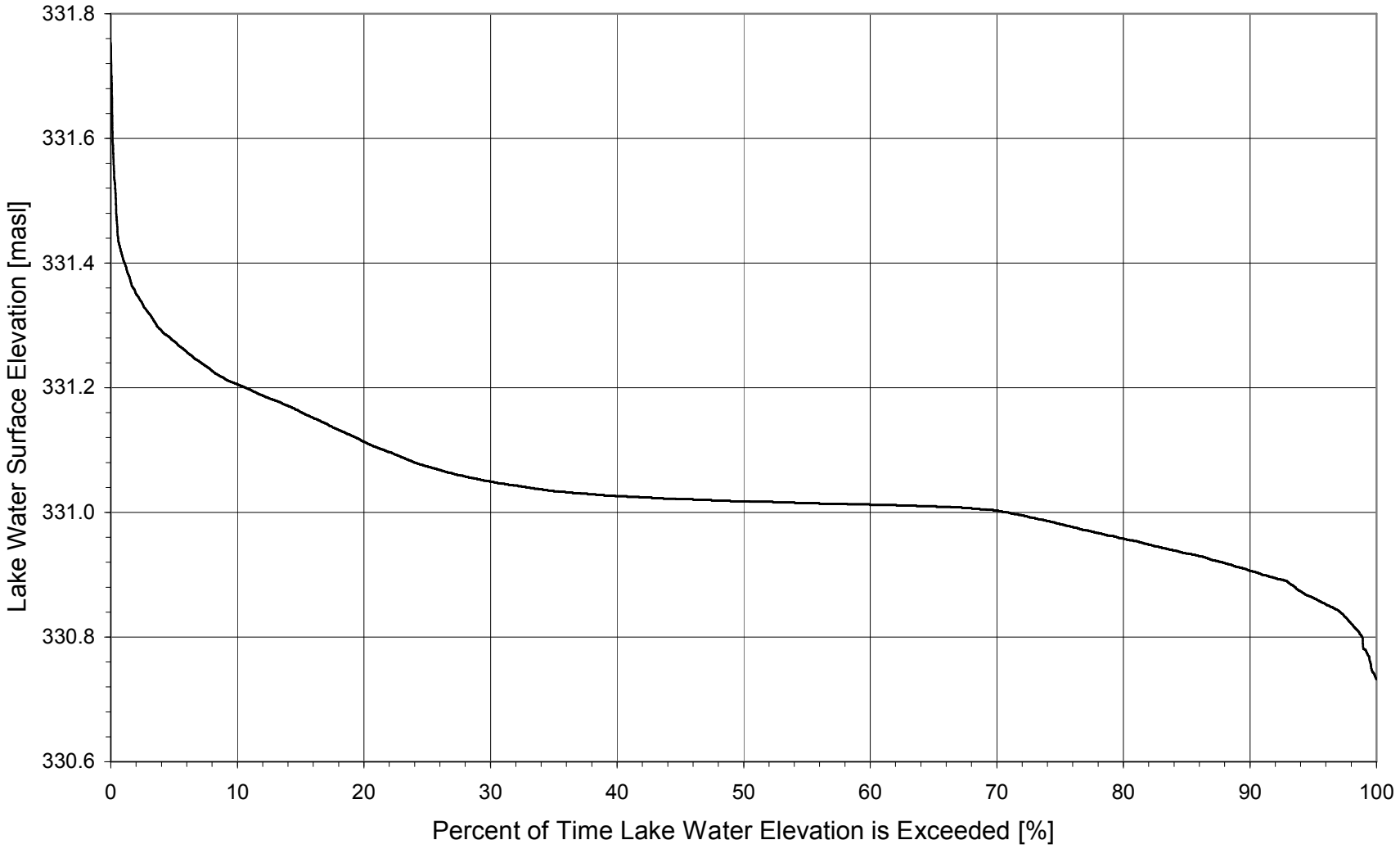
CADD	TY	18/11/07	**FIGURE: 2.4-2**	
CHECK	AS	18/11/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.4-3 exceedance curve of simulated daily keral lake water levels.dwg Nov 23, 2007 - 10:41am



PROJECT

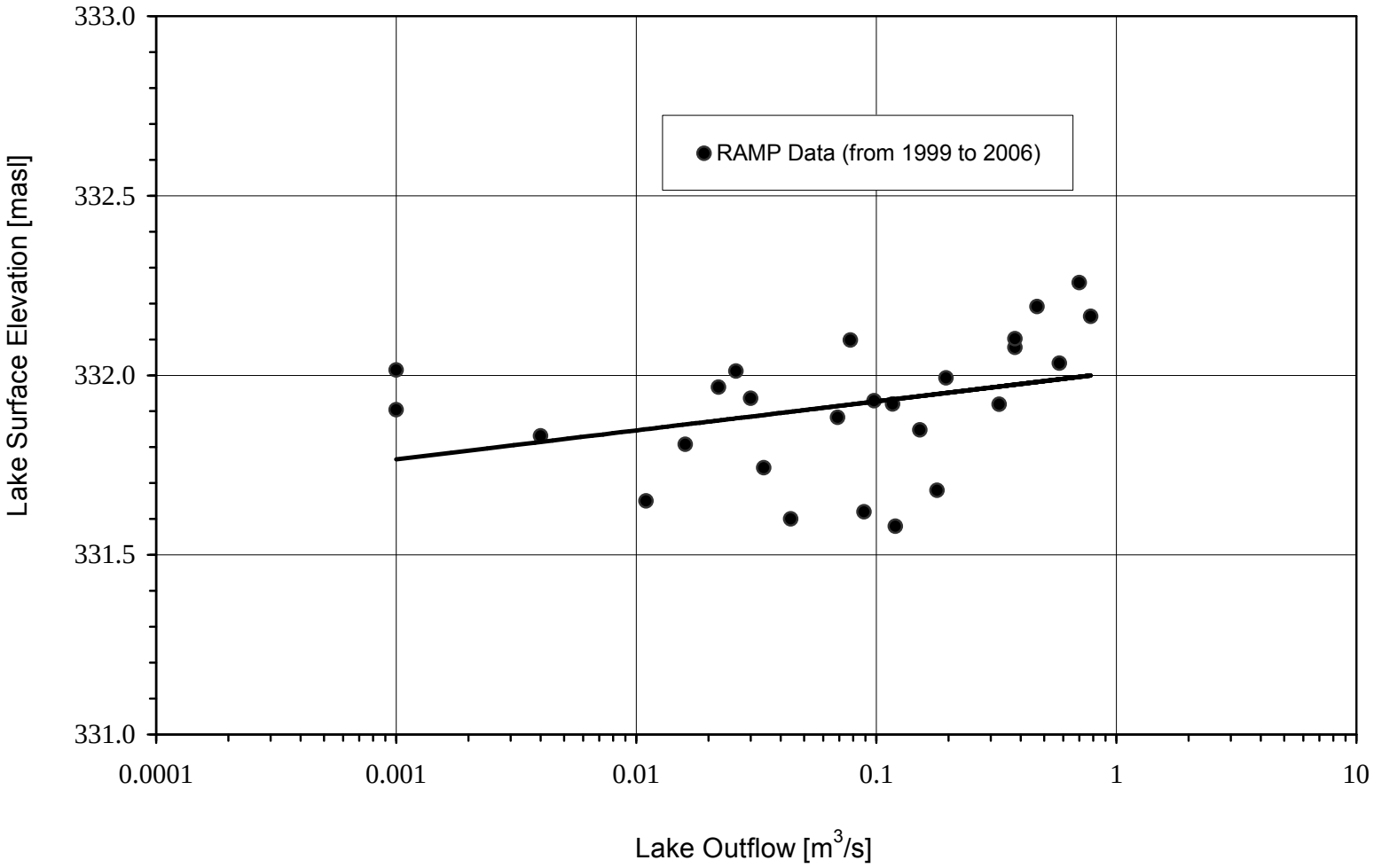
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

EXCEEDANCE CURVE OF SIMULATED DAILY KEARL LAKE WATER LEVELS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Exceedance curve	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.4-3**	
CHECK	AS	18/11/07		
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RATING CURVE FOR KEARL LAKE OUTFLOW

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.		Rating Curve
DESIGN	KM	09/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 2.4-4**		
CHECK	AS	18/11/07			
REVIEW	WES/TC	20/11/07			

2.5 PIERRE RIVER MINING AREA RESULTS

2.5.1 Climate

2.5.1.1 Air Temperature

Comparing the recorded daily air temperatures at the Fort McMurray Airport and Calumet River climate stations between June 2001 and November 2005 (Figure 2.5-1), a 1.8°C difference in the mean air temperatures was noted. Similar standard deviations of 13.6°C and 14.2°C, respectively, were also noted. This similarity of daily air temperature means and deviations between these two stations suggests that the long-term air temperature data and statistics at Fort McMurray (Section 2.3.1.1) are representative of conditions in the PRMA LSA.

2.5.1.2 Precipitation

Summer precipitation records (May to August) from Fort McMurray Airport and seasonal lookout stations (Figure 2.2-1) including Birch Mountain Lookout and Ells Lookout were compared and summarized in Table 2.5-1.

Table 2.5-1 Variation of Average Summer Precipitation With Station Elevation

Station	Elevation [masl]	Month				Average Summer Precipitation[a]
		May [mm]	June [mm]	July [mm]	August [mm]	
Birch Mountain Lookout[b]	853	45.7	88.2	108.9	69.9	312.7
Ells Lookout[c]	610	35.3	68.3	81.8	55.6	241.0
Fort McMurray Airport[d]	369	39.1	68.5	79.5	64.5	251.6

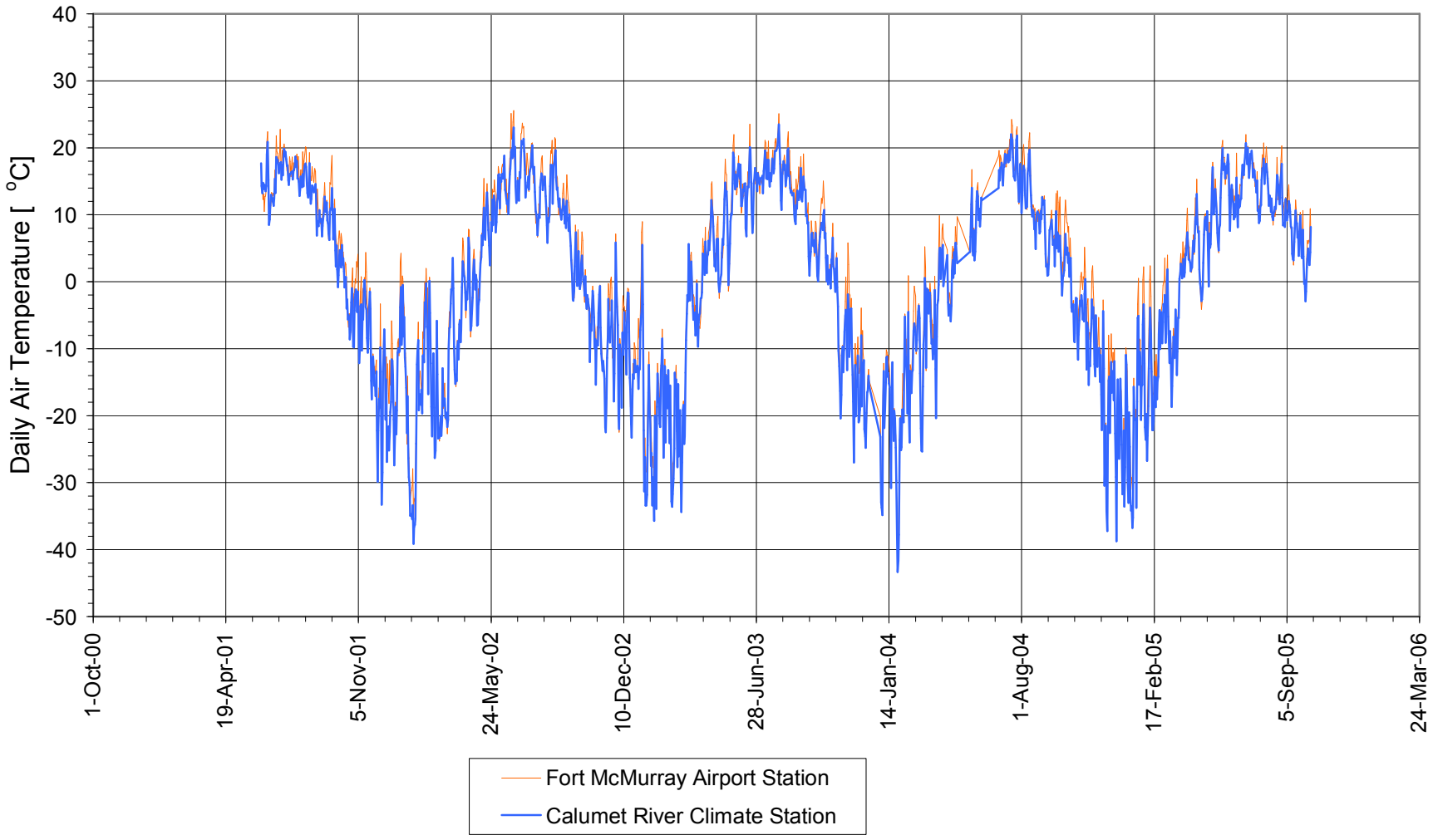
(a) Average summer precipitation is based on the total precipitation from May to August.

(b) Summer precipitation data available from 1960 to 2006.

(c) Summer precipitation data available from 1961 to 2006.

(d) Summer precipitation data available from 1953 to 2006.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig 2.5-1 daily air temp at fort mcmurray airport and calumet climate stations.dwg Nov 23, 2007 - 10:45am



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

DAILY AIR TEMPERATURES AT FORT McMURRAY AIRPORT AND CALUMET RIVER CLIMATE STATIONS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.		Air temp
DESIGN	KM	09/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	18/11/07	FIGURE: 2.5-1		
CHECK	AS	18/11/07			
REVIEW	WES/TC	20/11/07			

Typically, precipitation increases with increased elevation. When comparing precipitation at Fort McMurray with Ells Lookout, this relationship does not apply because of the rainshadow effect at Ells Lookout (Golder 2003). The PRMA LSA will be influenced by the adjacent Birch Mountains; therefore, where possible, precipitation data from rainshadow-affected areas are used to derive local precipitation.

To take into account the effect of elevation and the rainshadow effect of the Birch Mountains, the precipitation at the PRMA LSA (mean elevation of 404 masl), was estimated based on the regional equation for elevation adjustment (Golder 2003).

Using the regional equation, the elevation-adjusted precipitation records from Ells Lookout and Birch Mountain were compared and found to be similar. For the period of May to August, precipitation in the LSA was calculated as elevation-adjusted data from the Ells Lookout station. The Ells Lookout data were used because the elevation is closer to the elevation of the PRMA LSA than the Birch Mountain Lookout (853 masl at Birch Mountain, 610 masl at Ells Lookout and 404 masl at the PRMA LSA). For the period of September to April, precipitation data were calculated as elevation-adjusted precipitation from Fort McMurray because this is the closest station with long-term winter precipitation data.

Table 2.5-2 presents a derived summary of monthly precipitation throughout the year in the PRMA LSA for the period of 1953 to 2006. The mean annual precipitation in the LSA is estimated to be 374 mm. Based upon regional precipitation data, the precipitation was estimated to be 75% rainfall (mean annual rainfall of 281 mm) and 25% snowfall (mean annual snowfall of 93 mm). July receives the highest amount of precipitation (66 mm), and February and March have the lowest monthly precipitation (14 mm).

Table 2.5-2 Monthly Mean Precipitation Summary for the Pierre River Mining Area Local Study Area (1953 to 2006)

Month	Precipitation [mm]		
	Maximum	Average	Minimum
January	44.0	17.2	0.0
February	40.5	13.8	0.0
March	35.2	14.5	0.0
April	47.2	17.3	0.2
May	79.3	32.7	1.9
June	128.5	57.2	10.3
July	177.7	66.4	15.9

Table 2.5-2 Monthly Mean Precipitation Summary for the Pierre River Mining Area Local Study Area (1953 to 2006) (continued)

Month	Precipitation [mm]		
	Maximum	Average	Minimum
August	114.8	53.9	2.7
September	106.7	41.2	10.2
October	69.9	23.4	0.3
November	49.3	18.4	2.4
December	44.3	17.8	0.2

Note: September to April precipitation is elevation adjusted data from Fort McMurray Airport Station.
May to August precipitation is elevation adjusted data from Ells Lookout Station.

2.5.2 Hydrology

2.5.2.1 Physical Setting and Hydrological Conditions

As shown in Figure 2.1-2, the PRMA LSA includes four tributaries of the lower Athabasca River, namely:

- Pierre River;
- Eymundson Creek (tributaries include Asphalt Creek and Unnamed Creek 1);
- Big Creek (tributaries include First Creek, Unnamed Creek 2 and Unnamed Creek 5); and
- Redclay Creek.

These watercourses originate in the eastern slopes of the Birch Mountains. They drain east into a lowland area and collect flows from several tributaries before discharging into the Athabasca River.

The watersheds of these rivers include both upland and lowland areas. The Birch Mountains are located in the upper watershed where ground slopes are 4 to 8%. Ground slopes of less than 0.5% are typical of the poorly drained lowland area. Slopes of 1 to 3% are typical of the better-drained upland areas at elevations above 340 masl. The watercourses are fairly incised in the lower reaches with channel valley depths up to about 40 m.

No oil sands developments have started to date in the PRMA LSA. Descriptions of the major watercourses in the PRMA LSA are as follows:

- **Pierre River:** The Pierre River basin has a drainage area of 134 km^2 at the river mouth, which includes an upland area of 119 km^2 (89% of the total drainage area) and a lowland area of 15 km^2 (or 11% of the total drainage area). The confluence of the Pierre River with the Athabasca River is in the southeast portion of the PRMA.
- **Eymundson Creek:** Eymundson Creek discharges into the Athabasca River about 7 km downstream of the mouth of Pierre River. The Eymundson Creek basin has a drainage area of 313 km^2 at the river mouth, which includes a lowland area of 115 km^2 and an upland area of 198 km^2. Unnamed Creek 1 discharges into Eymundson Creek about 2 km upstream of the mouth of the Eymundson Creek. Asphalt Creek, as described below, also drains into Eymundson Creek.
- **Asphalt Creek:** Asphalt Creek is a major tributary which discharges into Eymundson Creek about 5 km upstream of the mouth of Eymundson Creek. The Asphalt Creek basin has a drainage area of 156 km^2 at the mouth, which includes an upland area of 109 km^2 (70% of the total drainage area) and a lowland area of 47 km^2 (or 30% of the total drainage area).
- **Big Creek:** The Big Creek basin is located north of the Eymundson Creek basin. It has a drainage area of 316 km^2 which includes the First Creek, Unnamed Creek 2 and Unnamed Creek 5 sub-basins. The Big Creek basin has an upland area of 147 km^2 and a lowland area of 169 km^2.
- **Redclay Creek:** Redclay Creek discharges into the Athabasca River about 10 km downstream of Big Creek's mouth. The Redclay Creek basin has a drainage area of 209 km^2 at the river mouth, including an upland area of 72 km^2 and a lowland area of 137 km^2 and it is the basin furthest downstream discharging to Athabasca River in the PRMA LSA.

2.5.2.2 Basin Water Yields

The simulated daily flows at various locations in the above four watersheds were analyzed to obtain the mean annual water yields. The annual water yield depends primarily on the drainage area, precipitation and the ratio of upland area to lowland area. Mean annual water yields have been derived for Pierre River, Eymundson Creek, Asphalt Creek, Big Creek and Redclay Creek (Table 2.5-3). The mean annual water yields of Pierre River, Eymundson Creek, Alphalt Creek, Big Creek and Redclay Creek are estimated to be 68, 68, 81, 49 and 48 mm respectively, corresponding to mean annual discharges of 0.29, 0.67, 0.40, 0.49 and 0.32 m^3/s, respectively. Compared with other watercourses in the region, including those in the JEMA LSA, the PRMA LSA watercourse mean annual water yields are low due to the rain shadow effects east of the Birch Mountains. In the HSPF model simulation, precipitation data from Ells Lookout were used to calculate precipitation of each sub-basin as discussed in Section 2.5.1.2.

Table 2.5-3 Simulated Mean Annual Water Yields for the Pierre River Mining Area

Name	Drainage Area [km^2]			Annual Water Yield	
	Upland Area	Lowland Area	Total Area	[m^3/s]	[mm/year]
Pierre River	119	15	134	0.29	68
Eymundson Creek	198	115	313	0.67	68
Asphalt Creek	109	47	156	0.40	81
Unnamed Creek 1	41	39	80	0.16	64
Big Creek	147	169	316	0.49	49
First Creek	7	24	31	0.02	24
Unnamed Creek 2	68	48	116	0.15	41
Unnamed Creek 5	0	16.9	16.9	0.011	21
Redclay Creek	72	137	209	0.32	48

Note: Period of simulation is from 1953 to 2006.

The simulated monthly flows at the river mouth of the Pierre River, Eymundson Creek, Asphalt Creek, Big Creek and Redclay Creek are summarized in Table 2.5-4. The simulated maximum monthly flows are 3.56, 8.97, 5.42, 6.57 and 4.02 m^3/s (May) respectively, and the simulated minimum mean monthly flows are zero (November to March) for these five streams. It should be noted that values for June through April are zero for Redclay Creek.

Table 2.5-4 Simulated Monthly Flows of Pierre River, Eymundson Creek, Big Creek, Asphalt Creek and Redclay Creek

Month	Simulated Monthly Flows [m^3/s]														
	Pierre River			Eymundson Creek			Big Creek			Redclay Creek			Asphalt Creek		
	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
January	0.04	0.01	0	0.06	0.01	0	0.07	0.01	0	0.03	0.01	0	0.03	0.01	0
February	0.08	0.01	0	0.22	0.02	0	0.3	0.02	0	0.24	0.01	0	0.15	0.01	0
March	0.42	0.04	0	1.04	0.08	0	0.58	0.08	0	0.51	0.07	0	0.64	0.03	0
April	1.62	0.49	0.02	3.88	1.09	0.02	3.31	0.97	0.05	2.23	0.62	0.05	2.11	0.57	0.01
May	3.56	1.08	0.04	8.97	2.77	0.08	6.57	1.95	0.07	4.02	1.25	0.05	5.42	1.69	0.05
June	2.64	0.46	0.01	6.57	1.08	0.01	4.34	0.73	0.01	2.80	0.46	0.01	4.13	0.67	0.01
July	2.24	0.34	0.01	5.01	0.70	0.01	3.69	0.49	0.01	2.24	0.28	0.01	2.99	0.43	0.01
August	1.6	0.27	0	3.43	0.57	0.01	2.43	0.39	0	1.44	0.23	0	2.07	0.36	0
September	2.31	0.38	0	5.46	0.88	0	4.07	0.63	0	2.68	0.41	0	3.27	0.54	0
October	1.56	0.27	0	3.49	0.63	0	3.27	0.51	0	2.06	0.35	0	1.81	0.36	0
November	0.36	0.07	0	0.63	0.13	0	0.69	0.12	0	0.39	0.07	0	0.31	0.07	0
December	0.1	0.02	0	0.18	0.03	0	0.15	0.03	0	0.06	0.01	0	0.07	0.01	0

Note: Based on simulated discharges for 1953 to 2006.

2.5.2.3 Flood Flows

The results of frequency analyses of simulated flood peak discharges are provided for the Pierre River, Eymundson Creek, Big Creek and Redclay watersheds (Table 2.5-5). Most of the flood peak discharges in these watersheds occurred as a result of snowmelt runoff, which produces higher peak flows than the rainfall events in these watersheds.

Table 2.5-5 Flood Peak Discharges in the Pierre River Mining Area Watersheds

Stream	Drainage Area [km^2]	Flood Peak Discharges for Various Return Periods[(a)] [m^3/s]		
		2-Year	10-Year	100-Year
Pierre River	134	3	8	14
Eymundson Creek	313	7.85	19.6	35.9
Asphalt Creek	156	4.9	13	28
Unnamed Creek 1	80	1.7	4.4	8
Big Creek	316	5.0	13	26
First Creek	31	0.26	0.7	2.1
Unnamed Creek 2	116	1.6	4.6	11
Unnamed Creek 5	16.9	0.17	0.38	0.87
Redclay Creek	209	3.1	7	15

(a) Peak flows were derived from simulated discharges (1953 to 2006).

2.5.2.4 Low Flows

The flow simulation conducted for PRMA LSA produces zero values for 2- and 10-year monthly low flows and the 7-day average low flow with a 10-year return period (7Q10) in the Pierre River, the Eymundson Creek and the Big Creek watersheds. These streams are expected to be dry or frozen to the stream bed during extreme low flow conditions.

2.5.2.5 Sediment Transport

In the PRMA watersheds, long-term TSS data were not available. Since 2005, water quality samples from streams in the PRMA watershed were collected by the Project field program. The TSS data were analyzed and the results are presented in Table 2.5-6.

Table 2.5-6 Total Suspended Solids Concentrations (mg/L) in the Pierre River Mining Area Watersheds

Data Source	Period of Record	Winter (November to March)				Spring (April to May)				Summer (June to August)				Fall (September to October)			
		Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count	Median	Min	Max	Count
Pierre River	2005 to 2006	14	5	24	2	6	<3	24	4	8	<3	10	3	<3	<3	6	3
Eymundson Creek	2005 to 2007	179	170	188	2	523	38	732	5	91	11	408	5	38	10	244	6
Big Creek	2005 to 2007	25	<3	910	16	22	<3	101	10	17	<3	256	9	<3	≤1	309	12
Redclay Creek	2006 to 2007	4	<3	16	8	14	5	26	4	0.5	<3	34	4	4	≤1	138	4

Note: Based on data collected by Alberta Environment, RAMP and the Project field program.

The recorded TSS data in the PRMA watersheds indicate that TSS concentrations varied greatly by season with TSS being greatest during snowmelt and summer flooding.

The mean annual basin sediment yield was determined based upon data for large gauged basins, as shown in Table 2.3-20, which are in the vicinity of the PRMA LSA on the west side of the Athabasca River (i.e., Poplar Creek, Beaver River, Joslyn Creek, Ells River and MacKay River). The mean annual basin sediment yield range for the PRMA LSA is 0.0074 to 0.0617 mm.

2.5.2.6 Geomorphic Conditions

In the PRMA LSA, the upper tributaries of most rivers are incised and are further incised in the lower reaches with channel valley depth up to about 40 m. Streams in upland areas have slopes greater than 0.5%, and therefore convey flows at a higher velocity. Lowland streams have slopes less than 0.5%. The lowland streams are slow-flowing, meandering streams flowing through a poorly drained area characterized by a high groundwater table. The surficial geology in the PRMA LSA is predominantly glaciofluvial (sandy).

The geomorphology of the PRMA area was surveyed in September 2005 and October 2007. The stream locations surveyed in 2005 are shown in Figure 2.2-3 and listed in Table 2.4-7. Available geomorphic data are presented in summary sheets (Appendix B), which include measured streamflow data, surveyed stream cross-section profiles, sediment gradation and site photographs.

2.6 SUMMARY

The key hydrologic statistics of the major streams in the RSA are summarized in Tables 2.6-1 and 2.6-2.

Table 2.6-1 Summary of Key Flow Statistics of Major Streams in the Regional Study Area

Watercourse (Station No.)	Mean Annual Discharge [m^3/s]	10-Year Flood Peak Discharge [m^3/s]	7Q10 Low Flow [m^3/s]
Athabasca River below Fort McMurray (07DA001)	630	3,734	100
Athabasca River below Muskeg River	638	3,747	101
Athabasca River below Eymundson Creek (S24)	656	3,781	102
Athabasca River at Embarras Airport (07DD001)	678	3,810	104
Muskeg River at Fort McKay at the Environment Canada Hydrometric Station (07DA008)	3.68[(a)]	50.4[(a)]	0.0157[(a)]
Firebag River at the Environment Canada Hydrometric Station (07DC001)	25.9	177	5.95

(a) Based on computer simulation under baseline conditions for the period of 1953 to 2006.

The key climatic and hydrologic parameters have been derived for each of the two project development areas, as summarized in Table 2.6-2.

Table 2.6-2 Key Climatic and Hydrologic Parameters for the Jackpine Expansion and Pierre River Mining Areas

Mining Area	Parameter	Value
Jackpine Expansion Mining Area	mean annual temperature	0.1°C
	mean annual precipitation	433 mm
	mean annual rainfall	325 mm
	mean annual snowfall	108 mm
	mean annual runoff	80 to 106 mm
	mean annual basin sediment yield[(a)]	0.0005 to 0.0015 mm
Pierre River Mining Area	mean annual temperature	0.0 °C
	mean annual precipitation	374 mm
	mean annual rainfall	281 mm
	mean annual snowfall	93 mm
	mean annual runoff	21 to 81 mm
	mean annual basin sediment yield[(b)]	0.0074 to 0.0617 mm

(a) Based upon mean annual sediment yields of large gauged basins in the vicinity of the JEMA LSA on the east side of the Athabasca River.

(b) Based upon mean annual sediment yields of large gauged basins in the vicinity of the PRMA LSA on the west side of the Athabasca River.

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APPENDIX A

LOCAL CLIMATE PROGRAM SUMMARY AND TREND ANALYSIS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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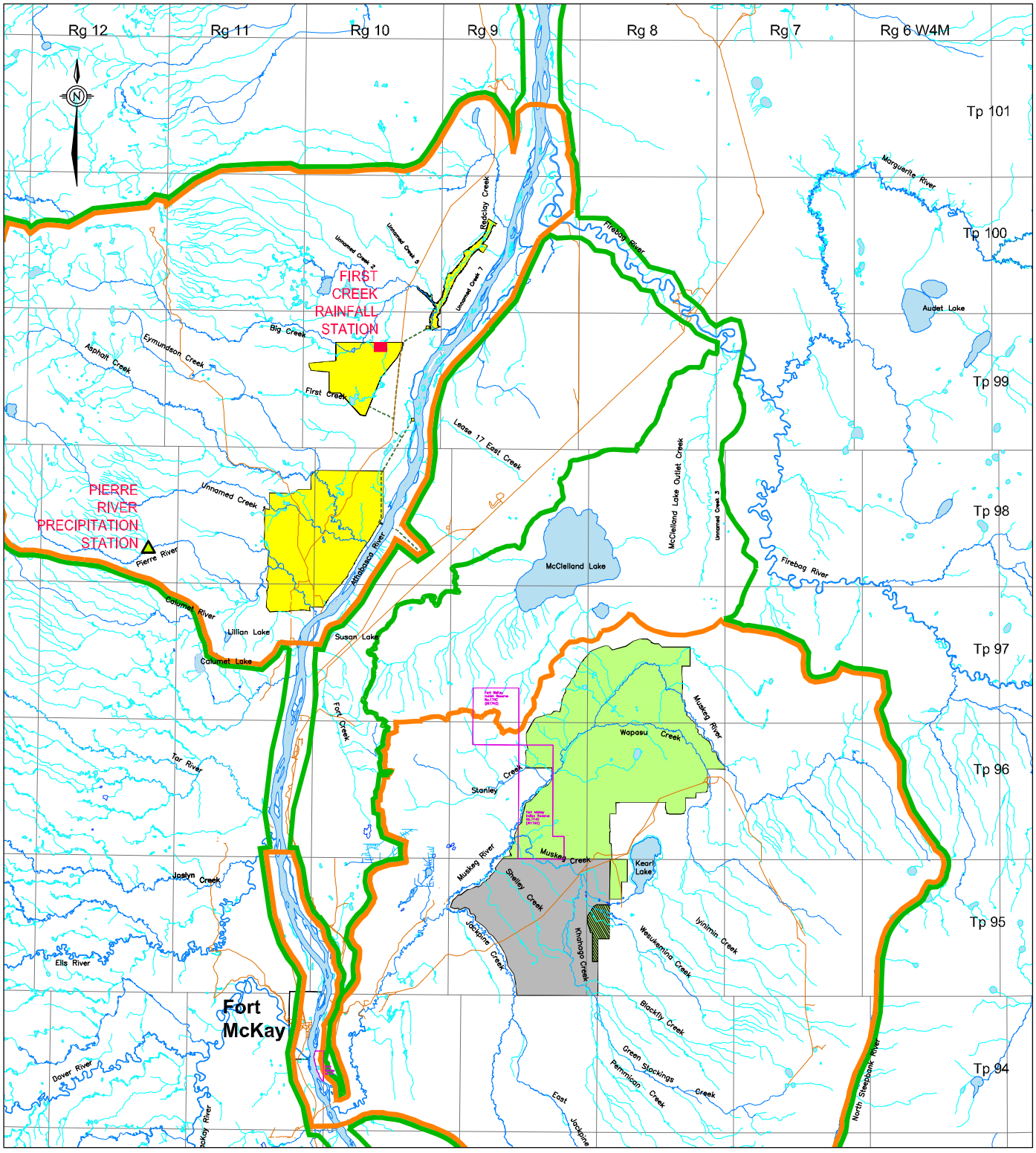
1 INTRODUCTION

This appendix presents a summary of the climate field program conducted during fall 2005, all four seasons of 2006 and 2007. The climate field program included installation of climate stations, station visits, downloading and analyzing data from these stations and a snow course survey.

The climate field program was completed as part of the surface water hydrology environmental setting study, which was designed to support the Shell Canada Limited (Shell) Jackpine Mine Expansion & Pierre River Mine Project (the Project) Environmental Impact Assessment (EIA), as well as to expand the climate and hydrology database required for planning and design of this Project.

Based on a review and understanding of the available regional and local climate and hydrology information, a field study program was developed to collect site-specific data. A climate monitoring program was completed as part of this program, including:

- installation of the Pierre River precipitation station and First Creek rainfall station at locations shown in Figure A-1;
- downloading of recorded data during field visits;
- compilation and analysis of downloaded data; and
- snow course surveys to measure snow depth, snow densities and snow re-distribution in various terrain types at 17 sites in and near the Pierre River Mining Area (PRMA), as shown in Figure A-2.



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- FIRST CREEK RAINFALL STATION
- PIERRE RIVER PRECIPITATION STATION

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PRECIPITATION AND RAINFALL STATIONS - FALL 2006

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Precipitation-Rainfall	
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CHECK	KG	15/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: A-1

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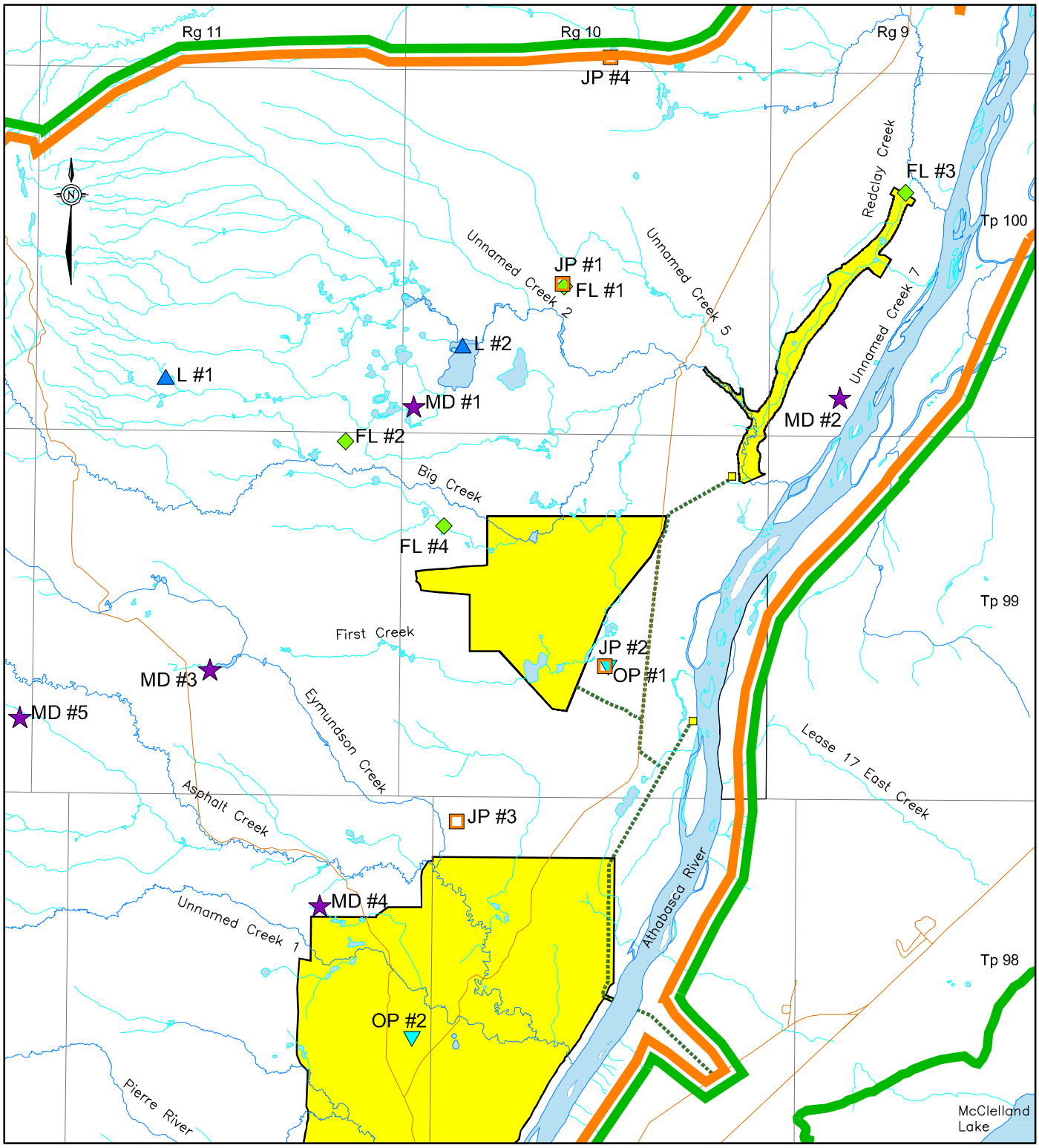

LEGEND

- PIERRE RIVER MINING AREA
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

SCALE 3 0 3 KILOMETRES

SNOW COURSE SURVEY TERRAIN TYPES

- FL FLAT LOW LYING
- OP OPEN LAND
- L LAKE
- MD MIXED DECIDUOUS
- JP JACKPINE

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

LOCATIONS OF SNOW COURSE SURVEY

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Snow Survey
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CADD	MM	16/11/07		
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: A-2

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2 LOCAL CLIMATE MONITORING PROGRAM

2.1 CLIMATE MONITORING PROGRAM OVERVIEW

During the fall 2005 field program, a precipitation station was installed in the Pierre River watershed to monitor year-round precipitation. Also during the fall 2005 field program, a second site was selected in the First Creek watershed for installation of a rainfall station. The First Creek rainfall station was installed during the spring 2006 and spring 2007 field programs and decommissioned for the winter season during the fall 2006 and fall 2007 field programs. The locations of the Pierre River precipitation station and the First Creek rainfall station are shown in Figure A-1.

2.2 CLIMATE STATION SUMMARIES

2.2.1 Pierre River Precipitation Station

The Pierre River precipitation station is a year-round precipitation station. The station was installed on September 25, 2005 and was decommissioned in fall 2007. The Pierre River precipitation station, which is located at the same site as the Pierre River hydrometric station (P03, Appendix B), was equipped with a datalogger, a tipping bucket rain gauge and a snow gauge adaptor. The snow gauge adaptor was removed during the spring 2006 program and re-installed on October 23, 2006. The snow gauge adapter was removed again during the spring 2007 program.

During the 2006 field program, the station was visited on March 4, April 10, July 16 and October 23, 2006, and the precipitation data recorded in the datalogger were downloaded during each field visit. The field crew found the station damaged on July 16, 2006, and data are not available for the period of June 7 to July 16, 2006. The station was not functioning properly from August 10 through October 23, 2006 and data are not available for this period. The station was repaired onsite on July 16 and October 23, 2006.

During the 2007 field program, the station was visited on February 9, April 18, May 10, July 27 and October 23, 2007. The station appeared to be damaged by animal activity on May 10. Data from April 26 to May 9, 2007 are not available. The station appeared to be damaged again by animal activity on May 18, 2007. Data from May 18 to July 27, 2007 are not available. The station was repaired onsite on May 10 and July 27, 2007. Data recorded at this station are presented in Figure A-3.

Figure A-3 Recorded Daily Precipitation at the Pierre River Precipitation Station

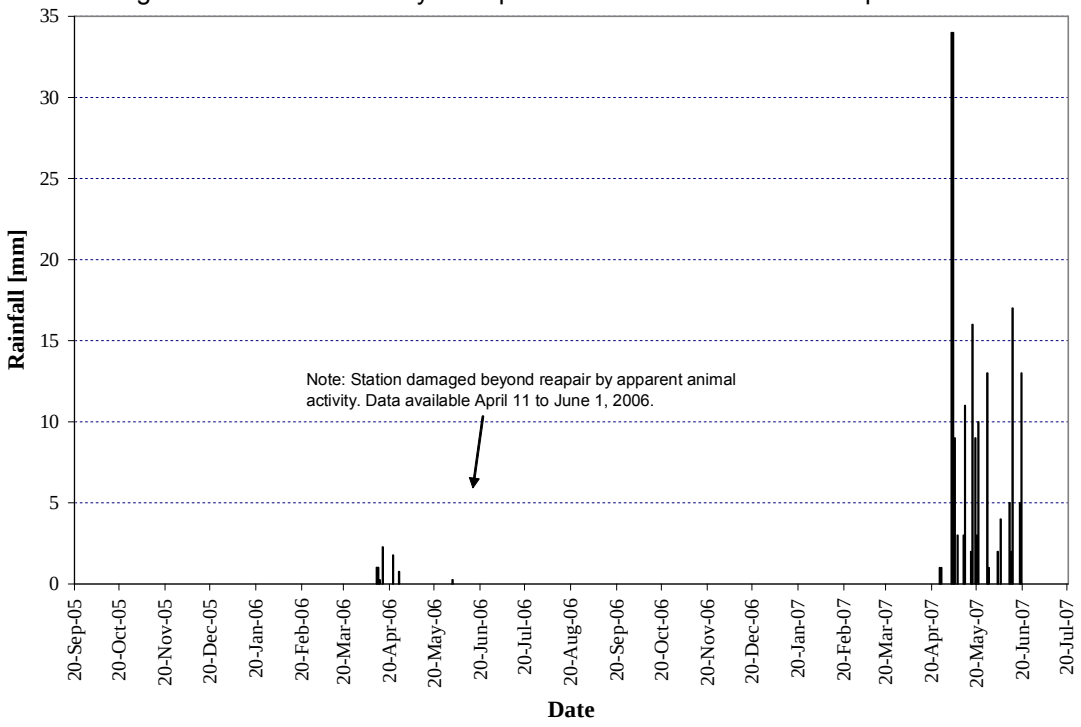
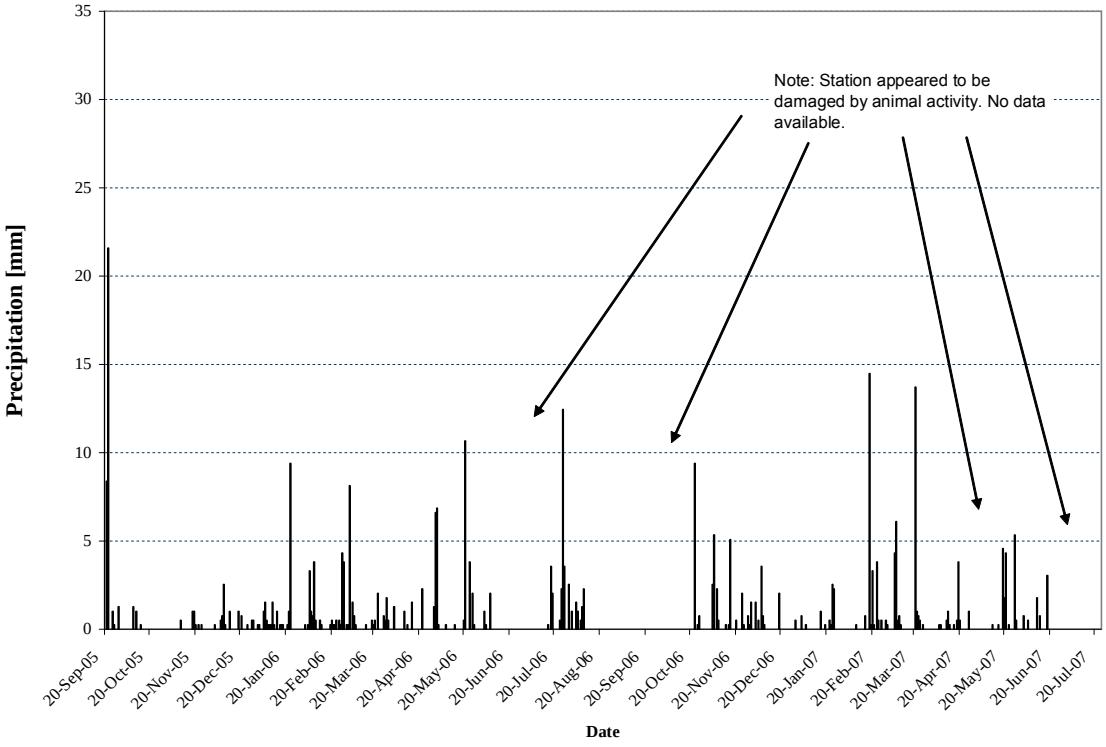


Figure A-4 Recorded Daily Precipitation at the First Creek Rainfall Station



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RECORDED DAILY PRECIPITATION AT THE PIERRE RIVER PRECIPITATION AND FIRST CREEK RAINFALL STATIONS

Shell Canada Limited

PROJECT	05.1344.027.6600		FILE No.	Precipitation
DESIGN	KG	30/10/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	KG	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: A-3 & A-4

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2.2.2 First Creek Rainfall Station

The First Creek rainfall station was installed during the spring 2006 and spring 2007 field programs and decommissioned for the winter season during the fall 2006 and fall 2007 field programs. The First Creek rainfall station, which is located at the same site as the First Creek hydrometric station (P05, Appendix B), was equipped with a datalogger and a tipping bucket rain gauge. The station was visited on April 11 and August 28, 2006 and the rainfall data recorded in the datalogger was downloaded during each field visit. The field crew found the station damaged beyond repair by animal activity on August 28, 2006, and the station was decommissioned for the 2006 season. The last date in 2006 with recorded data is June 1, 2006.

The First Creek rainfall station was reinstalled on April 20, 2007 approximately 20 m upstream due to flooding at the previous location. The station was visited on May 9, July 26 and October 25, 2007. The station appeared to be damaged by animal activity on June 18, 2007. It was repaired onsite. Data from June 18, 2007 to July 26, 2007 are not available. Data recorded at this station in 2006 and 2007 are presented in Figure A-4.

Figure A-3 Recorded Daily Precipitation at the Pierre River Precipitation Station

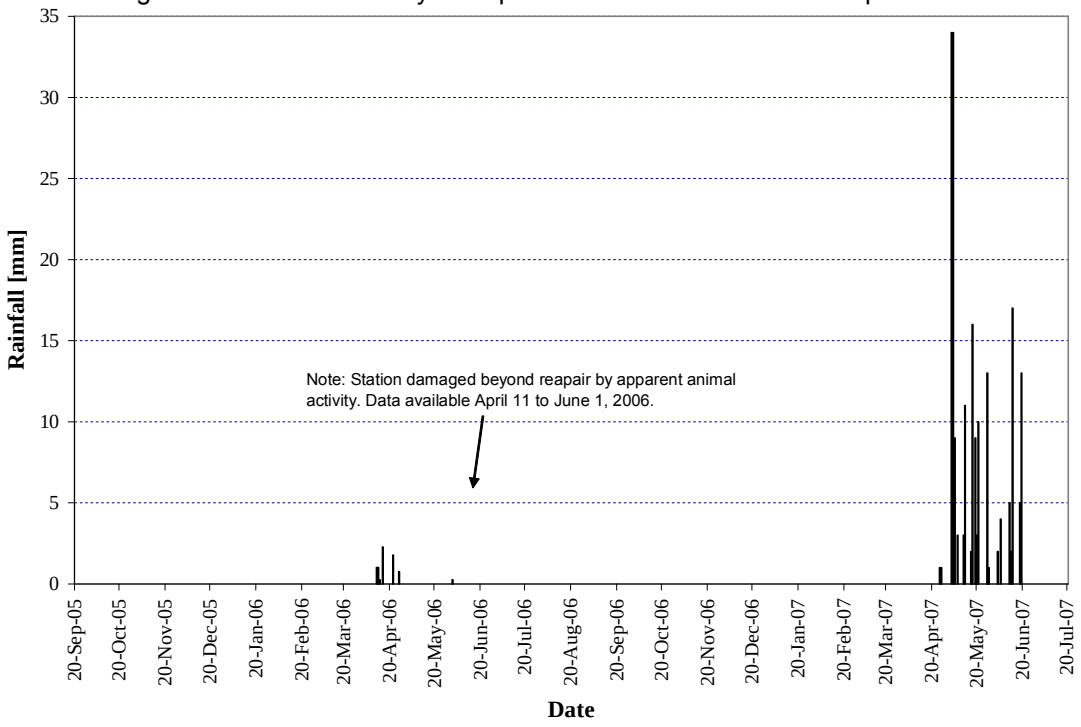
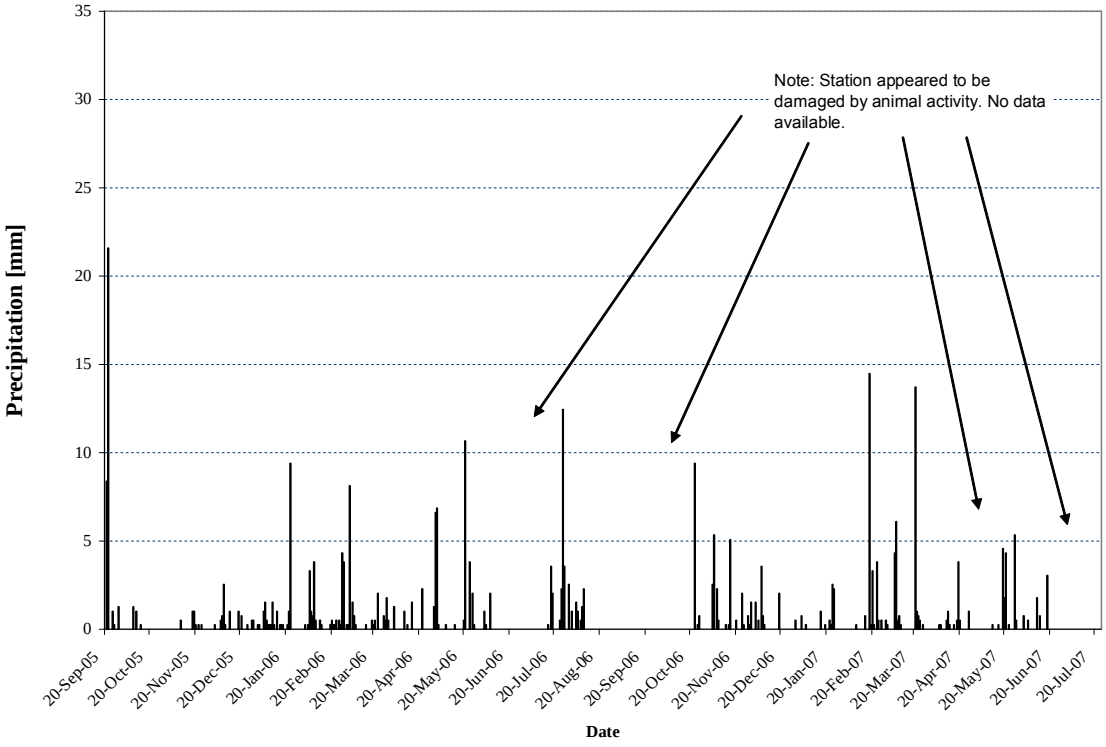


Figure A-4 Recorded Daily Precipitation at the First Creek Rainfall Station



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RECORDED DAILY PRECIPITATION AT THE PIERRE RIVER PRECIPITATION AND FIRST CREEK RAINFALL STATIONS

Shell Canada Limited

PROJECT	05.1344.027.6600		FILE No.	Precipitation
DESIGN	KG	30/10/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	KG	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: A-3 & A-4

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig A-3-A-4.dwg Nov 16, 2007 - 5:52pm

3 RECORDED LOCAL CLIMATE DATA

The data recorded at the Pierre River precipitation station and the First Creek rainfall station are presented in Figures A-3 and A-4, respectively.

4 SNOW COURSE SURVEY

4.1 SNOW COURSE SURVEY PURPOSE

The purpose of a snow course survey is to provide data for determining average, accumulated watershed snow depth and snow re-distribution in various terrain types. The resulting snow pack accumulation data are correlated with recorded snowfall data at a climate station to determine the snowfall under catch correction factor and to provide accurate snowfall input to a hydrologic model for accurate model calibration and verification.

A program of snow course surveys for several years (e.g., five years) is recommended to collect sufficient data for accomplishing the program objectives. Snow course surveys were previously undertaken in the Muskeg River basin from 1997 to 1999. The resulting snow pack data can be extrapolated to nearby basins and the Jackpine Expansion Mining Area (JEMA) Local Study Area (LSA), because the snow course data were collected for each terrain type and the nearby watersheds have similar terrain types as the Muskeg River basin. However, the PRMA LSA is located on the west side of the Athabasca River, along the east slope of the Birch Mountains. No prior snow course survey data are available for this area.

4.2 SNOW COURSE SURVEY PROGRAM OVERVIEW

A snow course survey was done in the winter of 2007 within the PRMA (Tables A-1 and A-2). The Snow Water Equivalent (SWE) of various terrain types is indicated in Figure A-5.

Snow pack accumulation is dependent on terrain type, which is a function of both topography and vegetation. In the PRMA LSA watersheds, vegetation is the dominant feature dictating classification of the terrain types. Photographs of the terrain types are provided in Section 5. The main terrain types defined for the 2007 snow course surveys included:

- flat low lying areas (with a mix of willow and shrub vegetation) (Figure A-6);
- jackpine areas (Figure A-7);
- mixed deciduous areas (with a mix of aspen, spruce and other trees) (Figure A-8);
- open land areas (such as harvested areas with little vegetation) (Figure A-9); and
- open lake areas.

A snow survey was performed at sites representative of each of the five terrain types, for a total of 17 sites, as shown in Figure A-2.

Table A-1 Summary of Winter 2007 Snow Course Survey Sites

Site number	Terrain Type	Visit Date	Station Location (UTM NAD 83 Zone 12)	
			Easting	Northing
FL #1	flat low lying	March 26, 2007	465698	6393007
FL #2	flat low lying	March 26, 2007	459849	6388871
FL #3	flat low lying	March 27, 2007	474816	6395512
FL #4	flat low lying	March 28, 2007	462478	6386604
JP #1	jackpine cover	March 26, 2007	465647	6393078
JP #2	jackpine cover	March 27, 2007	466774	6382860
JP #3	jackpine cover	March 27, 2007	462819	6378705
JP #4	jackpine cover	March 28, 2007	466934	6399131
MD #1	mixed deciduous	March 26, 2007	461667	6389781
MD #2	mixed deciduous	March 27, 2007	473053	6390016
MD #3	mixed deciduous	March 27, 2007	456218	6382749
MD #4	mixed deciduous	March 28, 2007	459153	6376443
MD #5	mixed deciduous	March 28, 2007	451138	6381483
OP #1	open land	March 27, 2007	466873	6382816
OP #2	open land	March 28, 2007	461625	6372890
L #1	open lake	March 28, 2007	455039	6390524
L #2	open lake	March 26, 2007	462983	6391357

Table A-2 Summary of 2007 Snow Course Survey Data

Terrain Type	Survey Plot No.	Snow Density [g/cm^3]	Snow Depth [cm]	Snow Water Equivalent [mm]	Description of Vegetation	Snow Cover Appearance
flat low lying	FL #1	0.170	48.1	81.6	understorey of birch – 30% understorey of willow – 40%	wet, sticky and fine to coarse grained
	FL #2	0.183	46.5	85.4	understorey of cattail – 30% understorey of willow – 35%	sticky, fine to coarse grained windswept
	FL #3	0.330	29.2	96.3	understorey of cattail – 30% understorey of willow – 25%	wet, compacted and fine to coarse grained
	FL #4	0.243	31.2	75.7	understorey of bog birch – 5% understorey of willow – 10%	wet, compacted and medium to coarse grained
	Mean	0.231	38.7	84.7	n/a	n/a
open land	OP #1	0.200	42.4	84.8	surrounded by white spruce and jackpine	dry, compacted and fine to coarse grained
	OP #2	0.196	40.4	78.9	surrounded by aspens	wet, compacted and fine to coarse grained
	Mean	0.198	41.4	81.9	n/a	n/a
open lake	L #1	0.268	28.7	77.0	n/a	wet, compacted and fine to coarse grained
	L #2	0.303	21.8	65.9	n/a	dry, crusted and fine to coarse grained
	Mean	0.285	25.2	71.4	n/a	n/a

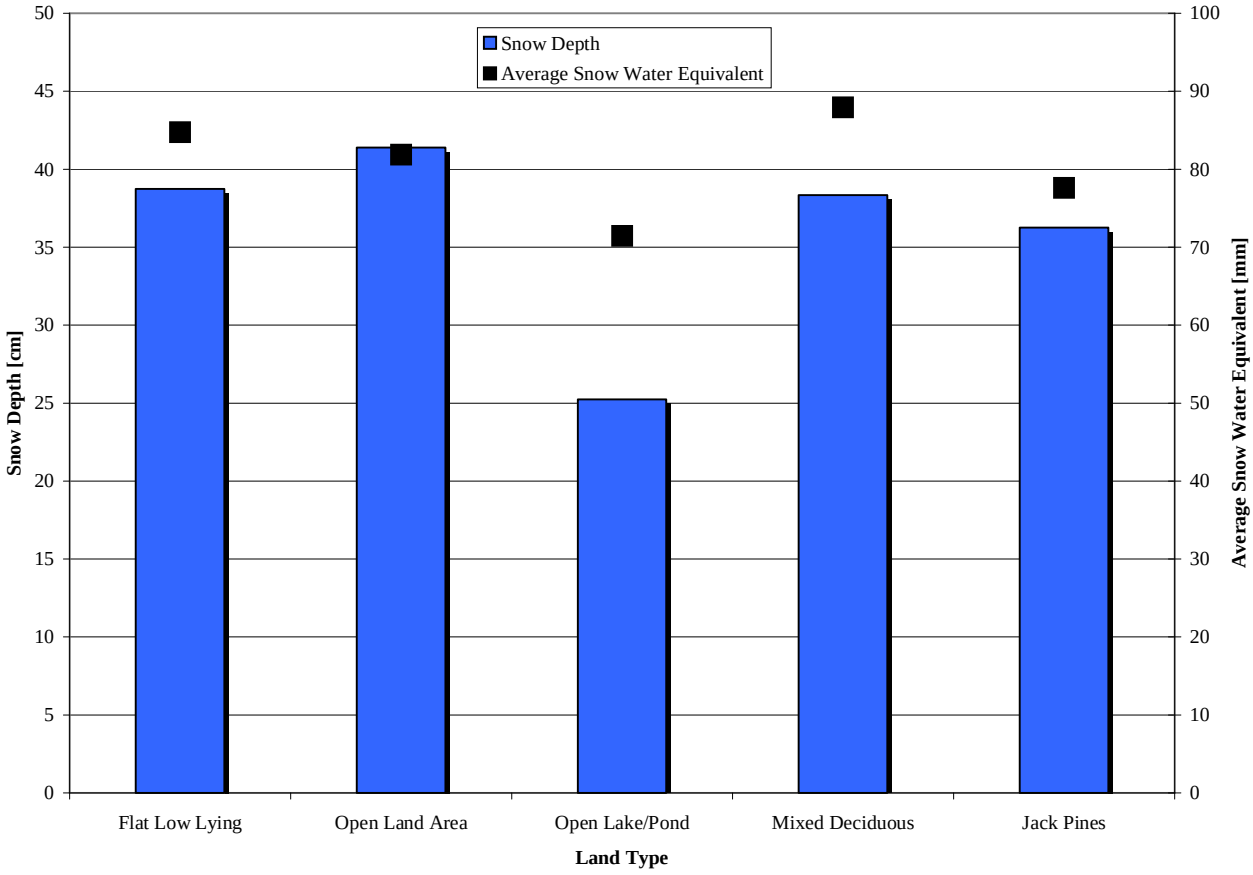
Table A-2 Summary of 2007 Snow Course Survey Data (continued)

Terrain Type	Survey Plot No.	Snow Density [g/cm^3]	Snow Depth [cm]	Snow Water Equivalent [mm]	Description of Vegetation	Snow Cover Appearance
mixed deciduous	MD #1	0.184	42.1	77.5	Aspen - 95%, av. ht.- 23m, dia. - 19cm. White spruce - 5%, av. ht. - 4m, dia. - 7cm. Understorey - cranberry - 15%, wild rose - 5%	wet, sticky and fine to coarse grained
	MD #2	0.255	45.1	115.1	Aspen - 70%, av. ht.- 20m, dia. - 19cm. White spruce - 20%, av. ht. - 17m, dia. - 21cm. Understorey - cranberry - 10%, green alder - 10%	wet and fine to coarse grained
	MD #3	0.237	39.4	93.2	Aspen - 40%, av. ht.- 25m, dia. - 35cm. White pine - 35%, av. ht. - 25m, dia. - 37cm. Understorey - cranberry - 15%, wild rose - 10%	wet and fine to coarse grained
	MD #4	0.226	31.3	70.8	Aspen - 40%, av. ht.- 18m, dia. - 22cm. White spruce - 45%, av. ht. - 16m, dia. - 19cm. Understorey – moss and lichen	dry, medium to coarse grained
	MD #5	0.245	33.8	83.0	Aspen - 40%, av. ht.- 20m, dia. - 30cm. White pine - 40%, av. ht. - 17m, dia. - 25cm. Understorey - cranberry - 5%, wild rose - 10%	wet and fine to coarse grained
	Mean	0.230	38.3	87.9	n/a	n/a

Table A-2 Summary of 2007 Snow Course Survey Data (continued)

Terrain Type	Survey Plot No.	Snow Density [g/cm^3]	Snow Depth [cm]	Snow Water Equivalent [mm]	Description of Vegetation	Snow Cover Appearance
jackpine	JP #1	0.192	35.9	69.0	Jackpine - 55%, av. ht.- 25-27m, dia. - 52cm. White spruce - 40%, av. ht. - 15-20m, dia. - 18cm. Understorey - green alder – 5%, moss and lichen - 80%	wet, sticky, compacted and fine to coarse grained
	JP #2	0.225	39.9	89.8	Jackpine - 60%, av. ht.- 23m, dia. - 40cm. White spruce - 15%, av. ht. - 18m, dia. - 22cm. Understorey - wild rose - 15%, moss and lichen	wet and fine to coarse grained
	JP #3	0.229	40.2	91.9	Jackpine - 50%, av. ht.- 25m, dia. - 33cm. White spruce - 30%, av. ht. - 15m, dia. - 20cm. Understorey - paper birch - 10%, wild rose - 15%	wet, compacted and fine to coarse grained
	JP #4	0.206	29.0	59.7	Jackpine - 40%, av. ht.- 18m, dia. - 36cm. White spruce - 25%, av. ht. - 20m, dia. - 28cm. Understorey - wild rose - 10%, cranberry - 5%	wet, compacted and fine to coarse grained
	Mean	0.213	36.3	77.6	n/a	n/a

n/a = Not applicable.



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

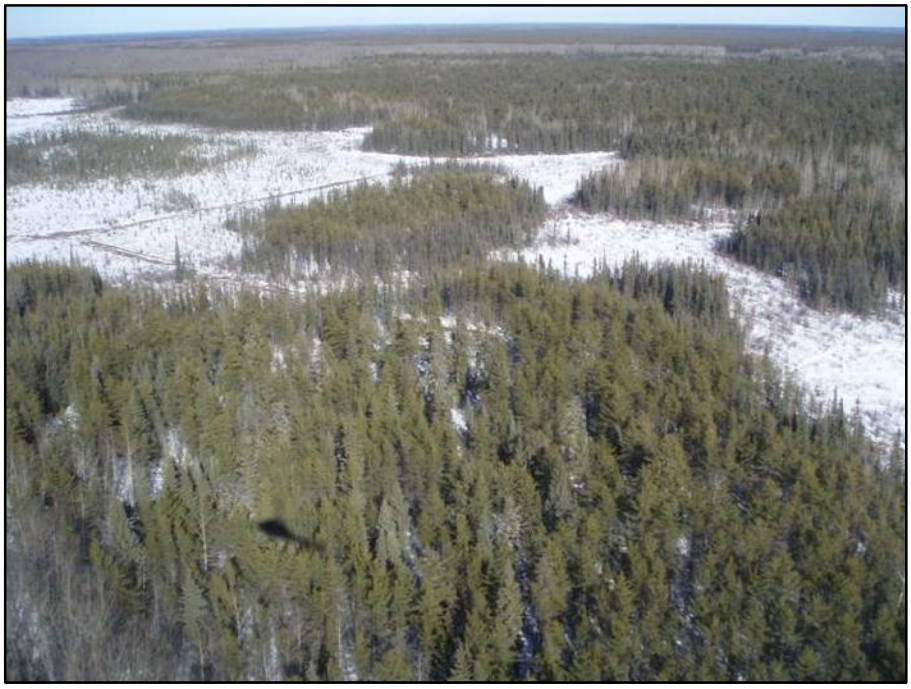
SNOW WATER EQUIVALENT OF SNOWPACKS IN VARIOUS TERRAIN TYPES

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Snow water
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	**FIGURE: A-5**	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig A-5.dwg Nov 22, 2007 - 2:50pm

PHOTOGRAPH OF SURVEY PLOT FL #1: FLAT LOW LYING AREA
(APPROXIMATELY 465698E, 6393007N, 26 MARCH 2007)



PHOTOGRAPH OF SURVEY PLOT JP #1: JACKPINE AREA
(APPROXIMATELY 465647E, 6393078N, 26 MARCH 2007)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

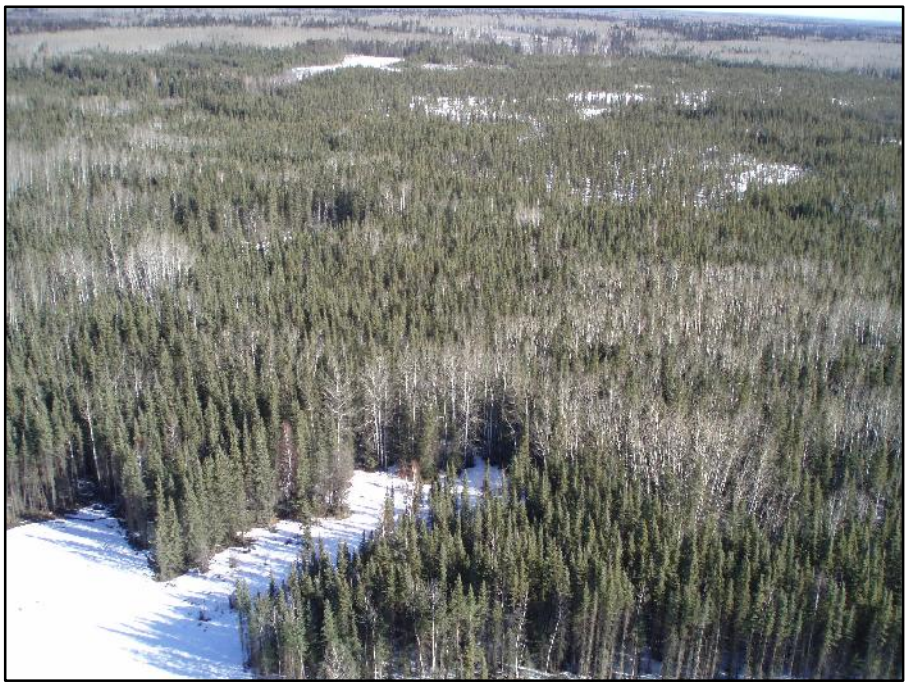
TITLE

PHOTOGRAPHS OF SNOW SURVEY PLOTS FL #1 AND JP #1

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photographs	
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	10/07/07	**FIGURE: A-6 & A-7**		
CHECK	FLA	17/11/07			
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig A-6 A-7 PHOTOGRAPHS OF SNOW SURVEY PLOTS FL1 AND JP1.dwg Nov 17, 2007 - 2:18pm



PHOTOGRAPH OF SURVEY PLOT MD #3: MIXED DECIDUOUS AREA
(APPROXIMATELY 456218E, 6382749N, 27 MARCH 2007)

PHOTOGRAPH OF SURVEY PLOT OP #2: OPEN LAND AREA
APPROXIMATELY 461625E, 6372890N, 28 MARCH 2007)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF SNOW SURVEY PLOTS MD #3 AND OP #2

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.		Photographs
DESIGN	KM	10/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE: A-8 & A-9**		
CHECK	FLA	11/17/07			
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig A-8 A-9 PHOTOGRAPHS OF SNOW SURVEY PLOTS.dwg Nov 22, 2007 - 2:53pm

4.3 SNOW COURSE SURVEY METHODS

The water equivalent of a snow pack (the equivalent depth of water if the snow pack is melted) is a product of snow depth and snow density. At each snow course survey plot, snow depths and snow densities were measured as discussed below.

Snow Depth Measurements

At each plot, 30 depth measurements were made at randomly selected locations. These depth measurements were taken by inserting a sharp rebar into the snow pack, reading the snowline mark and then measuring it with a measuring tape.

Snow Density Measurement

Three density measurements were taken at each plot, using an Atmospheric Environment Services (AES) density sampler. The AES sampler was inserted carefully into the snow pack. Snow depth was read on the tube, when the corer reached the soil surface. The corer was then inserted or twisted more deeply into the ground to get a plug of soil to prevent the granular snow from falling out of the bottom of the snow profile. The tube weight was measured (with and without snow) using the spring scale. The units of the spring scale directly provided the SWE of the snow pack in centimetres.

Additional notes were taken on vegetation cover type, colour of snow surface and snow consistency.

4.4 SUMMARY OF 2007 SNOW COURSE DATA

The snow course survey sampling locations for the 2007 program are shown in Figure A-2. The snow course data collected are summarized in Table A-2 and in Figure A-5. The data in Table A-2 show that the snow density is consistent throughout the five different terrain types surveyed. Therefore, the relative differences of snow depths between terrain types are directly reflected in variations in the SWE as follows:

- Two terrain types, jackpine and mixed deciduous, have similar snow water equivalent depths (77.6 and 87.9 mm in 2007). Forest canopies intercept a portion of precipitation (for both rain and snow) before it reaches the ground. The interception rate is proportional to the canopy coverage. Mixed deciduous tree sites, without leaves, have a more open canopy than jack pine sites and generally have a higher snow water equivalent.

- Flat low lying areas feature a dense shrub coverage, which has a low interception rate, and provides a wind-sheltered, calm area that maximizes snow accumulation potential (84.7 mm in 2007). Open lake areas have the smallest snow water equivalent depth (71.4 mm in 2007), due to the wind swept, open nature of the site. Open land areas (clearings) have a snow water equivalent similar to that of the flat low lying areas (81.9 mm in 2007).

5 CLIMATE TREND ANALYSIS METHODOLOGY AND RESULTS

5.1 GENERAL

Trend analyses of recorded air temperature and precipitation in the Oil Sands Region were conducted to determine:

- the presence of statistically significant trends in pertinent climate variables; and
- any linkages or correlations between trends in climate variables, if such trends were detected from the previous analyses.

The following sections present the methodology and results of the analyses.

5.2 AIR TEMPERATURE

The analysis of trends in air temperature in the Oil Sands Region specifically, as a result of climate change, climate variability, or both, was based on the long-term air temperature data recorded at the Fort McMurray Airport (1944 to 2006). This data were not combined with Fort McMurray Station air temperature data (1919 to 1944) to minimize errors in the trend analysis results. Air temperature trends were computed for eight statistical parameters at this station, including monthly mean, seasonal (spring, summer, fall and winter), annual mean, annual maximum and annual minimum air temperatures.

Three methods of testing for trends in air temperature were applied to the recorded air temperature data from the Fort McMurray Airport climate station (1944 to 2006).

First, the air temperature series for eight statistical parameters were plotted to determine if either an increasing or decreasing trend was evident based on the slope of the best fit line for each time series. The best fit lines suggest an increasing trend for all the air temperature parameters (Figure A-10 and A-11).

Secondly, both a parametric (Spearman) and a non-parametric (Mann-Kendall) test were conducted to identify trends (Table A-3). The Spearman and Mann-Kendall are tests that are commonly used for assessing trends in observed data. An analysis of mean annual, minimum and maximum daily air temperatures at the Fort McMurray Airport station indicates an increasing trend (i.e., statistically significant at the 5% level or 95% confidence that there is a trend).

Table A-3 Statistical Test for Trend in Air Temperature at Fort McMurray Airport Station

Station	Month	Mann-Kendall Test[a]			Spearman Rank Order Correlation Coefficient Test for Trend				Trend
		No. Data	p-value	Sen-slope	rs	t	t(α=0.05)[b]	t(α=0.01)[c]	
Air Temperature at Fort McMurray Airport station (1944 to 2006)	January	63	0.0133	0.073	-0.2774	-2.2551	-1.9996	-2.6589	(+)S
	February	63	0.0002	0.108	-0.4264	-3.6814	-1.9996	-2.6589	(+)S
	March	63	0.0034	0.073	-0.3279	-2.7105	-1.9996	-2.6589	(+)S
	April	63	0.0076	0.050	-0.2981	-2.4396	-1.9996	-2.6589	(+)S
	May	63	0.1189	0.017	-0.1632	-1.2920	-1.9996	-2.6589	(+)NS
	June	63	0.0016	0.031	-0.3871	-3.2792	-1.9996	-2.6589	(+)S
	July	63	0.0010	0.022	-0.3857	-3.2651	-1.9996	-2.6589	(+)S
	August	63	0.0422	0.020	-0.2126	-1.6994	-1.9996	-2.6589	(+)S
	September	63	0.1552	0.011	-0.1432	-1.1304	-1.9996	-2.6589	(+)NS
	October	63	0.0990	-0.017	0.1623	1.2850	1.9996	2.6589	(-)NS
	November	63	0.3948	0.010	-0.0327	-0.2558	-1.9996	-2.6589	(+)NS
	December	63	0.0502	0.051	-0.2091	-1.6705	-1.9996	-2.6589	(+)NS
	Annual	63	0.0000	0.037	-0.5327	-4.9166	-1.9996	-2.6589	(+)S
	Spring	63	0.0004	0.052	-0.4272	-3.6900	-1.9996	-2.6589	(+)S
	Summer	63	0.0001	0.025	-0.4678	-4.1337	-1.9996	-2.6589	(+)S
	Fall	63	0.4929	0.000	-0.0036	-0.0281	-1.9996	-2.6589	(+)NS
	Winter	63	0.0015	0.070	-0.3768	-3.1768	-1.9996	-2.6589	(+)S
	Annual Maximum	63	0.0004	0.036	-0.4121	-3.5326	-1.9996	-2.6589	(+)S
	Annual Minimum	63	0.005	0.060	-0.3122	-2.5670	-1.9996	-2.6589	(+)S

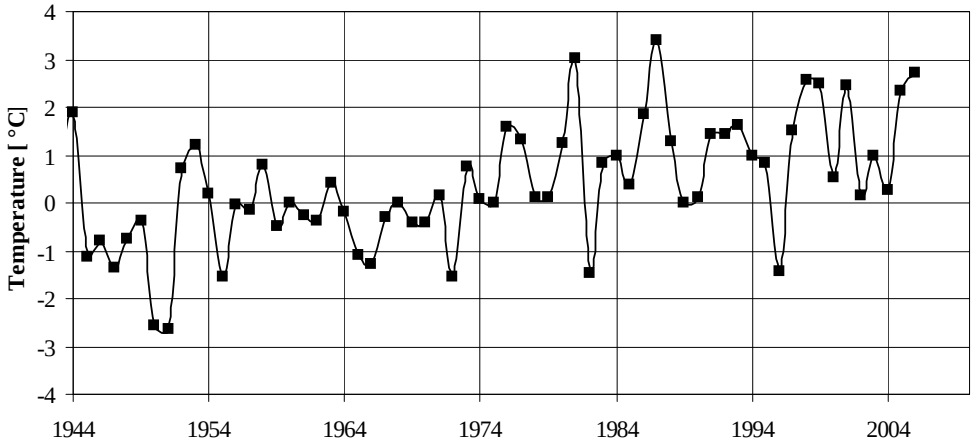
[a] Mann-Kendall test was performed as follows: For any given term, its feature vector consists of the probability P-value appearing in a given time, which is compared to all other ones and then Kendall's statistic Sen-slope is calculated. Generally, if a dataset displays a consistently increasing or decreasing trend the Sen-slope will be positive or negative respectively, with a larger magnitude indicating the trend is more consistent in its direction.

[b] If $|t|<|t(\alpha=0.05)|$, i.e., there is statistically significant level of less than 5%, then the correlation is not significantly different from zero. That is, the data do not display a statistically significant trend.

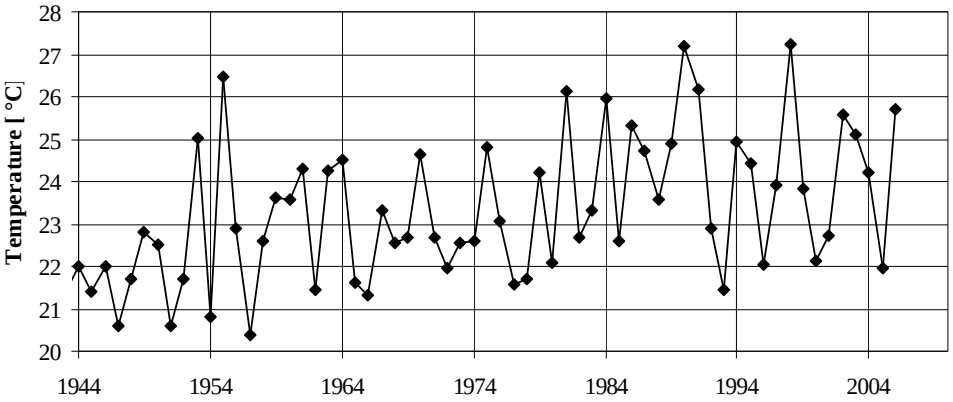
[c] $|t|<|t(\alpha=0.01)|$ represents a statistically significant level of less than 1%.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig A-10 ANNUAL MEAN, MAXIMUM AND MINIMUM TEMPERATURES AT FORT McMURRAY.dwg Nov 22, 2007 - 3:16p

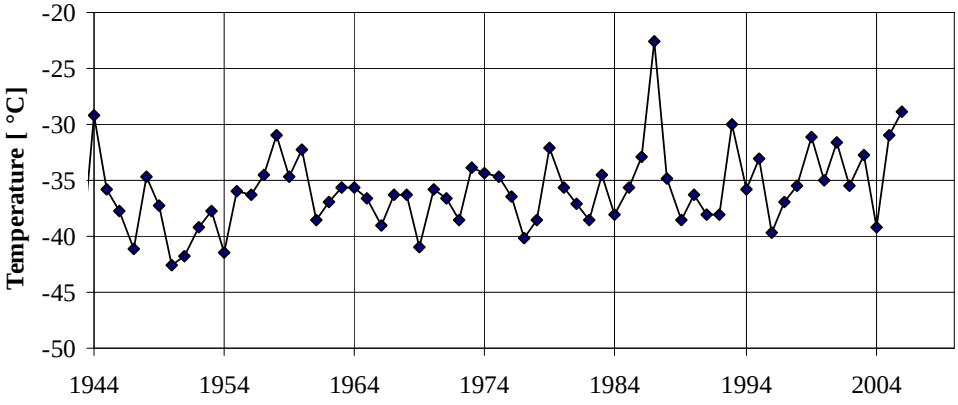
(a) Mean Annual Temperature



(b) Maximum Daily Temperature



(c) Minimum Daily Temperature



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

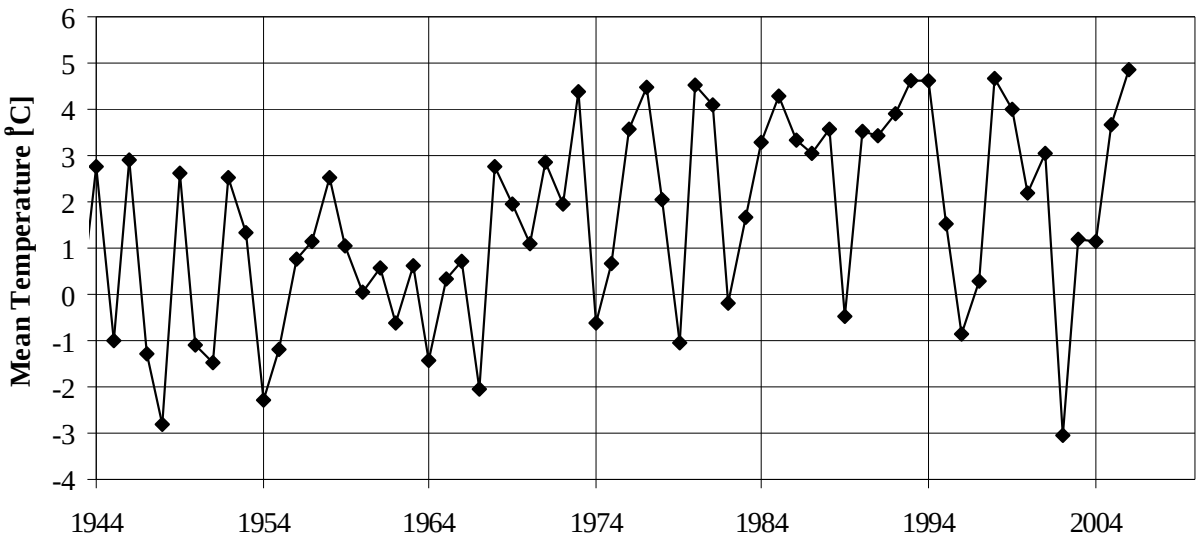
TITLE

ANNUAL MEAN, MAXIMUM AND MINIMUM TEMPERATURES AT FORT McMURRAY AIRPORT STATION

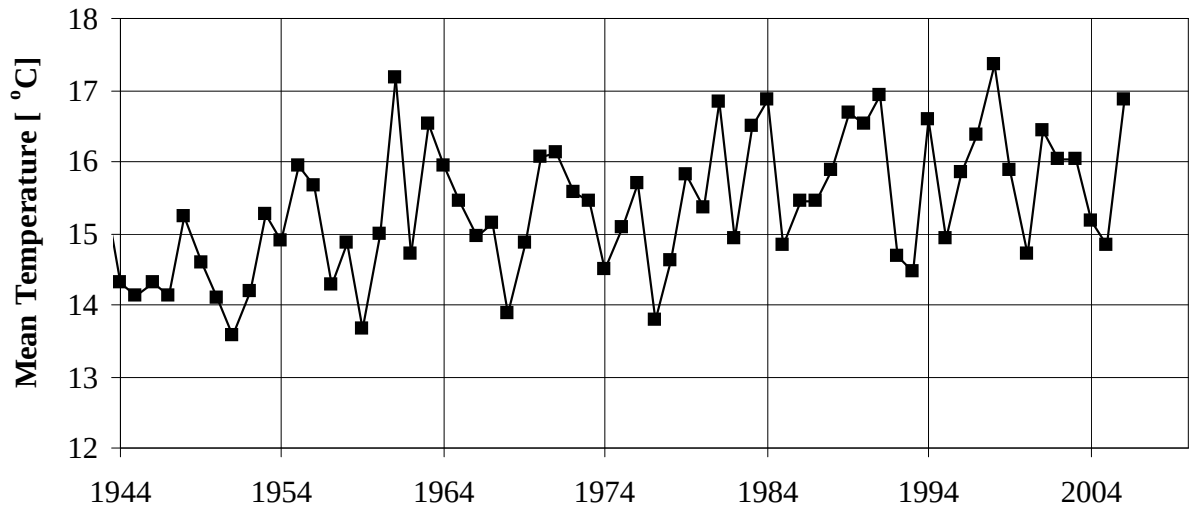
Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No. Annual temperatures	
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: A-10	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

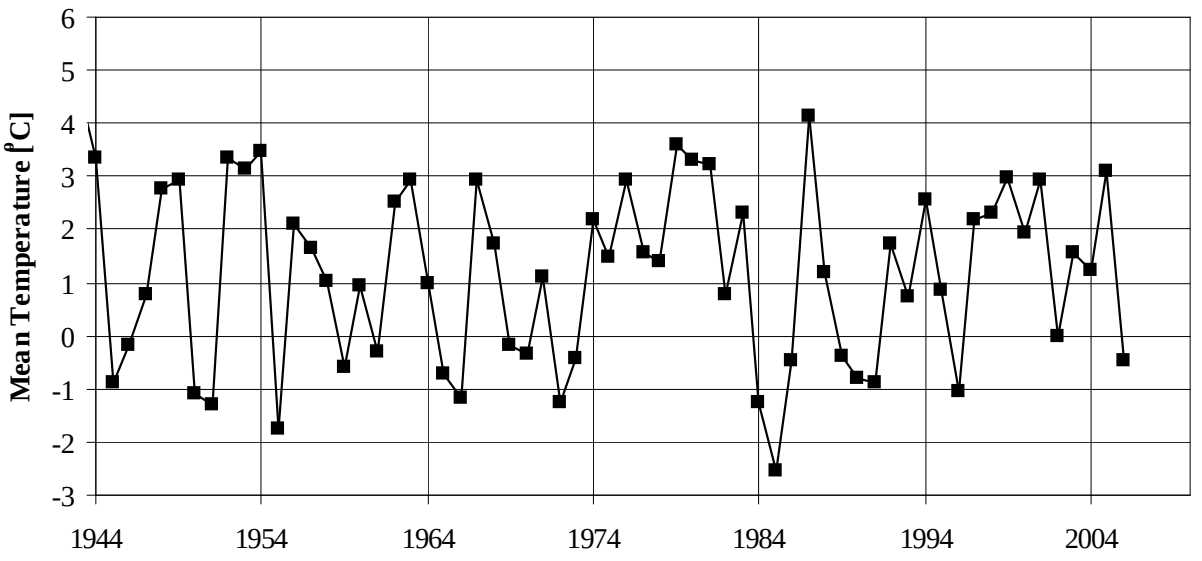
(a) Spring (March, April and May)



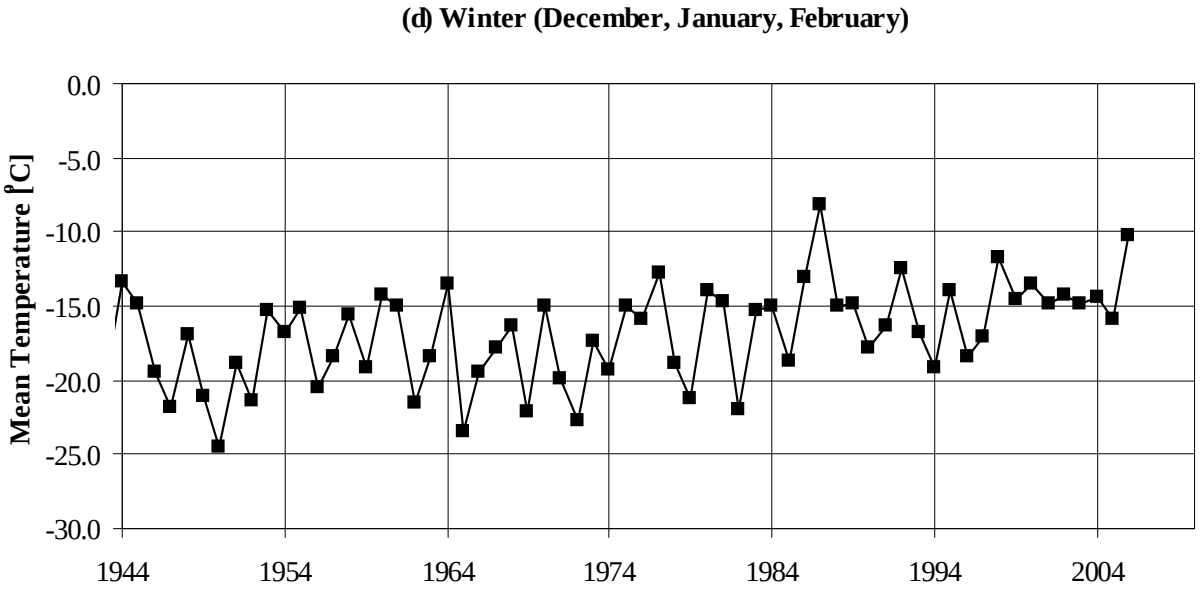
(b) Summer (June, July, August)



(c) Fall (September, October, November)



(d) Winter (December, January, February)



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

SPRING, SUMMER, FALL AND WINTER TEMPERATURES AT FORT McMURRAY AIRPORT STATION

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Temperature	
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV.	0
CADD	MM	16/11/07	**FIGURE: A-11**		
CHECK	FLA	16/11/07			
REVIEW	WES/TC	20/11/07			

Average daily air temperatures in spring, summer and winter also have increasing trends that are statistically significant at the 5% level. However, the apparent increasing trend in average fall daily air temperature is not statistically significant at the 5% level. The results of the Spearman and Mann-Kendall tests indicate an increasing trend in air temperature at both stations for all seasons except in the month of October for data recorded at Fort McMurray Airport station, which shows a decreasing trend.

Finally, the annual and seasonal mean air temperature series were divided into two equal time periods (1944 to 1974 and 1975 to 2006). For each time series, a two-sample t-test was conducted to determine whether there is a difference between the means of the two samples (Table A-4). A two-sample F-test was conducted to determine whether there is a difference between the variances of the two samples. Two-sample statistical t-tests of annual and seasonal mean air temperature corresponding to the periods 1944 to 1974 and 1975 to 2006 indicate the two samples have different mean spring, summer, winter and annual air temperatures. For the fall season, the mean air temperatures for the two samples are statistically similar based on the t-test. The results of the t-test suggest that there has been a statistically significant change (increase) in seasonal and annual mean air temperatures during the period 1975 to 2006 compared to the period 1944 to 1974. Based on the F-test, however, the variances in daily temperature for both periods are statistically similar, except for the winter period. The statistical t-test and F-test used here are the commonly used tests for assessing whether the means and variances from two samples are statistically different.

Table A-4 Statistical t-test and F-test for Two Periods (1944 to 1974 versus 1975 to 2006) of Air Temperature at Fort McMurray Airport Station

Test	Parameter	Spring		Summer		Fall		Winter		Annual	
		1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006
t-test	annual mean [°C]	0.485	2.324	14.898	15.596	1.089	1.331	-18.498	-15.579	-0.421	0.983
	variance	3.382	4.372	0.733	0.800	2.987	2.768	9.638	8.433	0.997	1.371
	observations	31	32	31	32	31	32	31	32	31	32
	hypothesized mean difference	0	–	0	–	0	–	0	–	0	–
	df	60	–	61	–	61	–	60	–	60	–
	t Stat	-3.710	–	-3.164	–	-0.568	–	-3.851	–	-5.126	–
	P(T<=t) one-tail	0.000	–	0.001	–	0.286	–	0.000	–	0.000	–
	t critical one-tail	1.671	–	1.670	–	1.670	–	1.671	–	1.671	–
	P(T<=t) two-tail	0.000	–	0.002	–	0.572	–	0.000	–	0.000	–
	t critical two-tail	2.000	–	2.000	–	2.000	–	2.000	–	2.000	–
	remark[(a)]	**rejected**		**rejected**		**accepted**		**rejected**		**rejected**	
F-test	df	30	–	30	–	30	–	30	–	30	–
	F	0.774	–	0.916	–	1.079	–	1.143	–	0.727	–
	P(F<=f) one-tail	0.242	–	0.406	–	0.417	–	0.357	–	0.192	–
	F critical one-tail	0.545	–	0.545	–	1.828	–	1.828	–	0.545	–
	remark[(a)]	**rejected**		**rejected**		**accepted**		**accepted**		**rejected**	

[(a)] accepted = the hypothesis that the mean and variance of the two series are the same is true; rejected = the hypothesis that the mean and variance of the two series are the same is false.

Notes: df = Degree of freedom; F = F-statistic; P = probability; t= t-statistic, "-" = not required.

5.3 PRECIPITATION

The analysis of trends in precipitation in the Oil Sands Region specifically, as a result of climate change, climate variability, or both, was based on precipitation recorded at the Fort McMurray Airport climate station (1944 to 2006). Precipitation trends were computed for three statistical parameters at this station, including monthly mean, seasonal and annual mean precipitation.

The three methods of testing for trends that were applied to the air temperature data (1944 to 2006) from Fort McMurray Airport climate station, as discussed above, were also applied to the recorded precipitation data from the Fort McMurray Airport climate station (1944 to 2006). For the t-test and F-test analysis the data were divided into two equal time periods (1944 to 1974 and 1975 to 2006).

First, the precipitation series for five statistical parameters were plotted. The best fit lines do not suggest any trend (Figure A-12).

Secondly, both a parametric (Spearman) and a non-parametric (Mann-Kendall) test were conducted to identify trends (Table A-5). An analysis of monthly, seasonal and annual precipitation based on the data recorded at the Fort McMurray Airport station from 1944 to 2006 does not suggest any statistically significant trend over the last 50 to 60 years, except for the month of December. The analysis of the monthly precipitation data and seasonal total precipitation at the Fort McMurray station shows that there has been an apparent decrease in precipitation in winter (i.e., November to February) and the beginning of autumn (i.e., August and September). Monthly precipitation apparently has increased in the spring and the beginning of summer (i.e., from April to July). However, the increasing and decreasing trends in monthly precipitation are not statistically significant at the 5% level, except in the month of December that shows a significant decreasing trend.

The third test was conducting two-sample t-tests and F-tests (Table A-6). The t-test indicates that the two samples have comparable total precipitation in spring, summer, fall and annually. For winter, the two samples have different total precipitation. The period of 1944 to 1974 had more precipitation than the period of 1974 to 2006. The variances in total precipitation in summer, fall and winter for both periods are statistically different based on the F-test.

Table A-5 Statistical Test for Trend in Precipitation at Fort McMurray Airport Station

Location	Period	Mann-Kendall Test[a]			Spearman Rank Order Correlation Coefficient Test for Trend				Trend
		No. Data	p-value	Sen-slope	rs	t	t (α=0.05)[b]	t (α=0.01)[c]	
Precipitation at Fort McMurray Airport station (1944 to 2006)	January	63	0.2186	-0.052	0.1035	0.8124	1.9996	2.6589	(-)NS
	February	63	0.3587	-0.021	0.0305	0.2386	1.9996	2.6589	(-)NS
	March	63	0.3029	0.027	-0.0744	-0.5826	-1.9996	-2.6589	(+)NS
	April	63	0.4693	0.010	-0.0075	-0.0585	-1.9996	-2.6589	(+)NS
	May	63	0.1154	0.179	-0.1504	-1.1883	-1.9996	-2.6589	(+)NS
	June	63	0.0826	0.296	-0.1862	-1.4803	-1.9996	-2.6589	(+)NS
	July	63	0.2082	0.193	-0.1141	-0.8967	-1.9996	-2.6589	(+)NS
	August	63	0.1900	-0.163	0.1207	0.9500	1.9996	2.6589	(-)NS
	September	63	0.1821	-0.137	0.1326	1.0446	1.9996	2.6589	(-)NS
	October	63	0.4294	0.020	-0.0446	-0.3490	-1.9996	-2.6589	(+)NS
	November	63	0.0900	-0.093	0.1541	1.2183	1.9996	2.6589	(-)NS
	December	63	0.0117	-0.171	0.2528	2.0403	1.9996	2.6589	(-)S
	annual	63	0.4834	0.044	0.0014	0.0112	1.9996	2.6589	(+)NS
	spring	63	0.1262	0.195	-0.1625	-1.2859	-1.9996	-2.6589	(+)NS
	summer	63	0.1442	0.363	-0.1390	-1.0963	-1.9996	-2.6589	(+)NS
	fall	63	0.2347	-0.212	0.0972	0.7626	1.9996	2.6589	(-)NS
	winter	63	0.0637	-0.231	0.1703	1.3496	1.9996	2.6589	(-)NS

[a] Mann-Kendall test was performed as follows: For any given term, its feature vector consists of the probability P-value appearing in a given time, which is compared to all other ones and then Kendall's statistic Sen-slope is calculated. Generally, if a dataset displays a consistently increasing or decreasing trend the Sen-slope will be positive or negative respectively, with a larger magnitude indicating the trend is more consistent in its direction.

[b] If $|t|<|t(\alpha=0.05)|$, i.e., there is statistically significant level of less than 5%, then the correlation is not significantly different from zero. That is, the data do not display a statistically significant trend.

[c] $|t|<|t(\alpha=0.01)|$ represents a statistically significant level of less than 1%.

Note: S = Significant; NS = Not Significant; rs = Spearman Rank Order Correlation Coefficient; t = Student's t.

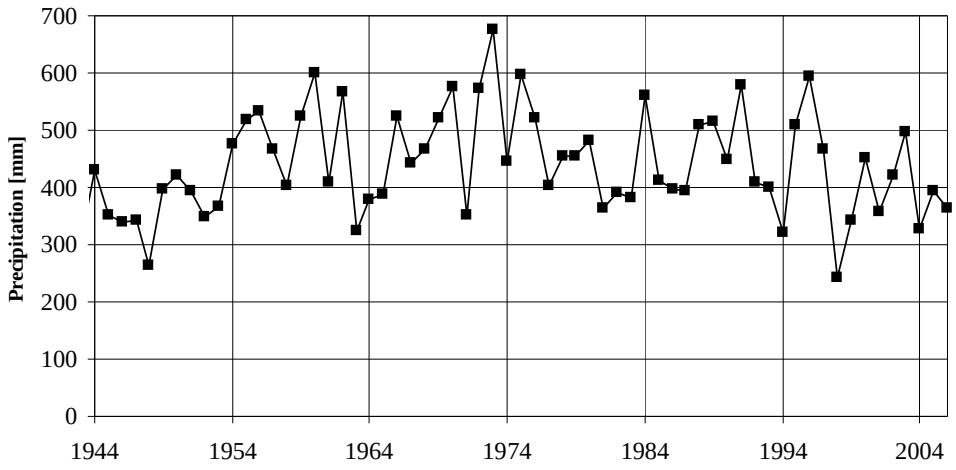
Table A-6 Statistical t-test and F-test for Two Periods (1944 to 1974 versus 1975 to 2006) of Precipitation at Fort McMurray Airport Station

Test and Parameter		Spring		Summer		Fall		Winter		Annual	
		1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006	1944 to 1974	1975 to 2006
t-test	total precipitation [mm]	71.474	76.188	204.655	219.431	104.410	91.784	65.016	48.688	445.781	435.744
	variance [mm^2]	993.261	665.777	3208.180	4473.598	1579.870	1344.452	684.615	185.664	9230.930	7211.949
	observations	31	32	31	32	31	32	31	32	31	32
	hypothesized total difference	0	–	0	–	0	–	0	–	0	–
	df	58	–	60	–	60	–	45	–	60	–
	t stat	-0.648	–	-0.947	–	1.309	–	3.092	–	0.439	–
	P(T<=t) one-tail	0.260	–	0.174	–	0.098	–	0.002	–	0.331	–
	t critical one-tail	1.672	–	1.671	–	1.671	–	1.679	–	1.671	–
	P(T<=t) two-tail	0.519	–	0.347	–	0.195	–	0.003	–	0.662	–
	t critical two-tail	2.002	–	2.000	–	2.000	–	2.014	–	2.000	–
	remark[(a)]	**accepted**		**accepted**		**accepted**		**rejected**		**accepted**	
F-test	df	30	–	30	–	30	–	30	–	30	–
	F	1.492	–	0.717	–	1.175	–	3.687	–	1.280	–
	P(F<=f) one-tail	0.137	–	0.183	–	0.329	–	0.000	–	0.249	–
	F critical one-tail	1.828	–	0.545	–	1.828	–	1.828	–	1.828	–
	remark[(a)]	**accepted**		**rejected**		**accepted**		**rejected**		**accepted**	

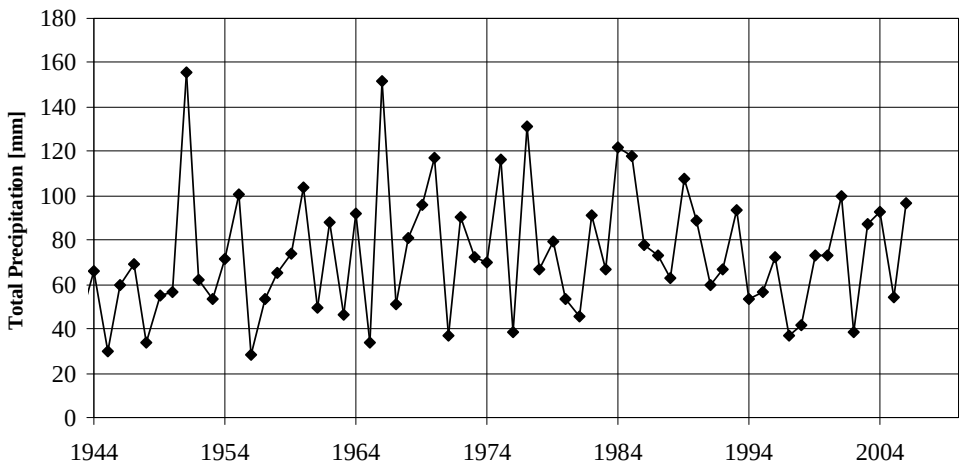
[(a)] accepted = the hypothesis that the mean and variance of the two series are the same is true; rejected = the hypothesis that the mean and variance of the two series are the same is false

Note: df = Degree of freedom; F = F-statistic; P = probability; T= t-statistic, "-" = not required.

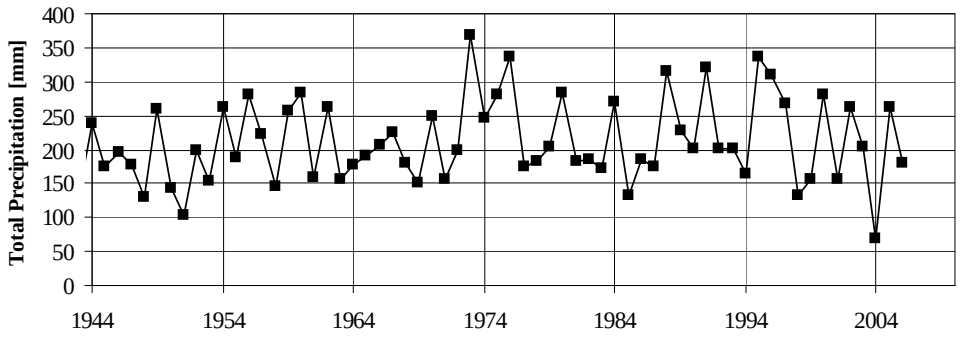
(a) Annual Precipitation



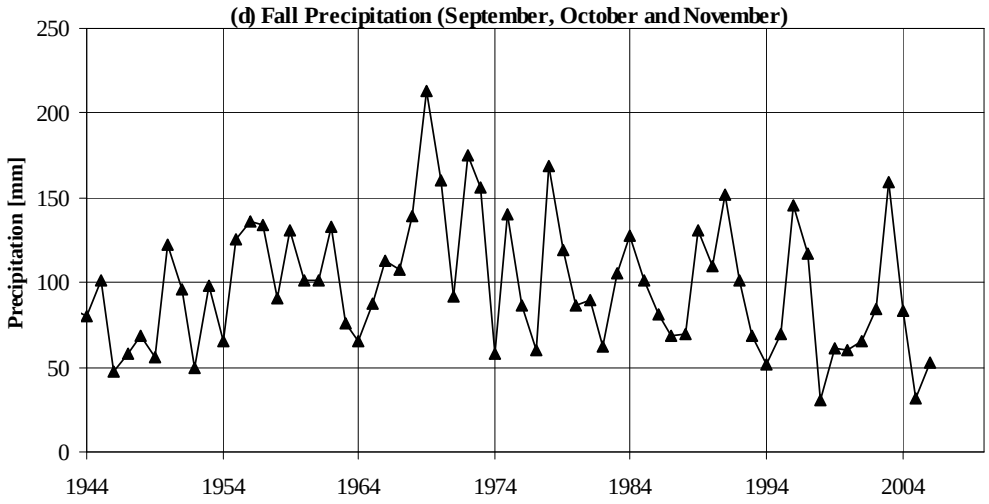
(b) Spring Precipitation (March, April and May)



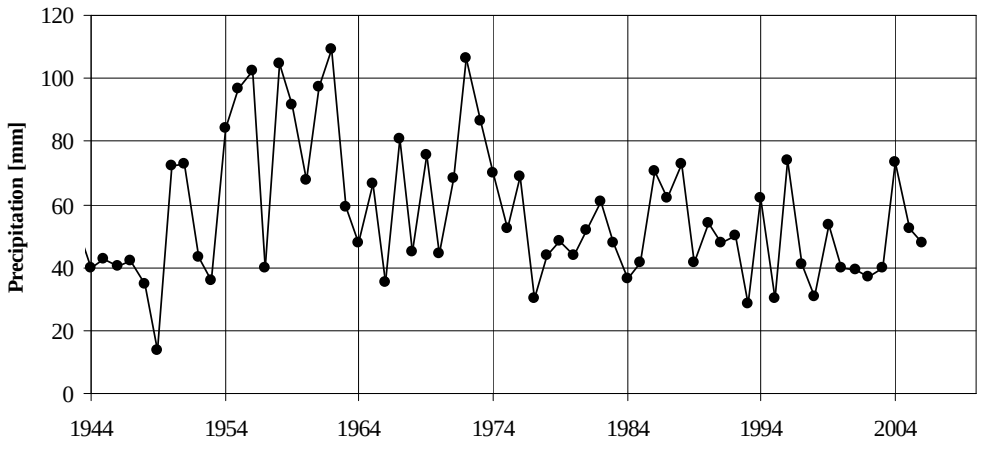
(c) Summer Precipitation (June, July and August)



(d) Fall Precipitation (September, October and November)



(e) Winter Precipitation (December, January and February)



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

TOTAL PRECIPITATION AT FORT McMURRAY AIRPORT STATION

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Precipitation
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: A-12

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APPENDIX B

LOCAL HYDROLOGY PROGRAM SUMMARY AND TREND ANALYSIS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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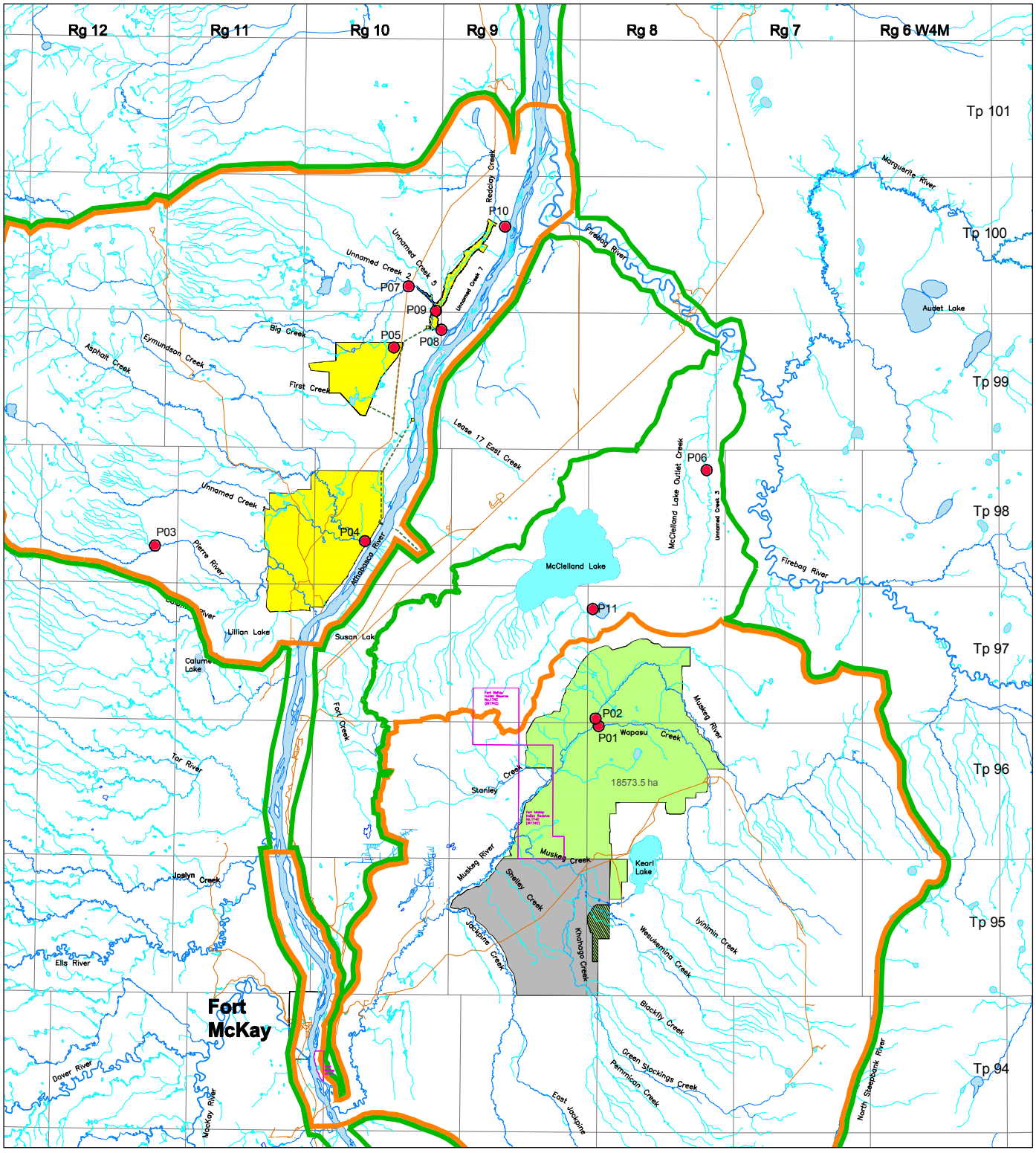
1 INTRODUCTION

This appendix presents a summary of hydrology field programs conducted during fall 2005 and all four seasons of 2006 and 2007. The hydrology field program was completed as part of the surface water hydrology environmental setting study, which was designed to support the Shell Canada Limited (Shell) Jackpine Mine Expansion & Pierre River Mine Project (the Project) Environmental Impact Assessment (EIA), as well as to expand the hydrology database required for planning and design of this Project. The hydrology field program included installation of hydrometric stations, manual discharge and water level measurements, downloading and analyzing data from these stations, and a geomorphic survey.

Based on a review and understanding of the available regional and local hydrology information, a field study program was developed to collect site-specific data. This program includes:

- installation of hydrometric stations to monitor flow and water levels at 11 hydrometric stations;
- seasonal manual measurement of discharge and water levels at 11 hydrometric stations (monitoring at three stations completed in fall 2006), as shown in Figure B-1;
- downloading of recorded data during field visits;
- compilation and analysis of downloaded data; and
- a field geomorphic survey to measure geomorphic parameters, including sinuosity, valley slope, bed slope, bankfull width, bankfull depth, bed and bank substrate and floodplain vegetation type, at 14 sites in Jackpine Expansion Mining Area (JEMA) and Pierre River Mining Area (PRMA), as shown in Figure B-2.



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- P06 INSTALLED HYDROMETRIC STATION SITES

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.) USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

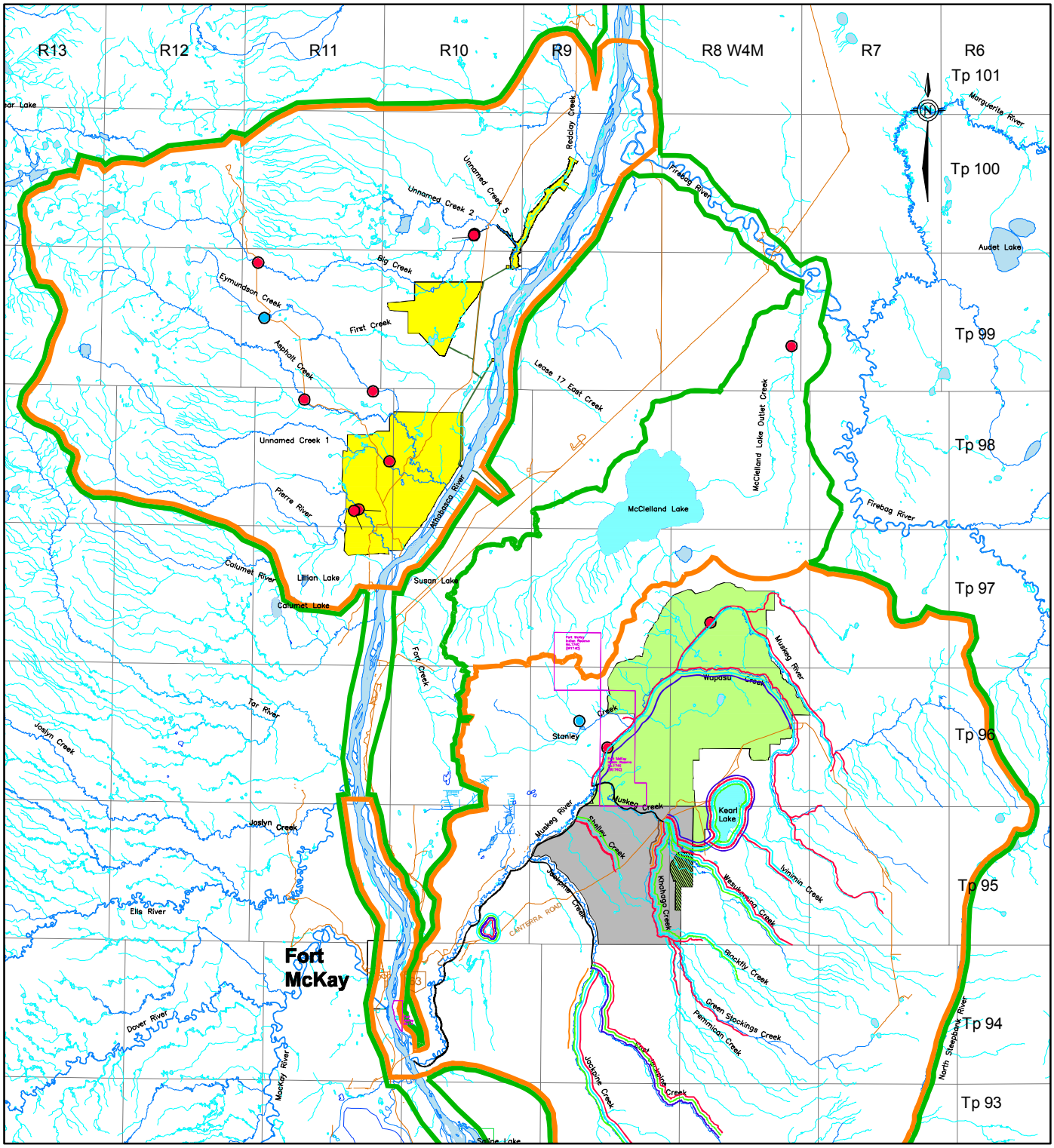
HYDROMETRIC STATIONS - FALL 2006

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Hydro Stns
DESIGN	CS	01/05/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	KM	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig B-1_HydrometricStations-Fall 2006.dwg Nov 30, 2007 - 10:40am



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- SURVEYED GEOMORPHIC SITES
- PROPOSED SITE, BUT UNSURVEYABLE DUE TO EXCESSIVE PONDING

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

SURVEYED GEOMORPHIC SITES

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Geomorphic Sites
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CADD	TY	17/11/07		
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-2

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig B-2 & F-1_Surveyed Geomorphic Sites.dwg Nov 30, 2007 - 11:15am

2 LOCAL HYDROMETRIC MONITORING PROGRAM

2.1 HYDROMETRIC MONITORING PROGRAM OVERVIEW

The following is an overview of the hydrometric monitoring program that was conducted during fall 2005, all four seasons of 2006 and 2007.

A one-year monitoring program was conducted from fall 2005 through fall 2006 for stations P01 (Wapasu Creek) and P02 (Muskeg River) in the JEMA Local Study Area (LSA), and for stations P03 (Pierre River) and P04 (Eymundson Creek) in the PRMA LSA. Regional Aquatics Monitoring Program (RAMP) data are available close to stations P01, P02 and P04, and a one-year data collection program was considered sufficient for these stations. However, because climate monitoring was planned to continue through fall 2007 at the Pierre River precipitation station (which is at the same location as station P03), and because there was no regional hydrometric data available near this station, monitoring at Station P03 was continued for 2007 as well.

A two-year monitoring program was conducted for stations P05, P07, P08, P09 and P10 in the northern leases (i.e., the Shell leases on the west side of the Athabasca River that are to the north of the PRMA development area) and for stations P06 and P11 in the tributary to Unnamed Creek 3 and the Unnamed Waterbody 4 Outlet (respectively). Sufficient regional data are not available at these locations.

The locations, basin areas and period of records for all hydrometric stations visited are provided in Table B-1. Figure B-1 shows the locations of these stations. Details of field activities and manual flow rate and water level measurements for each hydrometric station are provided in Section 2.2 and are summarized in Table B-2. Continuous flow and water level data collected during the field program were analyzed and the results are presented in Figures B-3 through B-23. Photographs of the hydrometric stations are provided in Figures B-24 through B-34.

Table B-1 Hydrometric Monitoring Stations

Station Number	Stream Name	Station Location (UTM NAD 83 Zone 12)		Basin Area [km^2]	Period of Completed and Planned Monitoring Activity
		Easting [m]	Northing [m]		
P01[(a)]	Wapasu Creek	482352	6359575	106	Winter/Spring/Summer/Fall 2006
P02[(a)]	Muskeg River	482140	6360109	290	Winter/Spring/Summer/Fall 2006
P03	Pierre River	450766	6372422	69	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P04[(a)]	Eymundson Creek	465722	6372730	313	Winter/Spring/Summer/Fall 2006
P05	First Creek	467137	6386706	26	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P06	Unnamed Creek 3	490039	6377785	45	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P07	Unnamed Creek 2	468831	6390858	110	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P08	Big Creek	471162	6387771	316	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P09	Unnamed Creek 7	470778	6389112	6	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P10	Redclay Creek	475697	6395108	211	Winter/Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007
P11[(b)]	Unnamed Waterbody 4 (Outlet)	481928	6367882	6	Spring/Summer/Fall 2006 Winter/Spring/Summer/Fall 2007

(a) Station was discontinued after one year of monitoring.

(b) Station P11 was added in spring 2006 following change in the potential JEMA development area.

Fall 2005. From September 23 to September 30, 2005, a site reconnaissance was completed to gain an improved understanding of the JEMA and PRMA LSAs and to identify locations for hydrometric monitoring stations.

Winter 2006. From February 28 to March 5, 2006, hydrometric stations P01 through P10 were visited to complete under-ice-cover flow rate and water level measurements. Temporary elevation benchmarks were also set up to have a constant datum for consecutive field programs.

Spring 2006. Eleven hydrometric stations were installed during the spring 2006 season over the course of two field visits. Station P11 was added to the program to address a potential Project feature that was eventually moved away from McClelland Lake. Seven hydrometric stations were installed during field visits from April 10 to April 12, 2006 and the remaining four stations were installed during field visits on May 25 and 26, 2006. Manual flow rate and water level measurements were completed at each station during station installation.

Table B-2 Discharge and Water Level Measurement Summary for 2006 and 2007 Field Programs

Station	Measurement Date	Discharge [m^3/s]	Water Level Elevation[a] [m]	Station Conditions
P01 – Wapasu Creek	March 4, 2006	0.000	n/a[b]	ice cover and ice thickness 49 cm
	May 26, 2006	0.236	98.65	open water
	July 14, 2006	0.133	98.87	open water
	October 24, 2006	0.000	n/a[b]	complete ice cover
P02 – Muskeg River	March 4, 2006	n/a	n/a[c]	ice thickness 8 cm, unsafe
	May 26, 2006	1.341	99.66	open water
	July 14, 2006	1.948	98.91	open water
	October 23, 2006	0.147	98.35	open water
P03 – Pierre River	March 4, 2006	0.000	n/a[b]	complete ice cover
	April 10, 2006	0.011	98.73	flow on top of ice
	July 16, 2006	0.010	97.97	open water, station damaged but repaired
	October 23, 2006	0.001	97.24	frozen, flow under ice estimated
	February 9, 2007	0.000	n/a[b]	complete ice cover
	May 10, 2007	0.026	97.94	open water
	July 27, 2007	0.000	97.79	open water, no flow
	October 23, 2007	n/a[e]	n/a[e]	n/a
P04 – Eymundson Creek	March 3, 2006	0.000	n/a[b]	complete ice cover
	April 10, 2006	0.591	97.20	open water
	July 15, 2006	2.666	97.21	open water
	October 23, 2006	0.132	96.46	ice on edge and 10% cover, station damaged
P05 – First Creek	March 3, 2006	0.000	98.25	open water but tiny flow
	April 11, 2006	0.005	98.08	open water
	August 28, 2006	0.001	98.13	open water, station damaged
	October 24, 2006	0.000	n/a[b]	complete ice cover at gauge
	February 9, 2007	0.000	n/a[b]	complete ice cover at gauge
	April 20, 2007	n/a	98.44	open water, flooded, no flow
	May 9, 2007	0.0003	98.11	open water
	July 26, 2007	0.001	98.12	open water
	October 25, 2007	n/a[e]	n/a[e]	n/a
P06 – Unnamed Creek 3	March 5, 2006	0.238	98.66	ice on edge with 19 cm thickness
	May 25, 2006	0.332	98.66	beaver dam spotted
	July 15, 2006	0.283	98.82	beaver dam spotted
	October 24,2006	0.272	98.69	channel ice free
	February 4, 2007	0.272	98.80	ice cover and ice thickness 15 cm
	April 17, 2007	0.370	98.60	beaver dams upstream and downstream
	May 4, 2007	0.437	98.86	open water
	July 26, 2007	0.217	98.58	open water
	October 23, 2007	n/a[e]	n/a[e]	n/a
P07 – Unnamed Creek 2	March 3, 2006	0.000	n/a[b]	complete ice cover
	April 12, 2006	0.807	98.40	open water
	July 18, 2006	1.822	98.23	open water
	October 25, 2006	0.050	97.79	open water
	February 10, 2007	0.000	n/a[b]	complete ice cover at gauge
	April 18, 2007	n/a[c]	99.34	flooded, water flowing over ice
	May 9, 2007	2.64	98.38	open water
	July 26, 2007	0.177	97.95	open water
	October 28,2007	n/a[e]	n/a[e]	n/a
P08 – Big Creek	March 4, 2006	0.049	98.43	small flow, average ice thickness 56 cm
	April 11, 2006	0.478	98.63	open water, some ice
	August 2, 2006	0.591	98.24	open water, station damaged
	October 24, 2006	0.141	n/a[d]	open water
	February 9, 2007	0.000	n/a[b]	complete ice cover at gauge
	April 20, 2007	n/a[c]	98.86	water flowing over shore ice
	May 10, 2007	3.242	100.175	open water, flooded
	July 25, 2007	0.252	98.06	open water
	October 25, 2007	n/a[e]	n/a[e]	n/a

Table B-2 Discharge and Water Level Measurement Summary for 2006 and 2007 Field Programs (continued)

Station	Measurement Date	Discharge [m^3/s]	Water Level Elevation[(a)] [m]	Station Conditions
P09 – Unnamed Creek 7	March 3, 2006	0.124	98.71	small flow, average ice thickness 47 cm
	April 12, 2006	0.406	98.93	open water
	August 2, 2006	0.667	98.72	open water, station damaged
	October 25, 2006	0.134	98.51	open water
	February 11, 2007	0.000	n/a[(b)]	complete ice cover at gauge
	April 20, 2007	n/a[(c)]	99.62	shelf, shore and bottom ice
	May 10, 2007	3.246	99.21	open water, installed
	July 25, 2007	0.247	98.51	open water
	October 28, 2007	n/a[(e)]	n/a[(e)]	n/a
P10 – Redclay Creek	March 3, 2006	0.079	97.73	small flow, average ice thickness 19 cm
	April 12, 2006	0.523	97.88	open water
	August 2, 2006	0.996	97.78	open water, station damaged
	October 24, 2006	0.484	97.70	open water, station damaged
	February 9, 2007	0.056	97.61	thin ice cover
	April 18, 2007	n/a[(c)]	97.94	shelf ice
	May 10, 2007	1.946	100.31	open water, flooded
	July 24, 2007	0.186	97.75	open water
	October 27, 2007	n/a[(e)]	n/a[(e)]	n/a
P11 – Unnamed Waterbody 4 Outlet	May 26, 2006	0.000	99.66	open water
	July 14, 2006	0.000	99.64	open water
	October 23, 2006	0.000	99.58	ice cover
	February 10, 2007	0.000	99.67	ice cover, ice thickness between 28 to 32 cm
	April 17, 2007	0.000	99.67	no flow, ponded water
	May 11, 2007	0.000	66.68	open water, no flow
	July 27, 2007	0.000	99.59	open water, no flow
	October 23, 2007	n/a[(e)]	n/a[(e)]	n/a

[(a)] Water level elevations were tied to a temporary benchmark elevation of 100 m.

[(b)] Complete ice cover, no water level to measure.

[(c)] Dangerous ice conditions on the river prevented water level measurement.

[(d)] The benchmark could not be located therefore no water level could be measured.

[(e)] Data from the fall 2007 field program will be provided in an EIA update.

n/a = Not available.

Summer 2006. All hydrometric monitoring stations were visited during the summer 2006 season over the course of three field visits. Equipment malfunctions, site access, bad weather and helicopter maintenance issues, and time required to repair damaged stations on site prevented completion of visits to all hydrometric stations during the initial summer field program, conducted from July 14 to July 18, 2006, when seven stations were visited. Three more stations were visited on August 1 and 2, 2006 and the remaining station was visited on August 28, 2006. During each hydrometric station field visit, manual flow rate and water level measurements were completed and recorded data were downloaded, and repairs to damaged stations were completed or attempted. Details are provided in Section 2.2.

Fall 2006. All hydrometric monitoring stations were visited during the fall 2006 field programs conducted from October 24 to 26, 2006. Manual flow rate and

water level measurements were taken at all hydrometric stations, and data were downloaded from 10 hydrometric stations (since damaged hydrometric station P05 had been removed during the summer 2006 field program). All hydrometric stations were also decommissioned during the fall 2006 field visit.

Winter 2007. From February 4 to 10, 2007, all eight hydrometric stations planned for continued monitoring in 2007 (P03, P05, P06, P07, P08, P09, P10 and P11) were visited to attempt under-ice-cover flow rate and water level measurements. Measurements were collected at stations P06 and P10, and the remaining six stations had complete ice cover frozen to the river bottom.

Spring 2007. From April 24 to 27, 2007, all eight hydrometric stations planned for continued monitoring in 2007 (P03, P05, P06, P07, P08, P09, P10 and P11) were visited to attempt to install hydrometric stations, and attempt to measure flow rate and water level. Water level measurements were collected at stations P03, P05, P06, P07, P08, P09, P10 and P11, and a discharge measurement was collected P06. The remaining seven stations had unsafe ice conditions and discharge measurements were not collected.

A second spring visit was completed from May 4 to 9 2007, all eight hydrometric stations were visited to measure flow rate and water level, as well as to download data loggers. During each hydrometric station field visit, manual flow rate and water level measurements were completed and recorded data were downloaded, and repairs to damaged stations were completed or attempted. Details are provided in Section 2.2.

Summer 2007. From July 24 to 27, 2007, all eight hydrometric stations (P03, P05, P06, P07, P08, P09, P10 and P11) were visited to measure flow rates and water levels, and to download the data loggers.

Fall 2007. From October 23 to 28, 2007, all eight hydrometric stations (P03, P05, P06, P07, P08, P09, P10 and P11) were visited to measure flow rates and water levels, to download the dataloggers and to decommission the stations. A geomorphic survey of Redclay Creek was conducted. Groundtruthing of the streams to determine intermittent and permanent reaches was completed. The results from the Fall 2007 field program will be included in an EIA update.

2.2 HYDROMETRIC STATION SUMMARIES

2.2.1 Wapasu Creek Station (P01)

The Wapasu Creek station site (P01) is located upstream of the confluence of Wapasu Creek, with the Muskeg River. The hydrometric station was installed on May 26, 2006 and was decommissioned on October 24, 2006. No additional monitoring was undertaken in 2007.

Manual flow rate and water level measurements were taken at this site on May 26 and July 14, 2006. This site was also visited on March 4, 2006 and October 24, 2006 and the creek was frozen to the bottom of the channel on these dates; thus, no under-ice flow was observed. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and compared to the measured water levels as shown in Figure B-3. The 2006 water level-discharge relationship is presented in Figure B-4. A rating curve was not developed because only two sets of measurements are available. A photograph of the site is presented in Figure B-24 (taken on July 14, 2006).

2.2.2 Muskeg River Station (P02)

The Muskeg River hydrometric station site (P02) is located on Muskeg River above Wapasu Creek. The hydrometric station was installed on May 26, 2006 and was decommissioned on October 23, 2006. No additional monitoring was undertaken in 2007.

Manual flow rate and water level measurements were taken at this site on May 26, July 14 and October 23, 2006. The site was also visited on March 4, 2006 but discharge measurements were not performed because the river had a thin ice cover and the performance of manual flow measurements would have been unsafe. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

The datalogger had some technical problems and recorded water levels could not be downloaded. The measured water levels are plotted in Figure B-5. The 2006 water level-discharge relationship is presented in Figure B-6. A rating curve could not be developed because of a lack of sufficient data. A photograph of the site is presented in Figure B-25 (taken on July 14, 2006).

2.2.3 Pierre River Station (P03)

The Pierre River hydrometric station site (P03) is located in the middle reach of Pierre River. The hydrometric station was installed on April 10, 2006, and was decommissioned on October 23, 2006. It was reinstalled on April 18, 2007 and decommissioned on October 23, 2007.

During the 2006 field season, manual flow rate and water level measurements were taken at this site on April 10, July 16 and October 23, 2006. The site was also visited on March 4, 2006 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed. During the July 16, 2006 field visit, it was determined that this station had not been functioning properly from May 2 to July 16, 2006. However, the station was repaired on site.

During the 2007 field season, manual flow rate and water level measurements were attempted February 9, 2007 but no measurements were taken because the water was frozen to the stream bottom. The station was reinstalled on May 10, 2007 and visited on July 27, 2007 and October 23, 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results for both the datalogger and the manual flow measurements are presented in Figure B-7. The water level-discharge relationship is presented in Figure B-8. A photograph of the site is presented in Figure B-26 (taken on April 10, 2006).

2.2.4 Eymundson Creek Station (P04)

The Eymundson Creek hydrometric station site (P04) is located near the mouth of Eymundson Creek. The hydrometric station was installed on April 10, 2006 and was decommissioned October 23, 2006. No additional monitoring was undertaken in 2007.

Manual flow rate and water level measurements were taken at this site on April 10, July 15 and October 23, 2006. The station was also visited on March 3, 2006 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed. During the October 23, 2006 visit, when the site was decommissioned, the sensor was found to be frozen in the river bank and the cable had been damaged by animals. Data for the period of August 17 to October 23, 2006 are therefore not available Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results for both the datalogger and the manual flow measurements are presented in Figure B-9. No data were recorded after August 17, 2006, presumably due to animal damage at the site. The 2006 water level-discharge relationship is presented in Figure B-10. A photograph of the site is presented in Figure B-27 (taken on April 10, 2006).

2.2.5 First Creek Station (P05)

The First Creek hydrometric station site (P05) is located on First Creek. The hydrometric station was installed on April 11, 2006 and was decommissioned on August 28, 2006. It was reinstalled on April 20, 2007 and decommissioned on October 25, 2007.

During the 2006 field season, manual flow rate and water level measurements were taken at this site on March 3, April 11 and August 28, 2006. A site visit originally scheduled for this station in early July 2006 was rescheduled until late August 2006 due to weather, helicopter, site access and station damage issues at other stations in the Project area. On August 28, 2006 the station was decommissioned after having sustained damaged beyond repair by animal activity, and very little data were salvageable. The site was also visited on October 24, 2006 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed

During the 2007 field season, manual flow rate and water level measurements were attempted on and February 9, 2007 and the creek was frozen to the bottom of the channel; thus no under-ice flow was observed. The station was reinstalled on April 20, 2007, and monitored on May 9, July 26 and October 25, 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded but there were equipment malfunctions during 2006, as shown in Figure B-11. The water level-discharge relationship is presented in Figure B-12. A rating curve has not been developed because some water level measurements are not consistent; the water levels may have been influenced by the variation of vegetation density from season to season. A photograph of the site is presented in Figure B-28 (taken on April 11, 2006).

2.2.6 Unnamed Creek 3 Station (P06)

The Unnamed Creek 3 hydrometric station site (P06) is located on the unnamed tributary to the McClelland Lake Outlet Creek, which is a tributary creek to the Firebag River. The station site is located downstream of a temporary steel bridge

that is used for a Project access road. Two beaver dams, and an island between the dams, were found between the bridge and the station. The hydrometric station was installed on May 25, 2006 and was decommissioned for winter storage on October 24, 2006. It was reinstalled on April 17, 2007 and decommissioned on October 23, 2007.

During the 2006 field season, manual flow and water level measurements were taken at this site on March 5, May 25, July 15 and October 24, 2006.

During the 2007 field season, the site was visited on February 4, 2007. It was reinstalled on April 17, 2007 and monitored on May 4, July 27, and October 23 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results for both the datalogger and the manual flow measurements are presented in Figure B-13. The water level-discharge relationship could not be determined because of beaver activity in the reach (Figure B-14). A photograph of the site is presented in Figure B-29 (taken on July 15, 2006).

2.2.7 Unnamed Creek 2 Station (P07)

The Unnamed Creek 2 hydrometric station site (P07) is located at the confluence of an unnamed tributary with Big Creek. The hydrometric station was installed on April 12, 2006 and was decommissioned for winter storage on October 25, 2006. It was reinstalled on April 18, 2007 and decommissioned on October 28, 2007.

During the 2006 field season, manual flow and water level measurements were taken at this site on April 12, July 18 and October 25, 2006. The site was also visited on March 3, 2006 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed.

During the 2007 field season, the site was visited on February 10, 2007 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed. The station was reinstalled temporarily on April 18, 2007 due to ice on the creek. It was out of the water but not damaged on May 9, 2007, and was reinstalled in a more secure location**.** It was monitored on July 26 and October 28, 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results for both the datalogger and the manual flow measurements are presented in Figure B-15. The water level-discharge relationship is presented in Figure B-16. A photograph of the site is presented in Figure B-30 (taken on April 12, 2006).

2.2.8 Big Creek Station (P08)

The Big Creek hydrometric station site (P08) is located near the mouth of Big Creek. The hydrometric station was installed on April 11, 2006 and was decommissioned for winter storage on October 24, 2006. The station was reinstalled on April 20, 2007 and decommissioned on October 25, 2007.

During the 2006 field season, manual flow rate and water level measurements were taken at this site on March 4, April 11 and August 2, 2006. When the site was visited on August 2, 2006, the station was found to have been damaged by animal activity and was fixed on site, although data were lost. Manual flow measurements were taken on October 24, 2006 but the benchmark could not be located, so no water level elevation was taken and this manual discharge data point could not be included in developing the water level-discharge relationship.

During the 2007 field season**,** the site was also visited on February 9, 2007 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed. It was monitored on April 20, May 10, July 25 and October 25, 2007. The original benchmark was located on April 20, 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results show a big fluctuation due to equipment malfunction from animal damage before August 2, 2006. Recorded water levels and the manual flow measurements are presented in Figure B-17. The water level-discharge relationship is presented in Figure B-18. A photograph of the site is presented in Figure B-31 (taken on April 11, 2006).

2.2.9 Unnamed Creek 7 Station (P09)

The Unnamed Creek 7 hydrometric station site (P09) is located at the confluence of an unnamed tributary with Big Creek. The hydrometric station was installed on April 12, 2006 and was decommissioned for winter storage on October 25, 2006. It was reinstalled on April 20, 2007 and decommissioned on October 28, 2007.

During the 2006 field season, manual flow rate and water level measurements were taken at this site on March 3, April 12, August 2 and October 25, 2006. When the site was visited on August 2, 2006, the station was found to have been damaged by animal activity.

During the 2007 field season, the site was visited on February 11, 2007 and the creek was frozen to the bottom of the channel; thus, no under-ice flow was observed. It was monitored on April 20, May 10, July 25, July 26 and October 28, 2007. The site was flooded on May 10, 2007. When the site was visited on July 25 2007, the probe appeared to have been damaged by animal activity and the logger was gone. The station was repaired on July 26, 2007. Data are not available from this station in 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded but could not be used due to equipment malfunction from animal damage as indicated in Figure B-19. The water level-discharge relationship and a rating curve are presented in Figure B-20. A photograph of the site is presented in Figure B-32 (taken on August 2, 2006).

2.2.10 Redclay Creek Station (P10)

The Redclay Creek hydrometric station site (P10) is located near the mouth of Redclay Creek. The hydrometric station was installed on April 12, 2006 and was decommissioned for winter storage on October 24, 2006. It was reinstalled on April 18, 2007 and decommissioned on October 27, 2007.

During the 2006 field program, manual flow rate and water level measurements were taken at this site on March 3, April 12, August 2 and October 24, 2006. When the site was visited on August 2, 2006, the station was found to have been damaged by animal activity and was fixed on site, although some data were lost. The data downloaded on October 24, 2006 indicate that the station had been damaged again on August 14, 2006.

During the 2007 field program, the site was visited on February 9, 2007. The station was reinstalled on April 18, 2007 and monitored on May 10, July 24 and October 27, 2007. On May 10, the site was flooded and the data were not recoverable. When the site was visited on July 24, the logger was not functioning. It was replaced on July 27, 2007. No recorded water level data are available in 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and the results for both the datalogger and the manual flow measurements are presented in Figure B-21. The water level-discharge relationship and rating curve are presented in Figure B-22. A photograph of the site is presented in Figure B-33 (taken on March 3, 2006).

2.2.11 Unnamed Waterbody 4 Station (P11)

The Unnamed Waterbody 4 Outlet hydrometric station site (P11) is located at the outlet channel of the unnamed lake that drains to McClelland Lake. This low-lying site was added during the spring 2006 field season. The hydrometric station was installed on May 26, 2006 and decommissioned for winter storage on October 23, 2006. It was reinstalled on April 17, 2007 and decommissioned on October 23, 2007.

During the 2006 field program, there were site visits on May 26, July 14 and October 23, 2006 and to measure water level and flow rate. Standing water in this outlet creek was observed in the site visits on May 26 and July 14, 2006, and complete ice cover was observed in the site visits on October 23, 2006 so no flow rate data were measured during the latter field visits.

During the 2007 field program, the station was visited on February 10, April 17, May 11, July 27 and October 23, 2007. Table B-2 provides summaries of the manual discharge, the water level measurements and the station conditions during field visits.

Recorded water levels were downloaded and compared to the measured water levels as shown in Figure B-23. Discharge could not be measured at this station because there was no flow observed. As a result no water level-discharge relationship or rating curve could be developed for this site. A photograph of the site is presented in Figure B-34 (taken on May 26, 2006).

3 RECORDED WATER LEVELS AND RATING CURVES

Figures B-3 through B-23 present recorded water levels and rating curves for stations at JEMA and PRMA.

FIGURE B-3 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P01 (WAPASU CREEK)

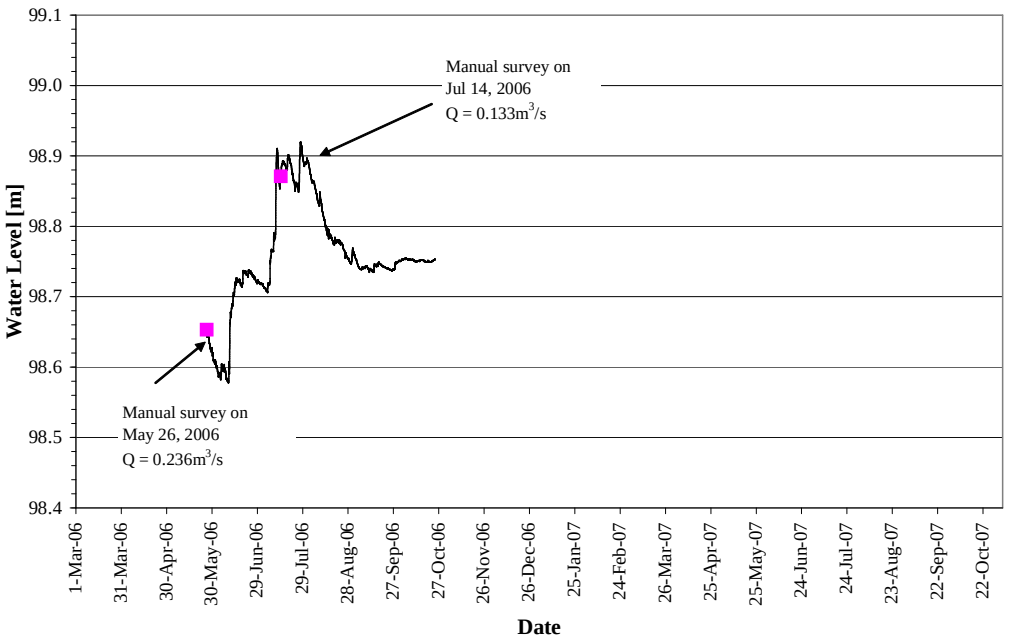
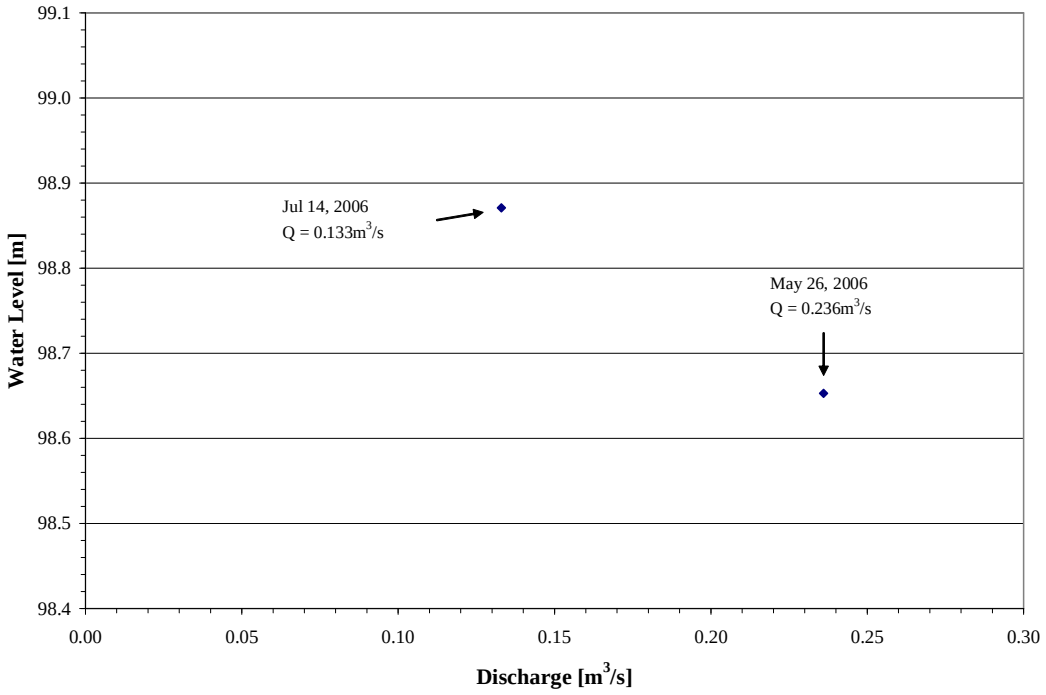


FIGURE B-4 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P01 (WAPASU CREEK)



PROJECT

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TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P01 (WAPASU CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P01
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-3 & B-4

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FIGURE B5 MANUAL WATER LEVEL MEASUREMENTS AT STATION P02 (MUSKEG RIVER)

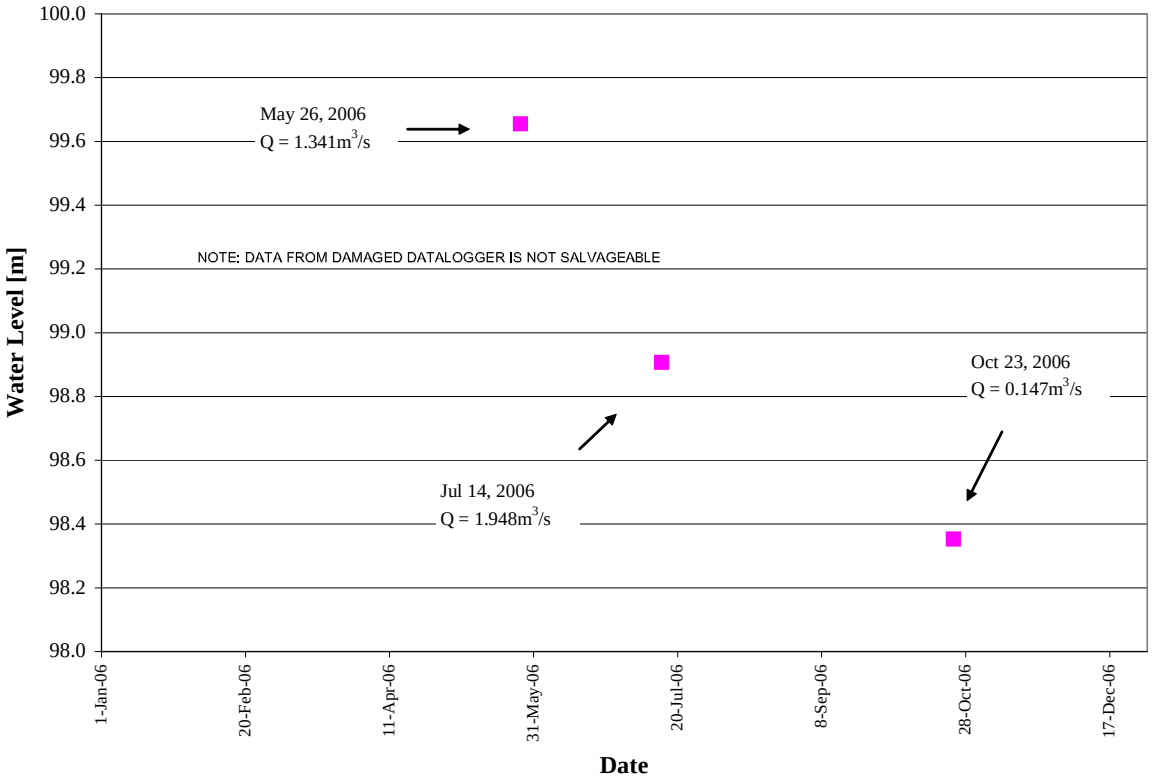
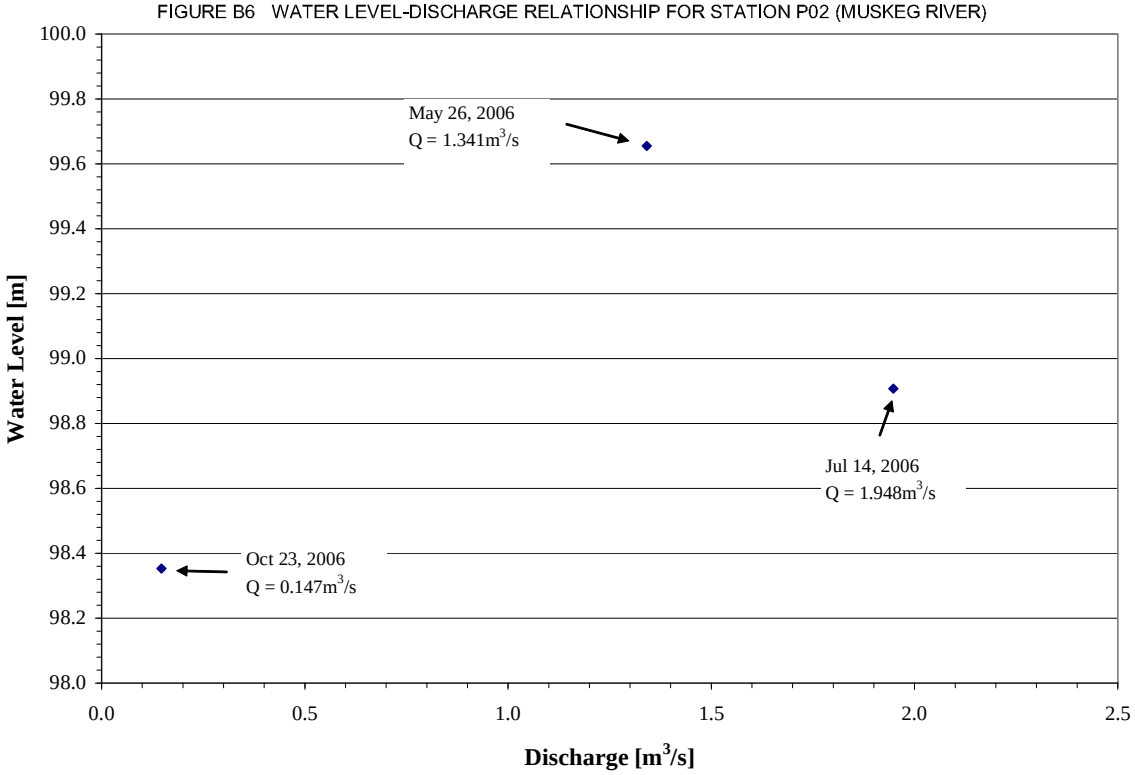


FIGURE B6 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P02 (MUSKEG RIVER)



PROJECT

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TITLE

MANUAL WATER LEVEL MEASUREMENTS AND WATER LEVEL - DISCHARGE RELATIONSHIP FOR STATION P02 (MUSKEG RIVER)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P02
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CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-5 & B-6

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FIGURE B-7 MANUAL WATER LEVEL MEASUREMENTS AT STATION P03 (PIERRE RIVER)

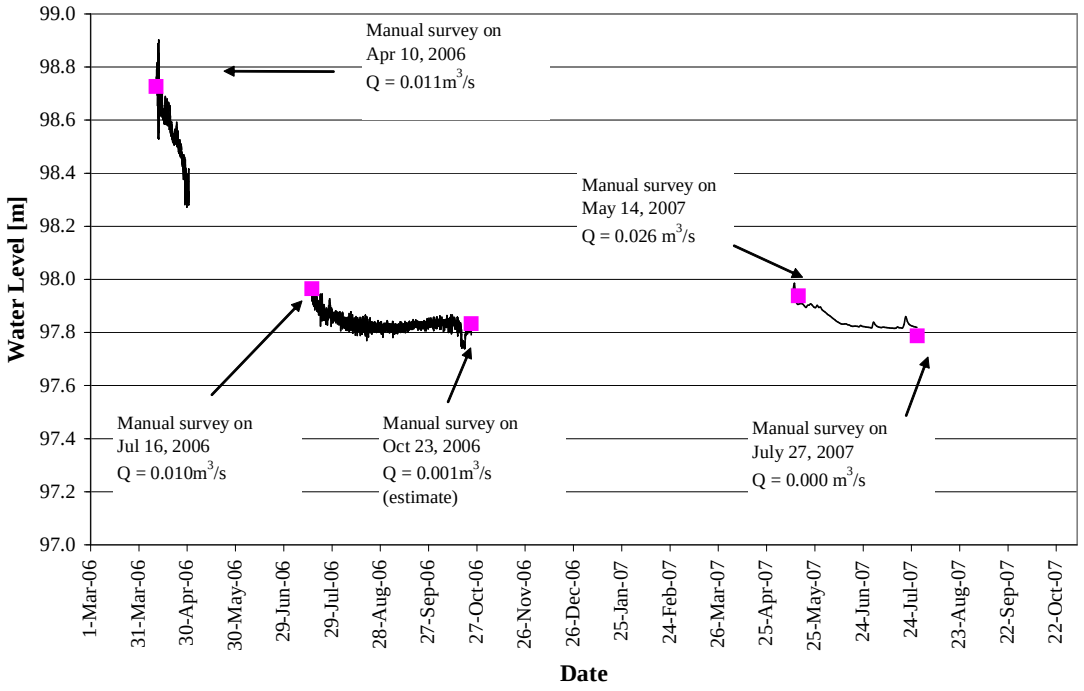
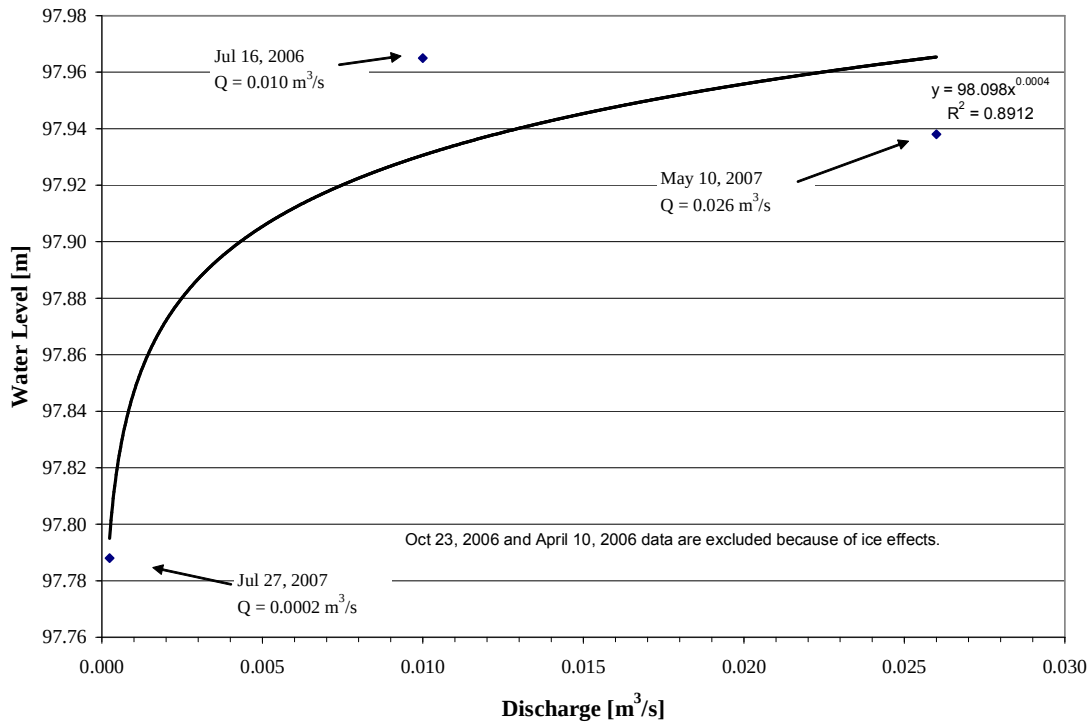


FIGURE B-8 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P03 (PIERRE RIVER)



PROJECT

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TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P03 (PIERRE RIVER)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.		P03
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CHECK	FLA	16/11/07			
REVIEW	WES/TC	20/11/07			

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FIGURE B-9 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P04 (EYMUNDSON CREEK)

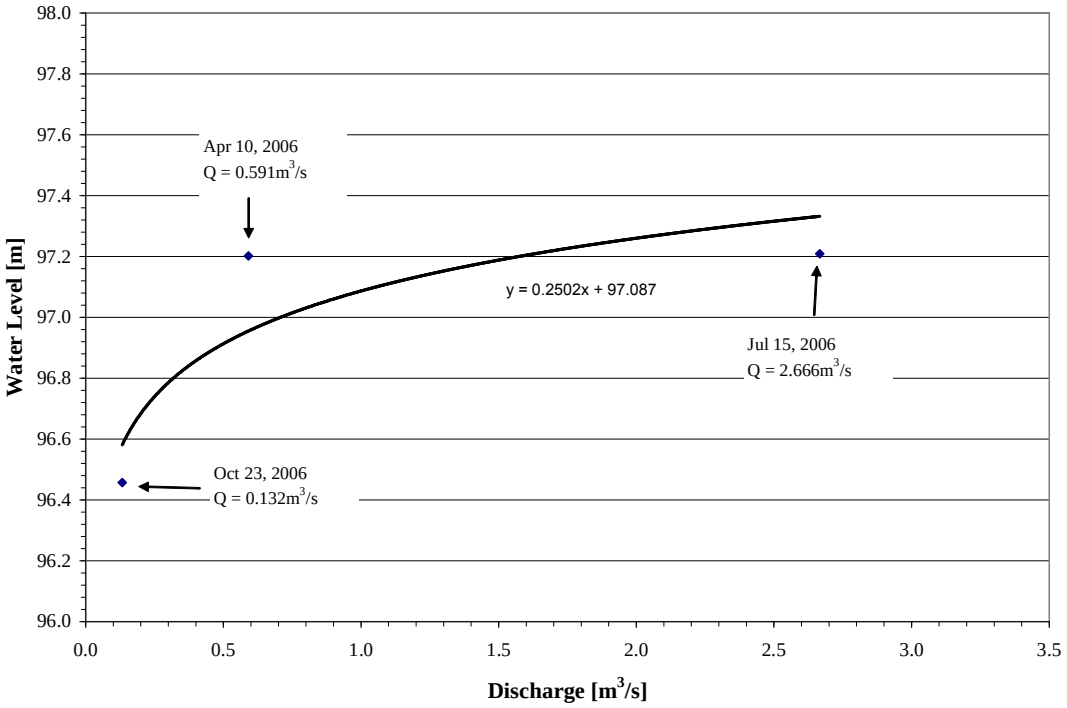
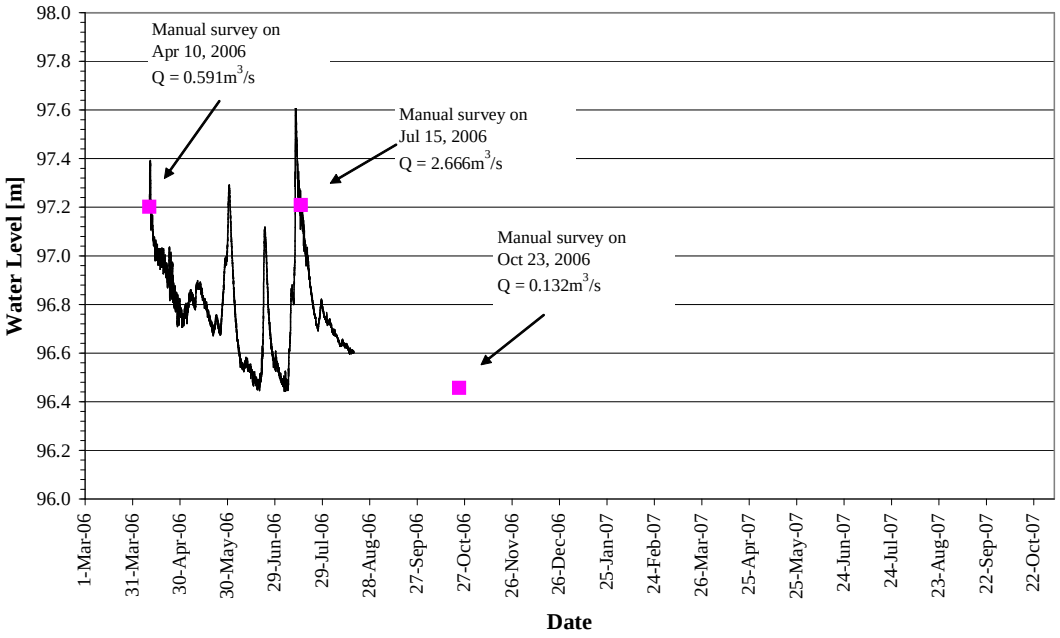


FIGURE B-10 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P04 (EYMUNDSON CREEK)



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TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P04 (EYMUNDSON CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P04
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
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CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-9 & B-10

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FIGURE B-11 MANUAL WATER LEVEL MEASUREMENTS AT STATION P05 (FIRST CREEK)

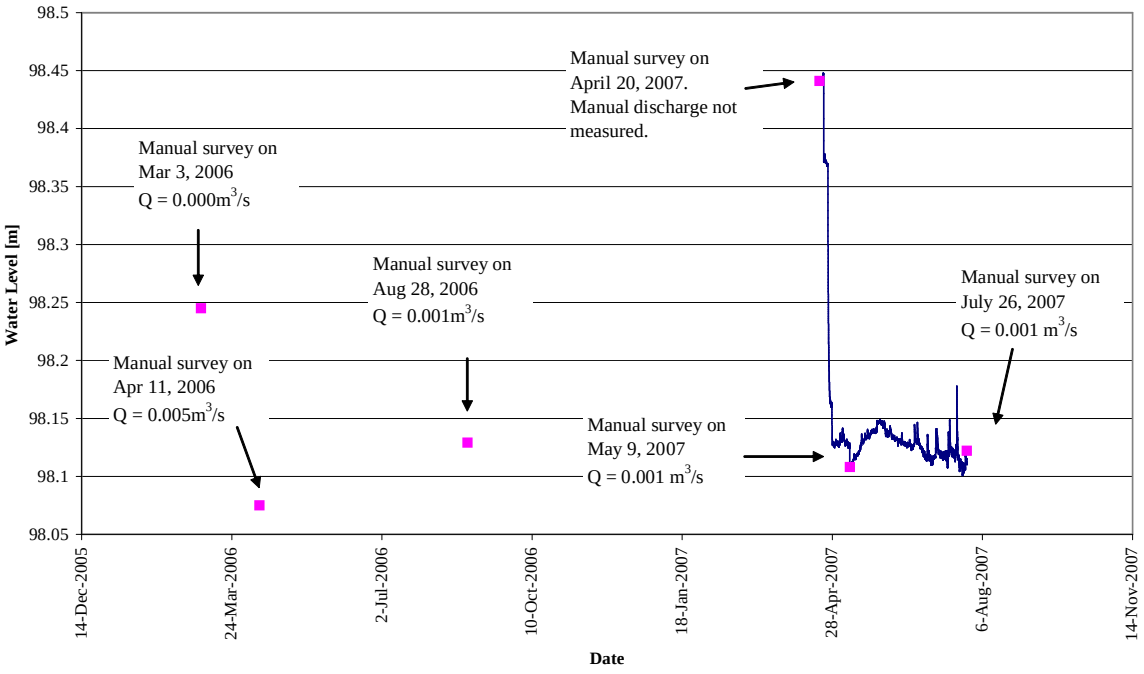
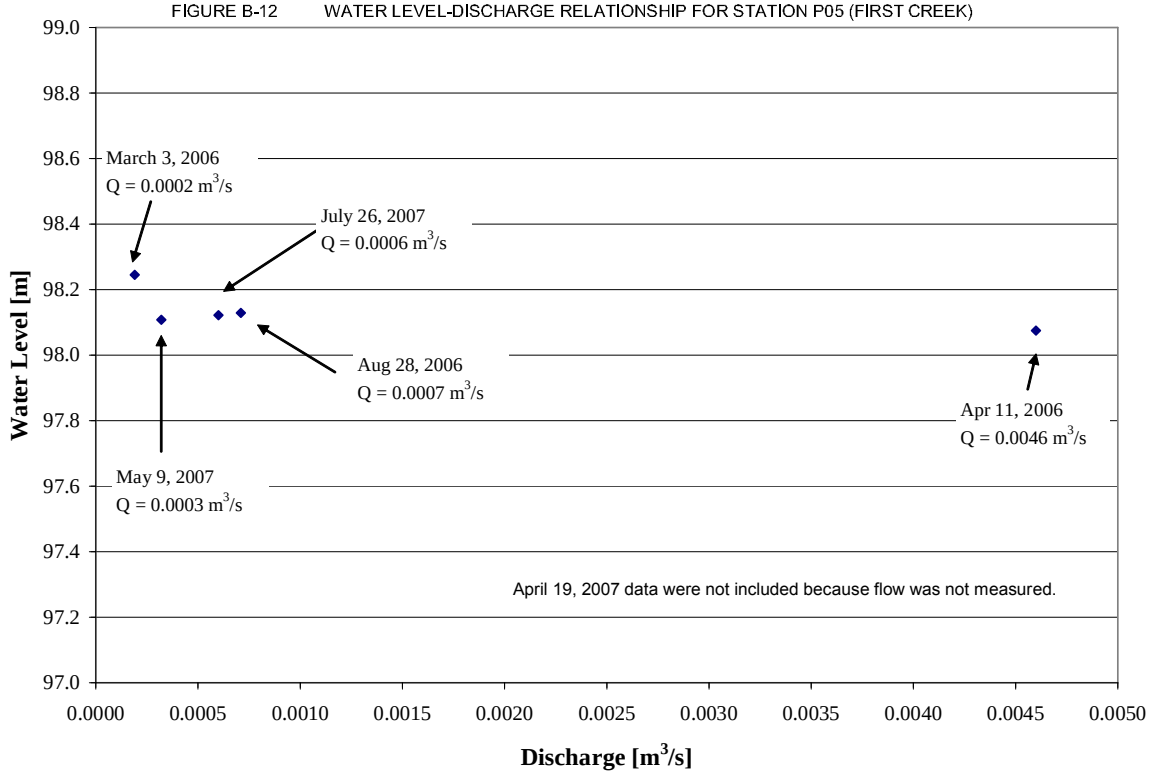


FIGURE B-12 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P05 (FIRST CREEK)



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TITLE

MANUAL WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P05 (FIRST CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P05
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: B-11 & B-12	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-13 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P06 (UNNAMED CREEK 3)

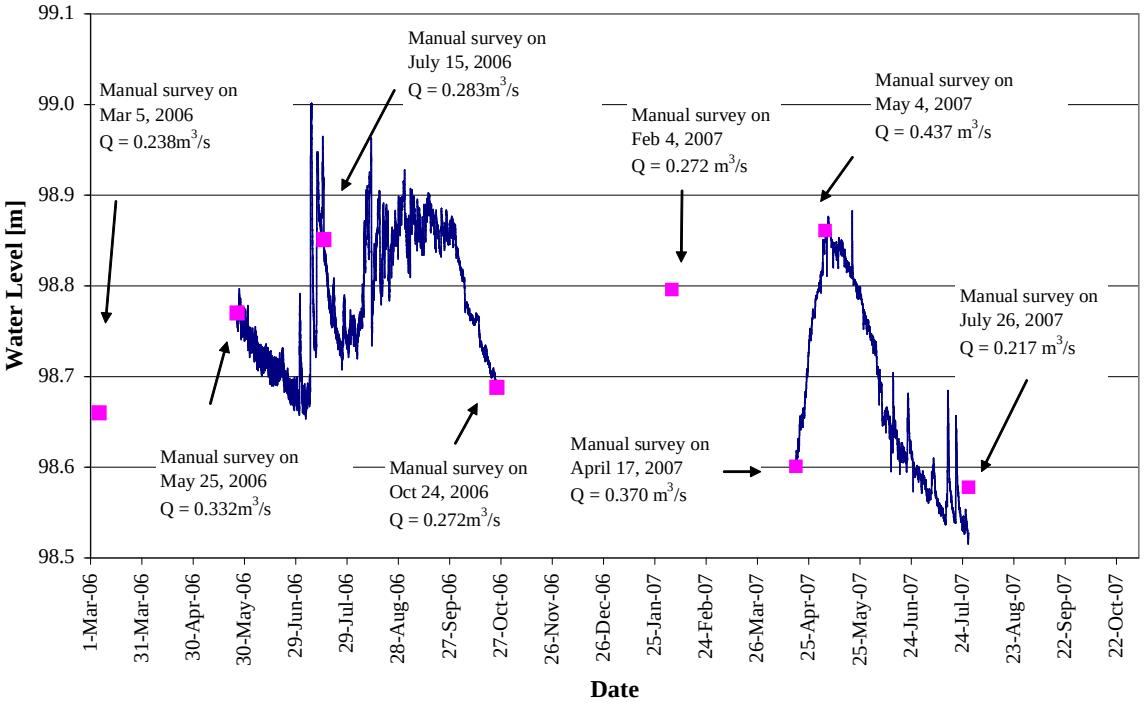
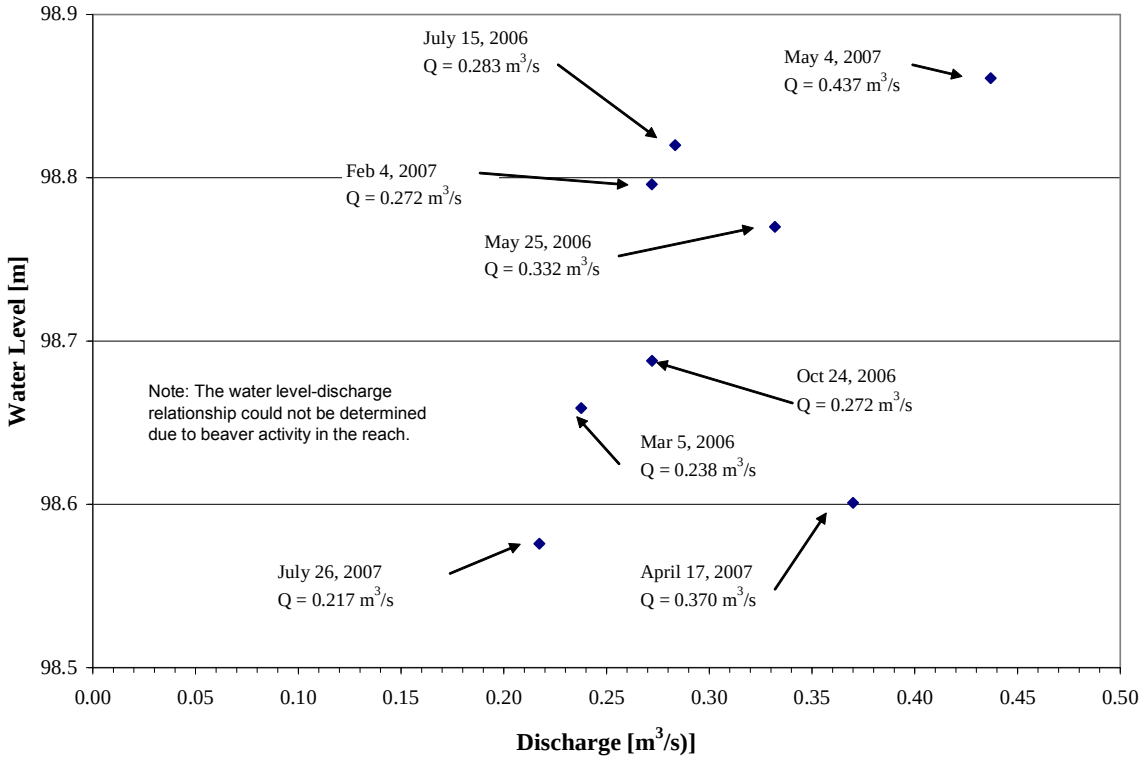


FIGURE B-14 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P06 (UNNAMED CREEK 3)



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P06 (UNNAMED CREEK 3)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P06
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: B-13 & B-14	
CHECK	KM	16/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-15 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P07 (UNNAMED CREEK 2)

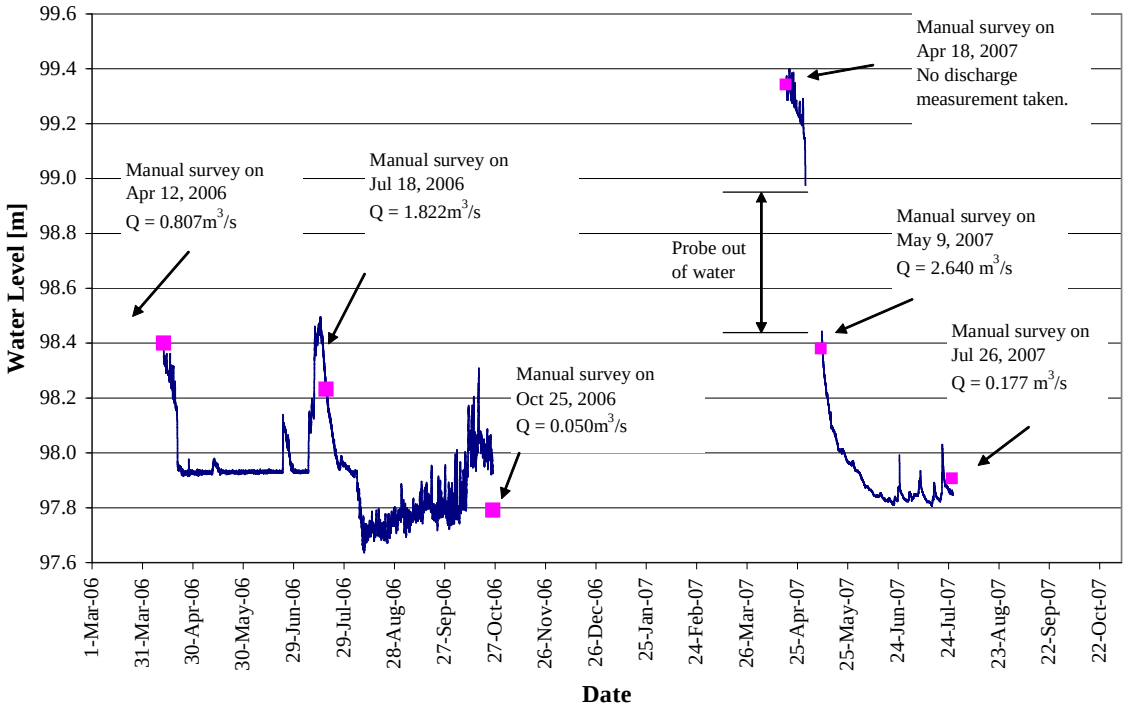
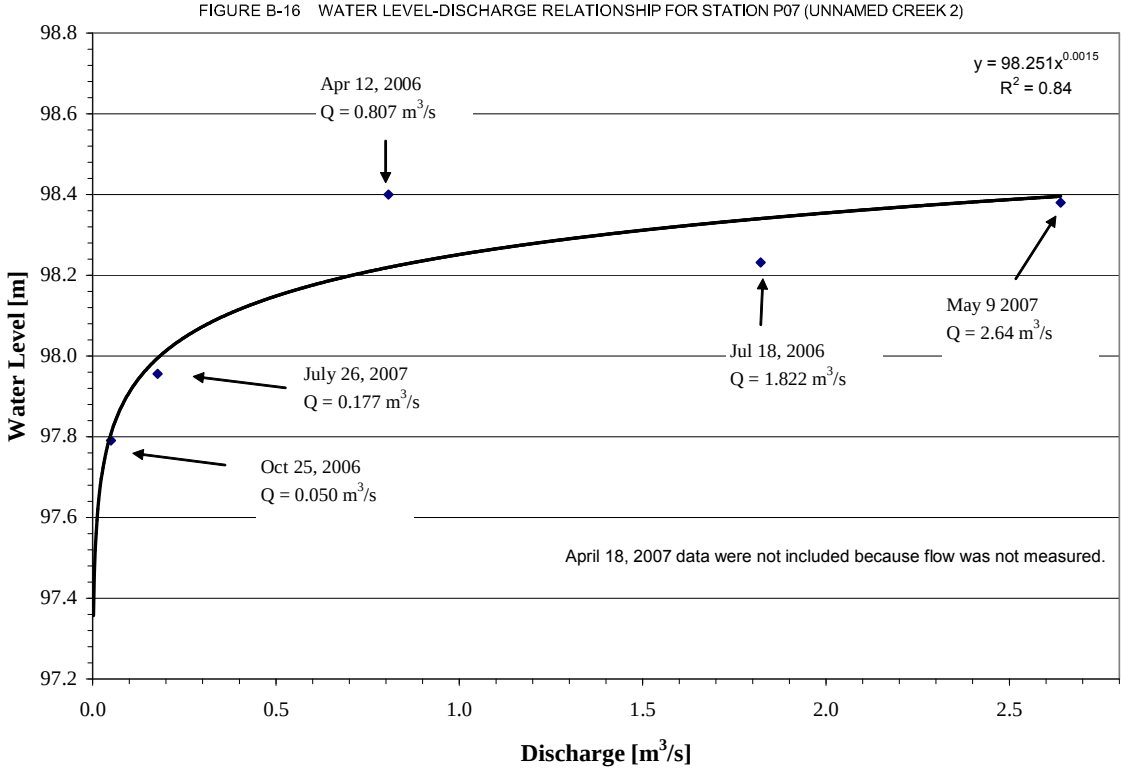


FIGURE B-16 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P07 (UNNAMED CREEK 2)



PROJECT: JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE: MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P07 (UNNAMED CREEK 2)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P07
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: B-15 & B-16	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-17 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P08 (BIG CREEK)

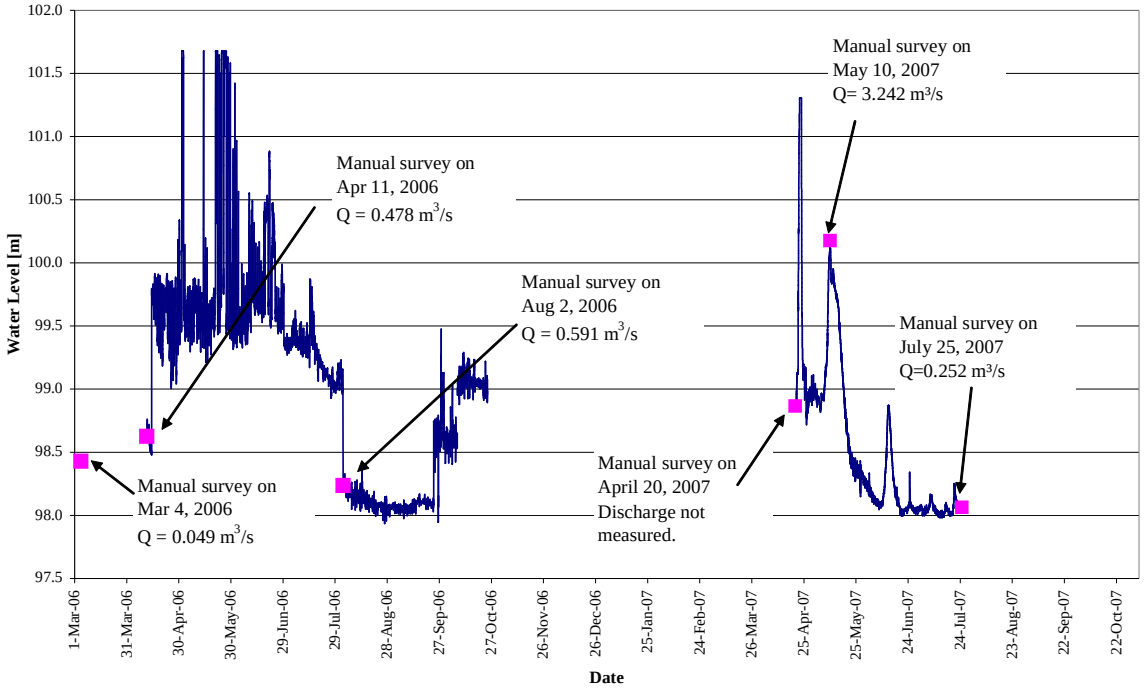
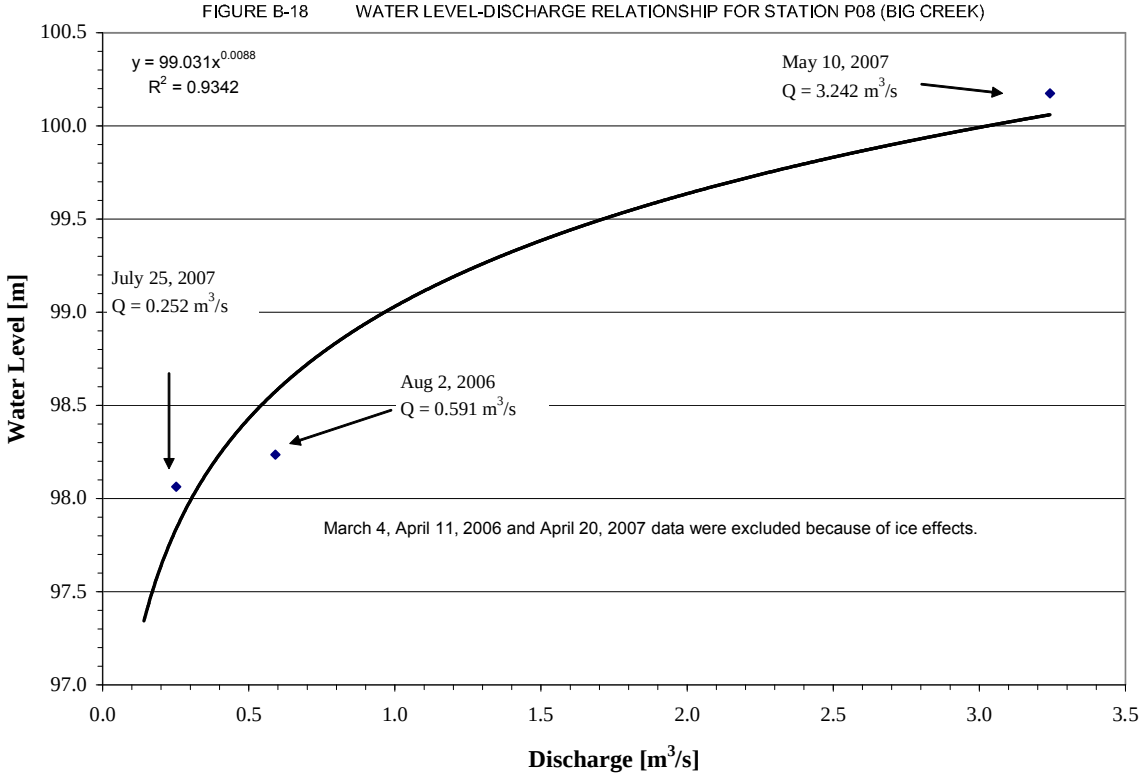


FIGURE B-18 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P08 (BIG CREEK)



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P08 (BIG CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P08
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-17 & B-18

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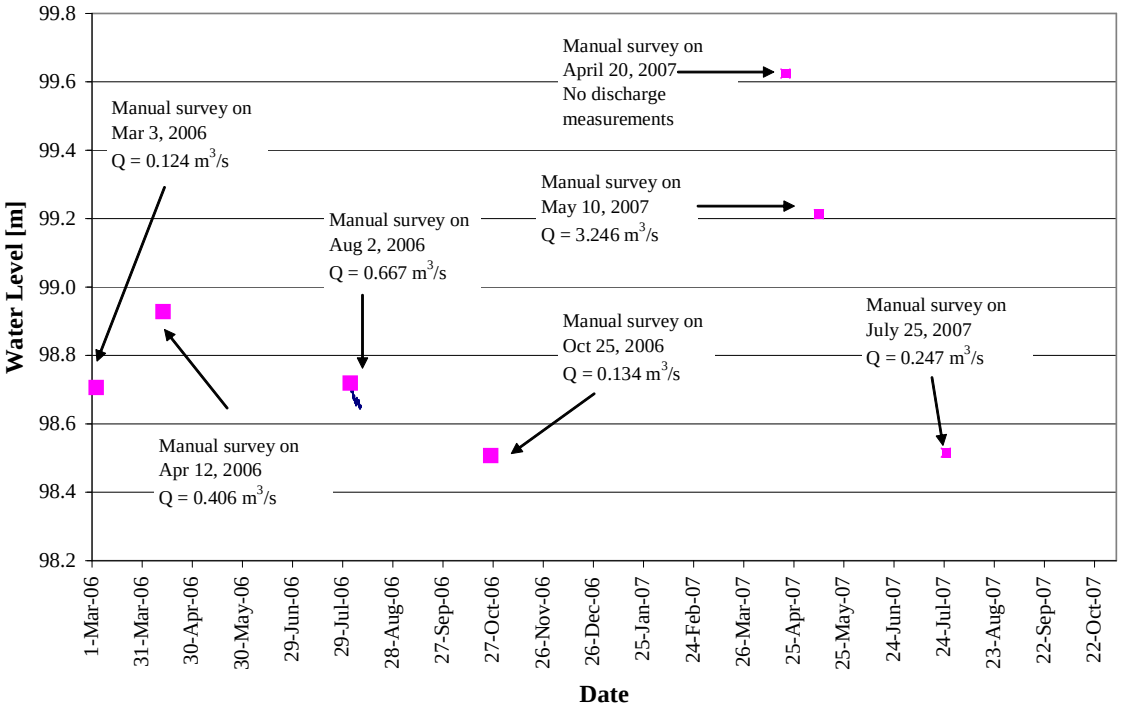
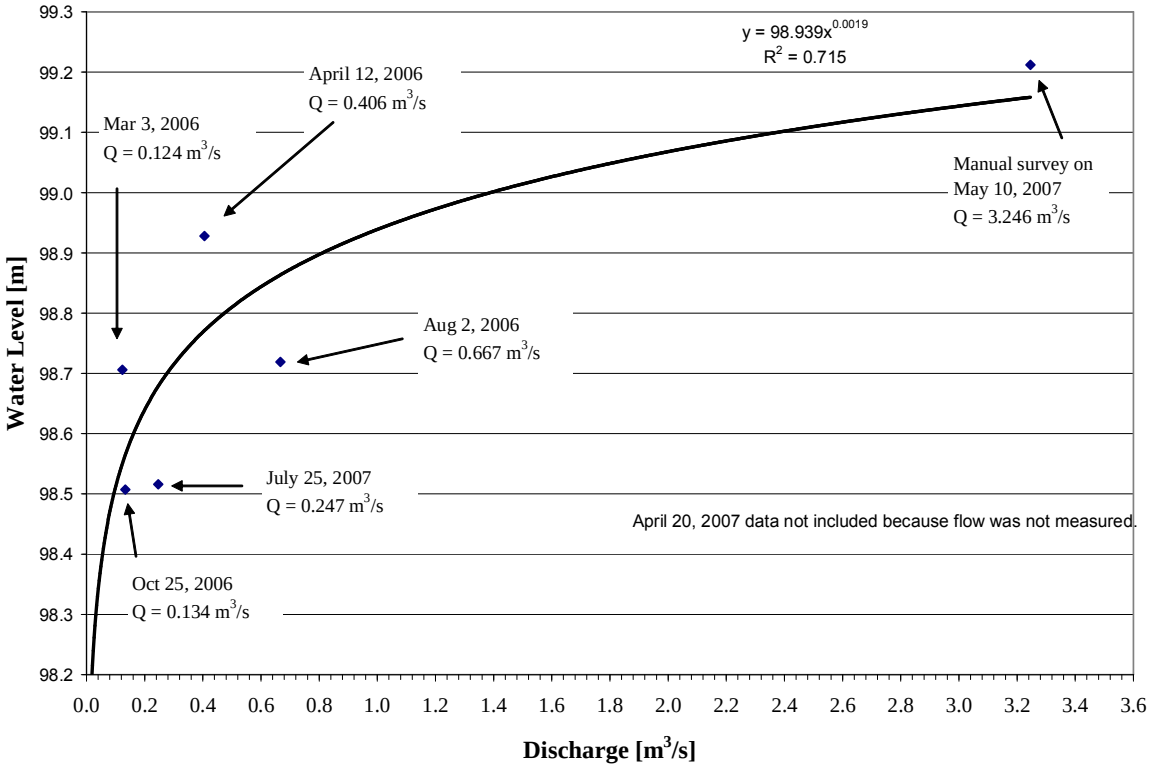
B19 MANUAL WATER LEVEL MEASUREMENTS AT STATION P09 (UNNAMED CREEK 7)



B20 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P09 (UNNAMED CREEK 7)



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL - DISCHARGE RELATIONSHIP FOR STATION P09 (UNNAMED CREEK 7)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P09-Measurement
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: B-19 & B-20	
CHECK	KM	16/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-21 MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P10 (REDCLAY CREEK)

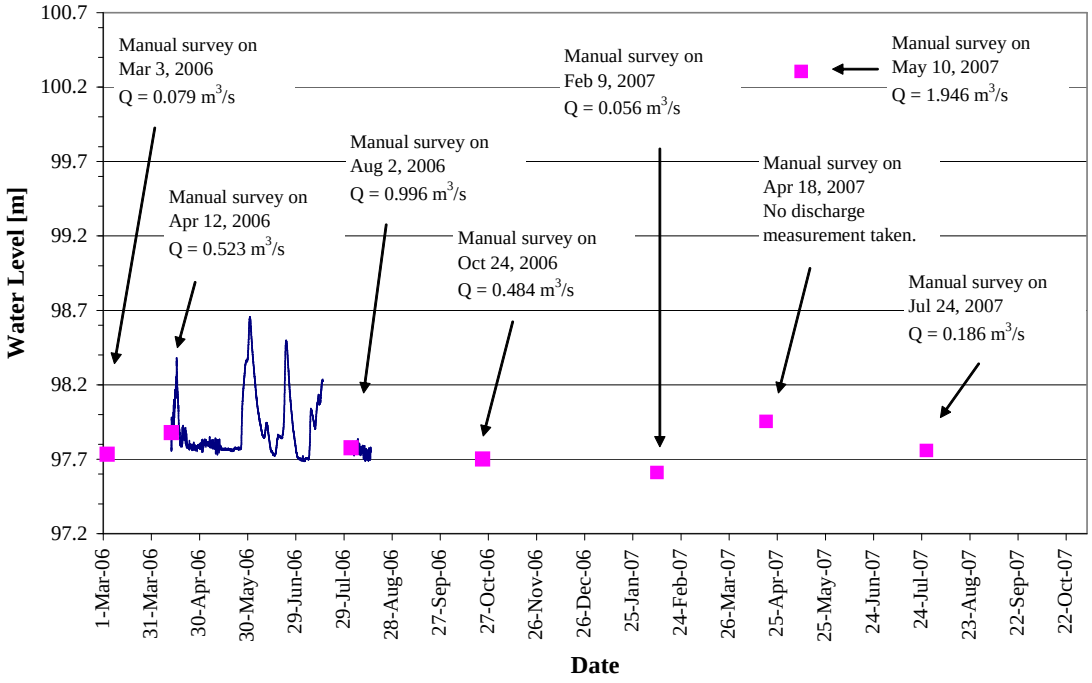
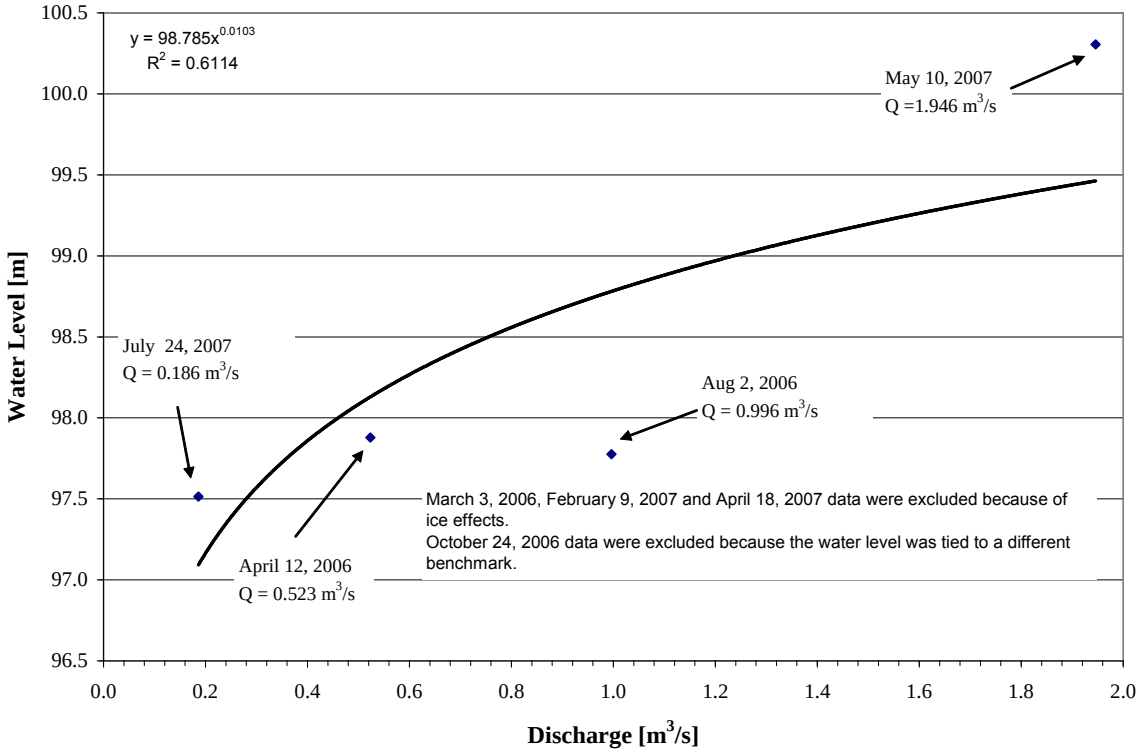


FIGURE B-22 WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P10 (REDCLAY CREEK)



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AND WATER LEVEL-DISCHARGE RELATIONSHIP FOR STATION P10 (REDCLAY CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	P10
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	FIGURE: B-21 & B-22	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

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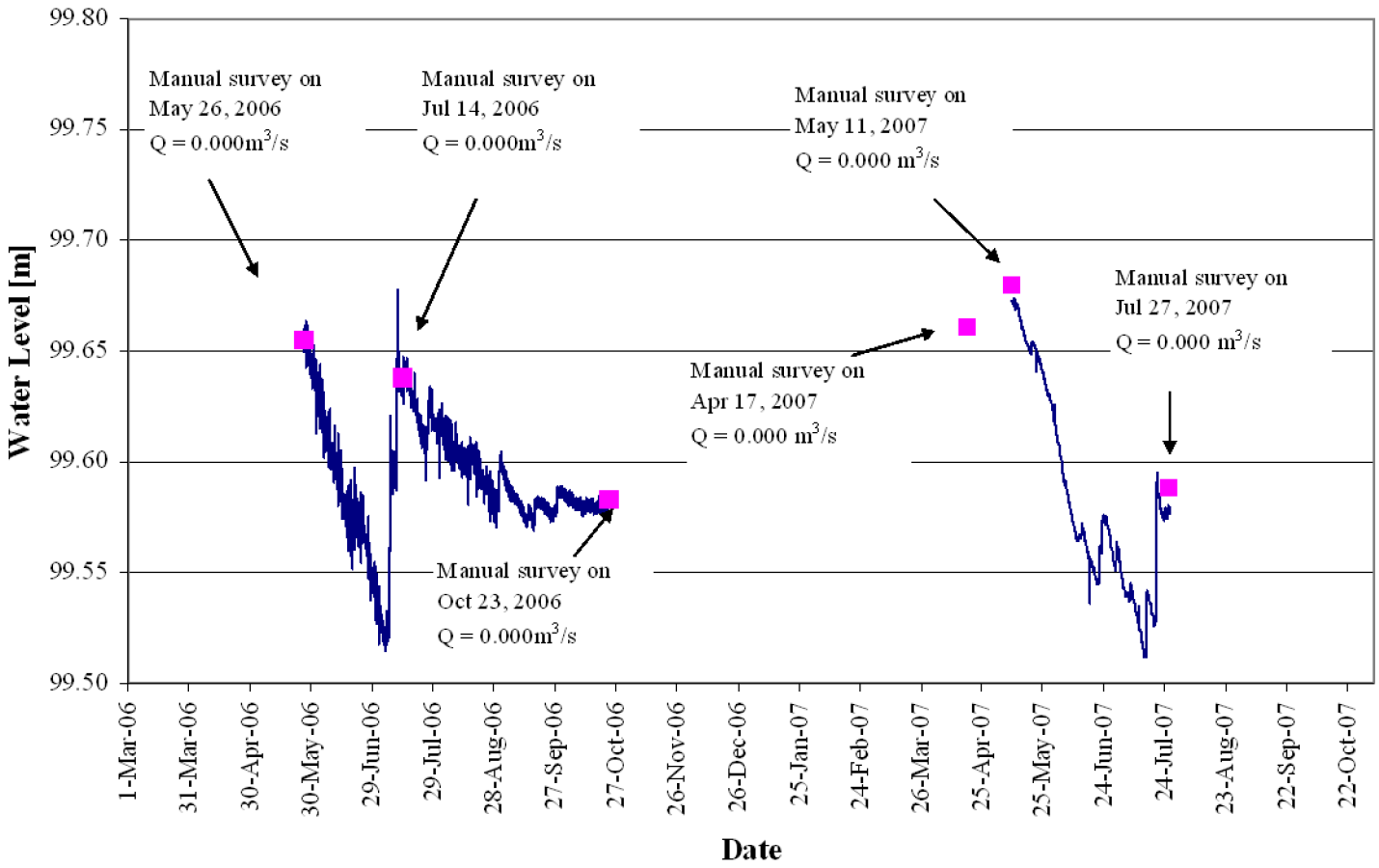

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MANUAL AND DATALOGGER WATER LEVEL MEASUREMENTS AT STATION P11 (UNNAMED WATERBODY 4 OUTLET CREEK)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Manu & datalogger	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	**FIGURE: B-23**	
CHECK	FLA	16/11/17		
REVIEW	WES/TC	20/11/07		

4 PHOTOGRAPHS OF HYDROMETRIC STATIONS

Figures B-24 through B-34 present photographs of hydrometric stations.

FIGURE B-24 STATION P01 (WAPASU CREEK) ON JULY 14, 2006

FIGURE B-25 STATION P02 (MUSKEG RIVER) ON JULY 14, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF STATIONS P01 AND P02

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P01-P02
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE:**	
CHECK	FLA	17/11/07	**B-24 & B-25**	
REVIEW	WES/TC	20/11/07		

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FIGURE B-26 STATION P03 (PIERRE RIVER) ON APRIL 10, 2006

FIGURE B-27 STATION P04 (EYMUNDSON CREEK) ON APRIL 10, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF STATIONS P03 AND P04

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P03-P04
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE: B-26 & B-27**	
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-28 STATION P05 (FIRST CREEK) ON APRIL 11, 2006

FIGURE B-29 STATION P06 (UNNAMED CREEK 3) ON JULY 15, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF STATIONS P05 AND P06

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P05-P06
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE: B-28 & B-29**	
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

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FIGURE B-30 STATION P07 (UNNAMED CREEK 2) ON APRIL 12, 2006

FIGURE B-31 STATION P08 (BIG CREEK) ON APRIL 11, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF STATIONS P07 AND P08

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P07-P08
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE:**	
CHECK	FLA	17/11/07	**B-30 & B-31**	
REVIEW	WES/TC	20/11/07		

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FIGURE B-32 STATION P09 (UNNAMED CREEK 7) ON AUGUST 2, 2006

FIGURE B-33 STATION P10 (REDCLAY CREEK) ON MARCH 3, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPHS OF STATIONS P09 AND P10

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P09-P10
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE: B-32 & B-33**	
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

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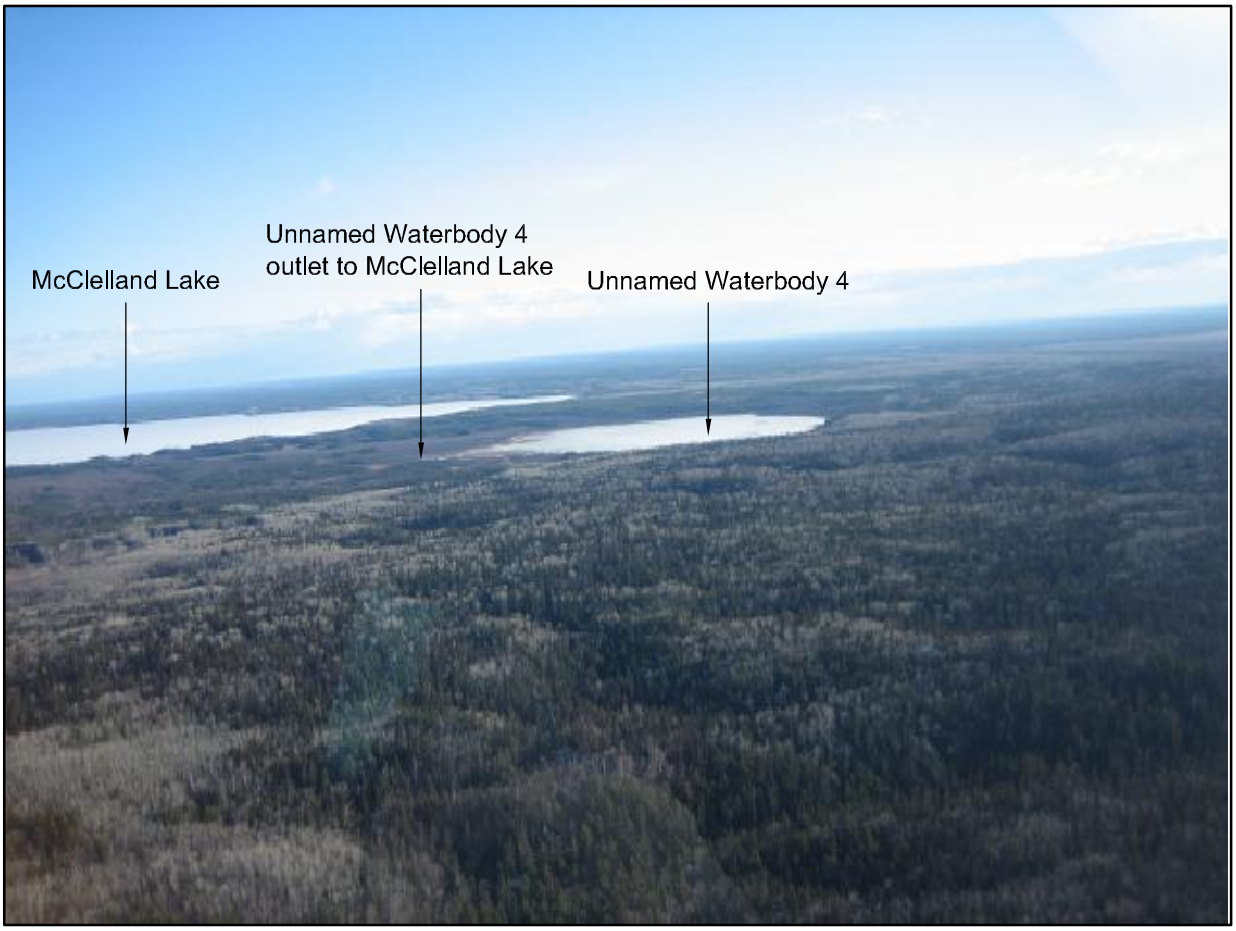


FIGURE B-34 STATION P11 (UNNAMED WATERBODY 4 OUTLET CREEK) ON MAY 26, 2006

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PHOTOGRAPH OF STATION P11

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Photo-P11
DESIGN	KM	10/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	**FIGURE: B-34**	
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Fig B-34.dwg Nov 23, 2007 - 10:51am

5 GEOMORPHIC SURVEY

During the fall 2005 field program, geomorphic surveys were conducted to supplement available geomorphic data in the region. The parameters measured included bankfull depth and width, flow depth and width, flow discharge, sinuosity, sediment bed sizes, entrenchment ratio and stream slope. In addition, creek descriptions, photos, video and waypoints were taken for each reach. Sites were selected in all streams that could be directly or indirectly impacted by Project development.

During this program, 11 stream reaches were surveyed out of the 13 stream reaches proposed. Two stream reaches were eliminated from the survey due to excessive ponding that resulted in unsurveyable conditions. Table B-3 shows a summary of the sites surveyed, dates and locations of the first cross-section surveyed. Figure B-2 shows the locations of the 11 surveyed and 2 unsurveyed geomorphic sites. Figures B-35 through B-47 are the geomorphic summary sheets.

During the fall 2007 field program, a geomorphic survey of Redclay Creek was conducted and a groundtruthing survey of all the streams in the PREAM was conducted to determine the intermittent and permanent reaches. The results of the fall 2007 field program are not provided in this Appendix but will be included in an EIA update.

Table B-3 Geomorphic Survey Stream Reaches

Site #	Stream Name	Date of Survey	Location (NAD 83)	
			Easting	Northing
5	Stanley Creek	not surveyed due to ponding	475181	6356066
10	Asphalt Creek	23-Sep-05	455957	6378600
11	Big Creek Upstream	25-Sep-05	452664	6388197
17	McClelland Lake Outlet Creek	28-Sep-05	490061	6382372
22A	Pierre River	27-Sep-05	459546	6370541
22B	Unnamed Creek 4	27-Sep-05	459427	6371235
25A	First Creek	24-Sep-05	467756	6390157
25B	Big Creek Downstream	24-Sep-05	467812	6390225
33	Eymundson Creek	26-Sep-05	460746	6379195
36	Eymundson Creek	not surveyed due to ponding	452858	6384425
37	Unnamed Creek 1	23-Sep-05	461780	6374215
38	Muskeg River above Wapasu Creek	29-Sep-05	484114	6362626
39	Muskeg River above Muskeg Creek	30-Sep-05	476996	6353663
P10	Redclay Creek	27-Oct-07 and 28-Oct-07	475797	6395108

Note: The geomorphic survey summary sheet for Redclay Creek will be included in an EIA update.

This channel reach is approximately 38 m long and it is located roughly 7.6 km upstream of Asphalt Creek's confluence with Eymundson Creek and in a glaciolacustrine surficial geology. The channel reach is in a lowland area while the headwaters are in an upland area. The channel slope is approximately 0.2% and the floodplain valley is vegetated with mixed forest with trees, shrubs and tall grasses to the top of bank.

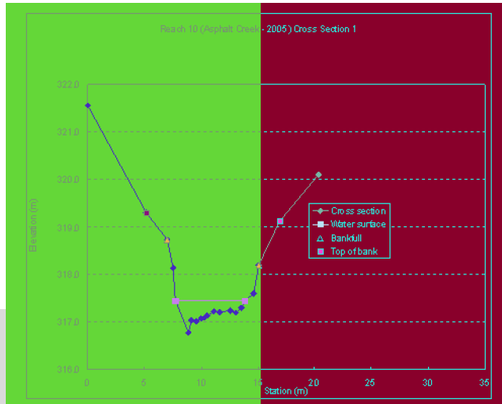
The reach contains a wide shallow box channel and has a low sinuosity of 1.091, an average bankfull depth of 0.909 m and an average bankfull width of 7.43 m. The channel banks are very soft consisting mostly of a well graded sand with some cobbles; there are also signs of slumping in areas. The channel bottom is silty and contains no aquatic vegetation and little wooden material. The channel has an entrenchment ratio of approximately 1.34 and a bankfull-width-to-bankfull-depth ratio of 8.18.

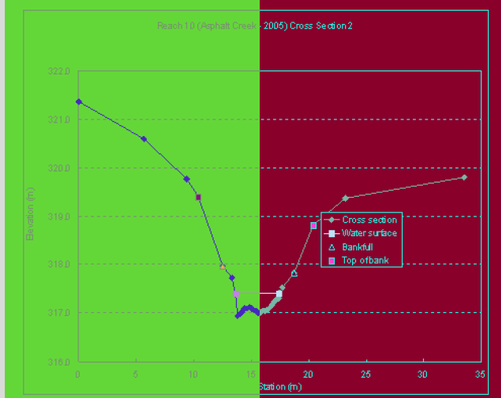
At the time of the survey, the reach had an average maximum water depth of 0.49 m, an average wetted width of 4.96 m and a discharge of 0.335 m3/s.

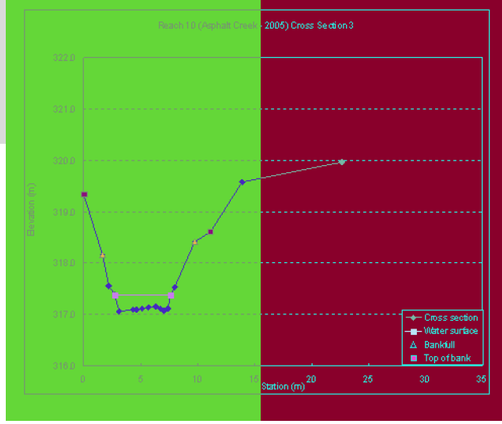
	CATION
	Asphalt Creek
North	455357 m East
	1345 hr (Discharge Measurement)

	km^2
	m/m
	m
	m
	m
	m^3/s
	m^3/s
	m^3/s
	all cross-sections

Aerial view







Cross Section 1 - Ground View Looking Upstream

Cross Section 1 - Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream

Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

GEOMORPHOLOGY SITE 10 - ASPHALT CREEK

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.		Site 10
DESIGN	KM	05/07/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07			
REVIEW	WES/TC	20/11/07			

FIGURE:B-35

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This channel reach is approximately 67 m long and it is located approximately 9 km upstream of Big Creek's confluence with First Creek. The channel reach is in an upland area with a glacial surficial geology. The floodplain valley is broad and flat with an average channel slope of 0.86% and is vegetated with willows and grasses near the channel and edged by mixed forest approximately 100 m from the top of bank.

The reach contains a wide deep channel with a moderate to high sinuosity of 1.191, an average bankfull depth of 0.96 m and an average bankfull width of 9.381 m. A channel bank sediment sample was not taken, but was observed to be primarily composed of clay/silt with some sand and dense vegetation to the water's edge. The channel bed is composed of silt and sand with little aquatic vegetation towards the edge of the water. The channel reach has an entrenchment ratio of 1.6 and a bankfull-width-to-bankfull-depth ratio of 9.773.

At the time of the survey, the reach had an average maximum water depth of 1.15 m and an average wetted width of 5.62 m and a discharge of 0.251m^3/s.

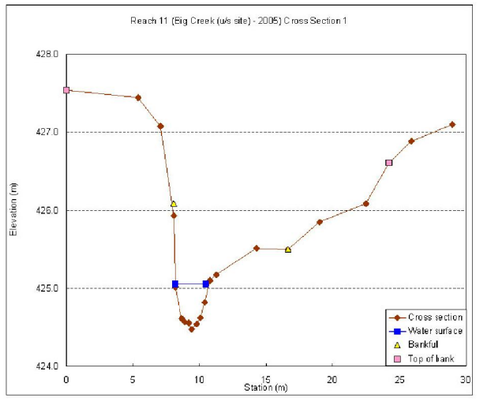
SITE LOCATION		
Stream	Big Creek Upstream	
UTM (NAD 83)	6388197 m North	452664 m East
Date and Time of Visit	25 September 2005	1045 hr (Discharge Measurement)

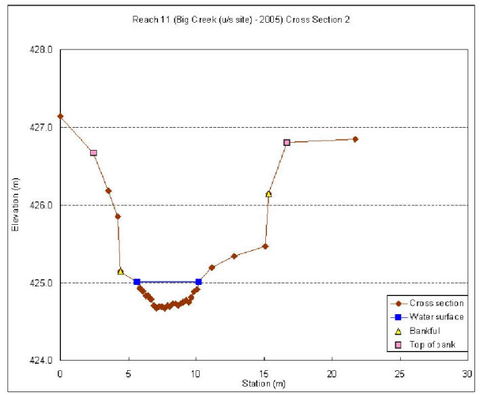
STREAM CHARACTERISTICS	
Basin Area	56.7 km^2
Channel Slope	0.0086 m/m
Channel Mean Bankfull Depth[1]	0.960 m
Channel Maximum Bankfull Depth[1]	1.236 m
Channel Bankfull Width[1]	9.381 m
Sinuosity	1.191
Measured Discharge	0.251 m^3/s
Estimated Mean Annual Discharge	0.199 m^3/s
Estimated Bankfull Discharge	2.537 m^3/s

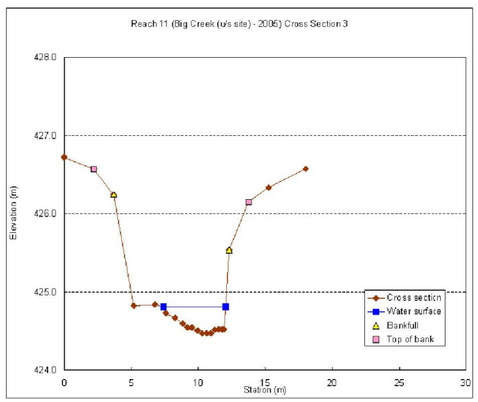
[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	N/A
D_{35}	N/A
D_{50}	N/A
D_{65}	N/A
D_{84}	N/A
D_{90}	N/A

Note: Bed material sample was not collected.







Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream

Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**GEOMORPHOLOGY SITE 11 -
BIG CREEK UPSTREAM SITE**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No. Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/17		

FIGURE:B-36

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 11 BIG CREEK UPSTREAM.dwg Nov 23, 2007 - 10:53am

This channel reach is approximately 70 m long and it is located roughly 2.4 km upstream of McClelland Lake Outlet Creek's confluence with the Firebag River and in a glaciolfluvial surficial geology. The channel reach is in a lowland area with a channel slope of 0.08%. The floodplain is broad and is vegetated with mixed forest and grasses and shrubs close to the channel. The tree line is located very close to the channel top of bank, approximately 20 m away.

The channel reach is defined as a shallow wide channel with a moderately high sinuosity of 1.5, an average bankfull depth of 0.44 m and an average bankfull width of 14.53 m. The reach bed material consists mostly of coarse and fine sand with silt and clay. There is a large amount of aquatic vegetation located within the reach. The channel bank material was observed to consist of sand and silt and show little sign of erosion. The entrenchment ratio could not be calculated with the recorded data, however the bankfull-width-to-bankfull-depth ratio was 33.39.

At the time of the survey, the water level of the reach was over bankfull and has an average maximum water depth of 0.44 m, an average wetted width of 12.32 m and a discharge of 0.923 m^3/s.

SITE LOCATION		
Stream	McClelland Lake Outlet Creek	
UTM (NAD 83)	6382372 m North	490061 m East
Date and Time of Visit	28 September 2005	1220 hr (Discharge Measurement)

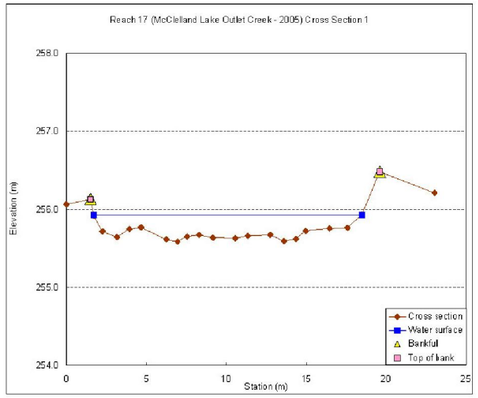
STREAM CHARACTERISTICS	
Basin Area	323.5 km^2
Channel Slope	0.0008 m/m
Channel Mean Bankfull Depth[1]	0.435 m
Channel Maximum Bankfull Depth[1]	0.705 m
Channel Bankfull Width[1]	14.525 m
Sinuosity	1.500
Measured Discharge	0.923 m^3/s
Estimated Mean Annual Discharge	N/A
Estimated Bankfull Discharge	N/A

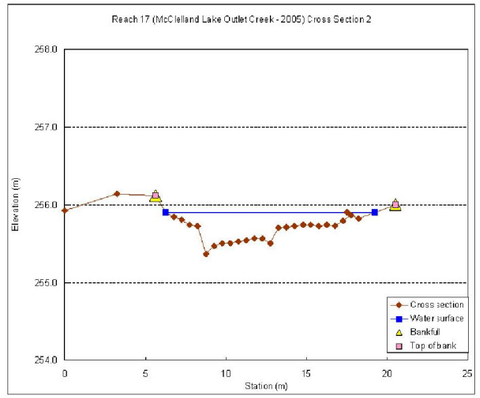
[1] Calculated using the average of measured values at all cross-sections.

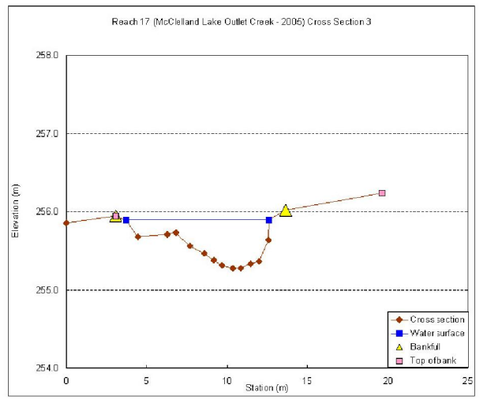
BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.110
D_{35}	0.190
D_{50}	0.270
D_{65}	0.380
D_{84}	0.600
D_{90}	0.720

Note: Percentage of finer particles (clay and silt) is 8.8%.

Aerial view







Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream

Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
**GEOMORPHOLOGY SITE 17 -
McCLELLAND LAKE OUTLET CREEK**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Asphalt Creek
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE:B-37

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 17 McCLELLAND LAKE OUTLET CREEK.dwg Nov 17, 2007 - 3:26pm

This channel reach is approximately 75 m long and it is located roughly 5.2 km upstream of the Pierre River's confluence with the Athabasca River and in a glaciolfluvial surficial geology. The channel reach is in an upland area with a channel slope of 0.01% and is a highly active beaver dam area. The floodplain is broad and is vegetated with mixed forest with grasses and shrubs close to the channel. The tree line is located very close to the channel top of bank, approximately 50 m away.

The channel reach is defined as having a large amount of beaver activity which causes the channel to form as a shallow wide channel with a moderately high sinuosity of 1.3, an average bankfull depth of 1.20 m and an average bankfull width of 13.43 m. The reach bed material consists mostly of silt and clay with some medium fine sand; there is also a large amount of aquatic vegetation located within the reach. The channel bank material was observed to consist of sand and silt and show some signs of slumping. The entrenchment ratio of the reach is 1.86 and the bankfull-width-to-bankfull-depth ratio of 11.16.

At the time of the survey, the reach has an average maximum water depth of 1.05 m, an average wetted width of 5.10 m and a discharge of 0.077 m^3/s.

SITE LOCATION		
Stream	Pierre River	
UTM (NAD 83)	6370541 m North	459546 m East
Date and Time of Visit	27 September 2005	1100 hr (Discharge Measurement)

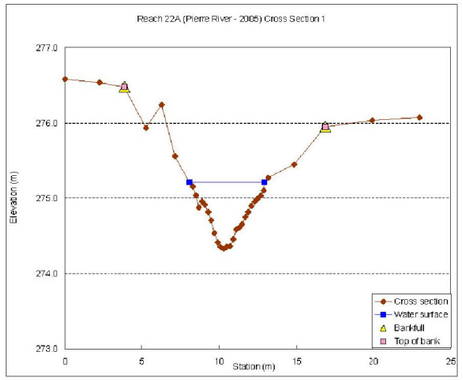
STREAM CHARACTERISTICS	
Basin Area	113 10 km^2
Channel Slope	0.00010 m/m
Channel Mean Bankfull Depth[1]	1.20 m
Channel Maximum Bankfull Depth[1]	1.973 m
Channel Bankfull Width[1]	13.43 m
Sinuosity	1.293
Measured Discharge	0.077 m^3/s
Estimated Mean Annual Discharge	0.254 m^3/s
Estimated Bankfull Discharge	2.737 m^3/s

[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.180
D_{35}	0.230
D_{50}	0.270
D_{65}	0.300
D_{84}	0.380
D_{90}	0.420

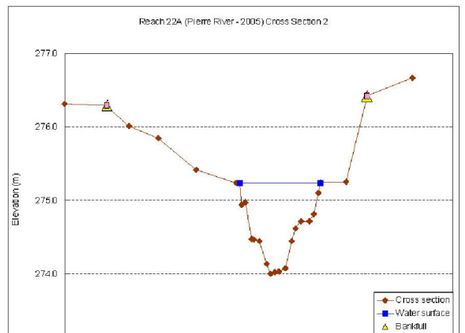
Note: Percentage of finer particles (clay and silt) is 21.28%.

Aerial view



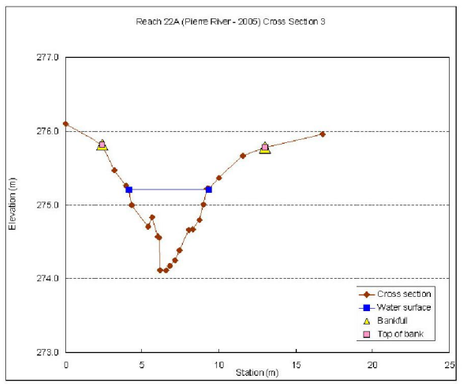
Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream



Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream



Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
GEOMORPHOLOGY SITE 22A - PIERRE RIVER

Shell Canada Limited

PROJECT 05–1344–027.6600			FILE No. Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	FLA	17/11/07	**FIGURE:B-38**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 22A – PIERRE RIVER.dwg Nov 17, 2007 – 3:28pm

This channel reach is approximately 116 m long and it is located roughly 0.9 km upstream of the Unnamed Creek 4's confluence with the Pierre River and in a glaciolfluvial surficial geology. The channel reach is in an upland area with a channel slope of 0.0002%. The floodplain is broad and is vegetated with mixed forest with tall grasses close to the channel. The tree line is located approximately 100 m away from the channel top of bank.

The channel reach is defined as a box channel with a high sinuosity of 1.7, an average bankfull depth of 0.701 m and an average bankfull width of 6.657 m. The reach bed material consists mostly of fine sand with some silt and clay; there is also a large amount of aquatic vegetation located within the reach. The channel bank material was observed to consist of sand and silt and showed no signs of slumping or erosion. The entrenchment ratio of the reach could not be calculated from the surveyed data and the bankfull-width-to-bankfull-depth ratio is 9.501.

At the time of the survey, the water level of the reach was over bankfull and had an average maximum water depth of 1.02 m, an average wetted width of 3.97 m and a discharge of 0.080 m^3/s.

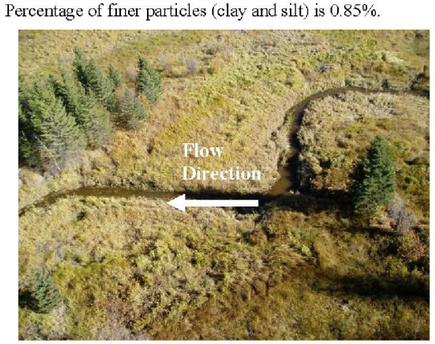
SITE LOCATION		
Stream	Pierre River Tributary	
UTM (NAD 83)	6371235 m North	459427 m East
Date and Time of Visit	27 September 2005	1340 hr (Discharge Measurement)

STREAM CHARACTERISTICS	
Basin Area	19.70 km^2
Channel Slope	0.000002 m/m
Channel Mean Bankfull Depth[1]	0.701 m
Channel Maximum Bankfull Depth[1]	1.326 m
Channel Bankfull Width[1]	6.657 m
Sinuosity	1.748
Measured Discharge	0.080 m^3/s
Estimated Mean Annual Discharge	0.028 m^3/s
Estimated Bankfull Discharge	0.215 m^3/s

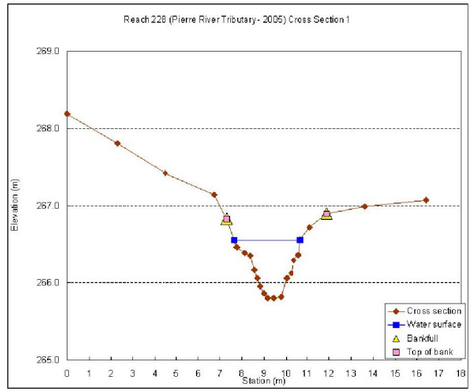
[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.030
D_{35}	0.170
D_{50}	0.240
D_{65}	0.320
D_{84}	0.510
D_{90}	0.660

Note: Percentage of finer particles (clay and silt) is 0.85%.

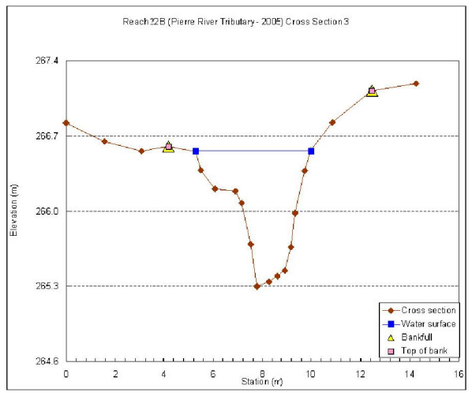


Aerial view



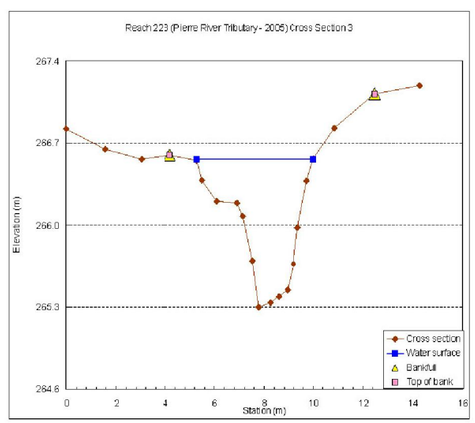
Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream



Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream



Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**GEOMORPHOLOGY SITE 22B -
UNNAMED CREEK 4**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-39**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 22B - UNNAMED CREEK 4.dwg Nov 17, 2007 - 3:30pm

This channel reach is approximately 63 m long and it is located roughly 7.3 km upstream of First Creek's confluence with the Athabasca River and in a glaciolfluvial surficial geology. The channel reach is in a lowland area with a channel slope of 0.23%. The floodplain is relatively narrow for a lowland reach and is vegetated with mixed forest and tall grasses close to the channel. The tree line is located close to the top of bank, approximately 20 m away.

The channel reach is defined as a shallow wide channel with a moderate sinuosity of 1.4, an average bankfull depth of 0.86 m and an average bankfull width of 8.30 m. The reach bed material consists mostly of fine sand with some silt and clay; there is also a large amount of aquatic vegetation and wooden debris located within the reach. There is also the presence of sandbars through the reach. The channel bank material was observed to consist of sand and silt and showed signs of slumping and some erosion. The entrenchment ratio of the reach is 2.3 and the bankfull-width-to-bankfull-depth ratio is 9.64.

At the time of the survey, the water reach had an average maximum water depth of 0.53 m, an average wetted width of 4.66 m and a discharge of 0.31 m^3/s.

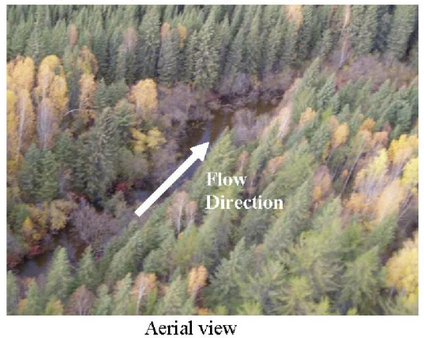
SITE LOCATION		
Stream	First Creek	
UTM (NAD 83)	6390157 m North	467756 m East
Date and Time of Visit	24 September 2005	1145 hr (Discharge Measurement)

STREAM CHARACTERISTICS	
Basin Area	31.23 km^2
Channel Slope	0.0023 m/m
Channel Mean Bankfull Depth[1]	0.861 m
Channel Maximum Bankfull Depth[1]	1.239 m
Channel Bankfull Width[1]	8.297 m
Sinuosity	1.412
Measured Discharge	0.309 m^3/s
Estimated Mean Annual Discharge	0.024 m^3/s
Estimated Bankfull Discharge	0.254 m^3/s

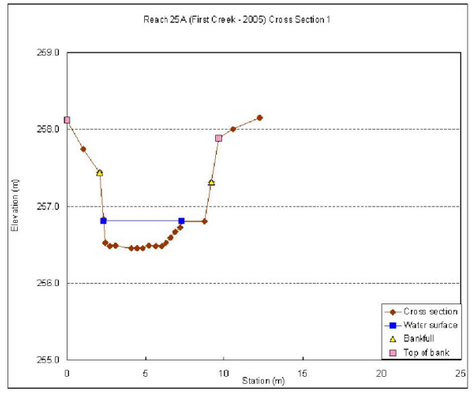
[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.200
D_{35}	0.280
D_{50}	0.365
D_{65}	0.480
D_{84}	0.680
D_{90}	0.770

Note: Percentage of finer particles (clay and silt) is 1.17%.

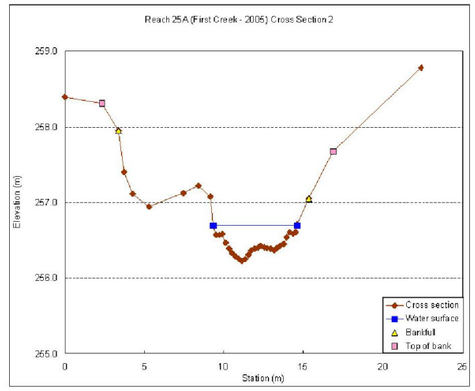


Aerial view



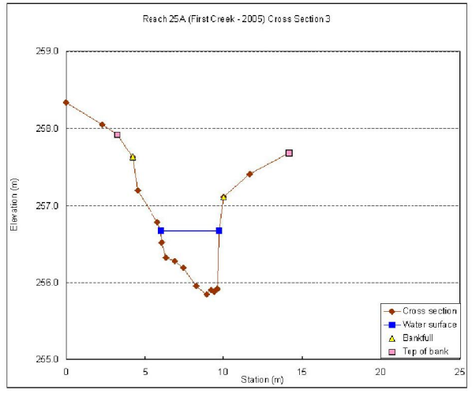
Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream



Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream



Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
GEOMORPHOLOGY SITE 25A - FIRST CREEK

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-40**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 25A - FIRST CREEK.dwg Nov 17, 2007 - 3:32pm

This channel reach is approximately 52 m long and it is located roughly 0.5 km upstream of Big Creek's confluence with the First Creek and in a glaciolfluvial surficial geology. The channel reach is in a upland area with a channel slope of 0.19%. The floodplain is relatively narrow for a lowland reach and is vegetated with mixed forest and tall grasses close to the channel. The tree line is located at the top of bank for this reach.

The channel reach is defined as a wide shallow channel with a low sinuosity of 1.1, an average bankful. depth of 0.68 m and an average bankfull width of 10.64 m. The reach bed material consists mostly of fine sand with silt and clay; there is also a large amount of aquatic vegetation and wooden debris located within the reach and the presence of sandbars through the reach. The channel bank material was observed to consist of sand and silt and showed signs of slumping and some erosion. The entrenchment ratio of the reach is 1.84 and the bankfull width-to-bankfull depth ratio is 15.63.

At the time of the survey, the reach had an average maximum water depth of 0.52 m, an average wetted width of 8.09 m and a discharge of 0.347 m^3/s.

SITE LOCATION		
Stream	Big Creek Downstream	
UTM (NAD 83)	6390225 m North	467812 m East
Date and Time of Visit	24 September 2005	1145 hr (Discharge Measurement)

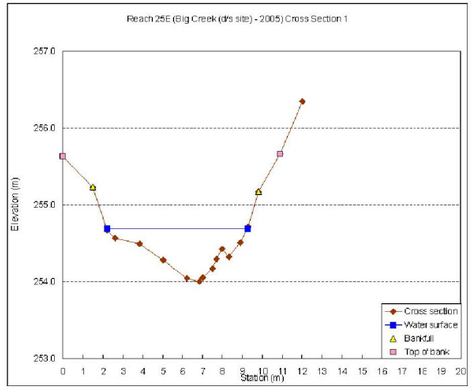
STREAM CHARACTERISTICS	
Basin Area	122.10 km^2
Channel Slope	0.0019 m/m
Channel Mean Bankfull Depth[1]	0.680 m
Channel Maximum Bankfull Depth[1]	1.024 m
Channel Bankfull Width[1]	10.635 m
Sinuosity	1.096
Measured Discharge	0.347 m^3/s
Estimated Mean Annual Discharge	0.317 m^3/s
Estimated Bankfull Discharge	3.561 m^3/s

[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.068
D_{35}	0.140
D_{50}	0.180
D_{65}	0.235
D_{84}	0.330
D_{90}	0.360

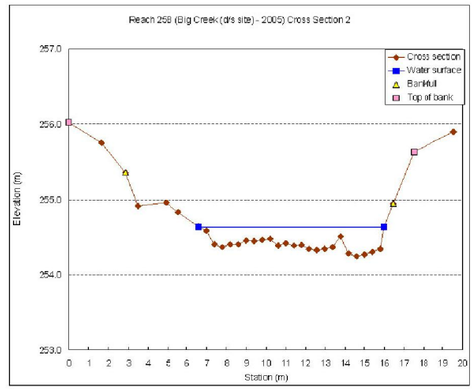
Note: Percentage of finer particles (clay and silt) is 17.85%.

Aerial view



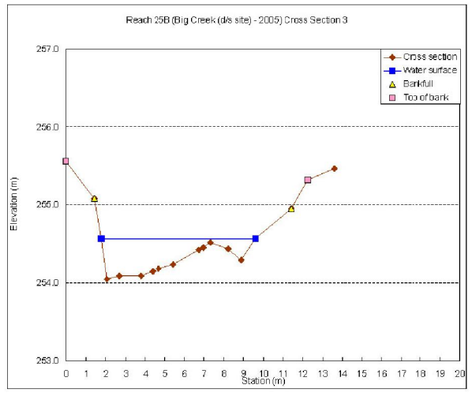
Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream

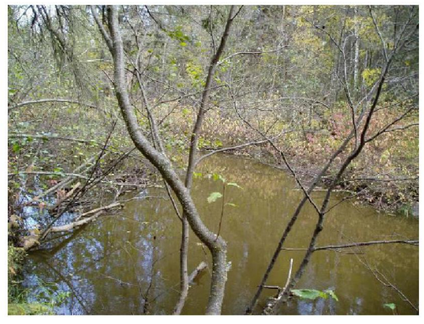


Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream



Cross Section 3 - Ground View Looking Upstream



Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**GEOMORPHOLOGY SITE 25B -
BIG CREEK DOWNSTREAM**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-41**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 25B - BIG CREEK DOWNSTREAM SITE.dwg Nov 17, 2007 - 3:36pm

This channel reach is approximately 74 m long and it is located roughly 3.5 km upstream of Eymundson Creek's confluence with the Asphalt Creek and in a glaciolacustrine surficial geology. The channel reach is in an upland area with a channel slope of 0.44%. The floodplain is wide and flat and is vegetated with jackpines and has tall grasses and shrubs close to the channel. The tree line is located 50 m from the top of bank for this reach.

The channel has a high amount of beaver activity and the reach has a low sinuosity of 1.0, an average bankfull depth of 0.38 m and an average bankfull width of 2.57 m. The reach bed material consists of fine sand with a high amount of silt, clay and organic material. There is a lot of aquatic vegetation and wooden debris within the reach. The channel bank material was observed to consist of sand and silt and showed signs of erosion and slumping. The entrenchment ratio of the reach was calculated to be 1.99 and the bankfull-width-to-bankfull-depth ratio is 6.75.

At the time of the survey the reach had an average maximum water depth of 0.06 m, an average wetted width of 2.02 m and a discharge of 0.004 m^3/s.

SITE LOCATION		
Stream	Eymundson Creek	
UTM (NAD 83)	6379195 m North	46C746 m East
Date and Time of Visit	26 September 2005	1220 hr (Discharge measurement)

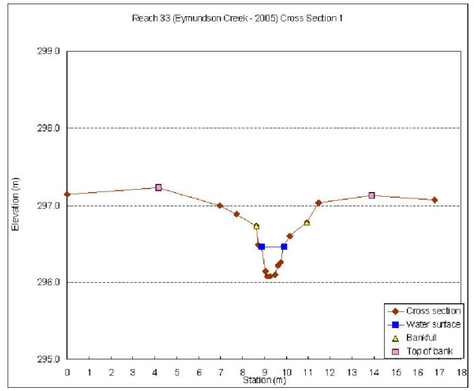
STREAM CHARACTERISTICS	
Basin Area	45.70 km^2
Channel Slope	0.0044 m/m
Channel Mean Bankfull Depth[1]	0.381 m
Channel Maximum Bankfull Depth[1]	0.549 m
Channel Bankfull Width[1]	2.568 m
Sinuosity	1.033
Measured Discharge	0.004 m^3/s
Estimated Mean Annual Discharge	0.069 m^3/s
Estimated Bankfull Discharge	0.664 m^3/s

[1] Calculated using the average of measured values at all cross-sections.

BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	N/A
D_{35}	N/A
D_{50}	N/A
D_{65}	N/A
D_{84}	0.135
D_{90}	0.230

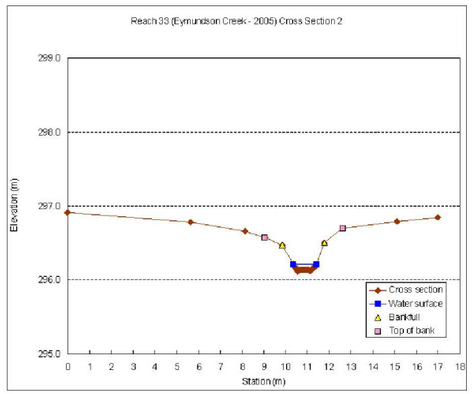
Note: Percentage of finer particles (clay and silt) is 81.07%.

Aerial view



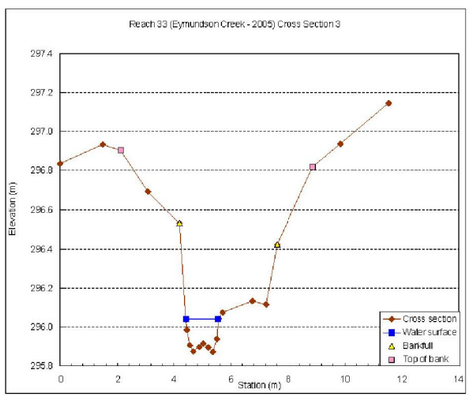
Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream



Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream



Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
GEOMORPHOLOGY SITE 33 - EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05–1344–027.6600			FILE No.	Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-42**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 33 - EYMUNDSON CREEK.dwg Nov 17, 2007 - 3:38pm

This channel reach is approximately 55 m long and it is located roughly 3.7 km upstream of Unnamed Creek 1's confluence with the Asphalt Creek and in a glaciofluvial surficial geology. The channel reach is in an upland area with a channel slope of 0.23%. The floodplain is wide and flat and is vegetated with poplars and has grasses and shrubs close to the channel. The tree line is located 100 m from the top of bank for this reach.

The channel reach has a sinuosity of 1.1, an average bankfull depth of 0.72 m and an average bankfull width of 3.21 m. The reach bed material consists mostly of medium fine sand with some silt and clay. There is also some wooden debris within the reach. The channel bank material was observed to consist of sand and silt and showed signs of erosion and undercutting. The entrenchment ratio of the reach is 1.08 and the bankfull-width-to-bankfull-depth ratio is 4.43.

At the time of the survey the reach had an average maximum water depth of 0.40 m, an average wetted width of 2.85 m and a discharge of 0.27 m^3/s.

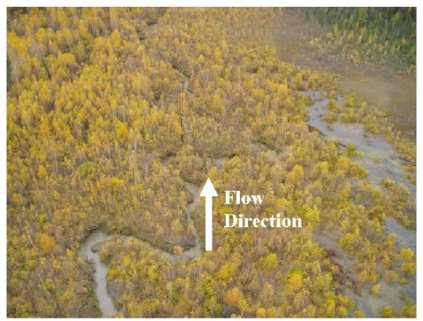
SITE LOCATION		
Stream	Asphalt Creek Tributary	
UTM (NAD 83)	6374215 m North	461780 m East
Date and Time of Visit	23 September 2005	1330 hr (Discharge Measurement)

STREAM CHARACTERISTICS	
Basin Area	64.70 km^2
Channel Slope	0.0023 m/m
Channel Mean Bankfull Depth[1]	0.723 m
Channel Maximum Bankfull Depth[1]	0.978 m
Channel Bankfull Width[1]	3.206 m
Sinuosity	1.126
Measured Discharge	0.271 m^3/s
Estimated Mean Annual Discharge	0.155 m^3/s
Estimated Bankfull Discharge	1.625 m^3/s

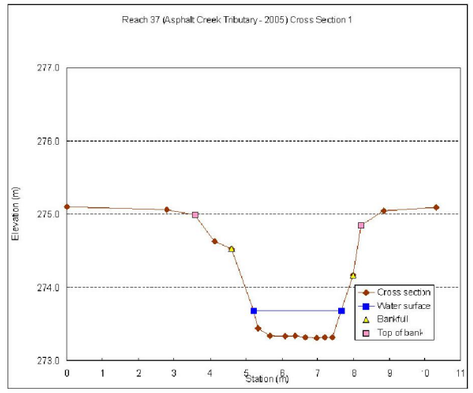
[1] Calculated using the average of measured values at all cross-sections.

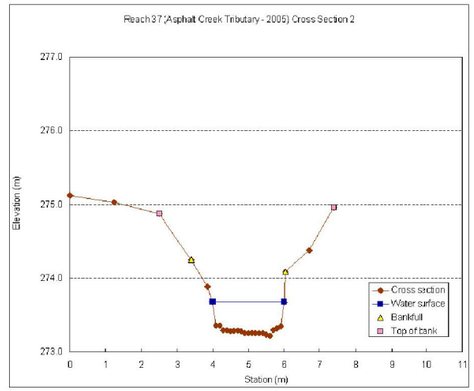
BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.21
D_{35}	0.33
D_{50}	0.43
D_{65}	0.61
D_{84}	0.83
D_{90}	1.31

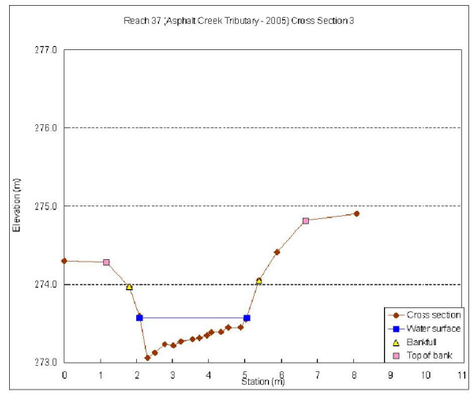
Note: Percentage of finer particles (clay and silt) is 3.50%.



Aerial view







Cross Section 1 – Ground View Looking Upstream

Cross Section 1 – Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream

Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

GEOMORPHOLOGY SITE 37 - UNNAMED CREEK 1

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No. Asphalt Creek		
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-43**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 37 - UNNAMED CREEK 1.dwg Nov 17, 2007 - 3:40pm

This channel reach is approximately 52 m long and it is located on Muskeg River roughly 3.7 km upstream of the confluence with the Wapasu Creek and in a glaciolfluvial surficial geology. The channel reach is in an upland area with a channel slope of 0.07%. The floodplain is wide and flat and is vegetated with tall grasses and shrubs close to the channel. The tree line is located 100 m from the top of bank for this reach.

The channel reach has a riffle pool system and has a high sinuosity of 1.3, an average bankfull depth of 1.32 m and an average bankfull width of 13.0 m. The reach bed material was not sampled but was observed to consist mostly of fine sand with some silt and clay. There is also some aquatic vegetation within the reach. The channel bank material was observed to consist of sand and silt and showed signs of slumping. The entrenchment ratio of the reach could not be calculated from the surveyed data and the bankfull-width-to-bankfull-depth ratio is 9.86.

At the time of the survey the reach had an average maximum water depth of 1.84 m, an average wetted width of 12.0 m and a discharge of 1.039 m3/s.

SITE LOCATION		
Stream	Muskeg River above Wapasu Creek	
UTM (NAD 83)	6362626 m North	484114 m East
Date and Time of Visit	29 September 2005	1220 hr (Discharge measurement)

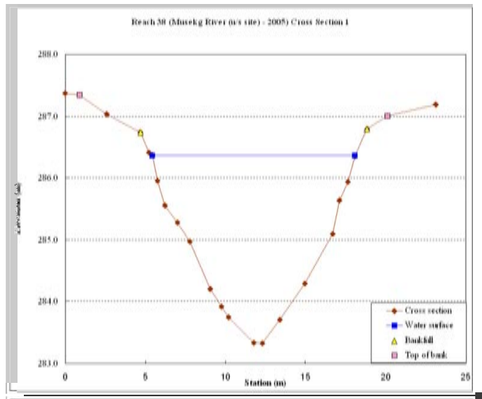
STREAM CHARACTERISTICS	
Basin Area	256.70 km^2
Channel Slope	0.0007 m/m
Channel Mean Bankfull Depth[1]	1.319 m
Channel Maximum Bankfull Depth[1]	2.305 m
Channel Bankfull Width[1]	13.00 m
Sinuosity	1.317
Measured Discharge	1.039 m^3/s
Estimated Mean Annual Discharge	0.884 m^3/s
Estimated Bankfull Discharge	8.28 m^3/s

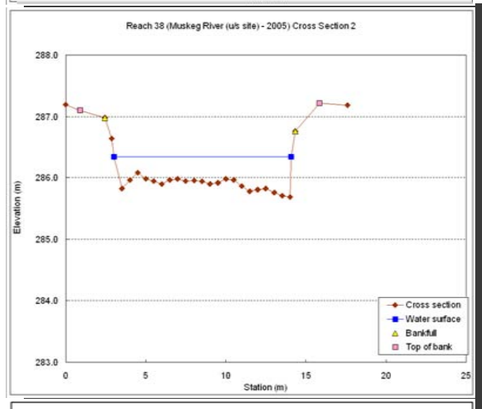
[1] Calculated using the average of measured values at all cross-sections.

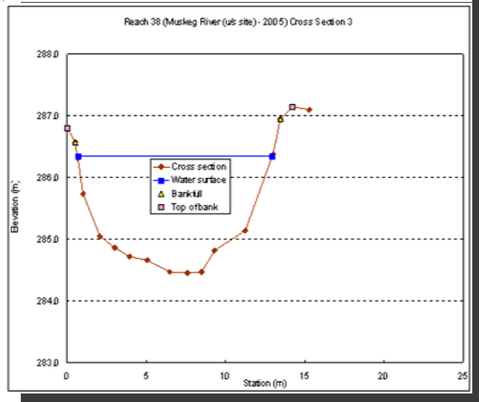
BED MATERIAL[2]	
PARTICLE	SIZE (mm)
D$_{16}$	N/A
D$_{35}$	N/A
D$_{50}$	N/A
D$_{65}$	N/A
D$_{84}$	N/A
D$_{90}$	N/A

[2] Bed material sample was not collected.

Aerial view





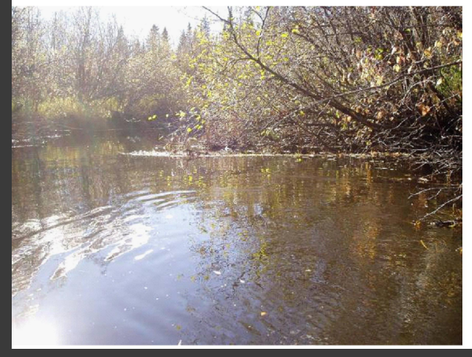


Cross Section 1 - Ground View Looking Upstream

Cross Section 1 - Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream

Cross Section 2 - Ground View Looking Downstream


Cross Section 3 - Ground View Looking Upstream

Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

GEOMORPHOLOGY SITE 38 - MUSKEG RIVER ABOVE WAPASU CREEK

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No. Pierre river	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	FLA	17/11/07	**FIGURE:B-44**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6600\6650\Surface Water Hydrology Report\Appendices\SITE 38 - MUSKEG RIVER ABOVE WAPASU CREEK.dwg Nov 23, 2007 - 10:57am

This channel reach is approximately 42 m long and it is located roughly 2.35 km upstream of Muskeg River's confluence with the Muskeg Creek and 3.02 km downstream of the confluence with Stanley Creek. The reach is in a glaciolfluvial surficial geology in an upland area with a channel slope of 0.2%. The floodplain is wide and flat and is vegetated with tall grasses and shrubs close to the channel. The tree line is located 120 m from the top of bank for this reach.

The channel reach has a riffle pool system and has a moderate sinuosity of 1.226, an average bankfull depth of 1.01 m and an average bankfull width of 12.94 m. The reach bed material was sampled consists mostly of medium fine sand with some silt and clay. There is also aquatic vegetation within the reach. The channel bank material was observed to consist of sand and silt and showed signs of undercutting. The entrenchment ratio of the reach could not be calculated from the surveyed data and the bankfull-width-to-bankfull-depth ratio is 12.87.

At the time of the survey the reach had an average maximum water depth of 1.24 m, an average wetted width of 12.04 m and a discharge of 1.95 m^3/s.

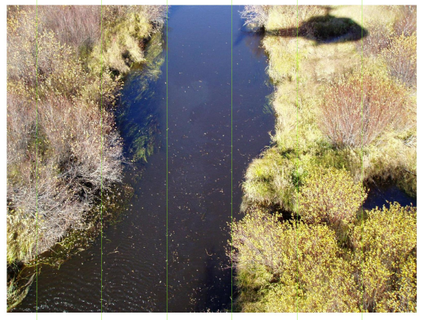
SITE LOCATION		
Stream	Muskeg River	
UTM (NAD 83)	6353663 m North	476996 m East
Date and Time of Visit	30 September 2005	1230 hr (Discharge Measurement)

STREAM CHARACTERISTICS	
Basin Area	541.70 km^2
Channel Slope	0.002 m/m
Channel Mean Bankfull Depth[1]	1.005 m
Channel Maximum Bankfull Depth[1]	1.587 m
Channel Bankfull Width[1]	12.935 m
Sinuosity	1.226
Measured Discharge	1.946 m^3/s
Estimated Mean Annual Discharge	1.468 m^3/s
Estimated Bankfull Discharge	9.812 m^3/s

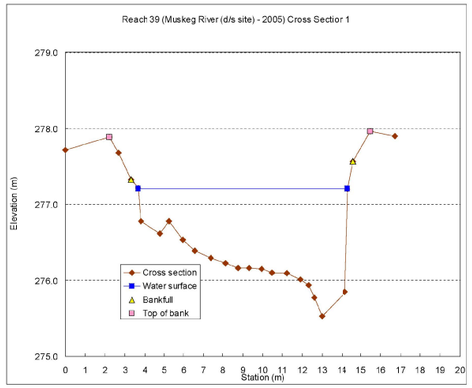
[1] Calculated using the average of measured values at all cross-sections.

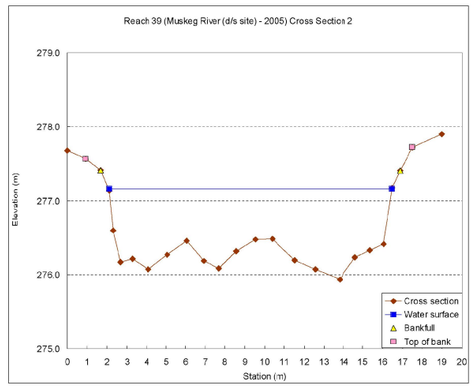
BED MATERIAL	
PARTICLE	SIZE (mm)
D_{16}	0.21
D_{35}	0.26
D_{50}	0.33
D_{65}	0.41
D_{84}	0.65
D_{90}	0.73

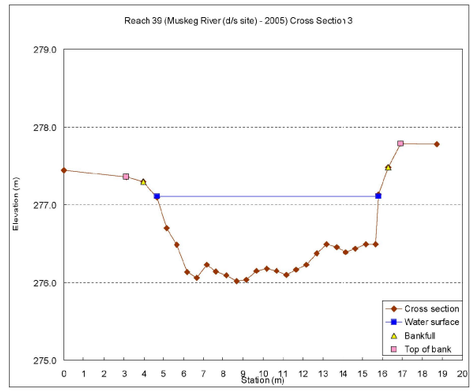
Note: Percentage of finer particles (clay and silt) is 12.1%.



Aerial view



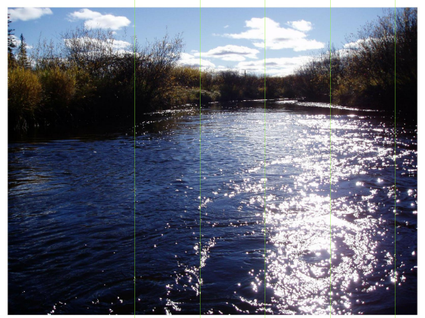




Cross Section 1 – Ground View Looking Upstream

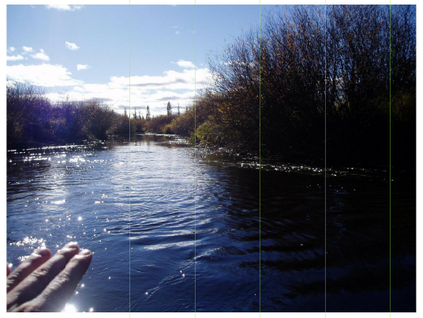
Cross Section 1 – Ground View Looking Downstream

Cross Section 2 - Ground View Looking Upstream



Cross Section 2 - Ground View Looking Downstream

Cross Section 3 - Ground View Looking Upstream



Cross Section 3 - Ground View Looking Downstream

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**GEOMORPHOLOGY SITE 39 -
MUSKEG RIVER ABOVE MUSKEG CREEK**

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Asphalt Creek	
DESIGN	KM	05/07/07	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	FLA	17/11/07	**FIGURE:B-45**		
REVIEW	WES/TC	20/11/07			

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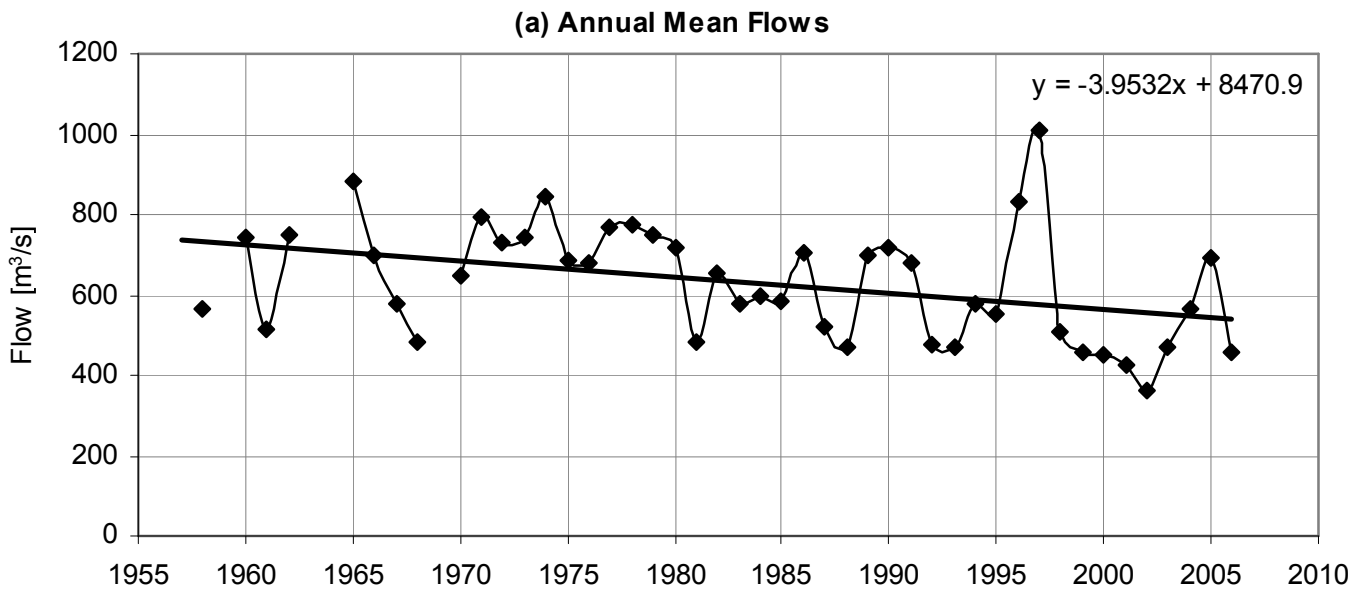
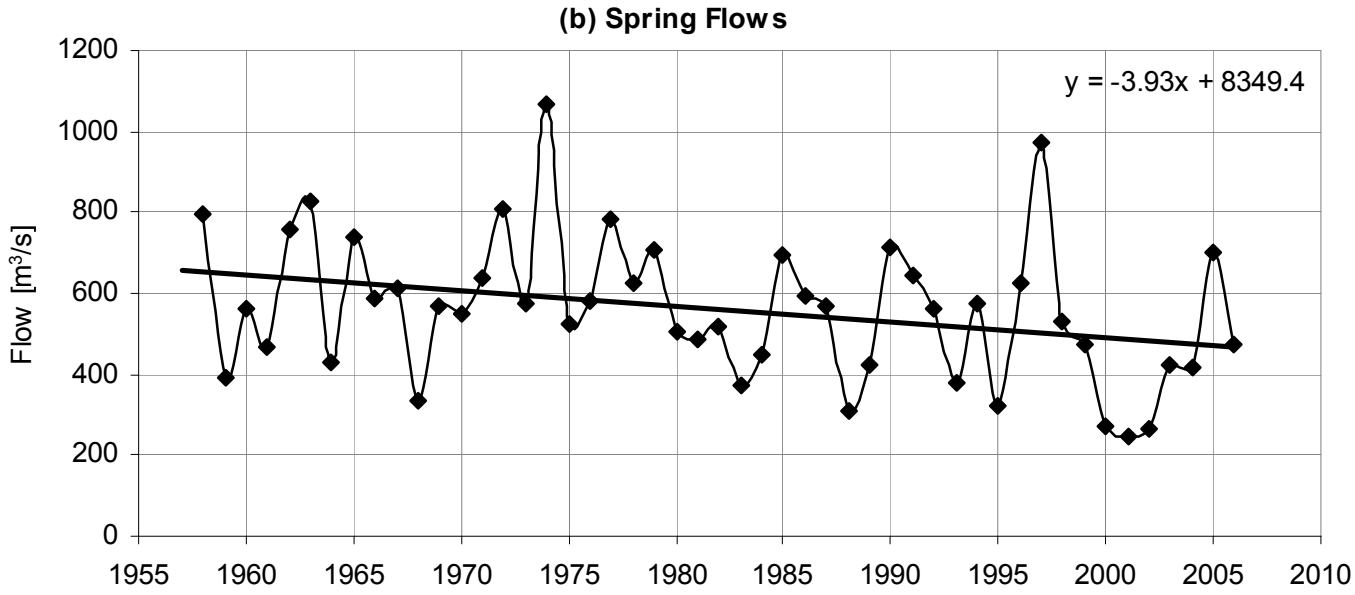
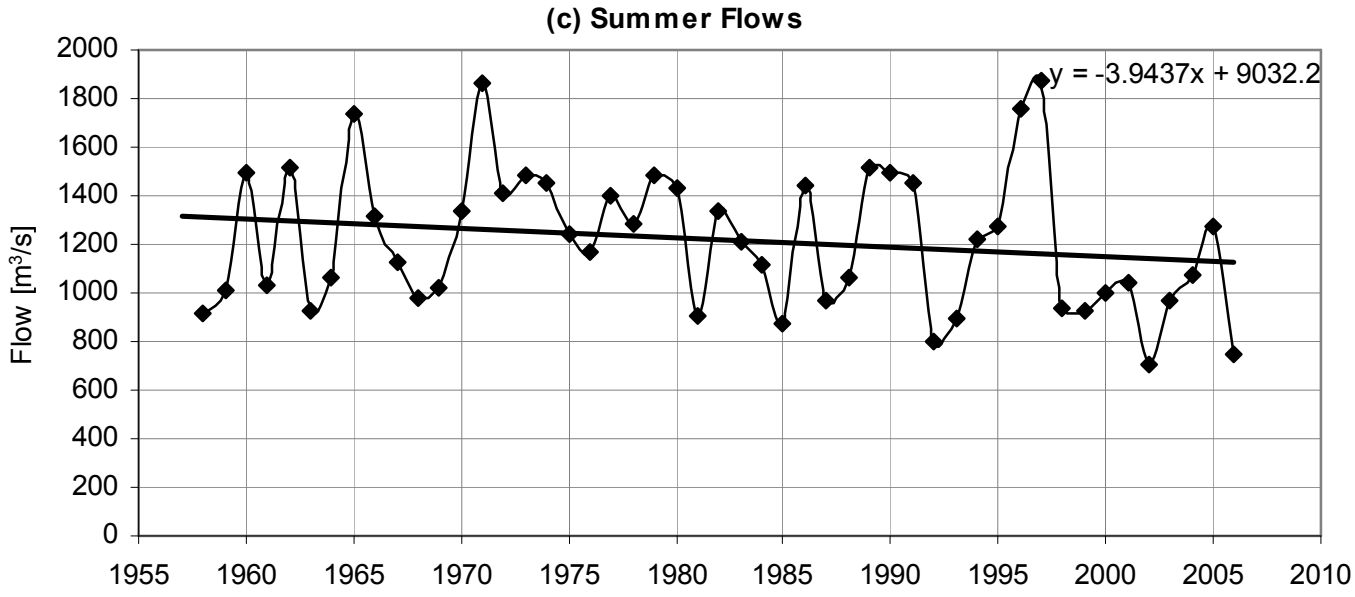
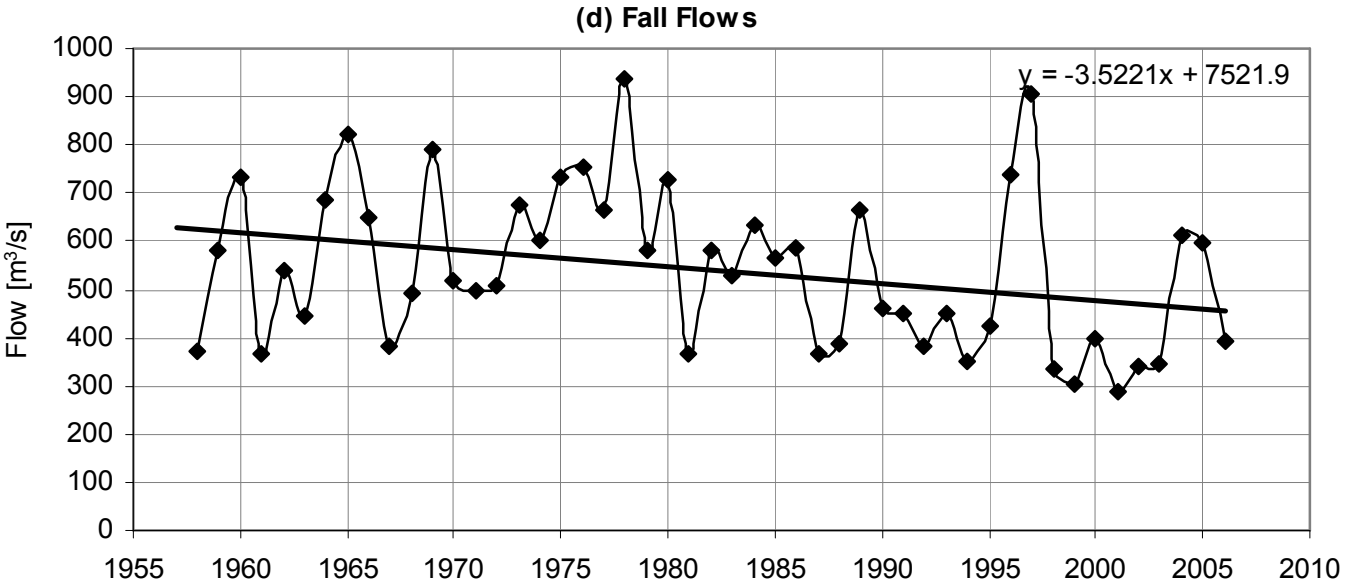








PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

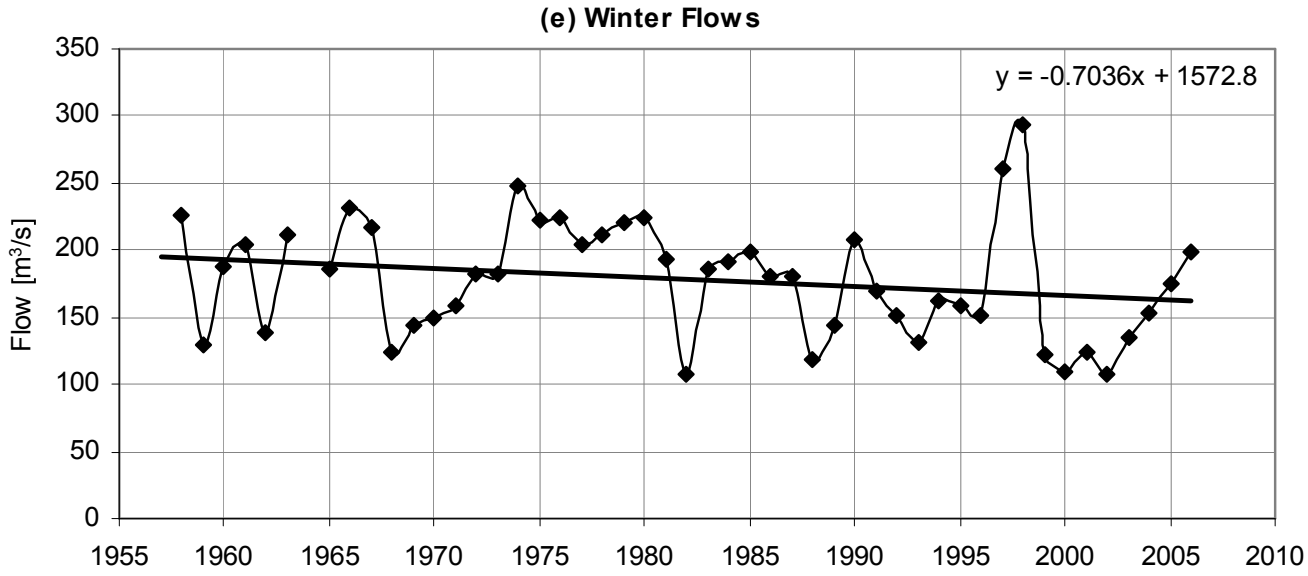
TITLE

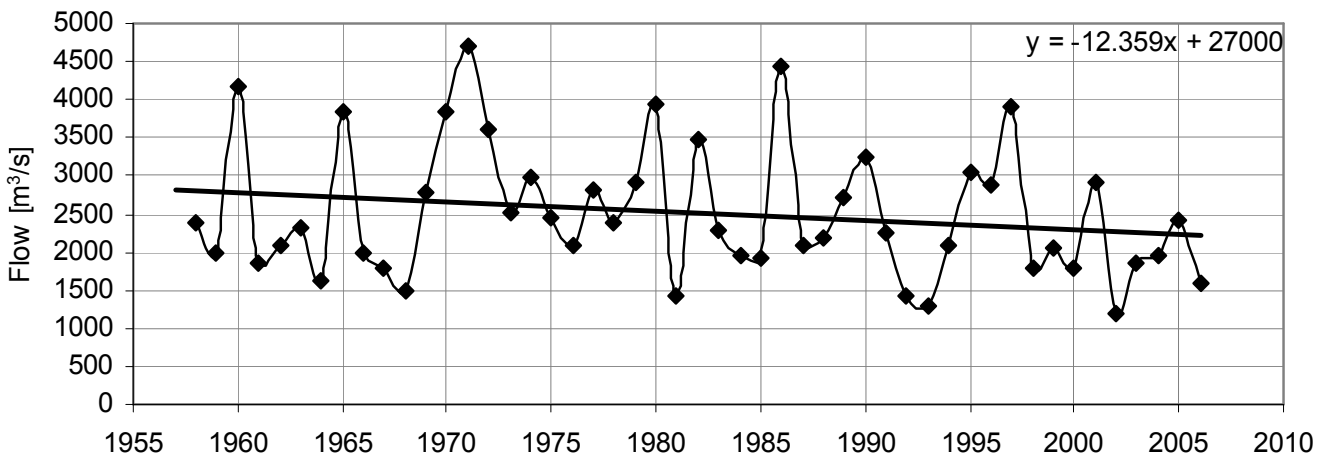
TRENDS OF ATHABASCA RIVER FLOWS BELOW FORT McMURRAY

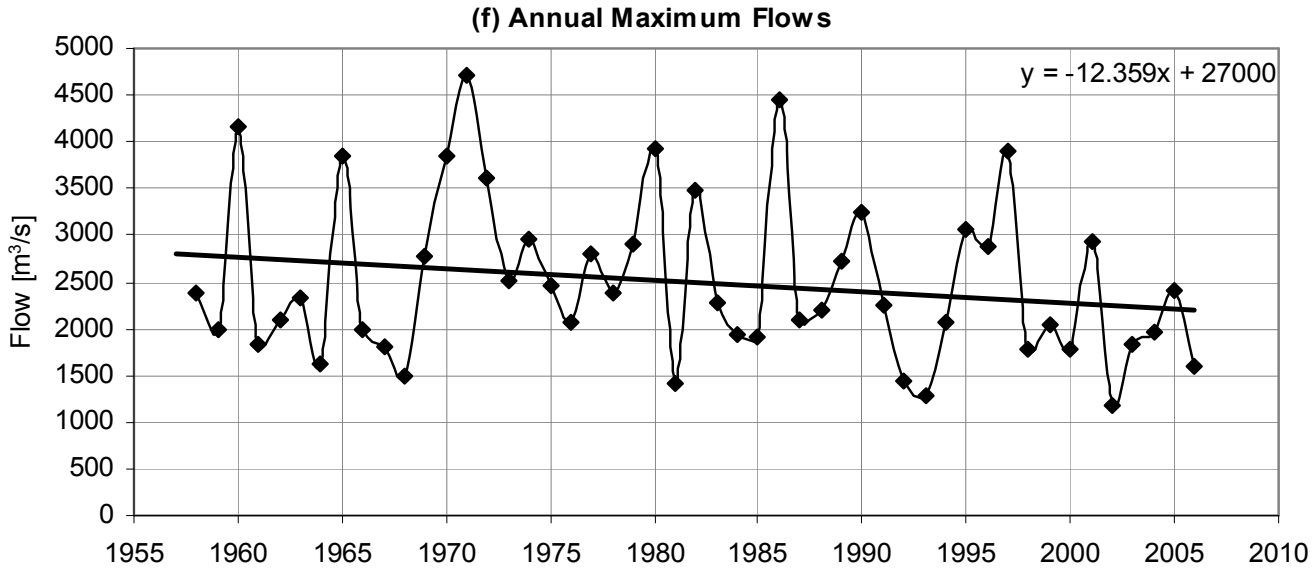
Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Trends
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07		
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: B-46a







PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

TRENDS OF ATHABASCA RIVER FLOWS BELOW FORT McMURRAY

Shell Canada Limited

PROJECT 05-1344-027.6600			FILE No.	Trends
DESIGN	KM	06/07/07	SCALE AS SHOWN	REV. 0
CADD	MM	16/11/07	**FIGURE: B-46b**	
CHECK	FLA	16/11/07		
REVIEW	WES/TC	20/11/07		

6 STREAMFLOW TREND ANALYSIS METHODOLOGY AND RESULTS

Trend analyses of recorded streamflows of the Athabasca River were conducted to determine:

- the presence of statistically significant trends in pertinent streamflow variables; and
- any linkages or correlations between trends in streamflow variables, if such trends were detected from the previous analyses.

The recorded flow data at Environment Canada Station 07DA001 (Athabasca River below Fort McMurray) were analyzed using Spearman and Mann-Kendall tests for trend to identify possible trends in annual maximum, annual mean, annual minimum, monthly mean and seasonal mean flows. The Spearman and Mann-Kendall tests are the standard tests used to identify statistically significant trends in observed data.

The results of the analysis suggest a statistically significant trend of decreasing flows at the 5% level for annual mean flow, and the mean flow in the spring, fall and winter seasons for the Athabasca River below Fort McMurray. The results also indicate a trend of decreasing flows in the summer, annual daily maximum and 7-day low flows. However, these trends are not statistically significant at the 5% level (Table B-4, Figures B-46a and B-46b).

Table B-4 Statistical Test for Trend in Streamflows of the Athabasca River

Time Period	Mann-Kendall Test[a]			Spearman Rank Order Correlation Coefficient Test for Trend			
	No. Data	p-value	senslope	rs	t[b]	t(α=0.05)[b]	t(α=0.01)[c]
Jan	48	0.0242	-1.190	0.3080	2.1954	2.0129	2.6870
Feb	48	0.0280	-0.750	0.2488	1.7426	2.0129	2.6870
Mar	49	0.3332	-0.260	0.0929	0.6394	2.0117	2.6846
Apr	47	0.2756	-1.456	0.0886	0.5965	2.0141	2.6896
May	49	0.0031	-9.805	0.3964	2.9603	2.0117	2.6846
Jun	49	0.0614	-6.149	0.2488	1.7612	2.0117	2.6846
Jul	49	0.1715	-3.768	0.1246	0.8609	2.0117	2.6846
Aug	49	0.2618	-1.897	0.1059	0.7302	2.0117	2.6846
Sep	49	0.0125	-5.578	0.3148	2.2737	2.0117	2.6846
Oct	50	0.0151	-3.806	0.3453	2.5491	2.0106	2.6822
Nov	49	0.0193	-1.912	0.3492	2.5547	2.0117	2.6846
Dec	48	0.0632	-0.988	0.2387	1.6672	2.0129	2.6870
Mean Annual	45	0.0003	-5.241	0.4765	3.5545	2.0167	2.6951
Spring	49	0.0068	-4.440	0.3371	2.4551	2.0117	2.6846
Summer	49	0.0951	-3.835	0.2143	1.5040	2.0117	2.6846
Fall	49	0.0091	-4.134	0.3269	2.3717	2.0117	2.6846
Winter	48	0.0188	-0.949	0.2958	2.1003	2.0129	2.6870
Annual Max	49	0.0737	-11.539	0.1962	1.3716	2.0117	2.6846
7Q10	46	0.0478	-0.643	0.2736	1.8870	2.0154	2.6923

(a) Mann-Kendall test was performed as follows: For any given term, its feature vector consists of the probability P-value appearing in a given time, which is compared to all other ones and then Kendall's statistic Sen-slope is calculated. Generally, if a data set displays a consistently increasing or decreasing trend the Sen-slope will be positive or negative respectively, with a larger magnitude indicating the trend is more consistent in its direction.

(b) If $|t|<|t(\alpha=0.05)|$, i.e., there is statistically significant level of less than 5%, then the correlation is not significantly different from zero. That is, the data do not display a statistically significant trend.

(c) $|t|<|t(\alpha=0.01)|$ represents a statistically significant level of less than 1%.

Golder Associates Ltd.

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Fax (403) 299-5606

APPENDIX C

HYDROLOGICAL SIMULATION PROGRAM-FORTRAN MODEL VALIDATION AND RESULTS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

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1 HSPF MODEL BACKGROUND AND CALIBRATION

The continuous (dynamic) Hydrological Simulation Program-Fortran (HSPF) model, developed by the U.S. Environmental Protection Agency (U.S. EPA), was selected for hydrologic studies in the Oil Sands Region. The HSPF model was used to generate synthetic hydrologic data series using the historical climate data series.

The HSPF model simulates stream flows as the sum of three components: surface flow, interflow and groundwater. The relative magnitude of each component depends on land use, soils and vegetation cover. The model user can specify specific parameters for various land use types to represent the physical processes in a basin.

The HSPF model was previously calibrated by AGRA (1996) and a calibration update was conducted later by Golder (1997). The HSPF model was last re-calibrated by Golder with funding from a consortium of oil sands mining companies (Golder 2003). In the re-calibration study, the previous calibration of the HSPF model was improved using updated climatic, hydrologic surficial geological and topographic information. Data from the Beaver River, Jackpine Creek and Muskeg River basins were used for this re-calibration. Regional hydrologic model parameters were derived for the Oil Sands Region using a systematic approach to account for various surficial geologic conditions, land types and the effects of spatially variable precipitation input.

A detailed description of the HSPF model and the re-calibration results are provided in the 2003 regional calibration report (Golder 2003).

2 MODEL VALIDATION RESULTS

The parameters of the calibrated regional HSPF model were validated using measured runoff data from basins with relatively long periods of records as well as from watersheds with short periods of records. In addition, simulated daily discharges were compared with observed daily discharges at selected stations. The regional calibration report (Golder 2003) documents the results of model validation using longer periods of flow records from Steepbank River and Joslyn Creek.

The regional HSPF model is continually validated when new climate and stream flow data become available. The model was recently used to compare observed and simulated daily flows at seven hydrometric stations in Jackpine Expansion Mining Area (JEMA) and Pierre River Mining Area (PRMA) Local Study Areas (LSAs), shown in Figure C-1. Table C-1 summarizes the pertinent information on these stations. Precipitation data for model simulations were taken from local climate stations: Aurora climate station for simulating flows in the JEMA LSA, and Ells Lookout station for simulating flows in the PRMA LSA. The Aurora climate station, maintained by Regional Aquatics Monitoring Program (RAMP), has data from 1995 to 2005. Additional data, prior to establishment of this station, were supplemented from the Fort McMurray climate station. Data recorded at the Ells Lookout station (spring/summer precipitation from 1961 to 2006) captures the rain shadow effect on precipitation in the PRMA LSA due to the mountainous range to the west of the LSA. Missing data and data prior to 1961 were supplemented from the climate station at Fort McMurray. Although the climate station at Calumet River is located within the LSA itself, it has been in operation for a short period of time, which does not coincide with the stream flow records at hydrometric stations within the PRMA LSA. Climate data, other than precipitation, were obtained from the Fort McMurray climate station records.

Figures C-2 through C-5 show comparisons of simulated and recorded daily flows at hydrometric stations in the JEMA LSA. The recorded peak daily flows at the Muskeg River Mouth, Jackpine Creek at Node S2 and Muskeg River at Node S5A are generally higher than the corresponding simulated flows. However, there seems to be good agreement for low flows and in response patterns to precipitation. Recorded and simulated peak flows tend to agree better for Iyinimin Creek at Node S3. Flows in the Muskeg River have been affected by muskeg drainage, overburden dewatering and close-circuit operation at the Aurora North Mine, the Muskeg River Mine (MRM) and Jackpine Mine – Phase 1. Mine water releases at MRM around 2002, with all drainage and dewatering waters being retained on-site in the subsequent years (AXYS 2004). Dewatering flows from the Aurora North and Muskeg River mines have been monitored at stations S1 and S13, respectively (Figure 2.2-2). The recorded flows

at S1 and S13 have small variations as a result of muskeg drainage and overburden dewatering. Dewatering flows generally result in increased flows to receiving stream and hence downstream gauging stations record higher flows compared to the natural water yield from the watershed.

This appears to be one of the reasons why the recorded flows shown in Figure C-2 (at Muskeg River Mouth) are higher than the simulated flows. In Figure C-3, the comparison in terms of timing of Jackpine Creek peak flows is good, but the simulated peak flows appear to be underpredicted. The comparison of flows at Muskeg River Node S5A and Iyinimim Creek is reasonable in terms of timing and magnitude of flows (Figures C-4 and C-5). This is reflected in the mean monthly flows as tabulated in Table C-2, and in the flow duration curves (Figures C-6, C-7, C-8 and C-9).

Recorded daily flows at various stations in the PRMA LSA compare reasonably well with the simulated flows. Figures C-10, C-11 and C-12 show comparisons of recorded and simulated daily flows for stations at Pierre River, Asphalt Creek and Unnamed Creek 2, respectively. Simulated and observed peak daily flows tend to differ in magnitude; however, the timing and response patterns seem to be reasonably similar between the observed and simulated series. Simulated and observed mean monthly flows, averaged from April to October for concurrent simulated and observed records, show good agreement. (See Table C-3). Figures C-13, C-14 and C-15 show comparisons of simulated and recorded flow duration curves. Figure C-15 (Unnamed Creek 2) shows the best comparison of flow duration curves. In Figure C-13 (Pierre River), flow duration curves compare better for percent exceedence greater than 20%; however, the simulated flows are lower than the recorded flows in this range. In Figure C-14 (Asphalt Creek), simulated flows are higher than the observed flows for percent exceedence less than 13%, otherwise they are lower than the recorded flows.

Given the limitations in the input precipitation data, the possible errors in the recorded data and the effects of beaver activities on flows in creeks for small watersheds, full replication of recorded flow series is not considered possible. However, if the calibrated and validated model replicates the range of observed flows for the local watersheds, responds to precipitation input as expected, and maintains the statistics of the recorded flow series, then the resulting calibration and validation of the model can be considered to be further confirmed. The present model has been satisfactorily calibrated and validated and the model results represent observed flows adequately.

Table C-1 Summary of Stream Flow Stations

LSA	Station ID/Node	Stream (location)	Period of Record	Maintenance Authority
JEMA	07DA008	Muskeg River (at mouth)	1995 to 2005	Environment Canada
	S2	Jackpine Creek	1995 to 2005	RAMP
	S5A	Muskeg River	1995 to 2005	RAMP
	S3	Iyinimin Creek	1995 to 2005	RAMP
PRMA	07DA013	Pierre River (at mouth)	1975 to 1977	Environment Canada
	07DA012	Asphalt Creek (upstream of confluence with Eymundson Creek)	1975 to 1977	Environment Canada
	07DA011	Unnamed Creek 2 (upstream of confluence with Big Creek)	1975 to 1993	Environment Canada

Table C-2 Comparison of Recorded and Simulated Mean Monthly Flows for the Jackpine Expansion Mining Area Local Study Area

Months	Muskeg River at Environmental Canada Hydrometric Station[(a)]		Muskeg River at RAMP Station S5A[(a)]		Jackpine Creek at RAMP Station S2 [(a)]		Iyinimin Creek at RAMP Station S3 [(a)]	
	Recorded [m³/s]	Simulated [m³/s]	Recorded [m³/s]	Simulated [m³/s]	Recorded [m³/s]	Simulated [m³/s]	Recorded [m³/s]	Simulated [m³/s]
April	5.240	4.700	0.970	1.254	2.897	1.329	0.352	0.478
May	7.665	6.208	1.784	2.414	1.712	1.909	0.446	0.321
June	8.109	3.323	1.133	0.557	2.266	0.787	0.293	0.307
July	6.705	4.058	1.003	0.765	1.903	1.089	0.305	0.312
August	7.442	4.122	1.130	1.348	2.724	1.265	0.293	0.325
September	6.810	3.959	1.208	1.178	1.977	1.043	0.317	0.274
October	6.300	3.638	1.563	0.969	1.545	1.056	0.295	0.204
Mean	**6.896**	**4.287**	**1.255**	**1.212**	**2.146**	**1.211**	**0.329**	**0.317**

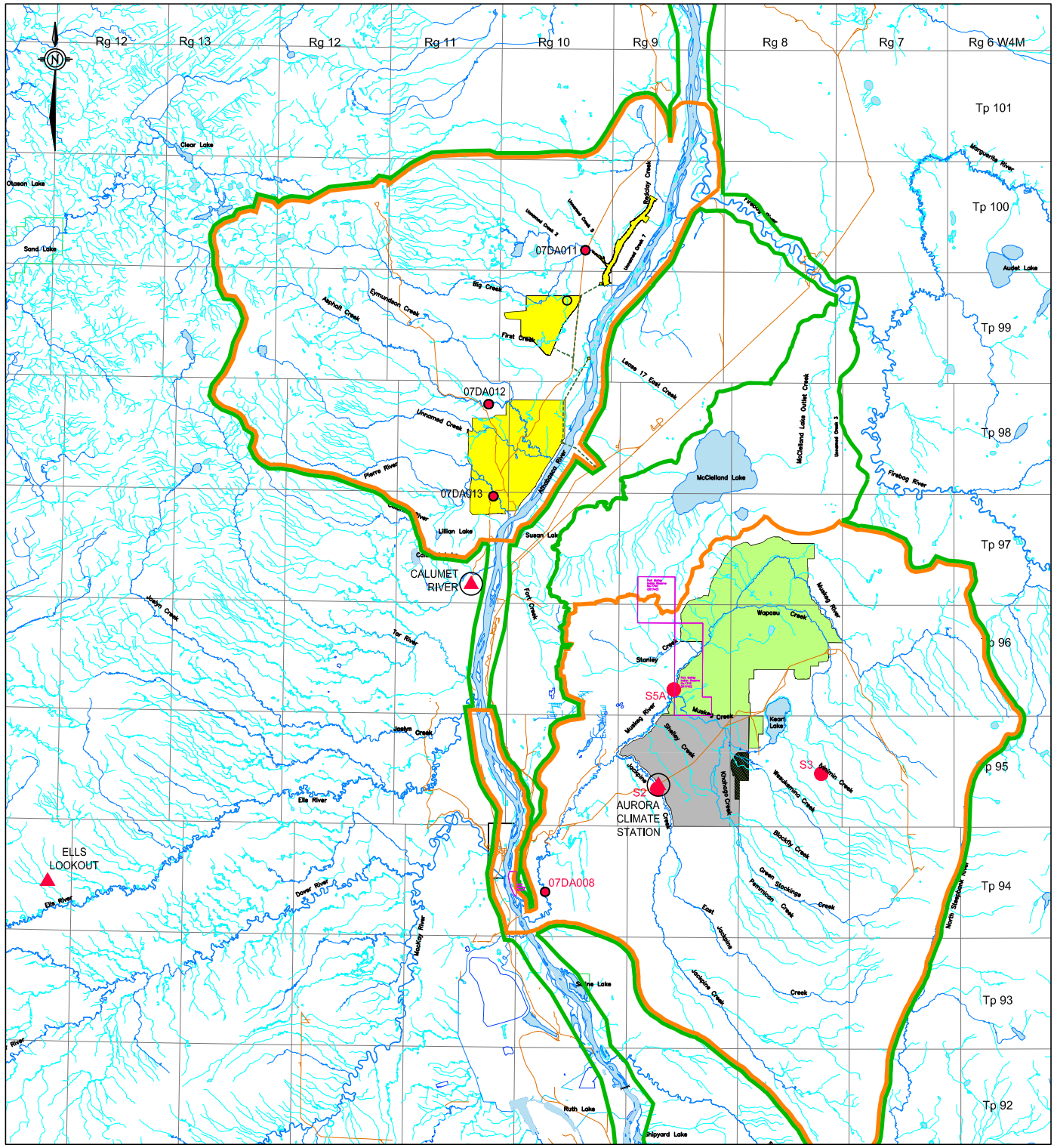
(a) Based on data from 1995 to 2005.

Table C-3 Comparison of Recorded and Simulated Mean Monthly Flows for Pierre River Mining Area Local Study Area

Months	Pierre River at Environment Canada Station[a]		Asphalt Creek at Environment Canada Station[a]		Unnamed Creek 2 Environment Canada Station[b]	
	Recorded [m³/s]	Simulated [m³/s]	Recorded [m³/s]	Simulated [m³/s]	Recorded [m³/s]	Simulated [m³/s]
April	0.418	0.678	0.558	0.937	0.577	0.742
May	0.372	0.409	0.597	0.699	1.444	1.301
June	0.275	0.136	0.421	0.194	0.932	0.497
July	0.496	0.627	1.152	0.800	0.481	0.511
August	0.184	0.269	0.578	0.355	0.312	0.383
September	0.297	0.808	0.415	1.130	0.445	0.714
October	0.303	0.302	0.497	0.351	0.391	0.396
Mean	**0.335**	**0.461**	**0.602**	**0.638**	**0.655**	**0.649**

[a] Based on data from 1975 to 1977.

[b] Based on data from 1975 to 1993.



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

VALIDATION NODES

- HYDROMETRIC STATION (ENVIRONMENT CANADA)
- PRECIPITATION CLIMATE STATION
- RAMP STATION

REFERENCE

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10 0 10
SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HSPF MODEL VALIDATION NODES

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	HSPF NODES
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CHECK	KG	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: C-1

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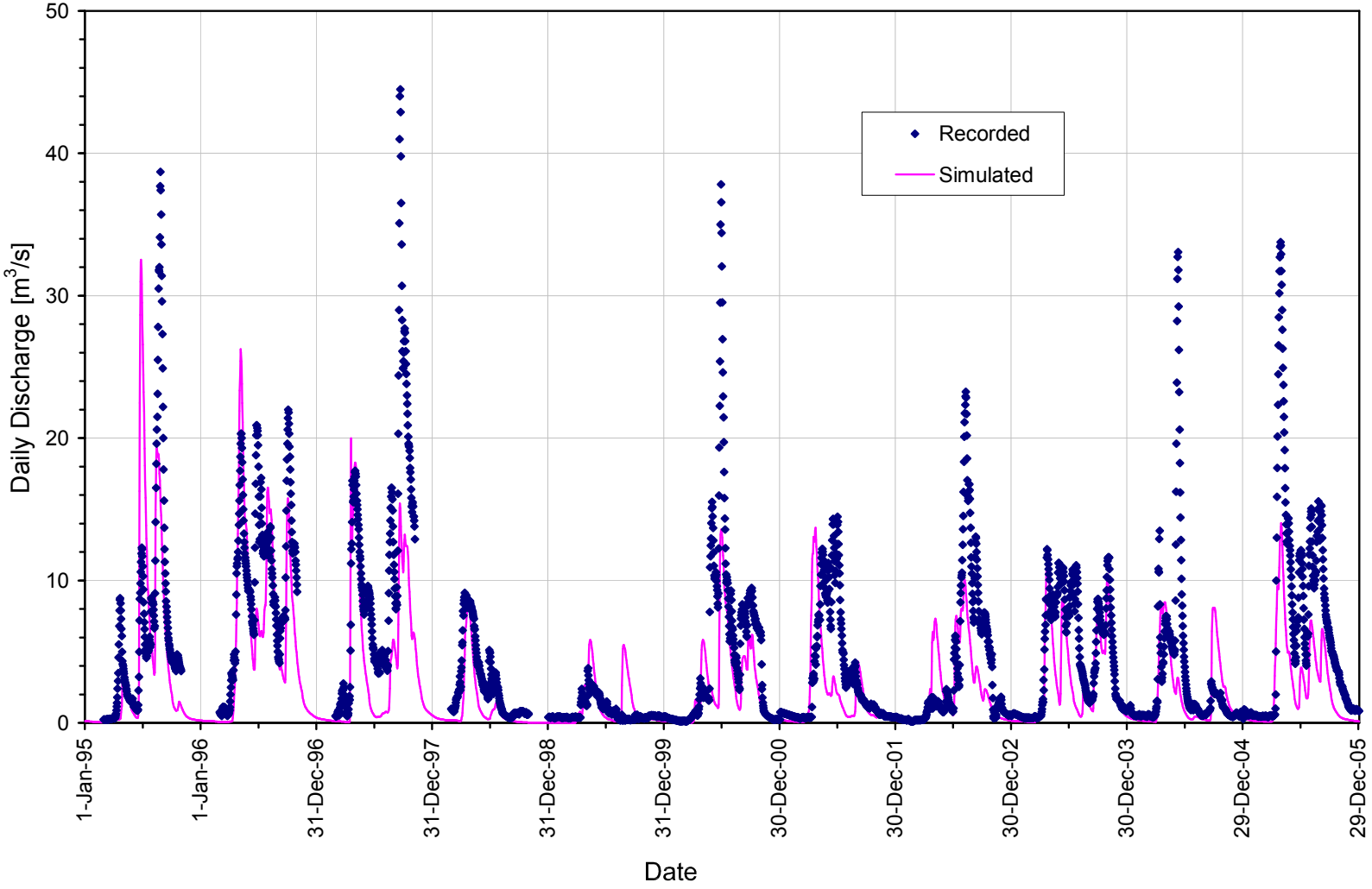

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND RECORDED FLOWS OF MUSKEG RIVER AT ENVIRONMENT CANADA HYDROMETRIC STATION (MUSKEG RIVER MOUTH)

Shell Canada Limited

PROJECT	05-1344-027.6650		FILE No.	Comparison Muskeg	
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REVIEW	WES/TC	20/11/07			

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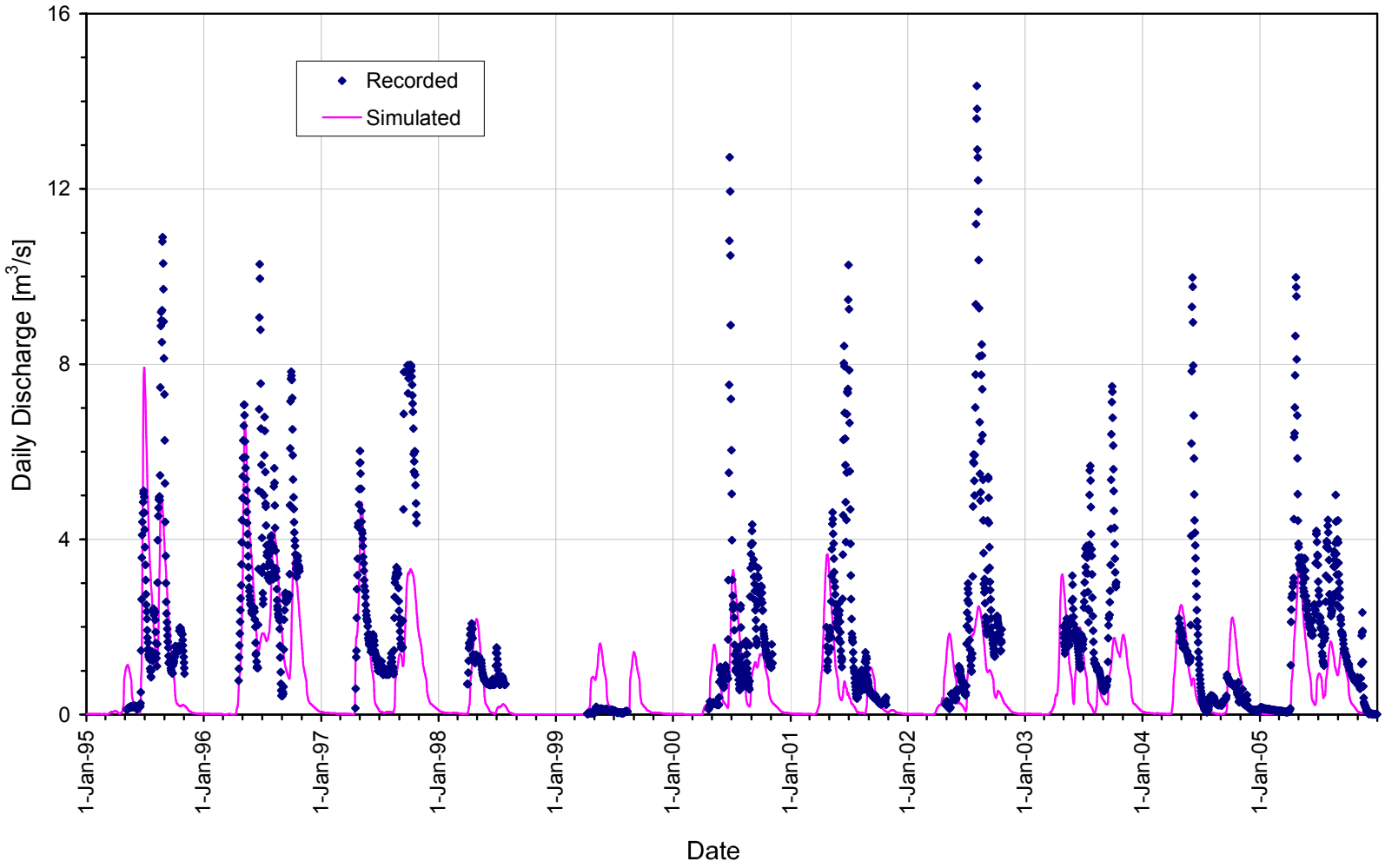

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND RECORDED FLOWS FOR JACKPINE CREEK AT NODE S2

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Jackpine creek	
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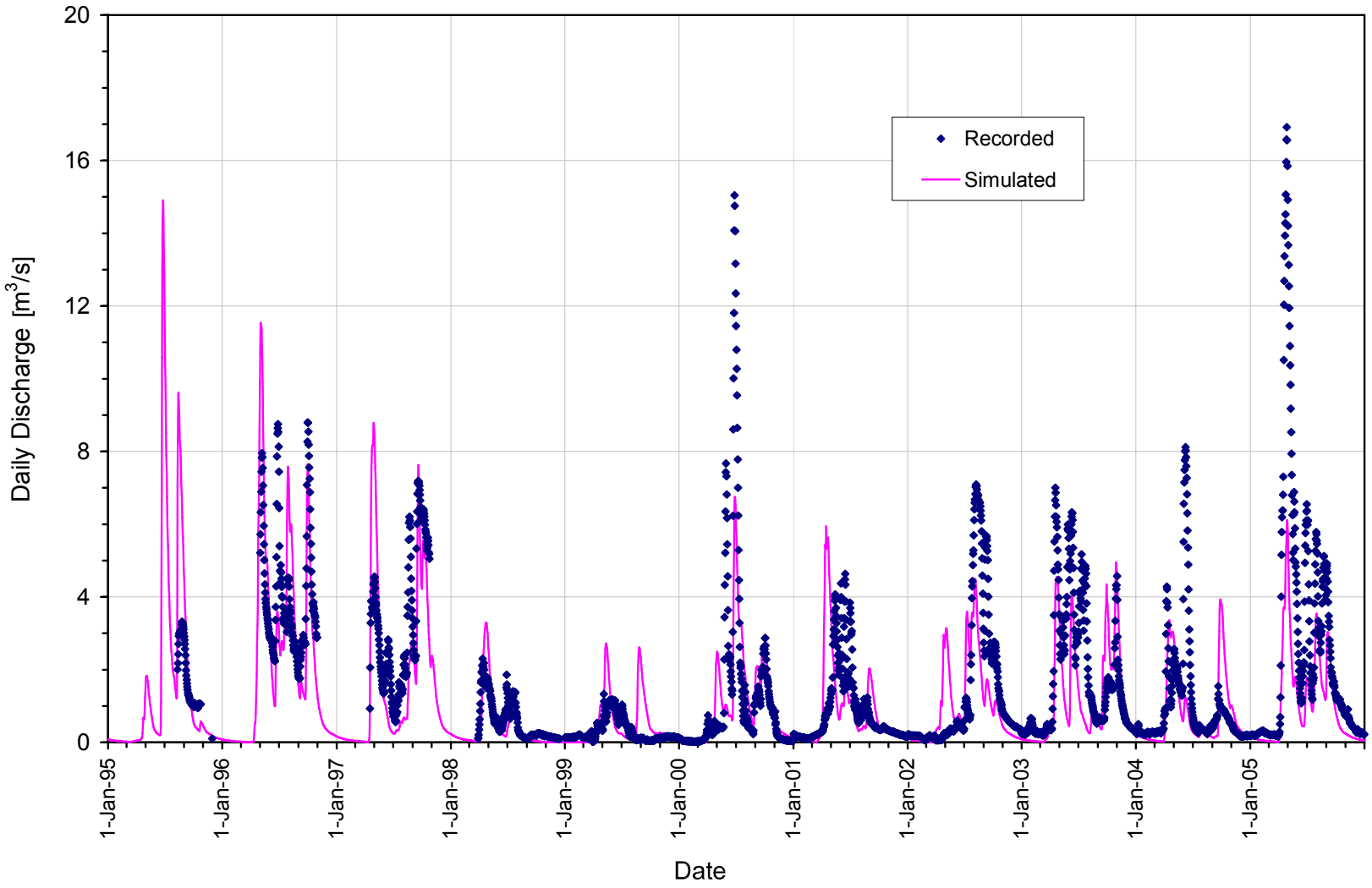

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND RECORDED FLOWS FOR MUSKEG RIVER AT NODE S5A

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Muskeg river S5A	
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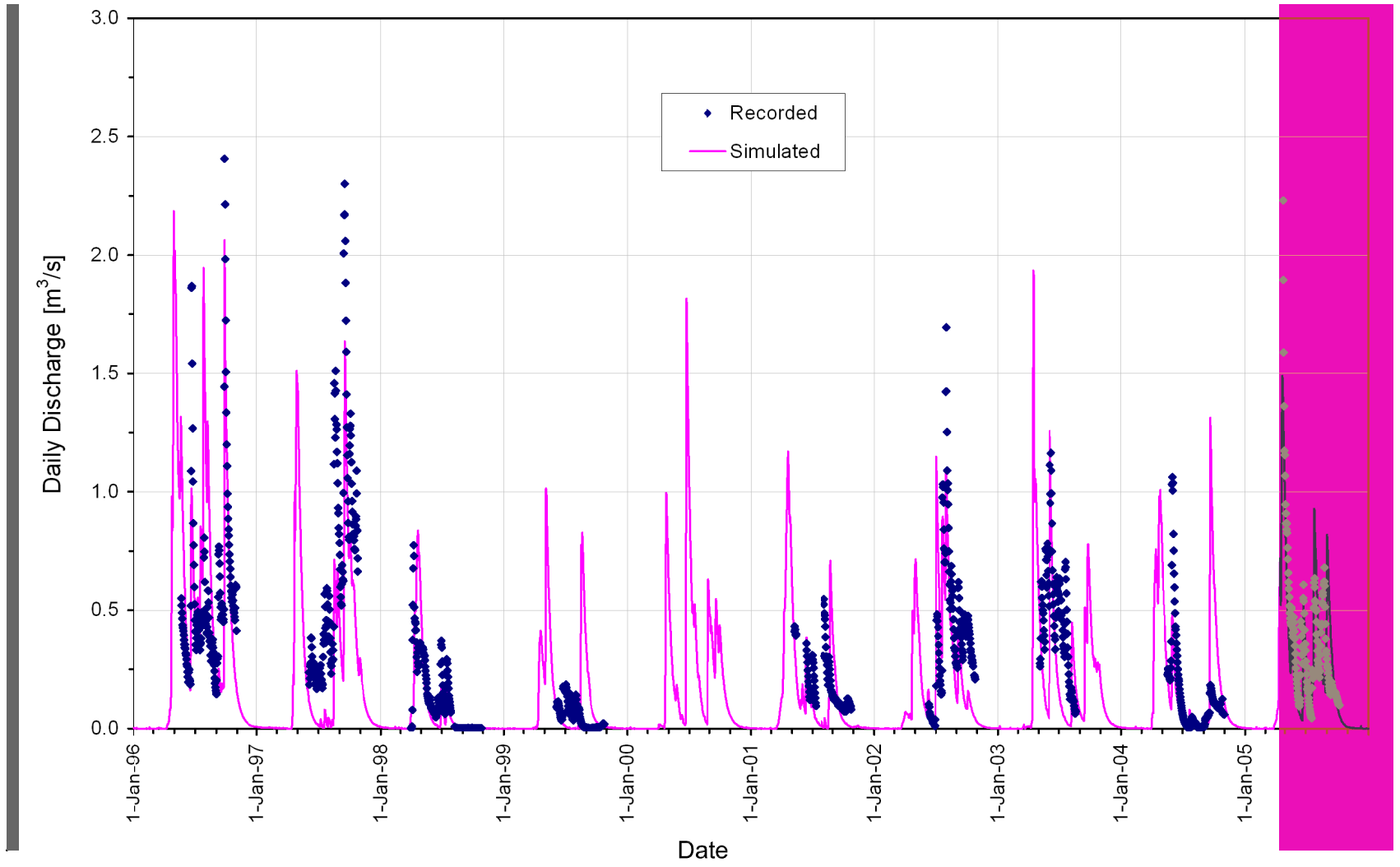

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND RECORDED FLOWS FOR IYINIMIN CREEK AT NODE S3

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	iyinimin creek
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REVIEW	WES/TC	20/11/07		

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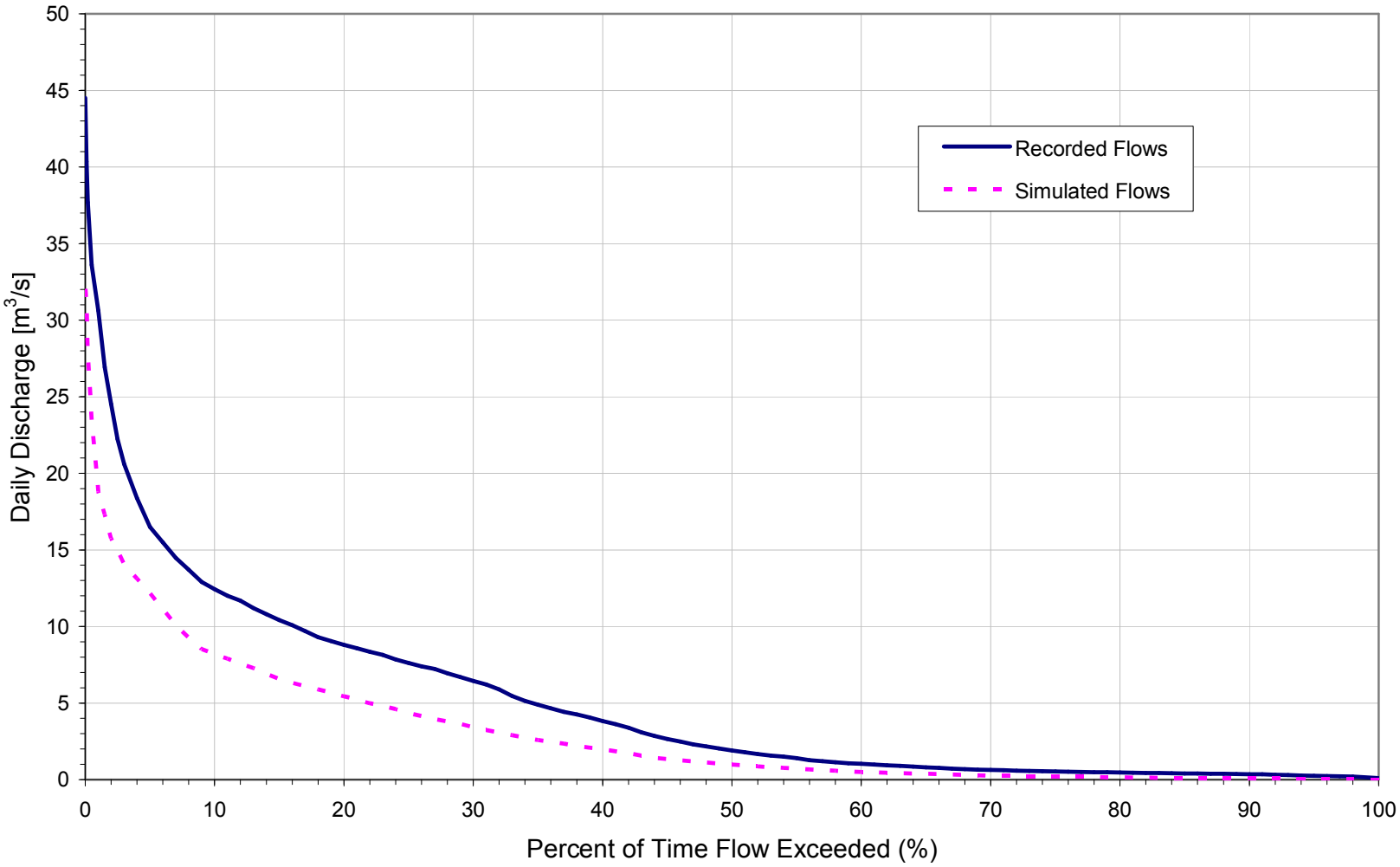

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT MUSKEG RIVER ENVIRONMENT CANADA HYDROMETRIC STATION (1995 TO 2005)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Muskeg river
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REVIEW	WES/TC	20/11/07		

FIGURE: C-6

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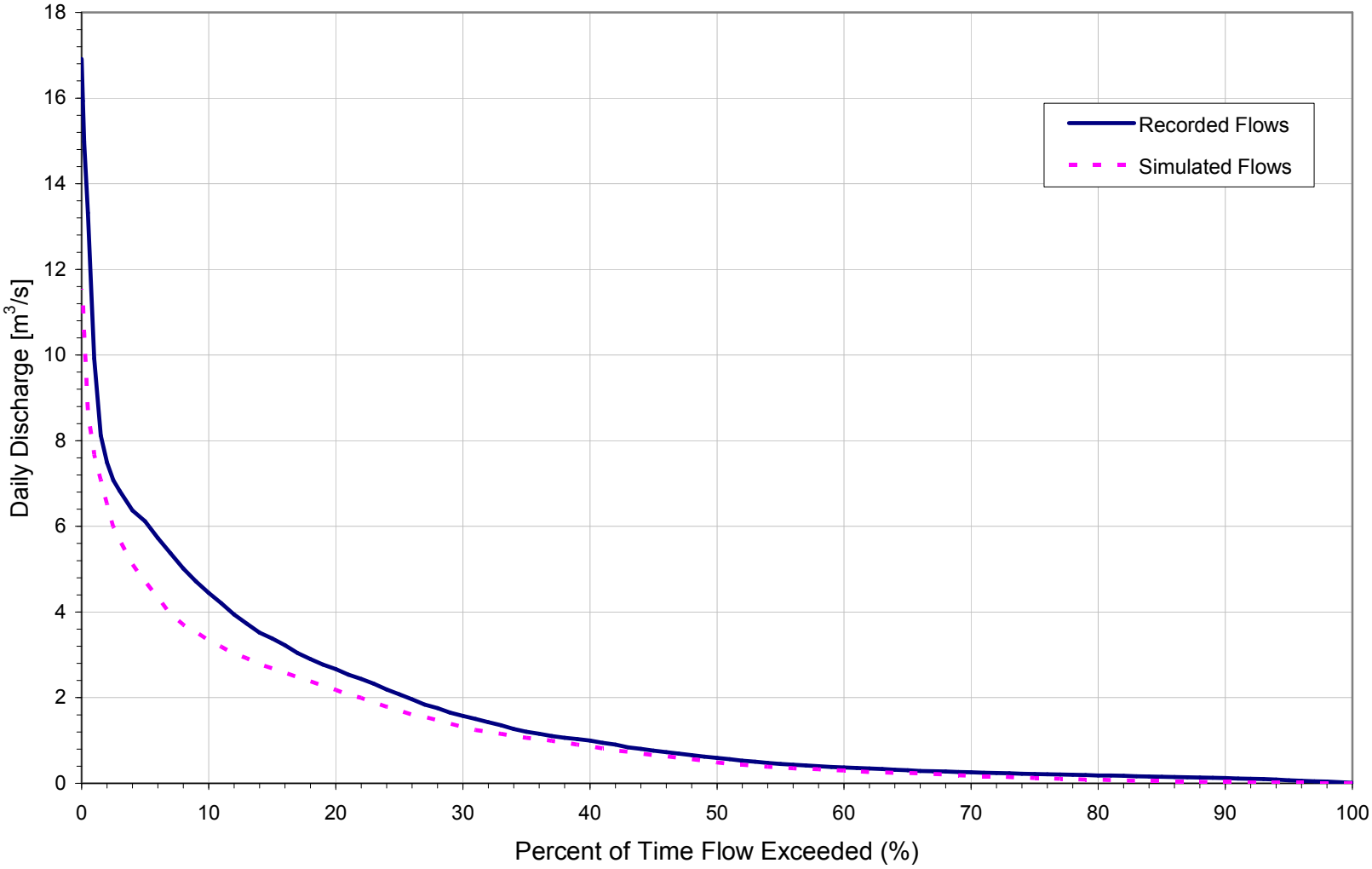

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT MUSKEG RIVER RAMP STATION S5A (1995 TO 2005)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Muskeg river RAMP	
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REVIEW	WES/TC	17/11/07		

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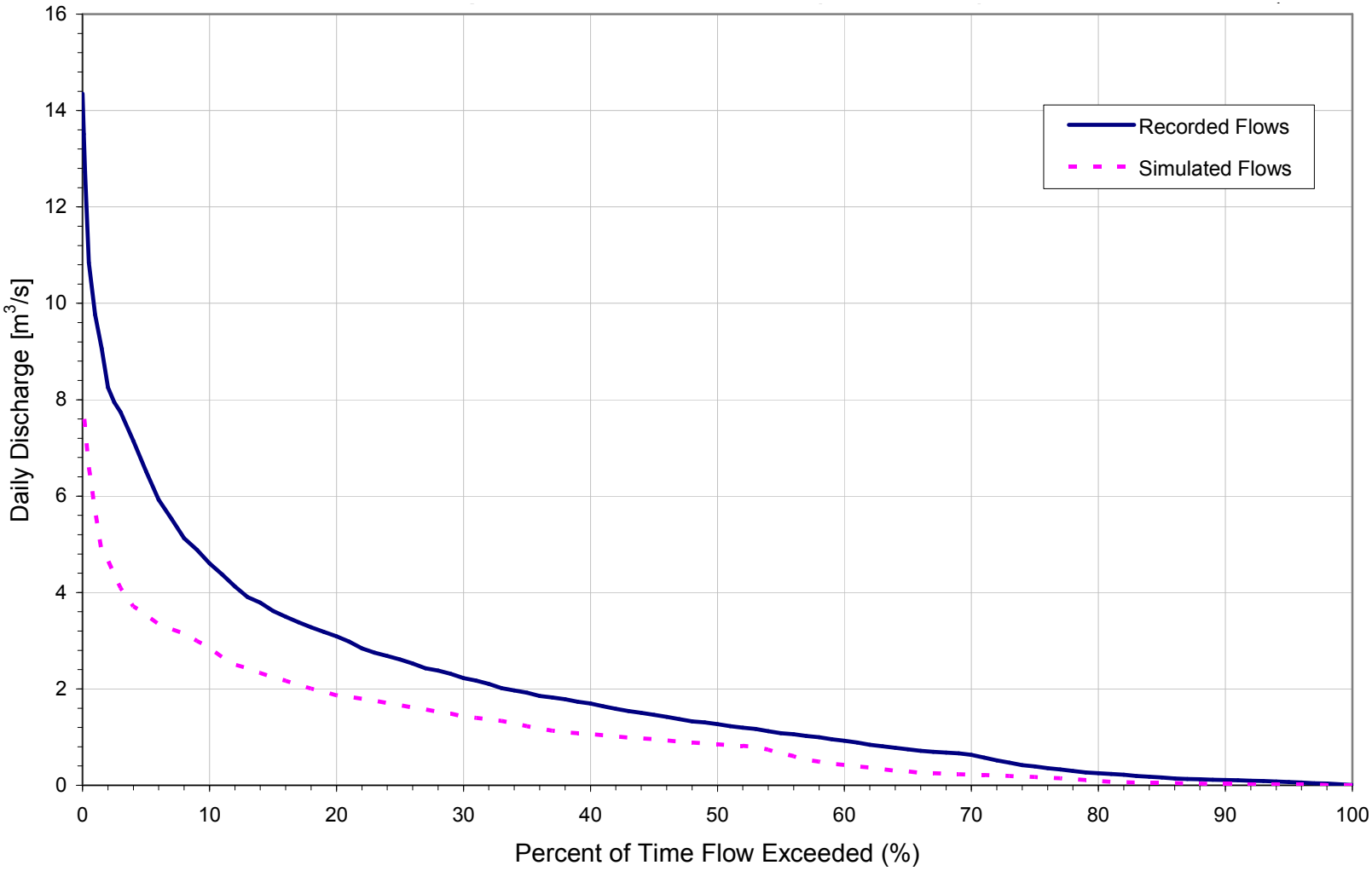

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT JACKPINE CREEK RAMP STATION S2 (1995 TO 2005)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Jackpine creek
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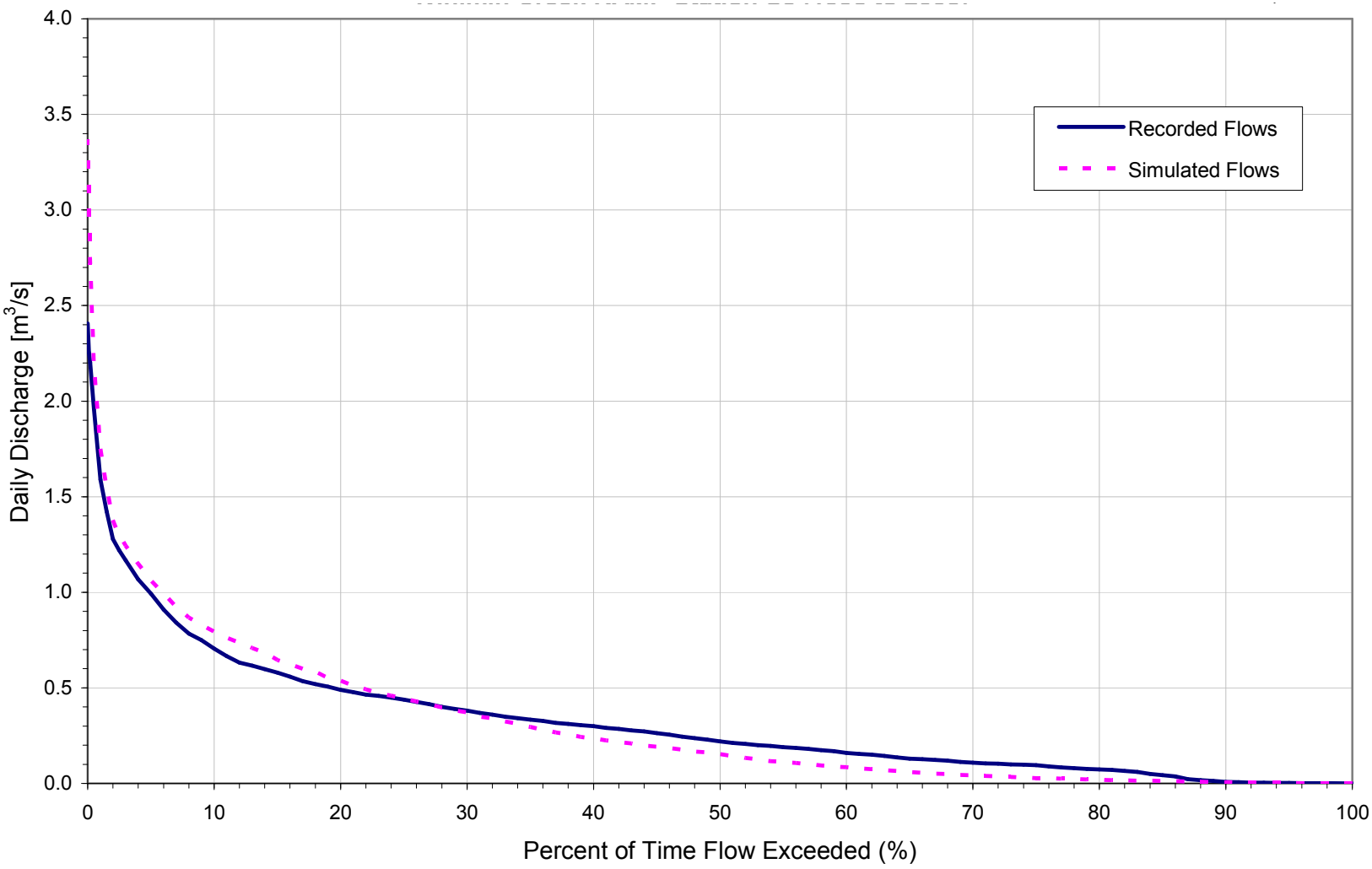

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT IYINIMIN CREEK RAMP STATION S3 (1995 TO 2005)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Iyinimin Creek
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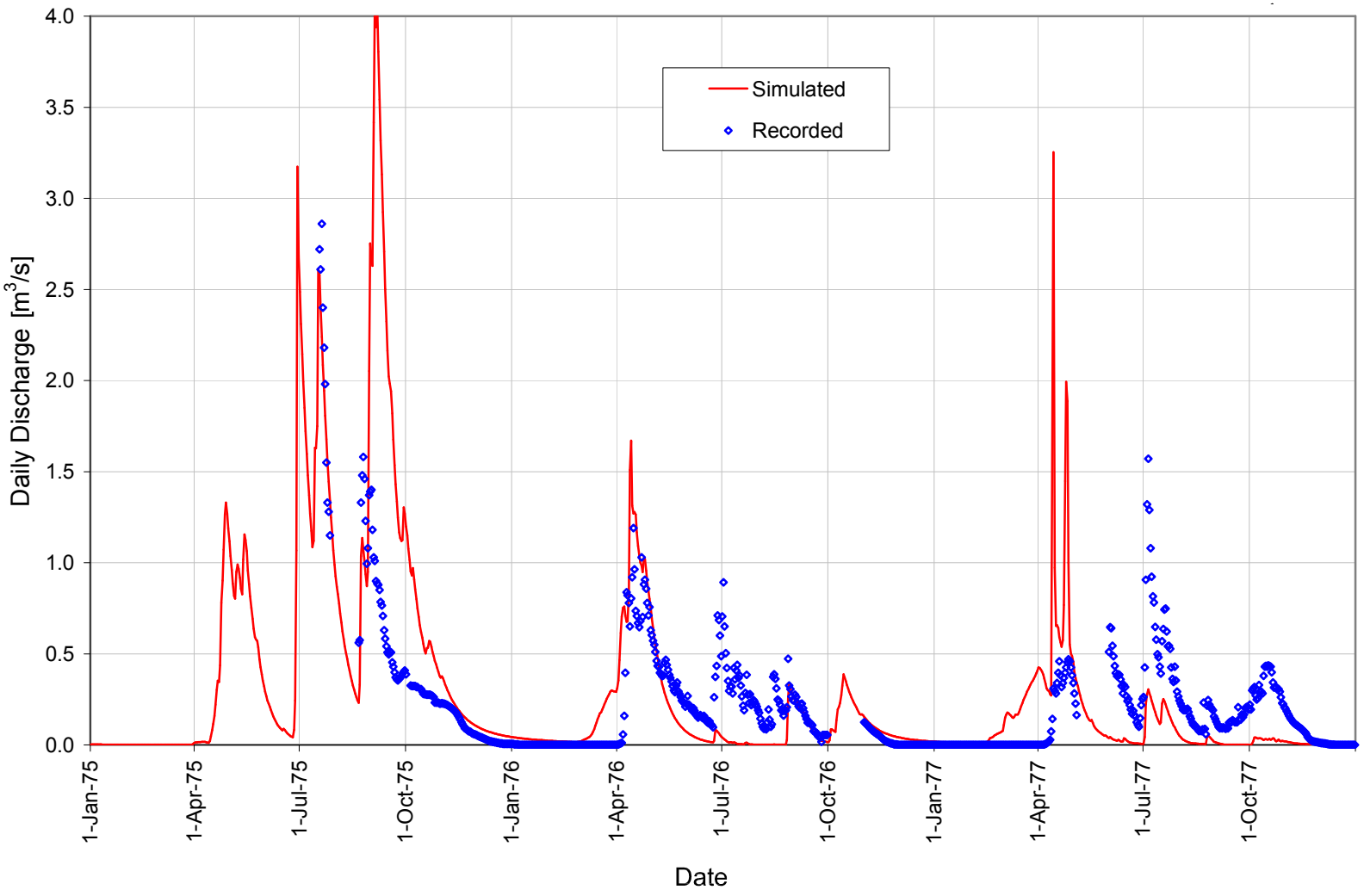

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND ENVIROMENT CANADA RECORDED FLOWS FOR PIERRE RIVER AT THE MOUTH

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Pipre river
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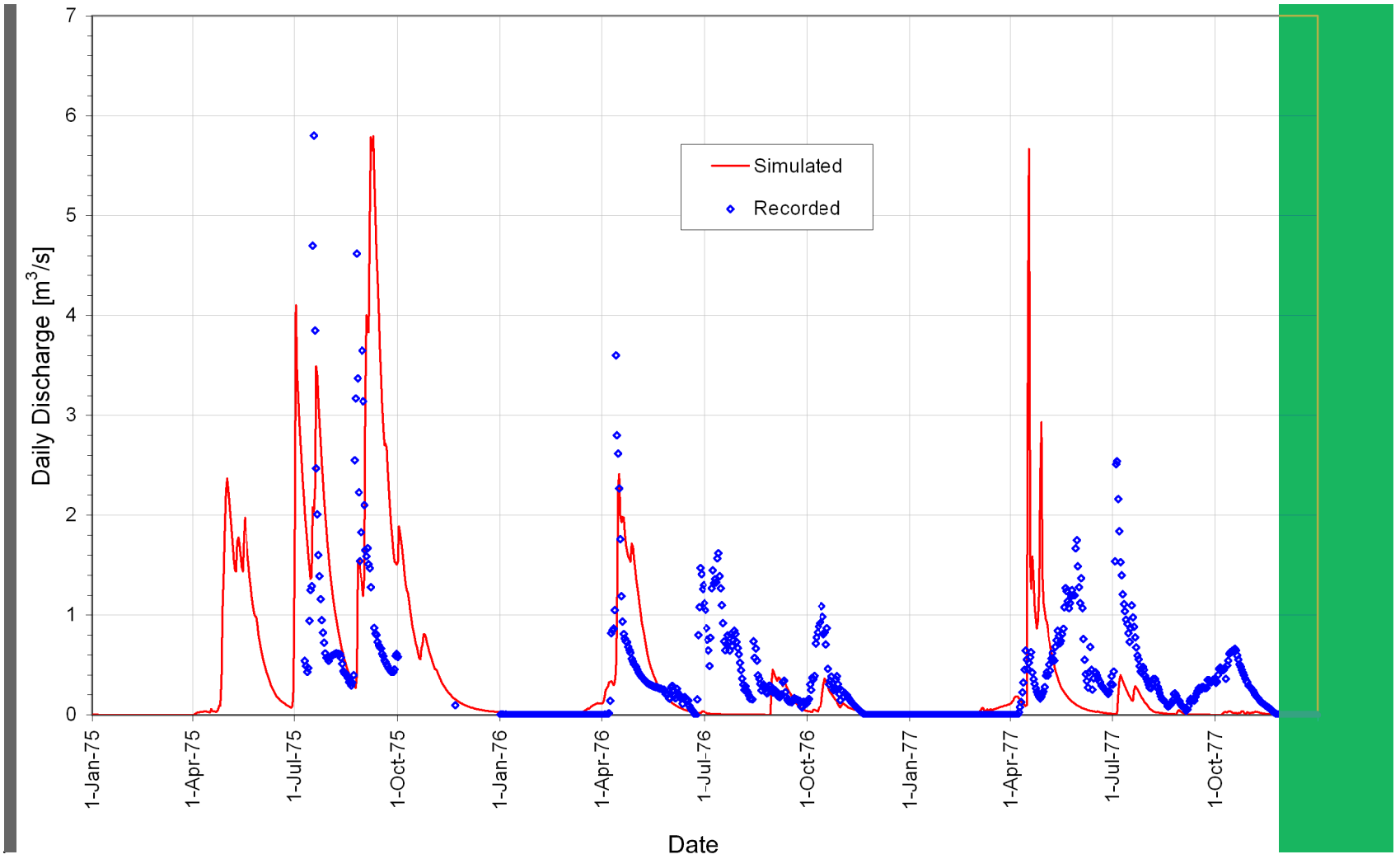

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND ENVIRONMENT CANADA RECORDED FLOWS FOR ASPHALT CREEK AT THE MOUTH

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Asphalt creek
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
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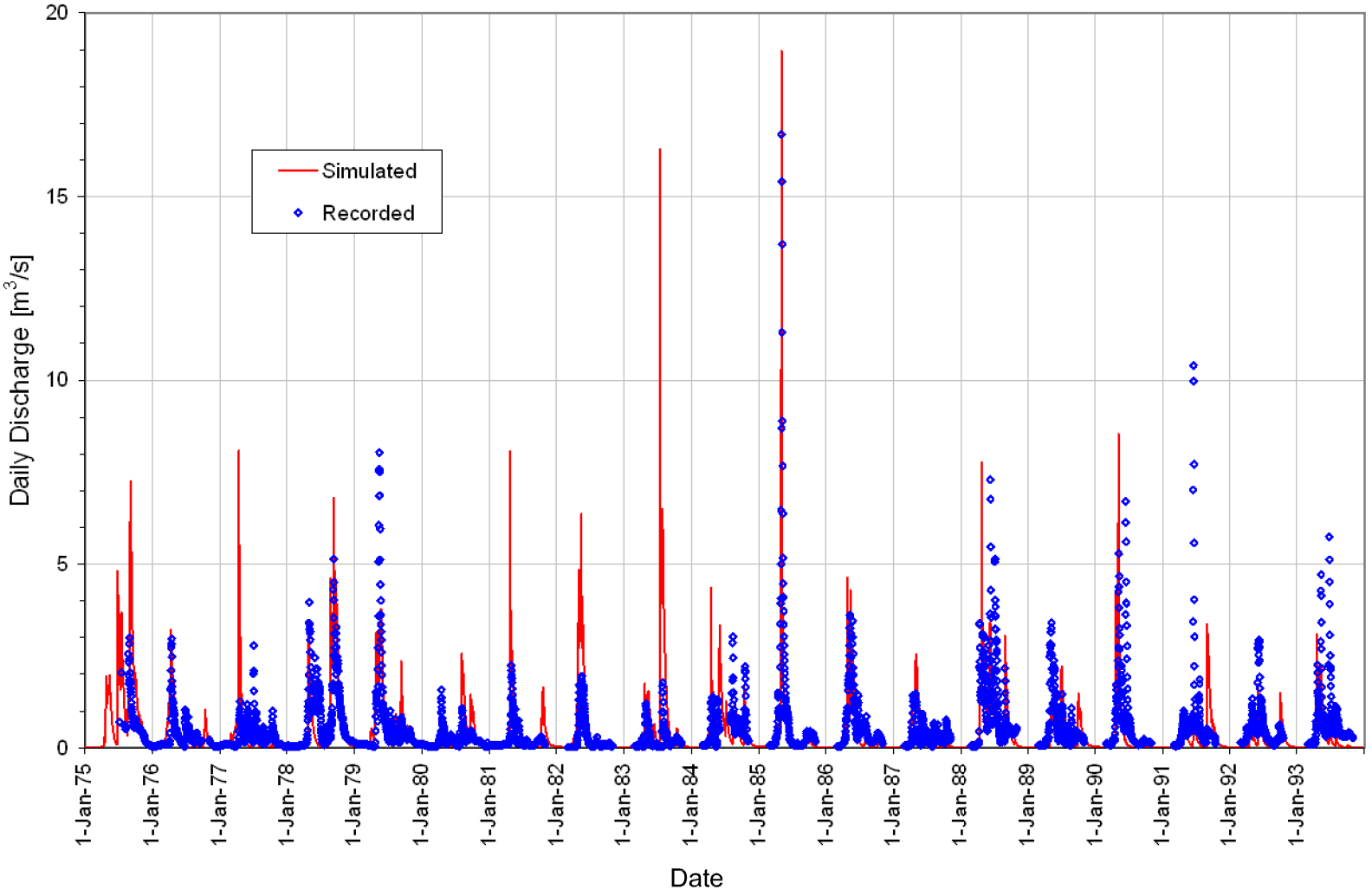

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF SIMULATED AND ENVIROMENT CANADA RECORDED FLOWS FOR UNNAMED CREEK 2 AT THE MOUTH

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Unnamed creek
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FIGURE: C-12

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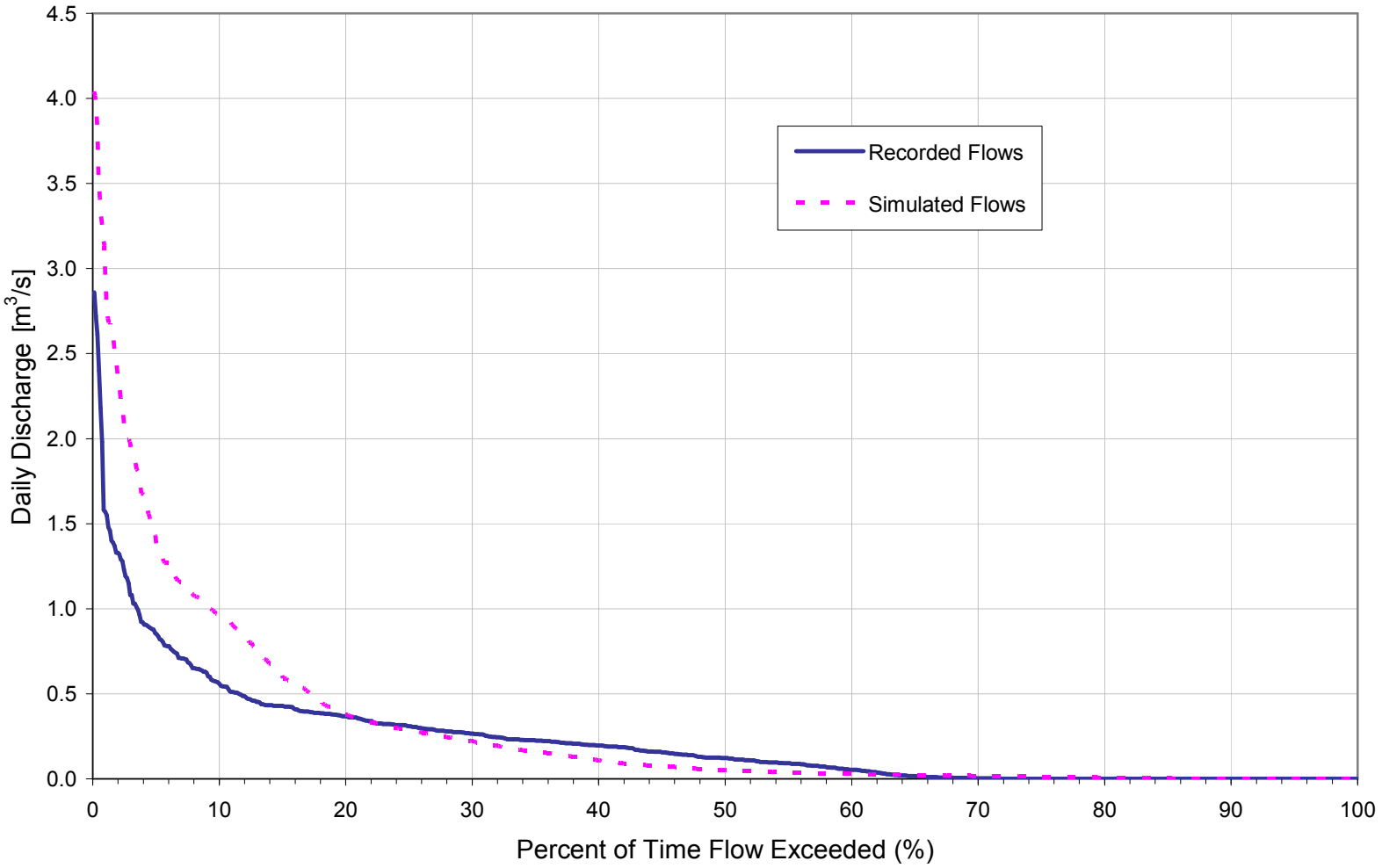

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT PIERRE RIVER ENVIRONMENT CANADA HYDROMETRIC STATION (1975 TO 1977)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Pierre river
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FIGURE: C-13

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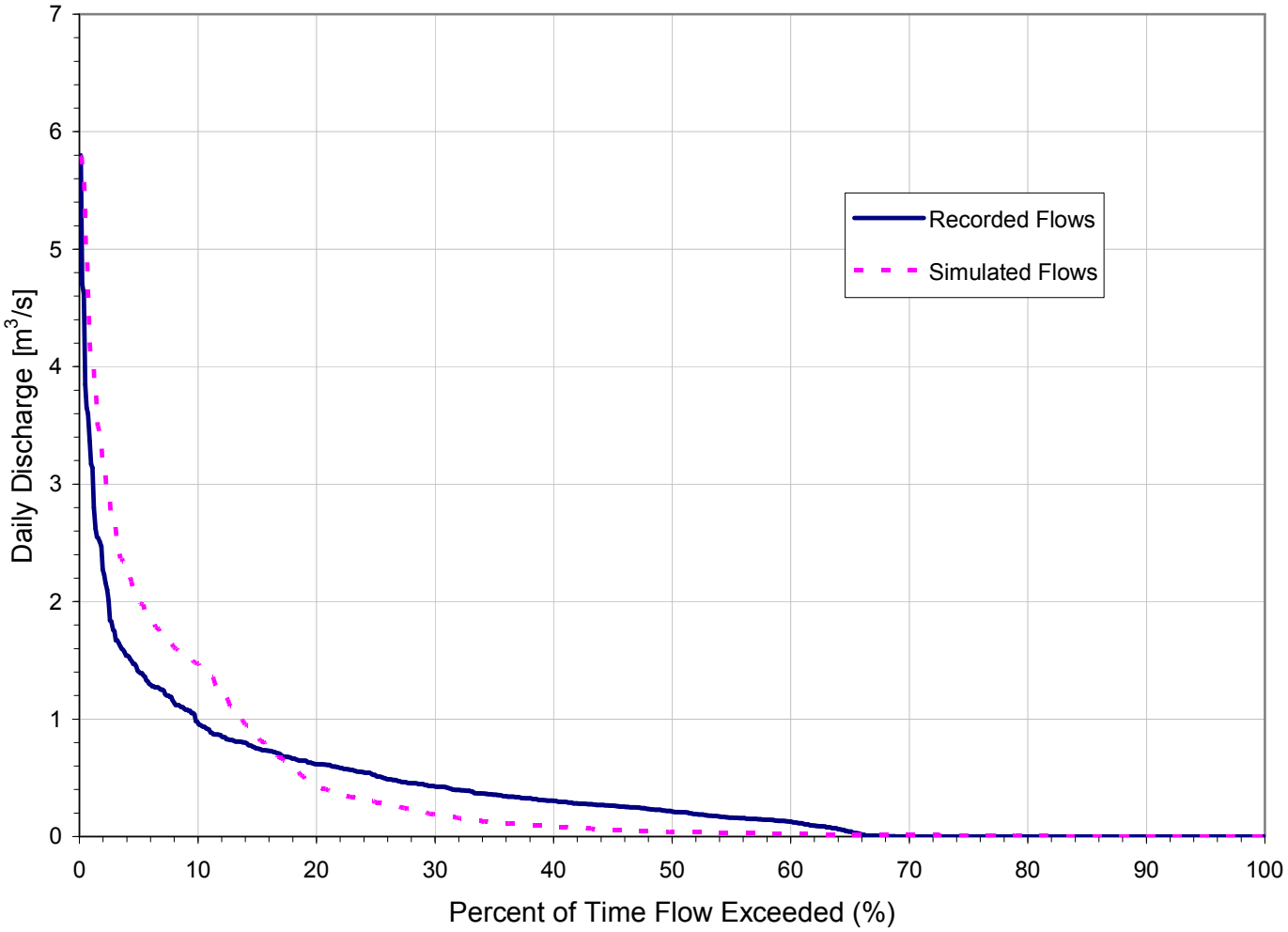

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT ASPHALT CREEK ENVIRONMENT CANADA HYDROMETIC STATION (1975 TO 1977)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	Asphalt creek
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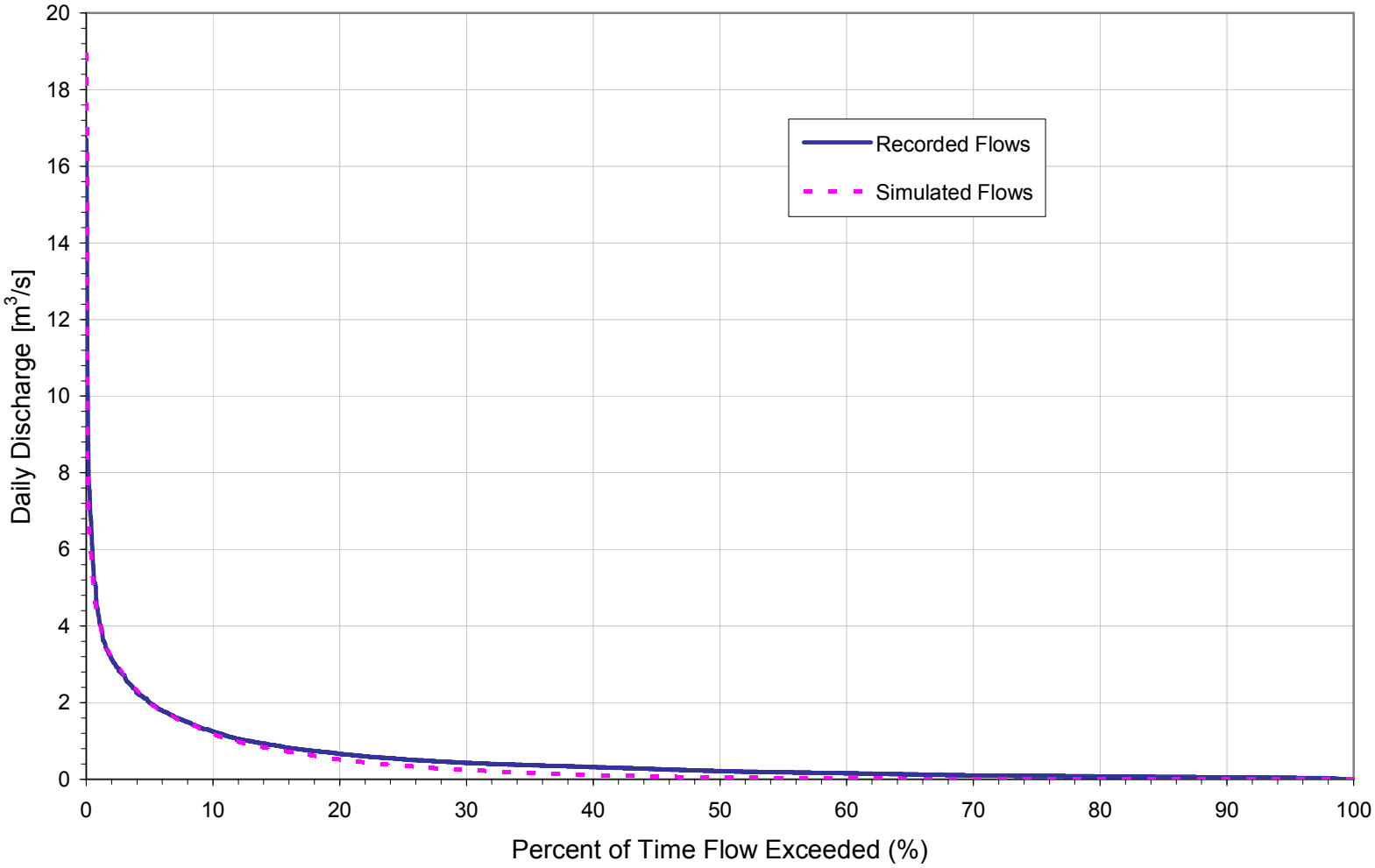

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

COMPARISON OF FLOW DURATION CURVES BASED ON RECORDED AND SIMULATED FLOWS AT UNNAMED CREEK 2 ENVIRONMENT CANADA HYDROMETRIC STATION (1975 TO 1993)

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No. Unnamed Creek	
DESIGN	KM	09/07/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07	FIGURE: C-15	
CHECK	FLA	17/11/07		
REVIEW	WES/TC	20/11/07		

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SURFACE WATER QUALITY ENVIRONMENTAL SETTING FOR THE JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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Appendix F Summary Tables for Water and Sediment Quality Data
Appendix G Box and Whisker Plots of Seasonal Trends and Time Series Graphs for Selected Water and Sediment Data
Appendix H Quality Assurance/Quality Control

3 WATER QUALITY

3.1 INTRODUCTION

This portion of the report provides environmental setting information regarding surface water and sediment quality on and near the Shell Canada Limited (Shell) Jackpine Mine Expansion & Pierre River Mine Project (the Project). The information will be used in the Environmental Impact Assessment (EIA) to evaluate potential future changes in water and sediment quality that might occur due to the Project. The information will also assist in quantifying the cumulative effects of approved and planned projects on watercourses and waterbodies near or downstream of the proposed mining areas.

The objectives of this surface water and sediment quality environmental setting study are to:

- describe and discuss the environmental setting water and sediment conditions in lakes, river and streams that may potentially be affected by the Project;
- discuss seasonal and spatial variation of water and sediment quality in lakes, river and streams; and
- compare environmental setting water and sediment quality data with relevant regulatory guidelines.

3.2 METHODS

3.2.1 Overview

The environmental setting information is derived from historical monitoring data and additional data collected specifically for the Project between fall 2005 and summer 2007. The historical data have been obtained from databases maintained by the Regional Aquatics Monitoring Program (RAMP), Alberta Environment (AENV) and various industries. Environmental setting water and sediment quality information is used to characterize current conditions in watercourses, such as rivers and streams, and waterbodies, such as lakes and ponds. Current conditions, including chemical concentrations and physical measurements, are compared to guidelines that have been established for protection of aquatic life.

Appendix D discusses various groups of water and sediment quality data, the relevant regulatory guidelines for characterizing environmental setting conditions, and methods for evaluating temporal and spatial trends when

environmental setting observations are viewed as a whole. This appendix also describes graphical figures and tables used to reveal trends and patterns in the environmental setting data.

3.2.2 Study Area

The study areas for environmental setting were selected to include surface watercourses and waterbodies that may have measurable changes in water and sediment quality due to Project activities. The areas were defined for field sampling and collection of historical water quality data prior to development of the final mine plan included in the Environmental Impact Assessment (EIA) for the Project. However, hydrogeology, hydrology and water quality modelling showed that some watercourses and waterbodies included in the environmental setting study will not be affected by the Project or will not have measurable changes in water and sediment quality. Therefore, the water and sediment quality study area for environmental setting conditions is larger than the assessment area for the EIA.

The watercourses and waterbodies within the study area are comprised of the following segments:

- areas that would potentially receive mine-related releases and could show measurable effects from regional developments and the Project; and
- reaches that are upstream of the Project and provide water and sediment quality data used to characterize and predict relative spatial changes within and downstream of the Project development area before and after the Project.

The watercourses and waterbodies are discussed under the following three groups:

- Regional Study Area (RSA);
- Local Study Area (LSA) for the Jackpine Expansion Mining Area (JEMA); and
- LSA for the Pierre River Mining Area (PRMA).

3.2.2.1 Regional Study Area

The RSA encompasses the following areas:

- Muskeg River watershed;
- McClelland Lake and McClelland Lake Outlet Creek watershed, and the downstream reach of the Firebag River below the confluence with the McClelland Lake Outlet Creek;
- Pierre River watershed, Asphalt and Eymundson Creek watershed, Big Creek watershed and Redclay Creek watershed; and
- reach of the Athabasca River from Fort McMurray to Embarras Portage.

The downstream limit of the RSA represents the point beyond which potential water and sediment quality changes resulting from oil sands development activities are expected to be negligible.

3.2.2.2 Local Study Area for the Jackpine Expansion Mining Area

The watercourses and waterbodies within the LSA for JEMA are Muskeg, Jackpine, Shelley, Khahago, Stanley and Wesukemina creeks, Muskeg River and Kearl Lake.

3.2.2.3 Local Study Area for the Pierre River Mining Area

The LSA for PRMA includes streams and waterbodies within the watersheds of Pierre River and Asphalt, Eymundson, First, Big and Redclay creeks.

3.2.3 Historical Data

A large body of historical water and sediment quality data for rivers, streams, lakes and ponds within the LSAs and RSA (Figure 3.2-1) was reviewed first to identify information gaps and to provide guidance for developing project-specific field sampling programs. Historical water and sediment quality data were obtained mainly from three sources:

- RAMP;
- AENV Water Data System (WDS); and
- industrial monitoring programs.

These data sources are described in the following subsections.

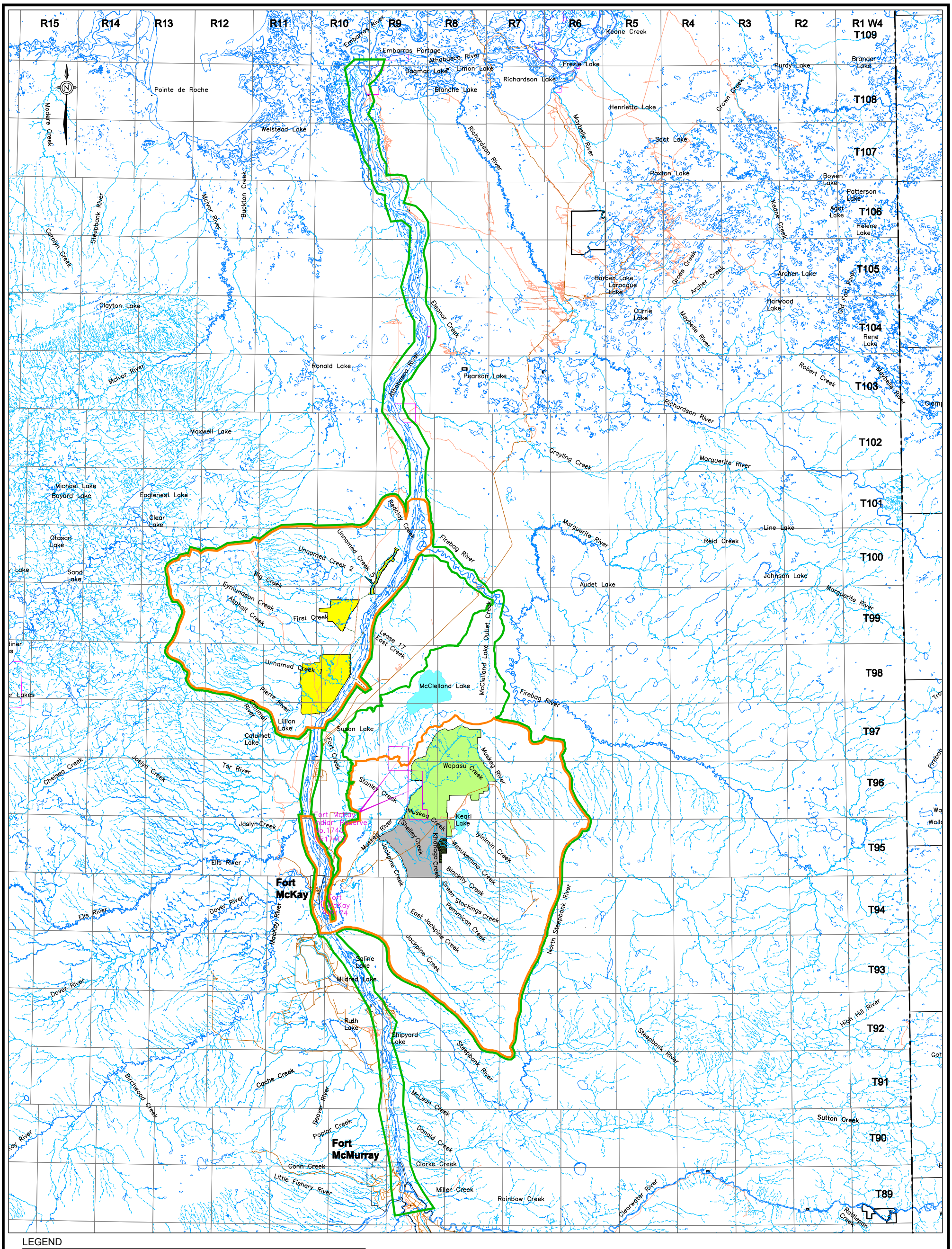
3.2.3.1 Regional Aquatics Monitoring Program

The RAMP is a long-term environmental monitoring program mandated to measure potential environmental changes to aquatic environments in the Oil Sands Region due to oil sands developments. The program, started in 1997, is supported by a multi-stakeholder group comprised of representatives from local communities, governing bodies and the oil sands industry. The RAMP water and sediment quality data from 1997 to 2006 (Golder 1998, 1999b, 2000, 2001a, 2002a, 2003a; Hatfield Consultants et al. 2004, 2005, 2006, 2007) for monitoring sites within the local and regional study areas are included in this environmental setting study (Sections 3.3, 3.4, 3.5 and 3.6).

Seasonal RAMP data are available for larger waterbodies and watercourses such as Kearl Lake, Athabasca River and Muskeg River. The RAMP sites located on smaller waterbodies are monitored less often and, in some cases, for fewer parameters. RAMP water quality sampling sites near the Project footprint are shown in Figure 3.2-2.

The RAMP sediment sampling typically occurs in the fall. However, sediment samples are occasionally collected in summer for some waterbodies and watercourses. Sediment samples are analyzed for particle size, carbon content, metals, organics, Polycyclic Aromatic Hydrocarbons (PAHs) and toxicity. RAMP sediment quality sampling sites near the Project footprint are shown in Figure 3.2-3.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6500\6550\Fig 3.2-1 Reginal and Local Study Areas.dwg Nov 23, 2007 - 11:26am



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

15 0 15
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
REGIONAL AND LOCAL STUDY AREAS

Shell Canada Limited

PROJECT 05-1344-027.6650			FILE No.	RSA-LSA
DESIGN	CS	07/05/07	SCALE AS SHOWN	REV. 0
CADD	TRE	16/11/07	FIGURE: 3.2-1	
CHECK	JV	16/11/07		
REVIEW	WES/TC	20/11/07		

3.2.3.2 Alberta Environment Water Data System

Alberta Environment has monitored water quality in the RSA since 1964. The AENV data are stored in a WDS database. While the WDS data for many monitoring sites are often sporadic, a nearly continuous set of seasonal data is available for some sites. The list of conventional parameters and major ions monitored at the WDS sites is similar to that used by the RAMP program. However, the WDS generally includes fewer metals and nutrients and does not include general organics, PAHs or toxicity. The WDS data (AENV 2007) for sites within the LSAs and RSA have been incorporated into this environmental setting study.

3.2.3.3 Industrial Data

Industrial data have been obtained from monitoring conducted for previous project applications, post-approval developments and research. The following industry information sources have been used in this environmental setting study:

- Environmental setting studies for previous oil sands project applications:
  - Kearl Oil Sands Project (Komex 1997; Imperial Oil 2005);
  - Meadow Creek Project (Petro-Canada 2001);
  - Mildred Lake Upgrader Expansion (Syncrude 1999);
  - Steepbank, Aurora North and Aurora South Mines (Golder 1996a, 1996b, 1996c);
  - Alsands (1978); and
  - Lease 13 Mining Project (Shell 1975), Muskeg River Mine (Golder 1997), Shell Jackpine – Phase 1 (Golder 2002b) and Muskeg River Mine Expansion (Shell 2005).
- Operational monitoring:
  - Muskeg River Mine (Albian Sands 2000, 2003, 2006);
  - Aurora North Mine (Syncrude 2003); and
  - Suncor Lease 17/86 Mine (Beak Consulting Ltd. 1988; Golder 1995).
- Research studies:
  - Northern River Basin Study on environmental contaminants in bottom sediments (Crosley 1996);
  - Northern River Basin Study on ecotoxicology of suspended and bottom sediments (Dobson et al. 1996);

- Other Six Lease Owners (OSLO) project (RL&L 1989);
- SandAlta Project (RL&L 1982);
- Great Canadian Oil Sands Ltd survey of sediment chemistry of the Athabasca River (Chemical and Geological Laboratories Ltd. 1979); and
- Alberta Oil Sands Environmental Research Program study on heavy metals in bottom sediments of the Athabasca River (Allan and Jackson 1978) and survey of levels of water and sediment quality parameters in aquatic biota (Lutz and Hendzel 1977).

Each set of industry data is based on a field program that covers specific time periods and waterbodies or watercourses. The measurement frequency and parameter list vary for each field program. However, most of the water and sediment constituents measured in the field programs are the same as the parameters sampled by RAMP.

3.2.4 Field Program

3.2.4.1 Sampling and Analytical Methods

Water and sediment samples were collected, preserved, stored and shipped as per the Golder Standard Technical Procedures (Golder 1999a). Sample locations were determined by Global Positioning System (GPS). Water samples from each lake, river or stream were collected at a depth of 30 cm. At stream sites, grab samples were collected from the centre of each stream. At lake sites, composite water samples were obtained by mixing grab samples from four representative locations within the lake. Sediment quality samples were drawn from a composite of four to six grab samples collected using an Ekman dredge.

The water and sediment quality parameters measured in the field program were the same as those measured by RAMP (Golder 2003b), with the addition of methyl mercury for water quality, as listed in Tables 3.2-1 and 3.2-2. These parameters were used in recent environmental setting studies to support the Muskeg River Mine Expansion (Shell 2005) and Kearl Oil Sands Project (Imperial Oil 2005) EIAs.

Table 3.2-1 Water Quality Parameter List and Analytical Laboratories Used

Group Name	Parameters	Laboratory
field-measured parameters	pH, conductance, temperature, dissolved oxygen	–
conventional parameters	colour, conductance, dissolved organic carbon, hardness, pH, total alkalinity, total dissolved solids, total organic carbon, total suspended solids	ALS
major ions	bicarbonate, calcium, carbonate, chloride, magnesium, potassium, sodium, sulphate, sulphide	ALS
nutrient and chlorophyll *a*	nitrate and nitrite, nitrogen - ammonia, nitrogen - Kjeldahl, total phosphorus, dissolved phosphorus, chlorophyll *a*	ALS
oxygen demand	biochemical oxygen demand	ALS
general organics	naphthenic acids, total phenolics[(a)], total recoverable hydrocarbons	ALS
metals (total and dissolved)	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silicon, strontium, sulphur, thallium, titanium, uranium, vanadium, zinc	ALS
metals (total and dissolved)[(b)]	mercury, silver	ARC
metals (total)[(b)]	methyl mercury	ARC
target PAHs and alkylated PAHs	see Appendix E[(a)]	ALS
target Polycyclic Aromatic Nitrogen Heterocycles (PANHs)	see Appendix E[(a)]	ALS
toxicity	see Appendix E[(a)]	HydroQual

[(a)] Appendix E, Table E-1 provides a detailed list of toxicity, phenolics and PAH parameters for water samples.

[(b)] Ultra low level analysis.

Notes: "–" represents in-situ measurement using YSI multi-meter.

ALS represents ALS Laboratory Group, Fort McMurray, Alberta.

ARC represents Alberta Research Council, Vegreville, Alberta.

HydroQual represents HydroQual Laboratories, Calgary, Alberta.

Analysis protocol for each parameter is available from the corresponding analytical laboratory.

Table 3.2-2 Sediment Quality Parameter List and Analytical Laboratories Used

Group Name	Parameters	Laboratory
particle size	% sand, % silt, % clay, moisture content	ALS
carbon content	total inorganic carbon, total organic carbon, total carbon	ALS
sulphide	sulphide	ALS
organics	total recoverable hydrocarbons, total volatile hydrocarbons (C_5-C_{10}), total extractable hydrocarbons (C_{11}-C_{30})	ALS
metals (total)	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, hexavalent chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silicon, silver, sodium, strontium, sulphur, thallium, titanium, uranium, vanadium, zinc	ALS
target PAHs and alkylated PAHs	see Appendix E[(a)]	AXYS
target PANHs	see Appendix E[(a)]	AXYS
toxicity	see Appendix E[(a)]	HydroQual

[(a)] Appendix E, Table E-2 provides a detailed list of toxicity, phenolics and PAH parameters for sediment samples.

Notes: ALS represents ALS Laboratory Group, Fort McMurray, Alberta.
AXYS represents AXYS Analytical Service Ltd., Sydney, British Columbia.
HydroQual represents HydroQual Laboratories, Calgary, Alberta.
Analysis protocol for each parameter is available from the corresponding analytical laboratory.

3.2.4.2 Location and Timing of Sampling

The collection of water and sediment quality data focused on relevant areas and seasons from the impact assessment perspective. A large amount of water and sediment quality data from past monitoring and current RAMP or WDS sites exists for the lower reaches of the Muskeg River from the mouth to Stanley Creek (Figures 3.2-2 and 3.2-3). However, very limited data were available for the upper reaches and small tributary streams of the Muskeg River and McClelland Lake watersheds. Furthermore, there were generally no water and sediment data for waterbodies and watercourses within the Pierre River Mining Area. Therefore, the density and duration of sampling locations was increased for waterbodies and watercourses with limited historical information (Figures 3.2-2 and 3.2-3).

The field sampling program started in fall 2005. The sampling program was completed in summer 2007. Generally, water quality parameters were measured every season, except water toxicity, which was measured during fall or winter. Similar to water toxicity, sediment quality and sediment toxicity were measured only during fall. Typically, water and sediment toxicity levels in fall were relatively higher than corresponding values in other seasons. Also, fall was noted as a critical period for assessment of sediment effects on benthic invertebrates and fish. Tables 3.2-3 and 3.2-4 show summaries of the sampling schedules for the Project.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6500\6550\Fig 3.2-2 surface water quality sampling locations-update.dwg Nov 19, 2007 - 4:41pm

T.102 T.101 T.100 T.99 T.98 T.97 T.96 T.95 T.94 T.93

R.13 R.12 R.11 R.10 R.9 R.8 R.7 W4M

WQ42 WQ38 WQ39 WQ34 WQ33 WQ14 WQ41 WQ40 WQ35 WQ20 WQ43 WQ36 WQ32 WQ27 WQ28 WQ19 WQ37 WQ13 WQ11 WQ29 WQ26 WQ21 WQ10 WQ25 WQ8 WQ7 WQ9 WQ45 WQ48 WQ49 WQ44 WQ24 WQ50 WQ5 WQ16 WQ4 WQ15 WQ2 WQ17 WQ3 WQ23 WQ1 WQ30 WQ22 WQ6 WQ18

ATR-FR-E ATR-FR AB07DC0090 FIR-1 AB07DC0110 AB07DA0970 AB07DA0980

AB07DC0060 AB07DC0100

AB07DA2770 AB07DA2300 AB07DA2290 MCL-1 AB07DA2320 AB07DA2310

ATR-DD AB07DA0860 AB07DA0870 AB07DA0850 AB07DA0820 AB07DA1550

AB07DA0680 AB07DA1540 AB07DA0640 AB07DA0410 AB07DA0390 ATR-MR-W ATR-MR-E AB07DA0400 AB07DA0320

Unnamed Waterbody 12 Unnamed Creek 8 Kelly Lake Redclay Creek Unnamed Waterbody 13 Redclay Creek Firebag River Unnamed Creek 2 Unnamed Creek 5 Unnamed Creek 7 Small Unnamed Lake Oatley Lake Unnamed Waterbody 11 Unnamed Creek 6 Unnamed Creek 14 Big Creek Eymundson Creek Asphalt Creek Unnamed Waterbody 6 First Creek Unnamed Waterbody 12 Unnamed Creek 10 Unnamed Waterbody 8 Unnamed Creek 15 Unnamed Creek 11 Lease 17 East Creek McClelland Lake Outlet Creek Unnamed Creek 3 Unnamed Waterbody 7 Unnamed Creek 1 Unnamed Waterbody 5 Pierre River Attabasca River Calumet River Unnamed Creek 4 Unnamed Creek16 Lillian Lake Susan Lake Calumet Lake Fort Creek Tar River Unnamed Creek 12 Unnamed Waterbody 14 Unnamed Waterbody 2 Unnamed Waterbody 1 Muskeg River Wapasu Creek Unnamed Creek 9 Unnamed Waterbody 3 Stanley Creek Unnamed Waterbody 13 Muskeg Creek Shelley Creek Joslyn Creek Ells River Jackpine Creek Khahago Creek Iyinimin Creek Wesukemina Creek Blackfly Creek Green Stockings Creek Pemmican Creek East Jackpine Mackay River Dover River McClelland Lake Unnamed Creek13 Unnamed Waterbody 4 Unnamed Waterbody 5 Unnamed Creek16 Fort McKay Indian Reserve No.174C (IR174C) Unnamed Waterbody 7 Unnamed Creek15 Unnamed Creek 11 Unnamed Creek 1 Unnamed Waterbody 6 Unnamed Creek 10 Unnamed Waterbody 8 Unnamed Creek 3 Unnamed Creek 12 Unnamed Waterbody 14 Unnamed Waterbody 2 Unnamed Waterbody 1 Unnamed Creek 9 Unnamed Waterbody 3 Unnamed Waterbody 13 Unnamed Creek 7 Unnamed Waterbody 12 Unnamed Creek 10 Unnamed Waterbody 8 Unnamed Creek 15 Unnamed Creek 11 Unnamed Waterbody 7 Unnamed Creek 1 Unnamed Waterbody 5 Unnamed Creek16 Unnamed Creek 4

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6500\6550\Fig 3.2-3 sediment quality sampling locations- update .dwg Nov 19, 2007 - 4:47pm

T.102 T.101 T.100 T.99 T.98 T.97 T.96 T.95 T.94 T.93

R.13 R.12 R.11 R.10 R.9 R.8 R.7 W4M

ATR-FR-W
ATR-FR-E
FIR-1
WQ49
WQ44
WQ34
WQ20
WQ43
WQ32
WQ27
WQ24
WQ13
WQ12
WQ50
WQ9
MCL-1
McClelland Lake
WQ7
ATR-DD-W
ATR-DD-E
WQ6
WQ5
WQ16
WQ2
MUR-D2
MUR-6
MUR-5
WQ30
MUR-4
KEL-1
JAC-1
MUR-2
ATR-MR-E
MUR-1
ATR-MR-W

Unnamed Waterbody 12
Unnamed Creek 6
Kelly Lake
Redclay Creek
Unnamed Waterbody 13
Firebag River
Unnamed Creek 2
Small Sandy Lake
Oakley Lakes
Unnamed Waterbody 11
Unnamed Creek 7
Unnamed Creek 4
Unnamed Creek 14
Bird Creek
Eymundson Creek
Asphalt Creek
First Creek
Unnamed Waterbody 6
Unnamed Waterbody 12
Unnamed Creek 10
Unnamed Waterbody 8
Unnamed Creek 15
Unnamed Creek 11
Unnamed Waterbody 7
Unnamed Creek 1
Leggat 17 East Creek
McClelland Lake Outlet Creek
Unnamed Creek 3
Unnamed Waterbody 5
Pierre River
Athabasca River
Unnamed Creek 8
Unnamed Creek13
Unnamed Waterbody 4
Calumet River
Unnamed Creek16
Lillian Lake
Calumet Lake
Susan Lake
Unnamed Creek 12
Unnamed Waterbody 14
Unnamed Waterbody 2
Unnamed Waterbody 1
Fort McKay Indian Reserve No.174C (R174C)
Fort Creek
Tar River
Wapasu Creek
Unnamed Creek 9
Unnamed Waterbody 3
Stanley Creek
Unnamed Waterbody 13
Musket River
Musket Creek
Kearl Lake
Joslyn Creek
Shelley Creek
Jackpine Creek
Khahago Creek
Iyinimin Creek
Wesukemina Creek
Ells River
Dover River
MacKay River
Blackfly Creek
Green Stockings Creek
Pennican Creek
East Jackpine
Jackpine Pipeline
North

LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- RAMP SEDIMENT QUALITY STATIONS
- SEDIMENT QUALITY SAMPLING STATION FOR CURRENT STUDY
- WATER QUALITY STATION FOR OTHER STUDIES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

5 0 5
SCALE KILOMETRES

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
SEDIMENT QUALITY SAMPLING LOCATIONS

Shell Canada Limited

PROJECT 05-1344-027.6500			FILE No.	Sediment Quality
DESIGN	TR	07/08/07	SCALE AS SHOWN	REV. 0
CADD	TRE	16/11/07		
CHECK	JV	16/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: 3.2-3

Table 3.2-3 Sampling Schedule for Jackpine Expansion Mining Area

Station	Lease	Site Description	Surface Water Type	Fall 2005	Winter 2006	Spring 2006	Summer 2006	Fall 2006	Winter 2007	Spring 2007	Summer 2007
WQ1	89	Muskeg River above Stanley Creek	stream	WQF	WQF	WQF	WQF	–	–	–	–
WQ2	88	Wapasu Creek mouth	stream	WQF, SQ, ST	WQF, WT	WQF	WQF	–	–	–	–
WQ3	88	upper Wapasu Creek	stream	WQF, PAH	NS	WQF, PAH	WQF, PAH	–	–	–	–
WQ4	88	upper Muskeg River	stream	WQF, PAH	WQF, PAH	WQF, PAH	WQF, PAH	–	–	–	–
WQ5	88	headwater tributary of Muskeg River	stream	WQF, SQ	WQF	WQF	WQF	–	–	–	–
WQ6	631	tributary stream to McClelland Lake	stream	WQF, SQ	WQF	WQF	WQF	–	–	–	–
WQ15	88	Unnamed Waterbody 1 at upper Muskeg River	lake	WQR	WQR	WQR	WQR	–	–	–	–
WQ16	89	Unnamed Waterbody 2 at upper Muskeg River	lake	WQF, WT, SQ, ST	WQF	WQF	WQF	–	–	–	–
WQ17	88	Unnamed Waterbody 3 south of Wapasu Creek	lake	NS	WQR	WQR	WQR	–	–	–	–
WQ18	631	Unnamed Waterbody 4 southeast of McClelland Lake	lake	WQR	WQR	WQR	WQR	WQF, WT	WQF	WQR	WQR
WQ22	north of 631	McClelland Lake	lake	–	WQF	WQR	WQR	WQF, PAH, WT	WQF, PAH	WQR	WQR
WQ23	88	Unnamed Creek 9, tributary of upper Muskeg River	stream	WQF	NS	WQF	WQF	–	–	–	–
WQ24	north of 631	Unnamed Creek 3, tributary of McClelland Lake Outlet Creek	stream	WQF	WQF	WQF	WQF	WQF, WT, SQ, ST	WQF	WQF	WQF
WQ30	west of 89	Muskeg Creek mouth	stream	WQF, PAH, SQ, ST	WQF, PAH	WQF, PAH	WQF, PAH	–	–	–	–
WQ50	north of 631	McClelland Lake Outlet Creek	stream	–	–	–	–	WQF, SQ	NS	NS	NS

– = Not included in the field program.

Notes: NS: Not sampled due to unfavourable field conditions.

PAH: Sampled for PAHs and alkylated PAHs in water (Appendix E provides a detailed list).

SQ: Sampled for sediment quality parameters (Table 3.2-2 and Appendix E, Table E-2 provides detailed lists).

ST: Sampled for sediment toxicity testing (Appendix E, Table E-2 provides a detailed list).

WQF: Sampled for full suite of water quality parameters (field-measured, conventional, major ions, nutrients and chlorophyll *a*, oxygen demand, general organics and metals; Table 3.2-1 provides a detailed list).

WQR: Sampled for only routine suite of water quality parameters (field-measured, conventional, major ions, nutrients and chlorophyll *a*, oxygen demand and general organics; Table 3.2-1 provides a detailed list).

WT: Sampled for water toxicity test (acute and chronic; Appendix E, Table E-2 provides a detailed list).

Table 3.2-4 Sampling Schedule for Pierre River Mining Area

Station	Lease	Site Description	Waterbody Type	Fall 2005	Winter 2006	Spring 2006	Summer 2006	Fall 2006	Winter 2007	Spring 2007	Summer 2007
WQ7	9	Pierre River near the mouth	stream	WQF, PAH, SQ	NS	WQF, PAH	WQF, PAH	–	–	–	–
WQ8	9	lower Pierre River	stream	WQF	WQF	WQF	WQF	–	–	–	–
WQ9	9	Asphalt Creek mouth	stream	WQF, PAH, WT, SQ, ST	NS	WQF, PAH	WQF, PAH	–	–	–	–
WQ10	9	Unnamed Creek 1, tributary of Asphalt Creek	stream	WQF	NS	WQF	WQF	–	–	–	–
WQ11	northwest of 9	Asphalt Creek upstream of Eymundson Creek	stream	WQF	NS	WQF	WQF	–	–	–	–
WQ13	17	middle Eymundson Creek	stream	WQF, SQ	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ14	351	lower Big Creek	stream	WQF	NS	WQF	WQF	WQF	WQF	WQF	WQF
WQ19	352	Unnamed Waterbody 6, near Eymundson Creek	lake	WQR	WQR	WQR	WQR	WQR	WQR	WQR	WQR
WQ20	351	Unnamed Waterbody 14, near Big Creek	stream	WQF, WT, SQ, ST	NS	WQF	WQF	WQF	WQF	WQF	WQF
WQ21	west of 9	Unnamed Waterbody 5, south of Asphalt Creek	lake	WQR	WQR	WQR	WQR	–	–	-	-
WQ25	9	Unnamed Creek 4, tributary of lower Pierre River	stream	WQF	WQF	WQF	WQF	–	–	-	-
WQ26	9	Unnamed Waterbody 7, north of lower Asphalt Creek	lake	WQF	NS	WQF	WQF	–	–	-	-
WQ27	351	First Creek	stream	WQF	WQF	WQF	WQF	WQF, SQ	WQF	WQF	WQF
WQ28	17	Unnamed Waterbody 15, near First Creek	lake	WQF	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ29	17	Unnamed Waterbody 8, west of Athabasca River	lake	WQF	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ32	309	Big Creek mouth	stream	–	WQF, PAH	WQF, PAH	WQF, PAH	WQF, PAH, WT, SQ, ST	WQF, PAH	WQF, PAH	WQF, PAH
WQ33	351	Unnamed Creek 5, tributary of lower Big Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ34	351	Unnamed Creek 2, tributary of lower Big Creek	stream	–	WQF, PAH	WQF, PAH	WQF, PAH	WQF, PAH, SQ	WQF, PAH	WQF, PAH	WQF, PAH
WQ35	351	Unnamed Creek 6, tributary of Big Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ36	352	middle Big Creek	stream	–	NS	WQF	WQF	WQF	NS	WQF	WQF
WQ37	352	middle Asphalt Creek	stream	–	NS	WQF	WQF	WQF	NS	WQF	WQF
WQ38	351	Oakley Lake	lake	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ39	351	Small Sandy Lake	lake	–	WQR	WQR	WQR	WQR	WQR	WQR	WQR

Table 3.2-4 Sampling Schedule for Pierre River Mining Area (continued)

Station	Lease	Site Description	Waterbody Type	Fall 2005	Winter 2006	Spring 2006	Summer 2006	Fall 2006	Winter 2007	Spring 2007	Summer 2007
WQ40	north of 352	Unnamed Waterbody 11, north of Big Creek	lake	–	WQR	WQR	WQR	WQR	WQR	WQR	WQR
WQ41	351	Unnamed Creek 7, tributary of lower Big Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ42	351	Unnamed Creek 2, tributary of lower Big Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ43	351	middle Big Creek	stream	–	WQF	WQF	WQF	WQF, SQ	NS	WQF	WQF
WQ44	309	Redclay Creek mouth	stream	–	WQF, PAH	WQF, PAH	WQF, PAH	WQF, PAH, WT, SQ, ST	WQF, PAH	WQF, PAH	WQF, PAH
WQ45	north of 309	Redclay Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ46	309 (north)	Unnamed Waterbody 12, north of Redclay Creek	lake	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ47	310	Unnamed Waterbody 13, near Redclay Creek	lake	–	NS	WQR	WQR	WQR	NS	WQR	WQR
WQ48	309 (north)	Unnamed Creek 8, tributary of Redclay Creek	stream	–	WQF	WQF	WQF	WQF	WQF	WQF	WQF
WQ49	309	Redclay Creek	stream	–	WQF	WQF	WQF	WQF, SQ	WQF	WQF	WQF

– = Not included in the field program.

Notes: NS: Not sampled due to unfavourable field conditions.

PAH: Sampled for PAHs and alkylated PAHs in water (Appendix E provides for a detailed list).

SQ: Sampled for sediment quality parameters (Table 3.2-2 and Appendix E, Table E-2 for detailed lists).

ST: Sampled for sediment toxicity testing (Appendix E, Table E-2 for a detailed list).

WQF: Sampled for full suite of water quality parameters (field-measured, conventional, major ions, nutrients and chlorophyll *a*, oxygen demand, general organics and metals; see Table 3.2-1 for a detailed list).

WQR: Sampled for only routine suite of water quality parameters (field-measured, conventional, major ions, nutrients and chlorophyll *a*, oxygen demand and general organics; see Table 3.2-1 for a detailed list).

WT: Sampled for water toxicity test (acute and chronic; see Appendix E provides for a detailed list).

3.2.4.3 Data Analysis

Data collected from the field sampling program were combined with available historical data to describe environmental setting water and sediment quality conditions. Statistical summaries, time series graphs, and box-whisker plots were then produced for selected water and sediment quality indicators to analyze their magnitudes, as well as their seasonal and spatial trends. Also, the compiled water and sediment quality data were compared with relevant guidelines to evaluate the compliance levels of different indicators in a waterbody or watercourse (Appendix D for more details on assessment tools for data analysis).

Water and Sediment Quality Indicators

Water and sediment quality are described by physical, chemical and toxicological parameters (Tables 3.2-1 and 3.2-2). Sampling locations are shown in Figures 3.2-2 and 3.2-3. This study focuses on key indicator parameters that could change and affect water and sediment quality due to the Project. The magnitude, seasonal variability and guideline compliance of these indicators are presented in Sections 3.3 to 3.5.

Water and sediment quality are described on a seasonal basis in Sections 3.3 to 3.5 to show the effects of climate, hydrology and land-use. The seasonal partitions (Table 3.2-5) are consistent with those used in recent EIA studies in the Oil Sands Region (Golder 2002b, 2002c; Imperial Oil 2005; Shell 2005; Golder 2007).

Table 3.2-5 Seasons in the Oil Sands Region

Season	Months
winter	November through March
spring	April and May
summer	June through August
fall	September and October

Seasonal data are compared among major waterbodies, watercourses or sub-watersheds to determine spatial variability. The main groups of waterbodies, watercourses or sub-watersheds are summarized in Table 3.2-6.

Table 3.2-6 Spatial Grouping of Surface Waters

Group	Description
Regional Study Area	
upper reach of the lower Athabasca River	Athabasca River between Fort McMurray and Muskeg River
middle reach of the lower Athabasca River	Athabasca River between Muskeg River and Firebag River
lower reach of the lower Athabasca River	Athabasca River between Fort McMurray and Embarras
Firebag River	lower Firebag River from McClelland Lake Outlet Creek to the mouth
McClelland Lake	McClelland Lake
McClelland Lake Inlet	inlet creeks to McClelland Lake
McClelland Lake Outlet	outlet creek or tributaries from McClelland Lake
McClelland Lake Fen	McClelland Lake Fen
Jackpine Expansion Mining Area	
upper Muskeg River	Wapasu Creek and the headwater tributaries of the Muskeg River upstream of Wapasu Creek
middle Muskeg River	Muskeg River upstream of Jackpine Creek to Wapasu Creek
lower Muskeg River	Muskeg River from Jackpine Creek to the mouth
Jackpine Creek	Jackpine Creek and its tributaries
Muskeg Creek	Muskeg Creek and its tributaries such as Blackfly Creek, Green Stockings Creek, Iyinimin Creek, Khahago Creek and Wesukemina Creek
Shelley Creek	Shelley Creek
Stanley Creek	Stanley Creek
Kearl Lake	Kearl Lake
Unnamed Waterbodies	unnamed waterbodies in Muskeg River watershed
Pierre River Mining Area	
Pierre River	Pierre River and its tributaries
Eymundson Creek	Eymundson Creek and its tributaries
Big Creek	Big Creek and its tributaries
Redclay Creek	Redclay Creek and its tributaries
Unnamed Waterbodies	unnamed waterbodies in the Pierre River, Eymundson Creek, Big Creek and Redclay Creek watersheds

Graphs and Summaries

Time series plots (Appendix G) were used to assess trends over the period of record. Also, the data were to create seasonal box and whisker plots, which showed seasonal variation patterns for key water quality parameters.

Statistical summaries provided seasonal minimum, median and maximum values for each indicator parameter. These were compared to relevant water and sediment quality guidelines. Values above a guideline are shown in bold in the summary tables.

Comparison to Water Quality Guidelines

Environmental setting water quality was compared to both acute and chronic water quality guidelines for the protection of freshwater aquatic life in Alberta

(AENV 1999). Acute guidelines protect aquatic organisms from short-term lethal effects, while chronic guidelines provide protection from long-term sub-lethal effects. Lethal effects could result in death and sub-lethal effects could result in reduced growth or impaired reproduction. For water quality guidelines used in this study, see Table 3.2-7.

Alberta guidelines (AENV 1999) were used to assess each water quality parameter, except for parameters with no Alberta guidelines and copper. For parameters with no Alberta guidelines, the most conservative, that is, the most restrictive, of the corresponding guidelines from Canadian Council of Ministers of the Environment (CCME) and the United States Environmental Protection Agency (U.S. EPA) (CCME 2001; U.S. EPA 2002) were used. The Alberta guideline for copper applies only to acid-extractable concentrations; therefore, guideline for total copper concentration is based on U.S. EPA (2002).

Table 3.2-7 Water Quality Guidelines for the Protection of Aquatic Life

Parameter	Units	Aquatic Life			
		Acute Value	Source	Chronic Value	Source
pH	-	6.5 to 8.5[a]	AENV	6.5 to 8.5[a]	AENV
dissolved oxygen	mg/L	5[a]	AENV	6.5 to 9.5[b]	AENV
Major Ions					
chloride	mg/L	860	U.S. EPA	230[d]	U.S. EPA
fluoride	mg/L	–	–	0.12	CCME
sulphide[e]	mg/L	–	–	0.002 to 0.117[d]	U.S. EPA
Nutrients					
ammonia (as N)[f]	mg/L	1.3 to 58.4	U.S. EPA	0.49 to 7.09[d]	U.S. EPA
nitrate (as N)	mg/L	–	–	2.93	CCME
nitrite	mg/L	–	–	0.06	CCME
total nitrogen	mg/L	–	–	1	AENV
total phosphorus	mg/L	–	–	0.05	AENV
Total Metals					
aluminum	mg/L	0.75	U.S. EPA	0.1	CCME
arsenic	mg/L	0.34	U.S. EPA	0.005	CCME
cadmium	mg/L	0.0006 to 0.0079	U.S. EPA	0.0001 to 0.0007[d]	U.S. EPA
chromium[g]	mg/L	0.016	U.S. EPA	0.001	CCME
copper[c,h]	mg/L	0.0044 to 0.047	U.S. EPA	0.002 to 0.004	CCME
Iron	mg/L	–	–	0.3	CCME
lead[h]	mg/L	0.0196 to 0.4199	U.S. EPA	0.001 to 0.007	U.S. EPA
mercury	mg/L	0.000013	AENV	0.000005	AENV
methyl mercury	mg/L	0.000002	AENV	0.000001	AENV
molybdenum	mg/L	–	–	0.073	CCME
nickel[h]	mg/L	0.1646 to 1.3932	U.S. EPA	0.018 to 0.155	U.S. EPA
selenium	mg/L	–	–	0.001	CCME
silver	mg/L	0.0005 to 0.0371[h]	U.S. EPA	0.0001	CCME
thallium	mg/L	–	–	0.0008	CCME
zinc	mg/L	0.042 to 0.3564[h]	U.S. EPA	0.03	CCME

Table 3.2-7 Water Quality Guidelines for the Protection of Aquatic Life (continued)

Parameter	Units	Aquatic Life			
		Acute Value	Source	Chronic Value	Source
Organics					
phenolics	µg/L	–	–	5[(a)]	AENV
PAHs					
acenaphthene	µg/L	–	–	5.8	CCME
anthracene	µg/L	–	–	0.012	CCME
benzo(a)anthracene	µg/L	–	–	0.018	CCME
benzo(a)pyrene	µg/L	–	–	0.015	CCME
fluoranthene	µg/L	–	–	0.04	CCME
fluorene	µg/L	–	–	3	CCME
naphthalene	µg/L	–	–	1.1	CCME
phenanthrene	µg/L	–	–	0.4	CCME
pyrene	µg/L	–	–	0.025	CCME

– = Not applicable.

Note: Acute value for dissolved oxygen guideline is minimum value, while specified range for chronic value defines the desired levels.

(a) AENV (1999).

(b) The chronic guideline (6.5 mg/L) should be increased to 9.5 mg/L for those areas and times where embryonic and larval stages (from spawning to 30 days after hatching) develop within gravel beds (e.g., some salmonids). Further comments as well as other jurisdiction guidelines can be found in AENV (1999).

(c) Based on U.S. EPA (1999) since Alberta guideline is for acid-extractable concentrations.

(d) U.S. EPA (2002).

(e) pH dependent guidelines. Guidelines calculated based on seasonal median values for pH.

(f) pH and temperature dependent guidelines. Guidelines calculated based on seasonal median values for pH and temperature.

(g) Chromium VI guidelines.

(h) Hardness dependent guidelines. Seasonal median values for hardness used to calculate guideline concentrations.

Comparison to Sediment Quality Guidelines

Sediment chemistry has been compared to values of the Canadian Interim Sediment Quality Guidelines (ISQG) and the probable effect level for the protection of aquatic life (CCME 1999, 2001, 2002) (Table 3.2-8). The ISQG has been derived solely from the threshold effects level (CCME 1999, 2001, 2002). The threshold effects level represents the concentration below which adverse biological effects are expected to occur rarely, while the probable effect level represents the concentration above which adverse biological effects are expected to be frequently observed. Further information regarding the development and framework of ISQG are described by the CCME (CCME 1999, 2001, 2002).

Table 3.2-8 Interim Sediment Quality Guidelines and Probable Effects Levels

Parameter	Units	Guideline	
		Interim Sediment Quality Guideline (ISQG)	Probable Effects Level (PEL)
Total Metals			
arsenic	µg/g	5.9	17
cadmium	µg/g	0.6	3.5
chromium	µg/g	37.3	90
copper	µg/g	35.7	197
lead	µg/g	35	91.3
mercury	µg/g	0.17	0.486
zinc	µg/g	123	315
PAHs			
acenaphthene	µg/g	0.00671	0.0889
acenaphthylene	µg/g	0.00587	0.128
anthracene	µg/g	0.0469	0.245
benzo(a)anthracene	µg/g	0.0317	0.385
benzo(a)pyrene	µg/g	0.0319	0.782
dibenzo(a,h)anthracene	µg/g	0.00622	0.135
fluoranthene	µg/g	0.111	2.355
fluorene	µg/g	0.0212	0.144
naphthalene	µg/g	0.0346	0.391
C1 substituted naphthalenes	µg/g	0.0202	0.201
phenanthrene	µg/g	0.0419	0.515
pyrene	µg/g	0.053	0.875
chrysene	µg/g	0.0571	0.862

3.2.4.4 Quality Assurance and Quality Control

A Quality Assurance and Quality Control (QA and QC) process was used to ensure that the information used to describe environmental setting conditions is of high quality. This process documented methods and procedures used to produce and validate data from the field program (see Appendix H for more details) and the statistical analysis.

The QA and QC process included the following elements:

- project management to communicate goals, ensure availability of resources to complete the various determined tasks, and co-ordinate activities and staff training;
- field and laboratory procedures based on approved protocols to ensure consistent and high-quality data;
- technical protocols for collecting, analyzing and validating the accuracy of information; and

- water quality analysis performed by the analytical laboratories are accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL) to do each particular analysis.

Data management procedures were also implemented to reduce the potential for error. For example, all analytical steps were clearly defined during data processing to account for potential discrepancies in data worksheets. In addition, duplicate, split and blank samples were collected during the field program to determine data quality. Field equipment was regularly calibrated, maintained and documented to ensure that the information collected was consistent.

3.3 REGIONAL RESULTS

3.3.1 Athabasca River

Water and sediment quality data for the Athabasca River from Fort McMurray to Embarras are summarized by monitoring sites (Tables 3.3-1 and 3.3-2). The data are grouped for monitoring sites within the upper, middle and lower reaches of the lower Athabasca River, as described in Table 3.2-6. Dividing the data into these groups allows for spatial comparison of water and sediment quality in the Athabasca River within the Oil Sands Region. Water and sediment quality in the three river segments are discussed based on information collected from 1960 to 2006 (Appendix F, Tables F-1 to F-6). All concentrations that exceed a guideline are shown in boldface in the water and sediment quality tables.

Table 3.3-1 Water Quality Data Sampling in the Athabasca River

River Segment	River Segment Description	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
					Total Number	Duration
upper reach of the lower Athabasca River	Fort McMurray to Muskeg River	42	AB07CC0010, AB07CC0020, AB07CC0030, AB07DA1470, AB07CC0070, AB07CC0080, AB07CC0090, AB07CC0100, AB07DA0090, AB07DA0100, AB07DA0140, AB07DA0150, AB07DA0155, AB07DA0160, AB07DA0170, AB07DA0180, AB07DA0190, AB07DA1500, AB07DA0030, AB07DA0040, AB07DA0050, AB07DA0060, AB07DA1520, AB07DA0410, AB07DA0400, AB07DA0390, AB07DA0320, AB07DA0270, AB07DA0280	WDS (AENV 2007)	714	1960 to 2006
			ATR-MR-E, ATR-MR-M, ATR-MR-W, ATR-DC-E, ATR-DC-M, ATR-DC-W, ATR-SR, ATR-SR-E, ATR-SR-M, ATR-SR-W, ATR-UTM	RAMP		
			Site AW004, Site AW009	Golder (1996a) Golder (1997)		
middle reach of the lower Athabasca River	Muskeg River to Firebag River	18	AB07DA1540, AB07DA1550, AB07DA0640, AB07DA0680, AB07DA0820, AB07DA0850, AB07DA0860, AB07DA0870, AB07DA0970, AB07DA0980	WDS (AENV 2007)	338	1968 to 2006
			ARB1-1, ARB1-2	Albian Sands (2000)		
			ATR-FC-E, ATR-FC-M, ATR-FC-W, ATR-FR, ATR-DD, ATR-FR-E	RAMP		
lower reach of the lower Athabasca River	Firebag River to Embarras	11	AB07DD0250, AB07DD0080, AB07DD0060, AB07DD0040, AB07DD0010, AB07DD0020, AB07DD0280	WDS (AENV 2007)	262	1987 to 2006
			EMR-1, ATR-ER, ATR-ER-W, ATR-OF	RAMP		

Table 3.3-2 Sediment Quality Data Sampling in the Athabasca River

River Segment	River Segment Description	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
					Total Number	Duration
upper reach of the lower Athabasca River	Fort McMurray to Muskeg River	50	ATR-UFM, ATR-MR-E, ATR-MR-W, ATR-DC-E, ATR-DC-W, ATR-SR-E, ATR-SR-W, ATR-S-2-E, ATR-S-2-W, ATR-S-3-E, ATR-S-3-W, ATR-S-W, ATR-S-B5, ATR-S-B6, ATR-SR-E, ATR-SR-W	RAMP	78	1975 to 2004
			Site 1, Site 2, Site 3, Site 4, Site 5, Site 6, Site 8, Site 11, Site 12, Site 14, Site 15	Golder (1995)		
			Site 1, Site 1A, Site 2, Site 3, Site 3A, Site 4, Site 5, Site 6, Site 7	Beak Consulting Ltd. (1988)		
			Site A-D-5, Site A-D-9	Allan and Jackson (1978)		
			Site E1, Site E2, Site W1, Site W2, Site W3, Site W4, Site W5, Site W6, Site W7, Site W8	Chemical and Geological Laboratories Ltd. (1979)		
			Site AR7	Dobson et. al. (1996)		
			Site 9	Lutz and Hendzel (1977)		
middle reach of the lower Athabasca River	Muskeg River to Firebag River	24	ATR-DD-E, ATR-DD-W, ATR-FC-E, ATR-FC-W, ATR-FR-E, ATR-FR-W, ATR-S-01-E, ATR-S-01-W, ATR-S-A1, ATR-S-A2, ATR-S-A3, ATR-S-A4, ATR-S-A5, ATR-S-A6	RAMP	42	1975 to 2004
			ARB1-1, ARB1-2	Albian Sands (2000)		
			Site A-D-19, Site A-D-21	Allan and Jackson (1978)		
			Site ARM-F, Site ARM-C	Crosley (1996)		
			Site 14	Lutz and Hendzel (1977)		
			AW015, AW016, AW017	Golder (1995)		
lower reach of the lower Athabasca River	Firebag River to Embarras	6	ATR-ER, ATH-ER, ATR-OF	RAMP	15	1976 to 2005
			Site AR8	Dobson et. al. (1996)		
			Site A-D-69, Site A-D-70	Allan and Jackson (1978)		

3.3.1.1 Upper Reach of the Lower Athabasca River

Water Quality

The upper reach of the lower Athabasca River was well oxygenated throughout all seasons (Appendix F, Table F-1). Two oxygen measurements were slightly below the acute aquatic guideline value of 5 mg/L in June 1977 and 1980. Furthermore, only one or two measurements in each season from spring through fall were below the chronic guideline value of 6.5 mg/L, while minimum winter concentration was higher than the chronic guideline value. Seasonal Dissolved Oxygen (DO) trends tended to follow inverse water temperature patterns likely due to lower oxygen saturation capacity of warmer water. Typically, DO concentrations were highest in winter, decreased in spring and reached lowest levels in summer. Fall DO concentrations were generally higher than spring and summer values.

Concentrations of Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC) were generally low. Organic carbon was mainly in the dissolved form, with seasonal median values of TOC and DOC ranging from 8 to 11 mg/L and 8 to 10 mg/L, respectively. Seasonal trends in organic carbon concentrations were not observed, but occasionally higher values of both TOC and DOC occurred in summer and fall relative to winter and spring concentrations.

The upper reach of the lower Athabasca River water was typically brown (i.e., high total colour units). Relatively lower total colour units typically occurred in the winter season due to low Total Suspended Solids (TSS) concentrations and a reduction in water contributions from typically frozen bog systems.

Laboratory-measured pH remained within the recommended range for the protection of aquatic life (6.5 to 8.5) (Appendix F, Table F-1). Winter median pH was slightly lower than corresponding values for other seasons.

The upper reach of the lower Athabasca River water was moderately hard. Seasonal variability of hardness was reflected in higher winter concentrations relative to concentrations in other seasons. The concentrations of Total Dissolved Solids (TDS), conductance, alkalinity and major ions (e.g., chloride, calcium, magnesium, sodium and sulphate) were low and showed seasonal variability similar to the corresponding trend for hardness. Sulphide levels were often below detection limits or were lower than the chronic aquatic guideline value with the exception of several high concentrations in summer, fall and winter before 1982.

Total Suspendid Solids (TSS) concentrations were substantially higher in summer compared to measured values in other seasons. However, the summer concentrations after 1982 tended to be lower than earlier summer measurements. Spring TSS concentrations were also generally high relative to fall and winter values. Winter and fall TSS concentrations were less than 95 and 390 mg/L with median values of 3 and 16 mg/L, respectively. The high spring and summer TSS concentrations carried high levels of nutrients and metals.

Total nitrogen and phosphorus concentrations in each season were higher than the corresponding chronic aquatic guideline values. Summer typically had higher total nitrogen and phosphorus concentrations than the corresponding values in other seasons, probably due to high summer TSS concentrations from upstream of the Oil Sands Region. The lowest total nitrogen and phosphorus concentrations often occurred during winter, but occasionally high winter values of these parameters were observed. Nitrogen was mostly in the organic form since ammonia, nitrate and nitrite concentrations were appreciably lower than total nitrogen concentrations. Similarly, total phosphorus was mainly in the particulate form with relatively smaller proportion in the dissolved form. The long-term trend for total phosphorus also indicated lower concentrations after 1997, especially during summer; however, dissolved phosphorus showed no long-term trend.

Total metal concentrations were generally low. However, concentrations of aluminum, chromium, copper and iron were often higher than acute or chronic aquatic guideline values. High concentrations of these parameters, especially aluminum, chromium and iron were associated with high TSS. Consequently, the high concentrations were composed of mostly particulate forms of the corresponding parameters with a relatively small percentage present in the dissolved phase. Concentrations of cadmium, lead and zinc were occasionally higher than acute or chronic guideline values. In addition, arsenic, nickel and selenium concentrations exceeded guideline values in a small number of samples.

The detected concentrations for cadmium, mercury and silver from the historical database were generally higher than the guideline values. However, the detection limits of most of the historical analyses for cadmium, mercury and silver were above the corresponding guideline levels. These detected concentrations were much higher than measured data after 1998, which were based on low-level detection limits. The older cadmium, mercury and silver measurements used less sophisticated analytical techniques and were less reliable. Therefore, cadmium, mercury and silver were based on data from 1999 to 2006.

Seasonal trends varied for each metal. The available data did not indicate clear seasonal trends for cadmium, zinc and nickel. Concentrations of total aluminum

chromium, copper and iron tended to be highest in summer, followed by spring and fall, when TSS loads were high. Arsenic concentrations were generally high in the summer and low in the winter. Lead concentrations were often higher in the winter and summer than in other seasons based on the historical record; however, data after 1988 did not show seasonal trends. Total and hexavalent chromium levels were lower during the winter. Selenium appeared to be slightly lower in spring. Long-term trends for arsenic, beryllium, cadmium, molybdenum, nickel and vanadium suggested that concentrations of these metals after 1997 were generally lower than measurement in earlier years.

Concentrations of total recoverable hydrocarbons and naphthenic acids were generally low. Levels of naphthenic acids were often below detection limits. Total phenolics concentrations were periodically higher than the guideline value in every season.

The PAH concentrations remained below analytical detection limits, but the detection limits for some historical PAH (e.g., anthracene, benzo(a)anthracene, benzo(a)pyrene, fluoranthene, phenanthrene and pyrene) measurements were above current guideline values. The generally low PAH concentrations discovered were consistent with the hydrophobic nature of these substances which generally partition into particulate form and attach to sediments.

Toxicity data were limited; however, available Microtox® test results from spring to fall showed no evidence of acute or substantial chronic toxicity. These results were consistent with studies conducted under the Panel for Energy Research and Development (Brownlee 1990; Dutka et al. 1990; Golder 1996a). The Panel's studies also found low or no toxicity on a variety of test organisms.

Sediment

The proportion of sand in sediments of the upper reach of the lower Athabasca River was quite variable, ranging between 20 and 98%. The median value of the proportion of sand was about 70%. The remaining fraction of sediment consisted of a small amount of clay and a moderate quantity of silt, which was about twice the amount of clay. Total carbon content in sediments was generally low and typically did not exceed 5%. Generally, organic carbon concentration was slightly lower than inorganic carbon concentration.

Parameter concentrations in sediments varied widely in the upper reach of the lower Athabasca River. Maximum concentrations of arsenic, cadmium, chromium and lead were higher than guideline values (Appendix F, Table F-4). Total recoverable and total extractable hydrocarbons and PAH concentrations were generally below detection limits, although some high concentrations of

these parameters were observed. Higher concentrations of hydrocarbons were observed near the east bank of the Athabasca River relative to measurements on the west bank, likely due to large amounts of exposed oil sands on the east side. Volatile hydrocarbon concentrations generally did not exceed 0.5 mg/kg, except for samples taken in fall 2002. Concentrations of the PAH groups were higher than the detection limits and occasionally exceeded the corresponding guideline values. The PAH groups with concentrations exceeding guidelines were naphthalenes, acenaphthenes, acenaphthylene, anthracene, benzo(a)pyrene, chrysene and pyrene. The PAH groups that had higher concentrations than guideline values were typical for sediment samples from the Oil Sands Regions (Imperial 2005; Shell 2005; Suncor 2005).

Limited information on the toxicity of the upper reach of the lower Athabasca River sediments downstream of Fort McMurray exists. Most of the sediment samples showed low or no toxic effects on standard test organisms in a laboratory. The low toxicity to standard test organisms suggests that acute or chronic effects would not be observed on aquatic organisms living in the upper reach of the lower Athabasca River under current environmental setting conditions.

3.3.1.2 Middle Reach of the Lower Athabasca River

Water and sediment quality of the middle reach of the lower Athabasca River adjacent to the LSA (Appendix F, Tables F-2 and F-5), was generally similar to that described for the upper reach of the river, with only few exceptions. Therefore, this section focuses on major differences between water and sediment conditions in the upper and middle reaches of the lower Athabasca River.

Water Quality

The middle reach of the lower Athabasca River generally had less measured water quality data for most parameters compared to data sets from the upstream reach, especially from 1976 to 1996 for most metals. The DO concentration was lower than the acute aquatic guideline in one sample collected in March 2002. Another sample collected in May 1997 had higher concentration than the chronic aquatic guideline. Other water quality parameters had values and trends similar to those discussed in Section 3.3.1.1 for the upper reach of the lower Athabasca River.

Sediment

Sediment quality in the middle reach of the lower Athabasca River (Appendix F, Table F-5), based on limited data for summer and fall, was similar to data for the

upstream reach. The available data showed that the sediments were dominated by sand with a median value of 66%, but the remaining fraction of sediments consisted of about equal amounts of silt and clay. Parameter concentrations in sediments were quite variable, similar to observations for the upper reach of the lower Athabasca River. Differences in guideline exceedences in this reach of the lower Athabasca River relative to the upstream reach, up to Fort McMurray, were as follows:

- concentrations of cadmium and lead were not higher than sediment quality guideline values;
- maximum concentration of mercury was higher than sediment quality guideline values; and
- maximum concentration of phenanthrene was higher than the sediment quality guideline value.

3.3.1.3 Lower Reach of the Lower Athabasca River

Water Quality

Water quality in the lower reach of the lower Athabasca River (Appendix F, Table F-3) was similar to that described for the upper and middle reaches of the lower Athabasca River. The following key exceptions were observed:

- DO concentrations were not lower than the chronic aquatic guideline values;
- sulphide concentrations were lower than the chronic aquatic life guideline value in every season; and
- nickel concentrations were lower than the corresponding aquatic life quality guideline value.

Sediment Quality

Sediment quality in the lower reach of the lower Athabasca River (Appendix F, Table F-6) was also similar to the corresponding conditions described in Sections 3.3.1.1 and 3.3.1.2 for upstream reaches of the river. However, maximum concentrations of organic carbon, metal and PAHs were lower in this reach. Chromium, naphthalene and substituted naphthalene were the only parameters with higher maximum concentrations than the corresponding sediment quality guideline values.

3.3.2 Lower Firebag River

Historical water and sediment quality data from 1975 to 2006 have been summarized for sampling locations on the portions of the Firebag River within the RSA (lower Firebag River) (Table 3.3-3). The summarized data are presented in Appendix F, Tables F-7 and F-8. Although the data covers more than 30 years, the number of datapoints is often small compared to the number of water and sediment records for the each of the three reaches of the lower Athabasca River.

Table 3.3-3 Water and Sediment Quality Data Sampling in the Lower Firebag River

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	12	AB07DC0060, AB07DC0090, AB07DC0100, AB07DC0110	AENV (2007)	76	1976 to 2006
		FIR-1	RAMP		
		FIR-W-R1, FIR-W-R3, FIR-W-R5, FIR-W-R6, Site-2, Site-3, Site-4	Suncor (2000)		
sediment quality	3	FIR-1, FBR-D1	RAMP	5	1975 to 2004
		Site-16	Lutz and Hendzel (1977)		

Water Quality

The lower Firebag River was well oxygenated throughout the year. However, winter DO concentrations were almost always lower than the chronic aquatic life guideline value and often lower than the acute aquatic life guideline value (Appendix F, Table F-7). The TOC and DOC concentrations and their seasonal trends were similar to those in the lower Athabasca River described in Sections 3.3.1.1, 3.1.1.2 and 3.1.1.3.

Laboratory-measured pH indicated that the river was slightly alkaline. The pH values were within the guideline range for the protection of aquatic life, except for one sample collected in July 1978 (pH equals 5.6).

Concentrations of hardness, TDS, conductance, alkalinity and major ions were generally similar or slightly lower than corresponding concentrations in the lower Athabasca River. The highest concentration of these parameters was generally observed in winter, except for sulphate which had higher spring concentrations and potassium with similar spring and winter values. Carbonate concentrations

were below the detection limit in all seasons. Several sulphide measurements were below the detection limit. However, some sulphide concentrations during winter, summer and fall were occasionally higher than the chronic aquatic life guideline value.

The TSS were generally low and did not exceed 20 mg/L, except in spring when the maximum concentration was 70 mg/L. Seasonal TSS concentrations were consistently lower than the corresponding data for the lower Athabasca River.

Generally, nutrient concentrations were low in the lower Firebag River. Total nitrogen concentrations in winter and spring were similar to or lower than data from the lower reach of the lower Athabasca River, but summer and fall values were generally higher for the lower Firebag River. Total phosphorus concentrations were lower for the lower Firebag River relative to corresponding seasonal measurements from the lower reach of the lower Athabasca River, except in winter when data from the two river reaches were similar. Maximum concentrations of total nitrogen were higher than the chronic aquatic guideline value in summer and fall, and total phosphorus concentrations in all seasons were often higher than the chronic aquatic guideline value. Ammonia and nitrate/nitrite were often below the analytical detection limit.

Similar to the lower Athabasca River, total metal concentrations in the lower Firebag River were generally low. However, the concentrations of almost all iron samples and aluminum samples in spring and summer were higher than the chronic aquatic life guideline value. Aluminum concentrations in fall were also often higher than the guideline value. Aluminum and iron occurred mostly in the particulate form with a relatively small percentage present in the dissolved phase. Total chromium and cadmium concentration data were available for only winter before 1998. These winter chromium and cadmium data were appreciably higher than the measured concentrations in every season since 1998, likely due to improved sampling and analytical techniques. Concentrations of arsenic, cadmium, copper, mercury, silver, selenium and zinc were occasionally higher than the corresponding aquatic life guideline values in at least one season. Mercury and silver data were not detected in some of the samples, and the detection limits for the measurement of these samples were higher than current aquatic life guideline values.

Naphthenic acids concentrations did not exceed 2 mg/L. Total phenolics and total recoverable hydrocarbons were often below the corresponding analytical detection limit. However, total phenolics concentrations had some detected values that were higher than the chronic aquatic guideline value in spring, fall and winter.

There were no measurements of PAHs and limited Microtox® test results in fall and winter showed no evidence of aquatic toxicity of water from the lower Firebag River.

Sediment

Available fall sediment data for the Lower Firebag River indicated that the river bottom was composed of primarily sand, although silt also formed an appreciable fraction of the sediments (Appendix F, Table F-8). The sediments contained an appreciably small fraction of clay. Similar to the findings for the lower Athabasca River, carbon content in the sediments was low. Metal and PAH concentrations were lower than the corresponding sediment quality guideline values, except one sample in summer 1975, which had higher chromium concentration than the ISQG value. The available sediment data showed low to negligible toxicity effects to standard laboratory test organisms.

3.3.3 McClelland Lake and Associated Surface Waters

Water and sediment quality samples for surface waters associated with the McClelland Lake watershed have been collected in 2006 and 2007 as part of the field program for this Project. The associated surface waters include the inlet and outlet creeks to the lake and the McClelland Lake Fen. Water and sediment quality measurements of these samples have been supplemented with historic data collected between 1976 and 2003 (Tables 3.3-4 and 3.3-5). The data are summarized in Appendix F, Tables F-9 to F-11.

Table 3.3-4 Water Quality Data Sampling in McClelland Lake and Associated Surface Waters

Location	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
McClelland Lake	7	AB07DA2290, AB07DA2300, AB07DA2310, AB07DA2320, AB07DA2770	AENV (2007)	31	1966 to 2007
		MCL-1	RAMP		
		WQ-18, WQ-22	Golder (current study)		
Unnamed Lake (Waterbody 4)	1	WQ-10	Golder (current study)	8	2005 to 2007
McClelland Lake Inlet	1	WQ-6	Golder (current study)	4	2005 to 2006
McClelland Outlet	1	WQ-50	Golder (current study)	1	2006
Unnamed Creek 3	1	WQ-24	Golder (current study)	6	2005 to 2007
McClelland Lake Fen	1	MCF-1	Golder (2001b)	1	2000

Table 3.3-5 Sediment Quality Data Sampling in McClelland Lake and Associated Surface Waters

Location	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
McClelland Lake	–	–	–	–	–
McClelland Lake Inlet	1	WQ-6	Golder (current study)	1	2005
McClelland Lake Outlet	1	WQ-50	Golder (current study)	1	2006
Unnamed Creek 3	1	WQ-24	Golder (current study)	1	2006
McClelland Lake Fen	–	–	–	–	–

– = Not applicable.

3.3.3.1 McClelland Lake

Water Quality

McClelland Lake and the Unnamed Lake were well oxygenated throughout the year; however, one of the two winter measurement (less than 2 mg/L) on February 2007 was lower than the acute aquatic life guideline value of 5 mg/L (Appendix F, Table F-9). The TOC and DOC concentrations tended to be slightly higher than corresponding data in the Athabasca and Firebag rivers, especially during the winter season. However, the lake has appreciably lighter colour than that observed in the lower Athabasca and Firebag rivers.

Laboratory-measured pH was slightly alkaline and within the range for aquatic life guideline values, except for two samples which had slightly higher pH than the upper guideline value.

Major ions concentrations were generally low and were dominated by bicarbonate ions. The high bicarbonate ion concentration contributed to high alkalinity, especially during winter. Concentrations of calcium, magnesium, hardness and TDS were also higher in winter than the corresponding concentrations in other seasons. Chloride and sulphate concentrations were similar to the corresponding concentrations in the lower Firebag River, but were appreciably lower than the measured data in the lower Athabasca River. Sulphide concentrations were typically lower than the aquatic life guideline value.

The TSS concentrations were low (less than 10 mg/L) with the exception of a sample on March 2006, which had a concentration of 80 mg/L. Ammonia and nitrate-nitrite concentrations were low throughout the year and were often below the detection limit. Total nitrogen concentrations were often higher than the chronic aquatic life guideline value in summer, fall and winter, but concentrations in spring were lower and consistently below the guideline value.

Total phosphorus concentrations were low with only the maximum concentrations in winter, summer and fall exceeding aquatic life guideline values. Generally low chlorophyll *a* levels and the low phosphorus concentrations observed throughout the year suggest that low photosynthetic productivity occurs within the water column.

Concentrations of naphthenic acids and total recoverable hydrocarbons were low during all seasons with several values below the detection limit. Total phenolics concentrations were occasionally high and exceeded the chronic aquatic life guideline value in winter and summer.

Metals concentrations were generally low in McClelland Lake and Unnamed Lake, although concentrations of some metals were higher than the corresponding guideline values. Total chromium, copper and lead concentrations were occasionally high in the spring and summer and exceeded the corresponding chronic aquatic life guideline value in McClelland Lake. In Unnamed Lake, the chromium concentration exceeded guideline in winter season. Total aluminum and iron concentrations exceeded chronic aquatic guideline values in water samples collected in winter and summer, while zinc concentrations were higher than the corresponding guideline values in winter and spring. Mercury and cadmium data before 1998 had some high values; however, more recent measurements were either below the detection limit or lower than the corresponding aquatic life guideline value.

The PAH concentrations were measured in four samples with data from each season. These samples showed that PAH levels were low in McClelland Lake with concentrations below detection, except naphthalene, which had a concentration of 0.17 μg/L in the winter 2007 and 0.03 μg/L in spring 2007. This detected naphthalene concentration was appreciably below the guideline value of 1.1 μg/L.

One toxicity measurement was available for McClelland Lake. This measurement showed no acute or chronic toxicity to test organisms.

Sediment

No sediment quality information was available for McClelland Lake during the study period.

3.3.3.2 McClelland Lake Inlet Creek

Water Quality

Four water quality samples, one for each season, were available for the McClelland Lake Inlet Creek. These samples were collected during 2005 and 2006. The water quality data showed that the surface waters of the McClelland Lake Inlet were low in DO (Appendix F, Table F-10). There was one DO measurement in each season and the measured concentrations were all lower than the acute aquatic life guideline value. The water was consistently alkaline with pH values within the range specified in the aquatic life guidelines.

Generally, concentrations of TOC, DOC, major ions, TDS, hardness and alkalinity tended to be similar to the corresponding parameter values observed in McClelland Lake. Major ions concentrations did not exceed applicable aquatic life guideline values, except sulphide measurements that were consistently higher than the chronic aquatic life guideline value.

The TSS and nutrient concentrations were similar to data for McClelland Lake. The TSS concentrations were less than 10 mg/L. Ammonia and nitrate-nitrite concentrations were low throughout the year. The maximum total nitrogen concentration in summer was slightly higher than the chronic aquatic guideline value. Total phosphorus concentrations were higher than the chronic aquatic guideline value with the exception of the spring measurement.

Metal concentrations were low in the McClelland Lake Inlet Creek; however, some parameter concentrations exceeded aquatic life guideline values, as summarized below:

- total iron concentrations for all samples;
- total zinc concentration in spring 2006; and
- total chromium concentrations in spring and summer 2006.

Concentrations of naphthenic acids and total recoverable hydrocarbons were low during all seasons with measured values equal to or below the detection limit. Total phenolics concentrations exceeded the chronic aquatic guideline in spring and summer.

There were no PAH or toxicity data for the McClelland Lake Inlet Creek.

Sediment

One sediment sample was collected from the McClelland Lake Inlet in the fall of 2005 (Appendix F, Table F-11). This sample shows that the sediments were composed of primarily silt and clay in about equal portions and 11% of sand. The sediments had relatively high organic carbon content. Metal and PAH concentrations were generally low with no values exceeding any of the sediment quality guideline values. There were no sediment toxicity measurements for this creek.

3.3.3.3 McClelland Lake Outlet Creek

Water Quality

Only one water quality sample from the McClelland Lake Outlet Creek was available. The sample was collected in fall and shows that the water had low DO concentration (Appendix F, Table F-10), similar to observed conditions in McClelland Lake and its inlet creek. Measurements of other water quality parameters in the creek tended to be different from those observed in McClelland Lake. The TOC and DOC concentrations and colour units were higher than corresponding values in other regional surface waters. The water was slightly acidic with a pH of 6.8 and appreciably lower alkalinity than the corresponding data in McClelland Lake and its inlet creek. The outlet creek has much lower concentrations of major ions, TDS and hardness.

The TSS concentration was high and appeared to be related to the fact that the sampling location was situated just below a logging bridge. The high TSS concentrations corresponded with exceptionally high total nitrogen and total phosphorus concentrations, but ammonia, nitrate-nitrite and dissolved phosphorus concentrations were low. Biological oxygen demand concentration (114 mg/L) was also significantly higher in the outlet channel than in any of the surrounding surface waters, which was due to the human activities through the logging bridge.

Metal concentrations were typically high and were likely associated with the high TSS concentration. Concentrations of total arsenic, cadmium, chromium, iron, lead, nickel and selenium were higher than the chronic aquatic guideline values, and aluminum, copper, mercury and zinc exceeded the acute aquatic guideline values.

Concentrations of organic parameters, including naphthenic acids, total phenolics and total recoverable hydrocarbons, were below the corresponding detection

limits. The field program at the outlet creek did not include PAH and water toxicity sampling.

Sediment Quality

One sediment sample was taken from McClelland Lake Outlet Creek in October 2006 (Appendix F, Table F-11). This sample shows that the sediments were primarily composed of sand particles with low organic carbon content. Metals and PAH concentrations were generally low and did not exceed sediment quality guideline values. Sediment toxicity was not measured for the creek.

3.3.3.4 Unnamed Creek 3

Seven water quality samples and one sediment sample have been collected between 2005 and 2007 from Unnamed Creek 3. This creek is located just east of the McClelland Lake Outlet Creek.

Water Quality

The available data showed that the water was generally oxygenated throughout the year. With the exception of summer 2007 DO concentrations, the DO concentrations were typically higher than the chronic aquatic life guideline value (Appendix F, Table F-10). The water was slightly alkaline. Concentrations of TOC, DOC, major ions, TDS, alkalinity and hardness were generally similar to corresponding values in McClelland Lake and its inlet creek. These concentrations did not exceed applicable aquatic life guideline values. Sulphide concentrations were moderately high, but still less than guideline values.

The TSS and nutrient concentrations were often low with none of the measurements exceeding applicable guideline values for total nitrogen and total phosphorus.

Total metal concentrations were generally low and only exceeded aquatic life guideline values in the following cases:

- total iron concentrations in all samples were higher than chronic aquatic guideline value;
- total chromium concentration in March 2006 was higher than the chronic aquatic guideline value; and
- selenium concentration in Summer 2007 exceeded the aquatic life guideline value.

Naphthenic acids and total recoverable hydrocarbons were not detected in all water samples. Total phenolics concentrations were also low, but one out of the five samples had a higher concentration than the aquatic life guideline value. PAHs were not sampled for Unnamed Creek 3.

One water sample was collected for toxicity analysis in fall 2006. The water was generally not toxic to laboratory test organisms. Fathead minnow showed a slight acute toxicity in the 7-day mortality test. However, this result appears to be inconsistent with the other measurements for the sample, which showed no chronic toxicity to fathead minnow and no chronic or acute toxicity to algae and ceriodaphnia.

Sediment Quality

The sediment sample shows that the sediments were primarily composed of sand particles with low organic carbon content (Appendix F, Table F-11). Metals and PAH concentrations were generally low and none of the parameter concentrations were higher than the applicable sediment quality guideline values. Sediment toxicity was negligible.

3.3.3.5 McClelland Lake Fen

Data for only one historical water quality sample collected from the McClelland Lake Fen in September 2000 (Table 3.3-4) were available. There was no sediment quality information for the fen.

The sample showed that the fen water was slightly alkaline. Concentrations of conventional parameters and major ions were similar to those measured in McClelland Lake and its inlet Creek. Nutrients, total metals and organics had low concentrations. None of the water quality parameter concentrations were higher than the corresponding aquatic life guideline value. Microtox® test results suggested that there was no toxicity to aquatic organisms. PAH measurements were not available for the fen.

3.4 JACKPINE EXPANSION MINING AREA RESULTS

3.4.1 Muskeg River

Water and sediment quality data for the Muskeg River and its headwater tributaries within the Project development area have been divided into three groups corresponding to the following three segments (Tables 3.4-1 and 3.4-2):

- upper Muskeg River: headwater tributaries of the Muskeg River, including the Wapasu Creek and the headwater tributaries to the Muskeg River upstream of Wapasu Creek;
- middle Muskeg River: the Muskeg River upstream of the Jackpine Creek; and
- lower Muskeg River: the Muskeg River downstream from the Jackpine Creek to the mouth.

The following sections present a summary of important indicator parameters for environmental setting water and sediment quality. For statistical summaries of the indicator parameters of the three segments within the Muskeg River watershed, refer to Appendix F, Tables F-12 to F-14 for water quality conditions and Tables F-15 to F-17 for sediment quality conditions.

Table 3.4-1 Water Quality Data Sampling in the Muskeg River and Its Head Tributaries

River Segment	River Segment Description	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
					Total Number	Duration
upper Muskeg River	Wapasu Creek and the headwater tributaries to the Muskeg River upstream of Wapasu Creek	30	AB07DA0420, AB07DA0430, AB07DA0440, AB07DA0480, AB07DA1125, AB07DA1126	AENV (2007)	157	1976 to 2006
			MUR-6, WAC-1	RAMP		
			MUR-6, WAP-1, UNT-1, UNT-2, UNT-3, UNT-5, WAP-1, MT-1, MT-2, MT-5	AXYS (2005)		
			WQ-2, WQ-3, WQ-4, WQ-5, WQ-23	Golder (current study)		
			Site-1, Site-6, Site-7, Site-19	RL&L (1989)		
			Wapasu Creek, Muskeg River upstream of Wapasu Creek	Husky sampled during 2002 and 2003 (Husky Energy 2004)		
			above Lease 36	Komex (1997)		
middle Muskeg River	mainstem of Muskeg River upstream of Jackpine Creek	17	AB07DA0470, AB07DA0475, AB07DA0595, AB07DA2750	AENV (2007)	393	1976 to 2006
			MUR-4, MUR-5, MUR-D2	RAMP		
			MUR-5	Komex (1997)		
			MUR-4	Albian Sands permit sampling (2000, 2003)		
			MUR-4, MUR-5	Syncrude permit sampling		
			Site-2, Site-3, Site-4, Site-5	RL&L (1989)		
			Site 36	Golder (1996a)		
			WQ-1	Golder (current study)		
lower Muskeg River	Muskeg River downstream of Jackpine Creek	13	AB07DA0610, AB07DA0620	AENV (2007)	512	1972 to 2006
			MUR-1, MUR-2	RAMP		
			Site-30, Site-90, MUR-2	Golder (1996a, 1997)		
			MUR-2	Syncrude permit sampling (2003)		
			MUR-2	Albian Sands permit sampling (2000, 2003)		
			Site-L10, Site-L11, Site-18	RL&L (1982, 1989)		
			MUR-2	Shell (1975)		

Table 3.4-2 Sediment Quality Data Sampling in the Muskeg River and Its Head Tributaries

River Segment	River Segment Description	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
					Total Number	Duration
upper Muskeg River	Wapasu Creek and the headwater tributaries to the Muskeg River upstream of Wapasu Creek	11	MUR-6	RAMP	16	1997 to 2005
			Mobil Oil Canada gauging station	Komex (1997)		
			upstream of Wapasu Creek	sampled by Environment Canada in 1998		
			WQ-2, WQ-5	Golder (current study)		
			UNT-1, UNT-2, UNT-3, UNT-5, UNT-6, WAP-1	Imperial Oil (2005)		
middle Muskeg River	mainstem of Muskeg River upstream of Jackpine Creek	4	MUR-4, MUR-5, MUR-D2, MUR-D3	RAMP	11	1997 to 2006
lower Muskeg River	Muskeg River downstream of Jackpine Creek	3	MUR-1, MUR-2	RAMP	19	1975 to 2005
			Site-12	Lutz and Hendzel (1977)		

3.4.1.1 Upper Muskeg River

Water Quality

Water quality data for the upper segment of the Muskeg River (herein referred to as upper Muskeg River) has been collected from 1976 to 2006 (Table 3.4-1). Within the upper Muskeg River, DO concentrations were variable with the highest values occurring in fall. This reach did not tend to be as well oxygenated as the two downstream sections.

Some DO concentrations below the acute guideline value of 5 mg/L were observed occasionally in all seasons, most commonly in winter and summer. Low winter DO concentrations resulted from a combination of oxygen depletion by stream bed material and lack of oxygen replenishment due to ice-cover. The low summer DO concentrations often occurred during periods of low flow and high temperature. Under these conditions, oxygen demand from bottom sediments and suspended organic material likely exceeded oxygen replenishment from atmospheric re-aeration.

The DO concentrations were generally lower than those in the lower Athabasca River, likely due to shallower water and smaller volume of oxygen-containing water in the Muskeg River. These conditions in the upper Muskeg River resulted in higher oxygen demand than the available DO during the winter period when ice cover eliminated oxygen replenishment from the atmosphere.

Water in the upper Muskeg River was typical of bog systems. The colour of the water was dark, primarily due to high concentrations of DOC. Much of the DOC was made up of humic and fulvic acids, which precipitated with metals such as iron. The colour was typically darker in headwater tributaries relative to downstream reaches and in the lower Athabasca River, especially during the low flow summer to winter seasons. Both colour and DOC were often lower in the spring than in other seasons due to dilution from overland flows.

In-situ pH measurements generally ranged from 6.3 to 10.3. However, laboratory-measured pH values were always within the aquatic guideline range of 6.5 to 8.5. Seasonal pH values showed a slightly increasing trend from winter through spring to summer and fall. Low pH in winter was likely due to carbon dioxide production under ice cover in the absence of photosynthetic activity, which would normally consume the carbon dioxide. In the spring, pH levels tended to rise as photosynthesis began; however, high overland flow from snowmelt and transport of winter-accumulated acid deposition contributed to low pH. During summer and fall, photosynthetic activity in the streams resulted in

relatively high pH levels. The range of pH values was generally similar to that for the lower Athabasca River.

Temperatures ranged from 0 to 0.8°C in the winter and 10.8 to 18.7°C in the summer, with variable, intermediate values observed in spring and fall.

Concentrations of hardness, alkalinity, TDS and major ions were generally low in the upper Muskeg River relative to the corresponding concentrations in the middle and lower segments. This longitudinal trend reflected higher proportions of groundwater discharge contributing TDS to the middle and lower segments. Concentrations of hardness, alkalinity, TDS and major ions (except carbonate, potassium and sulphate) followed a seasonal cycle in which they:

- peak in winter;
- decrease in spring;
- increase in summer; and
- increase in fall.

This general seasonal trend would correspond to a positive correlation between the proportion of groundwater in the stream flow and measured surface water concentrations of hardness, total alkalinity, TDS and major ions. Carbonate, potassium and sulphate concentrations tended to be higher in winter and spring compared to measurements in the other seasons.

Sulphide concentrations exceeding guideline values were observed in every season, which is typical of bog systems in the Oil Sands Region, especially during periods of low DO.

Bicarbonate, calcium and magnesium concentrations in the upper Muskeg River were higher than concentrations in the Athabasca River. However, spring concentrations of these parameters were similar to or lower than those in the middle reach of the lower Athabasca River downstream. These trends were similar to trends observed for hardness, TDS, alkalinity and conductance. Furthermore, the concentrations of chloride, sodium and sulphate were lower than the corresponding data in the lower Athabasca River within the RSA, possibly indicating the discharge of natural basal water into the Athabasca River. However, sulphide concentrations in the Athabasca River did not reflect the high sulphide levels often associated with basal water. It was likely that the sulphide from basal water quickly oxidized to sulphate when it contacted the oxygenated river water.

Concentrations of TSS were high in winter and low in other seasons. The high TSS levels in winter were likely due to resuspension of bottom sediments by beavers, which are prevalent in the Muskeg River watershed. Generally, winter TSS concentrations decreased in downstream segments along the Muskeg River. This decrease may have been due to settling of sediments or dilution by groundwater discharge, which was free of TSS. The observed TSS concentrations were much lower than those observed in the lower Athabasca River, especially during spring and summer. The relatively higher TSS concentrations in the lower Athabasca River were due to greater overland flow to the river upstream of the Oil Sands Region.

Total nitrogen and total phosphorus concentrations were generally higher in winter relative to observed concentrations in other seasons. Maximum values for these parameters often exceeded aquatic life guideline values of 1 mg/L for total nitrogen and 0.05 mg/L for total phosphorus, respectively, for all seasons. The high winter levels were likely associated with high TSS and negligible productivity due to low temperature and limited light to the ice-covered waters. Biochemical Oxygen Demand (BOD) was generally close to or below detection limits. However, extreme values that were an order of magnitude higher than the mean were observed in all seasons.

Total nitrogen concentrations in the upper Muskeg River and the downstream segments were generally higher than levels observed in the Athabasca River. In contrast, total phosphorus concentrations were slightly lower in the Muskeg River. The bog system and beaver dams in the Muskeg River watershed retained phosphorus, while the upstream watershed of the lower Athabasca River released a larger amount of phosphorus bound to particulates.

Seasonal trends were not apparent for most total metals. However, barium, manganese and strontium showed a seasonal cycle similar to that of hardness, alkalinity and TDS. When total metal concentrations in the upper Muskeg River were compared to aquatic life guideline values:

- iron frequently exceeded the chronic guideline value;
- aluminum, chromium, copper and zinc occasionally exceeded the chronic guideline value;
- arsenic, cadmium, lead and methyl mercury each exceeded the chronic guideline once; and
- mercury, selenium and silver were not detected in several samples, but the detection limits used to analyze these samples were generally higher than the corresponding guideline values.

Recent sampling and analytical methods designed for low detection limits for the Project indicated that concentrations of total silver, total mercury and methyl mercury were consistently below the chronic guideline values for aquatic life. There was only one methyl mercury measurement in summer 2005 that slightly exceeded the aquatic guideline value of 1 mg/L.

Several of the high total metal concentrations that exceeded aquatic life guideline values often occurred during periods of high TSS concentrations. The association of high metal concentrations with TSS suggested that an appreciable proportion of the observed concentrations were present as particulates, which have little or no effect on aquatic organisms.

There was no consistent trend between metal concentrations in the upper Muskeg River and Athabasca River within the RSA. Generally, concentrations of aluminum and iron, which were associated with TSS, were relatively lower in the upper Muskeg River during spring and summer. Guideline values for copper, arsenic, hexavalent chromium and lead were exceeded less often in the upper Muskeg River than in the Athabasca River. Concentrations of cadmium, selenium, zinc and nickel exceeded the corresponding guideline values at about the same frequency in the upper Muskeg and lower Athabasca rivers. For most other metals, trends regarding differences in concentrations or frequency of exceeding guidelines were not apparent.

Naphthenic acids and total recoverable hydrocarbons, which occur naturally in streams within the Muskeg River watershed mainly from soils that are rich in oil sands, were generally close to or below 2 mg/L. However, one sample with a naphthenic acids concentration of 12 mg/L was observed in fall 1998 and a total recoverable hydrocarbon concentration of 12.9 mg/L in summer 1981. Levels of total phenolics regularly exceeded the chronic aquatic life guideline value during all seasons, which is common in the Oil Sands Region. Target and alkylated PAHs and target Polycyclic Aromatic Nitrogen Heterocycles (PANHs) were below analytical detection limits with a few exceptions, none of which exceeded guidelines. Levels of organics, PAHs and PANHs were similar for the upper Muskeg River and the lower Athabasca River within the RSA.

Toxicity data indicated that the upper Muskeg River was generally not toxic to aquatic life. However, some samples occasionally showed increased mortality or reduced growth of fathead minnows and increased mortality or reduced reproduction of *Ceriodaphnia dubia* during all seasons except spring.

Sediment

Sediment quality data for the upper Muskeg River have been collected from 1997 to 2005 (Table 3.4-2). The stream bed was composed primarily of sand with smaller proportions of silt and clay. The total carbon content in the sediment was 25.5% with organic carbon contributing over 99% of the total carbon. Total metals in the sediments were generally within relevant guidelines. However, one RAMP sample collected in 2000 had a chromium concentration of 98.1 µg/g, which exceeded the corresponding ISQG value. A high chromium concentration in bottom sediments could contribute to the relatively high hexavalent concentrations in the water column, especially during periods when geochemical conditions favour oxidation of chromium to the hexavalent form.

Volatile hydrocarbon concentrations were below detection limits, but total extractable hydrocarbon concentrations were higher. Total extractable hydrocarbon concentrations ranged from 11 to 1,200 mg/kg with a median value of 91 mg/kg. Similarly, the median of total recoverable hydrocarbon concentration in the sediment was 2,200 mg/kg. With the exception of one measurement of C1-substituted naphthalenes concentration, the PAH concentrations were lower than the corresponding guideline values.

Two sediment toxicity measurements were available for the upper Muskeg River. The data showed slight survival effects on *Chironomus tentans* and *Hyalella azteca*. However, these effects occured naturally in the watershed, since the sampled locations had not experienced changes from development activities.

3.4.1.2 Middle Muskeg River

Water Quality

Water quality data available for the middle Muskeg River were collected from 1976 to 2006 (Table 3.4-1). Within the middle Muskeg River, DO concentrations were variable with the highest values occurring in fall. Low DO concentrations below the acute aquatic life guideline of 5 mg/L were often observed in winter and occasionally in other seasons.

The TOC and DOC concentrations were generally slightly lower than the corresponding data in the upper Muskeg River. Consequently, colour in the middle Muskeg River was lighter than in the upstream reach and the headwater tributaries of the river.

Seasonal pH values for the middle Muskeg River showed a slightly increasing trend from winter through spring to summer and fall, similar to the observed

trend for the upper Muskeg River. Temperatures ranged from -0.2 to 0.8°C in the winter and 0.1 to 22.4°C in the summer, with variable, intermediate values observed in spring and fall.

Concentrations of hardness, alkalinity, TDS and major ions were generally higher than the corresponding concentrations in the upper Muskeg River, but slightly lower than those in the lower Muskeg River. Concentrations of these constituents, except carbonate, potassium and sulphate, followed a seasonal cycle similar to that in the upper Muskeg River. This seasonal trend corresponded to a positive correlation between the proportion of groundwater in streamflow and measured surface water concentrations. Carbonate, potassium and sulphate concentrations were very low and did not show consistent seasonal trends. Sulphide concentrations exceeded the chronic guideline in all seasons.

Concentrations of TSS were low in spring, summer and fall. Marginally higher concentrations were observed in winter. The winter TSS concentrations were typically lower than those observed in the upper Muskeg River; however, the concentrations in other seasons were similar to those in the upper Muskeg River and lower Muskeg River.

Ammonia concentrations peaked in the winter then decreased in spring and remained relatively unchanged for the rest of the year. Ammonia and nitrate-nitrite concentrations were low throughout the year. Total nitrogen concentrations were generally higher in winter relative to observed concentrations in other seasons. Total phosphorus did not show seasonal trends, but dissolved phosphorus concentrations were much lower in winter. Total nitrogen and total phosphorus concentrations in all seasons were often higher than chronic aquatic guideline values. The high total nitrogen concentrations exceeding guideline values often occurred during winter. Longitudinal trends in nutrient concentrations were not observed along the Muskeg River.

Seasonal trends were not apparent for most total metals. However, barium, lithium, silicon, manganese and strontium showed a seasonal cycle similar to that of hardness, alkalinity and TDS in this segment of the river.

When total metal concentrations in the middle Muskeg River were compared to aquatic life guideline values:

- iron, aluminum and chromium concentrations were often higher than the chronic guideline value;
- copper, lead, thallium and zinc concentrations occasionally exceeded the chronic guideline value; and

- mercury, cadmium and silver were not detected in several samples, but the detection limits used to analyze these samples were generally higher than the corresponding guideline values.

Concentrations of total recoverable hydrocarbons were less than 4 mg/L, except for one sample collected in spring 2005, which had a value of 208 mg/L. With a few exceptions, naphthenic acid concentrations were below detection limits in all seasons. The naphthenic acids concentrations appeared to be slightly higher than in the upper Muskeg River. Levels of total phenolics regularly exceeded the chronic guideline during all seasons.

Concentrations of PAHs were typically below detection limits within the middle Muskeg River. However, detected concentrations of anthracene, benzo(a)anthracene/chrysene, benzo(a)pyrene, fluoranthene and pyrene in winter were higher that the corresponding aquatic life guideline value. Similar to data in the upper Muskeg River, PANHs and volatile organics were consistently below analytical detection limits.

Toxicity data showed that the middle Muskeg River was generally not toxic to aquatic life. Occasionally, water samples showed increased mortality or reduced growth of fathead minnows. Also, two winter samples showed slight reduction in reproduction of *Ceriodaphnia dubia*.

Sediment

Sediment quality data available for the middle Muskeg River were collected from 1997 to 2006 (Table 3.4-2). Similar to the upper Muskeg River, bottom sediment in the middle Muskeg River was composed mainly of sand and smaller amounts of silts and clay (Appendix F, Table F-16). However, the sand fraction in the sediment was sometimes as high as 94% and generally higher than those observed in the upper Muskeg River. Although the median value of total carbon was about half of the corresponding value in the upper Muskeg River, the percentage distribution between inorganic and organic carbon was similar for the two segments. With the exception of high zinc concentrations (222 µg/g) in fall 2004, all other total metal concentrations were lower than the ISQG value.

Total volatile organic carbon concentrations in the sediments were less than detection limits. However, concentrations of total recoverable hydrocarbons were higher than in the upper Muskeg River. Although the maximum concentrations of benzo(a)anthracene and chrysene exceeded the ISQG value, the remaining PAH values were below the corresponding guideline values.

One sediment sample in fall 2003 showed toxicity effects to survival and growth of laboratory test organisms. These effects tended to be higher than those for two samples in the upper Muskeg River, which showed slight survival effects on *Chironomus tentans* and *Hyalella azteca*.

3.4.1.3 Lower Muskeg River

Water Quality

Water quality data available for the lower Muskeg River were collected from 1972 to 2006 (Table 3.4-1). In the lower Muskeg River, DO concentrations were below the acute aquatic life guideline value frequently in winter and occasionally in spring (Appendix F, Table F-14). In addition, the concentrations in summer and fall were occasionally below the lower DO bound of the chronic aquatic life guideline values. Seasonal trends and guideline exceedances were similar for lower, middle and upper reaches of the Muskeg River.

Water temperature tended to be slightly warmer than middle Muskeg River temperatures from spring through fall. As water travelled downstream of the middle Muskeg River during the open-water period, solar energy heated the water and consequently the water temperature increased in the lower Muskeg River.

Median values of TOC, DOC and colour were similar to those in the middle Muskeg River, but the lower Muskeg River tended to have a wider range of these values in all season. Values and seasonal trends of pH were similar for the middle and lower segments of the Muskeg River. In general, the two segments also had similar values and seasonal trends for hardness, alkalinity, TDS and major ions. High sulphate concentrations occurred from 1998 to 2001 due to releases from the Alsands Drain. Sulphide concentrations were higher than aquatic life guideline values occasionally in all seasons.

Longitudinal trends for TSS, nutrients and metal were not apparent from the middle to the lower segment of the Muskeg River. When metal concentrations in the lower Muskeg River were compared to aquatic life guideline values:

- concentrations of iron and chromium frequently exceeded the chronic guideline value;
- concentrations of aluminum, arsenic, copper, lead, nickel and zinc occasionally exceeded the chronic guideline value; and
- concentrations of mercury, selenium, silver and cadmium in several samples were often below the corresponding detection limit, but the

detection limits used to analyze these samples were often higher than the corresponding guideline values. Also, high detected values of these parameters often exceeded the corresponding guideline values; however, these high values typically occurred for samples collected before 1998.

Metal concentrations did not show a consistent seasonal tend. However, concentrations exceeding guideline values often occurred during periods of high TSS concentrations, as observed for other segments of the Muskeg River.

Similar to upstream segments, the lower Muskeg River had total recoverable hydrocarbon and naphthenic acids concentrations that were typically low and often below detection limits. Concentrations of total phenolics were high and often exceeded aquatic life guideline values; however, high total phenolics concentrations naturally occur in streams within the Muskeg River watershed, mainly from soils that are naturally rich in oil sands. Total phenolics concentrations tended to be slightly lower compared to observed values in the middle Muskeg River.

Concentrations of PAHs were typically below detection limits in the lower Muskeg River. However some of the detected values of anthracene and benzo(a)anthracene/chrysene occasionally exceeded aquatic life guideline values in fall, while the maximum benzo(a)pyrene concentration was higher than the guideline value in winter.

Toxicity data generally indicated that the lower Muskeg River was not toxic to aquatic life. However, fathead minnow growth was inhibited slightly in 2 out of 26 samples and mortality of this laboratory test organism was affected in 1 out of 26 samples.

Sediment

The grain size distribution in the lower Muskeg River sediment was similar to that in middle Muskeg River, with 79% sand (Appendix F, Table F-17) in the former. Total carbon and organic carbon contents were lower than the corresponding concentrations in the upper and middle segments of the Muskeg River. Conversely, inorganic carbon concentration was significantly higher than those in the upper and middle segments.

Sediment quality data available for the lower Muskeg River ranged from 1975 to 2005 (Table 3.4-2). In general, total metal concentrations in lower Muskeg River sediments were below guideline values. However, a very high chromium concentration of 59 µg/g was reported in the spring of 1975.

The total volatile hydrocarbon concentrations in the sediments were at or below detection limit. High concentrations of total recoverable (11,300 mg/kg in 2000) and extractable (1,600 mg/kg in 2003) hydrocarbons were reported by RAMP. Although the average concentrations of both recoverable and extractable hydrocarbons were generally comparable to those in the upper and middle segments, sediment concentrations of more PAHs exceeded the corresponding guideline values in the lower Muskeg River. The PAHs with higher concentrations than the guideline values were dibenzo(a,h)anthracene, benzo(a)anthracene, chrysene, phenanthrene and pyrene.

The sediment showed slight toxicity to growth and survival of *chironomus tentans*, *hyalella azteca* and *lumbriculus variegates*. However, the toxicity effects were due to natural conditions, since the sediment quality and toxicity did not generally show any downstream and temporal trends.

3.4.1.4 Jackpine Creek

Water and sediment quality historical data for the Jackpine Creek and its tributaries have been collected between 1974 and 2006 (Table 3.4-3). The water and sediment quality data are summarized in Appendix F, Tables F-18 and F-19.

Table 3.4-3 Water and Sediment Quality Data Sampling in Jackpine Creek

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	22	AB07DA0600, AB07DA0900, AB07DA1140, AB07DA1150, AB07DA1220, AB07DA1230	AENV (2007)	199	1974 to 2006
		JAC-1	RAMP		
		JAC-1, JPC-1, JPC-2, JPC-3	Golder (2002b)		
		downstream of Canterra Road, between Canterra Road and East Jackpine Creek	AXYS (2005)		
		Jackpine mouth	Golder (1996a, 1997), Shell (1975)		
		Site-L4, Site-L5, Site-L6, Site-L7, Site-15, Site-16, Site-17	RL&L (1982, 1989)		
		Site-1, Site-3	Stanley Associates sampled in 1981 and 1982		
sediment quality	3	JAC-1, JAC-D1, JAC-D2	RAMP	4	1997 to 2006

Source: Stanley Associates Engineering Ltd., 1982. SANDALTA Project (1981) Report. Report No: Phase II-12.

Water Quality

The DO concentrations in Jackpine Creek were variable with the lowest values occurring in winter. Concentrations below the acute DO guideline value occurred in all seasons, except spring. The concentrations were often lower than the chronic guideline value throughout the year. The Biochemical Oxygen Demand (BOD) observations in all seasons were below 6 mg/L.

Seasonal values of TOC, DOC and colour were similar to those observed in the lower Muskeg River. Laboratory-measured pH ranged from 6.5 to 8.6, with one value in winter 1979 slightly above the upper guideline value. The pH values and seasonal trend were similar to those for the lower Muskeg River.

Concentrations of hardness, alkalinity, TDS, bicarbonate, calcium and magnesium were lower in Jackpine Creek relative to the corresponding concentrations in the middle and lower segments of Muskeg River. However these concentrations had the same seasonal trends described for all of the Muskeg River segments (see Sections 3.4.1.1 to 3.4.1.3 in which they peak in winter, decrease in spring and increase in summer and fall). Sulphate concentrations were lower than 15 mg/L and sulphide values exceeded the aquatic life guideline value on several occasions throughout the year. The TSS concentrations were typically below 50 mg/L, although a few extreme values up to 459 mg/L were observed in winter and summer before 1981. The high TSS levels in winter may have been due to beaver activity. TSS concentrations tended to be slightly higher that the corresponding values in the middle and lower segments of Muskeg River.

Levels of most major ions were lowest in the spring. With the exception of carbonate, potassium, sulphate and sulphide, the major ions generally showed seasonal trends similar to those described for TDS concentrations. Sulphide concentrations exceeded the chronic guideline in all seasons, which is typical in the Oil Sands Region.

Ammonia and nitrate-nitrite concentrations were lower than aquatic life guideline values. Total nitrogen and total phosphorus were often higher than the aquatic guideline values of 1 and 0.05 mg/L, respectively, in all seasons.

Seasonal trends were not apparent for most total metals. However, barium, iron, lithium, silicon and strontium showed a seasonal cycle similar to that of hardness, alkalinity and TDS. When total metal concentrations in Jackpine Creek were compared to guidelines:

- concentrations of iron often exceeded the chronic guideline value;

- concentrations of aluminum, arsenic, copper and zinc occasionally exceeded the chronic guideline value;
- concentration of selenium in three summer samples in 1981 were higher than the chronic aquatic life guideline value, but all other samples had concentrations below the detection limit or the guideline value; and
- cadmium, chromium lead, mercury and silver in some samples were below the corresponding detection limit, but the detection limits used to analyze these samples were often higher than the corresponding guideline values. Also, high detected concentration of these parameters often exceeded the corresponding guideline values for samples collected before 1998.

Concentrations of naphthenic acids and total recoverable hydrocarbons were generally similar to levels observed in the upper and middle segments of Muskeg River. Levels of total phenolics regularly exceeded the chronic guideline during all seasons, which is common in the Oil Sands Region.

Concentrations of PAHs, PANHs and volatile organics were below analytical detection limits with the exception of one naphthalene measurement in winter 2002. This detected concentration did not exceed chronic aquatic life guideline value.

There were two toxicity measurements in Jackpine Creek. The data indicated that the creek was generally not toxic to aquatic life. However, one sample collected in fall 2001 showed slight reduction in reproduction of *Ceriodaphnia dubia*.

Sediment

Sediment quality findings for Jackpine Creek were based on four samples collected between 1997 and 2006 (Table 3.4-3). The percentage of sand in the sediment was comparable to those in the lower and middle segments of the Muskeg River with silt and clay accounting for up to 19% of the bed material. Total carbon and organic carbon contents were lower than those in Muskeg Rivers. Inorganic carbon content was less than 10% of the total carbon. Total metal concentrations were below guideline values.

Like other rivers, the sediment was characterized by undetectable total volatile organic carbon and high total recoverable and total extractable carbon contents. Since the results were based on a small number samples, the distribution of concentration could not be generalized. Apart from one benzo(a)-anthracene concentration, the reported PAH values were below guideline values.

3.4.1.5 Shelley Creek

Water quality data for Shelley Creek cover the period between 1977 and 2001 (Table 3.4-4). No sediment quality data are available for the creek. The water quality data are summarized in Appendix F, Table F-20.

Table 3.4-4 Water and Sediment Quality Data Sampling in Shelley Creek

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	4	AB07DA1160, AB07DA2756	AENV (2007)	19	1977 to 2001
		SHC-1	RAMP		
		SHC-1	Golder (1997, 2002b)		
sediment quality	–	–	–	–	–

– = Not available.

Water Quality

Because datapoints were limited for Shelley Creek, extensive comparison could not be made between individual parameters in the creek and Muskeg River or its tributaries. However, the data for Shelley Creek indicated that its water quality tends to be similar to that of Jackpine Creek. Concentrations in Shelley Creek were generally within the range for Jackpine Creek, and seasonal water quality trends were similar for the two creeks.

Observed DO concentrations in Shelley Creek were highest in spring and lowest in fall, with concentrations below the acute guideline of 5 mg/L for two measurements in fall and one measurement each in summer and winter. Laboratory-measured pH ranged from 6.9 to 8.2; therefore, all samples were within the aquatic life guideline range.

Observed concentrations of hardness, alkalinity and TDS were highest in fall or winter and lowest in spring. With the exception of carbonate, chloride and sulphide, major ions generally showed seasonal trends similar to those described for TDS concentrations. Carbonate concentrations were below the detection limit, while chloride measurements were highest in fall and appreciably low in all other seasons. Sulphide did not show any defined seasonal trend, with all concentrations exceeding the chronic guideline value, except one measurement in fall and two in winter.

Concentrations of TSS were typically below 10 mg/L, although some high values up to 114 mg/L were observed in winter and fall. Levels of major ions were

lower in the spring. Total nitrogen and total phosphorus concentrations were generally higher in winter relative to observed concentrations in other seasons. These high concentrations were associated with high TSS levels. The concentrations of these parameters often exceeded aquatic life guideline values in all seasons.

Seasonal trends were not apparent for most total metals. However, arsenic, cobalt, iron, manganese, strontium and vanadium showed seasonal trends similar to that of hardness, alkalinity and TDS. When total metal concentrations in Shelley Creek were compared to guidelines:

- iron concentrations frequently exceeded the chronic guideline value;
- aluminum and chromium concentrations occasionally exceeded the chronic guideline value;
- copper and zinc concentrations exceeded the corresponding chronic guideline value once, while lead concentrations were higher than the guideline value in two samples; and
- mercury and silver concentrations of most samples were below the corresponding detection limit, but the detection limits used to analyze these samples were often higher than the corresponding guideline values. Also, the detected concentration of mercury exceeded the guideline value for a sample collected in summer 1997.

Recent measurements of total recoverable hydrocarbon concentrations after 1996 were below detection limit; however, older data in 1977 were as high as 6.6 mg/L. Naphthenic acids were generally close to or below detection limits, with the exception of a value of 24 mg/L observed in the fall 2001. Levels of total phenolics exceeded the chronic guideline once in winter and in summer.

One sample measurement was available for PAHs and PANHs. However, these parameters were not detected in the sample.

There were two toxicity sample measurements for Shelley Creek. Both samples indicated chronic toxicity based on reduced reproduction of *Ceriodaphnia dubia*.

Sediment

No sediment quality data were available for Shelley Creek.

3.4.1.6 Stanley Creek

Water and sediment quality historical data for Stanley Creek have been collected between 1976 and 2006 (Table 3.4-5). The water and sediment quality of the creek are summarized in Appendix F, Tables F-21 and F-22.

Table 3.4-5 Water and Sediment Quality Data Sampling in Stanley Creek

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	3	AB07DA0490	AENV (2007)	32	1976 to 2006
		STC-1	RAMP		
		Site-60	Golder (1996a)		
sediment quality	1	STC-1	RAMP	1	2003

Water Quality

Stanley Creek was poorly oxygenated in winter, summer and fall, with most DO values below the acute guideline during these seasons. Concentrations of DO below the chronic aquatic life guideline value were observed in all seasons. The BOD concentrations were generally low and often not detected in samples.

The TOC and DOC concentrations and colour values tended to be slightly lower than the corresponding values in Jackpine Creek and Muskeg River. Laboratory-measured pH values were consistently within the aquatic life guideline range.

Concentrations of hardness, alkalinity and major ions in Stanley Creek were similar to those in the middle and lower segments of Muskeg River. However, hardness, TDS, calcium and chloride tended to be more variable in Stanley Creek, with occasionally higher maximum values than in the Muskeg River segments. Concentrations of hardness, alkalinity and major ions followed the same seasonal trend in Muskeg River with high values in the winter followed by low values in the spring and intermediate values in summer and fall. In contrast to most other watercourses within the LSA, sulphide exceeded the chronic guideline in all seasons except winter, likely due to limited number of winter measurements.

The TSS measurements after 1993 were consistently less than 15 mg/L; however, some high concentrations up to 73 mg/L were observed in winter and fall before 1977. Ammonia and nitrate-nitrite concentrations were low and generally below detection limits. Seasonal trends in total nitrogen and total phosphorus concentrations were less apparent, probably due to the small data set available for

the creek. Concentrations of both total nitrogen and total phosphorus exceeded guideline values in all seasons.

Iron concentrations were often higher than the chronic aquatic life guideline value of 0.3 mg/L. Chromium concentrations were consistently lower than the chronic aquatic life guideline value, except for one value in fall 2001 and another in winter 2002. Two out of six spring measurements of zinc were higher than the chronic aquatic life guideline value, but concentrations in other seasons were lower than the guideline value. Total mercury concentrations were not detected in water samples, except in one sample collected in fall 1976. The concentration in this sample exceeded the chronic aquatic guideline value.

Concentrations of total recoverable hydrocarbons and naphthenic acids were often below detection limits, but several values of total phenolics were detected at concentrations that exceeded the aquatic life guideline value.

Only one sample was analyzed for PAHs, and the concentrations for these parameters were all below the corresponding detection limit. Toxicity data for Stanley Creek were limited to three Microtox® test analyses, all of which indicated no toxicity.

Sediment

Sediment quality in Stanley Creek is based on a single sample collected in 2003 (Table 3.4-5). The results do not include sediment grain size distribution analysis.

Like other watercourses, the total volatile hydrocarbon concentration was undetectable, but total recoverable hydrocarbon concentration was as high as 25,200 mg/kg. The total extractable hydrocarbon concentration was comparable to those in other watercourses in the Muskeg River watershed.

A high arsenic concentration was observed at 18.5 µg/g, which exceeded both ISQG and PEL values. The C1 substituted naphthalenes concentration exceeded the ISQG value. Other PAH concentrations were below the corresponding guideline values. Sediment toxicity was not measured for the Stanley Creek sample.

3.4.1.7 Muskeg Creek

Water and sediment quality data for the Muskeg Creek and its tributaries are available for the period between 1976 and 2006 (Table 3.4-6). The data are summarized in Appendix F, Tables F-23 and F-24.

Table 3.4-6 Water and Sediment Quality Data Sampling in Muskeg Creek and Its Tributaries

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	21	AB07DA0530, AB07DA1180, AB07DA1190, AB07DA2755	AENV (2007)	133	1976 to 2006
		MUC-1	RAMP		
		Muskeg Creek mouth	Husky sampled during 2002 and 2003 (2004)		
		Site-8, Site-9, Site-10, Site-11, Site-12, Site-13, Site-14	RL&L (1982, 1989)		
		Site-8, Site-9, Site-50, Site-55, MUC-1, MUC-2, KHC-1,	Golder (1996a, 1997, 2002b)		
		WQ-30	Golder (current study)		
sediment quality	1	WQ-30	Golder (current study)	1	2005

Water Quality

Water quality of Muskeg Creek was generally similar to that of Jackpine Creek, with only minor exceptions. The oxygen status of Muskeg Creek was variable, with some DO values below the acute aquatic guideline value in every season. However, seasonal median DO concentrations were higher than the chronic aquatic guideline value. The BOD concentrations tended to be generally higher than in Jackpine Creek, especially during winter before 1989.

The TOC and DOC concentrations and colour units tended to be higher in winter. Laboratory-measured pH values were within the aquatic life guideline range. Seasonal trends of hardness, alkalinity, TDS and major ion concentrations followed the same overall pattern of high values in the winter followed by low values in the spring and intermediate values in summer and fall. Nutrient concentrations were generally highest in winter with the exception of dissolved phosphorus, which was highest in summer. Concentrations of both total nitrogen and total phosphorus exceeded guideline values in all seasons. Several sulphide concentrations were higher than the chronic guideline value in all seasons.

Seasonal trends were not apparent for most of the total metal concentrations. When total metal concentrations were compared to aquatic life guideline values:

- concentrations of iron frequently exceeded the chronic guideline value;
- concentrations of aluminum, arsenic, chromium, lead, selenium and zinc were occasionally higher than the corresponding chronic guideline values;
- concentrations of copper in two samples exceeded the chronic guideline value; and
- concentrations of cadmium, mercury and silver in most samples were below the corresponding detection limit, but the detection limits used to analyze these samples were often higher than the corresponding guideline values. Also, detected concentrations of these parameters exceeded the guideline values in some samples.

Concentrations of total recoverable hydrocarbons and naphthenic acids were often below detection limits. However, total phenolics concentrations often exceeded the aquatic life guideline value in all seasons. One sample was analyzed for PAHs in each season, and the concentrations of these parameters were below the corresponding detection limits.

Whole effluent toxicity analyses for Muskeg Creek produced reproductive effects on *Ceriodaphnia dubia* during winter and fall, and lethal effects on fathead minnows during the fall.

Sediment

Sediment quality in the Muskeg Creek is based on a single sample collected in 2005 (Table 3.4-6).

Similar to other watercourses, the sediment was composed of mainly sand. Total carbon content was 5.8% with most of carbon in the organic form. Total metals concentrations in the sediment sample were below relevant guideline values.

Total volatile hydrocarbon concentrations were below the detection limit of 0.5 mg/kg. Extractable and recoverable hydrocarbon concentrations were similar to maximum values in Jackpine Creek. Sediment PAH concentrations were below guideline values. The sample had a slight effect on survival of *Lumbriculus variegates*.

3.4.1.8 Kearl Lake

Water and sediment quality data for Kearl Lake cover the period between 1966 and 2007 (Table 3.4-7). The data are summarized in Appendix F, Tables F-25 and F-26.

Table 3.4-7 Water and Sediment Quality Sampling in Kearl Lake

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	7	AB07DA2210, AB07DA2220	AENV (2007)	44	1966 to 2007
		KEL-1	RAMP		
		Kearl Lake	Erikson sampled in 1983		
		Site-80	Golder(1996a)		
		KL-1	Imperial Oil (2005)		
		Site-20	RL&L (1989)		
sediment quality	3	Kearl Lake	Environment Canada sampled in 1998	4	1998 to 2006
		KL-1	Imperial Oil sampled in 2006		
		Kearl Lake	RAMP		

Water Quality

The DO concentration varied with time and depended on factors such as water temperature, atmospheric regeneration and oxygen consumption by organic substances in the lake. In Kearl Lake, DO dropped below chronic aquatic life guideline levels in every season except spring. The DO concentrations were lower than acute aquatic guideline values during only the winter season. The highest observed DO concentrations occurred during fall. Due to the absence of atmospheric regeneration during the ice-covered winter season, DO concentrations were often below the guideline value. Occasionally, DO levels were less than 2 mg/L. The DO was below the chronic guideline level on August 16, 2001, when the water temperature in Kearl Lake exceeded 30^{o}C. The high water temperature decreased the capacity of the lake water to maintain high DO concentrations.

Water in Kearl Lake was typical of bog systems. The colour of the water was dark primarily due to high concentrations of DOC. Both colour and DOC were highest in the winter season.

There was little variability in pH. However, a single value slightly below guideline levels was recorded in spring 2003. This low pH coincided with the

lowest measured alkalinity value of 4 mg/L, and was likely due to base cation dilution from spring runoff.

Seasonal values of hardness, alkalinity, TDS and major ions were lowest in spring when snowmelt contributed to lake water. Winter values were higher due partly to a higher groundwater contribution. Also, as lake ice was formed from water, these substances were rejected from the ice into the water below resulting in higher concentrations in the water remaining under ice. Summer and fall concentrations of these parameters increased above spring levels due to reduced overland flow to the lake. The concentrations of sulphide in two winter samples were higher than the aquatic life guideline value. Also, one fall and two summer samples had sulphide concentrations that exceeded the aquatic life guideline value. The high sulphide concentrations in winter corresponded with low DO levels. The low DO concentration represented anoxic conditions, with nearly no oxygen present. Sulphate was likely reduced to sulphide under these conditions.

The TSS concentration was typically low in all seasons. Phosphorus levels suggested that Kearl Lake is mesotrophic to meso-eutrophic, which means the lake productivity is moderate to moderately high (Wetzel 2001). Phosphorus concentrations were consistently above guideline values. High total nitrogen concentrations exceeding the guideline value occurred in every season, except spring. All total nitrogen concentrations in winter exceeded the guideline value. Chlorophyll *a* was highest in summer and fall with values up to 15 µg/L when lake productivity was at its peak.

On rare occasions, some metal concentrations were higher than the corresponding guideline values. Concentrations of arsenic, chromium, copper, iron and zinc occasionally exceeded chronic aquatic life guideline values. One chromium sample in fall 1988 had a higher concentration than the acute aquatic life guideline value. Aluminum concentration exceeded the chronic aquatic life guideline value in one sample taken in fall 1998. Concentrations of cadmium, lead, mercury and silver in most samples were below the corresponding detection limit, but the detection limits used to analyze these samples were often higher than the corresponding guideline values. Also, detected concentrations of these parameters exceeded the guideline values in some samples.

Total recoverable hydrocarbons and naphthenic acids were usually below detection limits in samples from Kearl Lake. However, a relatively high concentration of total recoverable hydrocarbons, 27.9 mg/L, was measured in winter 1989. Total phenolics concentrations were often above the aquatic life guideline value, which is common in the Oil Sands Region. There were no data available for PAHs in Kearl Lake.

Five sets of Microtox® measurements were taken for Kearl Lake. All tests were done in summer and fall. All five test results showed negligible toxicity. However, one out of two full water toxicity tests in fall 2006 showed slight mortality and reproduction effects on *Ceriodaphnia dubia*.

Sediment

Unlike rivers within the RSA and LSA, Kearl Lake sediment was mainly composed of fine materials. Clays and silt dominated the lake bottom with sand constituting a minor proportion of the sediment. This observation was similar to the result for other lakes in the Muskeg River watershed, reinforcing that carbon in lake sediments exists mainly in organic form, which is common in boreal lakes where carbon mineralization of dead plant material typically occurs slowly.

Metal concentrations in Kearl Lake sediments were within guideline limits. Concentrations of total recoverable hydrocarbons in the lake reflected the naturally occurring high levels of hydrocarbons in the Oil Sands Region. Total volatile hydrocarbons were below detection limits while recoverable and extractable hydrocarbon levels were typical of the sediment content in the Muskeg River watershed. Concentrations of PAHs were generally below ISQG values, except dibenzo(a,h)anthracene and C1 substituted naphthalenes. Out of the four sediment samples, concentrations of dibenzo(a,h)anthracene in three samples and C1 substituted naphthalenes in one sample were higher than the corresponding ISQG values. Sediment toxicity data were not available for Kearl Lake.

3.4.1.9 Unnamed Waterbodies

Water and sediment quality data for unnamed waterbodies within the JEMA have been collected between 2003 and 2006 (Table 3.4-8). Six unnamed waterbodies have been sampled for water quality and two for sediment quality. The data are summarized in Appendix F, Tables F-27 and F-28.

Table 3.4-8 Water and Sediment Quality Data Sampling in Unnamed Waterbodies Within the Jackpine Expansion Mining Area

Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
				Total Number	Duration
water quality	6	WQ-15, WQ-16, WQ-17	Golder (current study)	16	2003 to 2006
		Muskeg River headwater lake	Husky sampled in 2003 (Husky Energy 2004)		
		UNL-1, UNL-2	Imperial Oil (2005)		
sediment quality	2	UNL-3	Imperial Oil (2005)	2	2003 to 2005
		WQ16	Golder (current study)		

Water Quality

The unnamed waterbodies in the JEMA were had DO concentrations that were consistently complied with aquatic life guidelines in all seasons, except winter. During winter, DO was observed below the acute guidelines in three out of four samples. The DO concentration in a sample collected in Summer 2007 was also below guideline value. The low DO levels in winter was anticipated given that these lakes are shallow and experience low DO levels due to sediment oxygen demand and limited atmospheric re-aeration during winter. Measured values and seasonal trends in BOD, TOC, DOC and colour were consistent with those observed for Kearl Lake.

Laboratory-measured pH varied from 7.3 to 8.5, which were within the aquatic life guideline range.

Seasonal trends in hardness, alkalinity, TDS and major ions were generally similar to those observed for Kearl Lake. However, the concentrations of these parameters were generally higher than those observed in Kearl Lake, except for sodium, carbonate, sulphate and sulphide. Sodium concentrations tended to be slightly lower in the unnamed waterbodies, and carbonate, sulphate and sulphide values were similar to those in Kearl Lake. The higher concentrations of hardness, alkalinity, TDS and major ions in the unnamed waterbodies were likely

due to larger proportion of groundwater contribution to these lakes relative to that in Kearl Lake. Sulphide concentrations exceeded guideline values mainly in winter and in one summer sample. Winter TSS concentrations were higher than concentrations in Kearl Lake; however, concentrations in summer and fall were similar for all lakes. Because the unnamed waterbodies are much smaller than Kearl Lake, they could have easily been affected by high TSS load from beaver activity.

Similar to Kearl Lake, the unnamed waterbodies had the highest nutrient concentrations in winter, lowest in spring and slight increase throughout summer and fall. Ammonia and nitrate-nitrite concentrations were lower than the aquatic life guideline values and these concentrations were often below the detection limit. Total nitrogen concentrations were often higher than the aquatic life guideline value in winter and summer. However, total phosphorus exceeded guideline values only during winter.

Total metal concentrations in the unnamed waterbodies were often low. The following guideline exceedences were observed:

- chromium and iron concentrations were higher than the chronic guideline values during about 50% of the time;
- methyl mercury concentration exceeded the chronic aquatic guideline value in one sample collected in winter 2006; and
- zinc concentrations exceeded the corresponding chronic guideline values in two samples.

Concentrations of total recoverable hydrocarbons and naphthenic acids were often below detection limits, but total phenolics levels in winter and summer frequently exceeded the aquatic life guideline value. There were no PAH data available for these lakes.

The limited data available for whole effluent toxicity indicated that the unnamed waterbodies were generally non-toxic, with the exception of minor reproductive and mortality effects on *Ceriodaphnia dubia* and slight mortality effects on fathead minnow in one sample.

Sediment

Sediment quality data for unnamed waterbodies consisted of two samples. The sediment tended to be composed of appreciable amounts of sand, silt and clay, although the sand fraction was higher than the other finer materials. This was different from what was observed for Kearl Lake whose sediments were

primarily made up of silt and clay with sand contributing only a minor fraction. However, total carbon and organic carbon content of the sediment was high and similar to those in Kearl Lake. The inorganic portion of the carbon content in the unnamed waterbodies was relatively small, but the levels were higher than those in Kearl Lake. Total metal and PAH concentrations were below guidelines in the sediments. Total recoverable hydrocarbon levels tended to be higher than in Kearl Lake, but total volatile hydrocarbons and total extractable hydrocarbon concentrations were similar for the unnamed waterbodies and Kearl Lake. Toxicity data indicated slight effects on survival of *Chironomus tentans* and both growth and survival effects on *Hyalella azteca*.

3.5 PIERRE RIVER MINING AREA RESULTS

Because no appropriate historical water and sediment quality data within the Pierre River Mining Area (PRMA) exists, all the water and sediment quality data used to describe environmental setting conditions in the PRMA have been collected between 2005 and 2007 (Table 3.5-1) from a field program specifically designed for this Project. The data have been grouped by monitoring locations as follows:

- Pierre River watershed;
- Eymundson Creek watershed;
- Big Creek watershed; and
- Redclay Creek watershed.

Dividing the data into these groups allows for spatial comparison of water quality within and outside the PRMA. However, comparison with water and sediment conditions in watersheds outside the PRMA is limited due to relatively small number and short duration of the sampling program in this mining area. The data are summarized in Appendix F, Tables F-29 to F-37.

Table 3.5-1 Water and Sediment Quality Data Sampling in the Pierre River Mining Area

Location	Category	Number of Sampling Sites	Sampling Site	Data Source	Measurements	
					Total Number	Duration
Pierre River watershed	water quality	3	WQ-7, WQ-8, WQ-25	Golder (current study)	13	2005 to 2006
	sediment quality	1	WQ-7	Golder (current study)	1	2005
Eymundson Creek watershed	water quality	5	WQ-9, WQ-10, WQ-11, WQ-13, WQ-37	Golder (current study)	22	2005 to 2007
	sediment quality	2	WQ-9, WQ-13	Golder (current study)	2	2005
Big Creek watershed	water quality	11	WQ-14, WQ-27, WQ-32, WQ-33, WQ-34, WQ-35, WQ-36, WQ-41, WQ-42, WQ-43, WQ-20	Golder (current study)	76	2005 to 2007
	sediment quality	5	WQ-27, WQ-32, WQ-34, WQ-43, WQ-20	Golder (current study)	5	2005 to 2006
Redclay Creek watershed	water quality	4	WQ-44, WQ-45, WQ-48, WQ-49	Golder (current study)	28	2006 to 2007
	sediment quality	2	WQ-44, WQ-49	Golder (current study)	2	2006
unnamed waterbodies[(a)]	water quality	10	WQ-19, WQ-21, WQ-26, WQ-28, WQ-29, WQ-38, WQ-39, WQ-40, WQ-46, WQ-47	Golder (current study)	64	2005 to 2007

(a) The unnamed waterbodies are located within the watersheds listed above.

3.5.1 Pierre River

Water Quality

Water quality data for the Pierre River watershed includes four seasons of data from two locations on the Pierre River and one location on an unnamed tributary to the river (Table 3.5-1). These data are summarized in Appendix F, Table F-29.

The DO levels were high with no concentrations lower than the acute or chronic aquatic life guideline values. However, the DO concentrations in winter tended to be lower that those in other seasons. The TOC, DOC and colour levels were similar to those in the lower Muskeg River. The Pierre River and its tributaries were alkaline with laboratory-measured pH ranging from 7.4 to 8.3.

Concentrations of hardness, alkalinity, TDS and major ions were generally similar to observed values in the lower Muskeg River. However, TDS levels in summer and chloride and sodium concentrations in winter tended to be higher than those in the lower Muskeg River, probably due to higher proportion of groundwater contribution to flows in the Pierre River. Available data for alkalinity, TDS and major ions indicated concentrations of these parameters were generally higher in winter than in other seasons. This seasonal trend resembled that observed for other watercourses and waterbodies within the LSA and RSA.

The higher winter chloride concentrations within the Pierre River watershed did not exceed the chronic aquatic life guideline value. However, sulphide concentrations occasionally exceeded the chronic aquatic life guideline value, despite the well-oxygenated conditions of streams within the watershed.

The TSS concentrations were lower than 25 mg/L, with values in the higher end of the range occurring in winter and spring. Beaver activity in winter and higher overland flow in spring likely contributed to the seasonal TSS trend. Ammonia and nitrate-nitrite concentrations were higher in the winter, but these concentrations did not exceed chronic aquatic life guideline values in all seasons. Total nitrogen concentrations occasionally exceeded the chronic aquatic guideline value, but total phosphorus levels were consistently higher than the guideline value, except for one sample collected in spring 2006. The phosphorus concentrations in winter tended to be associated with TSS and mainly in the particulate form, but the concentrations in other seasons had appreciable proportion in the dissolved form.

Total metal concentrations were generally low and often below the applicable aquatic life guideline values, with some exceptions. Total aluminum, iron and

chromium concentrations exceeded the chronic aquatic life guideline values in almost all samples. Arsenic, copper and selenium concentrations in the winter 2006 sample from WQ-8 and zinc concentration in a spring 2006 sample from WQ-25 exceeded the corresponding chronic aquatic life guideline values. Total recoverable hydrocarbon concentrations were below detection in all samples and naphthenic acid levels did not exceed 3 mg/L. Total phenolics concentrations were high with all samples exceeding or equal to the chronic aquatic life guideline value. PAH concentrations were all below detection limit, with the exception of naphthalene (0.03 mg/L) in fall 2005. This detected PAH value was appreciably lower than the aquatic life guideline value. Water toxicity was not measured in this watershed.

Sediment

One sediment sample was collected from the mouth of the Pierre River in September 2005 (Table 3.5-1). This sample showed that the sediments were composed primarily of sand and both organic and inorganic carbon content were lower than those in the lower Muskeg River (Appendix F, Table F-30). Total recoverable hydrocarbon and total volatile hydrocarbon concentrations were within the same order of magnitude as the corresponding median values in the lower Muskeg River. However, the total extractable hydrocarbon level was appreciably lower than the median value for the lower Muskeg River.

Metal concentrations in the sediments were generally low and no sediment quality guideline values were exceeded in the sample. The PAH levels for some parameters were slightly elevated. These parameters included benzo(a)anthracene and chrysene that had concentrations exceeding the corresponding ISQG values. The Pierre River watershed had no sediment toxicity data.

3.5.2 Eymundson Creek

Water Quality

Water quality information for the Eymundson Creek watershed consists of four seasons of data collected between 2005 and 2007 from five sampling locations on the creek and its tributaries (Table 3.5-1). Winter samples have been collected from only the mainstem of Eymundson Creek because the waters of all other sampling locations became frozen and dry to the ground. Data for the creek are summarized in Appendix F, Table F-31.

Watercourses in the Eymundson Creek watershed were well oxygenated from spring through fall. The winter season had low DO levels (less than 3 mg/L) that were appreciably below the acute aquatic life guideline value. One fall

measurement was lower than the chronic aquatic life guideline value, and one summer (2007) measurement (3.5 mg/L) was lower than the acute guideline value. The BOD concentrations did not exceed 6 mg/L.

The TOC and DOC concentrations and colour units were generally similar to those in the Pierre River watershed in spring through fall, but winter values of these parameters were much higher in the Eymundson Creek watershed. The water was neutral to alkaline, except one winter measurement which had a pH of 6.6. The pH values were within the compliance range for the aquatic life guideline.

Hardness, alkalinity, TDS and major ions tended to be similar to observed values and seasonal trends in the Pierre River watershed with the highest values during winter. Similar to other small streams in the LSA and RSA, sulphide concentrations were generally high in this watershed and often exceeded chronic aquatic guideline values in all seasons. The highest sulphide concentrations occurred in winter.

The TSS concentrations were appreciably higher than those observed in the Pierre River and streams in the Jackpine Expansion Mining Area (JEMA) in all seasons. Generally, the TSS levels were on the order of the concentrations in the Athabasca River. The TSS concentrations were high in all seasons, with the highest values in spring followed by summer, and the lowest concentrations in winter.

Ammonia and nitrate-nitrite concentrations were generally low, except for winter levels of ammonia, which were consistently much higher than values observed in the Pierre River and streams in the JEMA. The winter ammonia concentrations were up to 3.9 mg/L, but these concentrations were less than the chronic aquatic life guideline value for winter. Total nitrogen and total phosphorus concentrations in all seasons were generally higher than in Pierre River and streams in the JEMA. The concentrations were especially high during winter when all total nitrogen and phosphorus values exceeded the chronic aquatic life guideline value. Concentrations in the other seasons were also frequently higher than the corresponding guideline values. The high nitrogen and phosphorus concentrations were due to high proportion of particulate forms associated with the high TSS levels in Eymundson Creek and its tributaries.

Metals that occurred mostly in the particulate form had high concentrations exceeding aquatic life guideline values and a seasonal trend similar to that for TSS. The seasonal trend had the highest concentrations in spring and summer, followed by fall and the lowest concentrations in winter. These metals included aluminum, cadmium, chromium, copper, lead, mercury, silver, thallium and zinc.

Total aluminum, chromium, copper, lead, mercury and zinc concentrations were often higher than the chronic aquatic guideline values, while arsenic, cadmium, iron mercury, selenium and silver occasionally exceeded the corresponding guideline values. The thallium concentration in one spring sample exceeded the guideline value.

Iron concentrations were particularly high in Eymundson Creek in spring (more than 115 mg/L) when TSS concentration was exceptionally high and in winter (more than 80 mg/L) when the oxygen concentrations were low. A significant proportion of the iron was in the dissolved phase at the time as opposed to the other seasons when dissolved iron concentrations were much lower than the total concentration. Total iron and dissolved iron concentrations were higher than the chronic aquatic life guideline value in all samples.

Arsenic concentrations were high in winter, spring and summer with at least one value exceeding the chronic aquatic guideline in each of these seasons. Selenium concentrations in each season were often higher than the aquatic life guideline value. Concentrations of zinc during spring (0.542 mg/L) and summer (0.447 mg/L) of 2007 were significantly higher than observed values in other seasons.

The PAH levels were low and generally not detectable. The detected concentrations in a small number of samples were below the corresponding aquatic life guideline values.

Total recoverable hydrocarbon values were consistently below the detection limit, while naphthenic acids concentrations did not exceed 3 mg/L. Similar to other streams in the LSA, total phenolics were elevated with all concentrations at or exceeding the chronic aquatic life guideline value.

A water toxicity sample collected in fall 2005 showed reduction in reproduction of *Ceriodaphnia dubia*.

Sediment

Two sediment samples were collected from the Eymundson Creek watershed in October 2005: one from Asphalt Creek and the other from Eymundson Creek (Table 3.5-1). These samples showed that the sediments were composed of a mixture of sand, silt and clay particles with low carbon content (Appendix F, Table F-32). The inorganic, organic and total carbon content were similar to those in Pierre River. Metal concentrations in the sediments were generally low, except for arsenic and zinc. Arsenic concentrations in both samples exceeded the ISQG and PEL values and zinc concentration in one sample was higher than the

ISQG value. The PAH levels were low and did not exceed sediment quality guideline values. Based on the available limited data, total recoverable, volatile and extractable hydrocarbon levels were on the same order of magnitude as those observed in Pierre River. A sediment toxicity measurement showed slight reduction in survival of *Hyalella azteca* and *Lumbriculus variegates*.

3.5.3 Big Creek

Water Quality

Water quality data for the Big Creek watershed were based on four seasons of sampling between 2005 and 2007. The sampling locations included four sites on Big Creek, four on unnamed tributaries to Big Creek and one on First Creek.

Generally, water quality in streams within the Big Creek watershed was similar to that described for the Eymundson Creek watershed. However, the Big Creek watershed often showed a wider range of variability of parameter values, likely due to a larger number of sampling points pooled from several watercourses. There were few constituents with lower concentrations within the Big Creek watershed relative to the corresponding values in Eymundson Creek.

Watercourses in the Big Creek watershed, except First Creek, were well oxygenated throughout most of the year (Appendix F, Table F-33). Samples collected from First Creek and Unnamed Creek 2 exhibited low DO concentrations below the acute aquatic life guideline value throughout the year. The BOD concentrations typically did not exceed 10 mg/L, except for two winter 2007 samples in Unnamed Creek 2 and Big Creek at the mouth with values of 59 and 36 mg/L, respectively, and one fall measurement in First Creek with a value of 68 mg/L. All these high BOD measurements coincided with high TSS concentrations in the samples.

Generally, TOC and DOC concentrations and colour units tended to be slightly lower in the Big Creek watershed relative to values in Eymundson Creek. However, one winter 2007 sample from Unnamed Creek 2 had higher values than observed concentrations in Eymundson Creek. Colour units were also higher in winter 2006 samples from Unnamed Creeks 2 and 6.

The watercourses within the Big Creek watershed were typically neutral to alkaline with pH values within the aquatic life guideline range, except one measurement (pH equals 5.9) during spring 2007. Values and seasonal trends in hardness and alkalinity and major ions were similar to those for Eymundson Creek, with the highest concentrations occurring often in winter. Sulphide

concentrations were high in the Big Creek watershed with measured values typically exceeding the chronic aquatic life guideline in all seasons.

TSS concentrations were appreciably lower than observed values in Eymundson Creek, especially from spring to fall. The only exceptions in winter were four samples from Unnamed Creeks 2 and 7 and Big Creek north of Lease 17 and at the mouth, which had TSS values higher than the winter concentrations in Eymundson Creek. However, the TSS concentrations in watercourses within the Big Creek watershed were higher than those for streams in the Jackpine Expansion Mining Area. In contrast to TSS concentrations in the Big Creek watershed, the observed TSS concentration (6,120 mg/L) in an upstream site on Big Creek during spring 2007 was significantly higher than other TSS measurements within the watershed.

Ammonia and nitrate-nitrite concentrations were generally low, but similar to Eymundson Creek, some high ammonia concentrations were occasionally observed in winter. However, the ammonia concentrations did not exceed the aquatic life guideline value. Total nitrogen and total phosphorus concentrations were generally high with, at least, one value exceeding the chronic aquatic life guideline in each season. Concentrations of total nitrogen and phosphorus were especially high in one sample collected in February, 2007 (153 and 22.3 mg/L respectively). This sample had the highest TSS measurement for the watershed.

Metal concentrations showed less seasonal variations compared to trends observed in Eymundson Creek. However, the range of measured concentrations was often different among the seasons, likely due to pooling of data from several streams within the watershed. Metals that are generally in the particulate phase and often associated with TSS, such as aluminum, cadmium, chromium, copper, iron, lead, mercury, silver and zinc exceeded aquatic life guideline values. Among these metals, very high aluminium concentration of 51.1 mg/L was observed in a spring 2007 water sample from Big Creek. However, the concentrations of these metals were often lower than those in Eymundson Creek, except for few winter samples which had exceptionally high concentrations. Total iron concentration was particularly high in a winter 2007 sample (i.e., 908 mg/L) and a spring 2007 sample (i.e., 116 mg/L) from Big Creek , although the dissolved iron concentration in the samples were only 0.058 and 0.91 mg/L, respectively.

At least one arsenic sample collected during winter, spring, and summer exceeded chronic aquatic life guideline value. Selenium concentration exceeded the aquatic life guideline value in several winter, summer, and spring water samples. Unlike sampling sites within PRMA, watercourses in the Big Creek watershed had nickel concentration exceeding chronic guideline value in spring

2007. Similarly, silver concentration exceeded chronic guideline in winter, spring, and summer. Water samples collected during spring and summer 2007 had significantly higher zinc concentrations than corresponding measurements in the Big Creek watershed.

Total recoverable hydrocarbon and naphthenic acids and concentrations were below detection in most of the samples collected from the watershed. Exceptions to the non-detected concentrations were three naphthenic acids concentrations between 1 and 2 mg/L and one winter 2007 measurement of 12 mg/L in Unnamed Creek 2. Total phenolics concentrations were elevated in the watershed with values frequently exceeding the chronic aquatic life guideline value in each season.

Generally, PAH levels were not detected in water samples from the Big Creek watershed. Occasionally detected values in spring and summer were at low concentrations below aquatic life guideline values.

One toxicity sample collected during fall 2006 from the mouth of Big Creek showed no mortality, growth or reproductive effects on laboratory test organisms.

Sediment

Five sediment samples were collected from the Big Creek watershed in the fall of 2005 and 2006 - two from Big Creek, one from Asphalt Creek and one from the Unnamed Creeks 2 and 14 (Table 3.5-1). The statistical summary of these samples (Appendix F, Table F-34) showed that the sediments were composed primarily of sand with low carbon content. The carbon content and total recoverable, volatile and extractable hydrocarbons concentrations were within the same magnitude as the corresponding values in Eymundson Creek. Metal and PAH concentrations in the sediments were generally low as in Eymundson Creek with only arsenic exceeding the ISQG value and PEL. One toxicity measurement indicated that the sediment slightly reduced survival of *Chironomus tentans* and growth of *Lumbriculus variegates*.

3.5.4 Redclay Creek

Water Quality

Water quality data for the Redclay Creek watershed consist of four seasons of sampling in 2006 and 2007 from three locations on Redclay Creek and one site on an unnamed tributary to Redclay Creek (Table 3.5-1).

Watercourses in the Redclay Creek watershed were often well-oxygenated (Appendix F, Table F-35). However, three out of eight winter DO concentrations and two out of five summer DO concentrations were lower than the acute aquatic guideline value. The TOC and DOC concentrations and colour units were similar to corresponding values in the lower range for streams in the Big Creek watershed. The watercourses were alkaline with pH values consistently within the aquatic life guideline range.

Values of hardness, alkalinity, TDS and major ions in winter were often in the lower range for the corresponding concentrations in watercourses within the Big Creek watershed. However, values of these parameters in spring through fall were similar for watercourses in the Redclay and Big Creek watersheds. Therefore, concentrations of these parameters in the Redclay Creek watershed showed little or no seasonal trends with winter values that were often similar to slightly higher than those in other seasons. The lack of strong consistent variability of seasonal values for hardness, alkalinity, TDS and major ions confirmed that this watershed is different from most surface waters in the LSA and RSA. The similarity or small differences in seasonal parameter values further suggested that contribution of groundwater to streamflow is negligible or the groundwater input is mainly from a freshwater aquifer with low amounts of dissolved substances.

Again, unlike other small streams within the LSA and RSA, sulphide concentrations were lowest in winter and highest in summer. The sulphide concentrations, in at least one sample during each season from spring through fall, were higher than the guideline value. Winter concentrations of sulphide were consistently lower than the guideline value, with the exception of a sample collected in winter 2007.

The TSS concentrations were generally below 40 mg/L, except for one fall value of 138 mg/L. Apart from the single high TSS concentration in fall, there was little seasonal trend for this parameter. Ammonia and nitrate-nitrite concentrations were generally low and did not exceed any water quality guidelines. Total nitrogen concentrations were lower than those in the Pierre River, Eymundson and Big Creek watersheds, with only one value that exceeded the chronic aquatic life guideline value. Total phosphorus concentrations were lower than those observed values in the Eymundson and Big Creek watersheds, but similar to concentrations in Pierre River. The total phosphorus levels in every season frequently exceeded the chronic aquatic life guideline value.

In general, metal concentrations were appreciably lower in the Redclay Creek watershed than in the surrounding watersheds; however, the concentrations of some metals were higher than the corresponding guideline value. All of the total

iron values, except two summer measurements, exceeded the chronic aquatic life guideline value. Total chromium and zinc concentrations were high in spring, when all of the samples exceeded the chronic aquatic life guideline values. Maximum concentrations of chromium in winter and summer and zinc in winter also exceeded the corresponding guideline values. Total aluminum concentrations were appreciably lower in the Redclay Creek watershed; however, one value each in spring and summer exceeded the chronic aquatic guideline value. Selenium concentrations in two samples collected in the winter 2007 were higher than the chronic aquatic life guideline value.

Total recoverable hydrocarbon and naphthenic acids concentrations were low with all measurements below or at the detection limit. Total phenolics concentrations were lower that in the surrounding watersheds, but the concentrations still frequently exceeded the chronic aquatic life guideline value.

The PAH concentrations from the Redclay Creek watershed were generally not detected, except for naphthalene and C1 substituted naphthalenes concentrations. The detected concentrations of these parameters were below the aquatic life guideline value.

A toxicity measurement in fall 2006 showed slight reduction in reproduction of *Ceriodaphnia dubia*.

Sediment

Two sediment samples were collected from the Redclay Creek in fall 2006 (Table 3.5-1). These samples (Appendix F, Table F-36) showed that the sediments of Redclay Creek were composed of about the same proportions of sand, silt and clay. Carbon content in the sediments was moderate with values higher than those observed in Pierre River, Eymundson and Big Creek watersheds, but lower than those observed in the Muskeg River watershed. Metal and PAH levels in the sediments were generally low with only arsenic and C1 substituted naphthalenes concentrations in one sample exceeding the corresponding ISQG values.

Total recoverable and extractable hydrocarbon concentrations were appreciably higher than those measured in watercourses within the Pierre River Mining Area. However, the levels of these parameters were similar to observed concentrations in the lower Muskeg River. Total volatile hydrocarbons were below detection limits.

Sediment toxicity was measured in one fall sample. The measured data indicated small reduction in growth and survival of *Lumbriculus variegates*.

3.5.5 Unnamed Waterbodies

Water Quality

Water quality sampling and analysis of 10 lakes in the PRMA have been undertaken between 2005 and 2007. A summary of the water quality data is presented in Appendix F, Table F-37.

The unnamed waterbodies were often well oxygenated from spring through fall. However, winter DO levels below the acute aquatic life guideline value were frequently observed in several of the lakes. Unnamed Waterbody 11 had one summer DO value below the acute aquatic life guideline value and Unnamed Waterbody 12 had a spring concentration below this guideline value. The observed DO concentrations were typical for lakes within the LSA and RSA that experience declining oxygen levels during the winter ice-cover period due to lack of atmospheric oxygen reaeration and use of lake oxygen by bottom material.

The TOC, DOC and colour tended to have a wide range of values, likely due to the effect of pooling together data for several lakes within PRMA. Unnamed Waterbody 15 had particularly high values for these parameters during winter 2007. However, values of these parameters in the lower end of the range were similar to those observed in Kearl Lake and unnamed waterbodies within the Muskeg River watershed.

Values of pH generally ranged from neutral to alkaline. Unnamed Waterbodies 5, 8 and 10 consistently had seasonal pH levels higher than the upper limit of the aquatic life guideline value. The highest pH values occurred in Unnamed Waterbody 5 which also had the highest levels of alkalinity among all the lakes with pooled data.

Concentrations of hardness, alkalinity, TDS and major ions varied greatly between lakes and seasons. These concentrations were generally much higher than corresponding values in Kearl Lake, but only slightly higher than unnamed waterbodies in the Muskeg River watershed. Concentrations of these parameters were generally highest in winter and lowest in spring, which is typical for waterbodies in the LSA and RSA. Observed concentrations in summer showed a wide range and tended to be only slightly lower than winter levels. Concentrations in fall were intermediate between spring and summer. None of the parameter concentrations exceeded aquatic life guideline values.

Exceptionally high sulphide values, ranging from 1 to 7.1 mg/L were observed in winter in several samples from about 50% of the unnamed waterbodies. These sulphide concentrations in winter were appreciably higher than levels measured

in other waterbodies and watercourses within the LSA and RSA. Relatively high sulphate and low DO concentrations occurring simultaneously in the lakes could be responsible for these high sulphide values. The sulphide concentrations in winter and other seasons frequently exceeded aquatic life guideline values.

The TSS concentrations were high compared to values in other lakes within the JEMA. The concentrations were often less than 40 mg/L, but high values, up to 160 mg/L, were measured in Unnamed Waterbodies 6, 8, 14 and 15 during winter and from Unnamed Waterbody 8 during summer 2006. The higher winter concentrations were likely due to beaver activity.

Ammonia and nitrate-nitrite concentrations were generally low and did not exceed aquatic life guideline values. However, winter values of ammonia tended to be much higher than values in other seasons. Total nitrogen and total phosphorus concentrations in over half of the unnamed waterbodies and in every season frequently exceeded the aquatic life guideline values. Concentrations of nutrients, including ammonia, nitrate-nitrite, organic nitrogen, dissolved and particulate phosphorus, were generally higher than the corresponding levels in other waterbodies within the LSA and RSA.

The high nutrient levels produced consistently high chlorophyll *a* concentrations up to 40 µg/L and exceptionally high values of 94 and 136 µg/L in Unnamed Waterbody 11 (summer 2006) and Unnamed Waterbody 15 (summer 2007), respectively. These high concentrations were likely to contribute to the generally high pH values observed in these waterbodies.

Metal concentrations were generally low, except for aluminum and iron. Concentrations of aluminum and iron were highest in winter. Aluminum levels occasionally exceeded the chronic aquatic life guideline value, while iron concentrations in every season were often higher than the guideline value. Total chromium concentrations were high from winter through summer, with concentrations in more than 50% of the lakes exceeding the chronic aquatic life guideline values. Total arsenic, copper and methyl mercury concentrations in winter exceeded the chronic aquatic life guideline value in one of the lakes. Concentrations of zinc from winter to summer were occasionally higher than the chronic aquatic life guideline value.

Total recoverable hydrocarbon and naphthenic acids concentrations were low with measured values typically below or at the detection limit. Total phenolics concentrations were high in all seasons and often exceeded the chronic aquatic life guideline value.

The PAHs were measured in Unnamed Waterbody 6 during winter 2007. This sample showed that all of the PAHs were below the corresponding detection limit except for naphthalene and C1 substituted naphthalenes. The detected concentrations were appreciably lower than the corresponding aquatic life guideline values.

One toxicity sample was collected and analyzed for Unnamed Waterbody 14 during fall 2005. The sample showed no effects on laboratory test organisms. However, water quality for this sample included a high DO level, low sulphide, total phenolics and ammonia concentrations and pH value within the aquatic life guideline range. Toxicity samples from sites with low DO, high concentrations of sulphide, phenolics and ammonia, and pH values outside the guideline range could show some effects on laboratory test organisms.

Sediment

No sediment quality information exists for the unnamed waterbodies in the PRMA.

3.6 ACID SENSITIVITY

The various factors influencing the impact of acid deposition on surface waters include the amount of acid-causing substances deposited, buffering capacity of surrounding soils and water, and the characteristics and composition of acid-reaction products. Acid sensitivity is related to potential impacts on biotic communities. However, the commonly method for assessing acid sensitivity analyzes water parameters, such as alkalinity, pH and critical loads.

3.6.1 Watercourses

The primary concern regarding acidification of watercourses is episodic acidification, which is a decrease in pH that occurs during hydrological events such as spring snowmelt or rainfall. This episodic acidification, also referred to as a spring acid pulse, is a widespread natural phenomenon in surface waters (Sullivan 2000). However, acidic deposition from industrial sources can also contribute to episodic acidification, which can result in a more severe depression of pH and a longer recovery period.

The sensitivity of streams to spring acid pulse depends on several factors related to runoff and basin characteristics. Streams that are the most sensitive have the following characteristics (Sullivan 2000):

- small;
- high elevations;
- steep topography;
- extensive areas of exposed bedrock;
- deep snowpack; and
- shallow base-poor soils.

The primary indicator of acid sensitivity in streams is acid neutralizing capacity. The generally accepted categories of acid sensitivity (Table 3.6-1) are based on Boward et al. (1999). Musselman (1996) specified spring baseflow as the basis for assessing acid sensitivity. An annual average acid neutralizing capacity of 150 µeq/L (microequivalents per litre) is accepted as the minimum threshold for acid neutralization; that is, any stream with a capacity less than this threshold are designated as acid sensitive. This threshold is based on the lack of response by fish populations to acid deposition in streams with acid neutralizing capacity above 150 µeq/L (Brewer et al. 2000).

Table 3.6-1 Acid Sensitivity Values of Streams Based on Acid Neutralizing Capacity

Acid Sensitivity	Acid-Neutralization Capacity [µeq/L]
acidic	<0
highly sensitive	0 to 50
sensitive	50 to 200
not sensitive	>200

Source: Boward et al. (1999).

A study by AENV between 1998 and 2001 showed the presence of spring acid pulses of low magnitudes in rivers and streams, which was also confirmed by Western Resource Solutions (WRS 2002). Western Resource Solutions observed acid pulses in Firebag and Steepbank rivers and small pH depressions in Muskeg River. Their analysis further related the decline in acid neutralization capacity with melting waters (accounting for more than 90%) and natural organic acids (up to 6.5%). Additionally, the decline attributable to sulphate (presumably derived from air emissions) was typically more than 1% with a maximum of 4.5% in the Firebag River.

The available information suggests that rivers and streams in the LSA and RSA are not likely to be highly sensitive to spring acid pulses. Watershed characteristics in this area are generally inconsistent with those of acid-sensitive streams. The seasonal minimum alkalinity measurements in small streams and

rivers draining the LSA and RSA were between 8 and 103 mg/L as $CaCO_3$, or 160 and 2,060 µeq/L (Appendix F, Table F-38).

Generally, negligible or no decrease in pH was observed from winter to spring (Appendix F, Table F-38). Some of the recorded critical field pH values were 4.5 in the lower Muskeg River, 6.3 in Eymundson Creek and 6.4 in the Lower Athabasca River. Although observed field pH value in the lower Muskeg River was 4.5, the corresponding laboratory-measured pH value was 7.6. Therefore, the reliability of the field measurement was questionable in this particular case. Furthermore, as presented in Table L-38, only small pH depressions were recorded in some rivers and streams during different seasons. The maximum pH and alkalinity values were not shown because maximum values are not relevant to acid sensitivity.

3.6.2 Waterbodies

Lakes vary in their level of sensitivity to acid deposition, depending on a variety of factors within their drainage basins. The most important of these factors include surficial geology, topography, hydrology, vegetation and climate. Acid sensitivity is usually evaluated by analyzing samples of lake water for chemical constituents. Alkalinity is the most important constituent for evaluating acid sensitivity in lakes. Acid sensitivity can be evaluated by comparing alkalinity measured in a lake with a generally accepted scale of acid sensitivity. Acid-sensitive lakes share the following characteristics, as summarized by Sullivan (2000):

- concentrations of all major ions are low and conductance is less than 25 µS/cm ;
- alkalinity and acid neutralizing capacity are less than 10 mg/L as $CaCO_3$ or 0.2 meq/L;
- concentrations of base cations (Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}) in pristine areas are generally less than 0.1 meq/L;
- concentrations of organic acid or DOC are generally less than 5 mg/L;
- pH is generally below 6.5; and
- physical characteristics are as follows:
  - moderate to high elevation;
  - high relief;
  - severe short-term changes in hydrology;

- minimal contact between drainage waters and soils or geologic material that may contribute weathering products to solution; and
- small drainage basins that derive much of their hydrologic input as direct precipitation to the lake surface.

Saffran and Trew (1996) present a scale of lake sensitivity to acidification (Table 3.6-2) based on alkalinity and a sensitivity map of Alberta lakes using available data for 1,156 lakes.

Table 3.6-2 Acid Sensitivity Rankings for Lakes and Ponds

Acid Sensitivity	Alkalinity [mg/L as $CaCO_3$][(a)]
high	<10
moderate	11 to 20
low	21 to 40
least	>40

(a) Saffran and Trew (1996).

The lakes in the regional and local study areas do not typically have the characteristics of acid-sensitive lakes, with the exception that some of them have small basins. Using the lakes classification systems of Saffran and Trew (1996), alkalinity data (Appendix F, Table F-39) suggest that all the lakes have negligible sensitivity to acidification.

Lakes and ponds in the Oil Sands Region are generally not highly sensitive to acid deposition, with the exception of a few clusters of lakes in upland regions. Many of these lakes are monitored annually by RAMP for indicators of acidification (Hatfield et al. 2004). The potentially sensitive lakes are located in the Birch, Muskeg and Stony mountains (Petro-Canada 2001). The closest of these to the environmental setting sampling sites is the Muskeg Mountains located along the southeast edge of the regional and local study areas.

3.7 SUMMARY

3.7.1 Overview

Current surface water and sediment quality conditions in surface waters within the LSA and RSA were characterized based on historical information from fall 2005 to summer 2007. The data were collected by RAMP, Alberta Environment and various industries, and included recent data from an extensive two-year field program conducted by Shell Canada as part of the Project.

The Athabasca River shows little or no changes in water and sediment quality from upstream of the Oil Sands Region to the Embarras River. However, some differences exist between water and sediment quality in the Athabasca River and its tributaries downstream of Fort McMurray.

Water and sediment quality in the lower reach of the Firebag River and watercourses in the McClelland Lake and Muskeg River watersheds are typical for small streams in the Oil Sands Region. Water and sediment quality of lakes in these watersheds are also similar to those observed in other waterbodies in the region. Nevertheless, some water and sediment quality parameters show minor differences and slight spatial trends for the streams and lakes in the LSA and RSA.

General characteristics of streams and lakes in the PRMA show more variability in water and sediment quality among watersheds compared to conditions within the Jackpine Expansion Mining Area. Water quality in the Pierre River and Redclay Creek watersheds are generally closer to those in the Jackpine Expansion Mining Area, but conditions in Eymundson Creek and Big Creek watersheds are appreciably different for several parameters, such as major ions, TSS, nutrients and metals. Spatial trends of sediment quality in these watersheds appear to be different for each group of sediment parameters. Regulatory guideline values for some water and sediment quality parameters are being exceeded in certain watercourses and waterbodies. The substances that exceed guidelines are mainly from natural watershed contributions or water and sediment quality processes.

Some key differences between surface waters within JEMA and PRMA were observed for DO, TSS, nutrients and metals. Generally, DO concentration in small streams and lakes within JEMA and PRMA during winter and occasionally in other seasons was lower than acute or chronic aquatic life guideline values, but the lower Athabasca River had DO levels that consistently met these guidelines. TSS concentrations in streams within JEMA were significantly lower than those in the lower Athabasca River. Eymundson Creek and Big Creek had TSS concentrations that were often similar to or slightly lower than those observed in the lower Athabasca River. The high TSS values in the lower Athabasca River, Eymunson Creek and Big Creek corresponded to high nutrient and metal concentrations. However, the frequency of exceedances of guideline values by nutrients and metal concentrations in the lower Athabasca River, Eymundson Creek and Big Creek were not significantly different from those observed for surface waters within JEMA and other watercourses and waterbodies within PRMA.

Water quality and physical characteristics of lakes and streams within the LSA and RSA indicate that these surface waters have low sensitivity to acid input.

3.7.2 Athabasca River

3.7.2.1 Water Quality

Dissolved oxygen concentrations in the lower Athabasca River were often high, but were lower than chronic aquatic life guideline values on rare occasions in every season. The river was slightly alkaline and moderately soft. Its hardness, alkalinity, TDS and major ions concentrations generally increased in the winter, under low flow conditions. Concentrations of TSS and particulate-bound nutrients and total metals increased in the spring and summer, under higher flows. Total phosphorus and total nitrogen concentrations were higher than the corresponding water quality guidelines in all seasons, while guideline values were exceeded periodically for several metals, including aluminum, arsenic, cadmium, chromium, hexavalent chromium, copper, iron, lead, mercury, nickel, selenium, silver and zinc. The levels of organics and PAHs were generally low. Naphthenic acids were often lower than 1 mg/L, but occasionally had localized levels as high as 20 mg/L. There was little or no toxicity observed in the river.

Concentrations of conventional water quality parameters were typically different for the lower Athabasca and the Muskeg rivers, but seasonal trends were similar. The TOC, DOC and colour levels were lower in the lower Athabasca River than in the Muskeg River. The lower levels of these parameters in the lower Athabasca River were mainly due to the smaller proportion of bog areas relative to that in the Muskeg River watershed.

High TSS and associated particulate-bound nutrient and metal loadings were mainly from watershed sources upstream of the Oil Sands Region. These particulate-bound substances had concentrations that were often higher than guideline values, but as they were not biologically available, they had little effect on aquatic organisms. However, periods of high TSS concentrations in the Region have been noted to cause occasional stress to the aquatic ecosystem for short periods.

Bicarbonate, calcium and magnesium concentrations of the lower Athabasca River were lower than those in the Muskeg River. However, chloride, sodium, and sulphate levels were higher in the lower Athabasca River. Sulphide concentrations were typically under detection limits, but this parameter occasionally had concentrations in winter, summer and fall that exceeded the chronic aquatic life guideline value in the lower Athabasca River upstream of the Firebag River.

3.7.2.2 Sediment Quality

Particle size distribution and carbon content in sediments of the lower Athabasca River from Fort McMurrray to Embarras were generally similar to those in the Muskeg River downstream of Jackpine Creek. High sand and inorganic carbon contents were observed in the Athabasca River. Although median values of total recoverable hydrocarbon concentrations were comparable in all three segments, maximum concentration was higher in the upper Athabasca River. The highest maximum concentration of total extractable hydrocarbons occurred in the middle Athabasca River. Concentrations of a few metals were higher than the corresponding sediment quality guideline values. Chromium in all three segments, arsenic in the upper and middle reaches of the lower Athabasca River, cadmium and lead in the upper reach of the lower Athabasca River, and mercury in the middle reach of the lower Athabasca River exceeded the ISQG values. With few exceptions, concentrations of metals were higher in the Athabasca River relative to corresponding values in the Muskeg River. These exceptions included boron, calcium, iron, manganese, molybdenum, silver and uranium.

Concentrations of some PAHs exceeded sediment quality guideline values. These PAHs were naphthalene, C1-substituted naphthalenes, acenaphthene, acenaphthylene, dibenzo(a,h)anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, and phenanthrene and pyrene. The upper Athabasca River and middle Athabasca River had higher concentrations of PAHs exceeding guideline values compared to lower Athabasca River.

3.7.3 Lower Firebag River

3.7.3.1 Water Quality

The Firebag River was well oxygenated in all the seasons, except winter when DO concentrations were generally lower than the chronic aquatic life guideline value of 6.5 mg/L. The river was slightly alkaline with marginally higher TOC and DOC concentrations and darker colour than the Athabasca River.

Concentrations of hardness, TDS, conductance, alkalinity and major ions were generally similar or slightly lower than those observed in the lower Athabasca River. Seasonal trends of these parameters were similar in the Firebag and Athabasca rivers, with the lowest concentrations occurring in winter. Sulphide was often not detected, but occasionally some measured values, especially during winter and summer were higher than the chronic guideline values.

Total suspended solids concentrations in the Firebag River were considerably lower than in the lower Athabasca River. Consequently, concentrations of

phosphorus, nitrogen and metals often associated with TSS were also generally lower for the Firebag River.

In spite of the lower levels in the Firebag River, total phosphorus concentrations in every season exceeded the aquatic life guideline value, while total nitrogen concentrations in summer and fall were higher than the guideline value. Also, ten metals (aluminum, arsenic, cadmium, chromium, hexavalent chromium, copper, iron, mercury, silver and zinc) had higher concentrations than the corresponding aquatic life guideline values.

Recoverable hydrocarbons and naphthenic acids levels were very low and typically below detection limits. Total phenolics concentrations in every season, except summer, periodically exceeded aquatic life guideline values. Available toxicity data indicated that the background water in the Firebag River could cause slight or no toxic effects on aquatic life.

3.7.3.2 Sediment Quality

The particle size distribution of Firebag River sediment was dominated by sand with low carbon content compared to observed values in the upper Muskeg River. The general organic carbon concentrations were comparable to those in the lower Athabasca and Muskeg rivers. Maximum chromium concentration in the Firebag River sediment exceeded the ISQG. Metal concentrations in sediments were generally lower than those in the lower Athabasca and Muskeg rivers. None of the PAHs had concentrations exceeding the aquatic life guideline value.

3.7.4 McClelland Lake Watershed

3.7.4.1 Water Quality

McClelland Lake and Unnamed Creek 3, east of the lake, had high DO concentrations, except in winter when DO levels in the lake were occasionally less than 2 mg/L. However, the lake's inlet and outlet creek were poorly oxygenated in every season. Dissolved oxygen information was not available in the McClelland Lake Fen.

Total organic carbon, DOC and colour levels in the McClelland Lake Outlet Creek were appreciably higher than the levels of these parameters in other areas of the watershed. Laboratory-measured pH values were within the range for aquatic life guideline values, except one summer measurement in McClelland Lake with pH level higher than the guideline value. Concentrations of hardness,

TDS, alkalinity and major ions were typically lower than or similar to corresponding values in the Athabasca River; however, seasonal trends of these parameters were similar for surface waters in the McClelland Lake watershed and the lower Athabasca and lower Firebag rivers. Sulphide concentrations occasionally exceeded the chronic aquatic life guideline value.

Total suspended solids concentrations were appreciably low; therefore, concentrations of nutrients and metals often associated with and bound to suspended sediment were lower than levels in the Athabasca River. Total nitrogen and phosphorus concentrations only periodically exceeded aquatic life guideline values in McClelland Lake, and its inlet and outlet creeks. The number of metals with concentrations exceeding aquatic life guideline values was similar to that for Athabasca River, but the frequency of exceedance was typically lower for surface waters in the McClelland Lake watershed.

Recoverable hydrocarbons and naphthenic acids levels were appreciably low and typically below detection limits. Total phenolics concentrations in winter, spring or summer for McClelland Lake, McClelland Lake Inlet Creek and Unnamed Creek 3 frequently exceeded the aquatic life guideline value.

Polycyclic aromatic hydrocarbon and toxicity data were limited. The available PAH data showed concentrations that were generally lower than the detection limit, except concentrations of naphthalene in two samples from McClelland Lake. Toxicity effects were low and rare in the McClelland Lake watershed. Occasionally, laboratory tests using water from Unnamed Creek 3 resulted in slight mortality to fathead minnows.

3.7.4.2 Sediment Quality

Silt and clay dominated the particle size distribution of McClelland Lake sediment. Organic content was high in the sediment, contrary to levels in the lake's outlet and in Unnamed Creek 3. Parameter concentrations in sediments tended to be similar to those in the lower Firebag River, but were generally lower than the corresponding values in Muskeg River. Parameters concentrations in sediments within the McClelland Lake watershed were lower than the corresponding guideline values.

3.7.5 Jackpine Expansion Mining Area

3.7.5.1 Water Quality

The JEMA lies within the Muskeg River watershed. Watercourses and waterbodies in the watershed have water quality characteristics that are typical of bog systems in the Oil Sands Region. Low DO concentrations were observed only occasionally in spring through fall; however, low winter DO levels were frequent and sometimes lower than the acute aquatic life guideline value. The low DO concentrations were associated with high sulphide values that often exceeded aquatic life guideline values in watercourses and waterbodies.

The watercourses and waterbodies are dark brown due to high concentrations of TOC and DOC, especially in the headwater tributaries of the Muskeg River. Concentrations of TOC and DOC were lower and colour was less brown in the waterbodies, especially during spring. However, the Muskeg River was generally more brown than the lower Athabasca River. These surface waters were relatively alkaline with laboratory-measured pH values generally within guideline levels.

Levels of hardness, TDS, conductance, alkalinity and major ions were moderate, with higher values of these parameters occurring in winter. The high winter values can be attributed to a higher proportion of groundwater discharge in winter than in other seasons and salts expelled into the water column during the formation of ice-cover in early winter. Spring concentrations of the parameters in waterbodies within the watershed were slightly higher than the corresponding values in watercourses, except for sodium and sulphate. Hardness, TDS, conductance, alkalinity and major ions generally had higher concentrations in the upper Muskeg River than in the lower Athabasca River. However, spring concentrations were often similar to those in the middle reach of the lower Athabasca River. Furthermore, seasonal trends for these parameters were similar for surface waters in the Muskeg River watershed and in the Athabasca River.

Watercourses and waterbodies experience low TSS concentrations, with occasionally high levels in winter, likely due to beaver activity. Concentrations of TSS were typically lower in waterbodies than in watercourses. Nutrients and DOC were often high and the former exceeded water quality guideline values, reflecting inputs from peatlands. Total nitrogen and total phosphorus concentrations within the watersheds were much lower in lakes than in streams, with the exception of nitrogen concentrations in Kearl Lake.

Metals concentrations were generally low, but frequently or occasionally exceeded guideline values, depending on the parameter. The metals that

exceeded guideline values were aluminum, arsenic, cadmium, hexavalent chromium, copper, iron, lead, mercury, methyl mercury, nickel, selenium, silver and zinc. Recent measurements of mercury and silver, based on more sophisticated analytical methods, were below aquatic life guideline values. The high background concentrations of these metals are characteristic of natural surface waters in the Oil Sands Region.

Concentrations of organics were generally low. Naphthenic acids and total recoverable hydrocarbons were often below detection limits, but occasionally high concentrations occurred. However, concentration of total phenolics was often higher than the aquatic life guideline value. These organics occur naturally and originate mainly from soils that are rich in oil sands.

Toxic effects on laboratory test organisms were low and rare. Occasionally, laboratory tests using fathead minnows and *ceriodaphnia dubia* resulted in increased mortality or reduced growth relative to reference conditions. In addition, Microtox® tests suggested slight to no toxicity to aquatic organisms.

3.7.5.2 Sediment Quality

Bottom sediments of most streams in these watersheds were mainly sand with relatively small proportions of silt and clay. Kearl Lake sediment was dominated by clay and silt; however, sand was the major component of sediments in unnamed waterbodies. Carbon content mainly in the organic form was high in the upper Muskeg River, middle Muskeg River and in waterbodies. In the lower Muskeg River, organic and inorganic forms of carbon were present in approximately equal proportions. Volatile organic carbon was often not detected, but extractable and recoverable hydrocarbon concentrations showed a wide range of values.

Concentrations of metals and PAHs in sediments of watercourses and waterbodies were generally lower than the ISQG values. There were occasional exceedances of the ISQG values by concentrations of chromium in the upper Muskeg River, zinc in the middle Muskeg River and arsenic in Stanley Creek. Concentrations of six PAHs also occasionally exceeded the ISQG values. These PAHs were dibenzo(a,h)anthracene, C1-substituted naphthalenes, benzo(a)anthracene, chrysene, phenanthrene and pyrene. These PAH concentrations that exceeded guideline values occured naturally and are typical of conditions in the Oil Sands Region. The combined toxicity effect of all parameters in the sediments showed low to negligible reduction in the survival or growth of laboratory test organisms compared to reference samples.

3.7.6 Pierre River Mining Area

3.7.6.1 Water Quality

The PRMA includes the Pierre River, Eymundson Creek, Big Creek and Redclay Creek watersheds. With the exception of sampling locations on Pierre River, DO concentrations were similar to those in surface waters within the Muskeg River watershed, with generally high values in spring through fall and typically low concentration in winter. The DO concentrations in Pierre River were consistently higher than acute and chronic aquatic life guideline values.

The watercourses and waterbodies had some high concentrations of TOC and DOC, especially in the Big Creek watershed during winter. The TOC, DOC and TSS concentrations were typically lower in lakes with associated lighter colour than in streams, especially during open water periods. These surface waters were generally alkaline with laboratory-measured pH values generally within guideline values for watercourses. However, occasionally higher values than the upper bound of the aquatic life guideline range were observed for waterbodies within the Pierre River Mining Area.

Concentrations and seasonal trends of hardness, TDS, alkalinity and conductance and major ions in watercourses were generally similar to those in the Muskeg River. These concentrations for waterbodies were generally much higher than corresponding values in Kearl Lake, but only slightly higher than those in unnamed waterbodies in the Muskeg River watershed. However, seasonal trends for these parameters were generally similar for waterbodies in the JEMA and PRMA. Similar to other small watercourses and waterbodies in the Oil Sands Region, sulphide concentrations in every season frequently exceeded the aquatic life guideline value.

Concentrations of TSS in the Pierre River and Redclay Creek watersheds were generally low and comparable with TSS levels in the Muskeg River watershed. However, TSS levels were appreciably higher in the watercourses in the Eymundson and Big Creek watersheds. These extremely high TSS values occurred in all seasons, but more often in winter and spring, and were likely related to beaver activities in these watersheds. The high TSS concentrations were associated with high levels of particulate-bound phosphorus, nitrogen and metals, resulting in concentrations of these parameters that often exceeded aquatic life guideline values.

Metal concentrations were significantly higher in Eymundson and Big Creek watersheds than in Pierre River and Redclay Creek watersheds, especially for metals that are associated with TSS. Consequently, concentrations of a larger

number of metals in Eymundson and Big Creek watersheds exceeded aquatic life guideline values relative to those in the Pierre River and Redclay Creek watersheds. Metals with concentrations in the Pierre River Mining Area exceeding guideline values were aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, thallium and zinc.

Concentrations of organics were generally low. Naphthenic acids and total recoverable hydrocarbons were often below or only slightly higher than the detection limits. However, similar to other small watercourses and waterbodies in the Oil Sands Region, total phenolics concentrations in every season were often higher than the aquatic life guideline value.

Toxicity effects on laboratory test organisms were low and rare. Occasionally, laboratory tests using fathead minnows and *ceriodaphnia dubia* resulted in increased mortality or reduced growth relative to a reference sample.

3.7.6.2 Sediment Quality

Pierre River and Big Creek sediments were characterized by high sand fraction and low carbon content. However, sediment in Eymundson and Redclay creeks was made up of a mixture of sand, silt, and clay particles. Eymundson Creek had low carbon content, but Redclay sediments had high carbon levels. A sediment sample in an unnamed waterbody was composed of a high percentage of sand and low carbon content. Concentrations of few PAHs and metals occasionally exceeded sediment quality guideline values. The guideline exceedances occurred for benzo(a)anthracene and chrysene in Pierre River, arsenic in Big and Eymundson creeks, and C1 substituted naphthalenes and arsenic in Redclay Creek.

Sediment toxicity measurement showed slight reduction in survival or growth of *Hyalella azteca, Lumbriculus variegates and Chironomus tentans.*

3.7.7 Acid Sensitivity

Water quality and physical characteristics of watercouses and waterbodies within the LSA and RSA indicated these surface waters had a low sensitivity to acid input. With few exceptions, alkalinity, conductance, major ions, base cations, DOC and pH had relatively high values in the waterbodies. Furthermore, the waterbodies and their watersheds were located at low elevation and in low relief areas that were dominated by muskeg soils. These physical characteristics resulted in considerable contact between drainage waters and the muskeg soils. Watercourses showed little or no decrease in spring pH below winter levels. The

observed minimum pH and acid neutralizing capacity of the streams were higher than the corresponding thresholds for acid-sensitive streams. In addition, basin characteristics indicated that the streams would not be sensitive to acid deposition.

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APPENDIX D

WATER AND SEDIMENT PARAMETERS AND ASSESSMENT TOOLS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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1 WATER QUALITY PARAMETERS

In this Environmental Setting Report (ESR), the word *parameter* refers to the substances suspended or dissolved in the water that are included in the database. Many types of measurements are considered when describing the water quality parameters for a particular waterbody or watercourse. The measurements for a parameter provide specific information with respect to water quality. Parameters that provide similar or related information are commonly classified in groups. A brief description of the groups relevant to this environmental setting study is provided below.

1.1 FIELD-MEASURED PARAMETERS

This group includes parameters such as pH, electrical conductivity, temperature and Dissolved Oxygen (DO) that are measured in the field using hand-held instruments. Field measurements of parameters are simple and effective in providing quick information on overall water quality conditions, potential sources of discharge and substance loading to a waterbody or watercourse.

1.2 CONVENTIONAL PARAMETERS

This group is measured in the laboratory as part of most water quality programs and includes parameters such as colour, conductivity, Total Organic Carbon (TOC), hardness, total alkalinity, Total Dissolved Solids (TDS) or salts and Total Suspended Solids (TSS). Most of these parameters can also be classified as *indicator parameters* because each indicates the general trend of a larger group of chemical.

An example of an indicator parameter is TDS, which is a measure of all the dissolved ions in a sample of water. Thus, rising and falling TDS indicates that some individual ions, such as sodium, calcium, sulphate, bicarbonate or chloride, are also rising and falling at proportional rates.

Conductivity is a measure of the ability of water to conduct electrical current, and is also an indicator parameter that is strongly correlated with TDS. The more ions that are dissolved in water, the better it conducts electricity and therefore conductivity rises proportionally with TDS. Because the exact relationship between conductivity and TDS depends on the specific quantities of ions present, it varies among waterbodies and watercourses.

Hardness is a measure of mainly calcium and magnesium in the form of carbonated ions in solution. It is measured because the toxicity of many metals declines with increasing hardness.

Organic carbon is the main chemical form of decaying plants and animals. The TOC includes both Dissolved Organic Carbon (DOC) and particulate organic carbon. The DOC released from plants is responsible for most of the colour in natural water systems. This is especially true in muskeg and bog regions, which are naturally rich in organic matter. TOC is generally found in higher concentrations in lake sediments, because it is associated with suspended particles and tends to settle out under quiescent flow conditions.

Alkalinity is a general indicator of the water's capacity to neutralize or buffer acid-producing substances. Alkalinity mainly represents the presence of carbonates, bicarbonates and hydroxides. It is mainly affected by the bedrock, soils and vegetation in the region.

1.3 MAJOR IONS

This group is comprised of dissolved ions that can occur naturally at relatively high concentrations in freshwater system. These ions account for the majority of TDS. Sodium, calcium, magnesium, chloride, sulphate, bicarbonate and carbonate are examples of major ions.

1.4 NUTRIENTS AND CHLOROPHYLL *A*

Nutrients include phosphorus and nitrogen compounds that are required in small quantities for plant growth or productivity. While some plant growth is required to maintain a healthy ecosystem, excessive plant growth can lead to undesirable water quality conditions, such as the depletion of DO in aquatic systems.

Biological productivity in fresh water is usually limited by phosphorus, meaning that phosphorus is the nutrient in the shortest supply. Total phosphorus concentrations can range from 1 µg/L (micrograms per litre) in unproductive waters to greater than 100 µg/L in highly productive waters.

Nitrogen is another important nutrient that can affect and limit the productivity of a waterbody or watercourse. Nitrogen can be present in various forms in freshwater systems, such as ammonia, nitrate and organic nitrogen. Total Kjeldahl nitrogen (TKN) is a common measure of ammonia and organic nitrogen

that is used to assess the amount of unoxidized organic loading. Ammonia can become toxic to aquatic life at high concentrations.

Chlorophyll *a* is an indictor parameter that is used to classify the nutrient status and productivity of a waterbody or watercourse. Chlorophyll *a* is a pigment that is used by plants and green algae to convert sunlight to energy. Accordingly, chlorophyll *a* concentrations range from less than 8 µg/L in unproductive waters to greater than 75 µg/L in highly productive waters.

1.5 OXYGEN DEMAND

Many substances, especially biodegradable substances, can exert DO demand from natural water. The oxygen demand can result in low levels of DO in a waterbody or watercourse if large amounts of oxygen demanding substances are present. Biochemical Oxygen Demand (BOD) is widely tested as a measurement of the oxygen demanding substances present in a sample of water. Also, sediment oxygen demand may contribute to decreases in DO concentrations in waterbodies and watercourses.

1.6 METALS

Metals are a component of all waterbodies and watercourses as they are naturally present in small quantities (i.e., typically less than 1 mg/L). Higher metal concentrations are usually associated with suspended sediments and tend to settle out over time.

The effects of metals in water range from beneficial through troublesome to dangerously toxic, and are dependent on their concentrations in waters. Some metals are essential to the growth of aquatic life while others may adversely affect the survival of aquatic life. For example, iron enters waterways as a result of the weathering of naturally occurring minerals. It is required for aquatic life as a micro-nutrient and generally would not cause hazardous effects until at concentrations higher than 0.3 mg/L. Mercury, on the other hand, can impair the health of aquatic organisms, wildlife and humans even in trace quantities.

1.7 ORGANIC COMPOUNDS

Organic compounds are defined as chemicals made up of mainly carbon and hydrogen; they represent a vast collection of natural and synthetic chemicals. In this report, organic compounds are grouped by chemical properties such as molecular weight and structure.

Phenols, also called phenolics, are one class of the most frequently measured organic compounds in surface waters. Phenols are released by plants and decaying vegetation and can occur naturally in trace amounts in surface waters. Even at low concentrations, phenols can impart an undesirable taste and odour to water, and can be transported over long distances. Phenols can contribute to aquatic toxicity.

Naphthenic acids are a complex mixture of organic acids that are acutely toxic to many aquatic organisms. They are naturally occurring constituents in many petroleum sources, including bitumen in the Oil Sands Region of northern Alberta. Naphthenic acids enter surface water in the Oil Sands Region primarily through groundwater and erosion of riverbank oil-laden deposits.

Volatile Organic Compounds (VOC) are a group of organics that readily volatilize, or evaporate from liquid to gaseous state, such as acetone, benzene, toluene, vinyl chloride and methylene chloride. Due to their low water solubility, environmental persistence and widespread industrial use, they are commonly found in water and soil. Most of these compounds are harmful to the health of aquatic life even if they are present at very low concentrations in the water.

Polycyclic Aromatic Hydrocarbons (PAHs) and Polycyclic Aromatic Nitrogen Heterocyclics (PANHs) are sub-groups of organic compounds that are characterized by their molecular structures. The PAHs in surface waters are comprised of several different organics that could be toxic or carcinogenic.

1.8 WATER TOXICITY

The combined effect of a mixture of substances on a waterbody can be evaluated using the Whole Effluent Toxicity (WET) testing method, instead of directly analyzing the sample for individual water quality parameters. There are many tests used to assess the overall toxicity of a water sample on organisms. These generally involve exposing a large number of fish, plants or insects to a natural water or effluent sample, then observing the growth, reproduction and survival rate of the exposed organisms.

The toxicity tests used in this environmental setting study are classified as either chronic toxicity tests, which measure the response of organisms to long-term exposure, or acute toxicity tests, which measure the response of organisms to brief exposures. Guidelines for acute toxicity are normally higher than those for chronic toxicity, because organisms can tolerate higher concentrations of harmful chemicals if they are exposed for shorter periods of time.

2 SEDIMENT QUALITY PARAMETERS

Sediments are the ultimate repository of most of the physical, chemical and biological constituents that enter surface waterways and waterbodies. High concentrations of constituents in sediments could affect the health of organisms that use sediment as habitat, and may also pose a threat to organisms that exist in surface water, because of the intimate interaction between sediments and the overlying water.

Five groups of measurements are generally used to describe the sediment quality of a waterbody or watercourse, as discussed below.

2.1 PARTICLE SIZE

This group describes the physical properties of sediment which includes parameters such as textural class, percentages of sand, silt, or clay, and moisture content. Particle size influences both chemical and biological characteristics of sediment.

2.2 CARBON CONTENT

This group describes the composition of carbon in the sediment and includes parameters such as total organic carbon, total inorganic carbon and total carbon.

2.3 METALS

Metals are naturally present in all sediments. Mineral soils, which are composed of metals, often form part of sediments in waterbodies and watercourses. Most metals tend to be associated with suspended solids and settle out in the sediments over time. Accumulation of metals can occur in benthic organisms and create a long-term ecological risk to the aquatic system.

2.4 ORGANIC COMPOUNDS

Most of the organic compounds measured in the surface water column are usually also sampled for bed sediment, as sediment is the ultimate sink of most compounds. Another contributor to organic compounds in sediments is, the natural soils underlying the waterbodies and watercourses. Regardless of source, these organic and other constituents at the bottom of the waterbodies and

watercourses result in Sediment Oxygen Demand (SOD) that, in turn, influences DO levels in surface waters.

2.5 SEDIMENT TOXICITY

The combined toxic effect of all constituents in sediment can be evaluated using whole sediment toxicity testing methods. These generally involve exposing a sediment sample to naturally occurring benthic species, and observing the growth, reproduction and survival rates of the exposed organisms. The Microtox bioassay method is often used to determine the toxicity of sediment samples.

3 WATER AND SEDIMENT GUIDELINES

Water quality guidelines established by Alberta Environment (AENV 1999), the Canadian Council of Ministers of the Environment (CCME 1999, 2001, 2002) and the United States Environmental Protection Agency (U.S. EPA 1999) for the protection of freshwater aquatic life were used in part of the screening process to evaluate baseline water quality. The aquatic life guidelines are nationally endorsed indicators of environmental quality for the protection of aquatic ecosystems. They are intended to be protective of all forms and life stages of aquatic life over the long term.

Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (i.e., the sediment quality guidelines) have been developed for use throughout Canada and are available for some metals and hydrocarbons (CCME 1999). The sediment quality guidelines define an interim sediment quality guideline and a probable effect level. The interim sediment quality guideline represents the level at which adverse effects rarely occur. The probable effect level represents the concentration beyond which adverse biological effects are likely to occur.

Although these guidelines are adopted by regulators as benchmarks for the protection of aquatic life, they might not be applicable in certain cases. This is because the guidelines are based on experiments conducted in laboratory conditions that might not replicate natural conditions and on species that might not be present in the study area. Furthermore, in areas where certain compounds occur naturally in relatively high concentrations, the native species might have adapted to tolerate higher levels of these compounds.

Water and sediment quality guidelines are usually listed as maximum concentrations (i.e., adverse effects will likely not occur if concentrations in a water sample are lower than the guideline specified levels). However, there are two notable exceptions to maximum concentration guidelines. The first is low DO concentrations, which create harmful conditions for aquatic life. Therefore, DO must be above specified concentrations for the protection of aquatic life (i.e., minimum concentrations). The second is pH, which must be within a specified range for the protection of aquatic life.

The water and sediment quality guidelines used are presented in Section 3, Tables 3.2-7 and 3.2-8 of the ESR, respectively.

4 WATER AND SEDIMENT QUALITY TRENDS

In natural aquatic systems, trends are observed for most water and sediment quality parameters. These trends represent variation patterns that these parameters usually follow, such as seasonal cycles or changes with progression downstream. Understanding trends presented in the observed data is important for identifying the controlling factors for the physical, chemical and biological processes in the aquatic system. Also, the temporal and spatial trends help in assessing additional water and sediment quality changes due to the Project.

4.1 SEASONAL TRENDS

Seasonal trends exist for many water quality parameters in northern waterbodies and watercourses. These trends are closely related to seasonal meteorological cycles, such as changes in solar radiation, air temperature and precipitation throughout the year.

Winter water quality is characterized by low water temperature and minimal or no surface runoff. Winter TDS levels are high in waterbodies and watercourses. Salt is expelled during ice formation in winter; therefore, the water remaining under the ice becomes concentrated with TDS. Additionally, winter precipitation falls mainly as snow that does not melt until the following spring. Consequently, surface waters are recharged mostly by groundwater. Since groundwater contains much higher levels of TDS than surface runoff, concentrations of this constituent can increase concentrations in waterbodies and watercourses.

During winter, DO levels in surface waters typically decline because ice-cover prevents atmospheric re-aeration. DO concentrations can decrease further if SOD is high. Additionally, complete depletion of oxygen can lead to chemical reactions such as conversion of the relatively benign sulphate ion to the potentially toxic sulphide ion. Consequently, aquatic life may be impaired due to the lack of DO during winter.

Biochemical processes, for example, photosynthesis, usually become very slow due to minimal light and low water temperatures during winter. As such, chlorophyll *a* levels are typically low, while nutrient levels are much higher than the corresponding concentrations in other seasons.

Spring water quality is characterized by low TDS due to dilution by snow or ice meltwater. The freshets generated by spring melt can result in scouring of soils in

the watershed, river beds and banks, which in turn leads to high concentrations of TSS and total metals (e.g., aluminum and iron) in water.

Summer water quality is characterized by abundant light and high water temperature. Depending on nutrient levels, productivity can increase the trophic levels during summer. Aquatic plants grow much faster in warmer temperature and they obtain maximum energy from the sun for photosynthesis. The DO levels may decline in summer, because oxygen consumption rates for many biochemical processes will go up when water temperature increases. The solubility of DO, on the contrary, decreases with increasing temperatures. Summer DO decline could be pronounced at nighttime in productive surface waters due to the high oxygen consumption rate and absence of oxygen replenishment from photosynthesis.

Fall water quality depends to a large extent on the level on productivity during the summer. If the river or lake is highly productive during the summer, the aquatic plants can contribute significant amounts of oxygen demand on the waterbody when they die in the fall.

The seasonal variation cycles for sediment quality are much less obvious than for water quality. Sediment quality is less affected by the seasonal cycles of meteorological conditions; however, seasonal changes in flow may produce some spatial variability as high flows transport bottom sediments downstream. Sediment quality is insensitive to rapid variations in typical background concentrations of the overlying water column and potential temporal variability of sediment quality usually takes much longer to occur.

4.2 LONGITUDINAL TRENDS

As water flows from headwaters, through tributary streams and creeks to larger rivers, a series of naturally occurring changes is often observed. These are referred to as longitudinal trends. In the Oil Sands Region, headwater streams and lakes are strongly influenced by the surrounding muskeg and bog landscape. Consequently, they are low in DO but high in organic compounds and colour. The TSS and total metal concentrations in the upstream water tend to be high due to channel erosion and beaver activity. As the river progresses downstream, suspended solids settle out of the water column due to smaller channel slopes and slower flow velocity. Also, organic matter in the water is gradually decomposed by micro-organisms and DO levels tend to increase because of re-aeration. Meanwhile, metals and ions enter the river from surrounding surface runoffs or groundwater. Some of the ions increase the water's capacity to neutralize acids, so the pH rises. The resulting water at the mouth of a river is generally

characterized by relatively higher concentrations of TDS and DO, but lower levels of TSS and organic matter for low productivity waters.

The longitudinal trends observed for water quality parameters do not apply to the sediment quality parameters, because background sediment quality is less sensitive to variations in surface water quality. The spatial trends for sediment quality parameters are usually more difficult to define, but are influenced by erosion, transport and deposition of soils from the watershed and river bed.

5 STATISTICAL SUMMARY TABLES AND GRAPHICAL FIGURES

When examining large sets of environmental data, statistical tables or graphical figures are often used to reveal trends and patterns. These tables or figures summarize observed data and present them in specific formats to facilitate comprehension of overall trends without reading through each individual numerical value. The following sections describe tables and graphs often used to summarize background water and sediment quality data.

5.1 STATISTICAL SUMMARY TABLE

Statistical summary tables are used in environmental setting studies to present the range, average and data abundance for a given period and/or location. The summary table used in this study includes the following information:

- minimum – the lowest or smallest value;
- maximum – the largest or highest value;
- median – the middle or 50th percentile value; and
- sample size – the actual number of observed data points.

The statistical summary tables are presented in Appendix L.

5.2 TIME SERIES PLOTS

Time series plots are used to show temporal trends, which are patterns of one or more parameters through time. They are constructed by plotting the date along the horizontal axis and the value of each data point along the vertical axis. If a trend exists, it will be apparent as a series of data will slope diagonally upwards or downwards. Statistical tests can also be applied to different series of data and displayed on the graph to distinguish significant trends. Interesting associations might become apparent when several parameters are plotted along the same time scale. The time series plots are presented in Appendix M.

5.3 BOX AND WHISKER PLOTS

Box and whisker plots are like time series plots but with additional information. Instead of plotting individual points on the graphs, sub-sets of the data are grouped based on specific periods of time. Statistics are applied to the sub-groups and each one is displayed as a rectangle (the box) with bars (the whiskers) above, within or below each rectangle. The upper and lower sides of the box represent upper and lower quartiles. A bar near the middle of the box represents the median, which means half of the values lie above this line and the other half lie below it. The whiskers above the upper quartile or below the lower quartile represent, respectively, the highest and lowest recorded values in the sub-group The Box and Whisker plots are presented in Appendix M.

5.4 SCATTER PLOTS

Scatter plots are used to determine how two parameters are correlated. They are constructed by plotting the value of one constituent along the horizontal axis and the value of another constituent on the vertical axis. A common example of a scatter plot is electrical conductivity plotted against TDS. Since these two water quality parameters are closely correlated (both increase as dissolved ions increase), the plotted data will cluster diagonally from the bottom left corner to the top right corner of the graph.

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APPENDIX E

LIST OF TOXICITY, PHENOLICS AND POLYCYCLIC AROMATIC HYDROCARBON PARAMETERS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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Table E-1 Toxicity, Phenolics and Polycyclic Aromatic Hydrocarbon Parameters for Water Samples

Group Name	Parameter
toxicity	Microtox IC50 @ 15 min, Microtox IC25 @ 15 min, Algal Growth Inhibition Test (72 h) - IC25, Algal Growth Inhibition Test (72 h) - IC50, Algal Growth Inhibition Test (72 h) - LOEC, Algal Growth Inhibition Test (72 h) - NOEC, Ceriodaphnia 7 d Survival Test - LC25, Ceriodaphnia 7 d Survival Test - LC50, Ceriodaphnia 7 d Survival Test - LOEC, Ceriodaphnia 7 d Survival Test - NOEC, Ceriodaphnia 7 d Reproduction Test - IC25, Ceriodaphnia 7 d Reproduction Test - IC50, Ceriodaphnia 7 d Reproduction Test - LOEC, Ceriodaphnia 7 d Reproduction Test - NOEC, Daphnia 48 h Static Acute Test - LC25, Daphnia 48 h Static Acute Test - LC50, Daphnia 48 h Static Acute Test - LOEC, Daphnia 48 h Static Acute Test - NOEC, Fathead Minnow 7d Growth - IC25, Fathead Minnow 7d Growth - IC50, Fathead Minnow 7d Growth - LOEC, Fathead Minnow 7d Growth - NOEC, Fathead Minnow 7d Survival Test - LC25, Fathead Minnow 7d Survival Test - LC50, Fathead Minnow 7d Survival Test - LOEC, Fathead Minnow 7d Survival Test - NOEC, Trout 96 h Static Acute Test - LC25, Trout 96 h Static Acute Test - LC50, Trout 96 h Static Acute Test - LOEC, Trout 96 h Static Acute Test - NOEC
phenolics	phenol, o-Cresol, m-Cresol, p-Cresol, 2,4-Dimethylphenol, 2-Nitrophenol, 4-Nitrophenol, 2,4-Dinitrophenol, 4,6-Dinitro-2-methyl phenol
target PAHs and alkylated PAHs	naphthalene, C1 subst'd naphthalenes, C2 subst'd naphthalenes, C3 subst'd naphthalenes, C4 subst'd naphthalenes, acenaphthene, C1 subst'd acenaphthene, acenaphthylene, anthracene, dibenzo(a,h) anthracene, benzo(a)anthracene/chrysene, C1 subst'd benzo(a) anthracene/chrysene, C2 subst'd benzo(a) anthracene/chrysene, benzo(a)pyrene, C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene, C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene, benzo(b&k)fluoranthene, benzo(g,h,i)perylene, biphenyl, C1 subst'd biphenyl, C2 subst'd biphenyl, dibenzothiophene, C1 subst'd dibenzothiophene, C2 subst'd dibenzothiophene, C3 subst'd dibenzothiophene, C4 subst'd dibenzothiophene, Fluoranthene, C1 subst'd fluoranthene/pyrene, fluorene, C1 subst'd fluorene, C2 subst'd fluorene, Indeno(c,d-123)pyrene, phenanthrene, C1 subst'd phenanthrene/anthracene, C2 subst'd phenanthrene/anthracene, C3 subst'd phenanthrene/anthracene, C4 subst'd phenanthrene/anthracene, 1-methyl-7-isopropyl-phenanthrene (Retene), pyrene
target PANHs	Quinoline, 7-Methyl quinoline, C2 Subst'd quinoline, C3 Subst'd quinoline, Acridine, Methyl acridine, Phenanthridine, Carbazole, Methyl carbazole, C2 Subst'd carbazole

Table E-2 Toxicity and Polycyclic Aromatic Hydrocarbon Parameters for Sediment Samples

Group Name	Parameters
toxicity	Chironomus tentans - 10d survival, Chironomus tentans - 10d growth, Hyalella azteca - 10d survival, Hyalella azteca - 10d growth, Lumbriculus variegatus - 10d survival, Lumbriculus variegatus - 10d growth, Microtox IC50 @ 15 min, Microtox IC25 @ 15 min
target PAHs and alkylated PAHs	naphthalene, C1 subst'd naphthalenes, C2 subst'd naphthalenes, C3 subst'd naphthalenes, C4 subst'd naphthalenes, acenaphthene, C1 subst'd acenaphthene, acenaphthylene, anthracene, dibenzo(a,h) anthracene, benzo(a) anthracene, C1 subst'd benzo(a) anthracene/chrysene, C2 subst'd benzo(a) anthracene/chrysene, benzo(a)pyrene, C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene, C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene, benzofluoranthenes, benzo(g,h,i)perylene, biphenyl, C1 subst'd biphenyl, C2 subst'd biphenyl, chrysene, dibenzothiophene, C1 subst'd dibenzothiophene, C2 subst'd dibenzothiophene, C3 subst'd dibenzothiophene, C4 subst'd dibenzothiophene, fluoranthene, C1 subst'd fluoranthene/pyrene, C2 subst'd fluoranthene/pyrene, C3 subst'd fluoranthene/pyrene, fluorene, C1 subst'd fluorene, C2 subst'd fluorene, C3 subst'd fluorene, Indeno(1,2,3,cd)pyrene, phenanthrene, C1 subst'd phenanthrene/anthracene, C2 subst'd phenanthrene/anthracene, C3 subst'd phenanthrene/anthracene, C4 subst'd phenanthrene/anthracene, 1-methyl-7-isopropyl-phenanthrene (Retene), pyrene
target PANHs	quinoline, 7-methyl quinoline, C2 subst'd quinoline, C3 subst'd quinoline, acridine, methyl acridine, phenanthridine, carbazole, methyl carbazole, C2 subst'd carbazole

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APPENDIX F

SUMMARY TABLES FOR WATER AND SEDIMENT QUALITY DATA

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

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50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

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Table F-1 Water Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River)

Parameter	Units	Winter (1964 to 2006)				Spring (1968 to 2006)				Summer (1960 to 2006)				Fall (1968 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	–0.4	6.1	154	12.5	–0.3	18.3	47	18.2	0.1	26	152	9.5	0	19.3	124
dissolved oxygen	mg/L	12.3	7.5	16.5	150	10.4	5.3[a]	14.8	38	9.1	4.3[a][b]	14.5	151	11.6	6.2[a]	16	119
Conventional Parameters																	
colour	TCU	20	<5	80	103	30	10	90	33	35	<5	150	69	33	<5	190	101
specific conductance	µS/cm	395	260	1,200	164	248	142	477	64	223	155	322	189	261	132	390	153
dissolved organic carbon	mg/L	8	5	22	126	10	5	19	49	9	1	28	90	8	2	25	112
hardness	mg/L	169	23	656	105	113	<1	200	26	103	69	150	74	110	60	200	96
pH		7.8	7.1	8.5	178	7.9	7.4	8.4	68	7.9	7.1	8.5	178	8	6.8	8.4	152
total alkalinity	mg/L	152	86	720	178	102	67	186	68	95	8	151	197	99	62	194	158
total dissolved solids	mg/L	240	131	780	166	160	51	496	69	138	94	398	195	155	40	252	157
total organic carbon	mg/L	8	4	32	126	11	7	22	52	10	2	57	161	9	0	70	134
total suspended solids	mg/L	3	<0.4	92	175	58	<0.4	1,090	69	145	≤0.8	2,602	196	16	<1	386	158
Major Ions																	
bicarbonate	mg/L	208	139	329	60	133	93	227	24	119	≤97.7	144	49	124	81	193	80
calcium	mg/L	45	16	144	167	30	<0.5	54	69	29	18	40	195	30	16	54	157
carbonate	mg/L	<0.5	<0.5	10	40	<0.5	<0.5	0	23	<0.5	<0.5	1	42	<5	<0.5	0	76
chloride	mg/L	11	2	58	182	5	≤ 0.2	20	69	2	<0.5	18	201	5	≤0.3	36	162
magnesium	mg/L	12	7	72	169	8	<0.1	15	68	7	4	13	197	8	4	16	157
potassium	mg/L	2	0.1	5	171	2	<0.1	4	69	1	≤0.1	2	196	1	0.1	2	158
sodium	mg/L	20	7	54	175	12	<1	33	68	7	3	17	200	10	0.4	28	162
sulphate	mg/L	36	≤8.5	94	177	21	<0.5	66	69	16	0.2	37	179	21	0.5	55	151
sulphide	mg/L	<0.005	<0.001	0.01[a]	53	<0.01	<0.001	<0.01	15	<0.01	<0.001	0.4[a]	67	<0.004	<0.001	0.05[a]	88
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.2	≤0.003	0.3	24	0.01	<0.003	0.2	14	<0.003	<0.003	0.1	19	<0.1	<0.003	0.3	59
nitrogen – ammonia	mg/L	0.03	<0.01	0.49	64	0.01	<0.01	0.07	21	0.02	<0.01	0.14	37	<0.05	<0.01	0.27	74
nitrogen – kjeldahl	mg/L	0.4	0.2	8.9	116	0.6	0.2	1.5	38	0.8	≤0.15	4.9	109	0.4	≤0.13	2.7	117
nitrogen – total nitrogen	mg/L	0.5	0.2	8.9[a]	116	0.6	0.2	1.5[a]	38	0.8	≤0.15	4.9[a]	109	0.4	≤0.13	2.7[a]	117
phosphorus, total	mg/L	0.029	<0.003	1.8[a]	188	0.074[a]	0.02	2.5[a]	68	0.13[a]	<0.005	1.85[a]	192	0.035	0	0.55[a]	159
phosphorus, dissolved	mg/L	0.015	<0.003	0.049	71	0.015	0.005	0.055	23	0.011	<0.003	0.199	44	0.008	≤0.002	0.092	80
chlorophyll *a*	µg/L	0.3	≤0.2	13	60	3.8	<1	16.7	24	3	<1	19	73	3	≤0.8	8	84
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	<0.1	5	105	1	≤0.6	3	6	1	<0.1	5	11	<2	<0.1	8	53
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	7	<1	<1	2	4	<1	<1	<1	3	<1	<1	20	50
total phenolics	mg/L	0.003	<0.001	0.023[a]	169	0.002	<0.001	0.012[a]	52	0.002	<0.001	0.041[a]	165	0.002	<0.001	0.026[a]	145
total recoverable hydrocarbons	mg/L	0.6	≤0.08	6	130	0.2	<0.1	2.6	44	0.6	<0.1	5	139	<0.5	<0.1	7	123
Toxicity																	
Microtox® IC50 @ 15 Min	%	–	–	–	0	>100	>91	>100	3	>100	>100	>100	3	>91	>91	>100	12
Microtox® IC25 @ 15 Min	%	–	–	–	0	>100	>91	>100	3	>100	>100	>100	2	>91	>91	>100	12
Total Metals																	
aluminum	mg/L	0.053	<0.01	0.27[a]	27	1.44[a][b]	0.08	6.536[a][b]	17	2.12[a][b]	0.51[a]	22.576[a][b]	21	0.478[a]	0.03	4.1[a][b]	63
antimony	mg/L	<0.0001	≤0.00005	0.0001	16	0.0001	≤0.000075	0.0007	11	0.0001	≤0.0000837	0.0006	10	0.00005	≤0.0000245	0.0012	58
arsenic	mg/L	0.0004	<0.0002	0.01[a]	46	0.0012	0.0005	0.0022	19	0.0011	≤0.0003	0.02[a]	51	0.0006	≤0.0003	0.01[a]	87
barium	mg/L	0.081	0.05	0.122	44	0.079	0.05	0.123	18	0.071	0.0003	0.254	31	0.052	0.022	0.129	70
beryllium	mg/L	<0.001	≤0.0000038	0.004	21	<0.001	<0.00004	0.0004	16	0.0001	<0.00004	0.004	20	<0.0001	≤0.00000761	0.001	62
boron	mg/L	0.03	0.01	0.05	19	0.04	0.02	0.05	11	0.03	0.004	0.06	14	0.02	0.01	0.09	60
cadmium	mg/L	0.00004	<0.00002	0.005[a][b]	58	<0.0002	≤0.000031	0.002[a]	20	<0.001	≤0.000033	0.006[a][b]	38	<0.00004	≤0.00000844	0.0004[a]	74
chromium	mg/L	0.0026[a]	≤0.00022	0.006[a]	61	0.004[a]	≤0.00089	0.009[a]	20	0.004[a]	≤0.00194	0.032[a][b]	38	0.0009	≤0.00015	0.0076[a]	75
chromium – hexavalent	mg/L	<0.003	<0.001	0.012[a]	46	<0.003	<0.001	0.014[a]	22	<0.003	<0.001	0.086[a][b]	73	<0.003	<0.001	0.01[a]	44
cobalt	mg/L	<0.001	<0.00002	0.009	53	0.001	<0.0003	0.006	20	0.0017	<0.0003	0.011	38	0.0003	≤0.00012	0.003	74
copper	mg/L	0.001	<0.0001	0.033[a][b]	64	0.0036[a]	≤0.0009	0.009[a]	22	0.0042[a]	≤0.0008	0.0247[a][b]	40	0.0011	≤0.00063	0.021[a][b]	76

Table F-1 Water Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (1964 to 2006)				Spring (1968 to 2006)				Summer (1960 to 2006)				Fall (1968 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
iron	mg/L	0.2	<0.1	0.8[a]	45	2.49[a]	0.43[a]	7.51[a]	17	3.27[a]	0.4[a]	35[a]	25	0.69[a]	0.17	5.55[a]	64
lead	mg/L	0.0009	<0.00001	0.032[a]	36	0.0012	≤0.000373	0.0038[a]	17	0.0019	<0.0003	0.07[a]	23	0.0003	≤0.000078	0.0035[a]	62
lithium	mg/L	0.008	<0.004	0.02	19	0.009	<0.005	0.011	12	0.008	<0.004	0.025	15	0.006	≤0.004	0.017	59
manganese	mg/L	0.01	≤0.00241	0.231	62	0.056	0.016	0.229	22	0.076	0.017	1.03	40	0.034	0.01	0.159	76
mercury	mg/L	<0.0001	≤0.000000015	0.0036[a][b]	154	<0.0001	≤0.0000014	0.001[a][b]	57	<0.0001	<0.0000006	0.002[a][b]	165	<0.0001	<0.0000006	0.0044[a][b]	148
molybdenum	mg/L	0.0011	≤0.0006	0.007	49	0.0006	≤0.00049	0.004	20	0.0004	≤0.00021	0.01	35	0.0006	≤0.000202	0.018	74
nickel	mg/L	0.003	<0.0001	0.0279	57	0.0052	<0.001	0.0163	20	0.007	<0.0005	0.0685[a]	38	0.0012	<0.0001	0.0163	74
selenium	mg/L	<0.0002	<0.0001	0.02[a]	47	<0.0002	<0.0002	0.0008	19	0.00005	<0.0001	0.01[a]	32	<0.00038	<0.0001	0.0014[a]	74
silicon	mg/L	2.9	2.9	2.9	1	4.9	1.8	12.6	5	14.2	2.2	26.2	2	1.5	0.8	2.1	2
silver	mg/L	<0.000012	<0.0000005	0.000016	22	<0.000068	<0.000005	0.000037	12	0.000011	≤0.0000074	0.0009[a]	15	<0.000006	≤0.00000082	0.000031	60
strontium	mg/L	0.34	0.2	0.53	19	0.19	0.15	0.28	12	0.22	0.15	333	15	0.21	0.09	0.36	60
sulphur	mg/L	21.6	15.6	27.6	2	7	6.6	7.3	3	12	12	12	1	6.5	1.2	13.7	22
thallium	mg/L	<0.00006	<0.000003	0.00006	15	0.00006	≤0.0000461	0.00013	7	0.00005	≤0.0000269	0.00021	7	0.00002	<0.000003	0.00012	52
titanium	mg/L	0.0022	<0.0002	0.0073	17	0.0515	0.004	0.118	11	0.062	≤0.009	0.151	11	0.011	≤0.001	0.06	59
uranium	mg/L	0.0006	0.0005	0.0009	15	0.0006	≤0.000475	0.0007	11	0.0005	0.0004	0.0013	8	0.0004	0.0001	0.0007	56
vanadium	mg/L	<0.001	≤0.00034	0.022	134	0.002	<0.001	0.015	55	0.002	<0.001	0.05	155	0.001	≤0.00046	0.0142	133
zinc	mg/L	0.005	<0.001	0.1[a]	60	0.015	0.002	0.812[a][b]	23	0.014	0.003	0.095[a]	36	0.006	<0.001	0.058[a]	73
Dissolved Metals																	
aluminum	mg/L	0.0084	≤0.00402	1.1[a][b]	12	0.045	0.019	0.241[a]	9	0.02	<0.002	0.088	7	0.01	0.004	0.13[a]	54
antimony	mg/L	<0.0008	≤0.0000625	0.0024	9	<0.0002	≤0.00009	0.0001	6	0.0001	≤0.00008	0.0005	5	0.00004	≤0.000004	0.0006	53
arsenic	mg/L	0.0005	<0.0002	0.008[a]	103	0.0007	<0.0002	0.0059[a]	50	0.0009	<0.0002	0.026[a]	115	0.0005	≤0.0002	0.0124[a]	111
barium	mg/L	0.074	0.049	1.13	9	0.054	0.042	0.059	8	0.046	0.038	0.055	5	0.043	0.015	0.06	53
beryllium	mg/L	<0.001	<0.000003	0.000003	34	<0.001	≤0.0000093	0.00001	16	<0.001	≤0.000004	0.000004	18	<0.00004	<0.000003	0.0003	61
boron	mg/L	0.05	<0.01	0.2	57	0.06	0.02	0.18	27	0.05	<0.0002	1.51	58	0.02	0.01	0.45	89
cadmium	mg/L	0.00002	≤0.0000209	0.0197[a][b]	11	<0.001	≤0.0000138	0.006[a][b]	17	0.00002	≤0.000015	0.0028[a][b]	6	0.00001	≤0.00000323	0.0003	53
chromium	mg/L	0.0038[a]	≤0.000365	0.018[a][b]	9	0.0004	≤0.00035	0.002[a]	8	<0.0004	≤0.00021	0.0004	5	0.0001	≤0.0000755	0.001	53
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.00003	≤0.000031	0.0093	11	<0.002	≤0.000157	0.004	16	0.0001	≤0.000083	0.0002	7	0.0001	≤0.0000307	0.0008	53
copper	mg/L	<0.0006	<0.0002	0.0073[a]	11	0.002	<0.001	0.0043[a]	16	0.0014	<0.001	0.006[a]	7	0.0008	≤0.000346	0.0042[a]	54
iron	mg/L	0.08	<0.01	0.23	26	0.12	<0.01	1.14[a]	24	0.08	<0.01	0.48[a]	21	0.1	<0.01	0.67[a]	61
lead	mg/L	<0.0001	≤0.0000367	0.0961[a]	11	<0.003	≤0.0000883	0.005[a]	16	0.0001	≤0.000111	0.0113[a]	7	0.0001	≤0.0000153	0.0059[a]	53
lithium	mg/L	0.007	≤0.0023	0.009	9	0.007	0.005	0.009	6	0.005	<0.004	0.007	5	0.005	≤0.00331	0.007	50
manganese	mg/L	0.005	<0.001	0.04	28	0.003	<0.001	0.08	24	<0.004	<0.001	0.017	22	0.002	≤0.0005	0.051	62
mercury	mg/L	<0.0001	<0.00001	0.0002[a][b]	7	<0.0002	<0.0002	<0.0002	2	<0.0002	<0.0002	<0.0002	2	<0.000025	<0.00001	0.00005[a][b]	42
molybdenum	mg/L	0.0008	0.0006	0.0061	9	0.0005	0.0004	0.002	8	0.0005	0.0004	0.0009	5	0.0006	0.0002	0.005	53
nickel	mg/L	0.001	0.0001	0.0067	11	0.003	≤0.00113	0.009	16	0.002	0.0007	0.005	7	0.0004	<0.0001	0.0061	53
selenium	mg/L	<0.0005	<0.0002	0.006[a]	55	<0.00038	<0.0002	0.0005	32	<0.0002	<0.0001	0.0022[a]	51	<0.0003	<0.0001	0.0013[a]	80
silicon	mg/L	2.77	2.77	2.77	1	2.2	2.02	2.53	3	1.99	1.24	2.09	3	1.34	0.38	2.3	2
silver	mg/L	<0.0002	<0.0000005	0.0043[a]	9	<0.000052	<0.0000005	0.000002	6	<0.0001	<0.0000005	<0.0002	5	<0.000005	<0.0000005	0.0004[a]	53
strontium	mg/L	0.26	0.07	0.36	8	0.16	0.13	0.21	5	0.17	0.13	0.2	4	0.2	0.08	0.29	52
sulphur	mg/L	20.15	14.2	26.1	2	6.9	6.9	6.9	1	11.1	11.1	11.1	1	6.04	1.26	13.4	22
thallium	mg/L	<0.00005	≤0.0000047	0.0143[a]	9	0.00001	≤0.0000056	0.00006	4	0.00001	≤0.0000114	0.00004	3	0.00001	<0.0000003	0.0001	49
titanium	mg/L	0.0007	≤0.0005	0.0074	9	0.0025	≤0.0007	0.0031	6	0.0009	≤0.0003	0.0027	5	0.0007	≤0.000188	0.0032	53
uranium	mg/L	0.0006	0.0005	0.0008	9	0.0004	0.0003	0.0005	6	0.0003	≤0.00021	0.0004	5	0.0003	0.0001	0.0005	53
vanadium	mg/L	0.0003	≤0.000199	0.0167	12	<0.001	≤0.0002	0.0012	16	<0.0006	<0.0001	0.0006	7	0.0003	<0.0001	0.0067	53
zinc	mg/L	0.009	0.001	0.226[a][b]	11	0.001	<0.001	0.008	13	0.002	<0.001	0.038[a]	6	0.003	0.001	0.267[a][b]	53
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<1	<0.01	0.42	25	<0.22	<0.02	0.03	4	<0.02	≤0.005	0.005	10	<1	≤0.0004	0.0004	17
C1 subst'd naphthalenes	µg/L	<0.02	<0.02	<0.02	2	<0.02	<0.02	0.02	3	<0.02	<0.02	<0.02	3	<0.04	<0.02	<0.1	5
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5

Table F-1 Water Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (1964 to 2006)				Spring (1968 to 2006)				Summer (1960 to 2006)				Fall (1968 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
acenaphthene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.1	<0.01	<1	15
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
acenaphthylene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.1	<0.01	<1	15
anthracene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.05	<0.01	<1	15
dibenzo(a,h)anthracene	µg/L	<5	<0.01	<5	24	<0.02	<0.02	<5	4	<0.02	<0.01	<5	10	<5	<0.01	<5	13
benzo(a)anthracene/chrysene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.05	<0.01	<1	15
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
benzo(a)pyrene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.05	<0.01	<1	15
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.02	5	<0.02	<0.02	<0.02	3	<0.015	≤0.0084	0.0084	6	<0.02	<0.01	<0.05	8
benzo(g,h,i)perylene	µg/L	<2	<0.01	<2	24	<0.02	<0.02	<2	4	<0.02	≤0.0031	0.003	10	<0.05	<0.01	<2	15
biphenyl	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
dibenzothiophene	µg/L	<0.02	<0.02	<0.02	2	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.05	5
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
fluoranthene	µg/L	<1	≤0.0045	0.004	24	<0.02	<0.02	<1	4	<0.02	≤0.00087	0.005	10	<0.05	≤0.00006	0.0001	15
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
fluorene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	<0.01	<1	10	<0.05	≤0.00014	0.00014	15
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
indeno(c,d–123)pyrene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	≤0.0033	0.003	10	<0.05	<0.01	<1	15
phenanthrene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	≤0.00141	0.01	10	<0.05	≤0.00013	0.0001	15
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.1	5
1–methyl–7–isopropyl–phenanthrene (retene)	µg/L	–	–	–	0	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	1
pyrene	µg/L	<1	<0.01	<1	24	<0.02	<0.02	<1	4	<0.02	≤0.0014	0.004	10	<0.05	≤0.00004	0.00004	15
Target PANHs																	
quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
7–methyl quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
C2 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
C3 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
acridine	µg/L	<0.01	<0.01	<0.01	3	<0.02	<0.02	<0.02	3	<0.015	<0.01	<0.02	6	<0.01	<0.01	<0.02	4
methyl acridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
phenanthridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
methyl carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
C2 subst'd carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	1
Phenolics																	
phenol	µg/L	<1	<0.1	0	22	<0.1	<0.1	<1.3	3	<1	<0.1	<1	6	<1	<0.1	0	8
o–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1
m–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1
p–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1
2,4–dimethylphenol	µg/L	<2	<0.2	<2	22	<0.1	<0.1	<2	3	<2	<0.1	<2	6	<2	<0.1	<2	8

Table F-1 Water Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (1964 to 2006)				Spring (1968 to 2006)				Summer (1960 to 2006)				Fall (1968 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
2–nitrophenol	µg/L	<1	<0.1	<1	22	<0.2	<0.2	<1	3	<1	<0.2	<1	6	<1	<0.2	<1	8
4–nitrophenol	µg/L	<1	<0.1	<1	22	<2	<1	<2	3	<1	<1	<2	6	<1	<1	<2	8
2,4–dinitrophenol	µg/L	<1	<0.1	<1	22	<2	<1	<2	3	<1	<1	<2	6	<1	<1	<2	8
4,6–dinitro–2–methyl phenol	µg/L	–	–	–	0	<2	<2	<2	2	<2	<2	<2	2	<2	<2	<2	1
Volatile Organics																	
acetone	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
acrolein	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
acrylonitrile	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
benzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
bromodichloromethane	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0
bromoform	µg/L	<5	<0.5	<5	20	<1	<1	<1	2	<5	<5	<5	1	<5	<5	<5	6
bromomethane	µg/L	<1	<0.1	<1	20	<10	<10	<10	2	<1	<1	<1	1	<1	<1	<1	6
2–butanone (MEK)	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
carbon disulfide	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0
carbon tetrachloride	µg/L	<1	<0.1	4	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
chlorobenzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
chloroethane	µg/L	<1	<0.1	<1	20	<10	<10	<10	2	<1	<1	<1	1	<1	<1	<1	6
2–chloroethyl vinyl ether	µg/L	<4	<0.4	<4	20	<5	<5	<5	2	<4	<4	<4	1	<4	<4	<4	6
chloroform	µg/L	<1	≤0.02	2	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
chloromethane	µg/L	<5	<5	<5	1	<10	<10	<10	2	–	–	–	0	<5	<5	<5	2
dibromochloromethane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
dibromomethane	µg/L	<1	<0.1	<1	13	<1	<1	<1	2	–	–	–	0	<1	<1	<1	5
1,2–dichlorobenzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	0	6
1,3–dichlorobenzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	0	6
1,4–dichlorobenzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	0	6
cis–1,4–dichloro–2–butene	µg/L	<1	<0.1	<1	12	<2	<2	<2	2	–	–	–	0	<1	<1	<1	4
trans–1,4–dichloro–2–butene	µg/L	–	–	–	0	<5	<5	<5	2	–	–	–	0	–	–	–	0
dichlorodifluoromethane	µg/L	<5	<5	<5	1	<1	<1	<1	2	–	–	–	0	<5	<5	<5	2
1,1–dichloroethane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
1,2–dichloroethane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
1,1–dichloroethene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
trans–1,2–dichloroethene	µg/L	<1	<0.1	3	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
1,2–dichloropropane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
cis–1,3–dichloropropene	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0
trans–1,3–dichloropropene	µg/L	<3	<0.3	<3	18	<1	<1	<1	2	<3	<3	<3	1	<3	<3	<3	6
ethanol	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
ethylbenzene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
ethylene dibromide	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0
ethyl methacrylate	µg/L	–	–	–	0	<200	<200	<200	2	–	–	–	0	–	–	–	0
2–hexanone	µg/L	–	–	–	0	<200	<200	<200	2	–	–	–	0	–	–	–	0
iodomethane	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0
4–methyl–2–pentanone (MIBK)	µg/L	–	–	–	0	<200	<200	<200	2	–	–	–	0	–	–	–	0
methylene chloride	µg/L	2	<2	11	20	<1	<1	<1	2	1	1	1	1	6	0	6	6
styrene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
tetrachloroethylene	µg/L	<3	<0.3	<3	20	<1	<1	<1	2	<3	<3	<3	1	<3	<3	<3	6
1,1,2,2–tetrachloroethane	µg/L	<1	<0.1	<1	20	<5	<5	<5	2	<1	<1	<1	1	<1	<1	<1	6
toluene	µg/L	<1	≤0.04	0.1	20	<1	<1	<1	2	0	0	0	1	<1	<1	<1	6
1,1,1–trichloroethane	µg/L	<1	<0.1	2	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
1,1,2–trichloroethane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
1,2,3–trichloropropane	µg/L	<1	<0.1	<1	12	<2	<2	<2	2	–	–	–	0	<1	<1	<1	4
trichloroethene	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6
trichlorofluoromethane	µg/L	<1	<0.1	<1	20	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	6

Table F-1 Water Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (1964 to 2006)				Spring (1968 to 2006)				Summer (1960 to 2006)				Fall (1968 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
vinyl acetate	µg/L	–	–	–	0	<100	<100	<100	2	–	–	–	0	–	–	–	0
vinyl chloride	µg/L	<30	<0.5	<30	20	<20	<20	<20	2	<30	<30	<30	1	<30	<30	<30	6
xylenes	µg/L	–	–	–	0	<1	<1	<1	2	–	–	–	0	–	–	–	0

(a) Chronic aquatic life guideline exceeded.

(b) Acute aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to Total Kjeldahl Nitrogen (TKN) values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-2 Water Quality in the Middle Athabasca River (Between Muskeg River and Firebag River)

Parameter	Units	Winter (1968 to 2006)				Spring (1968 to 2006)				Summer (1973 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.1	0	1	36	12.5	0.5	16	17	18.8	0.1	24.5	70	11.2	1.5	18	52
dissolved oxygen	mg/L	11.8	3.6[a](b)	13.7	20	10.2	6[b]	14.8	16	9	6.8	12.2	63	10.2	8	14	53
Conventional Parameters																	
colour	TCU	20	5	130	29	55	25	120	14	40	10	250	30	36	<5	240	44
specific conductance	µS/cm	389	240	544	71	228	130	543	25	222	170	277	80	269	160	364	63
dissolved organic carbon	mg/L	8	2	62	38	11	6	21	19	10	3	28	40	8	3	22	41
hardness	mg/L	150	124	236	31	96	74	143	9	99	77	114	23	112	87	127	32
pH		7.7	7	8.3	71	7.8	7.4	8.2	25	7.9	7.1	8.3	66	7.9	7.4	8.3	59
total alkalinity	mg/L	138	102	177	71	88	71	180	25	94	49	107	80	99	76	135	63
total dissolved solids	mg/L	240	125	340	69	153	86	440	25	142	103	190	76	162	90	958	62
total organic carbon	mg/L	7	2	63	63	12	9	24	25	10	4	31	74	9	3	25	62
total suspended solids	mg/L	4	≤0.4	146	65	61	18	276	25	123	10	1,702	78	17	<1	317	63
Major Ions																	
bicarbonate	mg/L	170	154	198	13	106	88	112	6	106	95	118	12	120	109	133	28
calcium	mg/L	40	15	52	68	27	20	43	25	28	22	40	77	30	20	44	63
carbonate	mg/L	<5	<5	<5	13	<5	<5	<5	6	<5	<5	<5	12	<5	<5	<5	28
chloride	mg/L	22	1	49	71	8	1	47	25	5	1	11	79	9	2	30	63
magnesium	mg/L	12	8	28	71	7	6	20	25	7	4	10	79	9	6	12	63
potassium	mg/L	2	0.1	5	72	2	0.1	4	25	1	0.1	2	79	1	0.1	1	63
sodium	mg/L	22	12	53	71	12	7	42	25	8	4	14	78	12	7	26	63
sulphate	mg/L	32	<10	73	71	20	11	50	25	17	4	49	68	23	11	34	59
sulphide	mg/L	<0.006	<0.003	0.008[b]	23	<0.01	<0.002	0.007	15	<0.01	<0.003	0.33[b]	38	<0.005	<0.002	0.008	37
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.3	0.2	0.3	13	<0.1	≤0.06	0.2	6	<0.1	<0.1	<0.1	12	<0.1	<0.05	0.1	27
nitrogen – ammonia	mg/L	0.07	<0.05	0.16	13	<0.05	<0.05	0.05	6	<0.05	<0.05	<0.05	12	<0.05	<0.05	0.34	27
nitrogen – kjeldahl	mg/L	0.6	<0.2	1.4	35	0.8	0.5	1.6	18	0.8	0.3	3	41	0.4	<0.2	2	41
nitrogen – total nitrogen	mg/L	0.6	<0.2	1.4[b]	35	0.8	0.5	1.6[b]	18	0.8	0.3	3[b]	41	0.4	<0.2	2[b]	41
phosphorus, total	mg/L	0.029	≤0.007	0.7[b]	69	0.102[b]	0.037	0.35[b]	25	0.12[b]	0.014	1.8[b]	77	0.038	0.013	0.29[b]	62
phosphorus, dissolved	mg/L	0.024	0.016	0.101	13	0.017	0.015	0.02	6	0.009	0.003	0.024	12	0.009	0.004	0.02	27
chlorophyll *a*	µg/L	<1	<1	5	21	4	<1	10	10	2	<1	13	25	3	<1	8	27
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	<2	≤0.9	3	22	<2	<2	3	7	<2	≤0.9	1	14	<2	<2	3	27
General Organics																	
naphthenic acids	mg/L	<1	<1	1	13	<1	<1	1	6	<1	<1	1	12	<1	<1	5	28
total phenolics	mg/L	0.003	<0.001	0.027[b]	68	0.003	<0.001	0.016[b]	21	0.002	<0.001	0.095[b]	79	0.002	<0.001	0.024[b]	61
total recoverable hydrocarbons	mg/L	0.6	<0.1	4.9	60	0.4	<0.1	1.8	23	0.7	<0.1	176	60	0.2	<0.1	1.4	54
Toxicity																	
Microtox® IC50 @ 15 Min	%	–	–	–	0	–	–	–	0	–	–	–	0	>91	>91	>91	7
Microtox® IC25 @ 15 Min	%	–	–	–	0	–	–	–	0	–	–	–	0	>91	>91	>91	7
Total Metals																	
aluminum	mg/L	0.092	0.0289	0.217[b]	13	3.66[a](b)	0.46[b]	6.56[a](b)	7	3.685[a](b)	0.89[a](b)	8.34[a](b)	12	0.5515[b]	0.02	21.2[a](b)	28
antimony	mg/L	0.0001	≤0.0000364	0.0001	13	0.0001	≤0.0000682	0.0004	7	0.0001	0.0001	0.0006	12	0.0001	≤0.000036	0.001	28
arsenic	mg/L	0.0007	≤0.000522	0.0045	13	0.0016	0.0007	0.002	7	0.0018	≤0.00097	0.006[b]	14	0.0006	≤0.000569	0.009[b]	31
barium	mg/L	0.066	0.057	0.076	13	0.089	0.051	0.116	7	0.088	0.055	0.166	12	0.053	0.042	0.078	28
beryllium	mg/L	0.00001	≤0.00000426	0.0004	13	<0.0001	≤0.0000281	0.0001	7	0.0002	<0.00004	0.0003	12	<0.0002	≤0.0000156	0.0003	28
boron	mg/L	0.04	0.03	0.04	13	0.03	0.02	0.04	7	0.03	0.02	0.04	12	0.02	0.02	0.04	28
cadmium	mg/L	0.00004	≤0.0000212	0.005[a](b)	20	0.00004	≤0.0000362	0.0001	7	0.00005	≤0.0000253	0.002[b]	16	0.00002	≤0.0000137	0.004[a](b)	29
chromium	mg/L	0.0006	<0.00003	0.007[b]	20	0.0044[b]	0.0009	0.0076[b]	7	0.0061[b]	0.0015[b]	0.16[a](b)	16	0.0012[b]	≤0.00037	0.0038[b]	29
chromium – hexavalent	mg/L	<0.003	<0.001	0.006[b]	21	<0.003	<0.003	0.014[b]	12	0.003[b]	<0.003	0.012[b]	27	<0.003	<0.003	0.01[b]	14
cobalt	mg/L	0.0001	≤0.0000699	0.005	19	0.0016	0.0004	0.0021	7	0.0013	≤0.0005	0.075	16	0.0004	<0.0002	0.004	29
copper	mg/L	0.001	≤0.000616	0.031[a](b)	19	0.0049[b]	0.0027[b]	0.007[b]	7	0.0043[b]	0.0015	0.029[a](b)	16	0.0022[b]	0.0007	0.007[b]	29
iron	mg/L	0.44[b]	0.3	1.1[b]	19	4.3[b]	0.92[b]	5.27[b]	7	2.46[b]	0.2	7.08[b]	14	0.71[b]	0.07	2.74[b]	29

Table F-2 Water Quality in the Middle Athabasca River (Between Muskeg River and Firebag River) (continued)

Parameter	Units	Winter (1968 to 2006)				Spring (1968 to 2006)				Summer (1973 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
lead	mg/L	0.0003	≤0.0000734	0.051[(b)]	20	0.0023[(b)]	0.0004	0.0031[(b)]	7	0.0022[(b)]	≤0.0006	0.034[(b)]	16	0.0004	<0.0001	0.016[(b)]	29
lithium	mg/L	0.009	0.007	0.01	12	0.008	0.006	0.011	7	0.008	≤0.0057	0.013	12	0.006	≤0.00437	0.013	28
manganese	mg/L	0.018	0.003	0.046	19	0.106	0.036	0.123	7	0.081	0.029	0.209	16	0.036	0.004	0.092	29
mercury	mg/L	<0.0001	<0.0000006	0.002[(a)(b)]	69	<0.0001	<0.0000006	0.00054[(a)(b)]	25	<0.0001	<0.0000006	0.0006[(a)(b)]	64	<0.0001	<0.0000006	0.0003[(a)(b)]	58
molybdenum	mg/L	0.0009	0.0007	0.051	16	0.0005	0.0005	0.001	7	0.0005	0.0003	0.0011	12	0.0006	0.0005	0.0012	28
nickel	mg/L	0.0011	≤0.000194	0.11[(b)]	19	0.0047	0.0017	0.0072	7	0.0051	0.0013	0.062[(b)]	15	0.0014	0.0003	0.0164	29
selenium	mg/L	0.0004	≤0.000259	0.00123[(b)]	13	<0.0004	≤0.000114	0.00018	7	0.00025	≤0.000153	0.0013[(b)]	12	0.00018	≤0.000141	0.001	28
silicon	mg/L	–	–	–	0	9.8	9.8	9.8	1	–	–	–	0	–	–	–	0
silver	mg/L	0.000001	<0.0000005	0.000099	16	0.000016	≤0.00000424	0.00005	7	0.000035	<0.000005	0.00014[(b)]	12	0.0000005	<0.0000005	0.000016	28
strontium	mg/L	0.31	0.22	0.36	13	0.17	0.14	0.18	7	0.16	0.13	0.21	12	0.21	0.16	0.3	28
sulphur	mg/L	9.9	0.01	11.5	7	59.2	6.2	105	3	4.4	2.5	7.2	9	8.2	4	9.6	9
thallium	mg/L	0.00002	≤0.00000655	0.00004	13	0.00006	≤0.0000148	0.0001	6	0.00009	≤0.000023	0.00017	12	0.00003	≤0.0000239	0.0001	23
titanium	mg/L	0.0025	≤0.0019	0.037	22	0.0454	<0.01	0.192	11	0.0397	<0.01	0.133	16	0.0102	≤0.0008	0.0612	32
uranium	mg/L	0.0005	0.0003	0.0005	13	0.0005	0.0004	0.0007	7	0.0005	0.0003	0.0008	12	0.0003	0.0002	0.0005	28
vanadium	mg/L	<0.001	≤0.00014	0.008	58	0.0019	<0.001	0.0166	25	0.002	<0.001	0.0188	69	0.001	<0.0002	0.0065	59
zinc	mg/L	0.009	0.002	0.18[(a)(b)]	18	0.022	0.007	0.135[(a)(b)]	7	0.016	≤0.005	0.027	15	0.01	0.002	0.128[(b)]	29
Dissolved Metals																	
aluminum	mg/L	0.0046	0.0038	0.03	13	0.0113	0.008	0.415[(b)]	7	0.034	0.0102	0.14[(b)]	13	0.01	0.0043	0.17[(b)]	28
antimony	mg/L	0.00004	≤0.0000369	0.0002	13	0.0001	≤0.0000605	0.0002	7	0.0001	0.00003	0.006	13	0.00005	≤0.00002	0.0012	28
arsenic	mg/L	0.0004	<0.0002	0.011[(b)]	59	0.0008	<0.0004	0.0034	26	0.0008	0.0002	0.027[(b)]	60	0.0005	<0.0002	0.005	55
barium	mg/L	0.062	0.053	0.078	13	0.045	0.034	0.061	7	0.039	0.024	0.052	13	0.042	0.035	0.052	28
beryllium	mg/L	<0.00002	<0.000003	0.0005	14	<0.00004	<0.000003	0.00001	8	0.00001	≤0.00000407	0.0002	14	<0.0002	<0.000003	0.0004	28
boron	mg/L	0.04	<0.01	0.21	34	0.03	0.01	0.23	17	0.04	0.01	0.14	37	0.02	0.01	0.16	40
cadmium	mg/L	0.00004	0.00001	0.001[(b)]	14	0.0000001	<0.00001	0.0001	8	0.00001	≤0.00000482	0.0002	14	0.00001	≤0.00000757	0.0188[(a)(b)]	28
chromium	mg/L	0.0004	<0.00003	0.0009	13	0.0004	≤0.0002	0.0007	7	0.0003	≤0.0002	0.0034[(b)]	13	0.0001	<0.0001	0.0259[(a)(b)]	28
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0001	≤0.000038	0.0001	14	0.0001	≤0.00005	0.0013	8	0.0001	≤0.00003	0.0002	14	0.0001	0.00004	0.0012	28
copper	mg/L	0.0008	0.0006	0.0042[(b)]	14	0.0019	0.0011	0.0049[(b)]	8	0.0017	0.0005	0.003[(b)]	14	0.001	≤0.00051	0.0172[(a)(b)]	28
iron	mg/L	0.13	0.03	0.72[(b)]	14	0.16	0.08	1.93[(b)]	8	0.16	0.02	0.43[(b)]	14	0.12	0.06	0.32[(b)]	28
lead	mg/L	0.00004	≤0.000018	0.0004	14	0.0001	≤0.0000651	0.002	8	0.0001	≤0.000032	0.0017	14	0.0001	0.00003	0.0007	28
lithium	mg/L	0.008	0.007	0.01	12	0.006	0.004	0.007	7	0.005	0.004	0.01	13	0.006	0.004	0.012	28
manganese	mg/L	0.011	0.006	0.024	14	0.005	0.002	0.092	8	0.003	≤0.0007	0.025	14	0.003	0.001	0.024	28
mercury	mg/L	<0.0000189	<0.00001	0.0001[(a)(b)]	13	<0.00004	<0.00001	<0.0002	7	<0.00001	<0.00001	0.0000133[(a)(b)]	13	<0.00004	<0.00001	0.0000136[(a)(b)]	24
molybdenum	mg/L	0.0008	0.0006	0.0011	13	0.0006	0.0003	0.0007	7	0.0005	0.0002	0.0008	13	0.0006	0.0005	0.0022	28
nickel	mg/L	0.0006	0.0003	0.007	14	0.0015	0.0009	0.0056	8	0.0015	≤0.000426	0.0024	14	0.0007	<0.0001	0.0103	28
selenium	mg/L	<0.00026	≤0.000196	0.00099	34	<0.0002	<0.00004	0.0004	20	0.00003	<0.0001	0.0026[(b)]	40	<0.00029	<0.0001	0.0022[(b)]	40
silicon	mg/L	–	–	–	0	2.72	2.72	2.72	1	2.29	2.29	2.29	1	2.4	2.4	2.4	1
silver	mg/L	0.000001	<0.0000005	0.000044	13	<0.000005	<0.0000005	0.000001	7	0.000002	<0.0000005	0.000004	13	<0.000005	<0.0000005	0.000015	28
strontium	mg/L	0.3	0.2	0.36	13	0.16	0.12	0.17	7	0.15	0.09	0.21	13	0.2	0.15	0.26	28
sulphur	mg/L	9.54	0.013	10.6	7	56.9	6.14	101	3	4.04	2.47	7.12	9	7.41	3.962	9.55	9
thallium	mg/L	0.00002	≤0.00000491	0.00007	13	0.000005	≤0.000003	0.0001	6	0.00001	≤0.00000501	0.0001	12	0.00003	≤0.00000801	0.00013	23
titanium	mg/L	0.0013	0.0008	0.002	13	0.0025	0.0016	0.0037	7	0.0036	0.0005	0.0056	13	0.0008	0.0003	0.0282	28
uranium	mg/L	0.0004	0.0003	0.0005	13	0.0004	0.0003	0.0004	7	0.0003	<0.00005	0.0004	13	0.0003	0.0002	0.0097	28
vanadium	mg/L	0.0004	≤0.0000326	0.0006	14	0.0005	0.0003	0.002	7	0.0005	≤0.0001	0.0017	14	0.0003	<0.0001	0.0331	28
zinc	mg/L	0.004	0.002	0.014	14	0.004	0.001	0.068[(b)]	8	0.003	≤0.00099	0.016	14	0.005	0.001	0.086[(b)]	28
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	0.05	5
C1 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	0.04	5
C2 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C3 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C4 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
acenaphthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5

Table F-2 Water Quality in the Middle Athabasca River (Between Muskeg River and Firebag River) (continued)

Parameter	Units	Winter (1968 to 2006)				Spring (1968 to 2006)				Summer (1973 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C1 subst'd acenaphthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
acenaphthylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
dibenzo(a,h)anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
benzo(b&k)fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.02	<0.02	4
benzo(g,h,i)perylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C1 subst'd biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C3 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C4 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd fluoranthene/pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
indeno(c,d–123)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
phenanthrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5
C1 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.00004	<0.04	5
C2 subst'd phenanthren/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C3 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
C4 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	4
pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.00002	<0.02	5

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-3 Water Quality in the Lower Athabasca River (Between Firebag River and Embarras)

Parameter	Units	Winter (1987 to 2006)				Spring (1988 to 2006)				Summer (1988 to 2006)				Fall (1988 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	–0.3	0.9	38	6.8	0	14.1	17	18	1	23.5	34	10.4	0.1	16	34
dissolved oxygen	mg/L	11.2	10.1	13.6	41	9.9	8.5	13.3	20	8.3	7.3	9.8	48	10.2	8.5	13.6	30
Conventional Parameters																	
colour	TCU	20	10	100	48	40	10	90	23	40	<5	120	51	30	<5	80	36
specific conductance	µS/cm	440	271	553	51	248	163	446	23	225	194	296	51	298	210	392	36
dissolved organic carbon	mg/L	8	5	16	49	11	6	17	23	10	3	20	50	9	3	16	36
hardness	mg/L	153	122	190	47	98	67	175	20	100	83	120	41	118	85	140	31
pH		7.7	7	8.2	50	7.7	7	8.3	23	7.8	6.7	8.4	51	7.9	7.2	8.4	36
total alkalinity	mg/L	139	106	170	51	90	65	152	23	92	78	106	51	107	80	140	36
total dissolved solids	mg/L	255	180	320	51	154	70	276	22	149	100	290	51	170	132	245	35
total organic carbon	mg/L	8	6	16	44	11	6	19	22	11	4	20	35	10	4	17	29
total suspended solids	mg/L	4	<0.4	76	51	52	<1	419	23	116	22	505	51	22	4	197	36
Major Ions																	
bicarbonate	mg/L	170	129	207	50	109	79	185	23	111	≤95	129	51	130	98	171	36
calcium	mg/L	42	33	53	51	26	19	49	23	27	23	36	51	32	23	38	36
carbonate	mg/L	<0.5	<0.5	<5	50	<0.5	<0.5	<0.5	23	<0.5	<0.5	3	49	<0.5	<0.5	2	36
chloride	mg/L	31	13	64	51	12	4	27	23	6	1	14	51	14	6	25	36
magnesium	mg/L	12	9	16	51	7	5	13	23	7	6	9	51	9	7	11	36
potassium	mg/L	1	1	2	51	2	1	3	23	1	<0.3	2	51	1	1	2	36
sodium	mg/L	31	17	47	51	14	8	31	23	9	5	14	51	17	9	24	36
sulphate	mg/L	33	18	46	51	20	10	40	23	18	8	26	51	24	13	36	36
sulphide	mg/L	<0.002	<0.001	0.002	16	<0.001	<0.001	<0.01	7	<0.001	<0.001	0.002	11	<0.006	<0.001	0.007	14
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.04	0.02	0.3	8	0.02	<0.003	0.1	7	0.004	<0.003	0.4	23	<0.003	<0.003	0.04	16
nitrogen – ammonia	mg/L	0.06	0.01	0.13	49	0.02	<0.01	0.11	23	0.01	<0.01	1	49	0.01	<0.01	0.04	35
nitrogen – kjeldahl	mg/L	0.4	<0.02	1.9	49	0.6	0.2	1.1	22	0.6	<0.05	1.3	51	0.4	0.2	1.4	35
nitrogen – total nitrogen	mg/L	0.4	<0.02	1.9[a]	49	0.7	0.2	1.1[a]	22	0.6	<0.05	1.3[a]	51	0.4	0.2	1.4[a]	35
phosphorus, total	mg/L	0.03	0.014	0.098[a]	52	0.075[a]	0.029	0.29[a]	23	0.103[a]	0.035	0.37[a]	48	0.039	0.02	0.158[a]	36
phosphorus, dissolved	mg/L	0.015	0.005	0.03	51	0.019	0.003	0.096	22	0.014	<0.003	0.072	48	0.007	<0.003	0.023	35
chlorophyll *a*	µg/L	0.4	0	4.2	49	5.85	0.4	16.1	22	6.14	0.9	14.1	50	6.4	1.6	10.4	35
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	<0.1	1	17	1	1	1	1	–	–	–	0	<2	<2	<2	2
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	1	–	–	–	0	–	–	–	0	<1	<1	<1	3
total phenolics	mg/L	<0.001	<0.001	0.006[a]	43	<0.001	<0.001	0.006[a]	16	<0.001	<0.001	0.008[a]	29	<0.001	<0.001	0.009[a]	25
total recoverable hydrocarbons	mg/L	<0.5	<0.5	<0.5	1	–	–	–	0	–	–	–	0	<0.5	<0.5	<0.5	3
Toxicity																	
Microtox® IC50 @ 15 Min	%	>91	>91	>91	1	–	–	–	0	–	–	–	0	–	–	–	0
Microtox® IC25 @ 15 Min	%	>91	>91	>91	1	–	–	–	0	–	–	–	0	–	–	–	0
Total Metals																	
aluminum	mg/L	0.09	<0.01	0.3[a]	13	1.465[a][b]	0.06	4.791[a][b]	12	1.255[a][b]	0.033	6.3[a][b]	16	0.4945[a]	0.014	3.03[a][b]	14
antimony	mg/L	<0.0002	<0.0002	0.0002	3	0.0001	≤0.000078	0.0003	7	0.00005	≤0.00005	0.0003	7	0.0001	≤0.000058	0.0001	8
arsenic	mg/L	0.0004	<0.0002	0.0005	6	0.001	0.0004	0.018[a]	12	0.0014	0.0004	0.005	11	0.0007	≤0.0004	0.0016	12
barium	mg/L	0.069	0.054	0.075	6	0.071	0.043	0.167	11	0.069	0.057	0.128	12	0.057	0.036	0.269	12
beryllium	mg/L	<0.001	<0.0002	<0.001	4	<0.0002	≤0.000023	0.001	10	0.0001	≤0.000102	0.001	9	0.00004	≤0.000029	0.0004	11
boron	mg/L	0.04	0.04	0.08	3	0.03	0.02	0.06	8	0.03	<0.01	0.03	9	0.02	<0.01	0.14	10

Table F-3 Water Quality in the Lower Athabasca River (Between Firebag River and Embarras) (continued)

Parameter	Units	Winter (1987 to 2006)				Spring (1988 to 2006)				Summer (1988 to 2006)				Fall (1988 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
cadmium	mg/L	<0.0002	<0.0002	0.0002	5	<0.0002	≤0.000026	0.0006[a]	12	<0.0002	≤0.000147	0.002[a]	13	0.00002	≤0.000019	0.0006[a]	11
chromium	mg/L	0.0005	<0.001	0.0153[a]	14	0.0055[a]	<0.001	0.016[a]	14	0.0041[a]	<0.001	0.014[a]	20	0.0013[a]	≤0.00074	0.0075[a]	15
chromium – hexavalent	mg/L	<0.001	<0.001	<0.001	1	0.001	<0.001	0.002[a]	4	0.001	<0.001	0.003[a]	4	<0.001	<0.001	0.01[a]	3
cobalt	mg/L	<0.0005	<0.0003	0.0005	5	0.001	≤0.000249	0.0057	11	0.0016	<0.0003	0.004	12	0.0005	<0.0002	0.0018	11
copper	mg/L	0.002	<0.0002	0.0061[a]	15	0.0034[a]	0.001	0.0122[a]	15	0.0047[a]	<0.0002	0.01[a]	21	0.0022[a]	<0.001	0.0073[a]	15
iron	mg/L	0.52[a]	<0.01	0.89[a]	14	2.5[a]	0.48[a]	11.8[a]	14	2.7[a]	0.39[a]	10.6[a]	20	0.97[a]	0.39[a]	4.07[a]	15
lead	mg/L	0.0006	<0.0003	0.0129[a]	12	0.0015	≤0.000513	0.0099[a]	12	0.0015	<0.0003	0.0263[a]	16	0.001	<0.0001	0.0053[a]	14
lithium	mg/L	0.009	<0.004	0.013	3	0.009	0.004	0.054	7	0.007	0.005	0.009	7	0.007	0.005	0.008	8
manganese	mg/L	0.034	0.001	0.046	15	0.07	0.022	0.272	14	0.092	0.025	0.225	20	0.039	0.026	0.116	15
mercury	mg/L	<0.00005	≤0.000007	0.00014[a][b]	37	<0.00005	<0.0000006	0.00005[a][b]	20	<0.00005	≤0.0000028	0.00011[a][b]	29	<0.00005	<0.0000006	0.00022[a][b]	26
molybdenum	mg/L	0.0007	≤0.0007	0.0018	5	0.0007	≤0.0005	0.0011	11	0.0008	0.0004	0.0018	12	0.0007	0.0004	0.0054	11
nickel	mg/L	0.0042	≤0.0008	0.008	5	0.0053	0.0018	0.0189	11	0.0062	<0.0005	0.0203	12	0.0012	<0.0002	0.0154	11
selenium	mg/L	<0.0002	<0.0001	0.0002	7	<0.0002	≤0.00017	0.00029	12	0.0002	≤0.000199	0.00054	11	0.0002	<0.0002	0.0009	12
silicon	mg/L	3.3	3	3.6	2	4.4	1.6	7.2	4	4	2.6	7.3	4	2.9	2.9	2.9	2
silver	mg/L	<0.0004	<0.0001	0.0007[a]	3	0.000009	≤0.0000068	0.0004[a]	8	<0.0001	≤0.000012	0.0003[a]	9	<0.000062	≤0.0000041	0.000024	10
strontium	mg/L	0.28	0.24	0.3	3	0.17	0.12	0.2	7	0.18	0.16	0.21	7	0.21	0.16	0.23	8
sulphur	mg/L	10.7	10	11.4	2	6.8	5.8	6.8	4	6.2	5.6	7.1	4	9.5	3.5	10.8	3
thallium	mg/L	<0.0002	<0.0002	<0.0002	2	<0.0002	≤0.0000409	0.00012	7	<0.0002	≤0.0000545	0.00014	7	0.00005	≤0.000018	0.00027	8
titanium	mg/L	0.0067	0.003	0.008	3	0.031	0.009	0.08	7	0.027	0.006	0.108	7	0.012	0.001	0.0502	8
uranium	mg/L	0.0005	<0.0004	0.0006	3	0.0005	≤0.00024	0.001	9	0.0004	≤0.000372	0.003	10	0.0003	<0.0001	0.0005	11
vanadium	mg/L	<0.0016	<0.001	0.0016	5	0.004	<0.001	0.015	11	0.005	<0.001	0.018	12	0.0017	≤0.0007	0.0088	11
zinc	mg/L	0.012	0.003	0.023	14	0.012	0.007	0.043[a]	13	0.016	0.004	0.046[a]	18	0.008	0.001	0.029	13
Dissolved Metals																	
aluminum	mg/L	<0.01	≤0.005	0.1	32	0.0125	≤0.004	0.05	14	0.015	<0.002	0.12[a]	25	0.01	≤0.0058	0.07	23
antimony	mg/L	<0.0002	<0.0002	0.0008	3	0.0001	≤0.000073	0.0002	6	<0.0002	≤0.00004	0.0002	7	0.00003	≤0.000007	0.0001	8
arsenic	mg/L	0.0003	<0.0002	0.003	34	0.0004	<0.0002	0.0006	14	0.0005	<0.0002	0.0011	25	0.0004	<0.0002	0.0046	23
barium	mg/L	0.047	0.047	0.063	3	0.041	0.036	0.05	6	0.041	0.038	0.049	7	0.045	0.036	0.268	8
beryllium	mg/L	<0.0004	<0.0002	<0.001	4	<0.0002	≤0.000004	0.0002	7	<0.0002	≤0.000004	0.0002	8	<0.00003	<0.000003	0.00003	8
boron	mg/L	0.03	≤0.003	0.08	34	0.02	<0.01	0.04	15	0.02	<0.01	0.1	23	0.02	<0.01	0.04	23
cadmium	mg/L	<0.0002	<0.0002	0.0003	3	<0.0001	<0.00001	0.00004	6	<0.0002	≤0.000026	0.0001	7	0.00001	≤0.00000966	0.0005[a]	8
chromium	mg/L	<0.001	<0.0004	<0.001	3	0.0004	<0.00004	0.001	5	0.0002	≤0.000208	0.003[a]	7	0.0003	<0.0001	0.0052[a]	8
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	<0.0003	≤0.0002	0.0002	3	0.0001	≤0.0000743	0.0004	6	0.00005	≤0.00005	0.001	7	0.0001	0.0001	0.0008	8
copper	mg/L	0.0016	0.0014	0.0016	3	0.0014	0.0008	0.003[a]	6	0.002	0.0007	0.0058[a]	7	0.0014	0.0007	0.0025[a]	8
iron	mg/L	0.19	0.1	0.62[a]	39	0.22	0.08	0.57[a]	15	0.11	<0.01	1.16[a]	39	0.13	<0.01	0.22	29
lead	mg/L	0.0004	<0.0003	0.0006	3	<0.0003	≤0.000124	0.0002	6	0.00002	≤0.000022	0.0006	7	0.0001	≤0.000058	0.0003	8
lithium	mg/L	0.008	<0.004	0.009	3	0.006	0.003	0.007	6	0.005	0.003	0.006	7	0.006	0.004	0.008	8
manganese	mg/L	0.026	<0.002	0.082	38	0.004	<0.001	0.019	15	<0.004	<0.001	0.176	37	0.004	<0.001	0.043	29
mercury	mg/L	<0.0001	<0.0001	<0.0001	1	–	–	–	0	–	–	–	0	<0.00004	<0.00001	<0.0001	3
molybdenum	mg/L	0.0006	0.0006	0.0019	3	0.0006	0.0004	0.0009	6	0.0006	<0.0002	0.0008	7	0.0006	<0.0002	0.001	8
nickel	mg/L	0.0022	0.0005	0.0024	3	0.0018	0.0009	0.0051	6	0.0017	<0.0005	0.0034	7	0.0007	≤0.00041	0.0145	8
selenium	mg/L	<0.0002	<0.0002	0.0004	33	<0.0002	≤0.000128	0.0003	14	<0.0002	<0.0001	0.0004	25	<0.0002	≤0.000106	0.0012[a]	23
silicon	mg/L	2.84	2.78	2.9	2	2.48	1.34	2.64	3	2.125	1.58	2.46	4	2.065	1.65	2.48	2
silver	mg/L	<0.0001	<0.0001	<0.0002	3	<0.000052	≤0.0000009	0.000002	6	<0.0001	<0.0000005	<0.0001	7	<0.000052	<0.0000005	0.000001	10
strontium	mg/L	0.32	0.32	0.32	1	0.13	0.11	0.15	3	0.16	0.15	0.18	3	0.2	0.16	0.24	6
sulphur	mg/L	10.5	9.8	11.2	2	6.2	6.1	6.5	3	5.9	5.2	7	4	9.1	3.436	10.8	3
thallium	mg/L	<0.0002	<0.0002	<0.0002	2	<0.00015	≤0.0000054	0.0001	6	<0.0002	≤0.0000097	0.00007	7	0.00004	≤0.0000036	0.00027	8

Table F-3 Water Quality in the Lower Athabasca River (Between Firebag River and Embarras) (continued)

Parameter	Units	Winter (1987 to 2006)				Spring (1988 to 2006)				Summer (1988 to 2006)				Fall (1988 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
titanium	mg/L	<0.001	≤0.0008	0.0008	3	0.0028	<0.001	0.0034	6	0.001	≤0.0009	0.006	7	0.0017	≤0.00086	0.003	8
uranium	mg/L	0.0004	<0.0004	0.0006	3	0.0003	≤0.000227	0.0004	6	<0.0004	≤0.00023	0.0003	7	0.0003	≤0.00022	0.0004	8
vanadium	mg/L	<0.001	≤0.0002	0.0002	3	0.0006	≤0.000415	0.005	6	0.0004	≤0.000435	0.004	7	0.0004	≤0.00023	0.0011	8
zinc	mg/L	0.004	0.003	0.012	3	0.003	0.001	0.009	6	0.009	0.002	0.017	6	0.002	0.001	0.008	8
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<1	<1	<1	7	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.02	<0.02	1
C2 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd acenaphthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
anthracene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
dibenzo(a,h)anthracene	µg/L	<5	<5	<5	6	–	–	–	0	–	–	–	0	<0.5	<0.02	<5	7
benzo(a)anthracene/chrysene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.02	3
benzo(g,h,i)perylene	µg/L	<2	<2	<2	6	–	–	–	0	–	–	–	0	<0.2	<0.01	<2	9
biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C1 subst'd biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd fluoranthene/pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
fluorene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
indeno(c,d–123)pyrene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
phenanthrene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
C1 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1
pyrene	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.1	<0.01	<1	9
Target PANHs																	
acridine	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	2
Phenolics																	
phenol	µg/L	<1	<1	<1.3	6	–	–	–	0	–	–	–	0	<0.55	<0.1	<1	6

Table F-3 Water Quality in the Lower Athabasca River (Between Firebag River and Embarras) (continued)

Parameter	Units	Winter (1987 to 2006)				Spring (1988 to 2006)				Summer (1988 to 2006)				Fall (1988 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
2,4–dimethylphenol	µg/L	<2	<2	<2	6	–	–	–	0	–	–	–	0	<0.6	<0.2	<2	6
2–nitrophenol	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.55	<0.1	<1	6
4–nitrophenol	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.55	<0.1	<1	6
2,4–dinitrophenol	µg/L	<1	<1	<1	6	–	–	–	0	–	–	–	0	<0.55	<0.1	<1	6
Volatile Organics																	
benzene	µg/L	<1	<1	0	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
bromoform	µg/L	<5	<5	<5	5	–	–	–	0	–	–	–	0	<0.5	<0.5	<5	5
bromomethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
carbon tetrachloride	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
chlorobenzene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
chloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
2–chloroethyl vinyl ether	µg/L	<4	<4	<4	5	–	–	–	0	–	–	–	0	<0.4	<0.4	<4	5
chloroform	µg/L	<1	<1	0	5	–	–	–	0	–	–	–	0	<0.1	≤0.02	0.02	5
chloromethane	µg/L	<5	<5	<5	2	–	–	–	0	–	–	–	0	–	–	–	0
dibromochloromethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
dibromomethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,2–dichlorobenzene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,3–dichlorobenzene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,4–dichlorobenzene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	≤0.05	0.05	5
cis–1,4–dichloro–2–butene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	4
dichlorodifluoromethane	µg/L	<5	<5	<5	2	–	–	–	0	–	–	–	0	–	–	–	0
1,1–dichloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,2–dichloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,1–dichloroethene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
trans–1,2–dichloroethene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,2–dichloropropane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
trans–1,3–dichloropropene	µg/L	<3	<3	<3	4	–	–	–	0	–	–	–	0	<0.3	<0.3	<3	5
ethylbenzene	µg/L	<1	<1	0	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
methylene chloride	µg/L	0	0	0	5	–	–	–	0	–	–	–	0	1.05	≤1.05	1.05	5
styrene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
tetrachloroethylene	µg/L	<3	<3	<3	5	–	–	–	0	–	–	–	0	<0.3	<0.3	<3	5
1,1,2,2–tetrachloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
toluene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	≤0.01	0.01	5
1,1,1–trichloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,1,2–trichloroethane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
1,2,3–trichloropropane	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	4
trichloroethene	µg/L	<1	<1	<1	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
trichlorofluoromethane	µg/L	<1	<1	0	5	–	–	–	0	–	–	–	0	<0.1	<0.1	<1	5
vinyl chloride	µg/L	<30	<30	<30	5	–	–	–	0	–	–	–	0	<0.5	<0.5	<30	5

(a) Chronic aquatic life guideline exceeded.

(b) Acute aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied toTKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-4 Sediment Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River)

Parameter	Units	Winter (2001)				Summer (1975 to 1995)				Fall (1978 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Particle Size													
particle size – % sand	%	93	63	97	6	66	37	94	10	69	20	98	37
particle size – % silt	%	4	1	25	6	26	2	41	10	20	1	55	36
particle size – % clay	%	4	2	12	6	7	0.3	22	10	12	<1	25	37
moisture content	%	18	15	38	6	–	–	–	0	26	17	43	30
Carbon Content													
total inorganic carbon	% by wt	0.4	0.18	0.87	6	0.52	0.21	0.84	2	0.7	0.1	1.6	34
total organic carbon	% by wt	<0.1	<0.1	0.6	6	1.08	0.2	6.6	14	0.9	<0.1	4.5	47
total carbon	% by wt	0.45	0.2	1.5	6	–	–	–	0	2	0.2	5.1	34
Sulphide													
sulphide	mg/kg	–	–	–	0	–	–	–	0	<1	<1	<1	10
Toxicity													
chironomus tentans – 10d survival	# alive	7.3	6	8	6	–	–	–	0	8	2	9.6	12
chironomus tentans – 10d survival	% of control	110.5	97	121	6	–	–	–	0	102.5	24	167	12
chironomus tentans – 10d growth	mg/organism	2.7	2.5	2.9	6	–	–	–	0	1.27	0.68	1.57	5
chironomus tentans – 10d growth	% of control	89.5	83	95	6	–	–	–	0	114.5	68	156	12
hyalella azteca – 10d survival	# alive	9	8	10	6	–	–	–	0	8.6	1	9.25	12
hyalella azteca – 10d survival	% of control	94	80	98	6	–	–	–	0	97	13	215	12
hyalella azteca – 10d growth	mg/organism	0.1	0.1	0.2	6	–	–	–	0	0.18	0.12	0.32	5
hyalella azteca – 10d growth	% of control	148	136	209	6	–	–	–	0	115	84	286	12
lumbriculus variegatus – 10d survival	# alive	5	0	13	6	–	–	–	0	12.4	1.6	22	12
lumbriculus variegatus – 10d survival	% of control	53	0	151	6	–	–	–	0	108	90	124	12
lumbriculus variegatus – 10d growth	mg/organism	8.05	0	14.5	6	–	–	–	0	1.25	1.25	1.43	5
lumbriculus variegatus – 10d growth	% of control	140.5	0	254	6	–	–	–	0	88	73	133	12
Microtox® IC50 @ 15 Min.	%	–	–	–	0	99	73	120	11	–	–	–	0
Organics													
total recoverable hydrocarbons	mg/kg	50	<100	300	6	–	–	–	0	500	<100	39,900	35
Total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	<0.5	6	–	–	–	0	<0.5	<0.5	23	30
Total extractable hydrocarbons (C11–C30)	mg/kg	72	6	210	6	–	–	–	0	135	<5	13,000	30
Total Metals													
aluminum	µg/g	2,700	1,200	18,600	6	39,150	4,250	87,600	16	6,450	1,400	17,700	20
antimony	µg/g	–	–	–	0	–	–	–	0	<0.1	<0.02	<0.1	7
arsenic	µg/g	3.2	2.9	6.5[a]	6	1.6	≤1.3	5.2	9	4.2	1.2	8.4[a]	45
barium	µg/g	54	20	193	6	490	88	780	16	135	22	262	35
beryllium	µg/g	<1	<1	<1	6	0.4	0.2	2.4	16	0.4	<0.2	0.9	35
boron	µg/g	–	–	–	0	16	14	18	5	6	<2	21	15
cadmium	µg/g	<0.5	<0.5	<0.5	6	<0.5	≤0.06	0.1	16	0.2	<0.1	7.4[a][b]	45
calcium	µg/g	5,550	1,900	18,400	6	28,100	5,900	71,000	16	17,750	3,700	50,900	20
chromium	µg/g	5.8	2.4	30.9	6	28.8	10.3	587[a][b]	18	16.2	2	64.5[a]	45
cobalt	µg/g	4	2	8	6	11.8	2	21.3	16	7.4	2.3	25.2	45

Table F-4 Sediment Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (2001)				Summer (1975 to 1995)				Fall (1978 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
copper	µg/g	4	<2	13	6	9	2	17	18	14	≤1.1	28	45
iron	µg/g	7,950	5,200	19,500	6	14,800	10,200	27,800	17	14,750	5,700	26,800	20
lead	µg/g	<5	<5	7	6	6	<1	121[(a)(b)]	18	6.9	1.2	43.8[(a)]	45
lithium	µg/g	–	–	–	0	7.1	5.8	10.2	5	–	–	–	0
magnesium	µg/g	2,050	900	7,800	6	6,755	2,100	13,500	16	5,760	1,110	14,000	30
manganese	µg/g	245	140	360	6	335	189	425	17	322	107	576	20
mercury	µg/g	<0.05	<0.05	<0.05	6	0.023	≤0.01	0.07	17	<0.05	≤0.03	0.1	35
molybdenum	µg/g	<1	<1	<1	6	<1	≤0.9	1.4	14	0.4	≤0.1	1.2	35
nickel	µg/g	7.5	4	22	6	18.8	7.1	38.3	18	18.5	3.9	44.6	45
phosphorus, total	µg/g	225	130	530	6	950	350	1,750	15	568.5	539	644	4
potassium	µg/g	385	140	3,240	6	8,700	580	12,700	14	1,530	270	3,230	20
selenium	µg/g	<0.2	<0.2	0.5	6	<0.2	≤0.18	0.3	6	<0.4	<0.1	2.96	45
silicon	µg/g	–	–	–	0	1,310	986	1,670	5	–	–	–	0
silver	µg/g	<1	<1	<1	6	<0.5	<0.2	<0.5	14	<0.2	<0.1	0.2	35
sodium	µg/g	<100	<100	400	6	6,550	40	11,500	16	116	<20	244	20
strontium	µg/g	23	12	73	6	127	31	205	16	52	11	133	35
sulphur	µg/g	–	–	–	0	–	–	–	0	1,440	1,040	1,610	5
thallium	µg/g	<1	<1	<1	6	–	–	–	0	0.13	<0.05	0.29	30
titanium	µg/g	42	24	195	6	1,050	89.7	3,300	16	40.4	31.3	54	15
uranium	µg/g	<40	<40	<40	6	<50	<50	<50	5	0.7	0.2	1.3	30
vanadium	µg/g	9.5	4	48	6	28.5	14	118	17	23.3	4.2	94.3	45
zinc	µg/g	10	<10	40	6	42	14	60	18	48	12	110	45
Target PAHs and Alkylated PAHs													
naphthalene	µg/g	0.001	0.001	0.007	6	–	–	–	0	0.009	≤0.000989	0.079[(a)]	36
C1 subst'd naphthalenes	µg/g	0.002	0.001	0.024[(a)]	6	–	–	–	0	0.021[(a)]	<0.001	0.069[(a)]	36
C2 subst'd naphthalenes	µg/g	0.003	0.001	0.029	6	–	–	–	0	0.034	<0.001	0.092	36
C3 subst'd naphthalenes	µg/g	0.005	0.0004	0.039	6	–	–	–	0	0.037	≤0.001	0.162	36
C4 subst'd naphthalenes	µg/g	0.004	0.0001	0.03	6	–	–	–	0	0.034	≤0.001	0.56	36
Acenaphthene	µg/g	0.0002	≤0.000094	0.001	6	–	–	–	0	0.0006	<0.0001	0.0195[(a)]	36
C1 subst'd acenaphthene	µg/g	0.0002	<0.0001	0.0019	6	–	–	–	0	<0.0003	<0.00003	0.0018	36
acenaphthylene	µg/g	<0.0001	<0.0001	0.0001	6	–	–	–	0	<0.0004	<0.00004	0.0173[(a)]	36
anthracene	µg/g	0.00002	<0.00004	0.001	6	–	–	–	0	<0.002	≤0.0000564	0.0086	36
dibenzo(a,h)anthracene	µg/g	<0.00039	<0.00021	<0.0017	6	–	–	–	0	0.0003	≤0.000189	0.0389[(a)]	36
benzo(a)anthracene	µg/g	0.0006	<0.0001	0.0059	6	–	–	–	0	0.0036	≤0.000188	0.0448[(a)]	36
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.03	<0.001	0.26	6	–	–	–	0	0.21	<0.001	8.47	36
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.009	<0.0001	0.061	6	–	–	–	0	0.05	<0.001	3.72	36
benzo(a)pyrene	µg/g	0.0009	<0.0001	0.0084	6	–	–	–	0	0.007	≤0.000412	0.077[(a)]	36
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.003	<0.0002	0.038	6	–	–	–	0	0.034	<0.001	1.06	36
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.002	<0.0002	0.021	6	–	–	–	0	0.017	≤0.001	0.582	36
benzofluoranthenes	µg/g	0.004	0.0005	0.019	6	–	–	–	0	0.018	≤0.001	0.248	36

Table F-4 Sediment Quality in the Upper Athabasca River (Between Fort McMurray and Muskeg River) (continued)

Parameter	Units	Winter (2001)				Summer (1975 to 1995)				Fall (1978 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
benzo(g,h,i)perylene	µg/g	0.0012	<0.0002	0.0087	6	–	–	–	0	0.0097	≤0.0004	0.135	36
biphenyl	µg/g	0.0005	0.0003	0.0032	6	–	–	–	0	0.0021	≤0.0003	0.027	36
C1 subst'd biphenyl	µg/g	<0.00005	<0.00004	<0.0001	6	–	–	–	0	<0.0017	<0.0001	0.0118	36
C2 subst'd biphenyl	µg/g	<0.00004	<0.00002	0.0001	6	–	–	–	0	0.0042	<0.0003	0.0497	36
chrysene	µg/g	0.003	0.0004	0.023	6	–	–	–	0	0.022	0.001	0.665[a]	35
dibenzothiophene	µg/g	0.0002	<0.0001	0.0033	6	–	–	–	0	0.0007	≤0.0000526	0.0168	36
C1 subst'd dibenzothiophene	µg/g	0.0001	<0.0001	0.0039	6	–	–	–	0	0.0151	≤0.000273	0.514	36
C2 subst'd dibenzothiophene	µg/g	0.0015	<0.0001	0.054	6	–	–	–	0	0.0465	<0.0004	3.34	36
C3 subst'd dibenzothiophene	µg/g	0.007	<0.0002	0.099	6	–	–	–	0	0.0489	<0.0004	6.74	36
C4 subst'd dibenzothiophene	µg/g	0.004	0.001	0.042	6	–	–	–	0	0.061	<0.001	9.66	32
fluoranthene	µg/g	0.0011	0.0002	0.0052	6	–	–	–	0	0.0054	≤0.000348	0.071	36
C1 subst'd fluoranthene/pyrene	µg/g	0.004	0.0004	0.029	6	–	–	–	0	0.035	<0.001	1.25	36
C2 subst'd fluoranthene/pyrene	µg/g	0.01	0.001	0.06	6	–	–	–	0	0.082	<0.001	2.65	31
C3 subst'd fluoranthene/pyrene	µg/g	0.007	0.0004	0.034	6	–	–	–	0	0.058	<0.001	2.37	31
fluorene	µg/g	0.0003	0.0001	0.0021	6	–	–	–	0	0.0018	<0.0001	0.0191	36
C1 subst'd fluorene	µg/g	0.0004	<0.0001	0.0092	6	–	–	–	0	0.0025	<0.0002	0.0164	36
C2 subst'd fluorene	µg/g	0.0016	<0.0001	0.1	6	–	–	–	0	0.021	<0.0003	0.247	36
C3 subst'd fluorene	µg/g	0.003	<0.0001	0.033	6	–	–	–	0	0.0419	<0.0005	0.895	31
indeno(c,d–123)pyrene	µg/g	0.001	<0.0002	0.0058	6	–	–	–	0	0.0058	<0.0003	0.0806	36
phenanthrene	µg/g	0.002	0.0004	0.017	6	–	–	–	0	0.014	≤0.000549	0.037	36
C1 subst'd phenanthrene/anthracene	µg/g	0.005	0.0005	0.044	6	–	–	–	0	0.047	≤0.0012	0.136	36
C2 subst'd phenanthrene/anthracene	µg/g	0.006	0.001	0.059	6	–	–	–	0	0.058	≤0.00095	0.97	36
C3 subst'd phenanthrene/anthracene	µg/g	0.005	≤0.00019	0.064	6	–	–	–	0	0.042	<0.001	2.83	36
C4 subst'd phenanthrene/anthracene	µg/g	0.01	<0.0001	0.05	6	–	–	–	0	0.2	0.001	10.2	36
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.013	0.001	0.054	6	–	–	–	0	0.066	≤0.00234	0.72	31
pyrene	µg/g	0.002	0.0003	0.012	6	–	–	–	0	0.013	≤0.000829	0.325[a]	36

[a] Interim sediment quality guideline exceeded.

[b] Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-5 Sediment Quality in the Middle Athabasca River (Between Muskeg River and Firebag River)

Parameter	Units	Summer (1975 to 1976)				Fall (1994 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n
Particle Size									
particle size – % sand	%	–	–	–	0	66	24	100	33
particle size – % silt	%	–	–	–	0	17	<1	44	33
particle size – % clay	%	–	–	–	0	15	<1	46	33
moisture content	%	–	–	–	0	24	1	35	24
Carbon Content									
total inorganic carbon	% by wt	0.53	0.46	0.6	2	0.57	0.03	2.08	27
total organic carbon	% by wt	0.98	0.33	1.63	2	1.39	<0.1	4.7	37
total carbon	% by wt	–	–	–	0	2	<0.1	4.7	27
Sulphide									
sulphide	mg/kg	–	–	–	0	11.4	<0.1	22.9	2
Toxicity									
chironomus tentans – 10d survival	# alive	–	–	–	0	7.6	4	9.4	13
chironomus tentans – 10d survival	% of control	–	–	–	0	88.4	51	182	13
chironomus tentans – 10d growth	mg/organism	–	–	–	0	1.5	1	3	7
chironomus tentans – 10d growth	% of control	–	–	–	0	97	66	144	13
hyalella azteca – 10d survival	# alive	–	–	–	0	8	3.6	10	13
hyalella azteca – 10d survival	% of control	–	–	–	0	95	50	210	13
hyalella azteca – 10d growth	mg/organism	–	–	–	0	0.15	0.02	0.3	7
hyalella azteca – 10d growth	% of control	–	–	–	0	90	15	314	13
lumbriculus variegatus – 10d survival	# alive	–	–	–	0	18	5	25	13
lumbriculus variegatus – 10d survival	% of control	–	–	–	0	109	60	178	13
lumbriculus variegatus – 10d growth	mg/organism	–	–	–	0	1.2	0.7	16.9	7
lumbriculus variegatus – 10d growth	% of control	–	–	–	0	102	38	297	13
Organics									
total recoverable hydrocarbons	mg/kg	–	–	–	0	600	<100	14,900	28
total volatile hydrocarbons (C5–C10)	mg/kg	–	–	–	0	<0.5	<0.5	42	21
total extractable hydrocarbons (C11–C30)	mg/kg	–	–	–	0	140	<5	28,000	23
Total Metals									
aluminum	µg/g	40,850	31,900	49,800	2	5,275	1,850	19,000	20
antimony	µg/g	–	–	–	0	<0.1	<0.02	1.47	11
arsenic	µg/g	2.7	2.6	4.3	3	3.6	0.6	6.6[(a)]	30
barium	µg/g	620	560	680	2	108	21	222	30
beryllium	µg/g	1.6	1.3	1.9	2	0.3	<0.2	0.7	30
boron	µg/g	–	–	–	0	8	<1	16	14
cadmium	µg/g	0.04	0.04	0.04	1	<0.2	<0.1	0.6	30
calcium	µg/g	18,800	17,200	20,400	2	18,400	2,900	54,000	20
chromium	µg/g	52[(a)]	40[(a)]	72[(a)]	3	11.4	1.1	28.2	30
cobalt)	µg/g	12.5	12	13	2	5.6	1.9	9.6	30
copper	µg/g	8	4	10	3	8	1	18	30

Table F-5 Sediment Quality in the Middle Athabasca River (Between Muskeg River and Firebag River) (continued)

Parameter	Units	Summer (1975 to 1976)				Fall (1994 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n
iron	µg/g	13,900	10,700	20,800	3	12,950	7,830	24,800	20
lead	µg/g	2.9	2.5	5	3	5.7	1.1	11.5	30
lithium	µg/g	–	–	–	0	6.8	6.6	8.1	3
magnesium	µg/g	7,300	6,300	8,300	2	5,770	1,450	12,800	20
manganese	µg/g	201	101	318	3	322	176	759	20
mercury	µg/g	0.02	0.011	0.035	3	<0.05	≤0.03	36[(a)(b)]	32
molybdenum	µg/g	–	–	–	0	0.3	<0.1	0.6	30
nickel	µg/g	12.9	8.1	23.5	3	13.9	3.1	23.8	30
phosphorus, total	µg/g	–	–	–	0	480	410	613	7
potassium	µg/g	–	–	–	0	1,075	355	3,370	20
selenium	µg/g	0.13	0.13	0.13	1	0.3	<0.2	0.6	30
silicon	µg/g	–	–	–	0	993	915	1,250	3
silver	µg/g	–	–	–	0	<0.2	<0.1	0.4	30
sodium	µg/g	7,400	6,700	8,100	2	122	≤60	384	20
strontium	µg/g	172	153	190	2	44	8	116	30
sulphur	µg/g	–	–	–	0	1,910	1,290	1,970	4
thallium	µg/g	–	–	–	0	0.08	<0.05	0.28	23
titanium	µg/g	2,450	2,200	2,700	2	41.6	16	87	20
uranium	µg/g	–	–	–	0	0.5	≤0.1	1.2	26
vanadium	µg/g	43	33	95	3	16.3	2.6	36.7	30
zinc	µg/g	24	23	44	3	41	11	74	30
Target PAHs and Alkylated PAHs									
naphthalene	µg/g	–	–	–	0	0.006	≤0.000913	0.028	31
C1 subst'd naphthalenes	µg/g	–	–	–	0	0.015	≤0.000688	0.071[(a)]	31
C2 subst'd naphthalenes	µg/g	–	–	–	0	0.023	≤0.00346	0.184	31
C3 subst'd naphthalenes	µg/g	–	–	–	0	0.025	≤0.00236	0.794	31
C4 subst'd naphthalenes	µg/g	–	–	–	0	0.017	≤0.00177	3.54	31
Acenaphthene	µg/g	–	–	–	0	0.0005	<0.0001	0.0113[(a)]	31
C1 subst'd acenaphthene	µg/g	–	–	–	0	<0.0005	<0.00004	0.0035	29
acenaphthylene	µg/g	–	–	–	0	<0.0003	<0.00003	0.0092[(a)]	31
anthracene	µg/g	–	–	–	0	<0.001	<0.0001	0.0163	31
dibenzo(a,h)anthracene	µg/g	–	–	–	0	<0.0022	<0.00014	0.0417[(a)]	31
benzo(a)anthracene	µg/g	–	–	–	0	0.0027	≤0.000117	0.0308	31
C1 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.08	<0.001	10.2	29
C2 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.035	<0.001	3.92	29
benzo(a)pyrene	µg/g	–	–	–	0	0.0038	≤0.000225	0.095[(a)]	31
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.022	≤0.0021	1.35	29
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.011	≤0.0012	0.532	29
benzofluoranthenes	µg/g	–	–	–	0	0.014	≤0.000717	0.296	31
benzo(g,h,i)perylene	µg/g	–	–	–	0	0.006	≤0.000438	0.148	31
biphenyl	µg/g	–	–	–	0	0.0019	≤0.000209	0.0155	29
C1 subst'd biphenyl	µg/g	–	–	–	0	<0.0021	<0.00008	0.00725	29
C2 subst'd biphenyl	µg/g	–	–	–	0	0.0012	≤0.00029	0.0537	29
chrysene	µg/g	–	–	–	0	0.013	0.001	1.01[(a)(b)]	24
dibenzothiophene	µg/g	–	–	–	0	0.0013	<0.00004	0.19	31
C1 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0083	≤0.000384	1.19	31
C2 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0283	≤0.00133	5.4	31
C3 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0438	<0.0016	12.7	29

Table F-5 Sediment Quality in the Middle Athabasca River (Between Muskeg River and Firebag River) (continued)

Parameter	Units	Summer (1975 to 1976)				Fall (1994 to 2004)			
		Median	Min	Max	n	Median	Min	Max	n
C4 subst'd dibenzothiophene	µg/g	–	–	–	0	0.04	<0.002	18.3	27
fluoranthene	µg/g	–	–	–	0	0.0033	≤0.000177	0.0655	31
C1 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.028	≤0.00117	1.76	29
C2 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.04	0.003	2	22
C3 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.037	0.003	3.73	22
fluorene	µg/g	–	–	–	0	0.0012	<0.0001	0.0115	31
C1 subst'd fluorene	µg/g	–	–	–	0	0.0012	≤0.000374	0.111	29
C2 subst'd fluorene	µg/g	–	–	–	0	0.0141	≤0.00109	0.912	29
C3 subst'd fluorene	µg/g	–	–	–	0	0.0208	≤0.00206	2	22
indeno(c,d–123)pyrene	µg/g	–	–	–	0	0.0038	≤0.000355	0.0665	31
phenanthrene	µg/g	–	–	–	0	0.01	≤0.000322	0.189[(a)]	31
C1 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.03	≤0.00089	0.565	31
C2 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.04	≤0.00119	2.54	31
C3 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.052	0.001	7.91	31
C4 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.09	0.01	17.7	31
1–methyl–7–isopropyl–phenanthrene (retene)	µg/g	–	–	–	0	0.028	≤0.00259	1.21	25
pyrene	µg/g	–	–	–	0	0.007	≤0.000387	0.435[(a)]	31
Target PANHs									
quinoline	µg/g	–	–	–	0	<0.01	<0.01	0.01	3
7–methyl quinoline	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
c2 subst'd quinoline	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
c3 subst'd quinoline	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
acridine	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
methyl acridine	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
phenanthridine	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
carbazole	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
methyl carbazole	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3
C2 subst'd carbazole	µg/g	–	–	–	0	<0.01	<0.01	<0.01	3

[(a)] Interim sediment quality guideline exceeded.

[(b)] Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-6 Sediment Quality in the Lower Athabasca River (Between Firebag River and Embarras)

Parameter	Units	Summer (1976 to 1995)				Fall (2000 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n
Particle Size									
particle size – % sand	%	99	99	99	1	50	20	70	11
particle size – % silt	%	0.01	0.01	0.01	1	34	17	56	11
particle size – % clay	%	1	1	1	1	16	10	28	11
moisture content	%	–	–	–	0	30	26	40	8
Carbon Content									
total inorganic carbon	% by wt	0.52	0.35	0.69	2	0.73	0.33	0.93	11
total organic carbon	% by wt	0.32	0.18	1.45	3	1.1	0.8	1.5	11
total carbon	% by wt	–	–	–	0	1.7	1.4	2.4	11
Toxicity									
chironomus tentans – 10d survival	# alive	–	–	–	0	7	4	7.4	3
chironomus tentans – 10d survival	% of control	–	–	–	0	98	84	109	3
chironomus tentans – 10d growth	mg/organism	–	–	–	0	2.15	2.1	2.2	2
chironomus tentans – 10d growth	% of control	–	–	–	0	96	72	134	3
hyalella azteca – 10d survival	# alive	–	–	–	0	9	7	9	3
hyalella azteca – 10d survival	% of control	–	–	–	0	103	103	124	3
hyalella azteca – 10d growth	mg/organism	–	–	–	0	0.125	0.05	0.2	2
hyalella azteca – 10d growth	% of control	–	–	–	0	82	82	137	3
lumbriculus variegatus – 10d survival	# alive	–	–	–	0	19	6	22	3
lumbriculus variegatus – 10d survival	% of control	–	–	–	0	103	71	141	3
lumbriculus variegatus – 10d growth	mg/organism	–	–	–	0	7.25	1.3	13.2	2
lumbriculus variegatus – 10d growth	% of control	–	–	–	0	86	66	233	3
Organics									
total recoverable hydrocarbons	mg/kg	–	–	–	0	600	500	1,200	9
total volatile hydrocarbons (C5–C10)	mg/kg	–	–	–	0	<0.5	<0.5	0.6	9
total extractable hydrocarbons (C11–C30)	mg/kg	–	–	–	0	160	59	260	9
Total Metals									
aluminum	µg/g	42,500	33,900	51,100	2	9,390	4,540	14,500	9
antimony	µg/g	–	–	–	0	<0.02	<0.02	<0.02	4
arsenic	µg/g	2.1	≤2.1	4.8	3	4.6	3.8	5.9	11
barium	µg/g	1,070	890	1,250	2	140	94	185	11
beryllium	µg/g	1.6	1.3	2	2	0.5	0.4	0.8	11
boron	µg/g	–	–	–	0	12	4	25	9
cadmium	µg/g	<1	<1	<1	1	0.2	0.2	0.3	11
calcium	µg/g	18,950	14,900	23,000	2	19,200	11,900	23,900	9
chromium	µg/g	54[(a)]	3	85[(a)]	3	14.8	8.9	61.3[(a)]	11
cobalt	µg/g	16.5	12	21	2	7	5.5	8.3	11
copper	µg/g	4	2	11	3	12	8	19	11
iron	µg/g	18,750	13,900	23,600	2	15,000	12,100	20,800	9
lead	µg/g	4	1.3	5	3	7.2	5.3	9.5	11
magnesium	µg/g	8,000	5,700	10,300	2	6,570	3,930	8,510	9
manganese	µg/g	262	179	346	2	336	222	408	9
mercury	µg/g	0.022	0.009	0.036	2	<0.05	≤0.04	0.07	11

Table F-6 Sediment Quality in the Lower Athabasca River (Between Firebag River and Embarras) (continued)

Parameter	Units	Summer (1976 to 1995)				Fall (2000 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n
molybdenum	µg/g	–	–	–	0	0.4	0.3	1.9	11
nickel	µg/g	8.8	6	15	3	16.7	11.5	35.8	11
phosphorus, total	µg/g	144	144	144	1	–	–	–	0
potassium	µg/g	–	–	–	0	1,530	770	2,820	9
selenium	µg/g	–	–	–	0	0.4	0.3	1.2	11
silver	µg/g	–	–	–	0	<0.2	<0.1	0.2	11
sodium	µg/g	9,250	8,900	9,600	2	200	60	272	9
strontium	µg/g	186	182	189	2	53	39	69	11
thallium	µg/g	–	–	–	0	0.16	0.1	0.23	11
titanium	µg/g	2,800	2,700	2,900	2	48.6	38.4	62.8	9
uranium	µg/g	–	–	–	0	0.8	0.6	1.2	11
vanadium	µg/g	75	38	112	2	21.6	13.7	40	11
zinc	µg/g	21	11	50	3	53	40	61	11
Target PAHs and Alkylated PAHs									
naphthalene	µg/g	–	–	–	0	0.009	0.005	0.037[(a)]	12
C1 subst'd naphthalenes	µg/g	–	–	–	0	0.024[(a)]	0.016	0.036[(a)]	12
C2 subst'd naphthalenes	µg/g	–	–	–	0	0.035	0.024	0.05	12
C3 subst'd naphthalenes	µg/g	–	–	–	0	0.032	0.021	0.076	12
C4 subst'd naphthalenes	µg/g	–	–	–	0	0.021	<0.003	0.091	12
Acenaphthene	µg/g	–	–	–	0	<0.0011	≤0.00032	0.0013	12
C1 subst'd acenaphthene	µg/g	–	–	–	0	0.00005	<0.0001	0.0026	12
acenaphthylene	µg/g	–	–	–	0	<0.0005	<0.0001	<0.013	12
anthracene	µg/g	–	–	–	0	<0.001	<0.0005	0.0011	12
dibenzo(a,h)anthracene	µg/g	–	–	–	0	<0.00334	<0.0013	0.0025	12
benzo(a)anthracene	µg/g	–	–	–	0	<0.0024	≤0.0018	0.0043	12
C1 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.15	0.12	0.3	12
C2 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.053	0.04	0.13	12
benzo(a)pyrene	µg/g	–	–	–	0	0.0048	<0.004	0.0093	12
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.027	<0.002	0.067	12
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.012	<0.002	0.024	12
benzofluoranthenes	µg/g	–	–	–	0	0.017	0.01	0.027	12
benzo(g,h,i)perylene	µg/g	–	–	–	0	0.0105	0.0064	0.024	12
biphenyl	µg/g	–	–	–	0	0.0032	≤0.0024	0.0058	12
C1 subst'd biphenyl	µg/g	–	–	–	0	<0.00276	<0.00009	0.0061	12
C2 subst'd biphenyl	µg/g	–	–	–	0	0.0017	<0.0002	0.0086	12
chrysene	µg/g	–	–	–	0	0.017	0.012	0.032	12
dibenzothiophene	µg/g	–	–	–	0	0.0015	≤0.000973	0.0051	12
C1 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0123	0.0069	0.045	12
C2 subst'd dibenzothiophene	µg/g	–	–	–	0	0.048	0.017	0.31	12
C3 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0805	0.0526	0.54	12
C4 subst'd dibenzothiophene	µg/g	–	–	–	0	0.069	<0.003	0.143	12
fluoranthene	µg/g	–	–	–	0	0.004	0.0023	0.0163	12
C1 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.033	0.024	0.093	12
C2 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.067	0.048	0.18	12
C3 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.059	0.032	0.19	12
fluorene	µg/g	–	–	–	0	0.0017	≤0.0015	0.004	12

Table F-6 Sediment Quality in the Lower Athabasca River (Between Firebag River and Embarras) (continued)

Parameter	Units	Summer (1976 to 1995)				Fall (2000 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n
C1 subst'd fluorene	µg/g	–	–	–	0	0.0037	<0.003	0.0142	12
C2 subst'd fluorene	µg/g	–	–	–	0	0.0141	<0.0027	0.0543	12
C3 subst'd fluorene	µg/g	–	–	–	0	0.024	<0.0049	0.0912	12
indeno(c,d–123)pyrene	µg/g	–	–	–	0	0.0062	0.0034	0.018	12
phenanthrene	µg/g	–	–	–	0	0.015	0.007	0.028	12
C1 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.043	0.022	0.14	12
C2 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.046	0.032	0.2	12
C3 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.046	0.003	0.22	12
C4 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.15	0.01	0.24	12
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	–	–	–	0	0.05	0.033	0.081	12
pyrene	µg/g	–	–	–	0	0.011	0.007	0.018	12

(a) Interim sediment quality guideline exceeded.

(b) Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-7 Water Quality in the Lower Firebag River

Parameter	Units	Winter (1976 to 2005)				Spring (1976 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	–1	0.5	24	9.6	1	13	8	14.9	10.5	18.1	10	6.5	0	12.1	9
dissolved oxygen	mg/L	5.7[a]	3.6[a][b]	8.6	24	9.9	7.6	16.4	8	7.9	6.5	10.2	8	10	7.2	14	5
Conventional Parameters																	
colour	TCU	25	10	45	23	55	30	60	4	55	35	90	7	60	25	100	9
specific conductance	µS/cm	259	200	433	31	174	105	233	9	188	140	215	12	194	120	261	14
dissolved organic carbon	mg/L	5	2	13	33	10	<1	16	9	14	9	23	12	8	2	16	14
hardness	mg/L	128	112	227	27	87	64	123	9	100	78	129	11	107	94	124	13
pH		7.6	7.1	8.2	32	7.9	7.1	8.3	9	8	5.6[a][b]	8.4	12	8.1	7.5	8.3	14
total alkalinity	mg/L	129	112	219	32	89	43	124	9	98	80	116	12	105	84	123	14
total dissolved solids	mg/L	155	90	268	31	126	69	166	9	121	92	190	12	120	60	170	14
total organic carbon	mg/L	6	2	13	25	11	<1	18	9	14	9	24	12	10	7	18	14
total suspended solids	mg/L	4	≤1	13	33	11	4	70	9	7	≤1.2	18	12	5	<0.4	17	14
Major Ions																	
bicarbonate	mg/L	161	139	172	17	97	94	137	4	116	103	138	4	135	106	150	8
calcium	mg/L	34	30	60	32	23	17	32	9	26	20	33	12	28	20	33	14
carbonate	mg/L	<5	<0.5	<5	9	<5	<5	<5	4	<5	<5	<5	4	<5	<5	<5	8
chloride	mg/L	2	1	10	33	2	2	2	9	2	1	3	12	2	1	3	14
magnesium	mg/L	11	9	19	32	7	5	10	9	8	7	11	12	8	7	10	14
potassium	mg/L	1	0.5	2	32	1	1	2	9	0.5	<0.05	1	12	1	≤0.25	1	14
sodium	mg/L	4	3	9	33	4	2	5	9	3	2	4	12	4	1	5	14
sulphate	mg/L	5	≤2.9	10	33	5	4	18	9	4	2	6	12	3	0.1	10	14
sulphide	mg/L	<0.009	<0.001	0.019[a]	21	0.001	<0.003	0.008	4	<0.01	<0.003	0.02[a]	7	<0.004	<0.002	0.008	11
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.2	0.1	0.3	8	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1	4	<0.1	<0.05	0.1	8
nitrogen – ammonia	mg/L	0.02	<0.01	0.11	17	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	4	<0.05	<0.05	0.36	8
nitrogen – kjeldahl	mg/L	0.3	<0.2	1	32	0.5	0.3	0.6	7	0.8	<0.2	5.4	11	0.5	0.2	1.6	14
nitrogen – total nitrogen	mg/L	0.4	<0.2	1	32	0.5	0.3	0.6	7	0.8	<0.2	5.4[a]	11	0.5	0.2	1.6[a]	14
phosphorus, total	mg/L	0.047	0.024	0.18[a]	33	0.05	0.024	0.06[a]	9	0.049	0.023	0.182[a]	12	0.042	0.011	0.11[a]	14
phosphorus, dissolved	mg/L	0.025	0.015	0.046	17	0.02	0.015	0.028	4	0.036	0.017	0.041	4	0.022	0.007	0.057	8
chlorophyll *a*	µg/L	<1	≤0.1	3.4	11	4	3	5	3	2	1	16	3	<1	<1	3	6
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	0.5	<0.1	2	19	2	2	3	4	<2	<2	3	4	2	<2	3	8
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	8	<1	<1	1	4	1	<1	2	4	<1	<1	1	7
total phenolics	mg/L	0.001	<0.001	0.014[a]	28	<0.001	<0.001	0.008[a]	6	<0.001	<0.001	0.002	12	<0.001	<0.001	0.007[a]	11
total recoverable hydrocarbons	mg/L	<0.5	<0.1	1.3	18	<0.5	<0.1	<0.5	5	0.1	<0.1	1.6	11	<0.5	≤0.1	2.1	12
Toxicity																	
Microtox® IC50 @ 15 Min	%	>91	>91	>91	4	–	–	–	0	–	–	–	0	>91	>91	>91	1
Microtox® IC25 @ 15 Min	%	>91	>91	>91	4	–	–	–	0	–	–	–	0	>91	>91	>91	1
Total Metals																	
aluminum	mg/L	0.06	0.0142	0.0662	9	0.3345[a]	0.167[a]	0.41[a]	4	0.2245[a]	0.102[a]	0.31[a]	4	0.0645	0.0326	0.292[a]	8

Table F-7 Water Quality in the Lower Firebag River (continued)

Parameter	Units	Winter (1976 to 2005)				Spring (1976 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
antimony	mg/L	0.0002	<0.000004	0.0005	8	0.00001	≤0.00001	0.00001	4	0.00002	0.00001	0.0005	4	0.00001	<0.000004	0.0198	7
arsenic	mg/L	0.0002	≤0.0001	0.0003	17	0.0003	≤0.000339	0.0004	4	0.0005	0.0004	0.0005	4	0.0004	≤0.000276	0.019[(a)]	9
barium	mg/L	0.032	0.028	0.042	17	0.025	0.023	0.03	4	0.029	0.027	0.032	4	0.026	0.024	0.028	7
beryllium	mg/L	<0.001	<0.000003	0.0004	9	<0.00003	≤0.00001	0.00001	4	<0.00003	≤0.00000751	0.00001	4	0.00001	≤0.00000485	0.0003	8
boron	mg/L	0.02	0.01	0.03	8	0.02	0.01	0.02	4	0.02	≤0.0142	0.02	4	0.02	0.01	0.02	8
cadmium	mg/L	<0.0002	≤0.0000169	0.002[(a)]	17	0.00001	<0.000002	0.0004[(a)]	4	0.000003	≤0.00000303	0.00002	4	<0.00002	≤0.00000366	0.00001	7
chromium	mg/L	0.0014[(a)]	≤0.000114	0.004[(a)]	17	0.0007	0.0004	0.0011[(a)]	4	0.0003	≤0.000257	0.0005	4	0.0003	≤0.000279	0.0005	8
chromium – hexavalent	mg/L	<0.003	<0.003	0.004[(a)]	14	<0.003	<0.003	0.006[(a)]	3	<0.003	<0.003	0.004[(a)]	7	<0.003	<0.003	0.004[(a)]	6
cobalt	mg/L	<0.0008	≤0.0000283	0.0001	16	0.0002	0.0001	0.0005	4	0.0002	0.0001	0.0002	4	0.0001	0.0001	0.001	8
copper	mg/L	0.0004	≤0.000152	0.0035[(a)]	17	0.0005	0.0002	0.003[(a)]	4	0.0002	≤0.0000936	0.0003	4	0.0004	<0.0001	0.005[(a)]	8
iron	mg/L	0.61[(a)]	0.45[(a)]	0.89[(a)]	17	0.83[(a)]	0.58[(a)]	0.97[(a)]	4	0.78[(a)]	0.47[(a)]	0.97[(a)]	4	0.56[(a)]	0.24	1.06[(a)]	8
lead	mg/L	0.0003	<0.0001	0.0023	9	0.0002	0.0001	0.0009	4	0.0001	0.0001	0.0002	4	0.0001	0.00004	0.0004	7
lithium	mg/L	0.004	<0.003	0.006	8	0.003	≤0.00283	0.004	4	0.003	≤0.0023	0.004	4	0.003	≤0.00298	0.008	8
manganese	mg/L	0.033	0.014	0.149	17	0.048	0.046	0.052	4	0.072	0.064	0.076	4	0.037	0.02	0.079	8
mercury	mg/L	<0.0001	<0.0000006	0.0006[(a)(b)]	31	<0.000051	<0.0000006	0.0000019	8	<0.0001	<0.0000006	0.0000014	10	<0.0001	<0.0000006	0.0018[(a)(b)]	14
molybdenum	mg/L	0.0002	≤0.000176	0.002	17	0.0002	0.0002	0.0006	4	0.0001	<0.0001	0.0002	4	0.0002	0.0001	0.0002	7
nickel	mg/L	0.001	<0.000005	0.0275	17	0.0003	0.0002	0.0005	4	0.0002	<0.000005	0.0006	4	0.0003	<0.000005	0.0147	8
selenium	mg/L	<0.0001	<0.0001	0.0005	17	<0.00033	<0.0001	0.00015	4	<0.0003	<0.0001	0.00021	4	<0.0005	<0.0001	0.0185[(a)]	8
silver	mg/L	0.00001	≤0.00000138	0.0016[(a)]	8	0.000001	<0.0000005	0.000009	4	0.000001	<0.0000005	0.000007	4	<0.000011	<0.0000005	0.000011	7
strontium	mg/L	0.08	0.06	0.09	8	0.05	0.05	0.07	4	0.06	0.05	0.08	4	0.07	0.05	0.08	7
sulphur	mg/L	1.5	1.4	1.5	2	0.7	0.5	0.9	2	0.6	<0.2	1.5	2	0.3	<0.2	0.4	3
thallium	mg/L	0.00001	≤0.00000115	0.00002	4	0.00001	≤0.00000453	0.00004	4	0.000003	≤0.00000122	0.00005	4	0.00001	0.000003	0.00001	4
titanium	mg/L	0.0009	≤0.0009	0.0034	13	0.0061	≤0.0043	0.009	6	0.0056	0.0027	0.0068	4	0.0009	<0.0006	0.007	11
uranium	mg/L	<0.0001	≤0.0000547	0.0001	8	0.0001	0.0001	0.0005	4	0.00005	≤0.00004	0.0001	4	0.00004	≤0.0000377	0.0001	7
vanadium	mg/L	<0.001	≤0.000186	0.003	31	0.0007	≤0.000668	0.0015	7	<0.001	≤0.000573	0.003	11	0.0002	<0.0002	0.002	13
zinc	mg/L	0.005	<0.001	0.067[(a)]	17	0.004	0.002	0.02	4	0.003	≤0.0028	0.011	4	0.006	0.001	0.01	8
Dissolved Metals																	
aluminum	mg/L	0.0029	≤0.00272	0.0033	4	0.0076	0.0064	0.04	4	0.007	0.0042	0.02	4	0.0088	0.0028	0.11[(a)]	8
antimony	mg/L	0.000001	<0.000004	0.00002	4	0.00001	≤0.00000915	0.00001	4	0.00001	≤0.0000101	0.00004	4	0.00001	≤0.000006	0.0009	7
arsenic	mg/L	0.0001	≤0.0001	0.003	18	0.00001	<0.0002	0.0004	8	0.0002	<0.0002	0.001	12	<0.0004	<0.0002	0.0007	13
barium	mg/L	0.031	0.028	0.037	4	0.02	0.018	0.028	4	0.024	0.022	0.027	4	0.023	0.02	0.027	7
beryllium	mg/L	<0.001	<0.000003	0.0005	11	<0.00004	<0.000003	0.00001	5	<0.00004	<0.000003	0.000004	5	<0.0001	<0.000003	0.0001	8
boron	mg/L	0.03	<0.01	0.18	15	0.03	0.01	0.1	9	0.04	0.01	0.15	9	0.02	0.01	0.06	12
cadmium	mg/L	0.00001	<0.00001	0.001[(a)]	5	<0.00001	<0.000002	0.00001	5	<0.00001	<0.000002	0.000003	5	<0.00001	<0.000002	0.00001	7
chromium	mg/L	0.0002	0.0001	0.0005	4	0.0002	≤0.000164	0.0006	4	0.0001	≤0.000105	0.0004	4	0.0001	≤0.0000647	0.0003	8
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.00002	≤0.0000171	0.09	5	0.00004	≤0.0000398	0.00004	5	0.0001	≤0.00003	0.002	5	0.0001	0.00003	0.09	10
copper	mg/L	0.0003	≤0.000134	0.0021	4	0.0002	<0.0001	0.001	5	0.0001	≤0.00009287	0.0003	5	0.0004	<0.0001	0.001	8
iron	mg/L	0.19	0.14	0.23	4	0.24	0.2	0.32[(a)]	5	0.21	0.14	0.37[(a)]	5	0.26	0.15	0.54[(a)]	8
lead	mg/L	0.0001	≤0.0000747	0.0002	4	0.00001	≤0.00001	0.00003	5	0.00002	≤0.0000172	0.00003	5	0.00004	0.00002	0.0002	7
lithium	mg/L	0.005	0.003	0.006	4	0.003	0.003	0.004	4	0.003	0.002	0.004	4	0.004	0.003	0.008	8

Table F-7 Water Quality in the Lower Firebag River (continued)

Parameter	Units	Winter (1976 to 2005)				Spring (1976 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
manganese	mg/L	0.028	0.018	0.14	4	0.005	0.002	0.019	5	0.008	≤0.00663	0.02	5	0.01	0.005	0.031	8
mercury	mg/L	<0.000025	<0.00001	<0.0001	4	<0.00003	<0.00001	0.00005[a)(b)]	4	<0.000025	<0.00001	<0.0001	4	<0.00007	<0.00001	0.0001[a)(b)]	6
molybdenum	mg/L	0.0002	0.0002	0.0003	4	0.0002	0.0001	0.0003	4	0.0001	≤0.0001	0.0002	5	0.0001	0.0001	0.0003	7
nickel	mg/L	<0.0001	<0.000005	<0.0001	4	0.00003	≤0.0000317	0.004	5	0.0001	<0.000005	0.002	5	0.0002	<0.000005	0.0022	8
selenium	mg/L	<0.0002	<0.0001	0.0003	18	<0.0003	≤0.0001	0.00015	8	<0.0002	<0.0001	0.00012	12	<0.0002	<0.0001	0.0008	13
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	<0.000005	<0.0000005	<0.0002	4	0.0000002	<0.0000005	0.00001	4	<0.00001	<0.0000005	0.00002	4	<0.000005	<0.0000005	<0.0002	7
strontium	mg/L	0.08	0.08	0.09	4	0.05	0.05	0.07	4	0.06	0.05	0.08	4	0.06	0.05	0.08	7
sulphur	mg/L	1.385	1.35	1.42	2	0.518	0.421	0.614	2	0.597	<0.2	1.395	2	0.281	<0.2	0.429	3
thallium	mg/L	0.000004	≤0.00000113	0.00001	4	0.000002	<0.0000003	0.00005	4	0.000002	<0.0000003	0.00004	4	0.00001	0.000003	0.00002	4
titanium	mg/L	0.002	0.0016	0.0022	4	0.0009	0.0006	0.0018	4	0.0011	0.0006	0.0017	4	0.001	<0.0003	0.0015	8
uranium	mg/L	0.0001	0.0001	0.0001	4	0.00004	≤0.00004	0.00005	4	0.00004	≤0.00003	0.0001	4	0.00002	≤0.000023	0.00004	7
vanadium	mg/L	0.0001	≤0.0001	0.0002	5	0.0002	≤0.0001	0.0004	5	0.0003	≤0.0002	0.0003	5	0.0002	<0.0001	0.0004	8
zinc	mg/L	0.005	0.002	0.017	4	0.001	<0.001	0.004	5	0.001	<0.001	0.004	5	0.003	0.001	0.006	8

[a)] Chronic aquatic life guideline exceeded.

[b)] Acute aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.

n = Number of samples.

Table F-8 Sediment Quality in the Lower Firebag River

Parameter	Units	Summer (1975 to 1975)				Fall (2002 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n
Particle Size									
particle size – % sand	%	–	–	–	0	82	44	100	4
particle size – % silt	%	–	–	–	0	15	<1	50	4
particle size – % clay	%	–	–	–	0	2	<1	6	4
moisture content	%	–	–	–	0	22	16	30	4
Carbon Content									
total inorganic carbon	% by wt	–	–	–	0	0.26	0.06	0.4	4
total organic carbon	% by wt	–	–	–	0	1.5	<0.1	2.9	4
total carbon	% by wt	–	–	–	0	1.75	0.1	3.3	4
Toxicity									
chironomus tentans – 10d survival	# alive	–	–	–	0	8	7	9	3
chironomus tentans – 10d survival	% of control	–	–	–	0	97.5	95	100	2
chironomus tentans – 10d growth	mg/organism	–	–	–	0	1.9	1.9	1.9	2
chironomus tentans – 10d growth	% of control	–	–	–	0	89	78	100	2
hyalella azteca – 10d survival	# alive	–	–	–	0	7	5	9	2
hyalella azteca – 10d survival	% of control	–	–	–	0	80	60	100	2
hyalella azteca – 10d growth	mg/organism	–	–	–	0	0.1	0.1	0.1	1
hyalella azteca – 10d growth	% of control	–	–	–	0	102	100	104	2
lumbriculus variegatus – 10d survival	# alive	–	–	–	0	15.5	10	21	2
lumbriculus variegatus – 10d survival	% of control	–	–	–	0	105.5	100	111	2
lumbriculus variegatus – 10d growth	mg/organism	–	–	–	0	19.9	19.9	19.9	1
lumbriculus variegatus – 10d growth	% of control	–	–	–	0	137.5	118	157	2
Organics									
total recoverable hydrocarbons	mg/kg	–	–	–	0	1,100	300	2,500	3
total volatile hydrocarbons (C5–C10)	mg/kg	–	–	–	0	<0.5	<0.5	12	3
total extractable hydrocarbons (C11–C30)	mg/kg	–	–	–	0	81	62	1,100	3
Total Metals									
aluminum	µg/g	–	–	–	0	1,255	710	1,800	2
arsenic	µg/g	1	1	1	1	0.8	0.5	1.1	4
barium	µg/g	–	–	–	0	18	10	30	4
beryllium	µg/g	–	–	–	0	<0.2	<0.2	<0.2	4
boron	µg/g	–	–	–	0	2	<2	5	2
cadmium	µg/g	0.01	0.01	0.01	1	<0.1	<0.1	<0.1	4
calcium	µg/g	–	–	–	0	2,900	2,200	3,600	2
chromium	µg/g	**41**[(a)]	**41**[(a)]	**41**[(a)]	1	1.6	0.7	3.5	4
cobalt	µg/g	–	–	–	0	1	0.8	1.5	4
copper	µg/g	12	12	12	1	0.1	<0.5	1	4
iron	µg/g	6,680	6,680	6,680	1	4,900	4,500	5,300	2
lead	µg/g	2.4	2.4	2.4	1	1	<0.5	2	4
magnesium	µg/g	–	–	–	0	1,620	1,300	1,940	2
manganese	µg/g	102	102	102	1	126	111	142	2
mercury	µg/g	0.02	0.02	0.02	1	<0.05	<0.05	0.05	4
molybdenum	µg/g	–	–	–	0	0.2	<0.1	0.8	4
nickel	µg/g	9.4	9.4	9.4	1	1.4	1	3.2	4

Table F-8 Sediment Quality in the Lower Firebag River (continued)

Parameter	Units	Summer (1975 to 1975)				Fall (2002 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n
potassium	µg/g	–	–	–	0	275	200	350	2
selenium	µg/g	0.05	0.05	0.05	1	<0.2	<0.2	0.2	4
silver	µg/g	–	–	–	0	<0.2	<0.2	0.3	4
sodium	µg/g	–	–	–	0	<65	≤30	30	2
strontium	µg/g	–	–	–	0	7	4	11	4
thallium	µg/g	–	–	–	0	<0.05	<0.05	0.07	4
titanium	µg/g	–	–	–	0	34.5	23	46	2
uranium	µg/g	–	–	–	0	0.1	0.1	0.3	4
vanadium	µg/g	15	15	15	1	3.2	1.4	7.2	4
zinc	µg/g	16	16	16	1	7	6	12	4
Target PAHs and Alkylated PAHs									
naphthalene	µg/g	–	–	–	0	0.001	0.001	0.01	4
C1 subst'd naphthalenes	µg/g	–	–	–	0	0.002	0.001	0.006	4
C2 subst'd naphthalenes	µg/g	–	–	–	0	0.004	0.003	0.011	4
C3 subst'd naphthalenes	µg/g	–	–	–	0	0.012	0.001	0.015	4
C4 subst'd naphthalenes	µg/g	–	–	–	0	0.009	0.002	0.016	4
acenaphthene	µg/g	–	–	–	0	<0.0004	<0.0001	0.0012	4
C1 subst'd acenaphthene	µg/g	–	–	–	0	<0.0002	<0.0001	<0.0007	3
acenaphthylene	µg/g	–	–	–	0	<0.0003	<0.0001	0.001	4
anthracene	µg/g	–	–	–	0	<0.0012	<0.0001	0.0011	4
dibenzo(a,h)anthracene	µg/g	–	–	–	0	<0.00246	≤0.000411	0.0035	4
benzo(a)anthracene	µg/g	–	–	–	0	<0.0016	<0.0002	0.0014	4
C1 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.1	0.02	0.47	4
C2 subst'd benzo(a)anthracene/chrysene	µg/g	–	–	–	0	0.056	0.012	0.22	4
benzo(a)pyrene	µg/g	–	–	–	0	<0.0038	≤0.000708	0.0027	4
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.04	0.011	0.098	4
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	–	–	–	0	0.044	0.006	0.049	4
benzofluoranthenes	µg/g	–	–	–	0	0.008	0.001	0.015	3
benzo(g,h,i)perylene	µg/g	–	–	–	0	0.0085	0.0022	0.0207	4
biphenyl	µg/g	–	–	–	0	0.0005	0.0001	0.0016	4
C1 subst'd biphenyl	µg/g	–	–	–	0	<0.0003	<0.00009	0.0003	3
C2 subst'd biphenyl	µg/g	–	–	–	0	0.0018	0.0005	0.003	3
chrysene	µg/g	–	–	–	0	0.014	0.004	0.041	4
dibenzothiophene	µg/g	–	–	–	0	<0.0009	≤0.0000549	0.0005	4
C1 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0066	0.0006	0.014	4
C2 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0396	0.0018	0.0845	4
C3 subst'd dibenzothiophene	µg/g	–	–	–	0	0.0856	0.0072	0.182	4
C4 subst'd dibenzothiophene	µg/g	–	–	–	0	0.144	0.011	0.418	4
fluoranthene	µg/g	–	–	–	0	0.0005	≤0.000235	0.0037	4
C1 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.027	0.005	0.071	4
C2 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.066	0.014	0.206	4
C3 subst'd fluoranthene/pyrene	µg/g	–	–	–	0	0.058	0.015	0.276	4
fluorene	µg/g	–	–	–	0	0.0002	≤0.0000754	0.0016	4
C1 subst'd fluorene	µg/g	–	–	–	0	0.0027	0.0004	0.0048	4
C2 subst'd fluorene	µg/g	–	–	–	0	0.0102	0.0022	0.0345	4
C3 subst'd fluorene	µg/g	–	–	–	0	0.0309	0.0035	0.0829	4
indeno(c,d–123)pyrene	µg/g	–	–	–	0	0.0028	≤0.00103	0.0045	4

Table F-8 Sediment Quality in the Lower Firebag River (continued)

Parameter	Units	Summer (1975 to 1975)				Fall (2002 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n
phenanthrene	µg/g	–	–	–	0	0.003	0.0004	0.009	4
C1 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.012	0.001	0.031	4
C2 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.028	0.003	0.075	4
C3 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.041	0.004	0.128	4
C4 subst'd phenanthrene/anthracene	µg/g	–	–	–	0	0.2	0.02	0.7	4
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	–	–	–	0	0.035	0.002	0.125	3
pyrene	µg/g	–	–	–	0	0.005	0.002	0.017	4

(a) Interim sediment quality guideline exceeded.

(b) Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-9 Water Quality in McClelland Lake

Parameter	Units	Winter (1976 to 2007)				Spring (2000 to 2007)				Summer (1966 to 2007)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.4	0	1.8	6	13.4	7.5	16.1	4	19.7	16	22.7	9	10.4	5.1	15.1	8
dissolved oxygen	mg/L	1.8[(a)(b)]	0.5[(a)(b)]	7.3	5	10	9.1	11	4	9	4.6[(a)(b)]	12.1	9	10.2	7.8	12.5	8
Conventional Parameters																	
colour	TCU	12	3	60	6	12	<3	20	6	6	4	50	7	10	5	50	10
specific conductance	uS/cm	361	301	643	7	284	249	340	6	240	195	328	11	241	224	367	11
dissolved organic carbon	mg/L	17	12	47	7	12	10	22	6	12	12	23	7	12	11	25	10
hardness	mg/L	190	157	367	7	142	124	195	6	124	105	184	9	118	106	216	10
pH		8	7.6	8.3	7	8.3	8.2	8.4	6	8.1	7.4	8.9[(a)(b)]	11	8.4	7.4	8.5	11
total alkalinity	mg/L	196	155	349	7	152	137	187	6	135	54	210	11	128	117	199	11
total dissolved solids	mg/L	211	190	420	7	171	100	219	6	160	140	270	7	160	80	258	9
total organic carbon	mg/L	20	12	48	6	12	11	24	6	14	13	23	5	13	12	25	9
total suspended solids	mg/L	8	≤1	80	6	<3	<3	3	6	<3	<3	5	5	<3	<3	8	10
Major Ions																	
bicarbonate	mg/L	247	190	425	6	182	165	226	6	162	147	256	8	152	141	243	10
calcium	mg/L	36	31	101	7	29	25	54	6	23	6	51	9	22	19	58	11
carbonate	mg/L	<5	<5	<5	5	<5	<5	<5	6	<5	<5	8	6	<5	<5	6	10
chloride	mg/L	1	<1	2	7	1	<1	1	6	0.2	≤0.2	6	11	<1	≤0.38	2	11
magnesium	mg/L	24	19	29	7	15	13	18	6	15	14	19	11	16	11	18	11
potassium	mg/L	4	2	5	7	3	1	4	6	3	<0.5	3	10	3	<0.5	3	11
sodium	mg/L	6	5	7	7	4	2	6	6	4	<1	5	11	4	2	5	11
sulphate	mg/L	1	<0.5	6	7	2	1	3	6	3	<0.5	37	11	2	0.1	10	11
sulphide	mg/L	0.004	<0.003	0.031[(b)]	5	<0.003	<0.003	0.005	6	0.004	<0.003	0.03	5	<0.003	<0.003	0.003	9
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	<0.1	<0.1	<0.1	5	<0.1	<0.05	<0.1	6	<0.1	≤0.001	0.1	6	<0.1	≤0.00543	0.01	10
nitrogen - ammonia	mg/L	0.11	0.06	0.18	5	<0.055	<0.05	0.06	6	<0.05	≤0.013	0.013	6	<0.05	≤0.0156	0.016	10
nitrogen - kjeldahl	mg/L	1.2	1.2	2	6	0.8	0.6	1	6	1.2	0.9	1.3	7	0.9	0.5	1.9	9
nitrogen - total nitrogen	mg/L	1.2[(b)]	1.2[(b)]	2[(b)]	6	0.8	0.6	1	6	1.2[(b)]	0.9	1.3[(b)]	7	0.9	0.5	1.9[(b)]	9
phosphorus, total	mg/L	0.016	0.006	0.158[(b)]	7	0.014	0.011	0.021	6	0.017	≤0.008	0.45[(b)]	10	0.014	0.01	0.2[(b)]	11
phosphorus, dissolved	mg/L	0.006	0.005	0.021	5	0.007	0.002	0.01	6	0.007	0.002	0.012	7	0.008	0.002	0.015	10
chlorophyll *a*	µg/L	1.2	<1	33	6	2	<1	18	6	3.3	<1	7	9	1	1	6	9
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	3	<2	9	5	<2	<2	<2	6	<2	<2	3	5	<2	<2	2	9
General Organics																	
naphthenic acids	mg/L	0.5	<1	2	4	<1	<1	<1	4	<1	<1	2	4	<1	<1	2	7
total phenolics	mg/L	0.01[(b)]	<0.001	0.011[(b)]	3	<0.001	<0.001	<0.001	4	0.008[(b)]	<0.001	0.023[(b)]	8	<0.001	<0.001	0.003	9
total recoverable hydrocarbons	mg/L	<1	<0.5	<1	4	<1	≤0.7	1.3	4	<1	≤0.6	1.1	5	<0.7	<0.5	2.1	8
Toxicity																	
microtox® IC50 @ 15 min	%	–	–	–	0	–	–	–	0	–	–	–	0	>91	>91	>91	1
microtox® IC25 @ 15 min	%	–	–	–	0	–	–	–	0	–	–	–	0	>91	>91	>91	1
algal growth inhibition test (72h) - IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
algal growth inhibition test (72h) - IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
algal growth inhibition test (72h) - LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
algal growth inhibition test (72h) - NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0

Table F-9 Water Quality in McClelland Lake (continued)

Parameter	Units	Winter (1976 to 2007)				Spring (2000 to 2007)				Summer (1966 to 2007)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d mortality test - LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test - LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test - LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d mortality test - NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d reproduction test - IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d reproduction test - IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d reproduction test - LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d reproduction test - NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d growth - IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d growth - IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d growth - LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d growth - NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d mortality test - LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>88	76	>100	2
fathead minnow 7d mortality test - LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d mortality test - LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d mortality test - NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0
Total Metals																	
aluminum	mg/L	0.03	<0.02	0.12[(b)]	4	0.025	<0.02	0.07	4	0.06	<0.02	0.11[(b)]	4	<0.02	≤0.0052	0.08	8
antimony	mg/L	0.0002	<0.0004	0.0007	4	<0.0028	≤0.0007	0.0007	4	0.0006	≤0.0005	0.0009	4	<0.0028	<0.000004	0.0005	8
arsenic	mg/L	<0.0004	<0.0002	0.0005	5	<0.0007	<0.0004	<0.001	4	<0.0004	≤0.0001	0.0001	6	<0.001	≤0.0002	0.0002	9
barium	mg/L	0.052	0.035	0.168	5	0.039	0.036	0.045	4	0.037	0.027	0.043	6	0.031	0.026	0.071	8
beryllium	mg/L	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	4	<0.001	<0.00004	0.0001	8
boron	mg/L	0.09	0.05	0.13	4	0.06	0.06	0.08	4	0.08	0.06	0.1	4	0.07	0.05	0.09	8
cadmium	mg/L	<0.0002	<0.0002	<0.001	5	<0.0002	<0.0002	<0.0002	4	<0.0004	<0.0002	0.006[(a)(b)]	8	<0.0002	<0.00002	0.004[(a)(b)]	9
chromium	mg/L	<0.001	<0.0008	0.0016[(b)]	5	0.0007	<0.0008	0.0024[(b)]	4	0.0012[(b)]	<0.0008	0.015[(b)]	8	<0.0008	≤0.00016	0.003[(b)]	9
cobalt	mg/L	<0.0002	<0.0002	0.0002	5	<0.0002	<0.0002	<0.0002	4	<0.0004	<0.0002	0.0005	8	<0.0002	<0.00002	0.004	9
copper	mg/L	<0.001	<0.001	0.001	5	0.001	<0.001	0.037[(a)(b)]	4	<0.001	≤0.0005	0.07[(a)(b)]	8	<0.001	<0.0001	0.006[(b)]	9
iron	mg/L	0.47[(b)]	<0.005	4.08[(b)]	4	0.08	0.04	0.19	4	0.14	≤0.063	0.34[(b)]	7	0.06	<0.02	0.14	9
lead	mg/L	0.0003	<0.0001	0.0003	4	0.0004	<0.0001	0.0043[(b)]	4	0.0005	≤0.0003	0.006[(b)]	6	0.0003	≤0.00002	0.014[(b)]	9
lithium	mg/L	0.031	0.019	0.031	4	0.019	0.016	0.024	4	0.017	0.015	0.023	4	0.02	0.018	0.027	8
manganese	mg/L	0.05	<0.008	1.29	5	0.038	0.019	0.059	4	0.019	0.003	0.07	8	0.016	0.007	0.042	9
mercury	mg/L	<0.0000008	<0.0000006	0.0000011	4	<0.0000006	<0.0000006	<0.0000006	2	0.0000014	<0.0000006	0.0009[(a)(b)]	9	<0.0002	<0.0000006	<0.0005	9
methyl mercury	mg/L	<0.00000003	<0.00000003	<0.00000003	3	<0.00000003	<0.00000003	<0.00000003	2	<0.00000003	<0.00000003	<0.00000003	3	<0.00000003	<0.00000003	<0.00000003	2
molybdenum	mg/L	<0.0001	<0.0001	0.0006	5	0.0001	<0.0001	0.0002	4	<0.0001	<0.0001	0.0005	6	<0.0001	<0.00002	0.0001	8
nickel	mg/L	0.0009	<0.0002	0.0021	5	0.0012	0.0005	0.0039	4	0.0021	<0.0002	0.004	8	0.0009	<0.0001	0.004	9
selenium	mg/L	<0.0004	<0.0002	0.0041[(b)]	5	<0.0006	<0.0004	<0.0008	4	<0.00045	≤0.0001	0.0007	6	<0.00065	<0.0004	<0.0008	8
silver	mg/L	0.000008	0.000008	0.000015	3	<0.000207	≤0.0000094	0.000014	4	0.000016	0.000004	0.000044	4	<0.000206	≤0.0000046	0.000011	8
strontium	mg/L	0.21	0.14	0.47	4	0.16	0.15	0.19	4	0.16	0.13	0.21	4	0.13	0.11	0.27	8
thallium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.000003	<0.0001	8
titanium	mg/L	<0.005	≤0.0008	0.0008	4	<0.0029	<0.0006	0.0008	4	<0.005	<0.005	0.0061	4	0.001	≤0.0009	0.0018	8
uranium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.000003	<0.0001	8
vanadium	mg/L	<0.0004	<0.0002	0.001	5	0.0001	<0.0002	0.0005	4	<0.0002	<0.0002	0.001	6	0.0002	<0.0002	0.0003	8
zinc	mg/L	0.005	<0.001	1.26[(a)(b)]	5	0.008	0.006	0.048[(b)]	4	0.007	≤0.0005	0.021	8	0.008	≤0.001	0.077[(b)]	9

Table F-9 Water Quality in McClelland Lake (continued)

Parameter	Units	Winter (1976 to 2007)				Spring (2000 to 2007)				Summer (1966 to 2007)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	4	0.01	<0.01	0.05	4	<0.01	<0.01	<0.01	4	0.0016	≤0.0012	0.11[(b)]	8
antimony	mg/L	0.0006	≤0.0006	0.0008	4	<0.0008	≤0.0005	0.0007	4	0.0005	≤0.0005	0.0007	4	<0.0007	≤0.00001	0.0006	8
arsenic	mg/L	0.00005	<0.0004	0.0007	4	<0.0004	<0.0004	<0.0004	4	<0.0004	<0.0004	<0.0004	4	<0.0004	≤0.0002	0.0002	8
barium	mg/L	0.046	0.044	0.14	4	0.038	0.03	0.047	4	0.031	0.024	0.04	4	0.03	0.025	0.063	8
beryllium	mg/L	<0.0005	<0.0005	<0.001	5	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	0.0005	6	<0.0005	<0.00004	0.0001	8
boron	mg/L	0.09	0.06	0.11	4	0.08	0.06	0.09	3	0.06	0.01	0.08	4	0.06	0.05	0.08	8
cadmium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.00001	0.00002	8
chromium	mg/L	0.0004	<0.0004	0.0006	4	<0.0004	<0.0004	0.0036[(b)]	4	0.0002	<0.0004	0.0024[(b)]	4	0.0001	≤0.0001	0.0013[(b)]	8
cobalt	mg/L	0.0018	<0.0001	0.0065	4	0.0001	<0.0001	0.0004	4	0.0006	<0.0001	0.0121	4	<0.0001	<0.00002	0.0003	8
copper	mg/L	<0.0006	<0.0006	0.0008	4	<0.0006	<0.0006	<0.0006	4	0.0001	<0.0006	0.001	4	0.0002	<0.0001	0.003[(b)]	8
iron	mg/L	0.02	≤0.009	0.81[(b)]	4	<0.01	≤0.009	0.01	4	0.06	0.01	0.16	4	0.01	≤0.007	0.05	8
lead	mg/L	<0.0001	<0.0001	<0.0001	4	0.0002	<0.0001	0.0006	4	0.0001	<0.0001	0.0002	4	0.0001	≤0.00002	0.0016	8
lithium	mg/L	0.031	0.021	0.034	4	0.022	0.015	0.025	4	0.017	0.014	0.02	4	0.022	0.017	0.023	8
manganese	mg/L	0.068	0.001	1.19	4	0.016	<0.0001	0.039	4	0.014	<0.001	0.084	4	0.001	≤0.0005	0.016	8
mercury	mg/L	<0.0000006	<0.0000006	<0.0001	4	<0.0000103	<0.0000006	<0.00002	4	<0.0000022	<0.0000006	0.0000037	4	<0.00002	<0.0000006	<0.0001	7
molybdenum	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.00002	0.0002	8
nickel	mg/L	0.0008	<0.0001	0.0022	4	0.0007	0.0002	0.0008	4	0.0008	<0.0001	0.0011	4	0.0002	<0.0001	0.0027	8
selenium	mg/L	<0.0004	<0.0004	<0.0004	4	<0.0004	<0.0004	0.0005	4	<0.0004	<0.0004	0.0004	4	<0.0004	<0.0004	<0.0005	8
silver	mg/L	0.000004	≤0.0000037	0.000006	4	<0.000102	≤0.0000021	0.000003	4	<0.000105	≤0.0000086	0.000009	4	<0.000103	≤0.000003	0.000006	8
strontium	mg/L	0.2	0.14	0.41	4	0.16	0.15	0.2	4	0.16	0.12	0.2	4	0.13	0.11	0.23	8
thallium	mg/L	<0.00005	<0.00005	<0.00005	4	<0.00005	<0.00005	<0.00005	4	<0.00005	<0.00005	<0.00005	4	<0.00005	<0.000003	0.00001	8
titanium	mg/L	0.0009	0.0008	0.0014	4	0.0003	<0.0003	0.0003	4	<0.0003	<0.0003	0.0005	4	0.0005	<0.0003	0.0017	8
uranium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.000003	0.000005	8
vanadium	mg/L	0.0002	<0.0001	0.0004	4	<0.0001	<0.0001	0.0002	3	<0.0001	<0.0001	<0.0001	4	0.0001	<0.0001	0.0002	8
zinc	mg/L	0.006	<0.002	0.01	4	0.006	<0.002	0.011	4	0.0005	<0.002	0.005	4	0.006	≤0.0008	0.083[(b)]	8
Target PAHs And Alkylated PAHs																	
naphthalene	ppb	0.17	0.17	0.17	1	0.03	0.03	0.03	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd naphthalenes	ppb	0.2	0.2	0.2	1	0.03	0.03	0.03	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C2 subst'd naphthalenes	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd acenaphthene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
anthracene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(a)anthracene/chrysene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1

Table F-9 Water Quality in McClelland Lake (continued)

Parameter	Units	Winter (1976 to 2007)				Spring (2000 to 2007)				Summer (1966 to 2007)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
benzo(g,h,i)perylene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
biphenyl	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd biphenyl	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd dibenzothiophene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
c1 subst'd fluoranthene / pyrene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd fluorene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d-123)pyrene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
phenanthrene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd phenanthrene / anthracene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren / anthracene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene / anthracene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene / anthracene	ppb	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
1-methyl-7-isopropyl-phenanthrene (retene)	ppb	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	ppb	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
Phenolics																	
phenol	ppb	–	–	–	0	–	–	–	0	0.008	0.008	0.008	1	–	–	–	0

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-10 Water Quality in Surface Waters Associated with McClelland Lake

Parameter	Units	McClelland Lake Inlet Creek				Unnamed Creek 3												McClelland Lake Outlet	McClelland Lake Fen
		Winter 2006	Spring 2006	Summer 2006	Fall 2005	Winter (2006 to 2007)			Spring (2006 to 2007)			Summer (2006 to 2007)			Fall (2005 to 2006)			Fall 2006	Fall 2000
		n =1	n=1	n=1	n=1	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	n=1	n=1
Field Measured																			
temperature	°C	0.8	9.2	14.8	4.5	0.1	0.2	2	7.3	10.6	2	17.7	17.7	1	4.5	7.2	2	7.2	–
dissolved oxygen	mg/L	4.5[(a)(b)]	4.8[(a)(b)]	2[(a)(b)]	4[(a)(b)]	8.3	8.3	1	13.1	13.1	1	6.3[(b)]	6.3[(b)]	1	8.4	11.1	2	4.6[(a)(b)]	–
Conventional Parameters																			
colour	TCU	30	30	50	60	8	25	2	37	37	1	18	25	2	12	40	2	200	35
specific conductance	µS/cm	343	193	372	304	395	481	2	267	267	1	283	361	2	295	344	2	49	346
dissolved organic carbon	mg/L	8	11	21	14	5	6	2	8	10	2	9	10	2	8	8	2	38	11
hardness	mg/L	183	111	210	184	207	207	1	135	135	1	156	202	2	158	197	2	29	171
pH		7.3	8.1	8.1	7.9	8	8.3	2	8.2	8.2	1	7.7	8.2	2	8.2	8.3	2	6.8	7.8
total alkalinity	mg/L	183	113	214	180	204	207	2	143	143	1	156	214	2	153	187	2	22	177
total dissolved solids	mg/L	180	160	270	220	230	230	2	164	164	1	180	190	2	200	200	2	120	210
total organic carbon	mg/L	8	11	23	14	6	6	2	10	10	1	9	11	2	9	9	2	90	12
total suspended solids	mg/L	9	<3	3	<3	<3	5	2	7	7	1	<3	<3	2	<3	4	2	5710	4
Major Ions																			
bicarbonate	mg/L	223	137	261	220	249	252	2	175	175	1	190	262	2	187	227	2	27	216
calcium	mg/L	52	32	61	52	60	63	2	40	40	1	46	59	2	46	57	2	8	45
carbonate	mg/L	<5	<5	<5	<5	<5	<5	2	<5	<5	1	<5	<5	2	<5	<5	2	<5	<5
chloride	mg/L	1	2	2	2	1	1	2	1	1	1	0.4	2	2	2	2	2	3	<1
magnesium	mg/L	13	8	14	13	14	14	2	9	9	1	10	13	2	10	13	2	2	14
potassium	mg/L	2	1	<0.5	1	2	2	2	2	2	1	1	1	2	1	2	2	1	2
sodium	mg/L	3	2	2	3	3	4	2	3	3	1	3	3	2	3	4	2	1	4
sulphate	mg/L	3	1	3	5	5	5	1	3	3	1	1	2	2	2	3	2	2	4
sulphide	mg/L	0.031[(b)]	0.005[(b)]	0.007[(b)]	0.006[(b)]	<0.003	0.004	2	0.003	0.003	1	<0.003	<0.003	2	<0.003	0.004	2	0.097[(b)]	<0.003
Nutrients and Chlorophyll *a*																			
nitrogen - nitrate/nitrite	mg/L	<0.1	<0.1	0.2	<0.1	0.1	0.1	2	<0.1	<0.1	1	<0.1	<0.1	2	<0.1	<0.1	2	<0.1	<0.05
nitrogen - ammonia	mg/L	0.64	<0.05	<0.05	<0.05	0.23	0.28	2	0.08	0.08	1	<0.05	0.06	2	<0.05	<0.05	2	0.77	<0.1
nitrogen - kjeldahl	mg/L	1	0.6	0.9	0.5	0.5	0.6	2	0.4	0.4	1	0.4	0.5	2	0.4	0.5	2	412	0.3
nitrogen - total nitrogen	mg/L	1	0.6	1.1[(b)]	0.5	0.6	0.7	2	0.4	0.4	1	0.4	0.5	2	0.4	0.5	2	412[(b)]	0.3
phosphorus, total	mg/L	0.123[(b)]	0.032	0.228[(b)]	0.054[(b)]	0.019	0.026	2	0.032	0.032	1	0.014	0.028	2	0.023	0.03	2	4.21[(b)]	0.046
phosphorus, dissolved	mg/L	0.041	0.019	0.093	0.031	0.001	0.002	2	<0.001	0.01	2	0.003	0.012	2	0.005	0.007	2	0.041	0.012
chlorophyll *a*	µg/L	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	<1
Biochemical Oxygen Demand																			
biochemical oxygen demand	mg/L	3	<2	2	<2	<2	2	2	<2	<2	1	<2	<2	2	<2	<2	2	114	<2

Table F-10 Water Quality in Surface Waters Associated with McClelland Lake (continued)

Parameter	Units	McClelland Lake Inlet Creek				Unnamed Creek 3												McClelland Lake Outlet	McClelland Lake Fen
		Winter 2006	Spring 2006	Summer 2006	Fall 2005	Winter (2006 to 2007)			Spring (2006 to 2007)			Summer (2006 to 2007)			Fall (2005 to 2006)			Fall 2006	Fall 2000
		n =1	n=1	n=1	n=1	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	n=1	n=1
General Organics																			
naphthenic acids	mg/L	<1	<1	<1	2	<1	<1	2	<1	<1	1	<1	<1	2	<1	<1	2	<1	<1
total phenolics	mg/L	0.001	0.009[(b)]	0.013[(b)]	0.005	0.004	0.004	1	<0.001	<0.001	1	0.005	0.008[(b)]	2	<0.001	<0.001	2	<0.001	<0.001
total recoverable hydrocarbons	mg/L	<1	<1	<1	<1	<1	<1	2	<1	<1	1	<1	<1	2	<0.5	<1	2	<1	<0.5
Toxicity																			
Microtox® IC50 @ 15 min	%	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	>91
Microtox® IC25 @ 15 min	%	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	>91
algal growth inhibition test (72 h) - IC25	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
algal growth inhibition test (72 h) - IC50	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
ceriodaphnia 7d mortality test - LC25	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
ceriodaphnia 7d mortality test - LC50	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
ceriodaphnia 7d reproduction test - IC25	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
ceriodaphnia 7d reproduction test - IC50	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
fathead minnow 7d growth - IC25	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
fathead minnow 7d growth - IC50	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
fathead minnow 7d mortality test - LC25	%	–	–	–	–	–	–	0	–	–	0	–	–	0	63	63	1	–	–
fathead minnow 7d mortality test - LC50	%	–	–	–	–	–	–	0	–	–	0	–	–	0	>100	>100	1	–	–
Total Metals																			
aluminum	mg/L	0.04	<0.02	0.03	<0.02	<0.02	<0.02	2	0.11[(b)]	0.11[(b)]	1	<0.02	<0.02	2	0.02	0.09	2	40.1[(a)(b)]	<0.02
antimony	mg/L	0.0006	0.0009	0.0007	0.0018	0.0005	0.0008	2	0.0004	0.0004	1	0.0007	0.0011	2	0.0012	0.0013	2	0.0019	<0.005
arsenic	mg/L	<0.0004	<0.0004	0.0006	<0.0004	<0.0004	<0.0004	2	0.0005	0.0005	1	<0.0004	0.0004	2	<0.0004	<0.0004	2	0.0113[(b)]	<0.001
barium	mg/L	0.088	0.063	0.124	0.07	0.102	0.112	2	0.077	0.077	1	0.096	0.121	2	0.075	0.118	2	0.552	0.05
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2	<0.001	<0.001	1	<0.001	<0.001	2	<0.001	<0.001	2	<0.001	<0.001
boron	mg/L	0.02	0.05	0.03	<0.02	<0.02	0.03	2	0.03	0.03	1	0.03	0.04	2	0.02	0.03	2	0.08	0.05
cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	2	<0.0002	<0.0002	1	<0.0002	<0.0002	2	<0.0002	<0.0002	2	0.0011[(a)(b)]	<0.0002
chromium	mg/L	<0.0008	0.0041[(b)]	0.0012[(b)]	<0.0008	0.0008	0.0022[(b)]	2	0.0009	0.0009	1	<0.0008	<0.0008	2	<0.0008	<0.0008	2	0.0468[(a)(b)]	<0.0008
cobalt	mg/L	<0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	2	<0.0002	<0.0002	1	<0.0002	<0.0002	2	0.0002	0.0003	2	0.0084	<0.0002

Table F-10 Water Quality in Surface Waters Associated with McClelland Lake (continued)

Parameter	Units	McClelland Lake Inlet Creek				Unnamed Creek 3											McClelland Lake Outlet	McClelland Lake Fen
		Winter 2006	Spring 2006	Summer 2006	Fall 2005	Winter (2006 to 2007)			Spring (2006 to 2007)			Summer (2006 to 2007)			Fall (2005 to 2006)			Fall 2006	Fall 2000
		n =1	n=1	n=1	n=1	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	n=1	n=1
copper	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	2	<0.001	<0.001	1	<0.001	<0.001	2	<0.001	<0.001	2	0.038[a](b)	<0.001
iron	mg/L	2.19[b]	0.34[b]	4.02[b]	0.67[b]	1.56[b]	1.8[b]	2	1.91[b]	1.91[b]	1	0.87[b]	1.87[b]	2	1.23[b]	2.04[b]	2	52.8[b]	0.1
lead	mg/L	0.0006	0.0004	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	1	<0.0001	<0.0001	2	<0.0001	0.0002	2	0.0166[b]	<0.0001
lithium	mg/L	0.011	0.009	0.01	0.01	0.008	0.009	2	0.007	0.007	1	0.006	0.008	2	0.007	0.011	2	0.142	0.026
manganese	mg/L	0.211	0.037	0.65	0.098	0.173	0.174	2	0.067	0.067	1	0.08	0.096	2	0.044	0.086	2	0.326	0.033
mercury	mg/L	<0.0000006	<0.0000006	7E–07	<0.0000006	<0.0000006	<0.0000006	2	<0.0000006	<0.0000006	1	<0.0000006	1.9E–06	2	<0.0000006	<0.0000006	2	0.000051[a](b)	<0.0002
methyl mercury	mg/L	<0.00000003	<0.00000003	<0.00000003	–	<0.00000003	<0.00000003	2	1E–07	1E–07	1	<0.00000003	<0.00000003	2	<0.00000003	<0.00000003	1	<0.00000003	–
molybdenum	mg/L	<0.0001	0.0003	<0.0001	<0.0001	0.0001	0.0003	2	0.0001	0.0001	1	0.0002	0.0003	2	0.0001	0.0002	2	0.0005	<0.0001
nickel	mg/L	<0.0002	0.0018	<0.0002	<0.0002	0.0004	0.0009	2	0.0007	0.0007	1	<0.0002	0.001	2	0.0004	0.001	2	0.0314[b]	<0.0002
selenium	mg/L	<0.0004	<0.0004	0.0005	0.001	<0.0004	<0.0004	2	0.0013[b]	0.0013[b]	1	<0.0004	<0.0004	2	<0.0004	<0.0004	2	0.0035[b]	<0.0008
silver	mg/L	0.000004	0.000001	0.000041	0.000002	0.000003	0.000004	2	0.000037	0.000037	1	0.000005	0.000006	2	0.000007	0.000008	2	0.000069	<0.0004
strontium	mg/L	0.13	0.1	0.18	0.14	0.15	0.16	2	0.1	0.1	1	0.12	0.15	2	0.11	0.16	2	0.21	0.24
thallium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	1	<0.0001	<0.0001	2	<0.0001	<0.0001	2	0.0004	<0.0001
titanium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	2	<0.005	<0.005	1	<0.005	<0.005	2	<0.005	<0.005	2	0.427	0.0013
uranium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	1	<0.0001	<0.0001	2	<0.0001	<0.0001	2	0.002	<0.0001
vanadium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	2	0.0005	0.0005	1	<0.0002	<0.0002	2	<0.0002	<0.0002	2	0.0715	<0.0002
zinc	mg/L	0.004	0.048[b]	<0.004	<0.004	<0.004	0.008	2	0.014	0.014	1	<0.004	0.008	2	<0.004	<0.004	2	0.157[a](b)	0.006
Dissolved Metals																			
aluminum	mg/L	<0.01	0.01	<0.01	0.02	<0.01	<0.01	2	<0.01	0.02	2	<0.01	<0.01	2	<0.01	0.01	2	0.34[b]	<0.01
antimony	mg/L	0.0006	0.0007	0.0007	0.0008	<0.0004	0.0006	2	0.0006	0.0008	2	0.0006	0.0007	2	<0.0004	0.0005	2	0.0006	<0.0008
arsenic	mg/L	<0.0004	<0.0004	0.0004	<0.0004	<0.0004	<0.0004	2	<0.0004	<0.0004	2	<0.0004	<0.0004	2	<0.0004	<0.0004	2	0.0037	<0.0004
barium	mg/L	0.08	0.048	0.106	0.065	0.091	0.096	2	0.079	0.092	2	0.092	0.127	2	0.066	0.097	2	0.032	0.05
beryllium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	2	<0.0005	<0.0005	2	<0.0005	<0.0005	2	<0.0005	<0.0005
boron	mg/L	0.03	0.05	0.03	0.02	0.02	0.03	2	0.03	0.03	2	0.03	0.04	2	0.02	0.03	2	0.04	0.04
cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001
chromium	mg/L	0.0019[b]	0.0031[b]	<0.0004	<0.0004	0.0014[b]	0.003[b]	2	<0.0004	0.0035[b]	2	<0.0004	<0.0004	2	<0.0004	<0.0004	2	0.0007	<0.0004
chromium - hexavalent	mg/L	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	–
cobalt	mg/L	0.0003	0.0005	0.004	0.0004	0.0002	0.0002	2	0.0002	0.0003	2	0.0002	0.0002	2	0.0002	0.0003	2	0.0022	<0.0001
copper	mg/L	<0.0006	0.0011	<0.0006	<0.0006	<0.0006	<0.0006	2	<0.0006	0.0011	2	<0.0006	0.0014	2	<0.0006	<0.0006	2	0.0006	0.0008
iron	mg/L	1.39[b]	0.15	1.52[b]	0.55[b]	0.02	0.09	2	0.16	0.4[b]	2	0.06	0.66[b]	2	0.04	0.18	2	11[b]	0.04
lead	mg/L	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	0.0004	2	<0.0001	<0.0001	2	<0.0001	<0.0001	2	0.0002	0.0001
lithium	mg/L	0.011	0.01	0.01	0.01	0.008	0.009	2	0.006	0.008	2	0.007	0.008	2	0.006	0.009	2	0.004	0.026
manganese	mg/L	0.233	0.028	0.634	0.105	0.169	0.182	2	0.06	0.063	2	0.065	0.118	2	0.031	0.067	2	0.127	0.032
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	<0.0000006	<0.0000006	<0.0000006	2	<0.0000006	<0.0001	2	<0.0000006	<0.0001	2	<0.0000006	<0.0000006	2	<0.0000006	<0.0001
molybdenum	mg/L	0.0001	0.0003	<0.0001	<0.0001	0.0001	0.0002	2	0.0002	0.0003	2	0.0002	0.0002	2	0.0001	0.0002	2	0.0001	0.0021
nickel	mg/L	<0.0001	0.0019	<0.0001	<0.0001	<0.0001	0.0008	2	0.0007	0.0013	2	<0.0001	0.0011	2	<0.0001	0.0008	2	0.0014	0.0009
selenium	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	2	<0.0004	<0.0004	2	<0.0004	<0.0004	2	<0.0004	<0.0004	2	<0.0004	<0.0004
silicon	mg/L	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	–
silver	mg/L	<0.0000005	<0.0000005	<0.0002	<0.0002	0.000001	0.000002	2	≤0.0000064	0.000006	2	≤0.0000028	0.000003	2	≤0.0000018	0.000002	2	0.000008	<0.0002
strontium	mg/L	0.12	0.08	0.16	0.14	0.15	0.15	2	0.11	0.12	2	0.12	0.16	2	0.09	0.14	2	0.06	0.23
sulphur	mg/L	–	–	–	–	–	–	0	–	–	0	–	–	0	–	–	0	–	–
thallium	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	2	<0.00005	<0.00005	2	<0.00005	<0.00005	2	<0.00005	<0.00005	2	<0.00005	<0.00005

Table F-10 Water Quality in Surface Waters Associated with McClelland Lake (continued)

Parameter	Units	McClelland Lake Inlet Creek				Unnamed Creek 3											McClelland Lake Outlet	McClelland Lake Fen
		Winter 2006	Spring 2006	Summer 2006	Fall 2005	Winter (2006 to 2007)			Spring (2006 to 2007)			Summer (2006 to 2007)			Fall (2005 to 2006)			Fall 2006	Fall 2000
		n =1	n=1	n=1	n=1	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	n=1	n=1
titanium	mg/L	0.001	0.0003	0.0014	0.0009	<0.0003	0.0007	2	<0.0003	0.0006	2	0.0005	0.0008	2	<0.0003	0.0017	2	0.0101	0.0009
uranium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001	2	<0.0001	<0.0001
vanadium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	0.0009	2	<0.0001	<0.0001	2	<0.0001	0.0002	2	<0.0001	<0.0001	2	0.002	0.0001
zinc	mg/L	0.003	0.126[(b)]	0.007	<0.002	<0.002	0.003	2	0.006	0.13[(b)]	2	<0.002	0.032[(b)]	2	0.004	0.014	2	0.004	0.014

[(a)] Acute aquatic life guideline exceeded.

[(b)] Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-11 Sediment Quality of Surface Waters Associated with McClelland Lake

Parameter	Units	McClelland Lake Inlet Creek	McClelland Lake Outlet Creek	Unnamed Creek 3
		Fall (2005)	Fall (2006)	Fall (2006)
		n = 1	n = 1	n = 1
Particle Size				
particle size – % sand	%	11	95	82
particle size – % silt	%	48	3	13
particle size – % clay	%	41	2	5
moisture content	%	90	38	53
Carbon Content				
total inorganic carbon	% by wt	0.23	<0.1	0.1
total organic carbon	% by wt	34.7	1.5	3.1
total carbon	% by wt	34.9	1.5	3.2
Toxicity				
chironomus tentans – 10d survival	% of control	–	–	67
chironomus tentans – 10d growth	% of control	–	–	109
hyalella azteca – 10d survival	% of control	–	–	100
hyalella azteca – 10d growth	% of control	–	–	200
lumbriculus variegatus – 10d survival	% of control	–	–	106
lumbriculus variegatus – 10d growth	% of control	–	–	73
Organics				
total recoverable hydrocarbons	mg/kg	3,300	200	500
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	0.6	<2
total extractable hydrocarbons (C11–C30)	mg/kg	80	8	120
Total Metals				
aluminum	µg/g	2,350	620	1,830
arsenic	µg/g	2.9	0.3	5.6
barium	µg/g	640	29	231
beryllium	µg/g	<0.2	<0.2	<0.2
boron	µg/g	26	<2	6
cadmium	µg/g	0.2	<0.1	<0.1
calcium	µg/g	23,200	400	6,100
chromium	µg/g	6.3	0.6	4.4
cobalt	µg/g	2.4	0.2	1.9
copper	µg/g	5	1	2
iron	µg/g	41,100	1,100	50,900
lead	µg/g	2.2	1.2	1.7
magnesium	µg/g	2,000	140	1,320
manganese	µg/g	348	10	1,040
mercury	µg/g	0.11	<0.05	<0.05
molybdenum	µg/g	1.4	<0.1	0.2
nickel	µg/g	4.7	<0.5	3.2
potassium	µg/g	300	<100	300
selenium	µg/g	0.5	<0.2	0.3
silver	µg/g	<0.2	<0.2	<0.2
sodium	µg/g	200	<100	<100
strontium	µg/g	82	4	24

Table F-11 Sediment Quality of Surface Waters Associated with McClelland Lake (continued)

Parameter	Units	McClelland Lake Inlet Creek	McClelland Lake Outlet Creek	Unnamed Creek 3
		Fall (2005)	Fall (2006)	Fall (2006)
		n = 1	n = 1	n = 1
thallium	µg/g	<0.05	<0.05	<0.05
titanium	µg/g	27	9	28
uranium	µg/g	0.3	0.1	0.2
vanadium	µg/g	7.1	0.9	8.1
zinc	µg/g	52	<5	17
Target PAHs and Alkylated PAHs				
naphthalene	µg/g	0.006	0.002	0.004
C1 subst'd naphthalenes	µg/g	0.006	0.002	0.003
C2 subst'd naphthalenes	µg/g	0.091	0.005	0.008
C3 subst'd naphthalenes	µg/g	0.014	0.009	0.013
C4 subst'd naphthalenes	µg/g	0.009	0.003	0.004
acenaphthene	µg/g	0.0004	<0.0005	<0.0005
C1 subst'd acenaphthene	µg/g	0.0001	0.0007	0.0019
acenaphthylene	µg/g	<0.0001	<0.0003	<0.0004
anthracene	µg/g	0.0008	<0.0002	<0.0002
dibenzo(a,h)anthracene	µg/g	0.00088	<0.00021	<0.00181
benzo(a)anthracene	µg/g	0.0013	<0.0001	0.0007
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.06	0.001	0.01
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.014	<0.0003	0.011
benzo(a)pyrene	µg/g	0.0018	<0.0003	<0.0017
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.012	<0.0004	0.02
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.006	<0.001	0.009
benzofluoranthenes	µg/g	0.006	0.001	0.004
benzo(g,h,i)perylene	µg/g	0.0058	0.0003	<0.0041
biphenyl	µg/g	0.0049	0.0005	0.0017
C1 subst'd biphenyl	µg/g	0.00084	0.00089	0.00199
C2 subst'd biphenyl	µg/g	0.0041	0.0027	0.0087
chrysene	µg/g	0.01	0.001	0.006
dibenzothiophene	µg/g	0.0016	<0.0001	0.0005
C1 subst'd dibenzothiophene	µg/g	0.0037	<0.0001	0.0018
C2 subst'd dibenzothiophene	µg/g	0.0127	0.0014	0.0095
C3 subst'd dibenzothiophene	µg/g	0.0153	<0.0006	0.024
C4 subst'd dibenzothiophene	µg/g	0.037	0.002	0.022
fluoranthene	µg/g	0.0033	0.0005	0.001
C1 subst'd fluoranthene/pyrene	µg/g	0.022	0.001	0.01
C2 subst'd fluoranthene/pyrene	µg/g	0.014	0.001	0.022
C3 subst'd fluoranthene/pyrene	µg/g	0.016	<0.0004	0.013
fluorene	µg/g	0.0082	0.0003	0.0009
C1 subst'd fluorene	µg/g	0.0068	0.005	0.0093
C2 subst'd fluorene	µg/g	0.0369	0.0011	0.0046
C3 subst'd fluorene	µg/g	0.0147	<0.0006	0.0106
indeno(c,d–123)pyrene	µg/g	0.0035	<0.0003	0.0034
phenanthrene	µg/g	0.009	0.001	0.002
C1 subst'd phenanthrene/anthracene	µg/g	0.02	1.22	0.008

Table F-11 Sediment Quality of Surface Waters Associated with McClelland Lake (continued)

Parameter	Units	McClelland Lake Inlet Creek	McClelland Lake Outlet Creek	Unnamed Creek 3
		Fall (2005)	Fall (2006)	Fall (2006)
		n = 1	n = 1	n = 1
C2 subst'd phenanthrene/anthracene	µg/g	0.017	0.002	0.012
C3 subst'd phenanthrene/anthracene	µg/g	0.013	0.002	0.013
C4 subst'd phenanthrene/anthracene	µg/g	0.93	0.02	0.08
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.819	0.011	0.049
pyrene	µg/g	0.006	0.001	0.004

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	0	0.8	25	12.6	2.6	16.2	26	14.6	10.8	18.7	25	3.9	0	11.7	43
dissolved oxygen	mg/L	2.4[a][b]	0.8[a][b]	9	11	8.4	4[a][b]	12.3	25	6[b]	0[a][b]	10.8	22	9.4	3.4[a][b]	14.4	41
Conventional Parameters																	
colour	TCU	65	17	500	18	70	25	125	21	80	50	250	28	75	30	200	41
specific conductance	µS/cm	530	305	1,200	27	172	112	346	28	269	151	502	37	282	76	506	44
dissolved organic carbon	mg/L	22	8	44	27	19	9	32	21	24	13	37	31	19	12	27	35
hardness	mg/L	287	154	656	28	88	51	222	31	145	71	287	38	159	36	272	49
pH		7.4	6.9	8	27	7.6	7	8.3	24	8	7	8.3	35	7.9	7.1	8.4	38
total alkalinity	mg/L	301	162	720	31	92	53	214	32	147	77	273	41	164	36	281	50
total dissolved solids	mg/L	320	189	780	31	102	60	230	32	190	81	320	41	196	72	359	50
total organic carbon	mg/L	26	10	97	29	19	9	32	32	25	15	47	41	22	14	33	46
total suspended solids	mg/L	10	≤0.4	176	31	2	≤0.8	33	32	3	≤0.8	24	41	3	≤0.4	25	49
Major Ions																	
bicarbonate	mg/L	368	229	448	15	117	64	261	25	171	94	332	30	201	44	343	42
calcium	mg/L	75	<1	144	31	22	<1	55	32	38	<1	75	41	41	<1	77	48
carbonate	mg/L	<5	<5	89	11	<5	<0.5	27	25	<5	<0.5	30	30	<5	<0.5	22	34
chloride	mg/L	2	1	6	31	1	≤0.2	5	32	1	<0.1	3	41	2	≤0.3	3	50
magnesium	mg/L	23	12	72	31	7	4	21	32	13	6	26	41	13	4	24	50
potassium	mg/L	1	1	4	31	1	<0.5	3	32	0.4	≤0.1	2	41	1	≤0.3	2	50
sodium	mg/L	9	5	18	31	4	1	7	32	5	2	12	41	6	1	10	50
sulphate	mg/L	5	≤1	16	31	3	1	13	32	3	0.3	9	41	3	≤0.1	7	50
sulphide	mg/L	0.0005	<0.001	0.103[b]	14	0.007[b]	≤0.005	0.018[b]	13	0.008[b]	0.004	0.017[b]	16	0.004	≤0.001	0.014[b]	36
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.02	≤0.007	0.2	13	<0.05	<0.003	0.1	25	<0.1	≤0.008	0.4	30	<0.1	≤0.003	0.04	38
nitrogen – ammonia	mg/L	0.34	<0.1	1.48	13	<0.05	<0.01	0.08	25	<0.05	<0.01	0.14	30	<0.05	≤0.02	0.27	38
nitrogen – kjeldahl	mg/L	1.3	0.4	3.9	29	0.8	<0.05	1.3	27	1	0.5	4.9	37	0.7	<0.2	5.5	48
nitrogen – total nitrogen	mg/L	1.3[b]	0.4	3.9[b]	29	0.8	<0.05	1.3[b]	27	1	0.5	4.9[b]	37	0.7	<0.2	5.5[b]	48
phosphorus, total	mg/L	0.096[b]	<0.02	2.31[b]	29	0.021	≤0.007	0.101[b]	32	0.038	≤0.01	0.14[b]	41	0.024	≤0.003	0.32[b]	48
phosphorus, dissolved	mg/L	0.016	0.007	0.087	10	0.012	≤0.004	0.09	17	0.018	0.009	0.07	16	0.013	0.001	0.031	29
chlorophyll *a*	µg/L	<1	<1	7	7	<1	<1	<1	5	0.45	<0.1	6	8	1	<1	4	14
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	≤0.6	10	15	1	≤0.6	20	19	1	≤0.5	14	22	<2	≤0.9	12	42
General Organics																	
naphthenic acids	mg/L	<1	<1	2	9	<1	<1	2	14	<1	<1	1	19	<1	<1	12	26
total phenolics	mg/L	0.005	<0.001	0.023[b]	23	0.002	<0.001	0.12[b]	18	0.005	<0.001	0.017[b]	26	0.003	<0.001	0.016[b]	34
total recoverable hydrocarbons	mg/L	<0.5	<0.1	0.8	27	<0.5	<0.1	0.2	24	<0.5	<0.1	12.9	25	<0.5	<0.1	1.7	44
Toxicity																	
Microtox® IC50 @ 15 Min	%	>91	>91	>91	3	>91	>91	>91	1	>91	>91	>91	1	>91	>91	>91	5
Microtox® IC25 @ 15 Min	%	>91	>91	>91	3	>91	>91	>91	1	>91	>91	>91	1	>91	>91	>91	5
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	2	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	4
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	2	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	4
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	2	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	4
algal growth inhibition test (72h) – NOEC	%	100	100	100	2	100	100	100	1	100	100	100	1	100	100	100	5
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	4	–	–	–	0	>100	>100	>100	1	>100	>100	>100	5
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	5
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	4	50	50	50	1	>100	>100	>100	1	>100	>100	>100	5
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	4	25	25	25	1	100	100	100	1	100	100	100	5
ceriodaphnia 7d reproduction test – IC25	%	>100	97	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	35	>100	5

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d reproduction test – IC50	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	5
ceriodaphnia 7d reproduction test – LOEC	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	25	>100	5
ceriodaphnia 7d reproduction test – NOEC	%	100	100	100	4	100	100	100	1	100	100	100	1	100	12.5	100	5
daphnia 48h static acute test – LC25	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – LC50	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – LOEC	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – NOEC	%	100	100	100	2	–	–	–	0	–	–	–	0	100	100	100	2
fathead minnow 7d growth – IC25	%	>100	87	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	12	>100	5
fathead minnow 7d growth – IC50	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	39	>100	5
fathead minnow 7d growth – LOEC	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	50	>100	5
fathead minnow 7d growth – NOEC	%	100	50	100	4	100	100	100	1	100	100	100	1	100	25	100	5
fathead minnow 7d mortality test – LC25	%	>100	92	>100	4	>100	>100	>100	1	35	35	35	1	6.4	6.4	>100	5
fathead minnow 7d mortality test – LC50	%	>100	>100	>100	4	>100	>100	>100	1	>100	>100	>100	1	>100	13	>100	5
fathead minnow 7d mortality test – LOEC	%	>100	>100	>100	4	>100	>100	>100	1	50	50	50	1	>100	12.5	>100	5
fathead minnow 7d mortality test – NOEC	%	100	50	100	4	100	100	100	1	25	25	25	1	100	6.25	100	5
trout 96h static acute test – LC25	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – LC50	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – LOEC	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – NOEC	%	100	100	100	2	–	–	–	0	–	–	–	0	100	100	100	1
Total Metals																	
aluminum	mg/L	0.02	≤0.0022	0.17[(b)]	15	0.03	<0.01	0.72[(b)]	25	0.0305	≤0.01	0.28[(b)]	30	0.0094	≤0.004	0.11[(b)]	42
antimony	mg/L	0.0006	≤0.000007	0.011	12	0.0006	<0.0004	0.004	21	0.0007	<0.0004	0.004	23	0.00002	<0.000004	0.0069	34
arsenic	mg/L	<0.0004	<0.0002	0.0014	15	<0.0004	<0.0002	0.0009	25	<0.0004	<0.0002	0.005	28	<0.0004	≤0.00018	0.009[(b)]	47
barium	mg/L	0.057	0.042	0.2	12	0.022	≤0.0116	0.05	21	0.028	0.017	0.09	26	0.024	≤0.0152	0.088	34
beryllium	mg/L	<0.001	<0.00004	<0.001	12	<0.001	<0.0002	<0.001	21	<0.001	<0.0005	<0.001	26	<0.001	<0.000003	0.0001	34
boron	mg/L	0.05	<0.02	0.16	15	0.02	<0.004	0.07	25	0.03	≤0.017	0.07	30	0.01	≤0.006	0.09	42
cadmium	mg/L	<0.0002	<0.00002	<0.001	15	<0.0002	<0.0001	<0.001	25	<0.0002	<0.0001	0.0004	30	<0.0002	<0.000002	0.0321[(a)(b)]	42
chromium	mg/L	0.0009	<0.0008	0.0056[(b)]	15	<0.001	<0.0004	0.0057[(b)]	25	<0.0008	<0.0004	0.0161[(a)(b)]	30	<0.0008	≤0.0000859	0.006[(b)]	42
chromium – hexavalent	mg/L	<0.003	<0.003	0.012[(b)]	16	<0.003	<0.003	0.008[(b)]	5	0.003[(b)]	<0.003	0.006[(b)]	4	<0.003	<0.003	<0.003	8
cobalt	mg/L	0.0002	≤0.00018	0.0082	12	<0.0003	<0.0002	0.0005	21	<0.0003	<0.0002	0.0009	26	0.0001	≤0.00005	0.0006	34
copper	mg/L	0.0004	≤0.00017	0.005[(b)]	15	0.0004	≤0.0003	0.0021[(b)]	25	<0.001	≤0.0009	0.006[(b)]	30	<0.001	<0.0001	0.0029	42
iron	mg/L	2.37[(b)]	0.16	31.9[(b)]	15	0.28	0.07	1.84[(b)]	25	0.53[(b)]	0.25	2.89[(b)]	30	0.37[(b)]	0.1	13.9[(b)]	42
lead	mg/L	0.0002	<0.0001	0.003	15	0.0003	<0.0001	0.003[(b)]	25	<0.0001	<0.0001	0.0101[(b)]	30	<0.0001	≤0.00000654	0.002	42
lithium	mg/L	0.01	0.008	0.027	11	<0.006	<0.004	0.006	13	0.007	<0.006	0.012	16	0.006	≤0.0034	0.011	30
manganese	mg/L	0.54	0.066	1.2	15	0.017	≤0.0031	0.11	25	0.04	≤0.0049	0.345	30	0.036	0.004	0.786	42
mercury	mg/L	<0.0001	<0.0000006	0.0004[(a)(b)]	29	<0.000075	<0.0000006	0.0002[(a)(b)]	32	<0.000075	<0.0000006	0.000002	38	<0.00005	<0.0000006	0.0043[(a)(b)]	46
methyl mercury	mg/L	0.00000003	<0.00000003	0.0000004	4	0.00000004	<0.00000002	0.0000001	7	0.0000001	<0.00000003	0.0000012[(b)]	15	0.0000002	0.00000005	0.0000008	8
molybdenum	mg/L	0.00005	≤0.000041	0.0004	12	<0.0002	<0.0001	0.0005	21	<0.0001	≤0.000043	0.001	26	<0.0001	≤0.0000328	0.0005	34
nickel	mg/L	<0.0002	<0.0001	0.015	15	0.0009	<0.0002	0.007	25	0.0001	<0.0002	0.0254	30	<0.0003	<0.000005	0.0136	42
selenium	mg/L	<0.0004	<0.0004	0.0009	15	<0.0004	<0.0002	0.0005	25	<0.0004	<0.0002	0.0032[(b)]	27	<0.00045	<0.0001	0.016[(b)]	42
silicon	mg/L	6.4	6.4	6.4	1	1	0.4	4.2	13	4.4	1	5.5	10	2.8	1.1	3.4	4
silver	mg/L	<0.000213	≤0.0000016	0.000027	12	<0.000013	≤0.0000011	0.001[(b)]	21	0.000001	≤0.0000011	0.000036	25	<0.000005	<0.0000005	0.000019	31
strontium	mg/L	0.16	0.09	0.33	11	0.06	0.03	0.09	18	0.09	0.06	0.15	24	0.09	0.02	0.17	33
sulphur	mg/L	–	–	–	0	1.3	0.8	1.7	5	–	–	–	0	0.004	<0.2	0.6	6
thallium	mg/L	<0.0001	<0.000003	0.000004	8	<0.0001	<0.0001	<0.0002	12	<0.0001	<0.0001	0.0002	15	<0.0001	<0.0000003	0.00008	27
titanium	mg/L	<0.005	≤0.0022	0.0056	14	<0.0031	<0.0004	0.013	18	<0.005	<0.0004	0.0026	25	0.0008	<0.0006	0.0103	31
uranium	mg/L	0.0001	≤0.00001	0.0001	11	<0.0001	<0.0001	<0.0004	17	<0.0001	<0.0001	0.0008	24	<0.0001	<0.000003	0.0001	30
vanadium	mg/L	<0.001	<0.0002	0.002	31	<0.001	<0.0002	0.002	32	<0.0006	<0.0002	0.005	40	<0.0002	≤0.000119	0.0037	45

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
zinc	mg/L	0.005	<0.0002	0.044[(b)]	15	0.01	<0.001	0.126[(a)(b)]	25	0.007	<0.001	0.112[(b)]	30	0.003	≤0.00066	0.075[(b)]	42
Dissolved Metals																	
aluminum	mg/L	0.015	<0.01	0.08	10	0.01	≤0.007	0.05	17	<0.01	<0.01	0.26[(b)]	18	<0.01	≤0.00168	0.0519	30
antimony	mg/L	0.0007	≤0.0005	0.011	10	0.0006	<0.0002	0.003	17	0.0006	<0.0004	0.004	18	0.0001	≤0.00001	0.002	30
arsenic	mg/L	<0.0004	<0.0002	0.005	26	<0.0004	<0.0002	0.0007	24	0.0002	<0.0002	0.001	28	<0.0004	<0.0002	0.001	30
barium	mg/L	0.045	<0.03	0.125	10	0.021	≤0.016	0.06	17	0.029	0.02	0.08	18	0.024	0.016	0.07	30
beryllium	mg/L	<0.0005	<0.0005	<0.0005	10	<0.0005	<0.0002	<0.0005	17	<0.0005	<0.0005	<0.0005	18	<0.0005	<0.000003	0.0002	30
boron	mg/L	0.08	<0.002	0.3	25	0.02	≤0.006	0.29	23	0.03	≤0.014	0.18	26	0.02	≤0.003	0.24	38
cadmium	mg/L	<0.0001	<0.0001	0.0001	10	<0.0001	<0.0001	<0.001	17	<0.0001	<0.0001	<0.0001	18	<0.0001	<0.000002	0.0097[(a)(b)]	30
chromium	mg/L	0.0005	<0.0004	0.0026[(b)]	10	<0.001	≤0.0006	0.0045[(b)]	17	<0.001	<0.0004	0.0029[(b)]	16	0.0001	≤0.0000854	0.0064[(b)]	27
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0014	≤0.0002	0.0043	10	<0.0003	<0.0001	0.0009	17	0.0007	<0.0001	0.0034	14	0.0001	≤0.0000393	0.0008	29
copper	mg/L	0.0001	<0.0006	0.0026	10	0.0004	<0.0002	0.0012	17	<0.0006	<0.0006	0.0012	18	<0.0006	<0.0001	0.0021	30
iron	mg/L	0.46[(b)]	0.04	19[(b)]	12	0.15	0.05	0.94[(b)]	17	0.43[(b)]	0.16	1.26[(b)]	13	0.22	0.04	1.88[(b)]	34
lead	mg/L	<0.0001	<0.0001	0.0008	10	<0.0004	<0.0001	0.0005	17	<0.0001	<0.0001	0.0002	18	<0.0001	≤0.00000654	0.001	30
lithium	mg/L	0.009	0.007	0.023	9	0.005	<0.004	0.006	13	0.007	0.003	0.01	16	0.005	0.003	0.011	26
manganese	mg/L	0.496	0.065	0.866	12	0.011	<0.004	0.074	17	0.049	0.012	0.242	13	0.021	0.003	0.626	34
mercury	mg/L	<0.0001	<0.0000006	0.0000017	10	<0.00001	≤0.00000048	0.0000005	17	<0.0001	<0.0000006	0.0001[(a)(b)]	18	<0.00001	<0.0000006	0.0000016	29
molybdenum	mg/L	<0.0001	<0.0001	0.0001	10	<0.0002	<0.0001	0.0005	17	<0.0001	<0.0001	0.0004	18	0.00003	≤0.0000314	0.0002	28
nickel	mg/L	<0.0001	<0.0001	0.016	10	<0.0007	≤0.0003	0.004	17	<0.0001	<0.0001	0.012	16	0.0001	<0.000005	0.0072	27
selenium	mg/L	<0.0004	<0.0002	0.0007	26	<0.0004	<0.0002	0.0009	23	<0.0004	<0.0002	0.0005	28	<0.0004	<0.0001	0.0002	30
silicon	mg/L	6.53	6.53	6.53	1	0.93	<0.0002	1.84	10	4.765	4.01	5.52	2	2.827	1.14	3.502	4
silver	mg/L	<0.0002	≤0.0000007	0.000012	10	<0.0001	<0.0000005	0.0748[(a)(b)]	17	<0.0002	<0.0002	<0.0005	18	<0.0002	<0.0000005	0.00001	30
strontium	mg/L	0.14	0.11	0.31	9	0.06	0.04	0.08	13	0.1	0.07	0.16	16	0.08	0.02	0.15	29
sulphur	mg/L	–	–	–	0	0.95	<0.00005	1.5	6	–	–	–	0	<0.2	<0.2	0.513	6
thallium	mg/L	<0.00005	<0.00005	<0.00005	6	<0.00012	<0.00005	<0.0003	12	<0.00005	<0.00005	<0.00005	15	<0.00005	<0.0000003	0.000003	23
titanium	mg/L	0.001	0.0006	0.0028	9	<0.0005	<0.0001	0.0007	13	0.0008	<0.0003	0.0026	16	0.0007	<0.0003	0.0016	24
uranium	mg/L	0.0001	<0.0001	0.0001	9	<0.0001	<0.0001	0.0001	13	<0.0001	<0.0001	0.0003	16	<0.0001	≤0.0000122	0.0001	26
vanadium	mg/L	<0.0001	<0.0001	0.0007	10	<0.001	≤0.0002	0.017	17	0.0002	<0.0001	0.0008	18	0.0001	≤0.0000655	0.0016	28
zinc	mg/L	0.006	0.003	0.018	10	0.007	0.002	0.083[(b)]	16	<0.002	<0.002	0.009	18	0.002	≤0.0008	0.01	30
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	0.03	0.03	0.03	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	0.02	5
C1 subst'd naphthalenes	µg/L	0.05	0.05	0.05	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	3
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
acenaphthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
acenaphthylene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
anthracene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
Benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
biphenyl	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.04	3	<0.01	<0.01	<0.04	3	<0.02	<0.02	<0.02	3
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
dibenzothiophene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.02	<0.02	<0.02	3
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
fluoranthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
fluorene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
indeno(c,d–123)pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
phenanthrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	0.01	3	<0.01	<0.01	0.01	3	<0.01	<0.01	<0.01	5
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	3
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	5
Target PANHs																	
quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.1	3	–	–	–	0
7–methyl quinoline	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	0.06	3	–	–	–	0
C2 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.05	3	–	–	–	0
C3 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	3	–	–	–	0
acridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.06	3	<0.01	<0.01	<0.01	2
methyl acridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	3	–	–	–	0
phenanthridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.09	3	–	–	–	0
carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.09	3	–	–	–	0
methyl carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.08	3	–	–	–	0
C2 subst'd carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	0.05	3	–	–	–	0
Phenolics																	
phenol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
o–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
m–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
p–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
2,4–dimethylphenol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
2–nitrophenol	µg/L	–	–	–	0	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2	1	–	–	–	0
4–nitrophenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
2,4–dinitrophenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
4,6–dinitro–2–methyl phenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
Volatile Organics																	
acetone	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
acrolein	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
acrylonitrile	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
benzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
bromodichloromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
bromoform	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
bromomethane	µg/L	–	–	–	0	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
2–butanone (MEK)	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
carbon disulfide	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
carbon tetrachloride	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chlorobenzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chloroethane	µg/L	–	–	–	0	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
2–chloroethyl vinyl ether	µg/L	–	–	–	0	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
chloroform	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chloromethane	µg/L	–	–	–	0	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
dibromochloromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
dibromomethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichlorobenzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,3–dichlorobenzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,4–dichlorobenzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
cis–1,4–dichloro–2–butene	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
trans–1,4–dichloro–2–butene	µg/L	–	–	–	0	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
dichlorodifluoromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1–dichloroethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichloroethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1–dichloroethene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trans–1,2–dichloroethene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichloropropane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
cis–1,3–dichloropropene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trans–1,3–dichloropropene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
ethanol	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
ethylbenzene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
ethylene dibromide	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
ethyl methacrylate	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
2–hexanone	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
iodomethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
4–methyl–2–pentanone (MIBK)	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
methylene chloride	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
styrene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
tetrachloroethylene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1,2,2–tetrachloroethane	µg/L	–	–	–	0	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
toluene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0

Table F-12 Water Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
1,1,1–trichloroethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1,2–trichloroethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2,3–trichloropropane	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
trichloroethene	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trichlorofluoromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
vinyl acetate	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
vinyl chloride	µg/L	–	–	–	0	<20	<20	<20	1	<20	<20	<20	1	–	–	–	0
xylenes	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-13 Water Quality in the Middle Muskeg River

Parameter	Units	Winter (1980 to 2006)				Spring (1980 to 2006)				Summer (1980 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.1	–0.2	0.8	98	5.9	–0.3	18.1	58	16.1	0.1	22.4	65	4.8	–0.1	17.9	48
dissolved oxygen	mg/L	1.6[a)(b)]	0.05[a)(b)]	9.8	97	9.1	1[a)(b)]	11.8	57	6.9	2.1[a)(b)]	12.4	65	9.7	5.6[(b)]	12.4	46
Conventional Parameters																	
colour	TCU	46	10	200	34	70	14	100	24	88	60	150	34	70	33	200	34
specific conductance	µS/cm	550	274	589	21	264	114	485	18	328	223	433	22	452	197	548	26
dissolved organic carbon	mg/L	18	12	31	53	17	9	26	20	22	16	31	37	20	12	27	25
hardness	mg/L	287	226	303	21	127	49	230	21	168	110	240	23	195	105	289	31
pH		7.2	7	8.5	70	7.5	6.9	8.2	47	7.7	7.1	8.2	41	7.8	7.1	8.2	29
total alkalinity	mg/L	298	144	335	32	133	58	269	25	186	119	245	31	198	102	288	36
total dissolved solids	mg/L	306	188	367	30	159	62	319	27	197	122	304	31	210	124	540	36
total organic carbon	mg/L	22	15	27	16	18	14	20	13	25	19	31	16	22	17	34	20
total suspended solids	mg/L	7	<1	40	90	4	<1	16	49	4	<1	45	52	4	<0.4	25	37
Major Ions																	
bicarbonate	mg/L	365	291	409	27	170	70	328	22	220	145	298	26	241	124	351	32
calcium	mg/L	81	37	89	26	35	14	67	24	47	29	66	28	50	28	89	28
carbonate	mg/L	<0.5	<0.5	0.5	12	<0.5	<0.5	<5	17	<0.5	<0.5	<5	19	<0.5	<0.5	<5	16
chloride	mg/L	3	2	6	35	2	1	4	28	2	<0.5	8	34	2	<0.01	13	39
magnesium	mg/L	19	11	21	26	10	4	17	24	12	8	18	28	14	9	19	32
potassium	mg/L	1	0.4	2	31	1	1	4	25	1	<0.3	1	31	1	0.4	3	35
sodium	mg/L	11	7	20	32	6	3	14	25	7	4	20	31	9	4	30	35
sulphate	mg/L	2	≤0.4	7	35	2	≤0.8	8	28	1	≤0.1	6	34	3	≤0.5	26	39
sulphide	mg/L	<0.006	<0.001	0.01[(b)]	24	<0.01	<0.003	0.477[(b)]	16	<0.01	<0.003	0.15[(b)]	19	<0.01	≤0.001	0.17[(b)]	22
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.01	<0.003	0.1	19	0.01	<0.003	0.1	20	0.04	≤0.019	0.5	20	0.01	<0.003	0.1	23
nitrogen – ammonia	mg/L	0.82	0.08	1.18	34	0.045	<0.01	1.07	22	0.05	<0.01	0.17	23	0.06	≤0.01	0.15	22
nitrogen – kjeldahl	mg/L	1.4	0.5	3.4	22	0.7	0.6	1.7	17	0.9	0.6	1.3	22	0.8	0.3	1.3	28
nitrogen – total nitrogen	mg/L	1.4[(b)]	0.5	3.4[(b)]	22	0.8	0.6	1.8[(b)]	17	1	0.6	1.4[(b)]	22	0.9	0.3	1.4[(b)]	28
phosphorus, total	mg/L	0.063[(b)]	<0.01	0.3[(b)]	33	0.035	≤0.02	0.4[(b)]	28	0.044	≤0.027	1.6[(b)]	34	0.036	≤0.017	0.3[(b)]	36
phosphorus, dissolved	mg/L	0.005	0.003	0.009	11	0.017	≤0.014	0.06	9	0.022	0.017	0.032	11	0.013	0.004	0.03	14
chlorophyll *a*	µg/L	<1	<0.1	0	5	4	2	6	2	2	0	8	5	<1	≤0.4	0.4	4
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	2	<0.1	51	57	1	<0.1	5	27	1	<0.1	58	35	1	<0.1	2	31
General Organics																	
naphthenic acids	mg/L	<1	<1	2.7	12	<1	≤0.005	2	15	<1	<1	8	15	<1	<1	2	13
total phenolics	mg/L	0.005	<0.001	0.008[(b)]	18	0.005	<0.001	0.024[(b)]	17	0.003	<0.001	0.013[(b)]	21	0.005	<0.001	0.017[(b)]	18
total recoverable hydrocarbons	mg/L	0.5	≤0.3	4	20	<1	<0.1	208	20	0.1	<0.1	3	19	0.1	<0.1	3	24
Toxicity																	
Microtox® IC50 @ 15 Min	%	>91	>91	>91	1	>95.5	>91	>100	2	>100	>100	>100	1	>91	>91	>91	2
Microtox® IC25 @ 15 Min	%	>91	>91	>91	1	>95.5	>91	>100	2	>100	>100	>100	1	>91	>91	>91	2
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1
algal growth inhibition test (72h) – NOEC	%	100	100	100	1	100	100	100	1	100	100	100	1	100	100	100	1
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	7	>100	>100	>100	10	>100	>100	>100	7	>100	>100	>100	9
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	8	>100	>100	>100	11	>100	>100	>100	8	>100	>100	>100	9

Table F-13 Water Quality in the Middle Muskeg River (continued)

Parameter	Units	Winter (1980 to 2006)				Spring (1980 to 2006)				Summer (1980 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	2	100	100	100	2	100	100	100	2	100	100	100	1
ceriodaphnia 7d reproduction test – IC25	%	>100	83	>100	5	>100	>100	>100	8	>100	>100	>100	6	>100	>100	>100	7
ceriodaphnia 7d reproduction test – IC50	%	>100	>100	>100	6	>100	>100	>100	9	>100	>100	>100	6	>100	>100	>100	7
ceriodaphnia 7d reproduction test – LOEC	%	>100	>100	>100	3	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
ceriodaphnia 7d reproduction test – NOEC	%	75	50	100	2	100	100	100	2	100	100	100	2	100	100	100	1
fathead minnow 7d growth – IC25	%	>100	>62	>100	7	>100	>100	>100	10	>100	24.4	>100	7	>100	12.1	>100	8
fathead minnow 7d growth – IC50	%	>100	>88	>100	7	>100	>100	>100	10	>100	84.2	>100	7	>100	>100	>100	8
fathead minnow 7d growth – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
fathead minnow 7d growth – NOEC	%	75	50	100	2	100	100	100	2	75	50	100	2	100	100	100	1
fathead minnow 7d mortality test – LC25	%	>100	79.2	>100	8	>100	>27.3	>100	12	>100	21.2	>100	8	>100	4.3	>100	10
fathead minnow 7d mortality test – LC50	%	>100	>100	>100	9	>100	>100	>100	12	>100	54.8	>100	9	>100	9.1	>100	10
fathead minnow 7d mortality test – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>75	50	>100	2	12.5	12.5	12.5	1
fathead minnow 7d mortality test – NOEC	%	75	50	100	2	100	100	100	2	62.5	25	100	2	6.25	6.25	6.25	1
Total Metals																	
aluminum	mg/L	0.0195	≤0.0054	0.645[b]	28	0.03	≤0.008	0.16[b]	23	0.027	0.0092	0.233[b]	30	0.0232	<0.01	0.207[b]	34
antimony	mg/L	<0.0002	<0.000004	0.0221	20	<0.0002	≤0.00001	0.0008	17	<0.0002	≤0.00001	0.0016	22	0.00002	≤0.0000075	0.0025	22
arsenic	mg/L	<0.0002	<0.0001	0.0004	28	<0.0004	<0.0001	0.0004	22	<0.0003	<0.0001	0.0039	29	0.0002	≤0.00019	0.0005	35
barium	mg/L	0.086	0.074	0.102	18	0.04	<0.005	0.066	15	0.049	0.00004	0.084	22	0.062	0.02	0.08	21
beryllium	mg/L	<0.0002	≤0.0000048	0.001	21	<0.0002	<0.000003	0.037	18	<0.0002	<0.000003	0.002	25	<0.0002	<0.000003	0.004	23
boron	mg/L	0.05	0.03	0.09	25	0.02	≤0.0002	0.14	20	0.04	<0.01	0.07	26	0.03	<0.01	0.07	31
cadmium	mg/L	<0.0002	≤0.0000048	0.0032[b]	28	<0.0002	<0.000002	<0.003	23	<0.0002	<0.000002	0.0005[b]	30	<0.0002	<0.000002	0.0017[b]	34
chromium	mg/L	0.001	<0.0001	0.015[b]	27	<0.001	≤0.000197	0.008[b]	23	0.0003	≤0.000183	0.014[b]	30	0.0003	≤0.00019	0.012[b]	34
chromium – hexavalent	mg/L	0.001	<0.003	0.007[b]	4	<0.003	<0.003	0.006[b]	3	<0.003	<0.003	0.004[b]	5	<0.003	<0.003	<0.003	3
cobalt	mg/L	0.0004	≤0.00016	0.0014	16	<0.0003	≤0.000027	0.0004	14	0.0001	≤0.000055	0.005	22	0.0001	≤0.00004	0.0041	21
copper	mg/L	0.0003	≤0.00012	0.0029	27	0.0006	≤0.000184	0.0044[b]	23	0.0003	≤0.00019	0.0127[b]	29	0.0003	≤0.00012	0.0041[b]	34
iron	mg/L	3.72[b]	0.3	7.9[b]	28	1.25[b]	0.38[b]	3.33[b]	23	1.56[b]	0.61[b]	3.02[b]	30	1.14[b]	0.26	3.48[b]	34
lead	mg/L	0.0001	≤0.0000264	0.005	28	<0.0003	≤0.0000125	0.004	23	<0.0003	≤0.000022	0.0155[b]	30	<0.0003	≤0.000018	0.0011	34
lithium	mg/L	0.012	≤0.0105	0.014	18	<0.006	≤0.00391	0.01	14	0.007	<0.004	0.012	20	0.01	<0.004	0.075	21
manganese	mg/L	0.676	0.345	1.5	25	0.039	0.014	0.442	20	0.051	≤0.0233	0.224	27	0.069	0.011	0.206	31
mercury	mg/L	<0.00005	<0.0000006	0.000007[b]	29	<0.00005	<0.0000006	0.0004[a][b]	22	<0.00005	<0.0000006	0.0002[a][b]	26	<0.00005	<0.0000006	0.0021[a][b]	27
methyl mercury	mg/L	<0.00000003	<0.00000003	<0.00000003	1	<0.00000003	<0.00000003	<0.00000003	1	<0.00000003	<0.00000003	<0.00000003	1	–	–	–	0
molybdenum	mg/L	0.00004	<0.00002	0.0003	18	<0.0002	≤0.000089	0.004	15	<0.0001	≤0.000058	0.0006	22	0.00003	≤0.000028	0.0005	21
nickel	mg/L	<0.001	<0.000005	0.0111	28	0.00003	≤0.00003	0.0087	23	<0.001	<0.000005	0.0261	30	<0.001	<0.000005	0.0181	34
selenium	mg/L	<0.00045	≤0.000121	0.001	28	<0.0004	<0.0001	0.0005	22	<0.0002	<0.0001	0.00011	29	<0.0005	<0.0001	0.0008	34
silicon	mg/L	7.2	6.5	7.7	5	2.8	1.1	5.8	10	3.7	2	5.4	7	3.7	2	5.9	6
silver	mg/L	<0.0001	≤0.000002	0.0004[b]	21	<0.0001	≤0.0000011	0.000005	18	<0.0001	≤0.0000005	0.0012[b]	25	<0.000054	≤0.000001	0.000008	24
strontium	mg/L	0.2	0.16	0.22	18	0.08	0.03	0.17	15	0.12	0.08	0.17	21	0.15	0.04	0.19	21
sulphur	mg/L	0.9	0.4	15.9	7	1	0.8	7.9	7	0.6	0.4	1.5	7	1.3	0.9	2.4	5
thallium	mg/L	<0.00015	≤0.0000009	0.0018[b]	18	<0.0002	≤0.0000008	0.00001	15	<0.00015	<0.000003	0.0002	18	<0.0001	≤0.0000009	0.00017	21
titanium	mg/L	0.0026	<0.0006	0.075	16	0.0014	≤0.0008	0.005	15	0.0018	<0.0006	0.009	20	0.0025	<0.0006	0.006	20
uranium	mg/L	<0.0001	≤0.00002	0.0001	17	<0.0001	≤0.0000203	0.00003	15	<0.0001	≤0.000029	0.0017	19	0.00002	≤0.0000173	0.0001	20

Table F-13 Water Quality in the Middle Muskeg River (continued)

Parameter	Units	Winter (1980 to 2006)				Spring (1980 to 2006)				Summer (1980 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
vanadium	mg/L	<0.001	<0.00004	0.001	30	<0.001	<0.0002	0.003	23	<0.001	<0.0002	0.003	32	<0.001	≤0.00019	0.002	34
zinc	mg/L	0.008	≤0.00074	0.026	27	0.01	≤0.00082	0.054[(b)]	23	0.004	<0.001	0.18[(b)]	28	0.003	≤0.0004	0.162[(b)]	33
Dissolved Metals																	
aluminum	mg/L	0.005	<0.01	0.02	2	0.0075	≤0.0038	0.02	6	0.0035	≤0.00263	0.01	5	<0.0072	≤0.00251	0.0044	8
antimony	mg/L	<0.0008	≤0.0007	0.0007	2	0.0003	≤0.00002	0.0023	6	0.00002	<0.000004	0.0009	5	0.00001	≤0.000007	0.0014	8
arsenic	mg/L	<0.0003	<0.0002	0.0003	7	<0.0004	<0.0002	0.0022	9	0.0003	<0.0002	0.0023	10	0.0002	≤0.0002	0.007[(b)]	11
barium	mg/L	0.085	0.084	0.086	2	0.035	0.022	0.043	6	0.063	0.039	0.072	5	0.059	0.033	0.077	8
beryllium	mg/L	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.00004	<0.001	6	<0.00004	<0.00004	<0.0005	5	<0.0003	<0.00004	<0.001	8
boron	mg/L	0.1	0.04	0.13	6	0.03	≤0.019	0.07	9	0.04	0.01	0.14	10	0.04	≤0.01	0.11	11
cadmium	mg/L	<0.0001	<0.0001	<0.0001	2	<0.0001	≤0.00001	0.00001	6	<0.00002	<0.00001	0.0001	5	<0.0001	<0.00001	<0.0001	8
chromium	mg/L	0.0017[(b)]	<0.0004	0.0037[(b)]	2	<0.0022	<0.0001	0.0037[(b)]	6	0.0003	≤0.00019	0.002[(b)]	5	<0.0004	≤0.00011	0.0005	8
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0016	0.0003	0.003	2	0.0001	≤0.000048	0.0004	6	0.0001	0.00005	0.0012	5	0.0001	<0.00002	0.0005	8
copper	mg/L	0.0007	0.0006	0.0008	2	0.0004	≤0.00041	0.0011	6	0.0001	<0.0001	0.0015	5	<0.0005	≤0.0001	0.0004	8
iron	mg/L	0.49[(b)]	0.07	3.78[(b)]	30	0.49[(b)]	0.13	0.85[(b)]	14	0.74[(b)]	0.21	1.22[(b)]	16	0.29	0.09	1.2[(b)]	16
lead	mg/L	0.0001	<0.0001	0.0001	2	0.0001	≤0.000076	0.0004	6	<0.00004	<0.00001	0.0002	5	<0.0001	<0.00001	0.0001	8
lithium	mg/L	0.014	0.013	0.014	2	0.006	0.004	0.007	6	0.008	0.006	0.008	5	0.01	0.007	0.019	8
manganese	mg/L	0.41	<0.004	1.155	30	0.023	<0.004	0.066	14	0.017	<0.004	0.198	16	0.067	0.012	0.191	16
mercury	mg/L	<0.0000503	<0.0000006	<0.0001	2	<0.0001	<0.0000006	<0.0001	4	<0.0001003	<0.0000006	<0.0002	2	<0.00001	<0.0000006	<0.0001	4
molybdenum	mg/L	0.0001	<0.0001	0.0003	2	0.0001	≤0.000066	0.0004	6	0.0001	≤0.000045	0.0052	5	<0.0001	≤0.000026	0.0001	8
nickel	mg/L	0.0011	0.0002	0.002	2	<0.0014	<0.0001	0.002	6	<0.0001	<0.0001	0.0011	5	0.0001	<0.0001	0.001	8
selenium	mg/L	<0.0002	<0.0002	<0.0004	6	<0.0004	<0.0002	<0.0005	9	<0.0004	<0.0002	0.0004	10	<0.00045	<0.0002	0.0021[(b)]	10
silicon	mg/L	–	–	–	0	2.45	2.2	2.7	2	–	–	–	0	3.8	3.8	3.8	1
silver	mg/L	<0.000101	≤0.000002	0.000002	2	<0.000052	≤0.0000012	0.000001	6	<0.000005	<0.000005	0.0013[(b)]	5	<0.000052	<0.000005	<0.0002	8
strontium	mg/L	0.19	0.19	0.2	2	0.08	0.05	0.1	6	0.13	0.12	0.14	5	0.16	0.1	0.18	8
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	1	<0.00005	≤0.000006	0.00001	5	<0.000003	<0.000003	<0.00005	4	<0.00006	<0.000003	0.00009	6
titanium	mg/L	0.0004	<0.0003	0.001	2	0.0005	≤0.0003	0.0009	6	0.0009	0.0008	0.0013	5	0.0015	<0.0003	0.0019	8
uranium	mg/L	<0.0001	<0.0001	<0.0001	2	<0.0001	≤0.000031	0.00004	6	0.00003	≤0.000035	0.00004	5	<0.0001	≤0.000013	0.0001	8
vanadium	mg/L	0.0001	<0.0001	0.0001	2	0.0001	<0.0001	0.0003	6	0.0002	0.0002	0.0002	5	0.0002	<0.0001	0.0003	8
zinc	mg/L	0.004	0.002	0.005	2	0.008	0.0002	0.057[(b)]	6	0.003	≤0.00177	0.005	4	0.0004	<0.0002	0.006	8
Target PAHs and Alkylated PAH																	
naphthalene	µg/L	<0.1	≤0.0011	0.002	15	<0.05	<0.01	0.3	14	<0.05	<0.01	<0.1	11	<0.01	<0.01	0.01	17
C1 subst'd naphthalenes	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	–	–	–	0
C2 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
acenaphthene	µg/L	<0.1	<0.01	<0.1	14	<0.05	<0.01	<0.1	14	<0.05	<0.01	<0.1	11	<0.01	<0.01	0.1	17
C1 subst'd acenaphthene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
acenaphthylene	µg/L	<0.05	<0.01	<0.1	11	<0.05	<0.01	<0.1	10	<0.05	<0.01	<0.1	9	<0.01	<0.01	<0.1	13
anthracene	µg/L	<0.01	<0.01	0.06[(b)]	14	<0.01	<0.005	<0.05	14	<0.01	<0.005	<0.05	11	<0.01	<0.005	<0.05	17
dibenzo(a,h)anthracene	µg/L	<0.04	<0.01	<0.05	6	<0.03	<0.01	<0.05	12	<0.03	<0.01	<0.05	9	<0.03	<0.01	<0.05	12
benzo(a)anthracene/chrysene	µg/L	<0.035	<0.01	0.27[(b)]	14	<0.03	<0.01	<0.05	14	<0.03	<0.01	<0.05	11	<0.01	<0.01	<0.05	17
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.05	<0.05	<0.05	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
benzo(a)pyrene	µg/L	<0.01	<0.01	0.07[(b)]	14	<0.01	<0.005	<0.05	14	<0.01	<0.005	0.01	11	<0.01	<0.009	<0.05	17
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.1	6	<0.01	<0.01	<0.1	6	<0.01	<0.01	<0.02	3	<0.01	<0.01	<0.01	9

Table F-13 Water Quality in the Middle Muskeg River (continued)

Parameter	Units	Winter (1980 to 2006)				Spring (1980 to 2006)				Summer (1980 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
benzo(g,h,i)perylene	µg/L	<0.03	<0.01	<0.2	11	<0.03	<0.01	<0.05	10	<0.03	<0.01	<0.05	9	<0.01	<0.01	<0.05	13
biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C1 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
dibenzothiophene	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	–	–	–	0
C1 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
fluoranthene	µg/L	<0.04	<0.01	0.18[(b)]	14	<0.025	<0.01	<0.05	14	<0.02	<0.01	<0.05	11	<0.01	<0.01	<0.04	17
C1 subst'd fluoranthene/pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
fluorene	µg/L	<0.05	<0.01	<0.1	14	<0.03	<0.005	<0.05	14	<0.03	<0.01	<0.05	11	<0.01	<0.01	<0.05	17
C1 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
indeno(c,d–123)pyrene	µg/L	<0.05	<0.01	<0.1	11	<0.04	<0.01	<0.1	12	<0.05	<0.01	<0.1	9	<0.01	<0.01	<0.1	15
phenanthrene	µg/L	<0.05	<0.01	0.17	14	<0.03	<0.01	<0.05	14	<0.05	<0.01	<0.15	11	<0.01	≤0.006	0.01	17
C1 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd phenanthren/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	–	–	–	0
pyrene	µg/L	<0.02	<0.01	0.13[(b)]	14	<0.015	<0.005	<0.05	14	<0.02	<0.01	<0.05	11	<0.01	<0.01	<0.02	17
Target PANHs																	
quinoline	µg/L	<3	<0.2	<3	7	<3	<0.01	<3	9	<0.3	<0.02	<3	9	<3	<0.01	<3	7
7–methyl quinoline	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.02	<0.02	<0.02	2	–	–	–	0
C2 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
C3 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
acridine	µg/L	<0.2	<0.01	<0.5	12	<0.3	<0.01	<0.5	11	<0.2	<0.01	<0.5	11	<0.01	<0.01	<0.5	14
methyl acridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
phenanthridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
methyl carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
C2 subst'd carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	2	–	–	–	0
Phenolics																	
phenol	µg/L	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
o–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
m–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
p–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
2,4–dimethylphenol	µg/L	<0.2	<0.2	<0.2	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	–	–	–	0
2–nitrophenol	µg/L	<0.1	<0.1	<0.1	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2	1	–	–	–	0
4–nitrophenol	µg/L	<0.1	<0.1	<0.1	1	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
2,4–dinitrophenol	µg/L	<0.1	<0.1	<0.1	1	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
4,6–dinitro–2–methyl phenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
Volatile Organics																	
acetone	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
acrolein	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
acrylonitrile	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
benzene	µg/L	<0.4	<0.1	<0.4	15	<0.4	<0.2	<1	12	<0.4	<0.4	<1	11	<0.4	<0.4	<0.5	10
bromodichloromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
bromoform	µg/L	<0.5	<0.5	<0.5	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0

Table F-13 Water Quality in the Middle Muskeg River (continued)

Parameter	Units	Winter (1980 to 2006)				Spring (1980 to 2006)				Summer (1980 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
bromomethane	µg/L	<0.1	<0.1	<0.1	5	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
2–butanone (MEK)	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
carbon disulfide	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
carbon tetrachloride	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chlorobenzene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chloroethane	µg/L	<0.1	<0.1	<0.1	5	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
2–chloroethyl vinyl ether	µg/L	–	–	–	0	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
chloroform	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
chloromethane	µg/L	–	–	–	0	<10	<10	<10	1	<10	<10	<10	1	–	–	–	0
dibromochloromethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
dibromomethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,3–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,4–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
cis–1,4–dichloro–2–butene	µg/L	<0.1	<0.1	<0.1	5	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
trans–1,4–dichloro–2–butene	µg/L	–	–	–	0	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
dichlorodifluoromethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1–dichloroethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichloroethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1–dichloroethene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trans–1,2–dichloroethene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2–dichloropropane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
cis–1,3–dichloropropene	µg/L	<0.3	<0.3	<0.3	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trans–1,3–dichloropropene	µg/L	<0.3	<0.3	<0.3	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
ethanol	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
ethylbenzene	µg/L	<0.4	<0.1	<0.4	15	<0.4	<0.2	<1	12	<0.4	<0.4	<1	11	<0.4	<0.4	<0.5	10
ethylene dibromide	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
ethyl methacrylate	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
2–hexanone	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
iodomethane	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
4–methyl–2–pentanone (MIBK)	µg/L	–	–	–	0	<200	<200	<200	1	<200	<200	<200	1	–	–	–	0
methylene chloride	µg/L	–	–	–	0	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
styrene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
tetrachloroethylene	µg/L	<0.3	<0.3	<0.3	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1,2,2–tetrachloroethane	µg/L	<0.1	<0.1	<0.1	5	<5	<5	<5	1	<5	<5	<5	1	–	–	–	0
toluene	µg/L	<0.4	<0.1	0.8	15	<0.4	<0.2	<1	12	<0.4	<0.4	<1	11	<0.4	<0.4	<0.5	10
1,1,1–trichloroethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,1,2–trichloroethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
1,2,3–trichloropropane	µg/L	<0.1	<0.1	<0.1	5	<2	<2	<2	1	<2	<2	<2	1	–	–	–	0
trichloroethene	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
trichlorofluoromethane	µg/L	<0.1	<0.1	<0.1	5	<1	<1	<1	1	<1	<1	<1	1	–	–	–	0
vinyl acetate	µg/L	–	–	–	0	<100	<100	<100	1	<100	<100	<100	1	–	–	–	0
vinyl chloride	µg/L	<0.5	<0.5	<0.5	5	<20	<20	<20	1	<20	<20	<20	1	–	–	–	0
xylenes	µg/L	<0.8	<0.8	<0.8	7	<0.8	<0.3	<1	9	<0.8	<0.8	<1	9	<0.8	<0.5	<0.8	9

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-14 Water Quality in the Lower Muskeg River

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.1	–0.3	2	122	5	–0.3	20.1	62	16.4	6	23	94	7.2	–0.1	18.1	56
dissolved oxygen	mg/L	4[a][b]	0.2[a][b]	13.6	116	10	0.2[a][b]	13.4	56	8.3	5.2[b]	11.8	90	10.3	5[b]	16	55
Conventional Parameters																	
colour	TCU	50	10	128	52	65	40	125	28	91	20	165	44	80	29	150	43
specific conductance	µS/cm	492	120	1,360	72	220	115	645	41	294	170	450	70	304	160	666	63
dissolved organic carbon	mg/L	20	9	61	87	17	8	34	35	24	6	53	67	23	7	34	58
hardness	mg/L	260	134	638	38	140	60	350	29	158	90	203	43	173	96	361	44
pH		7.4	7	8.6[a][b]	118	7.7	7	8.3	67	7.9	7.2	8.5	87	8	7.3	8.5	64
total alkalinity	mg/L	264	61	790	75	115	56	295	43	162	66	232	73	156	101	291	64
total dissolved solids	mg/L	332	79	844	54	166	72	409	32	201	108	293	53	220	112	595	53
total organic carbon	mg/L	22	10	63	34	17	8	35	16	24	6	53	31	25	12	31	33
total suspended solids	mg/L	4	<0.4	72	136	5	<0.4	36	66	3	<0.4	16	87	2	<0.01	70	62
Major Ions																	
bicarbonate	mg/L	323	178	443	49	140	91	360	33	184	129	256	36	218	123	355	46
calcium	mg/L	74	18	160	48	38	2	105	32	44	24	67	54	40	26	115	47
carbonate	mg/L	<0.5	<0.5	7	10	<0.5	<0.5	3	18	<0.5	<0.5	3	18	<5	<0.5	8	27
chloride	mg/L	5	0.5	20	79	3	1	7	43	3	≤0.7	14	73	3	1	30	64
magnesium	mg/L	18	5	58	48	9	1	21	32	10	3	14	56	10	7	21	51
potassium	mg/L	1	0.4	6	74	2	0.2	3	43	0.5	≤0.03	4	73	1	0.2	3	63
sodium	mg/L	15	3	50	76	8	1	18	43	11	6	22	73	11	7	38	63
sulphate	mg/L	6	≤1	99	77	5	≤2.4	90	43	5	≤0.5	34	73	6	0.1	95	64
sulphide	mg/L	<0.01	<0.001	0.01[b]	41	<0.01	<0.003	0.027[b]	16	<0.01	<0.003	0.14[b]	32	<0.01	≤0.001	0.022[b]	40
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.04	≤0.004	0.3	8	<0.04	<0.003	0.1	16	0.01	≤0.005	0.1	14	<0.05	<0.002	0.1	25
nitrogen – ammonia	mg/L	0.5	0.04	1.63	28	0.015	<0.01	0.99	20	0.02	<0.01	0.16	17	<0.05	≤0.01	0.09	21
nitrogen – kjeldahl	mg/L	1.1	0.4	3.9	66	0.7	0.3	2.1	30	0.9	0.5	2.9	53	0.7	0.3	2.2	49
nitrogen – total nitrogen	mg/L	1.1[b]	0.4	3.9[b]	66	0.7	0.3	2.1[b]	30	0.9	0.5	2.9[b]	53	0.7	0.3	2.2[b]	49
phosphorus, total	mg/L	0.033	≤0.017	0.2[b]	74	0.031	≤0.015	0.3[b]	39	0.027	<0.005	0.6[b]	63	0.023	≤0.007	0.6[b]	59
phosphorus, dissolved	mg/L	0.011	≤0.005	0.031	42	0.014	≤0.004	0.04	20	0.016	0.009	0.047	24	0.012	≤0.002	0.025	32
chlorophyll *a*	µg/L	<1	<0.1	6	12	3.5	<1	4	3	0.7	≤0.7	8	13	<1	≤0.9	10	19
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	<0.1	5	65	2	<0.1	17	30	1	<0.1	3	32	1	<0.1	4	33
General Organics																	
naphthenic acids	mg/L	1	<1	3.1	7	<1	≤0.005	4	13	<1	<1	8	11	<1	<1	3.1	22
total phenolics	mg/L	0.004	<0.001	0.02[b]	39	0.004	<0.001	0.014[b]	18	0.001	<0.001	0.025[b]	38	0.002	<0.001	0.019[b]	40
total recoverable hydrocarbons	mg/L	0.9	<0.1	4	29	0.2	<0.1	3.1	20	0.7	<0.001	5	43	0.1	<0.1	3.5	40
Toxicity																	
Microtox® IC50 @ 15 Min	%	>95	>91	>99	2	>95.5	>91	>100	4	>91	>91	>100	6	>91	>91	>100	7
Microtox® IC25 @ 15 Min	%	>91	>91	>91	1	>95.5	>91	>100	4	>91	>91	>100	6	>91	>91	>100	7
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1	>100	>100	>100	1

Table F-14 Water Quality in the Lower Muskeg River (continued)

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
algal growth inhibition test (72h) – NOEC	%	100	100	100	1	100	100	100	1	100	100	100	1	100	100	100	1
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	6	>100	>100	>100	8	>100	>100	>100	4	>100	>100	>100	7
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	7	>100	>100	>100	8	>100	>100	>100	6	>100	>100	>100	7
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	2	100	100	100	2	100	100	100	2	100	100	100	1
ceriodaphnia 7d reproduction test – IC25	%	>100	>100	>100	7	>100	>100	>100	7	>100	>100	>100	6	>100	>100	>100	6
ceriodaphnia 7d reproduction test – IC50	%	>100	>100	>100	7	>100	>100	>100	7	>100	>100	>100	6	>100	>100	>100	6
ceriodaphnia 7d reproduction test – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
ceriodaphnia 7d reproduction test – NOEC	%	100	100	100	2	100	100	100	2	100	100	100	2	100	100	100	1
fathead minnow 7d growth – IC25	%	>100	>68	>100	7	>100	>44.8	>100	7	>100	>100	>100	6	>100	>100	>100	6
fathead minnow 7d growth – IC50	%	>100	>100	>100	7	>100	>100	>100	7	>100	>100	>100	6	>100	>100	>100	6
fathead minnow 7d growth – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
fathead minnow 7d growth – NOEC	%	100	100	100	2	100	100	100	2	100	100	100	2	100	100	100	1
fathead minnow 7d mortality test – LC25	%	>100	>100	>100	6	>100	>100	>100	8	>100	>100	>100	5	>100	>43.8	>100	7
fathead minnow 7d mortality test – LC50	%	>100	>100	>100	7	>100	>100	>100	8	>100	>100	>100	6	>100	>100	>100	7
fathead minnow 7d mortality test – LOEC	%	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	2	>100	>100	>100	1
fathead minnow 7d mortality test – NOEC	%	100	100	100	2	100	100	100	2	100	100	100	2	100	100	100	1
trout 96h static acute test – LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – NOEC	%	>100	>100	>100	2	–	–	–	0	–	–	–	0	–	–	–	0
Total Metals																	
aluminum	mg/L	0.036	0.018	0.27[b]	22	0.081	<0.01	0.379[b]	23	0.0565	0.0139	0.25[b]	25	0.0478	0.01	1.2[a][b]	38
antimony	mg/L	0.00002	≤0.000008	0.0012	20	0.00001	<0.000004	0.0038	21	0.00002	≤0.0000185	0.0045	21	0.00002	≤0.000014	0.0017	35
arsenic	mg/L	0.0002	≤0.0001	0.0006	29	0.0002	≤0.00014	0.041[b]	22	0.0003	<0.0002	0.0007	26	0.0003	≤0.00019	0.014[b]	41
barium	mg/L	0.071	0.037	0.102	29	0.04	0.022	0.921	22	0.036	0.00003	0.058	24	0.038	0.02	0.115	37
beryllium	mg/L	<0.0001	<0.000003	0.0003	22	<0.0002	≤0.00000383	0.001	22	<0.0002	<0.000003	0.009	24	<0.0001	<0.000003	0.003	37
boron	mg/L	0.05	0.04	0.07	21	0.04	≤0.023	1.21	23	0.05	0.03	0.13	24	0.04	≤0.01	0.16	38
cadmium	mg/L	<0.0002	<0.000002	0.002[b]	30	<0.0002	≤0.0000021	0.0008[b]	23	<0.0002	<0.000002	0.0004	28	<0.00003	<0.000002	0.004[a][b]	39
chromium	mg/L	0.001	<0.0001	0.01[b]	29	0.0002	≤0.0002	0.006[b]	23	0.0002	≤0.00011	0.017[a][b]	28	0.0004	≤0.0001	0.008[b]	39
chromium – hexavalent	mg/L	<0.003	<0.003	0.013[b]	25	<0.003	<0.003	0.006[b]	9	<0.003	<0.003	0.016[b]	26	<0.003	<0.003	0.007[b]	15
cobalt	mg/L	0.0004	≤0.000116	0.001	27	0.0001	<0.00002	0.0053	21	0.0001	≤0.00006	0.007	27	0.0001	≤0.00002	0.006	38
copper	mg/L	0.0003	≤0.00017	0.003	28	0.0003	<0.0001	0.0025	23	0.0004	<0.0001	0.022[a][b]	26	0.0005	≤0.00014	0.004[b]	39
iron	mg/L	1.39[b]	0.66[b]	4.42[b]	32	0.96[b]	0.41[b]	1.95[b]	23	0.76[b]	0.44[b]	1.3[b]	28	0.55[b]	0.1	1.91[b]	39

Table F-14 Water Quality in the Lower Muskeg River (continued)

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
lead	mg/L	0.0001	≤0.000032	0.0327[b]	23	0.0001	<0.00001	0.0013	23	0.0001	<0.00001	0.013[b]	28	0.00004	<0.000001	0.016[b]	39
lithium	mg/L	0.013	0.01	0.014	21	0.007	≤0.0037	0.014	22	0.008	<0.004	0.011	24	0.009	<0.004	0.015	37
manganese	mg/L	0.387	0.015	1.243	30	0.047	0.018	0.515	23	0.035	≤0.014	0.142	28	0.03	≤0.0155	0.115	39
mercury	mg/L	<0.0001	<0.000005	0.0011[a][b]	52	<0.0001	<0.000005	0.0003[a][b]	27	<0.0001	<0.000005	0.0021[a][b]	47	<0.0001	<0.0000006	0.0004[a][b]	45
molybdenum	mg/L	0.00004	≤0.00003	0.001	29	0.0001	≤0.000085	0.004	22	0.0001	≤0.000076	0.0009	24	0.0001	≤0.000038	0.005	37
nickel	mg/L	0.0003	<0.000005	0.0316	29	0.00005	≤0.00005	0.116[b]	23	0.0003	<0.000005	0.026	28	0.0002	<0.000005	0.196[b]	39
selenium	mg/L	<0.00026	<0.0001	0.0003	29	<0.0004	<0.0001	0.0013[b]	22	<0.0004	<0.0001	0.0006	24	<0.0005	≤0.00006	0.00021	37
silicon	mg/L	6.3	5.8	7.3	6	2.8	1.6	6	12	2.9	1.6	4.4	7	3.4	2	4.6	10
silver	mg/L	<0.000006	≤0.0000014	0.000012	21	<0.0001	<0.0000005	0.0005[b]	22	<0.0001	<0.0000005	0.0014[b]	24	<0.000005	<0.0000005	0.003[b]	37
strontium	mg/L	0.18	0.11	0.24	21	0.1	0.06	2.28	22	0.12	0.08	0.16	23	0.13	0.07	0.22	37
sulphur	mg/L	2.1	1	7.7	6	1.4	1.1	29.1	9	1.6	1.1	5.6	6	1	<0.2	21.1	11
thallium	mg/L	<0.00001	≤0.0000021	0.0002	18	<0.00004	<0.0000003	0.0002	17	<0.00001	<0.0000003	0.00001	17	<0.00002	<0.0000003	0.00016	30
titanium	mg/L	0.0024	≤0.0005	0.008	25	0.0018	<0.001	0.005	24	0.0015	<0.0006	0.005	24	0.0021	≤0.001	0.0167	38
uranium	mg/L	0.0001	≤0.000038	0.0004	20	<0.0001	≤0.000021	0.0038	22	0.00005	≤0.000027	0.0018	20	0.00004	≤0.000014	0.0005	36
vanadium	mg/L	<0.001	<0.00004	0.005	55	<0.001	≤0.000256	0.018	32	<0.001	≤0.00025	0.006	46	0.0002	<0.0002	0.003	52
zinc	mg/L	0.006	≤0.00092	0.043[b]	29	0.005	≤0.00093	0.075[b]	23	0.008	≤0.0005	0.115[b]	26	0.002	<0.0002	0.159[b]	38
Dissolved Metals																	
aluminum	mg/L	0.01	0.01	0.01	1	0.0082	≤0.0048	0.0315	9	0.006	≤0.00265	0.23[b]	4	0.0021	≤0.00184	0.09	17
antimony	mg/L	<0.0008	<0.0008	<0.0008	1	0.00002	<0.000004	0.0037	9	<0.0008	≤0.000017	0.0008	4	0.00002	≤0.000013	0.0016	16
arsenic	mg/L	0.0003	<0.0002	0.02[b]	27	<0.0004	<0.0002	0.0006	19	0.0005	<0.0002	0.005	32	0.0002	<0.0002	0.012[b]	31
barium	mg/L	0.093	0.093	0.093	1	0.026	0.019	0.795	9	0.051	0.029	0.057	4	0.04	0.024	0.093	17
beryllium	mg/L	<0.001	<0.0005	<0.001	7	<0.0005	<0.00004	0.0001	10	<0.0005	<0.00004	<0.005	5	<0.0001	<0.000003	0.0001	17
boron	mg/L	0.12	0.03	0.36	18	0.07	≤0.026	0.27	16	0.08	0.01	0.18	16	0.05	≤0.01	0.22	27
cadmium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.00001	0.00002	10	<0.0001	<0.00001	0.0001	5	<0.00002	<0.000002	0.00002	17
chromium	mg/L	<0.0004	<0.0004	<0.0004	1	0.0002	≤0.00018	0.0005	9	<0.0004	≤0.0002	0.0002	4	0.0001	≤0.0001	0.0025[b]	17
cobalt	mg/L	0.0004	0.0004	0.0004	1	0.0001	≤0.00003	0.0002	10	0.0001	≤0.00007	0.0002	5	0.0001	<0.00002	0.0002	17
copper	mg/L	0.001	0.001	0.001	1	0.0003	≤0.000167	0.0026	10	0.0006	≤0.00025	0.0015	5	0.0006	≤0.00012	0.0019	17
iron	mg/L	0.34[b]	0.04	0.93[b]	15	0.41[b]	0.06	1.89[b]	17	0.37[b]	0.12	0.7[b]	14	0.33[b]	0.02	0.87[b]	28
lead	mg/L	0.0003	0.0003	0.0003	1	0.00002	≤0.000019	0.0004	10	0.0002	≤0.000022	0.0038	5	0.00005	<0.00001	0.0009	17
lithium	mg/L	0.014	0.014	0.014	1	0.006	0.004	0.009	9	0.009	0.008	0.01	4	0.01	0.007	0.012	17
manganese	mg/L	0.377	0.024	1.04	15	0.032	0.005	0.491	17	0.012	≤0.0013	0.024	14	0.016	0.004	0.053	28
mercury	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0002	5	<0.0002	<0.0001	0.0002[a][b]	3	<0.00007	<0.00001	0.0002[a][b]	12
molybdenum	mg/L	0.0001	0.0001	0.0001	1	0.0001	≤0.000083	0.0003	9	0.0001	≤0.00009	0.0001	4	0.0001	≤0.0000619	0.0002	17
nickel	mg/L	0.0039	0.0039	0.0039	1	<0.0006	<0.0001	0.0027	9	0.0002	<0.0001	0.0014	5	0.0003	<0.000005	0.0087	17
selenium	mg/L	<0.0002	<0.0002	0.0009	26	<0.0004	<0.0002	0.0007	19	<0.0002	<0.0002	0.0008	32	<0.0004	<0.0001	0.0004	29
silicon	mg/L	–	–	–	0	1.36	0.2	2.1	3	3.66	3.66	3.66	1	3.785	3.5	4.07	2
silver	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.000005	0.0014[b]	9	<0.0002	<0.000005	<0.0002	4	<0.000005	<0.0000005	0.000001	17
strontium	mg/L	0.2	0.2	0.2	1	0.07	0.05	0.12	9	0.13	0.1	0.14	4	0.14	0.07	0.23	17
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	0.464	0.401	1.16	3
thallium	mg/L	–	–	–	0	0.0000005	<0.000003	0.00004	6	0.00001	0.00001	0.00001	1	0.000003	≤0.00000254	0.00008	13
titanium	mg/L	0.0015	0.0015	0.0015	1	0.0008	<0.0003	0.001	9	0.0006	0.0004	0.0007	4	0.001	≤0.0006	0.0023	17
uranium	mg/L	0.0003	0.0003	0.0003	1	0.00004	≤0.000017	0.0001	9	0.000004	<0.00005	0.0002	4	0.0002	≤0.0000221	0.0005	17
vanadium	mg/L	<0.0001	<0.0001	<0.0001	1	0.0002	≤0.0001	0.0004	10	0.0002	<0.0001	0.0005	5	0.0002	<0.0001	0.0003	17
zinc	mg/L	0.004	0.004	0.004	1	0.002	≤0.00044	0.074[b]	10	0.006	≤0.001	0.017	4	0.002	<0.0002	0.014	17
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.1	≤0.0008	0.89	18	<0.05	<0.01	<0.1	12	<0.1	<0.01	0.3	9	<0.08	<0.01	<1	20
C1 subst'd naphthalenes	µg/L	<0.02	<0.02	<0.02	1	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1

Table F-14 Water Quality in the Lower Muskeg River (continued)

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	<0.02	≤0.002	0.002	15	<0.05	<0.01	<0.1	12	<0.09	<0.01	<0.1	9	<0.01	≤0.00018	0.0002	19
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	<0.02	<0.01	0.04	13	<0.05	<0.01	<0.1	8	<0.05	<0.01	<0.1	7	<0.01	<0.01	<1	15
anthracene	µg/L	<0.01	<0.01	0.01	15	<0.01	<0.005	<0.1	12	<0.01	<0.005	<0.1	9	<0.01	<0.01	0.03[(b)]	19
dibenzo(a,h)anthracene	µg/L	<0.02	<0.01	<5	7	<0.02	<0.01	<0.5	10	<0.05	<0.01	<0.5	7	<0.02	<0.01	<5	13
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	0.01	15	<0.04	<0.01	<0.1	12	<0.05	≤0.0027	0.0027	9	<0.01	≤0.00015	0.16[(b)]	19
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.045	<0.04	<0.05	2	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	<0.01	<0.01	0.02[(b)]	15	<0.01	<0.005	<0.1	12	<0.01	<0.005	<0.1	9	<0.01	<0.01	<1	19
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.1	9	<0.01	<0.01	<0.01	5	<0.01455	≤0.0091	0.0091	2	<0.01	<0.01	<0.02	11
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<2	13	<0.04	<0.01	<0.2	8	<0.05	≤0.0022	0.002	7	<0.01	<0.01	<2	15
biphenyl	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	<0.02	<0.02	<0.02	1	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	<0.02	<0.01	<1	15	<0.03	<0.01	<0.1	12	<0.04	≤0.0037	0.004	9	<0.02	≤0.00008	0.0001	19
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	µg/L	<0.02	<0.01	0.012	15	<0.04	<0.01	<0.1	12	<0.05	<0.01	<0.1	9	<0.02	≤0.00015	0.00015	19
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d–123)pyrene	µg/L	<0.01	<0.01	<1	13	<0.03	<0.01	<0.1	10	<0.05	≤0.0036	0.004	7	<0.01	<0.01	<1	17
phenanthrene	µg/L	<0.05	<0.01	0.02	15	<0.04	<0.01	<0.1	12	<0.05	≤0.0027	0.003	9	<0.02	≤0.0005	0.15	19
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
pyrene	µg/L	<0.02	<0.01	<1	15	<0.015	<0.01	<0.1	12	<0.02	≤0.0042	0.004	9	<0.02	≤0.00014	0.0001	19
Target PANHs																	
quinoline	µg/L	<3	<0.02	<3	6	<3	<0.01	<3	9	<3	<0.02	<3	7	<3	<0.01	<3	9

Table F-14 Water Quality in the Lower Muskeg River (continued)

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
7–methyl quinoline	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C2 subst'd quinoline	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C3 subst'd quinoline	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
acridine	µg/L	<0.01	<0.01	<0.5	13	<0.035	<0.01	<0.5	12	<0.4	<0.01	<0.5	8	<0.01	<0.01	<0.5	17
methyl acridine	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
phenanthridine	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
carbazole	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
methyl carbazole	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C2 subst'd carbazole	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
Phenolics																	
phenol	µg/L	<0.1	<0.1	<1.3	5	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<1.3	4
o–cresol	µg/L	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
m–cresol	µg/L	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
p–cresol	µg/L	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
2,4–dimethylphenol	µg/L	<0.2	<0.1	<2	5	<0.15	<0.1	<0.2	2	<0.15	<0.1	<0.2	2	<0.2	<0.1	<2	4
2–nitrophenol	µg/L	<0.1	<0.1	<1	5	<0.15	<0.1	<0.2	2	<0.15	<0.1	<0.2	2	<0.15	<0.1	<1	4
4–nitrophenol	µg/L	<0.1	<0.1	<2	5	<1.05	<0.1	<2	2	<1.05	<0.1	<2	2	<0.55	<0.1	<2	4
2,4–dinitrophenol	µg/L	<0.1	<0.1	<2	5	<1.05	<0.1	<2	2	<1.05	<0.1	<2	2	<0.55	<0.1	<2	4
4,6–dinitro–2–methyl phenol	µg/L	<2	<2	<2	1	<2	<2	<2	1	<2	<2	<2	1	<2	<2	<2	1
Volatile Organics																	
acetone	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
acrolein	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
acrylonitrile	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
benzene	µg/L	<0.1	<0.1	<1	15	<0.4	<0.1	<1	10	<0.4	<0.1	<0.4	7	<0.4	<0.1	<1	13
bromodichloromethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
bromoform	µg/L	<0.5	<0.5	<5	10	<0.75	<0.5	<1	2	<0.5	<0.5	<0.5	1	<0.5	<0.5	<5	5
bromomethane	µg/L	<0.1	<0.1	<1	10	<5.05	<0.1	<10	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
2–butanone (MEK)	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
carbon disulfide	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
carbon tetrachloride	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
chlorobenzene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
chloroethane	µg/L	<0.1	<0.1	<1	10	<5.05	<0.1	<10	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
2–chloroethyl vinyl ether	µg/L	<2.2	<0.4	<4	2	<2.7	<0.4	<5	2	<0.4	<0.4	<0.4	1	<2.2	<0.4	<4	2
chloroform	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	0.12	0.12	0.12	1	<0.1	<0.1	<1	5
chloromethane	µg/L	–	–	–	0	<10	<10	<10	1	–	–	–	0	–	–	–	0
dibromochloromethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
dibromomethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,2–dichlorobenzene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,3–dichlorobenzene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,4–dichlorobenzene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
cis–1,4–dichloro–2–butene	µg/L	<0.1	<0.1	<1	10	<1.05	<0.1	<2	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
trans–1,4–dichloro–2–butene	µg/L	–	–	–	0	<5	<5	<5	1	–	–	–	0	–	–	–	0
dichlorodifluoromethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1–dichloroethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,2–dichloroethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,1–dichloroethene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
trans–1,2–dichloroethene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5

Table F-14 Water Quality in the Lower Muskeg River (continued)

Parameter	Units	Winter (1974 to 2006)				Spring (1976 to 2006)				Summer (1972 to 2006)				Fall (1972 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
1,2–dichloropropane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
cis–1,3–dichloropropene	µg/L	<0.3	<0.3	<0.3	8	<1	<1	<1	1	–	–	–	0	<0.3	<0.3	<0.3	3
trans–1,3–dichloropropene	µg/L	<0.3	<0.3	<3	10	<0.65	<0.3	<1	2	<0.3	<0.3	<0.3	1	<0.3	<0.3	<3	5
ethanol	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
ethylbenzene	µg/L	<0.1	<0.1	0.19	15	<0.4	<0.1	<1	10	<0.4	<0.1	<0.4	7	<0.4	<0.1	<1	13
ethylene dibromide	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
ethyl methacrylate	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
2–hexanone	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
iodomethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
4–methyl–2–pentanone (MIBK)	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
methylene chloride	µg/L	<1	<2	0	2	<1.5	<1	<2	2	<2	<2	<2	1	<1	<2	0	2
styrene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
tetrachloroethylene	µg/L	<0.3	<0.3	<3	10	<0.65	<0.3	<1	2	<0.3	<0.3	<0.3	1	<0.3	<0.3	<3	5
1,1,2,2–tetrachloroethane	µg/L	<0.1	<0.1	<1	10	<2.55	<0.1	<5	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
toluene	µg/L	<0.1	<0.1	0.4	15	<0.4	<0.1	<1	10	<0.4	<0.1	<0.4	7	<0.4	<0.1	<1	13
1,1,1–trichloroethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,1,2–trichloroethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
1,2,3–trichloropropane	µg/L	<0.1	<0.1	<1	10	<1.05	<0.1	<2	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
trichloroethene	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
trichlorofluoromethane	µg/L	<0.1	<0.1	<1	10	<0.55	<0.1	<1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<1	5
vinyl acetate	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
vinyl chloride	µg/L	<0.5	<0.5	<5	10	<10.25	<0.5	<20	2	<0.5	<0.5	<0.5	1	<0.5	<0.5	<30	5
xylenes	µg/L	<0.8	<0.8	<0.8	3	<0.8	<0.5	<1	7	<0.8	<0.8	<0.8	4	<0.8	<0.5	0.8	6

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-15 Sediment Quality in the Upper Muskeg River and Its Head Tributaries

Parameter	Units	Summer (1997)			Fall (1998 to 2005)			
		Min	Max	n	Median	Min	Max	n
Particle Size								
partice size – % sand	%	–	–	0	50	12	89	10
partice size – % silt	%	–	–	0	27	5	46	10
partice size – % clay	%	–	–	0	18	5	56	10
moisture content	%	–	–	0	82	21	92	13
Carbon Content								
total inorganic carbon	% by wt	–	–	0	0.1	0.04	0.19	12
total organic carbon	% by wt	–	–	0	25.4	0.7	38.1	12
total carbon	% by wt	–	–	0	25.45	0.7	38.1	12
Toxicity								
chironomus tentans – 10d survival	% of control	–	–	0	85	70	100	2
chironomus tentans – 10d growth	% of control	–	–	0	111	100	122	2
hyalella azteca – 10d survival	% of control	–	–	0	42	13	71	2
hyalella azteca – 10d growth	% of control	–	–	0	118	99	137	2
lumbriculus variegatus – 10d survival	% of control	–	–	0	127.5	90	165	2
lumbriculus variegatus – 10d growth	% of control	–	–	0	100	100	100	1
Organics								
total recoverable hydrocarbons	mg/kg	–	–	0	2,200	<100	4,900	13
total volatile hydrocarbons (C5–C10)	mg/kg	–	–	0	<0.5	<0.5	2.8	13
total extractable hydrocarbons (C11–C30)	mg/kg	–	–	0	91	11	1,200	13
Total Metals								
aluminum	µg/g	–	–	0	2,770	1,380	15,600	12
antimony	µg/g	–	–	0	<0.02	<0.02	<0.02	1
arsenic	µg/g	–	–	0	1.5	0.5	4.3	13
barium	µg/g	21	59	2	105	22	196	13
beryllium	µg/g	<1	<1	2	<0.2	<0.2	0.5	13
boron	µg/g	–	–	0	14	2	28	12
cadmium	µg/g	<0.5	<0.5	2	0.1	<0.1	0.3	13
calcium	µg/g	–	–	0	17,950	1,200	28,600	12
chromium	µg/g	8	11.8	2	5	2.4	98.1[(a)(b)]	13
cobalt	µg/g	1	2	2	1.8	1.2	5.1	13
copper	µg/g	4	5	2	6	2	15	13
iron	µg/g	–	–	0	13,250	3,400	34,800	12
lead	µg/g	<5	<5	2	2.3	1.6	5.7	13
magnesium	µg/g	–	–	0	2,375	600	3,580	12
manganese	µg/g	–	–	0	194	116	772	12
mercury	µg/g	–	–	0	<0.05	<0.05	0.13	13
molybdenum	µg/g	<1	<1	2	0.4	<0.1	5.5	13
nickel	µg/g	4	6	2	4.7	2.1	59.4	13
potassium	µg/g	–	–	0	365	230	1,920	12

Table F-15 Sediment Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Summer (1997)			Fall (1998 to 2005)			
		Min	Max	n	Median	Min	Max	n
selenium	µg/g	–	–	0	0.4	<0.2	0.8	13
silver	µg/g	<1	<1	2	<0.2	<0.1	<0.2	13
sodium	µg/g	–	–	0	194	<100	300	12
strontium	µg/g	2	19	2	43	6	109	13
thallium	µg/g	–	–	0	<0.05	<0.05	0.18	13
titanium	µg/g	–	–	0	26.5	16	181	12
uranium	µg/g	–	–	0	0.5	0.2	1.4	13
vanadium	µg/g	3	7	2	6.8	<0.1	38.7	13
zinc	µg/g	7	19	2	25	12	46	13
Target PAHs and Alkylated PAHs								
naphthalene	µg/g	<0.01	<0.01	2	0.005	0.001	0.012	14
C1 subst'd naphthalenes	µg/g	–	–	0	0.003	0.001	0.021[(a)]	14
C2 subst'd naphthalenes	µg/g	–	–	0	0.016	0.004	0.097	14
C3 subst'd naphthalenes	µg/g	–	–	0	0.012	0.004	0.037	14
C4 subst'd naphthalenes	µg/g	–	–	0	0.007	≤0.00154	0.018	14
acenaphthene	µg/g	<0.01	<0.01	2	<0.0004	<0.0001	0.0012	14
C1 subst'd acenaphthene	µg/g	–	–	0	<0.0002	<0.0001	0.003	13
acenaphthylene	µg/g	<0.01	<0.01	2	<0.0003	<0.0001	0.0004	14
anthracene	µg/g	<0.01	<0.01	2	0.0002	≤0.000071	0.0008	14
dibenzo(a,h)anthracene	µg/g	<0.01	<0.01	2	<0.00102	<0.00008	0.00187	13
benzo(a)anthracene	µg/g	<0.01	0.02	2	0.0009	≤0.000043	0.0124	14
C1 subst'd benzo(a)anthracene/ chrysene	µg/g	–	–	0	0.09	0.002	0.4	14
C2 subst'd benzo(a)anthracene/ chrysene	µg/g	–	–	0	0.01	<0.0001	0.054	14
Benzo(a)pyrene	µg/g	<0.01	<0.01	2	<0.0008	<0.0001	0.015	13
C1 subst'd benzo(b&k) fluoranthene/ benzo(a)pyrene	µg/g	–	–	0	0.009	<0.0002	0.025	13
C2 subst'd benzo(b&k) fluoranthene/ benzo(a)pyrene	µg/g	–	–	0	0.005	≤0.000276	0.014	13
benzofluoranthenes	µg/g	–	–	0	0.004	0.0002	0.013	14
benzo(g,h,i)perylene	µg/g	<0.01	<0.01	1	0.004	≤0.000126	0.109	14
biphenyl	µg/g	–	–	0	0.0028	0.0002	0.0068	13
C1 subst'd biphenyl	µg/g	–	–	0	0.00049	<0.00011	0.00194	13
C2 subst'd biphenyl	µg/g	–	–	0	0.0022	≤0.000596	0.0062	13
chrysene	µg/g	–	–	0	0.005	0.0002	0.018	13
dibenzothiophene	µg/g	–	–	0	0.0004	<0.00004	0.0026	14
C1 subst'd dibenzothiophene	µg/g	–	–	0	0.0016	<0.0001	0.0528	14
C2 subst'd dibenzothiophene	µg/g	–	–	0	0.008	<0.0001	0.0976	14
C3 subst'd dibenzothiophene	µg/g	–	–	0	0.0083	≤0.000259	0.082	14
C4 subst'd dibenzothiophene	µg/g	–	–	0	0.013	≤0.000727	0.108	13

Table F-15 Sediment Quality in the Upper Muskeg River and Its Head Tributaries (continued)

Parameter	Units	Summer (1997)			Fall (1998 to 2005)			
		Min	Max	n	Median	Min	Max	n
fluoranthene	µg/g	<0.01	<0.01	2	0.0027	0.0002	0.0059	14
C1 subst'd fluoranthene/pyrene	µg/g	–	–	0	0.012	0.0003	0.164	14
C2 subst'd fluoranthene/pyrene	µg/g	–	–	0	0.008	0.0004	0.042	13
C3 subst'd fluoranthene/pyrene	µg/g	–	–	0	0.006	<0.0001	0.018	13
fluorene	µg/g	<0.01	<0.01	2	0.0025	<0.0001	0.0093	14
C1 subst'd fluorene	µg/g	–	–	0	0.0041	≤0.000495	0.0294	14
C2 subst'd fluorene	µg/g	–	–	0	0.0075	≤0.000969	0.0696	14
C3 subst'd fluorene	µg/g	–	–	0	0.0108	≤0.000568	0.0439	13
indeno(c,d–123)pyrene	µg/g	<0.01	<0.01	2	0.0016	≤0.0002	0.0045	13
phenanthrene	µg/g	<0.01	<0.01	2	0.005	0.0003	0.011	14
C1 subst'd phenanthrene/anthracene	µg/g	–	–	0	0.007	0.001	0.042	14
C2 subst'd phenanthrene/anthracene	µg/g	–	–	0	0.012	0.001	0.06	14
C3 subst'd phenanthrene/anthracene	µg/g	–	–	0	0.006	0.001	0.103	13
C4 subst'd phenanthrene/anthracene	µg/g	–	–	0	0.3	0.01	4.73	13
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	–	–	0	0.25	0.008	4.73	14
pyrene	µg/g	<0.01	<0.01	2	0.004	0.0001	0.012	14

(a) Interim sediment quality guideline exceeded.

(b) Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-16 Sediment Quality in the Middle Muskeg River

Parameter	Units	Fall (1997 to 2006)			
		Median	Min	Max	n
Particle Size					
partice size – % sand	%	75	31	94	11
partice size – % silt	%	15	7	30	11
partice size – % clay	%	7	<1	40	11
moisture content	%	62	38	92	10
Carbon Content					
total inorganic carbon	%bywt	0.16	0.05	0.2	8
total organic carbon	%bywt	11.8	1.7	26	9
total carbon	%bywt	12.85	1.7	26.2	8
Toxicity					
chironomus tentans – 10d survival	#alive	7	3	9	5
chironomus tentans – 10d survival	%ofcontrol	37	37	37	1
chironomus tentans – 10d growth	mg/organism	2	1.43	2.2	4
chironomus tentans – 10d growth	%ofcontrol	56	56	56	1
hyalella azteca – 10d survival	#alive	8	8	8	1
hyalella azteca – 10d survival	%ofcontrol	85	85	85	1
hyalella azteca – 10d growth	%ofcontrol	86	86	86	1
lumbriculus variegatus – 10d survival	#alive	14	14	14	1
lumbriculus variegatus – 10d survival	%ofcontrol	75	75	75	1
lumbriculus variegatus – 10d growth	%ofcontrol	85	85	85	1
Organics					
total recoverable hydrocarbons	mg/kg	3,690	1,000	9,800	7
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	<0.5	6
total extractable hydrocarbons (C11–C30)	mg/kg	155	130	470	6
Total Metals					
aluminum	µg/g	2,890	770	9,040	7
antimony	µg/g	<0.02	<0.02	<0.1	3
arsenic	µg/g	1.5	0.8	2.8	11
barium	µg/g	118	19	302	11
beryllium	µg/g	0.2	<0.2	0.4	11
boron	µg/g	10	<2	21	6
cadmium	µg/g	<0.2	<0.1	0.2	11
calcium	µg/g	5,650	1,500	106,000	7
chromium	µg/g	7.6	1.6	12.3	11
cobalt	µg/g	2.6	0.9	4	11
copper	µg/g	8	1	10	11
iron	µg/g	12,400	4,700	51,900	7
lead	µg/g	3	≤0.8	8.9	11
magnesium	µg/g	1,420	720	3,290	7
manganese	µg/g	288	102	620	7
mercury	µg/g	<0.05	<0.04	0.04	11
molybdenum	µg/g	0.3	<0.1	0.4	11
nickel	µg/g	6.2	1.3	10.3	11
potassium	µg/g	350	200	1,260	7
selenium	µg/g	0.5	<0.2	0.9	11
silver	µg/g	<0.2	<0.1	<1	11
sodium	µg/g	112	≤83	200	7

Table F-16 Sediment Quality in the Middle Muskeg River (continued)

Parameter	Units	Fall (1997 to 2006)			
		Median	Min	Max	n
strontium	µg/g	33	6	267	11
sulphur	µg/g	2,780	2,780	2,780	1
thallium	µg/g	0.05	<0.05	0.08	10
titanium	µg/g	30	19	112	7
uranium	µg/g	0.3	0.1	0.4	10
vanadium	µg/g	14.4	2.5	19.5	11
zinc	µg/g	38	6	222[(a)]	11
Target PAHs and Alkylated PAHs					
naphthalene	µg/g	0.004	0.002	0.014	10
C1 subst'd naphthalenes	µg/g	0.003	≤0.00214	0.015	10
C2 subst'd naphthalenes	µg/g	0.017	0.007	0.03	10
C3 subst'd naphthalenes	µg/g	0.014	0.006	0.052	10
C4 subst'd naphthalenes	µg/g	0.017	<0.003	0.16	10
acenaphthene	µg/g	<0.0012	≤0.000347	0.002	10
C1 subst'd acenaphthene	µg/g	<0.0004	<0.0001	0.0015	8
acenaphthylene	µg/g	<0.0006	<0.0001	0.004	10
anthracene	µg/g	<0.0009	≤0.000226	0.0009	10
dibenzo(a,h)anthracene	µg/g	<0.00262	≤0.00105	0.00223	10
benzo(a)anthracene	µg/g	0.001	≤0.000841	0.057[(a)]	10
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.14	0.03	0.63	10
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.081	0.024	0.358	10
benzo(a)pyrene	µg/g	0.0017	<0.0013	0.016	10
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.025	<0.006	0.203	10
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.014	≤0.00558	0.211	10
benzofluoranthenes	µg/g	0.01	0.003	0.034	8
benzo(g,h,i)perylene	µg/g	0.0139	0.0027	0.0595	10
biphenyl	µg/g	0.0013	≤0.000823	0.0049	10
C1 subst'd biphenyl	µg/g	0.00039	≤0.00027	0.00106	8
C2 subst'd biphenyl	µg/g	0.0017	<0.0007	0.0034	8
chrysene	µg/g	0.016	0.007	0.099[(a)]	9
dibenzothiophene	µg/g	0.0009	≤0.000409	0.005	10
C1 subst'd dibenzothiophene	µg/g	0.005	≤0.0013	0.033	10
C2 subst'd dibenzothiophene	µg/g	0.0586	0.0103	0.529	10
C3 subst'd dibenzothiophene	µg/g	0.1242	0.0279	1.21	10
C4 subst'd dibenzothiophene	µg/g	0.068	<0.005	1.03	10
fluoranthene	µg/g	0.0018	≤0.000794	0.006	10
C1 subst'd fluoranthene/pyrene	µg/g	0.036	0.013	0.166	10
C2 subst'd fluoranthene/pyrene	µg/g	0.049	0.025	0.417	9
C3 subst'd fluoranthene/pyrene	µg/g	0.026	0.015	0.34	9
fluorene	µg/g	0.0011	<0.001	0.0065	10
C1 subst'd fluorene	µg/g	0.007	<0.0018	0.0334	10
C2 subst'd fluorene	µg/g	0.0173	<0.0019	0.198	10
C3 subst'd fluorene	µg/g	0.024	<0.004	0.268	9
indeno(c,d–123)pyrene	µg/g	0.0053	0.0021	0.017	10
phenanthrene	µg/g	0.006	0.003	0.014	10

Table F-16 Sediment Quality in the Middle Muskeg River (continued)

Parameter	Units	Fall (1997 to 2006)			
		Median	Min	Max	n
C1 subst'd phenanthrene/anthracene	µg/g	0.02	0.007	0.09	10
C2 subst'd phenanthrene/anthracene	µg/g	0.041	0.013	0.328	10
C3 subst'd phenanthrene/anthracene	µg/g	0.06	0.017	0.6	10
C4 subst'd phenanthrene/anthracene	µg/g	0.33	0.06	1.3	10
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.156	0.017	0.498	7
pyrene	µg/g	0.009	0.004	0.031	10

(a) Interim sediment quality guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-17 Sediment Quality in the Lower Muskeg River

Parameter	Units	Summer (1975)	Fall (1997 to 2005)			
		n = 1	Median	Min	Max	n
Particle Size						
partice size – % sand	%	–	79	56	90	13
partice size – % silt	%	–	13	4	28	13
partice size – % clay	%	–	6	2	16	13
moisture content	%	–	27	16	92	12
Carbon Content						
total inorganic carbon	% by wt	–	1.12	0.07	2.65	14
total organic carbon	% by wt	–	1.9	0.5	29.6	15
total carbon	% by wt	–	2.8	1.4	29.8	14
Toxicity						
chironomus tentans – 10d survival	# alive	–	7	5	8.8	8
chironomus tentans – 10d survival	% of control	–	85.5	68	147	4
chironomus tentans – 10d growth	mg/organism	–	1.78	0.68	2.8	6
chironomus tentans – 10d growth	% of control	–	104	86	135	4
hyalella azteca – 10d survival	# alive	–	8	8	8.4	4
hyalella azteca – 10d survival	% of control	–	89	84	93	4
hyalella azteca – 10d growth	mg/organism	–	0.095	0.09	0.1	2
hyalella azteca – 10d growth	% of control	–	99	86	101	4
lumbriculus variegatus – 10d survival	# alive	–	13.2	9	21	4
lumbriculus variegatus – 10d survival	% of control	–	94.5	90	115	4
lumbriculus variegatus – 10d growth	mg/organism	–	8.695	1.49	15.9	2
lumbriculus variegatus – 10d growth	% of control	–	87.5	61	129	4
Organics						
total recoverable hydrocarbons	mg/kg	–	2,100	800	11,300	13
total volatile hydrocarbons (C5–C10)	mg/kg	–	<0.5	<0.5	0.5	10
total extractable hydrocarbons (C11–C30)	mg/kg	–	280	<5	1,600	10
Total Metals						
aluminum	µg/g	–	4,385	2,000	9,440	10
antimony	µg/g	–	<0.02	<0.02	<0.1	6
arsenic	µg/g	3.5	1.9	0.6	5	15
barium	µg/g	–	78	27	1,260	15
beryllium	µg/g	–	<0.3	<0.2	0.4	15
boron	µg/g	–	13	<2	26	8
cadmium	µg/g	0.1	<0.1	<0.1	0.2	15
calcium	µg/g	–	40,100	2,020	64,800	10
chromium	µg/g	**59**[(a)]	6.9	2.9	36.8	15

Table F-17 Sediment Quality in the Lower Muskeg River (continued)

Parameter	Units	Summer (1975)	Fall (1997 to 2005)			
		n = 1	Median	Min	Max	n
cobalt	µg/g	–	3	1.5	7.1	15
copper	µg/g	26	6	2	11	15
iron	µg/g	22,400	15,750	5,370	21,000	10
lead	µg/g	9.9	3.4	≤1.8	8.9	15
magnesium	µg/g	–	3,895	670	6,150	10
manganese	µg/g	327	425	225	756	10
mercury	µg/g	0.04	<0.05	≤0.03	0.05	15
molybdenum	µg/g	–	0.2	<0.1	1.3	15
nickel	µg/g	20.5	6	3	26.9	15
phosphorus, total	µg/g	–	512	512	512	1
potassium	µg/g	–	940	270	1,870	10
selenium	µg/g	0.65	<0.2	<0.1	0.5	15
silver	µg/g	–	<0.2	<0.1	<1	15
sodium	µg/g	–	125	≤56	200	10
strontium	µg/g	–	62	8	99	15
sulphur	µg/g	–	2,010	<100	2,530	3
thallium	µg/g	–	0.06	<0.05	0.16	12
titanium	µg/g	–	30.5	2.6	88.9	10
uranium	µg/g	–	0.3	≤0.19	0.8	13
vanadium	µg/g	86	9	4.8	22	15
zinc	µg/g	57	25	14	50	15
Target PAHs and Alkylated PAHs						
Naphthalene	µg/g	–	0.008	≤0.00085	0.02	18
C1 subst'd naphthalenes	µg/g	–	0.001	<0.0002	0.02	17
C2 subst'd naphthalenes	µg/g	–	0.011	≤0.0017	0.036	17
C3 subst'd naphthalenes	µg/g	–	0.016	≤0.002	0.062	17
C4 subst'd naphthalenes	µg/g	–	0.029	≤0.002	1.2	17
acenaphthene	µg/g	–	<0.002	<0.0001	0.0048	18
C1 subst'd acenaphthene	µg/g	–	<0.0005	<0.0001	0.0031	17
acenaphthylene	µg/g	–	<0.0006	<0.0001	0.0004	18
anthracene	µg/g	–	<0.0012	≤0.000182	0.0011	18
dibenzo(a,h)anthracene	µg/g	–	<0.00346	<0.001	0.0107[(a)]	18
benzo(a)anthracene	µg/g	–	0.0028	<0.0006	0.0417[(a)]	18
C1 subst'd benzo(a)anthracene/ chrysene	µg/g	–	0.15	<0.002	3.6	17
C2 subst'd benzo(a)anthracene/ chrysene	µg/g	–	0.062	<0.002	1.6	17
benzo(a)pyrene	µg/g	–	0.003	<0.001	0.0173	18
C1 subst'd benzo(b&k) fluoranthene/ benzo(a)pyrene	µg/g	–	0.034	<0.005	0.296	17
C2 subst'd benzo(b&k) fluoranthene/ benzo(a)pyrene	µg/g	–	0.03	<0.005	0.3	16
benzofluoranthenes	µg/g	–	0.01	≤0.0031	0.062	17
benzo(g,h,i)perylene	µg/g	–	0.0131	0.0026	0.036	17
biphenyl	µg/g	–	0.0005	≤0.00019	0.0046	17

Table F-17 Sediment Quality in the Lower Muskeg River (continued)

Parameter	Units	Summer (1975)	Fall (1997 to 2005)			
		n = 1	Median	Min	Max	n
C1 subst'd biphenyl	µg/g	–	<0.00135	<0.00006	0.00375	17
C2 subst'd biphenyl	µg/g	–	0.001	<0.0001	0.0067	17
Chrysene	µg/g	–	0.017	0.005	**0.24**[(a)]	17
dibenzothiophene	µg/g	–	0.0005	≤0.00026	0.003	17
C1 subst'd dibenzothiophene	µg/g	–	0.0136	≤0.0017	0.2	17
C2 subst'd dibenzothiophene	µg/g	–	0.0688	≤0.004	2.8	17
C3 subst'd dibenzothiophene	µg/g	–	0.0873	<0.0036	7.6	17
C4 subst'd dibenzothiophene	µg/g	–	0.128	<0.002	2.44	14
fluoranthene	µg/g	–	0.0013	<0.0004	0.0065	18
C1 subst'd fluoranthene/pyrene	µg/g	–	0.026	0.006	0.51	17
C2 subst'd fluoranthene/pyrene	µg/g	–	0.064	0.02	1.4	13
C3 subst'd fluoranthene/pyrene	µg/g	–	0.065	0.021	1.9	13
fluorene	µg/g	–	0.0005	<0.0003	0.0027	18
C1 subst'd fluorene	µg/g	–	0.002	≤0.00037	0.0136	17
C2 subst'd fluorene	µg/g	–	0.0169	<0.002	0.347	17
C3 subst'd fluorene	µg/g	–	0.042	≤0.0017	2.3	13
indeno(c,d–123)pyrene	µg/g	–	0.0066	<0.0017	0.023	18
phenanthrene	µg/g	–	0.009	0.001	**0.058**[(a)]	18
C1 subst'd phenanthrene/anthracene	µg/g	–	0.033	0.006	0.464	17
C2 subst'd phenanthrene/anthracene	µg/g	–	0.067	0.005	2	17
C3 subst'd phenanthrene/anthracene	µg/g	–	0.077	0.007	2.9	17
C4 subst'd phenanthrene/anthracene	µg/g	–	0.15	0.01	3.67	17
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	–	0.024	<0.001	0.285	14
pyrene	µg/g	–	0.006	<0.001	0.11[(a)]	18

[(a)] Interim sediment quality guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-18 Water Quality in Jackpine Creek and Its Tributaries

Parameter	Units	Winter (1974 to 2004)				Spring (1977 to 2004)				Summer (1976 to 2004)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	–0.2	11	46	7	0	17.2	29	15.5	9	21.1	45	6.5	0	12.3	34
dissolved oxygen	mg/L	7.3	2.3[a](b)	12.2	29	10.9	5.3[b]	14.4	26	7.6	3.6[a](b)	12	47	9.6	4.2[a](b)	14.4	33
Conventional Parameters																	
colour	TCU	70	22	140	25	70	30	125	19	100	45	140	27	100	35	200	31
specific conductance	µS/cm	495	194	714	39	137	82	550	25	222	110	371	42	197	120	551	41
dissolved organic carbon	mg/L	21	12	89	45	14	7	30	26	24	12	52	37	22	5	36	31
hardness	mg/L	231	56	350	32	58	37	282	29	107	21	141	42	100	68	362	40
pH		7.7	7	8.6[a](b)	43	7.6	7.2	8.3	32	7.8	6.5	8.4	47	7.6	7.2	8.3	47
total alkalinity	mg/L	264	76	404	44	70	42	324	33	125	67	198	50	112	74	422	50
total dissolved solids	mg/L	310	79	551	43	100	53	363	33	148	77	240	50	146	92	467	50
total organic carbon	mg/L	25	12	96	39	18	7	31	30	26	12	52	47	27	18	104	44
total suspended solids	mg/L	5	<0.4	459	56	5	<0.4	36	36	2	<0.4	103	54	7	<0.4	52	51
Major Ions																	
bicarbonate	mg/L	354	92	493	18	84	70	139	17	162	122	188	18	178	102	514	26
calcium	mg/L	64	14	101	42	16	10	78	33	30	18	52	49	26	18	119	48
carbonate	mg/L	<5	<0.5	<5	10	<5	<0.5	<5	9	<0.5	<0.5	0	13	<5	<0.5	0	16
chloride	mg/L	7	1	24	45	2	0.5	17	33	2	≤0.6	14	50	2	0.3	16	50
magnesium	mg/L	17	5	24	42	4	3	21	33	8	5	13	50	8	5	16	50
potassium	mg/L	1	0.2	2	43	1	1	3	33	0.4	<0.01	1	49	1	≤0.2	4	50
sodium	mg/L	22	7	37	44	9	4	30	33	12	4	22	49	13	6	36	50
sulphate	mg/L	6	≤1	14	45	4	≤1.1	13	33	4	≤0.1	10	50	3	≤0.1	10	50
sulphide	mg/L	<0.01	<0.001	0.019[b]	22	0.005	≤0.003	0.021[b]	10	<0.01	<0.003	0.16[b]	15	0.002	≤0.001	0.15[b]	28
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.2	<0.003	0.8	7	<0.01	<0.003	0.1	15	0.003	<0.003	0.05	16	<0.01	<0.002	0.01	23
nitrogen – ammonia	mg/L	0.12	≤0.03	1.6	9	0.03	≤0.01	0.7	15	0.055	<0.01	0.24	16	0.01	≤0.01	0.1	21
nitrogen – kjeldahl	mg/L	0.8	0.3	4.2	38	0.8	<0.05	2.6	32	1	<0.2	2.1	49	0.8	<0.1	3.4	44
nitrogen – total nitrogen	mg/L	0.9	0.3	4.2[b]	38	0.8	<0.05	2.6[b]	32	1	<0.2	2.1[b]	49	0.8	<0.1	3.4[b]	44
phosphorus, total	mg/L	0.051[b]	0.006	0.5[b]	44	0.03	≤0.01	0.08[b]	36	0.03	<0.005	0.38[b]	50	0.03	<0.01	0.11[b]	51
phosphorus, dissolved	mg/L	0.006	≤0.005	0.071	8	0.011	≤0.006	0.016	9	0.021	0.015	0.03	7	0.014	0.006	0.026	13
chlorophyll *a*	µg/L	<1	<1	3	13	1.225	≤0.001	5	8	0.501	≤0.002	7	6	<1	≤0.001	24	24
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	≤0.6	4	17	1	≤0.9	5	12	0.5	<0.2	3	17	1	≤0.6	3	18
General Organics																	
naphthenic acids	mg/L	1	<1	1	3	<1	<1	1	8	<2	<1	3	6	<1	<1	1	12
total phenolics	mg/L	0.004	<0.001	0.126[b]	26	0.003	<0.001	0.018[b]	25	0.002	<0.001	0.01[b]	28	0.004	<0.001	0.032[b]	36
total recoverable hydrocarbons	mg/L	0.6	<0.1	3.9	27	0.1	<0.1	3.3	26	0.1	<0.1	3.6	30	0.3	<0.1	2.9	40
Toxicity																	
Microtox® IC50 @ 15 Min	%	>99	>99	>99	1	>91	>91	>100	4	>100	>100	>100	1	>91	>91	>100	6
Microtox® IC25 @ 15 Min	%	–	–	–	0	>100	>100	>100	1	>100	>100	>100	1	>91	>91	>100	6
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-18 Water Quality in Jackpine Creek and Its Tributaries (continued)

Parameter	Units	Winter (1974 to 2004)				Spring (1977 to 2004)				Summer (1976 to 2004)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d reproduction test – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d reproduction test – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	71	71	71	1
ceriodaphnia 7d reproduction test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d reproduction test – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d growth – IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d mortality Test – LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test – LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test – LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
Fathead minnow 7d mortality test – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
Total Metals																	
aluminum	mg/L	0.03	<0.01	0.197[b]	9	0.0673	0.02	0.152[b]	10	0.038	<0.01	0.3[b]	15	0.0524	<0.01	0.991[a][b]	18
antimony	mg/L	0.00002	≤0.000015	0.00002	7	0.00001	≤0.0000129	0.001	9	0.00004	≤0.000029	0.0005	8	0.00002	≤0.0000165	0.0011	15
arsenic	mg/L	0.0004	≤0.00024	0.0004	9	0.0003	≤0.000261	0.0008	10	0.0006	≤0.0003	0.015[b]	21	0.0004	≤0.0002	0.02[b]	24
barium	mg/L	0.105	0.081	0.195	7	0.016	0.01	0.04	9	0.035	0.02	0.074	8	0.026	0.013	0.056	15
beryllium	mg/L	<0.00004	<0.00004	0.0001	7	<0.001	≤0.00000388	0.003	9	<0.00004	≤0.000004	0.00001	8	<0.0002	≤0.00000354	0.001	15
boron	mg/L	0.09	0.05	0.11	9	0.05	0.04	0.07	10	0.05	0.02	0.1	15	0.04	0.02	0.07	18
cadmium	mg/L	<0.0002	<0.00002	0.0002	10	<0.0002	<0.00002	0.00003	10	<0.001	<0.000002	0.000004	15	<0.0002	<0.000002	0.004[a][b]	18
chromium	mg/L	0.0002	≤0.00015	0.002[b]	10	<0.0015	≤0.00015	0.0025[b]	16	<0.0028	≤0.00025	0.006[b]	18	0.0003	≤0.000188	0.04[a][b]	24
chromium – hexavalent	mg/L	<0.003	<0.002	0.008[b]	25	<0.003	<0.003	0.006[b]	15	<0.003	<0.003	0.19[a][b]	23	<0.003	<0.003	0.008[b]	22
cobalt	mg/L	0.0002	0.0002	0.0007	7	<0.0002	≤0.000092	0.0002	9	<0.0004	≤0.000149	0.0002	12	0.0001	≤0.0001	0.009	15
copper	mg/L	0.0003	≤0.00023	0.001	9	0.0007	<0.0001	0.003[b]	10	0.0003	≤0.00026	0.01[b]	14	0.0001	<0.0001	0.0053[b]	18
iron	mg/L	1.84[b]	0.26	3.73[b]	10	0.4[b]	0.3	0.77[b]	10	0.87[b]	0.48[b]	1.3[b]	15	0.72[b]	0.32[b]	2.83[b]	19
lead	mg/L	0.0003	0.00004	0.006	10	0.0002	≤0.000058	0.004[b]	10	0.00004	≤0.0000391	0.002	15	0.00005	≤0.0000318	0.0036[b]	18
lithium	mg/L	0.02	0.019	0.022	7	0.007	0.004	0.011	9	0.01	0.008	0.015	8	0.009	0.008	0.079	15
manganese	mg/L	0.077	<0.004	0.516	10	0.021	0.012	0.034	10	0.043	0.02	0.14	15	0.025	0.016	0.077	18
mercury	mg/L	<0.0001	<0.0000006	0.0007[a][b]	35	<0.0001	<0.0000006	0.00028[a][b]	31	<0.0001	<0.0000006	0.0002[a][b]	48	<0.0001	<0.0000006	0.0045[a][b]	39
methyl mercury	mg/L	0.0000001	0.0000001	0.0000002	2	0.00000005	0.00000004	0.0000001	2	0.0000001	0.0000001	0.0000001	2	–	–	–	0
molybdenum	mg/L	0.0001	0.00004	0.0002	7	0.0001	0.0001	0.006	9	0.0002	≤0.000128	0.0002	8	0.0001	0.0001	0.003	15
nickel	mg/L	<0.0002	<0.0001	0.0074	9	0.0003	≤0.00025	0.011	10	0.0004	≤0.00034	0.0035	15	0.0003	<0.0001	0.0054	18
selenium	mg/L	<0.0004	≤0.0003	0.0004	9	<0.0004	≤0.000106	0.0002	10	0.00016	≤0.00013	0.012[b]	15	<0.0004	<0.0001	0.0002	18
silicon	mg/L	7.3	6.6	8	2	1	1	1.2	4	3	3	3	1	2.9	2.9	2.9	1
silver	mg/L	<0.000005	<0.000005	<0.001	7	<0.000007	<0.0000005	0.000007	9	<0.000008	<0.0000005	0.00001	12	<0.000006	<0.0000005	0.005[a][b]	15
strontium	mg/L	0.27	0.24	0.32	7	0.06	0.05	0.1	9	0.12	0.09	0.14	8	0.09	0.08	0.19	15
sulphur	mg/L	3.1	3.1	3.1	1	1.1	0.8	1.3	2	0.9	0.9	0.9	1	0.5	0.5	0.7	4
thallium	mg/L	0.000002	<0.000003	0.00031	6	<0.000003	<0.0000003	0.00001	5	<0.000002	≤0.000000628	0.000001	6	<0.00001	≤0.00000152	0.00016	10
titanium	mg/L	0.0022	≤0.0005	0.0054	10	0.0015	≤0.0008	0.007	11	0.0014	≤0.00113	0.003	11	0.0025	≤0.00126	0.0109	17
uranium	mg/L	0.0001	0.0001	0.0002	7	<0.0001	≤0.0000138	0.00004	9	0.0001	≤0.000038	0.0001	7	0.00002	≤0.00001	0.0001	15

Table F-18 Water Quality in Jackpine Creek and Its Tributaries (continued)

Parameter	Units	Winter (1974 to 2004)				Spring (1977 to 2004)				Summer (1976 to 2004)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
vanadium	mg/L	<0.001	≤0.00026	0.006	38	<0.001	<0.0002	0.011	32	<0.001	<0.0002	0.01	43	<0.001	<0.0002	0.002	42
zinc	mg/L	0.003	0.001	0.045[(b)]	10	0.007	0.001	0.025	10	0.009	≤0.0009	0.433[(a)(b)]	15	0.005	≤0.00046	0.186[(a)(b)]	18
Dissolved Metals																	
aluminum	mg/L	0.0026	0.0015	0.1	3	0.0069	0.0043	0.07	5	0.0051	0.0039	0.01	5	0.0087	≤0.00325	0.17[(b)]	13
antimony	mg/L	0.00001	≤0.00001	0.00002	3	0.00001	≤0.0000129	0.00004	5	0.00002	≤0.00002	0.00002	5	0.00002	≤0.000009	0.0008	13
arsenic	mg/L	0.0003	<0.0002	0.02[(b)]	30	0.0003	<0.0002	0.0136[(b)]	27	0.0005	<0.0002	0.038[(b)]	34	0.0002	<0.0002	0.009[(b)]	36
barium	mg/L	0.109	0.097	0.172	3	0.014	0.01	0.036	5	0.045	0.027	0.071	5	0.023	0.012	3.31	13
beryllium	mg/L	<0.00004	<0.00004	<0.0005	3	<0.00004	<0.000003	<0.0005	5	0.000004	≤0.000004	0.00001	5	<0.0001	<0.000003	0.0001	13
boron	mg/L	0.12	0.01	0.32	29	0.1	0.02	0.33	26	0.1	0.01	0.19	40	0.06	0.01	1.31	41
cadmium	mg/L	<0.00001	<0.00001	<0.0001	3	0.00001	<0.00001	0.00002	5	<0.000003	<0.000002	0.000003	5	<0.0001	<0.000002	0.0001	15
chromium	mg/L	0.0002	0.0001	0.0009	3	0.0001	≤0.0000926	0.0024[(b)]	5	0.0002	≤0.00019	0.0002	5	0.0002	≤0.0001	0.0009	13
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0001	0.0001	0.0002	3	0.0001	≤0.000053	0.0001	5	0.0001	0.0001	0.0001	5	0.0001	≤0.00007	0.0003	13
copper	mg/L	0.0002	0.0002	0.0013	3	0.0005	<0.0001	0.0014	5	0.0003	0.0002	0.0008	5	0.0002	<0.0001	0.0056[(b)]	13
iron	mg/L	0.11	0.03	0.13	6	0.17	0.16	0.42[(b)]	6	0.55[(b)]	0.32[(b)]	0.95[(b)]	6	0.33[(b)]	0.17	0.7[(b)]	14
lead	mg/L	<0.00001	<0.00001	0.0004	3	0.00005	0.00002	0.0015[(b)]	5	0.00002	0.00001	0.0002	5	0.00003	≤0.00001	0.0018	13
lithium	mg/L	0.021	0.02	0.022	3	0.006	0.004	0.011	5	0.011	0.008	0.013	5	0.008	0.007	0.023	13
manganese	mg/L	0.092	0.022	0.464	6	0.008	0.004	0.02	6	0.009	0.005	0.027	6	0.021	0.003	0.049	14
mercury	mg/L	<0.0001	<0.0001	<0.0001	1	<0.000055	<0.00001	<0.0001	2	0.000045[(a)(b)]	<0.00001	0.0001[(a)(b)]	2	<0.00007	<0.00001	<0.0002	10
molybdenum	mg/L	0.0001	≤0.000086	0.0001	3	0.0001	<0.0001	0.0001	5	0.0001	0.0001	0.0002	5	0.0001	≤0.0000687	0.0002	13
nickel	mg/L	<0.0001	<0.0001	0.0014	3	0.0003	0.0001	0.0063	5	0.0004	0.0002	0.0005	5	0.0005	<0.0001	0.0013	13
selenium	mg/L	<0.0005	<0.0001	0.0014[(b)]	29	<0.0005	<0.0001	<0.0005	21	<0.0002	<0.0001	0.0009	30	<0.0004	<0.0001	0.0002	28
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	<0.000005	<0.000005	0.0004[(b)]	3	<0.000005	<0.0000005	<0.0002	5	<0.0000005	<0.0000005	<0.0002	5	<0.000006	<0.0000005	0.000006	13
strontium	mg/L	0.28	0.27	0.32	3	0.06	0.05	0.09	5	0.12	0.12	0.14	5	0.09	0.08	0.18	13
sulphur	mg/L	–	–	–	0	0.568	0.568	0.568	1	0.866	0.866	0.866	1	0.452	0.357	0.705	3
thallium	mg/L	<0.000003	<0.000003	<0.00005	3	<0.000003	<0.0000003	0.00001	5	<0.0000005	<0.0000003	0.0000005	5	0.000001	≤0.000000929	0.00015	9
titanium	mg/L	0.0018	0.0016	0.0018	3	0.0004	<0.0003	0.0007	5	0.0008	0.0006	0.0013	5	0.0008	<0.0003	0.0021	13
uranium	mg/L	0.0001	0.0001	0.0001	3	0.00001	≤0.0000106	0.00004	5	0.0001	≤0.000053	0.0001	5	0.00001	≤0.00001	0.0001	13
vanadium	mg/L	0.0002	0.0001	0.0003	3	0.0002	0.0001	0.0002	5	0.0003	0.0002	0.0003	5	0.0002	<0.0001	0.0005	13
zinc	mg/L	0.002	0.001	0.014	3	0.004	0.001	0.182[(a)(b)]	5	0.003	<0.002	0.003	4	0.002	<0.0002	1.78[(a)(b)]	13
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.01	≤0.0013	0.001	5	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd naphthalenes	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	<0.01	<0.01	<0.01	4	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	<0.01	<0.01	<0.02	4	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
anthracene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	2	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.02	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.02	4	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3

Table F-18 Water Quality in Jackpine Creek and Its Tributaries (continued)

Parameter	Units	Winter (1974 to 2004)				Spring (1977 to 2004)				Summer (1976 to 2004)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d–123)pyrene	µg/L	<0.01	<0.01	<0.01	4	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
phenanthrene	µg/L	<0.01	<0.01	<0.01	4	<0.02	<0.01	<0.02	2	<0.02	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
pyrene	µg/L	<0.01	<0.01	<0.01	4	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
Target PANHs																	
quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
7–methyl quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C2 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C3 subst'd quinoline	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
acridine	µg/L	<0.01	<0.01	<0.01	3	<0.015	<0.01	<0.02	2	<0.015	<0.01	<0.02	2	<0.01	<0.01	<0.02	3
methyl acridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
phenanthridine	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
methyl carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
C2 subst'd carbazole	µg/L	–	–	–	0	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1
Phenolics																	
phenol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
o–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
m–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
p–cresol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
2,4–dimethylphenol	µg/L	–	–	–	0	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	1
2–nitrophenol	µg/L	–	–	–	0	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2	1
4–nitrophenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	<2	<2	<2	1
2,4–dinitrophenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	<2	<2	<2	1
4,6–dinitro–2–methyl phenol	µg/L	–	–	–	0	<2	<2	<2	1	<2	<2	<2	1	<2	<2	<2	1
Volatile Organics																	
acetone	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
acrolein	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
acrylonitrile	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
benzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
bromodichloromethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
bromoform	µg/L	<0.5	<0.5	<0.5	2	<1	<1	<1	1	–	–	–	0	–	–	–	0

Table F-18 Water Quality in Jackpine Creek and Its Tributaries (continued)

Parameter	Units	Winter (1974 to 2004)				Spring (1977 to 2004)				Summer (1976 to 2004)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
bromomethane	µg/L	<0.1	<0.1	<0.1	2	<10	<10	<10	1	–	–	–	0	–	–	–	0
2–butanone (MEK)	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
carbon disulfide	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
carbon tetrachloride	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
chlorobenzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
chloroethane	µg/L	<0.1	<0.1	<0.1	2	<10	<10	<10	1	–	–	–	0	–	–	–	0
2–chloroethyl vinyl ether	µg/L	–	–	–	0	<5	<5	<5	1	–	–	–	0	–	–	–	0
chloroform	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
chloromethane	µg/L	–	–	–	0	<10	<10	<10	1	–	–	–	0	–	–	–	0
dibromochloromethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
dibromomethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,2–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,3–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,4–dichlorobenzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
cis–1,4–dichloro–2–butene	µg/L	<0.1	<0.1	<0.1	2	<2	<2	<2	1	–	–	–	0	–	–	–	0
trans–1,4–dichloro–2–butene	µg/L	–	–	–	0	<5	<5	<5	1	–	–	–	0	–	–	–	0
dichlorodifluoromethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1–dichloroethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,2–dichloroethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1–dichloroethene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
trans–1,2–dichloroethene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,2–dichloropropane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
cis–1,3–dichloropropene	µg/L	<0.3	<0.3	<0.3	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
trans–1,3–dichloropropene	µg/L	<0.3	<0.3	<0.3	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
ethanol	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
ethylbenzene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
ethylene dibromide	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
ethyl methacrylate	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
2–hexanone	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
iodomethane	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
4–methyl–2–pentanone (MIBK)	µg/L	–	–	–	0	<200	<200	<200	1	–	–	–	0	–	–	–	0
methylene chloride	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0
styrene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
tetrachloroethylene	µg/L	<0.3	<0.3	<0.3	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1,2,2–tetrachloroethane	µg/L	<0.1	<0.1	<0.1	2	<5	<5	<5	1	–	–	–	0	–	–	–	0
toluene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1,1–trichloroethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,1,2–trichloroethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
1,2,3–trichloropropane	µg/L	<0.1	<0.1	<0.1	2	<2	<2	<2	1	–	–	–	0	–	–	–	0
trichloroethene	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
trichlorofluoromethane	µg/L	<0.1	<0.1	<0.1	2	<1	<1	<1	1	–	–	–	0	–	–	–	0
vinyl acetate	µg/L	–	–	–	0	<100	<100	<100	1	–	–	–	0	–	–	–	0
vinyl chloride	µg/L	<0.5	<0.5	<0.5	2	<20	<20	<20	1	–	–	–	0	–	–	–	0
xylenes	µg/L	–	–	–	0	<1	<1	<1	1	–	–	–	0	–	–	–	0

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-19 Sediment Quality in Jackpine Creek and Its Tributaries

Parameter	Units	Fall (1997 to 2006)			
		Median	Min	Max	n
Particle Size					
partice size – % sand	%	88	81	99	4
partice size – % silt	%	2	0.3	11	4
partice size – % clay	%	5	<1	19	4
moisture content	%	21	16	42	3
Carbon Content					
total inorganic carbon	% by wt	0.07	0.04	0.1	2
total organic carbon	% by wt	1	0.5	2	3
total carbon	% by wt	0.9	0.7	1.1	2
Toxicity					
chironomus tentans – 10d survival	# alive	9	7	10	3
chironomus tentans – 10d growth	mg/organism	2.4	2.3	3.2	3
Organics					
total recoverable hydrocarbons	mg/kg	4,130	2,600	5,660	2
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	<0.5	1
total extractable hydrocarbons (C11–C30)	mg/kg	180	180	180	1
Total Metals					
aluminum	µg/g	3,060	300	6,640	3
antimony	µg/g	<0.1	<0.1	<0.1	1
arsenic	µg/g	0.8	0.2	2.1	4
barium	µg/g	24	4	68	4
beryllium	µg/g	<0.3	<0.2	0.4	4
boron	µg/g	5	<2	12	2
cadmium	µg/g	<0.1	<0.1	<0.5	4
calcium	µg/g	2,380	200	4,000	3
chromium	µg/g	4.8	0.4	13.3	4
cobalt	µg/g	1.4	0.2	4.3	4
copper	µg/g	3	<0.5	7	4
iron	µg/g	5,430	500	11,400	3
lead	µg/g	0.4	<0.5	4.7	4
magnesium	µg/g	855	100	2,580	3
manganese	µg/g	124	5	128	3
mercury	µg/g	<0.05	≤0.03	0.03	4
molybdenum	µg/g	<0.1	<0.1	<1	4
nickel	µg/g	3.8	<0.5	8.4	4
potassium	µg/g	520	<100	1,100	3
selenium	µg/g	<0.2	≤0.1	0.6	4
silver	µg/g	<0.2	<0.2	<1	4
sodium	µg/g	<100	<100	100	3
strontium	µg/g	11	4	23	4
sulphur	µg/g	1,080	1,080	1,080	1
thallium	µg/g	0.06	<0.05	0.07	3
titanium	µg/g	18	11	66	3
uranium	µg/g	0.2	0.05	0.4	3
vanadium	µg/g	7.4	1	21.5	4
zinc	µg/g	16	<5	37	4
Target PAHs and Alkylated PAHs					
naphthalene	µg/g	<0.002	≤0.00157	0.002	4
C1 subst'd naphthalenes	µg/g	0.002	≤0.00159	0.003	4
C2 subst'd naphthalenes	µg/g	0.005	0.002	0.02	4

Table F-19 Sediment Quality in Jackpine Creek and Its Tributaries (continued)

Parameter	Units	Fall (1997 to 2006)			
		Median	Min	Max	n
C3 subst'd naphthalenes	µg/g	0.019	0.006	0.04	4
C4 subst'd naphthalenes	µg/g	0.044	0.001	0.09	4
acenaphthene	µg/g	<0.0006	<0.0003	<0.003	4
C1 subst'd acenaphthene	µg/g	<0.0104	<0.0007	<0.02	2
acenaphthylene	µg/g	<0.0006	<0.0002	<0.003	4
anthracene	µg/g	<0.0021	<0.0004	0.0013	4
dibenzo(a,h)anthracene	µg/g	<0.00198	<0.00074	0.00097	4
benzo(a)anthracene	µg/g	<0.0025	≤0.000361	0.034[(a)]	4
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.03	0.002	0.48	4
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.054	0.003	0.148	4
benzo(a)pyrene	µg/g	<0.005	≤0.000818	0.015	4
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.051	0.006	0.12	4
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.036	<0.001	0.1	4
benzofluoranthenes	µg/g	0.017	0.011	0.023	2
benzo(g,h,i)perylene	µg/g	0.0073	0.0029	0.0148	4
biphenyl	µg/g	0.0006	≤0.000418	0.0009	4
C1 subst'd biphenyl	µg/g	<0.01036	<0.00072	<0.02	2
C2 subst'd biphenyl	µg/g	<0.011	≤0.00208	0.0021	2
chrysene	µg/g	0.005	0.002	0.038	3
dibenzothiophene	µg/g	0.00001	<0.0002	0.005	4
C1 subst'd dibenzothiophene	µg/g	0.0141	≤0.00027	0.03	4
C2 subst'd dibenzothiophene	µg/g	0.0834	0.0024	0.295	4
C3 subst'd dibenzothiophene	µg/g	0.1452	0.0024	0.671	4
C4 subst'd dibenzothiophene	µg/g	0.163	0.002	0.64	4
fluoranthene	µg/g	0.0004	≤0.000271	0.004	4
C1 subst'd fluoranthene/pyrene	µg/g	0.02	0.003	0.061	4
C2 subst'd fluoranthene/pyrene	µg/g	0.032	0.008	0.179	3
C3 subst'd fluoranthene/pyrene	µg/g	0.03	0.004	0.17	3
fluorene	µg/g	<0.0007	<0.0002	0.0003	4
C1 subst'd fluorene	µg/g	0.0036	<0.0013	0.02	4
C2 subst'd fluorene	µg/g	0.0425	<0.0014	0.145	4
C3 subst'd fluorene	µg/g	0.0083	0.0007	0.311	3
indeno(c,d–123)pyrene	µg/g	<0.0027	≤0.00189	0.0025	4
phenanthrene	µg/g	0.001	≤0.00103	0.008	4
C1 subst'd phenanthrene/anthracene	µg/g	0.016	<0.001	0.08	4
C2 subst'd phenanthrene/anthracene	µg/g	0.042	0.002	0.19	4
C3 subst'd phenanthrene/anthracene	µg/g	0.101	0.002	0.21	4
C4 subst'd phenanthrene/anthracene	µg/g	0.08	0.04	0.71	4
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.061	0.061	0.061	1
pyrene	µg/g	0.004	0.001	0.01	4

[(a)] Interim sediment quality guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-20 Water Quality in Shelley Creek

Parameter	Units	Winter (1977 to 2001)				Spring (1977 to 2001)				Summer (1977 to 2001)				Fall (1998 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	0	1.8	5	12	8.7	14.7	4	16.2	12	21.5	3	6.4	4.2	8.3	3
dissolved oxygen	mg/L	5.2[a]	3.7[a](b)	6.7	2	7.7	6.6	12.2	4	6.1[a]	3.2[a](b)	6.3[a]	3	0.9[a](b)	0.7[a](b)	5.3[a]	3
Conventional Parameters																	
colour	TCU	60	60	60	2	100	90	125	3	105	105	120	4	100	65	165	4
specific conductance	µS/cm	510	431	600	5	168	110	170	5	223	155	269	6	526	357	890	4
dissolved organic carbon	mg/L	29	15	40	5	20	10	37	5	24	19	33	6	27	25	29	4
hardness	mg/L	243	204	280	5	64	40	68	5	99	77	125	6	218	166	265	4
pH		7.2	6.9	7.3	5	7.5	7.3	7.8	5	7.7	7.2	8.2	6	7.2	7.1	7.9	4
total alkalinity	mg/L	284	220	323	5	82	54	88	5	111	96	132	6	268	193	354	4
total dissolved solids	mg/L	290	280	376	5	112	68	190	5	165	110	216	6	410	290	500	4
total organic carbon	mg/L	34	21	41	5	25	10	37	5	29	20	33	6	32	31	33	2
total suspended solids	mg/L	14	2	114	5	3	≤2	7	5	2	<0.4	9	6	14	5	39	4
Major Ions																	
bicarbonate	mg/L	310	268	351	2	100	73	100	3	136	135	161	4	327	235	432	4
calcium	mg/L	64	54	76	5	17	10	18	5	26	20	34	6	59	46	70	3
carbonate	mg/L	<5	<5	<5	2	<5	<5	<5	3	<5	<5	<5	4	<5	<5	<5	2
chloride	mg/L	3	1	5	5	1	<0.5	1	5	1	≤0.9	2	6	16	1	80	4
magnesium	mg/L	20	16	23	5	5	4	6	5	8	6	10	6	13	12	16	4
potassium	mg/L	2	1	7	5	1	1	2	5	0.1	0.1	1	6	1	0.5	3	4
sodium	mg/L	27	10	30	5	11	8	13	5	13	12	15	6	39	19	96	4
sulphate	mg/L	7	6	10	5	4	1	7	5	4	3	9	6	3	<0.5	10	4
sulphide	mg/L	<0.002	<0.002	<0.003	2	0.028[a]	0.005	0.029[a]	3	0.01[a]	0.009[a]	0.014[a]	4	0.01[a]	0.002	0.023[a]	4
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.1	<0.05	0.3	2	<0.1	<0.05	<0.1	3	<0.05	<0.05	<0.1	4	<0.1	<0.1	<0.1	2
nitrogen – ammonia	mg/L	0.49	0.47	0.51	2	<0.05	<0.05	<0.05	3	<0.05	<0.05	0.14	4	<0.05	<0.05	<0.05	2
nitrogen – kjeldahl	mg/L	2.2	0.8	2.8	5	1.1	0.7	1.3	5	0.4	<0.2	1.8	6	1.2	1.1	1.3	3
nitrogen – total nitrogen	mg/L	2.2[a]	0.8	2.8[a]	5	1.1[a]	0.7	1.3[a]	5	0.4	<0.2	1.8[a]	6	1.2[a]	1.1[a]	1.3[a]	3
phosphorus, total	mg/L	0.2[a]	0.14[a]	0.56[a]	5	0.013	≤0.012	0.05	5	0.026	0.02	0.078[a]	6	0.051[a]	0.048	0.078[a]	3
phosphorus, dissolved	mg/L	0.007	<0.02	0.033	2	0.009	≤0.009	0.013	3	0.018	0.017	0.063	4	0.02	0.018	0.06	3
chlorophyll *a*	µg/L	–	–	–	0	0.89	≤0.89	2	3	3	3	3	1	4	4	4	1
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	5	5	5	2	<2	<2	<2	3	2	<2	4	4	2	2	10	4
General Organics																	
naphthenic acids	mg/L	<2	≤1	1	2	<1	<1	<1	3	<1	<1	<1	4	11.5	<1	24	2
total phenolics	mg/L	<0.001	<0.001	0.012[a]	4	0.004	0.001	0.004	5	<0.001	<0.001	0.009[a]	4	0.008[a]	0.004	0.013[a]	2
total recoverable hydrocarbons	mg/L	<0.5	<0.1	2.5	5	<0.5	<0.5	6.6	5	<0.5	<0.5	<0.5	4	<0.8	<0.5	<1	2
Toxicity																	
Microtox® IC50 @ 15 Min	%	>99	>99	>99	1	>91	>91	>91	1	–	–	–	0	–	–	–	0
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
algal growth inhibition test (72h) – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1

Table F-20 Water Quality in Shelley Creek (continued)

Parameter	Units	Winter (1977 to 2001)				Spring (1977 to 2001)				Summer (1977 to 2001)				Fall (1998 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d reproduction test – IC25	%	12	12	12	1	–	–	–	0	–	–	–	0	9	9	9	1
ceriodaphnia 7d reproduction test – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
ceriodaphnia 7d reproduction test – LOEC	%	12.5	12.5	12.5	1	–	–	–	0	–	–	–	0	12.5	12.5	12.5	1
ceriodaphnia 7d reproduction test – NOEC	%	6.25	6.25	6.25	1	–	–	–	0	–	–	–	0	6.25	6.25	6.25	1
fathead minnow 7d growth – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d growth – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d growth – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d growth – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d mortality test – LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d mortality test – LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d mortality test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	–	–	–	0
fathead minnow 7d mortality test – NOEC	%	100	100	100	1	–	–	–	0	–	–	–	0	–	–	–	0
Total Metals																	
aluminum	mg/L	1.024[(a)(b)]	0.368[(a)]	1.68[(a)(b)]	2	0.05	0.033	0.12[(a)]	3	0.0405	0.032	0.07	4	0.0572	0.0142	0.088	4
antimony	mg/L	<0.0027	<0.0004	<0.005	2	<0.005	<0.0004	<0.005	3	0.0005	≤0.0005	0.0005	4	0.00002	≤0.000021	0.00003	4
arsenic	mg/L	0.0011	0.001	0.0011	2	<0.001	≤0.0004	0.0004	3	<0.0004	<0.0004	<0.001	4	0.0008	0.0004	0.001	4
barium	mg/L	0.057	0.057	0.058	2	0.01	0.008	0.01	3	0.014	0.014	0.024	4	0.072	0.038	0.171	4
beryllium	mg/L	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	4	<0.0001	≤0.00000408	0.0001	4
boron	mg/L	0.02	0.02	0.03	2	0.06	0.06	0.1	3	0.06	0.05	0.06	4	0.15	0.05	0.22	4
cadmium	mg/L	0.0001	<0.0002	0.0005	2	<0.0002	<0.0002	<0.0002	3	<0.0002	<0.0002	0.0002	4	<0.00002	≤0.00000649	0.00001	4
chromium	mg/L	0.0015[(a)]	<0.0004	0.0033[(a)]	2	<0.0008	<0.0004	<0.0008	3	0.0006	<0.0004	0.0018[(a)]	4	0.0006	≤0.00039	0.0012[(a)]	4
chromium – hexavalent	mg/L	<0.003	<0.003	<0.003	3	<0.003	<0.003	<0.003	2	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0022	0.0018	0.0026	2	<0.0002	<0.0002	<0.0005	3	<0.0005	<0.0005	0.0007	4	0.0016	0.0011	0.0024	4
copper	mg/L	0.0036	0.0012	0.006[(a)]	2	<0.001	<0.001	0.0012	3	0.001	≤0.0009	0.002	4	0.0004	0.0003	0.002	4
iron	mg/L	9.21[(a)]	7.92[(a)]	10.5[(a)]	2	0.31[(a)]	0.09	0.34[(a)]	3	0.6[(a)]	0.39[(a)]	2.86[(a)]	4	5.5[(a)]	2.5[(a)]	14.81[(a)]	4
lead	mg/L	0.0009	0.0004	0.0014	2	<0.0001	<0.0001	0.0003	3	0.003[(a)]	<0.0001	0.0298[(a)]	4	0.0001	0.0001	0.0004	4
lithium	mg/L	0.007	0.007	0.007	2	0.007	0.006	0.007	3	0.012	0.008	0.015	4	0.026	0.01	0.043	4
manganese	mg/L	1.631	0.972	2.29	2	0.02	0.013	0.021	3	0.047	0.046	0.448	4	1.403	0.851	1.72	4
mercury	mg/L	<0.0001	≤0.0000047	0.0000047	5	<0.0001	<0.0000006	<0.0002	5	0.0000504[(a)(b)]	≤0.00000078	0.0002[(a)(b)]	6	<0.0000006	<0.0000006	<0.0000006	2
molybdenum	mg/L	0.0002	<0.0001	0.0004	2	0.0001	0.0001	0.0001	3	0.0002	<0.0001	0.0002	4	0.0001	0.0001	0.0002	4
nickel	mg/L	0.003	0.0019	0.0042	2	0.0009	0.0009	0.0011	3	0.0019	0.0011	0.0026	4	0.0002	≤0.0000403	0.0008	4
selenium	mg/L	<0.0006	<0.0004	<0.0008	2	<0.0008	<0.0004	<0.0008	3	<0.0004	<0.0004	<0.0008	4	0.0005	≤0.000201	0.001	4
silicon	mg/L	7.2	7.2	7.2	1	0.5	0.5	0.5	1	3.2	3.1	3.2	3	–	–	–	0
silver	mg/L	<0.000507	≤0.000014	0.000014	2	<0.000005	<0.000005	<0.001	3	<0.0001	<0.000005	<0.0001	4	0.000006	≤0.00000129	0.000013	4
strontium	mg/L	0.14	0.12	0.15	2	0.05	0.04	0.05	3	0.09	0.09	0.1	4	0.26	0.13	0.44	4
sulphur	mg/L	2.8	2.8	2.8	1	–	–	–	0	–	–	–	0	<0.2	<0.2	<0.2	1
thallium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	1	0.00005	≤0.0000121	0.00012	4
titanium	mg/L	0.0224	0.0059	0.039	2	0.002	0.0007	0.007	3	0.0016	<0.0004	0.0028	4	0.0033	0.0013	0.007	4
uranium	mg/L	0.0002	0.0001	0.0002	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	4	0.00002	≤0.000016	0.00004	4
vanadium	mg/L	<0.001	≤0.0009	0.0046	5	<0.0002	<0.0002	<0.001	5	<0.0007	<0.0002	0.0007	6	0.0005	0.0004	0.0018	4
zinc	mg/L	0.022	0.016	0.027	2	0.005	<0.004	0.016	3	0.021	0.011	0.103[(a)]	4	0.006	0.002	0.008	4
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	1	0.06	0.06	0.06	2	<0.01	<0.01	<0.01	1	<0.0066	≤0.00315	0.0032	2
antimony	mg/L	<0.0008	<0.0008	<0.0008	1	<0.0008	<0.0008	<0.0008	2	<0.0008	<0.0008	<0.0008	1	<0.0004	≤0.0000282	0.00003	2
arsenic	mg/L	<0.001	≤0.0008	0.0024	4	<0.0005	<0.0004	0.0005	4	0.0005	<0.0002	0.0008	3	0.0007	0.0006	0.0008	2
barium	mg/L	0.043	0.043	0.043	1	0.01	0.01	0.01	2	0.023	0.023	0.023	1	0.036	0.035	0.037	2
beryllium	mg/L	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0003	≤0.00000402	0.000004	2

Table F-20 Water Quality in Shelley Creek (continued)

Parameter	Units	Winter (1977 to 2001)				Spring (1977 to 2001)				Summer (1977 to 2001)				Fall (1998 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
boron	mg/L	0.1	0.02	0.32	4	0.07	0.06	0.24	4	0.12	0.05	0.19	3	0.06	0.05	0.07	2
cadmium	mg/L	<0.0001	<0.0001	<0.0001	1	0.0001	<0.0001	0.0001	2	<0.0001	<0.0001	<0.0001	1	<0.0001	≤0.0000022	0.000002	2
chromium	mg/L	<0.0004	<0.0004	<0.0004	1	0.0005	0.0005	0.0006	2	0.0008	0.0008	0.0008	1	0.0009	0.0002	0.0016[(a)]	2
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0009	0.0009	0.0009	1	<0.0001	<0.0001	<0.0001	2	0.0006	0.0006	0.0006	1	0.0012	0.0008	0.0017	2
copper	mg/L	0.0009	0.0009	0.0009	1	0.0018	0.0008	0.0028[(a)]	2	<0.0006	<0.0006	<0.0006	1	<0.0004	≤0.000173	0.0002	2
iron	mg/L	4.78[(a)]	4.78[(a)]	4.78[(a)]	1	0.19	0.19	0.2	2	1.64[(a)]	1.64[(a)]	1.64[(a)]	1	0.84[(a)]	0.01	2.44[(a)]	4
lead	mg/L	<0.0001	<0.0001	<0.0001	1	0.0014	0.001	0.0017	2	0.0001	0.0001	0.0001	1	<0.0001	≤0.000026	0.00003	2
lithium	mg/L	0.006	0.006	0.006	1	0.007	0.007	0.007	2	0.008	0.008	0.008	1	0.013	0.011	0.015	2
manganese	mg/L	0.9	0.9	0.9	1	0.018	0.018	0.019	2	0.382	0.382	0.382	1	0.712	0.001	1.06	4
mercury	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	1	<0.000055	<0.00001	<0.0001	2
molybdenum	mg/L	0.0003	0.0003	0.0003	1	0.0002	0.0001	0.0002	2	0.0001	0.0001	0.0001	1	0.0002	0.0001	0.0002	2
nickel	mg/L	0.0009	0.0009	0.0009	1	0.0036	0.0028	0.0043	2	0.0005	0.0005	0.0005	1	0.0002	0.00004	0.0003	2
selenium	mg/L	<0.0005	<0.0005	0.0007	4	<0.00045	<0.0004	<0.0005	4	<0.0002	<0.0002	0.0002	3	<0.0003	≤0.000199	0.0002	2
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	2	<0.0002	<0.0002	<0.0002	1	<0.0001	<0.0000005	<0.0002	2
strontium	mg/L	0.11	0.11	0.11	1	0.05	0.05	0.05	2	0.1	0.1	0.1	1	0.17	0.14	0.19	2
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.2	<0.2	<0.2	1
thallium	mg/L	<0.00005	<0.00005	<0.00005	1	<0.00005	<0.00005	<0.00005	2	<0.00005	<0.00005	<0.00005	1	<0.00003	≤0.0000105	0.00001	2
titanium	mg/L	0.0013	0.0013	0.0013	1	<0.0003	<0.0003	<0.0003	2	0.0014	0.0014	0.0014	1	0.0012	0.0007	0.0018	2
uranium	mg/L	0.0001	0.0001	0.0001	1	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	1	<0.0001	≤0.0000121	0.00001	2
vanadium	mg/L	0.0014	0.0014	0.0014	1	0.0005	0.0005	0.0006	2	<0.0001	<0.0001	<0.0001	1	0.0001	0.0001	0.0002	2
zinc	mg/L	0.005	0.005	0.005	1	0.166[(a)(b)]	0.121[(a)(b)]	0.212[(a)(b)]	2	<0.002	<0.002	<0.002	1	0.005	0.003	0.007	2
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
acenaphthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
acenaphthylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(b&k)fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(g,h,i)perylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
indeno(c,d–123)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
phenanthrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<10	<10	<10	1
Target PANHs																	
acridine	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1

(a) Chronic aquatic life guideline exceeded.

(b) Acute aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-21 Water Quality in Stanley Creek

Parameter	Units	Winter (1976 to 2004)				Spring (1977 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	0	0.5	4	4.7	3.4	8.1	6	13.2	10.9	17.8	6	8.7	2.1	12.6	8
dissolved oxygen	mg/L	1.5[a][b]	1.5[a][b]	1.5[a][b]	1	6.3[b]	5.1[b]	9.4	6	4.2[a][b]	1.6[a][b]	7.1	7	7.6	2.4[a][b]	9.3	7
Conventional Parameters																	
colour	TCU	150	150	150	1	32	20	40	4	35	30	70	4	25	15	45	7
specific conductance	µS/cm	310	300	597	5	230	185	563	7	287	233	705	8	310	266	760	9
dissolved organic carbon	mg/L	5	2	17	5	10	1	14	7	10	9	24	7	8	6	14	8
hardness	mg/L	169	161	316	5	126	102	296	7	156	133	347	8	165	139	361	9
pH		7.5	7.2	8	5	7.9	6.8	8.2	7	7.9	7	8.4	8	7.8	7.4	8.2	9
total alkalinity	mg/L	172	152	319	5	121	103	200	7	165	139	270	8	170	142	260	9
total dissolved solids	mg/L	196	192	320	5	148	120	360	7	190	143	480	8	200	150	480	9
total organic carbon	mg/L	9	5	19	5	8	2	16	6	10	10	17	7	8	7	16	9
total suspended solids	mg/L	29	7	73	5	<3	<0.4	13	7	1	<0.4	4	8	<3	<3	58	9
Major Ions																	
bicarbonate	mg/L	389	389	389	1	166	145	244	5	258	172	330	5	207	176	317	7
calcium	mg/L	48	45	91	5	36	28	90	7	46	38	107	8	49	40	112	9
carbonate	mg/L	<5	<5	<5	1	<5	<0.5	<5	5	<5	<0.5	<5	5	<5	<5	<5	6
chloride	mg/L	0.5	0.4	3	5	1	≤0.3	9	7	0.4	≤0.2	14	8	1	≤0.2	14	9
magnesium	mg/L	12	12	22	5	9	8	17	7	10	9	21	8	11	10	20	9
potassium	mg/L	1	1	2	5	1	1	2	7	1	0.1	1	8	1	0.5	2	9
sodium	mg/L	2	2	10	5	3	2	11	7	2	1	24	8	2	2	26	9
sulphate	mg/L	4	2	9	5	3	2	90	7	5	<0.5	111	8	5	≤0.5	126	9
sulphide	mg/L	<0.026	<0.003	<0.05	2	<0.003	<0.003	0.007[b]	5	0.007[b]	0.004	0.011[b]	4	0.004	≤0.002	0.013[b]	10
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	<0.1	<0.1	<0.1	1	<0.1	<0.003	<0.1	5	<0.1	<0.03	<0.1	5	<0.1	<0.1	<0.1	7
nitrogen – ammonia	mg/L	0.97	0.97	0.97	1	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	4	<0.05	<0.05	0.09	7
nitrogen – kjeldahl	mg/L	0.8	0.4	1.2	5	0.4	0.3	1.2	6	0.4	0.05	2.1	7	0.5	0.2	2.4	10
nitrogen – total nitrogen	mg/L	0.8	0.4	1.2[b]	5	0.4	0.3	1.2[b]	6	0.4	0.05	2.1[b]	7	0.5	0.2	2.4[b]	10
phosphorus, total	mg/L	0.16[b]	0.078[b]	0.24[b]	5	0.033	0.011	0.14[b]	7	0.046	0.023	0.215[b]	8	0.034	0.016	0.32[b]	10
phosphorus, dissolved	mg/L	0.003	0.003	0.003	1	0.008	0.007	0.013	4	0.02	0.011	0.04	4	0.014	0.01	0.032	8
chlorophyll *a*	µg/L	<1	<1	<1	2	<1	<1	<1	3	3	<1	6	3	0.5	<1	4	6
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	4	4	4	1	<2	<2	2	4	<2	<2	<2	4	<2	≤0.4	0.4	8
General Organics																	
naphthenic acids	mg/L	1	1	1	1	<1	<1	1	5	<1	<1	3	5	<1	<1	1	7
total phenolics	mg/L	0.005	<0.001	0.02[b]	5	<0.001	<0.001	0.008[b]	5	<0.001	<0.001	0.003	5	<0.001	<0.001	0.052[b]	9
total recoverable hydrocarbons	mg/L	<0.1	<0.1	1.9	5	<0.5	<0.5	6.6	6	<0.5	<0.1	<1	6	<0.5	≤0.2	0.8	9
Toxicity																	
Microtox® IC50 @ 15 Min	%	–	–	–	0	>100	>100	>100	1	>100	>100	>100	1	>91	>91	>91	1
Microtox® IC25 @ 15 Min	%	–	–	–	0	>100	>100	>100	1	>100	>100	>100	1	>91	>91	>91	1
Total Metals																	
aluminum	mg/L	<0.02	<0.02	<0.02	1	0.025	0.0009	0.0469	6	0.0114	≤0.00107	0.06	5	0.0092	≤0.000994	0.0369	8
antimony	mg/L	<0.005	<0.005	<0.005	1	0.00001	≤0.00000998	0.0005	5	0.00002	0.00001	0.0005	4	0.00001	≤0.00000767	0.00001	8
arsenic	mg/L	<0.001	<0.001	<0.001	1	0.0001	≤0.0000996677	0.0002	5	0.0005	<0.0004	0.0008	5	0.0001	≤0.0001	0.0005	10
barium	mg/L	0.102	0.102	0.102	1	0.058	0.036	0.104	6	0.097	0.059	0.175	5	0.064	0.037	0.117	8
beryllium	mg/L	<0.001	<0.001	<0.001	1	<0.0001	<0.000003	0.0002	6	<0.00004	<0.000003	0.00001	5	<0.00004	<0.000003	0.0001	8
boron	mg/L	0.05	0.05	0.05	1	0.03	≤0.0160579	0.05	6	0.04	0.02	0.12	5	0.02	0.02	0.09	8

Table F-21 Water Quality in Stanley Creek (continued)

Parameter	Units	Winter (1976 to 2004)				Spring (1977 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
cadmium	mg/L	0.0002	0.0002	0.0002	1	<0.00002	<0.000002	0.00003	6	<0.00001	<0.000002	0.000004	5	<0.00002	<0.000002	0.00002	8
chromium	mg/L	0.0024[(b)]	0.0024[(b)]	0.0024[(b)]	1	0.00002	<0.0001	0.0002	6	0.0001	≤0.000137	0.0004	5	0.0002	≤0.0000375	0.0024[(b)]	8
chromium – hexavalent	mg/L	<0.003	<0.003	0.007[(b)]	4	<0.003	<0.003	<0.003	1	<0.003	<0.003	<0.003	3	<0.003	<0.003	<0.003	2
cobalt	mg/L	<0.0002	<0.0002	<0.0002	1	<0.00004	≤0.0000019	0.00004	6	<0.00002	<0.000001	0.00002	5	<0.00002	<0.000001	0.00003	8
copper	mg/L	<0.001	<0.001	<0.001	1	0.0004	≤0.0003	0.002	6	0.0002	≤0.000182	0.0004	4	0.0003	<0.0001	0.0007	8
iron	mg/L	4.74[(b)]	4.74[(b)]	4.74[(b)]	1	0.16	0.06	0.56[(b)]	6	1.3[(b)]	0.13	1.98[(b)]	5	0.23	<0.002	1.54[(b)]	8
lead	mg/L	<0.0001	<0.0001	<0.0001	1	0.0001	≤0.0000197	0.0004	6	0.00001	≤0.0000117	0.0002	5	0.00002	≤0.00000298	0.0001	8
lithium	mg/L	0.014	0.014	0.014	1	0.006	≤0.005	0.012	6	0.007	0.006	0.012	5	0.009	0.006	0.078	8
manganese	mg/L	0.483	0.483	0.483	1	0.025	0.011	0.122	6	0.053	0.019	0.224	5	0.021	0.003	0.093	8
mercury	mg/L	<0.0001	<0.0000006	<0.0001	5	<0.0000006	<0.0000006	<0.0001	6	<0.0000006	<0.0000006	<0.0002	7	<0.0000006	<0.0000006	0.0036[(a)(b)]	9
molybdenum	mg/L	<0.0001	<0.0001	<0.0001	1	0.0001	≤0.0000684766	0.0001	6	0.0001	≤0.0000525	0.0001	5	0.0001	≤0.000039	0.0002	8
nickel	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0001	<0.000005	0.0001	6	<0.0001	<0.000005	0.006	5	<0.0001	<0.000005	0.0009	8
selenium	mg/L	<0.0008	<0.0008	<0.0008	1	<0.0005	<0.0001	0.00013	5	<0.00039	≤0.000149	0.00039	4	<0.0005	<0.0001	0.00024	8
silicon	mg/L	–	–	–	0	3.1	3.1	3.1	1	–	–	–	0	–	–	–	0
silver	mg/L	0.000008	0.000008	0.000008	1	0.000005	<0.0000005	0.000044	6	<0.000005	<0.0000005	0.000001	5	<0.000006	<0.0000005	0.000034	8
strontium	mg/L	0.2	0.2	0.2	1	0.09	0.07	0.17	6	0.13	0.08	0.22	5	0.09	0.08	0.25	8
sulphur	mg/L	–	–	–	0	3.2	0.5	24.3	3	16.2	0.6	31.8	2	15.4	1.3	67.5	3
thallium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.00001	<0.0000003	0.00002	5	0.00001	<0.0000003	0.00004	4	0.00001	≤0.000000968	0.00004	7
titanium	mg/L	<0.005	<0.005	<0.005	1	0.0008	≤0.000723322	0.0011	6	0.0018	≤0.00156	0.009	5	0.0013	<0.0006	0.0031	8
uranium	mg/L	<0.0001	<0.0001	<0.0001	1	0.00001	≤0.00000346737	0.0001	6	0.00005	≤0.0000124	0.0001	4	0.00004	≤0.000006	0.0002	8
vanadium	mg/L	<0.001	<0.001	0.0013	5	<0.0002	≤0.0000683406	0.0001	8	<0.0006	≤0.000105	0.0006	7	0.0001	≤0.0000468	0.0003	8
zinc	mg/L	0.008	0.008	0.008	1	0.008	<0.004	0.127[(b)]	6	0.006	≤0.00342	0.03	5	0.003	0.001	0.009	8
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	1	0.0006	≤0.000257	0.0035	5	0.0004	≤0.000345	0.0004	4	0.0004	≤0.000292	0.02	7
antimony	mg/L	<0.0008	<0.0008	<0.0008	1	0.00001	≤0.00000543	0.0008	5	0.00001	≤0.00000812	0.00004	4	0.00001	<0.000004	0.00001	7
arsenic	mg/L	<0.001	<0.0004	0.003	5	0.0001	≤0.0000640936	0.0002	7	0.0003	<0.0002	0.0006	6	0.0001	<0.00002	0.0003	7
barium	mg/L	1.21	1.21	1.21	1	0.071	0.036	0.098	5	0.108	0.06	0.132	4	0.068	0.039	0.113	7
beryllium	mg/L	<0.0005	<0.0005	<0.0005	1	<0.00004	<0.000003	<0.0005	5	<0.00002	<0.000003	<0.0005	4	<0.00004	<0.000003	0.00005	7
boron	mg/L	0.18	0.04	0.4	5	0.03	0.01	0.11	7	0.04	0.03	0.12	7	0.03	0.02	0.09	9
cadmium	mg/L	0.0002	0.0002	0.0002	1	<0.00001	<0.000002	0.000005	5	<0.00001	<0.000002	0.00001	4	<0.00001	<0.000002	0.00002	7
chromium	mg/L	0.0012[(b)]	0.0012[(b)]	0.0012[(b)]	1	0.0002	≤0.000137	0.0008	5	0.0002	≤0.0000543	0.0004	4	0.00004	≤0.0000373	0.0005	7
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0002	0.0002	0.0002	1	0.000002	≤0.00000192	0.00003	5	0.000002	<0.000001	0.00003	4	<0.00002	<0.000001	0.00001	7
copper	mg/L	<0.0006	<0.0006	<0.0006	1	0.0007	0.0003	0.0021	5	0.0002	≤0.000172	0.0004	4	0.0005	0.0003	0.0012	7
iron	mg/L	0.02	0.02	0.02	1	0.1	<0.002	0.12	5	0.06	<0.002	0.58[(b)]	4	0.11	<0.002	0.54[(b)]	8
lead	mg/L	<0.0001	<0.0001	<0.0001	1	0.00002	0.00001	0.0011	5	0.00001	≤0.00000461	0.0002	4	0.00001	≤0.00000294	0.0002	7
lithium	mg/L	0.014	0.014	0.014	1	0.006	0.006	0.011	5	0.008	0.007	0.011	4	0.01	0.006	0.027	7
manganese	mg/L	0.158	0.158	0.158	1	0.011	0.006	0.057	5	0.03	0.004	0.086	4	0.018	0.002	0.068	8
mercury	mg/L	<0.0001	<0.0001	<0.0001	1	<0.00004	<0.00001	<0.0001	5	<0.000025	<0.00001	<0.0001	4	<0.00001	<0.00001	<0.0001	6
molybdenum	mg/L	<0.0001	<0.0001	<0.0001	1	0.0001	≤0.0000443587	0.0001	5	0.00005	≤0.0000392	0.0001	4	0.0001	≤0.0000341	0.0002	7
nickel	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.000005	<0.0001	5	<0.0001	<0.000005	0.0005	4	<0.0001	<0.000005	0.0006	7
selenium	mg/L	<0.0005	<0.0004	0.0013[(b)]	5	<0.0005	<0.0001	0.00012	7	<0.00025	≤0.000111	0.0003	6	<0.0004	<0.0001	0.0006	7
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	<0.0002	<0.0002	<0.0002	1	<0.000005	<0.0000005	<0.0002	5	<0.000005	<0.0000005	0.00001	4	<0.00001	<0.0000005	0.000013	7
strontium	mg/L	0.2	0.2	0.2	1	0.1	0.06	0.17	5	0.17	0.09	0.22	4	0.1	0.08	0.24	7
sulphur	mg/L	–	–	–	0	13.16	3.12	23.2	2	14.893	0.586	29.2	2	14.2	1.245	65.6	3
thallium	mg/L	<0.00005	<0.00005	<0.00005	1	<0.000004	<0.0000003	0.00002	5	0.00001	<0.0000003	0.00003	4	<0.00001	<0.0000003	0.00004	6

Table F-21 Water Quality in Stanley Creek (continued)

Parameter	Units	Winter (1976 to 2004)				Spring (1977 to 2005)				Summer (1976 to 2005)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
titanium	mg/L	0.0018	0.0018	0.0018	1	0.0006	0.0004	0.0009	5	0.0011	0.0009	0.002	4	0.0012	0.0007	0.0023	7
uranium	mg/L	<0.0001	<0.0001	<0.0001	1	0.00002	<0.000003	0.0001	5	0.00004	≤0.0000114	0.0001	4	0.00001	≤0.000006	0.0002	7
vanadium	mg/L	0.0002	0.0002	0.0002	1	0.0001	≤0.000045	0.0001	5	0.0001	≤0.000055	0.0001	4	0.0001	0.00001	0.0003	7
zinc	mg/L	0.572[(a)(b)]	0.572[(a)(b)]	0.572[(a)(b)]	1	0.005	0.002	0.029	5	0.003	<0.002	0.011	4	0.002	0.001	0.005	7
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
acenaphthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
acenaphthylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(a)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(b&k)fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
benzo(g,h,i)perylene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
fluoranthene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
fluorene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
indeno(c,d–123)pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
phenanthrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
pyrene	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1
Target PANHs																	
acridine	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of Nitrate + Nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-22 Sediment Quality in Stanley Creek

Parameter	Units	Fall (2003)
		n = 1
Particle Size		
moisture content	%	91
Carbon Content		
total inorganic carbon	% by wt	0.23
total organic carbon	% by wt	41.5
total carbon	% by wt	41.8
Organics		
total recoverable hydrocarbons	mg/kg	25,200
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5
total extractable hydrocarbons (C11–C30)	mg/kg	610
Total Metals		
arsenic	µg/g	18.5[(a)(b)]
barium	µg/g	232
beryllium	µg/g	<0.2
cadmium	µg/g	0.3
chromium	µg/g	2.2
cobalt	µg/g	9.1
copper	µg/g	7
lead	µg/g	6.1
mercury	µg/g	0.13
molybdenum	µg/g	2.9
nickel	µg/g	7
selenium	µg/g	0.4
silver	µg/g	<0.2
strontium	µg/g	47
thallium	µg/g	<0.05
uranium	µg/g	0.5
vanadium	µg/g	13.4
zinc	µg/g	108
Target PAHs and Alkylated PAHs		
naphthalene	µg/g	0.012
C1 subst'd naphthalenes	µg/g	0.025[(a)]
C2 subst'd naphthalenes	µg/g	2.53
C3 subst'd naphthalenes	µg/g	0.068
C4 subst'd naphthalenes	µg/g	0.063
acenaphthene	µg/g	<0.0007
C1 subst'd acenaphthene	µg/g	<0.0005
acenaphthylene	µg/g	<0.0008
anthracene	µg/g	0.001
dibenzo(a,h)anthracene	µg/g	<0.00327
benzo(a)anthracene	µg/g	0.002
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.51
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.023
benzo(a)pyrene	µg/g	0.0022
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.008
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.021
benzofluoranthenes	µg/g	0.004
benzo(g,h,i)perylene	µg/g	<0.0038

Table F-22 Sediment Quality in Stanley Creek (continued)

Parameter	Units	Fall (2003)
		n = 1
biphenyl	µg/g	0.0036
C1 subst'd biphenyl	µg/g	0.00327
C2 subst'd biphenyl	µg/g	0.0292
chrysene	µg/g	0.005
dibenzothiophene	µg/g	0.0014
C1 subst'd dibenzothiophene	µg/g	0.0123
C2 subst'd dibenzothiophene	µg/g	0.0608
C3 subst'd dibenzothiophene	µg/g	0.126
C4 subst'd dibenzothiophene	µg/g	0.122
fluoranthene	µg/g	0.0076
C1 subst'd fluoranthene/pyrene	µg/g	1.32
C2 subst'd fluoranthene/pyrene	µg/g	0.064
C3 subst'd fluoranthene/pyrene	µg/g	0.004
fluorene	µg/g	0.0026
C1 subst'd fluorene	µg/g	0.011
C2 subst'd fluorene	µg/g	0.0938
C3 subst'd fluorene	µg/g	0.134
indeno(c,d–123)pyrene	µg/g	<0.0039
phenanthrene	µg/g	0.007
C1 subst'd phenanthrene/anthracene	µg/g	0.116
C2 subst'd phenanthrene/anthracene	µg/g	0.233
C3 subst'd phenanthrene/anthracene	µg/g	0.506
C4 subst'd phenanthrene/anthracene	µg/g	124
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	123
pyrene	µg/g	0.042

(a) Interim sediment quality guideline exceeded.

(b) Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-23 Water Quality in Muskeg Creek and Its Tributaries

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	0	1	29	11.4	1	16.2	19	16.5	11	22	23	5	0	13.4	33
dissolved oxygen	mg/L	7.8	0.4[(a)(b)]	11.5	18	10.4	3.1[(a)(b)]	13.4	18	7.6	1.8[(a)(b)]	10.4	23	9.6	2.8[(a)(b)]	14.5	31
Conventional Parameters																	
colour	TCU	100	40	350	17	100	40	125	14	100	65	175	17	125	59	200	29
specific conductance	µS/cm	308	210	664	20	156	67	310	14	202	101	370	24	222	60	671	25
dissolved organic carbon	mg/L	32	19	41	20	20	12	40	12	28	16	35	18	24	6	31	24
hardness	mg/L	146	89	292	31	62	34	150	21	95	54	165	31	89	30	244	40
pH		7.3	6.7	7.8	21	7.6	6.8	8.1	13	7.7	6.5	8.1	23	7.7	6.6	8.2	25
total alkalinity	mg/L	169	102	370	31	78	35	179	21	117	55	230	31	110	29	313	40
total dissolved solids	mg/L	200	129	504	31	95	61	204	21	134	69	246	31	129	60	417	40
total organic carbon	mg/L	34	23	42	30	21	13	40	19	29	18	38	27	29	21	53	34
total suspended solids	mg/L	5	≤0.5	81	32	4	<0.4	38	22	4	<0.4	171	30	3	<0.4	20	42
Major Ions																	
bicarbonate	mg/L	220	149	451	17	96	42	134	16	149	67	212	21	135	35	382	33
calcium	mg/L	37	22	79	31	16	1	38	21	24	<1	45	31	23	1	71	39
carbonate	mg/L	<5	<0.5	0	8	<0.5	<0.5	9	16	<0.5	<0.5	15	21	<5	<0.5	8	23
chloride	mg/L	2	1	7	31	1	≤0.2	3	21	1	≤0.1	6	31	1	≤0.1	36	40
magnesium	mg/L	13	8	29	31	6	3	14	21	9	5	15	31	8	3	17	40
potassium	mg/L	2	1	5	31	1	0.5	2	21	0.5	<0.02	2	31	1	0.3	2	40
sodium	mg/L	20	11	56	31	11	1	22	21	14	2	24	31	15	2	64	40
sulphate	mg/L	7	3	28	31	4	2	9	21	4	0.5	11	29	4	≤0.5	11	40
sulphide	mg/L	<0.007	<0.001	0.007	11	0.014[(b)]	0.004	0.03[(b)]	5	0.018[(b)]	≤0.009	0.038[(b)]	9	0.002	<0.002	0.068[(b)]	20
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.1	<0.003	0.4	16	<0.01	<0.0003	0.1	16	<0.03	<0.003	0.02	21	<0.01	<0.003	0.02	31
nitrogen – ammonia	mg/L	0.49	0.13	2.8	16	<0.05	<0.01	0.08	15	0.05	<0.05	0.15	17	0.03	≤0.02	0.28	27
nitrogen – kjeldahl	mg/L	1.7	0.4	3.4	30	0.8	0.6	2.4	18	1	<0.2	3.5	27	0.8	<0.2	1.5	35
nitrogen – total nitrogen	mg/L	1.7[(b)]	0.4	3.4[(b)]	30	0.9	0.6	2.4[(b)]	18	1	<0.2	3.5[(b)]	27	0.8	<0.2	1.5[(b)]	35
phosphorus, total	mg/L	0.063[(b)]	≤0.015	0.55[(b)]	31	0.024	≤0.014	0.12[(b)]	21	0.034	≤0.01	0.2[(b)]	30	0.03	<0.01	0.12[(b)]	40
phosphorus, dissolved	mg/L	0.011	≤0.01	0.017	5	0.01	<0.001	0.02	6	0.025	0.006	0.036	7	0.018	<0.01	0.034	14
chlorophyll *a*	µg/L	7.5	<1	21	6	1	<1	6	5	1	<1	7	8	1	<1	21	15
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	2	≤1	15	17	1	≤0.8	3	13	1	≤0.6	3	17	0.5	≤0.2	8	29
General Organics																	
naphthenic acids	mg/L	1	<1	3	4	<1	<1	<1	7	<1	<1	2	11	<1	<1	2	16
total phenolics	mg/L	0.005	<0.001	0.026[(b)]	16	0.006[(b)]	<0.001	0.012[(b)]	9	0.005	<0.001	0.018[(b)]	12	0.005	<0.001	0.049[(b)]	19
total recoverable hydrocarbons	mg/L	0.6	<0.1	5.5	27	<0.1	<0.1	4.3	19	<0.5	<0.1	6.7	25	<0.5	<0.1	3.5	37
Toxicity																	
Microtox® IC50 @ 15 Min	%	>99	>99	>99	1	>100	>91	>100	3	>100	>100	>100	4	>95.5	>91	>100	8
Microtox® IC25 @ 15 Min	%	–	–	–	0	>100	>100	>100	2	>100	>100	>100	4	>95.5	>91	>100	8
algal growth inhibition test (72h) – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-23 Water Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
algal growth inhibition test (72h) – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – NOEC	%	100	100	100	3	–	–	–	0	–	–	–	0	100	100	100	3
ceriodaphnia 7d mortality test – LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test – LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test – NOEC	%	100	100	100	3	–	–	–	0	–	–	–	0	100	100	100	4
ceriodaphnia 7d reproduction test – IC25	%	10.2	10.2	>100	3	–	–	–	0	–	–	–	0	>57.5	15	>100	2
ceriodaphnia 7d reproduction test – IC50	%	>73.55	47.1	>100	2	–	–	–	0	–	–	–	0	>78	56	>100	2
ceriodaphnia 7d reproduction test – LOEC	%	12.5	12.5	100	3	–	–	–	0	–	–	–	0	>62.5	25	>100	2
ceriodaphnia 7d reproduction test – NOEC	%	50	6.25	100	3	–	–	–	0	–	–	–	0	100	12.5	100	4
daphnia 48h static acute test – LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
daphnia 48h static acute test – NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d growth – IC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – IC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – NOEC	%	100	100	100	3	–	–	–	0	–	–	–	0	100	100	100	3
fathead minnow 7d mortality test – LC25	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	15	15	15	1
fathead minnow 7d mortality test – LC50	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	35	35	35	1
fathead minnow 7d mortality test – LOEC	%	>100	>100	>100	1	–	–	–	0	–	–	–	0	25	25	25	1
fathead minnow 7d mortality test – NOEC	%	100	100	100	3	–	–	–	0	–	–	–	0	100	12.5	100	3
trout 96h static acute test – LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
trout 96h static acute test – NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1

Table F-23 Water Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Total Metals																	
aluminum	mg/L	0.05	<0.01	0.31[(b)]	17	0.04	<0.01	0.11[(b)]	15	0.06	≤0.01	1.2[(a)(b)]	21	0.0311	<0.01	0.142[(b)]	33
antimony	mg/L	<0.0013	≤0.000033	0.0013	7	<0.0014	≤0.0000222	0.0008	6	<0.004	≤0.0000455	0.003	8	0.00002	≤0.00002	0.0046	15
arsenic	mg/L	0.0004	≤0.0002	0.0015	17	0.0003	≤0.000272	0.0007	13	0.0002	<0.0002	0.025[(b)]	20	0.0003	≤0.0002	0.012[(b)]	33
barium	mg/L	0.029	0.026	0.105	7	0.014	0.011	0.06	8	0.021	0.014	0.044	12	0.02	≤0.0124	0.067	19
beryllium	mg/L	<0.001	<0.00004	<0.001	7	<0.001	≤0.00000414	0.002	8	<0.001	≤0.0000186	0.00002	12	<0.001	≤0.00000641	0.00001	19
boron	mg/L	0.08	0.06	0.27	17	0.06	≤0.04	0.12	15	0.06	≤0.01	0.19	21	0.06	<0.01	0.15	33
cadmium	mg/L	<0.001	<0.00002	<0.001	17	<0.001	≤0.00000945	0.00001	15	<0.001	≤0.0000128	0.00001	21	<0.001	≤0.00000233	0.003[(a)(b)]	33
chromium	mg/L	<0.001	<0.0004	0.0023[(b)]	17	<0.001	≤0.000336	0.0066[(b)]	15	<0.001	≤0.000422	0.01[(b)]	21	<0.001	≤0.000154	0.0762[(a)(b)]	33
chromium – hexavalent	mg/L	<0.003	<0.003	0.007[(b)]	14	<0.003	<0.003	0.004[(b)]	4	<0.003	<0.003	<0.003	5	<0.003	<0.003	<0.003	7
cobalt	mg/L	<0.0002	≤0.00009	0.0008	7	<0.0004	≤0.0000928	0.0003	8	<0.0005	<0.0002	0.0002	13	0.0002	≤0.0000807	0.006	19
copper	mg/L	<0.001	≤0.0003	0.002	17	<0.001	≤0.0007	0.003[(b)]	15	<0.001	≤0.000357	0.0013	17	<0.001	<0.0001	0.011[(b)]	33
iron	mg/L	1.2[(b)]	0.43[(b)]	9.1[(b)]	17	0.34[(b)]	0.13	0.72[(b)]	15	0.6[(b)]	0.21	2.69[(b)]	21	0.47[(b)]	0.13	1.81[(b)]	33
lead	mg/L	0.00004	≤0.000042	0.003	17	0.0005	≤0.0000831	0.006[(b)]	15	<0.002	<0.0001	0.0037[(b)]	21	<0.002	≤0.00002	0.05[(b)]	33
lithium	mg/L	0.011	0.009	0.024	7	0.007	0.006	0.008	7	0.009	0.002	0.014	11	0.008	0.005	0.095	18
manganese	mg/L	0.24	0.023	2.12	17	0.013	<0.004	0.048	15	0.036	0.012	0.11	21	0.021	0.003	0.534	33
mercury	mg/L	<0.0001	<0.0000006	0.0006[(a)(b)]	29	<0.00005	<0.0000006	0.0001[(a)(b)]	18	<0.0001	<0.0000006	0.0002[(a)(b)]	27	<0.0001	<0.0000006	0.0013[(a)(b)]	34
methyl mercury	mg/L	0.0000001	0.0000001	0.0000001	1	0.0000001	0.0000001	0.0000001	1	0.0000001	0.0000001	0.0000001	1	–	–	–	0
molybdenum	mg/L	0.0002	<0.0001	0.0002	7	0.0001	≤0.0000987	0.004	8	<0.0001	≤0.0000876	0.0002	12	0.0001	≤0.0000479	0.0064	19
nickel	mg/L	<0.001	<0.0001	0.009	17	0.0005	≤0.000527	0.0032	15	0.0009	<0.0002	0.01	21	0.0002	<0.0001	0.0363	33
selenium	mg/L	<0.0004	<0.0002	0.0005	17	0.0003	<0.0001	0.0004	13	0.0002	<0.0002	0.012[(b)]	17	0.00012	<0.0001	0.0012[(b)]	29
silicon	mg/L	5	5	5	1	1.1	0.5	1.3	4	3	2.5	3.5	2	2.6	2.3	3.7	5
silver	mg/L	<0.000005	<0.000005	0.000006	6	<0.000252	≤0.00000236	0.000005	8	<0.00035	<0.0000005	0.0006[(b)]	14	0.000002	<0.0000005	0.004[(a)(b)]	19
strontium	mg/L	0.12	0.1	0.34	7	0.06	0.04	0.08	7	0.1	0.04	0.12	11	0.09	0.02	0.3	19
sulphur	mg/L	2.7	2.7	2.7	1	1.6	1.2	2.2	3	0.7	0.7	0.7	1	0.4	<0.2	1.3	7
thallium	mg/L	<0.0001	<0.000003	<0.0001	6	<0.0001	≤0.00000168	0.000002	4	<0.0001	≤0.00000276	0.000003	6	<0.00007	<0.0000003	0.00016	12
titanium	mg/L	0.0021	≤0.0021	0.0032	9	0.0011	≤0.0009	0.005	8	0.0023	≤0.0022	0.01	12	0.0018	≤0.0012	0.009	19
uranium	mg/L	<0.0001	<0.0001	0.0001	7	<0.0001	≤0.0000195	0.00002	7	<0.0001	≤0.0000973	0.0001	7	<0.0001	≤0.0000159	0.0002	18
vanadium	mg/L	<0.001	<0.0002	0.001	31	<0.001	<0.0002	0.005	20	<0.001	<0.0002	0.007	28	<0.001	<0.0002	0.003	36
zinc	mg/L	0.005	≤0.002	0.038[(b)]	17	0.003	≤0.002	0.052[(b)]	15	0.011	<0.001	0.13[(a)(b)]	21	0.004	≤0.00082	0.054[(b)]	33
Dissolved Metals																	
aluminum	mg/L	0.02	0.01	0.02	4	0.04	0.0075	0.07	5	0.01	≤0.00644	0.04	7	0.0054	≤0.00292	0.0505	13
antimony	mg/L	<0.0008	<0.0008	0.0008	4	<0.0008	≤0.00002	0.0008	5	<0.0008	≤0.0000216	0.0006	7	<0.0008	≤0.000014	0.0004	13
arsenic	mg/L	<0.001	<0.0002	0.0096[(b)]	18	<0.0004	<0.0002	0.0003	10	0.0004	<0.0002	0.0009	14	<0.0004	<0.0002	0.0006	16
barium	mg/L	0.03	0.026	0.091	4	0.012	≤0.0094	0.014	5	0.021	0.013	0.04	7	0.019	0.011	0.063	13
beryllium	mg/L	<0.0005	<0.0005	<0.0005	4	<0.0005	≤0.00000408	0.000004	5	<0.0005	≤0.0000061	0.00001	7	<0.0005	≤0.00000327	0.00001	13
boron	mg/L	0.14	0.01	0.35	18	0.08	≤0.028	0.2	10	0.09	≤0.04	0.21	17	0.06	≤0.025	0.17	20
cadmium	mg/L	<0.0001	<0.0001	<0.0001	4	0.00001	≤0.00000918	0.0007[(b)]	5	<0.0001	≤0.00000456	0.000005	7	<0.0001	<0.000002	0.000003	13
chromium	mg/L	0.0005	0.0004	0.0009	4	0.0004	≤0.000307	0.0034[(b)]	5	0.0002	≤0.000184	0.0015[(b)]	7	0.0001	≤0.0001	0.0008	13
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0004	<0.0001	0.0008	4	<0.0001	≤0.0000682	0.0002	5	0.0001	<0.0001	0.0018	7	0.0001	≤0.0000552	0.0007	13
copper	mg/L	0.0012	0.0007	0.0022	4	0.001	≤0.001	0.0026[(b)]	5	<0.0006	≤0.00021	0.0057[(b)]	7	0.0001	<0.0001	0.001	13
iron	mg/L	0.57[(b)]	0.19	0.97[(b)]	5	0.17	0.1	0.2	5	0.42[(b)]	0.07	0.65[(b)]	7	0.35[(b)]	0.17	1.02[(b)]	15
lead	mg/L	0.0001	0.0001	0.0002	4	0.0004	≤0.0000324	0.0018	5	<0.0001	≤0.0000242	0.0002	7	0.00002	≤0.00001	0.0001	13
lithium	mg/L	0.011	0.009	0.027	4	0.008	0.006	0.008	4	0.008	0.006	0.01	6	0.01	0.007	0.033	12
manganese	mg/L	0.048	0.019	0.746	5	0.008	0.006	0.015	5	0.024	<0.001	0.028	7	0.019	0.001	0.522	15

Table F-23 Water Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
mercury	mg/L	<0.0001	<0.0000006	<0.0001	4	<0.0001	<0.0000006	<0.01	5	<0.0001	<0.0000006	<0.01	7	<0.00007	<0.0000006	0.0000155[a)(b)]	12
molybdenum	mg/L	0.0002	0.0001	0.0002	4	0.0002	≤0.0000956	0.002	5	<0.0001	≤0.0000821	0.0001	7	<0.0001	≤0.0000374	0.0001	13
nickel	mg/L	0.001	0.0004	0.0014	4	0.002	0.0005	0.0047	5	0.0005	0.0001	0.006	7	0.0005	<0.0001	0.0045	13
selenium	mg/L	<0.0005	<0.0002	0.0006	18	<0.0005	<0.0001	0.0012[(b)]	10	<0.0002	≤0.000181	0.0004	14	<0.0004	<0.0001	0.0012[(b)]	16
silicon	mg/L	–	–	–	0	1.23	1.23	1.23	1	2.54	2.54	2.54	1	2.539	2.539	2.539	1
silver	mg/L	<0.0002	≤0.0000026	0.0009[(b)]	4	<0.0002	≤0.00000063	0.000002	5	<0.0002	<0.0000005	<0.0005	7	<0.0002	<0.0000005	0.000001	13
strontium	mg/L	0.12	0.1	0.34	4	0.06	0.05	0.07	4	0.1	0.06	0.12	6	0.1	0.02	0.27	13
sulphur	mg/L	–	–	–	0	1	1	1	1	0.695	0.695	0.695	1	<0.2	<0.2	0.247	3
thallium	mg/L	<0.00005	<0.00005	<0.00005	4	<0.00005	≤0.00000119	0.000001	4	<0.00005	<0.0000003	<0.00005	6	<0.00003	≤0.000001331	0.00001	10
titanium	mg/L	0.001	0.0007	0.0025	4	<0.0003	≤0.000275	0.0003	4	0.0011	0.0003	0.0013	6	0.0007	<0.0003	0.0016	12
uranium	mg/L	<0.0001	<0.0001	0.0001	4	<0.0001	≤0.000014	0.00001	4	<0.0001	≤0.0000882	0.0001	6	0.00001	≤0.00001	0.0002	12
vanadium	mg/L	0.0002	0.0002	0.0003	4	0.0002	≤0.000152	0.0004	5	0.0001	<0.0001	0.0004	7	0.0002	<0.0001	0.0005	12
zinc	mg/L	0.007	0.004	0.009	4	0.009	0.004	0.22[(a)(b)]	5	<0.002	<0.002	0.012	7	0.003	≤0.0008	0.009	13
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd naphthalenes	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
anthracene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
biphenyl	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2

Table F-23 Water Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Winter (1976 to 2006)				Spring (1977 to 2006)				Summer (1976 to 2006)				Fall (1976 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d–123)pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
phenanthrene	µg/L	<0.01	<0.01	<0.01	1	0.01	0.01	0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	µg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2
Target PANHs																	
acridine	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	<0.01	<0.01	<0.01	1

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-24 Sediment Quality in Muskeg Creek and Its Tributaries

Parameter	Units	Fall (2005)
		n = 1
Particle Size		
partice size – % sand	%	75
partice size – % silt	%	18
partice size – % clay	%	7
moisture content	%	42
Carbon Content		
total inorganic carbon	% by wt	0.11
total organic carbon	% by wt	5.7
total carbon	% by wt	5.8
Toxicity		
chironomus tentans – 10d survival	% of control	100
chironomus tentans – 10d growth	% of control	154
hyalella azteca – 10d survival	% of control	113
hyalella azteca – 10d growth	% of control	126
lumbriculus variegatus – 10d survival	% of control	80
Organics		
total recoverable hydrocarbons	mg/kg	3,100
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5
total extractable hydrocarbons (C11–C30)	mg/kg	400
Total Metals		
aluminum	µg/g	3,580
arsenic	µg/g	1.5
barium	µg/g	78
beryllium	µg/g	0.3
boron	µg/g	13
cadmium	µg/g	0.1
calcium	µg/g	9,700
chromium	µg/g	7.7
cobalt	µg/g	4.3
copper	µg/g	6
iron	µg/g	9,700
lead	µg/g	3.8
magnesium	µg/g	2,050
manganese	µg/g	612
mercury	µg/g	0.11
molybdenum	µg/g	0.3
nickel	µg/g	7.5
potassium	µg/g	600
selenium	µg/g	0.4
silver	µg/g	<0.2
sodium	µg/g	200

Table F-24 Sediment Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Fall (2005)
		n = 1
strontium	µg/g	40
thallium	µg/g	0.08
titanium	µg/g	26
uranium	µg/g	0.6
vanadium	µg/g	11.8
zinc	µg/g	28
Target PAHs and Alkylated PAHs		
naphthalene	µg/g	0.004
C1 subst'd naphthalenes	µg/g	0.004
C2 subst'd naphthalenes	µg/g	0.015
C3 subst'd naphthalenes	µg/g	0.031
C4 subst'd naphthalenes	µg/g	0.035
acenaphthene	µg/g	0.0008
C1 subst'd acenaphthene	µg/g	<0.0003
acenaphthylene	µg/g	0.0002
anthracene	µg/g	0.0006
dibenzo(a,h)anthracene	µg/g	0.00327
benzo(a)anthracene	µg/g	0.0028
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.25
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.085
benzo(a)pyrene	µg/g	<0.0033
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.043
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.047
benzofluoranthenes	µg/g	0.01
benzo(g,h,i)perylene	µg/g	0.0151
biphenyl	µg/g	0.0021
C1 subst'd biphenyl	µg/g	0.00042
C2 subst'd biphenyl	µg/g	0.002
chrysene	µg/g	0.032
dibenzothiophene	µg/g	0.002
C1 subst'd dibenzothiophene	µg/g	0.026
C2 subst'd dibenzothiophene	µg/g	0.128
C3 subst'd dibenzothiophene	µg/g	0.222
C4 subst'd dibenzothiophene	µg/g	0.202
fluoranthene	µg/g	0.0016
C1 subst'd fluoranthene/pyrene	µg/g	0.037
C2 subst'd fluoranthene/pyrene	µg/g	0.077
C3 subst'd fluoranthene/pyrene	µg/g	0.069
fluorene	µg/g	0.0028
C1 subst'd fluorene	µg/g	0.0063

Table F-24 Sediment Quality in Muskeg Creek and Its Tributaries (continued)

Parameter	Units	Fall (2005)
		n = 1
C2 subst'd fluorene	µg/g	0.0309
C3 subst'd fluorene	µg/g	0.0582
indeno(c,d–123)pyrene	µg/g	0.005
phenanthrene	µg/g	0.01
C1 subst'd phenanthrene/anthracene	µg/g	0.045
C2 subst'd phenanthrene/anthracene	µg/g	0.082
C3 subst'd phenanthrene/anthracene	µg/g	0.074
C4 subst'd phenanthrene/anthracene	µg/g	0.32
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.148
pyrene	µg/g	0.008

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-25 Water Quality in Kearl Lake

Parameter	Units	Winter (1983 to 2007)				Spring (1988 to 2006)				Summer (1966 to 2006)				Fall (1983 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.5	0	1.7	5	17.3	16	17.5	4	20.4	19	23.3	3	13	2	19	8
dissolved oxygen	mg/L	4.4[a][b]	0[a][b]	12.2	5	9.7	7.7	12.8	4	7.6	5.5[b]	8.2	4	9.8	6.4[b]	13.7	8
Conventional Parameters																	
colour	TCU	100	70	200	5	40	0	60	5	55	25	100	13	50	30	100	10
specific conductance	µS/cm	281	201	354	4	144	1	146	4	166	141	190	13	178	150	201	10
dissolved organic carbon	mg/L	40	32	40	3	18	<0.2	20	4	21	15	25	13	21	15	26	9
hardness	mg/L	125	67	161	6	59	<0.5	62	5	74	62	83	11	76	66	84	12
pH		8	7.8	8.4	4	7.8	6.4[a][b]	8.1	4	8	7.8	8.2	13	8	7.6	8.4	10
total alkalinity	mg/L	141	100	181	6	72	4	75	5	83	67	97	14	85	72	100	12
total dissolved solids	mg/L	157	104	280	6	77	2	100	5	125	90	192	12	122	90	220	12
total organic carbon	mg/L	41	27	42	4	20	<0.2	20	5	21	19	26	8	25	18	29	10
total suspended solids	mg/L	4	0.5	6	4	<1	<0.4	9	5	3	≤1	10	10	4	≤1	15	11
Major Ions																	
bicarbonate	mg/L	172	118	220	6	88	5	91	5	102	82	118	14	104	87	118	12
calcium	mg/L	33	17	42	6	15	<0.3	16	5	18	14	28	14	19	16	22	12
carbonate	mg/L	<4	<0.5	2	4	<0.5	<0.5	<5	5	<5	<0.5	0	10	<5	<0.5	<5	11
chloride	mg/L	0.5	≤0.5	2	5	<0.5	<0.5	1	4	0.5	≤0.279	2	13	<1	<0.5	2	11
magnesium	mg/L	10	6	14	6	6	<0.2	6	5	7	6	7	14	7	6	8	12
potassium	mg/L	1	1	2	5	1	<0.3	1	4	1	<0.005	1	13	1	1	1	11
sodium	mg/L	15	13	19	6	7	<0.5	12	5	10	8	12	14	10	8	13	12
sulphate	mg/L	6	3	11	6	3	<0.1	5	5	6	3	8	14	5	3	6	12
sulphide	mg/L	0.025[b]	0.019[b]	0.031[b]	2	<0.01	<0.003	<0.01	4	0.003	<0.002	0.04[b]	7	0.005	<0.002	0.01[b]	8
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.01	≤0.009	0.02	5	<0.005	<0.003	0.005	5	<0.05	≤0.00038	0.004	13	<0.1	<0.003	0.02	11
nitrogen – ammonia	mg/L	1.03	0.014	2.01	5	0.01	<0.01	0.03	5	0.014	≤0.011	0.248	12	0.085	≤0.04	0.53	10
nitrogen – kjeldahl	mg/L	2	1.3	3.5	6	0.7	<0.05	0.9	5	0.9	0.8	1.9	13	1.3	0.4	1.7	11
nitrogen – total nitrogen	mg/L	2[b]	1.3[b]	3.5[b]	6	0.7	<0.05	0.9	5	0.9	0.8	1.9[b]	13	1.3[b]	0.4	1.7[b]	11
phosphorus, total	mg/L	0.024	0.015	0.04	6	<0.1	≤0.017	0.025	5	0.018	0.009	0.041	14	0.025	0.009	0.04	12
phosphorus, dissolved	mg/L	0.008	0.008	0.009	2	<0.1	≤0.007	0.007	4	0.007	0.005	0.017	11	0.008	0.002	0.013	8
chlorophyll *a*	µg/L	<0.95	≤0.9	0.9	2	2	<1	4	4	5.6	1	15	12	4	1	12	7
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	1	≤0.7	6	4	2	≤1.1	3	5	<2	≤1.8	3	8	<2	≤1.7	4	10
General Organics																	
naphthenic acids	mg/L	0.5	<1	2	2	<1	<1	<1	4	<1	<1	2	8	<1	<1	1	9
total phenolics	mg/L	0.006[b]	<0.001	0.013[b]	2	<0.002	<0.002	0.008[b]	4	0.005	<0.001	0.022[b]	8	<0.001	<0.001	0.012[b]	8
total recoverable hydrocarbons	mg/L	0.1	<0.5	27.9	4	<4	<0.1	<4	5	<0.5	<0.1	<1	5	<0.5	<0.1	0.4	10
Toxicity																	
Microtox® IC50 @ 15 Min	%	–	–	–	0	–	–	–	0	>91	>91	>91	2	>91	>91	>91	3
Microtox® IC25 @ 15 Min	%	–	–	–	0	–	–	–	0	>91	>91	>91	2	>91	>91	>91	3
algal growth inhibition test (72h) – IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) – IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test – LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	89	89	89	1
ceriodaphnia 7d reproduction test – IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	58	58	58	1
fathead minnow 7d growth – IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth – IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test – LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test – LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-25 Water Quality in Kearl Lake (continued)

Parameter	Units	Winter (1983 to 2007)				Spring (1988 to 2006)				Summer (1966 to 2006)				Fall (1983 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Total Metals																	
aluminum	mg/L	0.0197	<0.01	0.03	4	0.015	0.01	0.03	5	0.02	<0.01	0.03	9	0.02	<0.01	0.13[(b)]	11
antimony	mg/L	0.0007	0.00002	0.0013	2	0.0008	0.0004	0.0009	4	<0.0008	≤0.0000203	0.0005	7	0.00002	≤0.00001	0.0023	8
arsenic	mg/L	0.0004	<0.0002	0.0005	5	<0.0002	<0.0002	0.006[(b)]	5	<0.0004	≤0.0001	0.0003	10	0.00004	<0.0002	0.0006	10
barium	mg/L	0.034	0.024	0.038	3	0.008	0.001	0.009	4	0.013	0.01	0.016	10	0.017	0.012	0.115	9
beryllium	mg/L	<0.001	≤0.0005	0.0005	2	<0.0002	<0.0002	<0.001	4	<0.001	<0.000003	0.00001	8	<0.001	<0.000003	0.000005	9
boron	mg/L	0.07	0.07	0.08	4	0.04	<0.01	0.04	5	0.05	0.04	0.06	9	0.05	0.01	0.07	11
cadmium	mg/L	<0.001	<0.00002	<0.001	5	<0.0002	<0.0002	<0.001	5	<0.0002	<0.000002	0.0005[(b)]	11	<0.0002	<0.00001	0.00004	11
calcium	mg/L	37	34	39	2	15	<0.3	16	4	18	15	20	7	19	15	49	8
chromium	mg/L	<0.001	≤0.0003	0.0003	5	0.003[(b)]	<0.0008	0.005[(b)]	5	<0.0008	≤0.000142	0.0005	11	0.0002	≤0.00018	0.348[(a)(b)]	11
cobalt	mg/L	<0.0002	≤0.0001	0.0001	3	<0.0003	<0.0002	<0.0003	4	<0.0002	≤0.0000375	0.0005	10	0.00003	≤0.00003	0.016	9
copper	mg/L	<0.001	<0.001	0.0077[(b)]	5	0.0004	≤0.0004	0.0005	5	<0.001	<0.00005	0.001	10	0.0001	≤0.00008	0.0023[(b)]	11
iron	mg/L	1.26[(b)]	0.25	2.4[(b)]	4	0.08	<0.01	0.11	5	0.07	≤0.003	0.1	12	0.07	0.04	0.19	11
lead	mg/L	0.0009	≤0.0002	0.005[(b)]	4	<0.0003	<0.0001	<0.002	5	<0.0001	≤0.000037	0.0002	9	0.0001	≤0.00002	0.0008	11
lithium	mg/L	0.009	0.009	0.009	2	<0.004	<0.004	<0.006	4	0.005	≤0.002	0.007	8	0.005	≤0.00431	0.007	9
magnesium	mg/L	11	11	11	1	6	<0.2	6	4	6	6	7	5	7	7	12	5
manganese	mg/L	0.26	0.074	0.299	5	0.007	<0.004	0.012	5	0.028	0.012	0.04	11	0.017	0.007	0.05	11
mercury	mg/L	<0.00005	<0.0000006	0.0000026	5	<0.0000006	<0.0000006	0.0000016	5	<0.0000008	<0.0000006	0.0001[(a)(b)]	10	<0.0000006	<0.0000006	0.0003[(a)(b)]	10
methyl mercury	mg/L	0.0000007	0.0000007	0.0000007	1	0.0000001	0.0000001	0.0000001	1	<0.00000003	<0.00000003	<0.00000003	1	0.00000005	0.00000005	0.00000005	1
molybdenum	mg/L	0.0001	≤0.0001	0.0002	3	<0.0002	≤0.0001	0.0001	4	<0.0001	<0.0001	0.0005	10	0.0001	≤0.00006	0.003	9
nickel	mg/L	<0.001	<0.001	0.0013	5	<0.0005	<0.0002	0.0017	5	0.0003	≤0.0000751	0.002	11	0.0006	<0.0002	0.0057	11
potassium	mg/L	1	1	1	1	1	<0.3	1	4	1	1	1	5	1	0.5	1	5
selenium	mg/L	0.0004	<0.0002	0.0006	5	<0.0002	<0.0002	0.0003	5	<0.0003	<0.0001	0.0001	10	<0.0006	<0.0001	0.0009	10
silicon	mg/L	–	–	–	0	0.4	<0.04	0.5	3	–	–	–	0	2.3	2.3	2.3	1
silver	mg/L	<0.000008	≤0.000005	0.000005	2	<0.000005	<0.000005	0.000026	4	<0.000005	<0.0000005	0.000002	8	<0.000005	<0.0000005	0.003[(a)(b)]	9
sodium	mg/L	15	15	15	1	8	<0.5	9	4	9	8	10	5	9	8	10	5
strontium	mg/L	0.12	0.12	0.12	2	0.04	<0.02	0.05	4	0.06	0.05	0.07	8	0.06	0.06	0.22	9
sulphur	mg/L	–	–	–	0	1.9	1.2	3	3	1.4	1.1	1.7	2	1.4	1	1.9	3
thallium	mg/L	<0.00005	<0.000003	<0.0001	2	<0.0002	<0.0001	<0.0002	4	<0.0001	≤0.000000564	0.000004	6	<0.00001	≤0.00000149	0.00001	7
titanium	mg/L	<0.0031	≤0.0012	0.0012	2	<0.001	<0.001	<0.005	4	<0.0006	<0.0006	0.0012	8	0.001	≤0.0003	0.004	9
uranium	mg/L	<0.0001	≤0.00001	0.00001	2	<0.0004	<0.0001	<0.0004	4	<0.0001	≤0.00000779	0.00001	7	0.00001	≤0.00000772	0.0003	9
vanadium	mg/L	0.0004	≤0.0004	0.005	5	<0.001	<0.0002	<0.001	5	<0.0003	<0.0002	0.002	11	0.0002	≤0.000187	0.002	11
zinc	mg/L	0.036[(b)]	0.002	0.062[(b)]	5	0.009	<0.004	0.022	5	0.012	≤0.0005	0.033[(b)]	11	0.007	0.001	0.024	11
Dissolved Metals																	
aluminum	mg/L	<0.008	≤0.006	0.006	2	0.0035	≤0.003	0.013	4	<0.01	≤0.00094	0.01	8	0.0017	≤0.00139	0.03	8
antimony	mg/L	0.0003	0.00001	0.0005	2	<0.0002	<0.0002	0.0008	4	<0.0008	≤0.0000199	0.0006	7	0.00001	≤0.00001	0.0007	8
arsenic	mg/L	0.0005	0.0005	0.0006	2	<0.0002	<0.0002	0.0002	4	0.0002	≤0.00025	0.0006	7	0.0002	≤0.0001	0.0004	8
barium	mg/L	0.034	0.032	0.035	2	0.008	0.0003	0.009	4	0.015	0.01	0.016	7	0.016	0.011	0.018	8
beryllium	mg/L	<0.0005	<0.00004	<0.001	3	<0.0002	<0.0002	<0.0005	4	<0.0005	<0.000003	0.0005	9	<0.0004	<0.000003	0.0002	8
boron	mg/L	0.07	0.07	0.07	2	0.01	<0.01	0.04	4	0.05	0.04	0.05	7	0.05	0.04	0.06	8
cadmium	mg/L	<0.0001	<0.00001	<0.0001	2	<0.0002	<0.0001	<0.0002	4	<0.0001	<0.000002	0.00001	7	<0.0001	<0.000002	0.00002	8
chromium	mg/L	<0.0004	≤0.0003	0.0003	2	<0.001	<0.001	0.001	4	<0.0004	≤0.0000895	0.0009	7	0.0002	≤0.00016	0.0007	8
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0002	0.0001	0.0003	2	<0.0003	<0.0003	0.0007	4	0.00003	≤0.0000144	0.0011	7	0.00004	≤0.00002	0.0012	8
copper	mg/L	0.0024	<0.0006	0.0054[(b)]	2	<0.0002	<0.0002	0.0008	4	0.0006	<0.00005	0.0046[(b)]	7	0.0003	≤0.00013	0.0031[(b)]	8
iron	mg/L	1.1[(b)]	0.94[(b)]	1.26[(b)]	2	0.04	<0.01	0.05	4	0.02	0.002	0.1	7	0.01	≤0.0081	0.12	8
lead	mg/L	0.0007	0.0002	0.0012	2	<0.0002	<0.0001	0	4	0.00001	≤0.00000726	0.0001	7	0.00003	≤0.00000977	0.0004	8

Table F-25 Water Quality in Kearl Lake (continued)

Parameter	Units	Winter (1983 to 2007)				Spring (1988 to 2006)				Summer (1966 to 2006)				Fall (1983 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
lithium	mg/L	0.01	0.009	0.01	2	<0.004	<0.004	0.005	4	0.006	0.003	0.006	7	0.006	0.004	0.007	8
manganese	mg/L	0.273	0.242	0.305	2	<0.004	≤0.002	0.002	4	0.001	0.001	0.008	7	0.002	≤0.000285	0.018	8
mercury	mg/L	<0.0000203	<0.0000006	<0.00004	2	<0.00001	<0.0000006	<0.00001	4	<0.0001	<0.0000006	<0.0001	6	<0.00007	<0.0000006	<0.0001	6
molybdenum	mg/L	0.0002	0.0001	0.0002	2	<0.0002	≤0.0001	0.0001	4	0.0001	≤0.0000981	0.0002	7	0.0001	≤0.00006	0.0002	8
nickel	mg/L	0.0008	0.0005	0.0011	2	<0.0005	≤0.0001	0.0001	4	0.0001	<0.000005	0.001	7	0.0002	<0.0001	0.0016	8
selenium	mg/L	0.0004	<0.0004	0.0012[(b)]	2	<0.0002	<0.0002	<0.0004	4	<0.0004	<0.0001	0.0004	7	<0.0004	<0.0001	<0.0005	8
silicon	mg/L	–	–	–	0	0.28	<0.04	0.29	3	–	–	–	0	–	–	–	0
silver	mg/L	<0.000005	<0.0000005	<0.00001	2	<0.0001	<0.0001	<0.0002	4	<0.0002	<0.0000005	<0.0002	7	<0.000005	<0.0000005	0.000005	8
strontium	mg/L	0.12	0.12	0.12	2	0.04	<0.02	0.05	4	0.06	0.05	0.07	7	0.06	0.06	0.07	8
sulphur	mg/L	–	–	–	0	1.2	<0.2	1.3	3	1.34	1.08	1.6	2	1.4	1.01	1.79	2
thallium	mg/L	<0.00003	≤0.00002	0.00002	2	<0.0002	<0.00005	<0.0002	4	<0.00005	<0.0000003	0.000003	6	<0.00001	≤0.00000128	0.00001	7
titanium	mg/L	0.0009	0.0005	0.0013	2	<0.001	≤0.0003	0.0003	4	0.0004	<0.0003	0.0007	7	0.0001	<0.0002	0.0009	8
uranium	mg/L	<0.0001	≤0.00001	0.00001	2	<0.0004	<0.0001	<0.0004	4	<0.0001	≤0.00000526	0.00001	7	<0.0001	≤0.000003	0.00001	8
vanadium	mg/L	0.0004	0.0003	0.0004	2	<0.001	≤0.0003	0.0003	4	<0.0001	<0.0001	0.0003	7	0.0002	<0.0001	0.0005	8
zinc	mg/L	0.004	0.003	0.006	2	0.003	<0.001	0.011	4	0.005	<0.002	0.028	7	0.005	0.002	0.011	8
Phenolics																	
phenol	µg/L	–	–	–	0	–	–	–	0	0.014	0.014	0.014	1	–	–	–	0

[(a)] Acute aquatic life guideline exceeded.

[(b)] Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-26 Sediment Quality in Kearl Lake

Parameter	Units	Fall (1998 to 2006)			
		Median	Min	Max	n
Particle Size					
partice size – % sand	%	8	7	9	2
partice size – % silt	%	52	33	71	2
partice size – % clay	%	40	22	58	2
moisture content	%	92	92	96	3
Carbon Content					
total inorganic carbon	% by wt	0.02	≤ 0.02	0.06	3
total organic carbon	% by wt	34.4	33.1	35.8	3
total carbon	% by wt	34.4	33.1	35.8	3
Toxicity					
chironomus tentans – 10d survival	% of control	100	100	100	1
chironomus tentans – 10d growth	% of control	55.2	55.2	55.2	1
hyalella azteca – 10d survival	% of control	111.1	111.1	111.1	1
hyalella azteca – 10d growth	% of control	300	300	300	1
lumbriculus variegatus – 10d survival	% of control	107.7	107.7	107.7	1
lumbriculus variegatus – 10d growth	% of control	87.5	87.5	87.5	1
Organics					
total recoverable hydrocarbons	mg/kg	1,400	1,200	1,600	3
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	<40	3
total extractable hydrocarbons (C11–C30)	mg/kg	190	78	270	3
Total Metals					
aluminum	µg/g	5,330	4,880	7,020	3
arsenic	µg/g	4.3	3.6	4.7	3
barium	µg/g	79	78	93	3
beryllium	µg/g	0.2	<0.2	0.3	3
boron	µg/g	30	14	30	3
cadmium	µg/g	0.4	0.4	0.4	3
calcium	µg/g	12,100	11,800	12,800	3
chromium	µg/g	10	9.3	11.6	3
cobalt	µg/g	4	3.7	4.3	3
copper	µg/g	10	10	29	3
iron	µg/g	7,450	7,020	8,000	3
lead	µg/g	5.8	4	6	3
magnesium	µg/g	2,190	2,170	2,380	3
manganese	µg/g	123	118	154	3
mercury	µg/g	0.06	<0.05	0.06	3
molybdenum	µg/g	0.9	0.7	1.1	3

Table F-26 Sediment Quality in Kearl Lake (continued)

Parameter	Units	Fall (1998 to 2006)			
		Median	Min	Max	n
nickel	µg/g	15.1	14.5	15.5	3
potassium	µg/g	1,120	800	1,300	3
selenium	µg/g	0.9	0.9	1	3
silver	µg/g	<0.1	<0.1	<0.2	3
sodium	µg/g	356	356	400	3
strontium	µg/g	47	45	49	3
thallium	µg/g	0.09	0.08	0.09	3
titanium	µg/g	73.9	16	108	3
uranium	µg/g	0.7	0.6	0.7	3
vanadium	µg/g	15.7	14.7	16.3	3
zinc	µg/g	81	78	103	3
Target PAHs and Alkylated PAHs					
naphthalene	µg/g	0.013	0.01	0.026	4
C1 subst'd naphthalenes	µg/g	0.015	0.014	0.057[(a)]	4
C2 subst'd naphthalenes	µg/g	0.066	0.019	0.305	4
C3 subst'd naphthalenes	µg/g	0.018	0.016	0.03	4
C4 subst'd naphthalenes	µg/g	0.01	0.004	0.018	4
acenaphthene	µg/g	0.0037	0.0029	0.0057	4
C1 subst'd acenaphthene	µg/g	0.012	0.0005	0.014	3
acenaphthylene	µg/g	0.0009	0.0003	0.0016	4
anthracene	µg/g	0.0038	0.003	0.0052	4
dibenzo(a,h)anthracene	µg/g	0.0107[(a)]	0.00318	0.028[(a)]	4
benzo(a)anthracene	µg/g	0.0078	0.002	0.0208	4
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.07	0.02	0.13	4
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.035	0.019	0.04	4
benzo(a)pyrene	µg/g	0.0061	0.0017	0.0134	4
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.013	<0.006	0.016	3
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.018	0.009	0.027	3
benzofluoranthenes	µg/g	0.032	<0.0004	0.079	4
benzo(g,h,i)perylene	µg/g	0.0251	0.004	0.036	4
biphenyl	µg/g	0.0042	0.0033	0.0067	3
C1 subst'd biphenyl	µg/g	<0.0007	<0.00063	0.00171	3
C2 subst'd biphenyl	µg/g	0.0016	0.0013	0.0052	3
chrysene	µg/g	0.015	0.004	0.033	3
dibenzothiophene	µg/g	0.0025	0.0017	0.0043	4

Table F-26 Sediment Quality in Kearl Lake (continued)

Parameter	Units	Fall (1998 to 2006)			
		Median	Min	Max	n
C1 subst'd dibenzothiophene	µg/g	0.0076	0.0058	0.1645	4
C2 subst'd dibenzothiophene	µg/g	0.0096	0.004	0.0865	4
C3 subst'd dibenzothiophene	µg/g	0.007	<0.0014	0.012	4
C4 subst'd dibenzothiophene	µg/g	0.008	0.004	0.01	3
fluoranthene	µg/g	0.0167	0.009	0.024	4
C1 subst'd fluoranthene/pyrene	µg/g	0.017	0.015	0.026	4
C2 subst'd fluoranthene/pyrene	µg/g	0.011	0.011	0.017	3
C3 subst'd fluoranthene/pyrene	µg/g	0.004	0.004	0.007	3
fluorene	µg/g	0.0145	0.0121	0.0193	4
C1 subst'd fluorene	µg/g	0.0311	0.018	0.069	4
C2 subst'd fluorene	µg/g	0.1555	0.0295	0.23	4
C3 subst'd fluorene	µg/g	0.016	0.01	0.0227	3
indeno(c,d–123)pyrene	µg/g	0.025	0.0038	0.0429	4
phenanthrene	µg/g	0.028	0.02	0.038	4
C1 subst'd phenanthrene/anthracene	µg/g	0.071	0.022	0.204	4
C2 subst'd phenanthrene/anthracene	µg/g	0.039	0.028	0.196	4
C3 subst'd phenanthrene/anthracene	µg/g	0.023	0.014	0.132	4
C4 subst'd phenanthrene/anthracene	µg/g	0.01	0	0.1	4
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.056	0.047	0.065	4
pyrene	µg/g	0.011	0.007	0.021	4

(a) Interim sediment quality guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-27 Water Quality in Unnamed Lakes within the Jackpine Expansion Mining Area

Parameter	Units	Winter (2004 to 2006)				Spring (2006 to 2006)				Summer (2003 to 2006)				Fall (2003 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.5	0.2	1.8	4	14.5	6.8	16.2	3	17.3	15.5	18	4	6.9	5.4	10.1	5
dissolved oxygen	mg/L	2.1[(a)(b)]	0.7[(a)(b)]	6.8	4	9.4	7	12.4	3	10.5	6.8	14.1	3	10	8.2	11.7	5
Conventional Parameters																	
colour	TCU	55	35	100	4	25	20	35	3	42	20	60	4	40	30	50	5
specific conductance	uS/cm	695	306	762	4	251	243	320	3	296	211	353	4	290	33	422	5
dissolved organic carbon	mg/L	24	16	44	4	13	11	20	3	15	2	19	3	18	13	24	4
hardness	mg/L	370	147	457	4	132	123	160	3	160	118	194	4	169	8	261	5
pH		7.8	7.3	7.9	4	8.4	8.3	8.5	3	8.2	8.1	8.5	4	8.2	8.2	8.4	4
total alkalinity	mg/L	356	152	444	4	134	128	170	3	164	115	194	4	154	7	235	5
total dissolved solids	mg/L	425	190	490	4	140	140	200	3	205	160	240	4	220	72	290	5
total organic carbon	mg/L	26	18	47	4	14	12	21	3	20	17	24	4	19	13	22	5
total suspended solids	mg/L	10	3	48	4	<3	<3	3	3	0.5	<3	6	4	3	<3	6	5
Major Ions																	
bicarbonate	mg/L	434	185	542	4	163	148	202	3	200	134	237	4	182	9	282	5
calcium	mg/L	108	44	114	4	37	37	44	3	46	29	53	4	48	2	59	5
carbonate	mg/L	<5	<5	<5	4	<5	<5	<5	3	<5	<5	<5	4	<5	<1	<5	5
chloride	mg/L	2	1	6	4	1	1	3	3	1	1	2	4	2	≤0.1	2	5
magnesium	mg/L	24	9	42	4	10	7	12	3	12	8	15	4	12	1	27	5
potassium	mg/L	2	1	4	4	1	1	2	3	0.1	<0.5	1	4	1	<0.5	1	5
sodium	mg/L	5	4	20	4	5	1	9	3	4	1	8	4	3	2	9	5
sulphate	mg/L	8	4	12	4	3	2	5	3	3	2	6	4	3	1	5	5
sulphide	mg/L	0.027[(b)]	0.005[(b)]	0.108[(b)]	4	<0.003	<0.003	<0.003	3	<0.003	<0.003	0.01	4	<0.003	<0.003	0.004	4
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	0.1	<0.1	0.1	4	<0.1	<0.1	0.1	3	0.1	<0.1	0.6	4	<0.1	<0.05	<0.1	5
nitrogen - ammonia	mg/L	0.12	0.09	0.13	4	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.1	5
nitrogen - kjeldahl	mg/L	1.3	0.7	2.1	4	0.8	0.6	0.9	3	1	0.5	1.3	4	0.8	0.5	1	5
nitrogen - total nitrogen	mg/L	1.3[(b)]	0.8	2.2[(b)]	4	0.9	0.6	0.9	3	1.2[(b)]	0.6	1.6[(b)]	4	0.8	0.5	1	5
phosphorus, total	mg/L	0.066[(b)]	0.007	0.122[(b)]	4	0.016	0.005	0.019	3	0.016	0.004	0.03	4	0.016	0.006	0.022	5
phosphorus, dissolved	mg/L	0.023	0.002	0.071	4	0.007	0.003	0.008	3	0.005	0.003	0.007	4	0.004	≤0.003	0.006	5
chlorophyll *a*	µg/L	10	<1	23	3	<1	<1	3	3	5	2	6	3	<1	<1	<1	1
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	<2	<2	4	3	<2	<2	3	3	2	<2	3	4	<2	<2	3	5
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	1	<1	<1	<1	1	<1	<1	<1	1	<1	<1	<1	1
total phenolics	mg/L	0.016[(b)]	0.016[(b)]	0.016[(b)]	1	0.004	0.004	0.004	1	0.018[(b)]	0.018[(b)]	0.018[(b)]	1	0.004	0.004	0.004	1
total recoverable hydrocarbons	mg/L	<1	<1	<1	1	<1	<1	<1	1	<1	<1	<1	1	<0.3	≤0.1	0.1	2
Toxicity																	
algal growth inhibition test (72h) - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	89	89	89	1
ceriodaphnia 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-27 Water Quality in Unnamed Lakes within the Jackpine Expansion Mining Area (continued)

Parameter	Units	Winter (2004 to 2006)				Spring (2006 to 2006)				Summer (2003 to 2006)				Fall (2003 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	50	50	50	1
ceriodaphnia 7d reproduction test - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	68	68	68	1
ceriodaphnia 7d reproduction test - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	92	92	92	1
ceriodaphnia 7d reproduction test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d reproduction test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	50	50	50	1
fathead minnow 7d growth - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
Total Metals																	
aluminum	mg/L	0.03	0.03	0.03	1	0.02	0.02	0.02	1	<0.02	<0.02	<0.02	1	0.02	<0.02	0.06	2
antimony	mg/L	0.0007	0.0007	0.0007	1	0.001	0.001	0.001	1	0.0012	0.0012	0.0012	1	0.0034	0.0018	0.005	2
arsenic	mg/L	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0027	<0.0004	<0.005	2
barium	mg/L	0.162	0.162	0.162	1	0.049	0.049	0.049	1	0.043	0.043	0.043	1	0.015	<0.03	0.06	2
beryllium	mg/L	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.0005	<0.001	2
boron	mg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.06	<0.02	<0.1	2
cadmium	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	1	<0.0001	<0.0001	<0.0002	2
chromium	mg/L	<0.0008	<0.0008	<0.0008	1	0.0085[(b)]	0.0085[(b)]	0.0085[(b)]	1	0.0014[(b)]	0.0014[(b)]	0.0014[(b)]	1	<0.0009	<0.0008	<0.001	2
cobalt	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	1	<0.0006	<0.0002	<0.001	2
copper	mg/L	<0.001	<0.001	<0.001	1	0.001	0.001	0.001	1	<0.001	<0.001	<0.001	1	<0.0015	<0.001	<0.002	2
iron	mg/L	0.5[(b)]	0.5[(b)]	0.5[(b)]	1	0.09	0.09	0.09	1	0.01	0.01	0.01	1	<0.06	≤0.013	0.01	2
lead	mg/L	0.0002	0.0002	0.0002	1	0.0005	0.0005	0.0005	1	0.0001	0.0001	0.0001	1	<0.001	<0.0001	<0.002	2
lithium	mg/L	0.011	0.011	0.011	1	<0.006	<0.006	<0.006	1	<0.006	<0.006	<0.006	1	<0.006	<0.006	<0.006	1
manganese	mg/L	0.418	0.418	0.418	1	0.004	0.004	0.004	1	0.008	0.008	0.008	1	0.006	0.003	0.009	2
mercury	mg/L	0.0000019	0.0000019	0.0000019	1	<0.0002	<0.0002	<0.0002	1	0.0000007	0.0000007	0.0000007	1	<0.0050003	<0.0000006	<0.01	2
methyl mercury	mg/L	0.0000019[(b)]	0.0000019[(b)]	0.0000019[(b)]	1	–	–	–	0	0.0000001	0.0000001	0.0000001	1	–	–	–	0
molybdenum	mg/L	0.0001	0.0001	0.0001	1	0.0003	0.0003	0.0003	1	<0.0001	<0.0001	<0.0001	1	<0.0006	≤0.0001	0.0001	2
nickel	mg/L	<0.0002	<0.0002	<0.0002	1	0.0012	0.0012	0.0012	1	<0.0002	<0.0002	<0.0002	1	<0.0011	<0.0002	<0.002	2
selenium	mg/L	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	0.0005	0.0005	0.0005	1	<0.0027	<0.0004	<0.005	2
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	0.2	0.2	0.2	1
silver	mg/L	0.000004	0.000004	0.000004	1	<0.0004	<0.0004	<0.0004	1	0.000018	0.000018	0.000018	1	<0.00025	<0.0000005	<0.0005	2
strontium	mg/L	0.12	0.12	0.12	1	0.05	0.05	0.05	1	0.05	0.05	0.05	1	0.06	0.06	0.06	1
thallium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1
titanium	mg/L	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1
uranium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1
vanadium	mg/L	<0.0002	<0.0002	<0.0002	1	<0.0002	<0.0002	<0.0002	1	0.0004	0.0004	0.0004	1	<0.0006	<0.0002	<0.001	2
zinc	mg/L	0.006	0.006	0.006	1	0.059[(b)]	0.059[(b)]	0.059[(b)]	1	<0.004	<0.004	<0.004	1	<0.014	<0.004	<0.025	2
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	1	0.01	0.01	0.01	1	<0.01	<0.01	<0.01	1	0.03	<0.01	0.07	2

Table F-27 Water Quality in Unnamed Lakes within the Jackpine Expansion Mining Area (continued)

Parameter	Units	Winter (2004 to 2006)				Spring (2006 to 2006)				Summer (2003 to 2006)				Fall (2003 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
antimony	mg/L	0.0006	0.0006	0.0006	1	0.0005	0.0005	0.0005	1	0.0007	0.0007	0.0007	1	<0.0014	≤0.0007	0.0007	2
arsenic	mg/L	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0027	<0.0004	<0.005	2
barium	mg/L	0.16	0.16	0.16	1	0.05	0.05	0.05	1	0.042	0.042	0.042	1	0.064	0.058	0.07	2
beryllium	mg/L	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	2
boron	mg/L	0.02	0.02	0.02	1	0.01	0.01	0.01	1	0.01	0.01	0.01	1	<0.05	≤0.006	0.01	2
cadmium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	2
chromium	mg/L	0.0016[(b)]	0.0016[(b)]	0.0016[(b)]	1	0.0032[(b)]	0.0032[(b)]	0.0032[(b)]	1	<0.0004	<0.0004	<0.0004	1	<0.0007	<0.0004	<0.001	2
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0001	0.0001	0.0001	1	0.0004	0.0004	0.0004	1	0.0013	0.0013	0.0013	1	<0.0006	<0.0001	<0.001	2
copper	mg/L	0.0006	0.0006	0.0006	1	0.0015	0.0015	0.0015	1	0.0009	0.0009	0.0009	1	<0.0013	<0.0006	<0.002	2
iron	mg/L	0.44[(b)]	0.44[(b)]	0.44[(b)]	1	0.03	0.03	0.03	1	0.01	0.01	0.01	1	0.01	0.01	0.02	2
lead	mg/L	0.0002	0.0002	0.0002	1	0.0005	0.0005	0.0005	1	<0.0001	<0.0001	<0.0001	1	<0.0006	<0.0001	<0.001	2
lithium	mg/L	0.011	0.011	0.011	1	0.004	0.004	0.004	1	0.004	0.004	0.004	1	0.004	0.004	0.004	1
manganese	mg/L	0.423	0.423	0.423	1	0.003	0.003	0.003	1	0.002	0.002	0.002	1	0.002	0.002	0.003	2
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	1	<0.0001	<0.0001	<0.0001	1	<0.0000006	<0.0000006	<0.0000006	1	<0.0050003	<0.0000006	<0.01	2
molybdenum	mg/L	0.0001	0.0001	0.0001	1	0.0003	0.0003	0.0003	1	<0.0001	<0.0001	<0.0001	1	<0.0006	<0.0001	<0.001	2
nickel	mg/L	<0.0001	<0.0001	<0.0001	1	0.0014	0.0014	0.0014	1	<0.0001	<0.0001	<0.0001	1	<0.001	<0.0001	<0.002	2
selenium	mg/L	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0004	<0.0004	<0.0004	1	<0.0027	<0.0004	<0.005	2
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	0.15	0.15	0.15	1
silver	mg/L	0.000001	0.000001	0.000001	1	–	–	–	0	<0.0002	<0.0002	<0.0002	1	<0.00035	<0.0002	<0.0005	2
strontium	mg/L	0.12	0.12	0.12	1	0.04	0.04	0.04	1	0.04	0.04	0.04	1	0.05	0.05	0.05	1
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	1	<0.00005	<0.00005	<0.00005	1	<0.00005	<0.00005	<0.00005	1	<0.00005	<0.00005	<0.00005	1
titanium	mg/L	0.002	0.002	0.002	1	0.0004	0.0004	0.0004	1	<0.0003	<0.0003	<0.0003	1	0.0009	0.0009	0.0009	1
uranium	mg/L	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1	<0.0001	<0.0001	<0.0001	1
vanadium	mg/L	0.0001	0.0001	0.0001	1	0.0004	0.0004	0.0004	1	0.0002	0.0002	0.0002	1	<0.0006	<0.0001	<0.001	2
zinc	mg/L	0.006	0.006	0.006	1	0.057[(b)]	0.057[(b)]	0.057[(b)]	1	0.007	0.007	0.007	1	0.003	0.002	0.004	2

[(a)] Acute aquatic life guideline exceeded.

[(b)] Chronic aquatic life guideline exceeded.

– = No data.

Notes: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-28 Sediment Quality in Unnamed Lakes Within the Jackpine Expansion Mining Area

Parameter	Units	Fall (2003 to 2005)		
		Min	Max	n
Particle Size				
partice size – % sand	%	15	67	2
partice size – % silt	%	25	39	2
partice size – % clay	%	8	46	2
moisture content	%	92	95	2
Carbon Content				
total inorganic carbon	% by wt	0.09	3.55	2
total organic carbon	% by wt	26.5	42.9	2
total carbon	% by wt	30.1	42.9	2
Toxicity				
chironomus tentans – 10d survival	% of control	67	67	1
chironomus tentans – 10d growth	% of control	132	132	1
hyalella azteca – 10d survival	% of control	88	88	1
hyalella azteca – 10d growth	% of control	74	74	1
lumbriculus variegatus – 10d survival	% of control	100	100	1
Organics				
total recoverable hydrocarbons	mg/kg	1,600	3,000	2
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	2
total extractable hydrocarbons (C11–C30)	mg/kg	30	500	2
Total Metals				
aluminum	µg/g	940	3,500	2
arsenic	µg/g	1.1	2.2	2
barium	µg/g	76	309	2
beryllium	µg/g	<0.2	<0.2	2
boron	µg/g	32	41	2
cadmium	µg/g	0.2	0.2	2
calcium	µg/g	22,000	170,000	2
chromium	µg/g	2.5	7.6	2
cobalt	µg/g	1	1.9	2
copper	µg/g	6	6	2
iron	µg/g	4,700	8,200	2
lead	µg/g	1.8	4.8	2
magnesium	µg/g	2,260	4,160	2
manganese	µg/g	113	213	2
mercury	µg/g	<0.05	0.11	2
molybdenum	µg/g	0.9	1.2	2
nickel	µg/g	3.2	6.7	2

Table F-28 Sediment Quality in Unnamed Lakes Within the Jackpine Expansion Mining Area (continued)

Parameter	Units	Fall (2003 to 2005)		
		Min	Max	n
potassium	µg/g	220	800	2
selenium	µg/g	0.2	0.5	2
silver	µg/g	<0.2	<0.2	2
sodium	µg/g	200	400	2
strontium	µg/g	69	104	2
thallium	µg/g	<0.05	0.07	2
titanium	µg/g	10	18	2
uranium	µg/g	0.2	0.5	2
vanadium	µg/g	3.8	12.4	2
zinc	µg/g	58	67	2
Target PAHs and Alkylated PAHs				
naphthalene	µg/g	0.009	0.011	2
C1 subst'd naphthalenes	µg/g	0.009	0.009	2
C2 subst'd naphthalenes	µg/g	0.066	0.411	2
C3 subst'd naphthalenes	µg/g	0.015	0.036	2
C4 subst'd naphthalenes	µg/g	0.006	0.016	2
acenaphthene	µg/g	0.0005	0.0018	2
C1 subst'd acenaphthene	µg/g	<0.0001	<0.0003	2
acenaphthylene	µg/g	0.0003	0.0005	2
anthracene	µg/g	0.0009	0.0014	2
dibenzo(a,h)anthracene	µg/g	<0.0008	<0.00151	2
benzo(a)anthracene	µg/g	0.0016	0.0016	2
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.04	0.07	2
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.006	0.014	2
benzo(a)pyrene	µg/g	≤0.000783	0.0008	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.004	0.01	2
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.003	0.008	2
benzofluoranthenes	µg/g	0.002	0.005	2
benzo(g,h,i)perylene	µg/g	0.0021	0.0023	2
biphenyl	µg/g	0.0049	0.0051	2
C1 subst'd biphenyl	µg/g	0.00081	0.00106	2
C2 subst'd biphenyl	µg/g	0.0038	0.0067	2
chrysene	µg/g	0.001	0.002	2
dibenzothiophene	µg/g	0.0006	0.0009	2
C1 subst'd dibenzothiophene	µg/g	0.0025	0.0067	2

Table F-28 Sediment Quality in Unnamed Lakes Within the Jackpine Expansion Mining Area (continued)

Parameter	Units	Fall (2003 to 2005)		
		Min	Max	n
C2 subst'd dibenzothiophene	µg/g	0.0046	0.007	2
C3 subst'd dibenzothiophene	µg/g	0.0028	0.0115	2
C4 subst'd dibenzothiophene	µg/g	0.005	0.014	2
fluoranthene	µg/g	0.0023	0.0059	2
C1 subst'd fluoranthene/pyrene	µg/g	0.005	0.009	2
C2 subst'd fluoranthene/pyrene	µg/g	0.005	0.008	2
C3 subst'd fluoranthene/pyrene	µg/g	0.004	0.004	2
fluorene	µg/g	0.0042	0.0069	2
C1 subst'd fluorene	µg/g	0.0064	0.0131	2
C2 subst'd fluorene	µg/g	0.013	0.0319	2
C3 subst'd fluorene	µg/g	0.0097	0.0251	2
indeno(c,d–123)pyrene	µg/g	0.002	0.0034	2
phenanthrene	µg/g	0.005	0.008	2
C1 subst'd phenanthrene/anthracene	µg/g	0.01	0.012	2
C2 subst'd phenanthrene/anthracene	µg/g	0.01	0.018	2
C3 subst'd phenanthrene/anthracene	µg/g	0.008	0.021	2
C4 subst'd phenanthrene/anthracene	µg/g	0.02	0.09	2
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.017	0.038	2
pyrene	µg/g	0.002	0.004	2

– = No data.

Notes: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-29 Water Quality of Watercourses in the Pierre River Watershed

Parameter	Units	Winter (2006 to 2006)				Spring (2006 to 2006)				Summer (2006 to 2006)				Fall (2005 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.5	0.3	0.7	2	0.4	0.2	10.1	3	16.5	12.7	20.4	2	7.8	5.8	8.4	3
dissolved oxygen	mg/L	7.3	6.8	7.9	2	13.7	13.7	13.7	1	11.2	7.8	14.7	2	8.2	8	8.5	2
Conventional Parameters																	
colour	TCU	82	63	100	2	85	15	120	4	70	70	70	3	125	80	200	3
specific conductance	µS/cm	974	707	1240	2	354	291	439	4	389	332	393	3	423	421	442	3
dissolved organic carbon	mg/L	16	11	20	2	18	15	18	3	26	25	29	3	29	27	37	3
hardness	mg/L	–	–	–	0	150	104	170	4	161	145	163	3	171	156	174	3
pH		7.5	7.4	7.6	2	7.9	7.6	8.3	4	8	8	8.1	3	8.1	8	8.2	3
total alkalinity	mg/L	390	314	466	2	88	85	179	4	117	67	120	3	131	79	138	3
total dissolved solids	mg/L	555	390	720	2	235	200	290	4	270	260	560	3	310	300	320	3
total organic carbon	mg/L	18	13	23	2	16	9	18	4	27	26	30	3	29	27	37	3
total suspended solids	mg/L	14	5	24	2	6	<3	24	4	8	<3	10	3	<3	<3	6	3
Major Ions																	
bicarbonate	mg/L	476	384	569	2	107	104	216	4	143	82	146	3	159	96	169	3
calcium	mg/L	87	80	95	2	39	26	51	4	41	39	42	3	44	39	46	3
carbonate	mg/L	<5	<5	<5	2	<5	<5	<5	4	<5	<5	<5	3	<5	<5	<5	3
chloride	mg/L	59	4	113	2	7	2	8	4	4	3	5	3	7	4	8	3
magnesium	mg/L	28	26	28	2	11	9	13	4	14	11	14	3	14	14	15	3
potassium	mg/L	4	3	5	2	5	1	9	4	3	2	3	3	3	2	3	3
sodium	mg/L	84	16	151	2	19	3	30	4	26	20	29	3	27	21	33	3
sulphate	mg/L	–	–	–	0	66	2	112	4	79	77	104	3	74	69	109	3
sulphide	mg/L	0.019[a]	0.003	0.034[a]	2	0.004	<0.003	0.011[a]	4	0.022[a]	0.015[a]	0.041[a]	3	0.022[a]	0.016[a]	0.023[a]	3
Nutrients and Chlorophyll *a*																	
nitrogen – nitrate/nitrite	mg/L	0.03	<0.05	0.1	2	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1	3
nitrogen – ammonia	mg/L	0.525	0.23	0.82	2	0.005	<0.05	0.19	4	<0.05	<0.05	0.06	3	<0.05	<0.05	<0.05	3
nitrogen – kjeldahl	mg/L	1.2	0.7	1.7	2	0.8	0.4	1.1	4	1	1	1.4	3	1	0.9	1.2	3
nitrogen – total nitrogen	mg/L	1.3[a]	0.7	1.8[a]	2	0.8	0.4	1.1[a]	4	1	1	1.4[a]	3	1	0.9	1.2[a]	3
phosphorus, total	mg/L	0.116[a]	0.097[a]	0.136[a]	2	0.092[a]	0.018	0.129[a]	4	0.062[a]	0.056[a]	0.104[a]	3	0.089[a]	0.07[a]	0.111[a]	3
phosphorus, dissolved	mg/L	0.005	0.004	0.005	2	0.063	0.029	0.093	3	0.059	0.035	0.067	3	0.054	0.025	0.081	3
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	4	2	7	2	0.5	<2	3	4	<2	<2	2	3	<2	<2	<2	3
General Organics																	
naphthenic acids	mg/L	2	1	3	2	<1	<1	<1	4	<1	<1	<1	3	1	<1	2	3
total phenolics	mg/L	0.055[a]	0.006[a]	0.104[a]	2	0.01[a]	0.005	0.026[a]	3	0.016[a]	0.016[a]	0.02[a]	3	0.013[a]	0.012[a]	0.014[a]	3
total recoverable hydrocarbons	mg/L	<1	<1	<1	2	<1	<1	<1	4	<1	<1	<1	3	<0.5	<0.5	<0.5	3
Total Metals																	
aluminum	mg/L	0.425[a]	0.2[a]	0.65[a]	2	0.26[a]	<0.02	0.74[a]	4	0.27[a]	0.1	0.27[a]	3	0.14[a]	0.11[a]	0.53[a]	3
antimony	mg/L	0.0006	0.0006	0.0007	2	0.001	<0.0004	0.0012	4	0.001	0.0009	0.0017	3	0.0015	0.0008	0.0015	3
arsenic	mg/L	0.0038	0.001	0.0067[a]	2	0.0011	<0.0004	0.0023	4	0.0016	0.0014	0.0016	3	0.0012	0.0011	0.0013	3
barium	mg/L	0.095	0.076	0.113	2	0.044	0.034	0.094	4	0.038	0.027	0.039	3	0.033	0.025	0.038	3

Table F-29 Water Quality of Watercourses in the Pierre River Watershed (continued)

Parameter	Units	Winter (2006 to 2006)				Spring (2006 to 2006)				Summer (2006 to 2006)				Fall (2005 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
beryllium	mg/L	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	3
boron	mg/L	0.26	0.08	0.43	2	0.05	0.03	0.13	4	0.14	0.12	0.14	3	0.09	0.09	0.1	3
cadmium	mg/L	<0.0002	<0.0002	<0.0002	2	<0.0002	<0.0002	<0.0002	4	<0.0002	<0.0002	<0.0002	3	<0.0002	<0.0002	<0.0002	3
chromium	mg/L	0.0034[(a)]	0.0027[(a)]	0.004[(a)]	2	0.0018[(a)]	0.001	0.0057[(a)]	4	0.0021[(a)]	0.0012[(a)]	0.0023[(a)]	3	0.0013[(a)]	<0.0008	0.0015[(a)]	3
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0062	0.004	0.0085	2	0.0018	<0.0002	0.0182	4	0.0011	0.0008	0.0013	3	0.0013	0.0008	0.0019	3
copper	mg/L	0.0035[(a)]	0.001	0.006[(a)]	2	0.0015	<0.001	0.003	4	0.002	0.001	0.003	3	0.002	<0.001	0.002	3
iron	mg/L	6.28[(a)]	2.35[(a)]	10.2[(a)]	2	2.79[(a)]	1.17[(a)]	7.52[(a)]	4	1.45[(a)]	1.13[(a)]	1.57[(a)]	3	2.05[(a)]	1.9[(a)]	2.54[(a)]	3
lead	mg/L	0.0002	0.0001	0.0004	2	0.0004	<0.0001	0.0006	4	0.0003	0.0002	0.0004	3	0.0002	<0.0001	0.0003	3
lithium	mg/L	0.07	0.042	0.099	2	0.032	0.008	0.049	4	0.045	0.043	0.054	3	0.049	0.046	0.05	3
manganese	mg/L	3.155	1.38	4.93	2	1.062	0.057	2.44	4	0.111	0.105	0.298	3	0.16	0.069	0.196	3
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	2	<0.0000006	<0.0000006	0.0000008	4	0.0000012	0.0000008	0.000002	3	0.0000007	<0.0000006	0.0000011	3
methyl mercury	mg/L	<0.00000003	<0.00000003	<0.00000003	2	<0.00000003	<0.00000003	<0.00000003	4	<0.00000003	<0.00000003	0.00000003	3	–	–	–	0
molybdenum	mg/L	0.0022	0.0005	0.0038	2	0.0011	0.0001	0.0017	4	0.0008	0.0006	0.0009	3	0.0008	0.0005	0.0011	3
nickel	mg/L	0.008	0.0061	0.01	2	0.0087	<0.0002	0.0217	4	0.0108	0.0072	0.0191	3	0.0163	0.0154	0.0248	3
selenium	mg/L	0.00055	<0.0004	0.0015[(a)]	2	0.00075	<0.0004	0.0009	4	<0.0004	<0.0004	0.0005	3	0.0006	0.0005	0.0007	3
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	0.000008	0.000005	0.000012	2	<0.000207	≤ 0.0000046	0.000014	4	0.000012	0.000004	0.000026	3	0.000005	0.000004	0.000009	3
strontium	mg/L	0.39	0.29	0.49	2	0.16	0.13	0.2	4	0.22	0.19	0.22	3	0.22	0.2	0.22	3
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	0.00005	<0.0001	0.0002	2	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
titanium	mg/L	0.0095	0.006	0.013	2	0.0075	<0.005	0.027	4	<0.005	<0.005	0.006	3	0.005	<0.005	0.011	3
uranium	mg/L	0.0012	0.0005	0.0018	2	0.0002	<0.0001	0.0008	4	0.0002	0.0002	0.0003	3	0.0004	0.0002	0.0005	3
vanadium	mg/L	0.0022	0.001	0.0033	2	0.0016	<0.0002	0.0035	4	0.0016	0.0013	0.0016	3	0.0009	<0.0002	0.001	3
zinc	mg/L	0.001	<0.004	0.006	2	0.012	0.005	0.054[(a)]	4	0.006	0.005	0.012	3	0.005	0.005	0.01	3
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	2	0.02	0.02	0.04	3	0.02	0.02	0.03	3	0.01	0.01	0.03	3
antimony	mg/L	0.0008	0.0007	0.0009	2	0.0008	0.0008	0.0008	3	0.0008	0.0007	0.0011	3	0.0006	0.0006	0.0007	3
arsenic	mg/L	0.0024	0.0006	0.0042	2	0.0009	0.0007	0.0015	3	0.0013	0.0011	0.0014	3	0.0011	0.0009	0.0013	3
barium	mg/L	0.069	0.044	0.094	2	0.031	0.027	0.035	3	0.03	0.025	0.031	3	0.025	0.023	0.033	3
beryllium	mg/L	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	3
boron	mg/L	0.24	0.08	0.39	2	0.08	0.05	0.12	3	0.11	0.1	0.13	3	0.11	0.09	0.12	3
cadmium	mg/L	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
chromium	mg/L	0.0012[(a)]	0.0011[(a)]	0.0013[(a)]	2	0.003[(a)]	0.0018[(a)]	0.0047[(a)]	3	0.0018[(a)]	0.001	0.0019[(a)]	3	<0.0004	<0.0004	0.0006	3
chromium – hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0061	0.0041	0.0081	2	0.0035	0.0007	0.0177	3	0.0011	0.0009	0.0025	3	0.0011	0.0005	0.0015	3
copper	mg/L	0.0034[(a)]	0.0007	0.006[(a)]	2	0.0015	0.0015	0.0019	3	0.0012	0.0009	0.002	3	0.0016	0.0015	0.0019	3
iron	mg/L	1.86[(a)]	0.15	3.56[(a)]	2	2.96[(a)]	0.6[(a)]	4.53[(a)]	3	0.79[(a)]	0.58[(a)]	0.81[(a)]	3	0.77[(a)]	0.56[(a)]	1.82[(a)]	3
lead	mg/L	<0.0001	<0.0001	<0.0001	2	0.0005	0.0005	0.0006	3	<0.0001	<0.0001	<0.0001	3	0.0001	0.0001	0.0002	3
lithium	mg/L	0.068	0.043	0.094	2	0.037	0.026	0.049	3	0.046	0.044	0.046	3	0.05	0.046	0.053	3
manganese	mg/L	3.105	1.43	4.78	2	2	0.06	2.48	3	0.088	0.076	0.262	3	0.155	0.06	0.198	3

Table F-29 Water Quality of Watercourses in the Pierre River Watershed (continued)

Parameter	Units	Winter (2006 to 2006)				Spring (2006 to 2006)				Summer (2006 to 2006)				Fall (2005 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	2	<0.0000006	<0.0000006	<0.0001	5	<0.0000006	<0.0000006	<0.0000006	3	<0.0000006	<0.0000006	0.0000008	3
molybdenum	mg/L	0.0014	0.0004	0.0023	2	0.0012	0.0011	0.0015	3	0.0008	0.0005	0.0009	3	0.0007	0.0006	0.001	3
nickel	mg/L	0.007	0.0052	0.0089	2	0.0095	0.0091	0.0214	3	0.0095	0.0067	0.0163	3	0.0149	0.0142	0.0216	3
selenium	mg/L	0.0009	0.0005	0.0013[(a)]	2	<0.0004	<0.0004	<0.0004	3	0.0007	<0.0004	0.0008	3	<0.0004	<0.0004	0.0006	3
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	0.000001	<0.0000005	0.000003	2	<0.0002	≤0.0000024	0.000002	4	<0.0002	≤0.0000043	0.000004	3	<0.0002	<0.0002	<0.0002	3
strontium	mg/L	0.36	0.29	0.44	2	0.16	0.11	0.18	3	0.21	0.2	0.22	3	0.2	0.18	0.21	3
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	2	<0.00005	<0.00005	<0.00005	3	<0.00005	<0.00005	<0.00005	3	<0.00005	<0.00005	<0.00005	3
titanium	mg/L	0.0013	0.0012	0.0014	2	0.0011	0.0009	0.0018	3	0.0015	0.0015	0.0016	3	0.0009	0.0008	0.001	3
uranium	mg/L	0.0012	0.0005	0.0019	2	0.0002	0.0002	0.0008	3	0.0002	0.0002	0.0002	3	0.0003	0.0002	0.0004	3
vanadium	mg/L	0.0001	<0.0001	0.0001	2	0.0004	<0.0001	0.0006	3	0.0005	<0.0001	0.0006	3	<0.0001	<0.0001	0.0001	3
zinc	mg/L	0.002	<0.002	0.006	2	0.058[(a)]	0.057[(a)]	0.064[(a)]	3	0.009	0.003	0.01	3	0.011	0.005	0.013	3
Target PAHs and Alkylated PAH																	
naphthalene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	0.03	0.03	0.03	1
C1 subst'd naphthalenes	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C2 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd acenaphthene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
anthracene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
benzo(g,h,i)perylene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
biphenyl	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1

Table F-29 Water Quality of Watercourses in the Pierre River Watershed (continued)

Parameter	Units	Winter (2006 to 2006)				Spring (2006 to 2006)				Summer (2006 to 2006)				Fall (2005 to 2005)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C4 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd fluoranthene/pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d–123)pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
phenanthrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1

(a) Chronic aquatic life guideline exceeded.

– = No data.

Notes: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-30 Sediment Quality of Watercourses in the Pierre River Watershed

Parameter	Units	Fall (2005)
		n = 1
Particle Size		
partice size – % sand	%	92
partice size – % silt	%	6
partice size – % clay	%	2
moisture content	%	25
Carbon Content		
total inorganic carbon	% by wt	0.13
total organic carbon	% by wt	0.9
total carbon	% by wt	1.1
Organics		
total recoverable hydrocarbons	mg/kg	3,600
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5
total extractable hydrocarbons (C11–C30)	mg/kg	17
Total Metals		
aluminum	µg/g	1,770
arsenic	µg/g	3.4
barium	µg/g	84
beryllium	µg/g	0.2
boron	µg/g	6
cadmium	µg/g	0.1
calcium	µg/g	4,900
chromium	µg/g	3.7
cobalt	µg/g	3.8
copper	µg/g	3
iron	µg/g	6,500
lead	µg/g	2.3
magnesium	µg/g	1,650
manganese	µg/g	118
mercury	µg/g	<0.05
molybdenum	µg/g	0.4
nickel	µg/g	8.9
potassium	µg/g	400
selenium	µg/g	0.3
silver	µg/g	<0.2
sodium	µg/g	100
strontium	µg/g	17
thallium	µg/g	0.08
titanium	µg/g	20

Table F-30 Sediment Quality of Watercourses in the Pierre River Watershed (continued)

Parameter	Units	Fall (2005)
		n = 1
uranium	µg/g	0.3
vanadium	µg/g	10.5
zinc	µg/g	26
Target PAHs and Alkylated PAHs		
naphthalene	µg/g	0.002
C1 subst'd naphthalenes	µg/g	0.003
C2 subst'd naphthalenes	µg/g	0.012
C3 subst'd naphthalenes	µg/g	0.042
C4 subst'd naphthalenes	µg/g	0.124
acenaphthene	µg/g	0.0007
C1 subst'd acenaphthene	µg/g	0.0002
acenaphthylene	µg/g	<0.0003
anthracene	µg/g	<0.0023
dibenzo(a,h)anthracene	µg/g	0.00703[(a)]
benzo(a)anthracene	µg/g	0.0051
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.9
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.371
benzo(a)pyrene	µg/g	0.0089
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.18
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.098
benzofluoranthenes	µg/g	0.022
benzo(g,h,i)perylene	µg/g	0.0303
biphenyl	µg/g	0.0011
C1 subst'd biphenyl	µg/g	0.00032
C2 subst'd biphenyl	µg/g	0.0023
chrysene	µg/g	0.072[(a)]
dibenzothiophene	µg/g	0.0018
C1 subst'd dibenzothiophene	µg/g	0.0613
C2 subst'd dibenzothiophene	µg/g	0.436
C3 subst'd dibenzothiophene	µg/g	0.898
C4 subst'd dibenzothiophene	µg/g	0.487
fluoranthene	µg/g	<0.0018
C1 subst'd fluoranthene/pyrene	µg/g	0.114
C2 subst'd fluoranthene/pyrene	µg/g	0.279
C3 subst'd fluoranthene/pyrene	µg/g	0.314
fluorene	µg/g	0.0012
C1 subst'd fluorene	µg/g	0.0096

Table F-30 Sediment Quality of Watercourses in the Pierre River Watershed (continued)

Parameter	Units	Fall (2005)
		n = 1
C2 subst'd fluorene	µg/g	0.0792
C3 subst'd fluorene	µg/g	0.192
indeno(c,d–123)pyrene	µg/g	0.0123
phenanthrene	µg/g	0.006
C1 subst'd phenanthrene/anthracene	µg/g	0.045
C2 subst'd phenanthrene/anthracene	µg/g	0.135
C3 subst'd phenanthrene/anthracene	µg/g	0.2
C4 subst'd phenanthrene/anthracene	µg/g	0.99
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.047
pyrene	µg/g	0.02

(a) Interim sediment quality guideline exceeded.

– = No data.

Notes: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-31 Water Quality of Watercourses in the Eymundson Creek Watershed

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.1	0	0.2	2	5.7	0.1	11	7	11.9	11.1	20.9	5	5.1	2.4	7.3	6
dissolved oxygen	mg/L	1.8[(a)(b)]	1[(a)(b)]	2.7[(a)(b)]	2	13.7	11.3	14	6	13.9	3.5[(a)(b)]	15.3	5	9.2	6[(b)]	11.8	6
Conventional Parameters																	
colour	TCU.	215	130	300	2	60	35	150	7	66	50	120	7	250	30	400	6
specific conductance	uS/cm	816	810	823	2	280	162	429	7	294	229	335	7	350	262	435	6
dissolved organic carbon	mg/L	73	56	90	2	15	12	23	7	19	15	40	7	18	15	37	6
hardness	mg/L	312	308	316	2	103	47	157	7	129	84	138	7	136	105	184	6
pH		7	6.6	7.4	2	7.7	6.9	8	7	7.8	7	8.1	7	8	7.8	8.2	6
total alkalinity	mg/L	289	199	379	2	42	8	72	7	67	25	101	7	96	42	118	6
total dissolved solids	mg/L	595	590	600	2	270	160	430	7	250	200	290	7	285	250	300	6
total organic carbon	mg/L	85	66	104	2	17	14	27	7	19	15	40	7	22	14	38	6
total suspended solids	mg/L	179	170	188	2	523	38	7,200	7	91	11	408	7	38	10	244	6
Major Ions																	
bicarbonate	mg/L	353	243	463	2	51	9	88	7	82	30	123	7	117	51	144	6
calcium	mg/L	74	72	75	2	27	12	44	7	32	19	36	7	35	25	48	6
carbonate	mg/L	<5	<5	<5	2	<5	<5	<5	7	<5	<5	<5	7	<5	<5	<5	6
chloride	mg/L	9	8	10	2	4	2	5	7	3	1	4	7	4	3	5	6
magnesium	mg/L	31	31	31	2	9	4	12	7	10	7	12	7	12	8	16	6
potassium	mg/L	9	9	9	2	4	2	8	7	2	1	4	7	2	1	5	6
sodium	mg/L	62	60	63	2	18	11	33	7	16	13	28	7	24	14	29	6
sulphate	mg/L	142	63	220	2	84	22	152	7	85	27	111	7	80	27	113	6
sulphide	mg/L	0.065[(b)]	0.022[(b)]	0.108[(b)]	2	0.018[(b)]	<0.003	0.023[(b)]	7	0.02[(b)]	<0.003	0.051[(b)]	7	0.01[(b)]	<0.003	0.025[(b)]	6
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	<0.1	<0.1	<0.1	2	0.1	<0.1	0.3	7	<0.1	<0.1	0.2	7	<0.1	<0.1	<0.1	6
nitrogen - ammonia	mg/L	3.055	2.19	3.92	2	<0.05	<0.05	0.27	7	<0.05	<0.05	<0.05	7	<0.05	<0.05	<0.05	6
nitrogen - kjeldahl	mg/L	6.5	4.5	8.5	2	1.8	0.5	7.9	7	1.3	0.8	2.7	7	0.8	0.5	2	6
nitrogen - total nitrogen	mg/L	6.5[(b)]	4.5[(b)]	8.5[(b)]	2	1.8[(b)]	0.5	7.9[(b)]	7	1.3[(b)]	0.8	2.8[(b)]	7	0.8	0.5	2[(b)]	6
phosphorus, total	mg/L	1.578[(b)]	0.097[(b)]	3.06[(b)]	2	0.374[(b)]	0.214[(b)]	4.15[(b)]	7	0.057[(b)]	0.021	0.169[(b)]	7	0.143[(b)]	0.1[(b)]	0.361[(b)]	6
phosphorus, dissolved	mg/L	0.027	0.022	0.032	2	0.048	0.014	0.151	7	0.037	0.021	0.059	7	0.041	0.021	0.063	6
chlorophyll *a*	µg/L	–	–	–	0	–	–	–	0	<1	<1	<1	1	–	–	–	0
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	<8	≤6	6	2	<2	<2	5	7	<2	<2	2	7	<2	<2	6	6
General Organics																	
naphthenic acids	mg/L	1	<1	3	2	<1	<1	<1	7	<1	<1	<1	7	1	<1	3	6
total phenolics	mg/L	0.034[(b)]	0.034[(b)]	0.034[(b)]	1	0.006[(b)]	<0.001	0.038[(b)]	7	0.013[(b)]	0.009[(b)]	0.021[(b)]	7	0.007[(b)]	<0.001	0.015[(b)]	6
total recoverable hydrocarbons	mg/L	<1	<1	<1	2	<1	<1	<1	7	<1	<1	<1	7	<1	<0.5	<1	6
Toxicity																	
algal growth inhibition test (72h) - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d reproduction test - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	39	39	39	1
ceriodaphnia 7d reproduction test - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-31 Water Quality of Watercourses in the Eymundson Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d reproduction test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	50	50	50	1
ceriodaphnia 7d reproduction test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	25	25	25	1
fathead minnow 7d growth - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
Total Metals																	
aluminum	mg/L	0.875[a][b]	0.52[b]	1.23[a][b]	2	18.2[a][b]	1.31[a][b]	47[a][b]	7	5.63[a][b]	0.06	22.5[a][b]	7	1.83[a][b]	0.34[b]	10.2[a][b]	6
antimony	mg/L	0.0008	0.0007	0.0008	2	0.001	0.0009	0.0013	7	0.001	0.0004	0.0013	7	0.0014	0.0009	0.0018	6
arsenic	mg/L	0.0213[b]	0.0143[b]	0.0283[b]	2	0.0077[b]	0.0024	0.06[b]	7	0.0028	0.0014	0.0104[b]	7	0.0023	0.0016	0.0045	6
barium	mg/L	0.128	0.108	0.147	2	0.246	0.044	1.14	7	0.087	0.02	0.323	7	0.045	0.034	0.141	6
beryllium	mg/L	<0.001	<0.001	<0.001	2	<0.001	<0.001	0.005	7	<0.001	<0.001	0.001	7	<0.001	<0.001	<0.001	6
boron	mg/L	0.24	0.19	0.3	2	0.14	0.03	0.28	7	0.11	0.09	0.17	7	0.08	0.07	0.13	6
cadmium	mg/L	<0.0002	<0.0002	<0.0002	2	0.0002	<0.0002	0.0017[b]	7	<0.0002	<0.0002	0.0007[b]	7	<0.0002	<0.0002	0.0003	6
chromium	mg/L	0.0025[b]	0.002[b]	0.003[b]	2	0.0341[a][b]	0.0031[b]	0.131[a][b]	7	0.0093[b]	<0.0008	0.0451[a][b]	7	0.003[b]	<0.0008	0.021[a][b]	6
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0279	0.0197	0.0361	2	0.0074	0.0042	0.0498	7	0.0028	0.0006	0.0134	7	0.0016	0.0014	0.0054	6
copper	mg/L	0.0025	0.002	0.003	2	0.022[a][b]	0.002	0.145[a][b]	7	0.008[b]	0.002	0.031[a][b]	7	0.004[b]	0.002	0.011[b]	6
iron	mg/L	81.95[b]	80.8[b]	83.1[b]	2	18.8[b]	5.7[b]	116[b]	7	5.87[b]	0.94[b]	26.8[b]	7	4.38[b]	2.17[b]	11.2[b]	6
lead	mg/L	0.0006	0.0006	0.0007	2	0.0132[b]	0.0013	0.0974[a][b]	7	0.0034	0.0001	0.0159[b]	7	0.0014	0.0002	0.0058[b]	6
lithium	mg/L	0.108	0.087	0.13	2	0.057	0.021	0.166	7	0.044	0.032	0.061	7	0.04	0.037	0.053	6
manganese	mg/L	8.425	5.45	11.4	2	0.473	0.158	1.28	7	0.125	0.061	0.302	7	0.166	0.099	0.236	6
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	2	0.000003	<0.0000006	0.0000073[b]	7	0.0000071[b]	0.0000007	0.000031[a][b]	7	0.0000011	<0.0000006	0.0000021	6
methyl mercury	mg/L	0.00000004	<0.00000003	0.0000001	2	<0.00000003	<0.00000003	<0.00000003	7	<0.00000003	<0.00000003	<0.00000003	7	<0.00000003	<0.00000003	<0.00000003	2
molybdenum	mg/L	0.0011	0.0008	0.0014	2	0.0028	0.0006	0.0153	7	0.0018	0.0009	0.0053	7	0.0018	0.0006	0.0047	6
nickel	mg/L	0.0236	0.0142	0.0329	2	0.0298	0.0108	0.153[b]	7	0.0167	0.0148	0.0574	7	0.0135	0.0115	0.03	6
selenium	mg/L	0.0013[b]	0.0008	0.0018[b]	2	0.0012[b]	0.0008	0.0062[b]	7	0.0006	<0.0004	0.0016[b]	7	0.0007	<0.0004	0.0012[b]	6
silver	mg/L	0.000024	0.000023	0.000025	2	0.000142[b]	≤0.000121	0.000522[b]	7	0.000042	0.000006	0.000116[b]	7	0.000029	0.000018	0.000053	6
strontium	mg/L	0.52	0.51	0.52	2	0.22	0.08	0.45	7	0.17	0.14	0.25	7	0.19	0.16	0.22	6
thallium	mg/L	<0.0001	<0.0001	<0.0001	2	0.0004	<0.0001	0.0018[b]	7	0.0002	<0.0001	0.0007	7	<0.0001	<0.0001	0.0003	6
titanium	mg/L	0.0225	0.013	0.032	2	0.189	0.038	0.269	7	0.047	<0.005	0.261	7	0.017	<0.005	0.073	6
uranium	mg/L	0.0013	0.0009	0.0017	2	0.002	0.0003	0.0124	7	0.0009	0.0001	0.0035	7	0.0008	0.0003	0.0016	6
vanadium	mg/L	0.0067	0.0067	0.0067	2	0.074	0.0053	0.236	7	0.0211	0.0004	0.103	7	0.0072	0.0012	0.0516	6
zinc	mg/L	0.04[b]	0.022	0.057[b]	2	0.105[b]	0.036[b]	0.542[a][b]	7	0.038[b]	<0.004	0.447[a][b]	7	0.026	0.008	0.063[b]	6
Dissolved Metals																	
aluminum	mg/L	0.02	0.02	0.02	2	0.17[b]	0.07	0.24[b]	7	0.1	<0.01	0.17[b]	7	0.09	0.01	0.12[b]	6
antimony	mg/L	0.0008	0.0008	0.0008	2	0.0009	0.0005	0.0012	7	0.0008	<0.0004	0.0013	7	0.0008	0.0006	0.0011	6
arsenic	mg/L	0.0082[b]	0.0042	0.0122[b]	2	0.0008	0.0005	0.0017	7	0.0009	0.0009	0.0014	7	0.001	0.0008	0.0015	6
barium	mg/L	0.04	0.027	0.052	2	0.017	0.011	0.029	7	0.017	0.015	0.022	7	0.015	0.013	0.021	6
beryllium	mg/L	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	7	<0.0005	<0.0005	<0.0005	7	<0.0005	<0.0005	<0.0005	6
boron	mg/L	0.25	0.19	0.3	2	0.08	0.04	0.12	7	0.08	0.03	0.16	7	0.1	0.08	0.12	6
cadmium	mg/L	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	7	<0.0001	<0.0001	<0.0001	7	<0.0001	<0.0001	0.0001	6
chromium	mg/L	0.0014[b]	0.0007	0.0022[b]	2	0.0032[b]	<0.0004	0.0049[b]	7	0.001	<0.0004	0.0015[b]	7	0.0005	<0.0004	0.0016[b]	6

Table F-31 Water Quality of Watercourses in the Eymundson Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0294	0.025	0.0338	2	0.0032	0.0016	0.0081	7	0.0021	0.0006	0.0102	7	0.0015	0.0007	0.0039	6
copper	mg/L	0.0012	<0.0006	0.0029	2	0.0036[(b)]	0.0012	0.0041[(b)]	7	0.0025	0.0016	0.0029	7	0.0016	0.001	0.0035[(b)]	6
iron	mg/L	46.7[(b)]	45.7[(b)]	47.7[(b)]	2	0.55[(b)]	0.27	5.38[(b)]	7	0.6[(b)]	0.42[(b)]	0.81[(b)]	7	0.96[(b)]	0.32[(b)]	2.28[(b)]	6
lead	mg/L	<0.0001	<0.0001	<0.0001	2	0.0006	0.0003	0.0008	7	0.0002	<0.0001	0.0002	7	0.0002	<0.0001	0.0003	6
lithium	mg/L	0.113	0.096	0.131	2	0.03	0.017	0.043	7	0.031	0.024	0.042	7	0.039	0.028	0.045	6
manganese	mg/L	7.585	4.87	10.3	2	0.239	0.045	0.958	7	0.083	0.046	0.165	7	0.11	0.082	0.193	6
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	2	<0.0000006	<0.0000006	0.0000019	7	<0.0000006	<0.0000006	0.000001	7	<0.0000006	<0.0000006	0.0000011	6
molybdenum	mg/L	0.001	0.0008	0.0013	2	0.001	0.0005	0.0049	7	0.0014	0.0007	0.0032	7	0.0013	0.0005	0.0034	6
nickel	mg/L	0.0214	0.0137	0.029	2	0.0107	0.008	0.0182	7	0.0113	0.0083	0.0181	7	0.0113	0.0088	0.0272	6
selenium	mg/L	0.0008	0.0006	0.001	2	<0.0004	<0.0004	0.0007	7	0.0007	0.0006	0.0008	7	0.0001	<0.0004	0.0009	6
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	0.000007	0.000003	0.00001	2	0.000006	≤0.0000065	0.000011	7	<0.0002	≤0.0000029	0.000004	7	<0.0002	≤0.0000023	0.00001	6
strontium	mg/L	0.46	0.45	0.47	2	0.13	0.07	0.18	7	0.16	0.12	0.17	7	0.16	0.12	0.2	6
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	2	0.00006	<0.00005	0.00012	7	<0.00005	<0.00005	<0.00005	7	<0.00005	<0.00005	<0.00005	6
titanium	mg/L	0.0016	0.0015	0.0017	2	0.0065	0.001	0.0169	7	0.0041	0.0006	0.0075	7	0.0036	0.0007	0.0115	6
uranium	mg/L	0.001	0.0005	0.0015	2	0.0003	<0.0001	0.0007	7	0.0004	0.0001	0.0007	7	0.0007	0.0003	0.001	6
vanadium	mg/L	0.0009	0.0006	0.0013	2	0.0004	<0.0001	0.0015	7	<0.0001	<0.0001	0.0012	7	0.0003	<0.0001	0.0005	6
zinc	mg/L	0.008	0.004	0.011	2	0.067[(b)]	0.016	0.132[(a)(b)]	7	0.005	0.003	0.011	7	0.009	0.005	0.022	6
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd naphthalenes	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	0.02	0.02	0.02	1	<0.01	<0.01	<0.01	1
C2 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	0.06	0.06	0.06	1	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	0.06	0.06	0.06	1	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
Acenaphthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	0.01	0.01	0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd acenaphthene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
anthracene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
benzo(g,h,i)perylene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
biphenyl	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.02	<0.02	<0.02	1
C1 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1

Table F-31 Water Quality of Watercourses in the Eymundson Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C4 subst'd dibenzothiophene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	0.02	0.02	0.02	1	<0.01	<0.01	<0.01	1
C1 subst'd fluoranthene/pyrene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
fluorene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	0.02	0.02	0.02	1	<0.01	<0.01	<0.01	1
C1 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
indeno(c,d-123)pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1
phenanthrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	0.1	0.1	0.1	1	<0.01	<0.01	<0.01	1
C1 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	0.07	0.07	0.07	1	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	0.04	0.04	0.04	1	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	–	–	–	0	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1	<0.04	<0.04	<0.04	1
pyrene	µg/L	–	–	–	0	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Notes: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-32 Sediment Quality of Watercourses in the Eymundson Creek Watershed

Parameter	Units	Fall (2005)		
		Min	Max	n
Particle Size				
partice size – % sand	%	6	88	2
partice size – % silt	%	6	40	2
partice size – % clay	%	6	54	2
moisture content	%	22	56	2
Carbon Content				
total inorganic carbon	% by wt	0.04	0.07	2
total organic carbon	% by wt	0.5	1.8	2
total carbon	% by wt	0.6	1.9	2
Toxicity				
chironomus tentans – 10d survival	% of control	113	113	1
chironomus tentans – 10d growth	% of control	134	134	1
hyalella azteca – 10d survival	% of control	88	88	1
hyalella azteca – 10d growth	% of control	111	111	1
lumbriculus variegatus – 10d survival	% of control	90	90	1
Organics				
total recoverable hydrocarbons	mg/kg	400	1,500	2
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	2
total extractable hydrocarbons (C11–C30)	mg/kg	<10	60	2
Total Metals				
aluminum	µg/g	2,940	14,000	2
arsenic	µg/g	8.8[(a)]	17.9[(a)(b)]	2
barium	µg/g	187	274	2
beryllium	µg/g	0.5	1.1	2
boron	µg/g	10	17	2
cadmium	µg/g	0.2	0.4	2
calcium	µg/g	2,000	3,900	2
chromium	µg/g	5.7	25.9	2
cobalt	µg/g	9.1	12.6	2
copper	µg/g	8	26	2
iron	µg/g	19,800	25,700	2
lead	µg/g	5.3	17.5	2
magnesium	µg/g	1,060	4,130	2
manganese	µg/g	216	277	2
mercury	µg/g	0.12	0.16	2
molybdenum	µg/g	0.9	2.4	2
nickel	µg/g	18	31.3	2

Table F-32 Sediment Quality of Watercourses in the Eymundson Creek Watershed (continued)

Parameter	Units	Fall (2005)		
		Min	Max	n
potassium	µg/g	800	2,900	2
selenium	µg/g	1.2	1.2	2
silver	µg/g	<0.2	<0.2	2
sodium	µg/g	200	300	2
strontium	µg/g	33	77	2
thallium	µg/g	0.16	0.35	2
titanium	µg/g	9	16	2
uranium	µg/g	1.5	2.1	2
vanadium	µg/g	18.4	41.2	2
zinc	µg/g	61	137[a]	2
Target PAHs and Alkylated PAHs				
naphthalene	µg/g	0.003	0.004	2
C1 subst'd naphthalenes	µg/g	0.002	0.004	2
C2 subst'd naphthalenes	µg/g	0.007	0.009	2
C3 subst'd naphthalenes	µg/g	0.01	0.015	2
C4 subst'd naphthalenes	µg/g	0.008	0.048	2
acenaphthene	µg/g	0.0005	0.0007	2
C1 subst'd acenaphthene	µg/g	<0.0001	0.0003	2
acenaphthylene	µg/g	<0.0002	<0.0002	2
anthracene	µg/g	≤0.000172	0.0002	2
dibenzo(a,h)anthracene	µg/g	<0.0005	0.00145	2
benzo(a)anthracene	µg/g	0.0003	0.0021	2
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.04	0.18	2
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.002	0.055	2
benzo(a)pyrene	µg/g	<0.0006	0.0021	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.005	0.024	2
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.003	0.018	2
benzofluoranthenes	µg/g	0.004	0.006	2
benzo(g,h,i)perylene	µg/g	0.0008	0.005	2
biphenyl	µg/g	0.0009	0.0021	2
C1 subst'd biphenyl	µg/g	≤0.000325	0.00032	2
C2 subst'd biphenyl	µg/g	0.0018	0.0021	2
chrysene	µg/g	0.004	0.014	2
dibenzothiophene	µg/g	≤0.000816	0.0008	2
C1 subst'd dibenzothiophene	µg/g	0.0008	0.0147	2
C2 subst'd dibenzothiophene	µg/g	0.002	0.132	2

Table F-32 Sediment Quality of Watercourses in the Eymundson Creek Watershed (continued)

Parameter	Units	Fall (2005)		
		Min	Max	n
C3 subst'd dibenzothiophene	µg/g	0.0012	0.29	2
C4 subst'd dibenzothiophene	µg/g	0.004	0.349	2
fluoranthene	µg/g	0.0011	0.0017	2
C1 subst'd fluoranthene/pyrene	µg/g	0.004	0.03	2
C2 subst'd fluoranthene/pyrene	µg/g	0.005	0.061	2
C3 subst'd fluoranthene/pyrene	µg/g	0.002	0.077	2
fluorene	µg/g	0.0004	0.0008	2
C1 subst'd fluorene	µg/g	0.003	0.0031	2
C2 subst'd fluorene	µg/g	0.0098	0.0311	2
C3 subst'd fluorene	µg/g	0.0045	0.0665	2
indeno(c,d–123)pyrene	µg/g	<0.0005	0.002	2
phenanthrene	µg/g	0.001	0.002	2
C1 subst'd phenanthrene/anthracene	µg/g	0.004	0.014	2
C2 subst'd phenanthrene/anthracene	µg/g	0.004	0.047	2
C3 subst'd phenanthrene/anthracene	µg/g	0.002	0.084	2
C4 subst'd phenanthrene/anthracene	µg/g	0.01	0.2	2
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.011	0.023	2
pyrene	µg/g	0.001	0.005	2

(a) Interim sediment quality guideline exceeded.

(b) Probable effects level exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-33 Water Quality of Watercourses in the Big Creek Watershed

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.1	0	0.6	17	5.6	0	12.6	21	17.2	12.4	20.4	19	7.1	3.9	8.8	14
dissolved oxygen	mg/L	7.1	0.3[a)(b)]	18.6	12	10.5	1.5[a)(b)]	16.6	21	7.5	1.8[a)(b)]	9.3	19	13.3	3.2[a)(b)]	17.2	14
Conventional Parameters																	
colour	TCU	24	5	600	17	39	7	125	22	45	5	125	22	30	5	100	14
specific conductance	uS/cm	468	329	1,860	17	294	156	428	22	420	238	761	22	408	270	429	14
dissolved organic carbon	mg/L	10	3	162	17	12	4	23	22	18	1	33	22	14	4	28	14
hardness	mg/L	246	163	1,010	15	132	56	236	17	174	114	348	22	196	139	246	14
pH		7.8	7	8.2	17	7.6	6.6	8.3	22	7.8	6.9	8.3	22	8.2	8	8.4	14
total alkalinity	mg/L	218	113	628	17	62	<5	216	22	129	35	266	22	172	68	229	14
total dissolved solids	mg/L	290	160	1,660	17	220	140	303	22	285	160	590	22	275	180	310	14
total organic carbon	mg/L	13	3	183	17	13	4	23	22	19	4	72	22	14	3	28	14
total suspended solids	mg/L	29	<3	910	17	22	<3	6120	22	10	<3	605	20	<3	≤1	309	14
Major Ions																	
bicarbonate	mg/L	265	137	766	17	76	5	263	22	157	43	325	22	208	83	279	14
calcium	mg/L	72	49	270	17	34	15	70	22	43	29	90	22	54	38	73	14
carbonate	mg/L	<5	<5	<5	17	<5	<5	<5	22	<5	<5	<5	22	<5	<5	<5	14
chloride	mg/L	2	<1	8	17	2	1	3	22	1	<0.1	3	22	2	1	3	14
magnesium	mg/L	16	9	81	17	10	5	15	22	14	10	33	22	16	8	17	14
potassium	mg/L	2	1	19	17	3	1	7	22	2	0.3	6	22	2	1	4	14
sodium	mg/L	9	4	112	17	12	3	19	22	14	2	33	22	14	3	30	14
sulphate	mg/L	27	<0.5	679	15	58	4	113	17	94	1	332	21	48	3	124	14
sulphide	mg/L	0.007[(b)]	<0.003	0.795[(b)]	17	0.009[(b)]	<0.003	0.029[(b)]	22	0.02[(b)]	<0.003	0.203[(b)]	22	0.007	<0.003	0.136[(b)]	14
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	<0.1	<0.05	0.3	17	<0.1	<0.05	0.2	22	<0.1	<0.1	0.4	22	<0.1	<0.1	0.2	14
nitrogen - ammonia	mg/L	0.23	<0.05	3.35	17	0.05	<0.05	0.52	22	<0.05	<0.05	0.4	22	<0.05	<0.05	0.11	14
nitrogen - kjeldahl	mg/L	0.8	<0.2	153	17	0.8	<0.2	7.8	22	1	<0.2	2.7	22	0.6	<0.2	1.2	14
nitrogen - total nitrogen	mg/L	1	<0.2	153[(b)]	17	0.9	<0.2	7.8[(b)]	22	1	<0.2	3.1[(b)]	22	0.6	<0.2	1.3[(b)]	14
phosphorus, total	mg/L	0.219[(b)]	0.043	22.3[(b)]	17	0.134[(b)]	0.027	3.87[(b)]	22	0.131[(b)]	0.015	2.18[(b)]	22	0.046	0.024	0.156[(b)]	14
phosphorus, dissolved	mg/L	0.019	0.007	0.813	17	0.034	0.01	0.096	22	0.037	0.012	0.951	22	0.018	0.009	0.044	14
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	<2	<2	59	17	<2	<2	8	22	<2	<2	10	22	<2	<2	68	14
General Organics																	
naphthenic acids	mg/L	<1	<1	12	17	<1	<1	<1	22	<1	<1	<1	22	1	<1	3	14
total phenolics	mg/L	0.005	0.002	0.036[(b)]	8	<0.001	<0.001	0.035[(b)]	22	0.01[(b)]	0.001	0.024[(b)]	22	<0.001	<0.001	0.009[(b)]	14
total recoverable hydrocarbons	mg/L	<1	<1	<1	17	<1	<1	<1	22	<1	<1	<1	21	<1	<0.5	<1	14
Toxicity																	
algal growth inhibition test (72h) - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
algal growth inhibition test (72h) - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
algal growth inhibition test (72h) - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
ceriodaphnia 7d reproduction test - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d reproduction test - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
ceriodaphnia 7d reproduction test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1

Table F-33 Water Quality of Watercourses in the Big Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
ceriodaphnia 7d reproduction test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d growth - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d growth - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d growth - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
fathead minnow 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	2
fathead minnow 7d mortality test - LOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - NOEC	%	–	–	–	0	–	–	–	0	–	–	–	0	100	100	100	1
Total Metals																	
aluminum	mg/L	0.72[b]	<0.02	9.03[a][b]	17	0.405[b]	<0.02	51.1[a][b]	22	0.07	<0.02	14.7[a][b]	22	0.1	<0.02	0.88[a][b]	14
antimony	mg/L	0.001	0.0005	0.0018	17	0.0008	0.0006	0.0017	22	0.0007	0.0006	0.0017	22	0.0011	0.0004	0.0021	14
arsenic	mg/L	0.0016	<0.0004	0.0408[b]	17	0.0008	<0.0004	0.0597[b]	22	0.001	<0.0004	0.0079[b]	22	0.0005	<0.0004	0.0014	14
barium	mg/L	0.128	0.037	0.536	17	0.07	0.031	1.41	22	0.068	0.013	0.24	22	0.028	0.007	0.131	14
beryllium	mg/L	<0.001	<0.001	<0.001	17	<0.001	<0.001	0.005	22	<0.001	<0.001	0.001	22	<0.001	<0.001	<0.001	14
boron	mg/L	0.07	0.03	0.37	17	0.05	0.03	0.25	22	0.11	0.04	0.29	22	0.1	0.04	0.12	14
cadmium	mg/L	<0.0002	<0.0002	0.0007[b]	17	<0.0002	<0.0002	0.002[b]	22	<0.0002	<0.0002	0.0004	22	<0.0002	<0.0002	<0.0002	14
calcium	mg/L	65	45	897	17	33	21	63	22	44	27	85	22	48	34	67	14
chromium	mg/L	0.0022[b]	<0.0008	0.0394[a][b]	17	0.002[b]	<0.0008	0.131[a][b]	22	<0.0008	<0.0008	0.0245[a][b]	22	<0.0008	<0.0008	0.0014[b]	14
cobalt	mg/L	0.001	<0.0002	0.168	17	0.0018	<0.0002	0.0475	22	0.0004	<0.0002	0.0113	22	0.0003	<0.0002	0.0015	14
copper	mg/L	0.001	<0.001	0.019[b]	17	0.002	<0.001	0.135[a][b]	22	0.001	<0.001	0.021[b]	22	<0.001	<0.001	0.003	14
iron	mg/L	6.58[b]	0.77[b]	908[b]	17	3.06[b]	0.07	116[b]	22	1.21[b]	0.09	19[b]	22	0.69[b]	0.37[b]	3.58[b]	14
lead	mg/L	0.0005	<0.0001	0.0095[b]	17	0.0004	<0.0001	0.0967[b]	22	0.0001	<0.0001	0.0132[b]	22	<0.0001	<0.0001	0.0006	14
lithium	mg/L	0.025	0.008	0.239	17	0.032	0.006	0.165	22	0.043	0.012	0.087	22	0.04	0.007	0.089	14
magnesium	mg/L	15	8	216	17	10	6	23	22	13	8	33	22	13	8	14	14
manganese	mg/L	0.785	0.076	44	17	0.367	0.032	3.29	22	0.244	0.065	4.63	22	0.136	0.094	0.224	14
mercury	mg/L	<0.0000006	<0.0000006	0.0000009	17	0.0000004	<0.0000006	0.000012[b]	22	0.0000013	<0.0000006	0.000044[a][b]	23	<0.0000006	<0.0000006	0.0000017	14
methyl mercury	mg/L	<0.00000003	<0.00000003	<0.00000003	17	<0.00000003	<0.00000003	0.0000002	22	<0.00000003	<0.00000003	0.0000002	23	<0.00000003	<0.00000003	0.0000004	11
molybdenum	mg/L	0.0004	0.0002	0.0031	17	0.0006	<0.0001	0.009	22	0.0003	<0.0001	0.0037	22	0.0004	<0.0001	0.0015	14
nickel	mg/L	0.0062	0.0004	0.106	17	0.0074	<0.0002	0.15[b]	22	0.0048	<0.0002	0.0454	22	0.0034	<0.0002	0.0165	14
potassium	mg/L	2	1	55	17	4	1	19	22	2	0.5	7	22	2	1	4	14
selenium	mg/L	0.0007	<0.0004	0.008[b]	17	<0.0004	<0.0004	0.0069[b]	22	0.0005	<0.0004	0.002[b]	22	<0.0004	<0.0004	0.0008	14
silver	mg/L	0.000019	0.000001	0.000153[b]	17	0.000009	≤0.000003	0.000859[b]	22	0.000013	0.000004	0.000222[b]	23	0.000004	0.000002	0.00004	13
sodium	mg/L	8	4	180	17	12	2	18	22	14	3	29	22	14	3	28	14
strontium	mg/L	0.2	0.11	1.25	17	0.14	0.09	0.4	22	0.19	0.11	0.44	22	0.18	0.09	0.27	14
thallium	mg/L	<0.0001	<0.0001	0.0002	17	<0.0001	<0.0001	0.002[b]	22	<0.0001	<0.0001	0.0005	22	<0.0001	<0.0001	<0.0001	14
titanium	mg/L	0.015	<0.005	0.096	17	0.014	<0.005	0.21	22	<0.005	<0.005	0.111	22	<0.005	<0.005	0.01	14
uranium	mg/L	0.0003	<0.0001	0.0035	17	0.0002	<0.0001	0.0119	22	0.0001	<0.0001	0.0019	22	0.0002	<0.0001	0.0008	14
vanadium	mg/L	0.004	<0.0002	0.0424	17	0.0017	<0.0002	0.265	22	0.0006	<0.0002	0.0656	22	0.0004	<0.0002	0.0025	14
zinc	mg/L	0.013	<0.004	0.211[b]	17	0.012	<0.004	12.9[a][b]	22	0.01	<0.004	4.48[a][b]	22	0.006	<0.004	0.017	14
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	0.07	17	0.02	<0.01	0.74[b]	22	<0.01	<0.01	0.18[b]	22	<0.01	<0.01	0.08	14
antimony	mg/L	0.0006	<0.0004	0.0017	17	0.0007	0.0005	0.0009	22	0.0006	<0.0004	0.001	22	0.0006	<0.0004	0.0008	14
arsenic	mg/L	<0.0004	<0.0004	0.0043	17	0.0004	<0.0004	0.0013	22	0.0006	<0.0004	0.0015	22	0.0005	<0.0004	0.0007	14
barium	mg/L	0.071	0.017	0.14	17	0.03	0.014	0.123	22	0.041	0.009	0.146	22	0.022	0.004	0.114	14
beryllium	mg/L	<0.0005	<0.0005	0.001	17	<0.0005	<0.0005	<0.0005	22	<0.0005	<0.0005	<0.0005	22	<0.0005	<0.0005	<0.0005	14
boron	mg/L	0.05	0.02	0.4	17	0.05	0.03	0.08	22	0.1	0.04	0.28	22	0.08	0.04	0.12	14
cadmium	mg/L	<0.0001	<0.0001	0.0001	17	<0.0001	<0.0001	0.0001	22	<0.0001	<0.0001	<0.0001	22	<0.0001	<0.0001	<0.0001	14

Table F-33 Water Quality of Watercourses in the Big Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
chromium	mg/L	0.0008	<0.0004	0.0073[(b)]	17	0.0008	<0.0004	0.0042[(b)]	22	<0.0004	<0.0004	0.0012[(b)]	22	<0.0004	<0.0004	0.0009	14
cobalt	mg/L	0.0012	0.0002	0.157	16	0.002	0.0001	0.0125	22	0.0007	0.0002	0.008	22	0.0004	0.0001	0.0041	13
copper	mg/L	<0.0006	<0.0006	0.002	17	0.0011	<0.0006	0.006[(b)]	22	0.0008	<0.0006	0.0029	22	<0.0006	<0.0006	0.0017	14
iron	mg/L	0.08	0.01	39.5[(b)]	17	0.63[(b)]	0.02	2.22[(b)]	22	0.31[(b)]	0.02	1.45[(b)]	22	0.2	0.02	0.7[(b)]	14
lead	mg/L	<0.0001	<0.0001	0.0006	17	0.0004	<0.0001	0.0009	22	<0.0001	<0.0001	0.0002	22	<0.0001	<0.0001	<0.0001	14
lithium	mg/L	0.023	0.008	0.241	17	0.029	0.007	0.042	22	0.04	0.012	0.078	22	0.039	0.009	0.076	14
manganese	mg/L	0.387	0.066	40.1	17	0.316	0.03	3.3	22	0.177	0.023	3.67	22	0.128	0.054	0.183	14
mercury	mg/L	<0.0000006	<0.0000006	0.0000014	17	<0.0000006	<0.0000006	0.0000015	22	<0.0000006	<0.0000006	0.0000043	23	<0.0000006	<0.0000006	0.0000008	14
molybdenum	mg/L	0.0003	<0.0001	0.0027	17	0.0004	<0.0001	0.001	22	0.0003	<0.0001	0.0022	22	0.0004	<0.0001	0.0014	14
nickel	mg/L	0.0029	0.0002	0.0948	17	0.0053	0.0009	0.0237	22	0.0046	<0.0001	0.0126	22	0.0031	<0.0001	0.0146	14
selenium	mg/L	<0.0004	<0.0004	0.0043[(b)]	17	<0.0004	<0.0004	<0.0004	22	<0.0004	<0.0004	0.0011[(b)]	22	0.0004	<0.0004	0.0006	14
silver	mg/L	0.000003	<0.0000005	0.000009	17	0.000003	≤0.0000016	0.000066	20	0.000001	<0.0000005	0.000005	22	0.000001	<0.0000005	0.000007	14
strontium	mg/L	0.18	0.11	1.05	17	0.12	0.07	0.17	22	0.18	0.11	0.44	22	0.17	0.09	0.23	14
thallium	mg/L	<0.00005	<0.00005	<0.00005	17	<0.00005	<0.00005	0.00018	22	<0.00005	<0.00005	<0.00005	22	<0.00005	<0.00005	<0.00005	14
titanium	mg/L	0.0012	<0.0003	0.0025	17	0.0012	<0.0003	0.0481	22	0.001	0.0004	0.0049	22	0.0006	<0.0003	0.0014	14
uranium	mg/L	0.0002	<0.0001	0.0028	17	0.0001	<0.0001	0.0007	22	<0.0001	<0.0001	0.0006	22	0.0002	<0.0001	0.0008	14
vanadium	mg/L	<0.0002	<0.0001	0.0008	17	0.0001	<0.0001	0.0023	22	<0.0001	<0.0001	0.0007	22	<0.0001	<0.0001	0.0003	14
zinc	mg/L	0.005	<0.002	0.052[(b)]	17	0.048[(b)]	0.005	0.089[(b)]	22	0.004	<0.002	0.78[(a)(b)]	22	0.005	0.002	0.016	13
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd naphthalenes	µg/L	<0.01	<0.01	0.01	3	<0.01	<0.01	<0.01	4	0.01	<0.01	0.02	4	<0.01	<0.01	<0.01	2
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	0.1	4	<0.04	<0.04	<0.04	2
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	0.04	4	<0.04	<0.04	<0.04	2
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
acenaphthene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
acenaphthylene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
anthracene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
benzo(a)anthracene / chrysene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
biphenyl	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
dibenzothiophene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
fluoranthene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
fluorene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	0.01	4	<0.01	<0.01	<0.01	2

Table F-33 Water Quality of Watercourses in the Big Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
indeno(c,d-123)pyrene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2
phenanthrene	µg/L	<0.01	<0.01	<0.01	3	0.01	<0.01	0.02	4	0.005	<0.01	0.03	4	<0.01	<0.01	<0.01	2
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	0.08	4	<0.04	<0.04	<0.04	2
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	2
1-methyl-7-isopropyl-phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	µg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01	2

[a] Acute aquatic life guideline exceeded.

[b] Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to TKN values due to low levels of nitrate + nitrite and lack of total nitrogen values.
n = Number of samples.

Table F-34 Sediment Quality of Watercourses in the Big Creek Watershed

Parameter	Units	Fall (2006)			
		Median	Min	Max	n
Particle Size					
partice size – % sand	%	94	82	97	4
partice size – % silt	%	4	2	12	4
partice size – % clay	%	3	1	6	4
moisture content	%	26	18	40	4
Carbon Content					
total inorganic carbon	% by wt	<0.1	<0.1	0.1	4
total organic carbon	% by wt	0.65	0.2	2.8	4
total carbon	% by wt	0.65	0.4	2.8	4
Toxicity					
chironomus tentans – 10d survival	% of control	89	89	89	1
chironomus tentans – 10d growth	% of control	152	152	152	1
hyalella azteca – 10d survival	% of control	100	100	100	1
hyalella azteca – 10d growth	% of control	200	200	200	1
lumbriculus variegatus – 10d survival	% of control	118	118	118	1
lumbriculus variegatus – 10d growth	% of control	80	80	80	1
Organics					
total recoverable hydrocarbons	mg/kg	300	100	400	4
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<0.5	0.6	4
total extractable hydrocarbons (C11–C30)	mg/kg	55	20	77	4
Total Metals					
aluminum	µg/g	1,085	490	4,910	4
arsenic	µg/g	1.8	0.2	22.6[(a)(b)]	4
barium	µg/g	37	9	491	4
beryllium	µg/g	<0.2	<0.2	0.7	4
boron	µg/g	3	<2	11	4
cadmium	µg/g	<0.1	<0.1	0.3	4
calcium	µg/g	1,550	600	2200	4
chromium	µg/g	1.6	0.4	9.7	4
cobalt	µg/g	1.8	0.3	16.9	4
copper	µg/g	1	<0.5	13	4
iron	µg/g	4,750	800	27,400	4
lead	µg/g	1.2	0.6	8.6	4
magnesium	µg/g	765	160	1,460	4
manganese	µg/g	176	10	573	4
mercury	µg/g	<0.05	<0.05	<0.05	4
molybdenum	µg/g	0.1	<0.1	3.2	4
nickel	µg/g	3.2	0.9	30.2	4
potassium	µg/g	250	<100	1,200	4
selenium	µg/g	<0.2	<0.2	1.7	4
silver	µg/g	<0.2	<0.2	<0.2	4
sodium	µg/g	<100	<100	200	4
strontium	µg/g	8	5	49	4
thallium	µg/g	0.01	<0.05	0.21	4
titanium	µg/g	26	11	32	4
uranium	µg/g	0.2	0.1	2.3	4
vanadium	µg/g	4.4	1.2	28.6	4
zinc	µg/g	14	6	95	4
Target PAHs and Alkylated PAHs					
naphthalene	µg/g	0.002	0.001	0.004	4
C1 subst'd naphthalenes	µg/g	0.003	0.002	0.003	4
C2 subst'd naphthalenes	µg/g	0.008	0.006	0.015	4
C3 subst'd naphthalenes	µg/g	0.01	0.009	0.014	4
C4 subst'd naphthalenes	µg/g	0.003	<0.001	0.008	4
acenaphthene	µg/g	<0.0005	<0.0004	0.0007	4
C1 subst'd acenaphthene	µg/g	0.0005	≤0.000371	0.0008	4

Table F-34 Sediment Quality of Watercourses in the Big Creek Watershed (continued)

Parameter	Units	Fall (2006)			
		Median	Min	Max	n
acenaphthylene	µg/g	<0.0002	<0.0002	<0.0006	4
anthracene	µg/g	<0.0003	<0.0002	0.0003	4
dibenzo(a,h)anthracene	µg/g	0.00014	<0.00059	0.0009	4
benzo(a)anthracene	µg/g	0.0005	0.0002	0.0009	4
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.01	0.002	0.01	4
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.005	0.002	0.009	4
benzo(a)pyrene	µg/g	0.0002	<0.0004	0.001	4
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.005	<0.001	0.009	4
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.003	<0.001	0.004	4
benzofluoranthenes	µg/g	0.000004	<0.0003	0.004	4
benzo(g,h,i)perylene	µg/g	0.0026	0.0007	0.0031	4
biphenyl	µg/g	0.0005	0.0004	0.0007	4
C1 subst'd biphenyl	µg/g	0.00104	0.00076	0.00118	4
C2 subst'd biphenyl	µg/g	0.0042	0.003	0.0046	4
chrysene	µg/g	0.003	0.0005	0.003	4
dibenzothiophene	µg/g	0.0002	≤ 0.000186	0.0005	4
C1 subst'd dibenzothiophene	µg/g	0.0007	<0.0002	0.001	4
C2 subst'd dibenzothiophene	µg/g	0.0045	0.0019	0.0088	4
C3 subst'd dibenzothiophene	µg/g	0.0076	0.0018	0.0157	4
C4 subst'd dibenzothiophene	µg/g	0.008	<0.0002	0.013	4
fluoranthene	µg/g	0.0004	<0.0003	0.002	4
C1 subst'd fluoranthene/pyrene	µg/g	0.006	0.002	0.009	4
C2 subst'd fluoranthene/pyrene	µg/g	0.008	0.003	0.011	4
C3 subst'd fluoranthene/pyrene	µg/g	0.004	0.002	0.007	4
fluorene	µg/g	0.00005	<0.0003	0.0005	4
C1 subst'd fluorene	µg/g	0.0066	0.0054	0.0098	4
C2 subst'd fluorene	µg/g	0.0016	0.0011	0.0085	4
C3 subst'd fluorene	µg/g	0.004	0.0022	0.0072	4
indeno(c,d–123)pyrene	µg/g	0.0012	0.0006	0.0018	4
phenanthrene	µg/g	0.001	0.001	0.002	4
C1 subst'd phenanthrene/anthracene	µg/g	0.002	0.001	0.005	4
C2 subst'd phenanthrene/anthracene	µg/g	0.004	0.002	0.007	4
C3 subst'd phenanthrene/anthracene	µg/g	0.005	0.002	0.006	4
C4 subst'd phenanthrene/anthracene	µg/g	0.03	0.02	0.04	4
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.007	<0.004	0.026	4
pyrene	µg/g	0.001	0.0004	0.003	4

(a) Interim sediment quality guideline exceeded.

(b) Probable effects levels exceeded.

– = No data.

Note: Total nitrogen guideline applied TKN values due to low levels of nitrate + nitrate and lack of total nitrogen values.
n = Numbers of samples.

Table F-35 Water Quality of Watercourses in the Redclay Creek Watershed

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2006 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0	–0.4	0.6	8	3.3	0	7.1	8	16.5	13.7	19.8	5	6	4.2	6.2	4
dissolved oxygen	mg/L	8.8	1.6[a)(b)]	13.4	8	11.7	7.9	14.9	6	7.2	3.2[a)(b)]	9.1	5	11	8.8	15.9	4
Conventional Parameters																	
colour	TCU	20	12	83	8	25	12	75	8	27	20	92	8	15	10	30	4
specific conductance	uS/cm	550	521	576	8	400	310	528	8	501	374	514	8	502	455	529	4
dissolved organic carbon	mg/L	8	6	12	8	8	7	12	8	12	9	17	8	11	9	15	4
hardness	mg/L	269	243	278	8	192	180	222	4	230	168	254	8	254	225	278	4
pH		7.7	7.4	7.9	8	7.7	7.3	7.9	8	7.7	7.3	8	8	8.2	8.1	8.4	4
total alkalinity	mg/L	186	148	229	8	84	42	120	8	151	64	235	8	191	156	242	4
total dissolved solids	mg/L	360	320	370	8	272	200	376	8	360	250	690	8	330	290	350	4
total organic carbon	mg/L	10	7	15	8	10	7	20	8	12	9	20	8	11	9	16	4
total suspended solids	mg/L	4	<3	16	8	8	<3	28	8	3	<3	34	8	4	≤1	138	4
Major Ions																	
bicarbonate	mg/L	227	181	280	8	102	51	147	8	184	78	287	8	232	190	287	4
calcium	mg/L	74	66	77	8	46	36	57	8	62	46	68	8	67	58	76	4
carbonate	mg/L	<5	<5	<5	8	<5	<5	<5	8	<5	<5	<5	8	<5	<5	<5	4
chloride	mg/L	3	2	3	8	2	2	3	8	2	1	3	8	3	2	3	4
magnesium	mg/L	20	19	21	8	15	12	19	8	20	13	21	8	21	19	21	4
potassium	mg/L	3	3	4	8	5	4	6	8	3	2	3	8	4	3	4	4
sodium	mg/L	16	14	19	8	13	8	19	8	18	13	20	8	18	14	19	4
sulphate	mg/L	99	69	147	8	157	143	209	4	107	67	155	8	61	46	107	4
sulphide	mg/L	0.004	<0.003	0.008[b)]	8	0.008[b)]	<0.003	0.022[b)]	8	0.011[b)]	0.006[b)]	0.054[b)]	8	0.006[b)]	<0.003	0.014[b)]	4
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	0.1	<0.1	0.2	8	<0.1	<0.05	0.3	8	<0.1	<0.1	0.1	8	<0.1	<0.1	<0.1	4
nitrogen - ammonia	mg/L	0.225	0.19	0.46	8	0.025	<0.05	0.11	8	<0.05	<0.05	0.22	8	<0.05	<0.05	0.19	4
nitrogen - kjeldahl	mg/L	0.6	0.4	1.2	8	0.5	<0.2	0.7	8	0.5	0.3	0.9	8	0.5	0.4	0.9	4
nitrogen - total nitrogen	mg/L	0.6	0.5	1.2[b)]	8	0.6	<0.2	0.7	8	0.5	0.3	1	8	0.5	0.4	0.9	4
phosphorus, total	mg/L	0.112[b)]	0.039	0.229[b)]	8	0.119[b)]	0.023	0.194[b)]	8	0.073[b)]	0.028	0.274[b)]	8	0.064[b)]	0.007	0.141[b)]	4
phosphorus, dissolved	mg/L	0.006	0.003	0.041	8	0.023	0.014	0.072	8	0.018	0.011	0.039	8	0.029	0.014	0.045	4
chlorophyll *a*	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	<2	<2	5	8	<2	<2	2	8	<2	<2	3	8	2	<2	4	4
General Organics																	
naphthenic acids	mg/L	<1	<1	1	8	<1	<1	1	8	<1	<1	<1	8	<1	<1	<1	4
total phenolics	mg/L	0.005	0.003	0.007[b)]	4	0.001	<0.001	0.011[b)]	8	0.006[b)]	<0.001	0.014[b)]	8	<0.001	<0.001	<0.001	4
total recoverable hydrocarbons	mg/L	<1	<1	<1	8	<1	<1	<1	8	<1	<1	1	4	<1	<1	<1	4
Toxicity																	
algal growth inhibition test (72h) - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
algal growth inhibition test (72h) - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
ceriodaphnia 7d reproduction test - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	82	82	82	1
ceriodaphnia 7d reproduction test - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - IC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d growth - IC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LC25	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
fathead minnow 7d mortality test - LC50	%	–	–	–	0	–	–	–	0	–	–	–	0	>100	>100	>100	1
Total Metals																	
aluminum	mg/L	0.03	<0.02	0.1	8	0.07	<0.02	0.33[b)]	8	0.035	<0.02	0.62[b)]	8	0.035	<0.02	0.06	4
antimony	mg/L	0.0006	0.0005	0.001	8	0.0006	0.0004	0.0011	8	0.0007	0.0006	0.0008	8	0.001	0.0008	0.0015	4
arsenic	mg/L	<0.0004	<0.0004	0.0009	8	<0.0004	<0.0004	<0.0004	8	<0.0004	<0.0004	0.0006	8	<0.0004	<0.0004	<0.0004	4
barium	mg/L	0.05	0.035	0.066	8	0.034	0.018	0.045	8	0.039	0.021	0.052	8	0.029	0.018	0.038	4

Table F-35 Water Quality of Watercourses in the Redclay Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2006 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
beryllium	mg/L	<0.001	<0.001	<0.001	8	<0.001	<0.001	<0.001	8	<0.001	<0.001	<0.001	8	<0.001	<0.001	<0.001	4
boron	mg/L	0.12	0.1	0.12	8	0.1	0.05	0.13	8	0.14	0.12	0.17	8	0.12	0.1	0.13	4
cadmium	mg/L	<0.0002	<0.0002	<0.0002	8	<0.0002	<0.0002	<0.0002	8	<0.0002	<0.0002	<0.0002	8	<0.0002	<0.0002	<0.0002	4
chromium	mg/L	<0.0008	<0.0008	0.0024[(b)]	8	0.0011[(b)]	<0.0008	0.0028[(b)]	8	<0.0008	<0.0008	0.0016[(b)]	8	<0.0008	<0.0008	<0.0008	4
cobalt	mg/L	<0.0002	<0.0002	0.0003	8	<0.0002	<0.0002	0.0004	8	0.0002	<0.0002	0.0007	8	<0.0002	<0.0002	0.0005	4
copper	mg/L	<0.001	<0.001	0.002	8	<0.001	<0.001	0.001	8	<0.001	<0.001	0.001	8	<0.001	<0.001	0.002	4
iron	mg/L	3.73[(b)]	1.05[(b)]	10.7[(b)]	8	2.85[(b)]	0.34[(b)]	5.14[(b)]	8	1.51[(b)]	0.18	11.1[(b)]	8	1.14[(b)]	0.52[(b)]	5.67[(b)]	4
lead	mg/L	0.0001	<0.0001	0.0002	8	0.0003	<0.0001	0.0005	8	0.0001	<0.0001	0.0005	8	<0.0001	<0.0001	0.0002	4
lithium	mg/L	0.051	0.045	0.066	8	0.045	0.03	0.072	8	0.058	0.041	0.068	8	0.062	0.049	0.079	4
manganese	mg/L	1.08	0.541	2.84	8	0.554	0.08	1.45	8	0.332	0.066	1.5	8	0.4	0.165	1.02	4
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	8	<0.0000006	<0.0000006	0.0000007	8	0.000001	<0.0000006	0.0000027	8	<0.0000006	<0.0000006	0.0000008	4
methyl mercury	mg/L	<0.00000003	<0.00000003	0.0000001	8	0.00000002	<0.00000003	0.0000001	8	<0.00000003	<0.00000003	0.0000002	8	<0.00000003	<0.00000003	<0.00000003	4
molybdenum	mg/L	0.0002	<0.0001	0.0002	8	0.0002	<0.0001	0.0003	8	0.0001	<0.0001	0.0002	8	0.0002	0.0001	0.0002	4
nickel	mg/L	0.0004	<0.0002	0.0018	8	0.0014	0.0002	0.0026	8	0.0015	<0.0002	0.0028	8	0.0015	0.0012	0.0021	4
selenium	mg/L	<0.0004	<0.0004	0.0025[(b)]	8	<0.0004	<0.0004	0.0009	8	<0.0004	<0.0004	0.0007	8	<0.0004	<0.0004	0.0005	4
silver	mg/L	0.000007	0.000003	0.000023	8	<0.00025	≤0.0000077	0.000099	8	0.000016	0.000003	0.000038	8	0.000005	0.000002	0.000009	4
strontium	mg/L	0.28	0.26	0.3	8	0.2	0.16	0.29	8	0.28	0.21	0.32	8	0.27	0.25	0.29	4
thallium	mg/L	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	4
titanium	mg/L	<0.005	<0.005	<0.005	8	<0.005	<0.005	0.059	8	<0.005	<0.005	0.015	8	<0.005	<0.005	<0.005	4
uranium	mg/L	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	0.0001	8	<0.0001	<0.0001	<0.0001	4
vanadium	mg/L	0.0003	<0.0002	0.0021	8	0.0005	<0.0002	0.0016	8	0.00005	<0.0002	0.0026	8	<0.0002	<0.0002	0.0006	4
zinc	mg/L	0.008	<0.004	0.051[(b)]	8	0.028	0.004	0.116[(b)]	8	0.012	0.006	0.015	8	<0.004	<0.004	0.011	4
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	<0.01	8	<0.01	<0.01	0.02	8	<0.01	<0.01	0.02	8	<0.01	<0.01	0.01	4
antimony	mg/L	0.0005	0.0004	0.0007	8	0.0006	0.0006	0.0007	8	0.0006	0.0005	0.0008	8	0.0006	0.0005	0.0006	4
arsenic	mg/L	<0.0004	<0.0004	<0.0004	8	<0.0004	<0.0004	<0.0004	8	<0.0004	<0.0004	<0.0004	8	<0.0004	<0.0004	<0.0004	4
barium	mg/L	0.041	0.027	0.06	8	0.027	0.018	0.034	8	0.028	0.017	0.043	8	0.023	0.015	0.036	4
beryllium	mg/L	<0.0005	<0.0005	<0.0005	8	<0.0005	<0.0005	<0.0005	8	<0.0005	<0.0005	<0.0005	8	<0.0005	<0.0005	<0.0005	4
boron	mg/L	0.12	0.09	0.14	8	0.1	0.06	0.16	8	0.14	0.11	0.16	8	0.11	0.1	0.11	4
cadmium	mg/L	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	4
chromium	mg/L	<0.0004	<0.0004	0.0026[(b)]	8	0.0002	<0.0004	0.0035[(b)]	8	0.0005	<0.0004	0.0009	8	<0.0004	<0.0004	<0.0004	4
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0002	0.0002	0.0015	8	0.0005	0.0003	0.0024	8	0.001	<0.0001	0.0042	8	0.0003	0.0001	0.0006	4
copper	mg/L	0.0007	<0.0006	0.0014	8	0.0008	<0.0006	0.0027	8	0.0006	<0.0006	0.0125[(b)]	8	<0.0006	<0.0006	0.0022	4
iron	mg/L	0.62[(b)]	0.02	4.41[(b)]	8	0.27	0.09	1.12[(b)]	8	0.08	0.04	1.87[(b)]	8	0.03	0.02	1.46[(b)]	4
lead	mg/L	<0.0001	<0.0001	<0.0001	8	0.0002	<0.0001	0.0004	8	<0.0001	<0.0001	0.0001	8	<0.0001	<0.0001	<0.0001	4
lithium	mg/L	0.051	0.046	0.069	8	0.045	0.029	0.072	8	0.055	0.044	0.068	8	0.051	0.046	0.066	4
manganese	mg/L	1.11	0.513	2.91	8	0.383	0.075	1.45	8	0.164	0.056	1.39	8	0.584	0.131	0.999	4
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	8	<0.0000006	<0.0000006	<0.0000006	8	<0.0000006	<0.0000006	<0.0000006	8	<0.0000006	<0.0000006	<0.0000006	4
molybdenum	mg/L	0.0001	<0.0001	0.0003	8	0.0001	<0.0001	0.0003	8	0.0001	<0.0001	0.0002	8	0.0001	<0.0001	0.0002	4
nickel	mg/L	0.0005	<0.0001	0.0021	8	0.0014	0.0007	0.0026	8	0.0016	<0.0001	0.0039	8	0.0014	0.001	0.002	4
selenium	mg/L	<0.0004	<0.0004	<0.0004	8	<0.0004	<0.0004	0.0006	8	<0.0004	<0.0004	0.0006	8	<0.0004	<0.0004	0.0004	4
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	0.000002	<0.0000005	0.000006	8	<0.000105	≤0.000003	0.00001	8	0.0000001	<0.0000005	0.000005	8	0.0000001	<0.0000005	0.000002	4
strontium	mg/L	0.26	0.24	0.28	8	0.19	0.15	0.3	8	0.27	0.2	0.32	8	0.25	0.24	0.26	4
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	8	<0.00005	<0.00005	0.0001	8	<0.00005	<0.00005	<0.00005	8	<0.00005	<0.00005	<0.00005	4
titanium	mg/L	0.0007	0.0006	0.001	8	0.0006	<0.0003	0.0009	8	0.001	0.0005	0.0011	8	0.0001	<0.0003	0.0006	4
uranium	mg/L	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	4
vanadium	mg/L	<0.0001	<0.0001	0.0002	8	<0.0001	<0.0001	0.0003	8	0.0002	<0.0001	0.0008	8	<0.0001	<0.0001	0.0003	4
zinc	mg/L	0.006	<0.002	0.02	8	0.025	0.004	0.121[(b)]	8	0.008	<0.002	0.028	8	0.006	0.005	0.008	3
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	0.12	<0.01	0.26	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1

Table F-35 Water Quality of Watercourses in the Redclay Creek Watershed (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2006 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
C1 subst'd naphthalenes	µg/L	0.07	<0.01	0.15	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
acenaphthene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
acenaphthylene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
anthracene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
biphenyl	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
dibenzothiophene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
fluoranthene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
fluorene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
indeno(c,d-123)pyrene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
phenanthrene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.16	<0.01	<0.3	2	<0.01	<0.01	<0.01	1
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	2	<0.17	<0.04	<0.3	2	<0.04	<0.04	<0.04	1
1-methyl-7-isopropyl-phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	µg/L	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	2	<0.155	<0.01	<0.3	2	<0.01	<0.01	<0.01	1

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to total kjeldahl nitorgen values due to low levels nitrate + nitrate and lack of total nitrogen levels.
n = Number of samples.

Table F-36 Sediment Quality of Watercourses in the Redclay Creek Watershed

Parameter	Units	Fall (2006)		
		Min	Max	n
Particle Size				
partice size – % sand	%	25	28	2
partice size – % silt	%	43	48	2
partice size – % clay	%	24	32	2
moisture content	%	42	70	2
Carbon Content				
total inorganic carbon	% by wt	0.2	1.2	2
total organic carbon	% by wt	2.5	14	2
total carbon	% by wt	3.7	14.2	2
Toxicity				
chironomus tentans – 10d survival	% of control	100	100	1
chironomus tentans – 10d growth	% of control	122	122	1
hyalella azteca – 10d survival	% of control	100	100	1
hyalella azteca – 10d growth	% of control	200	200	1
lumbriculus variegatus – 10d survival	% of control	53	53	1
lumbriculus variegatus – 10d growth	% of control	60	60	1
Organics				
total recoverable hydrocarbons	mg/kg	800	16,500	2
total volatile hydrocarbons (C5–C10)	mg/kg	<0.5	<4	2
total extractable hydrocarbons (C11–C30)	mg/kg	220	430	2
Total Metals				
aluminum	µg/g	7,490	10,500	2
arsenic	µg/g	1.9	6.6[(a)]	2
barium	µg/g	220	683	2
beryllium	µg/g	0.7	0.8	2
boron	µg/g	14	24	2
cadmium	µg/g	0.1	0.3	2
calcium	µg/g	16,500	31,000	2
chromium	µg/g	15.8	19.2	2
cobalt	µg/g	4.4	8.9	2
copper	µg/g	15	17	2
iron	µg/g	27,700	84,100	2
lead	µg/g	10.5	10.6	2
magnesium	µg/g	2,810	8,700	2
manganese	µg/g	1,550	3,050	2
mercury	µg/g	<0.05	<0.05	2
molybdenum	µg/g	0.6	0.7	2
nickel	µg/g	23	23.5	2
potassium	µg/g	1,000	1,800	2
selenium	µg/g	0.6	1.2	2
silver	µg/g	<0.2	<0.2	2
sodium	µg/g	200	200	2
strontium	µg/g	81	110	2
thallium	µg/g	0.24	0.25	2
titanium	µg/g	16	43	2
uranium	µg/g	1	1	2
vanadium	µg/g	31.7	37.5	2
zinc	µg/g	45	74	2

Table F-36 Sediment Quality of Watercourses in the Redclay Creek Watershed (continued)

Parameter	Units	Fall (2006)		
		Min	Max	n
Target PAHs and Alkylated PAHs				
naphthalene	µg/g	0.003	0.01	2
C1 subst'd naphthalenes	µg/g	0.003	0.022[(a)]	2
C2 subst'd naphthalenes	µg/g	0.01	0.039	2
C3 subst'd naphthalenes	µg/g	0.008	0.032	2
C4 subst'd naphthalenes	µg/g	0.023	0.061	2
acenaphthene	µg/g	0.0007	0.0016	2
C1 subst'd acenaphthene	µg/g	0.0004	0.004	2
acenaphthylene	µg/g	<0.0002	<0.0002	2
anthracene	µg/g	<0.0004	<0.0007	2
dibenzo(a,h)anthracene	µg/g	<0.00154	<0.00433	2
benzo(a)anthracene	µg/g	0.0012	0.0028	2
C1 subst'd benzo(a)anthracene/chrysene	µg/g	0.02	0.03	2
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.023	0.025	2
benzo(a)pyrene	µg/g	<0.0022	0.0084	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.02	0.025	2
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/g	0.014	0.018	2
benzofluoranthenes	µg/g	<0.001	0.008	2
benzo(g,h,i)perylene	µg/g	0.0063	0.0086	2
biphenyl	µg/g	0.0016	0.0042	2
C1 subst'd biphenyl	µg/g	0.00231	0.00714	2
C2 subst'd biphenyl	µg/g	0.0121	0.0161	2
chrysene	µg/g	0.01	0.011	2
dibenzothiophene	µg/g	0.0009	0.0015	2
C1 subst'd dibenzothiophene	µg/g	<0.0004	0.0062	2
C2 subst'd dibenzothiophene	µg/g	0.0058	0.028	2
C3 subst'd dibenzothiophene	µg/g	0.0053	0.0421	2
C4 subst'd dibenzothiophene	µg/g	0.009	0.032	2
fluoranthene	µg/g	0.0031	0.0043	2
C1 subst'd fluoranthene/pyrene	µg/g	0.013	0.019	2
C2 subst'd fluoranthene/pyrene	µg/g	0.037	0.05	2
C3 subst'd fluoranthene/pyrene	µg/g	0.011	0.03	2
fluorene	µg/g	0.0016	0.0018	2
C1 subst'd fluorene	µg/g	0.0126	0.017	2
C2 subst'd fluorene	µg/g	0.0122	0.0125	2
C3 subst'd fluorene	µg/g	0.0128	0.0132	2
indeno(c,d–123)pyrene	µg/g	0.0034	0.0045	2
phenanthrene	µg/g	0.004	0.009	2

Table F-36 Sediment Quality of Watercourses in the Redclay Creek Watershed (continued)

Parameter	Units	Fall (2006)		
		Min	Max	n
C1 subst'd phenanthrene/anthracene	µg/g	<0.004	0.019	2
C2 subst'd phenanthrene/anthracene	µg/g	0.01	0.03	2
C3 subst'd phenanthrene/anthracene	µg/g	0.013	0.025	2
C4 subst'd phenanthrene/anthracene	µg/g	0.11	0.11	2
1–methyl–7–isopropyl–phenanthrene (Retene)	µg/g	0.041	0.042	2
pyrene	µg/g	0.004	0.005	2

(a) Interim sediment quality guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied TKN values due to low levels of nitrate + nitrate and lack of total nitrogen values.
n = Numbers of samples.

Table F-37 Water Quality of Unnamed Lakes Within the Pierre River Mining Area

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
Field Measured																	
temperature	°C	0.6	0	2.3	15	10.8	–1	15.5	17	22.4	0	24.4	19	7.7	4.4	9.3	13
dissolved oxygen	mg/L	2.2[(a)(b)]	0.3[(a)(b)]	8	15	9.7	2.8[(a)(b)]	13.6	17	8.3	2.8[(a)(b)]	16	19	9.3	6.6	15.8	13
Conventional Parameters																	
colour	TCU	50	20	1,500	15	23	8	300	17	28	12	256	19	50	15	200	13
specific conductance	uS/cm	775	440	1,780	15	361	113	628	17	402	182	1,530	19	336	212	1,530	13
dissolved organic carbon	mg/L	56	26	212	15	23	8	38	17	27	7	51	19	35	12	50	13
hardness	mg/L	334	121	500	15	153	25	283	17	172	44	487	19	155	59	498	13
pH		7.8	6.9	9.1[(a)(b)]	15	8.2	7.3	8.9[(a)(b)]	17	8.3	6.5	9.2[(a)(b)]	19	8.2	7.4	9.2[(a)(b)]	13
total alkalinity	mg/L	351	70	782	15	114	21	287	17	119	17	892	19	131	32	855	13
total dissolved solids	mg/L	530	380	1,390	15	230	135	420	17	295	180	1,100	19	254	218	1,100	13
total organic carbon	mg/L	58	29	257	15	23	8	38	17	34	7	54	16	38	15	56	13
total suspended solids	mg/L	16	<3	160	15	4	<3	23	17	5	<3	96	19	5	<3	35	13
Major Ions																	
bicarbonate	mg/L	425	86	856	15	130	25	330	17	132	21	756	19	153	39	723	13
calcium	mg/L	67	12	113	15	34	6	64	17	26	11	74	19	26	12	57	13
carbonate	mg/L	<5	<5	98	15	<5	<5	23	17	<5	<5	164	19	<5	<5	158	13
chloride	mg/L	5	2	25	15	3	1	6	17	2	≤0.6	22	19	3	2	23	13
magnesium	mg/L	32	12	113	15	14	2	55	17	18	4	111	19	17	6	114	13
potassium	mg/L	7	5	28	15	4	2	12	17	3	2	28	19	4	2	27	13
sodium	mg/L	36	12	227	15	21	4	26	17	23	5	224	19	23	5	220	13
sulphate	mg/L	71	22	299	15	47	8	264	17	50	7	275	19	45	8	190	13
sulphide	mg/L	0.612[(b)]	≤0.013	7.07[(b)]	15	0.013[(b)]	0.004	0.038[(b)]	17	0.014	<0.003	0.062[(b)]	19	0.008	<0.003	0.035	13
Nutrients and Chlorophyll *a*																	
nitrogen - nitrate/nitrite	mg/L	<0.1	<0.1	0.3	15	<0.1	<0.1	0.2	17	<0.1	<0.1	1.3	19	<0.1	<0.1	0.2	13
nitrogen - ammonia	mg/L	1.29	0.28	3.59	15	<0.05	<0.05	0.36	17	<0.05	<0.05	0.17	19	<0.05	<0.05	0.26	13
nitrogen - kjeldahl	mg/L	4.1	2.2	15.2	15	1.4	0.4	3.1	17	1.5	0.6	5.4	19	1.6	0.9	4.5	13
nitrogen - total nitrogen	mg/L	4.1[(b)]	2.2[(b)]	15.2[(b)]	15	1.4[(b)]	0.4	3.1[(b)]	17	1.7[(b)]	0.6	5.4[(b)]	19	1.8[(b)]	0.9	4.5[(b)]	13
phosphorus, total	mg/L	0.088[(b)]	0.039	2.44[(b)]	15	0.048	0.024	0.298[(b)]	17	0.063[(b)]	0.017	0.476[(b)]	19	0.057[(b)]	0.014	0.215[(b)]	13
phosphorus, dissolved	mg/L	0.019	0.009	2.43	15	0.017	0.004	0.204	17	0.017	0.006	0.167	19	0.016	0.006	0.156	13
chlorophyll *a*	µg/L	11	<1	37	15	7	<1	24	17	7.5	<1	136	18	12.5	3	34	10
Biochemical Oxygen Demand																	
biochemical oxygen demand	mg/L	5	<2	24	15	2	<2	5	17	3	<2	24	18	<2	<2	7	13
General Organics																	
naphthenic acids	mg/L	1	<1	4	8	<1	<1	<1	9	<1	<1	2	9	<1	<1	3	7
total phenolics	mg/L	0.031[(b)]	0.015[(b)]	0.052[(b)]	4	0.005	<0.001	0.025[(b)]	8	0.019[(b)]	0.011[(b)]	0.032[(b)]	9	0.008[(b)]	<0.001	0.035[(b)]	7
total recoverable hydrocarbons	mg/L	<1	<1	<1	8	<1	<1	<1	9	<1	<1	<1	5	<1	<0.5	<1	6
Total Metals																	
aluminum	mg/L	0.03	<0.02	1.36[(a)(b)]	8	0.04	<0.02	0.11[(b)]	9	0.025	<0.02	0.3[(b)]	10	<0.02	<0.02	0.05	7
antimony	mg/L	0.0007	0.0005	0.0011	8	0.0014	0.0005	0.0028	9	0.0008	0.0006	0.0031	10	0.0008	<0.0004	0.0019	7
arsenic	mg/L	0.0006	<0.0004	0.0062[(b)]	8	0.0005	<0.0004	0.0011	9	0.0002	<0.0004	0.0014	10	<0.0004	<0.0004	0.0012	7
barium	mg/L	0.098	0.039	0.27	8	0.023	0.011	0.062	9	0.023	0.011	0.065	10	0.032	0.015	0.067	7
beryllium	mg/L	<0.001	<0.001	<0.001	8	<0.001	<0.001	<0.001	9	<0.001	<0.001	<0.001	10	<0.001	<0.001	<0.001	7
boron	mg/L	0.18	0.09	0.64	8	0.08	0.04	0.12	9	0.12	0.05	0.2	10	0.13	0.05	0.16	7
cadmium	mg/L	<0.0002	<0.0002	<0.0002	8	<0.0002	<0.0002	<0.0002	9	<0.0002	<0.0002	0.0003	10	<0.0002	<0.0002	<0.0002	7
calcium	mg/L	81	28	109	8	34	7	44	9	26	11	59	10	27	11	56	7
chromium	mg/L	0.0012[(b)]	<0.0008	0.0041[(b)]	8	0.0008	<0.0008	0.0048[(b)]	9	0.0008	<0.0008	0.0018[(b)]	10	<0.0008	<0.0008	0.0009	7
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.0003	<0.0002	0.0043	8	<0.0002	<0.0002	0.0005	9	<0.0002	<0.0002	0.0007	10	0.0003	<0.0002	0.0005	7
copper	mg/L	0.001	<0.001	0.06[(a)(b)]	8	<0.001	<0.001	0.002	9	0.001	<0.001	0.002	10	<0.001	<0.001	0.001	7
iron	mg/L	1.34[(b)]	0.04	33.8[(b)]	8	0.36[(b)]	0.03	2.89[(b)]	9	0.08	0.03	2.79[(b)]	10	0.06	0.02	2.04[(b)]	7
lead	mg/L	0.0002	<0.0001	0.004	8	0.0002	<0.0001	0.0005	9	0.0006	0.0001	0.0018	10	<0.0001	<0.0001	0.0004	7
lithium	mg/L	0.091	0.024	0.146	8	0.028	0.009	0.051	9	0.04	0.009	0.08	10	0.03	0.01	0.069	7

Table F–37 Water Quality of Unnamed Lakes Within the Pierre River Mining Area (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
magnesium	mg/L	31	11	55	8	13	3	18	9	14	4	20	10	14	5	19	7
manganese	mg/L	1.53	0.095	4.53	8	0.111	0.009	1.8	9	0.167	0.015	0.805	10	0.026	0.009	0.245	7
mercury	mg/L	<0.0000006	<0.0000006	0.0000044	8	<0.0000006	<0.0000006	<0.0000006	9	0.00000005	<0.0000006	0.0000039	10	<0.0000006	<0.0000006	0.0000037	7
methyl mercury	mg/L	0.0000002	<0.00000003	0.0000012[b]	8	<0.00000003	<0.00000003	0.0000003	9	0.00000004	<0.00000003	0.0000002	9	0	<0.00000003	0.0000001	4
molybdenum	mg/L	0.0002	<0.0001	0.0017	8	0.0002	<0.0001	0.0004	9	0.0001	<0.0001	0.0004	10	<0.0001	<0.0001	0.0005	7
nickel	mg/L	0.0048	<0.0002	0.0377	8	0.0028	<0.0002	0.0051	9	0.0021	<0.0002	0.0073	10	0.0006	<0.0002	0.0085	7
potassium	mg/L	6	4	24	8	3	2	6	9	3	1	5	10	2	1	6	7
selenium	mg/L	0.00005	<0.0004	0.001	8	<0.0004	<0.0004	0.0007	9	<0.0004	<0.0004	0.0009	10	<0.0004	<0.0004	0.0005	7
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	0.000004	0.000002	0.000048	8	0.000004	0.000001	0.000019	9	0.000007	≤0.0000016	0.000103[b]	10	0.000003	0.000001	0.000026	7
sodium	mg/L	32	10	241	8	14	4	20	9	16	5	22	10	17	5	23	7
strontium	mg/L	0.35	0.18	0.54	8	0.14	0.04	0.21	9	0.14	0.08	0.41	10	0.11	0.09	0.25	7
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.0001	<0.0001	0.0001	8	<0.0001	<0.0001	<0.0001	9	<0.0001	<0.0001	<0.0001	10	<0.0001	<0.0001	<0.0001	7
titanium	mg/L	<0.005	<0.005	0.027	8	<0.005	<0.005	<0.005	9	<0.005	<0.005	<0.005	10	<0.005	<0.005	<0.005	7
uranium	mg/L	0.0001	<0.0001	0.0004	8	<0.0001	<0.0001	0.0002	9	<0.0001	<0.0001	0.0001	10	<0.0001	<0.0001	0.0001	7
vanadium	mg/L	0.0001	<0.0002	0.0086	8	0.0005	<0.0002	0.0016	9	0.0004	<0.0002	0.0011	10	0.0004	<0.0002	0.0012	7
zinc	mg/L	0.016	0.005	0.095[b]	8	0.018	0.005	0.13[b]	9	0.005	<0.004	0.024	10	0.004	<0.004	0.017	7
Dissolved Metals																	
aluminum	mg/L	<0.01	<0.01	0.09	8	0.01	<0.01	0.06	10	0.01	<0.01	0.03	10	<0.01	<0.01	0.03	7
antimony	mg/L	0.0008	0.0006	0.001	8	0.0007	0.0006	0.0009	10	0.0006	<0.0004	0.0009	10	0.0006	0.0004	0.0009	7
arsenic	mg/L	0.0007	<0.0004	0.0039	8	0.0004	<0.0004	0.0012	10	0.0001	<0.0004	0.0012	10	0.0004	<0.0004	0.0009	7
barium	mg/L	0.088	0.039	0.243	8	0.021	0.008	0.058	10	0.021	0.009	0.056	10	0.025	0.012	0.06	7
beryllium	mg/L	<0.0005	<0.0005	<0.0005	8	<0.0005	<0.0005	<0.0005	10	<0.0005	<0.0005	<0.0005	10	<0.0005	<0.0005	<0.0005	7
boron	mg/L	0.2	0.1	0.61	8	0.09	0.04	0.15	10	0.11	0.05	0.17	10	0.13	0.05	0.14	7
cadmium	mg/L	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	0.0005[b]	10	<0.0001	<0.0001	0.0002	10	<0.0001	<0.0001	<0.0001	7
chromium	mg/L	0.0006	<0.0004	0.0019[b]	8	0.003[b]	<0.0004	0.005[b]	10	0.0004	<0.0004	0.0009	10	<0.0004	<0.0004	0.0009	7
chromium - hexavalent	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
cobalt	mg/L	0.004	0.0003	0.0084	8	0.0006	<0.0001	0.0031	10	0.0002	<0.0001	0.0062	10	0.0005	0.0001	0.0047	7
copper	mg/L	0.001	<0.0006	0.0034	8	0.001	<0.0006	0.0026	10	0.0006	<0.0006	0.0017	10	<0.0006	<0.0006	0.001	7
iron	mg/L	0.19	0.06	17.8[b]	8	0.06	0.01	2.7[b]	10	0.02	<0.005	2.3[b]	10	0.02	<0.005	1.82[b]	7
lead	mg/L	<0.0001	<0.0001	0.001	8	0.0004	<0.0001	0.0006	10	0.0002	<0.0001	0.0015	10	<0.0001	<0.0001	0.0003	7
lithium	mg/L	0.091	0.023	0.157	8	0.034	0.008	0.094	10	0.028	0.009	0.076	10	0.032	0.01	0.062	7
manganese	mg/L	1.065	0.098	4.69	8	0.028	0.002	1.62	10	0.01	<0.001	0.527	10	0.005	0.001	0.072	7
mercury	mg/L	<0.0000006	<0.0000006	<0.0000006	8	<0.0000006	<0.0000006	<0.0001	10	<0.0000006	<0.0000006	0.0000032	10	<0.0000006	<0.0000006	<0.0000006	7
molybdenum	mg/L	0.0002	<0.0001	0.0011	8	0.0003	<0.0001	0.0006	10	0.0002	<0.0001	0.0003	10	0.0001	<0.0001	0.0004	7
nickel	mg/L	0.0049	<0.0001	0.0299	8	0.003	0.0005	0.0071	10	0.0023	0.0001	0.0069	10	0.0009	<0.0001	0.0067	7
selenium	mg/L	<0.0004	<0.0004	0.0009	8	<0.0004	<0.0004	0.0006	10	<0.0004	<0.0004	<0.0004	10	<0.0004	<0.0004	0.0008	7
silicon	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
silver	mg/L	<0.0000005	<0.0000005	0.000019	8	<0.000102	≤0.0000005	0.000003	10	0.000002	≤0.0000007	0.00001	10	<0.000007	<0.0000005	0.000007	7
strontium	mg/L	0.34	0.18	0.51	8	0.14	0.04	0.39	10	0.14	0.07	0.4	10	0.09	0.08	0.23	7
sulphur	mg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
thallium	mg/L	<0.00005	<0.00005	<0.00005	8	<0.00005	<0.00005	0.00007	10	<0.00005	<0.00005	0.00025	10	<0.00005	<0.00005	<0.00005	7
titanium	mg/L	0.0016	0.0009	0.0052	8	0.0004	<0.0003	0.0008	10	0.0006	<0.0003	0.0016	10	0.0005	<0.0003	0.002	7
uranium	mg/L	0.0001	<0.0001	0.0002	8	<0.0001	<0.0001	0.0002	10	<0.0001	<0.0001	0.0001	10	<0.0001	<0.0001	<0.0001	7
vanadium	mg/L	0.0002	<0.0001	0.0022	8	0.0004	<0.0001	0.001	10	0.0002	<0.0001	0.0009	10	0.0004	<0.0001	0.0007	7
zinc	mg/L	0.01	0.002	0.022	8	0.054[b]	0.007	0.105[b]	10	0.004	<0.001	0.03	10	0.005	<0.002	0.011	7
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	0.03	0.03	0.03	1	–	–	–	0	0.01	0.01	0.01	1	–	–	–	0
C1 subst'd naphthalenes	µg/L	0.05	0.05	0.05	1	–	–	–	0	0.01	0.01	0.01	1	–	–	–	0
C2 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd naphthalenes	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0

Table F–37 Water Quality of Unnamed Lakes Within the Pierre River Mining Area (continued)

Parameter	Units	Winter (2006 to 2007)				Spring (2006 to 2007)				Summer (2006 to 2007)				Fall (2005 to 2006)			
		Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n	Median	Min	Max	n
acenaphthene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd acenaphthene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
acenaphthylene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
anthracene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
dibenzo(a,h)anthracene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
benzo(a)anthracene/chrysene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd benzo(a)anthracene/chrysene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
benzo(a)pyrene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
benzo(b&k)fluoranthene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
benzo(g,h,i)perylene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
biphenyl	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd biphenyl	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
dibenzothiophene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd dibenzothiophene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
fluoranthene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd fluoranthene/pyrene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
fluorene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd fluorene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
indeno(c,d-123)pyrene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
phenanthrene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0
C1 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C2 subst'd phenanthren/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C3 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
C4 subst'd phenanthrene/anthracene	µg/L	<0.04	<0.04	<0.04	1	–	–	–	0	<0.04	<0.04	<0.04	1	–	–	–	0
1-methyl-7-isopropyl-phenanthrene (Retene)	µg/L	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0
pyrene	µg/L	<0.01	<0.01	<0.01	1	–	–	–	0	<0.01	<0.01	<0.01	1	–	–	–	0

(a) Acute aquatic life guideline exceeded.

(b) Chronic aquatic life guideline exceeded.

– = No data.

Note: Total nitrogen guideline applied to total kjeldahl nitorgen values due to low levels nitrate + nitrate and lack of total nitrogen levels.
n = Number of samples.

Table F-38 Seasonal Water Chemistry Data Related to Acid Sensitivity of Rivers and Streams in the Local Study Area and Regional Study Area

River/Stream			Parameter	Units	Winter			Spring			Summer			Fall			Minimum alkalinity [µeq/L]
					Median	Minimum	n	Median	Minimum	n	Median	Minimum	n	Median	Minimum	n	
Local Surface Waters	**Jackpine Expansion Mining Area**	Muskeg River – upper	pH (Field)	n/a	7.8	**6.3**	13	7.4	7.0	23	7.5	6.9	25	7.5	**6.2**	35	720
			pH (Lab)	n/a	7.4	6.9	27	7.6	7.0	24	8.0	7.0	35	7.9	7.1	38	
			alkalinity	mg/L	301	162	31	92	53	32	147	77	41	164	36	50	
			alkalinity	µeq/L	6,020	3,240	31	1,840	1,060	32	2,940	1,540	41	3,280	720	50	
		Muskeg River – middle	pH (Field)	n/a	7.1	6.6	53	7.5	6.6	30	7.6	7.0	46	7.7	6.8	37	1,160
			pH (Lab)	n/a	7.2	7.0	70	7.5	6.9	47	7.7	7.1	41	7.8	7.1	29	
			alkalinity	mg/L	298	144	32	133	58	25	186	119	31	198	102	36	
			alkalinity	µeq/L	5,960	2,880	32	2,660	1,160	25	3,720	2,380	31	3,960	2,040	36	
		Muskeg River – lower	pH (Field)	n/a	7.2	6.7	72	7.7	**4.5**	35	7.9	7.1	73	7.9	7.4	47	1,120
			pH (Lab)	n/a	7.4	7.0	118	7.7	7.0	67	7.9	7.2	87	8.0	7.3	64	
			alkalinity	mg/L	264	61	75	115	56	43	162	66	73	156	101	64	
			alkalinity	µeq/L	5,280	1,220	75	2,300	1,120	43	3,240	1,320	73	3,120	2,020	64	
		Jackpine Creek	pH (Field)	n/a	7.4	6.8	28	7.7	7.0	15	7.8	7.0	36	7.8	7.1	22	840
			pH (Lab)	n/a	7.7	7.0	43	7.6	7.2	32	7.8	6.5	47	7.6	7.2	47	
			alkalinity	mg/L	264	76	44	70	42	33	125	67	50	112	74	50	
			alkalinity	µeq/L	5,280	1,520	44	1,400	840	33	2,500	1,340	50	2,240	1,480	50	
		Shelley Creek	pH (Field)	n/a	8.2	7.6	2	7.5	7.5	3	7.7	7.0	3	6.7	6.7	3	1,080
			pH (Lab)	n/a	7.2	6.9	5	7.5	7.3	5	7.7	7.2	6	7.2	7.1	3	
			alkalinity	mg/L	284	220	5	82	54	5	111	96	6	295	193	3	
			alkalinity	µeq/L	5,680	4,400	5	1,640	1,080	5	2,220	1,920	6	5,900	3,860	3	
		Stanley Creek	pH (Field)	n/a	7.0	7.0	1	7.4	6.9	2	7.4	7.1	4	7.2	6.9	5	2,060
			pH (Lab)	n/a	7.5	7.2	5	7.9	6.8	7	7.9	7.0	8	7.8	7.4	9	
			alkalinity	mg/L	172	152	5	121	103	7	165	139	8	170	142	9	
			alkalinity	µeq/L	3,440	3,040	5	2,420	2,060	7	3,300	2,780	8	3,400	2,840	9	
		Muskeg Creek	pH (Field)	n/a	7.6	6.8	19	7.6	6.9	15	7.7	7.0	22	7.7	7.1	27	580
			pH (Lab)	n/a	7.3	6.7	21	7.6	6.8	13	7.7	6.5	23	7.7	6.6	26	
			alkalinity	mg/L	169	102	31	78	35	21	117	55	31	111	29	41	
			alkalinity	µeq/L	3,380	2,040	31	1,560	700	21	2,340	1,100	31	2,220	580	41	
Local Surface Waters	**Pierre River Mining Area**	Pierre River	pH (Field)	n/a	7.6	7.5	2	7.8	7.7	3	7.8	7.5	2	7.5	7.4	3	1,340
			pH (Lab)	n/a	7.5	7.4	2	7.9	7.6	4	8.0	8.0	3	8.1	8.0	3	
			alkalinity	mg/L	390	314	2	88	85	4	117	67	3	131	79	3	
			alkalinity	µeq/L	7,800	6,280	2	1,760	1,700	4	2,340	1,340	3	2,620	1,580	3	
		Eymundson Creek	pH (Field)	n/a	7.5	6.6	2	7.5	**6.3**	5	7.5	7.2	3	7.5	6.7	6	500
			pH (Lab)	n/a	7.0	6.6	2	7.8	7.0	5	7.9	7.4	5	8.0	7.8	6	
			alkalinity	mg/L	289	199	2	49	37	5	64	25	5	96	42	6	
			alkalinity	µeq/L	5,780	3,980	2	980	740	5	1,280	500	5	1,920	840	6	
		Big Creek	pH (Field)	n/a	7.3	6.7	11	7.6	6.9	9	7.4	7.0	6	7.8	6.8	12	720
			pH (Lab)	n/a	7.8	7.0	16	7.5	6.8	10	7.9	7.7	10	8.2	8.0	12	
			alkalinity	mg/L	217	113	16	74	50	10	64	36	10	175	68	12	
			alkalinity	µeq/L	4,340	2,260	16	1,480	1,000	10	1,280	720	10	3,500	1,360	12	
		Redclay Creek	pH (Field)	n/a	7.6	6.8	8	7.5	7.2	4	7.4	7.4	1	7.4	7.0	4	1,280
			pH (Lab)	n/a	7.7	7.4	8	7.4	7.3	4	8.0	7.8	4	8.2	8.1	4	
			alkalinity	mg/L	186	148	8	111	97	4	80	64	4	191	156	4	
			alkalinity	µeq/L	3,720	2,960	8	2,220	1,940	4	1,600	1,280	4	3,820	3,120	4	

Table F–38 Seasonal Water Chemistry Data Related to Acid Sensitivity of Rivers and Streams in the Local Study Area and Regional Study Area (continued)

River/Stream		Parameter	Units	Winter			Spring			Summer			Fall			Minimum alkalinity [µeq/L]
				Median	Minimum	n	Median	Minimum	n	Median	Minimum	n	Median	Minimum	n	
Regional Surface Waters	Upper Athabasca River	pH (Field)	n/a	7.6	**5.8**	112	8.2	6.8	41	8.1	7.1	112	8.2	6.5	72	160
		pH (Lab)	n/a	7.8	7.1	178	7.9	7.4	68	7.9	7.1	178	8.0	6.8	152	
		alkalinity	mg/L	152	86	178	102	67	68	95	8	197	99	62	158	
		alkalinity	µeq/L	3,040	1,720	178	2,040	1,340	68	1,900	160	197	1,980	1,240	158	
	Middle Athabasca River	pH (Field)	n/a	7.6	6.7	24	8.2	7.4	11	8.0	7.4	43	8.2	7.5	27	980
		pH (Lab)	n/a	7.7	7.0	71	7.8	7.4	25	7.9	7.1	66	7.9	7.4	59	
		alkalinity	mg/L	138	102	71	88	71	25	94	49	80	99	76	63	
		alkalinity	µeq/L	2,760	2,040	71	1,760	1,420	25	1,880	980	80	1,980	1,520	63	
	Lower Athabasca River	pH (Field)	n/a	7.7	6.9	30	7.8	6.6	10	7.8	6.9	22	8.0	**6.4**	20	1,300
		pH (Lab)	n/a	7.7	7.0	50	7.7	7.0	23	7.8	6.7	51	7.9	7.2	36	
		alkalinity	mg/L	139	106	51	90	65	23	92	78	51	107	80	36	
		alkalinity	µeq/L	2,780	2,120	51	1,800	1,300	23	1,840	1,560	51	2,140	1,600	36	
	Lower Firebag River	pH (Field)	n/a	7.2	6.8	15	8.1	7.4	4	8.0	7.5	6	7.8	7.5	3	860
		pH (Lab)	n/a	7.6	7.1	32	7.9	7.1	9	8.0	**5.6**	12	8.1	7.5	14	
		alkalinity	mg/L	129	112	32	89	43	9	98	80	12	105	84	14	
		alkalinity	µeq/L	2,580	2,240	32	1,780	860	9	1,960	1,600	12	2,100	1,680	14	

n/a = Not applicable.

Table F-39 Water Chemistry Data Related to Acid Sensitivity of Lakes in the Local Study Area and Regional Study Area

Lake Name	Season	Field pH	Field Conductivity [µS/cm]	Lab pH	Lab Conductivity [µS/cm]	TDS [mg/L]	DOC [mg/L]	Color TCU	Alkalinity (as $CaCO_3$) [mg/L]
Kearl Lake	spring	8.3	151	7.8	144	77	18	40	72
	summer	7.9	153	8.0	166	125	21	55	83
	fall	7.7	170	8.0	178	122	21	50	85
McClelland Lake	spring	8.5	238	8.3	262	110	10	10	137
	summer	8.5	266	8.5	240	143	12	4	126
	fall	9.0	227	8.4	241	159	12	9	127
Unnamed Lake (Muskeg)	spring	8.0	274	8.4	286	170	16	22	152
	summer	7.8	265	8.2	320	190	17	50	180
	fall	7.3	331	8.2	290	220	20	40	161
Unnamed Lake (Pierre)	spring	7.7	372	8.2	369	240	21	30	111
	summer	8.2	362	8.2	396	310	28	25	117
	fall	8.4	413	8.2	366	254	30	50	131

Note: TDS = Total Dissolved Solids; DOC = Dissolved Organic Carbon, TCU = True Colour Unit.

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APPENDIX H

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Submitted to:
Shell Canada Limited

Prepared by:
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December 2007 **05-1344-027**

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1 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

The quality assurance/quality control (QA/QC) procedures implemented for this environmental setting study were consistent with procedures used by the Regional Aquatic Monitoring Program (RAMP) (Golder 1998, 1999b, 2000, 2001a, 2002a, 2003a; Hatfield Consultants 2004, 2005, 2006, 2007) and those used by other Environmental Impact Assessments (EIAs).

1.1 SURFACE WATER QUALITY

1.1.1 Laboratory QA/QC

The analytical laboratories selected for water quality analysis and toxicity testing were accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL) to conduct the corresponding analysis. Under this accreditation, these laboratories were required to participate in an annual performance evaluation of procedures, methods and internal quality control. The selected water quality laboratories performed specific internal quality control procedures to guarantee analytical precision and sample integrity during sample analysis (e.g., spiked samples, duplicate samples, method blanks, reference standards). For every toxicity test performed, a comparable test was conducted using a reference toxicant to ensure the validity of the test. All water quality and toxicity samples analyzed met the relevant laboratories' in-house QA/QC requirements.

1.1.2 Field QA/QC

Water quality meters were maintained and calibrated according to manufacturers' instructions. All calibration solutions were properly stored and used before their expiry date. Water quality meters were field calibrated at least daily when in use.

Two field blank samples per water quality sampling season were taken and analyzed for all parameters to assess possible sample contamination by field and/or transportation procedures. Ultra-pure deionized water supplied by the relevant laboratory was used to fill a set of standard sample bottles. The deionized water was treated exactly the same way as the actual samples (i.e., if required, it was filtered/passed through tubing).

Four split samples or duplicate samples were taken during each sampling season. The split samples were labelled with different names and shipped to the analytical laboratory for analysis of all parameters to assess laboratory precision.

The results of the surface water quality QA/QC program were assessed using the following criteria to determine if there was sample contamination or analytical bias:

- *Field blanks*: contamination was identified to have occurred if the concentration of the given parameter in the field blank sample was greater than five times the corresponding analytical detection limit, or Method Detection Limit (MDL). This procedure takes into account the increased potential for reduced accuracy close to the analytical detection limit.
- *Split/duplicate samples*: differences between split/duplicate samples were investigated to confirm consistency and accuracy of analytical data.

1.1.2.1 Results of Field Blank Sample Assessment

For all seasons, concentrations of most of the parameters in the field blank samples were found to be less than five times of the reported MDL. A total of 35 field blank samples for 19 parameters exceeded the five times of MDL (Table H-1) for the field samplings from 2005 to 2007. Conductivity was found to exceed the five times of MDL most frequently. However, a conductivity exceedence is not indicative of contamination during sampling; rather it reflects the conductivity of the deionized water provided by the laboratory for that sampling trip. Given the magnitude of the sampling, the occasional exceedences were relatively minor, and all other parameters satisfied the QA/QC criteria for all seasons.

Table H-1 Summary of Surface Water Blank Samples Higher Than Five Times of Method Detection Limits (MDL)

Parameter	Units	5 × MDL	Ranges Exceeding 5 × MDL[(a)]
conductance	µS/cm	1	1.1 to 6.5 (n=6)
phosphorus (total)	mg/L	0.005	0.015
chlorophyll *a*	µg/L	5	18 to 28 (n=2)
boron (total)	mg/L	0.1	0.51
nickel (total)	mg/L	0.001	0.0024
strontium (total)	mg/L	0.001	0.0011
zinc (total)	mg/L	0.02	0.052
aluminum (total)	mg/L	0.05	0.09
barium (dissolved)	mg/L	0.0005	0.0007 to 0.0012 (n=3)
boron (dissolved)	mg/L	0.01	0.045 to 0.052 (n=3)
chromium (dissolved)	mg/L	0.002	0.0023 to 0.0035 (n=2)

Table H-1 Summary of Surface Water Blank Samples Higher Than Five Times of Method Detection Limits (MDL) (continued)

Parameter	Units	5 × MDL	Ranges Exceeding 5 × MDL[(a)]
cobalt (dissolved)	mg/L	0.0001	0.0019
iron (dissolved)	mg/L	0.025	0.077
lithium (dissolved)	mg/L	0.0005	0.0007 to 0.0009 (n=5)
nickel (dissolved)	mg/L	0.0005	0.0008 to 0.0022 (n=2)
strontium (dissolved)	mg/L	0.0005	0.0017
titanium (dissolved)	mg/L	0.0015	0.0028
zinc (dissolved)	mg/L	0.01	0.1
naphthalene	µg/L	0.05	0.1

(a) Variation ranges with number of samples exceeding 5xMDL within the parenthesis.

MDL = Method Detection Limit.

1.1.2.2 Results of Split/Duplicate Sample Assessment

A number of samples were found exceeding a difference of 20% between original and split/duplicate samples, as presented in Table H-2. Given the magnitudes of these sampling programs and the number of collected samples, these differences were expected. The parameters exceeding the difference of 20% between original and split/duplicate samples included total suspended solid, sulphide, antimony (total), silver (total), zinc (total and dissolved), cobalt (dissolved) and titanium (dissolved).

Table H-2 Summary of Split/Duplicate Surface Water Samples With Specific Differences from Their Original Samples

Seasons	Number of Split/Duplicate Samples Exceeding Specific Differences from Original Samples			
	<20%	20 to 50%	50 to 100%	>100%
fall 2005	41	10	5	1
winter 2006	97	37	12	3
spring 2006	165	34	18	0
summer 2006	120	21	12	2
fall 2006	94	26	9	0
winter 2007	88	13	4	0

1.2 SEDIMENT QUALITY

All analytical laboratories selected for sediment quality analysis and toxicity testing were also accredited by the CAEAL to perform the corresponding analysis. These laboratories performed specific internal QA/QC procedures as well to guarantee analytical precision and sample integrity during analysis.

Significant differences between the split samples and original samples were also identified when a split/duplicate sample differed from the original sample by more than 20%.

Compared to water quality, the assessment of laboratory precision for sediment quality yielded more instances where significant differences between split/duplicate samples and original samples were detected (Table H-3). Sediment samples are inherently more heterogeneous compared to water samples, even when a composite sample was taken. With few exceptions, most samples exceeding 20% of difference were Polycyclic Aromatic Hydrocarbons (PAHs), indicating variability in measured concentrations of PAHs in sediment samples.

Table H-3 Summary of Split/Duplicate Sediment Samples With Specific Differences From Their Original Samples

Seasons	Number of Split/Duplicate Samples Exceeding Specific Differences From Original Samples			
	<20%	20 to 50%	50 to 100%	>100%
fall 2005	101	41	18	1
fall 2006	62	39	15	4

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APPENDIX G

BOX AND WHISKER PLOTS OF SEASONAL TRENDS AND TIME SERIES GRAPHS FOR SELECTED WATER AND SEDIMENT DATA

Prepared For:
Shell Canada Limited

Prepared By:
Golder Associates Ltd.

December 2007 **05-1344-027**

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Table G–1 List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Regional WaterBodies and WaterCourses

Table G–2 List of Box/Whisker and Scatter Plots of Observed Water Quality Data for WaterBodies and WaterCourses in Jackpine Mine Expansion Area

Table G–3 List of Box/Whisker and Scatter Plots of Observed Water Quality Data for WaterBodies and WaterCourses in Pierre River Mine Expansion Area

Note: Figure numbers in Blue Color are linked to the respective Figures. No data available for Figrue Numbers in Black Color

Table G-1. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Regional WaterBodies and WaterCourses

Water Quality Parameters	Lower Athabaska River			Lower Firebag River	McClelland Lake and Associated Surface Waterbodies				
	Upper Reach	Middle Reach	Lower Reach		McClelland Lake	McClelland Lake Inlet	McClelland Lake Outlet	Unnamed Creek3	McClelland Lake Fen
	Athabasca River between Fort McMurray and Muskeg River	Athabasca River between Muskeg River and Firebag River	Athabasca River between Fort McMurray and Embarras	Lower Firebag River from McClelland Lake Outlet Creek to the mouth	McClelland Lake	Inlet creeks to McClelland Lake	Outlet creek or tributaries from McClelland Lake		McClelland Lake Fen
pH	G-1-1-1	G-1-2-1	G-1-3-1	G-1-4-1	G-1-5-1	G-1-6-1	G-1-7-1	G-1-8-1	G-1-9-1
Specific Conductance	G-1-1-2	G-1-2-2	G-1-3-2	G-1-4-2	G-1-5-2	G-1-6-2	G-1-7-2	G-1-8-2	G-1-9-2
Temperature	G-1-1-3	G-1-2-3	G-1-3-3	G-1-4-3	G-1-5-3	G-1-6-3	G-1-7-3	G-1-8-3	G-1-9-3
Dissolved Oxygen	G-1-1-4	G-1-2-4	G-1-3-4	G-1-4-4	G-1-5-4	G-1-6-4	G-1-7-4	G-1-8-4	G-1-9-4
Colour	G-1-1-5	G-1-2-5	G-1-3-5	G-1-4-5	G-1-5-5	G-1-6-5	G-1-7-5	G-1-8-5	G-1-9-5
Dissolved Organic Carbon	G-1-1-6	G-1-2-6	G-1-3-6	G-1-4-6	G-1-5-6	G-1-6-6	G-1-7-6	G-1-8-6	G-1-9-6
Hardness	G-1-1-7	G-1-2-7	G-1-3-7	G-1-4-7	G-1-5-7	G-1-6-7	G-1-7-7	G-1-8-7	G-1-9-7
Total Alkalinity	G-1-1-8	G-1-2-8	G-1-3-8	G-1-4-8	G-1-5-8	G-1-6-8	G-1-7-8	G-1-8-8	G-1-9-8
Total Dissolved Solids	G-1-1-9	G-1-2-9	G-1-3-9	G-1-4-9	G-1-5-9	G-1-6-9	G-1-7-9	G-1-8-9	G-1-9-9
Total Organic Carbon	G-1-1-10	G-1-2-10	G-1-3-10	G-1-4-10	G-1-5-10	G-1-6-10	G-1-7-10	G-1-8-10	G-1-9-10
Total Suspended Solids	G-1-1-11	G-1-2-11	G-1-3-11	G-1-4-11	G-1-5-11	G-1-6-11	G-1-7-11	G-1-8-11	G-1-9-11
Bicarbonate	G-1-1-12	G-1-2-12	G-1-3-12	G-1-4-12	G-1-5-12	G-1-6-12	G-1-7-12	G-1-8-12	G-1-9-12
Calcium	G-1-1-13	G-1-2-13	G-1-3-13	G-1-4-13	G-1-5-13	G-1-6-13	G-1-7-13	G-1-8-13	G-1-9-13
Carbonate	G-1-1-14	G-1-2-14	G-1-3-14	G-1-4-14	G-1-5-14	G-1-6-14	G-1-7-14	G-1-8-14	G-1-9-14
Chloride	G-1-1-15	G-1-2-15	G-1-3-15	G-1-4-15	G-1-5-15	G-1-6-15	G-1-7-15	G-1-8-15	G-1-9-15
Magnesium	G-1-1-16	G-1-2-16	G-1-3-16	G-1-4-16	G-1-5-16	G-1-6-16	G-1-7-16	G-1-8-16	G-1-9-16
Potassium	G-1-1-17	G-1-2-17	G-1-3-17	G-1-4-17	G-1-5-17	G-1-6-17	G-1-7-17	G-1-8-17	G-1-9-17
Sodium	G-1-1-18	G-1-2-18	G-1-3-18	G-1-4-18	G-1-5-18	G-1-6-18	G-1-7-18	G-1-8-18	G-1-9-18
Sulphate	G-1-1-19	G-1-2-19	G-1-3-19	G-1-4-19	G-1-5-19	G-1-6-19	G-1-7-19	G-1-8-19	G-1-9-19
Sulphide	G-1-1-20	G-1-2-20	G-1-3-20	G-1-4-20	G-1-5-20	G-1-6-20	G-1-7-20	G-1-8-20	G-1-9-20
Nitrate/Nitrite	G-1-1-21	G-1-2-21	G-1-3-21	G-1-4-21	G-1-5-21	G-1-6-21	G-1-7-21	G-1-8-21	G-1-9-21
Ammonia	G-1-1-22	G-1-2-22	G-1-3-22	G-1-4-22	G-1-5-22	G-1-6-22	G-1-7-22	G-1-8-22	G-1-9-22
Kjeldahl Nitrogen	G-1-1-23	G-1-2-23	G-1-3-23	G-1-4-23	G-1-5-23	G-1-6-23	G-1-7-23	G-1-8-23	G-1-9-23
Total Nitrogen	G-1-1-24	G-1-2-24	G-1-3-24	G-1-4-24	G-1-5-24	G-1-6-24	G-1-7-24	G-1-8-24	G-1-9-24
Total Phosphorus	G-1-1-25	G-1-2-25	G-1-3-25	G-1-4-25	G-1-5-25	G-1-6-25	G-1-7-25	G-1-8-25	G-1-9-25
Dissolved Phosphorus	G-1-1-26	G-1-2-26	G-1-3-26	G-1-4-26	G-1-5-26	G-1-6-26	G-1-7-26	G-1-8-26	G-1-9-26
Chlorophyll *a*	G-1-1-27	G-1-2-27	G-1-3-27	G-1-4-27	G-1-5-27	G-1-6-27	G-1-7-27	G-1-8-27	G-1-9-27
Biochemical Oxygen Demand	G-1-1-28	G-1-2-28	G-1-3-28	G-1-4-28	G-1-5-28	G-1-6-28	G-1-7-28	G-1-8-28	G-1-9-28
Naphthenic acids	G-1-1-29	G-1-2-29	G-1-3-29	G-1-4-29	G-1-5-29	G-1-6-29	G-1-7-29	G-1-8-29	G-1-9-29
Total Phenolics	G-1-1-30	G-1-2-30	G-1-3-30	G-1-4-30	G-1-5-30	G-1-6-30	G-1-7-30	G-1-8-30	G-1-9-30
Total Recoverable Hydrocarbons	G-1-1-31	G-1-2-31	G-1-3-31	G-1-4-31	G-1-5-31	G-1-6-31	G-1-7-31	G-1-8-31	G-1-9-31
Microtox IC50 @ 15 min	G-1-1-32	G-1-2-32	G-1-3-32	G-1-4-32	G-1-5-32	G-1-6-32	G-1-7-32	G-1-8-32	G-1-9-32
Microtox IC25 @ 15 min	G-1-1-33	G-1-2-33	G-1-3-33	G-1-4-33	G-1-5-33	G-1-6-33	G-1-7-33	G-1-8-33	G-1-9-33
Algal Growth Inhibition Test (72 h) - IC25	G-1-1-34	G-1-2-34	G-1-3-34	G-1-4-34	G-1-5-34	G-1-6-34	G-1-7-34	G-1-8-34	G-1-9-34
Algal Growth Inhibition Test (72 h) - IC50	G-1-1-35	G-1-2-35	G-1-3-35	G-1-4-35	G-1-5-35	G-1-6-35	G-1-7-35	G-1-8-35	G-1-9-35
Algal Growth Inhibition Test (72 h) - LOEC	G-1-1-36	G-1-2-36	G-1-3-36	G-1-4-36	G-1-5-36	G-1-6-36	G-1-7-36	G-1-8-36	G-1-9-36
Algal Growth Inhibition Test (72 h) - NOEC	G-1-1-37	G-1-2-37	G-1-3-37	G-1-4-37	G-1-5-37	G-1-6-37	G-1-7-37	G-1-8-37	G-1-9-37
Ceriodaphnia 7 d Mortality Test - LC25	G-1-1-38	G-1-2-38	G-1-3-38	G-1-4-38	G-1-5-38	G-1-6-38	G-1-7-38	G-1-8-38	G-1-9-38
Ceriodaphnia 7 d Mortality Test - LC50	G-1-1-39	G-1-2-39	G-1-3-39	G-1-4-39	G-1-5-39	G-1-6-39	G-1-7-39	G-1-8-39	G-1-9-39
Ceriodaphnia 7 d Mortality Test - LOEC	G-1-1-40	G-1-2-40	G-1-3-40	G-1-4-40	G-1-5-40	G-1-6-40	G-1-7-40	G-1-8-40	G-1-9-40

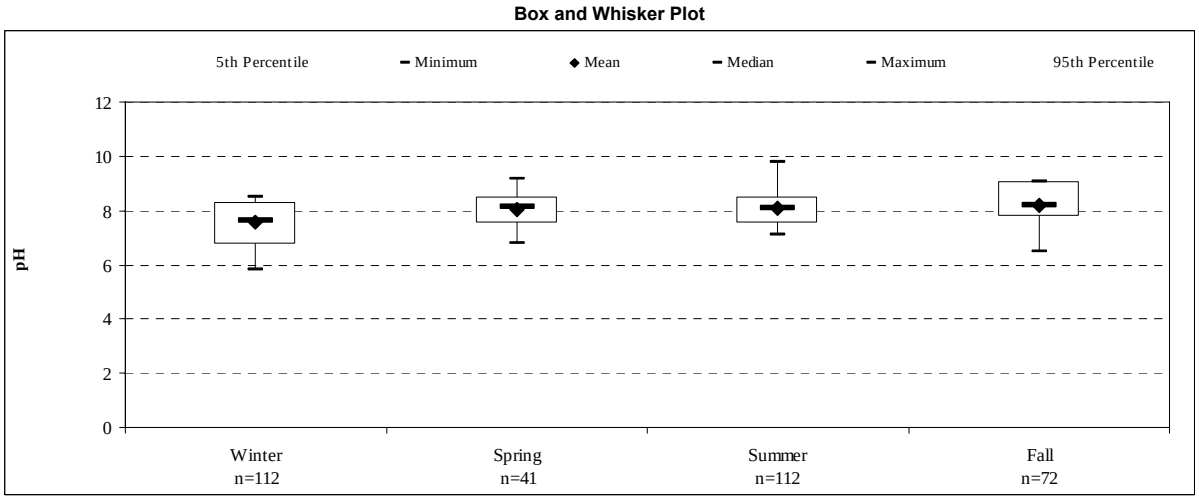
Table G-1. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Regional WaterBodies and WaterCourses

Water Quality Parameters	Lower Athabaska River			Lower Firebag River	McClelland Lake and Associated Surface Waterbodies				
	Upper Reach	Middle Reach	Lower Reach		McClelland Lake	McClelland Lake Inlet	McClelland Lake Outlet	Unnamed Creek3	McClelland Lake Fen
Ceriodaphnia 7 d Mortality Test - NOEC	G-1-1-41	G-1-2-41	G-1-3-41	G-1-4-41	G-1-5-41	G-1-6-41	G-1-7-41	G-1-8-41	G-1-9-41
Ceriodaphnia 7 d Reproduction Test - IC25	G-1-1-42	G-1-2-42	G-1-3-42	G-1-4-42	G-1-5-42	G-1-6-42	G-1-7-42	G-1-8-42	G-1-9-42
Ceriodaphnia 7 d Reproduction Test - IC50	G-1-1-43	G-1-2-43	G-1-3-43	G-1-4-43	G-1-5-43	G-1-6-43	G-1-7-43	G-1-8-43	G-1-9-43
Ceriodaphnia 7 d Reproduction Test - LOEC	G-1-1-44	G-1-2-44	G-1-3-44	G-1-4-44	G-1-5-44	G-1-6-44	G-1-7-44	G-1-8-44	G-1-9-44
Ceriodaphnia 7 d Reproduction Test - NOEC	G-1-1-45	G-1-2-45	G-1-3-45	G-1-4-45	G-1-5-45	G-1-6-45	G-1-7-45	G-1-8-45	G-1-9-45
Daphnia 48 h Static Acute Test - LC25	G-1-1-46	G-1-2-46	G-1-3-46	G-1-4-46	G-1-5-46	G-1-6-46	G-1-7-46	G-1-8-46	G-1-9-46
Daphnia 48 h Static Acute Test - LC50	G-1-1-47	G-1-2-47	G-1-3-47	G-1-4-47	G-1-5-47	G-1-6-47	G-1-7-47	G-1-8-47	G-1-9-47
Daphnia 48 h Static Acute Test - LOEC	G-1-1-48	G-1-2-48	G-1-3-48	G-1-4-48	G-1-5-48	G-1-6-48	G-1-7-48	G-1-8-48	G-1-9-48
Daphnia 48 h Static Acute Test - NOEC	G-1-1-49	G-1-2-49	G-1-3-49	G-1-4-49	G-1-5-49	G-1-6-49	G-1-7-49	G-1-8-49	G-1-9-49
Fathead Minnow 7d Growth - IC25	G-1-1-50	G-1-2-50	G-1-3-50	G-1-4-50	G-1-5-50	G-1-6-50	G-1-7-50	G-1-8-50	G-1-9-50
Fathead Minnow 7d Growth - IC50	G-1-1-51	G-1-2-51	G-1-3-51	G-1-4-51	G-1-5-51	G-1-6-51	G-1-7-51	G-1-8-51	G-1-9-51
Fathead Minnow 7d Growth - LOEC	G-1-1-52	G-1-2-52	G-1-3-52	G-1-4-52	G-1-5-52	G-1-6-52	G-1-7-52	G-1-8-52	G-1-9-52
Fathead Minnow 7d Growth - NOEC	G-1-1-53	G-1-2-53	G-1-3-53	G-1-4-53	G-1-5-53	G-1-6-53	G-1-7-53	G-1-8-53	G-1-9-53
Fathead Minnow 7d Mortality Test - LC25	G-1-1-54	G-1-2-54	G-1-3-54	G-1-4-54	G-1-5-54	G-1-6-54	G-1-7-54	G-1-8-54	G-1-9-54
Fathead Minnow 7d Mortality Test - LC50	G-1-1-55	G-1-2-55	G-1-3-55	G-1-4-55	G-1-5-55	G-1-6-55	G-1-7-55	G-1-8-55	G-1-9-55
Fathead Minnow 7d Mortality Test - LOEC	G-1-1-56	G-1-2-56	G-1-3-56	G-1-4-56	G-1-5-56	G-1-6-56	G-1-7-56	G-1-8-56	G-1-9-56
Fathead Minnow 7d Mortality Test - NOEC	G-1-1-57	G-1-2-57	G-1-3-57	G-1-4-57	G-1-5-57	G-1-6-57	G-1-7-57	G-1-8-57	G-1-9-57
Trout 96 h Static Acute Test - LC25	G-1-1-58	G-1-2-58	G-1-3-58	G-1-4-58	G-1-5-58	G-1-6-58	G-1-7-58	G-1-8-58	G-1-9-58
Trout 96 h Static Acute Test - LC50	G-1-1-59	G-1-2-59	G-1-3-59	G-1-4-59	G-1-5-59	G-1-6-59	G-1-7-59	G-1-8-59	G-1-9-59
Trout 96 h Static Acute Test - LOEC	G-1-1-60	G-1-2-60	G-1-3-60	G-1-4-60	G-1-5-60	G-1-6-60	G-1-7-60	G-1-8-60	G-1-9-60
Trout 96 h Static Acute Test - NOEC	G-1-1-61	G-1-2-61	G-1-3-61	G-1-4-61	G-1-5-61	G-1-6-61	G-1-7-61	G-1-8-61	G-1-9-61
Aluminum	G-1-1-62	G-1-2-62	G-1-3-62	G-1-4-62	G-1-5-62	G-1-6-62	G-1-7-62	G-1-8-62	G-1-9-62
Antimony	G-1-1-63	G-1-2-63	G-1-3-63	G-1-4-63	G-1-5-63	G-1-6-63	G-1-7-63	G-1-8-63	G-1-9-63
Arsenic	G-1-1-64	G-1-2-64	G-1-3-64	G-1-4-64	G-1-5-64	G-1-6-64	G-1-7-64	G-1-8-64	G-1-9-64
Barium	G-1-1-65	G-1-2-65	G-1-3-65	G-1-4-65	G-1-5-65	G-1-6-65	G-1-7-65	G-1-8-65	G-1-9-65
Beryllium	G-1-1-66	G-1-2-66	G-1-3-66	G-1-4-66	G-1-5-66	G-1-6-66	G-1-7-66	G-1-8-66	G-1-9-66
Boron	G-1-1-67	G-1-2-67	G-1-3-67	G-1-4-67	G-1-5-67	G-1-6-67	G-1-7-67	G-1-8-67	G-1-9-67
Cadmium	G-1-1-68	G-1-2-68	G-1-3-68	G-1-4-68	G-1-5-68	G-1-6-68	G-1-7-68	G-1-8-68	G-1-9-68
Chromium	G-1-1-69	G-1-2-69	G-1-3-69	G-1-4-69	G-1-5-69	G-1-6-69	G-1-7-69	G-1-8-69	G-1-9-69
Chromium - hexavalent	G-1-1-70	G-1-2-70	G-1-3-70	G-1-4-70	G-1-5-70	G-1-6-70	G-1-7-70	G-1-8-70	G-1-9-70
Cobalt	G-1-1-71	G-1-2-71	G-1-3-71	G-1-4-71	G-1-5-71	G-1-6-71	G-1-7-71	G-1-8-71	G-1-9-71
Copper	G-1-1-72	G-1-2-72	G-1-3-72	G-1-4-72	G-1-5-72	G-1-6-72	G-1-7-72	G-1-8-72	G-1-9-72
Iron	G-1-1-73	G-1-2-73	G-1-3-73	G-1-4-73	G-1-5-73	G-1-6-73	G-1-7-73	G-1-8-73	G-1-9-73
Lead	G-1-1-74	G-1-2-74	G-1-3-74	G-1-4-74	G-1-5-74	G-1-6-74	G-1-7-74	G-1-8-74	G-1-9-74
Lithium	G-1-1-75	G-1-2-75	G-1-3-75	G-1-4-75	G-1-5-75	G-1-6-75	G-1-7-75	G-1-8-75	G-1-9-75

Table G-1. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Regional WaterBodies and WaterCourses

Water Quality Parameters	Lower Athabaska River			Lower Firebag River	McClelland Lake and Associated Surface Waterbodies				
	Upper Reach	Middle Reach	Lower Reach		McClelland Lake	McClelland Lake Inlet	McClelland Lake Outlet	Unnamed Creek3	McClelland Lake Fen
Manganese	G-1-1-76	G-1-2-76	G-1-3-76	G-1-4-76	G-1-5-76	G-1-6-76	G-1-7-76	G-1-8-76	G-1-9-76
Mercury	G-1-1-77	G-1-2-77	G-1-3-77	G-1-4-77	G-1-5-77	G-1-6-77	G-1-7-77	G-1-8-77	G-1-9-77
Methyl Mercury	G-1-1-78	G-1-2-78	G-1-3-78	G-1-4-78	G-1-5-78	G-1-6-78	G-1-7-78	G-1-8-78	G-1-9-78
Molybdenum	G-1-1-79	G-1-2-79	G-1-3-79	G-1-4-79	G-1-5-79	G-1-6-79	G-1-7-79	G-1-8-79	G-1-9-79
Nickel	G-1-1-80	G-1-2-80	G-1-3-80	G-1-4-80	G-1-5-80	G-1-6-80	G-1-7-80	G-1-8-80	G-1-9-80
Selenium	G-1-1-81	G-1-2-81	G-1-3-81	G-1-4-81	G-1-5-81	G-1-6-81	G-1-7-81	G-1-8-81	G-1-9-81
Silicon	G-1-1-82	G-1-2-82	G-1-3-82	G-1-4-82	G-1-5-82	G-1-6-82	G-1-7-82	G-1-8-82	G-1-9-82
Silver	G-1-1-83	G-1-2-83	G-1-3-83	G-1-4-83	G-1-5-83	G-1-6-83	G-1-7-83	G-1-8-83	G-1-9-83
Strontium	G-1-1-84	G-1-2-84	G-1-3-84	G-1-4-84	G-1-5-84	G-1-6-84	G-1-7-84	G-1-8-84	G-1-9-84
Sulphur	G-1-1-85	G-1-2-85	G-1-3-85	G-1-4-85	G-1-5-85	G-1-6-85	G-1-7-85	G-1-8-85	G-1-9-85
Thallium	G-1-1-86	G-1-2-86	G-1-3-86	G-1-4-86	G-1-5-86	G-1-6-86	G-1-7-86	G-1-8-86	G-1-9-86
Titanium	G-1-1-87	G-1-2-87	G-1-3-87	G-1-4-87	G-1-5-87	G-1-6-87	G-1-7-87	G-1-8-87	G-1-9-87
Uranium	G-1-1-88	G-1-2-88	G-1-3-88	G-1-4-88	G-1-5-88	G-1-6-88	G-1-7-88	G-1-8-88	G-1-9-88
Vanadium	G-1-1-89	G-1-2-89	G-1-3-89	G-1-4-89	G-1-5-89	G-1-6-89	G-1-7-89	G-1-8-89	G-1-9-89
Zinc	G-1-1-90	G-1-2-90	G-1-3-90	G-1-4-90	G-1-5-90	G-1-6-90	G-1-7-90	G-1-8-90	G-1-9-90
Aluminum	G-1-1-91	G-1-2-91	G-1-3-91	G-1-4-91	G-1-5-91	G-1-6-91	G-1-7-91	G-1-8-91	G-1-9-91
Antimony	G-1-1-92	G-1-2-92	G-1-3-92	G-1-4-92	G-1-5-92	G-1-6-92	G-1-7-92	G-1-8-92	G-1-9-92
Arsenic	G-1-1-93	G-1-2-93	G-1-3-93	G-1-4-93	G-1-5-93	G-1-6-93	G-1-7-93	G-1-8-93	G-1-9-93
Barium	G-1-1-94	G-1-2-94	G-1-3-94	G-1-4-94	G-1-5-94	G-1-6-94	G-1-7-94	G-1-8-94	G-1-9-94
Beryllium	G-1-1-95	G-1-2-95	G-1-3-95	G-1-4-95	G-1-5-95	G-1-6-95	G-1-7-95	G-1-8-95	G-1-9-95
Boron	G-1-1-96	G-1-2-96	G-1-3-96	G-1-4-96	G-1-5-96	G-1-6-96	G-1-7-96	G-1-8-96	G-1-9-96
Cadmium	G-1-1-97	G-1-2-97	G-1-3-97	G-1-4-97	G-1-5-97	G-1-6-97	G-1-7-97	G-1-8-97	G-1-9-97
Chromium	G-1-1-98	G-1-2-98	G-1-3-98	G-1-4-98	G-1-5-98	G-1-6-98	G-1-7-98	G-1-8-98	G-1-9-98
Chromium - hexavalent	G-1-1-99	G-1-2-99	G-1-3-99	G-1-4-99	G-1-5-99	G-1-6-99	G-1-7-99	G-1-8-99	G-1-9-99
Cobalt	G-1-1-100	G-1-2-100	G-1-3-100	G-1-4-100	G-1-5-100	G-1-6-100	G-1-7-100	G-1-8-100	G-1-9-100
Copper	G-1-1-101	G-1-2-101	G-1-3-101	G-1-4-101	G-1-5-101	G-1-6-101	G-1-7-101	G-1-8-101	G-1-9-101
Iron	G-1-1-102	G-1-2-102	G-1-3-102	G-1-4-102	G-1-5-102	G-1-6-102	G-1-7-102	G-1-8-102	G-1-9-102
Lead	G-1-1-103	G-1-2-103	G-1-3-103	G-1-4-103	G-1-5-103	G-1-6-103	G-1-7-103	G-1-8-103	G-1-9-103
Lithium	G-1-1-104	G-1-2-104	G-1-3-104	G-1-4-104	G-1-5-104	G-1-6-104	G-1-7-104	G-1-8-104	G-1-9-104
Manganese	G-1-1-105	G-1-2-105	G-1-3-105	G-1-4-105	G-1-5-105	G-1-6-105	G-1-7-105	G-1-8-105	G-1-9-105
Mercury	G-1-1-106	G-1-2-106	G-1-3-106	G-1-4-106	G-1-5-106	G-1-6-106	G-1-7-106	G-1-8-106	G-1-9-106
Molybdenum	G-1-1-107	G-1-2-107	G-1-3-107	G-1-4-107	G-1-5-107	G-1-6-107	G-1-7-107	G-1-8-107	G-1-9-107
Nickel	G-1-1-108	G-1-2-108	G-1-3-108	G-1-4-108	G-1-5-108	G-1-6-108	G-1-7-108	G-1-8-108	G-1-9-108
Selenium	G-1-1-109	G-1-2-109	G-1-3-109	G-1-4-109	G-1-5-109	G-1-6-109	G-1-7-109	G-1-8-109	G-1-9-109
Silicon	G-1-1-110	G-1-2-110	G-1-3-110	G-1-4-110	G-1-5-110	G-1-6-110	G-1-7-110	G-1-8-110	G-1-9-110
Silver	G-1-1-111	G-1-2-111	G-1-3-111	G-1-4-111	G-1-5-111	G-1-6-111	G-1-7-111	G-1-8-111	G-1-9-111
Strontium	G-1-1-112	G-1-2-112	G-1-3-112	G-1-4-112	G-1-5-112	G-1-6-112	G-1-7-112	G-1-8-112	G-1-9-112
Sulphur	G-1-1-113	G-1-2-113	G-1-3-113	G-1-4-113	G-1-5-113	G-1-6-113	G-1-7-113	G-1-8-113	G-1-9-113
Thallium	G-1-1-114	G-1-2-114	G-1-3-114	G-1-4-114	G-1-5-114	G-1-6-114	G-1-7-114	G-1-8-114	G-1-9-114
Titanium	G-1-1-115	G-1-2-115	G-1-3-115	G-1-4-115	G-1-5-115	G-1-6-115	G-1-7-115	G-1-8-115	G-1-9-115
Uranium	G-1-1-116	G-1-2-116	G-1-3-116	G-1-4-116	G-1-5-116	G-1-6-116	G-1-7-116	G-1-8-116	G-1-9-116
Vanadium	G-1-1-117	G-1-2-117	G-1-3-117	G-1-4-117	G-1-5-117	G-1-6-117	G-1-7-117	G-1-8-117	G-1-9-117
Zinc	G-1-1-118	G-1-2-118	G-1-3-118	G-1-4-118	G-1-5-118	G-1-6-118	G-1-7-118	G-1-8-118	G-1-9-118

Figure G-1-1-1 Box Whisker and Time Series Scatter Plots of Observed pH in Upper Reach of Lower Athabasca River



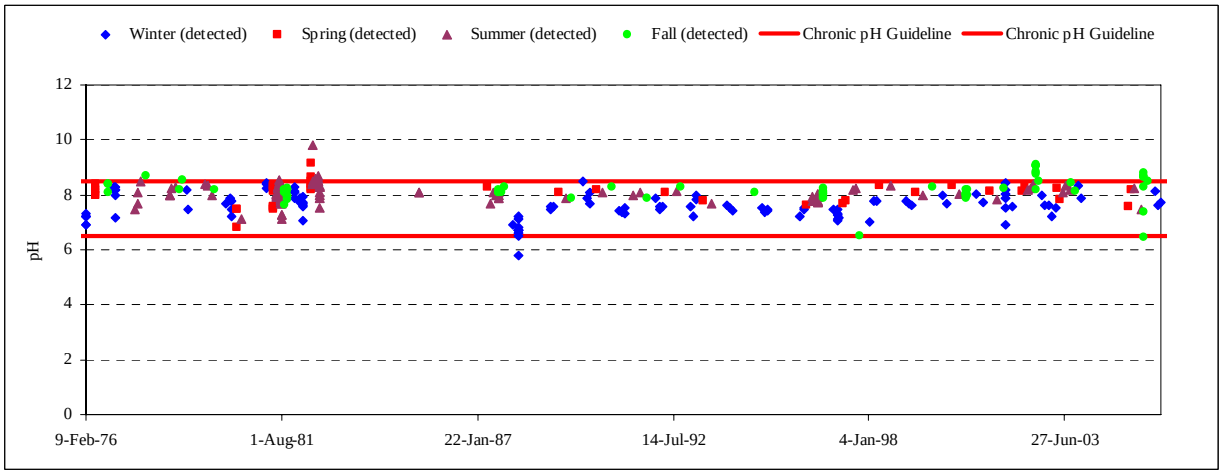
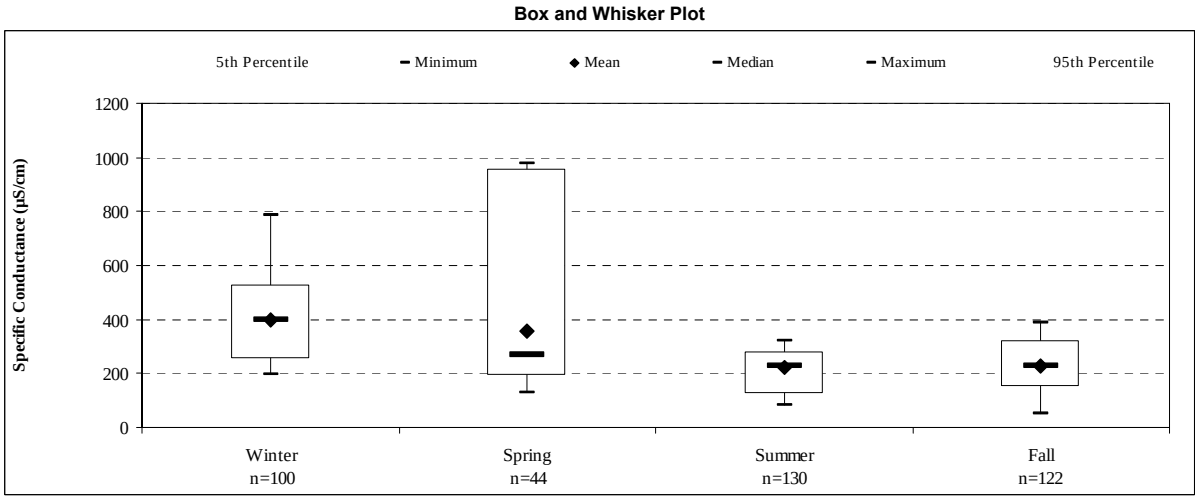


Figure G-1-1-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Upper Reach of Lower Athabasca River



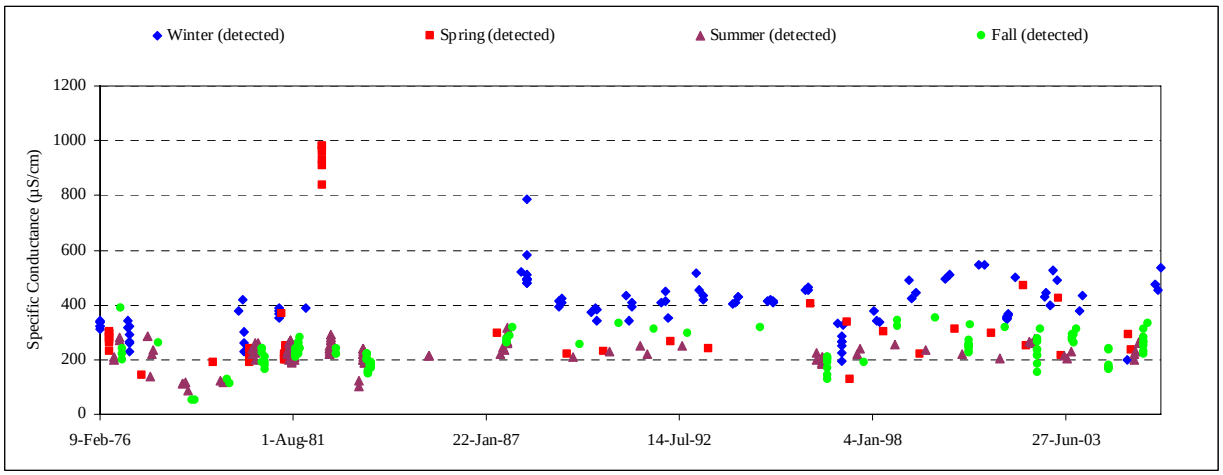
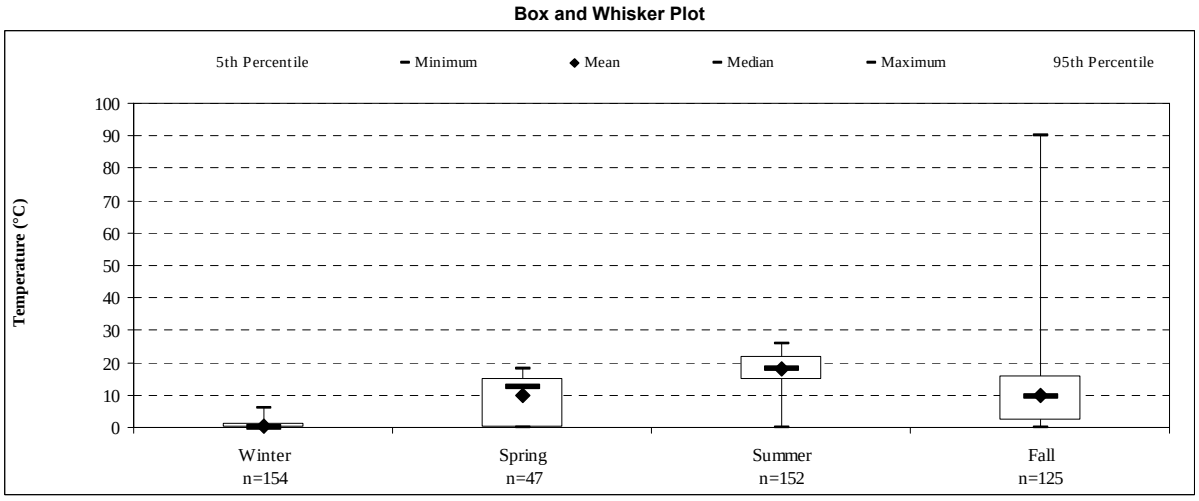


Figure G-1-1-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Upper Reach of Lower Athabasca River



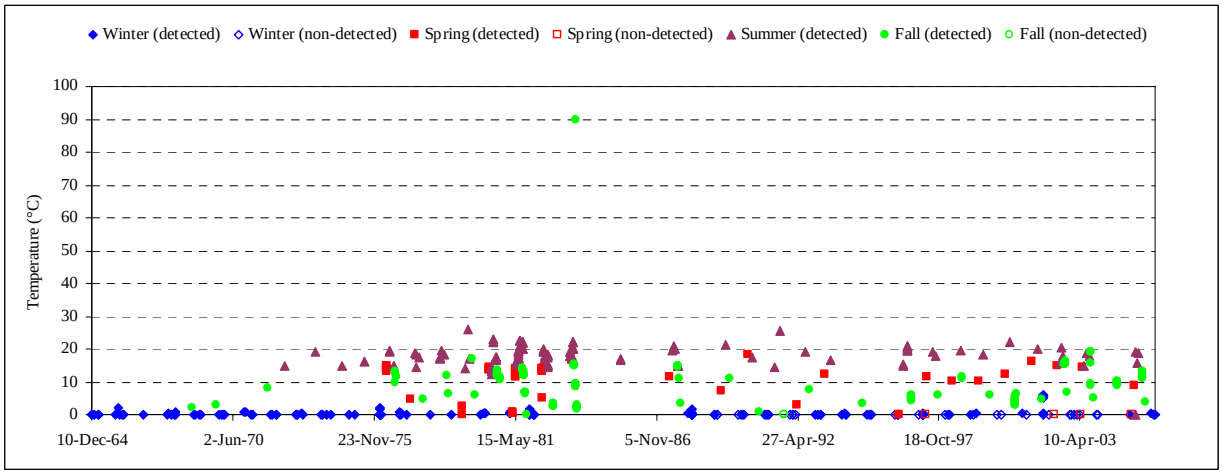
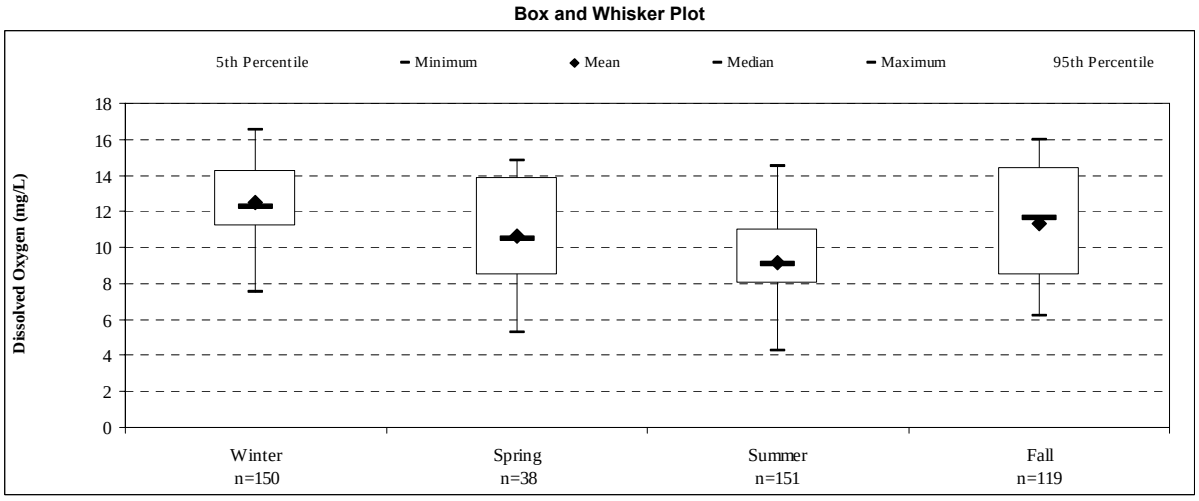


Figure G-1-1-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Upper Reach of Lower Athabasca River



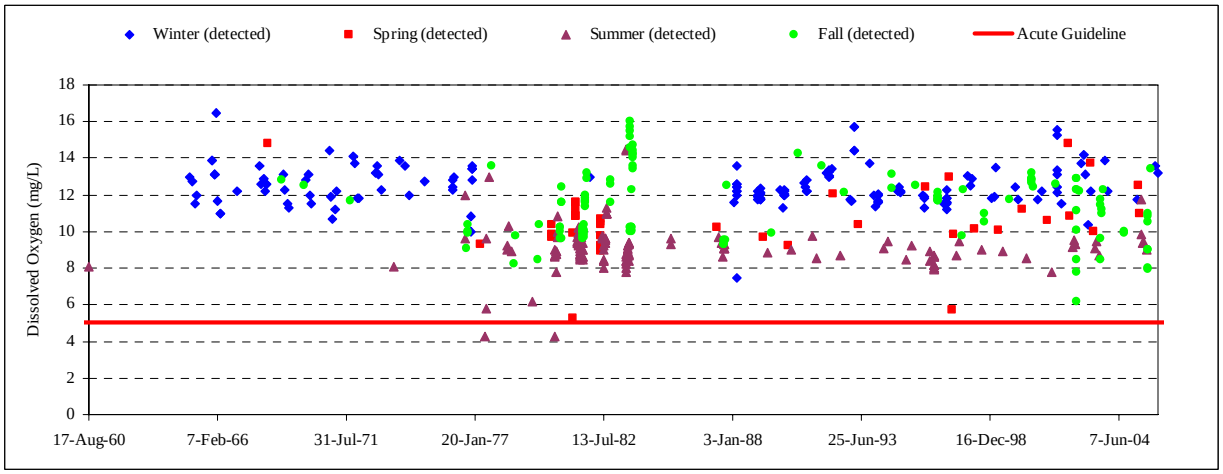
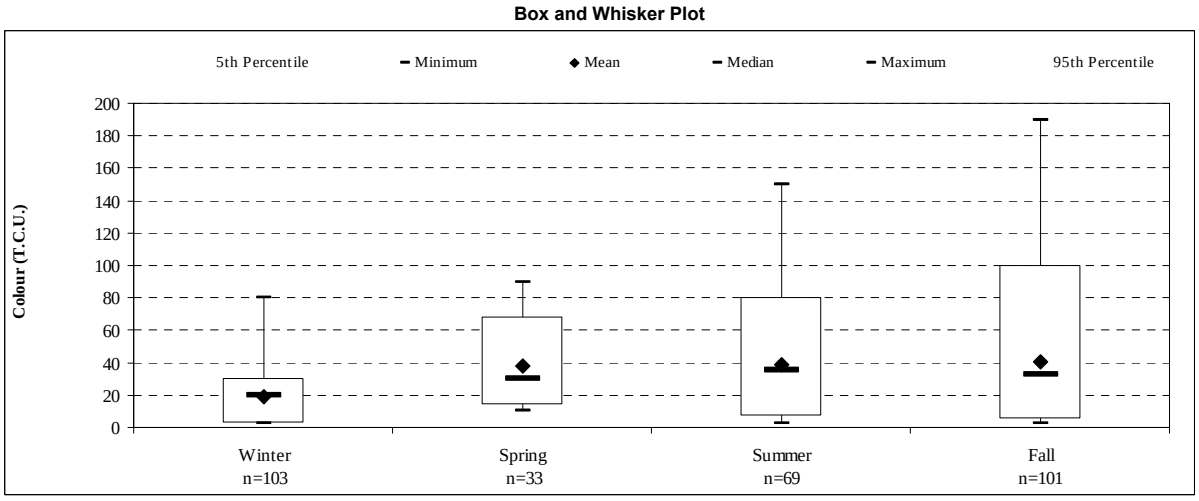


Figure G-1-1-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Upper Reach of Lower Athabasca River



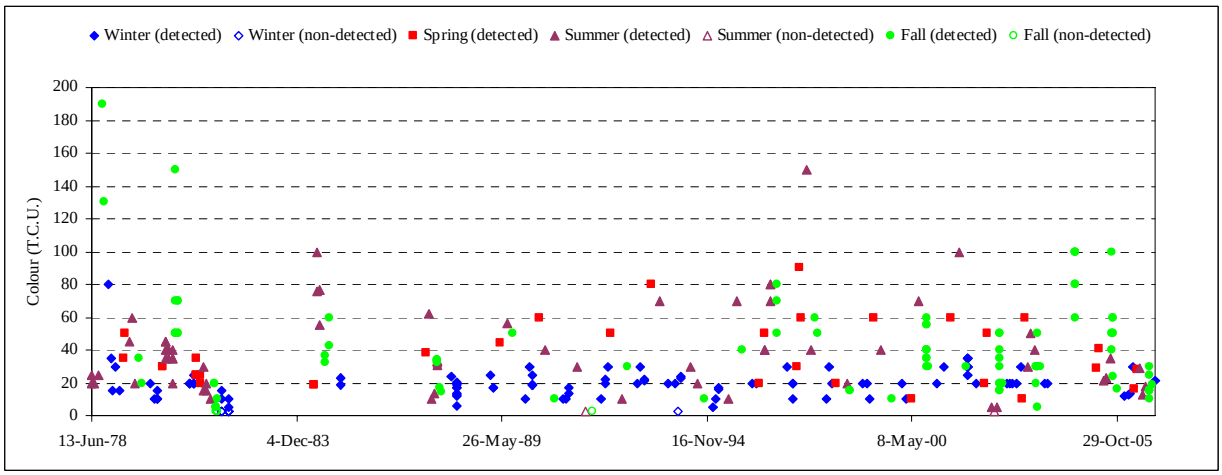
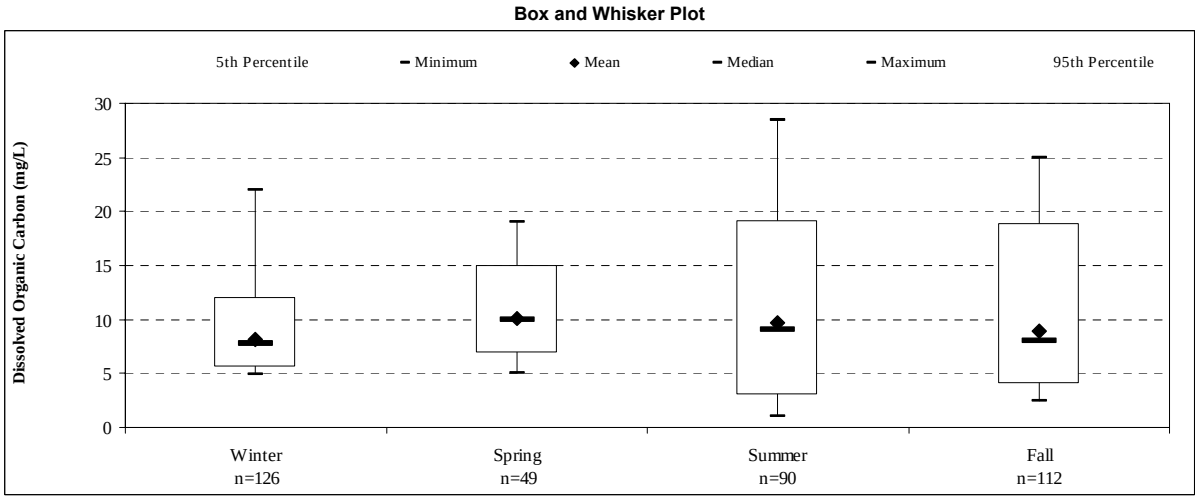


Figure G-1-1-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Upper Reach of Lower Athabasca River



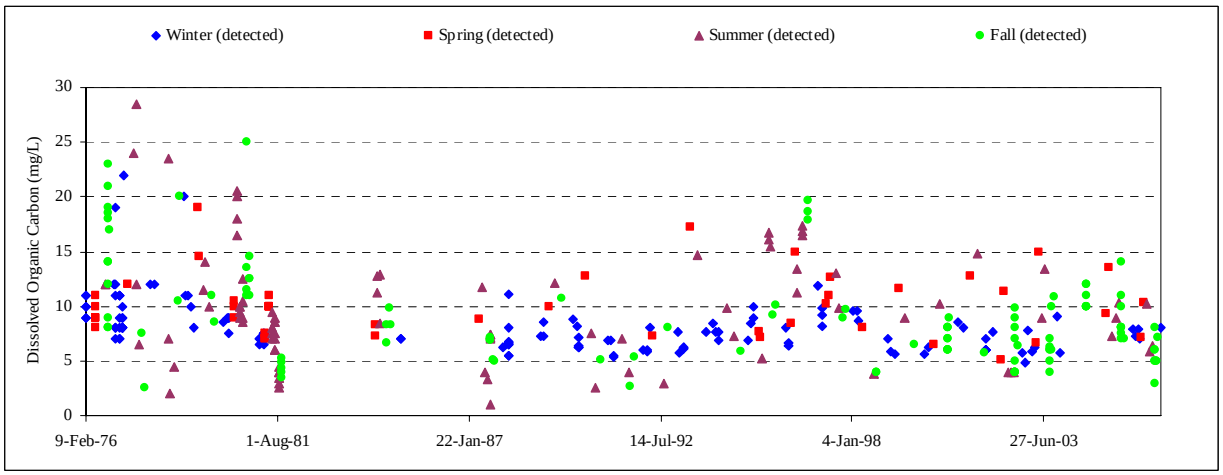
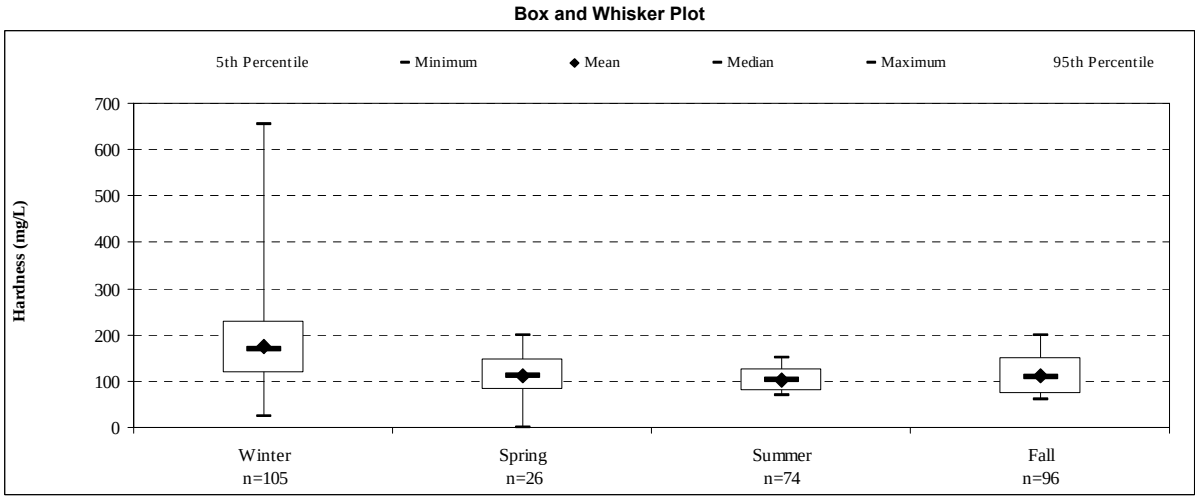


Figure G-1-1-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Upper Reach of Lower Athabasca River



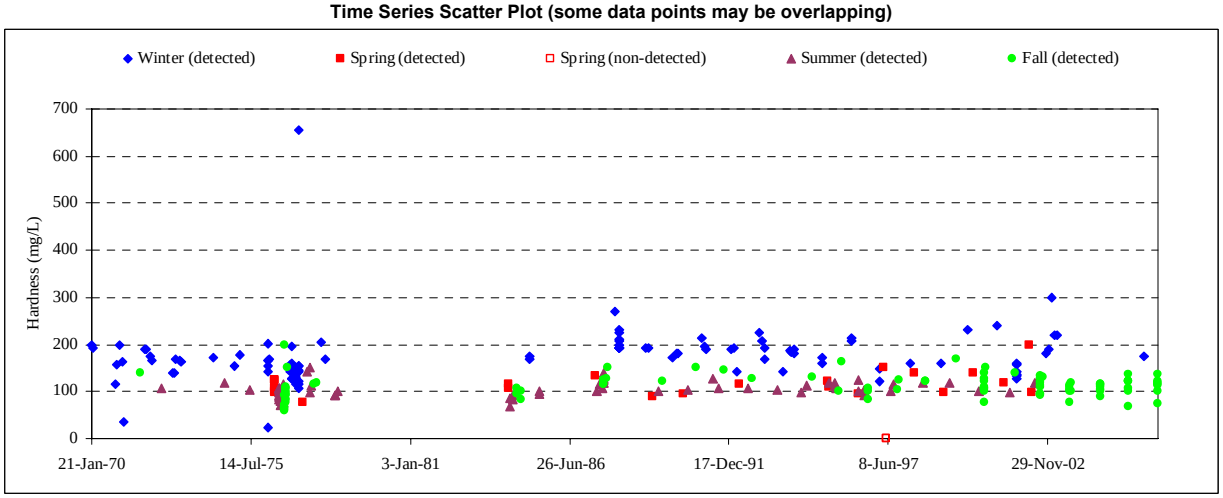
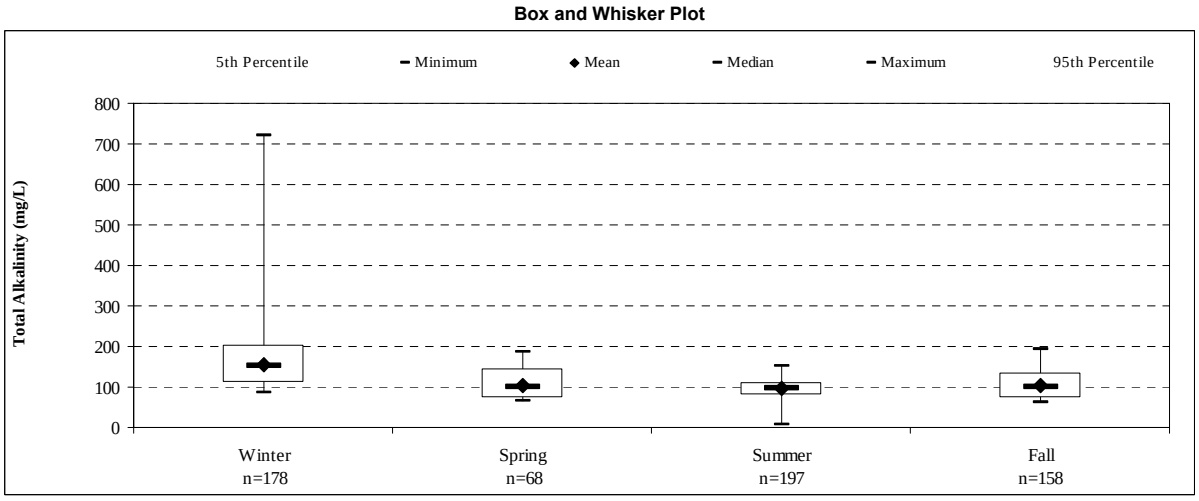


Figure G-1-1-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Upper Reach of Lower Athabasca River



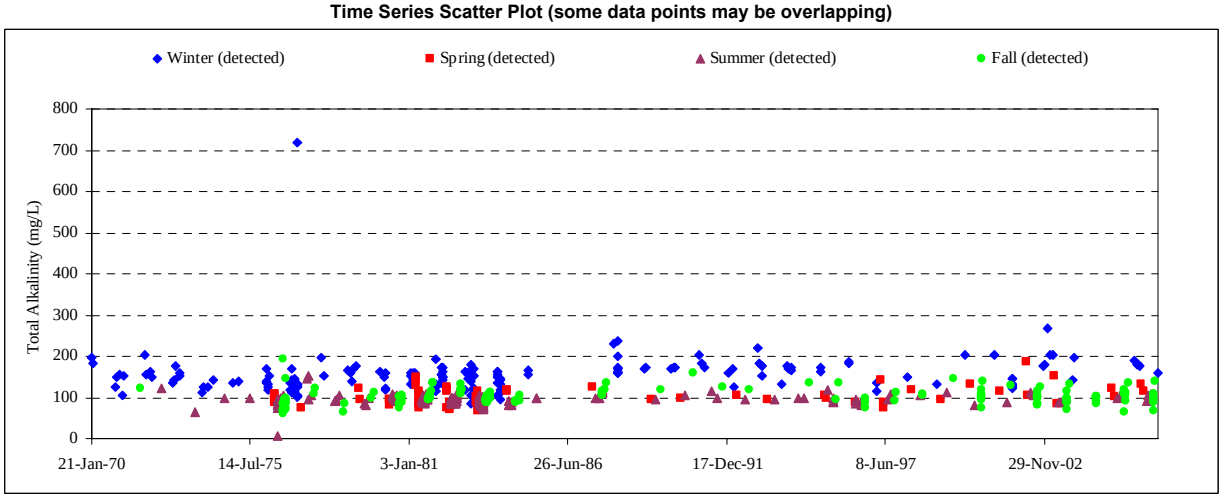
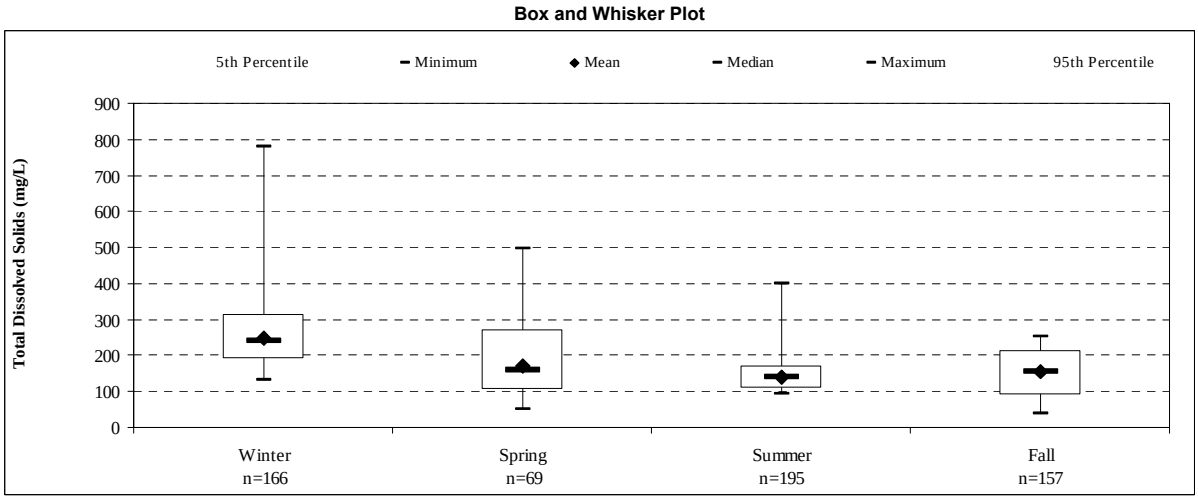


Figure G-1-1-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Upper Reach of Lower Athabasca River



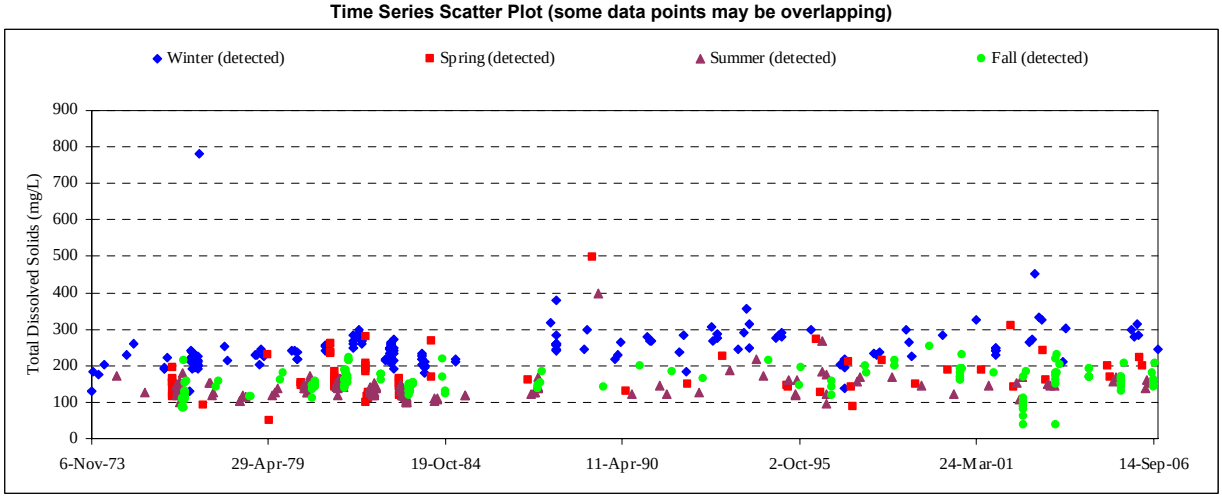
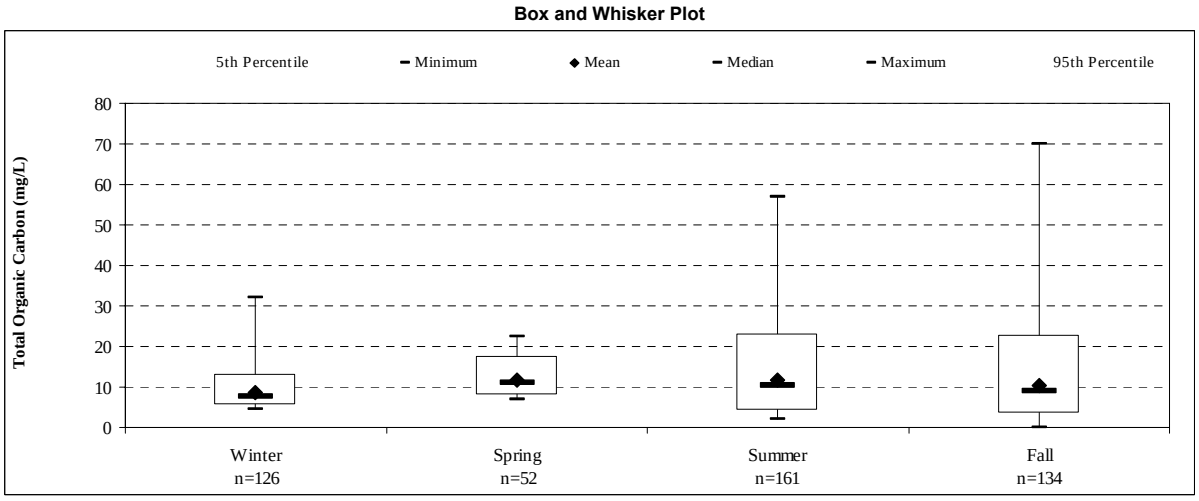


Figure G-1-1-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Upper Reach of Lower Athabasca River



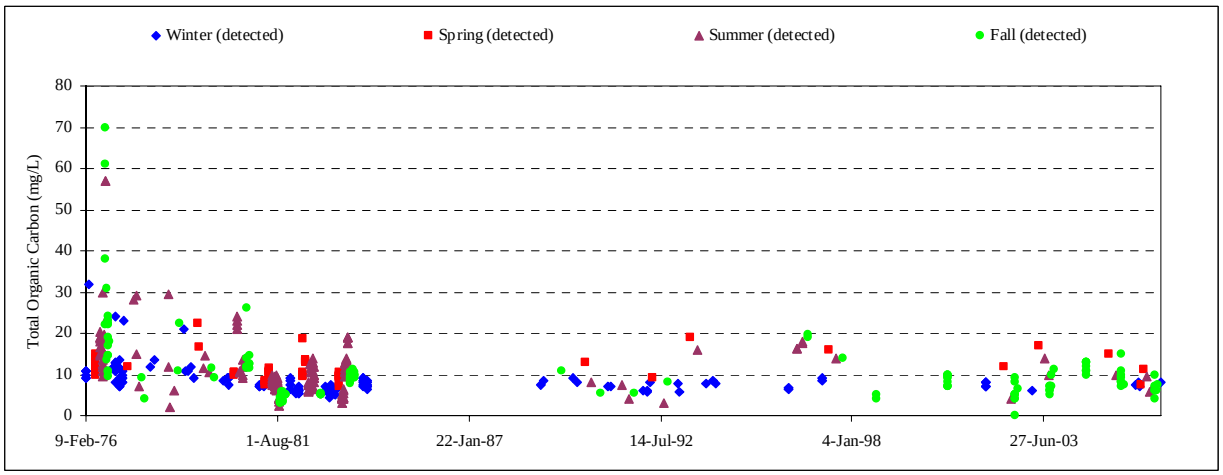
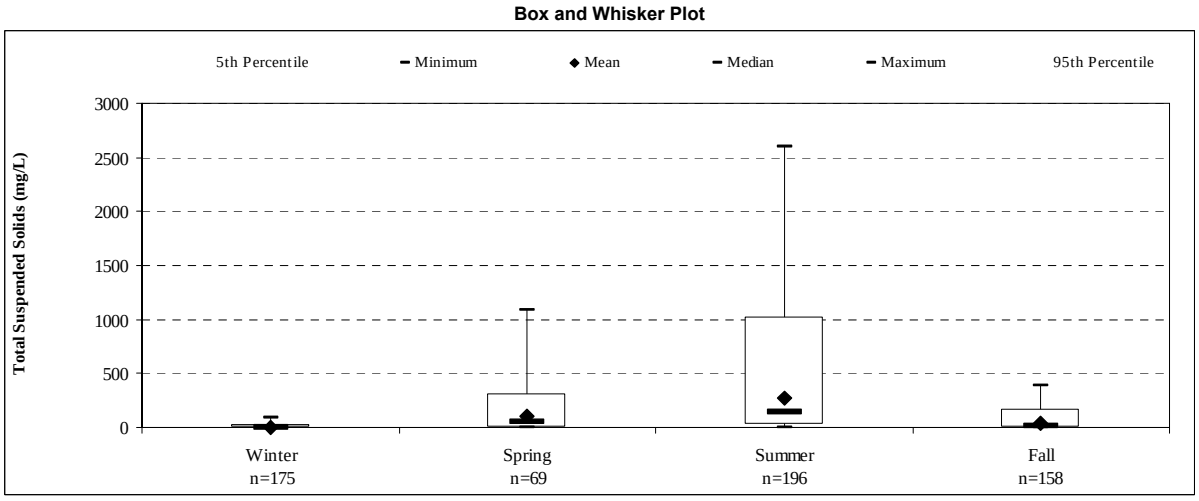


Figure G-1-1-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Upper Reach of Lower Athabasca River



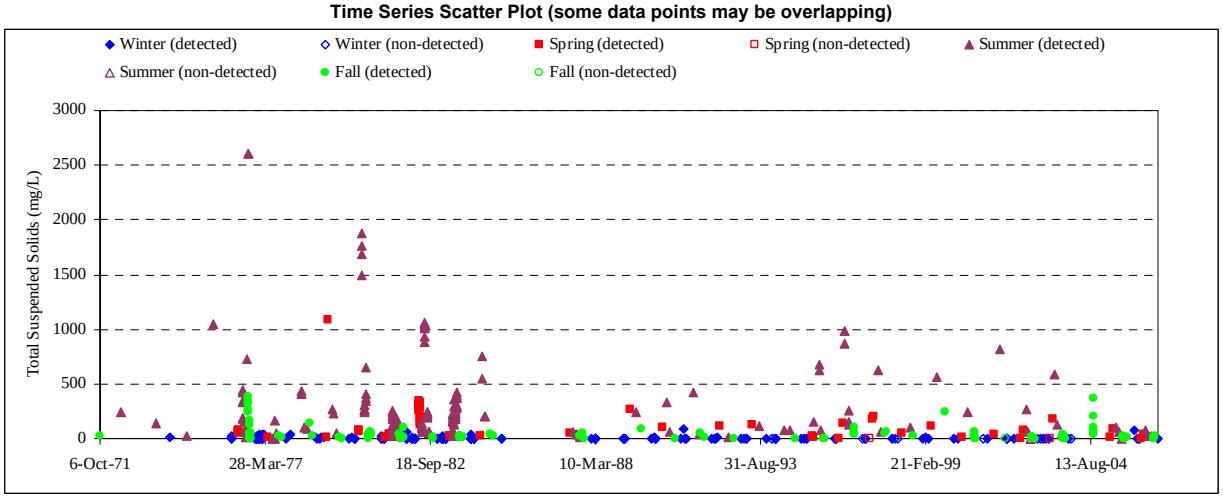
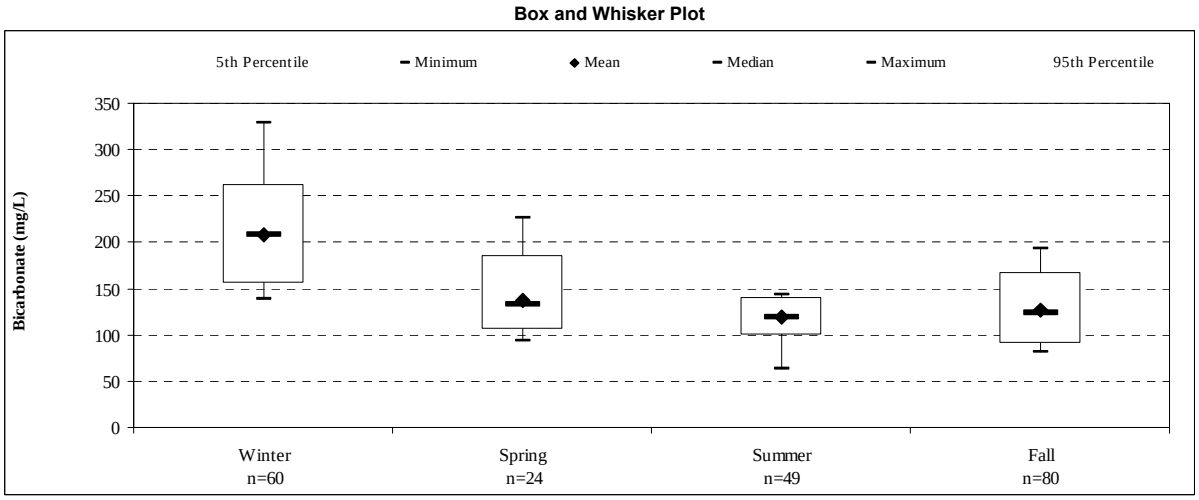


Figure G-1-1-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Upper Reach of Lower Athabasca River



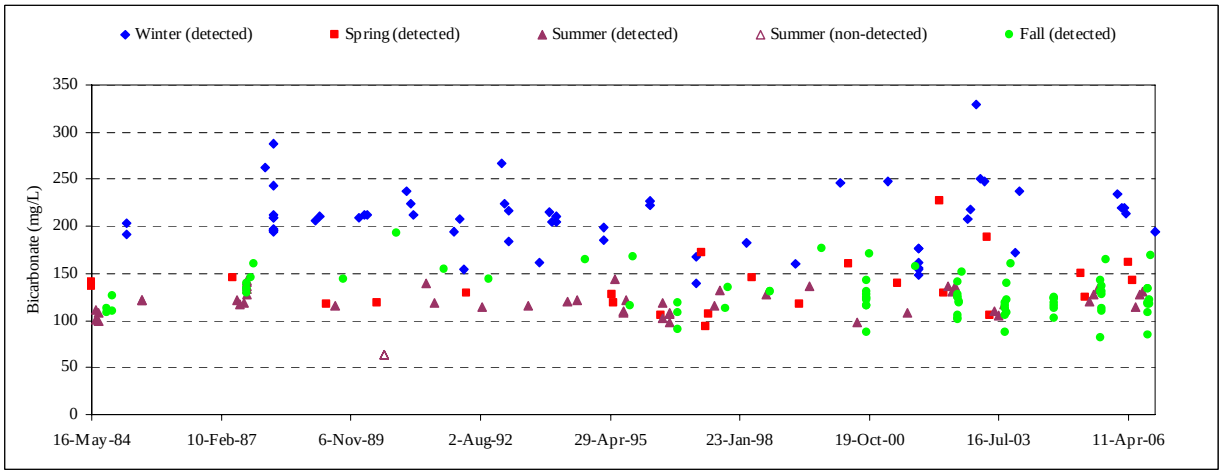
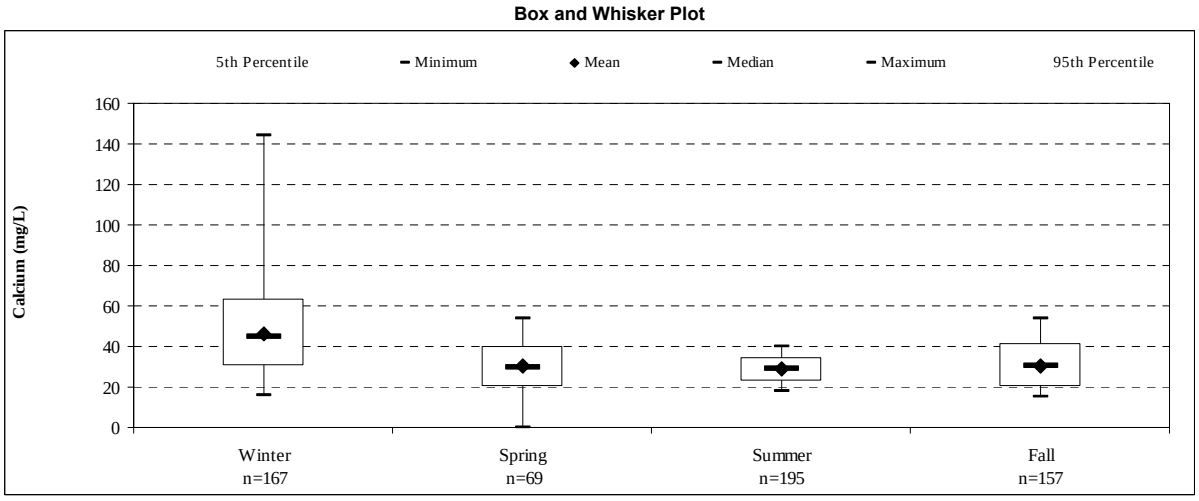


Figure G-1-1-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Upper Reach of Lower Athabasca River



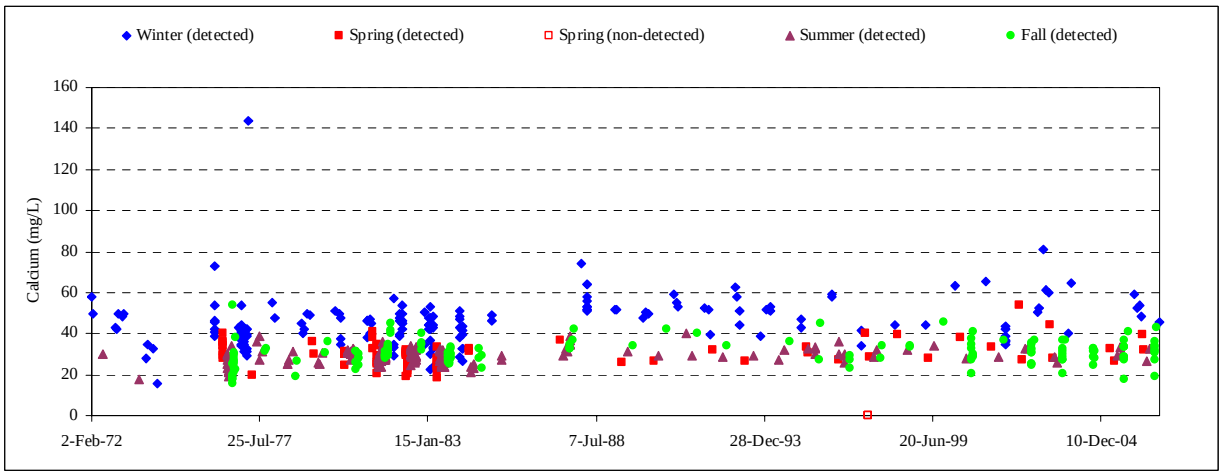
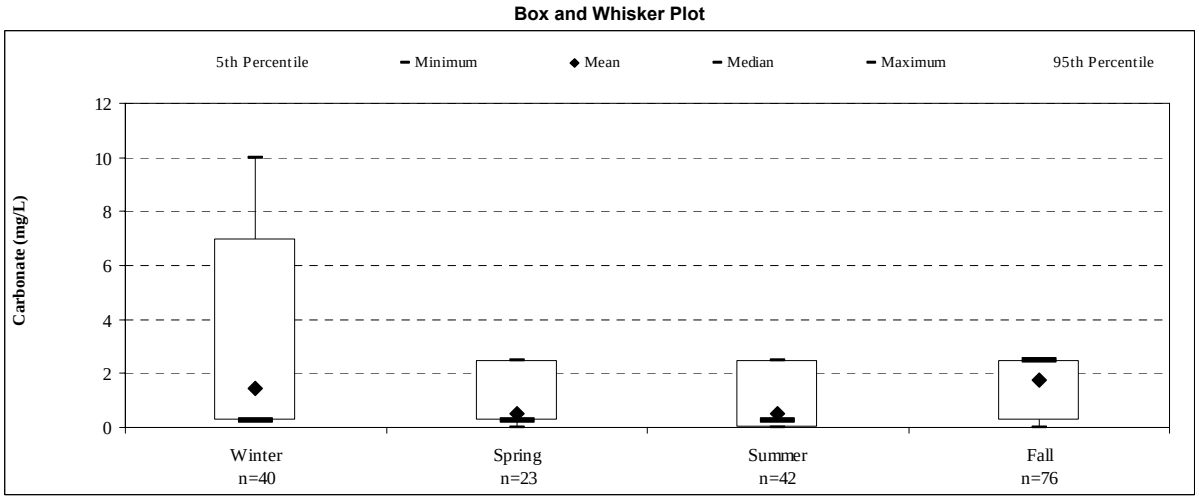


Figure G-1-1-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Upper Reach of Lower Athabasca River



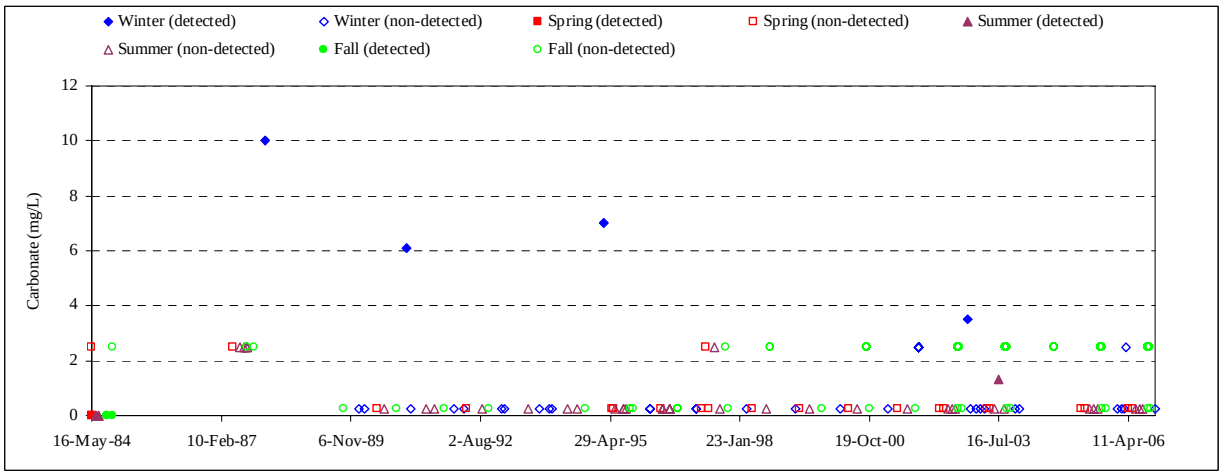


Figure G-1-1-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Upper Reach of Lower Athabasca River

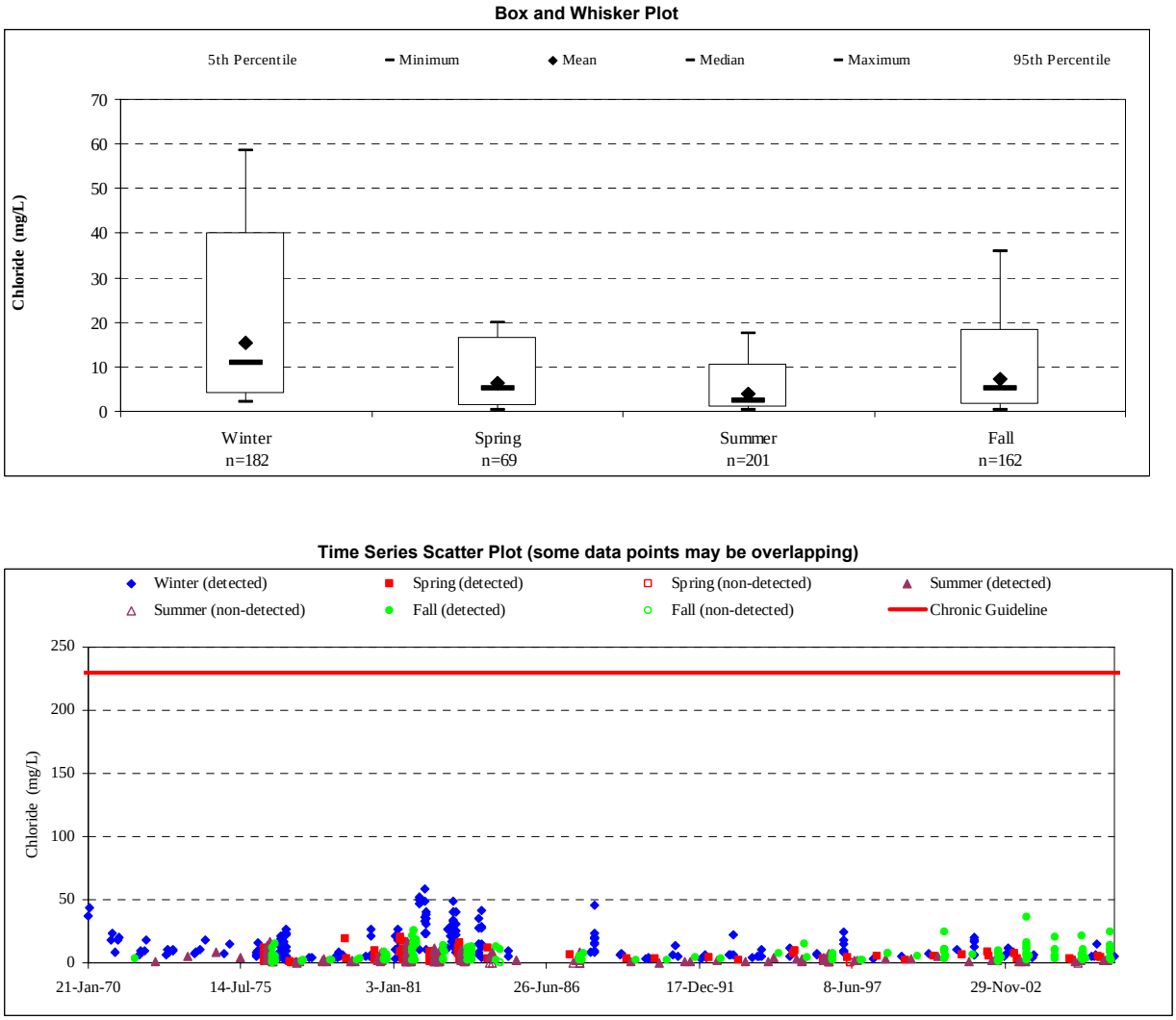
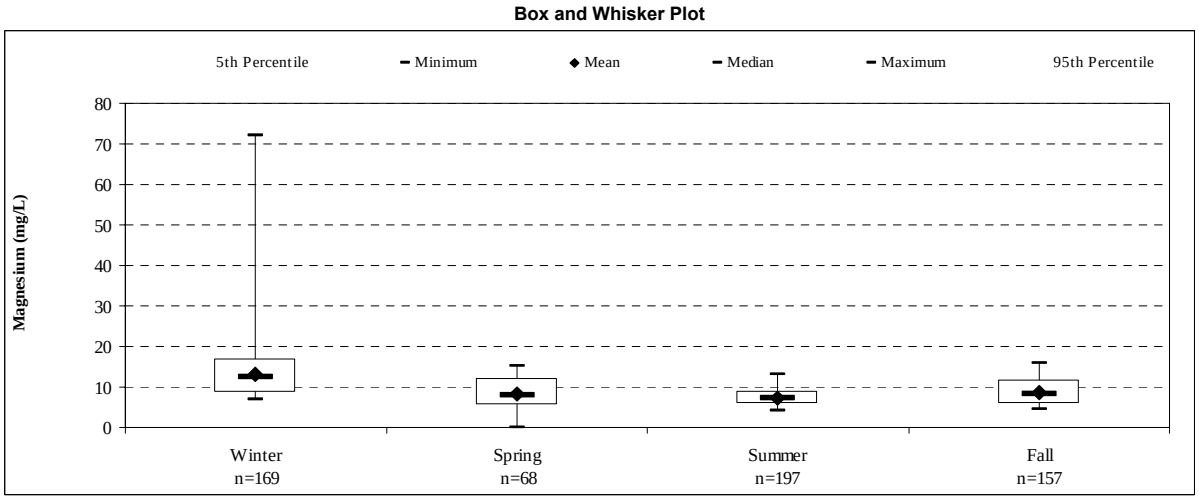


Figure G-1-1-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Upper Reach of Lower Athabasca River



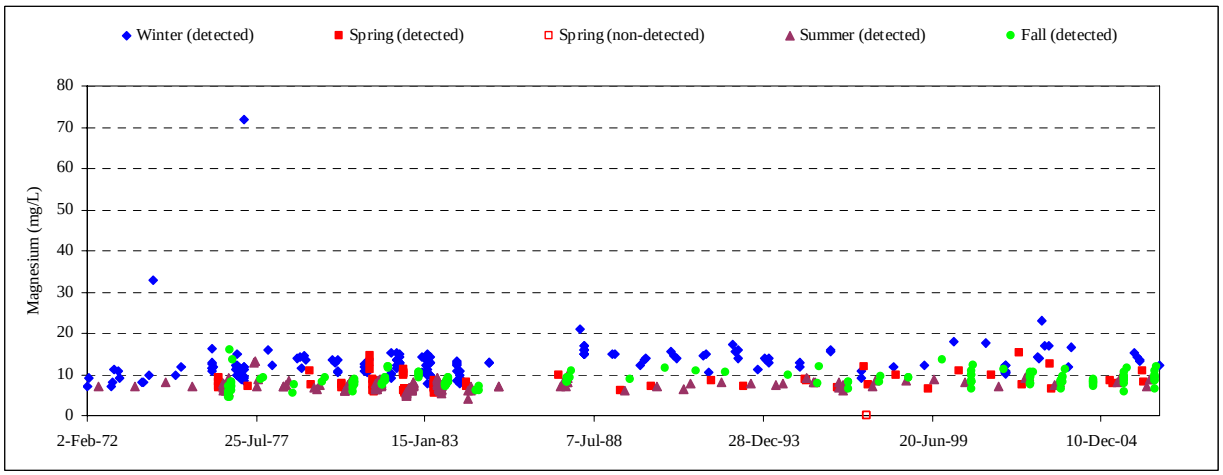
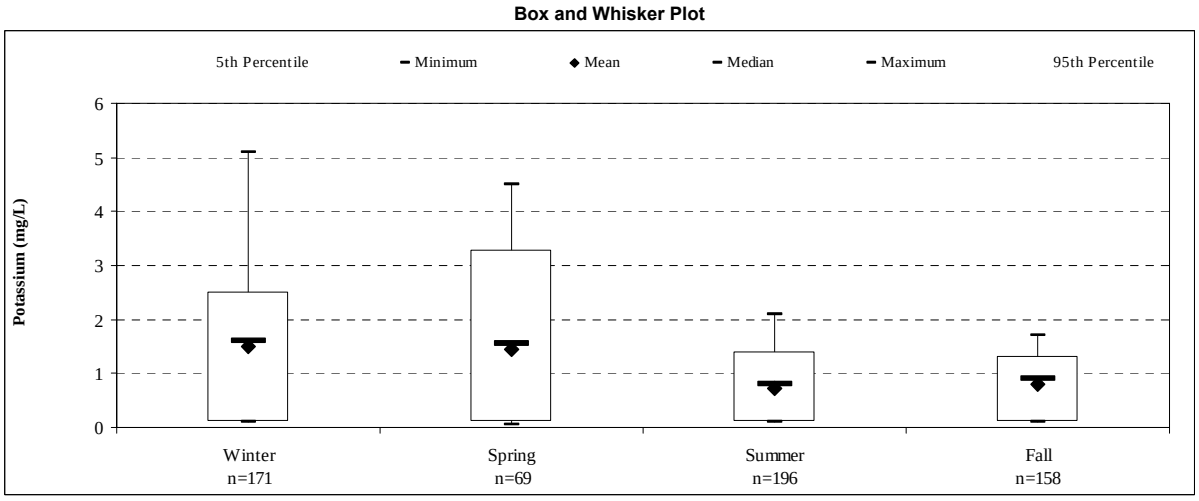


Figure G-1-1-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Upper Reach of Lower Athabasca River



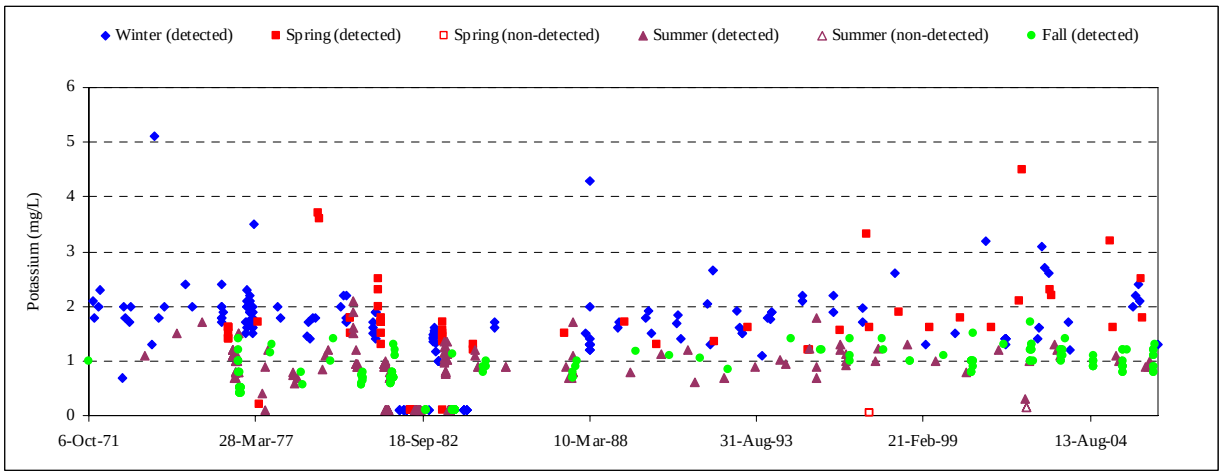
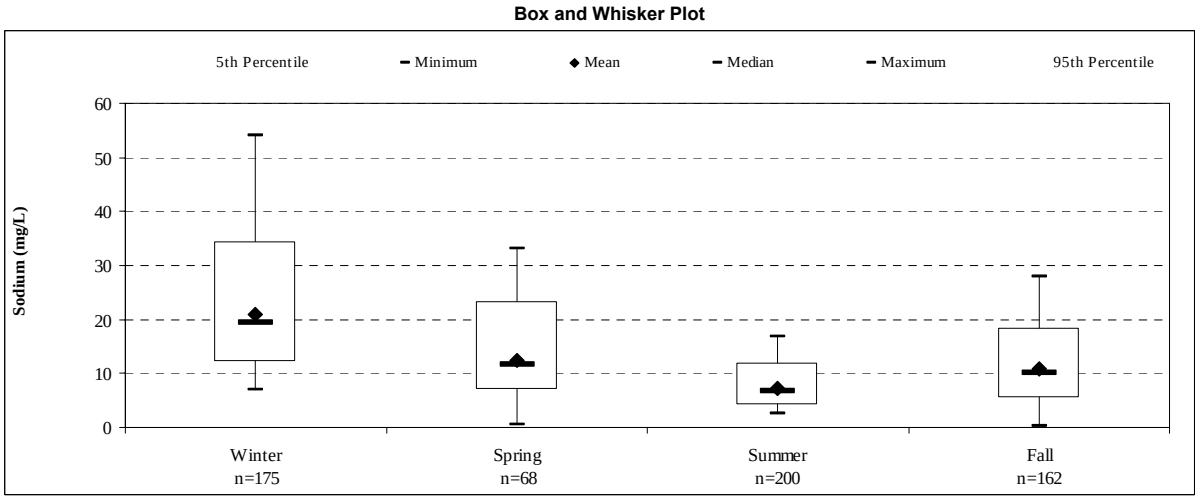


Figure G-1-1-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Upper Reach of Lower Athabasca River



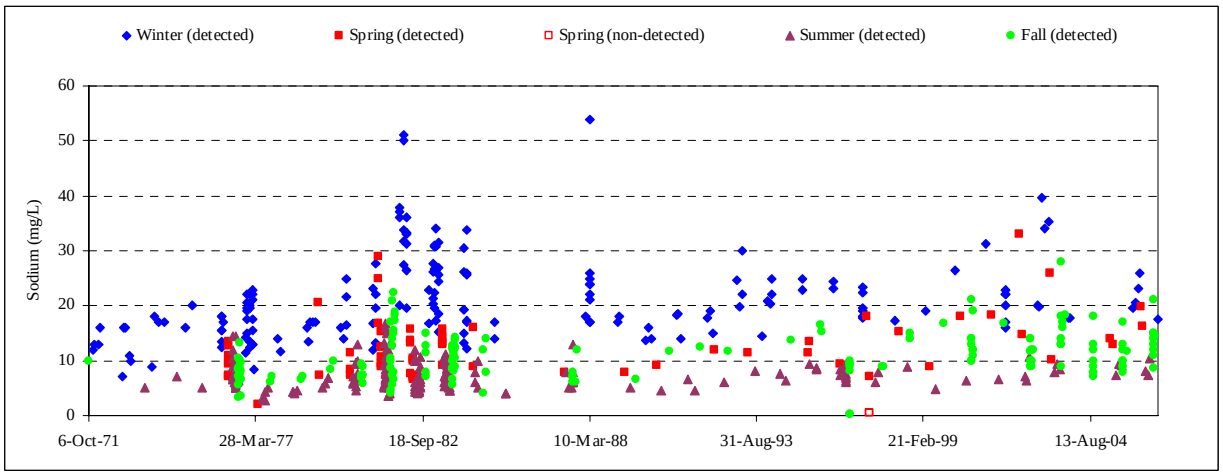
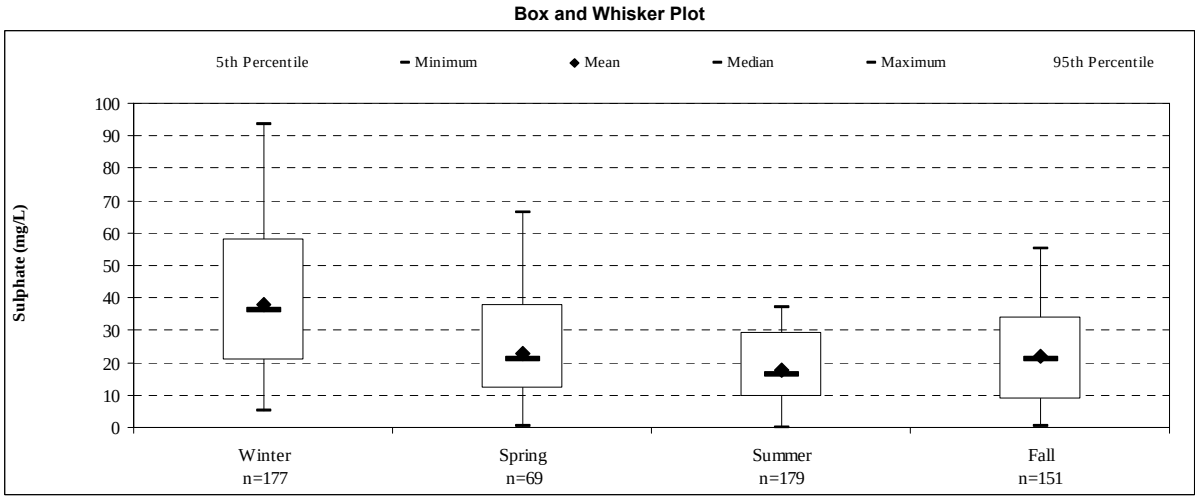


Figure G-1-1-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Upper Reach of Lower Athabasca River



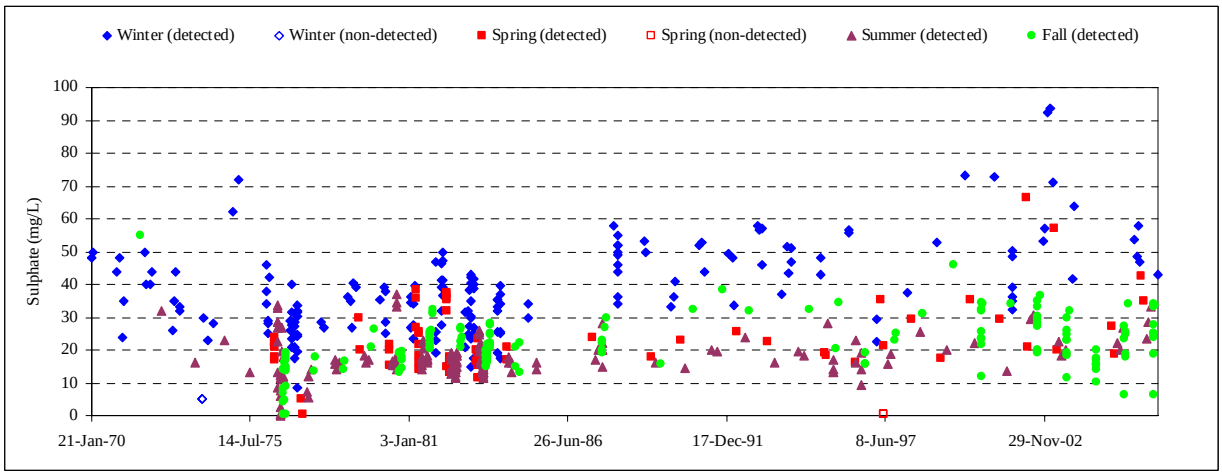
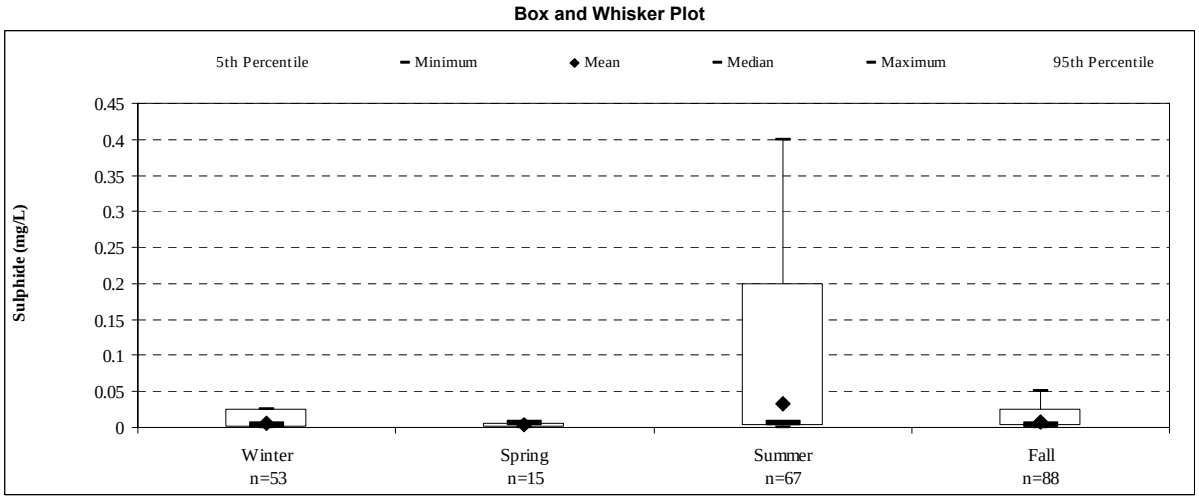


Figure G-1-1-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Upper Reach of Lower Athabasca River



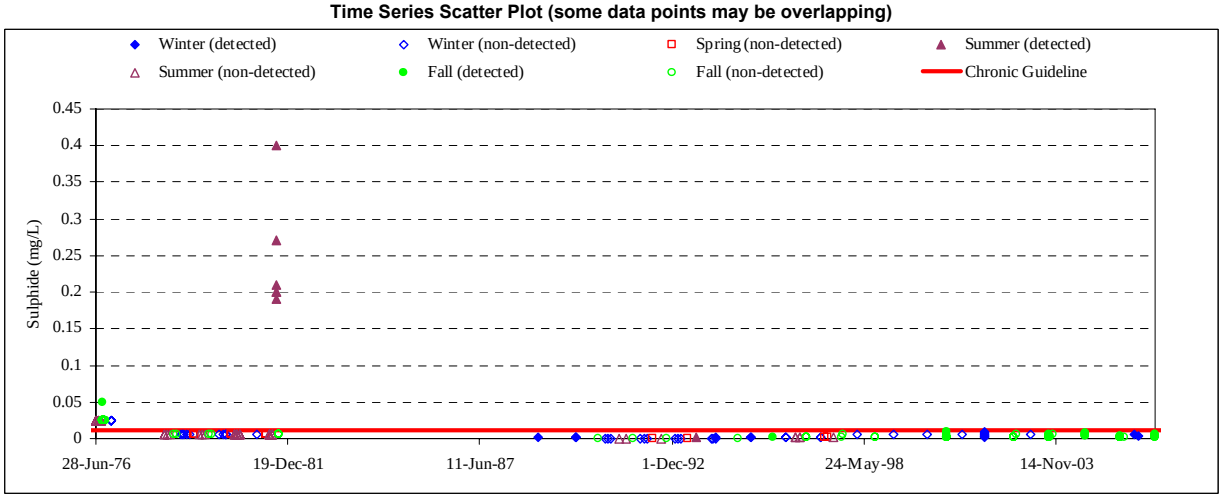
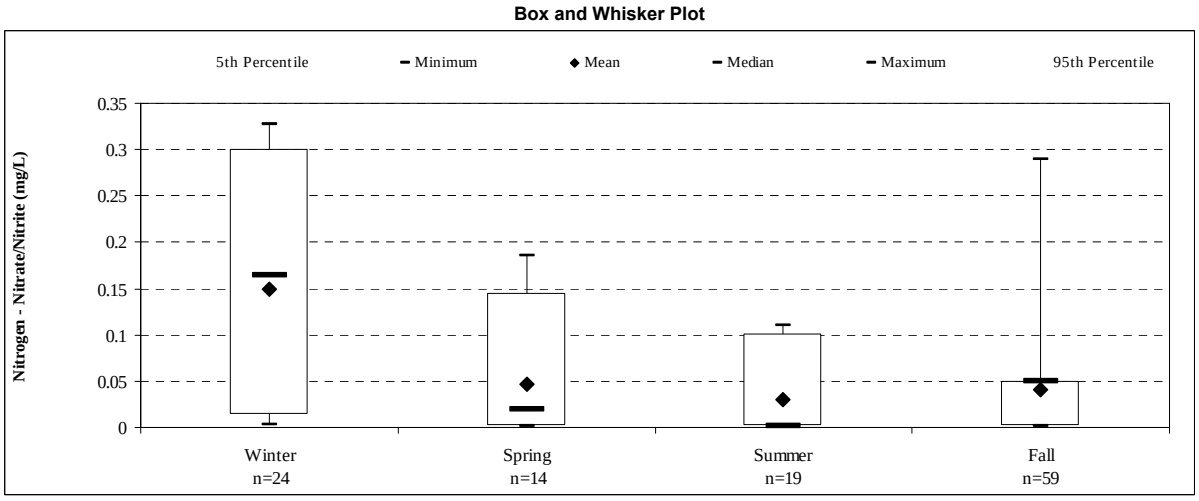


Figure G-1-1-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Upper Reach of Lower Athabasca River



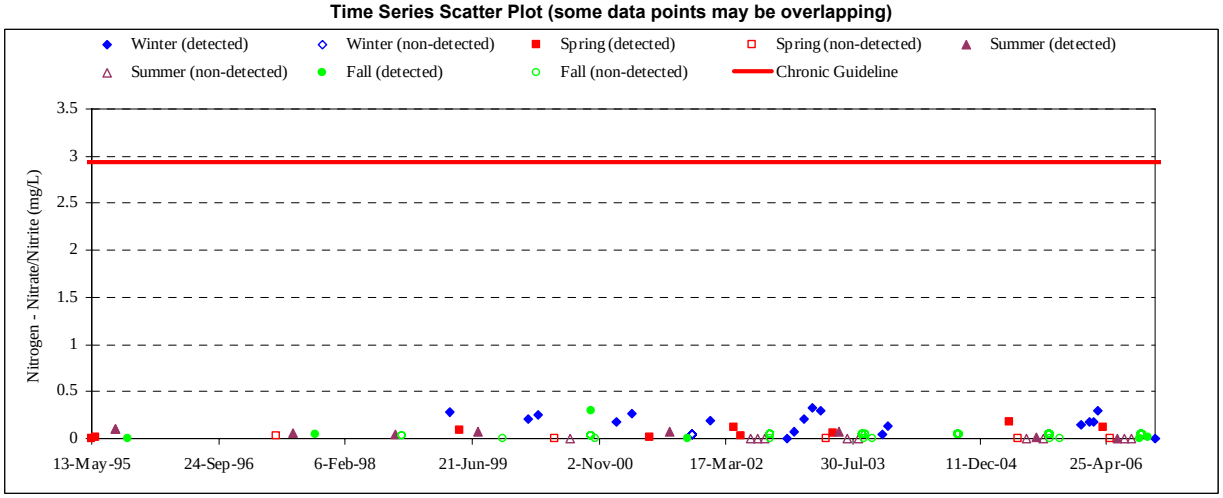
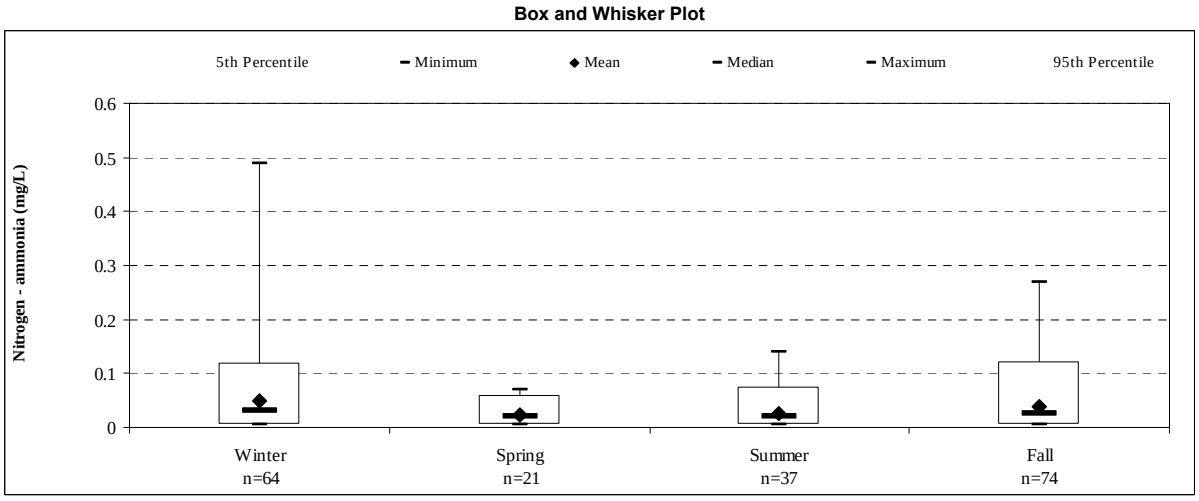


Figure G-1-1-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Upper Reach of Lower Athabasca River



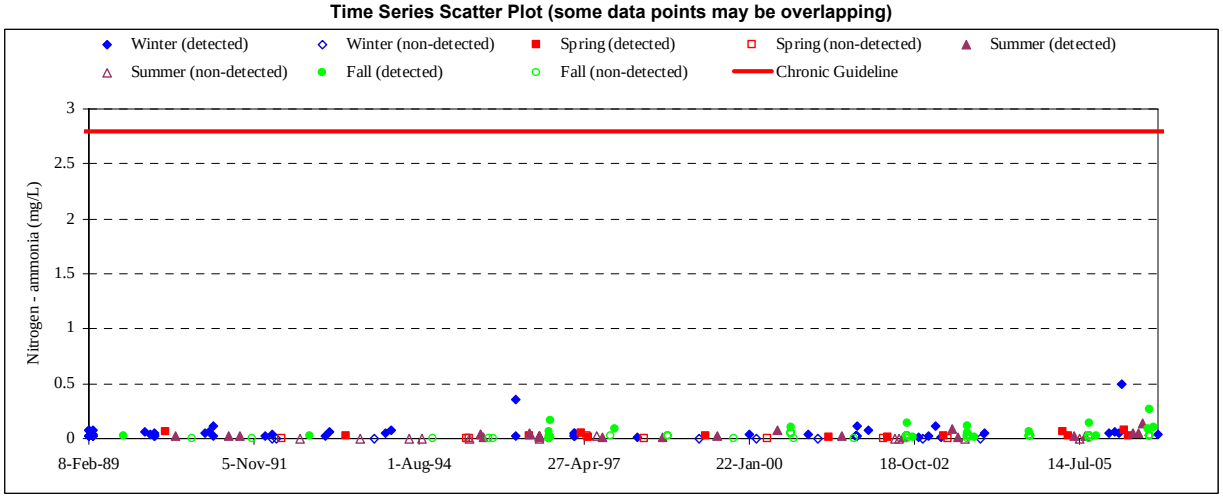
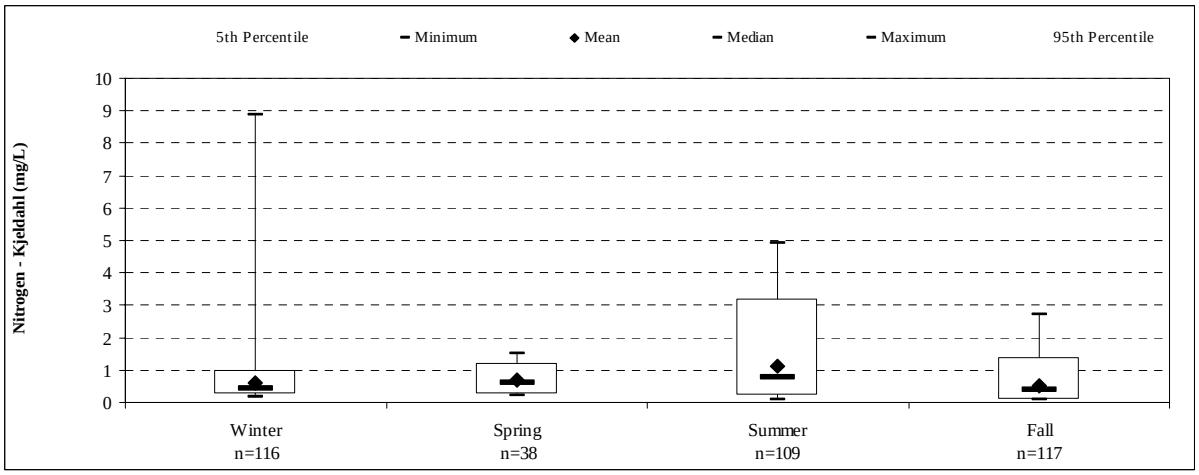


Figure G-1-1-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Upper Reach of Lower Athabasca River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

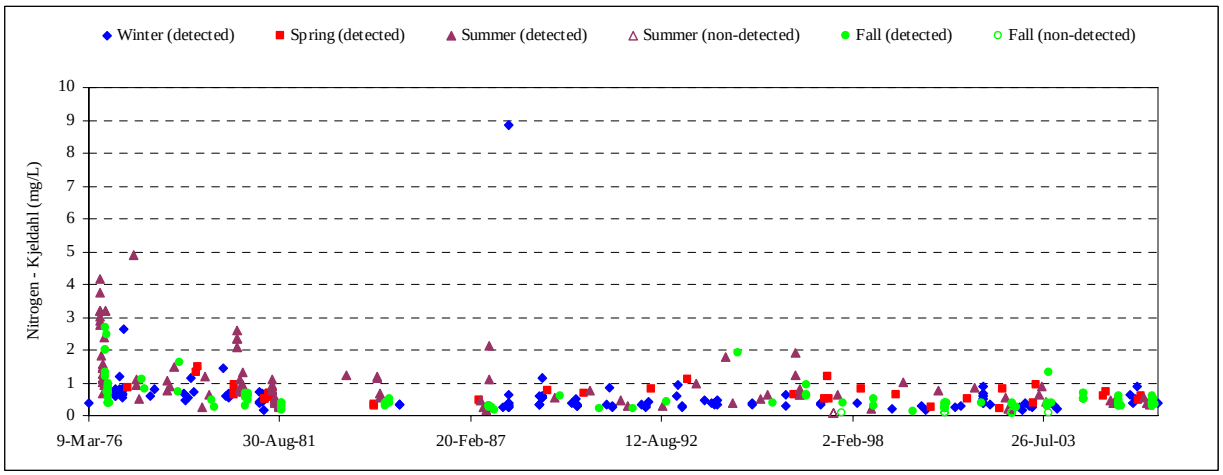


Figure G-1-1-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Upper Reach of Lower Athabasca River

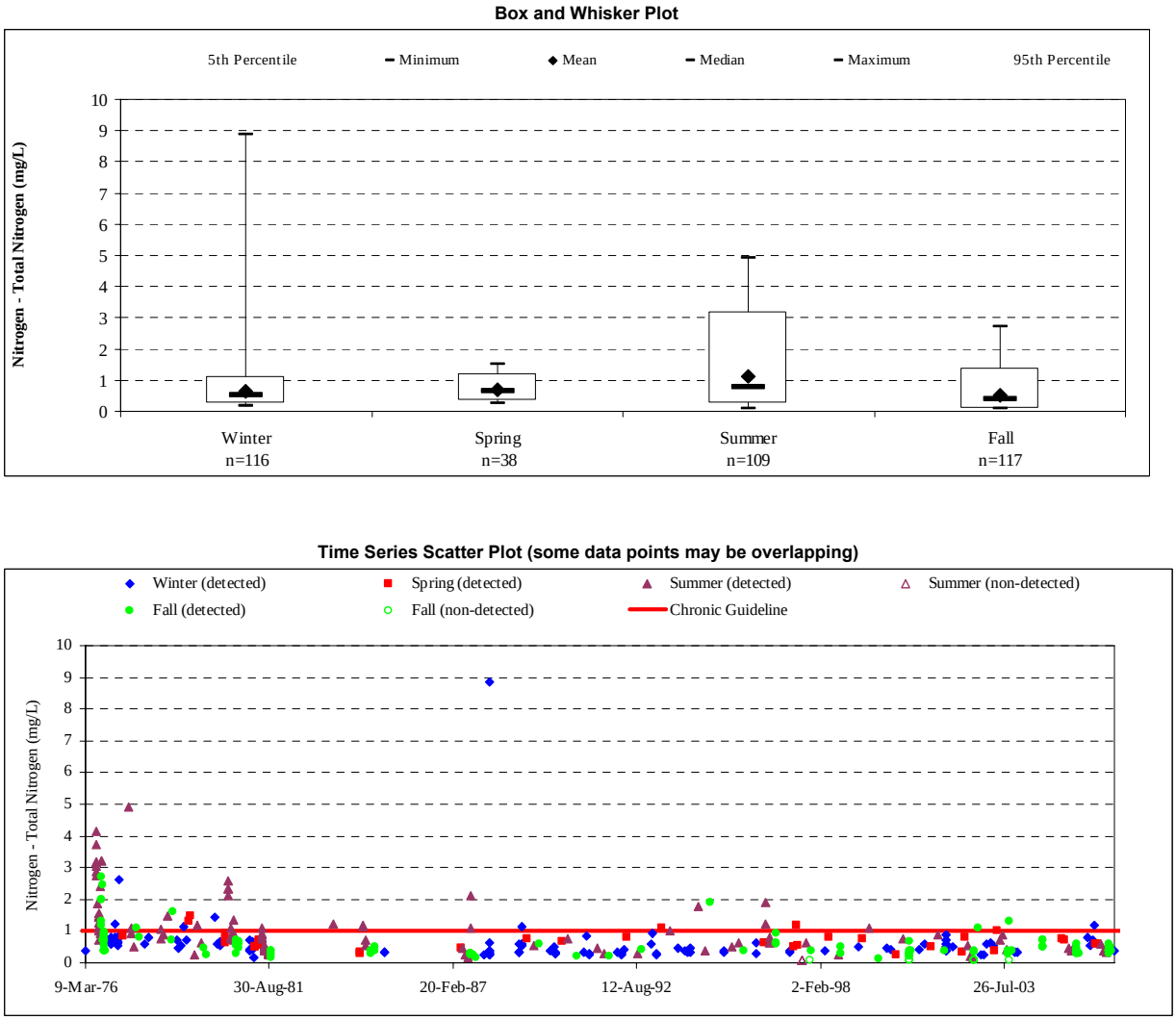
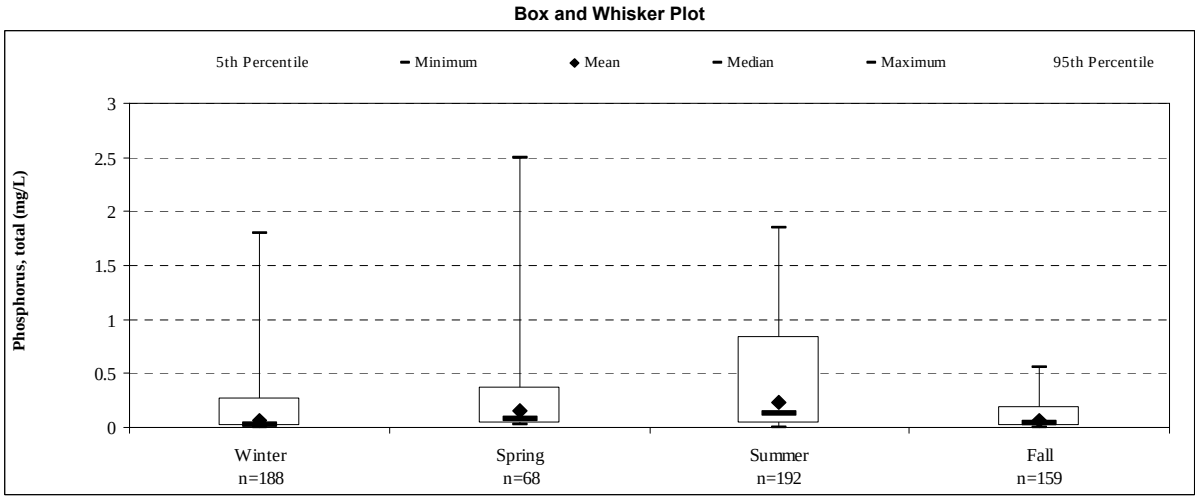


Figure G-1-1-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Upper Reach of Lower Athabasca River



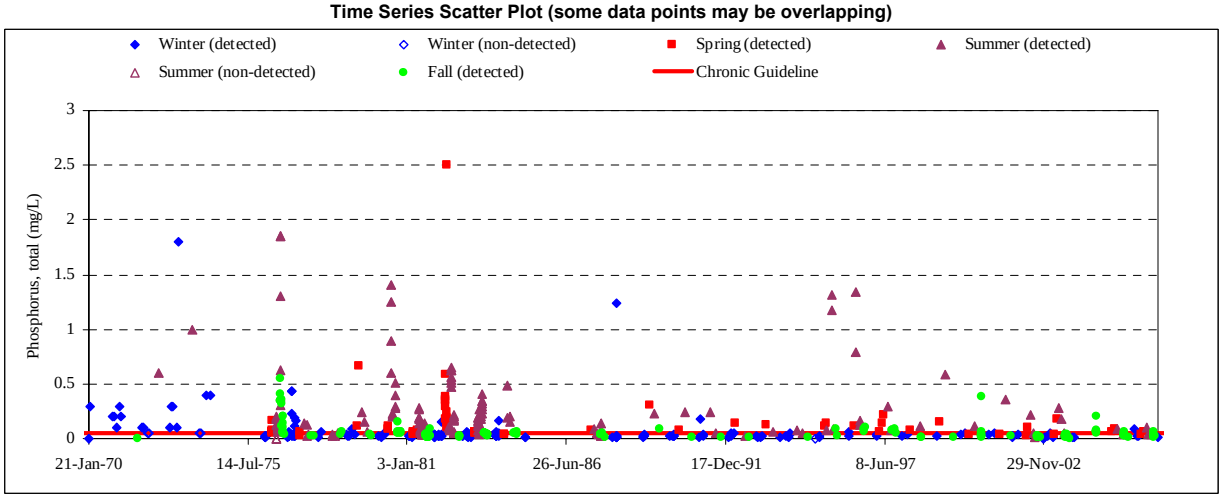
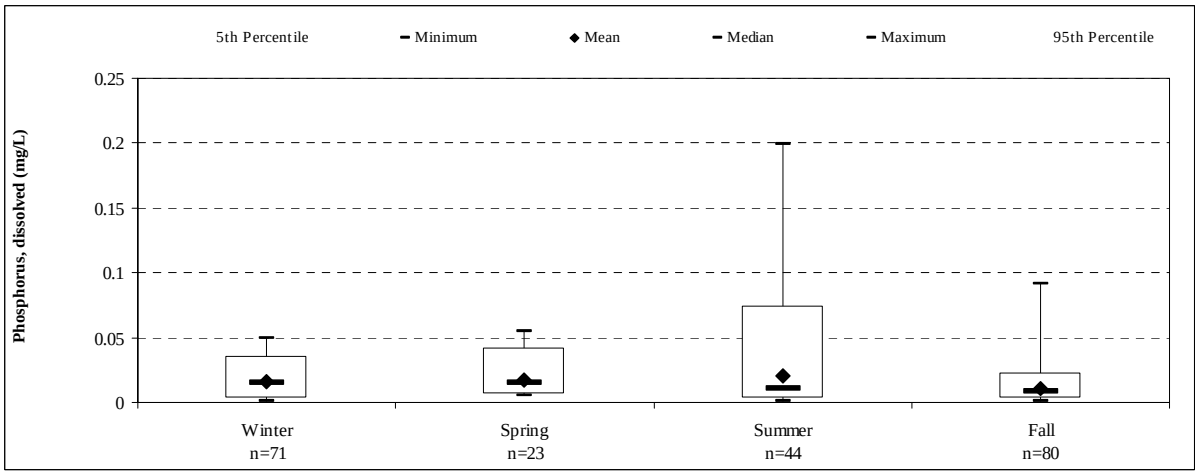


Figure G-1-1-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Upper Reach of Lower Athabasca River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

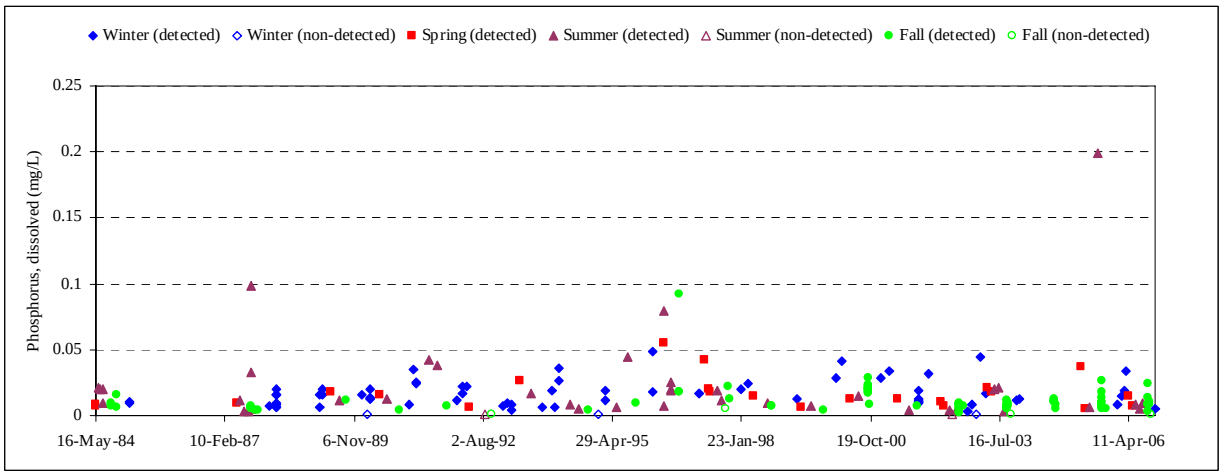
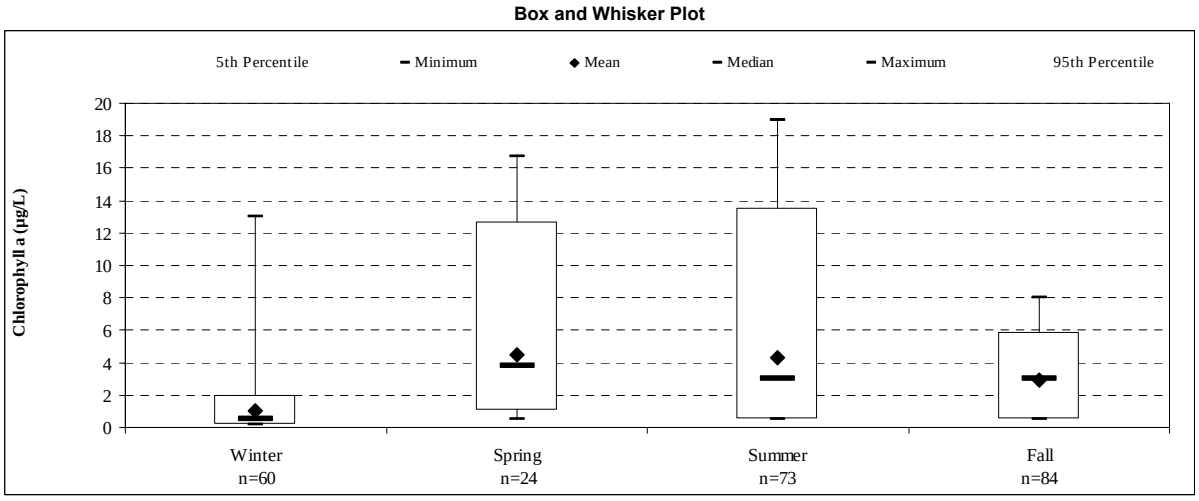


Figure G-1-1-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Upper Reach of Lower Athabasca River



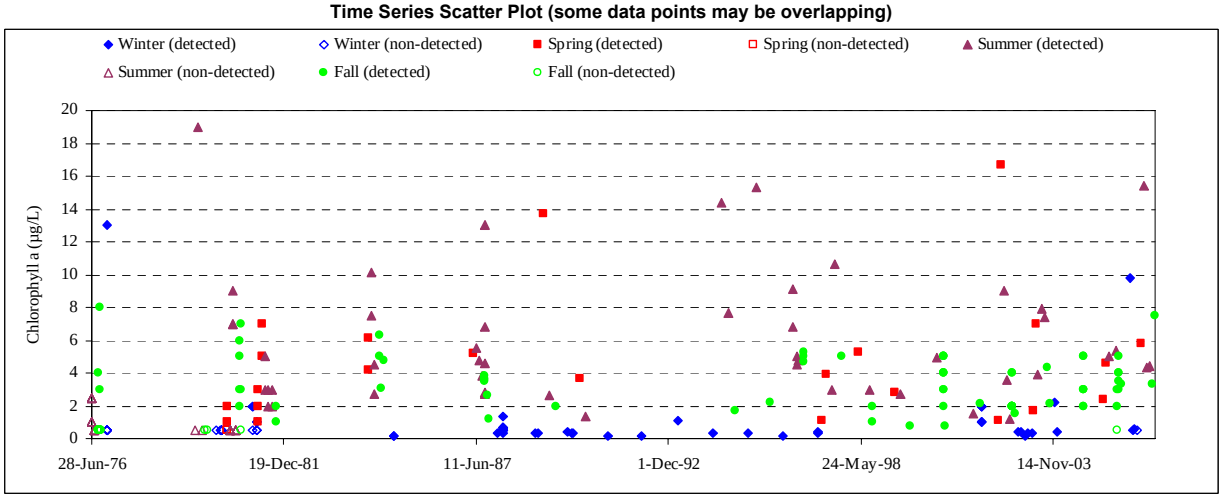
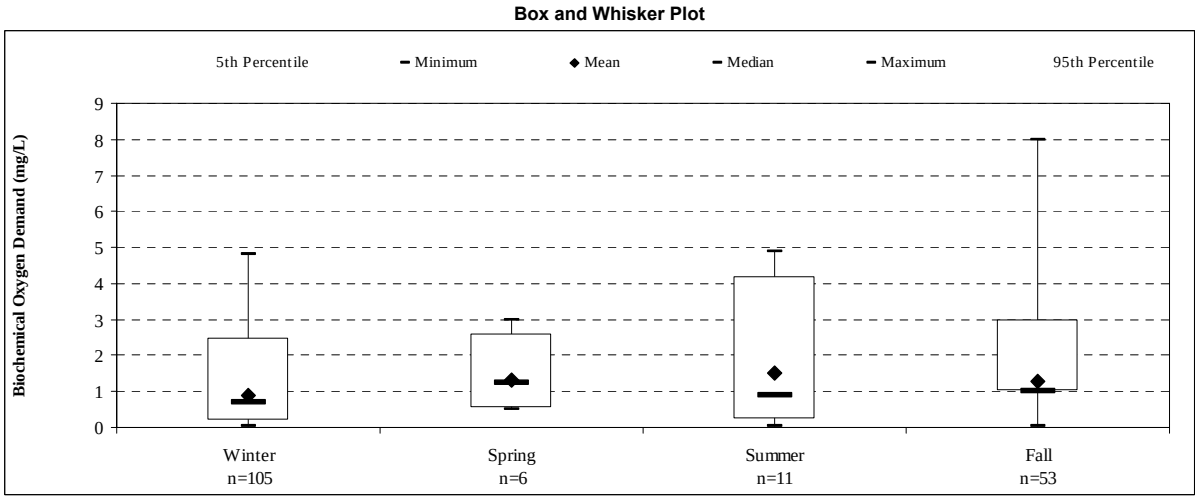


Figure G-1-1-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Upper Reach of Lower Athabasca River



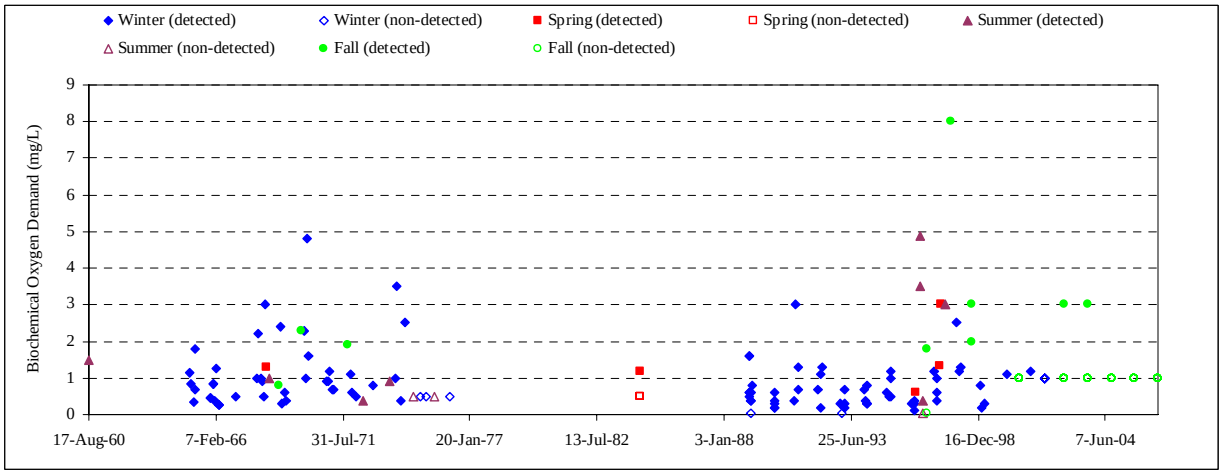


Figure G-1-1-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Upper Reach of Lower Athabasca River

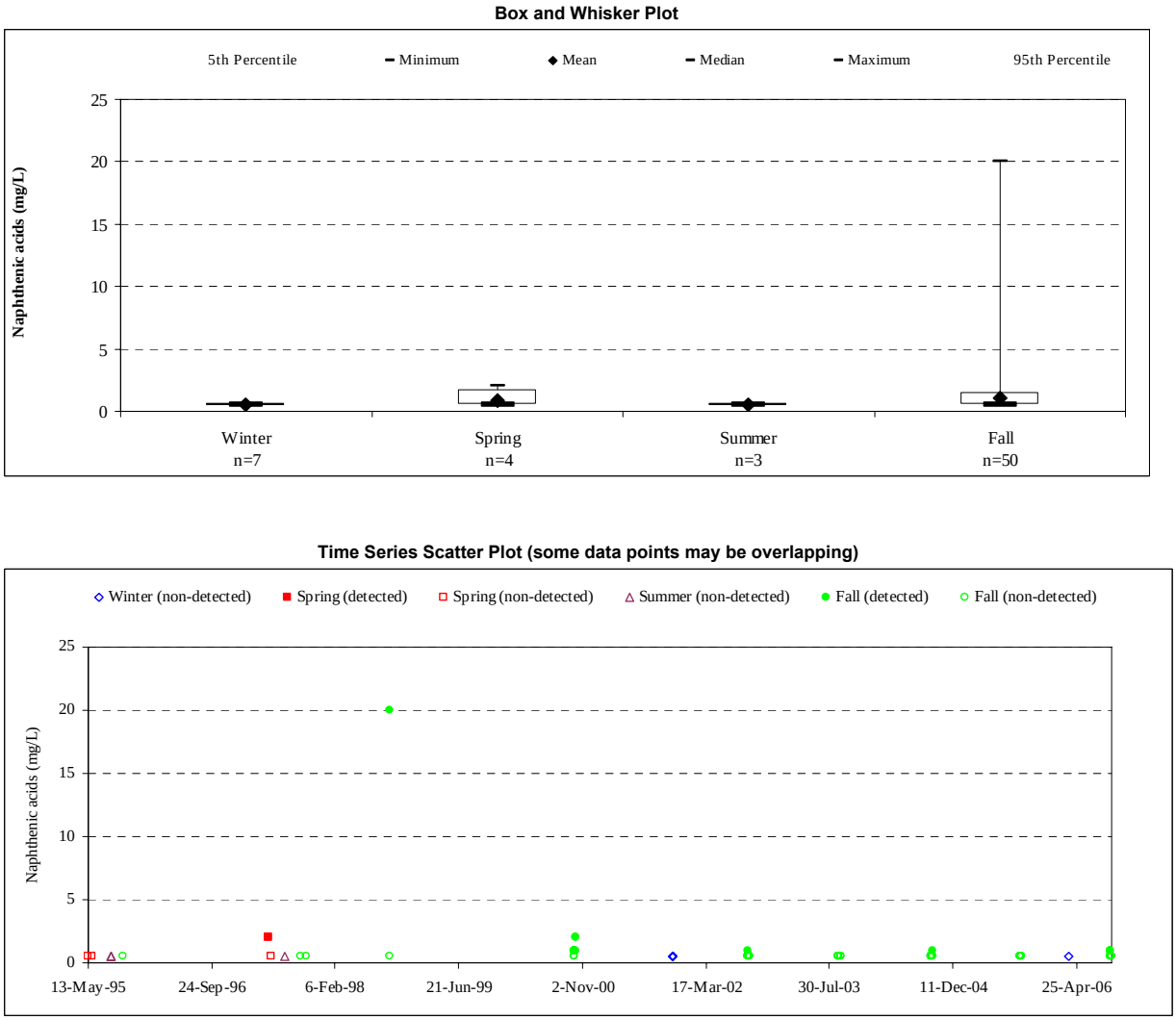
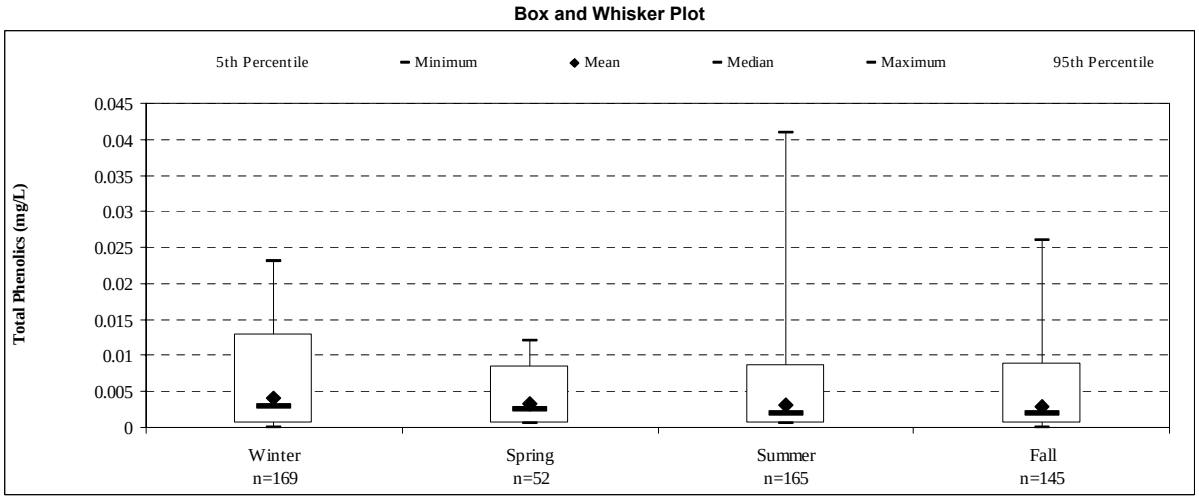


Figure G-1-1-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Upper Reach of Lower Athabasca River



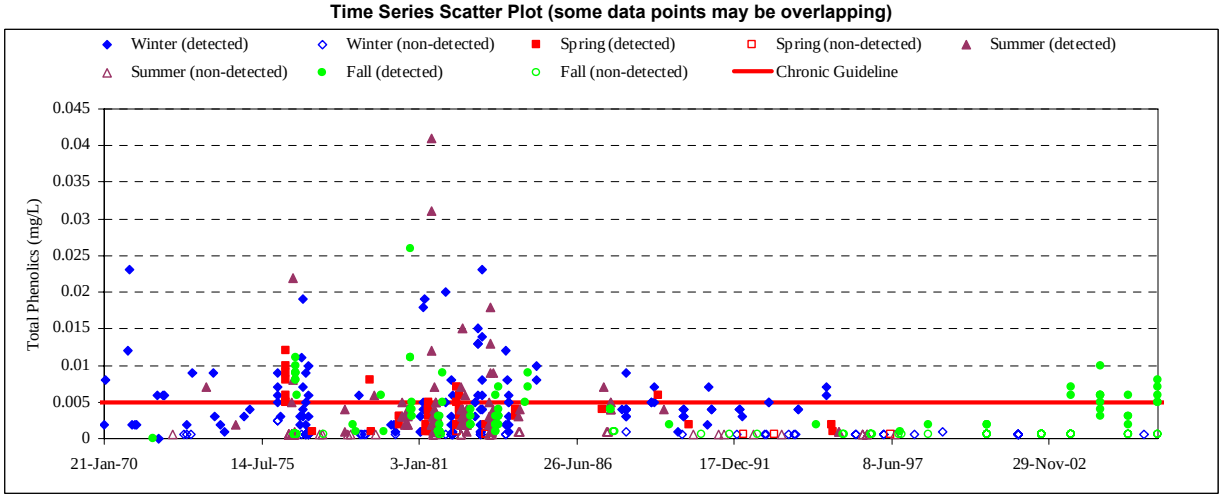
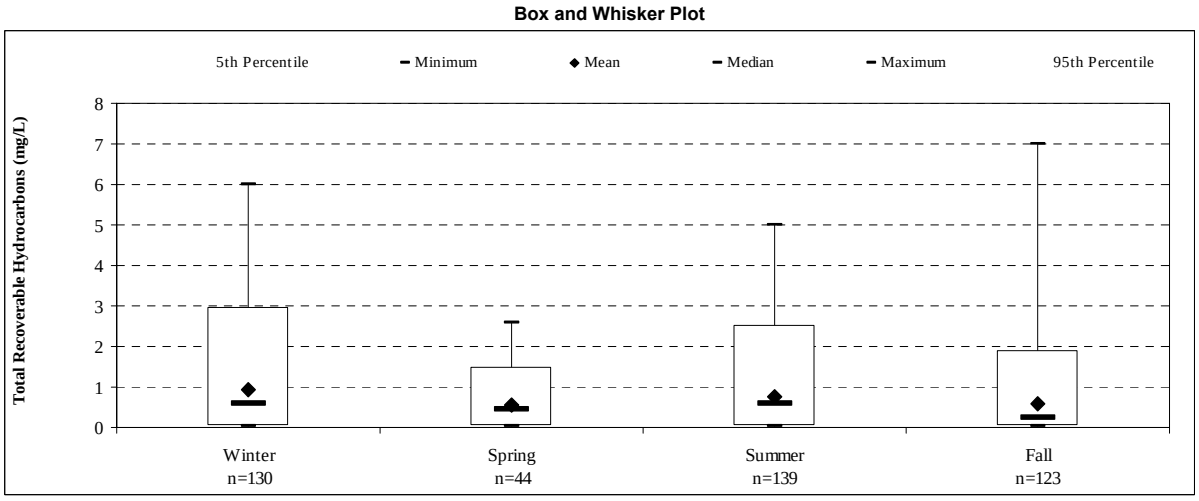


Figure G-1-1-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Upper Reach of Lower Athabasca River



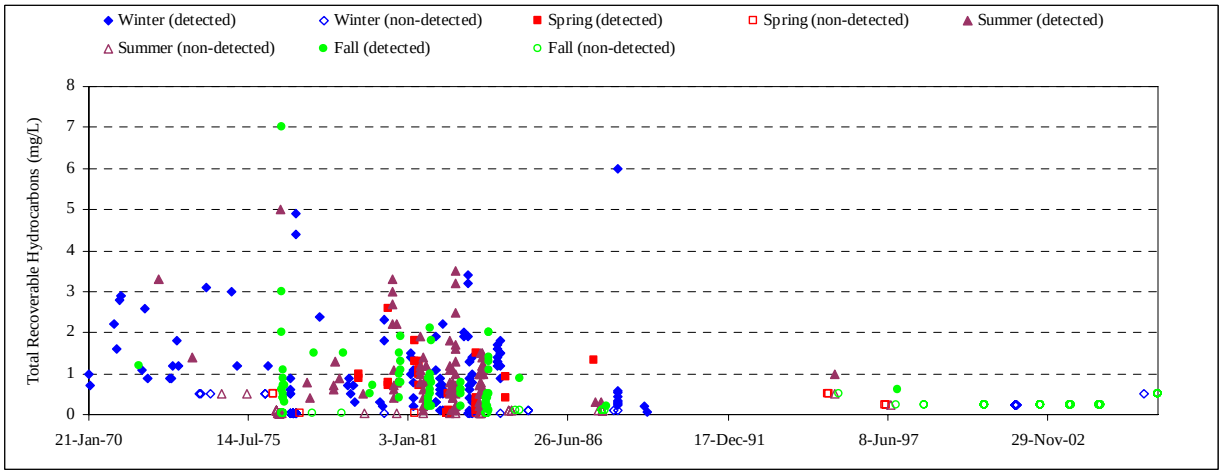
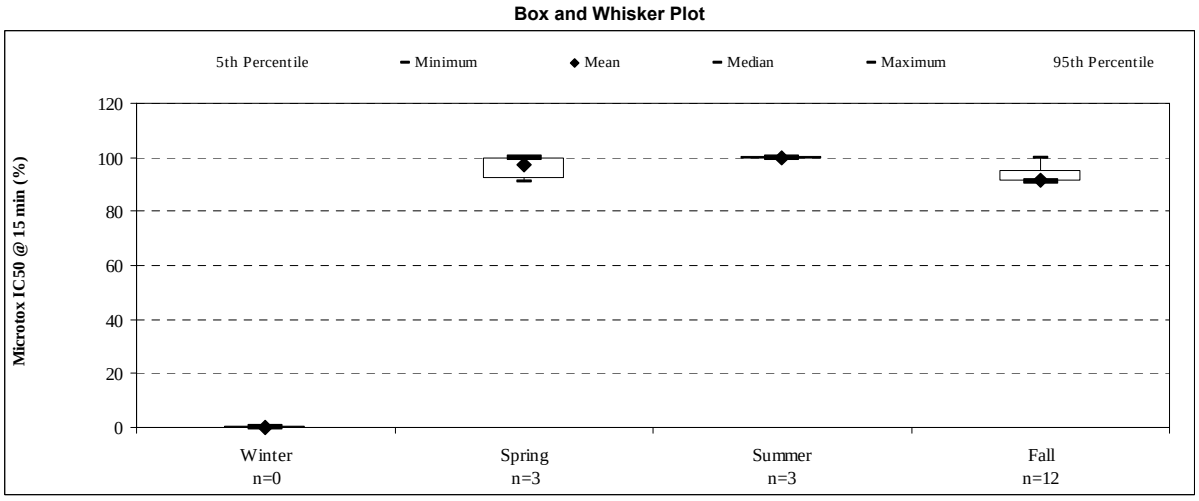


Figure G-1-1-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Upper Reach of Lower Athabasca River



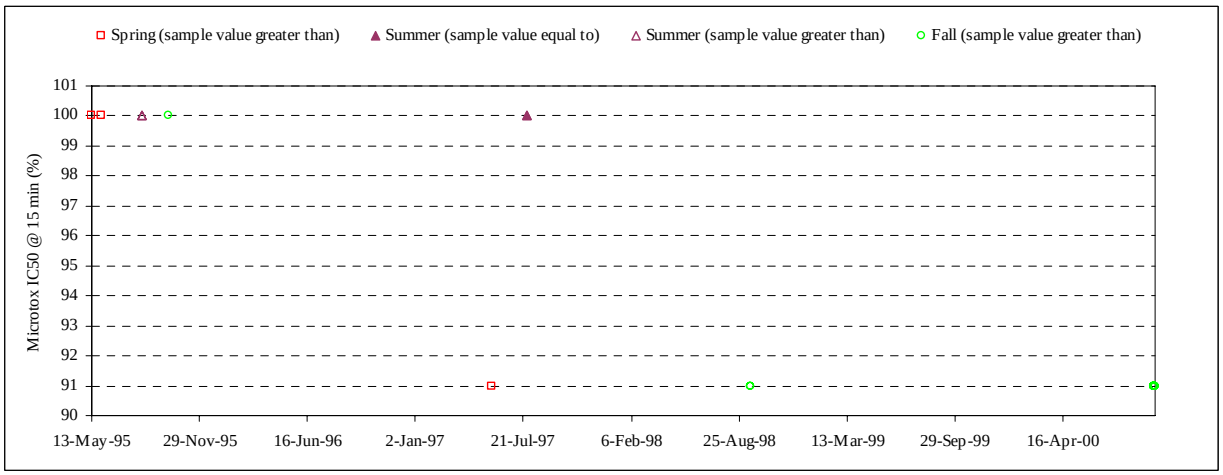
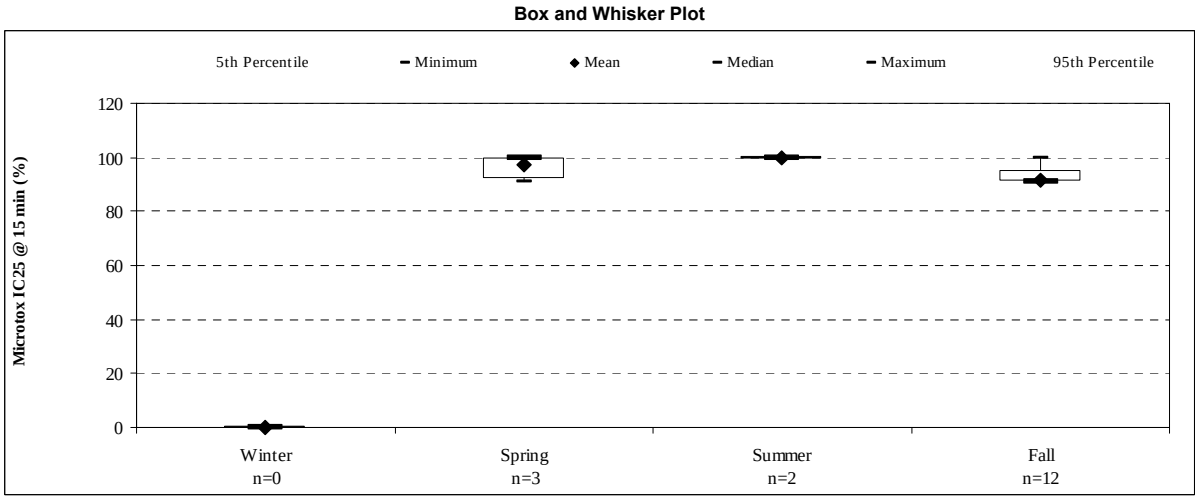


Figure G-1-1-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Upper Reach of Lower Athabasca River



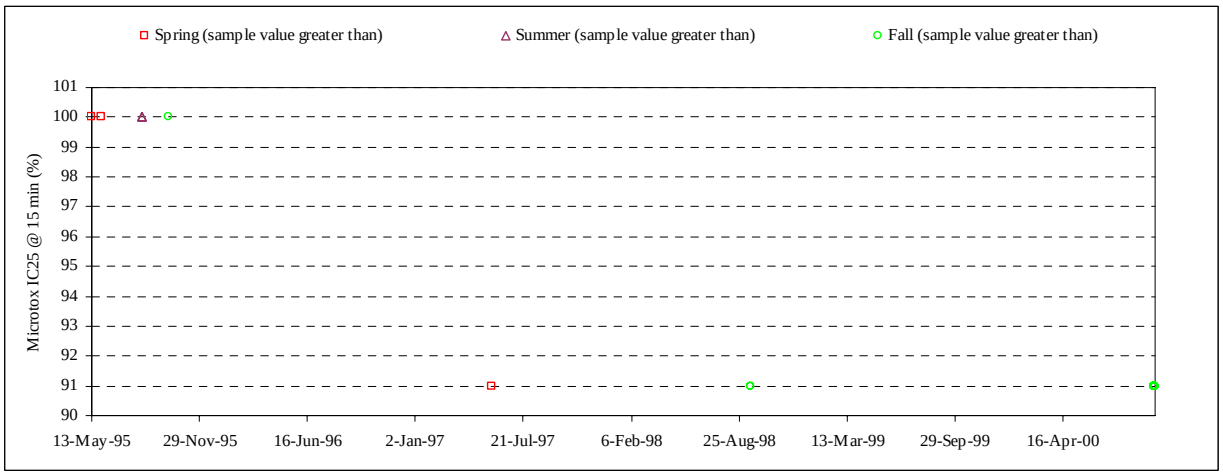


Figure G-1-1-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Upper Reach of Lower Athabasca River

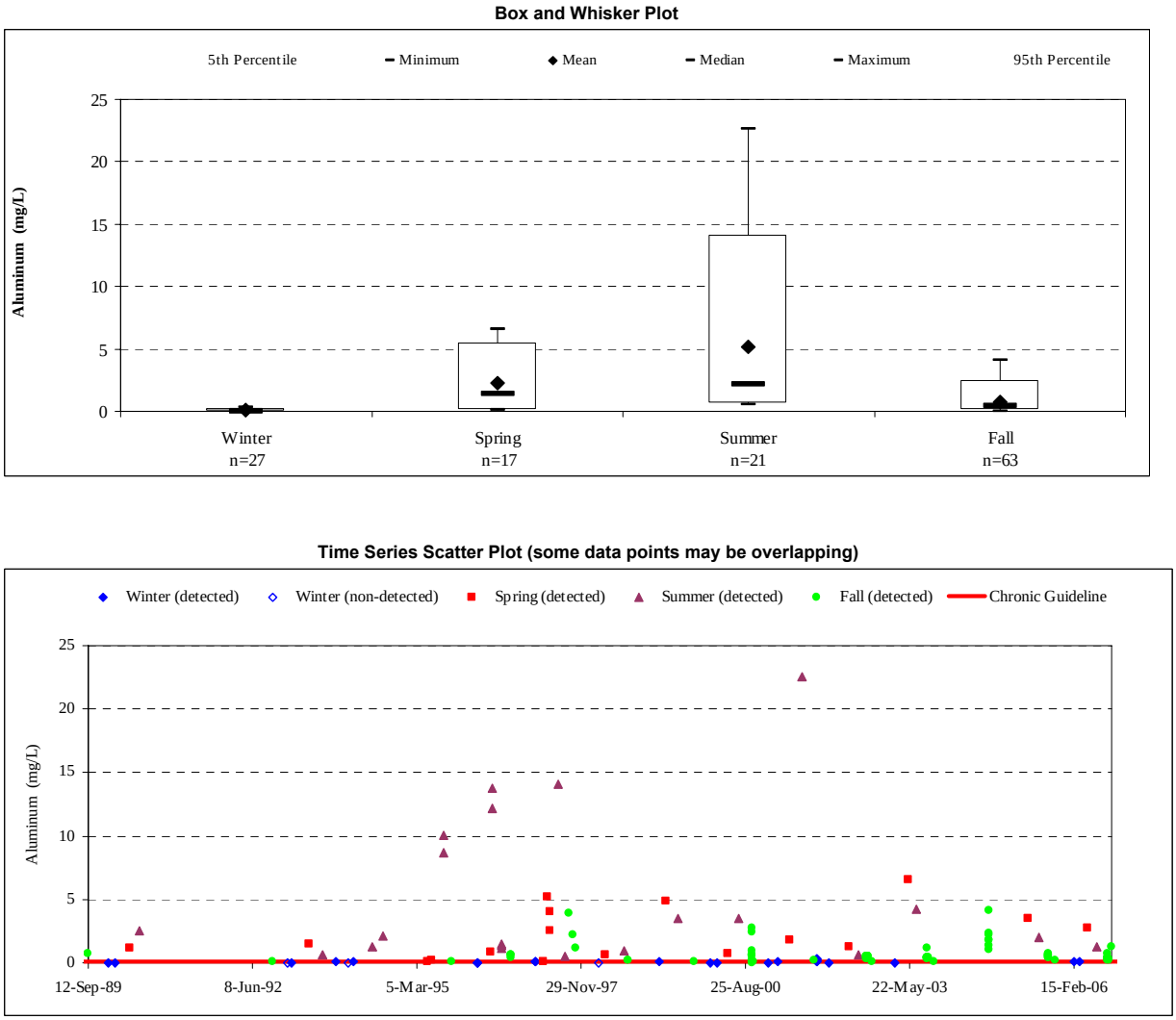


Figure G-1-1-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Upper Reach of Lower Athabasca River

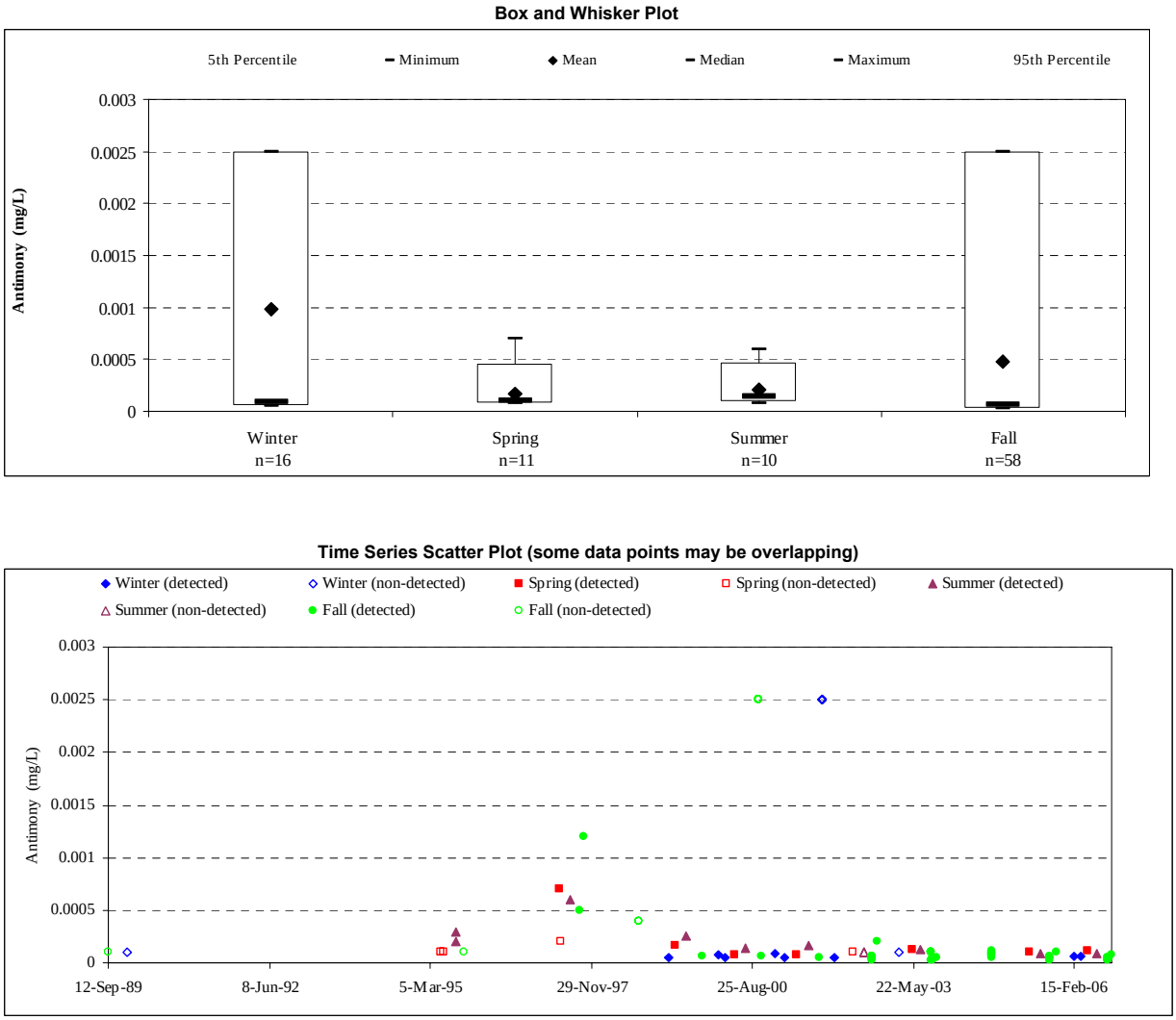


Figure G-1-1-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Upper Reach of Lower Athabasca River

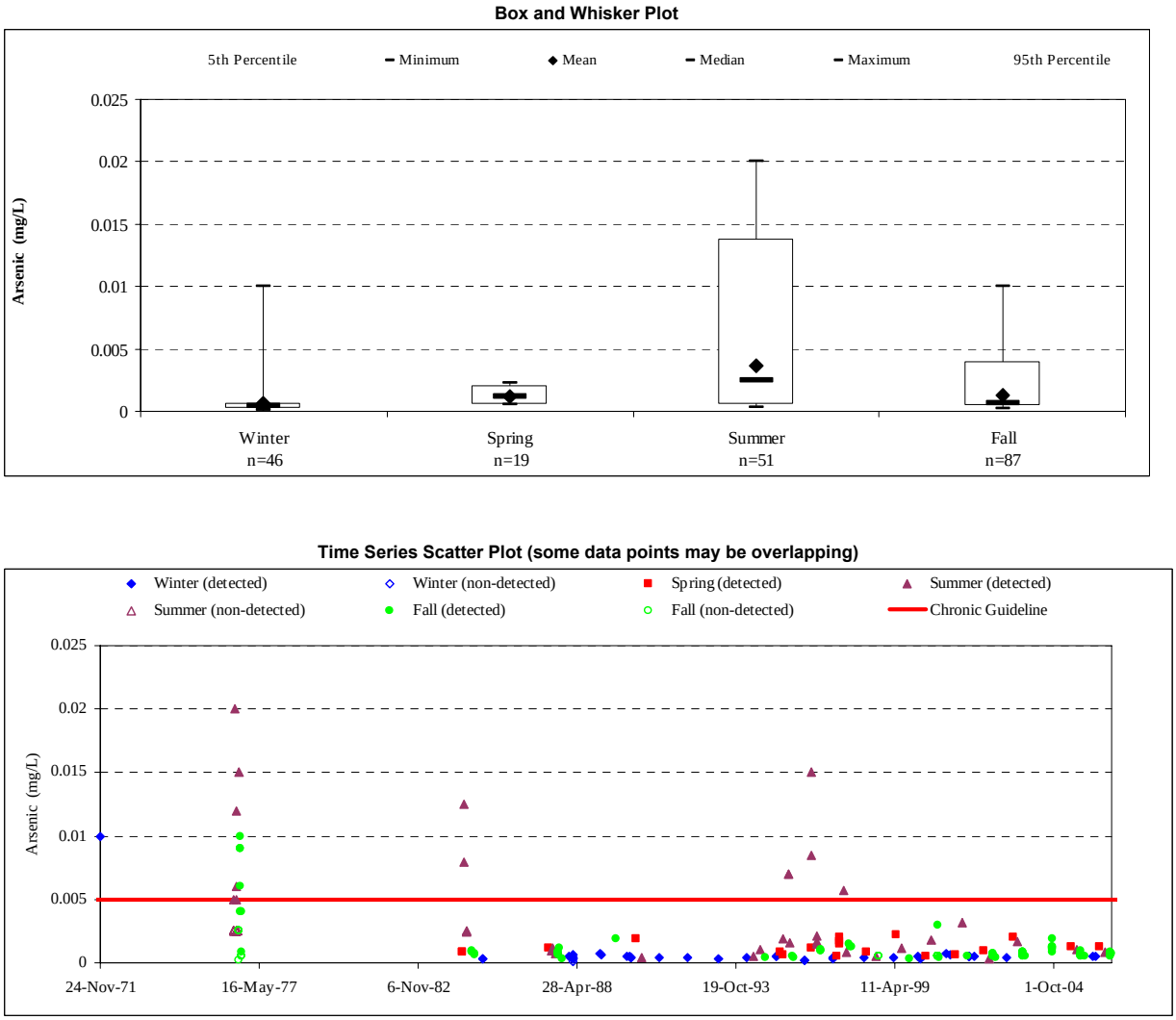
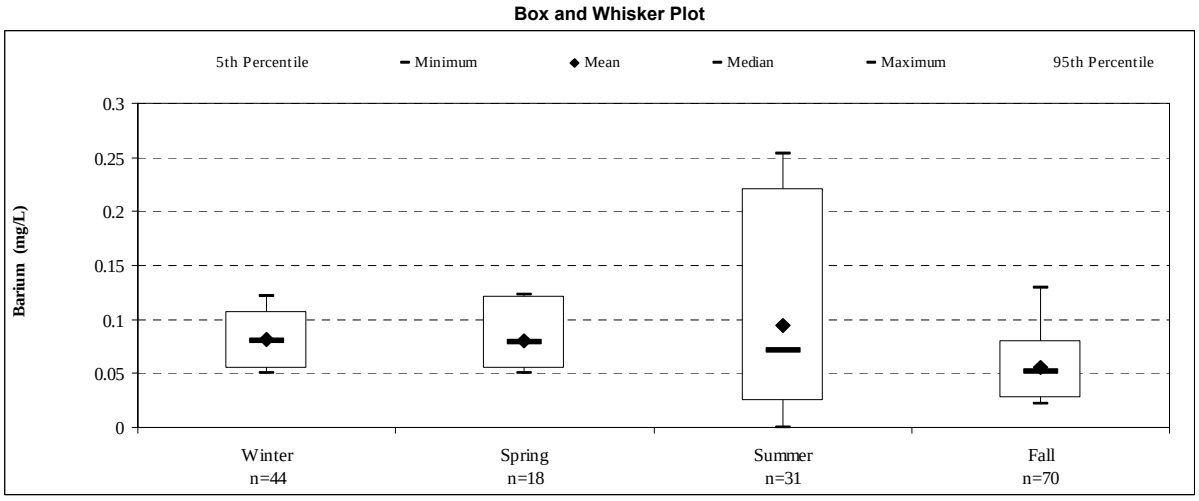


Figure G-1-1-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Upper Reach of Lower Athabasca River



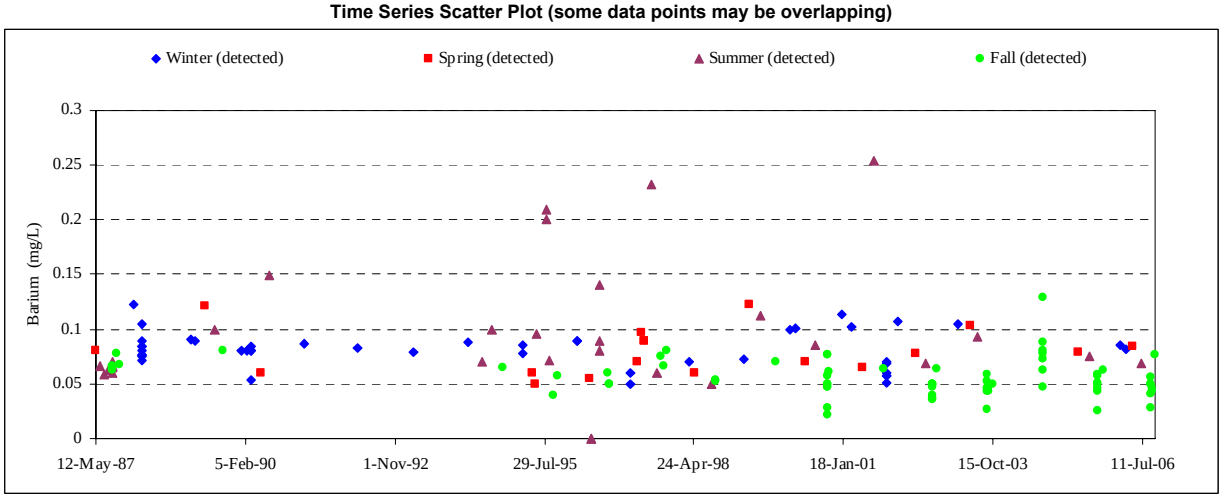
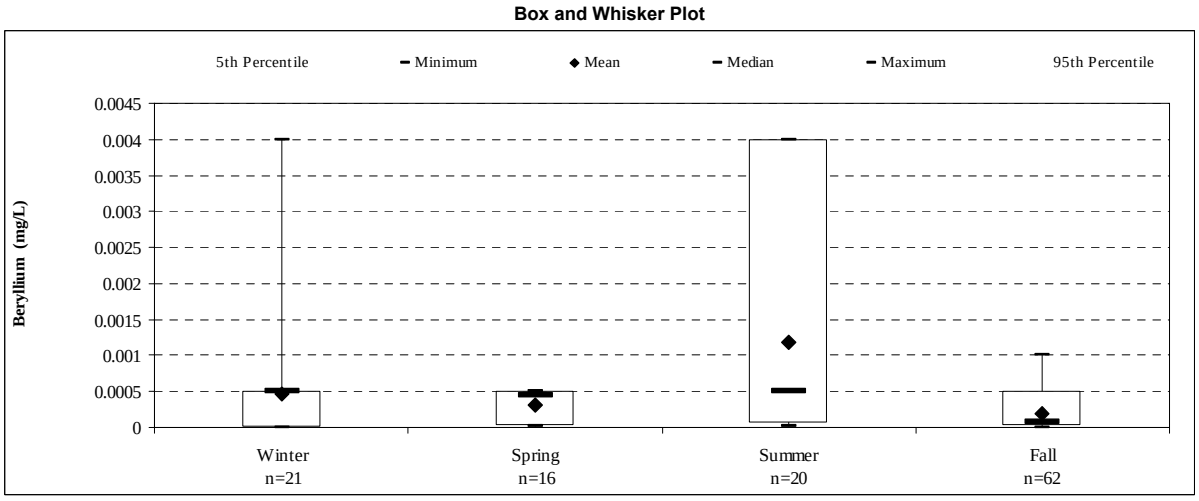


Figure G-1-1-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Upper Reach of Lower Athabasca River



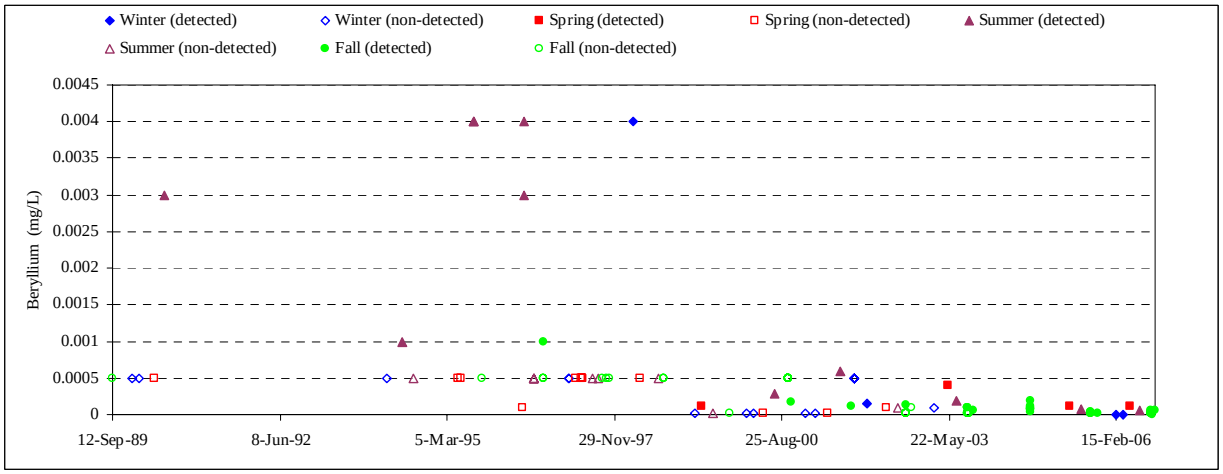
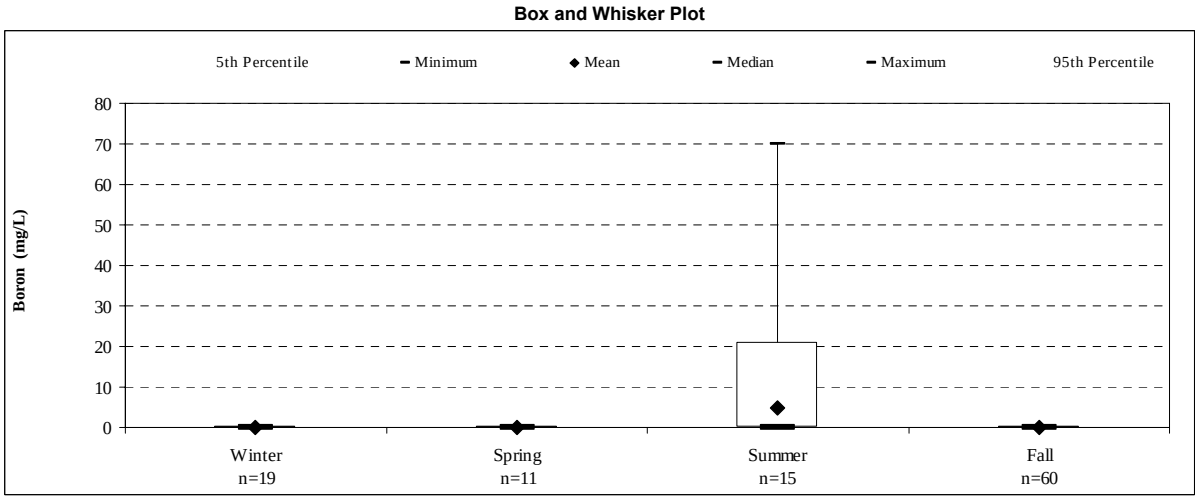


Figure G-1-1-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Upper Reach of Lower Athabasca River



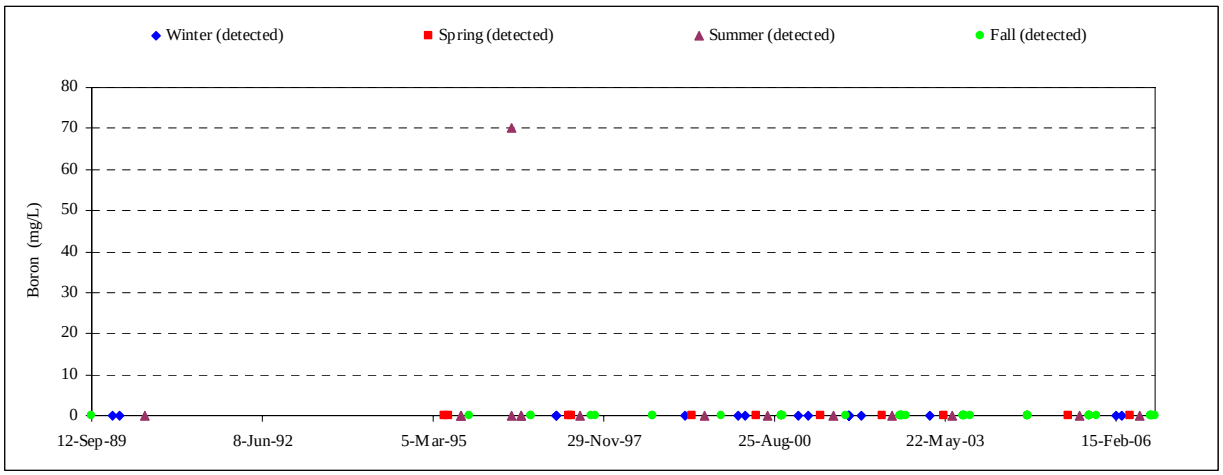
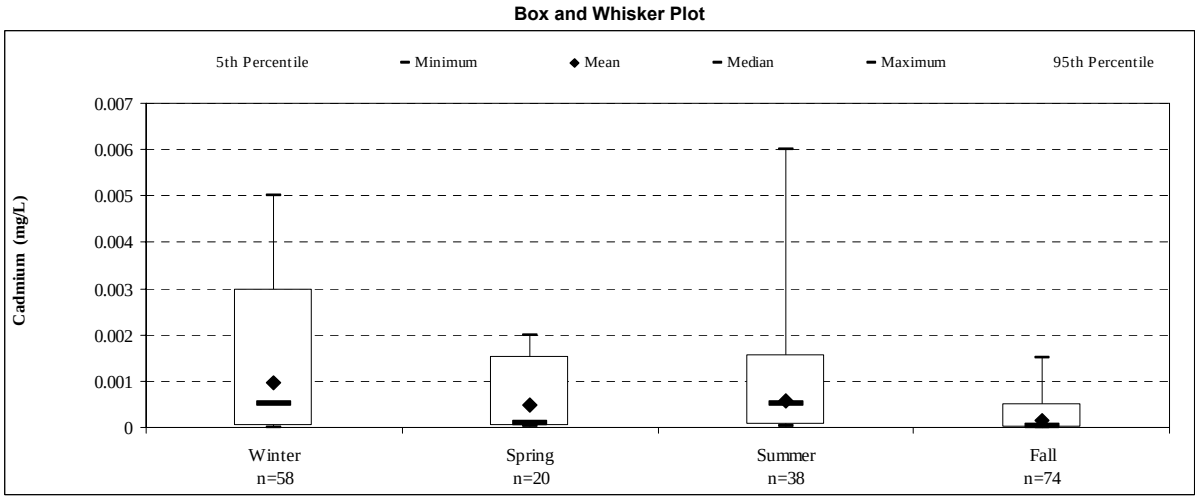


Figure G-1-1-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Upper Reach of Lower Athabasca River



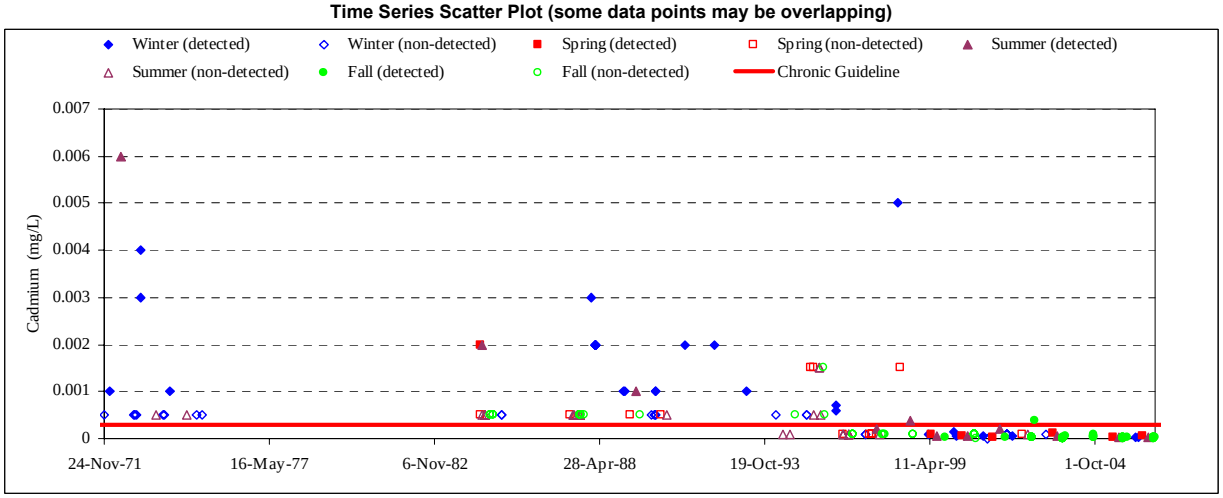
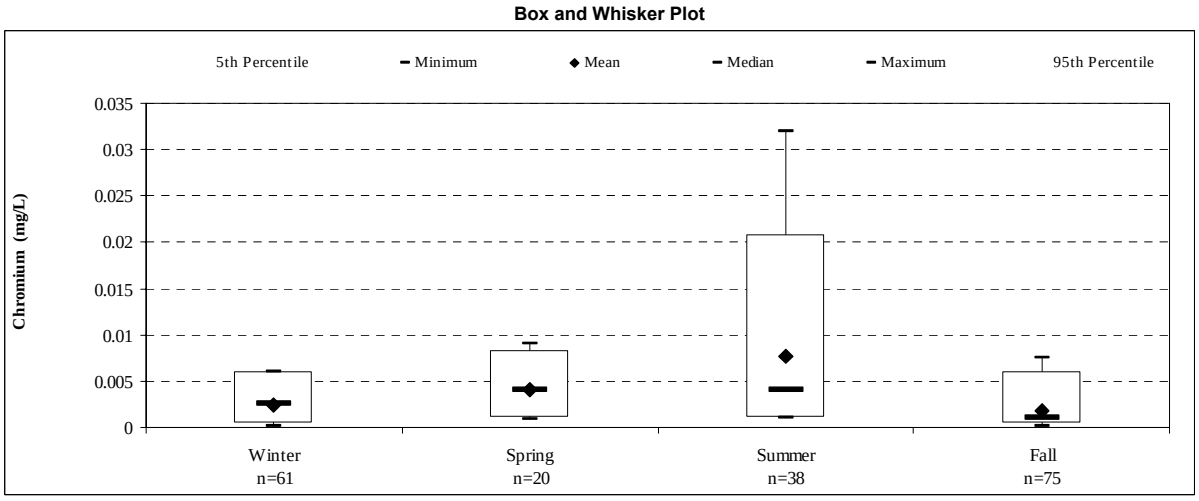


Figure G-1-1-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Upper Reach of Lower Athabasca River



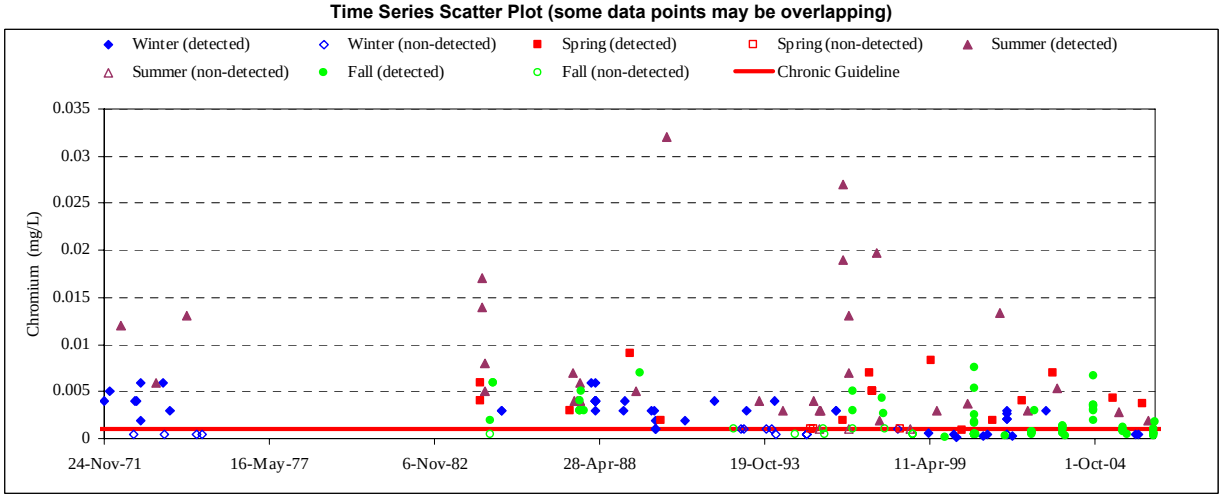
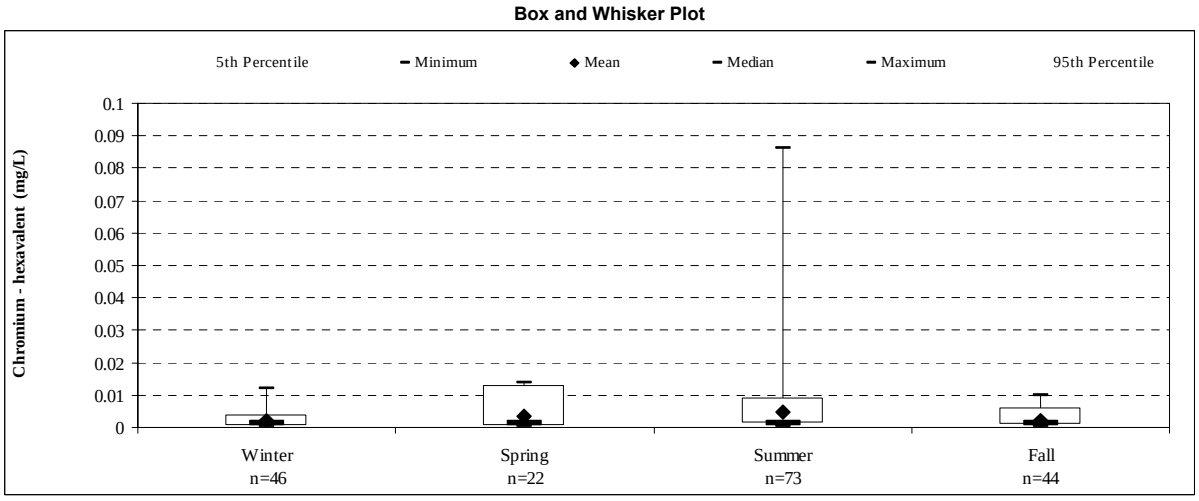


Figure G-1-1-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Upper Reach of Lower Athabasca River



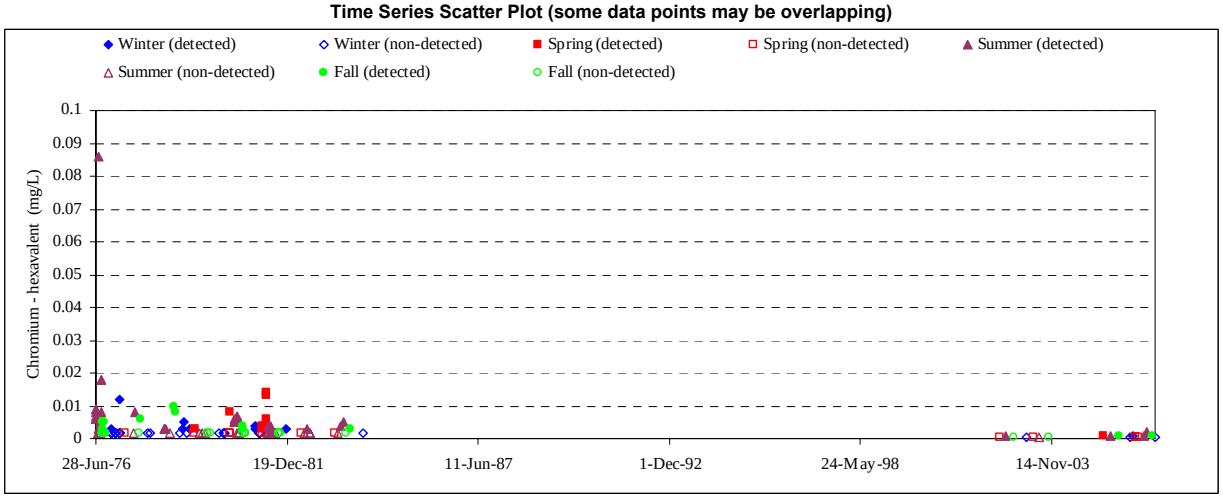
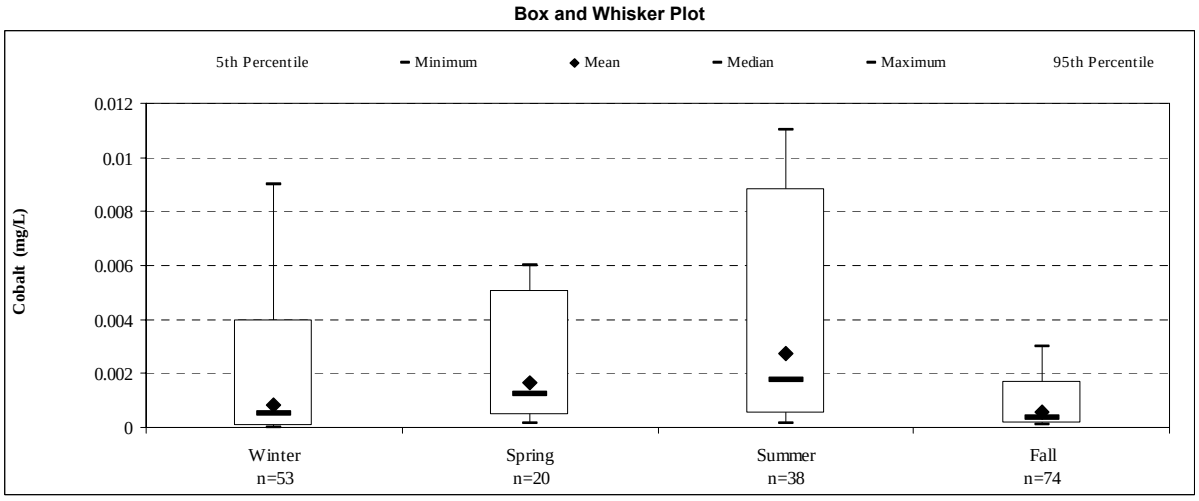


Figure G-1-1-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Upper Reach of Lower Athabasca River



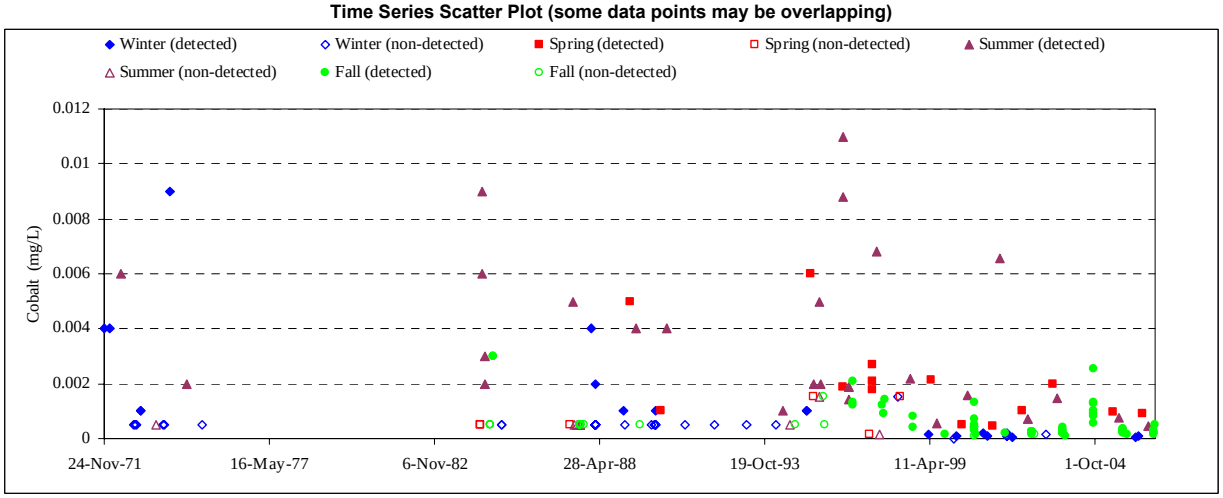
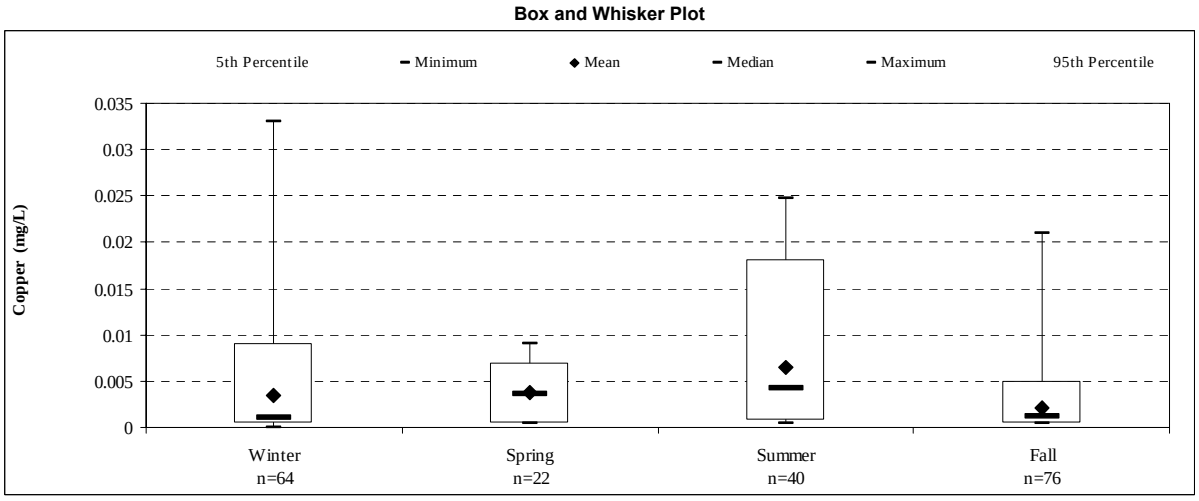


Figure G-1-1-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Upper Reach of Lower Athabasca River



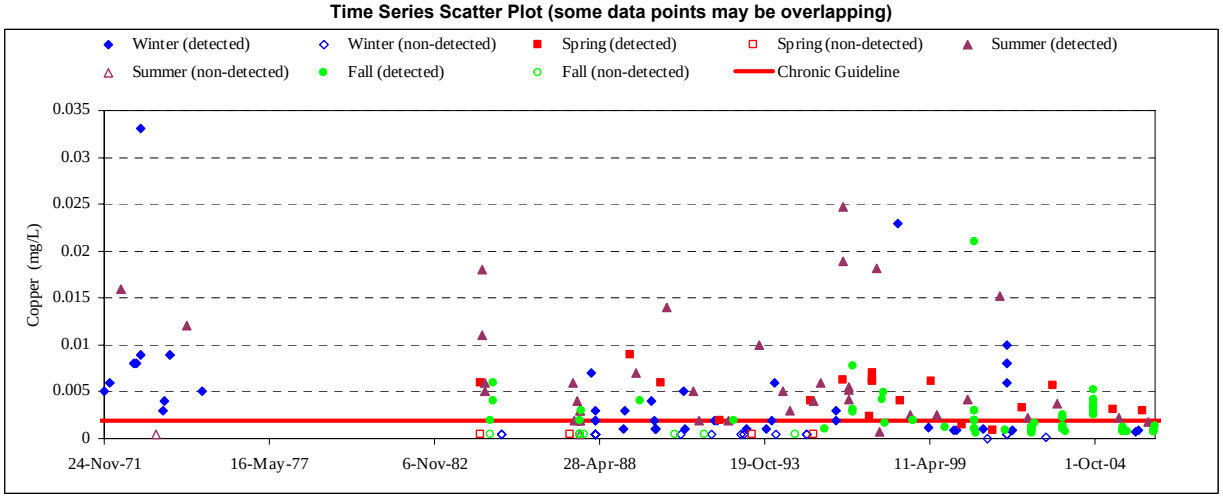
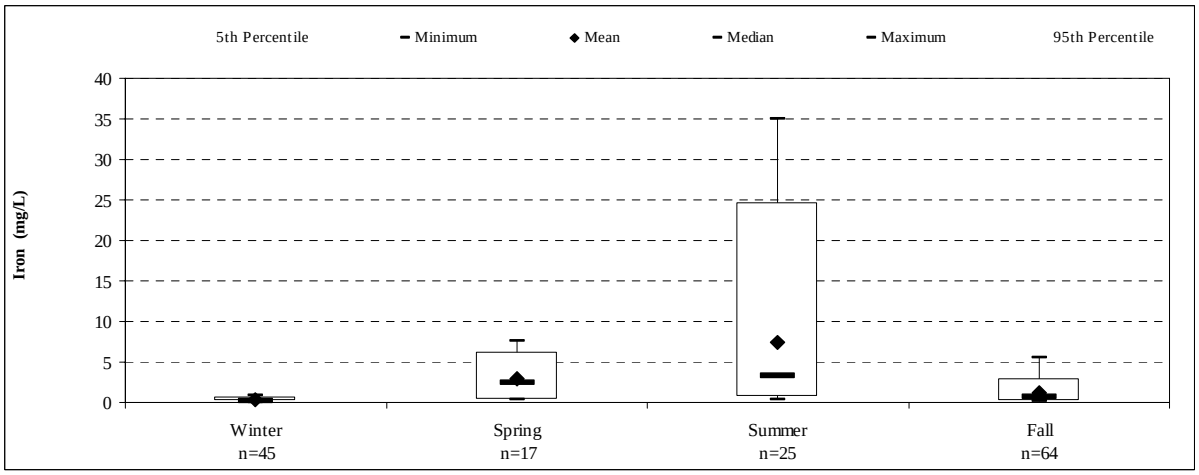


Figure G-1-1-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Upper Reach of Lower Athabasca River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

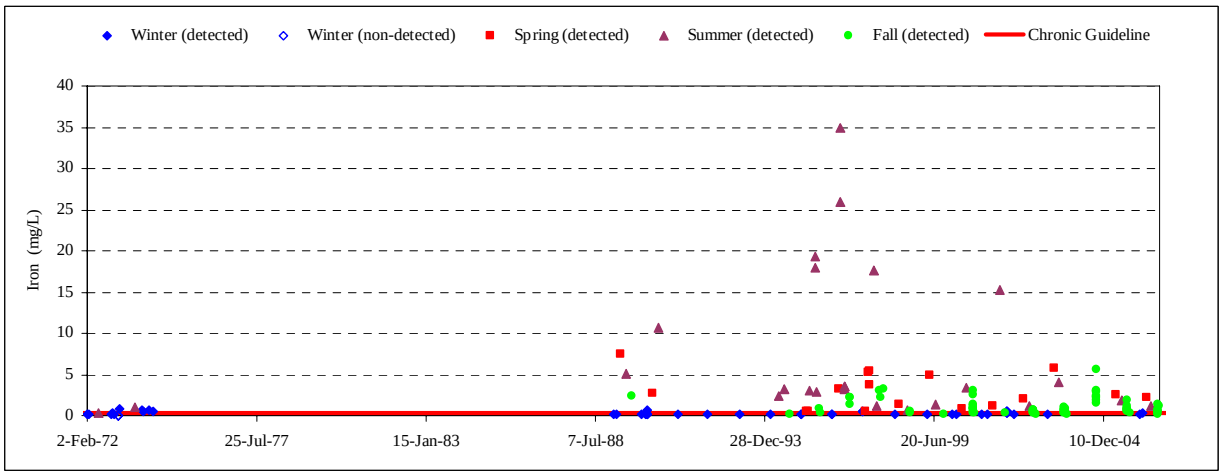


Figure G-1-1-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Upper Reach of Lower Athabasca River

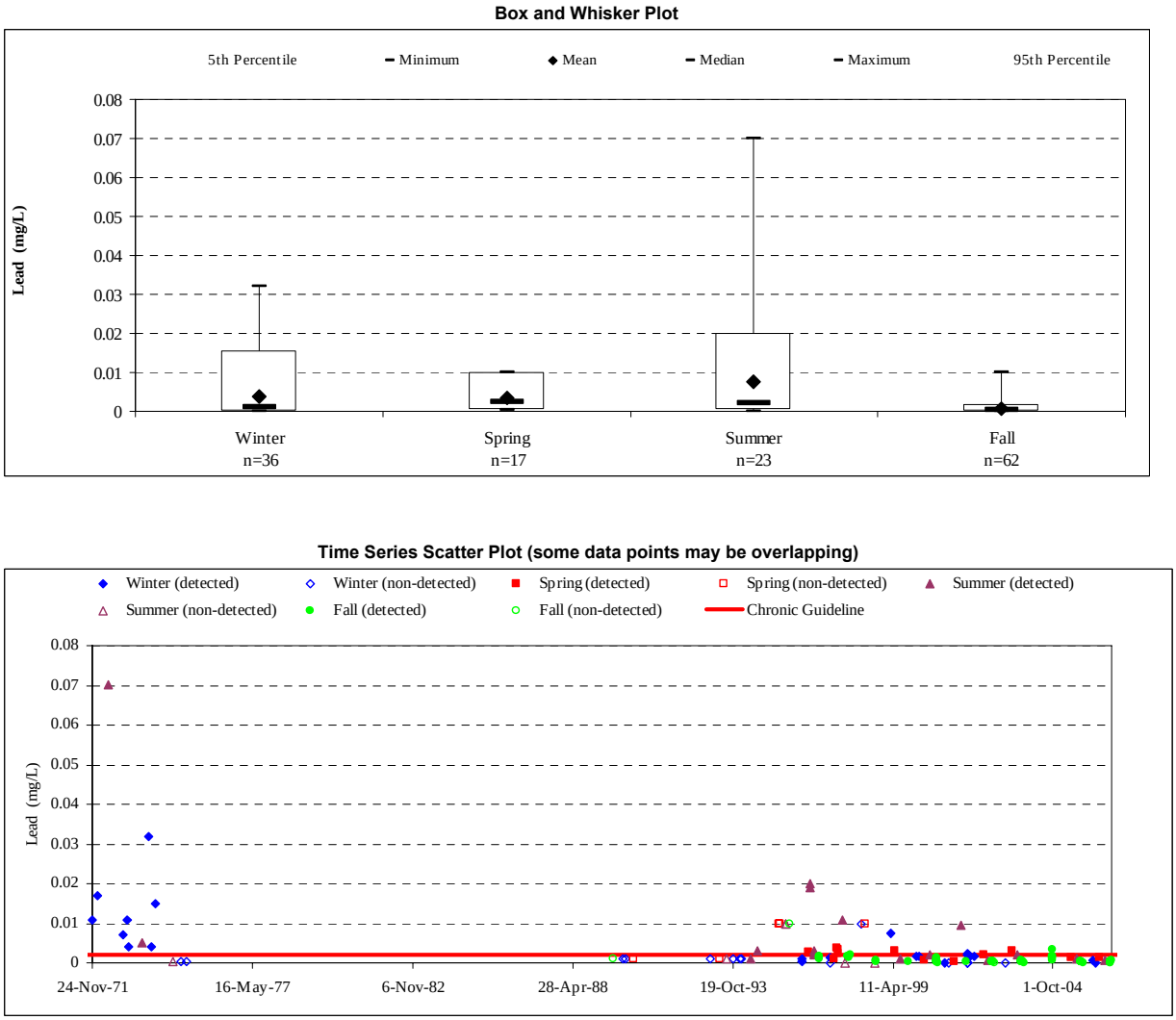
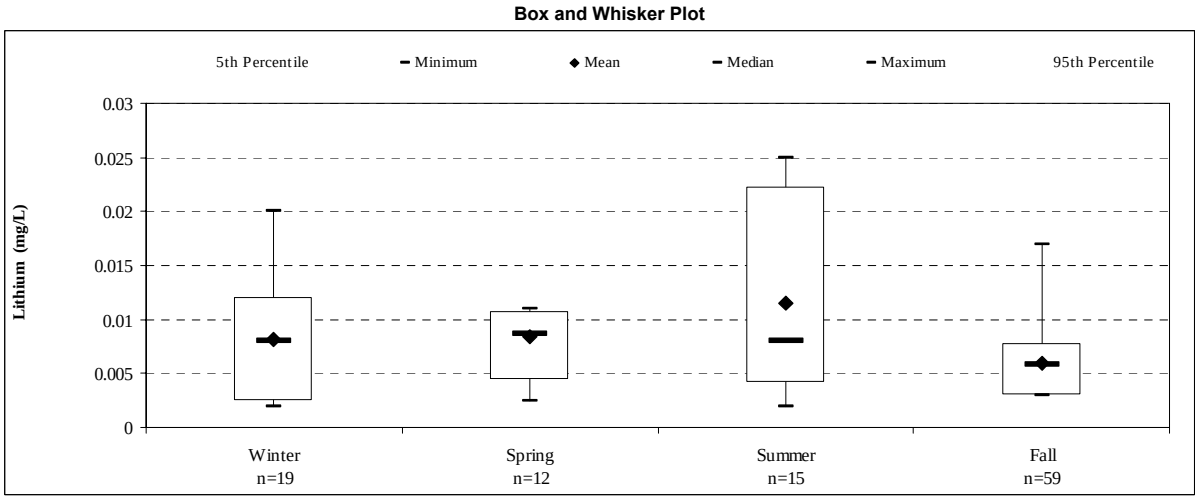


Figure G-1-1-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Upper Reach of Lower Athabasca River



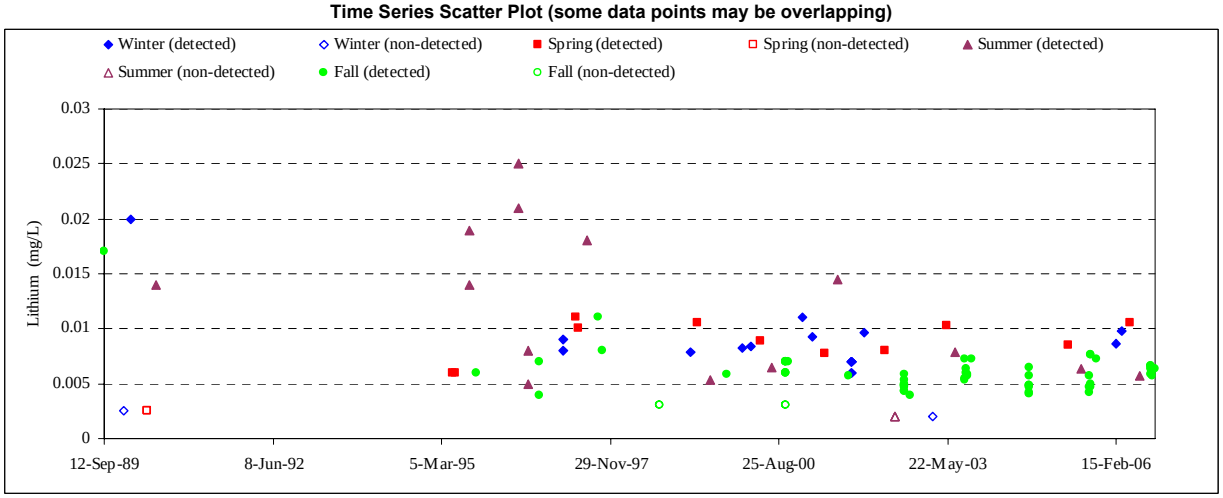


Figure G-1-1-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Upper Reach of Lower Athabasca River

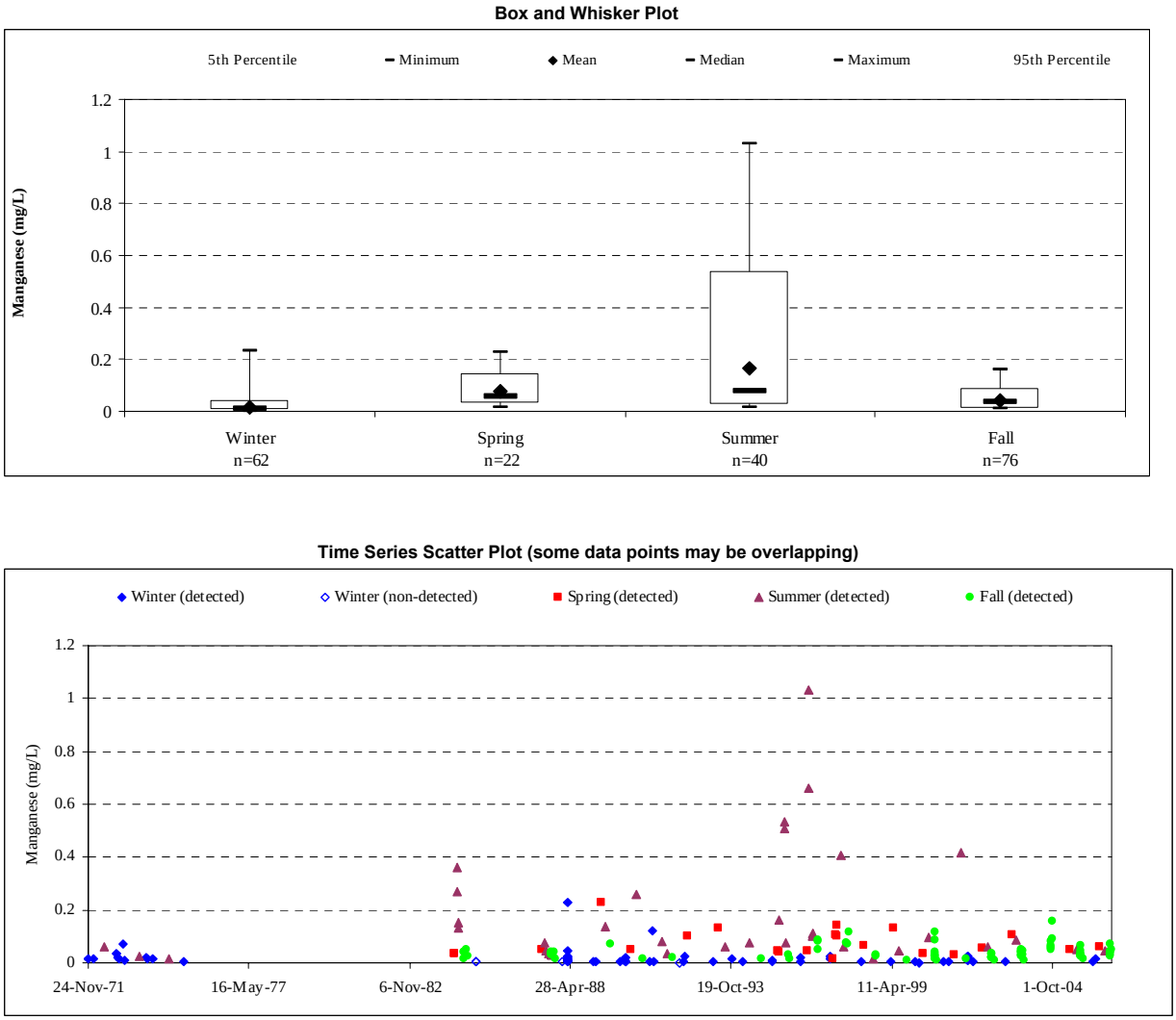
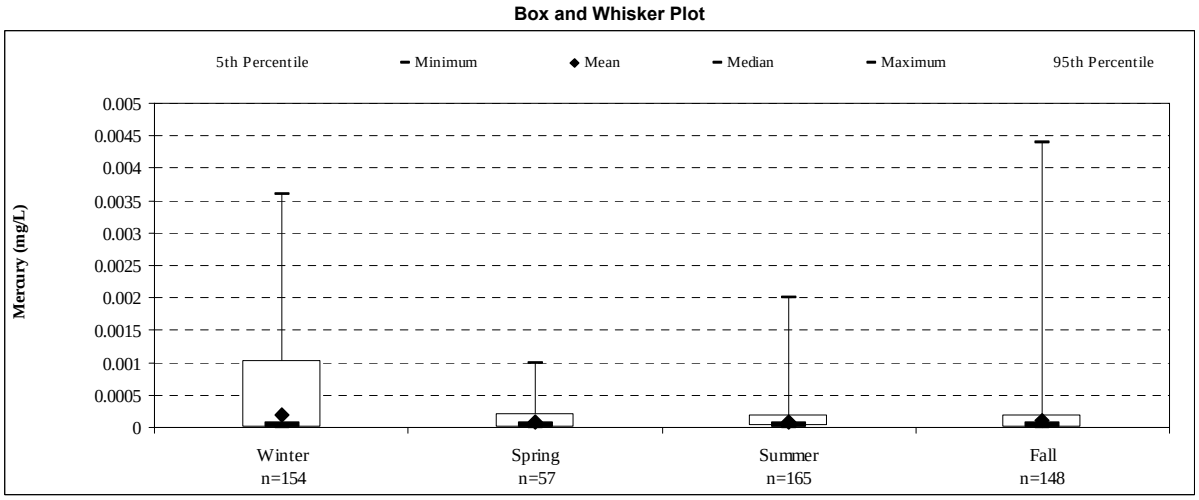


Figure G-1-1-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Upper Reach of Lower Athabasca River



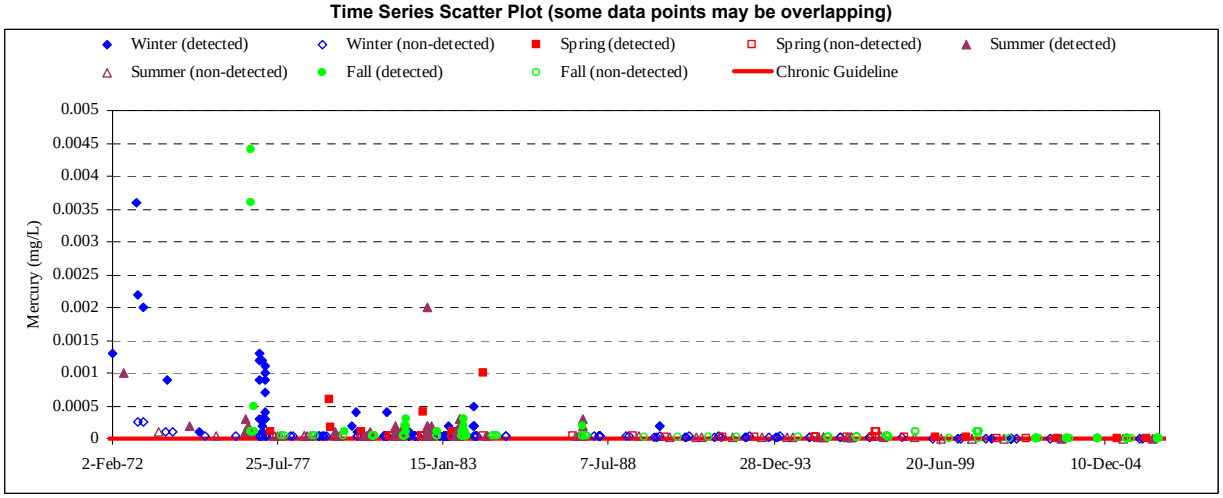


Figure G-1-1-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Upper Reach of Lower Athabasca River

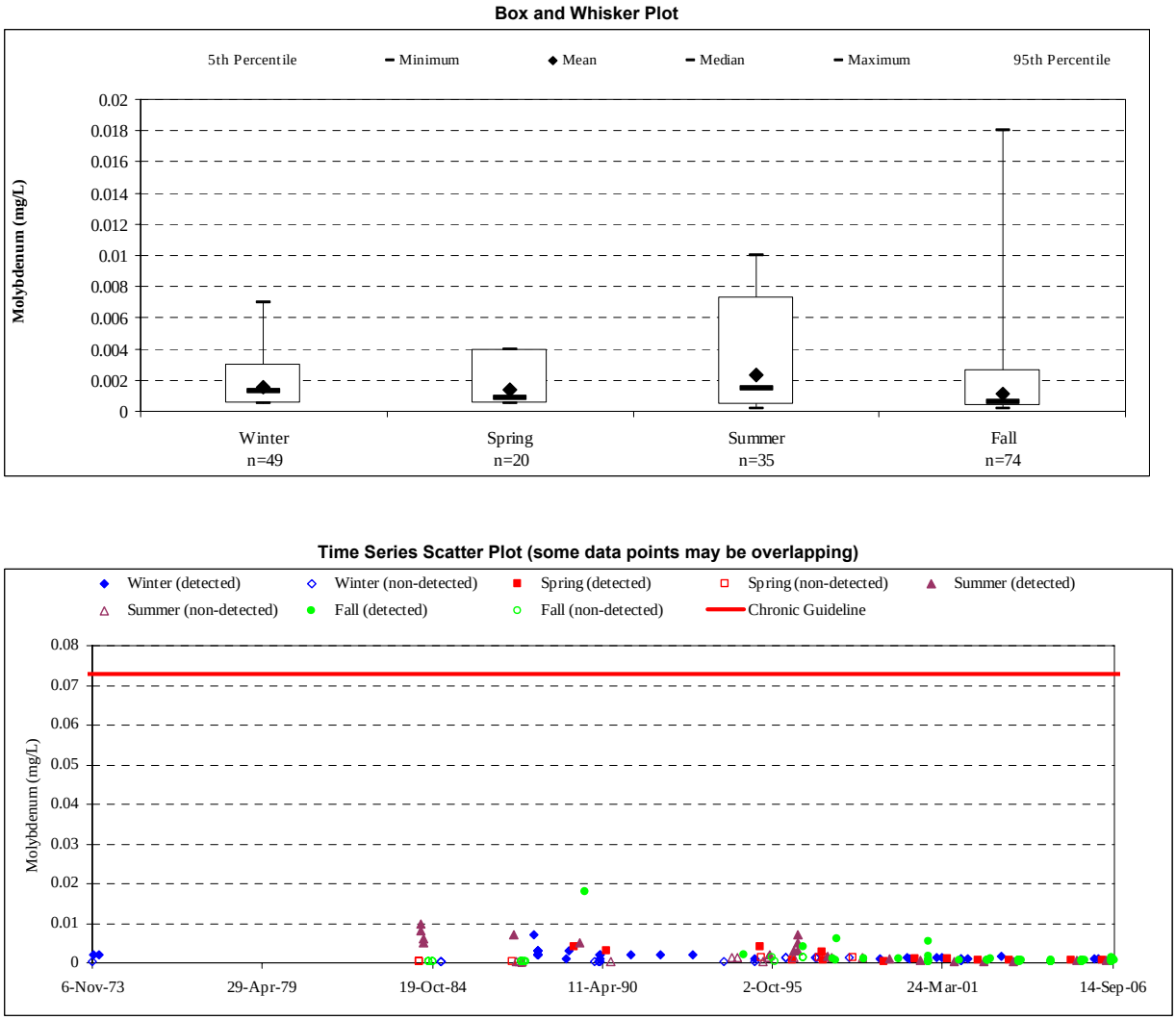
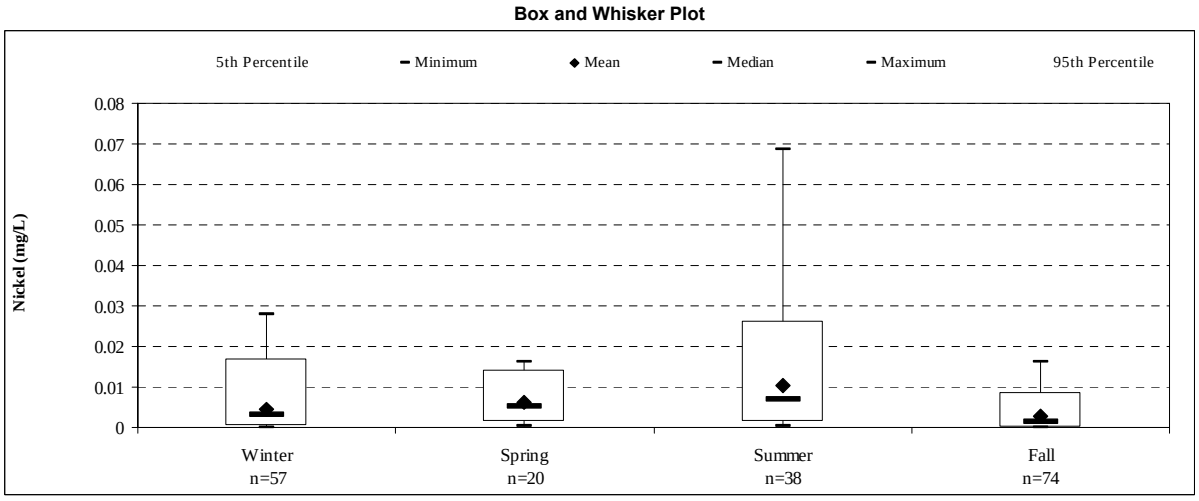


Figure G-1-1-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Upper Reach of Lower Athabasca River



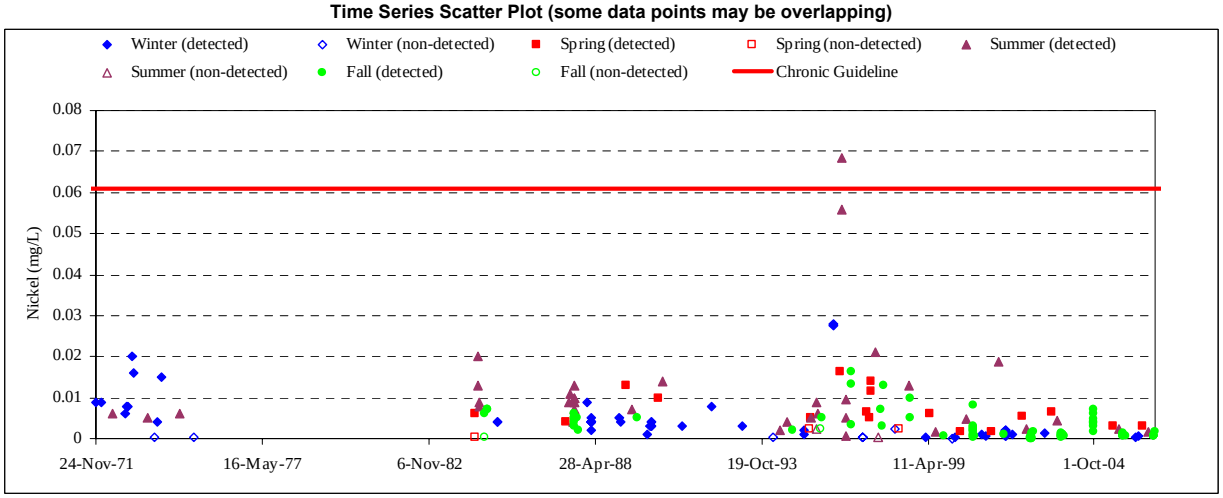
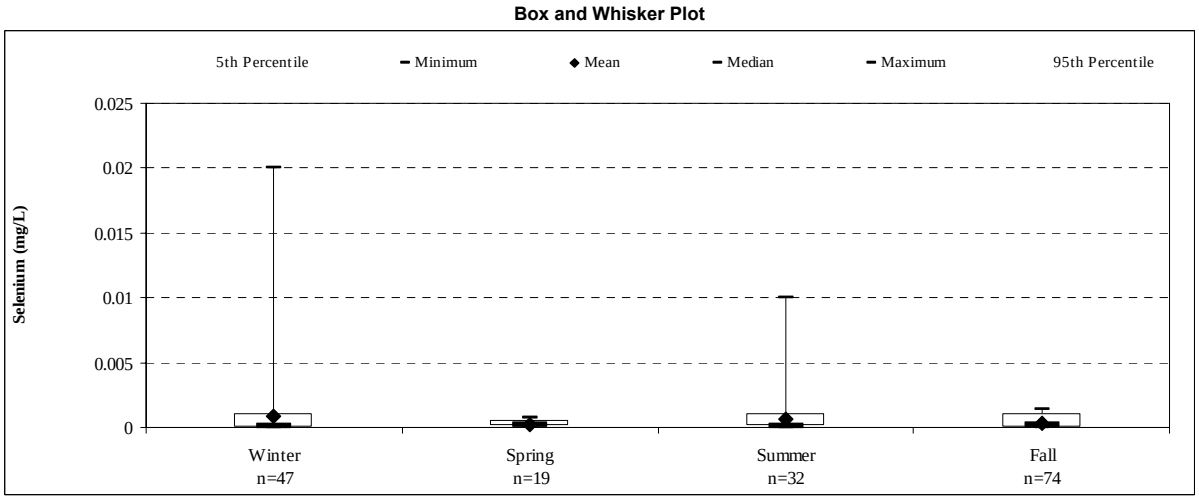


Figure G-1-1-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Upper Reach of Lower Athabasca River



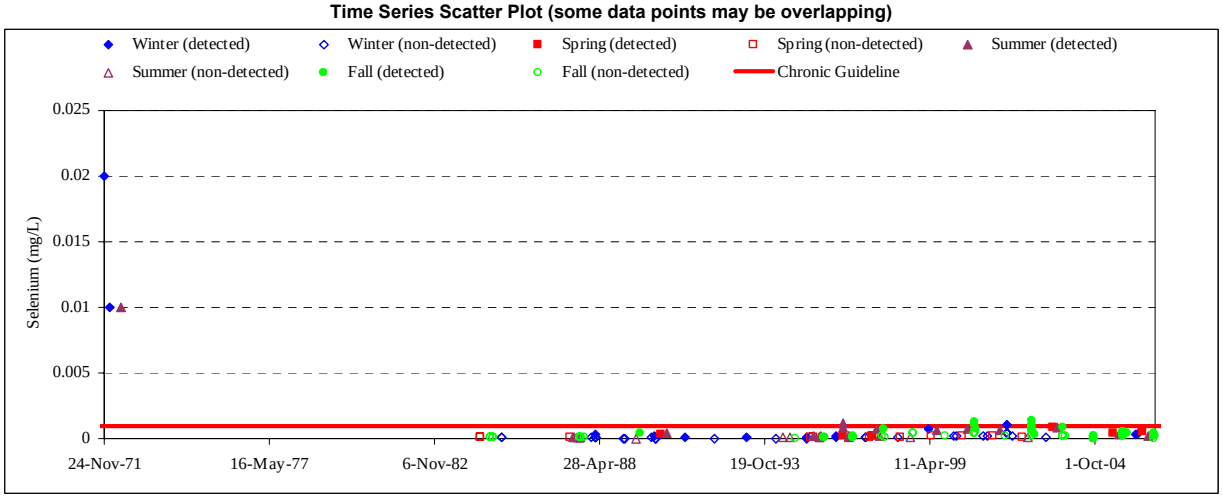


Figure G-1-1-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Upper Reach of Lower Athabasca River

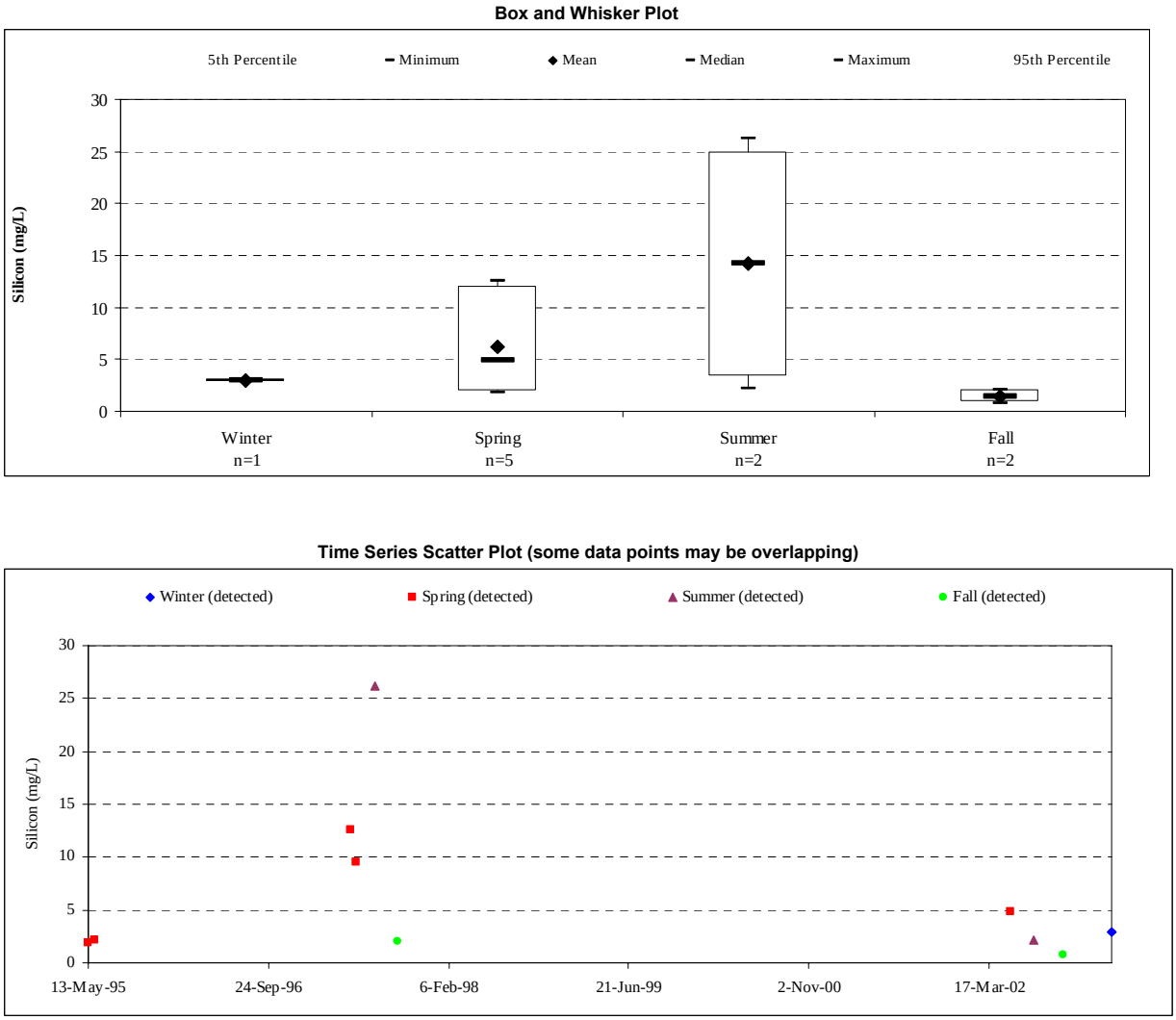
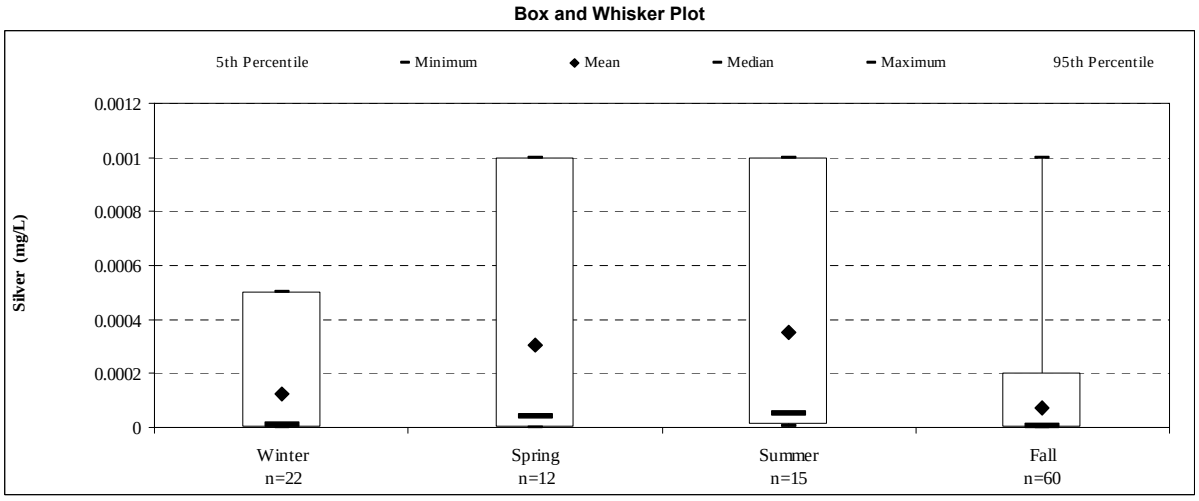


Figure G-1-1-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Upper Reach of Lower Athabasca River



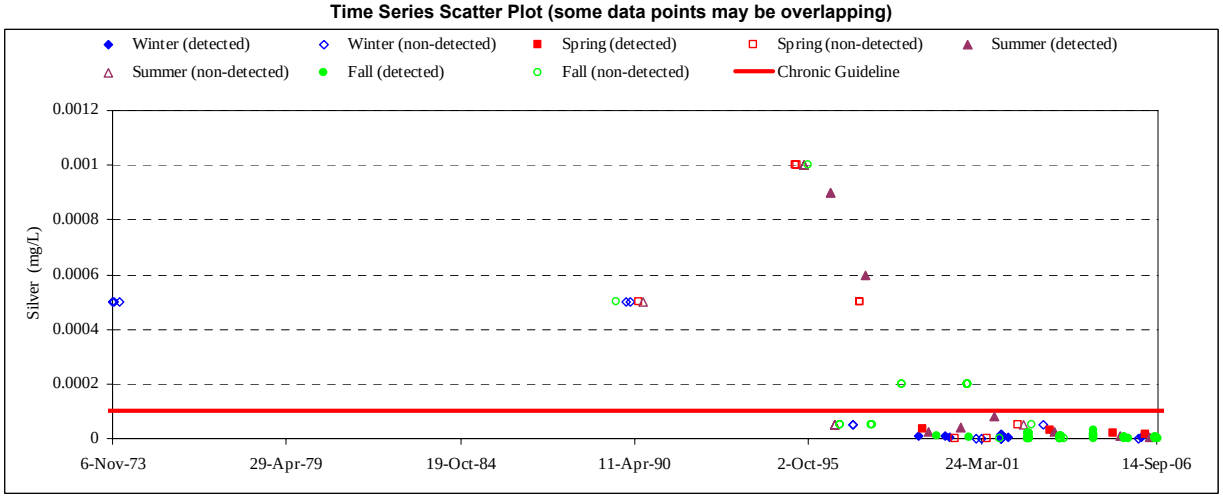


Figure G-1-1-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Upper Reach of Lower Athabasca River

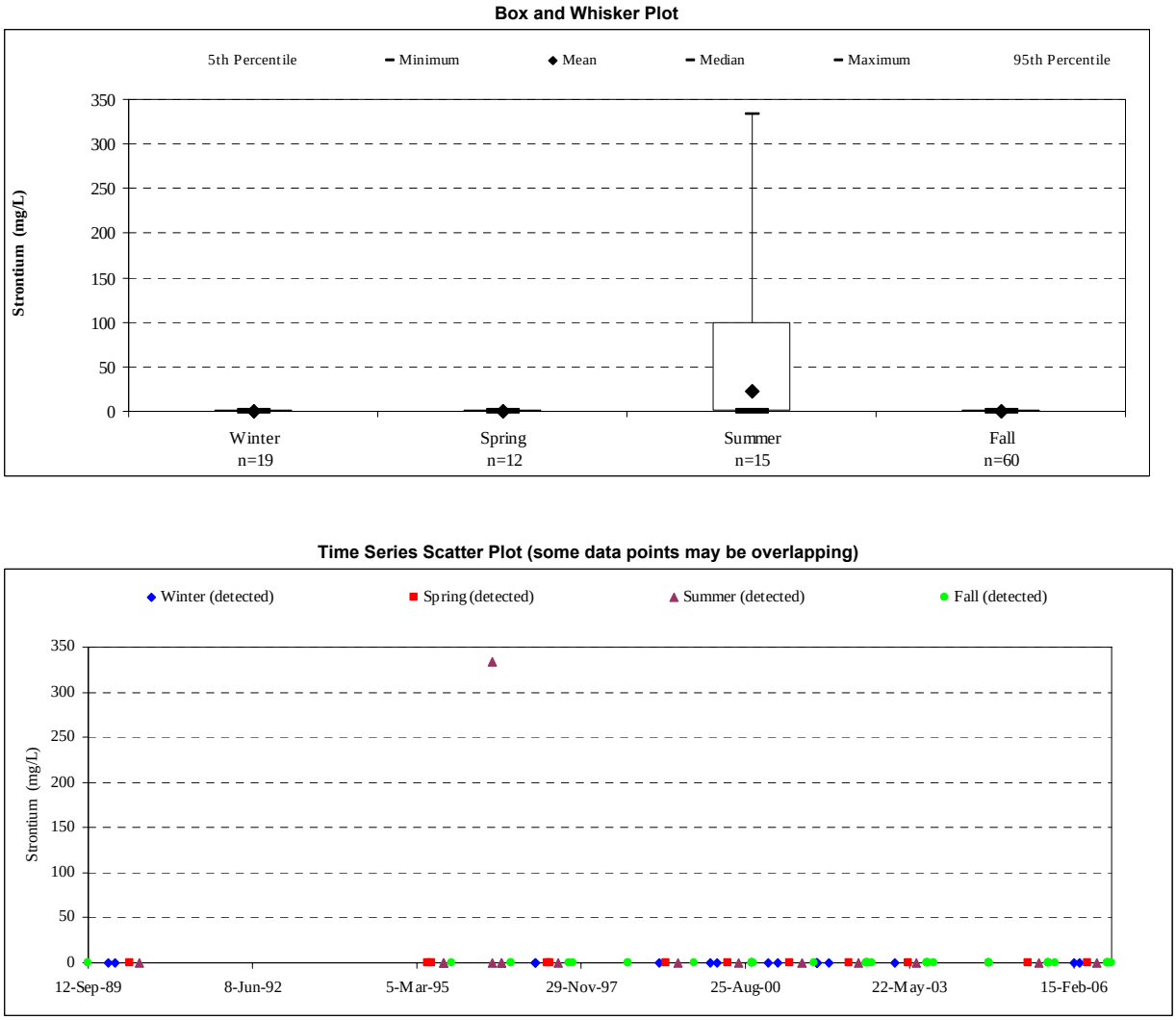
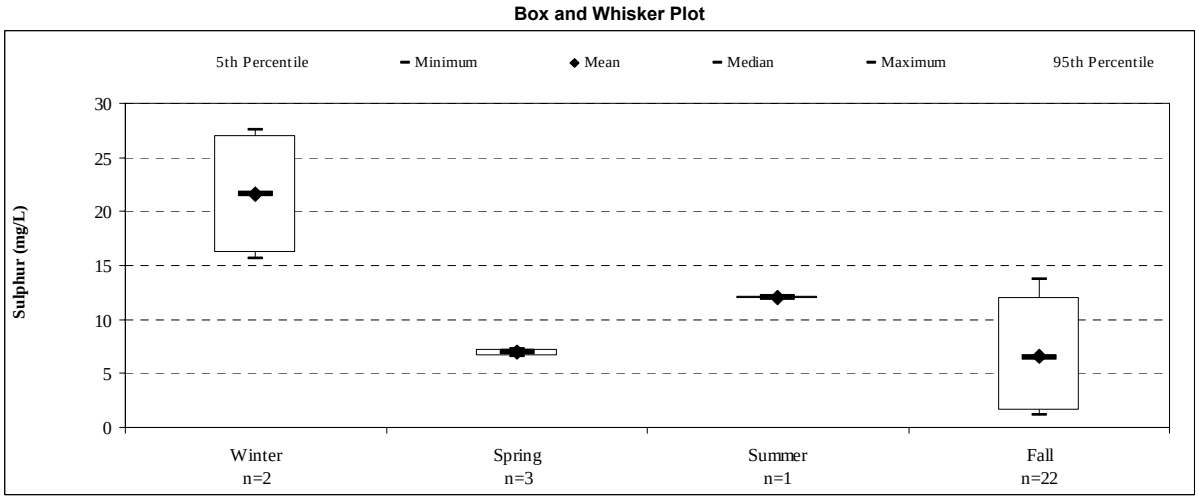


Figure G-1-1-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Upper Reach of Lower Athabasca River



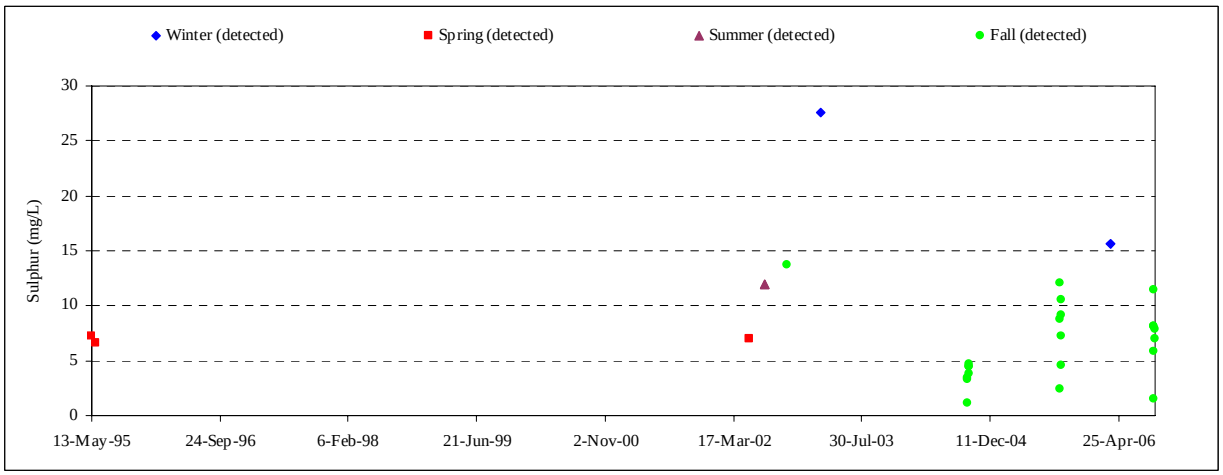
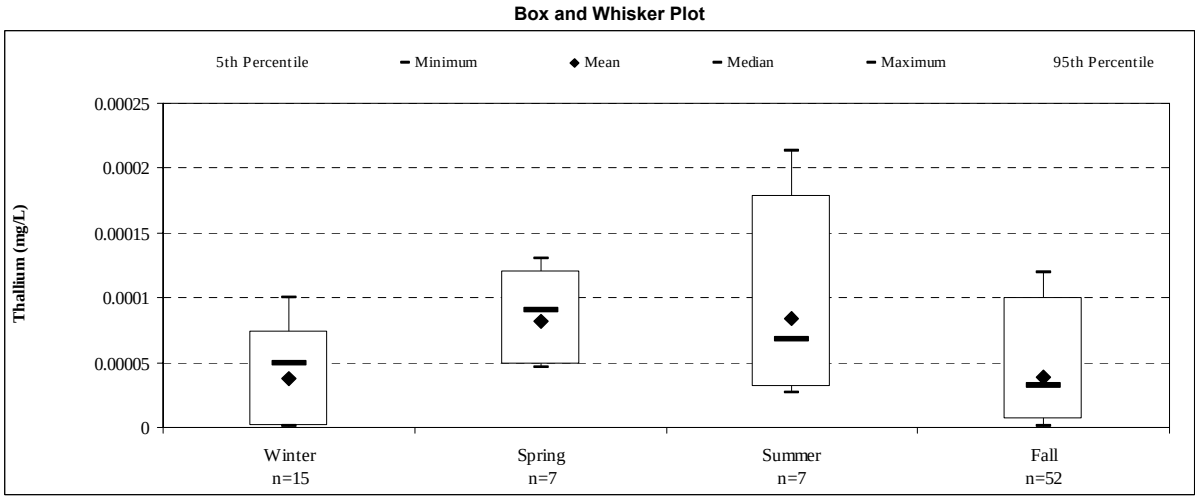


Figure G-1-1-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Upper Reach of Lower Athabasca River



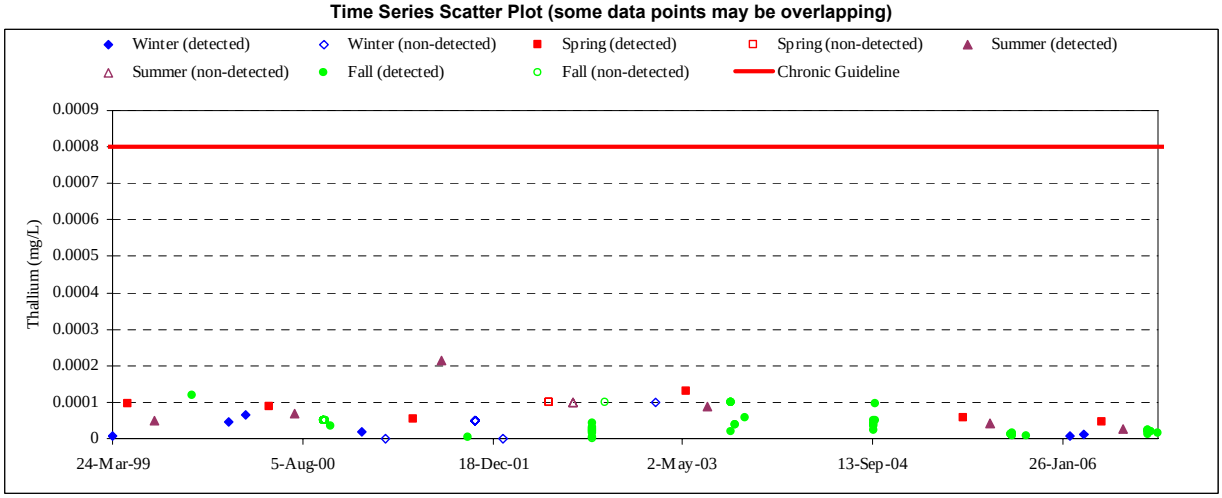
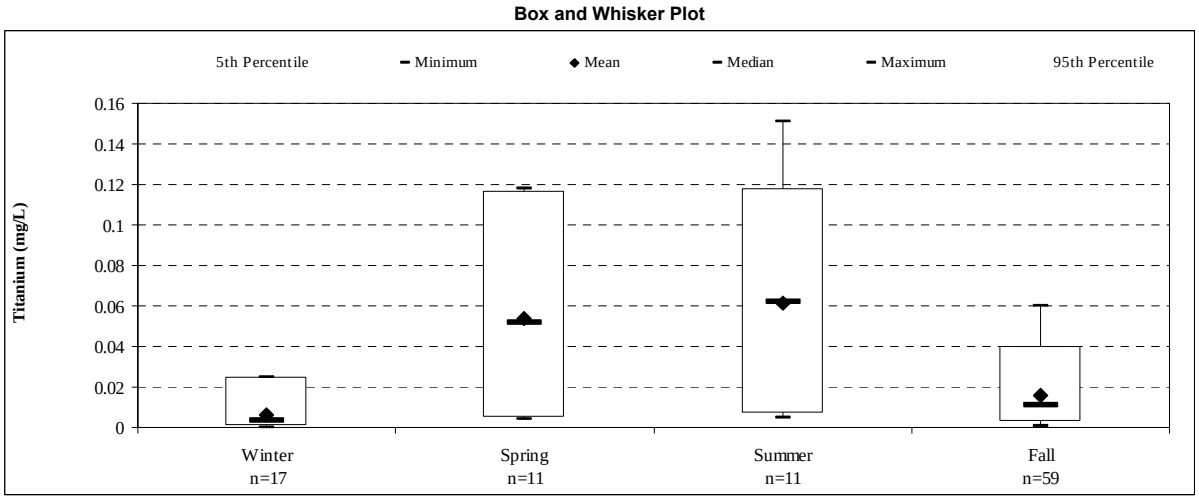


Figure G-1-1-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Upper Reach of Lower Athabasca River



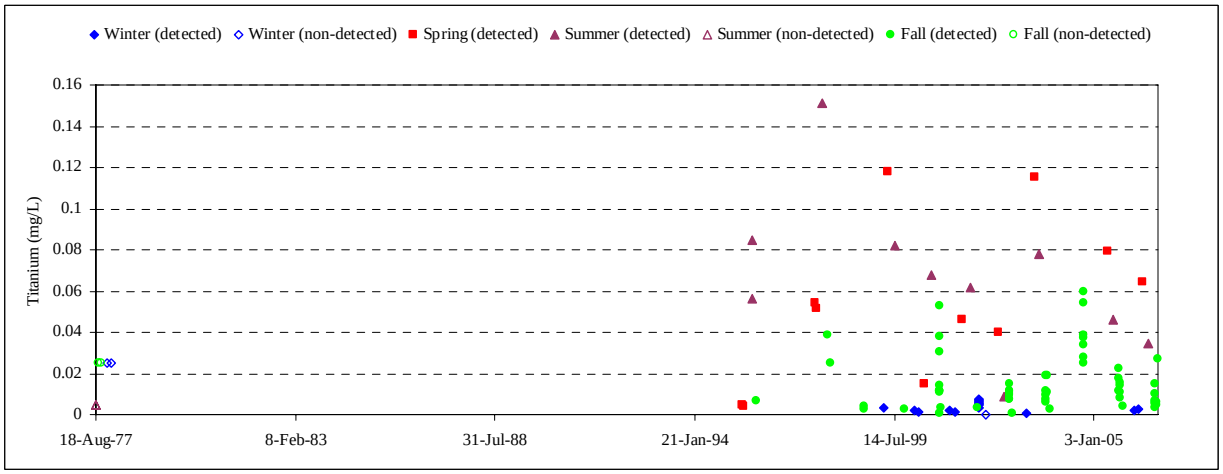


Figure G-1-1-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Upper Reach of Lower Athabasca River

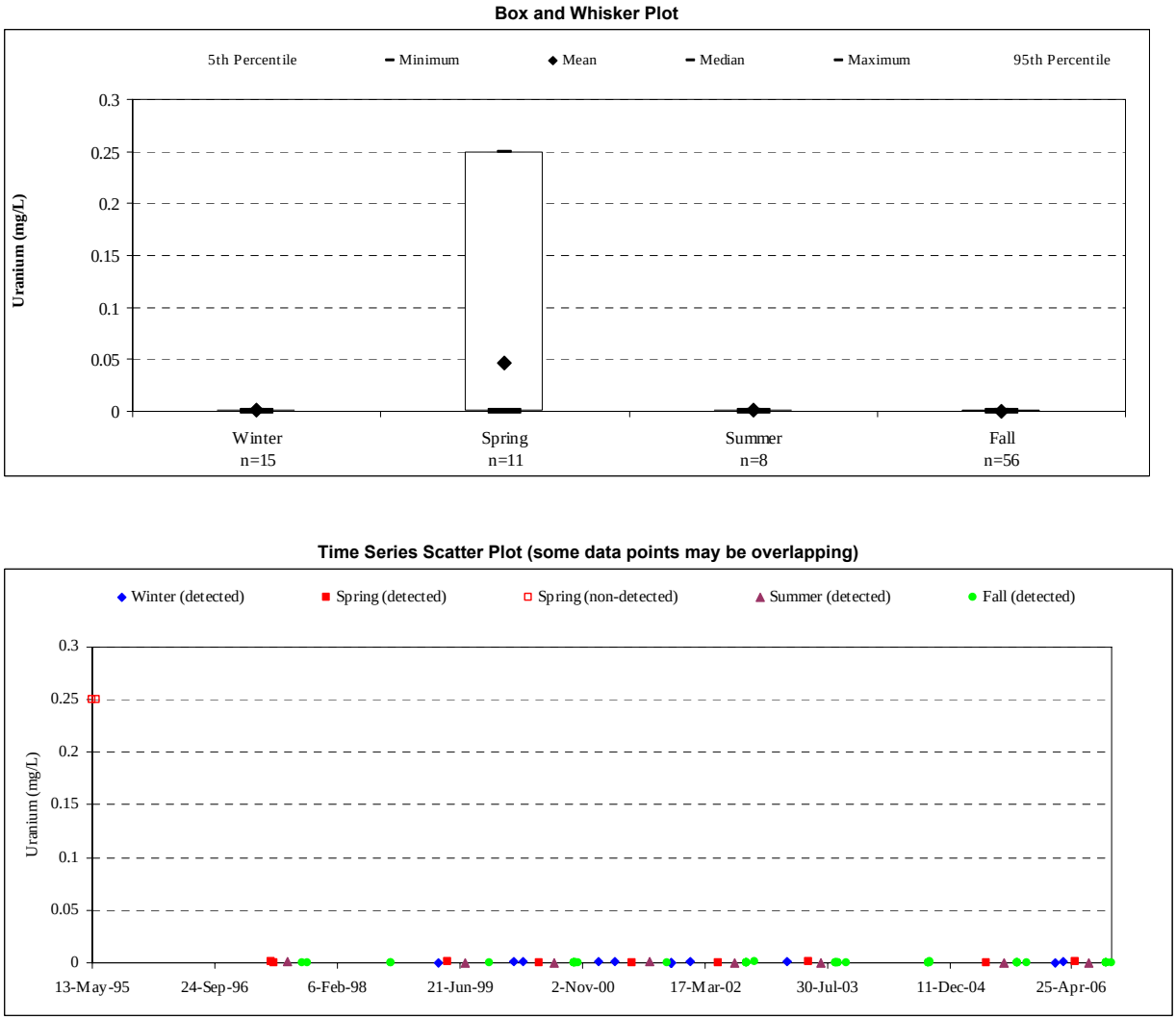
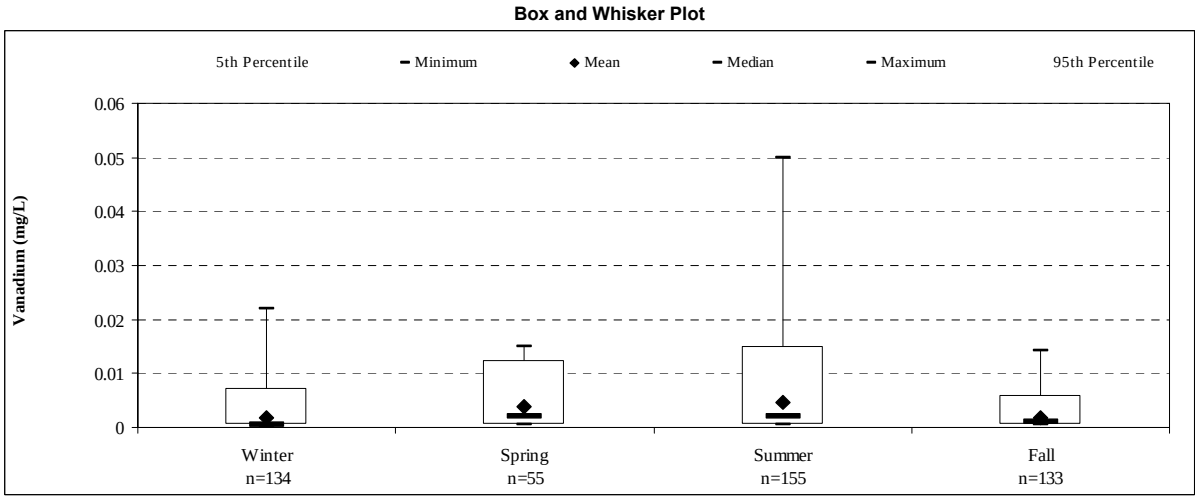


Figure G-1-1-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Upper Reach of Lower Athabasca River



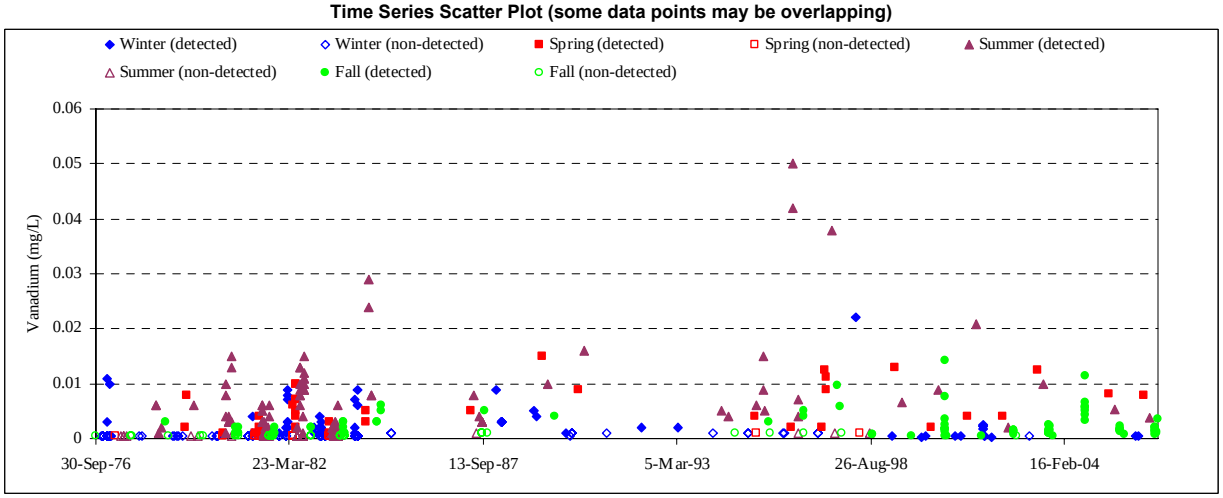
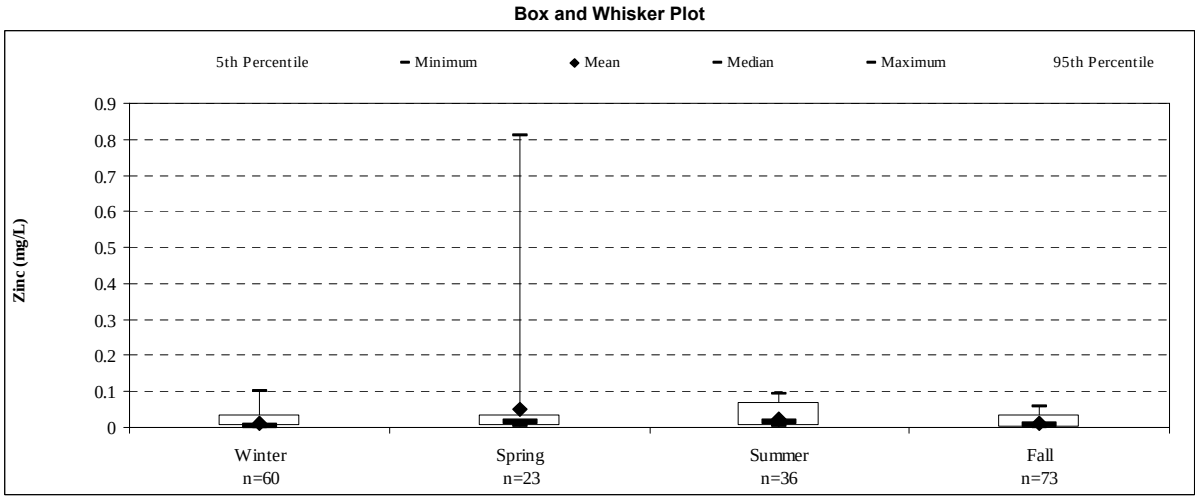


Figure G-1-1-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Upper Reach of Lower Athabasca River



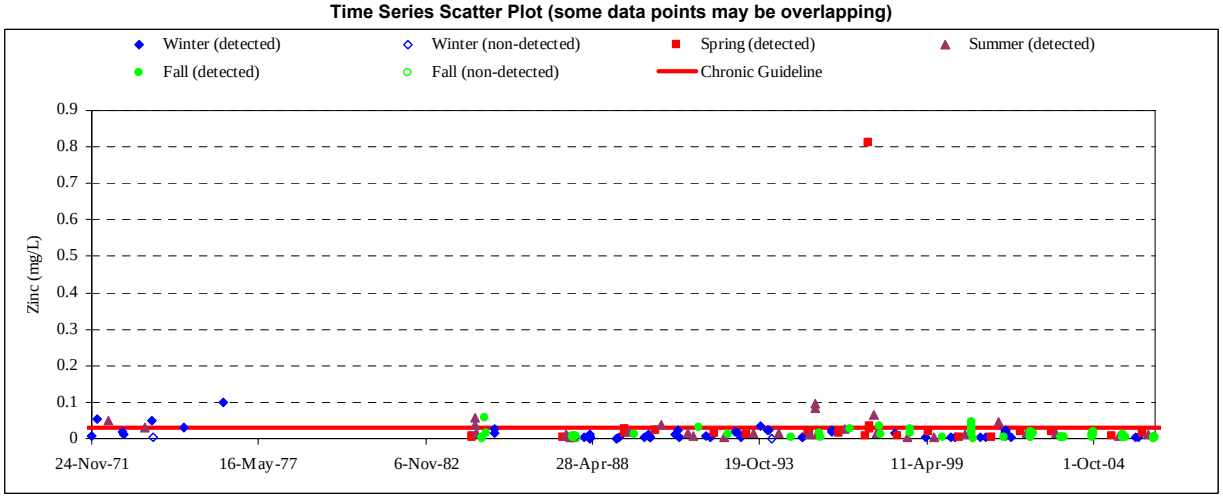


Figure G-1-1-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Upper Reach of Lower Athabasca River

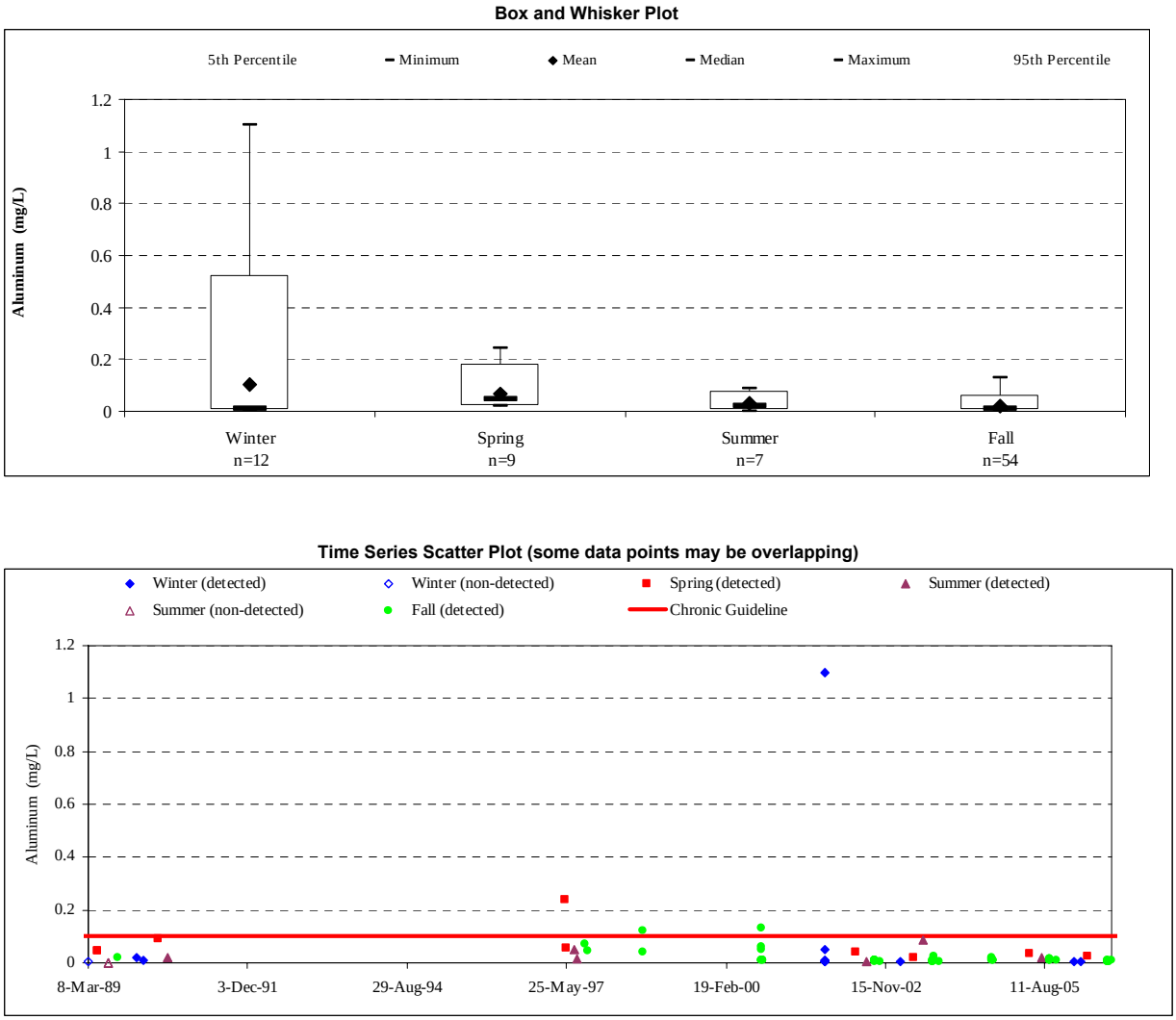
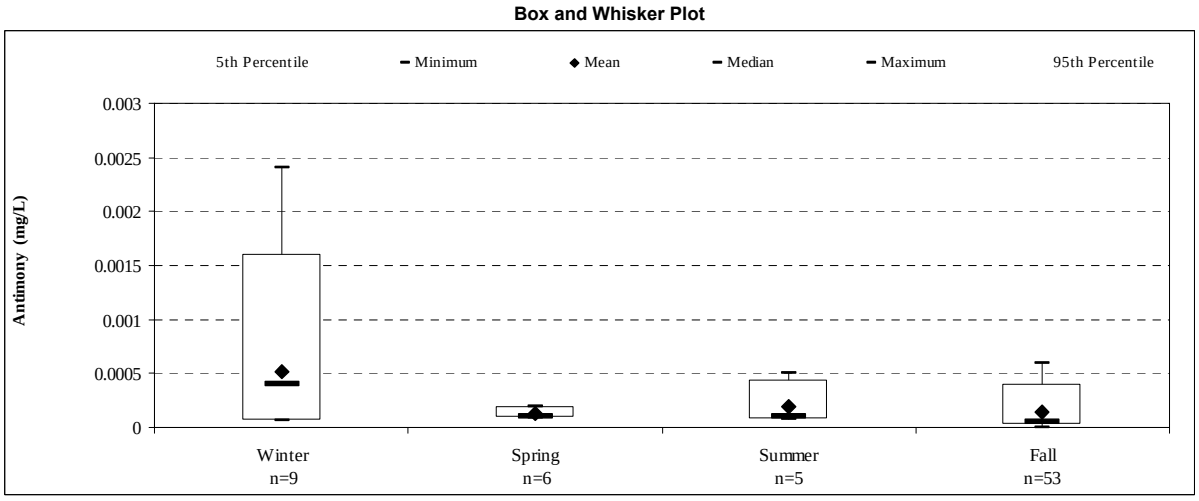


Figure G-1-1-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Upper Reach of Lower Athabasca River



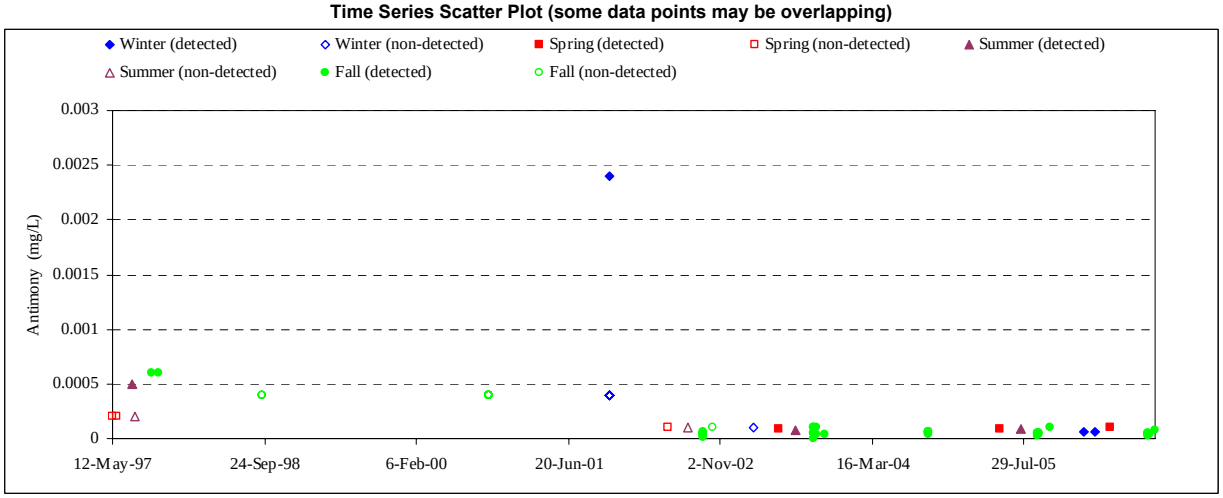
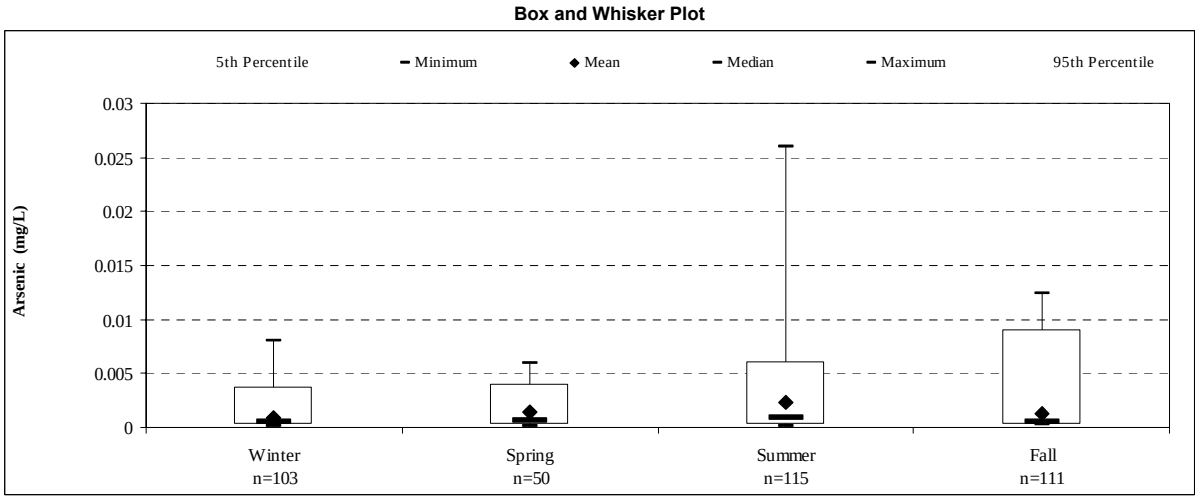


Figure G-1-1-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Upper Reach of Lower Athabasca River



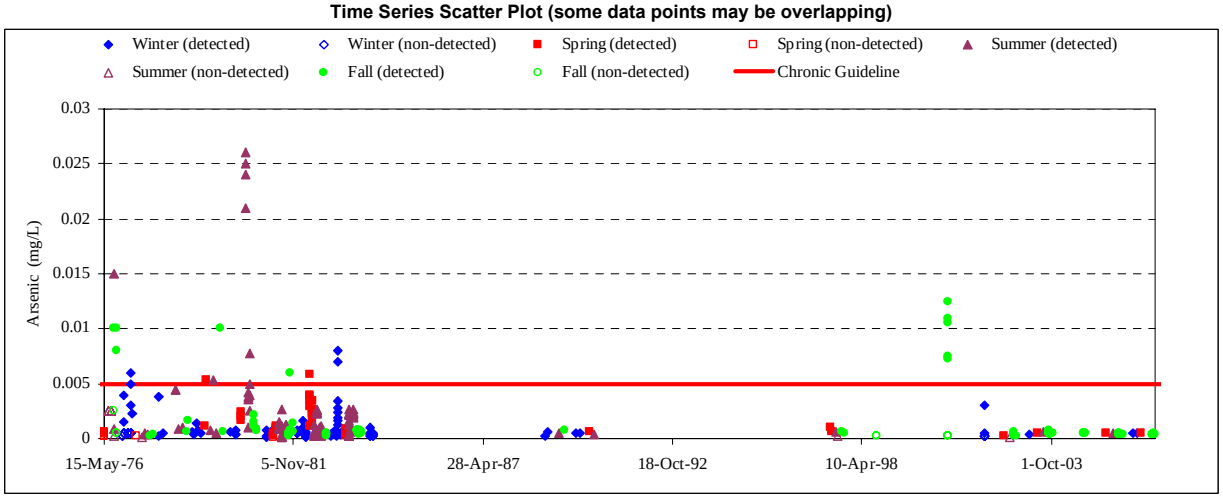
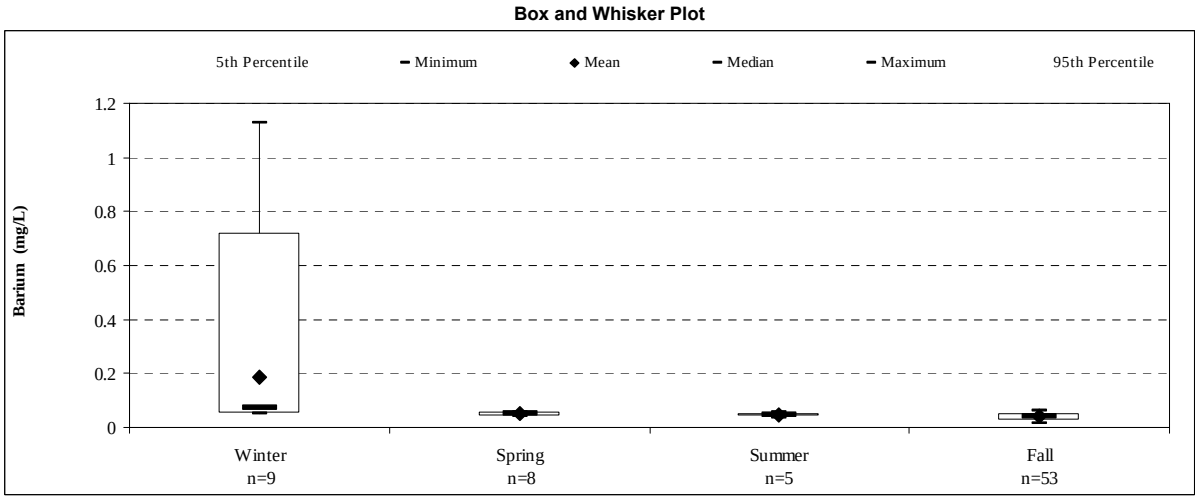


Figure G-1-1-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



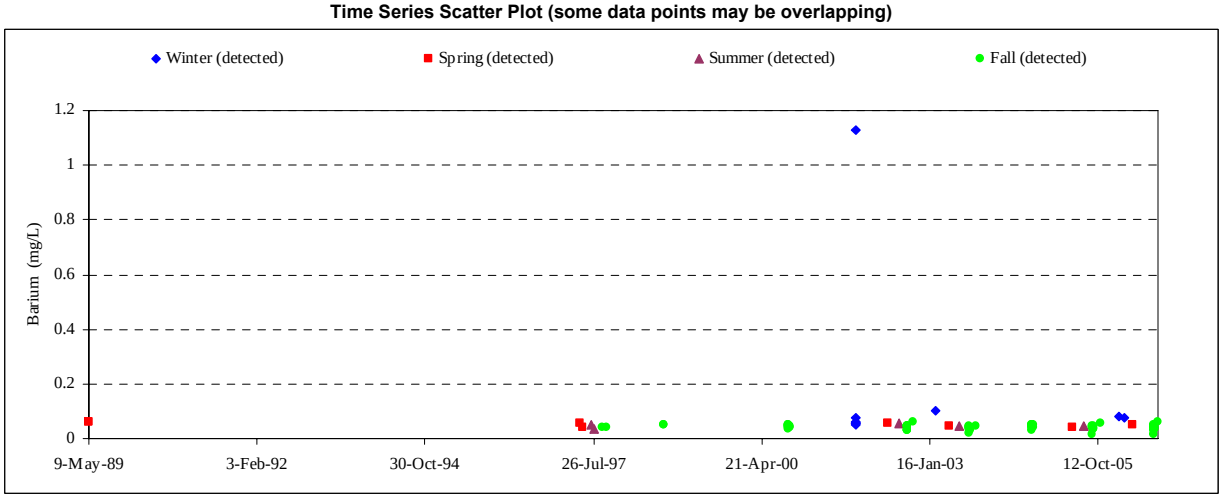
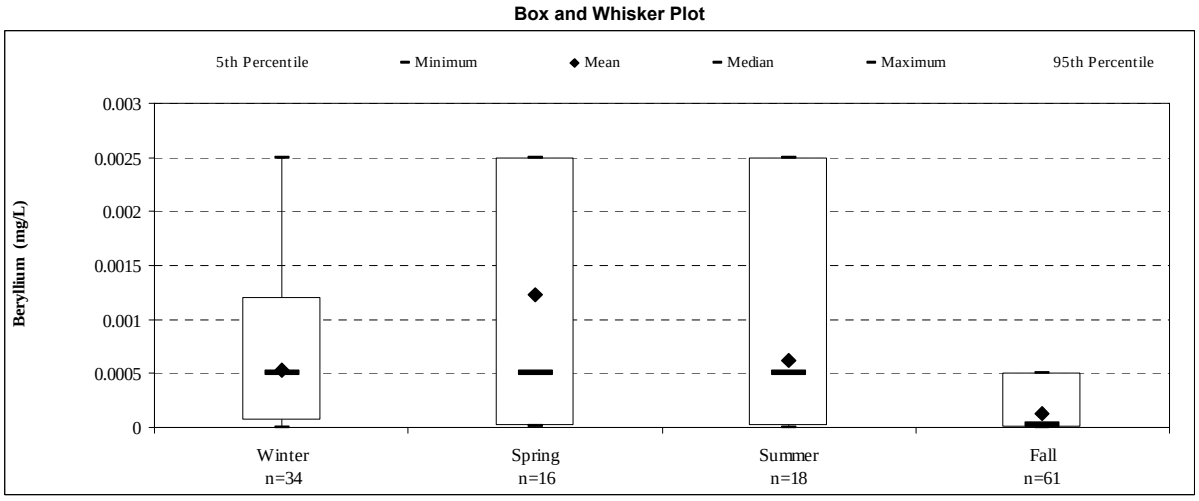


Figure G-1-1-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



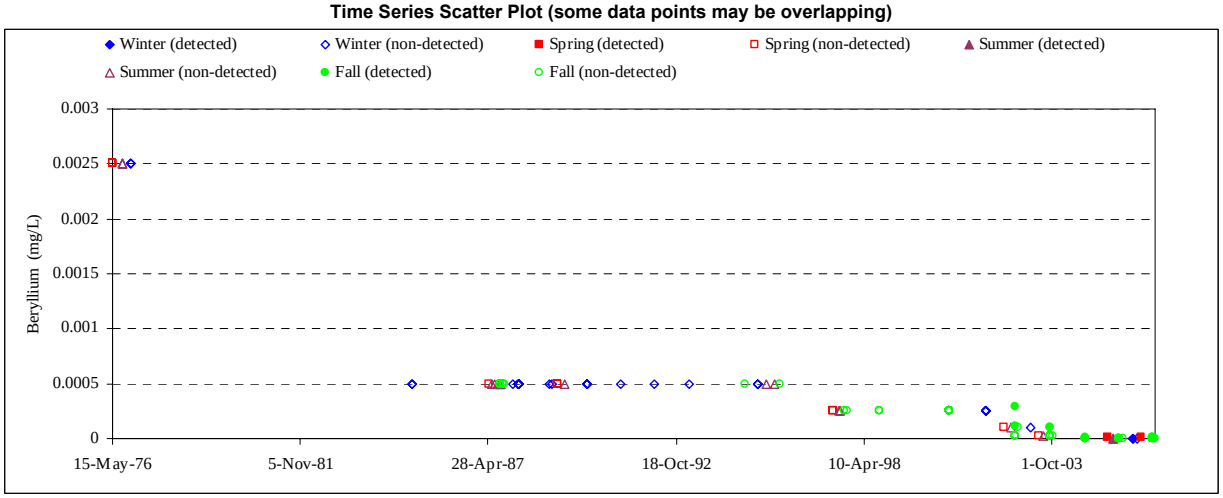
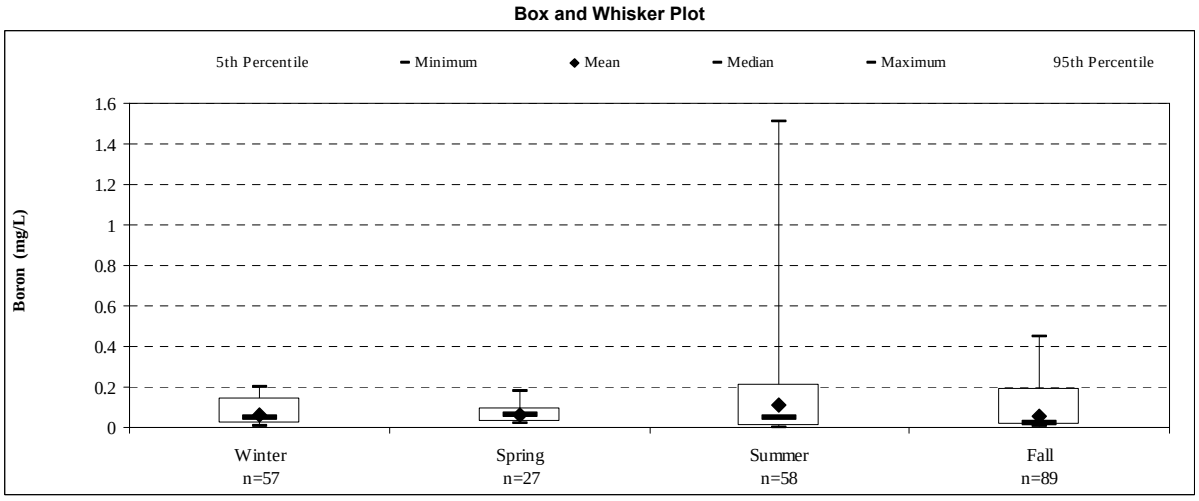


Figure G-1-1-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Upper Reach of Lower Athabasca River



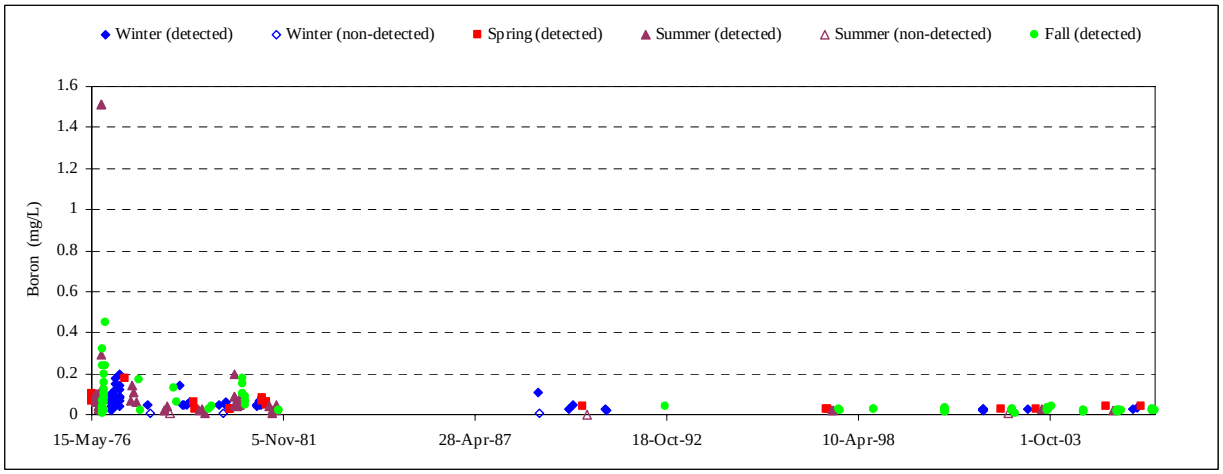
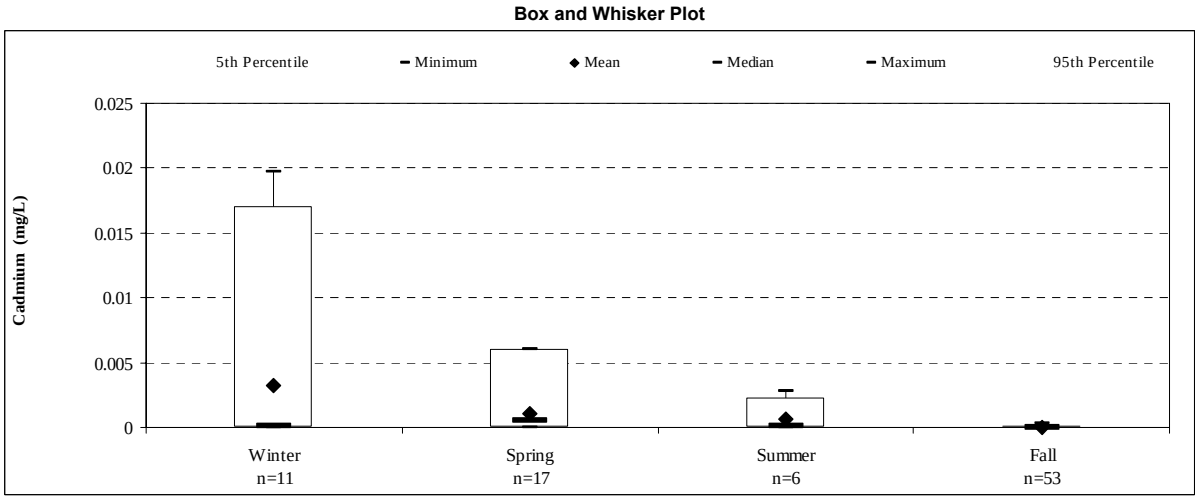


Figure G-1-1-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



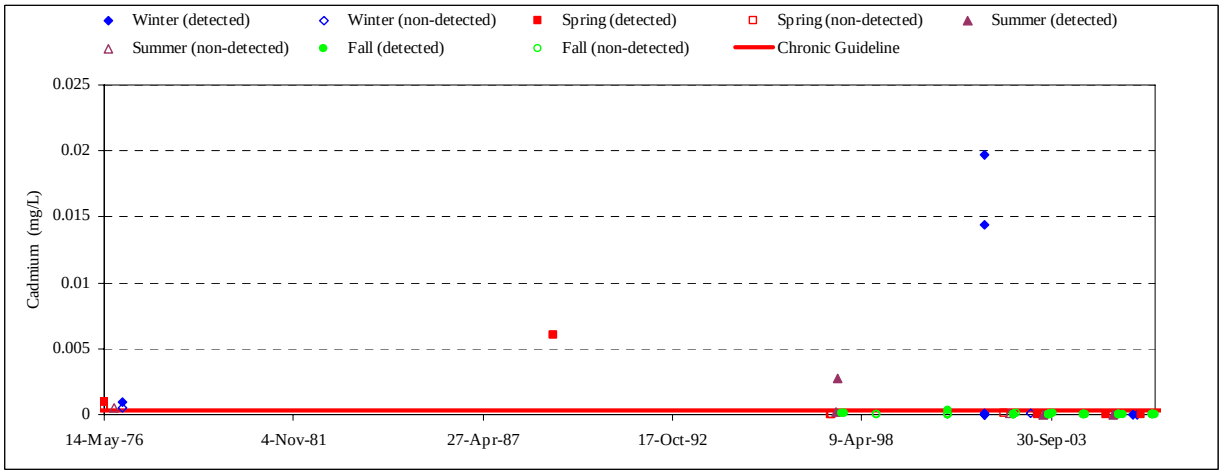
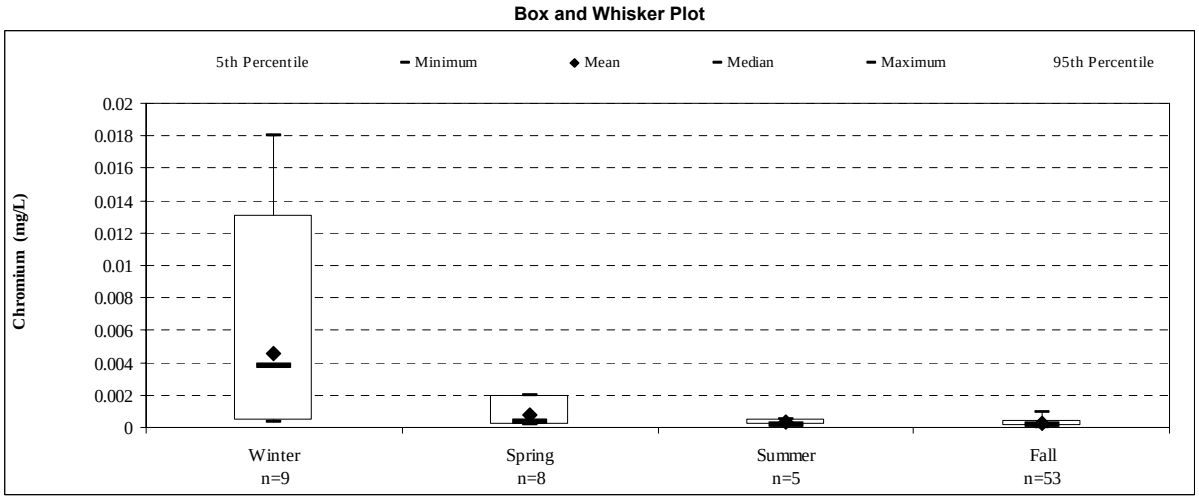


Figure G-1-1-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



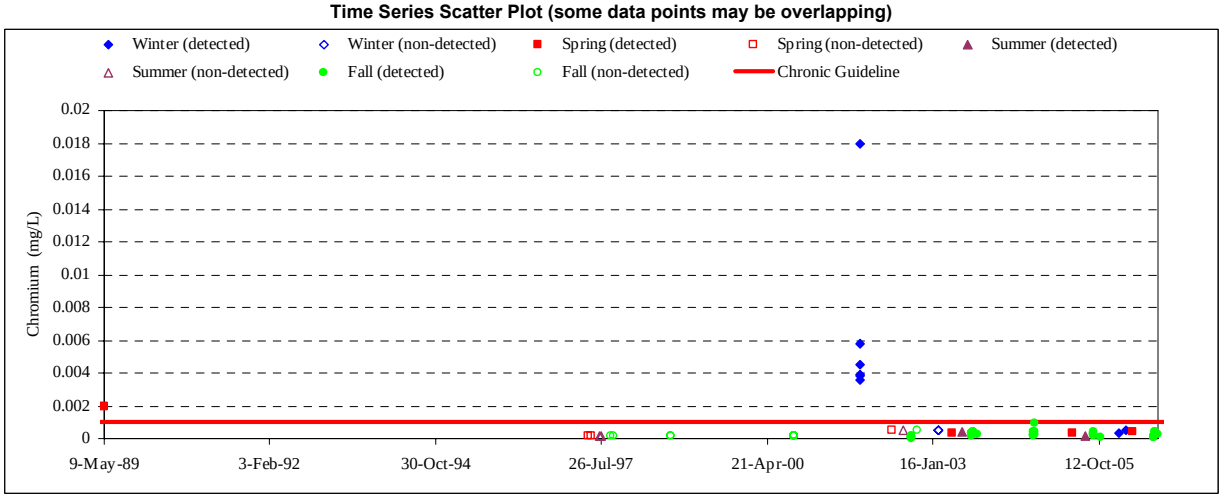
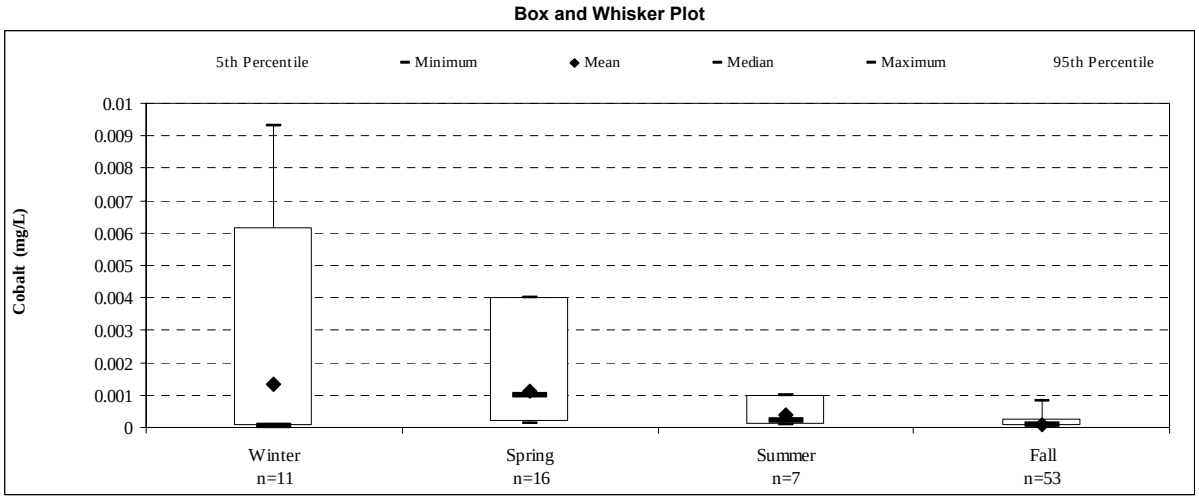


Figure G-1-1-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Upper Reach of Lower Athabasca River



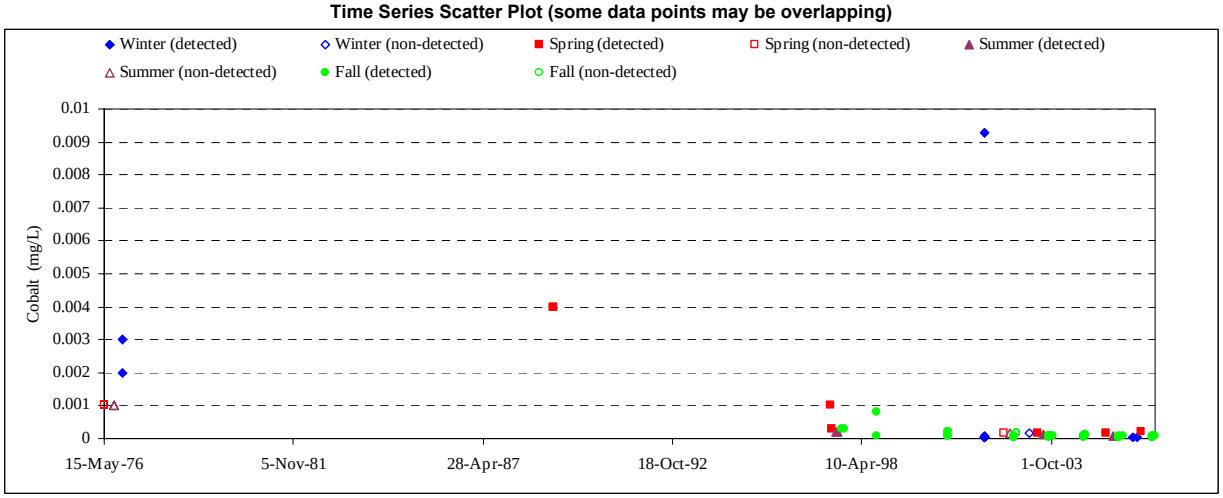
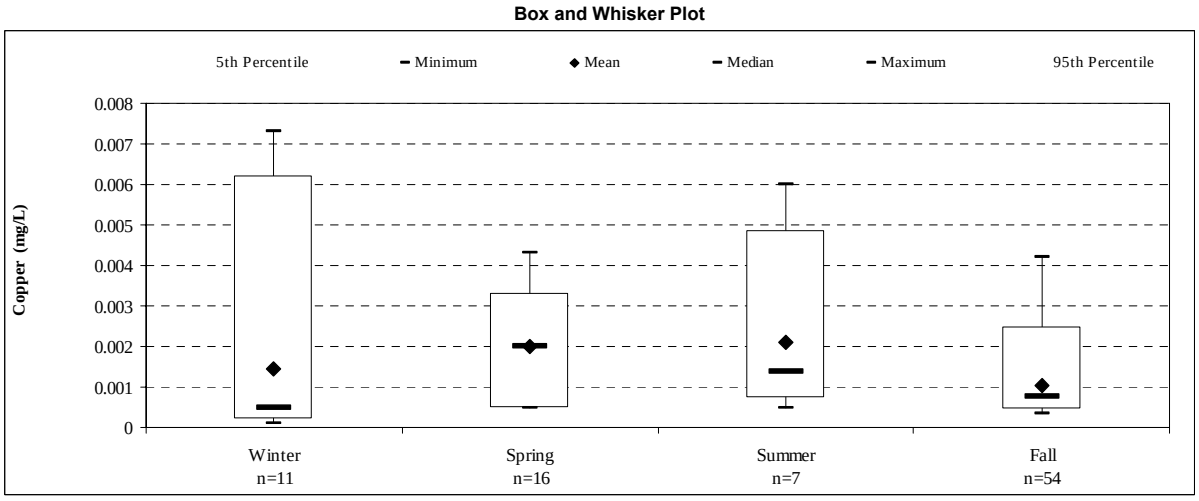


Figure G-1-1-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Upper Reach of Lower Athabasca River



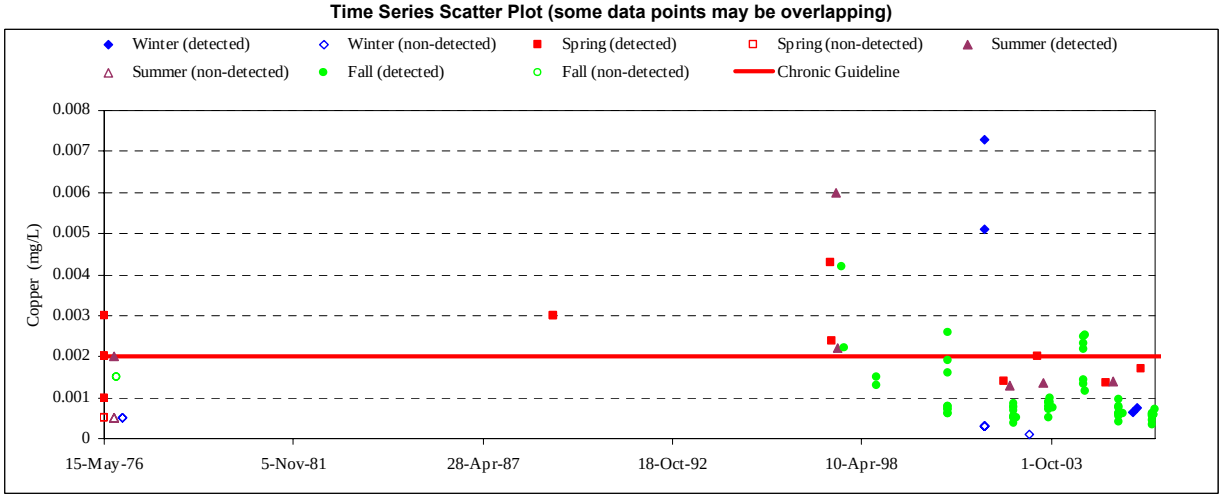


Figure G-1-1-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Upper Reach of Lower Athabasca River

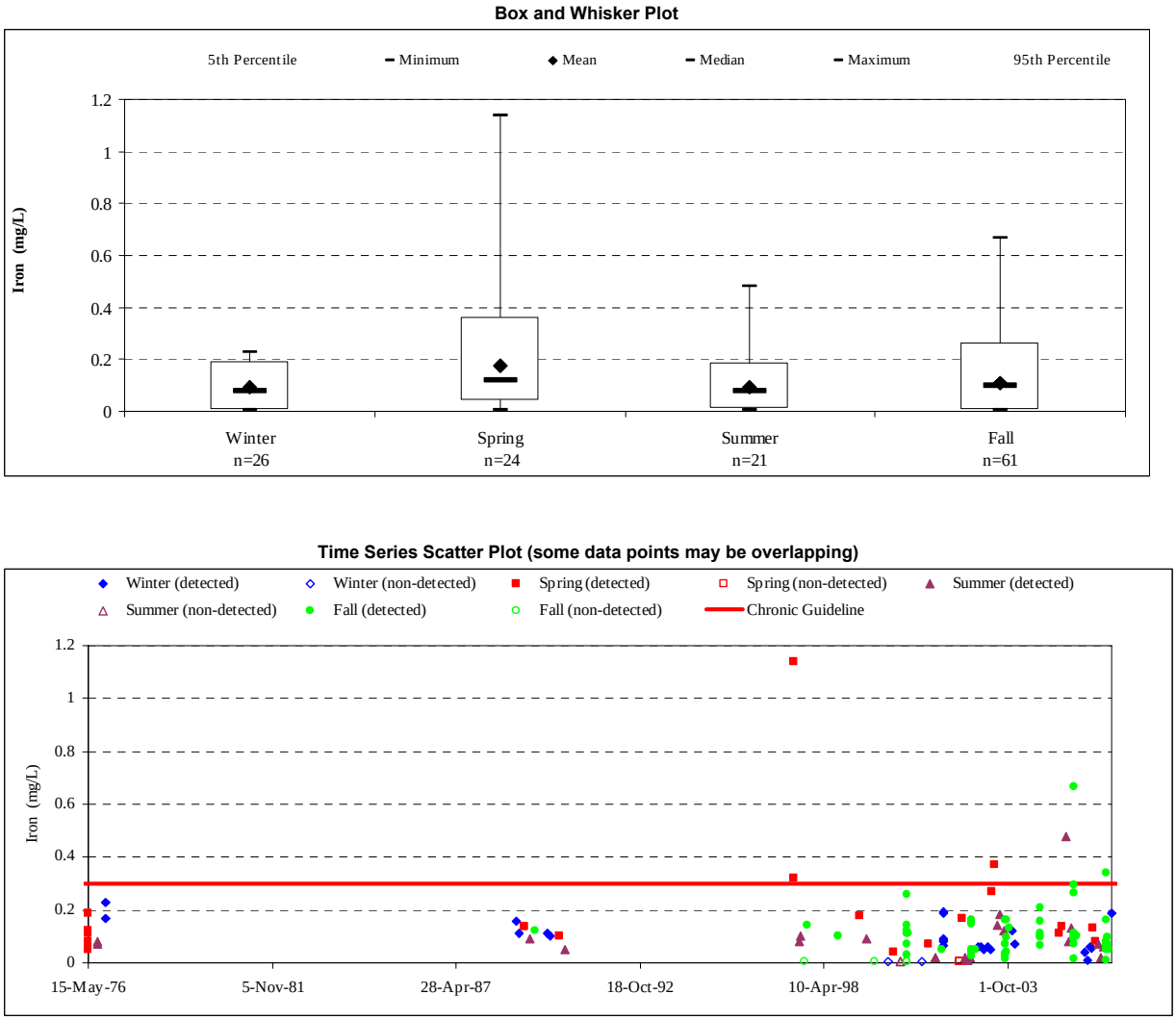
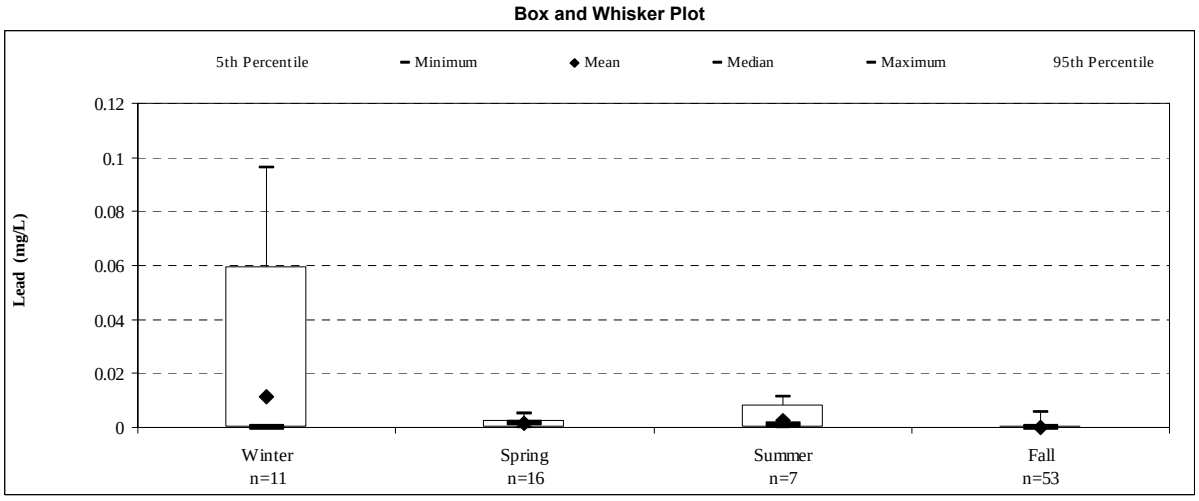


Figure G-1-1-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Upper Reach of Lower Athabasca River



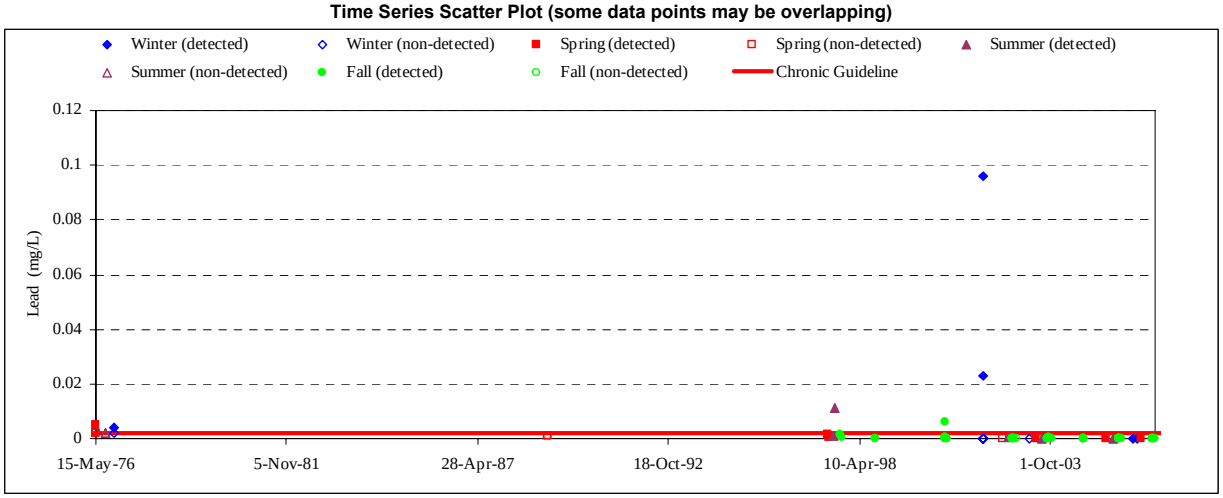
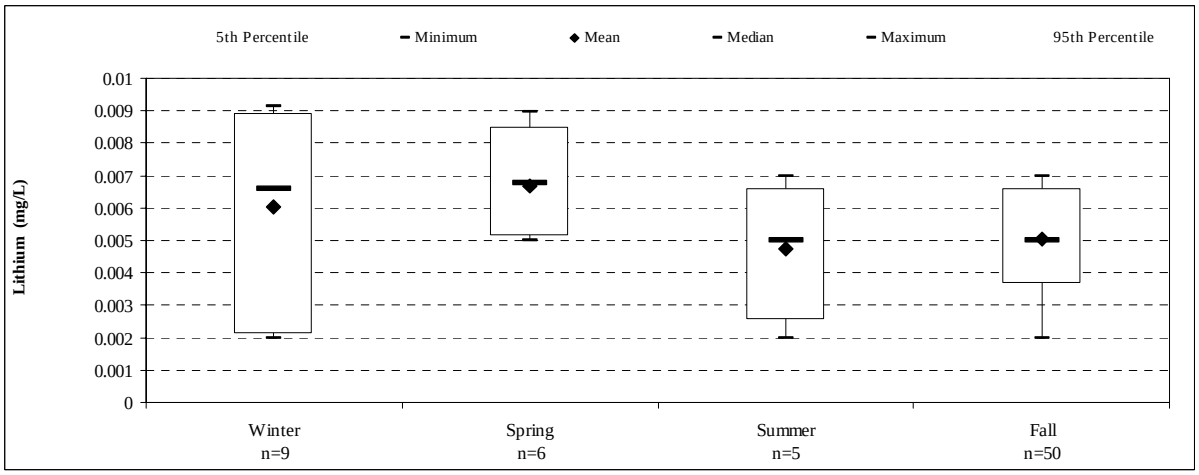


Figure G-1-1-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Upper Reach of Lower Athabasca River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

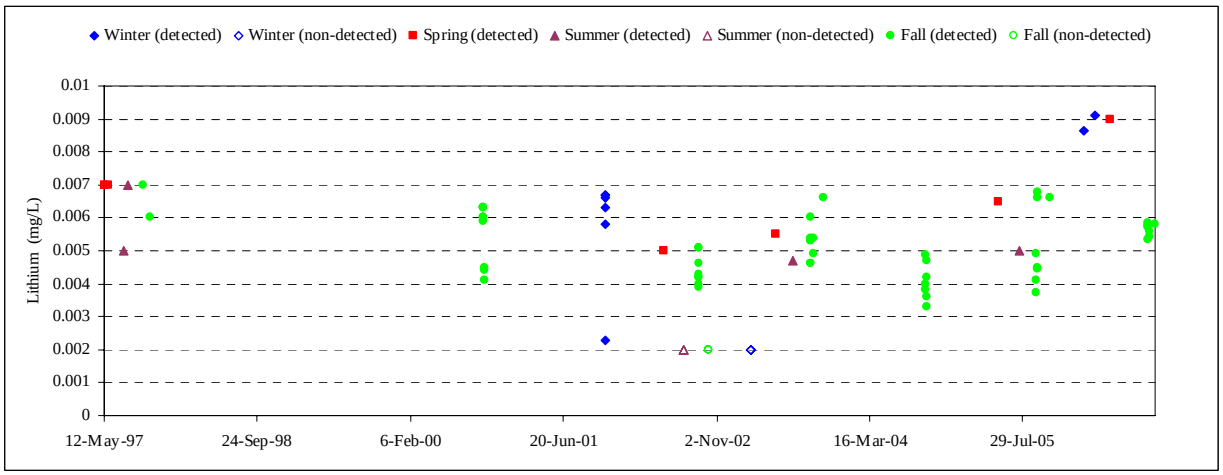
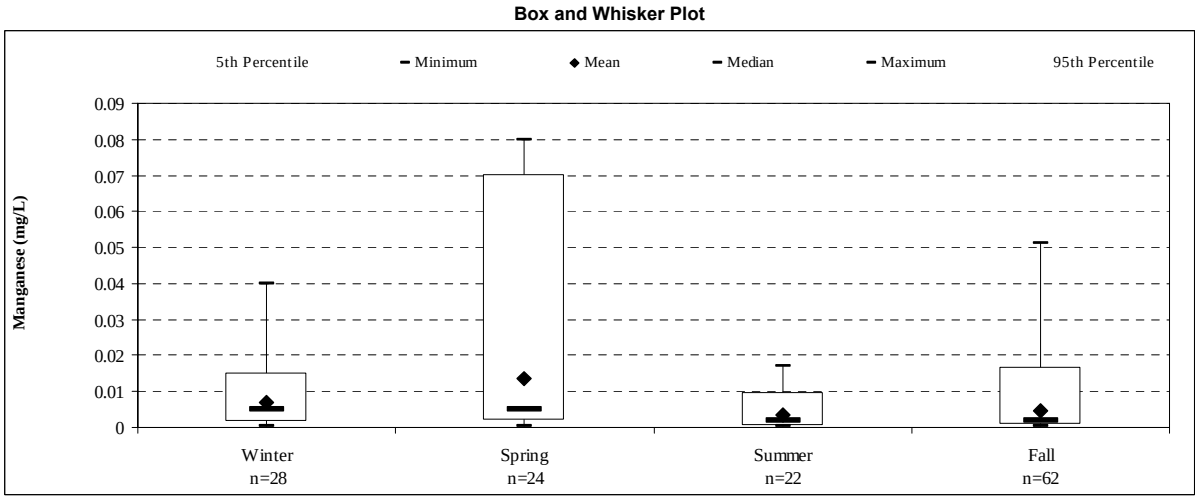


Figure G-1-1-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Upper Reach of Lower Athabasca River



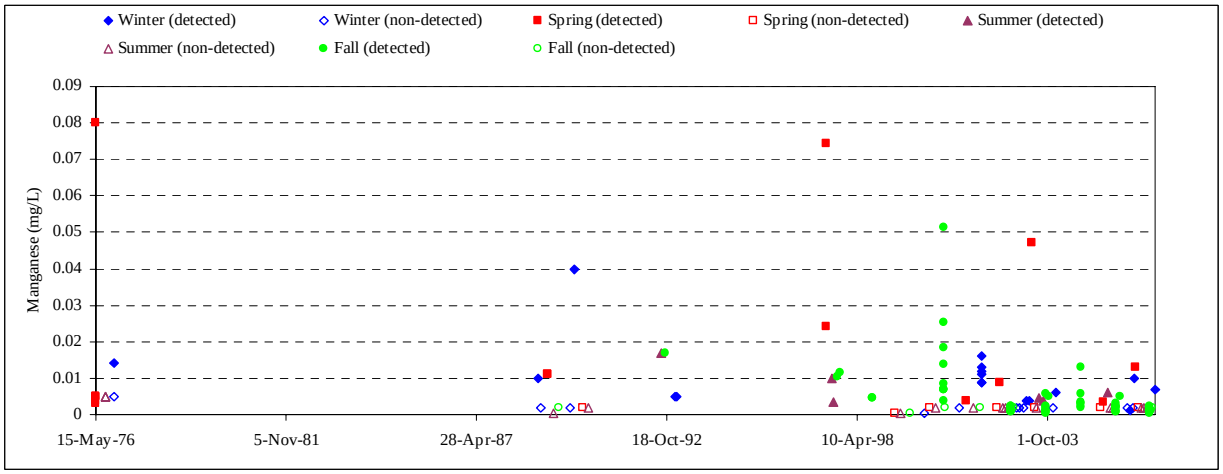
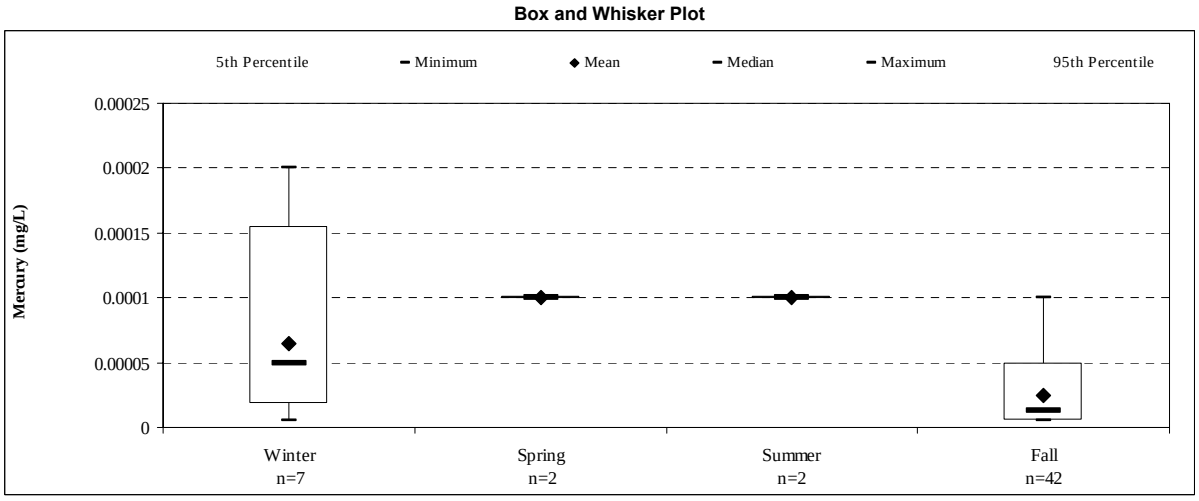


Figure G-1-1-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Upper Reach of Lower Athabasca River



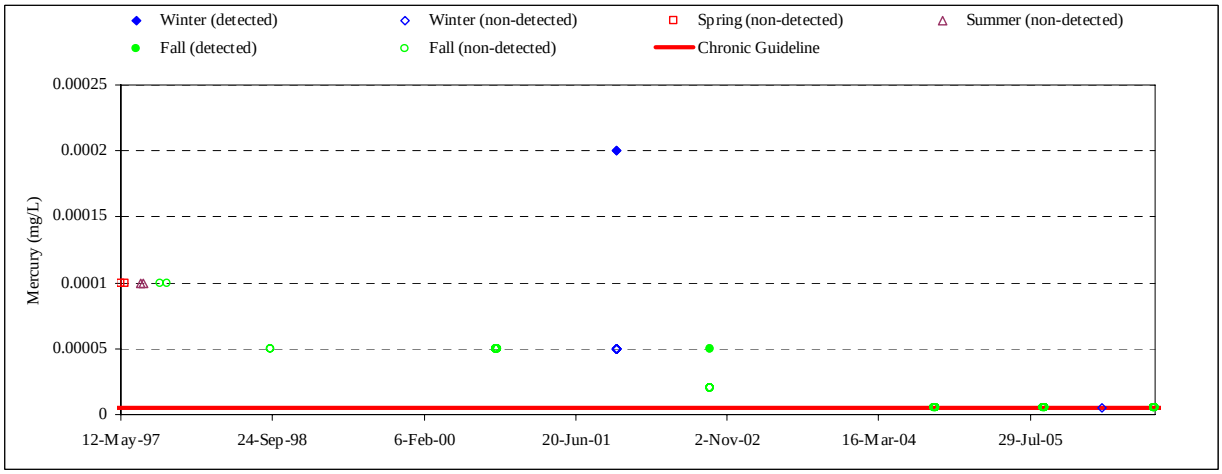
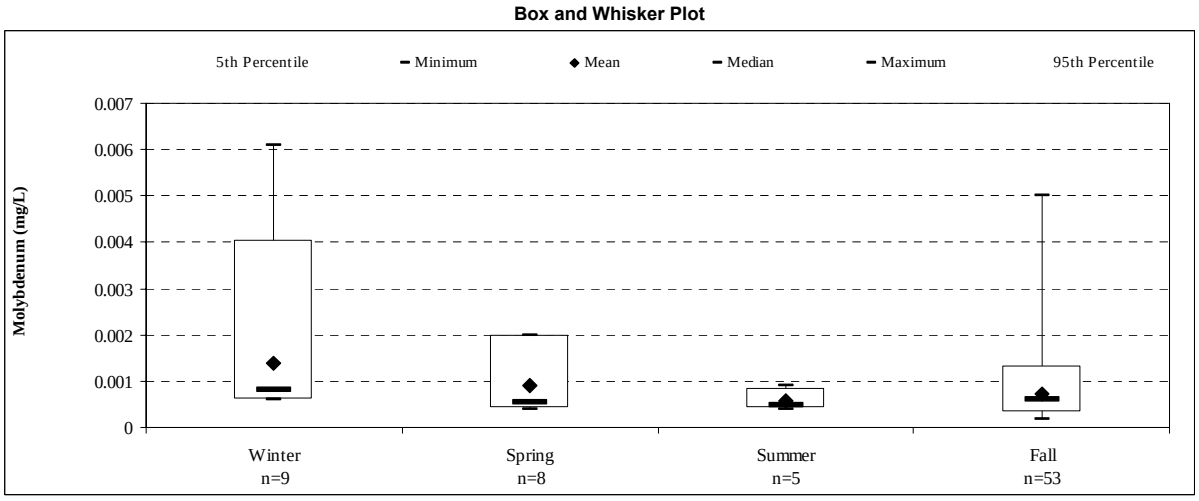


Figure G-1-1-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Upper Reach of Lower Athabasca River



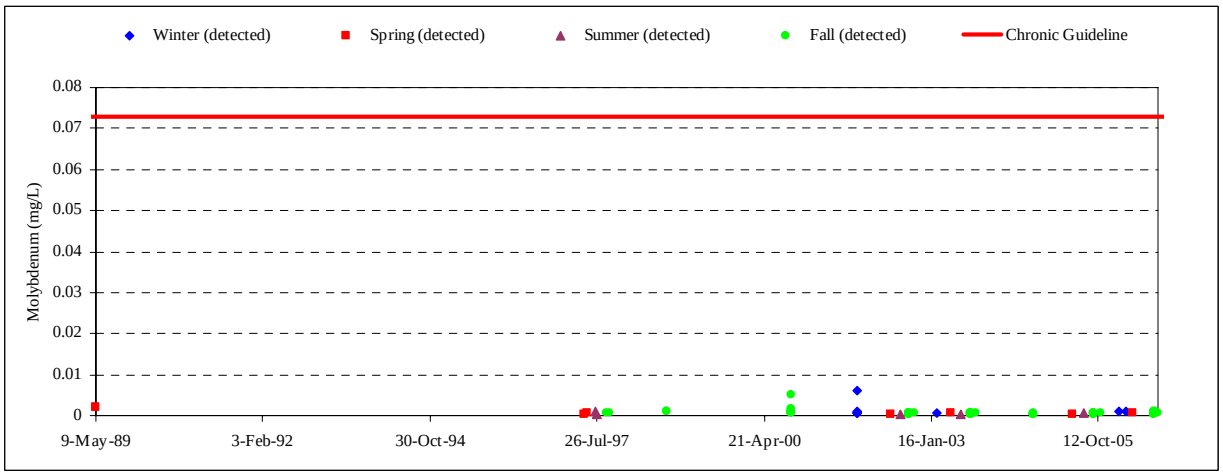


Figure G-1-1-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Upper Reach of Lower Athabasca River

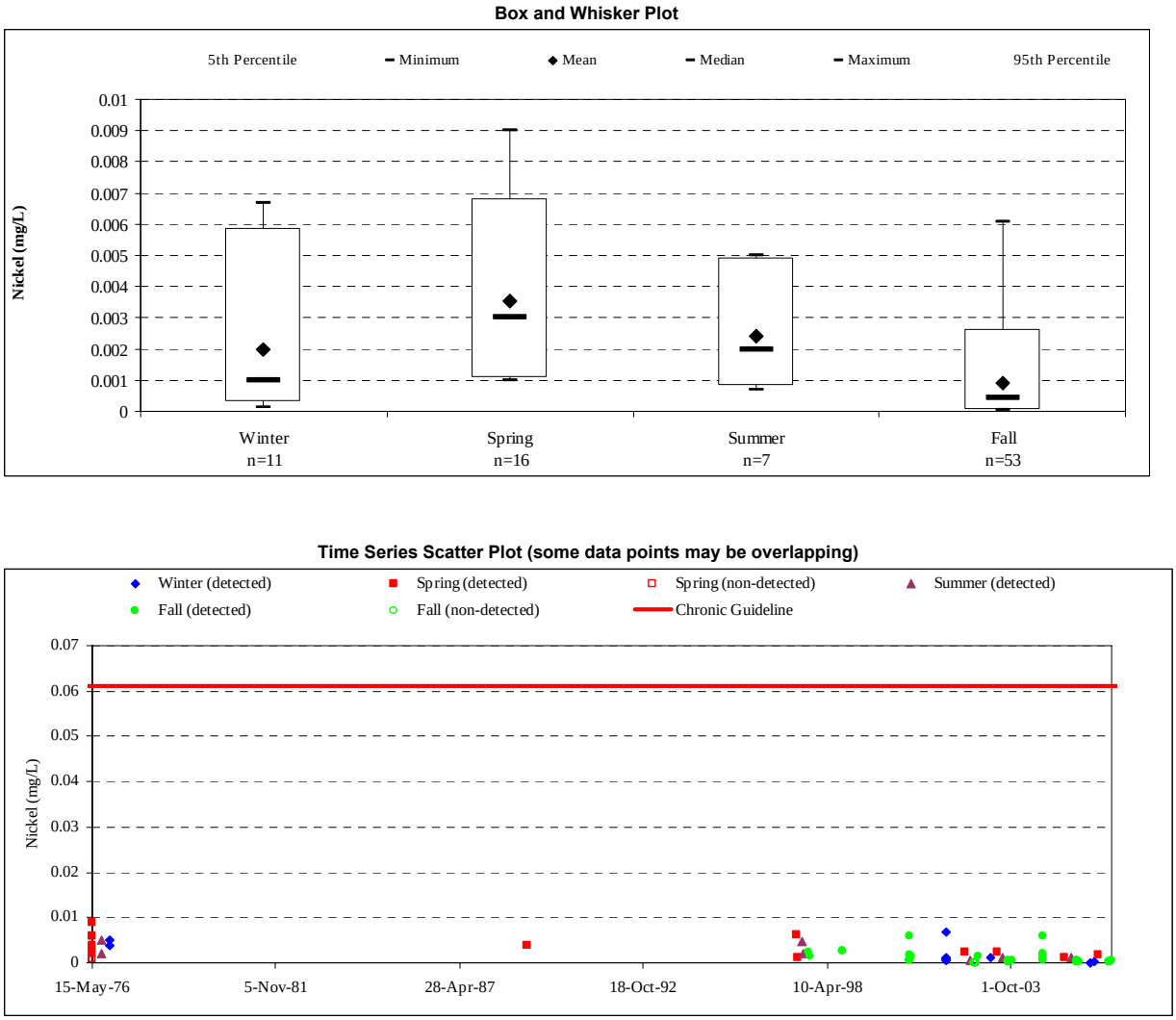
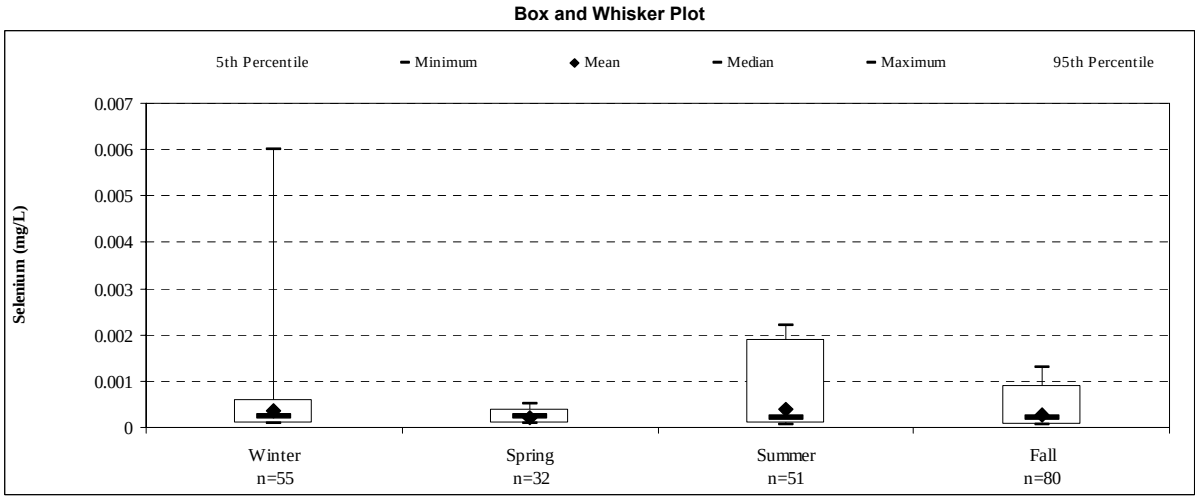


Figure G-1-1-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



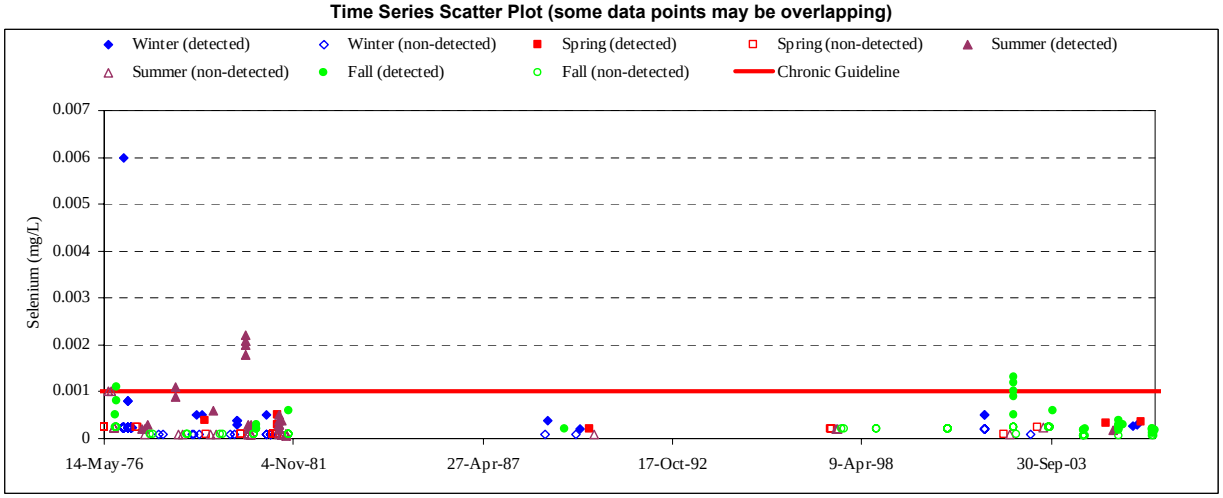
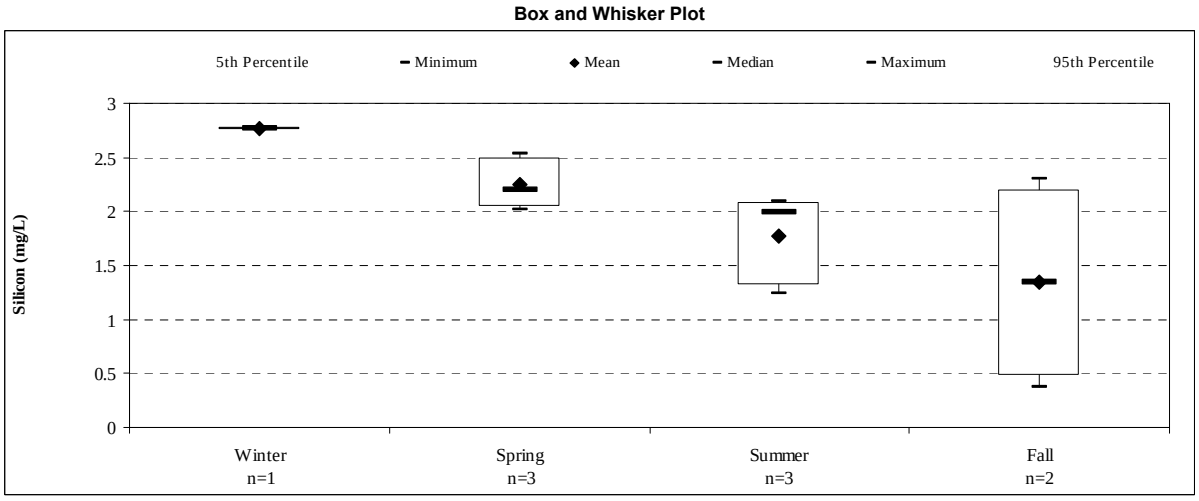


Figure G-1-1-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Upper Reach of Lower Athabasca River



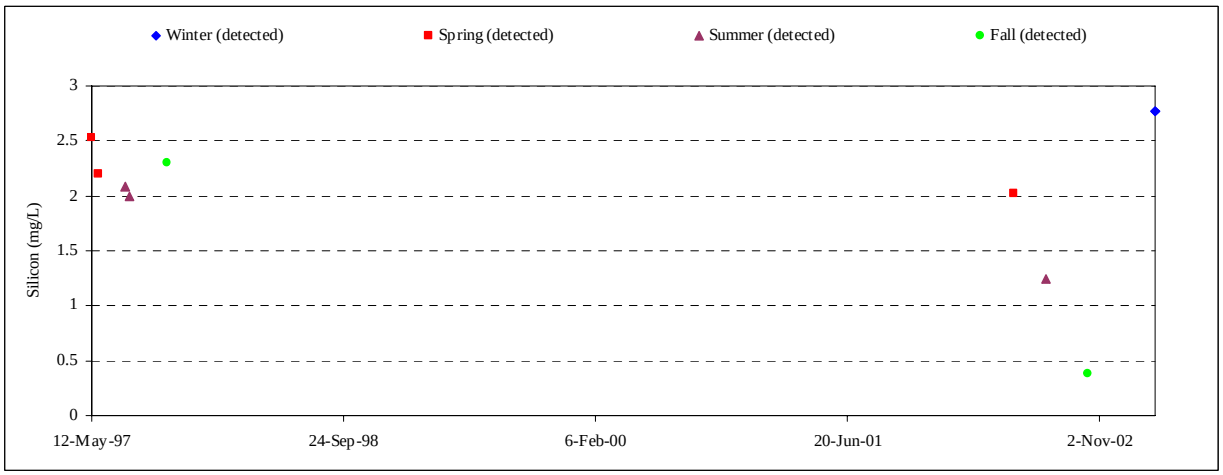


Figure G-1-1-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Upper Reach of Lower Athabasca River

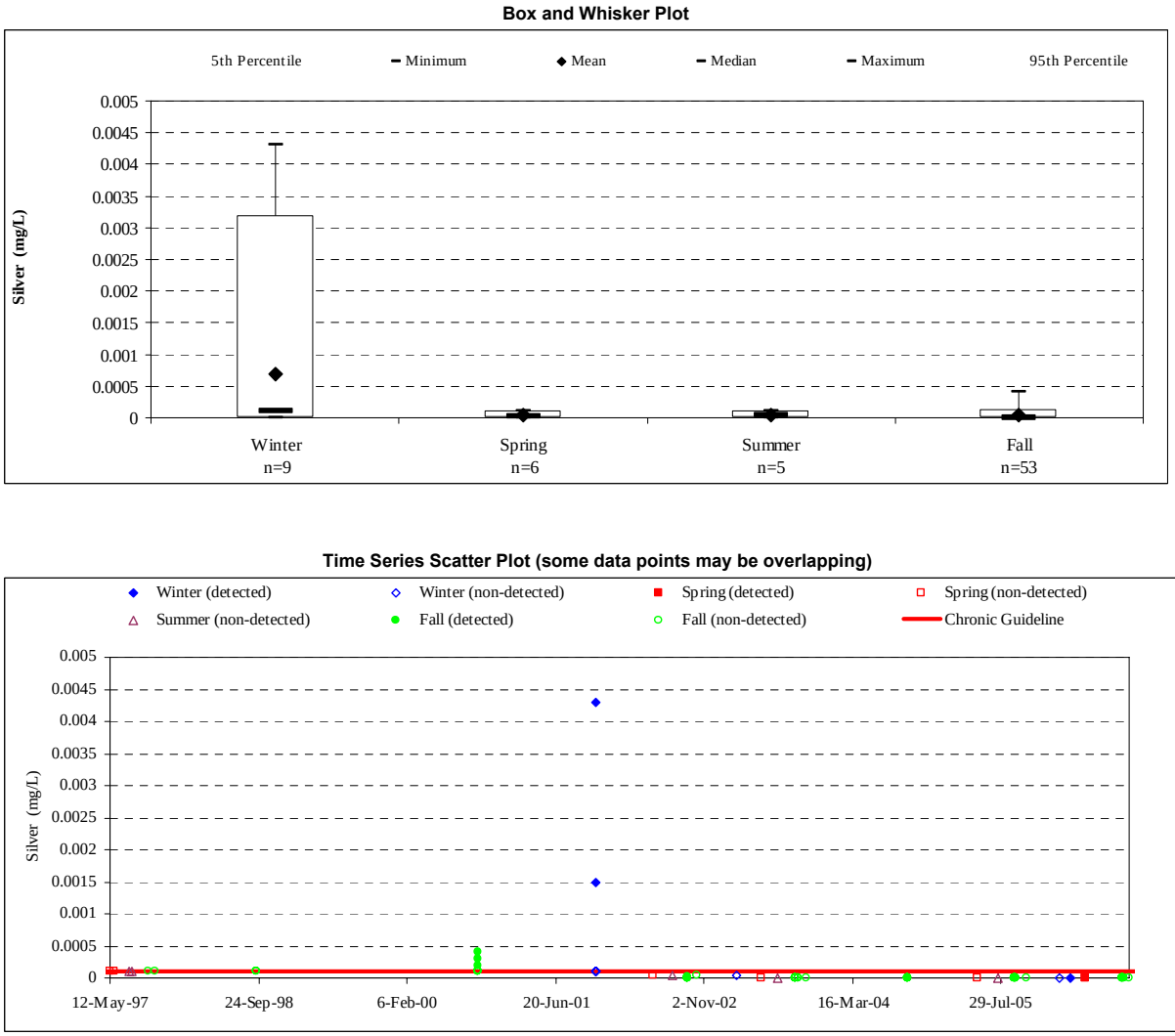


Figure G-1-1-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Upper Reach of Lower Athabasca River

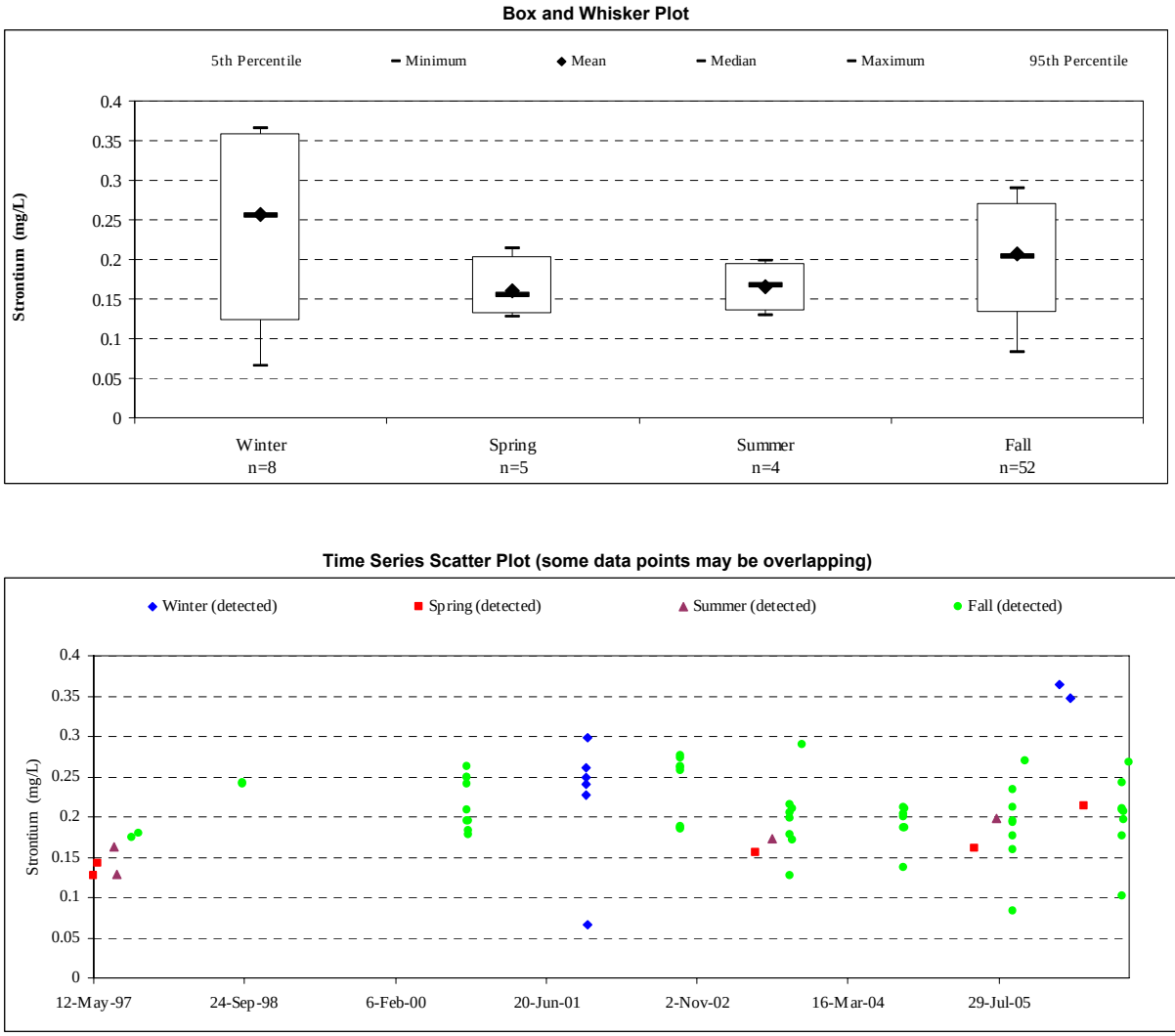
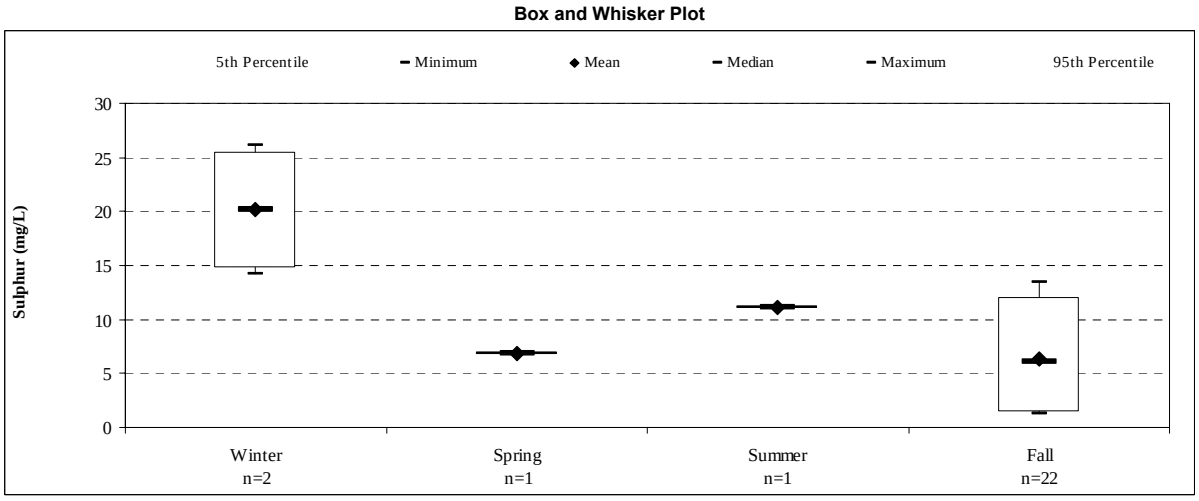


Figure G-1-1-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Upper Reach of Lower Athabasca River



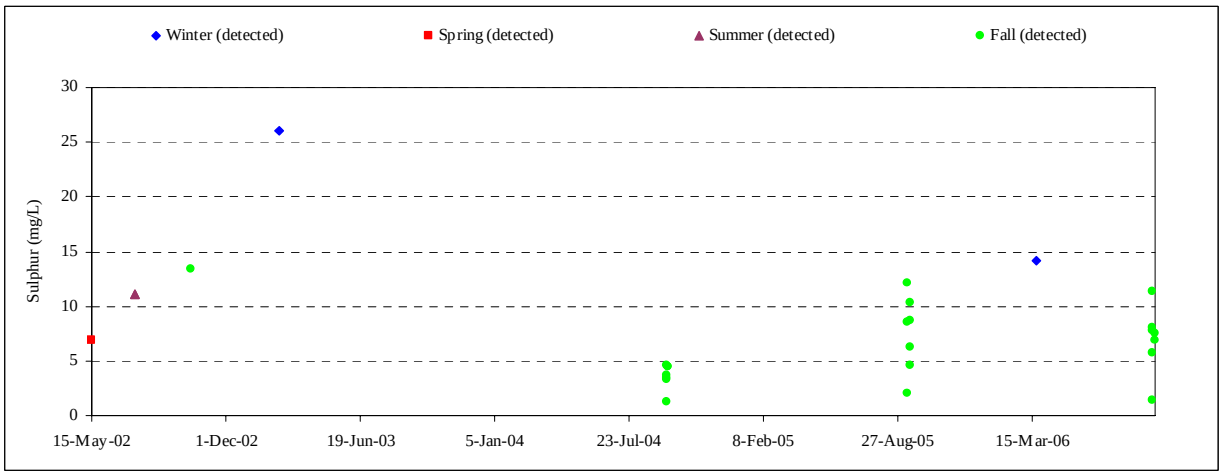


Figure G-1-1-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Upper Reach of Lower Athabasca River

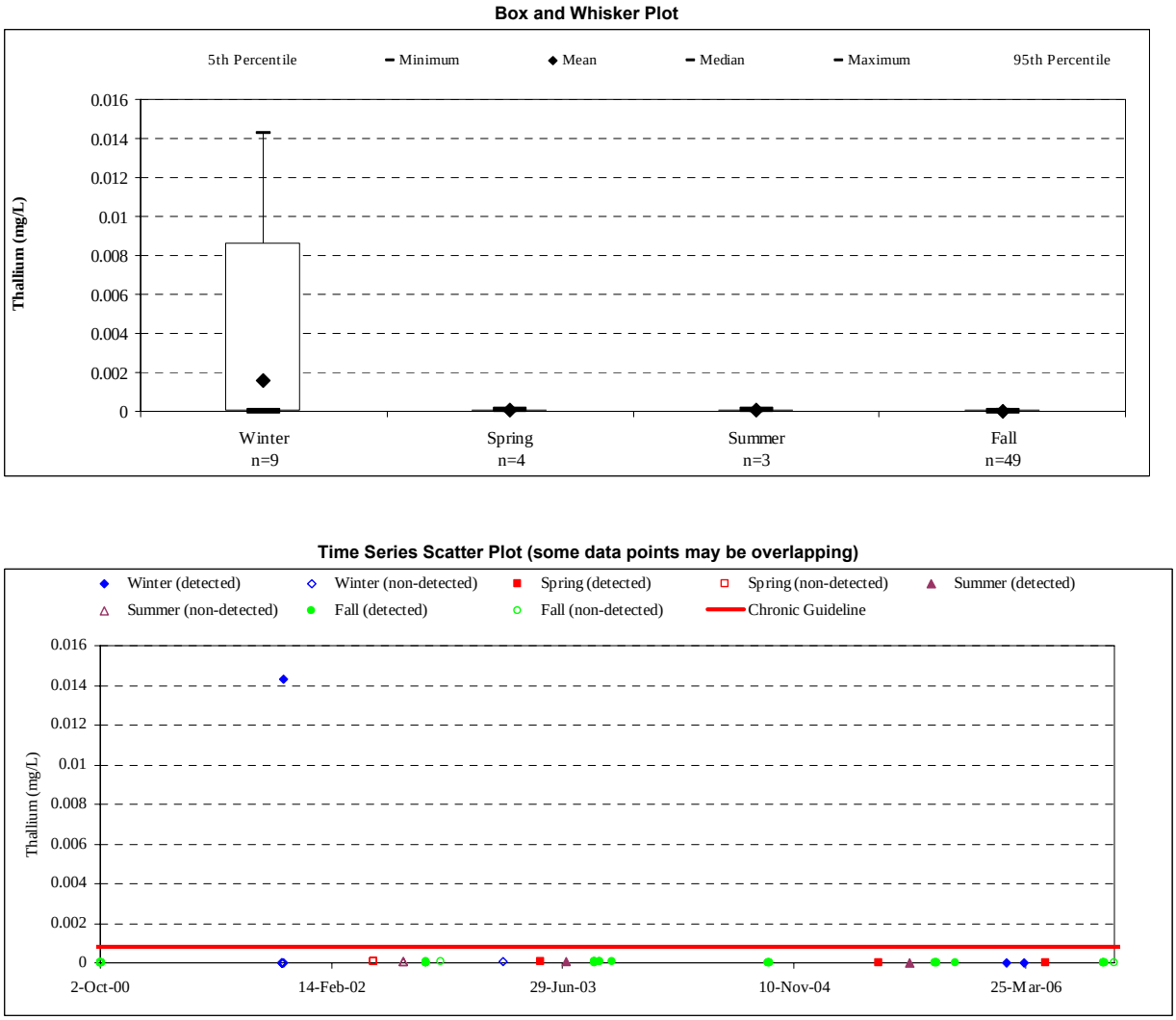
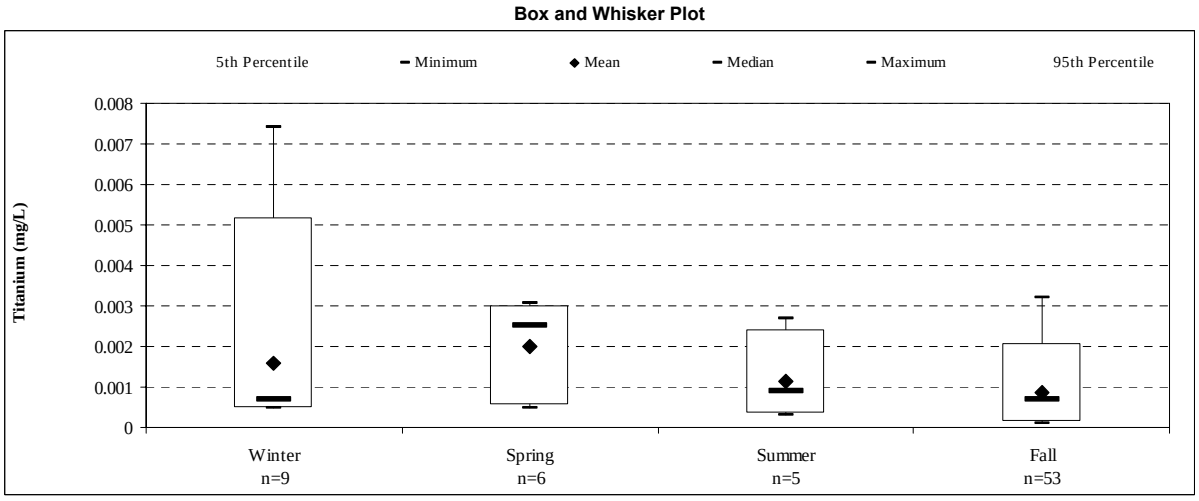


Figure G-1-1-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Upper Reach of Lower Athabasca River



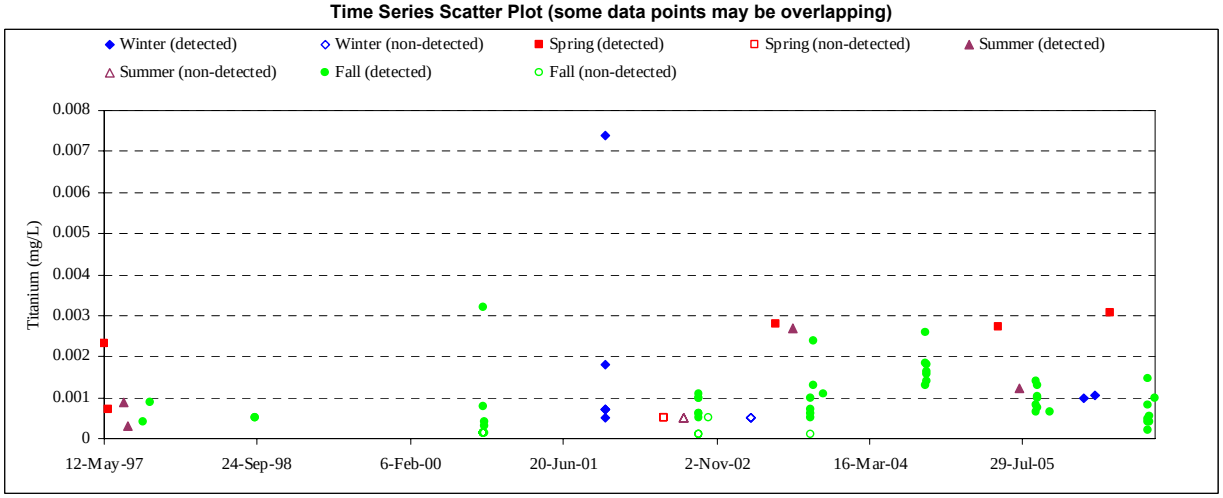


Figure G-1-1-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Upper Reach of Lower Athabasca River

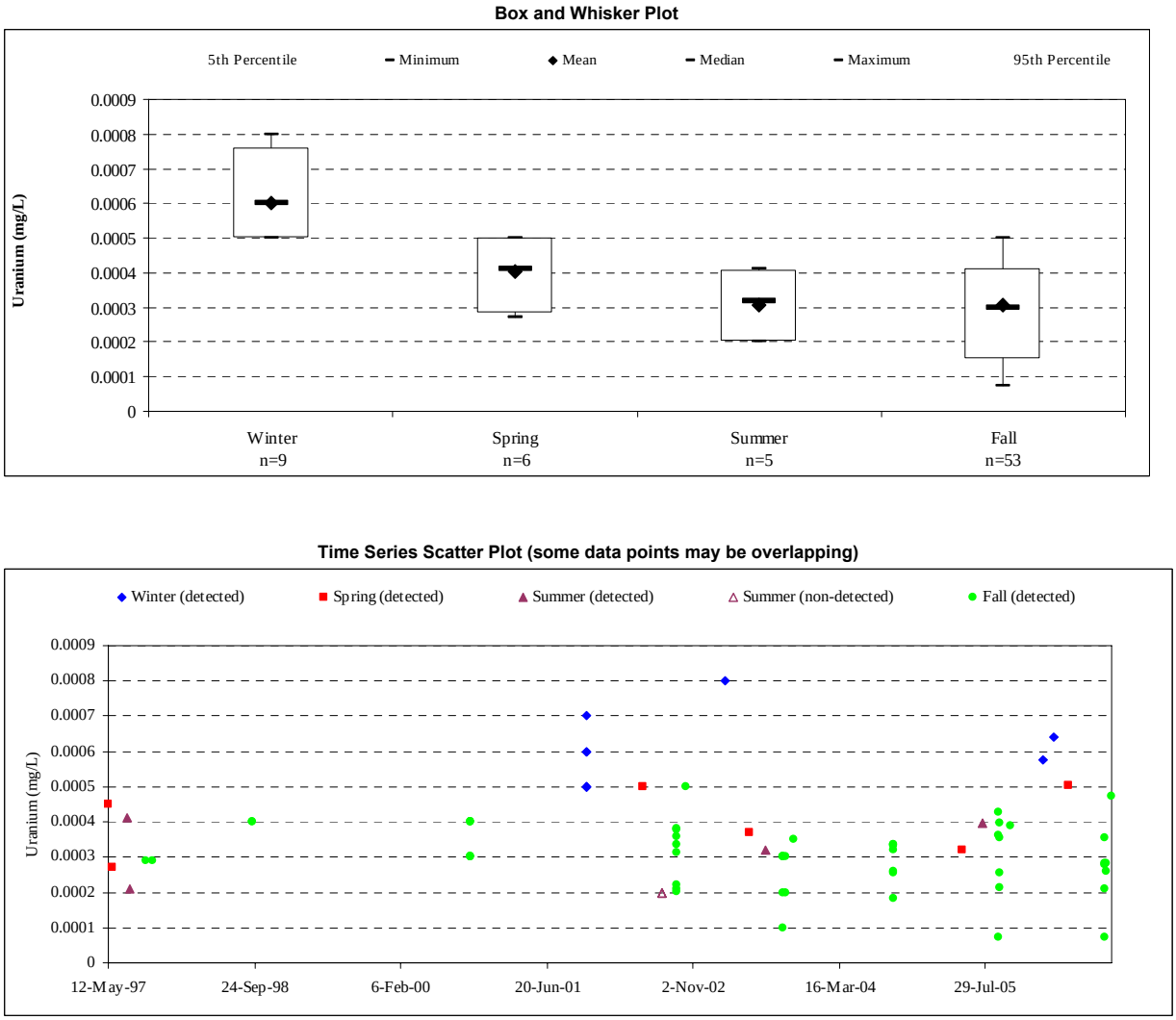


Figure G-1-1-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Upper Reach of Lower Athabasca River

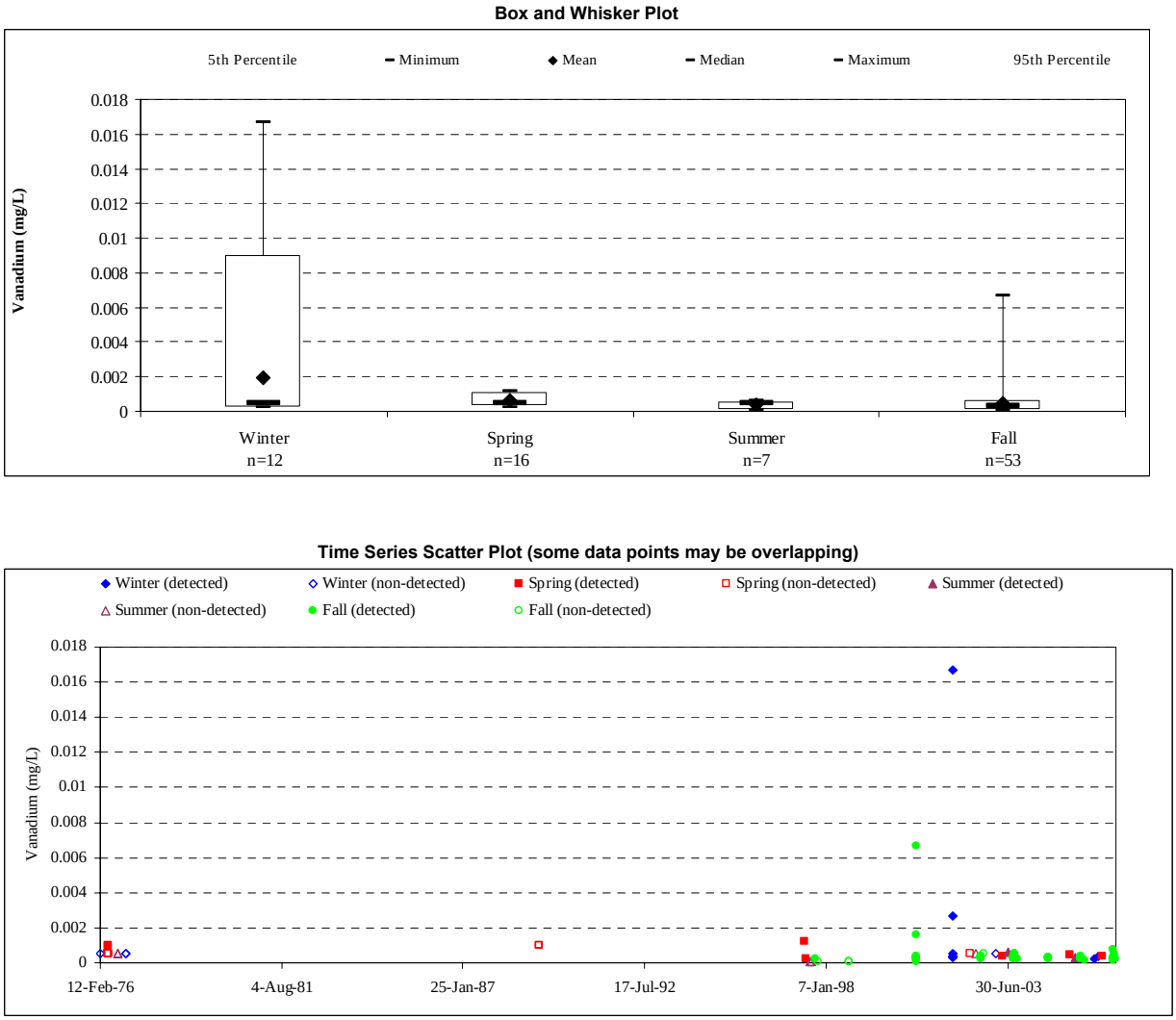
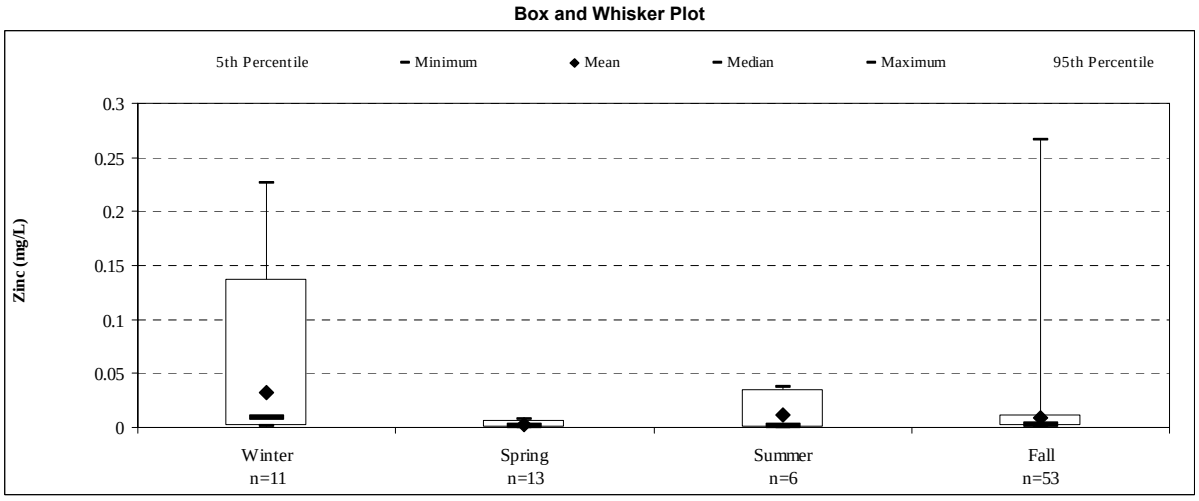


Figure G-1-1-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Upper Reach of Lower Athabasca River



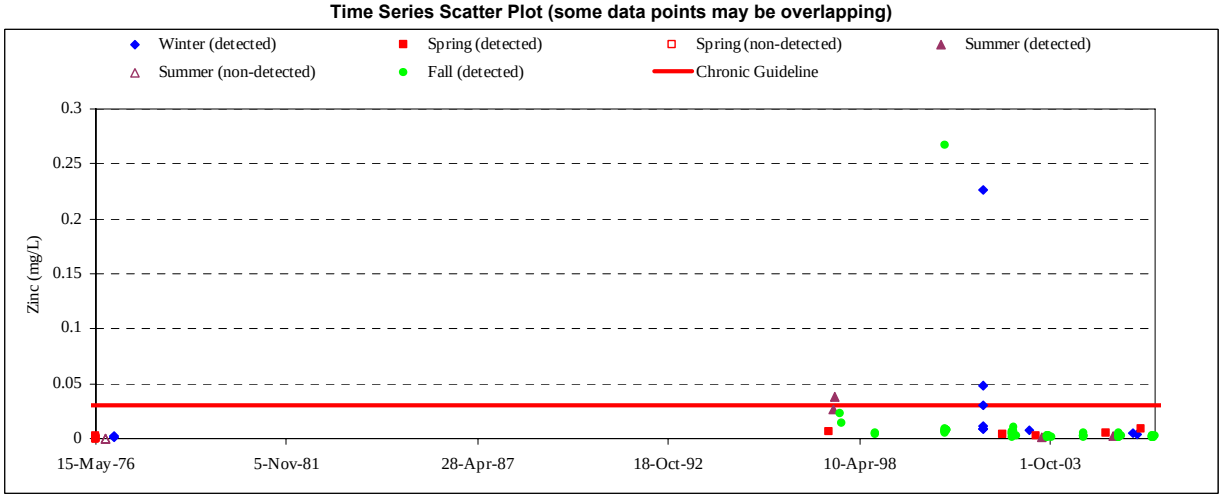
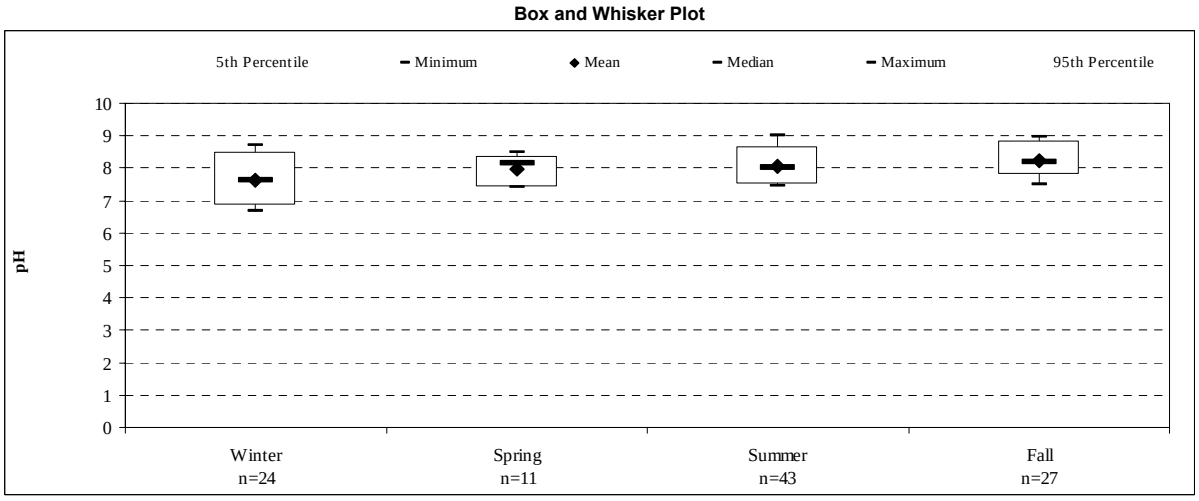


Figure G-1-2-1 Box Whisker and Time Series Scatter Plots of Observed pH in Middle Reach of Lower Athabasca River



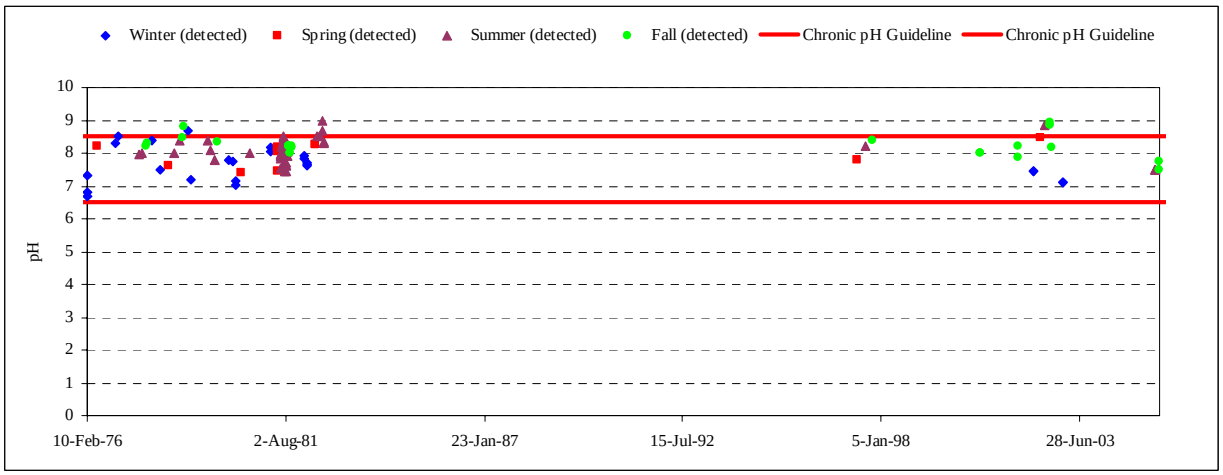
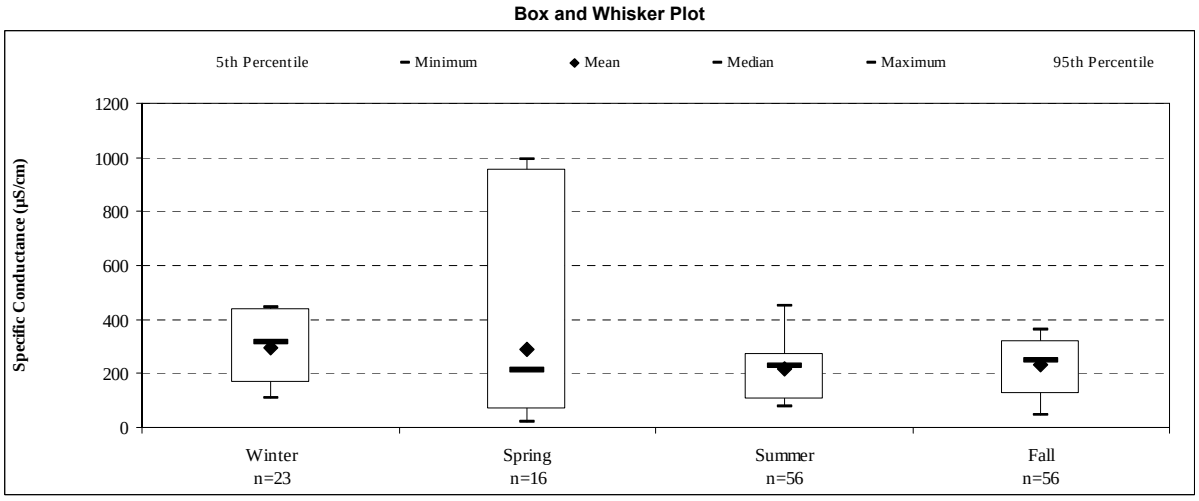


Figure G-1-2-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Middle Reach of Lower Athabasca River



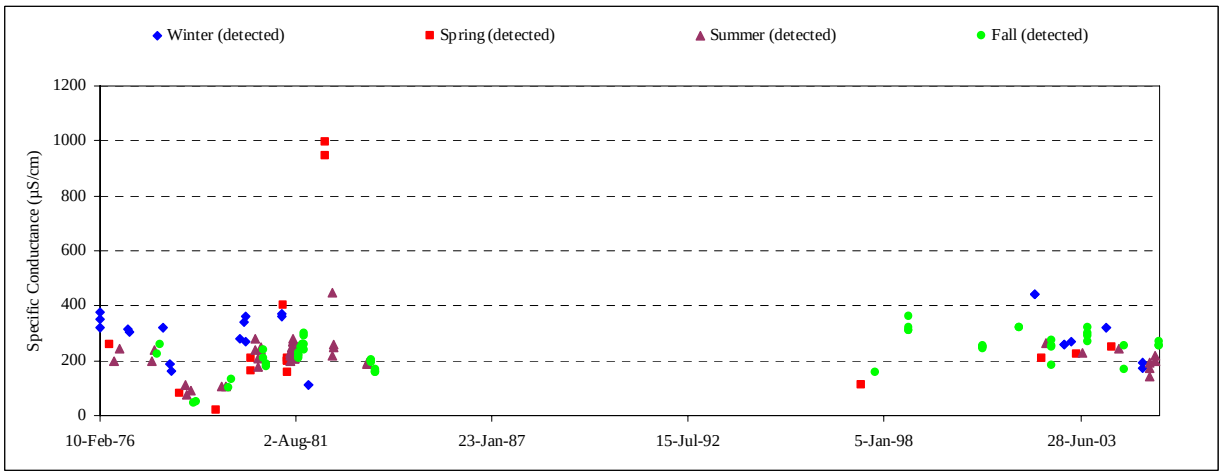
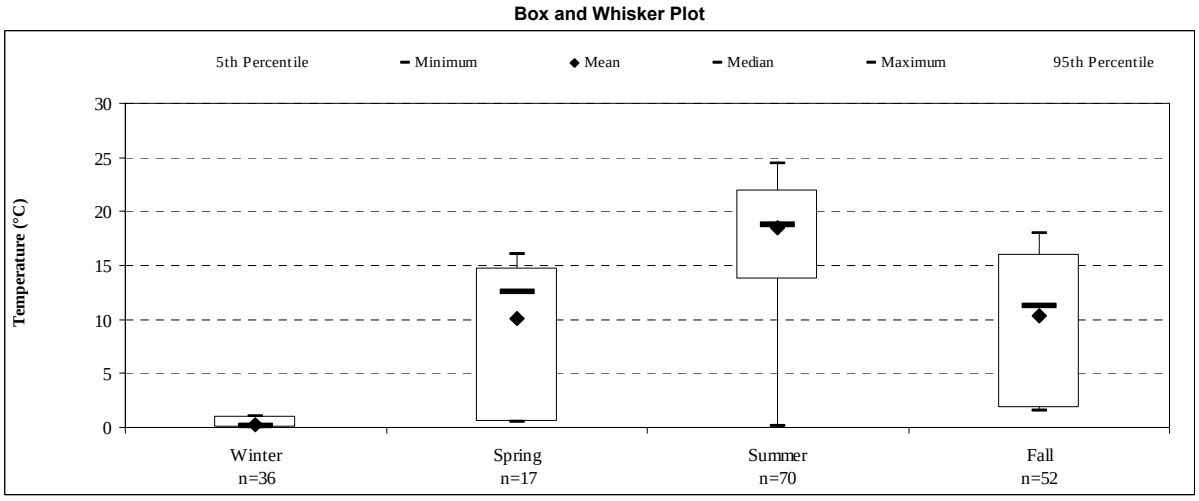


Figure G-1-2-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Middle Reach of Lower Athabasca River



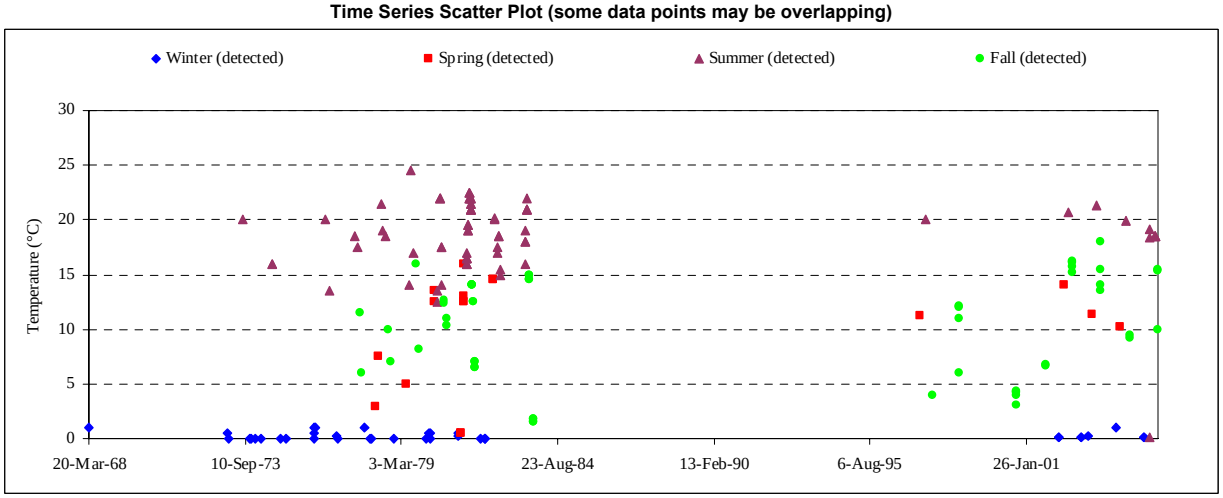
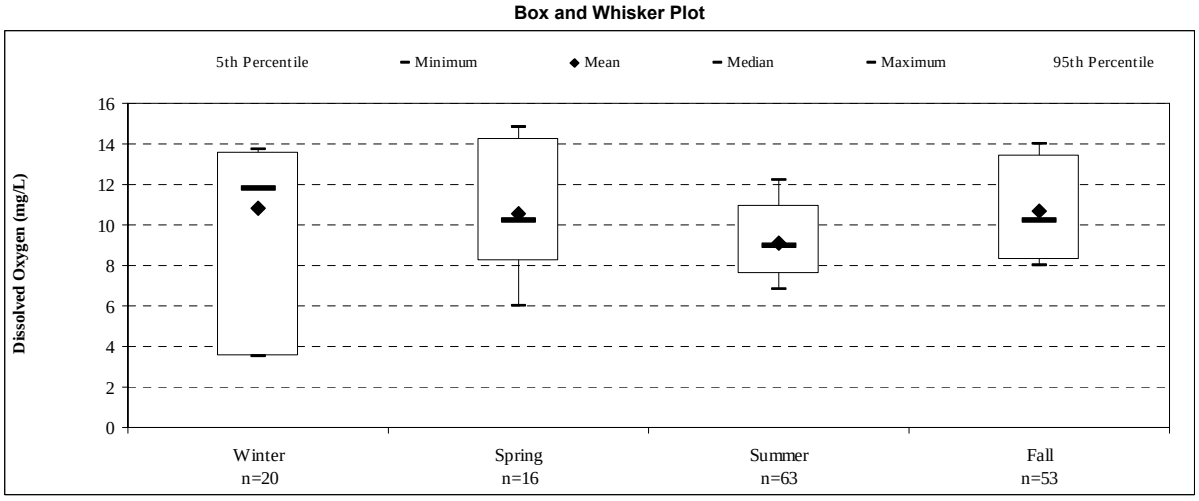


Figure G-1-2-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Middle Reach of Lower Athabasca River



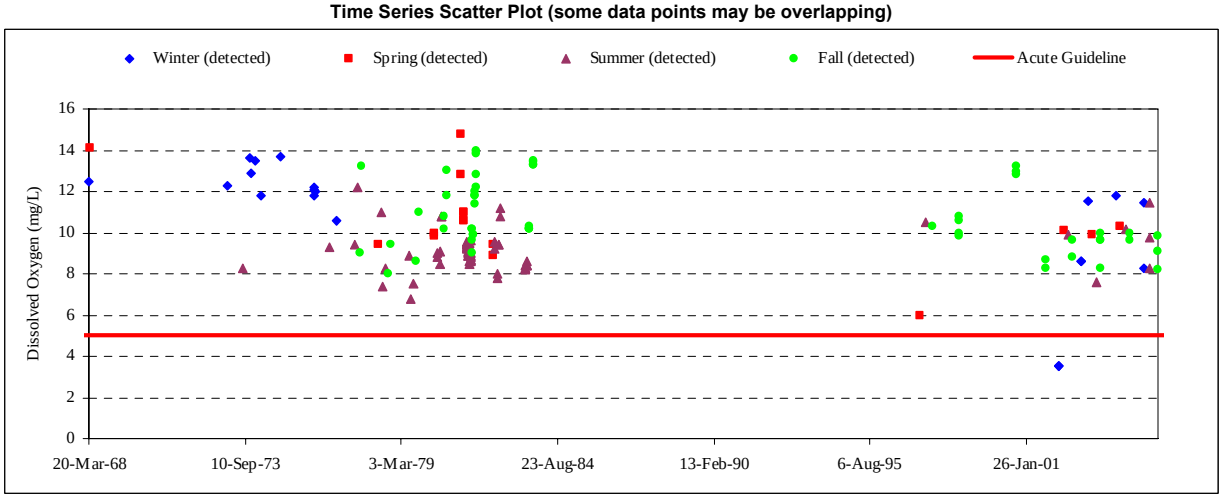
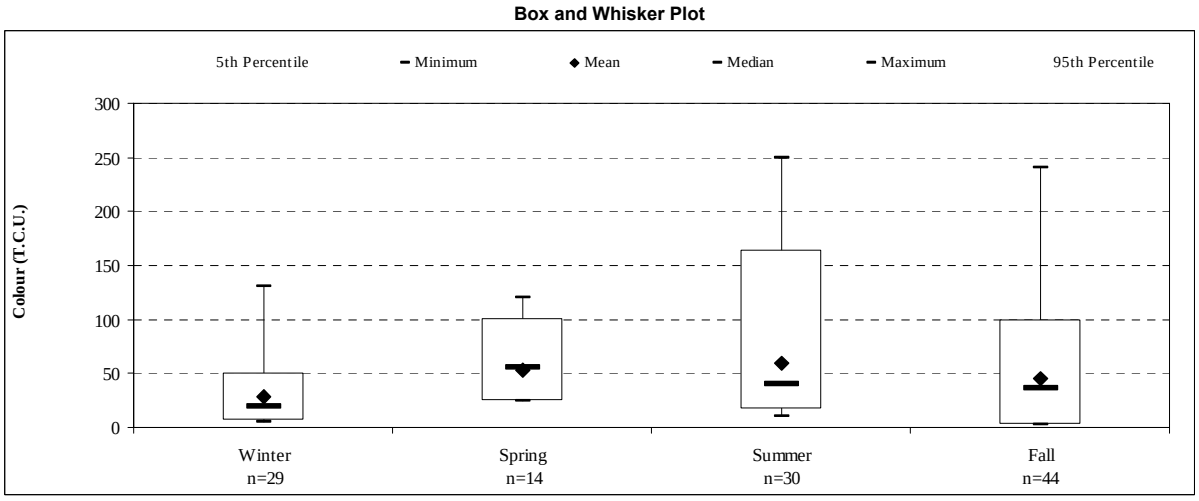


Figure G-1-2-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Middle Reach of Lower Athabasca River



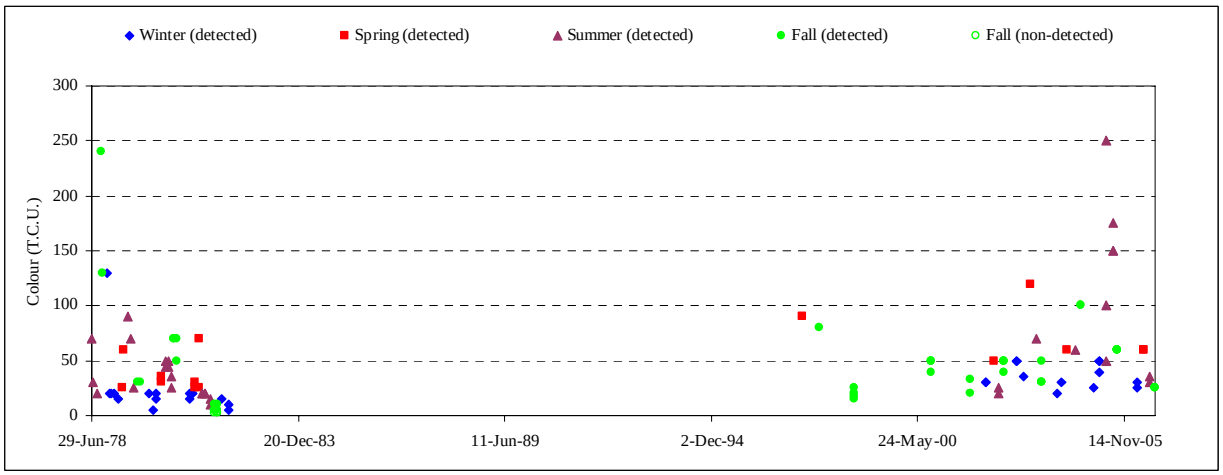


Figure G-1-2-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Middle Reach of Lower Athabasca River

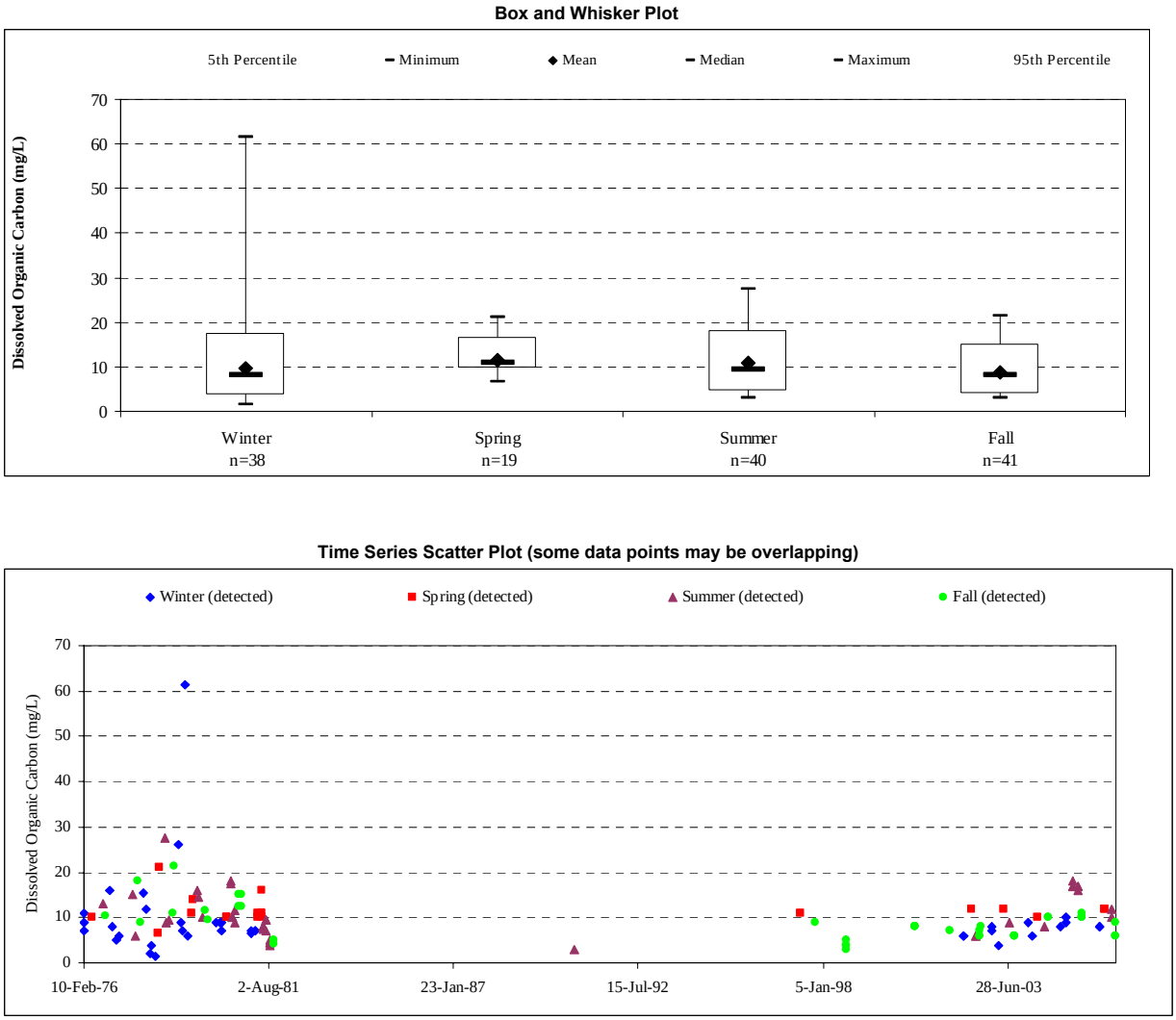
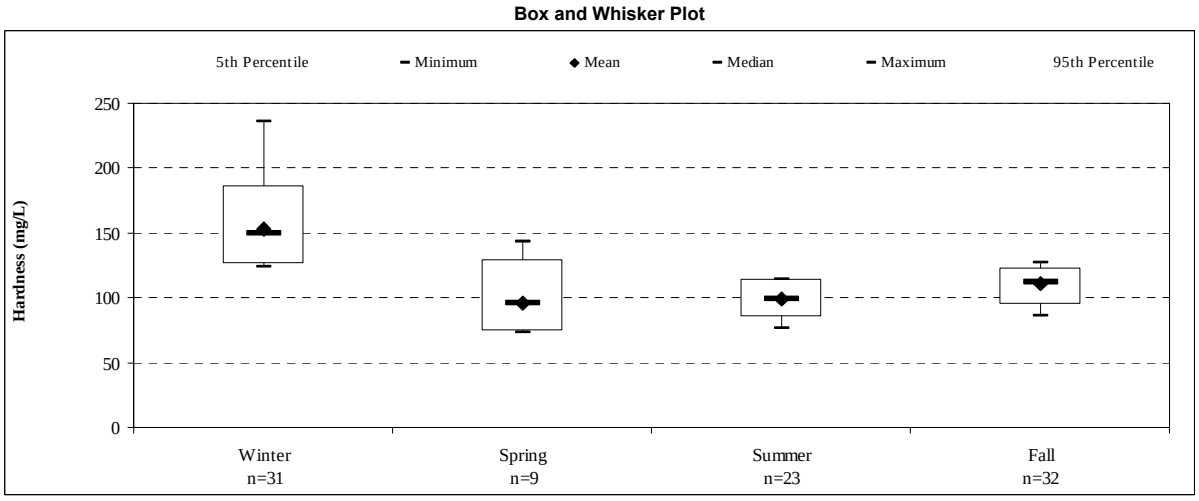


Figure G-1-2-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Middle Reach of Lower Athabasca River



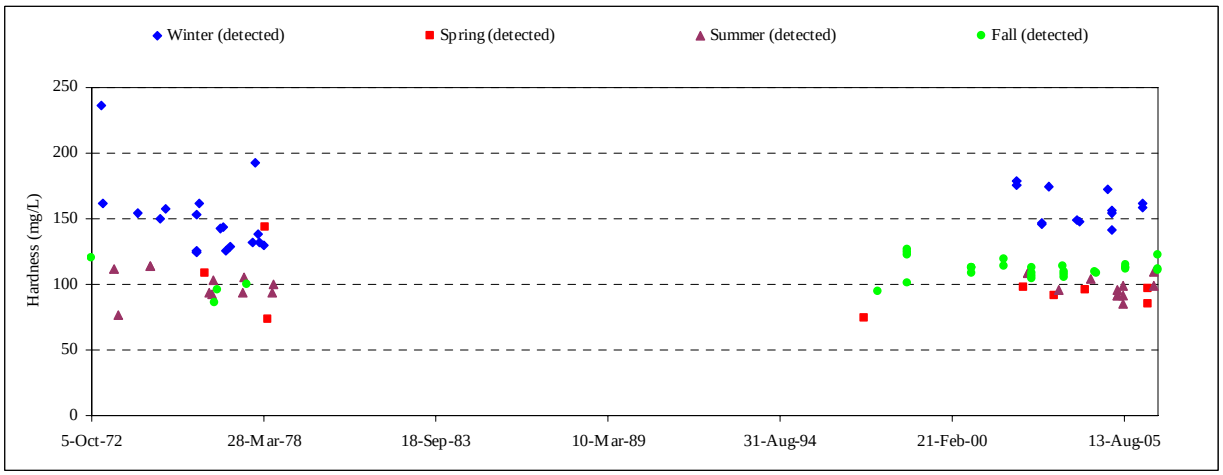
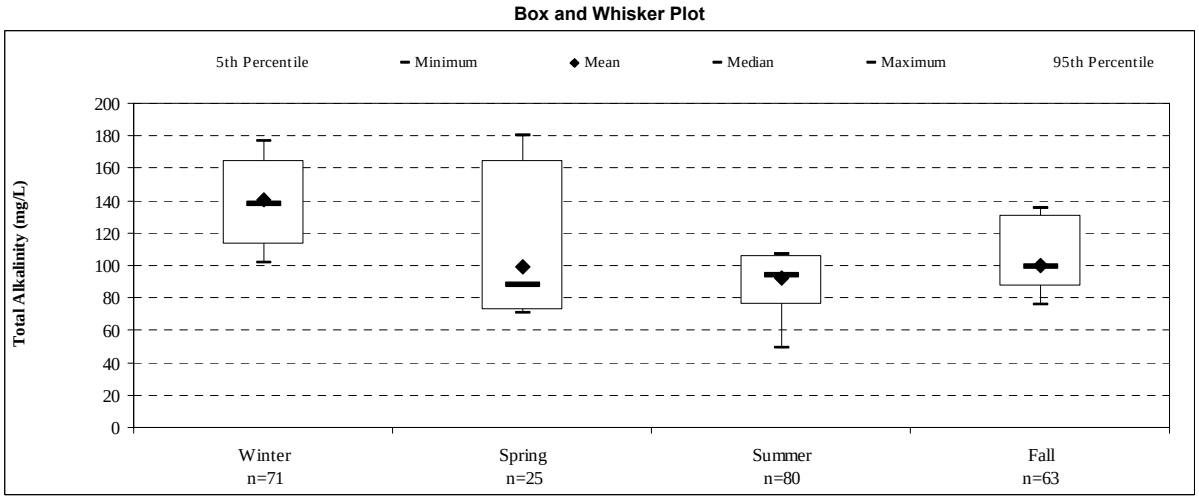


Figure G-1-2-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Middle Reach of Lower Athabasca River



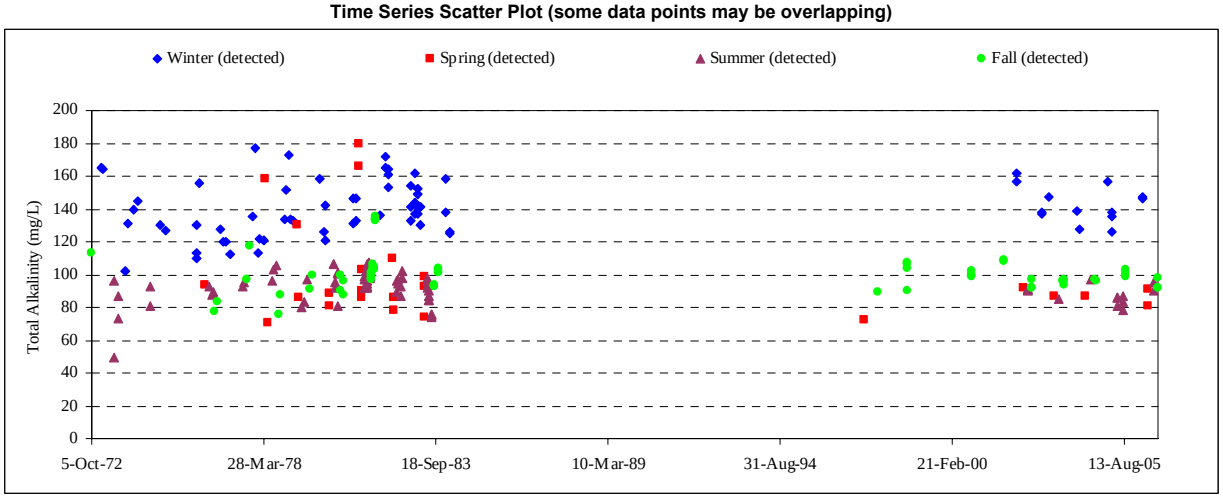
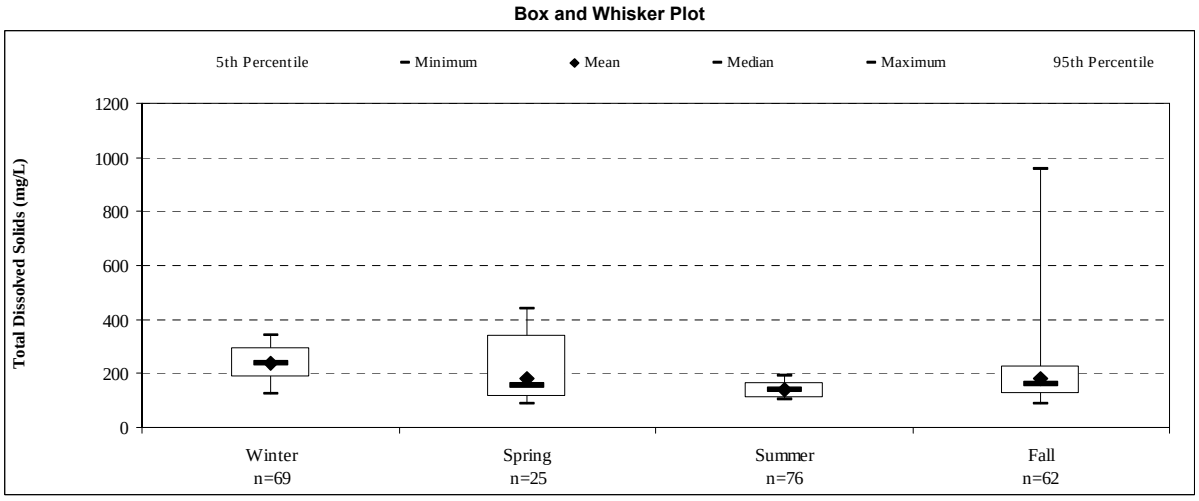


Figure G-1-2-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Middle Reach of Lower Athabasca River



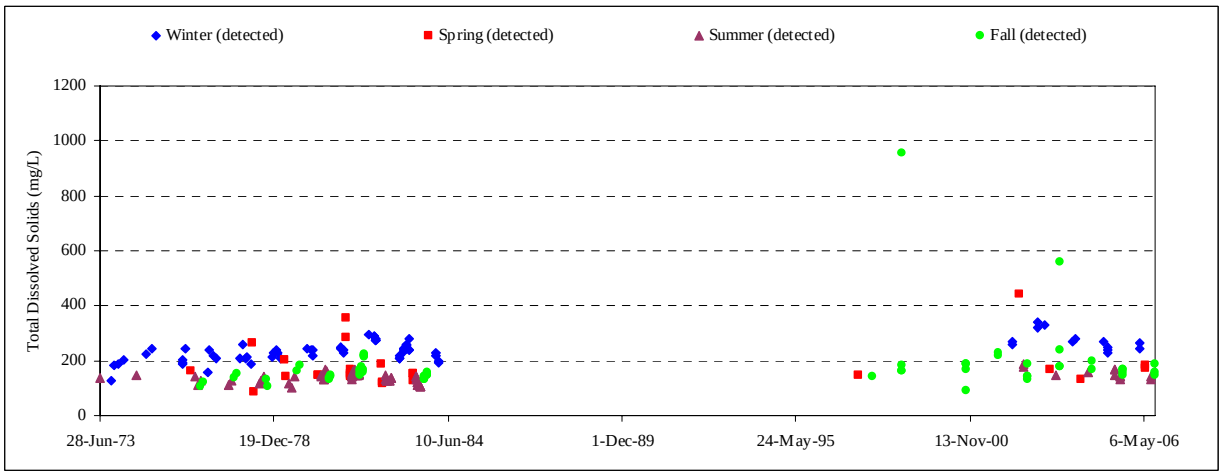
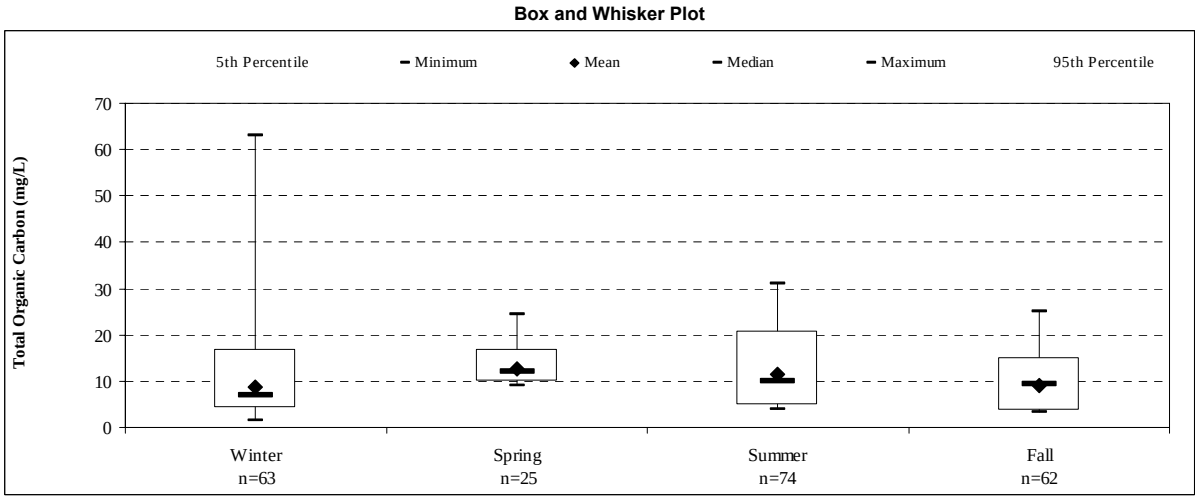


Figure G-1-2-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Middle Reach of Lower Athabasca River



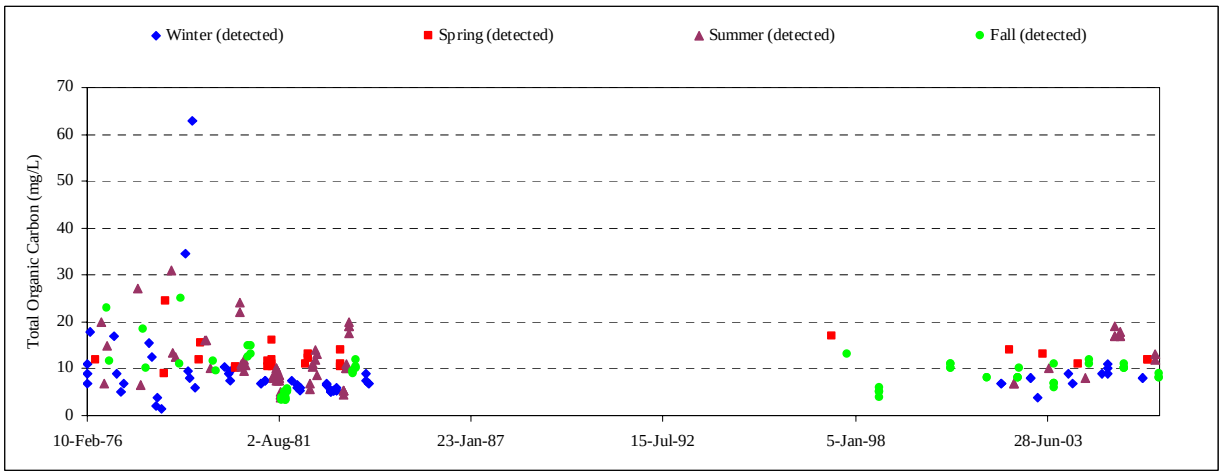
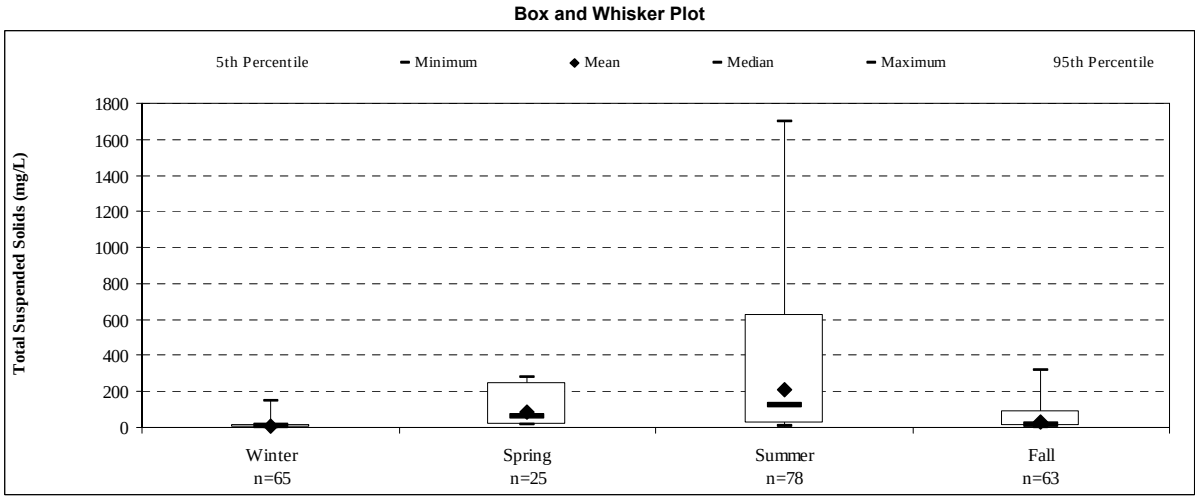


Figure G-1-2-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Middle Reach of Lower Athabasca River



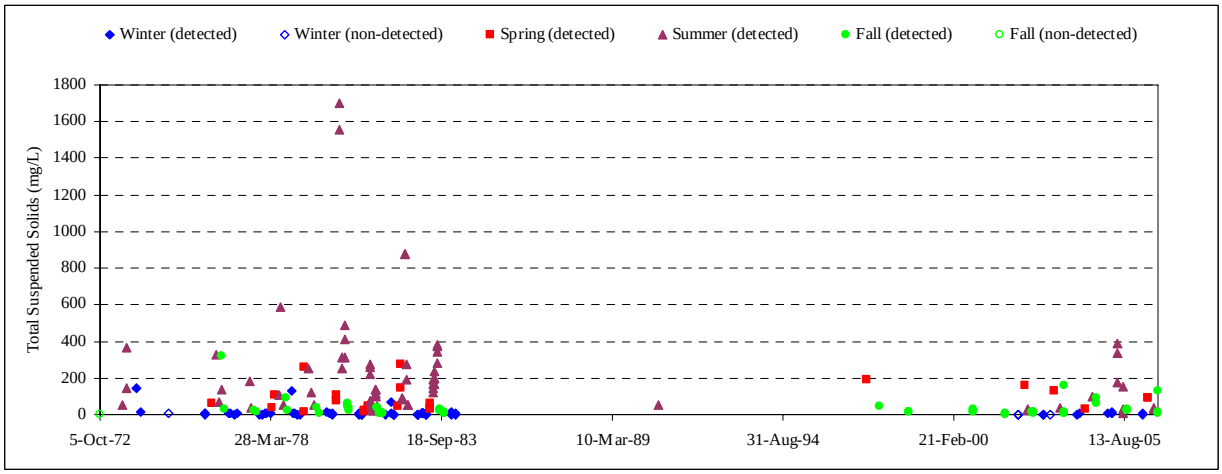
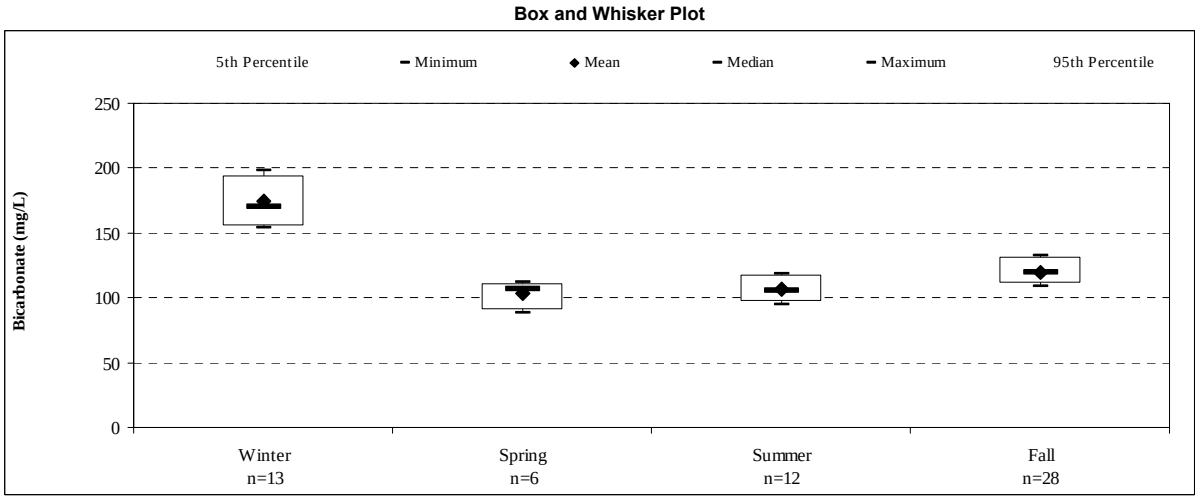


Figure G-1-2-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Middle Reach of Lower Athabasca River



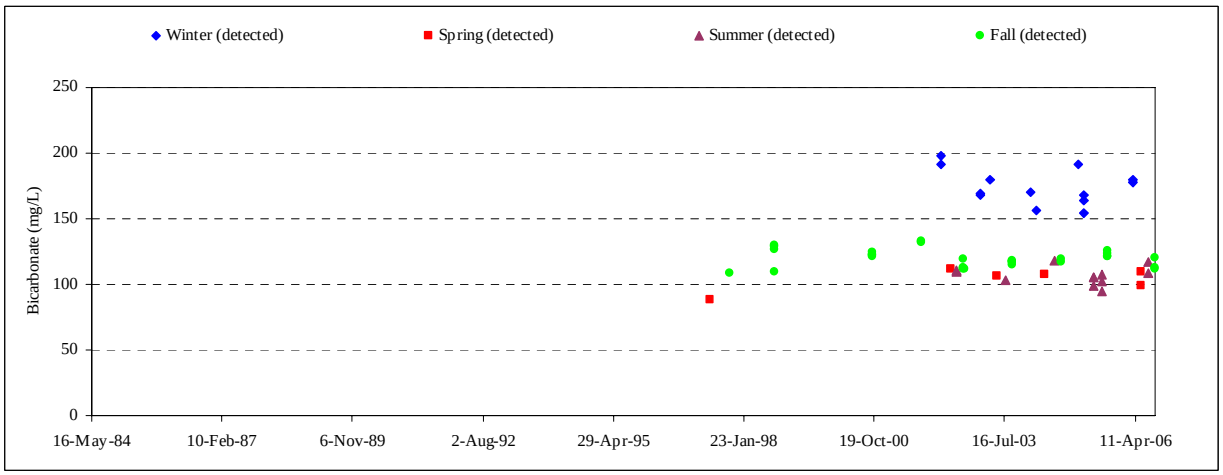
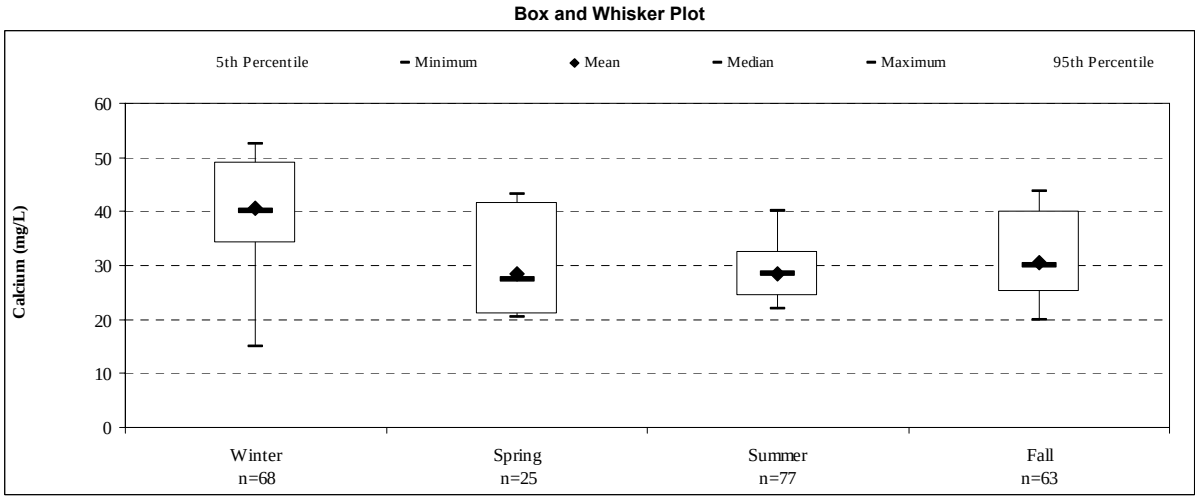


Figure G-1-2-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Middle Reach of Lower Athabasca River



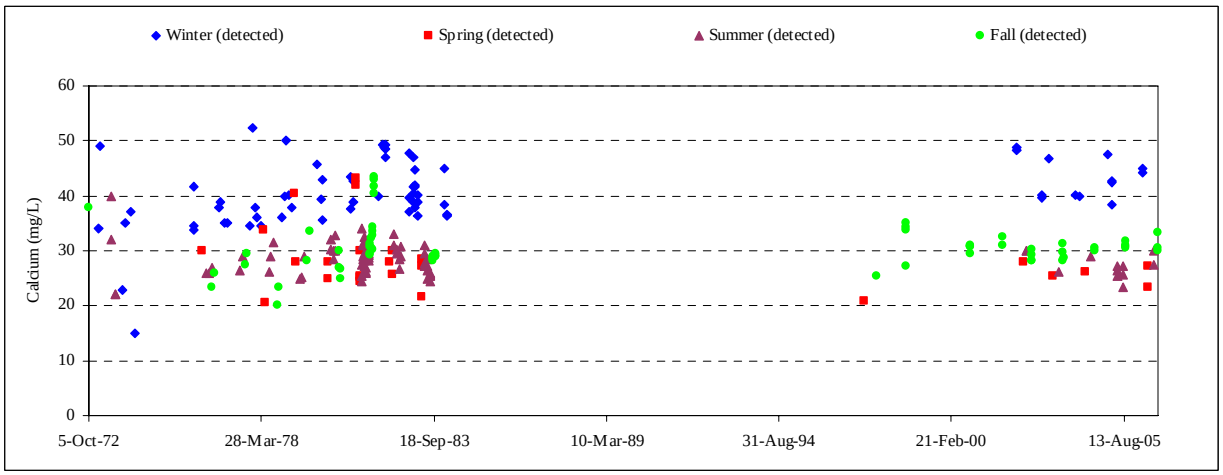
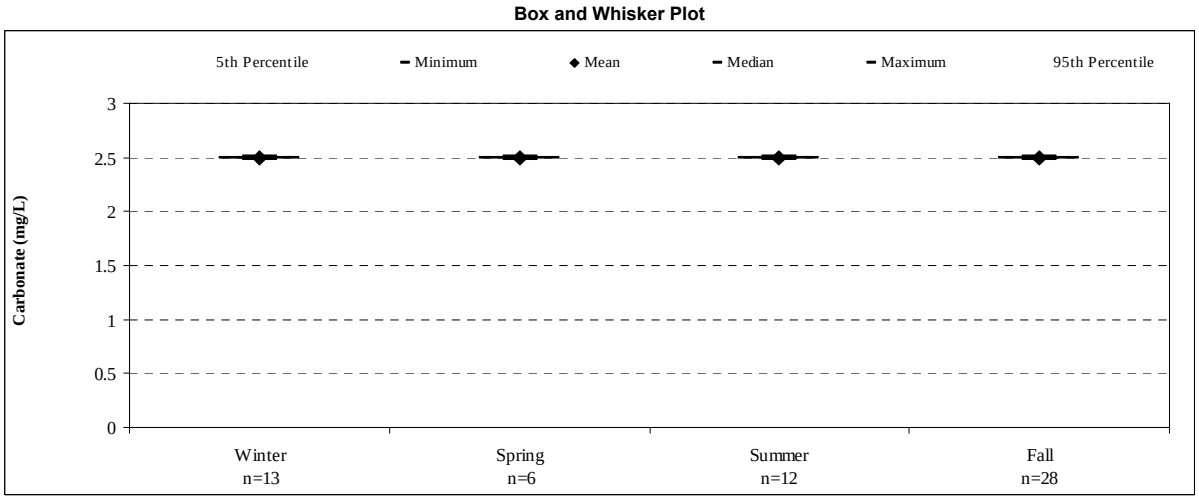


Figure G-1-2-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Middle Reach of Lower Athabasca River



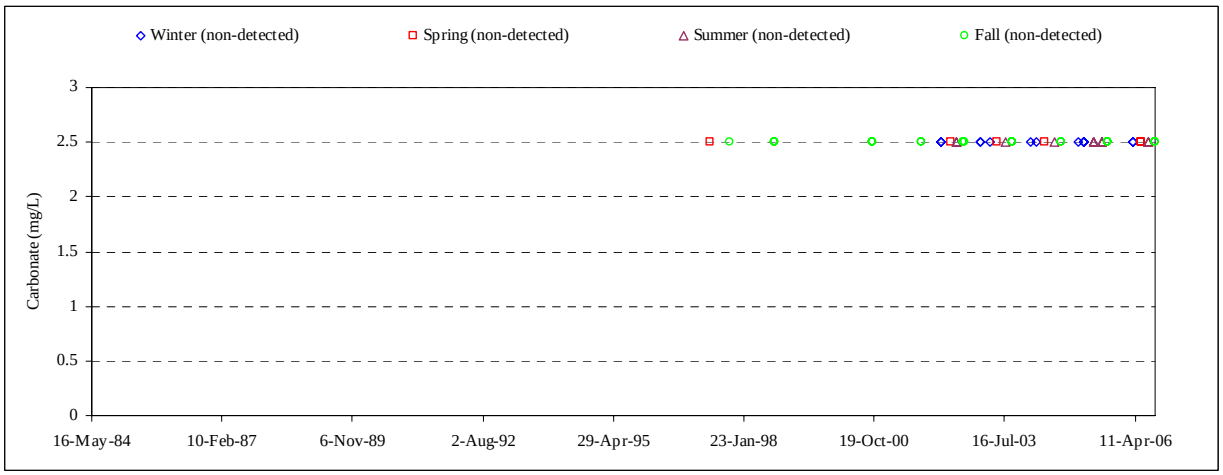
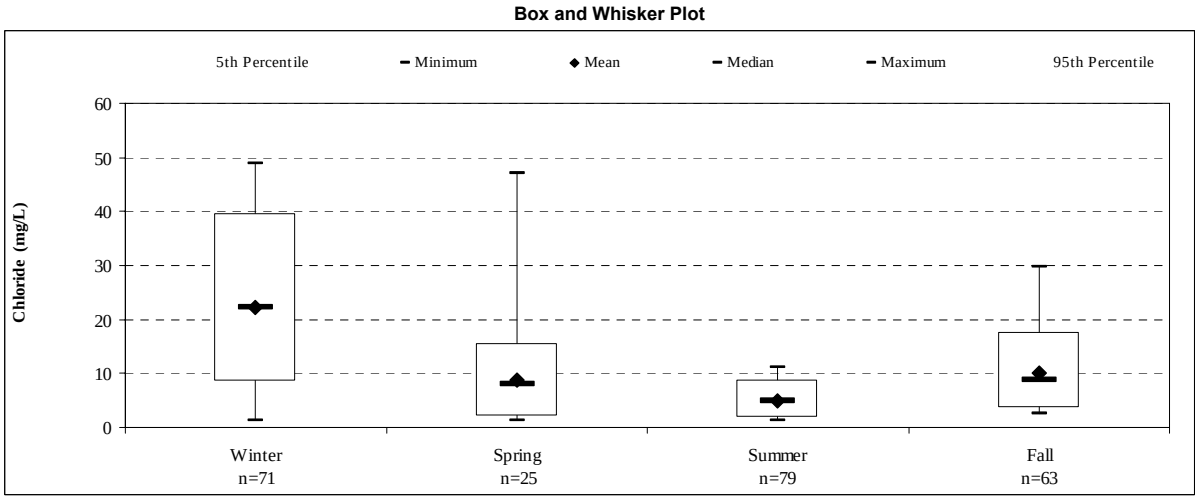


Figure G-1-2-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Middle Reach of Lower Athabasca River



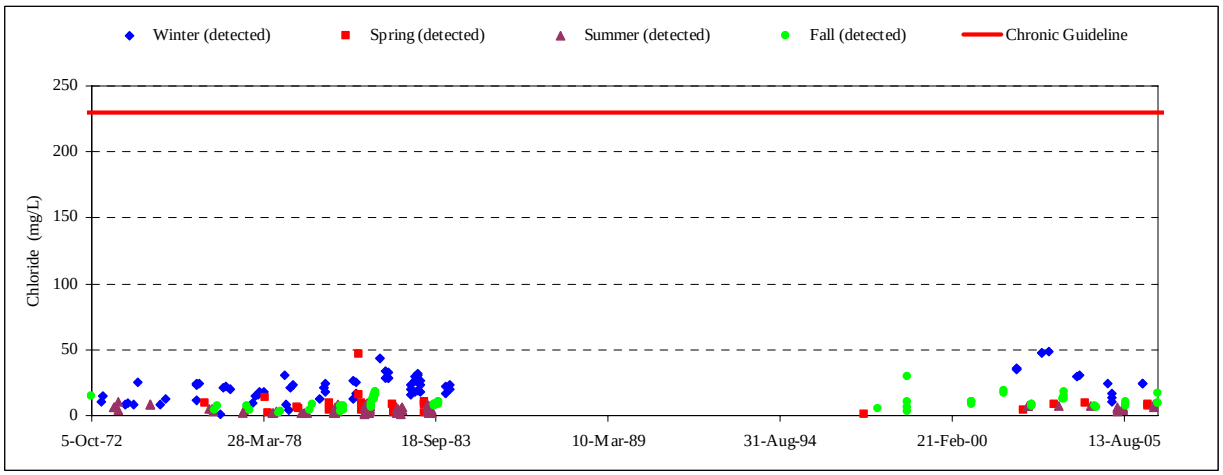
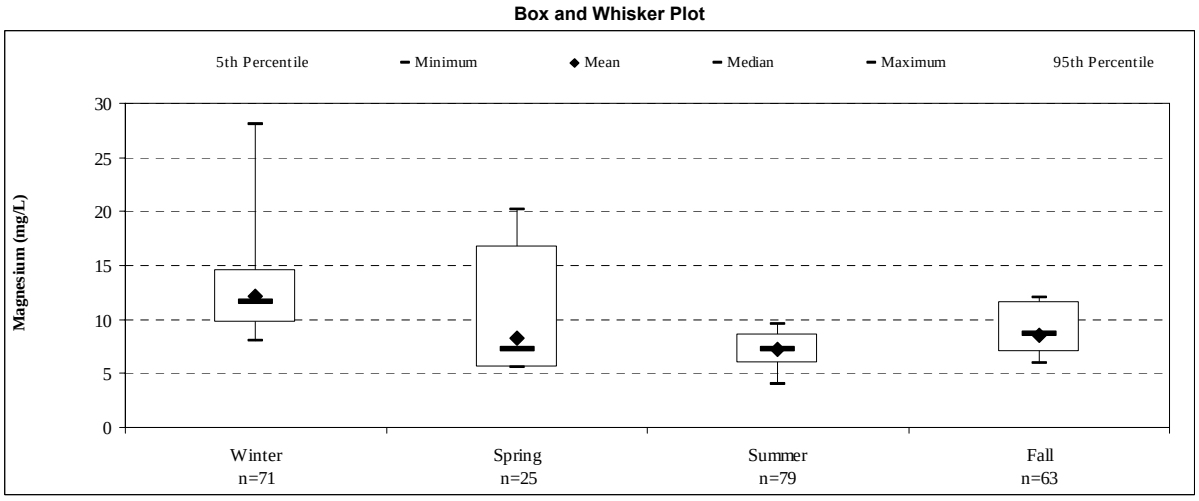


Figure G-1-2-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Middle Reach of Lower Athabasca River



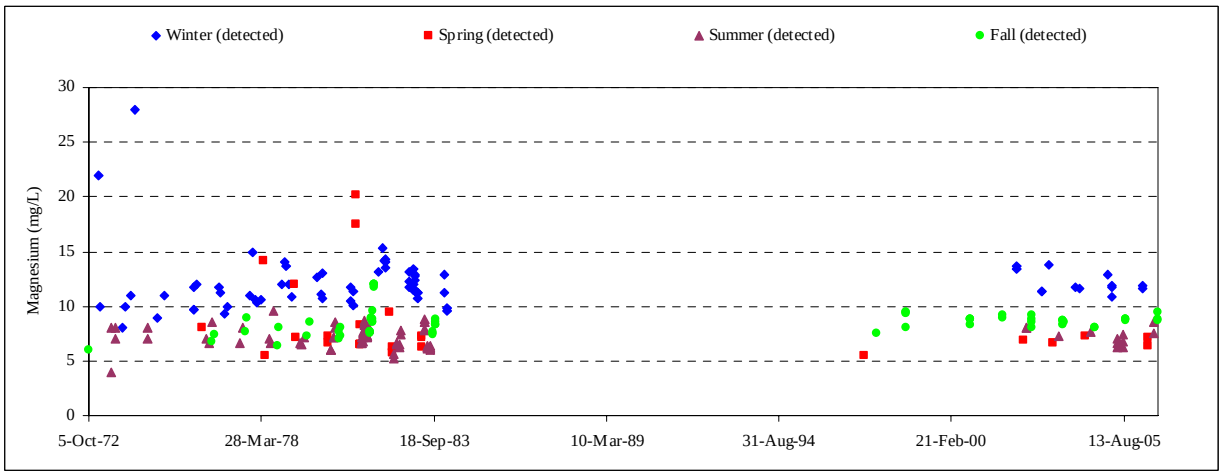
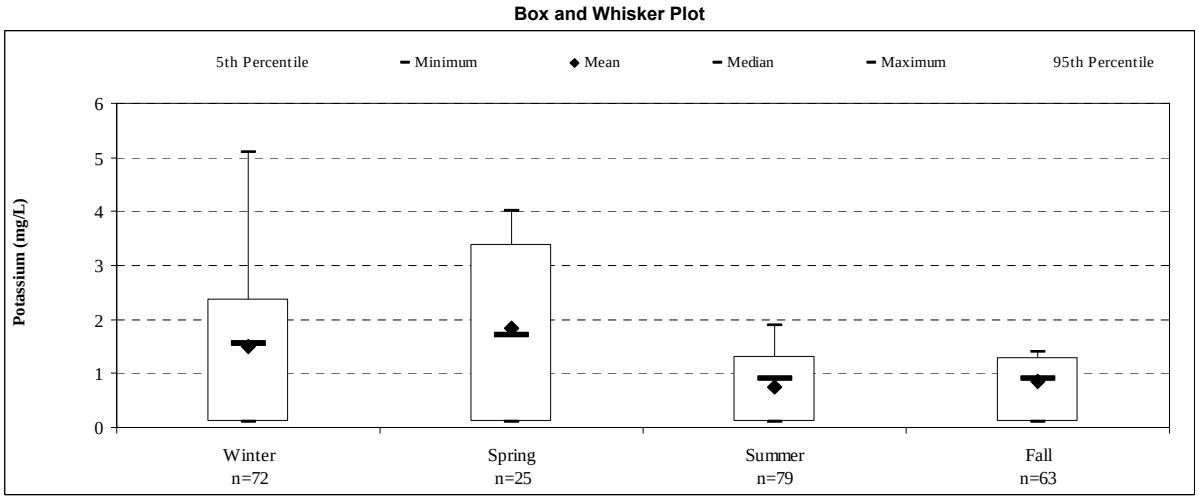


Figure G-1-2-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Middle Reach of Lower Athabasca River



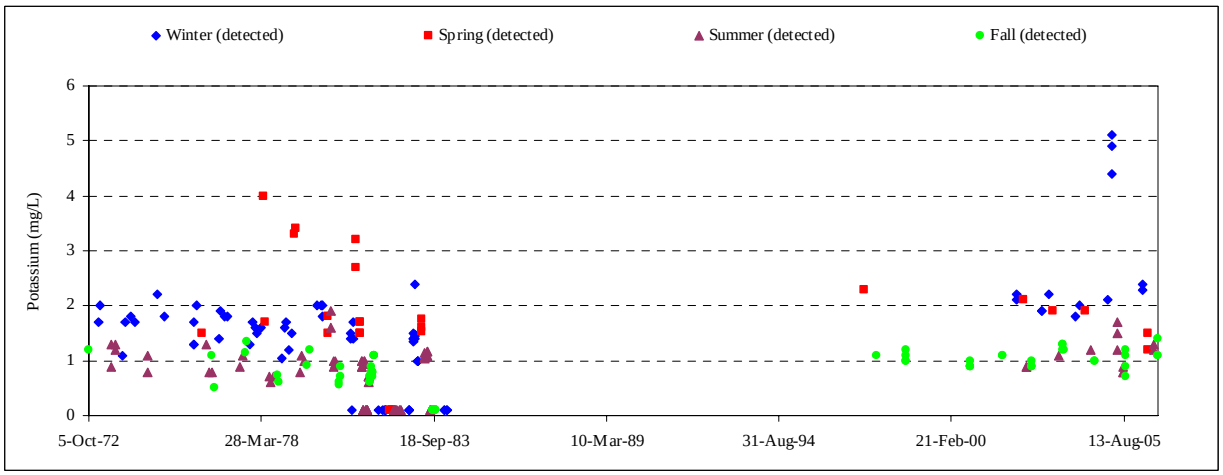
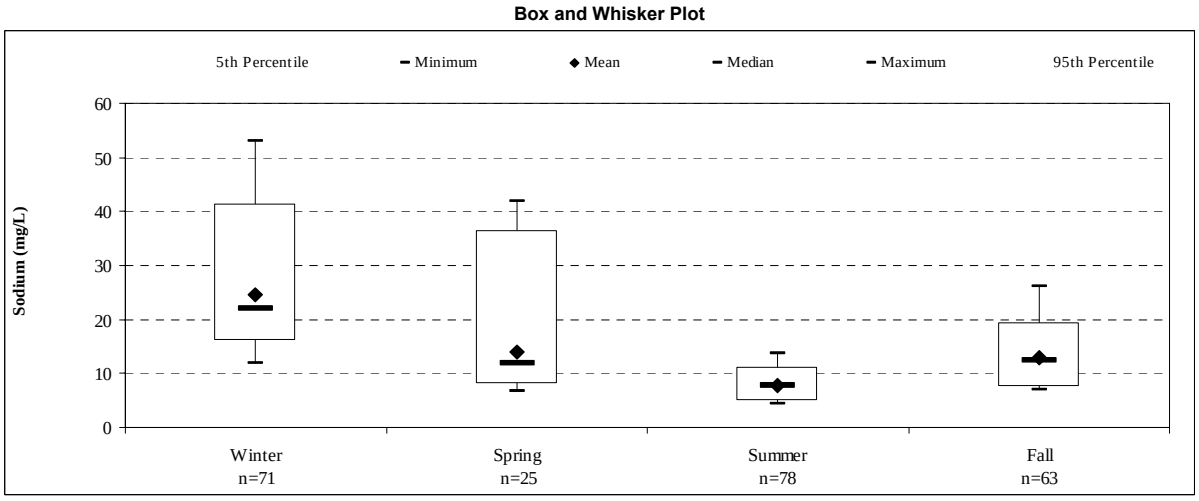


Figure G-1-2-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Middle Reach of Lower Athabasca River



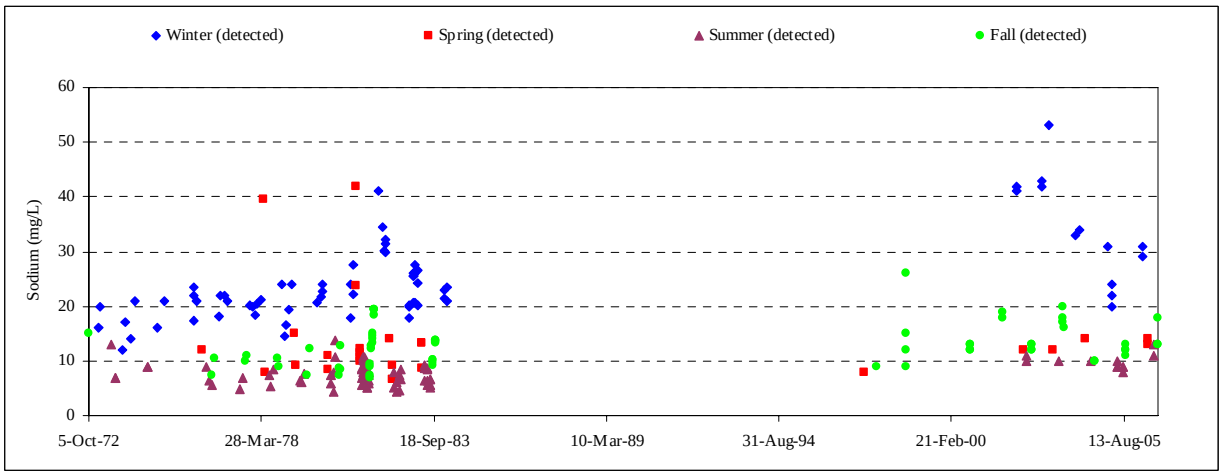
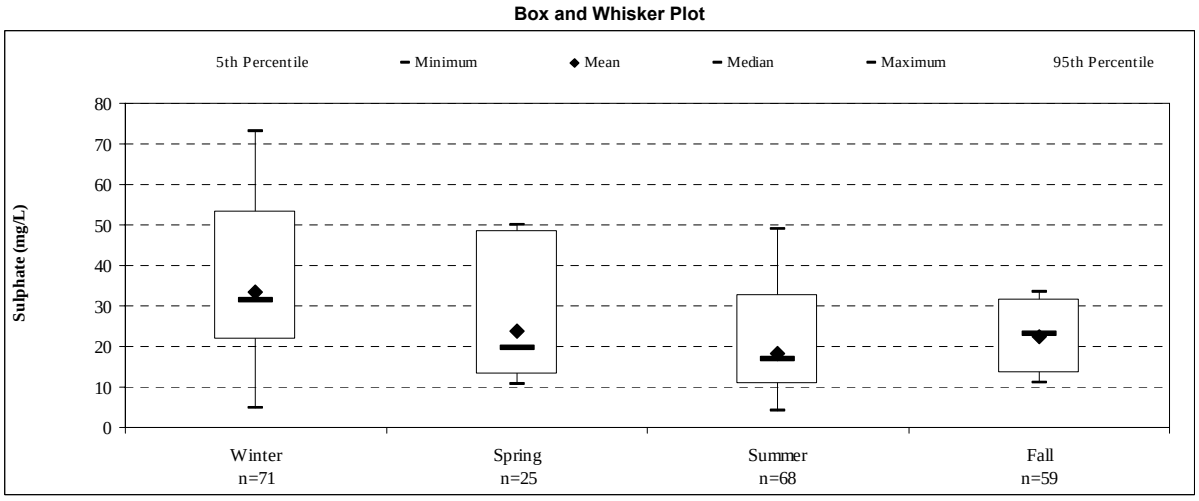


Figure G-1-2-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Middle Reach of Lower Athabasca River



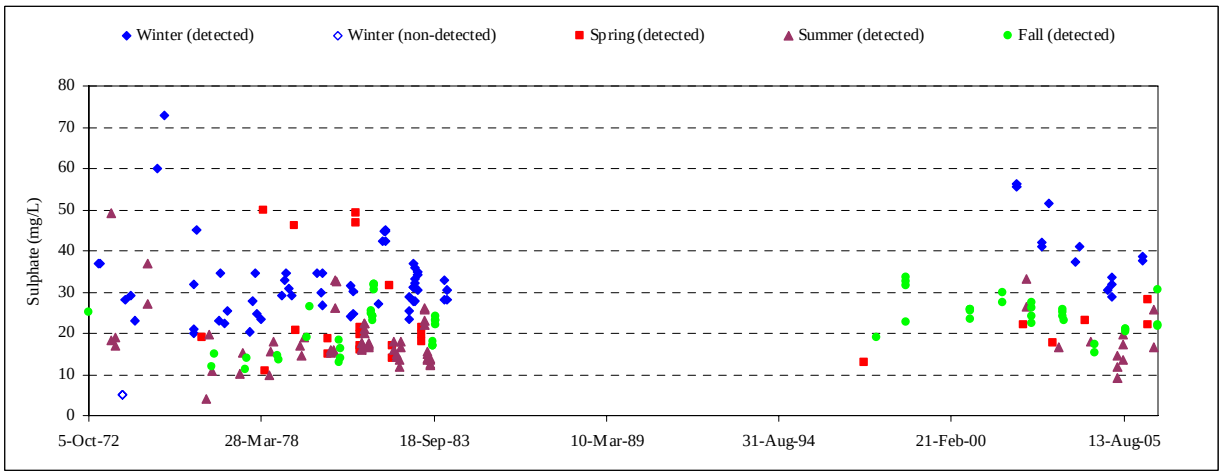
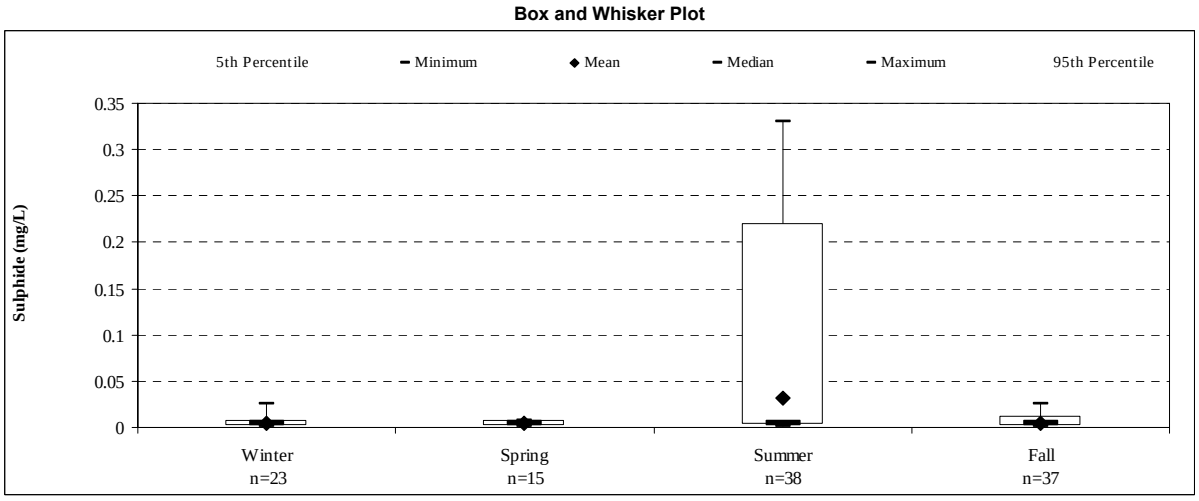


Figure G-1-2-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Middle Reach of Lower Athabasca River



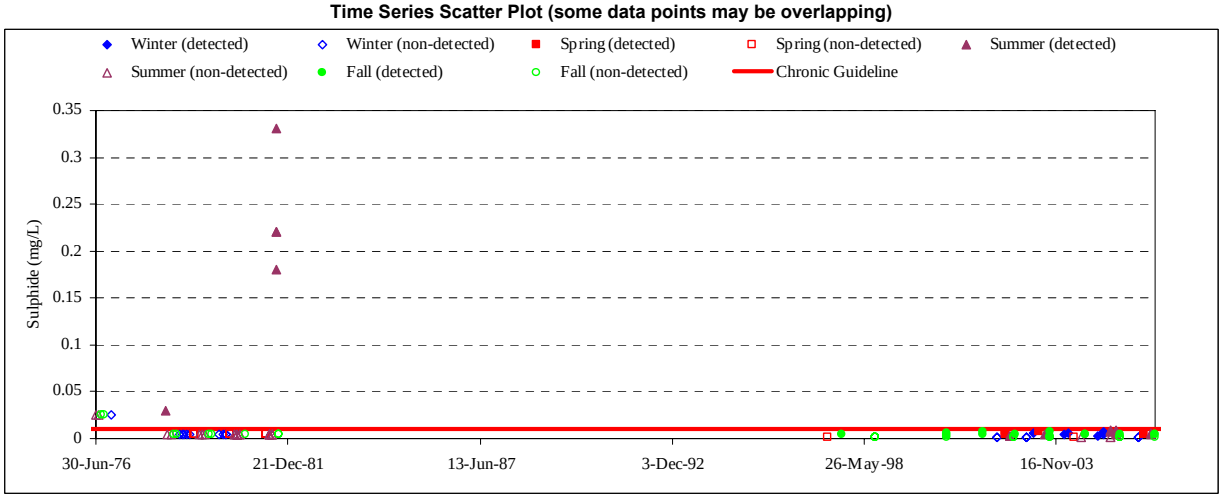
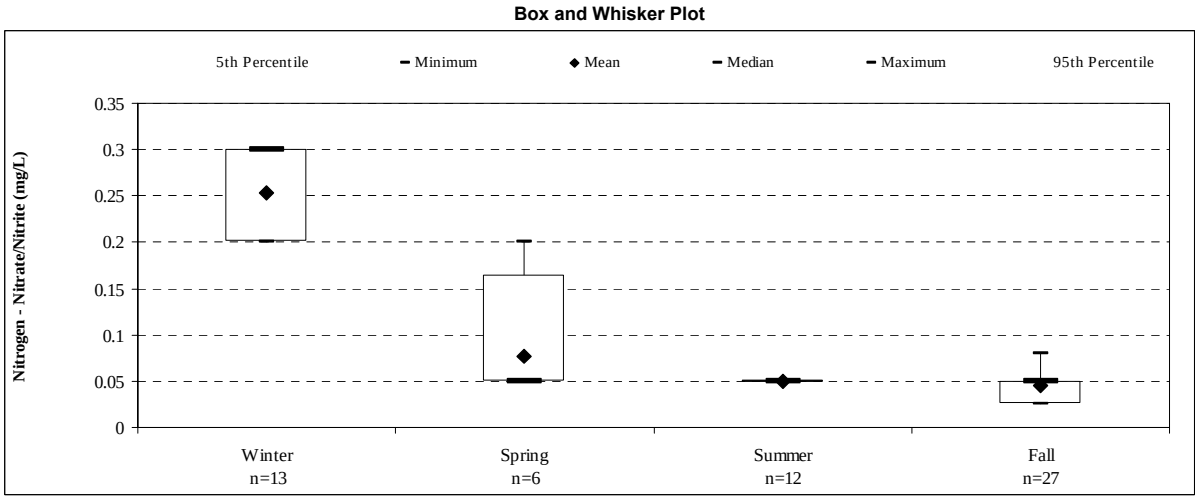


Figure G-1-2-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Middle Reach of Lower Athabasca River



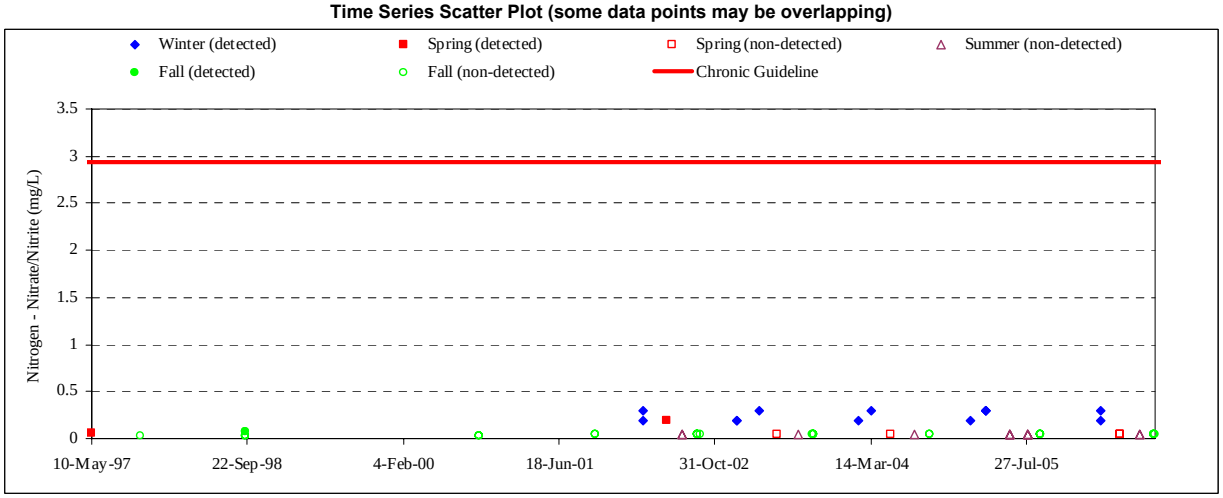
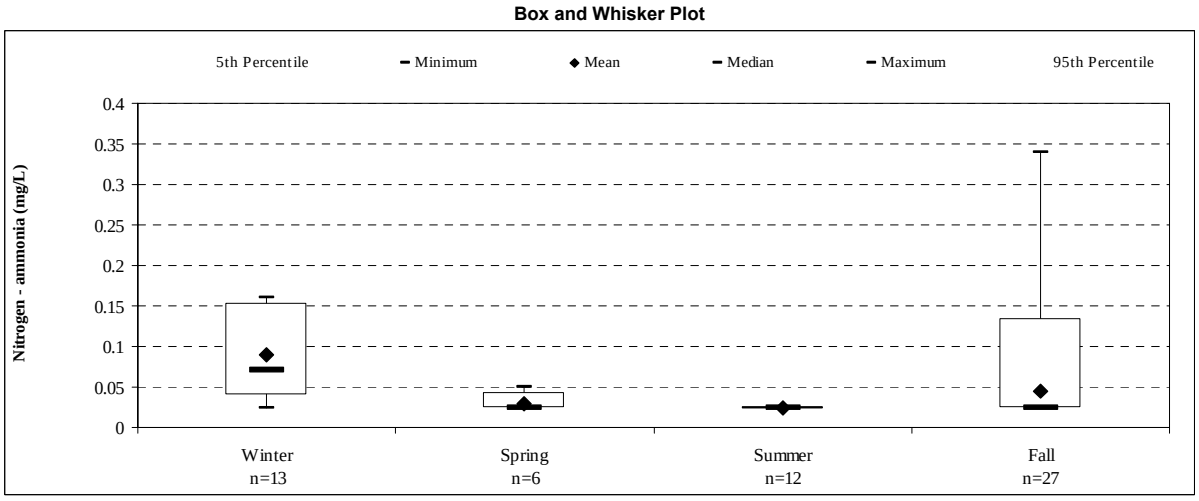


Figure G-1-2-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Middle Reach of Lower Athabasca River



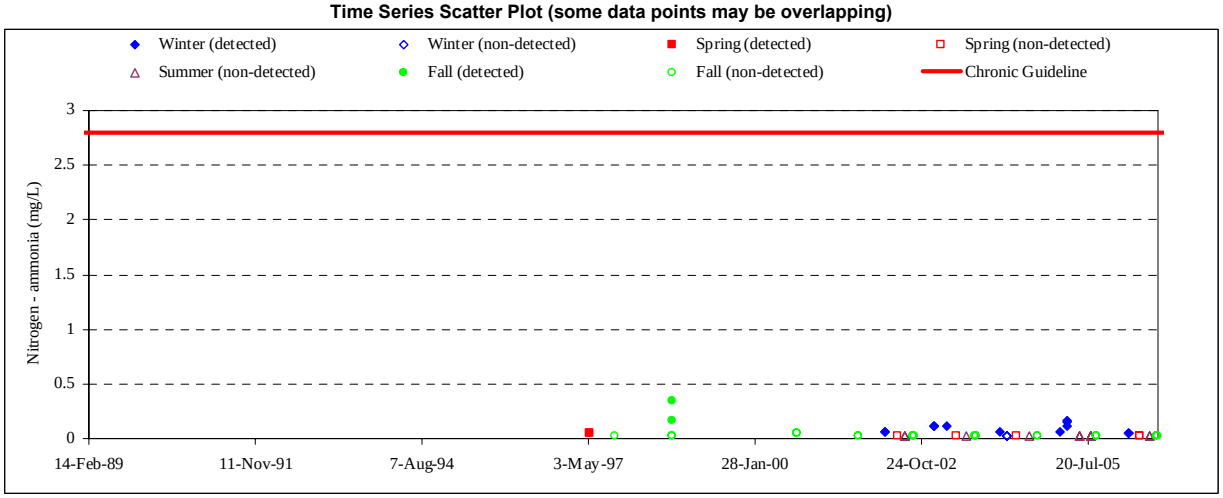
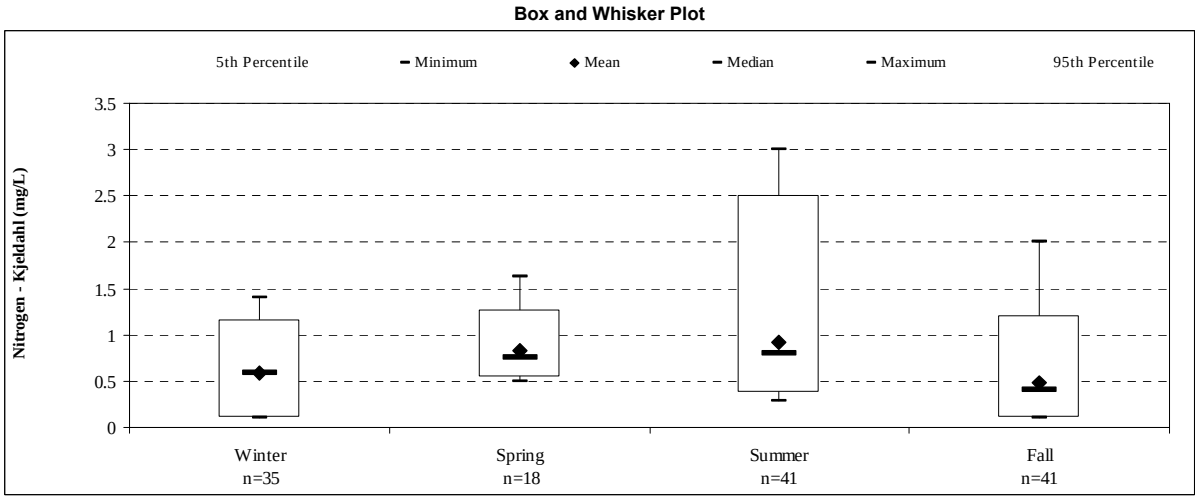


Figure G-1-2-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Middle Reach of Lower Athabasca River



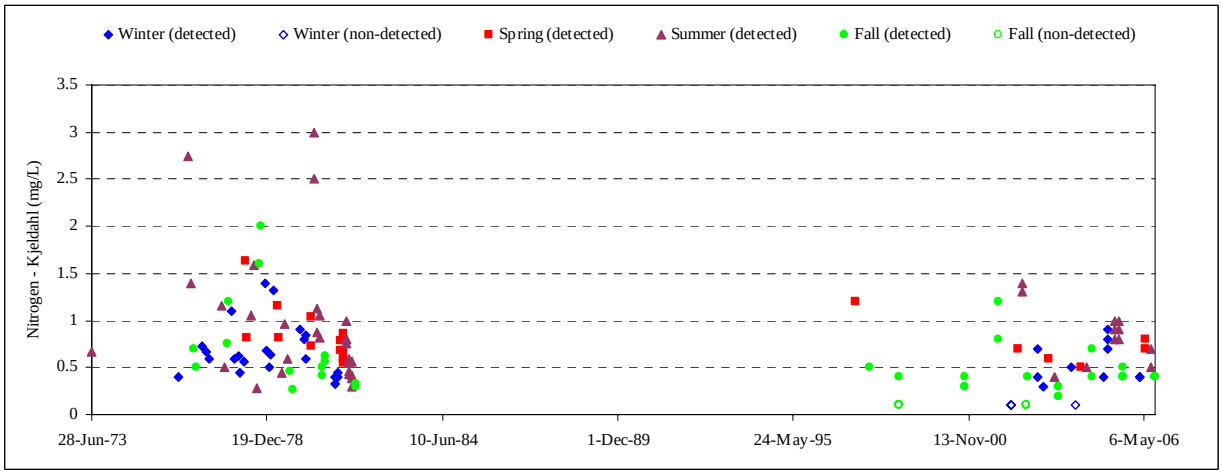
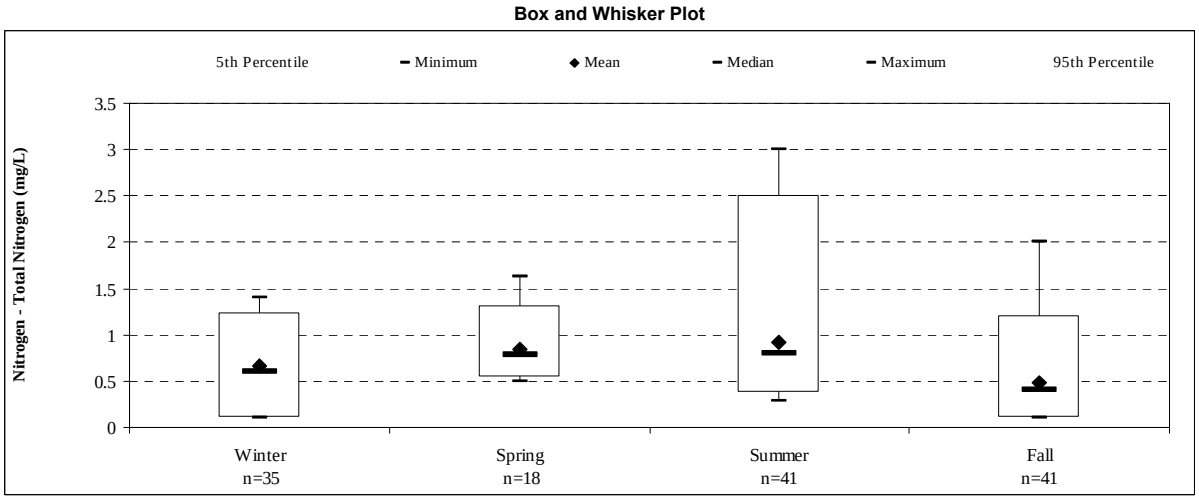


Figure G-1-2-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Middle Reach of Lower Athabasca River



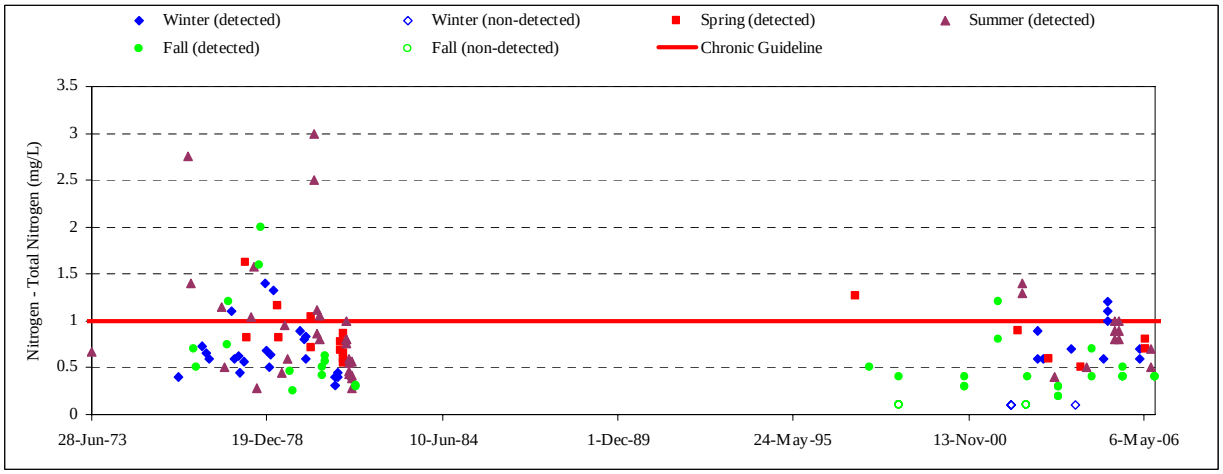
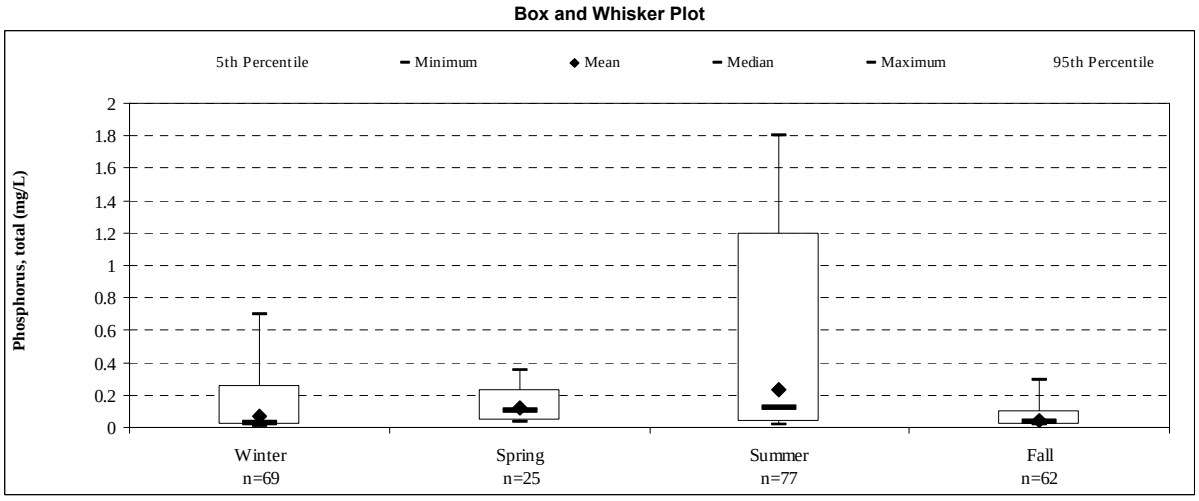


Figure G-1-2-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Middle Reach of Lower Athabasca River



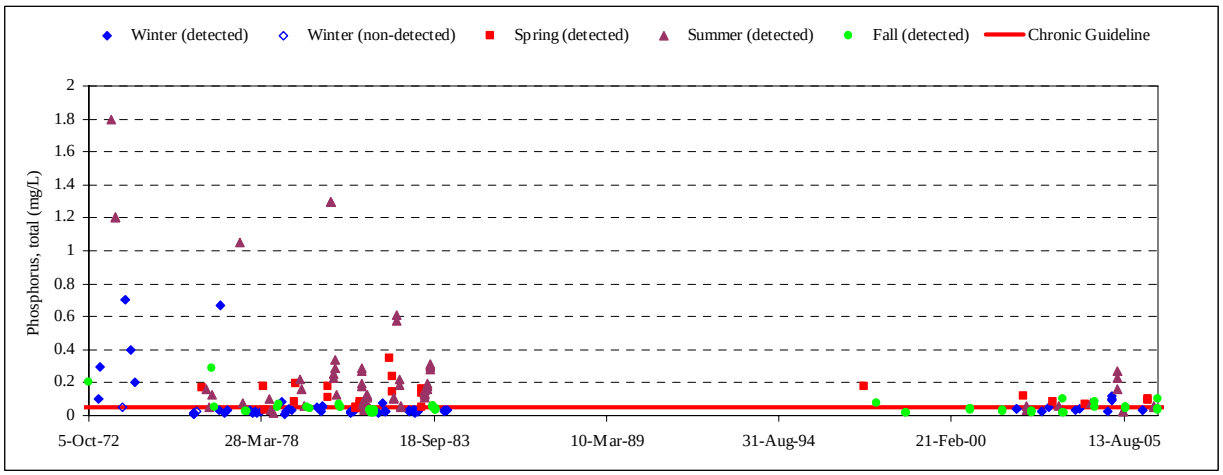
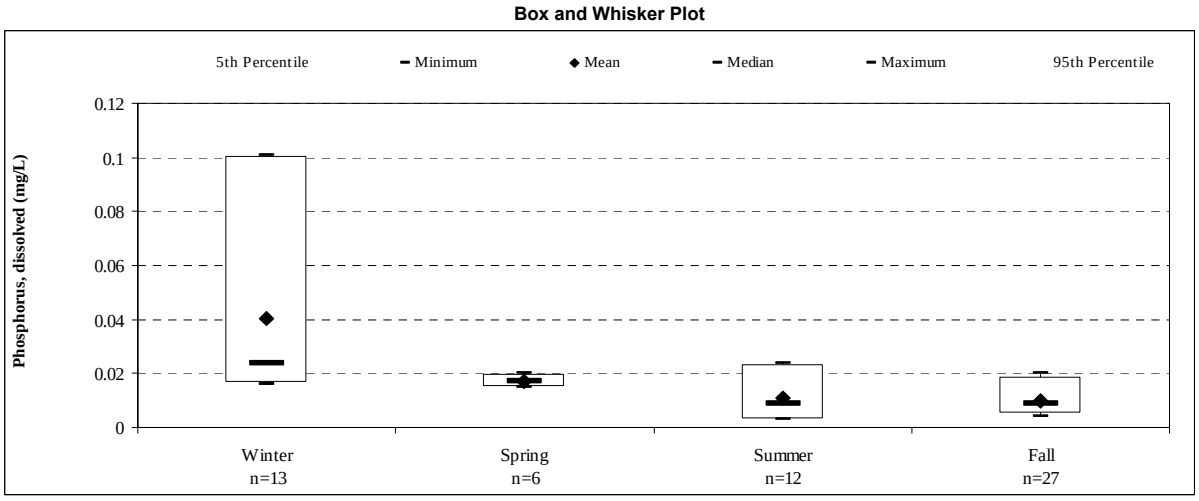


Figure G-1-2-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Middle Reach of Lower Athabasca River



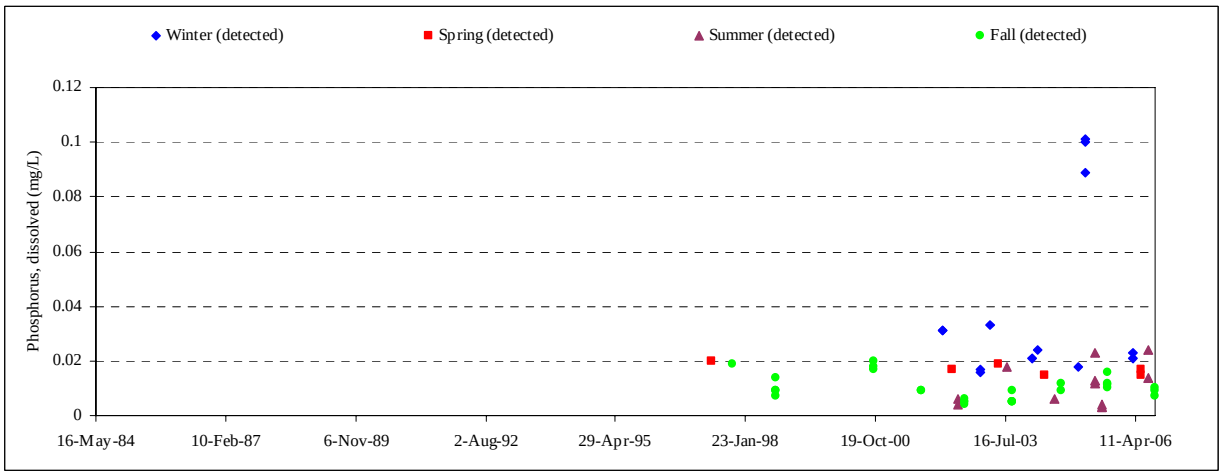
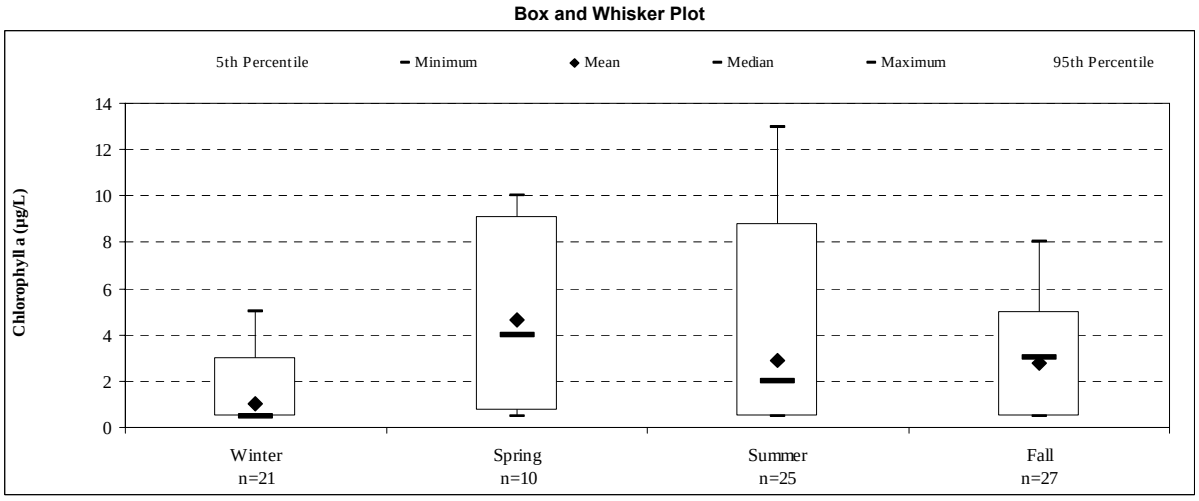


Figure G-1-2-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Middle Reach of Lower Athabasca River



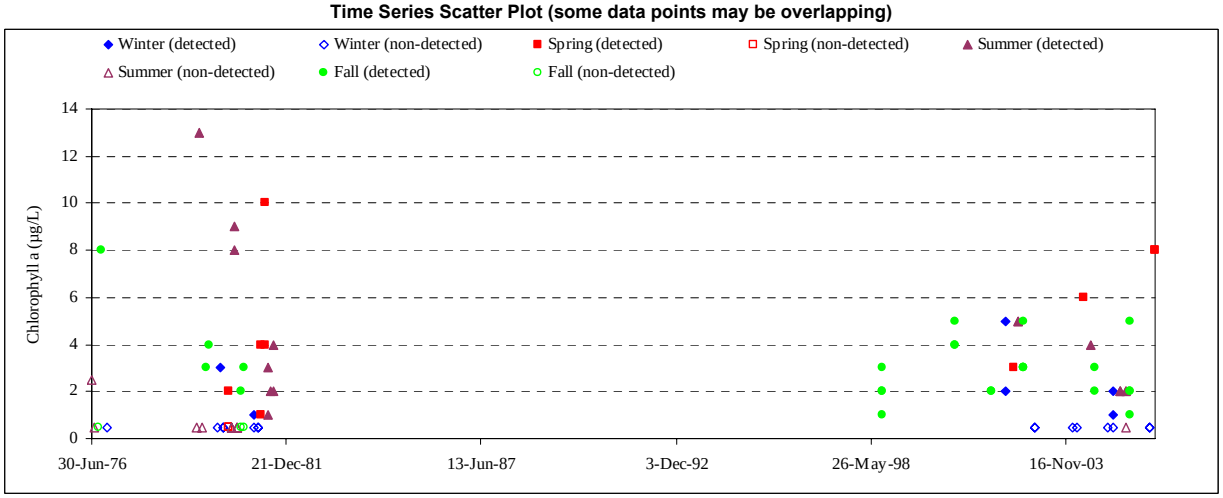
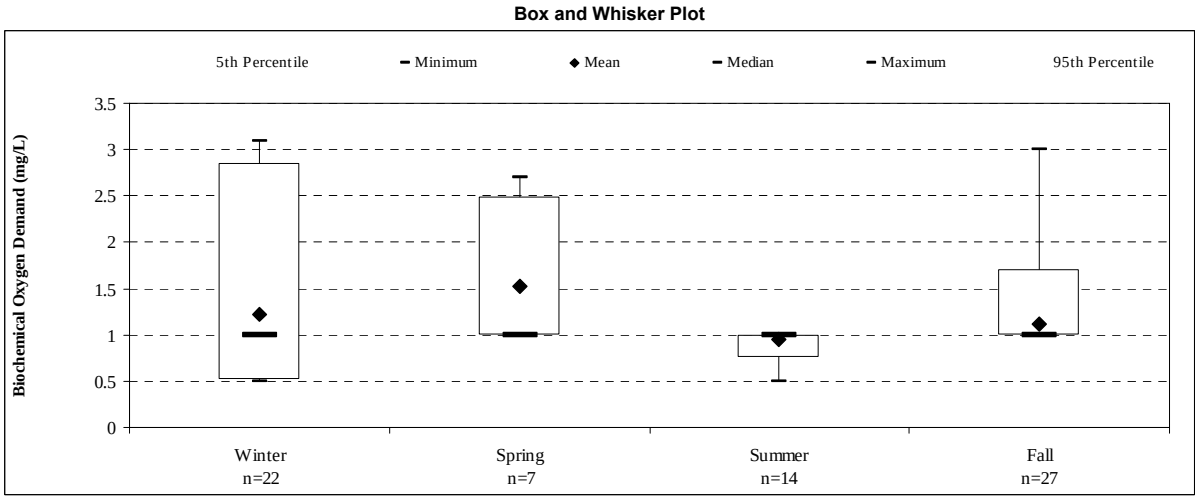


Figure G-1-2-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Middle Reach of Lower Athabasca River



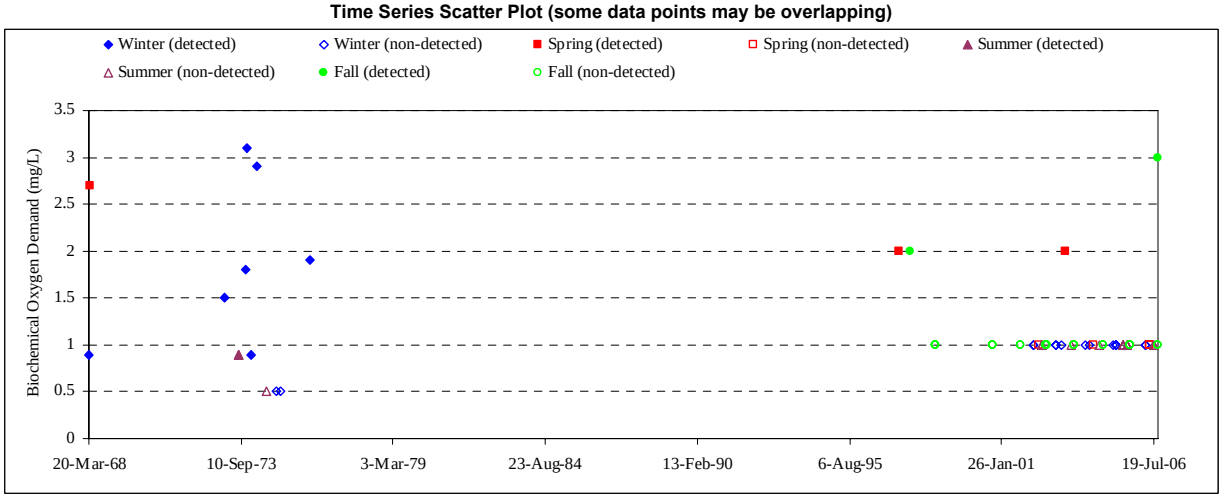
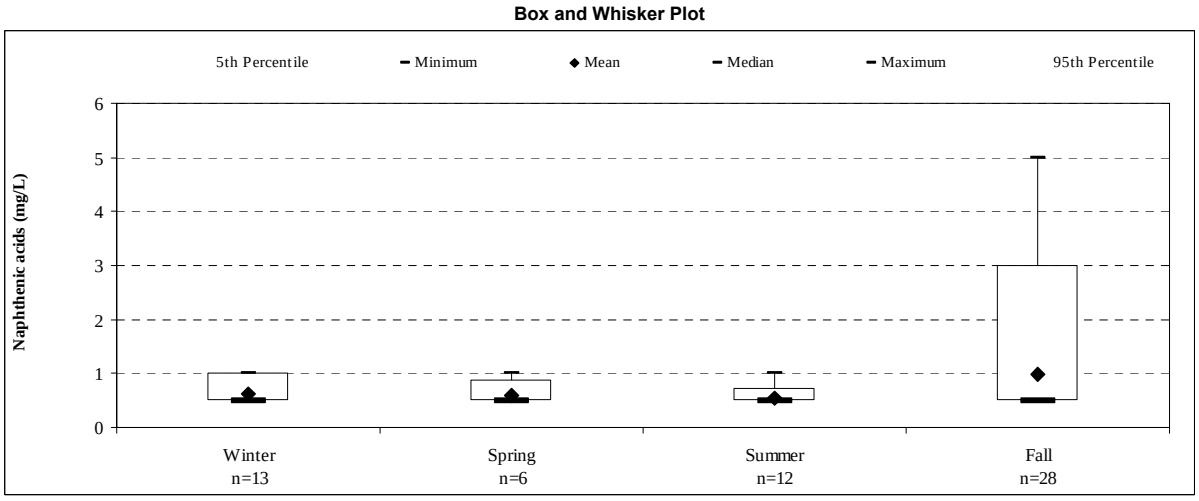


Figure G-1-2-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Middle Reach of Lower Athabasca River



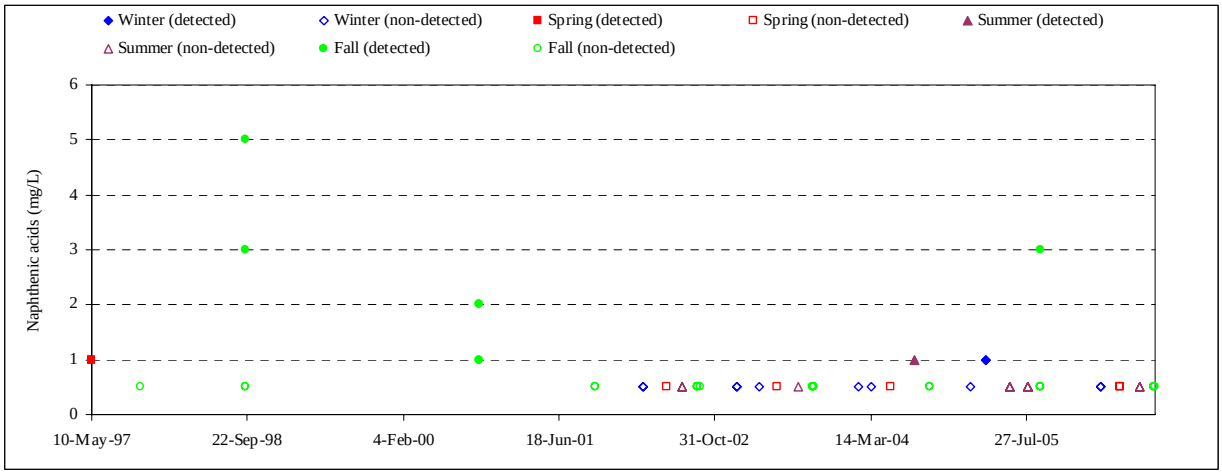
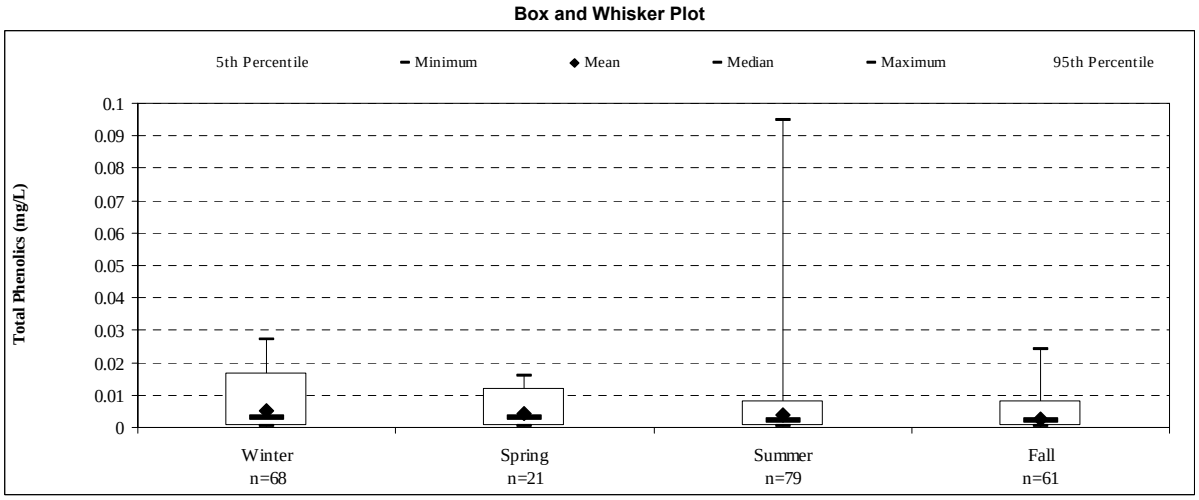


Figure G-1-2-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Middle Reach of Lower Athabasca River



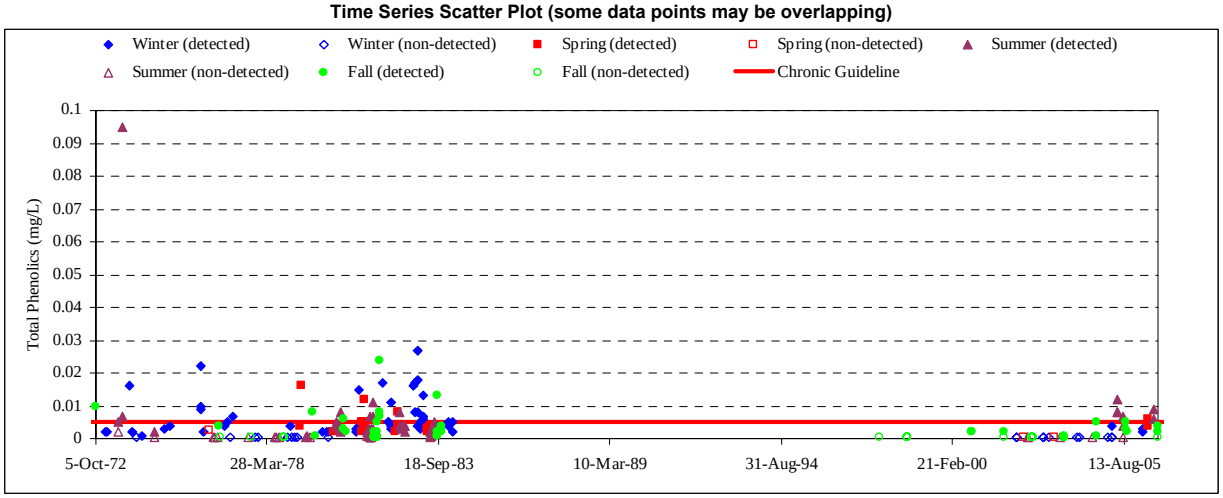


Figure G-1-2-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Middle Reacl of Lower Athabasca River

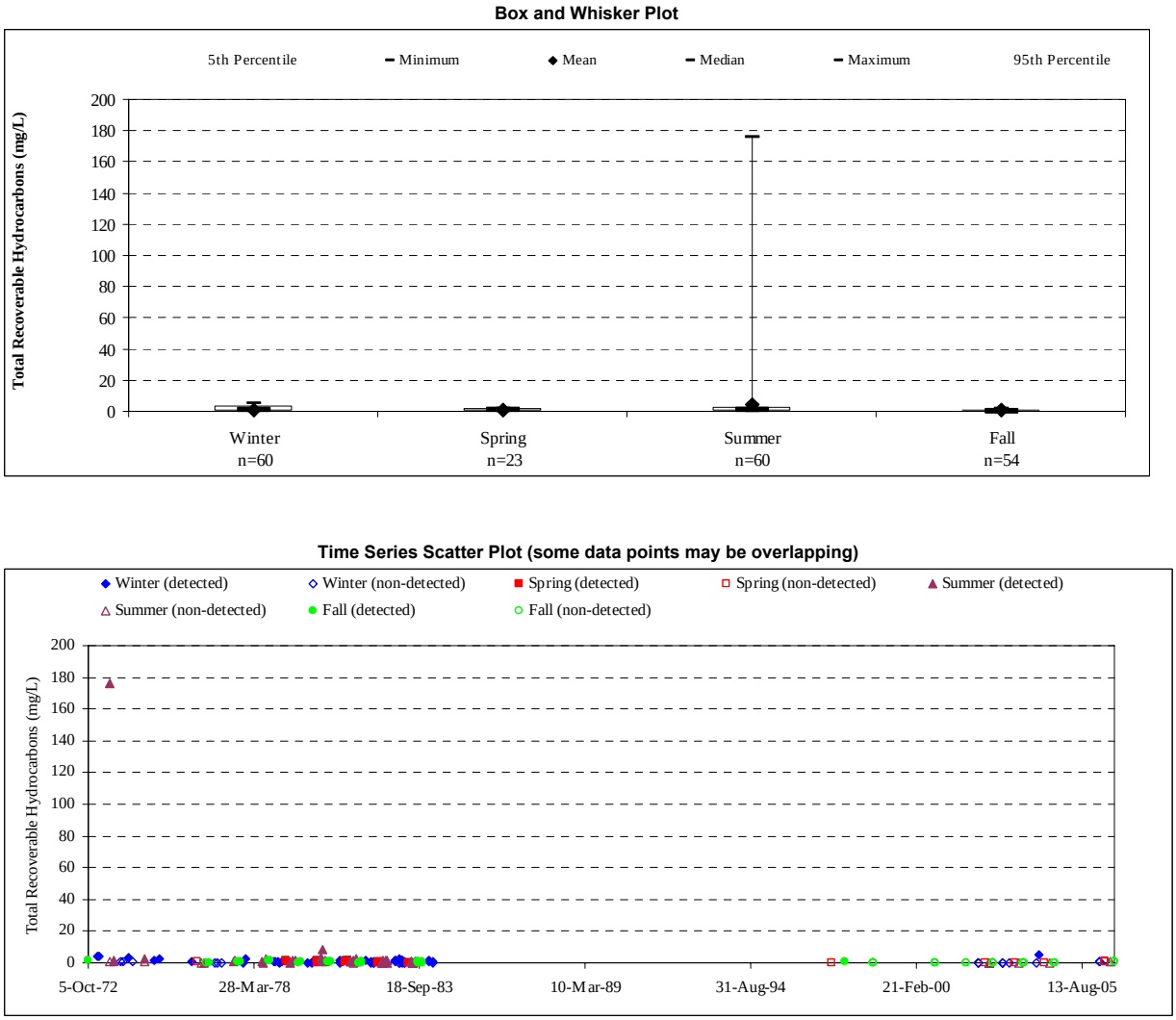


Figure G-1-2-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Middle Reach of Lower Athabasca River

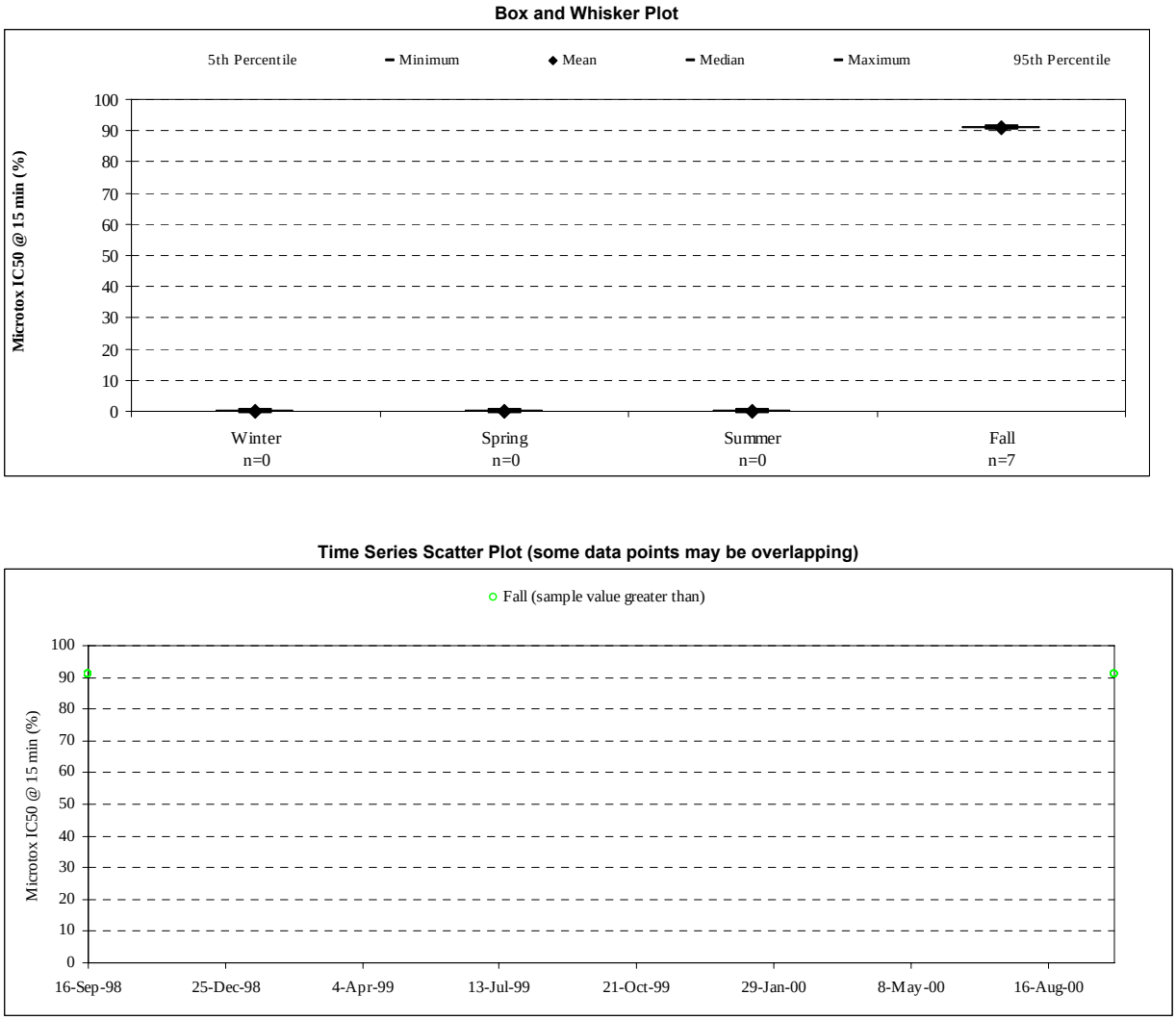
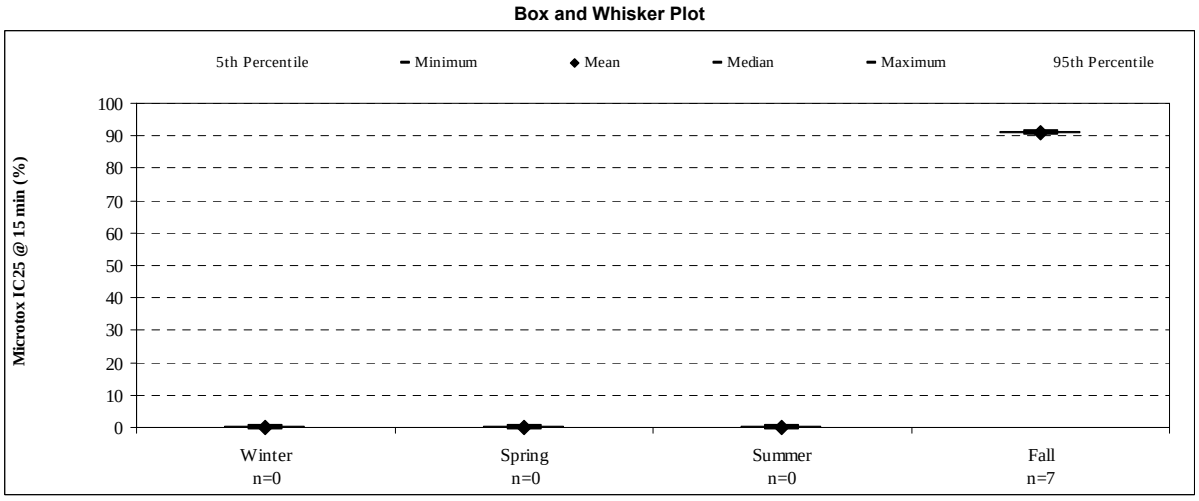


Figure G-1-2-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Middle Reach of Lower Athabasca River



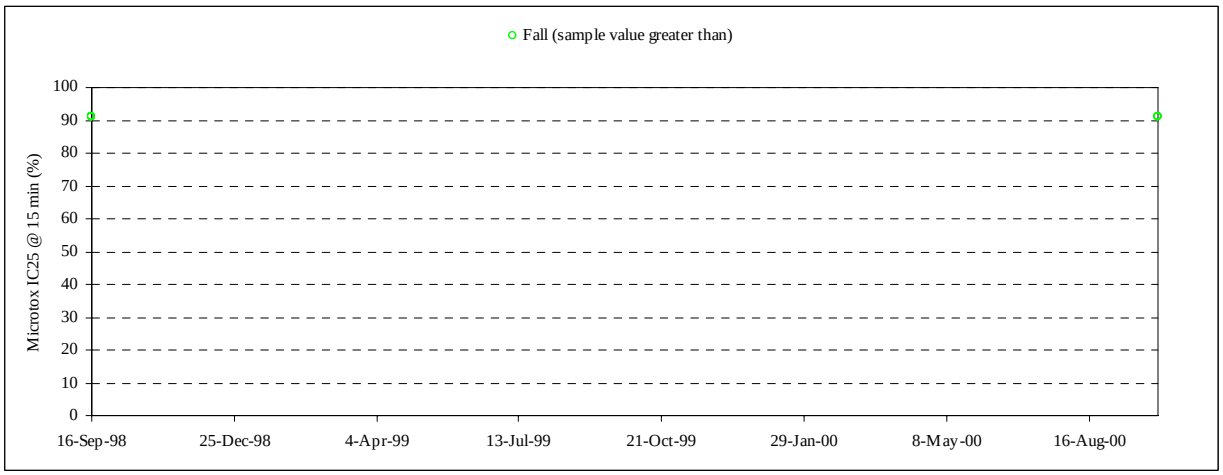


Figure G-1-2-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Middle Reach of Lower Athabasca River

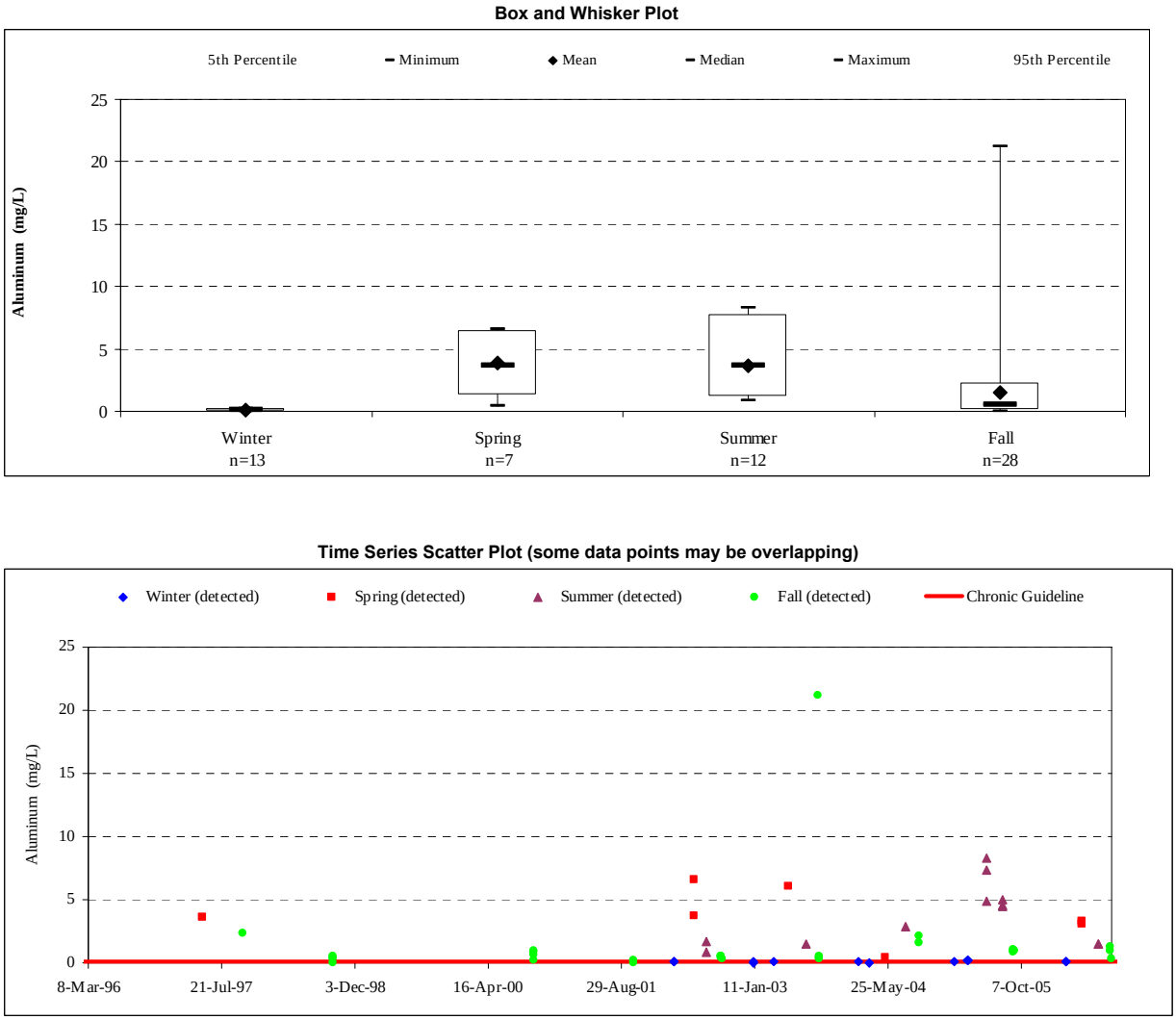


Figure G-1-2-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Middle Reach of Lower Athabasca River

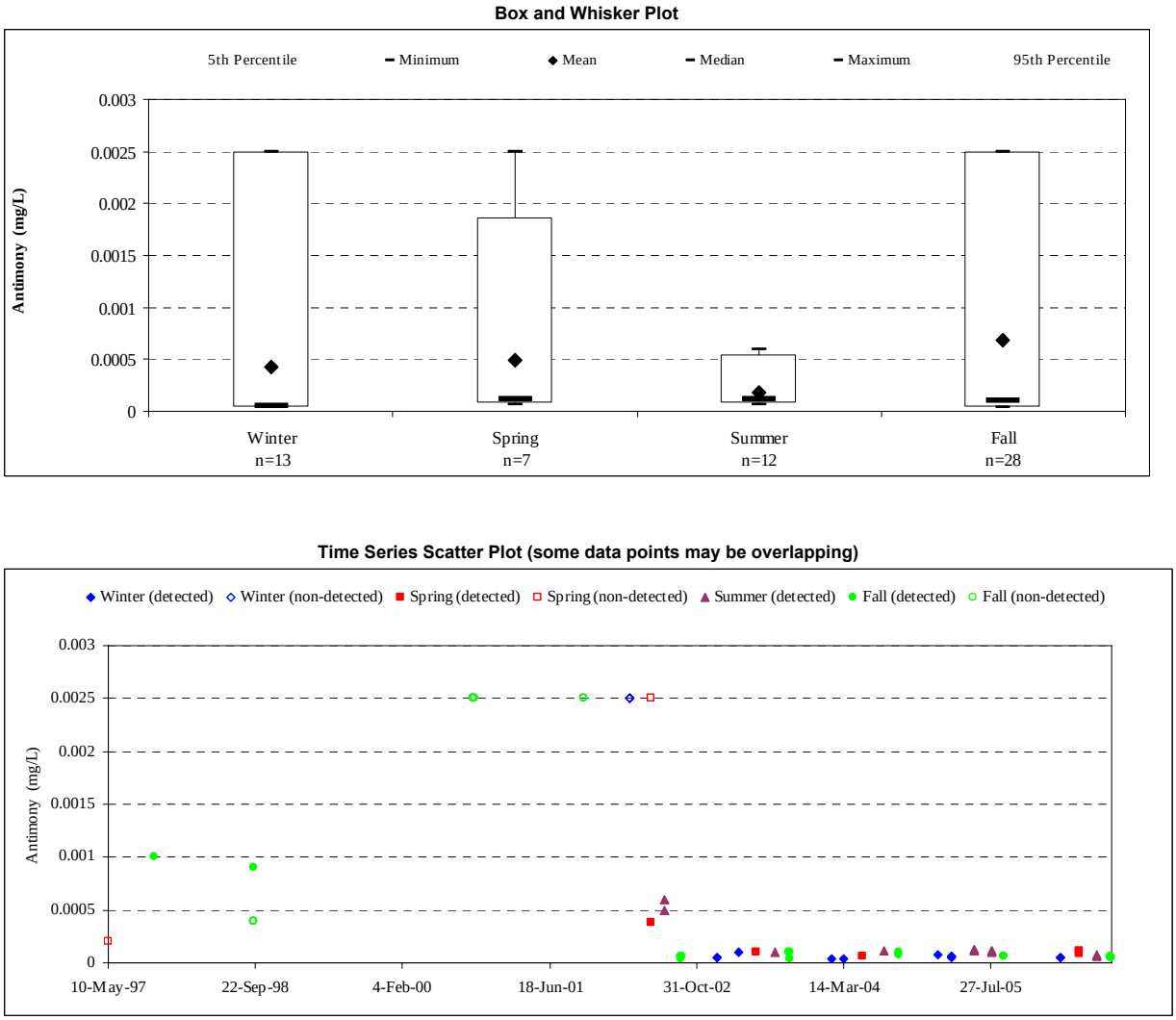
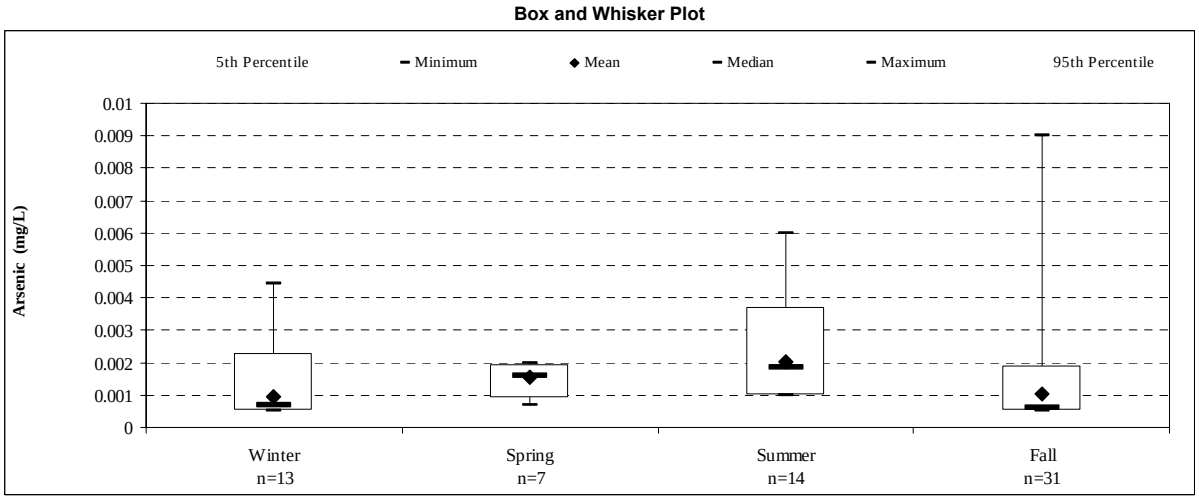


Figure G-1-2-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Middle Reach of Lower Athabasca River



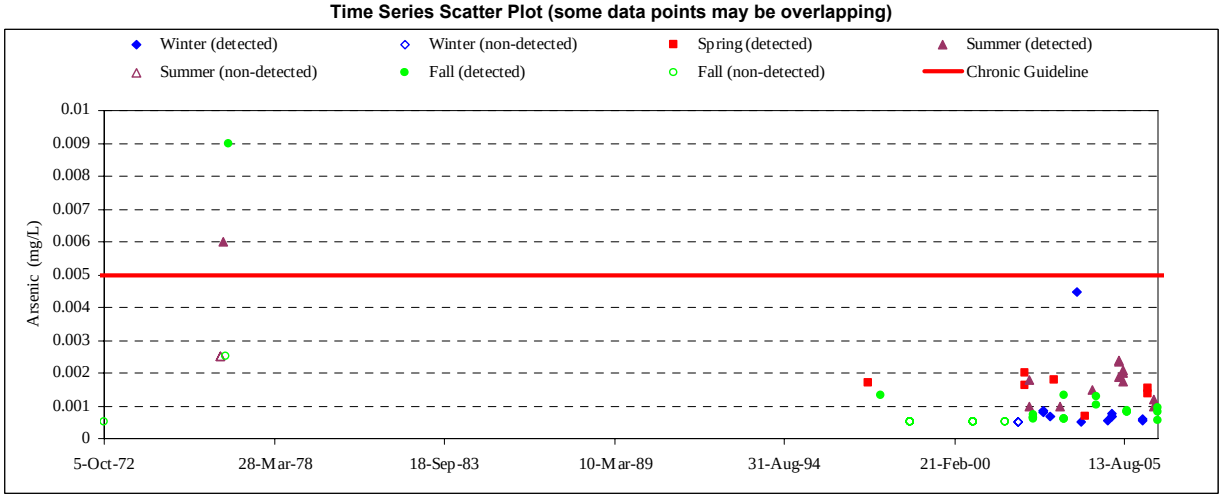
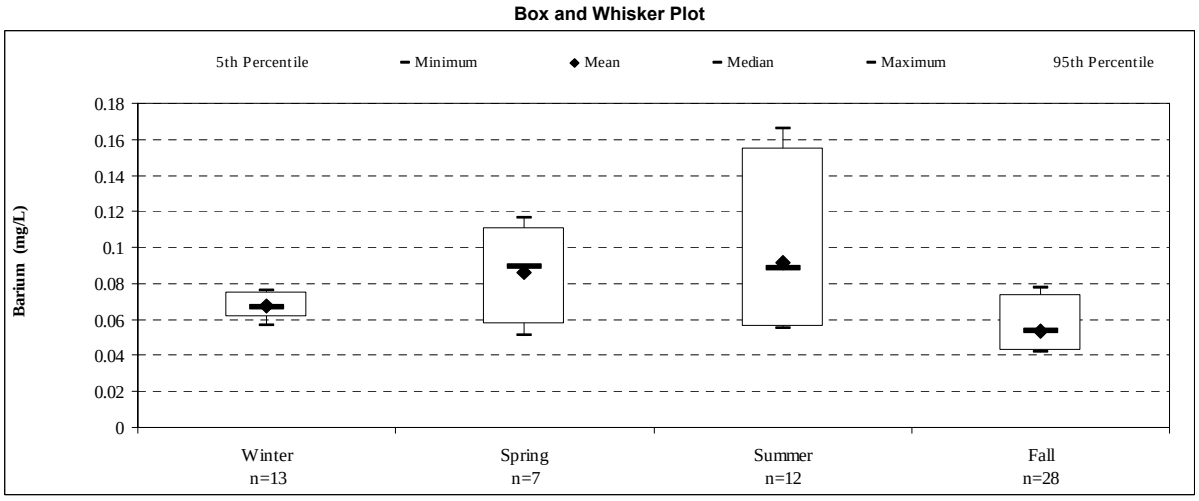


Figure G-1-2-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Middle Reach of Lower Athabasca River



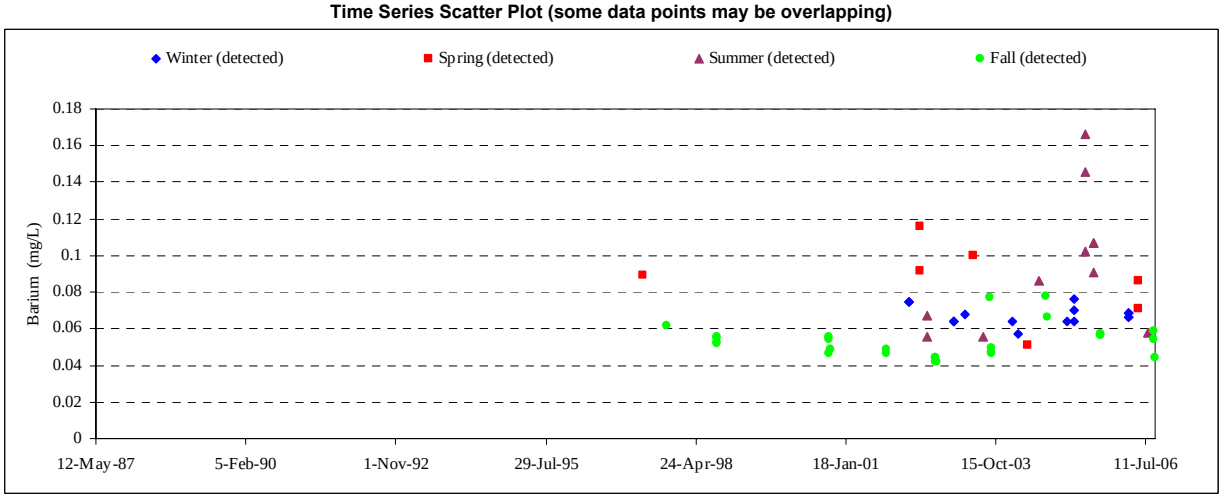


Figure G-1-2-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Middle Reach of Lower Athabasca River

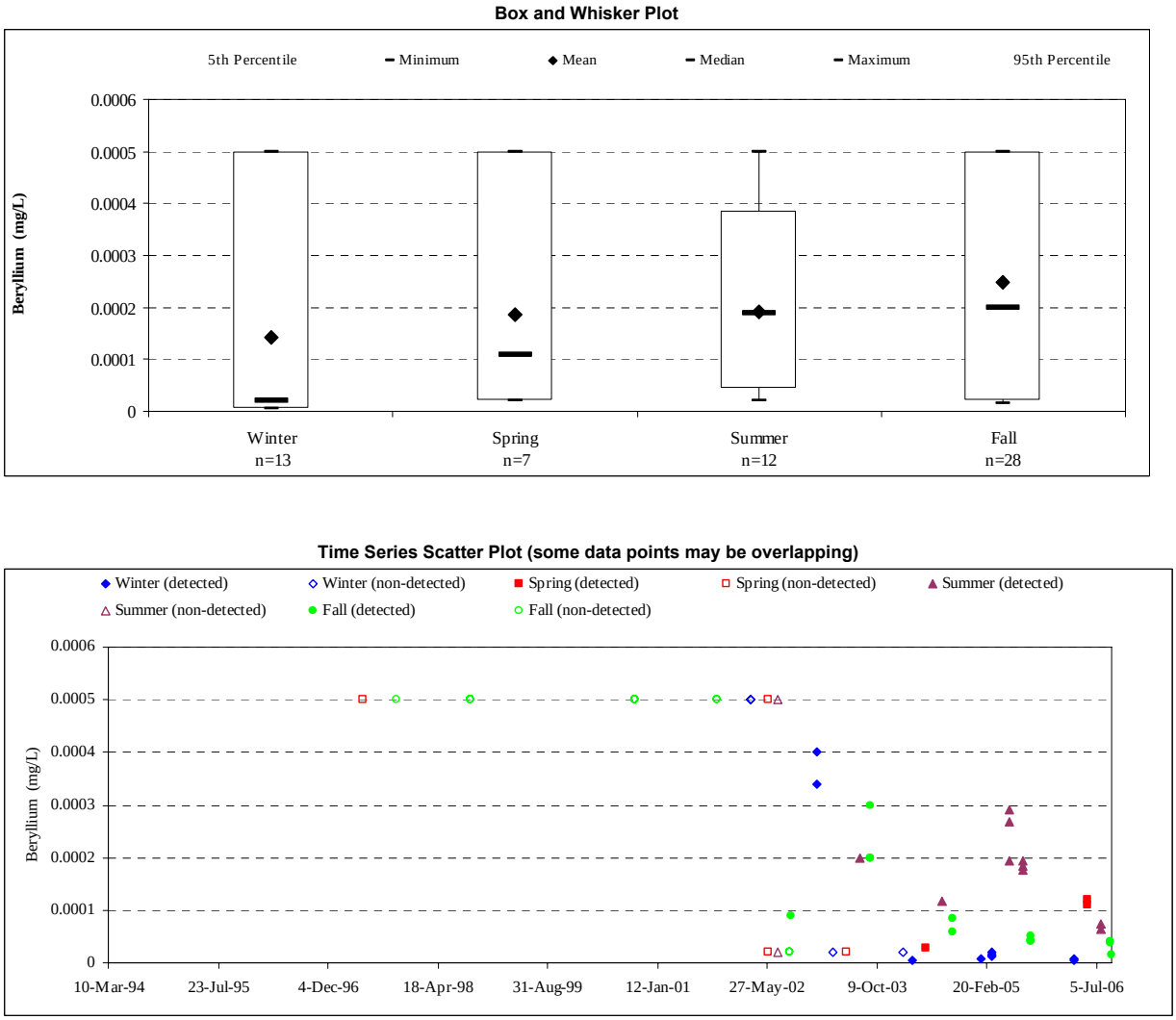
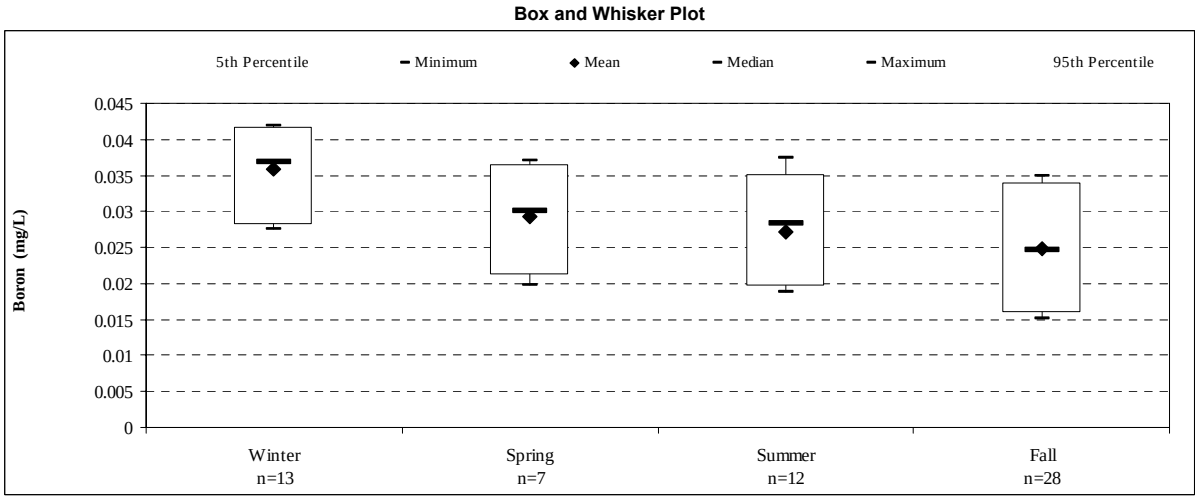


Figure G-1-2-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Middle Reach of Lower Athabasca River



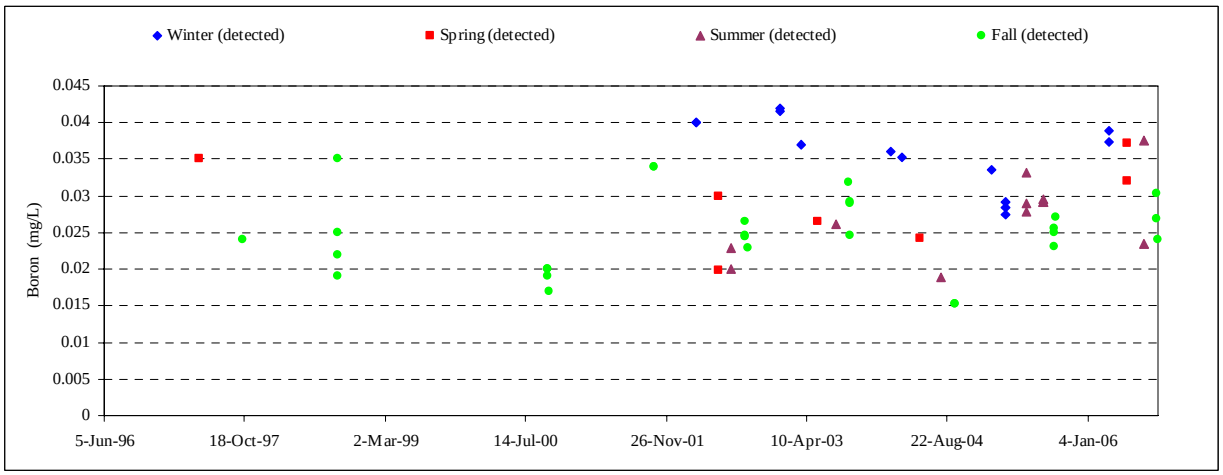
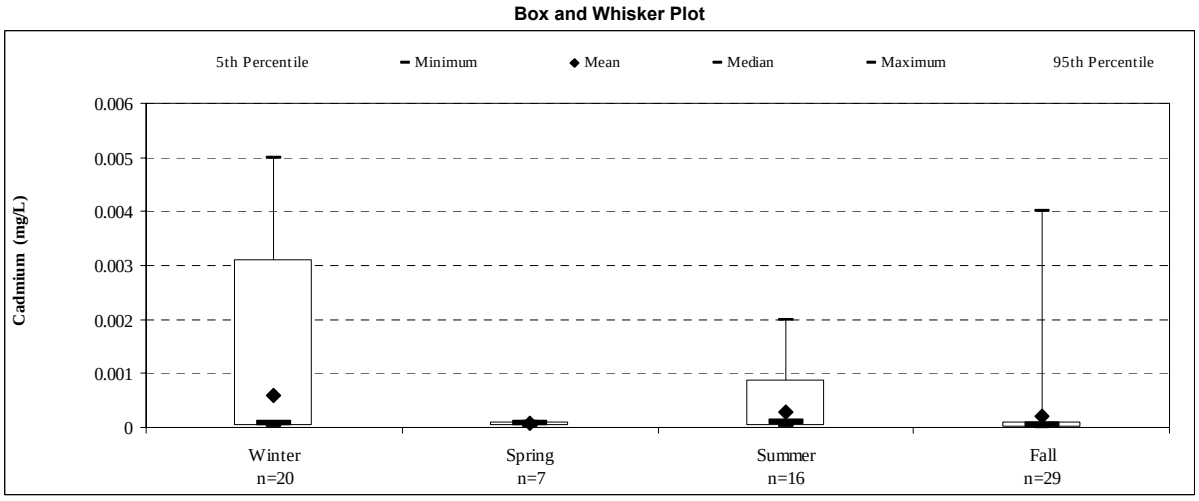


Figure G-1-2-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Middle Reach of Lower Athabasca River



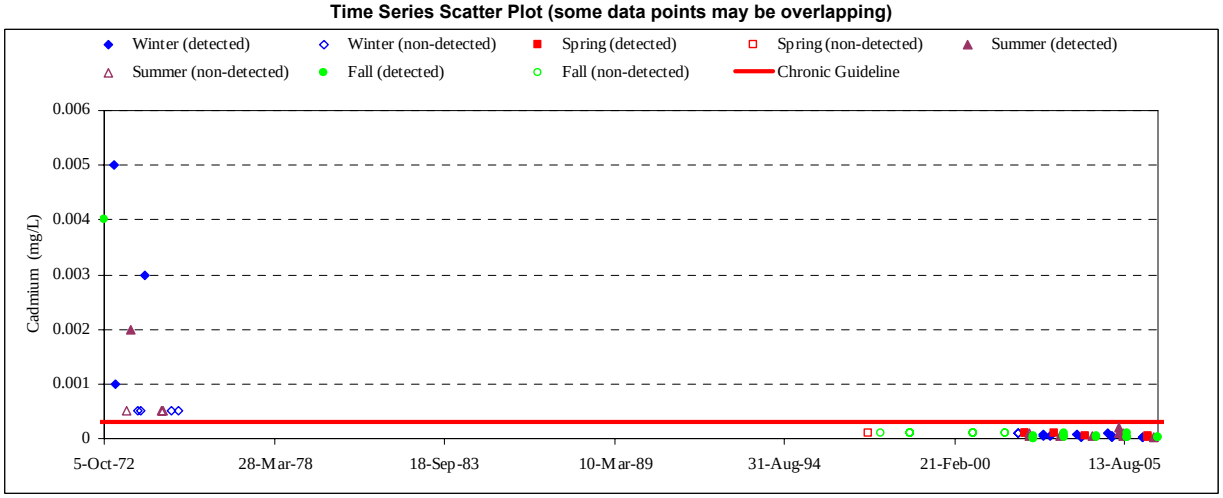
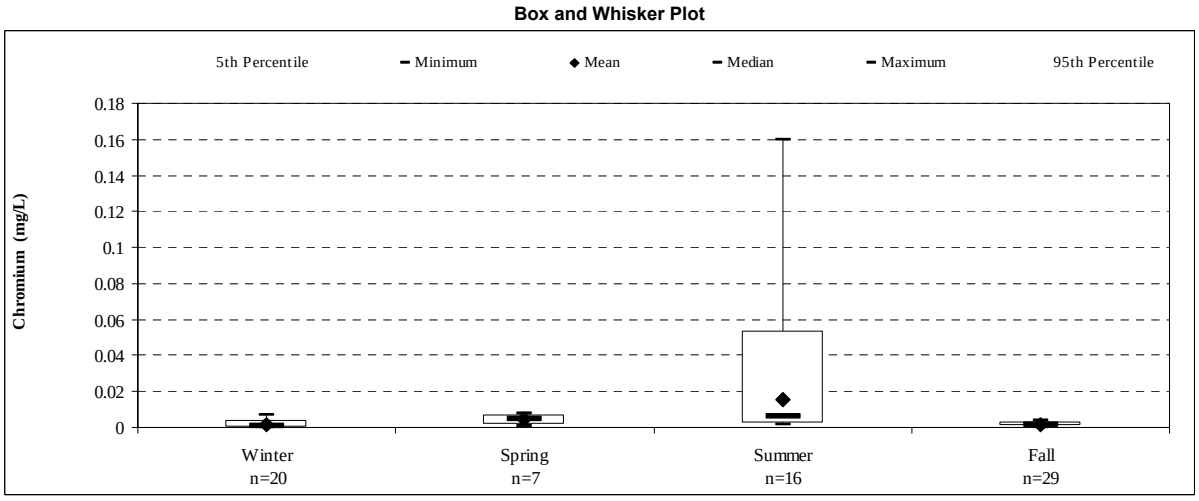


Figure G-1-2-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Middle Reach of Lower Athabasca River



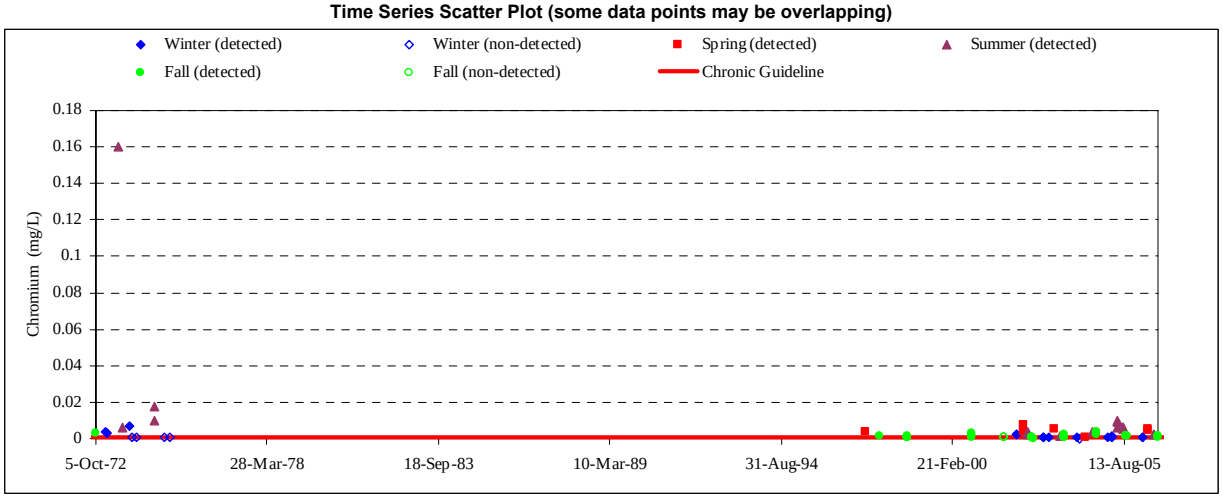


Figure G-1-2-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Middle Reach of Lower Athabasca River

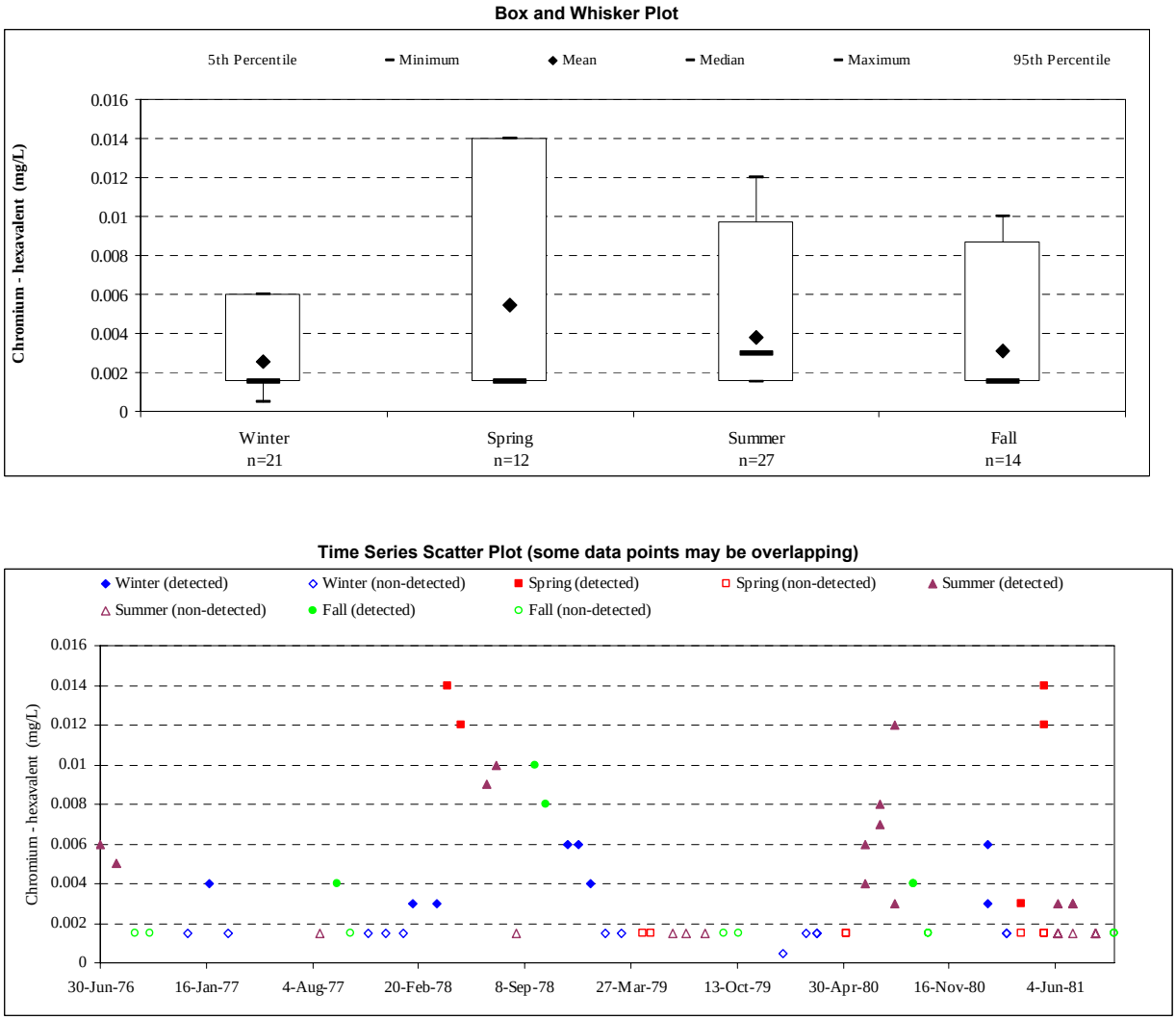


Figure G-1-2-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Middle Reach of Lower Athabasca River

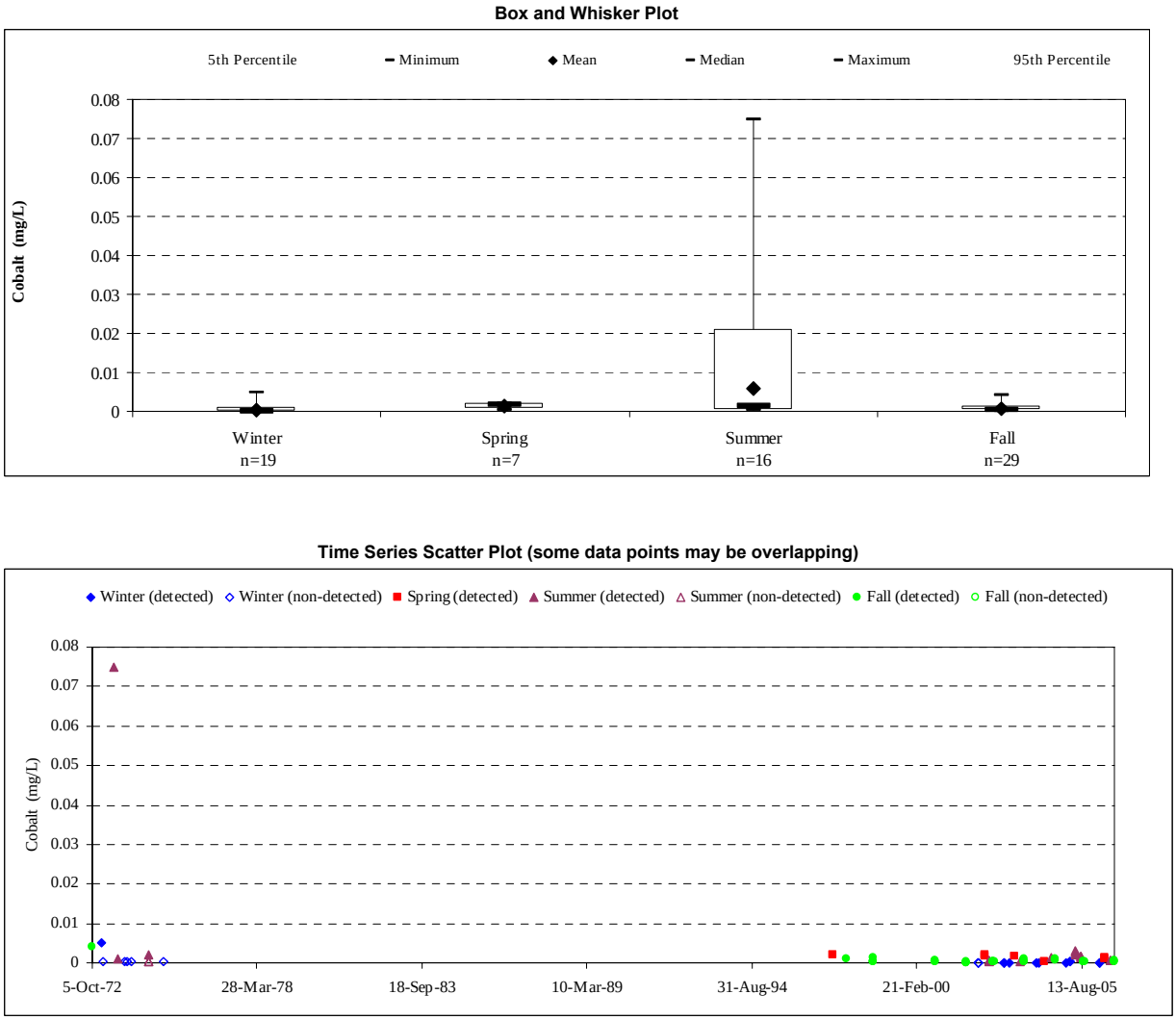
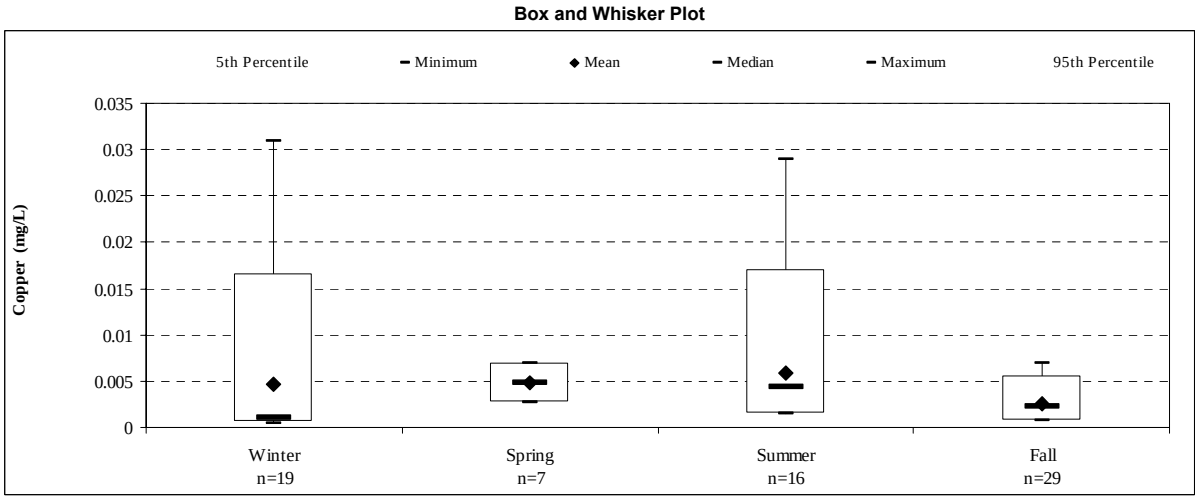


Figure G-1-2-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Middle Reach of Lower Athabasca River



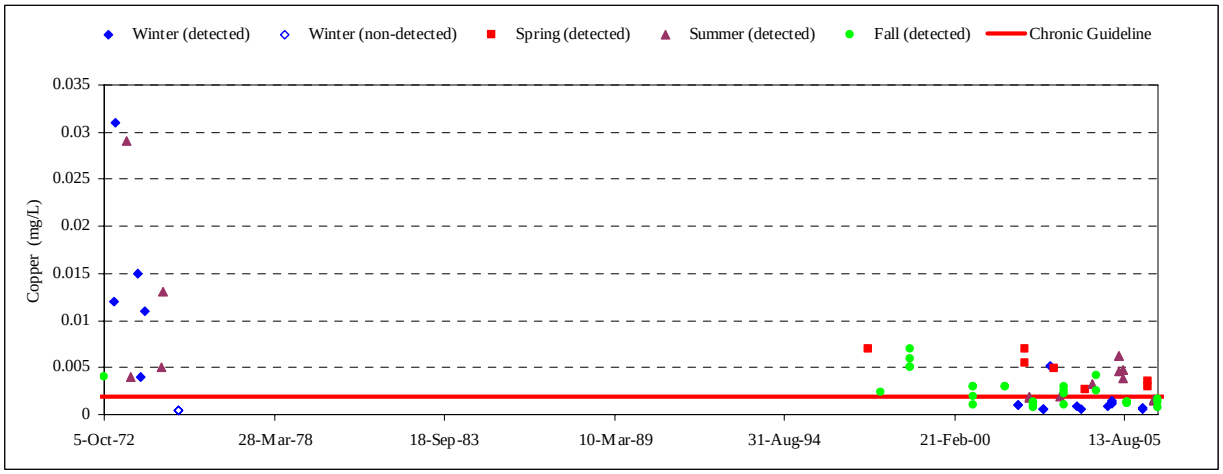


Figure G-1-2-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Middle Reach of Lower Athabasca River

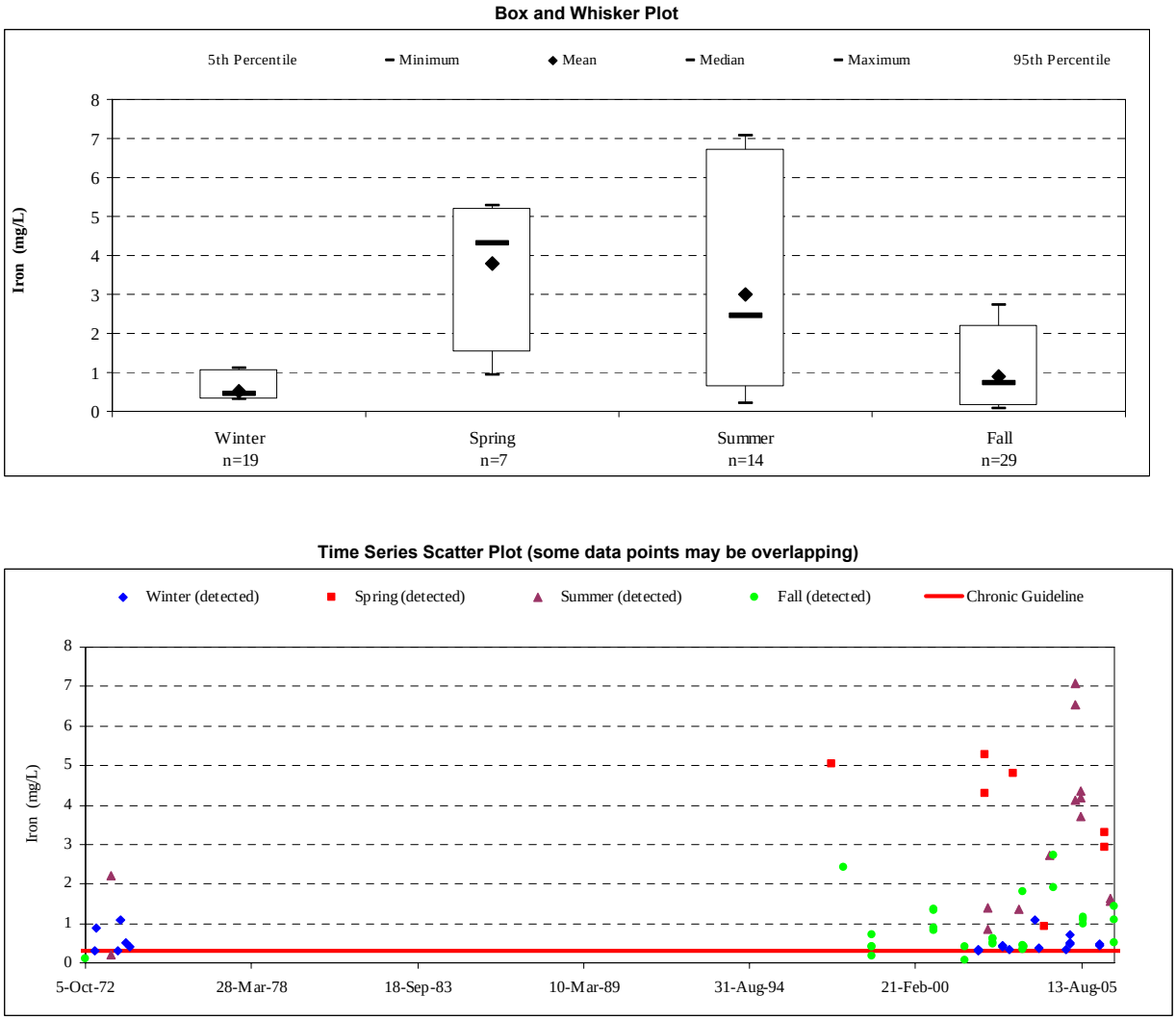
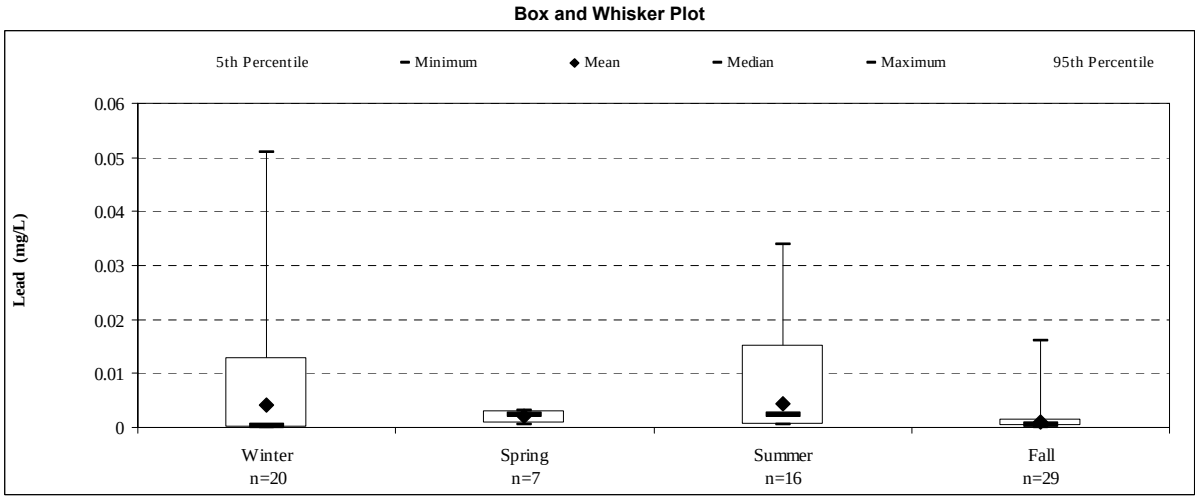


Figure G-1-2-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Middle Reach of Lower Athabasca River



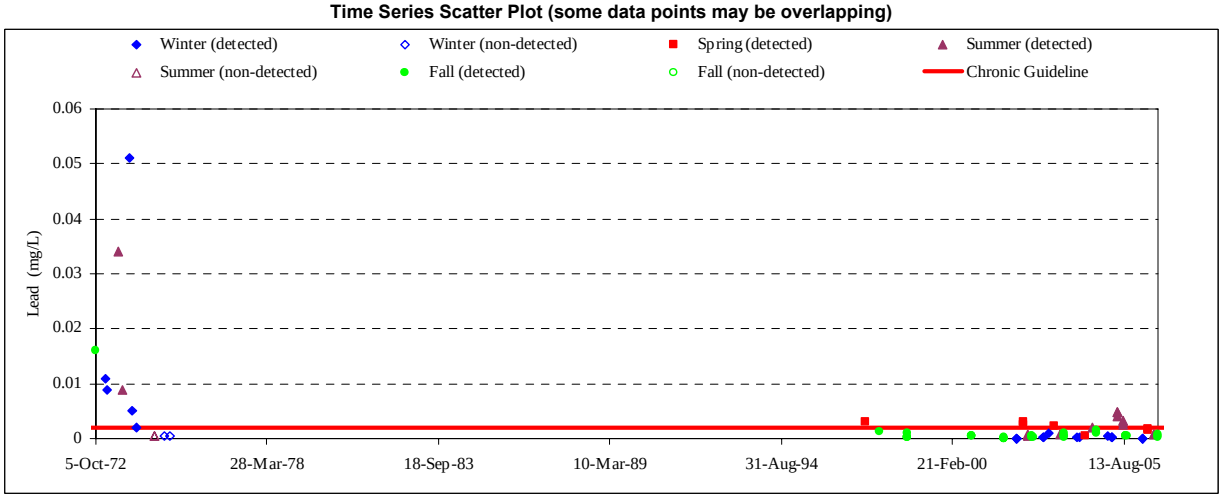
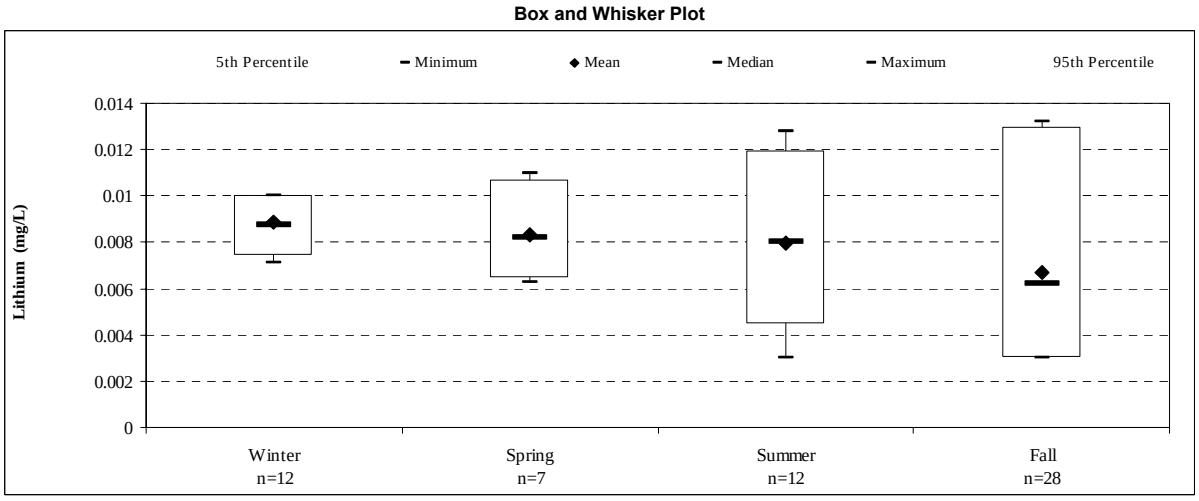


Figure G-1-2-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Middle Reach of Lower Athabasca River



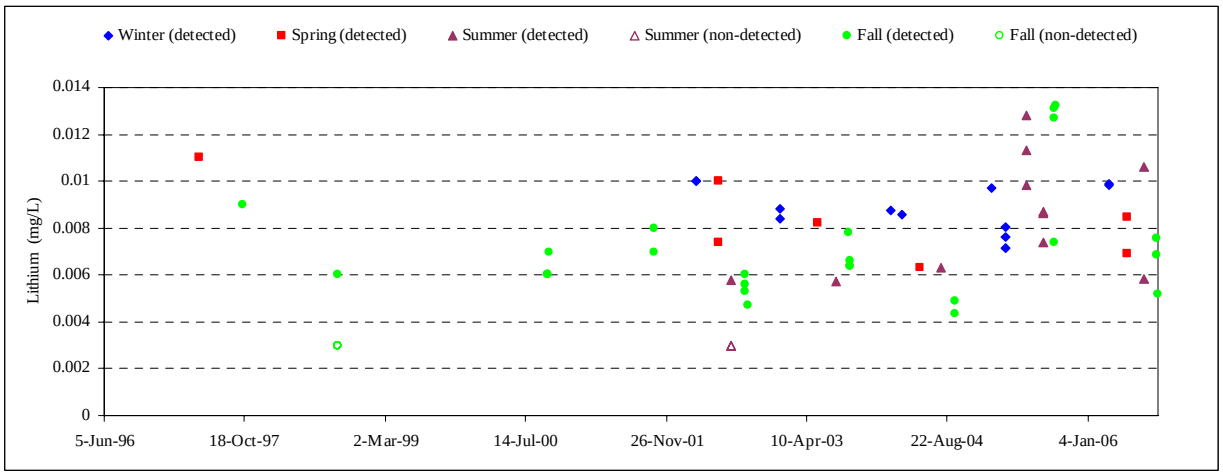


Figure G-1-2-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Middle Reach of Lower Athabasca River

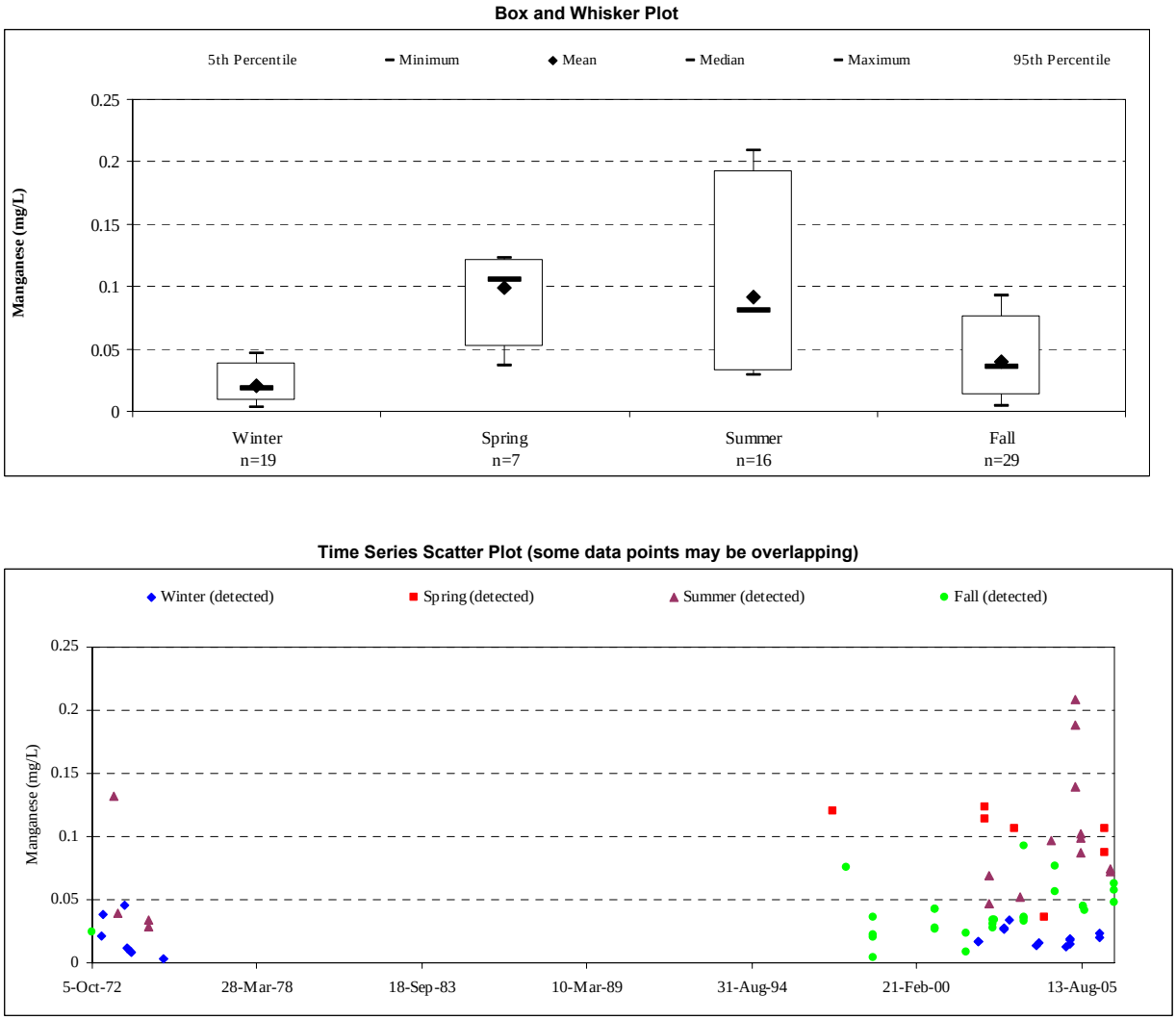
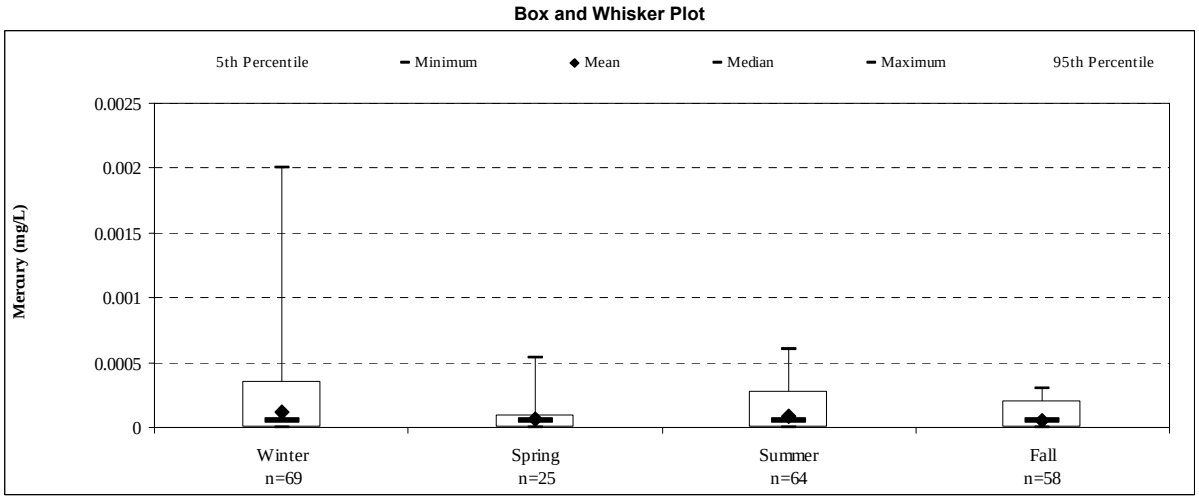


Figure G-1-2-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Middle Reach of Lower Athabasca River



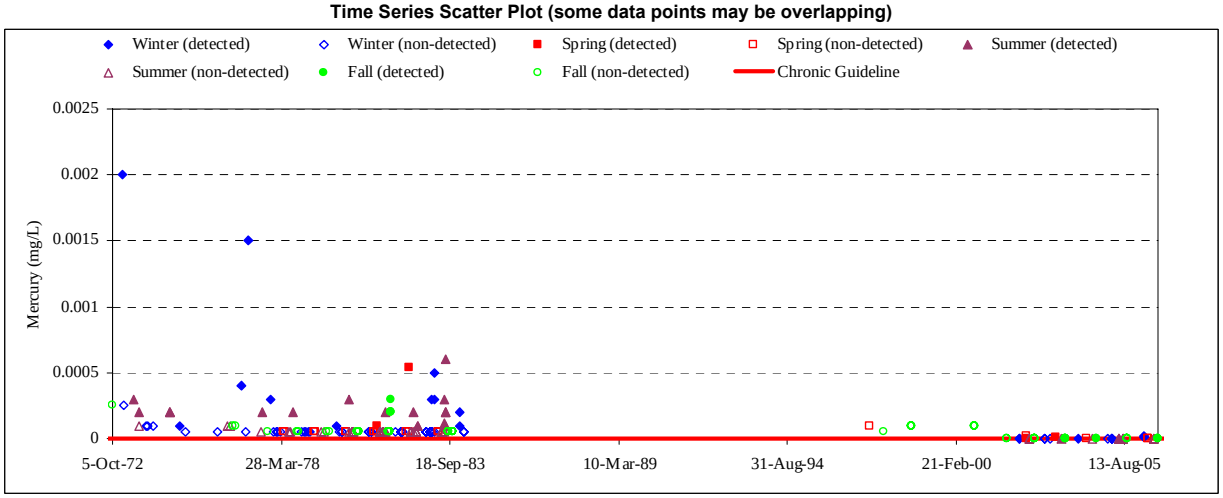


Figure G-1-2-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Middle Reach of Lower Athabasca River

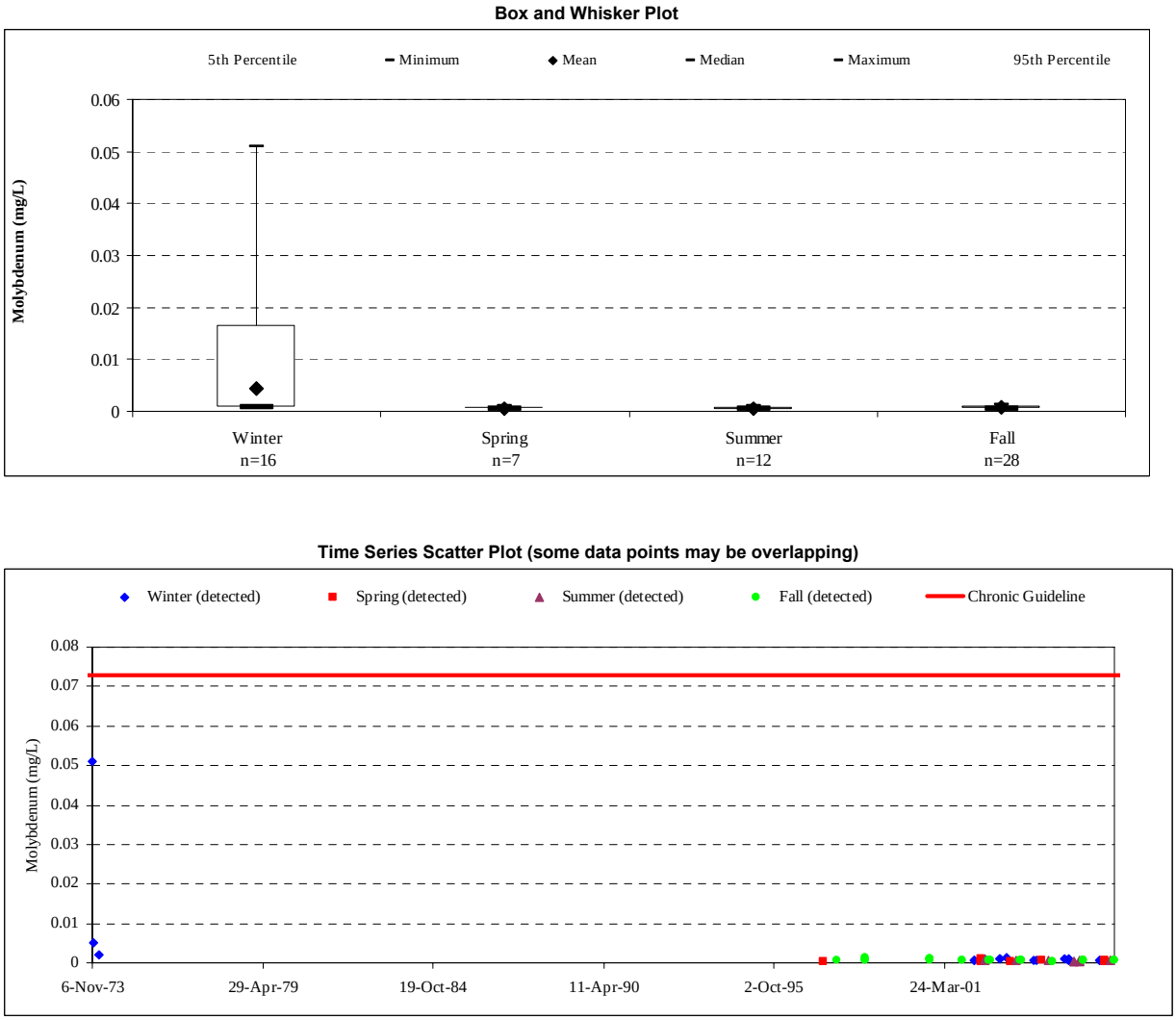
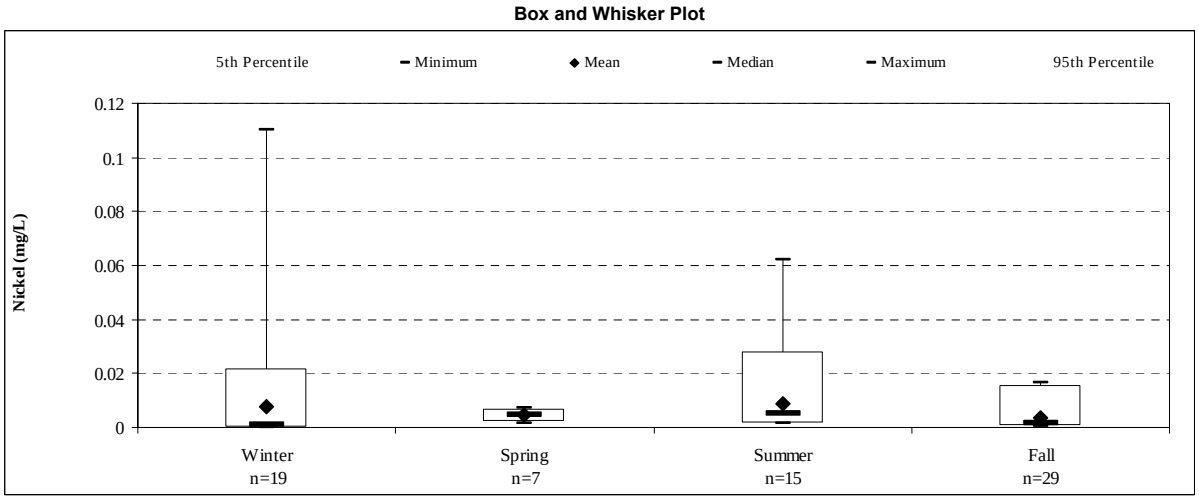


Figure G-1-2-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Middle Reach of Lower Athabasca River



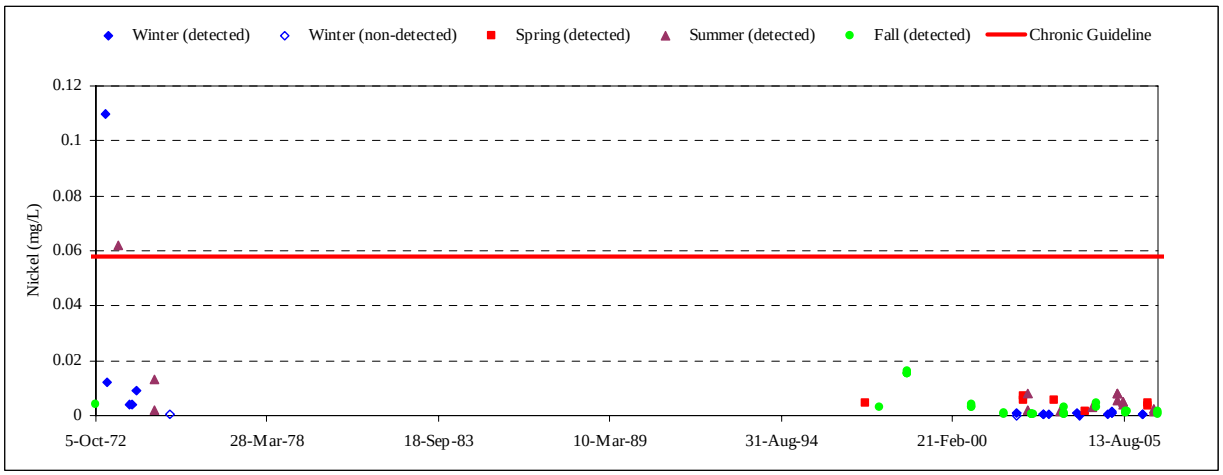
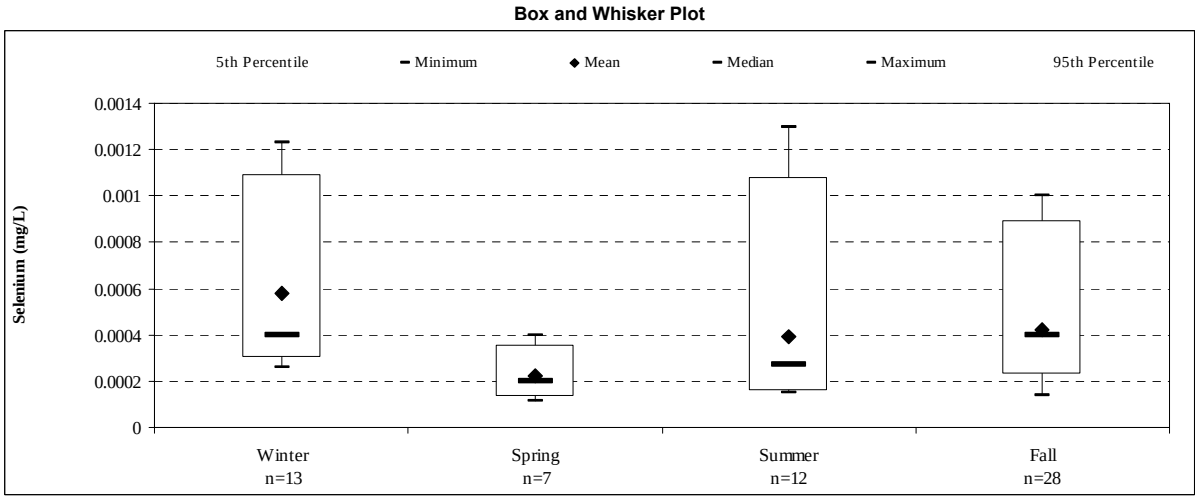


Figure G-1-2-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Middle Reach of Lower Athabasca River



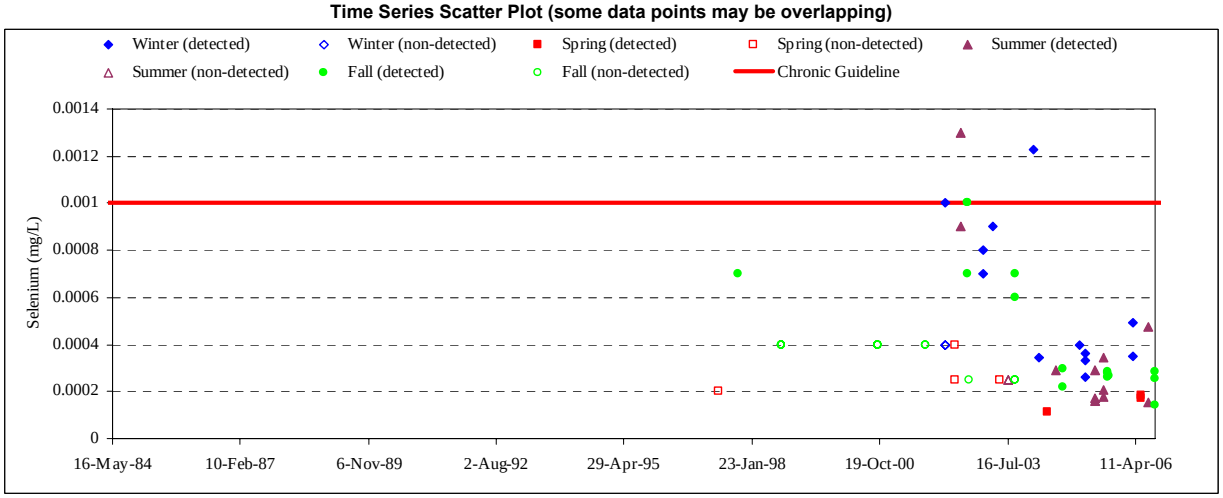
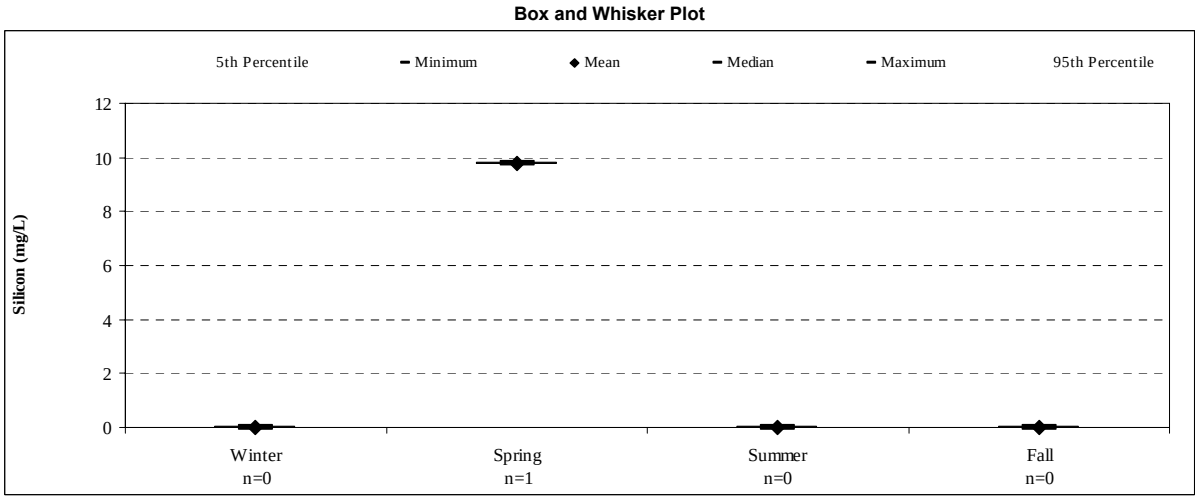


Figure G-1-2-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Middle Reach of Lower Athabasca River



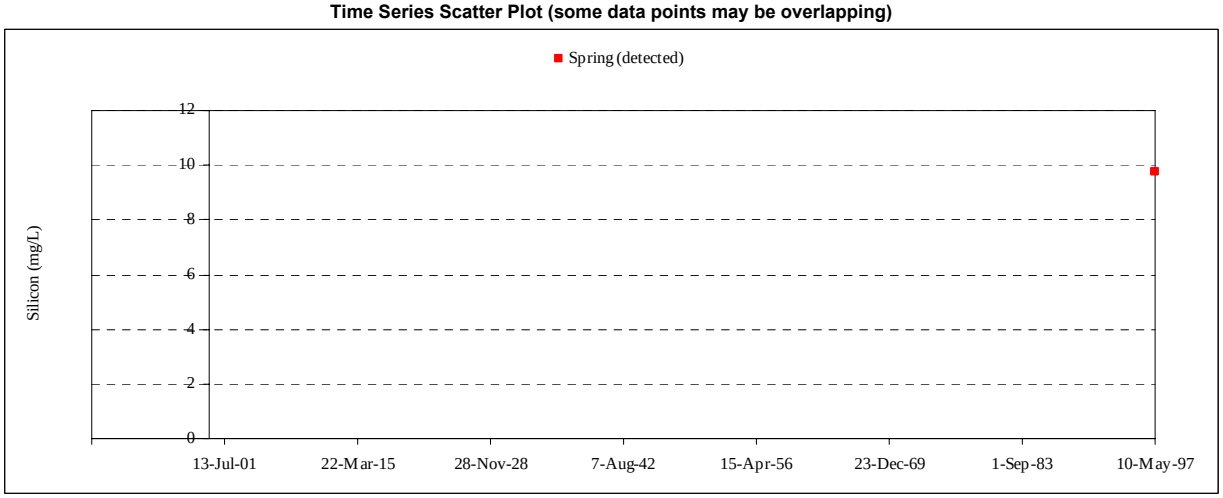
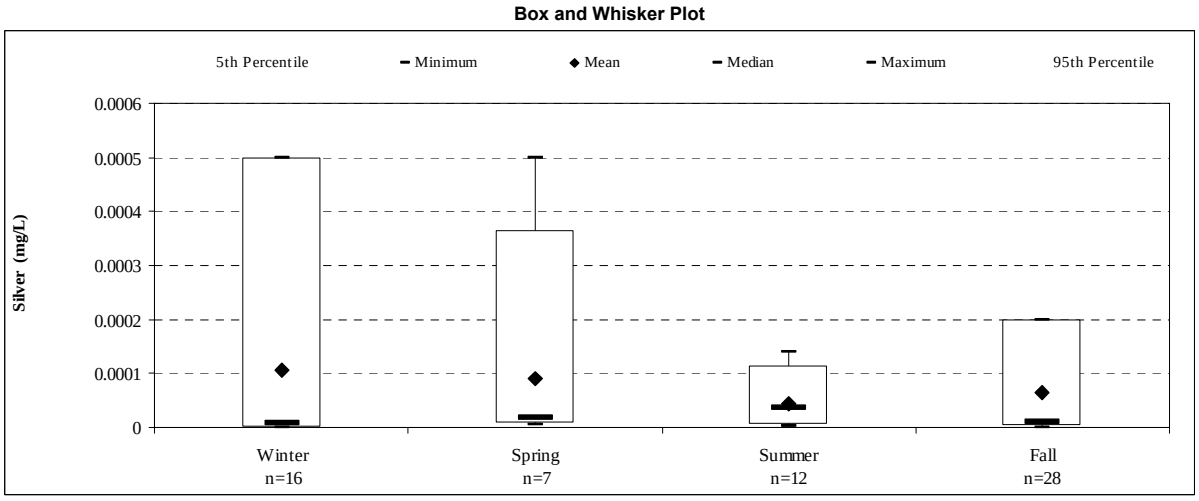


Figure G-1-2-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Middle Reach of Lower Athabasca River



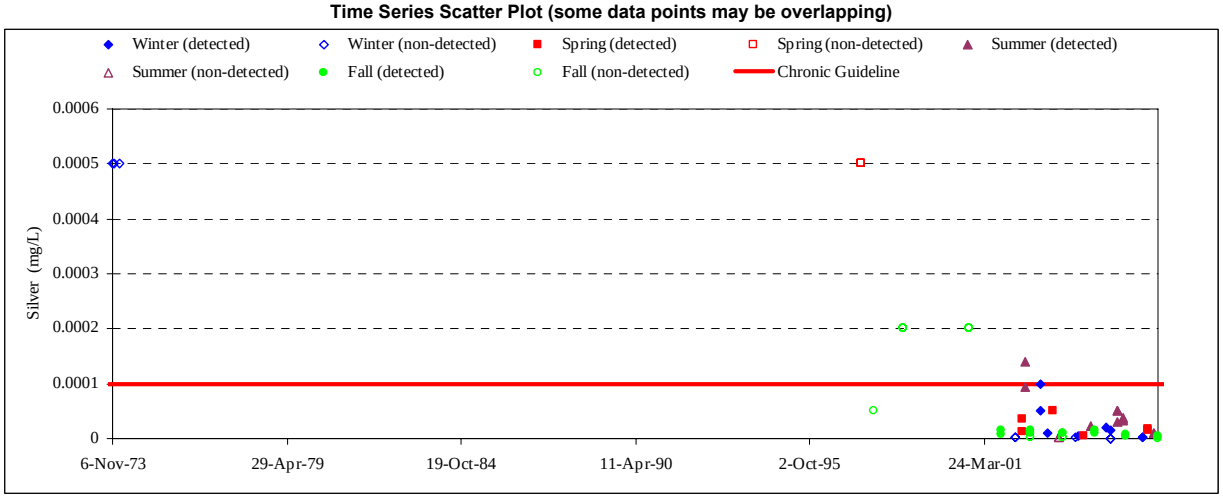
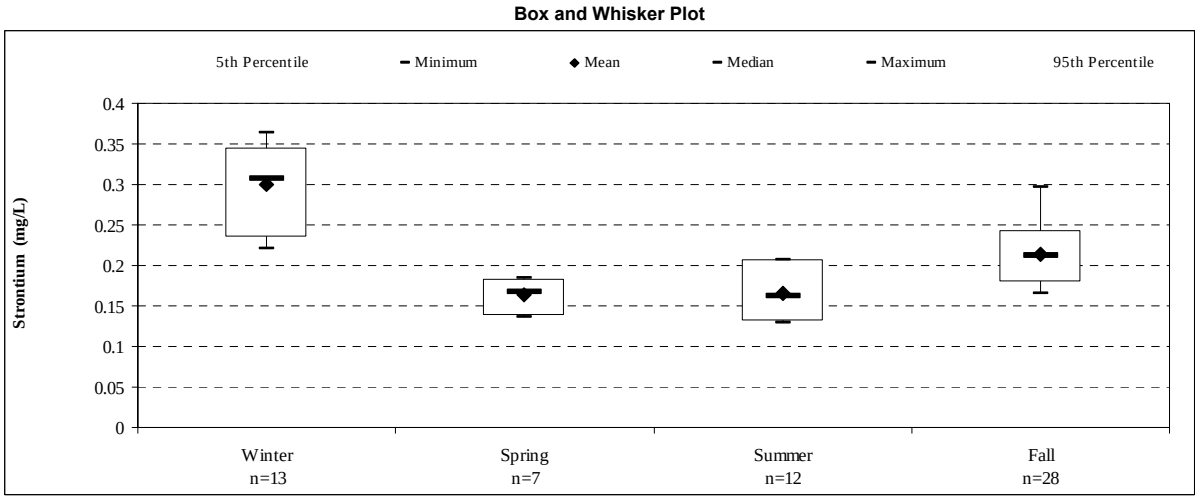


Figure G-1-2-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Middle Reach of Lower Athabasca River



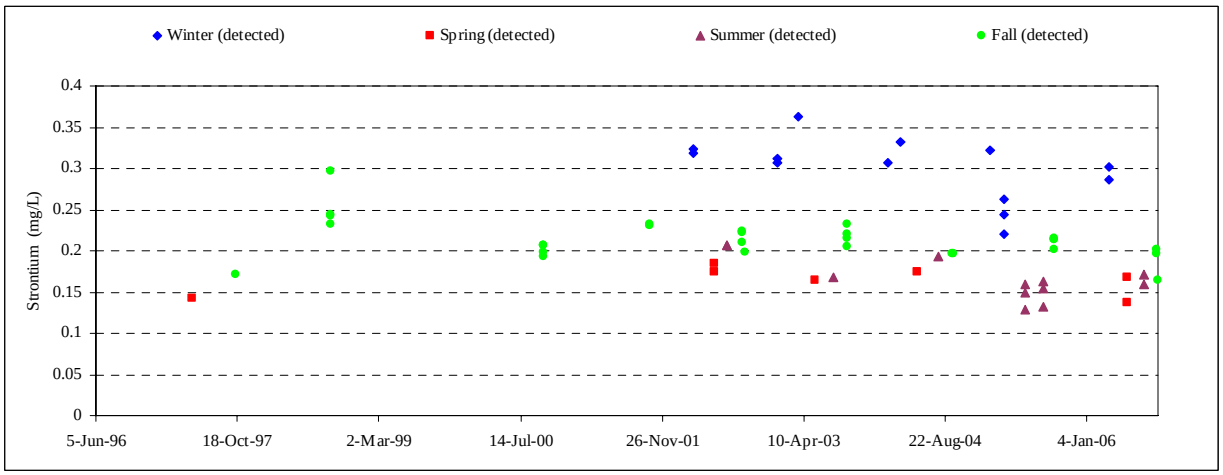
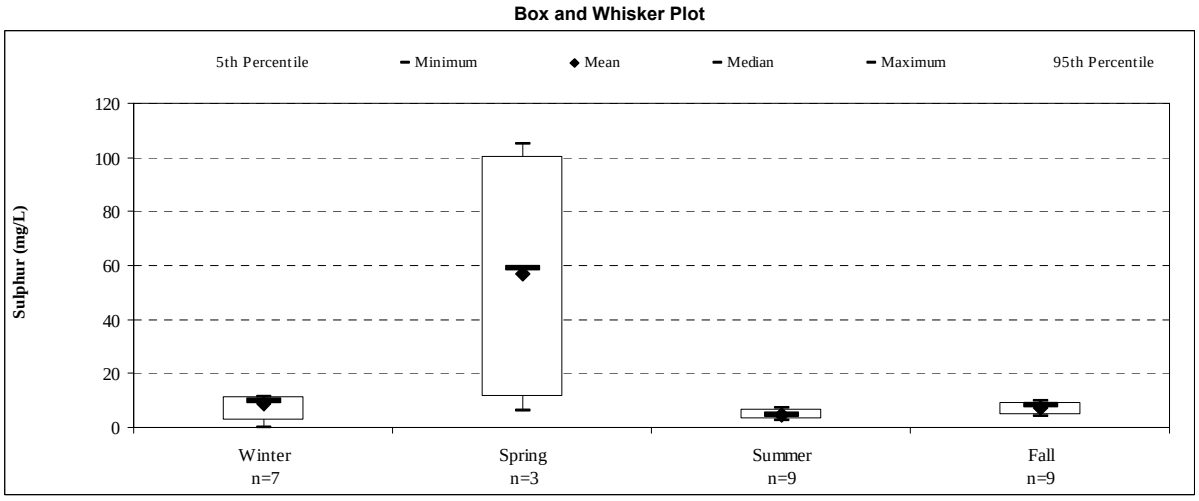


Figure G-1-2-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Middle Reach of Lower Athabasca River



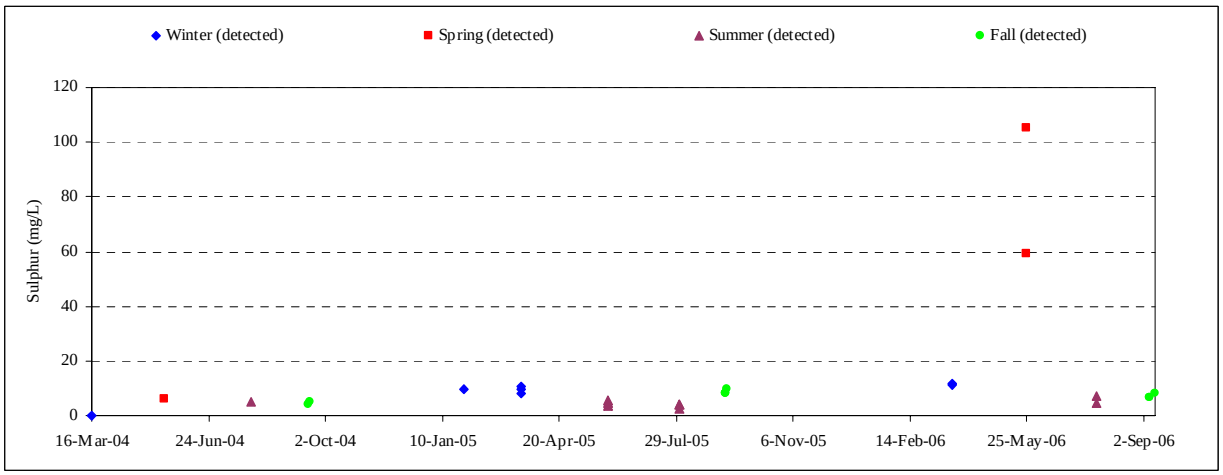
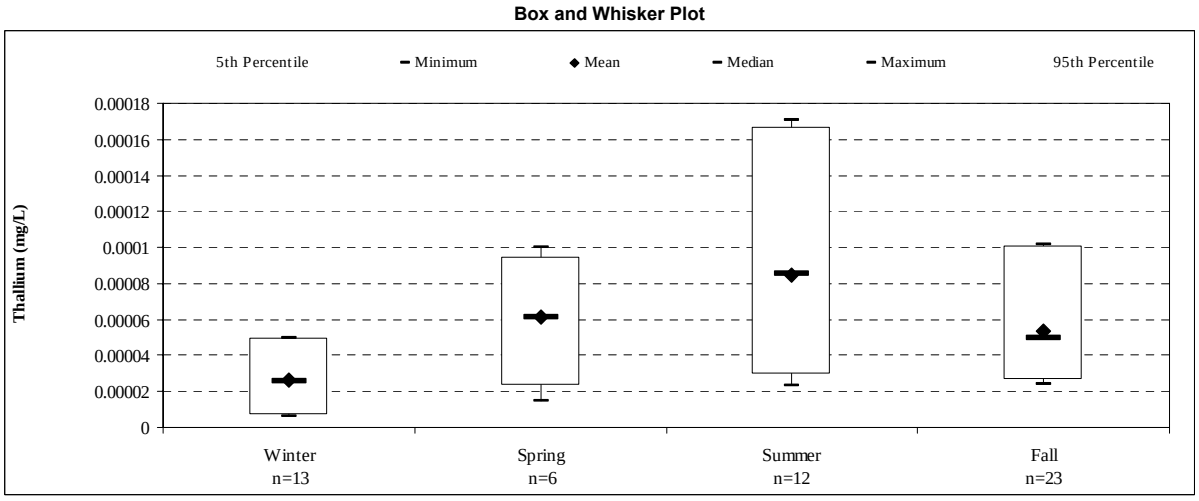


Figure G-1-2-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Middle Reach of Lower Athabasca River



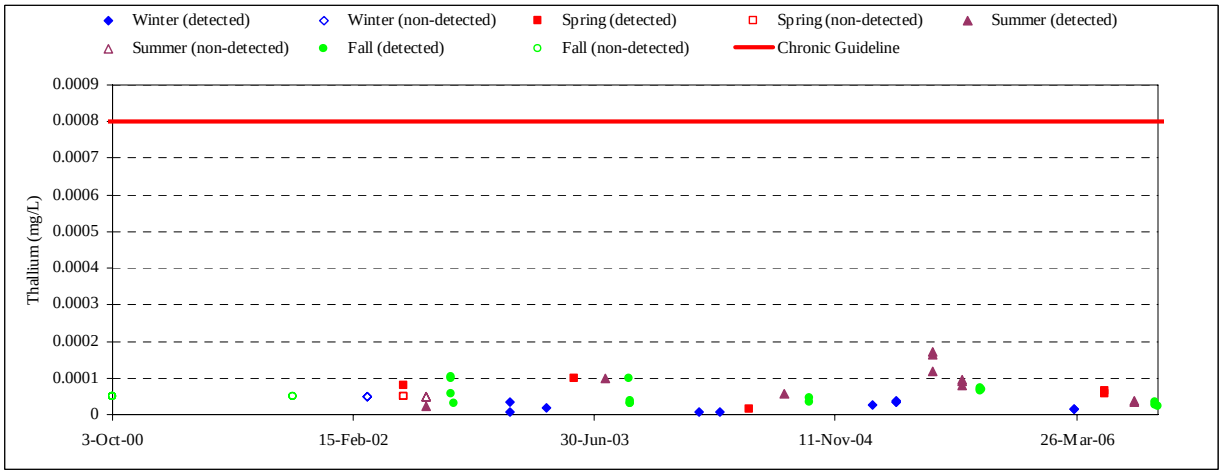


Figure G-1-2-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Middle Reach of Lower Athabasca River

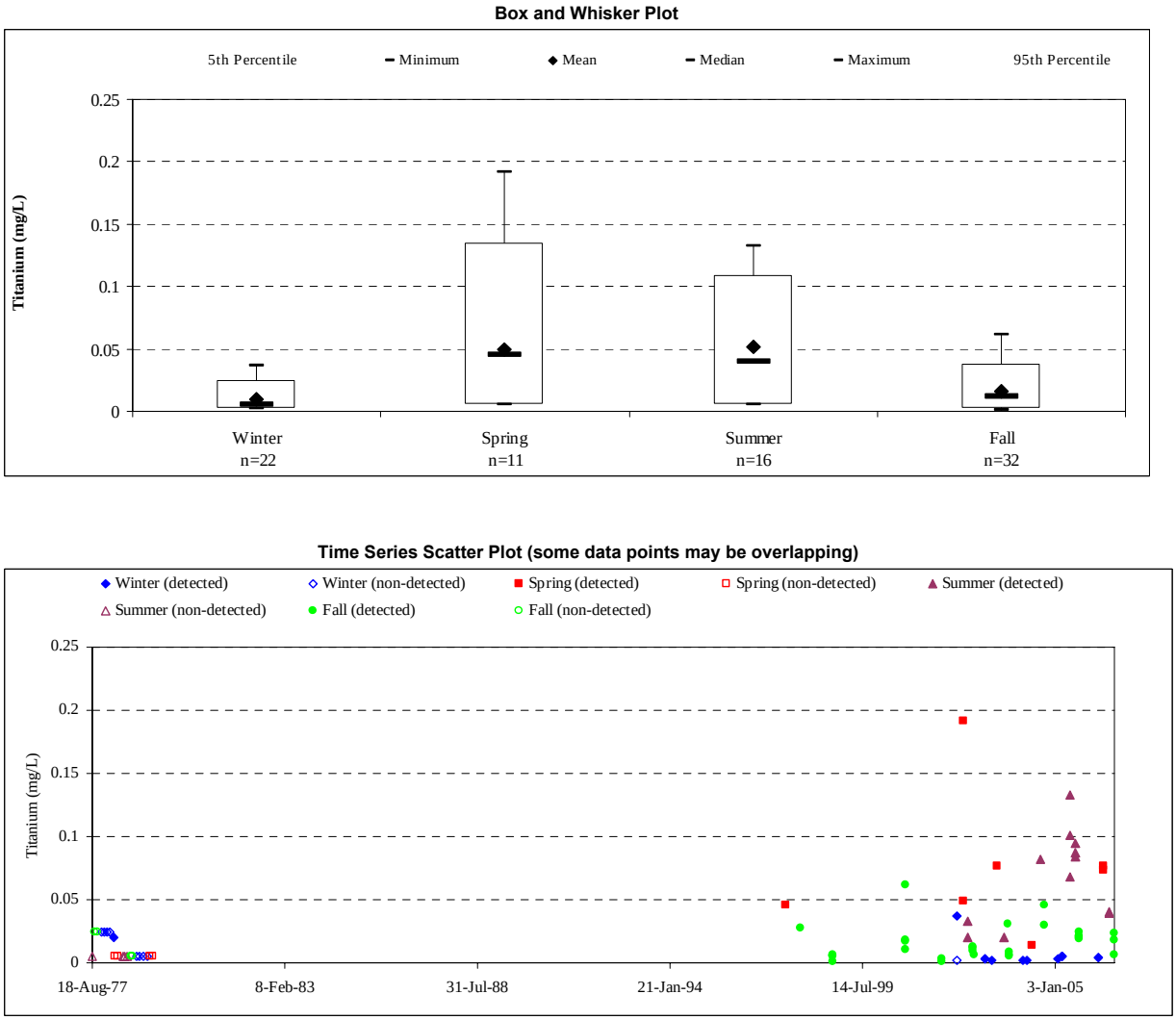
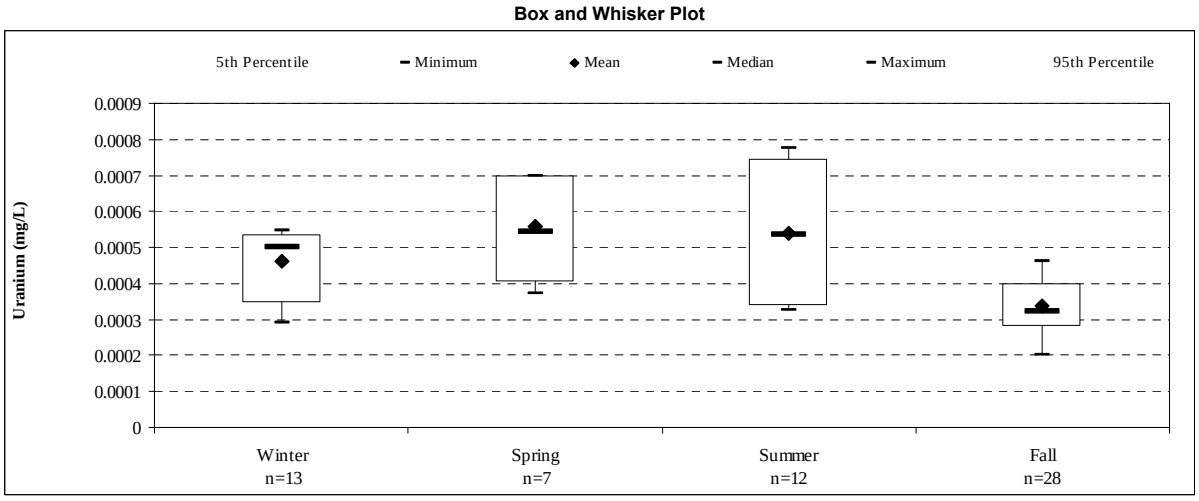


Figure G-1-2-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Middle Reach of Lower Athabasca River



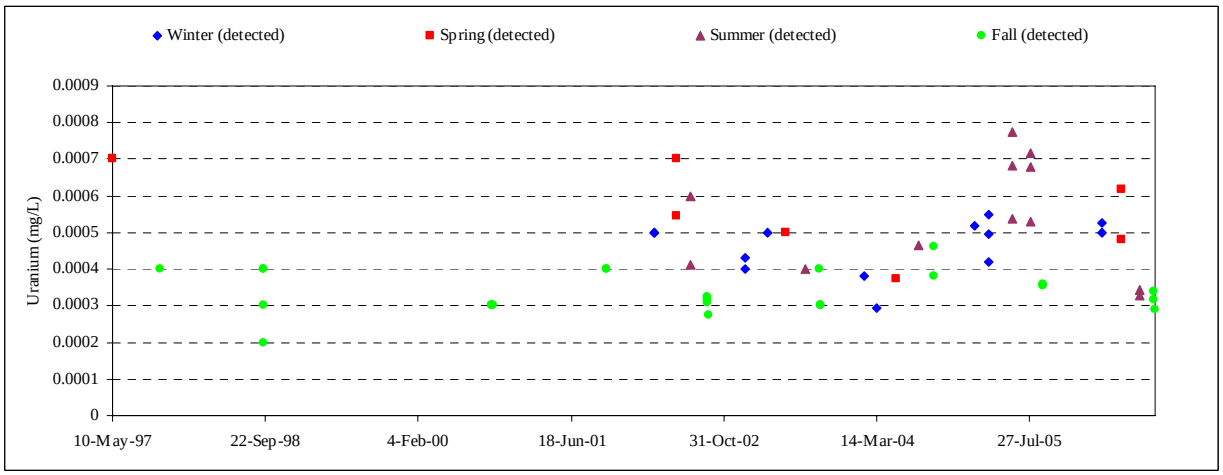
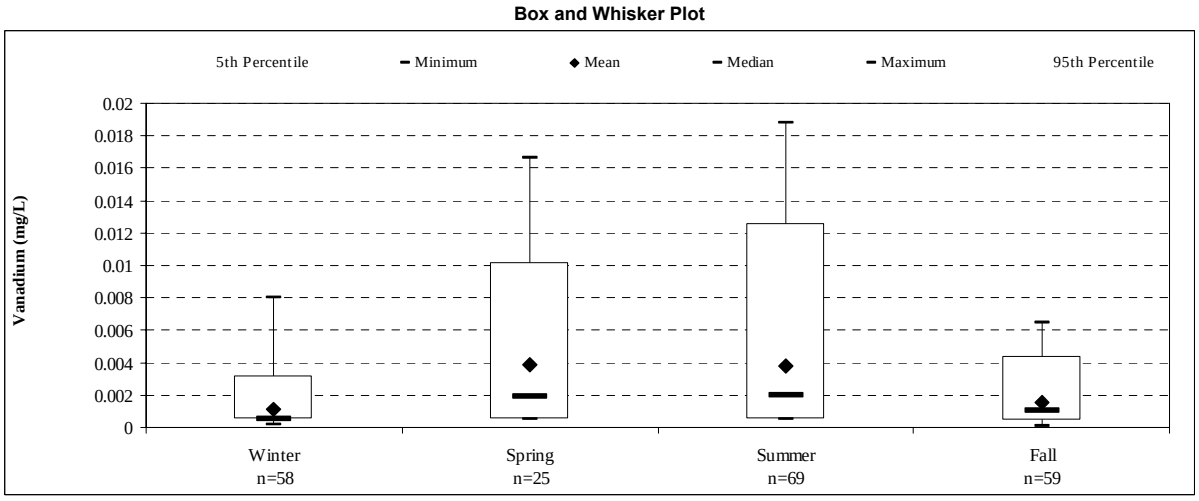


Figure G-1-2-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Middle Reach of Lower Athabasca River



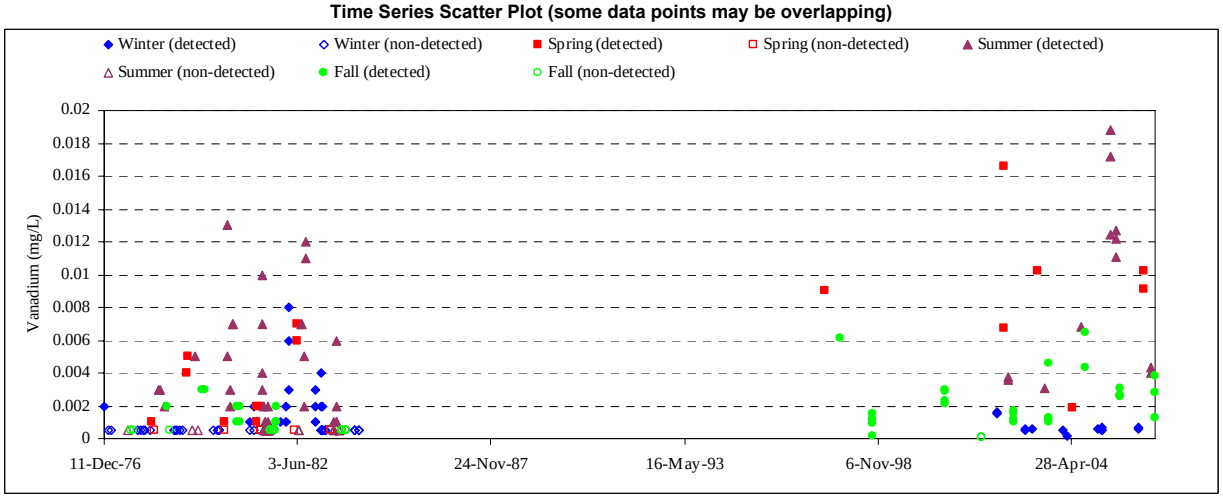
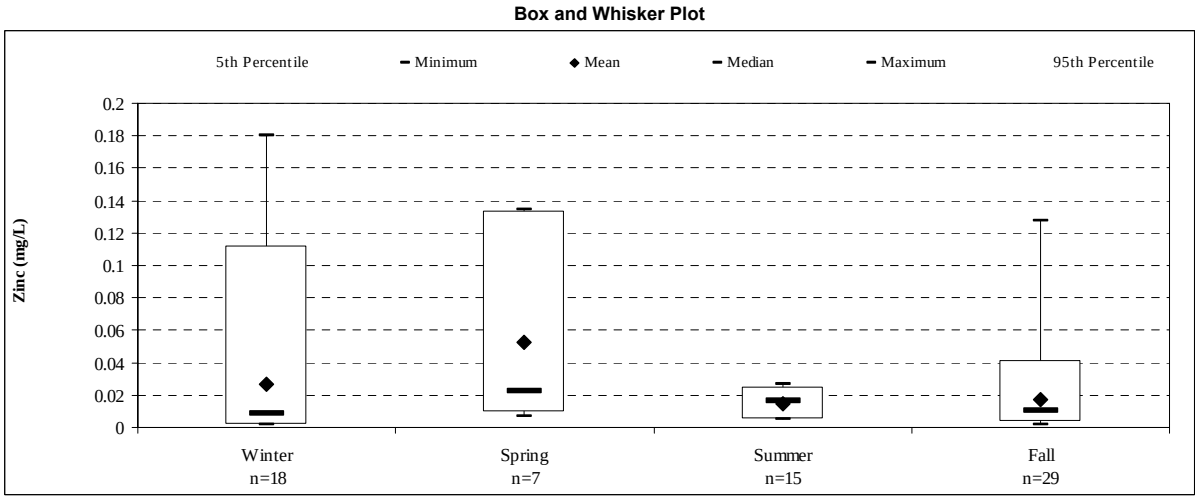


Figure G-1-2-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Middle Reach of Lower Athabasca River



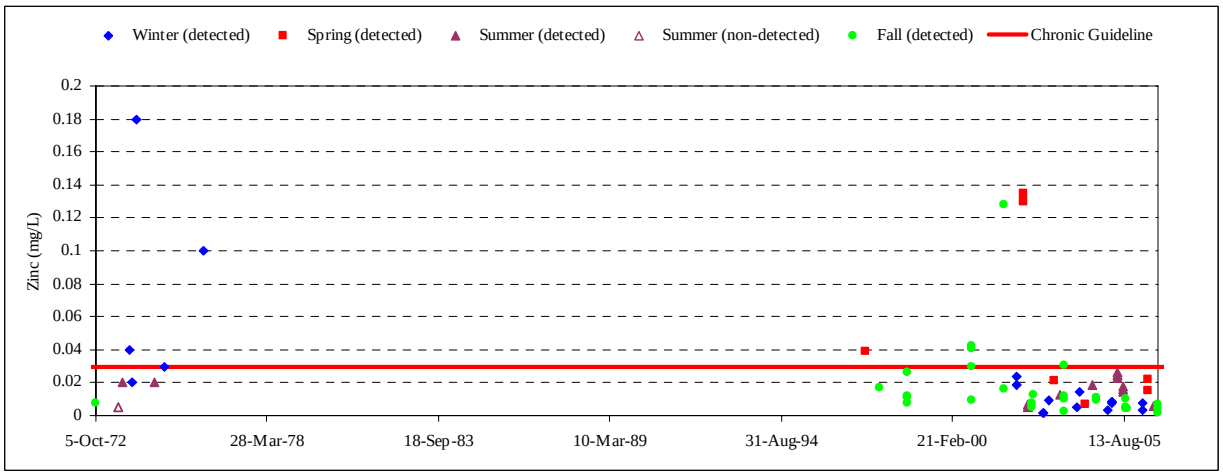


Figure G-1-2-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Middle Reach of Lower Athabasca River

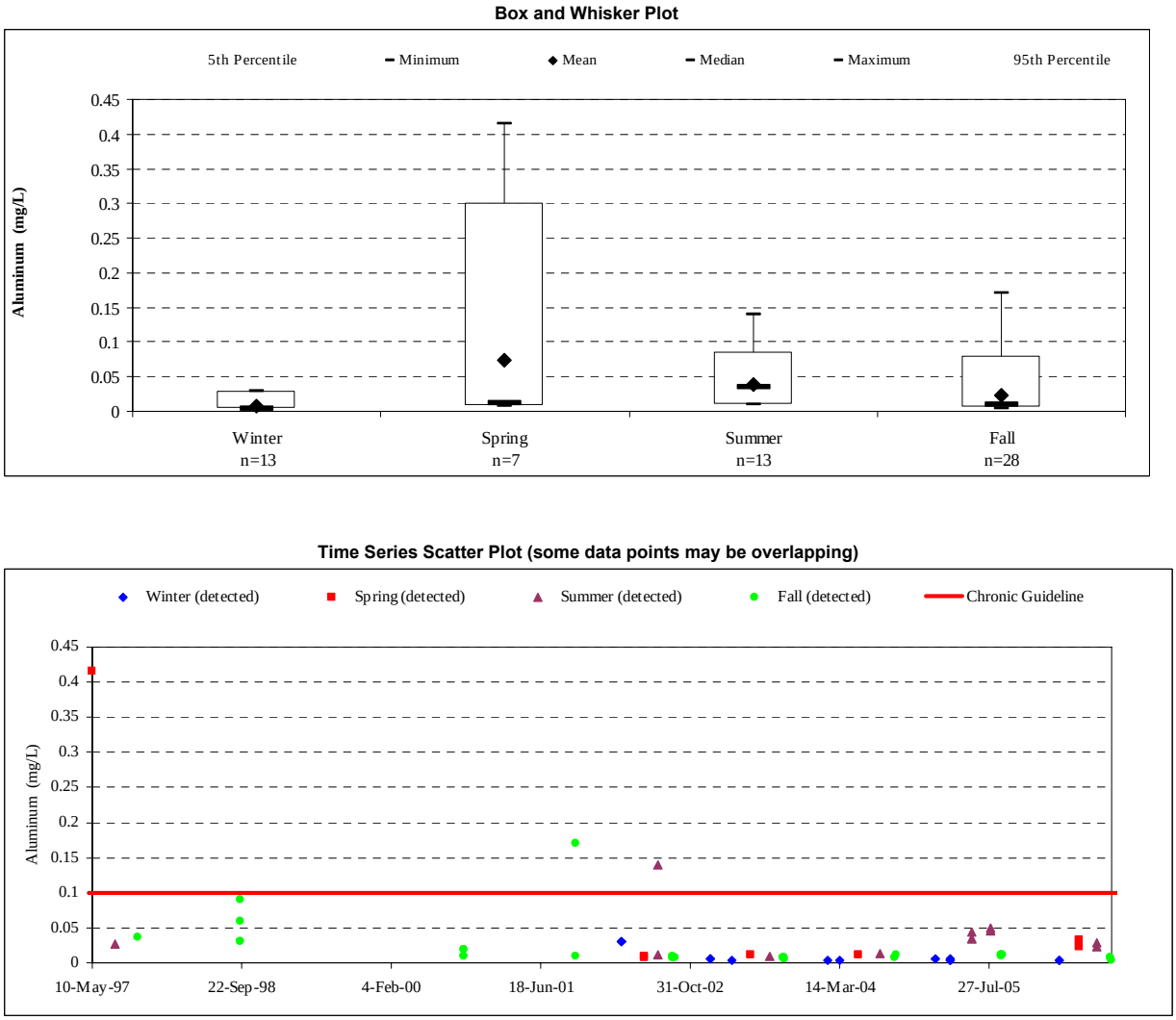


Figure G-1-2-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Middle Reach of Lower Athabasca River

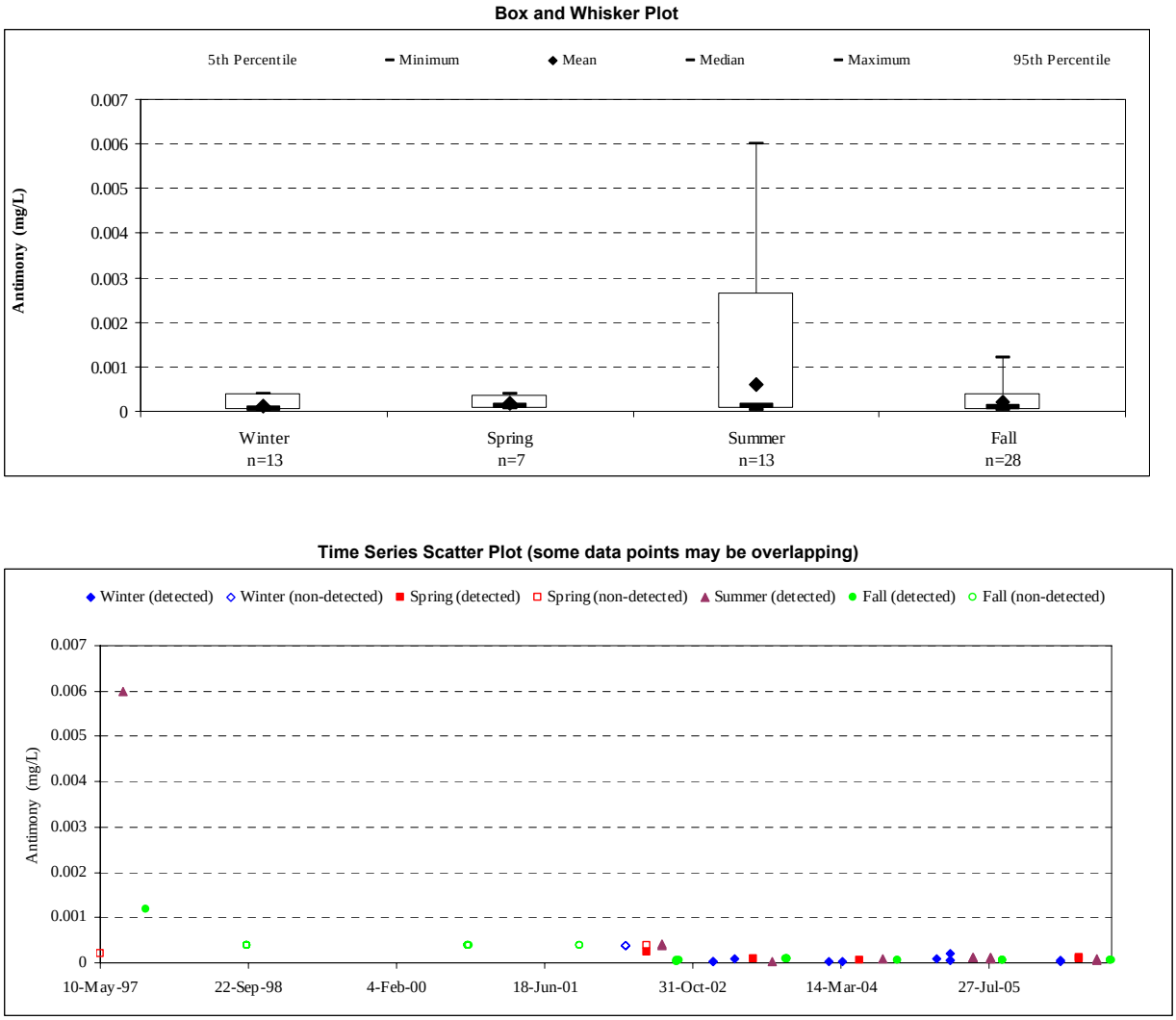
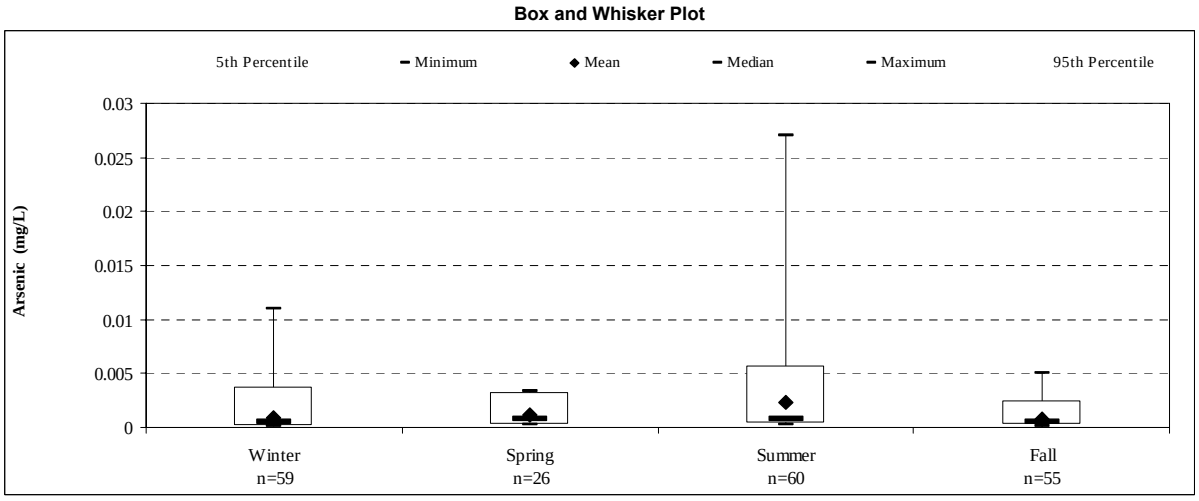


Figure G-1-2-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Middle Reach of Lower Athabasca River



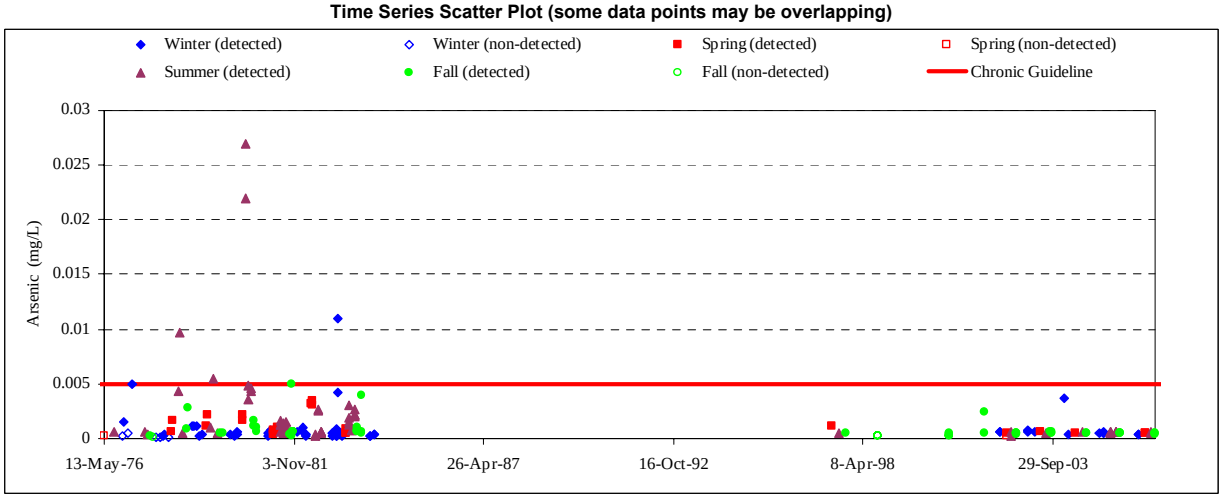
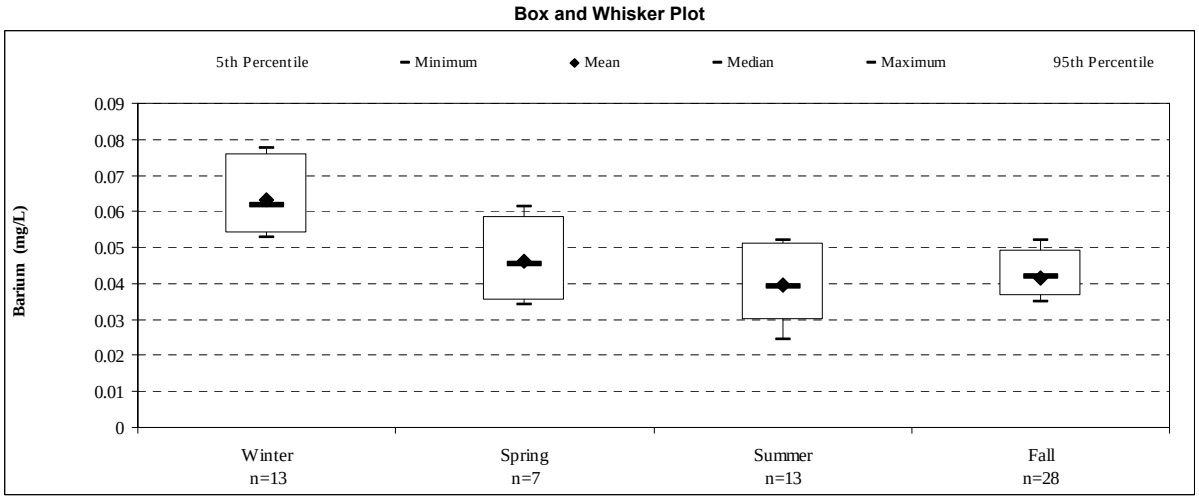


Figure G-1-2-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



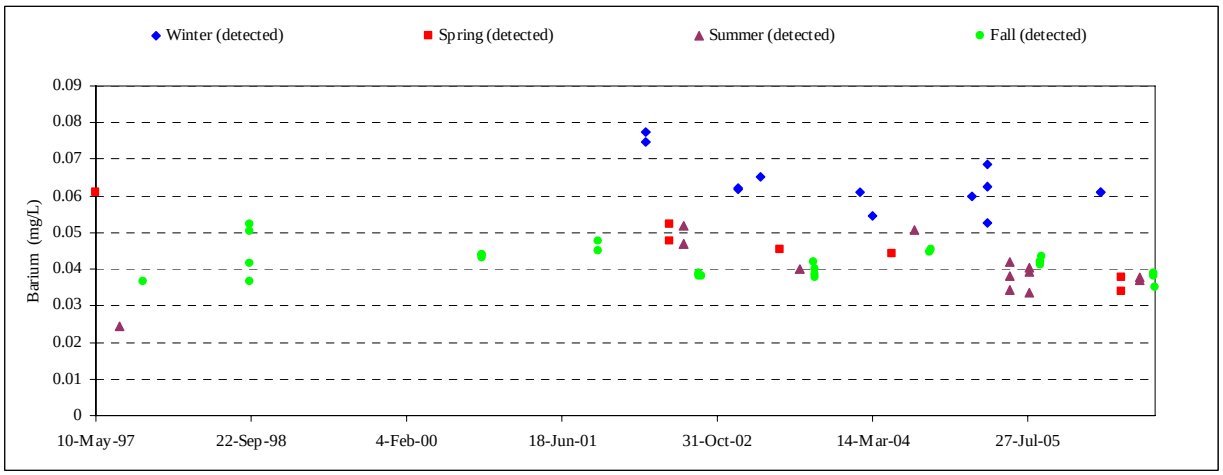
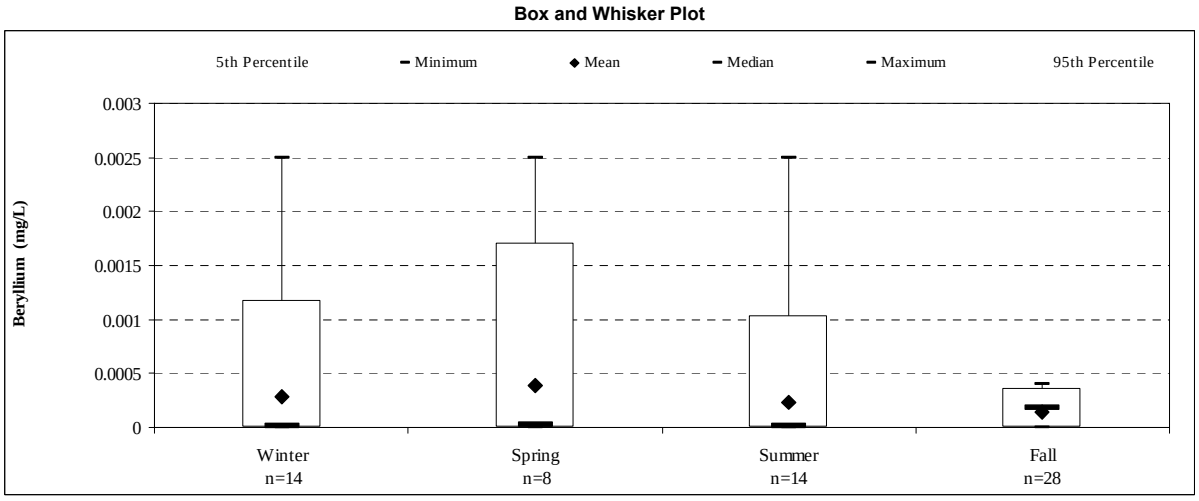


Figure G-1-2-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



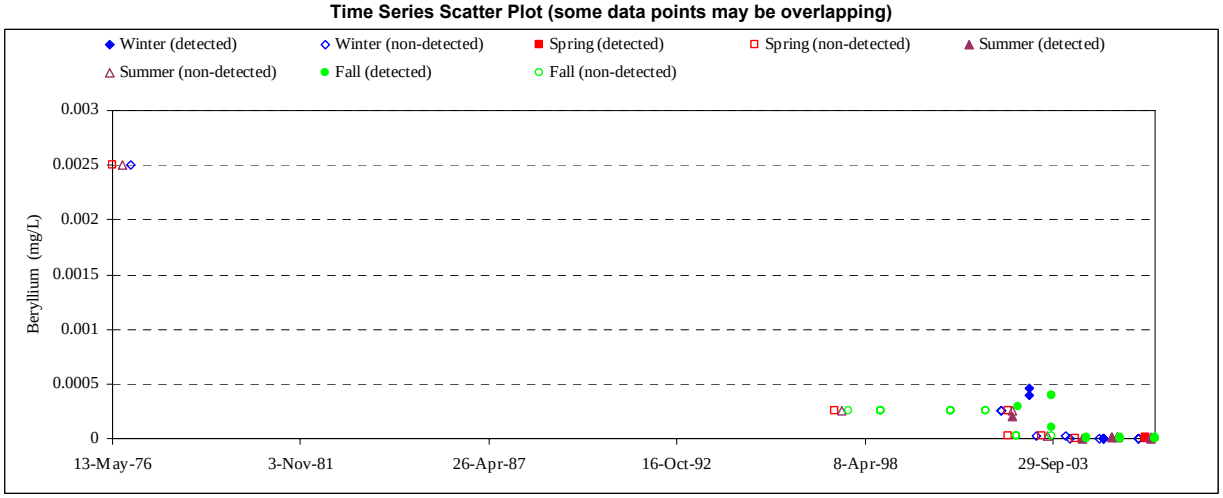


Figure G-1-2-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Middle Reach of Lower Athabasca River

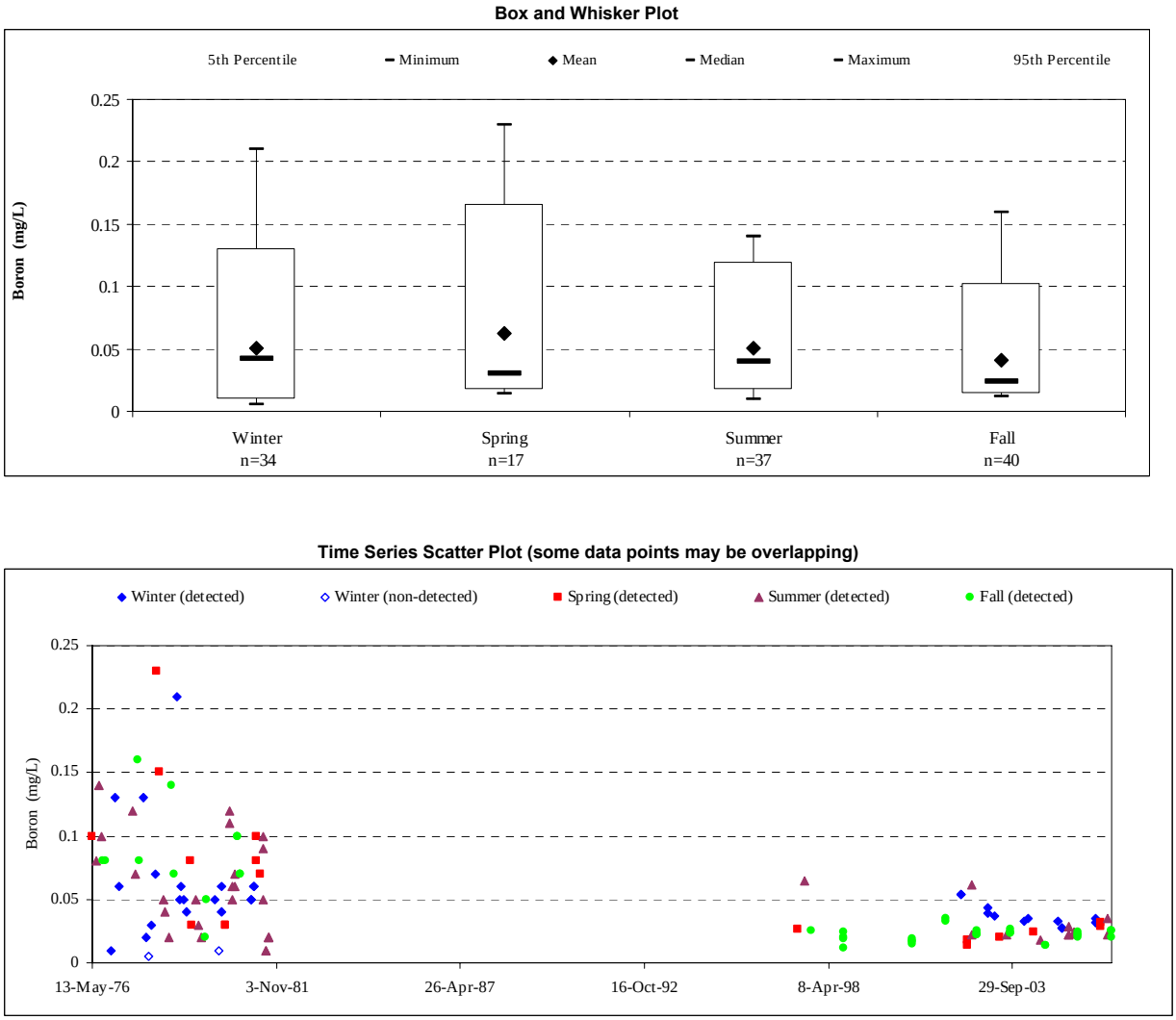
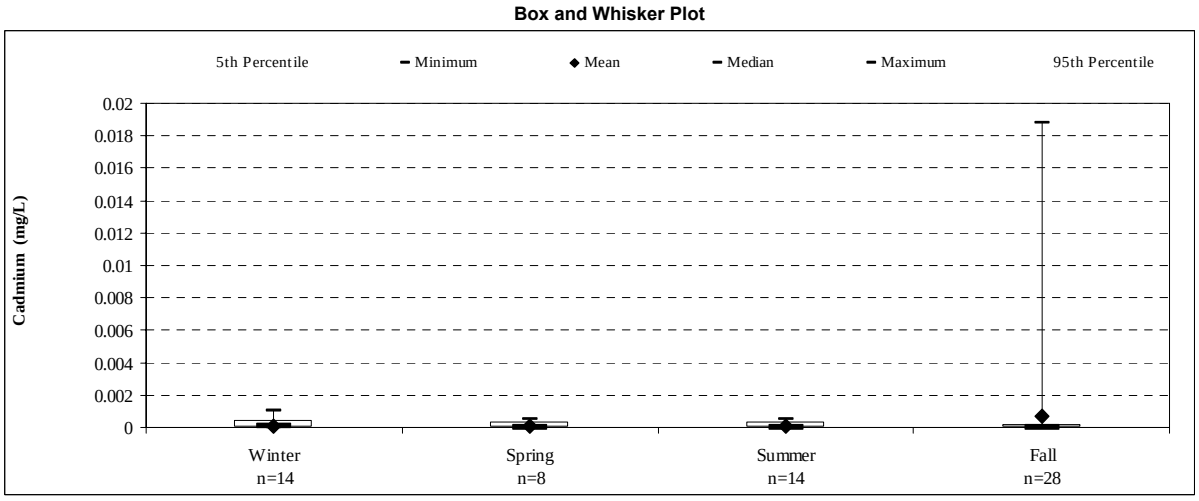


Figure G-1-2-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



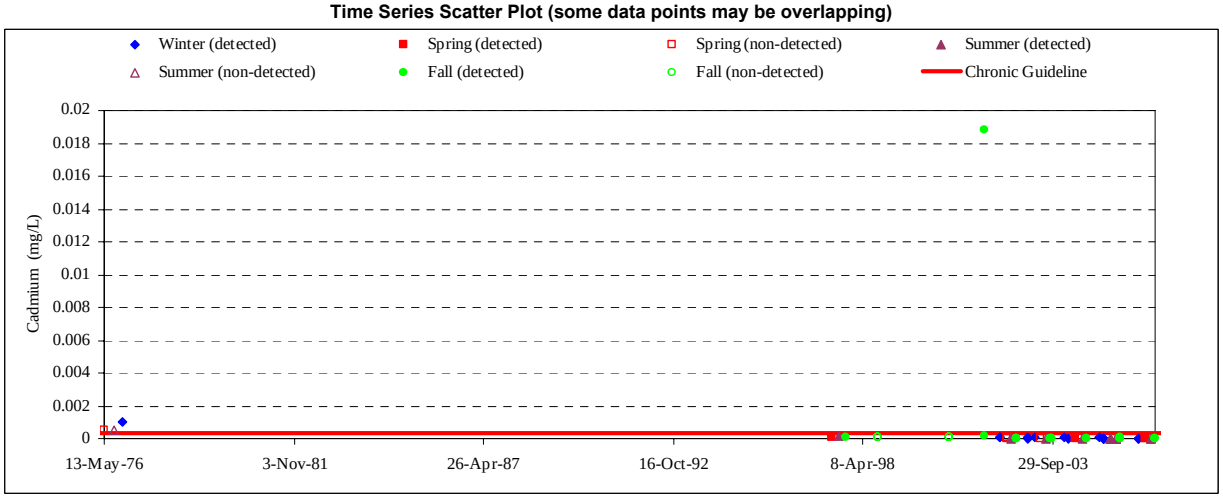
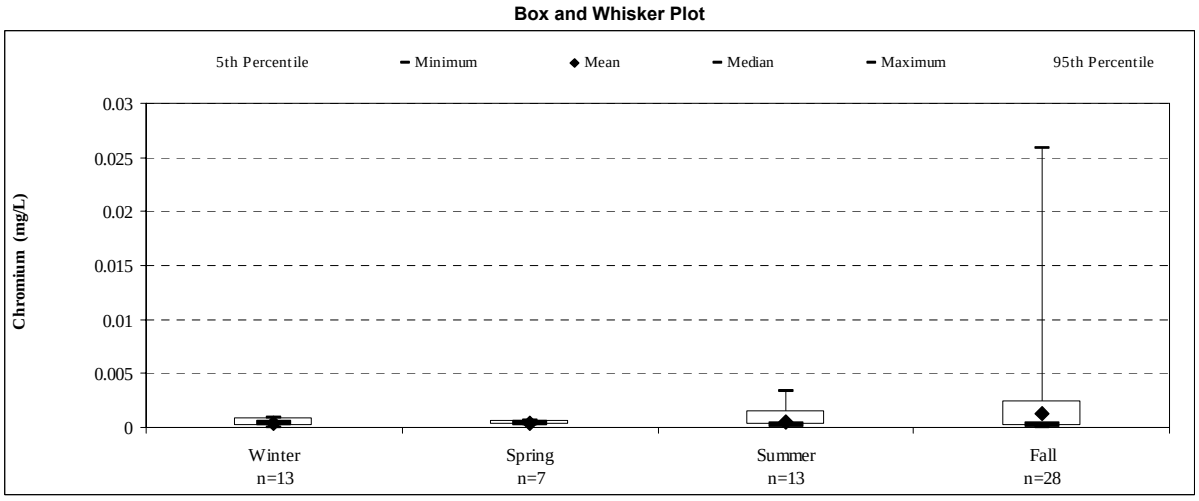


Figure G-1-2-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



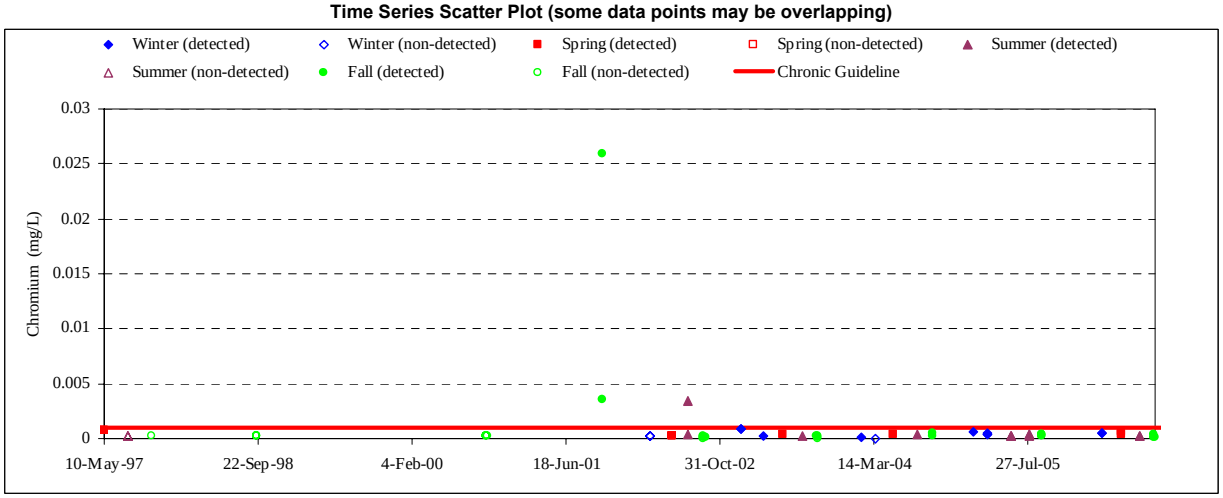
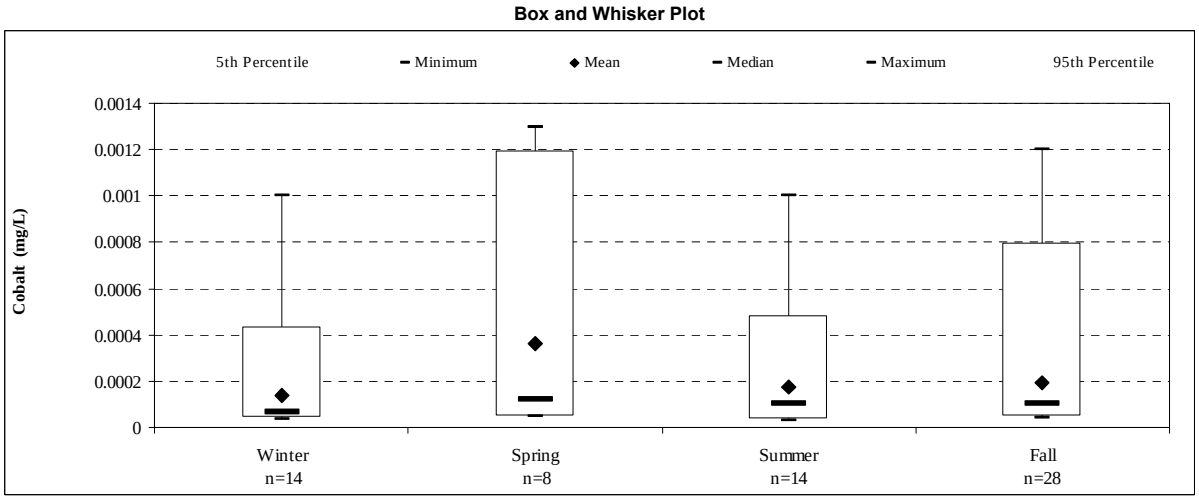


Figure G-1-2-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Middle Reach of Lower Athabasca River



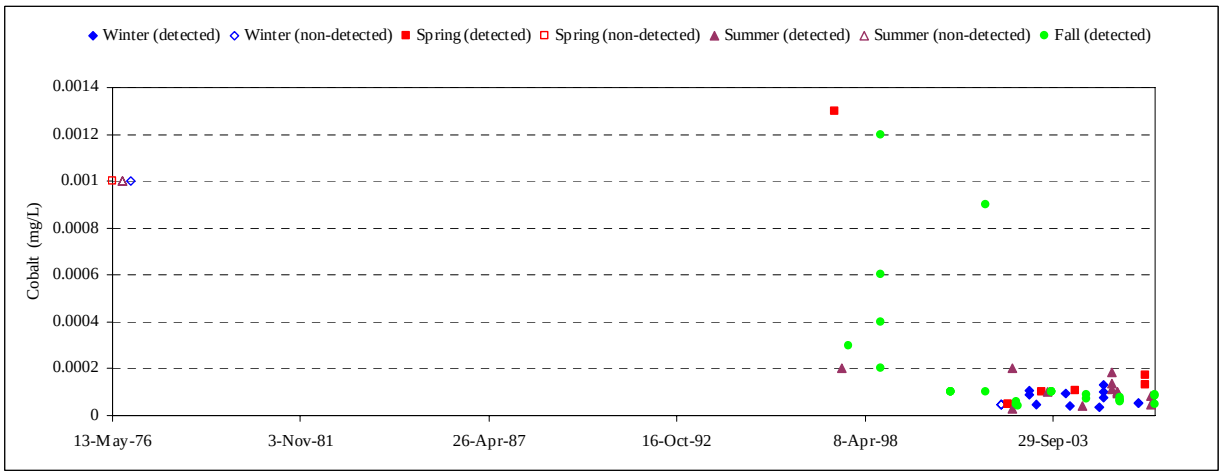
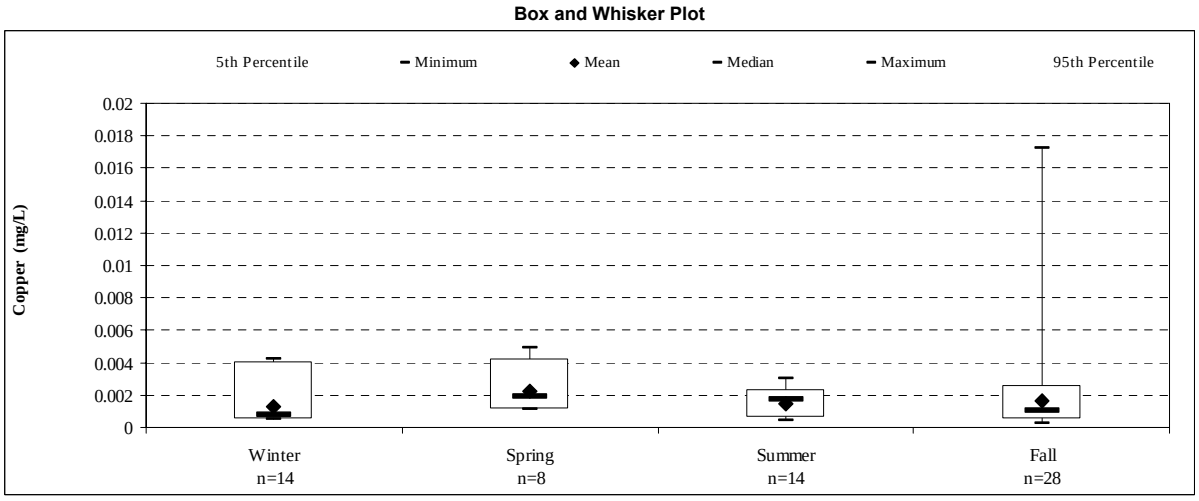


Figure G-1-2-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Middle Reach of Lower Athabasca River



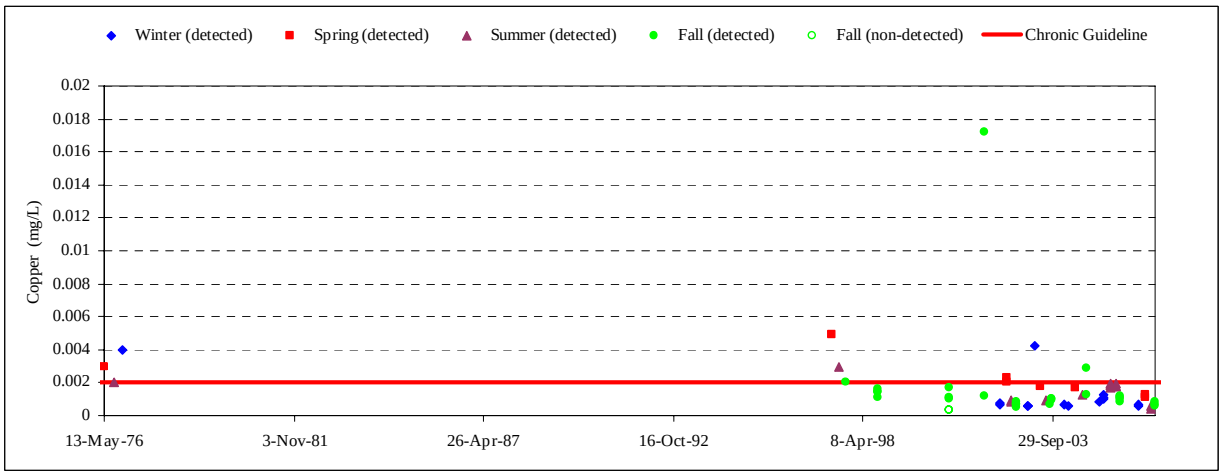


Figure G-1-2-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Middle Reach of Lower Athabasca River

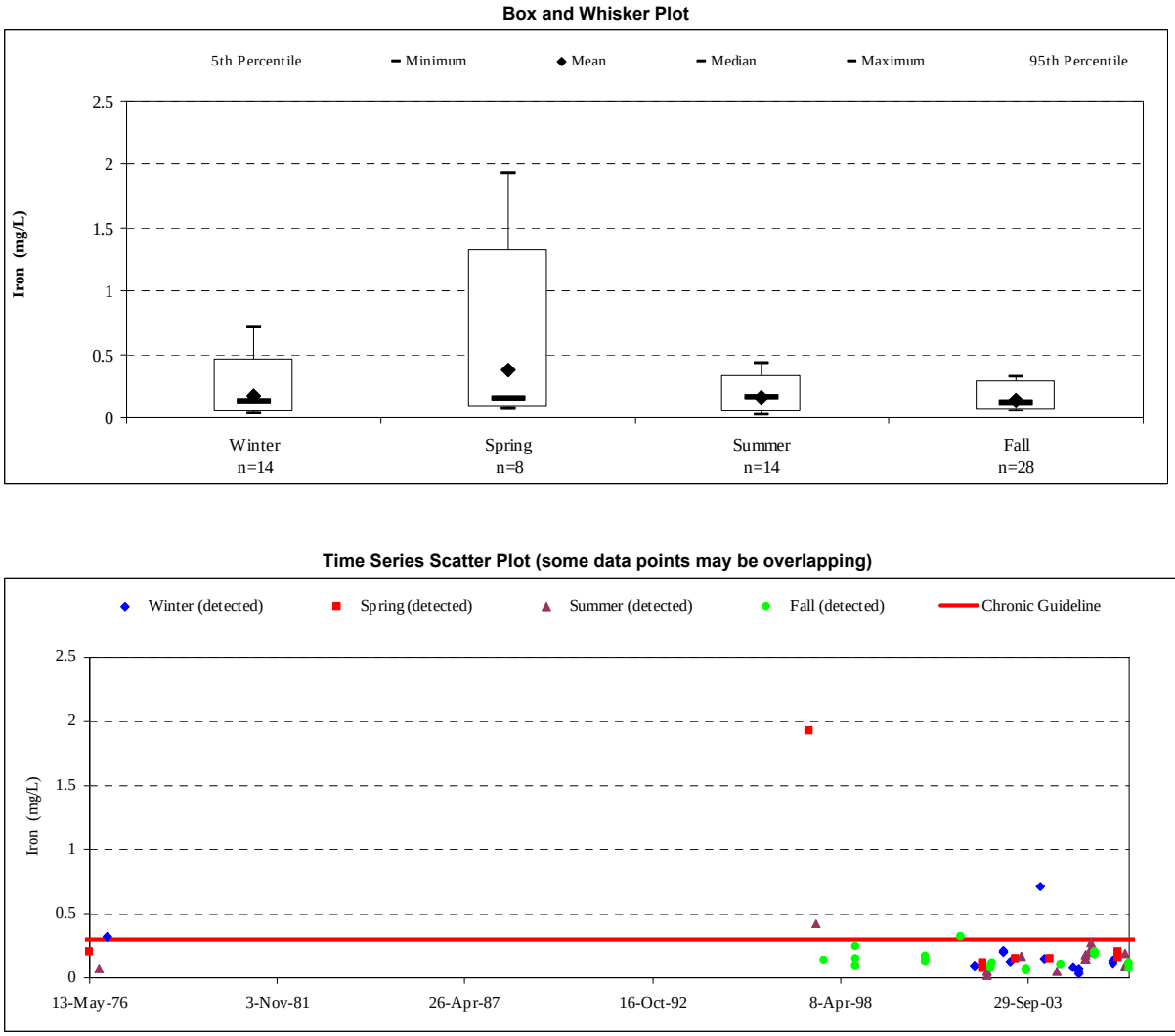


Figure G-1-2-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Middle Reach of Lower Athabasca River

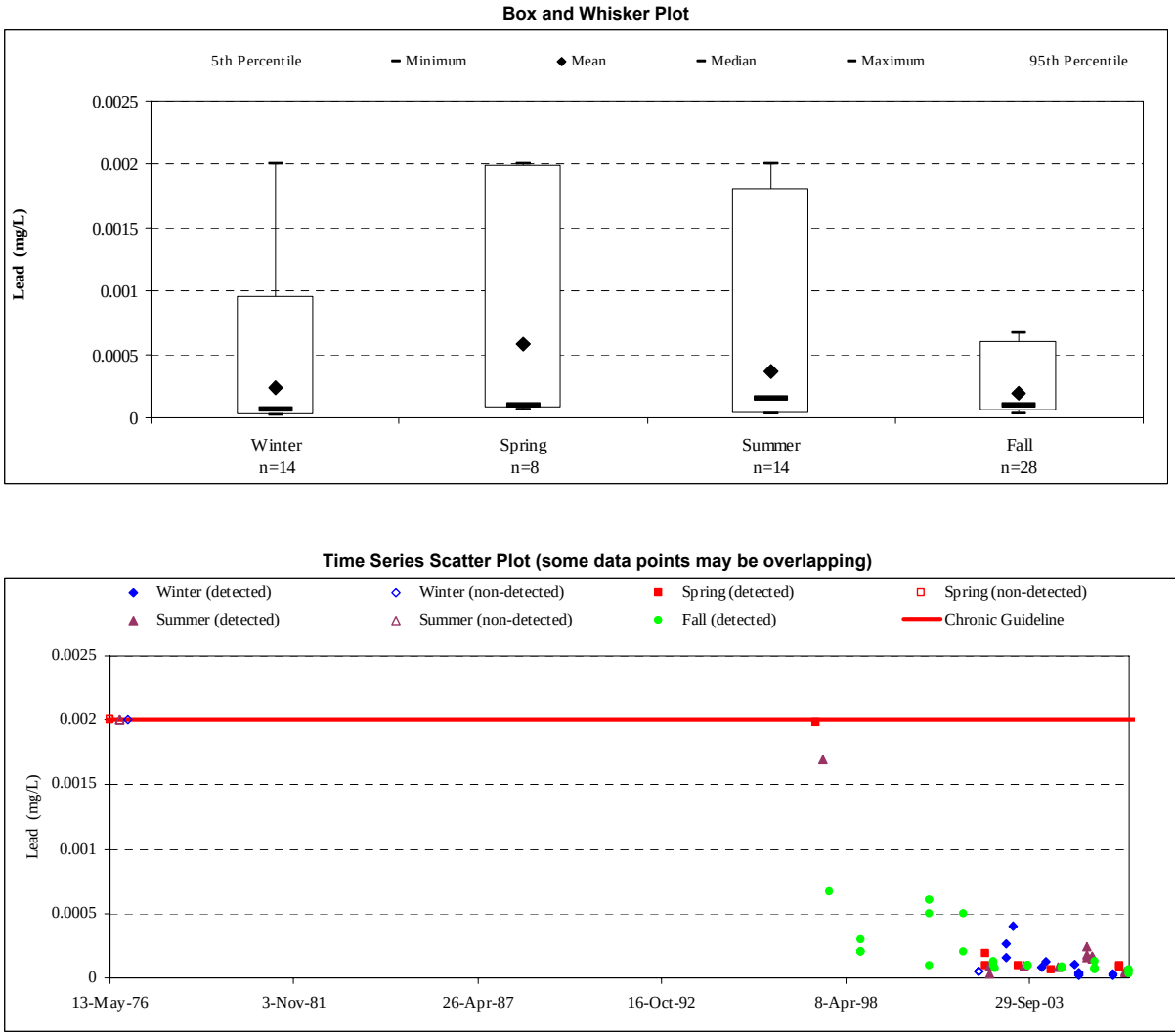
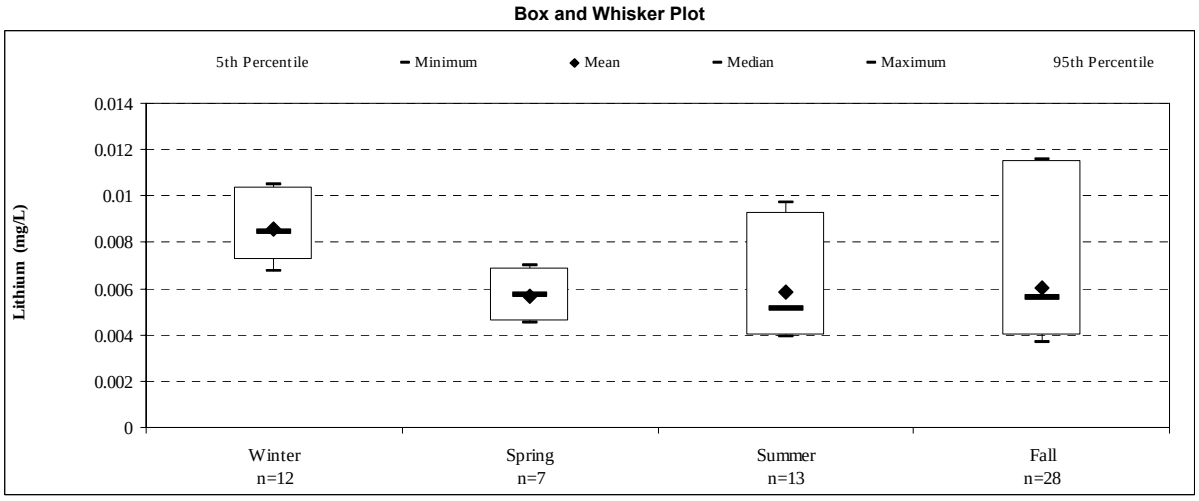


Figure G-1-2-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



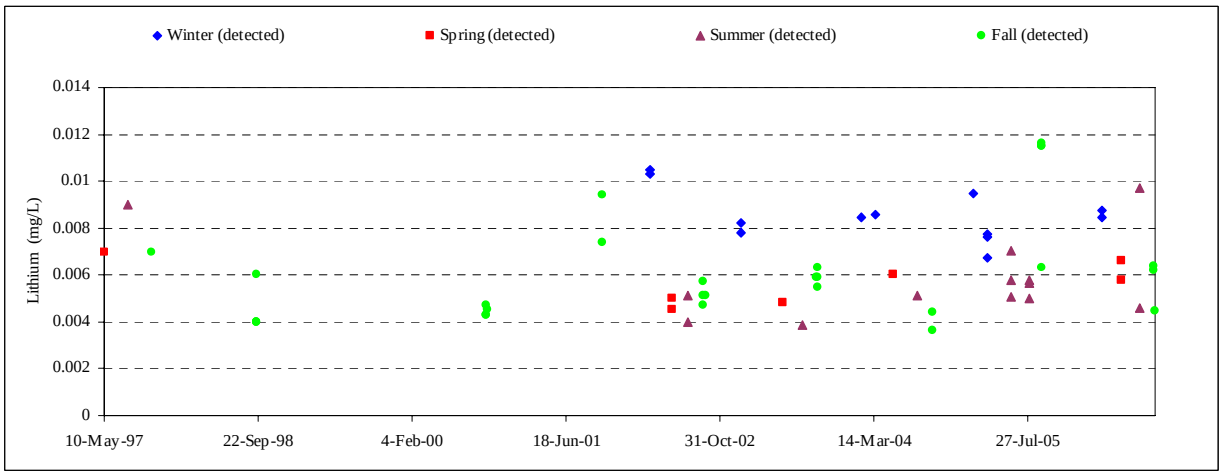
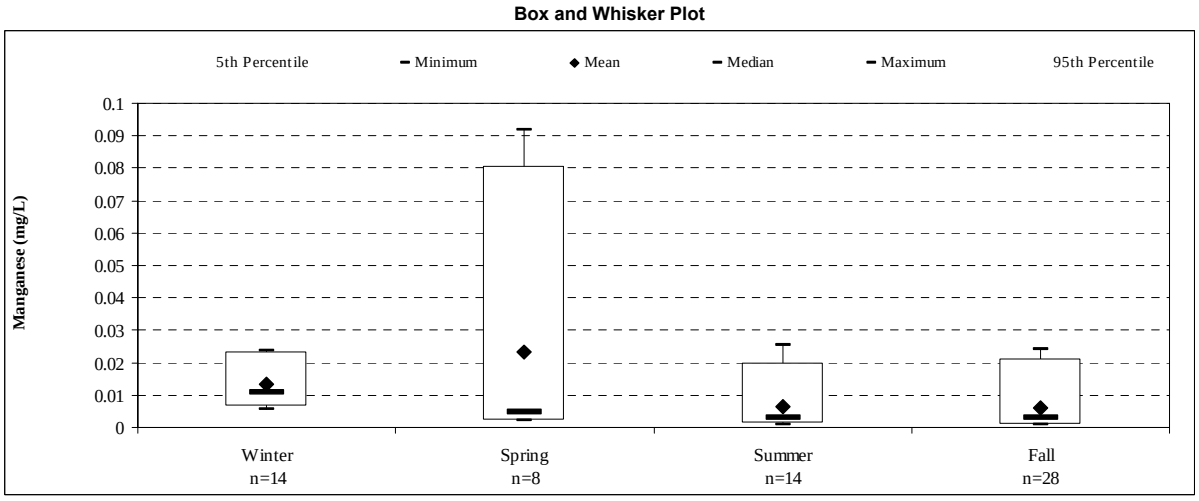


Figure G-1-2-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Middle Reach of Lower Athabasca River



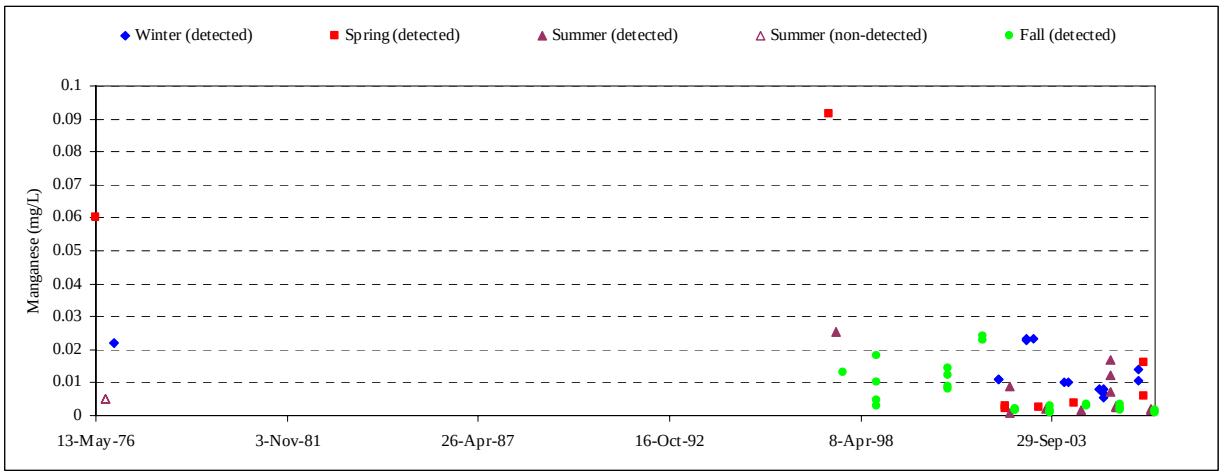
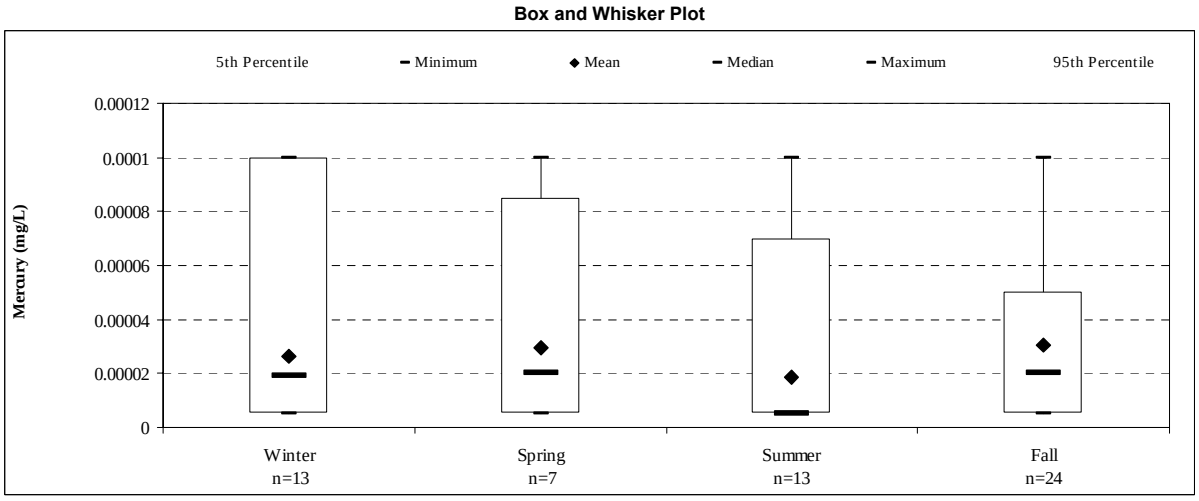


Figure G-1-2-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Middle Reach of Lower Athabasca River



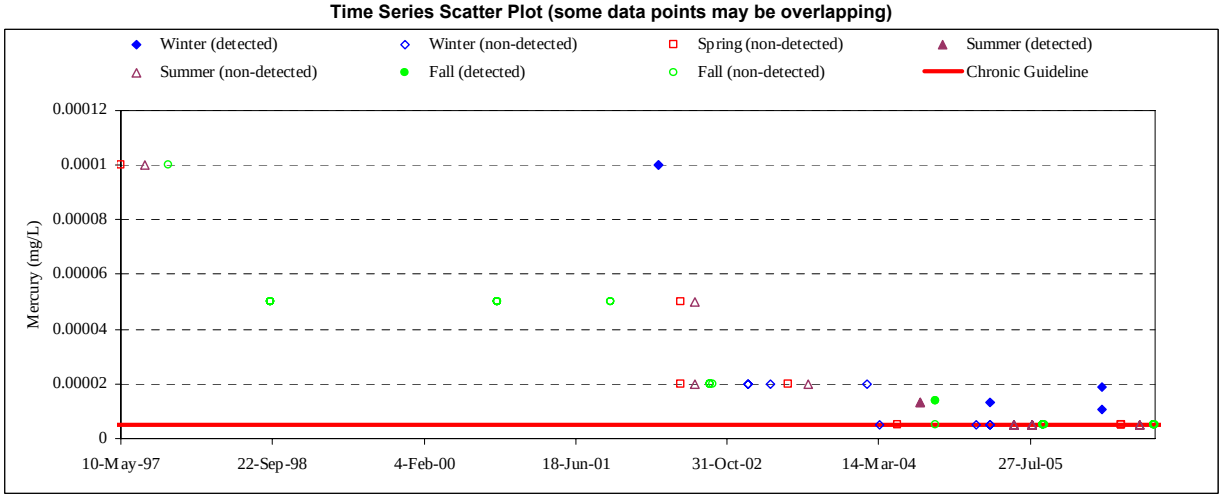
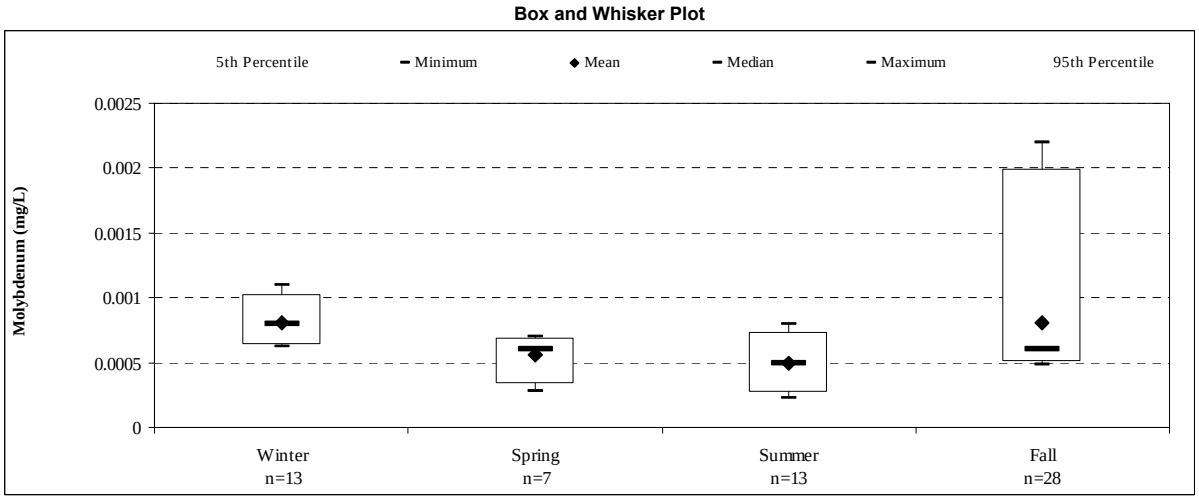


Figure G-1-2-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Middle Reach of Lower Athabasca River



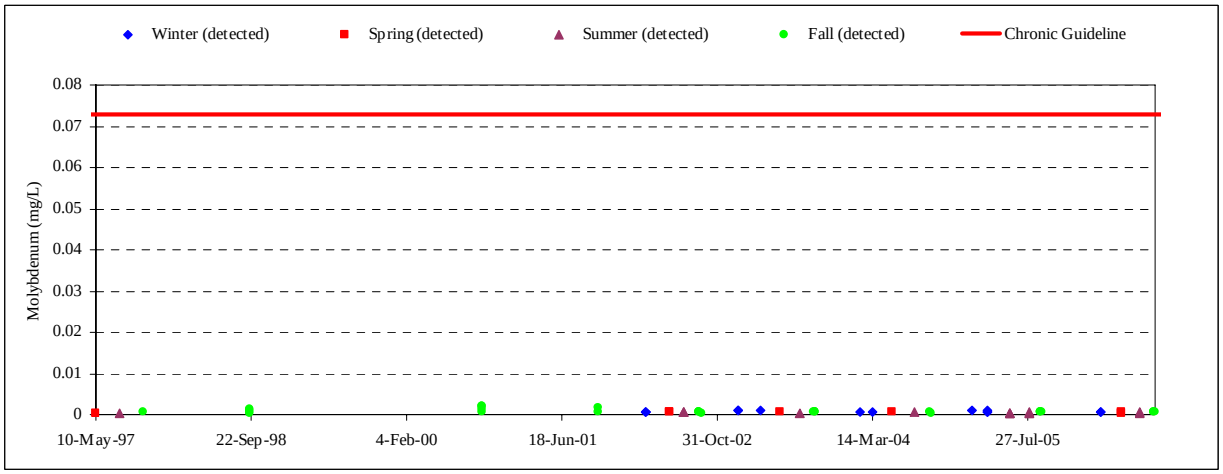


Figure G-1-2-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Middle Reach of Lower Athabasca River

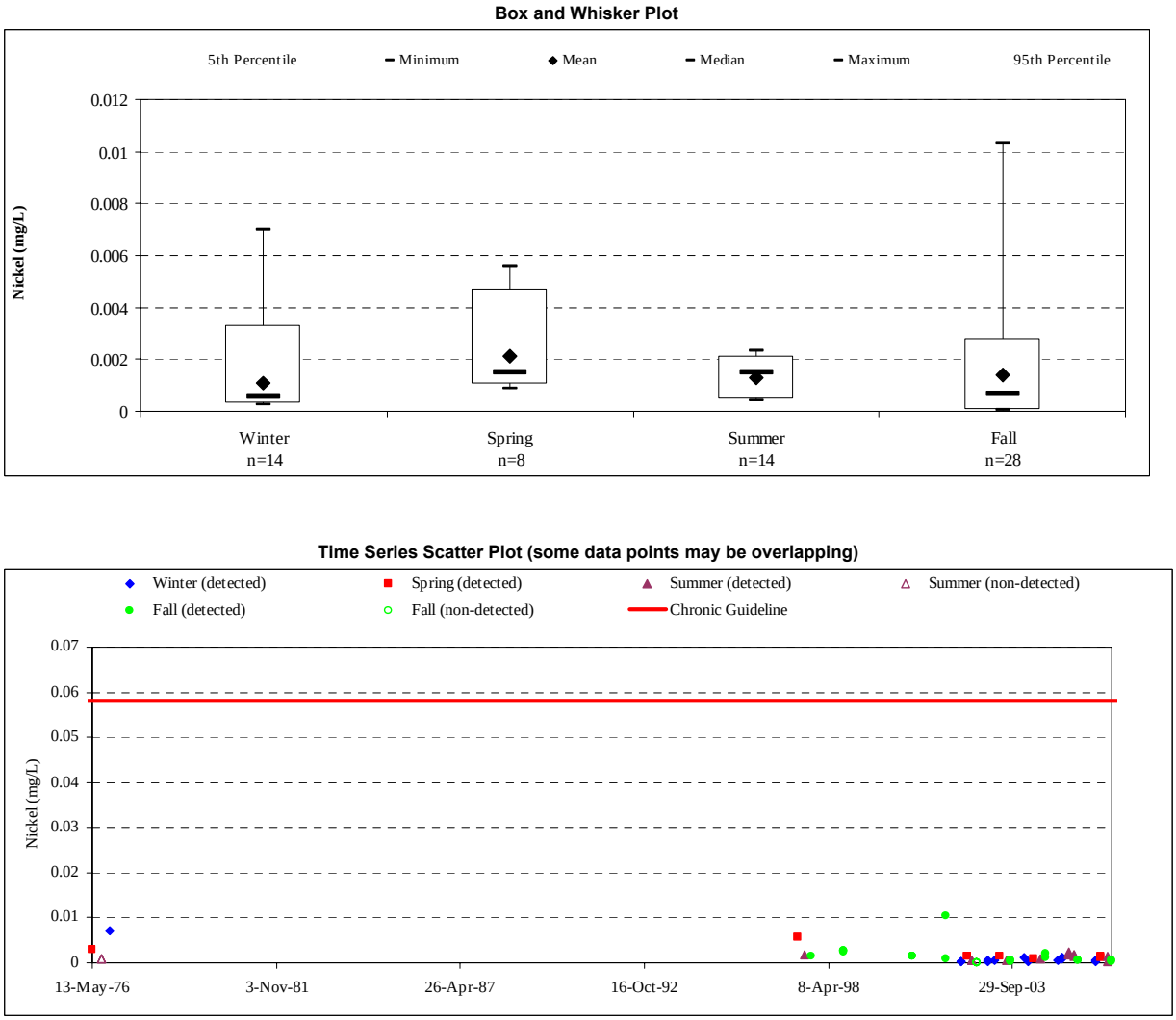


Figure G-1-2-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Middle Reach of Lower Athabasca River

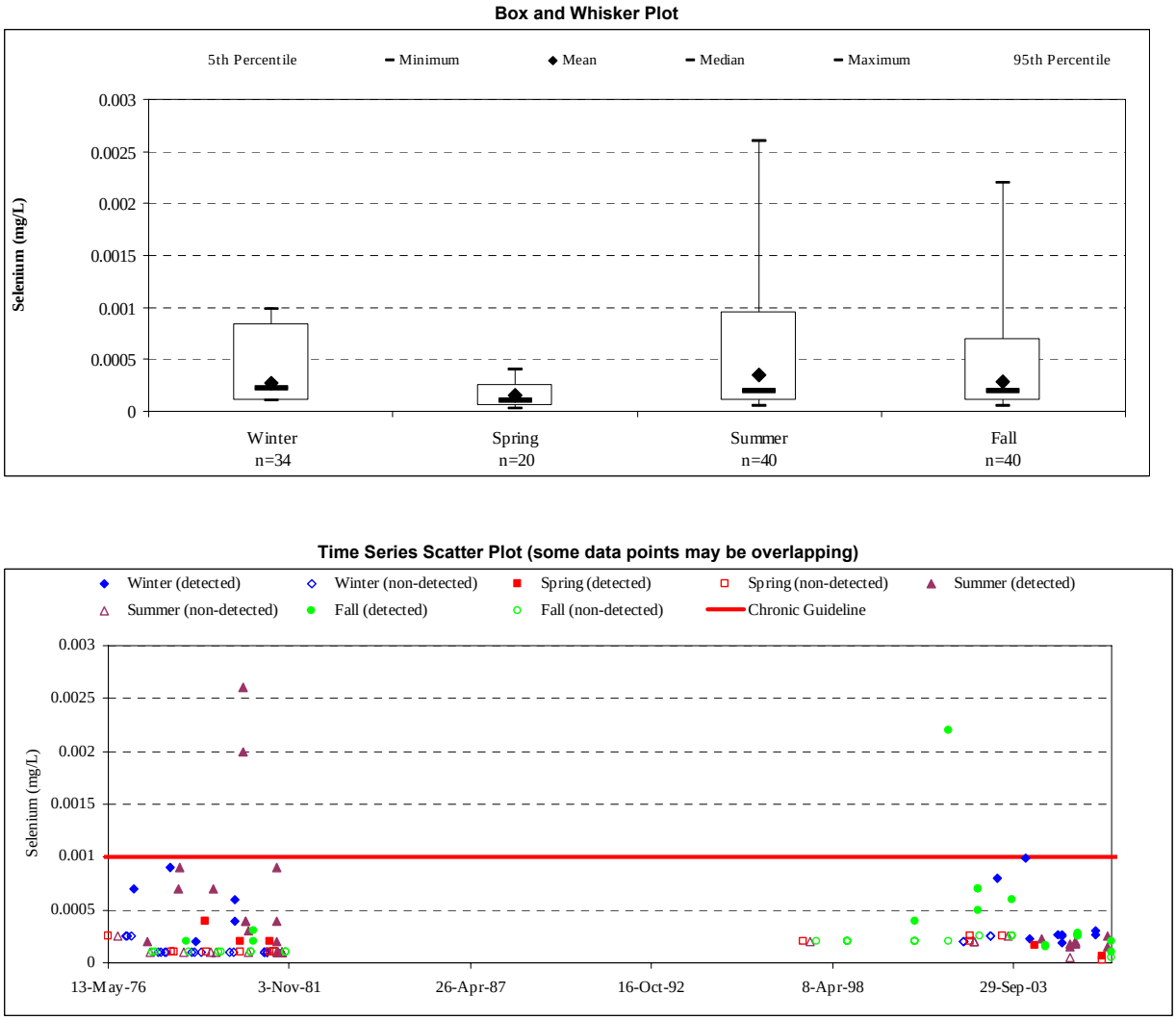
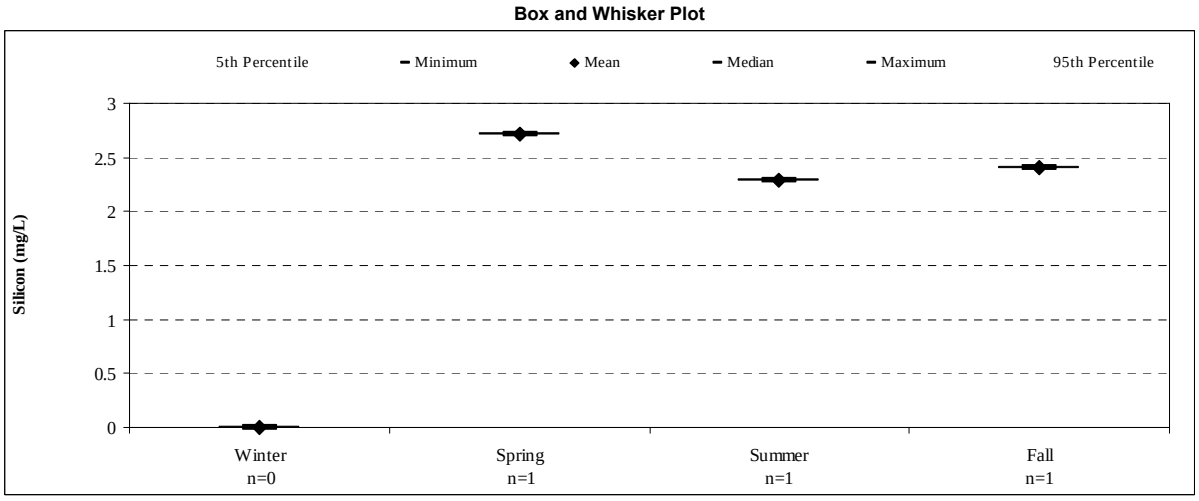


Figure G-1-2-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Middle Reach of Lower Athabasca River



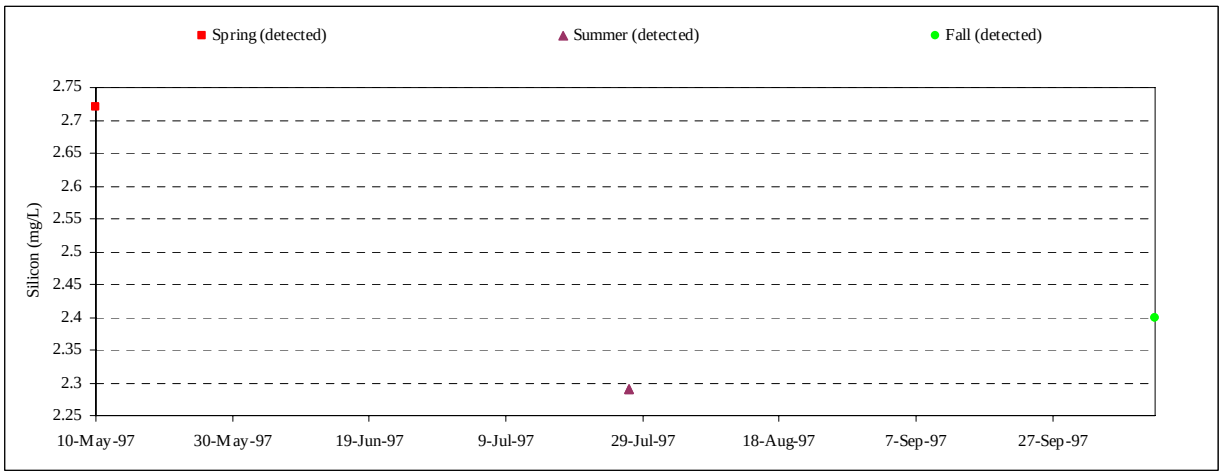


Figure G-1-2-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Middle Reach of Lower Athabasca River

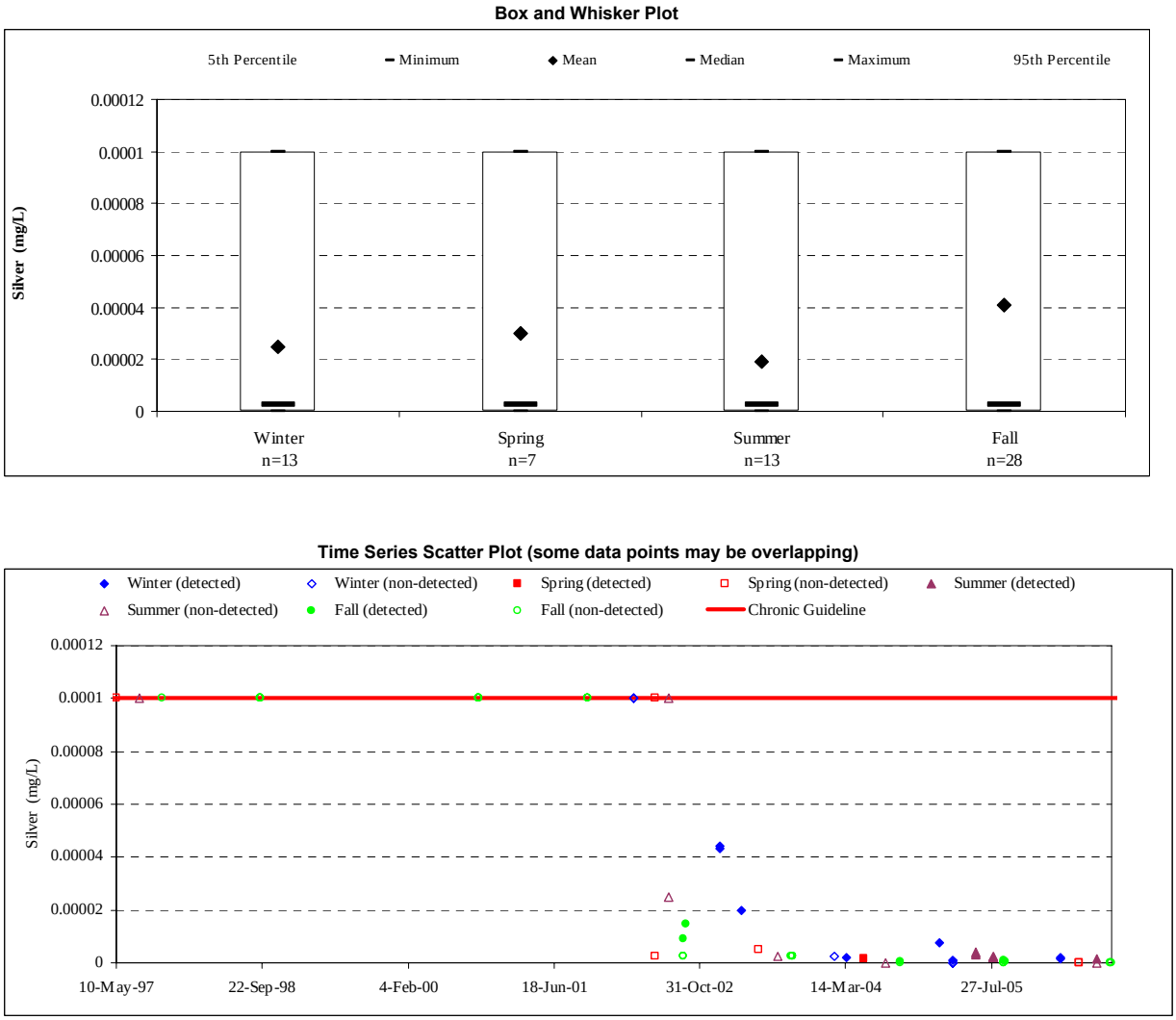


Figure G-1-2-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Middle Reach of Lower Athabasca River

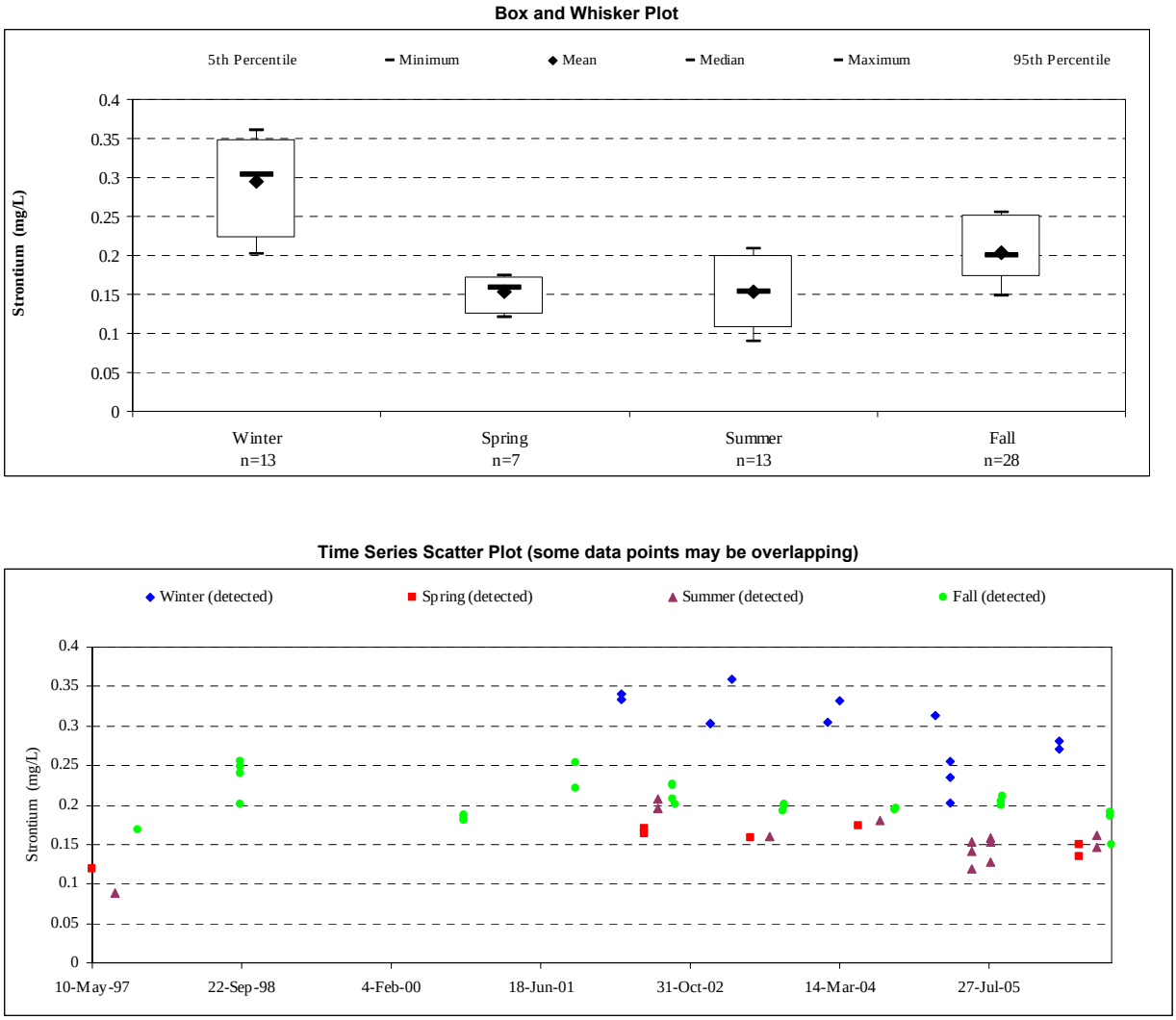
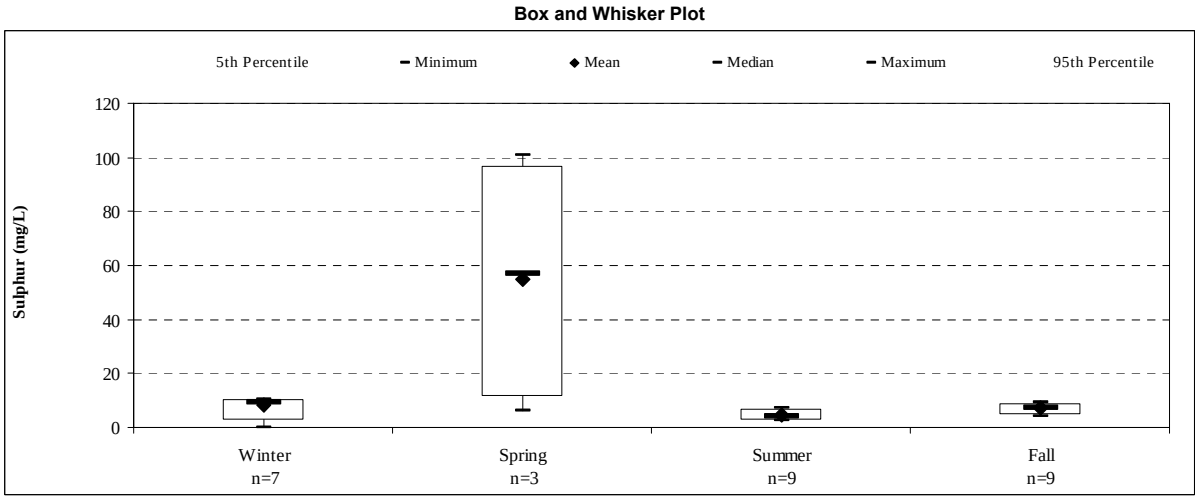


Figure G-1-2-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Middle Reach of Lower Athabasca River



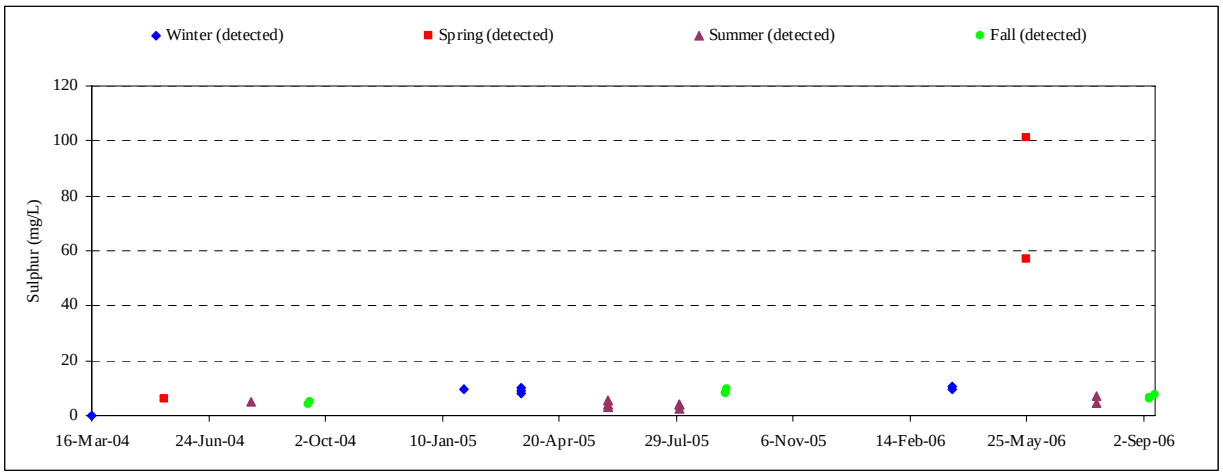
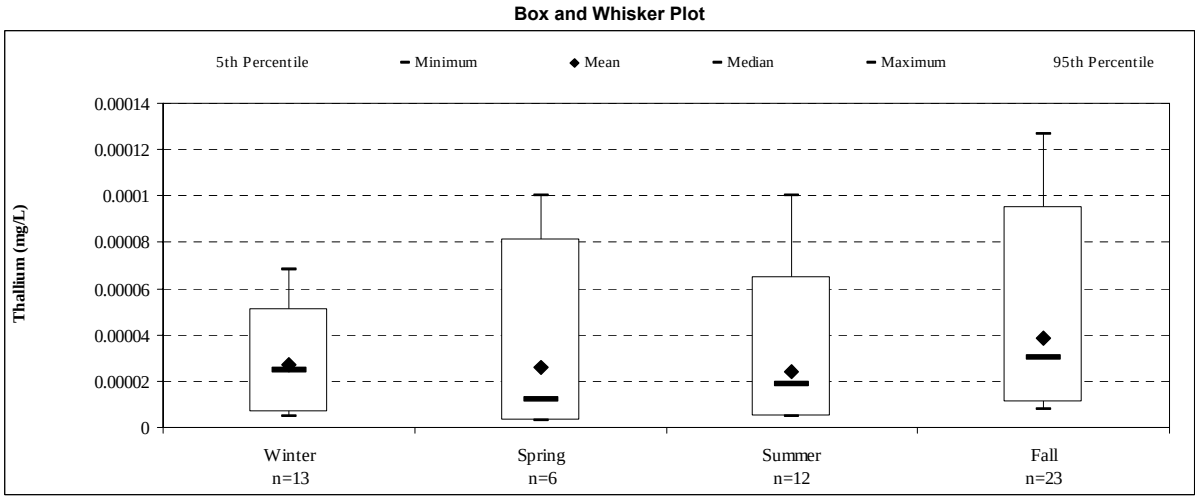


Figure G-1-2-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



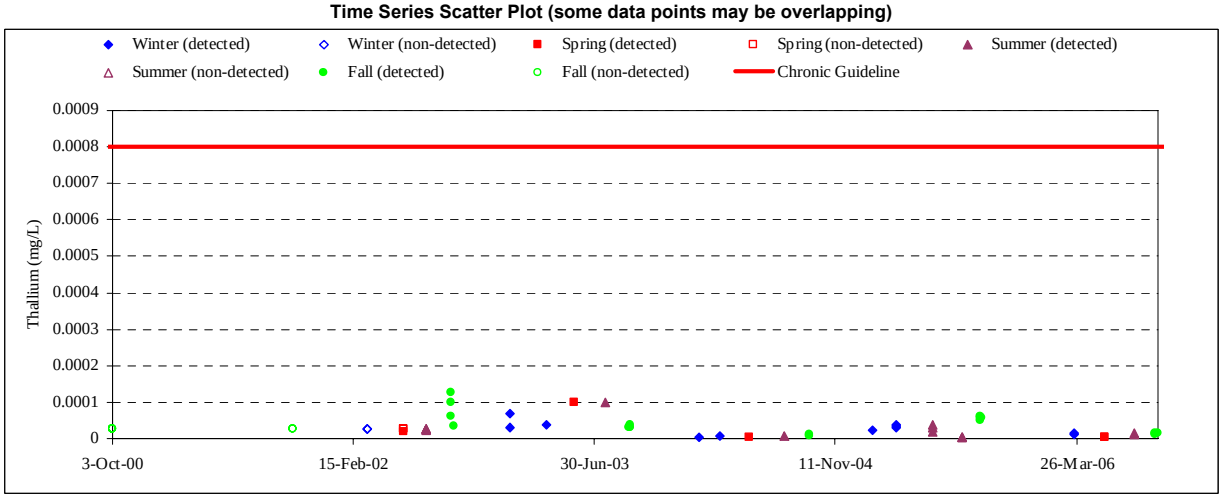
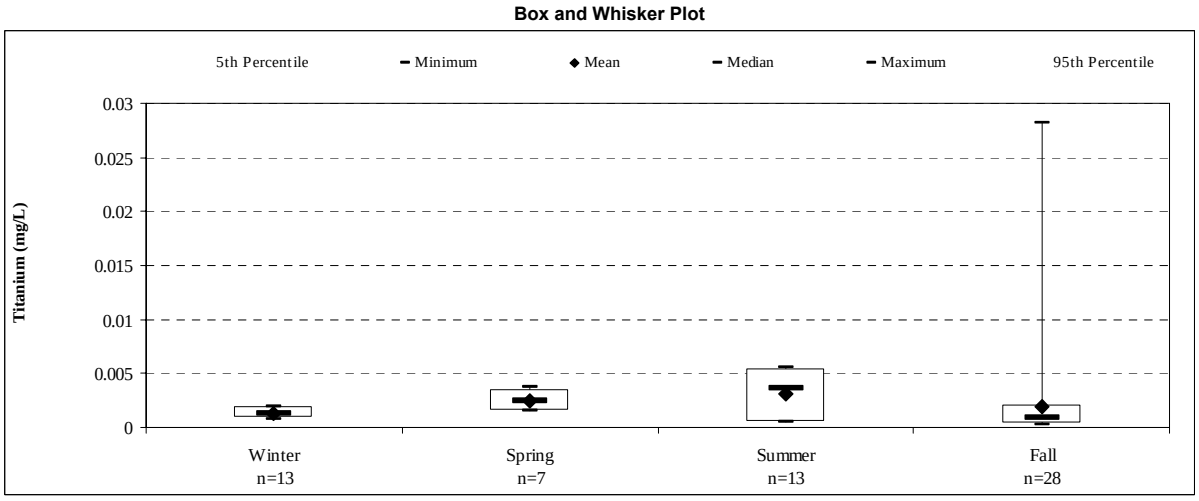


Figure G-1-2-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



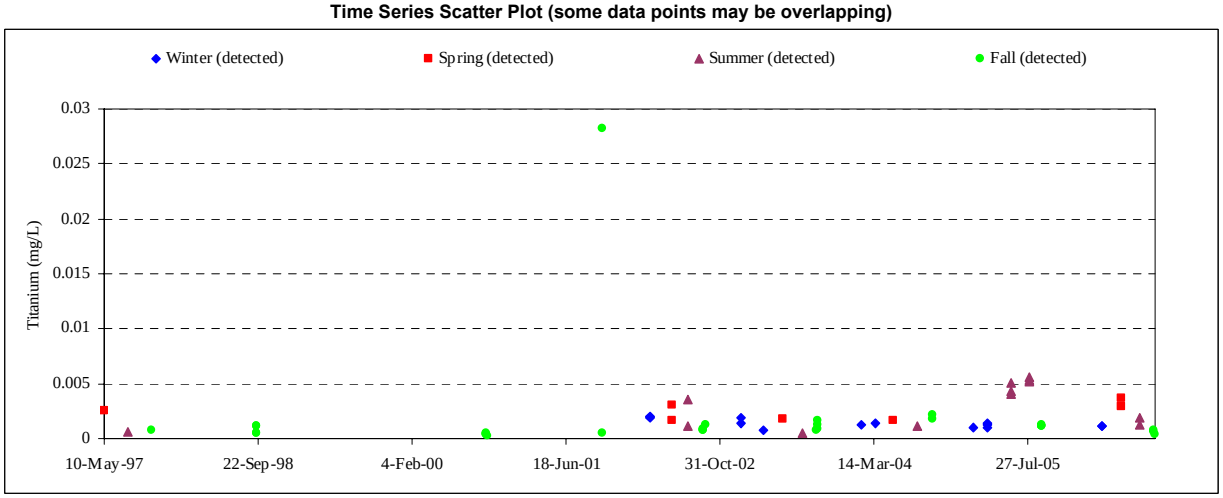
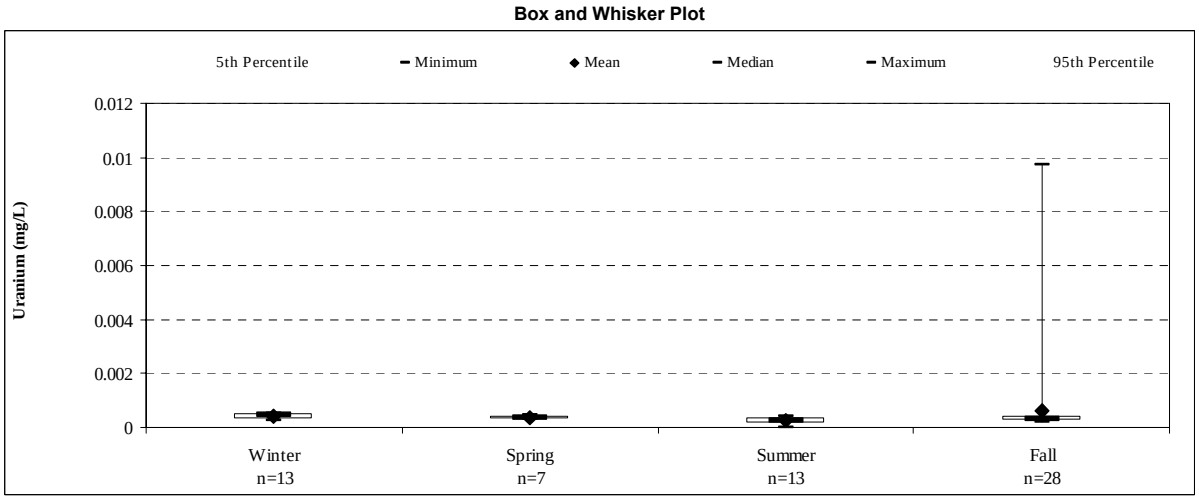


Figure G-1-2-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



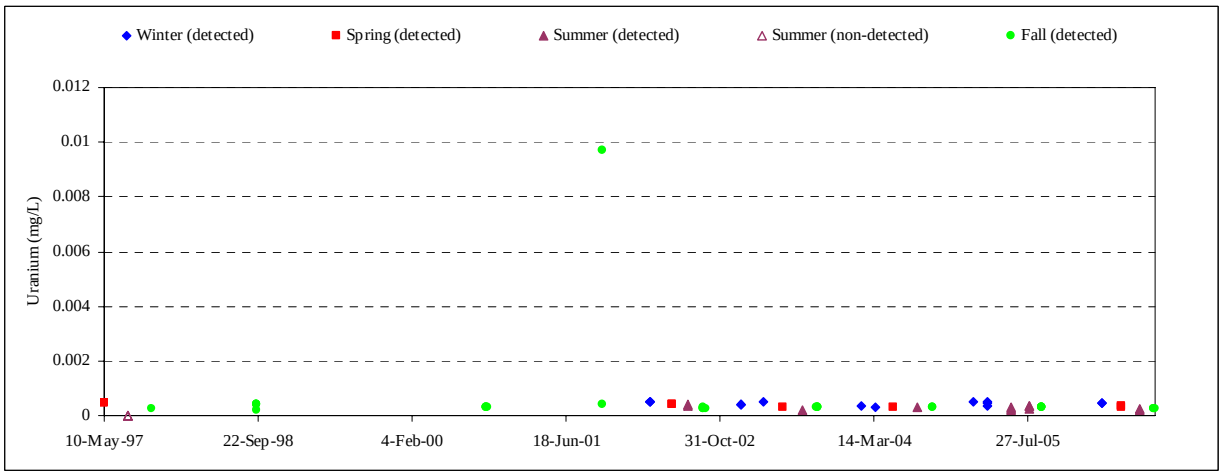
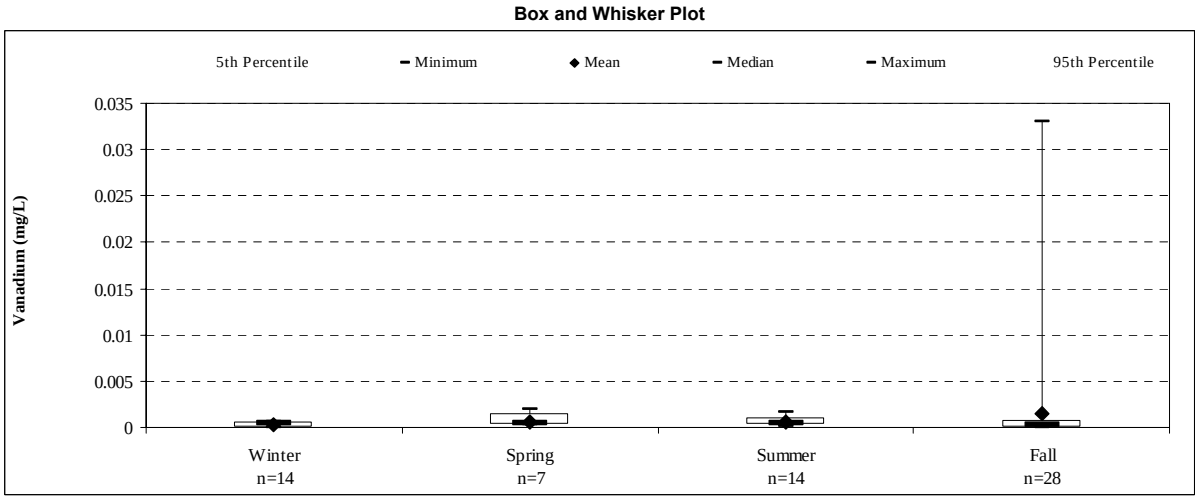


Figure G-1-2-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Middle Reach of Lower Athabasca River



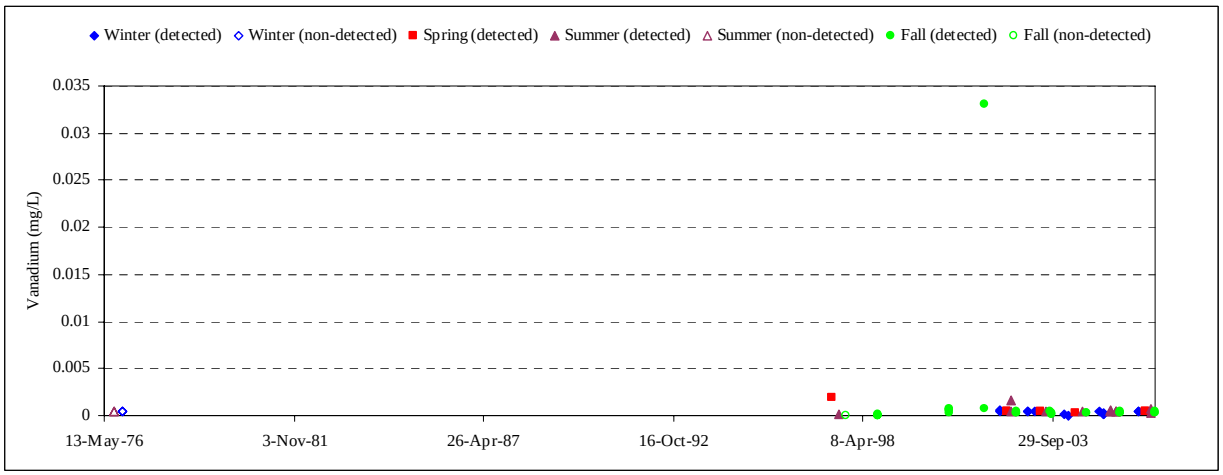
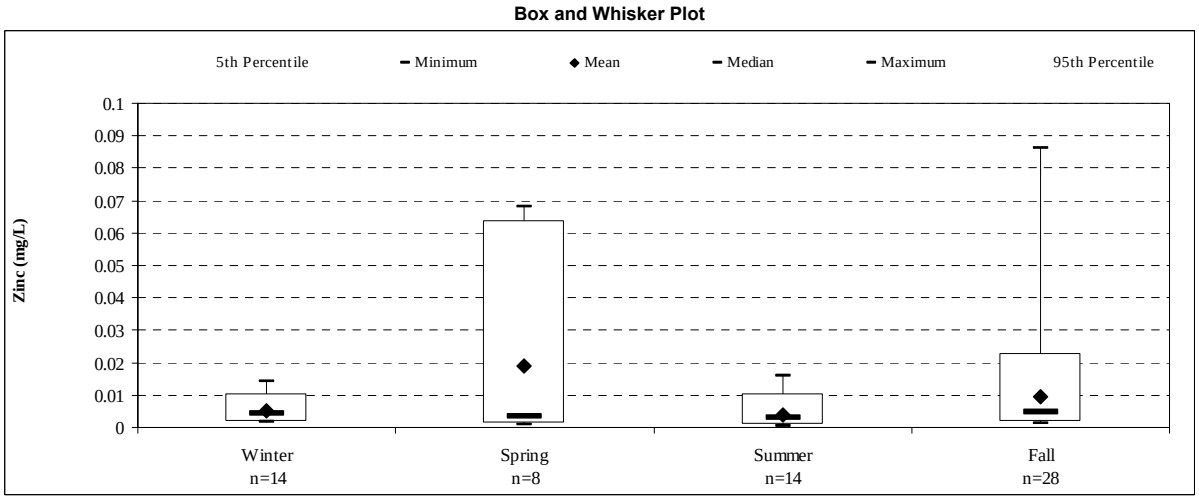


Figure G-1-2-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Middle Reach of Lower Athabasca River



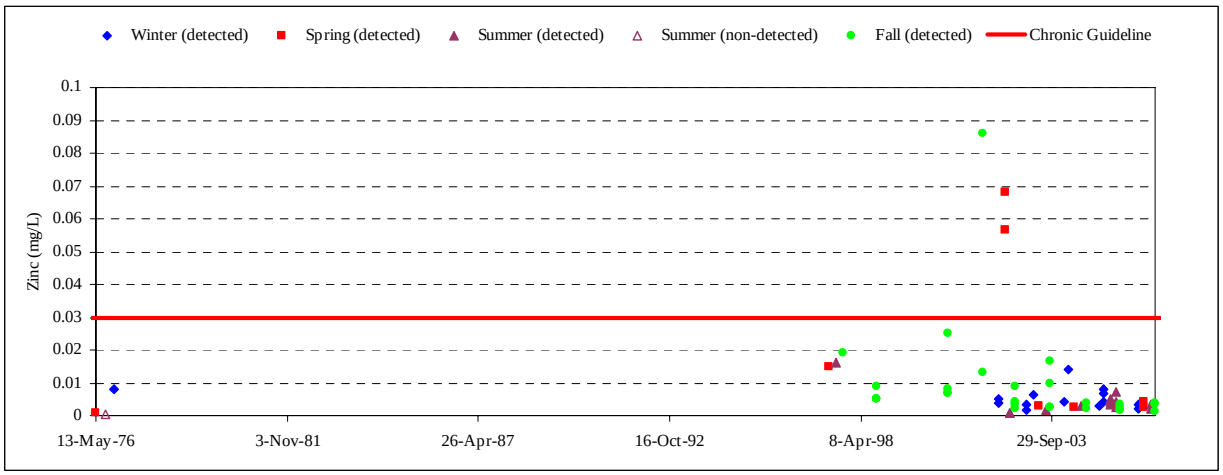
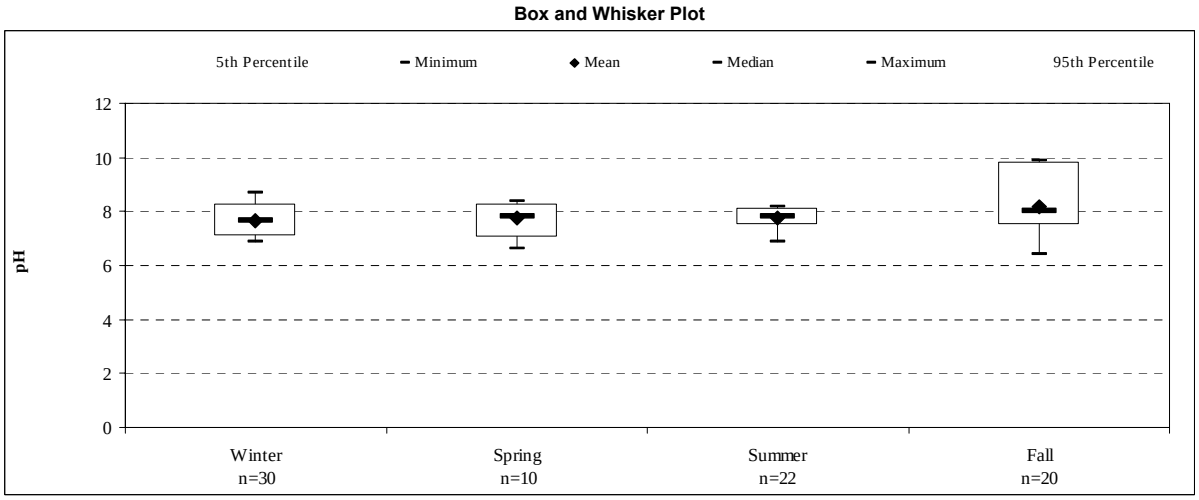


Figure G-1-3-1 Box Whisker and Time Series Scatter Plots of Observed pH in Lower Reach of Lower Athabasca River



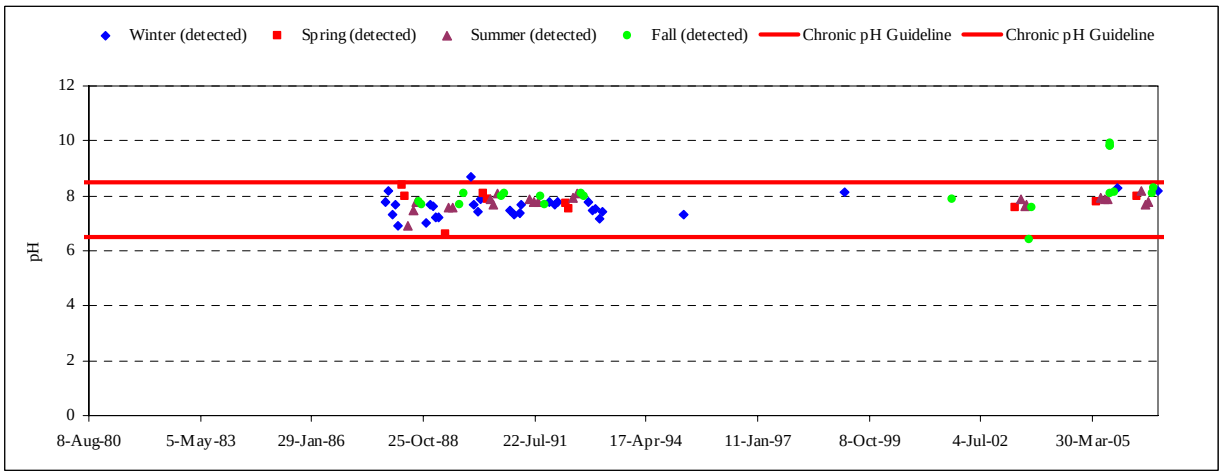
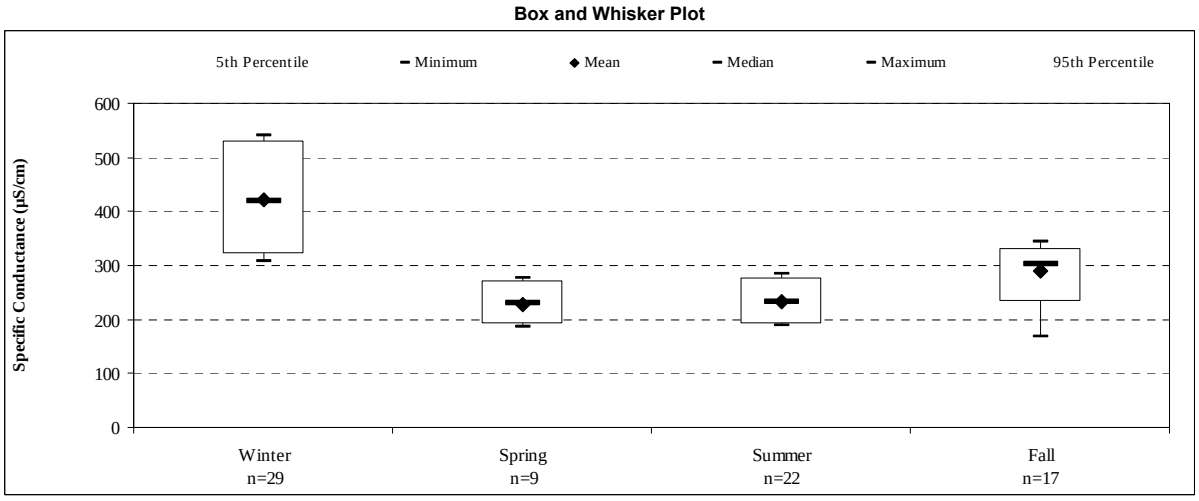


Figure G-1-3-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Lower Reach of Lower Athabasca River



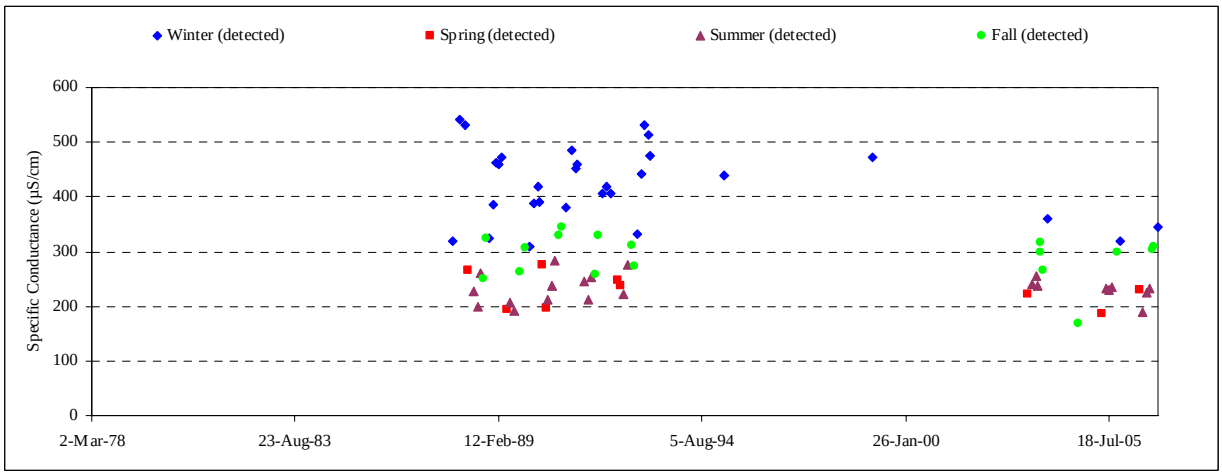
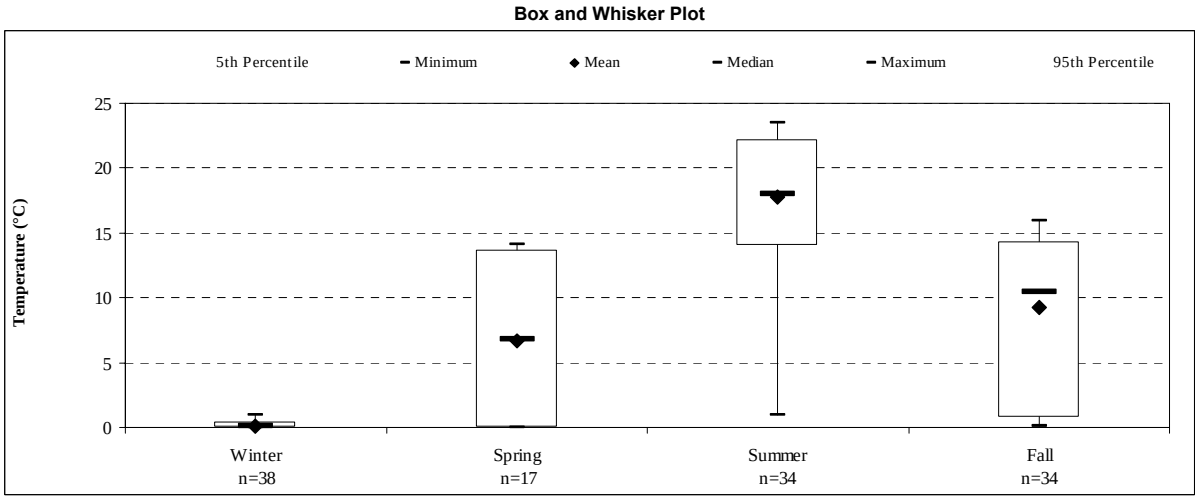


Figure G-1-3-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Lower Reach of Lower Athabasca River



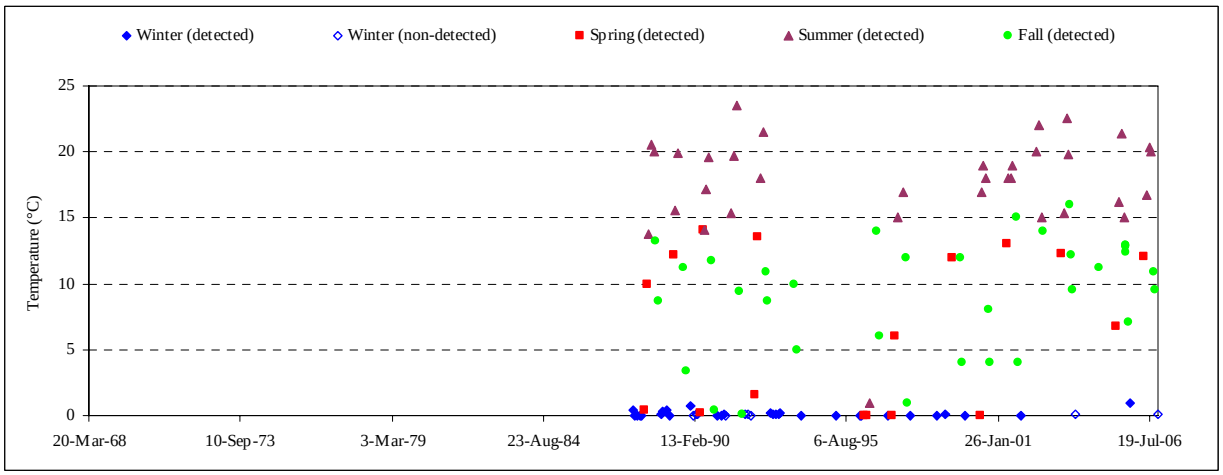
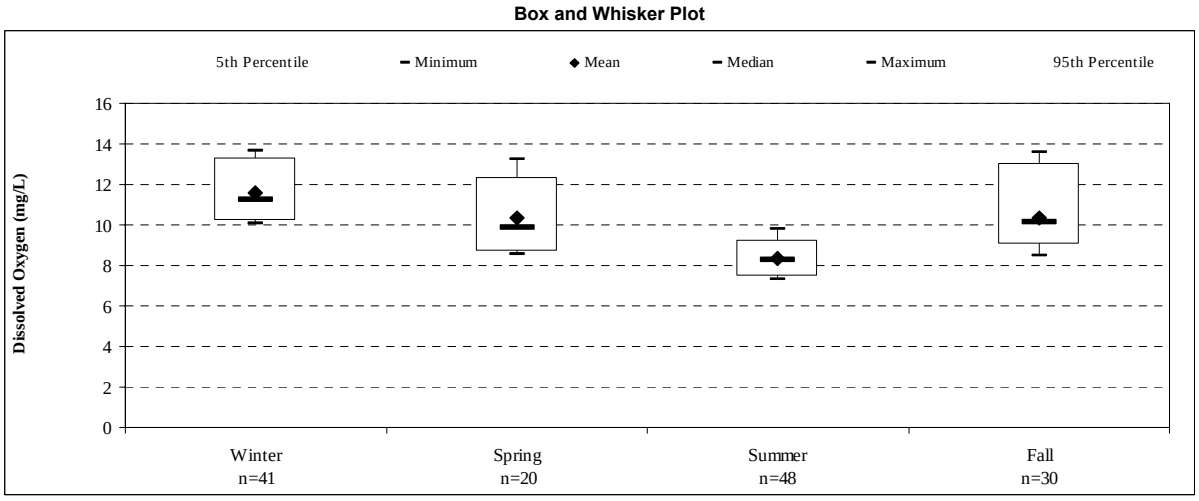


Figure G-1-3-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Lower Reach of Lower Athabasca River



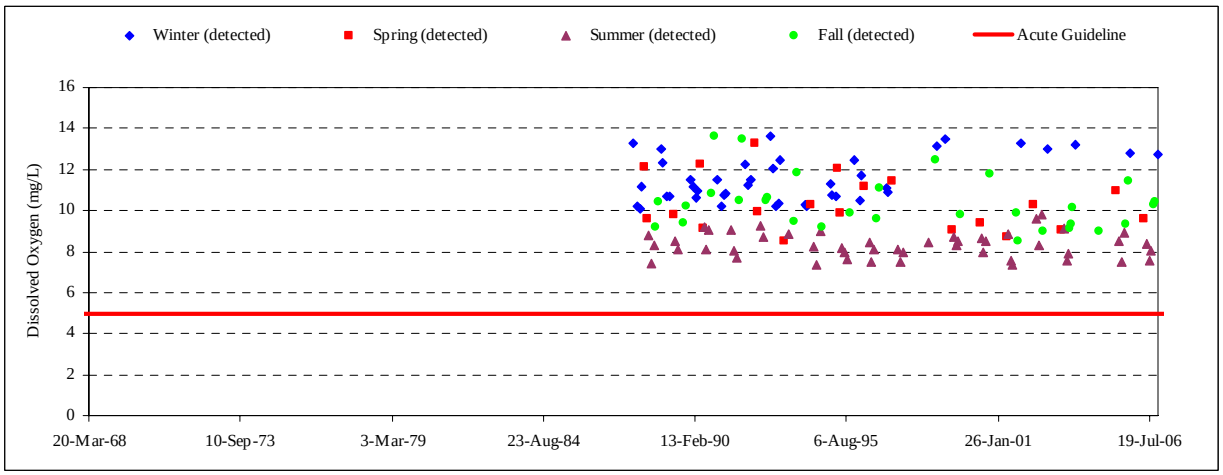
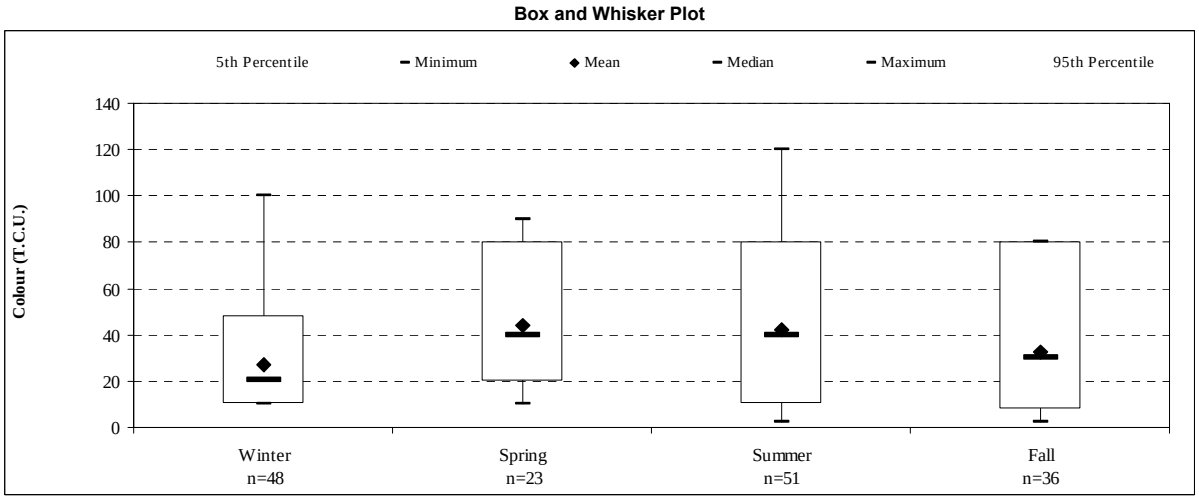


Figure G-1-3-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Lower Reach of Lower Athabasca River



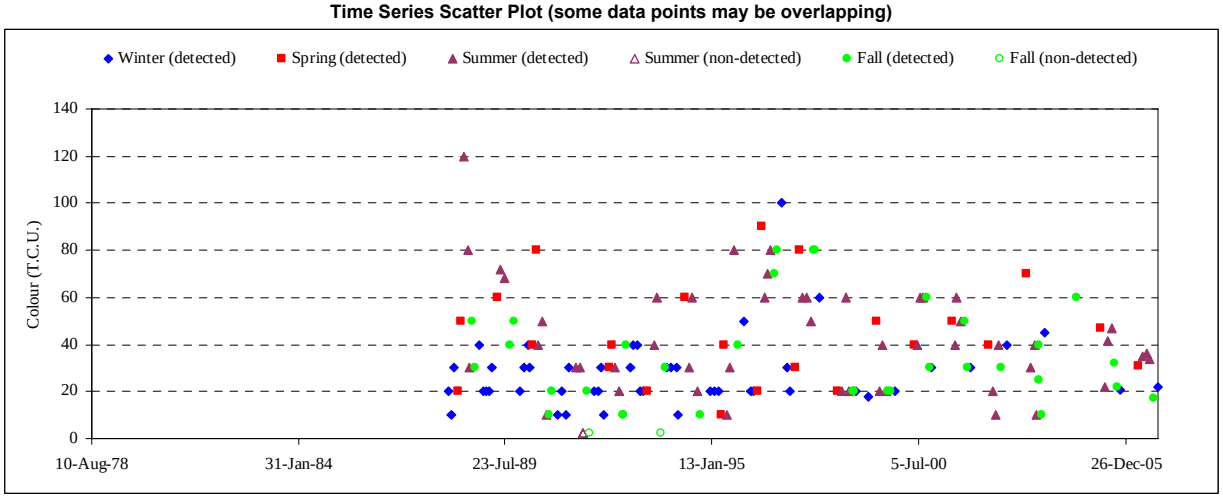


Figure G-1-3-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Lower Reach of Lower Athabasca River

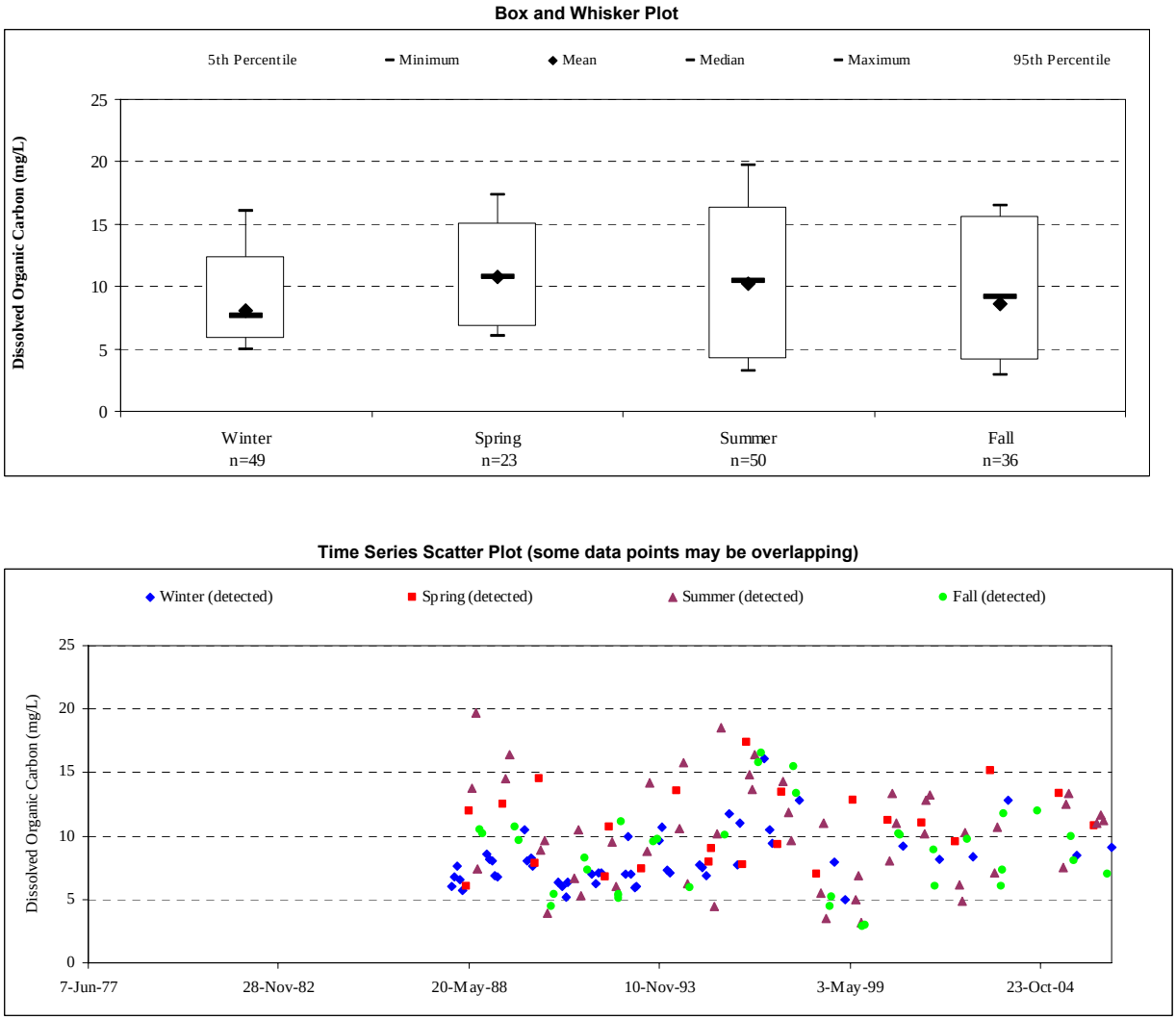
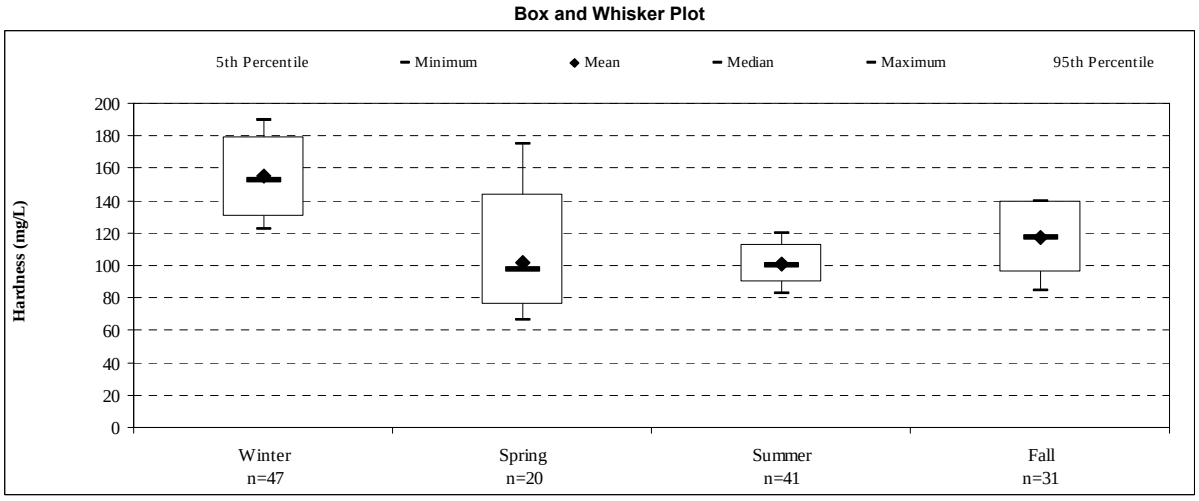


Figure G-1-3-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Lower Reach of Lower Athabasca River



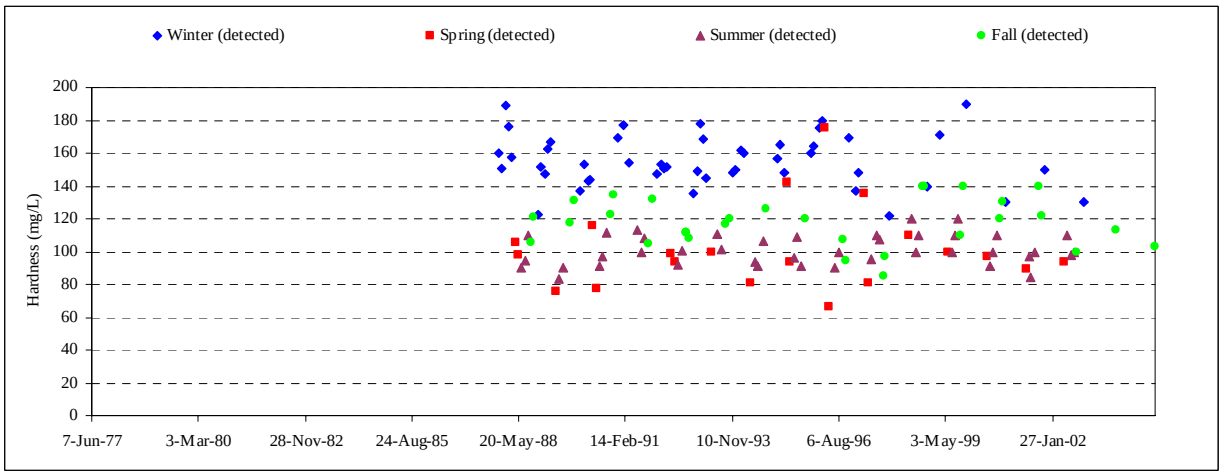
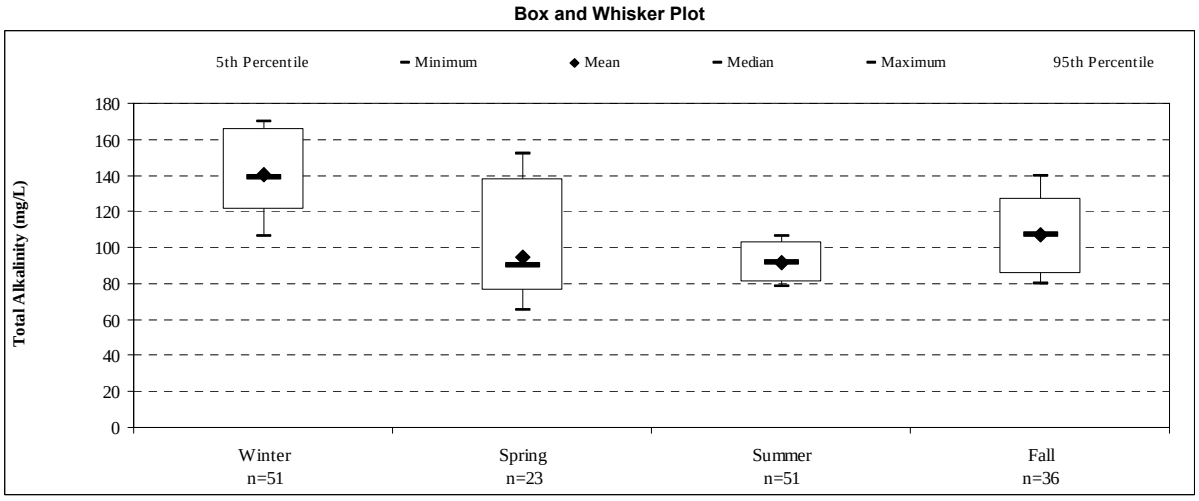


Figure G-1-3-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Lower Reach of Lower Athabasca River



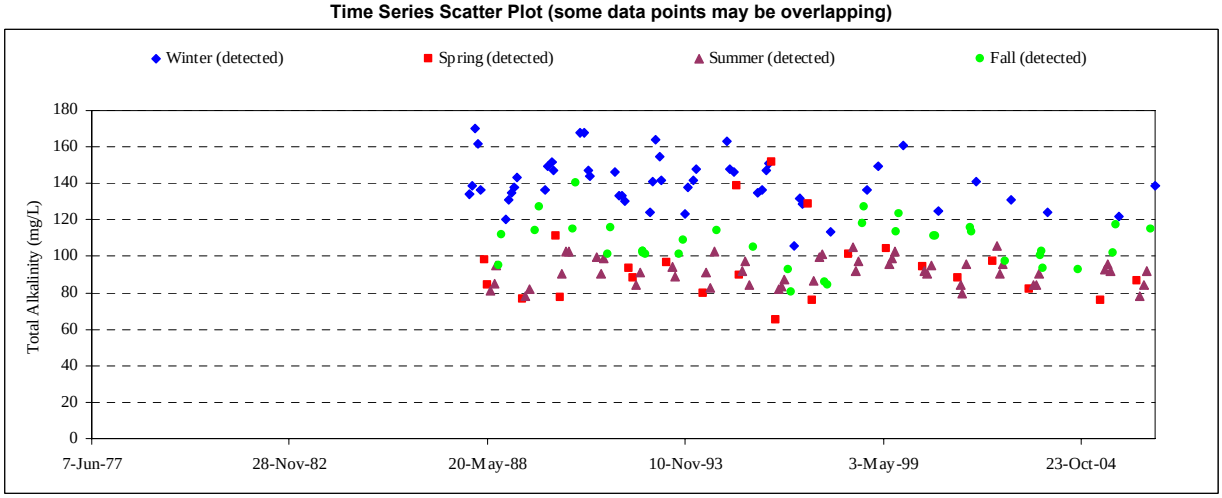
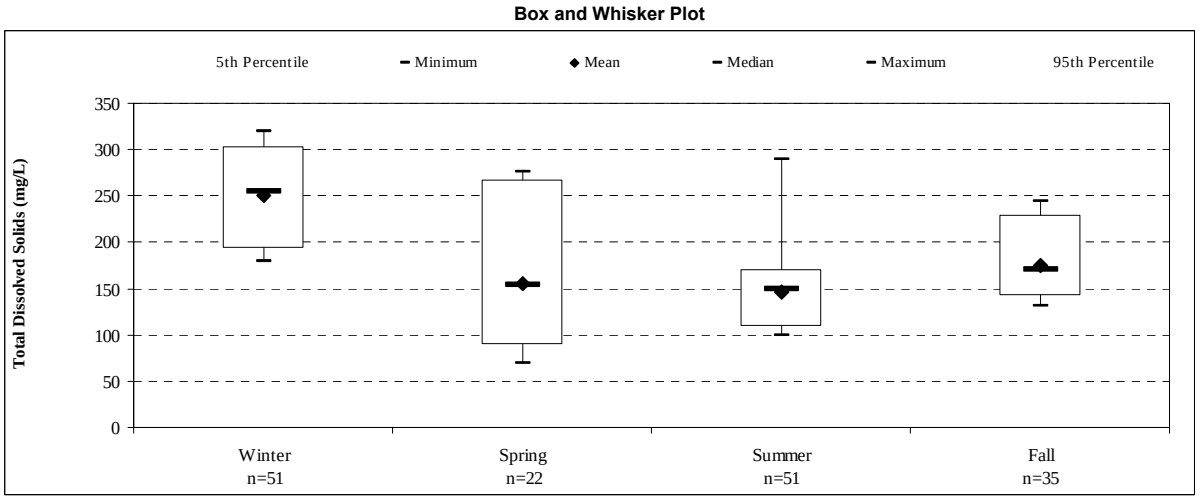


Figure G-1-3-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Lower Reach of Lower Athabasca River



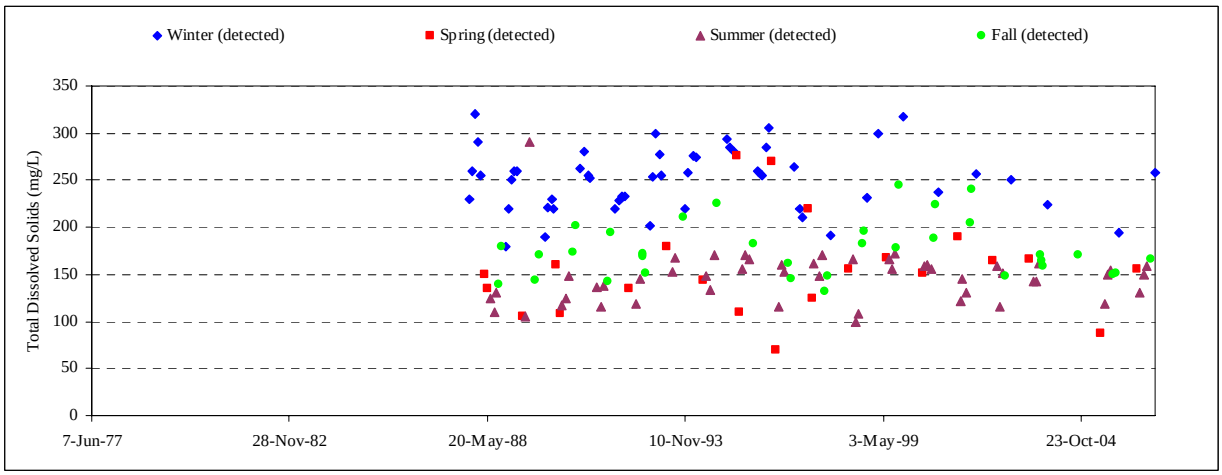
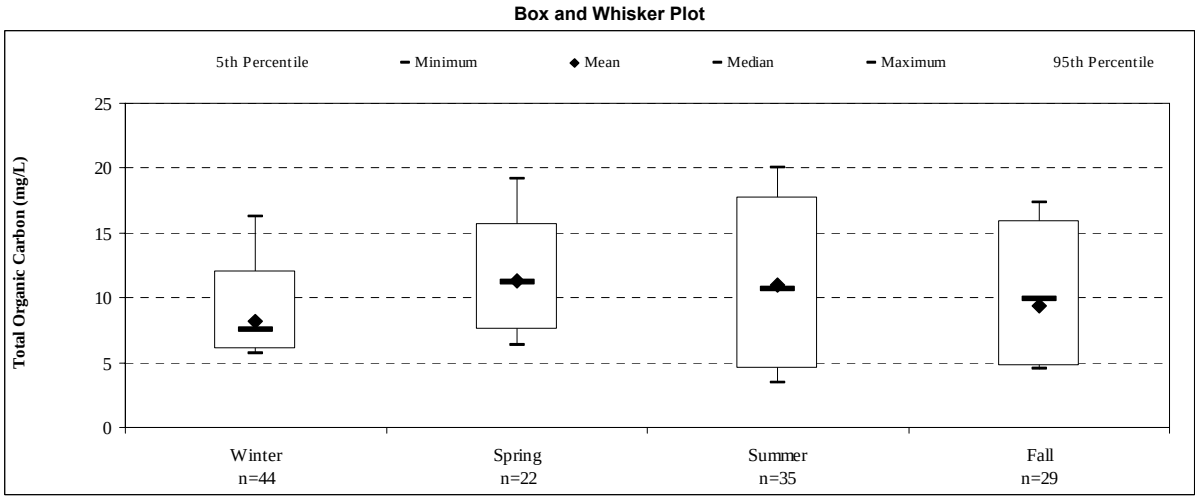


Figure G-1-3-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Lower Reach of Lower Athabasca River



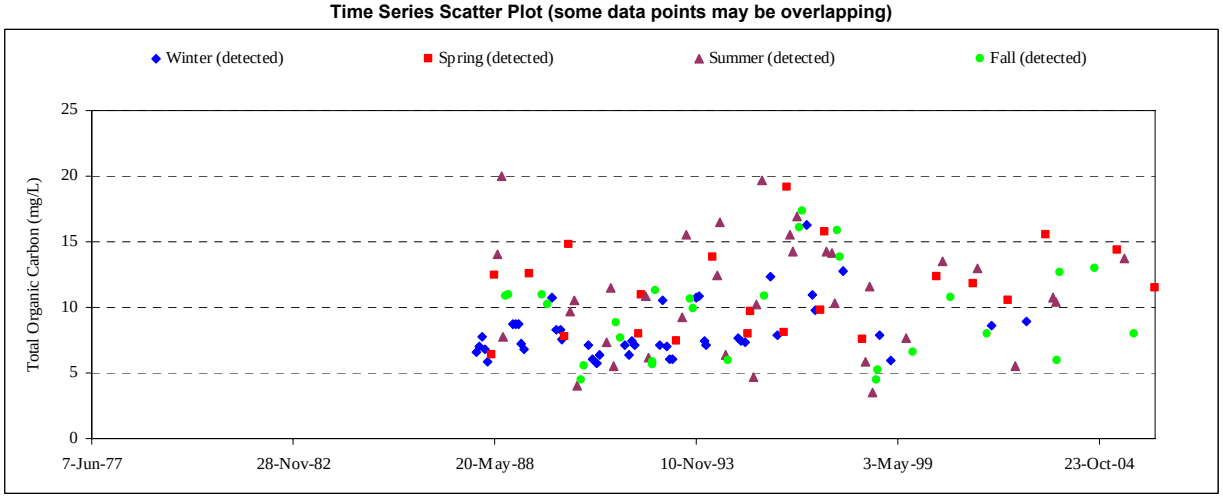
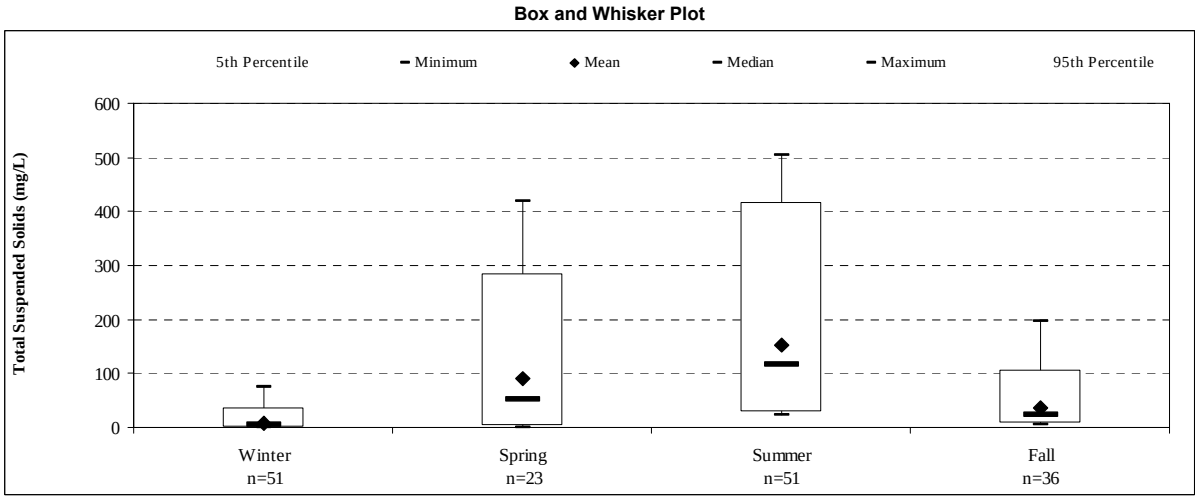


Figure G-1-3-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Lower Reach of Lower Athabasca River



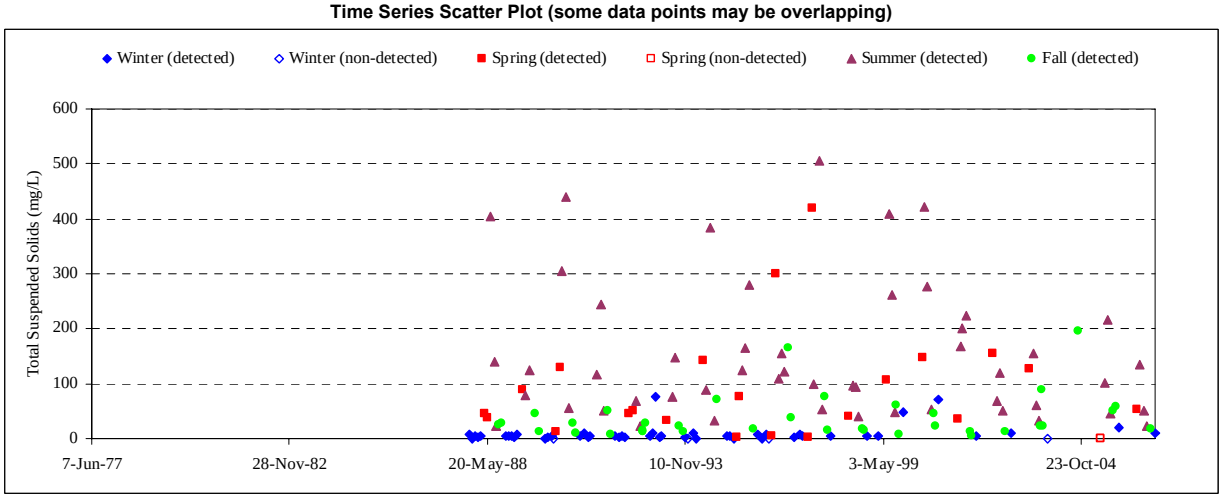


Figure G-1-3-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Lower Reach of Lower Athabasca River

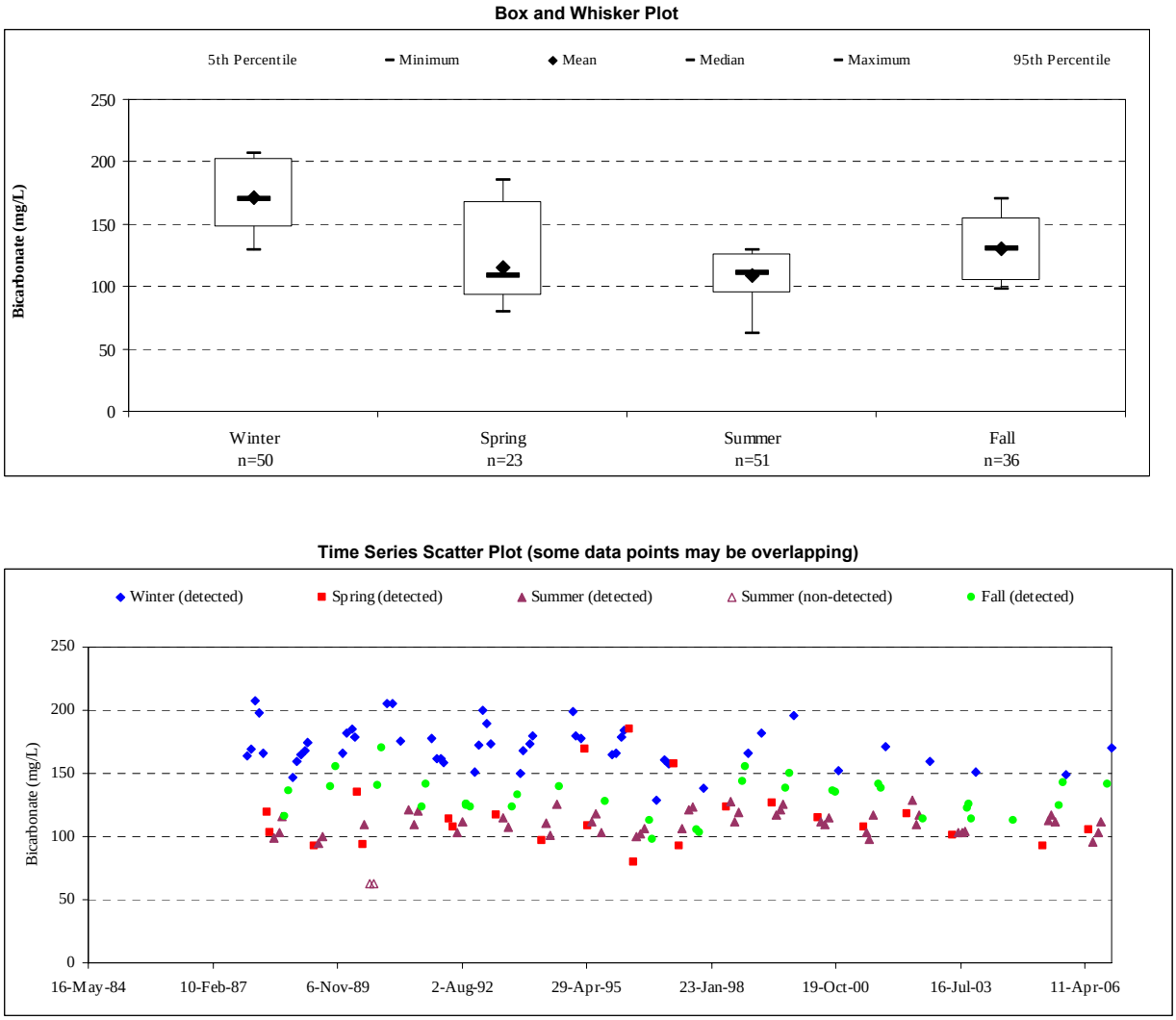
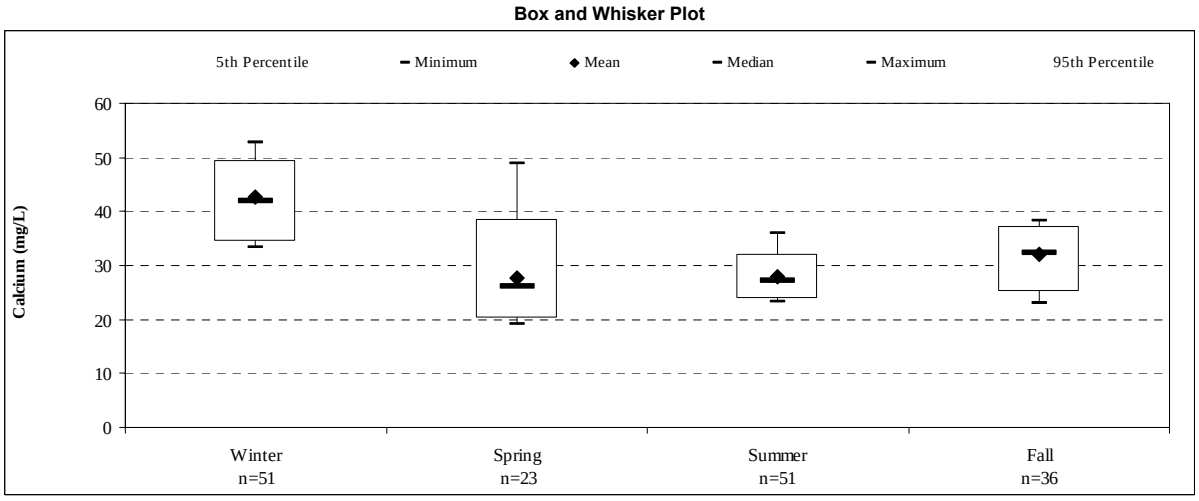


Figure G-1-3-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Lower Reach of Lower Athabasca River



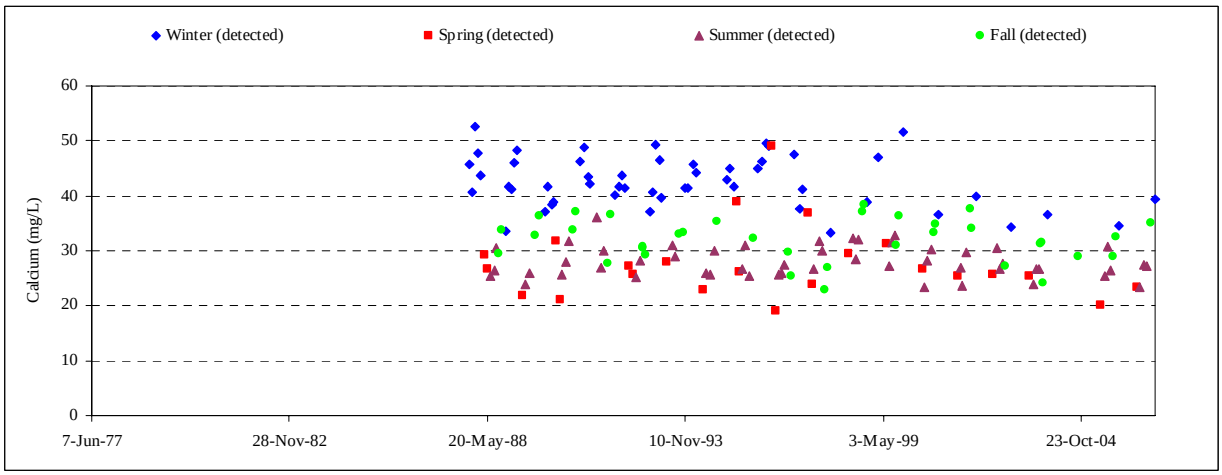
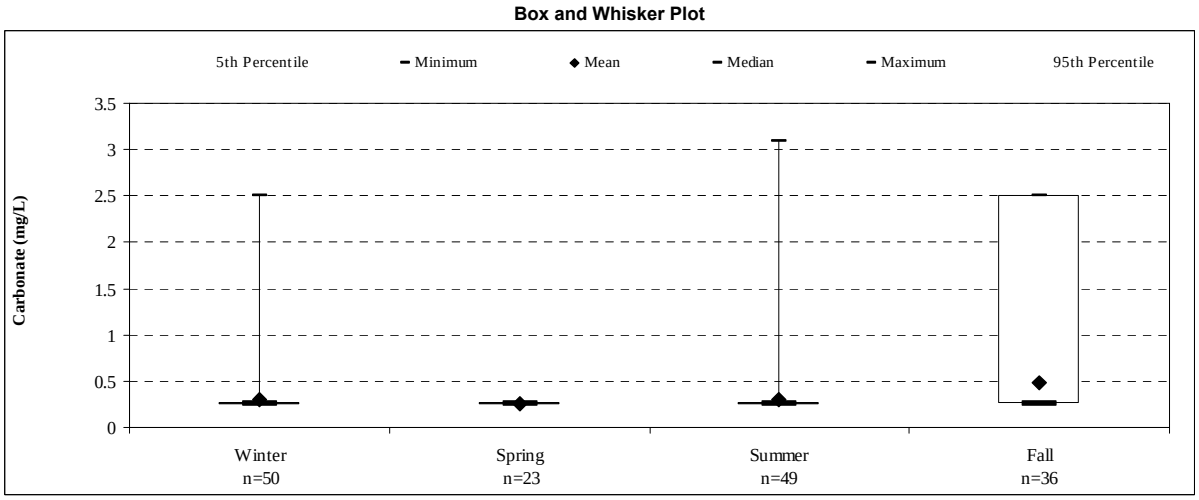


Figure G-1-3-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Lower Reach of Lower Athabasca River



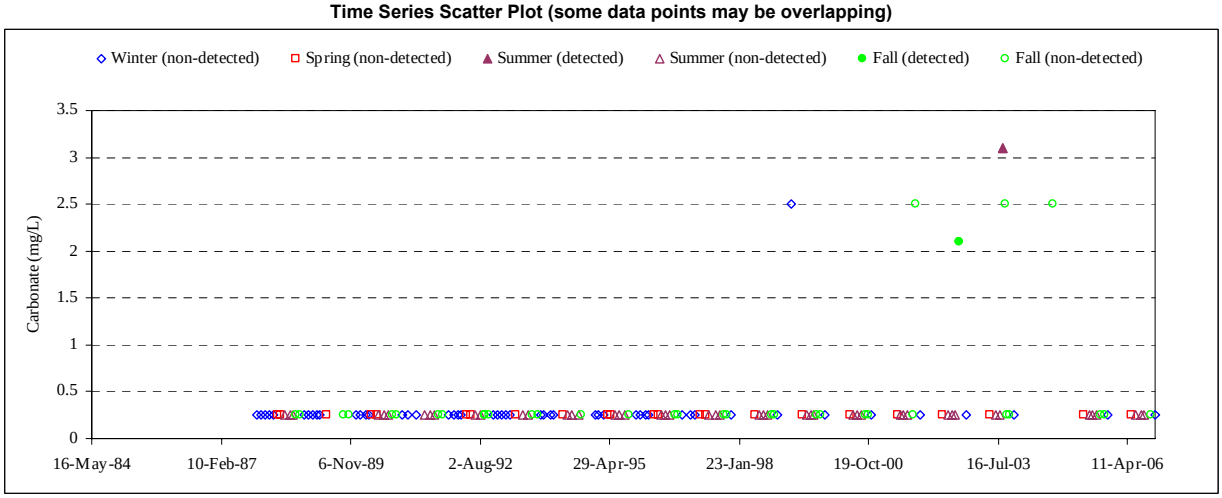


Figure G-1-3-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Lower Reach of Lower Athabasca River

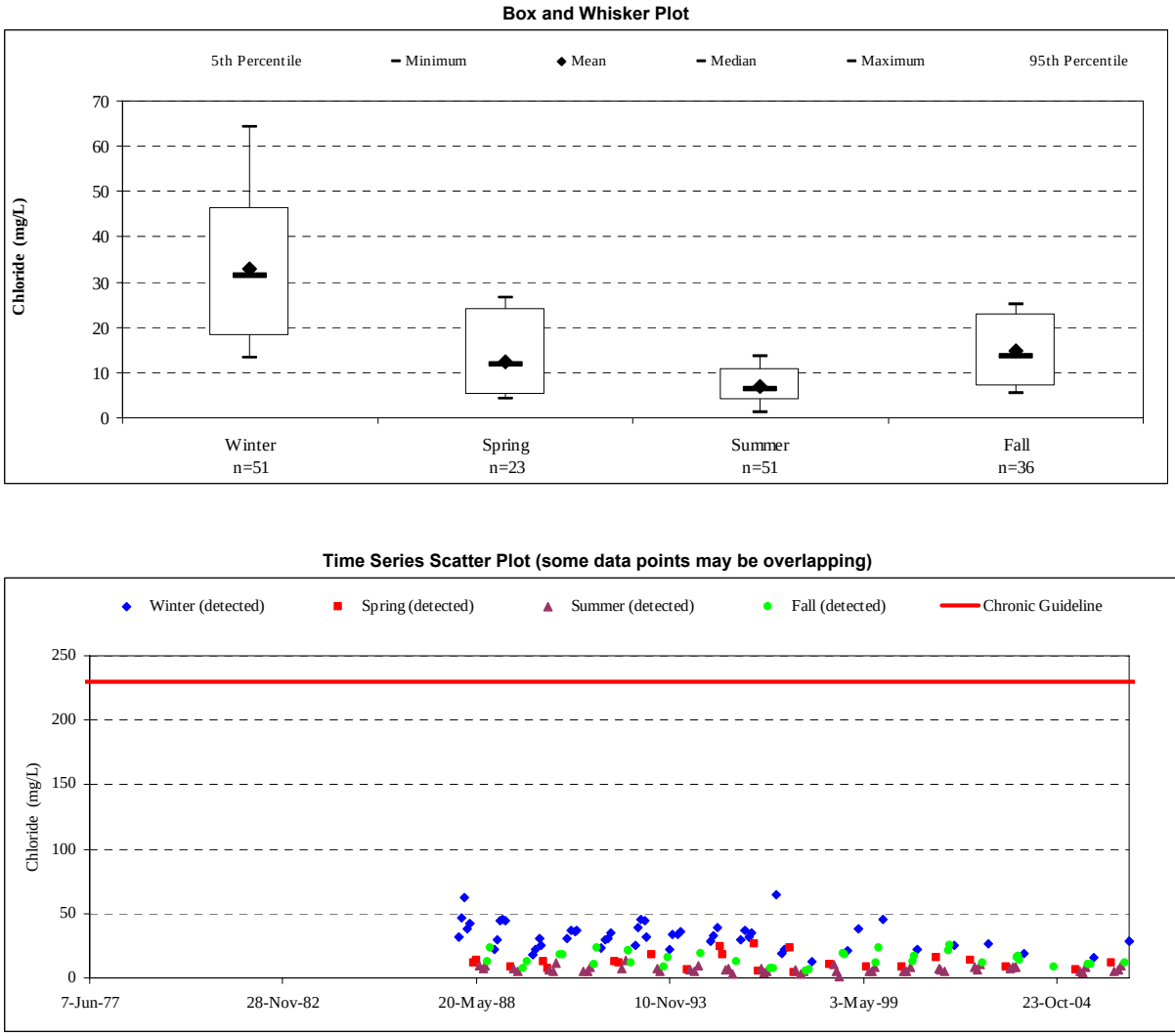
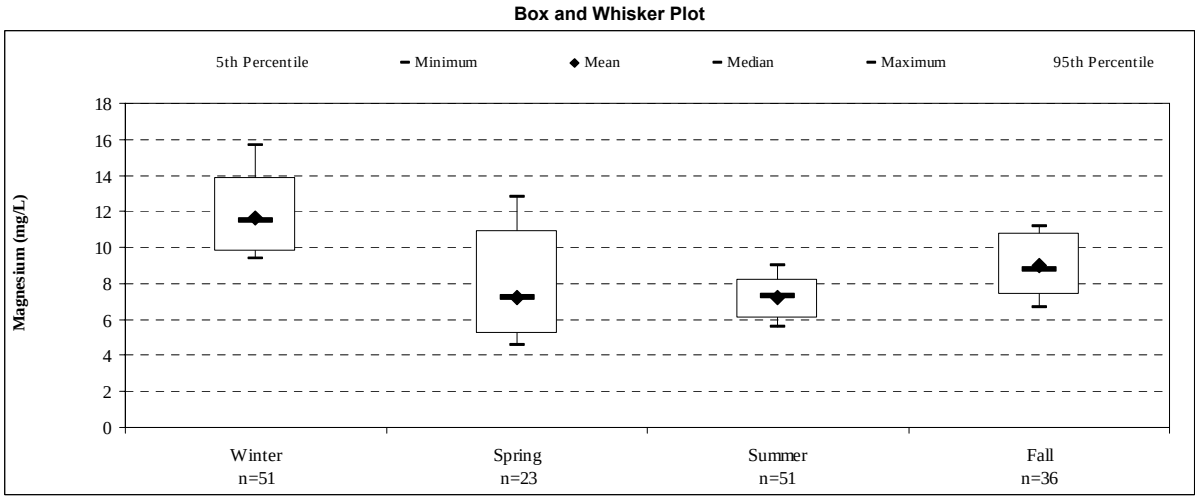


Figure G-1-3-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Lower Reach of Lower Athabasca River



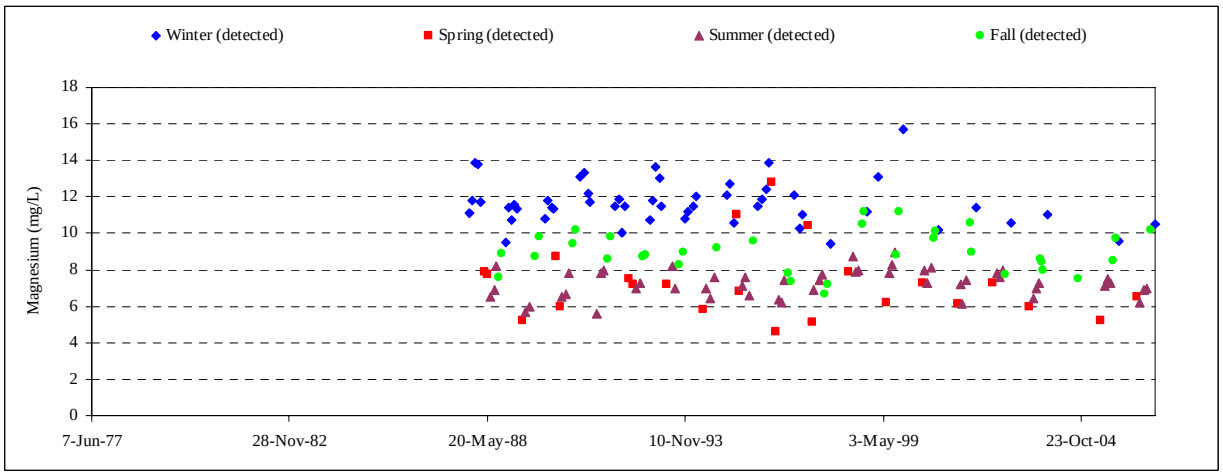
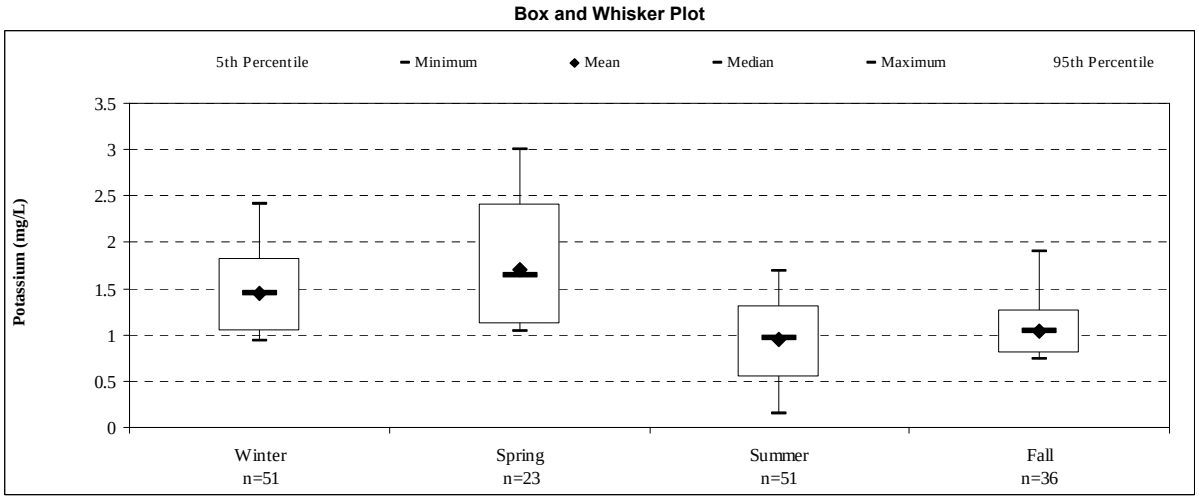


Figure G-1-3-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Lower Reach of Lower Athabasca River



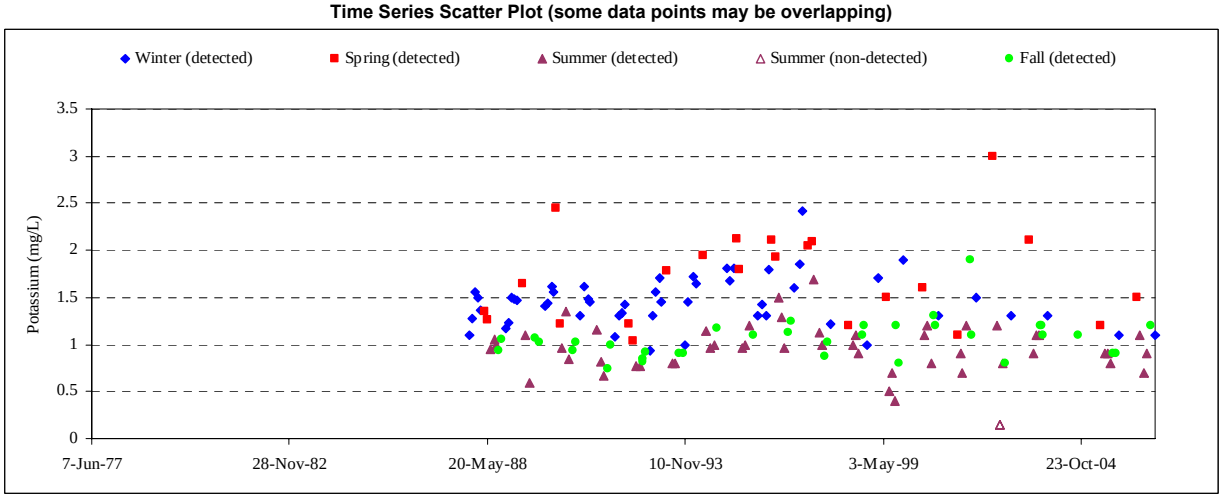
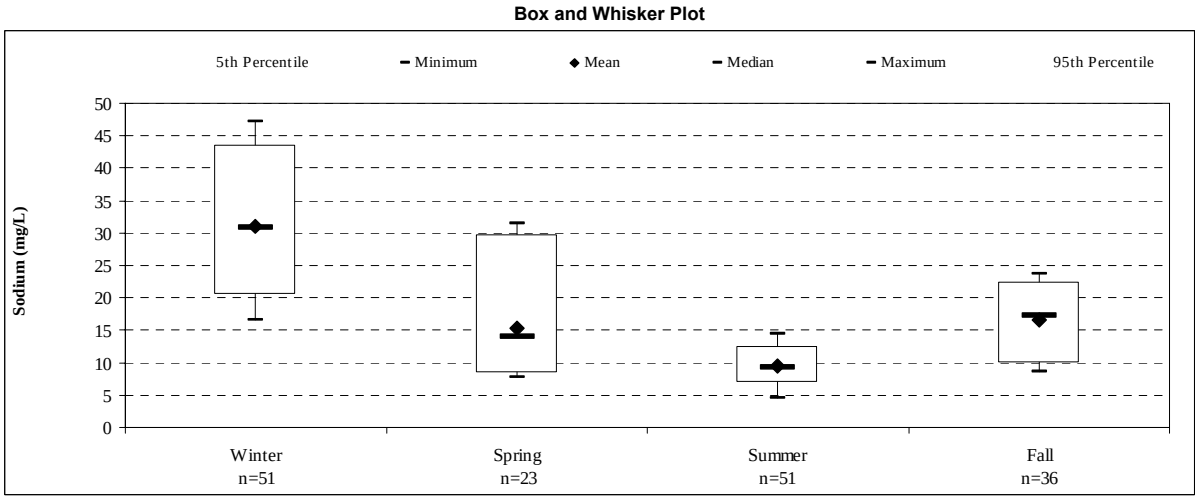


Figure G-1-3-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Lower Reach of Lower Athabasca River



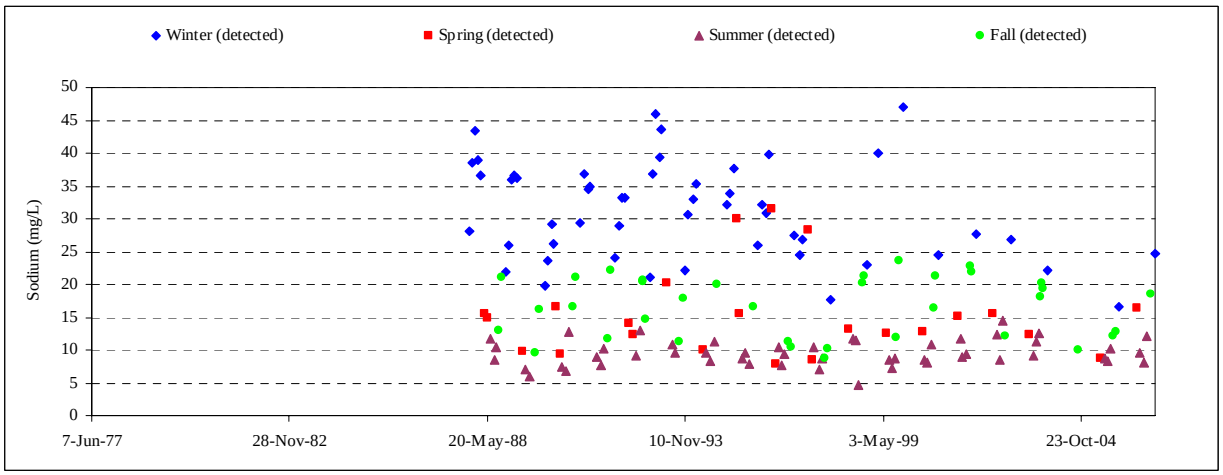
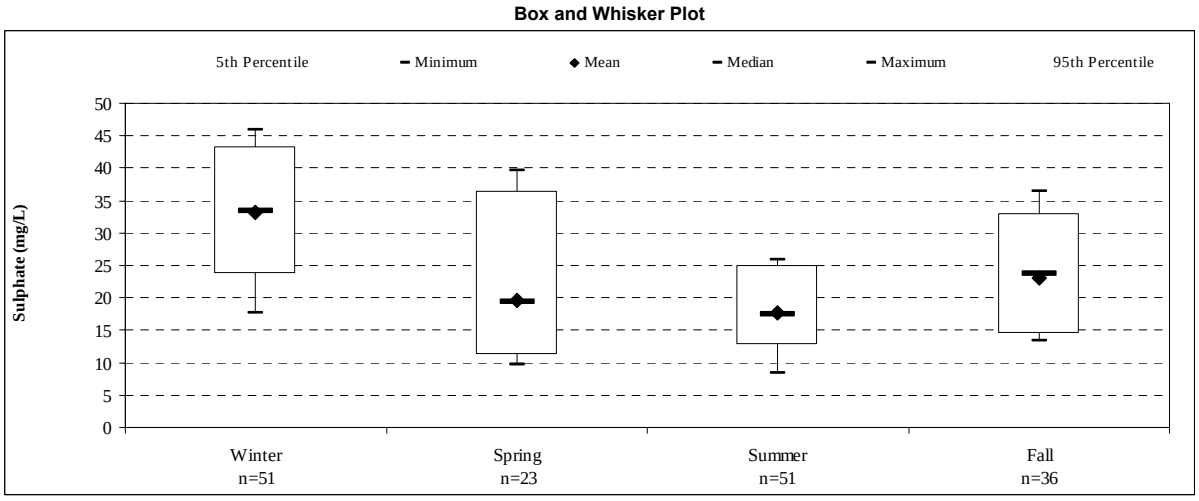


Figure G-1-3-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Lower Reach of Lower Athabasca River



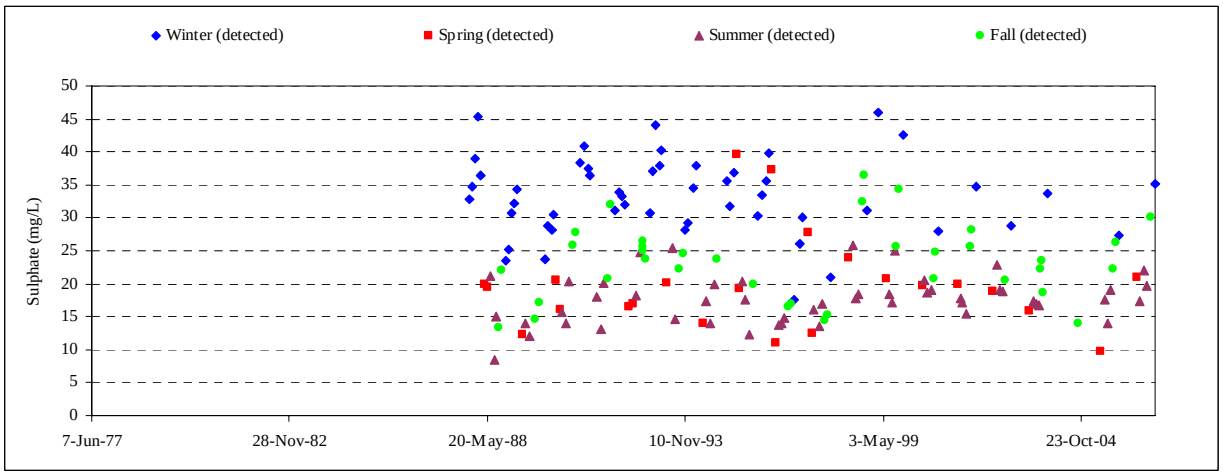
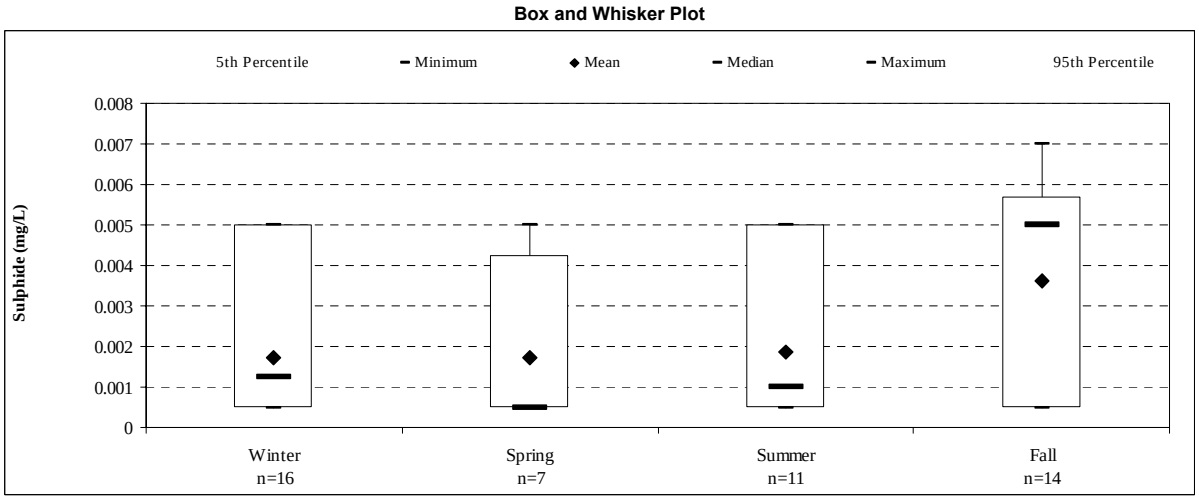


Figure G-1-3-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Lower Reach of Lower Athabasca River



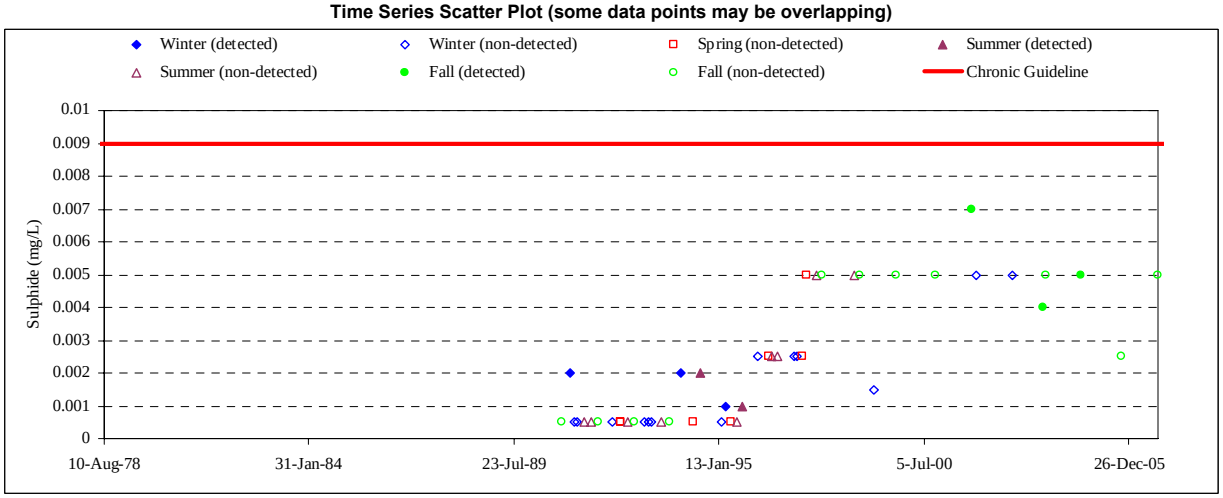


Figure G-1-3-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Lower Reach of Lower Athabasca River

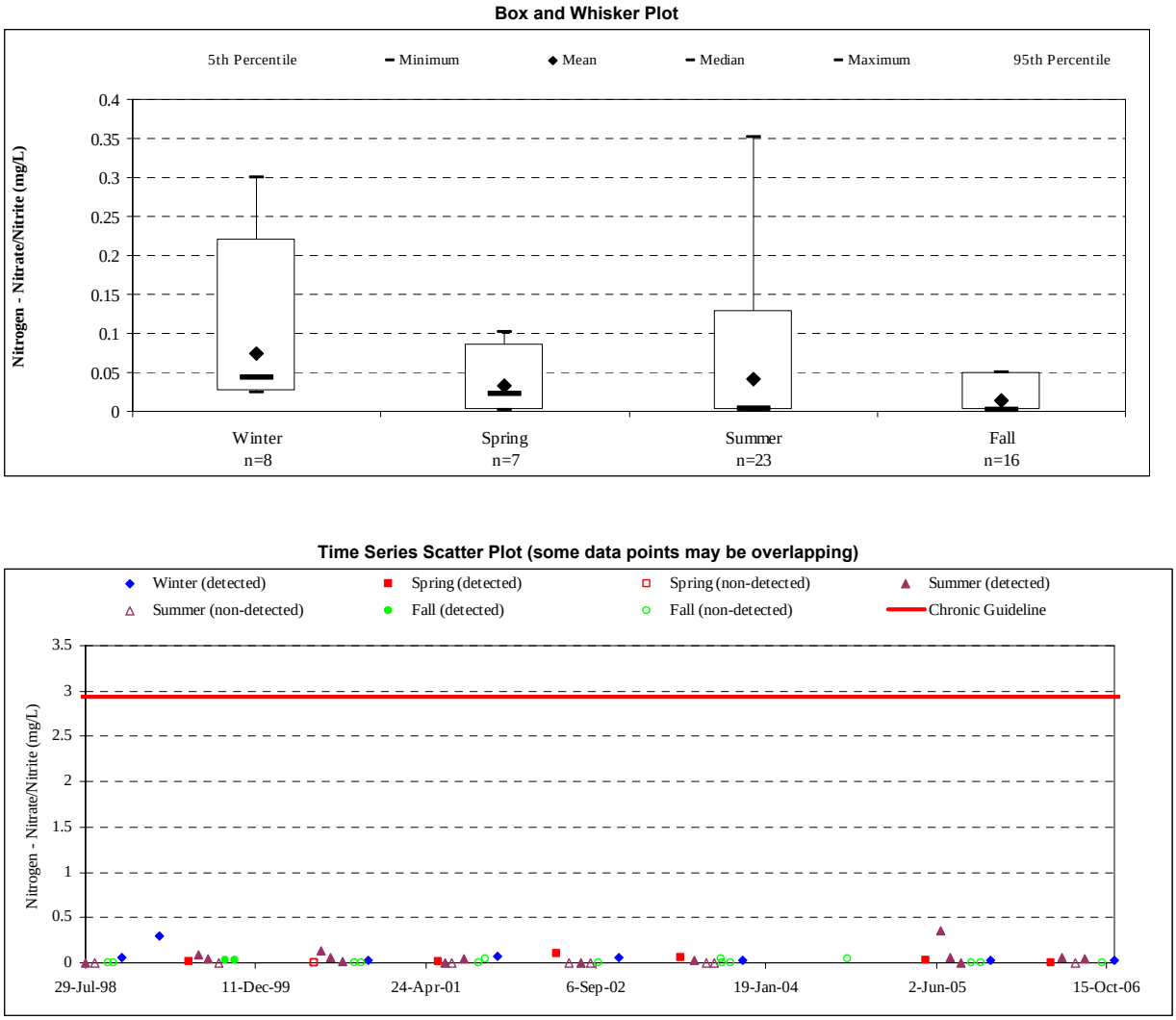
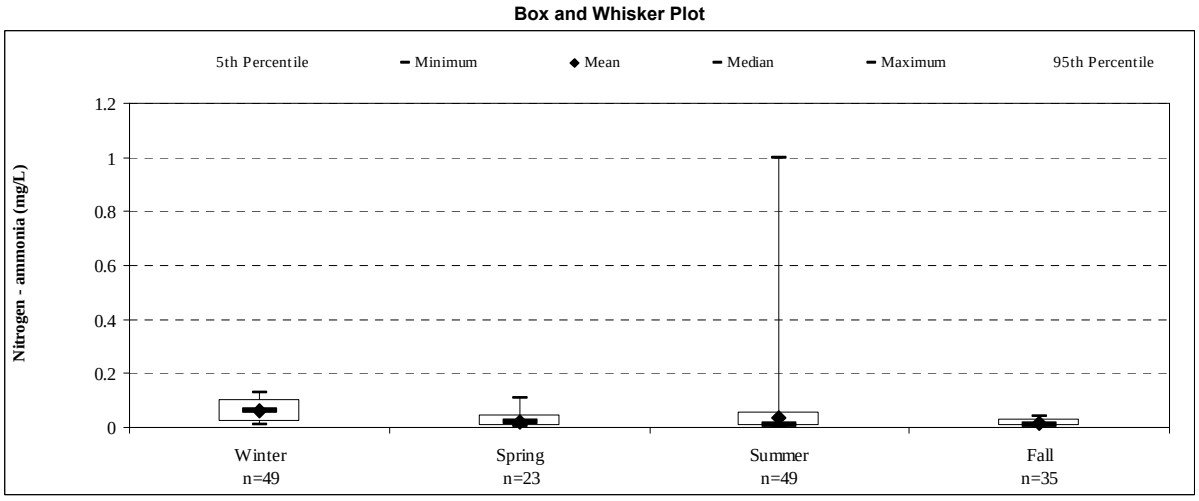


Figure G-1-3-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Lower Reach of Lower Athabasca River



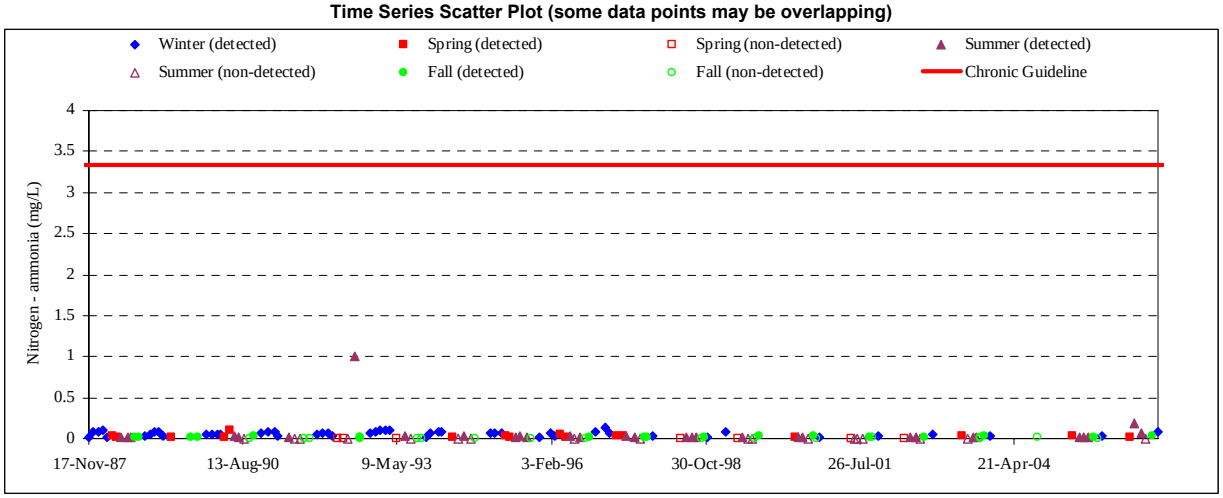


Figure G-1-3-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Lower Reach of Lower Athabasca River

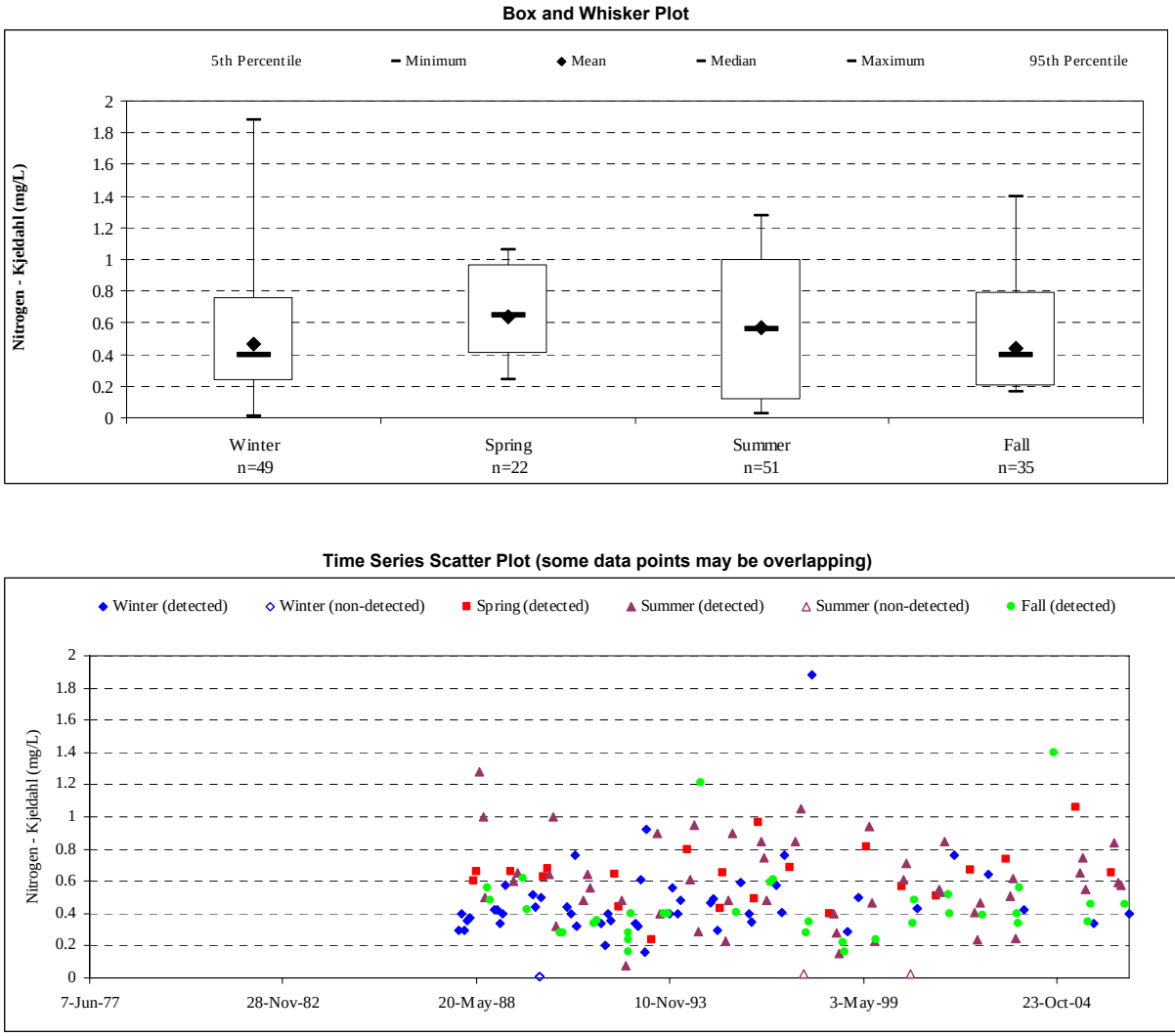
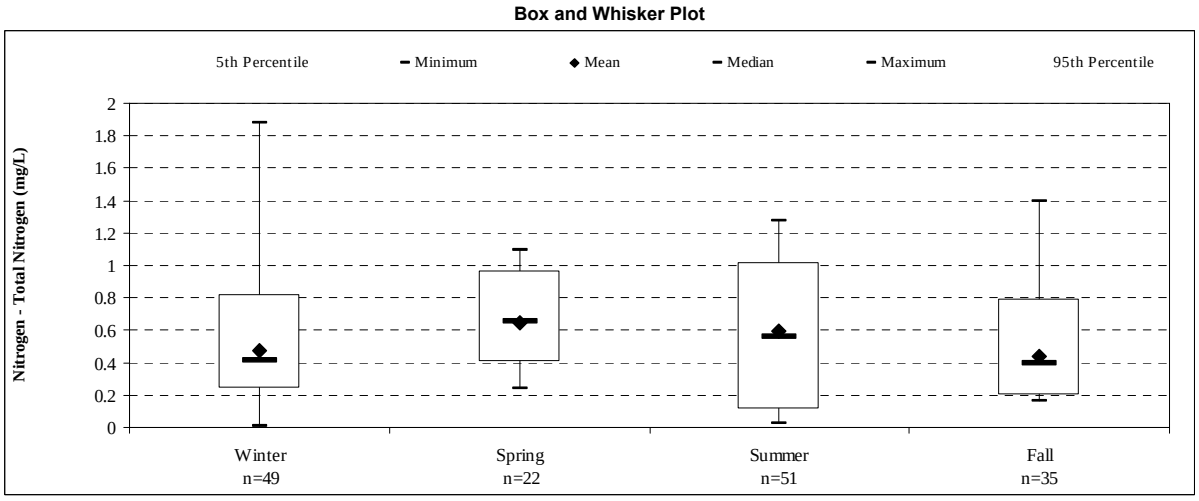


Figure G-1-3-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Lower Reach of Lower Athabasca River



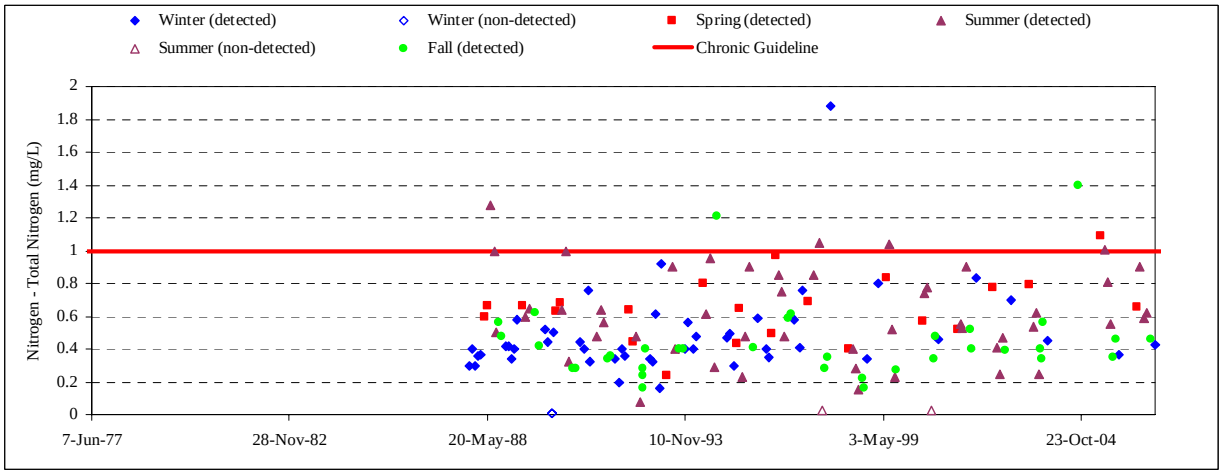


Figure G-1-3-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Lower Reach of Lower Athabasca River

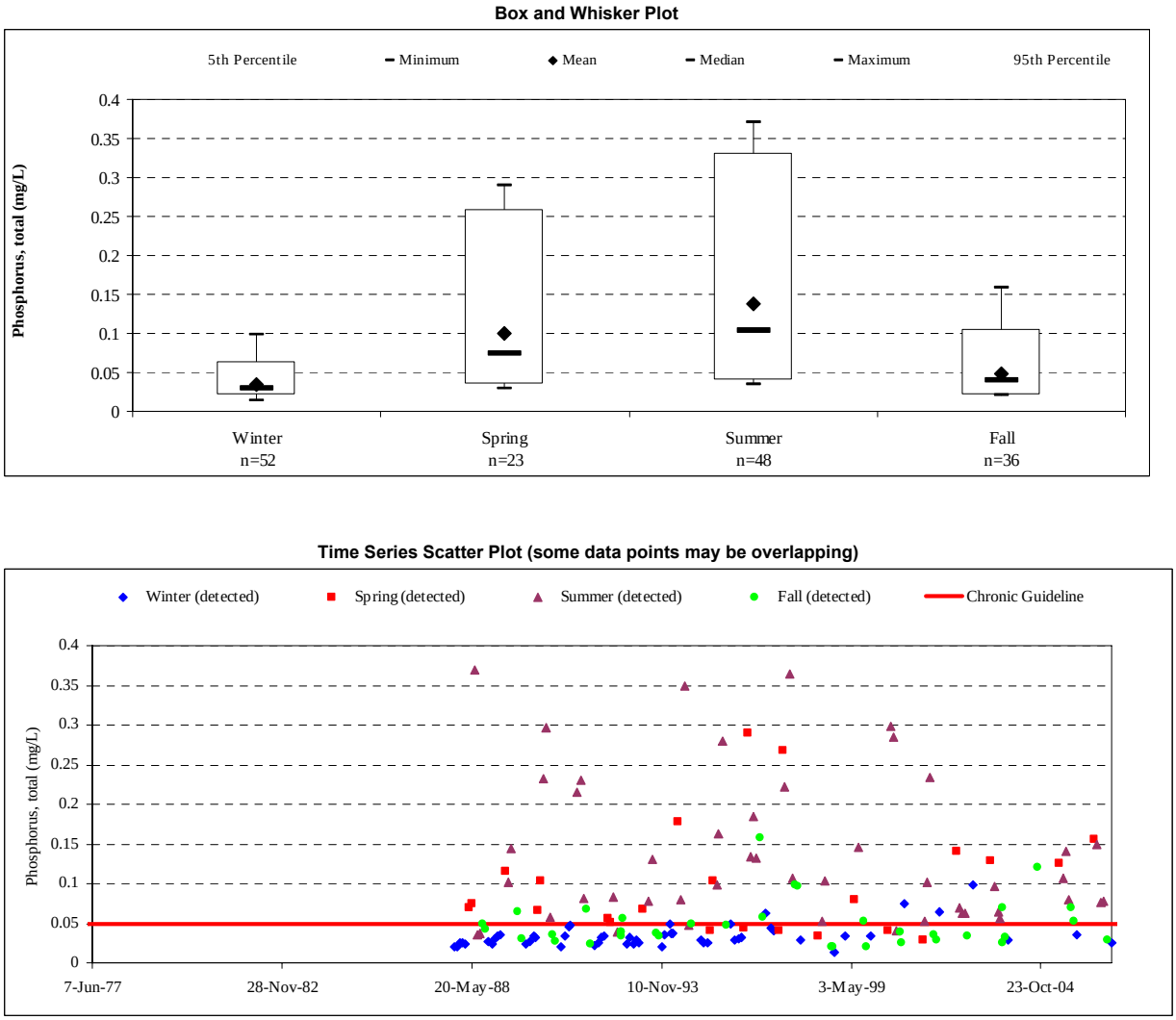
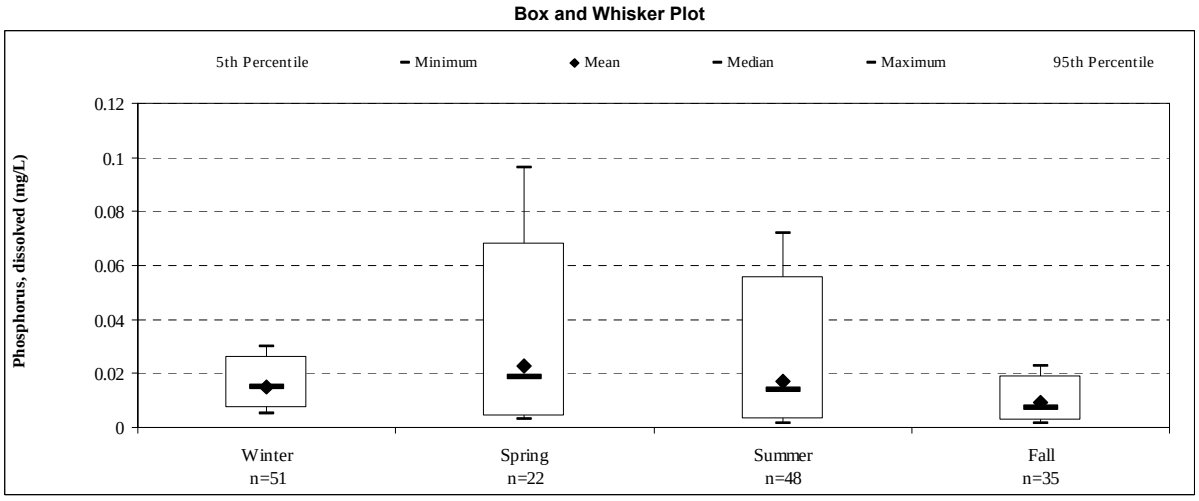


Figure G-1-3-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Lower Reach of Lower Athabasca River



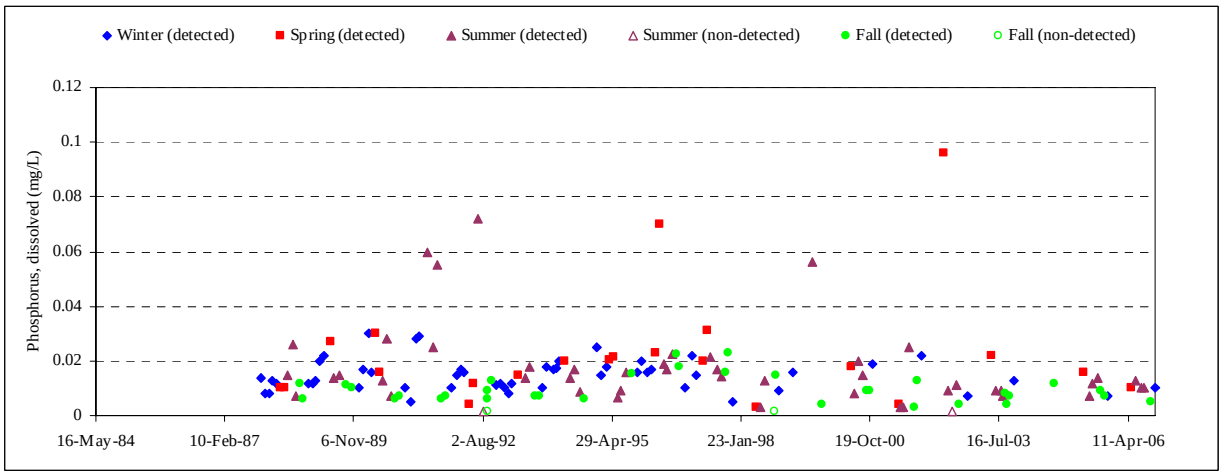
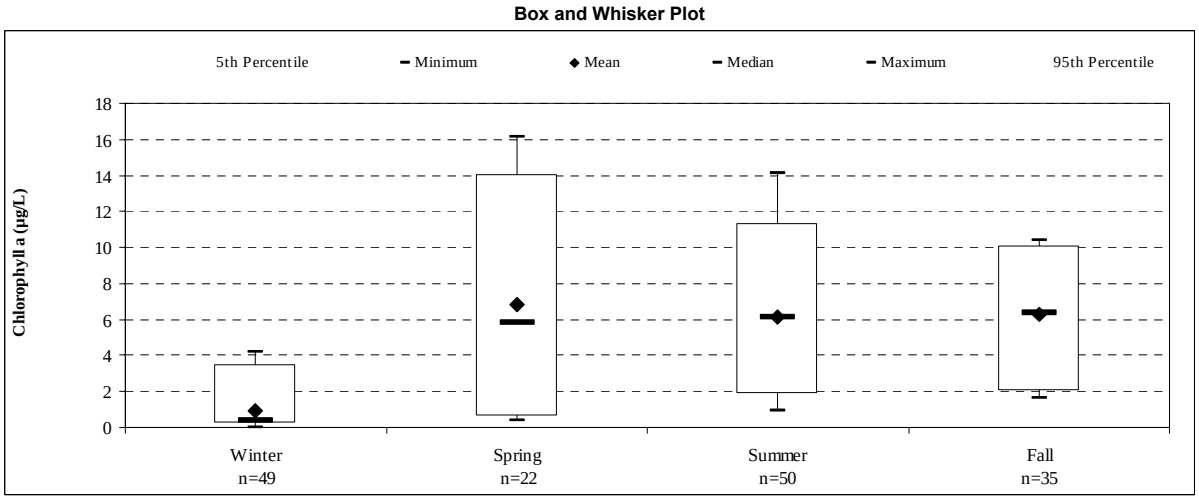


Figure G-1-3-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Lower Reach of Lower Athabasca River



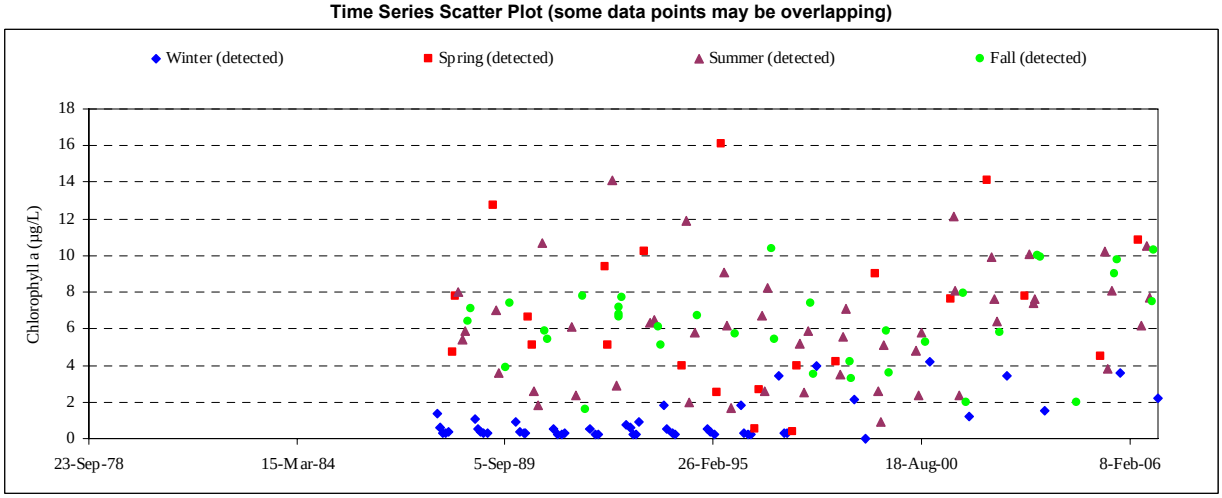


Figure G-1-3-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Lower Reach of Lower Athabasca River

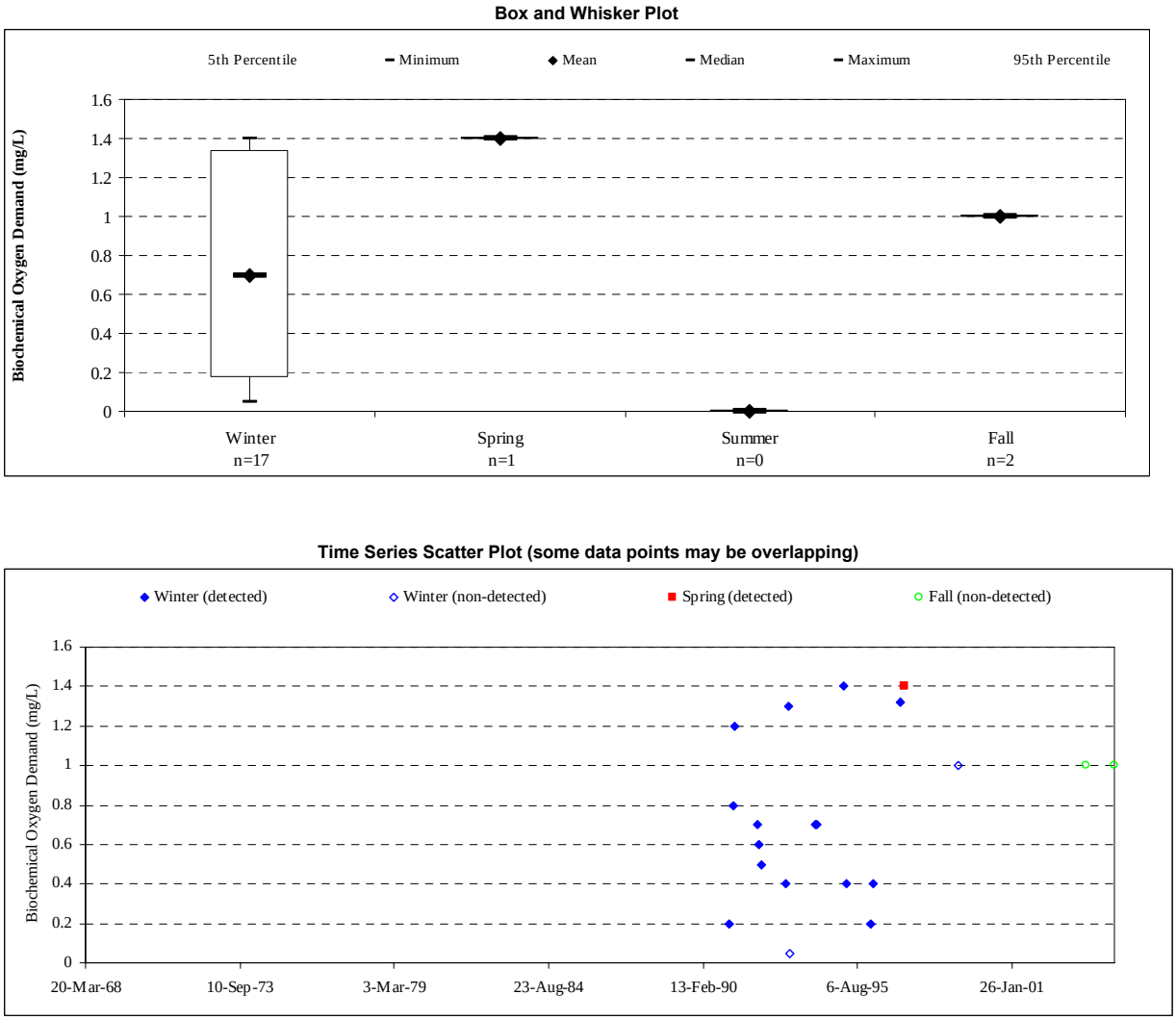
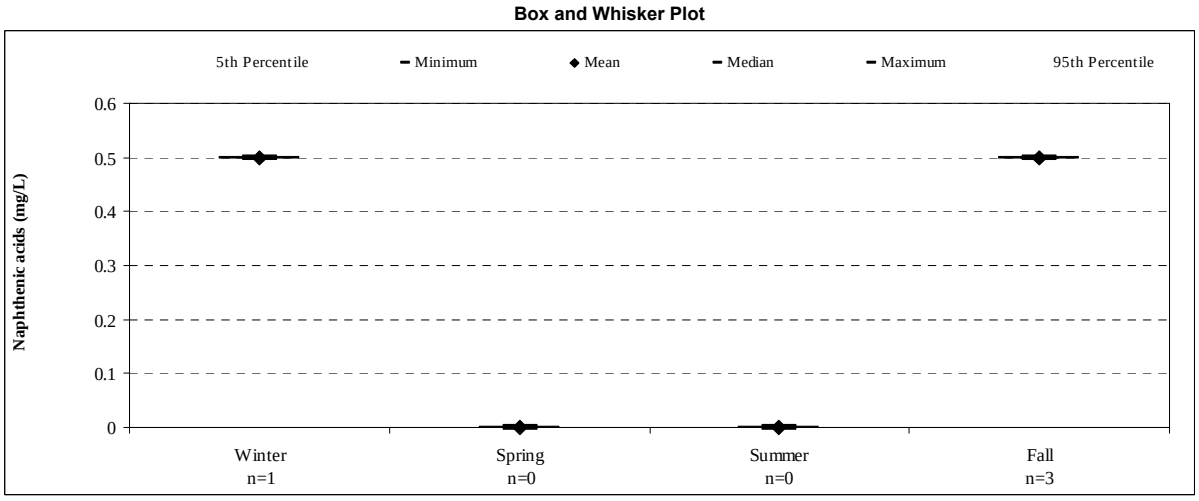


Figure G-1-3-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Lower Reach of Lower Athabasca River



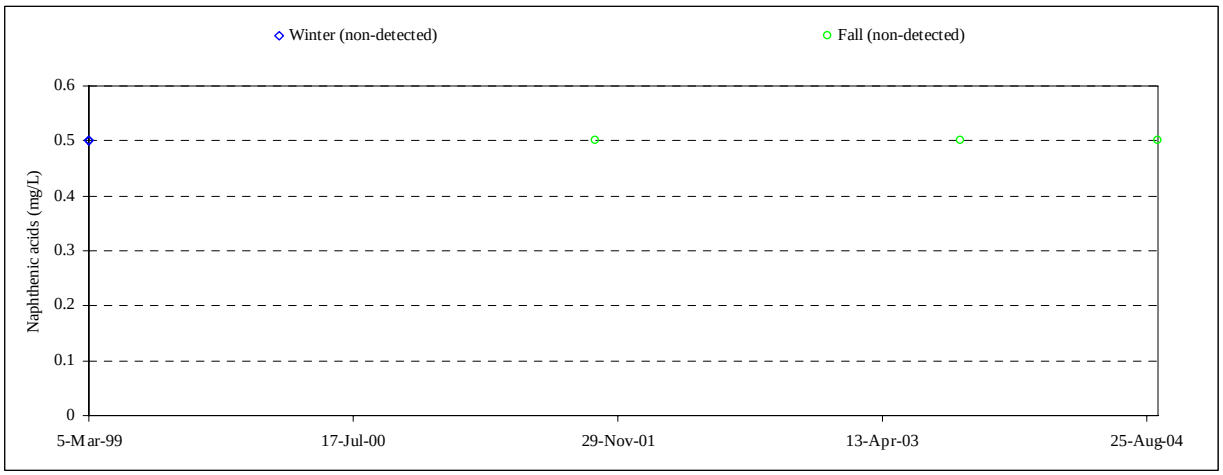


Figure G-1-3-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Lower Reach of Lower Athabasca River

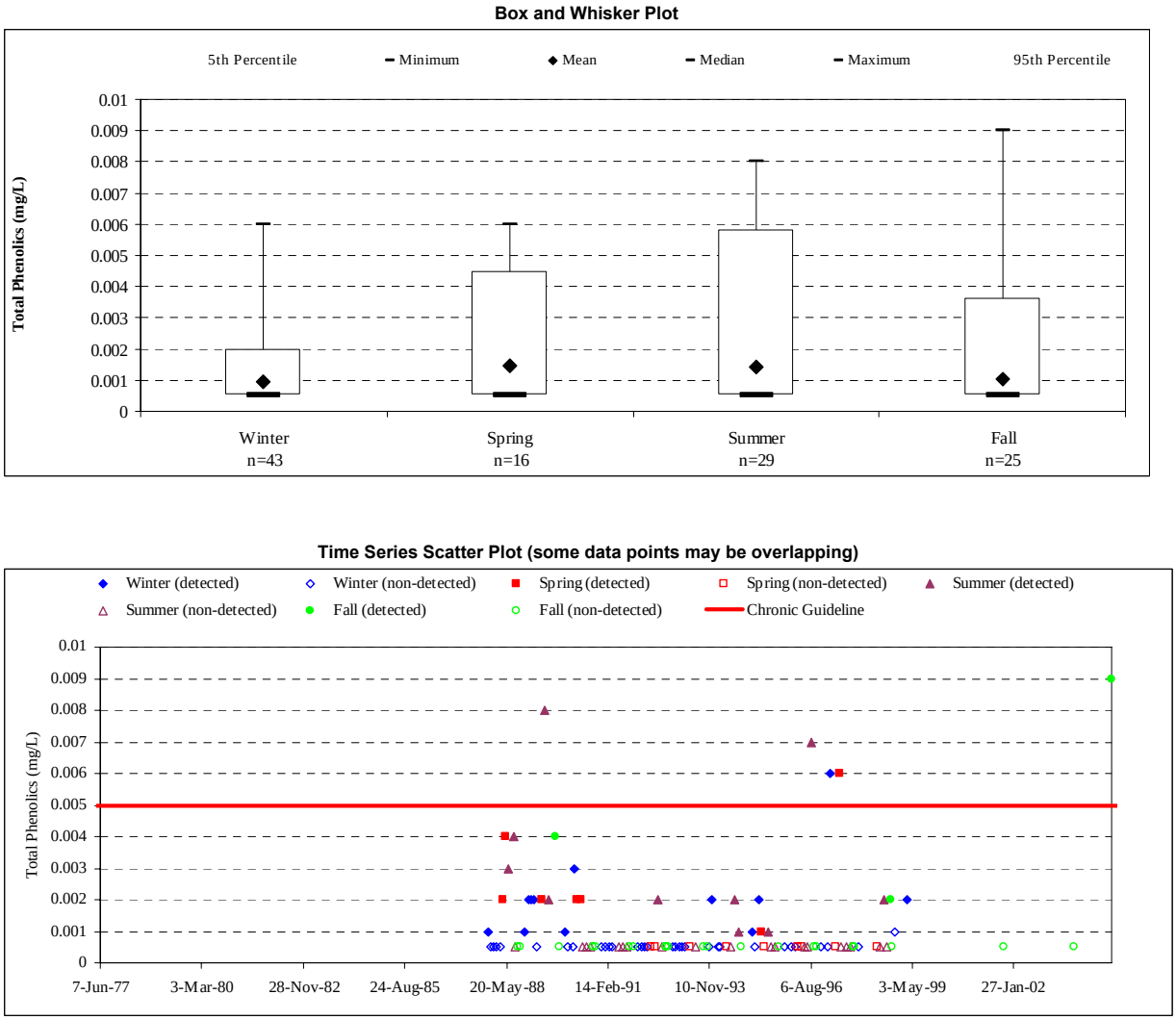


Figure G-1-3-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Lower Reach of Lower Athabasca River

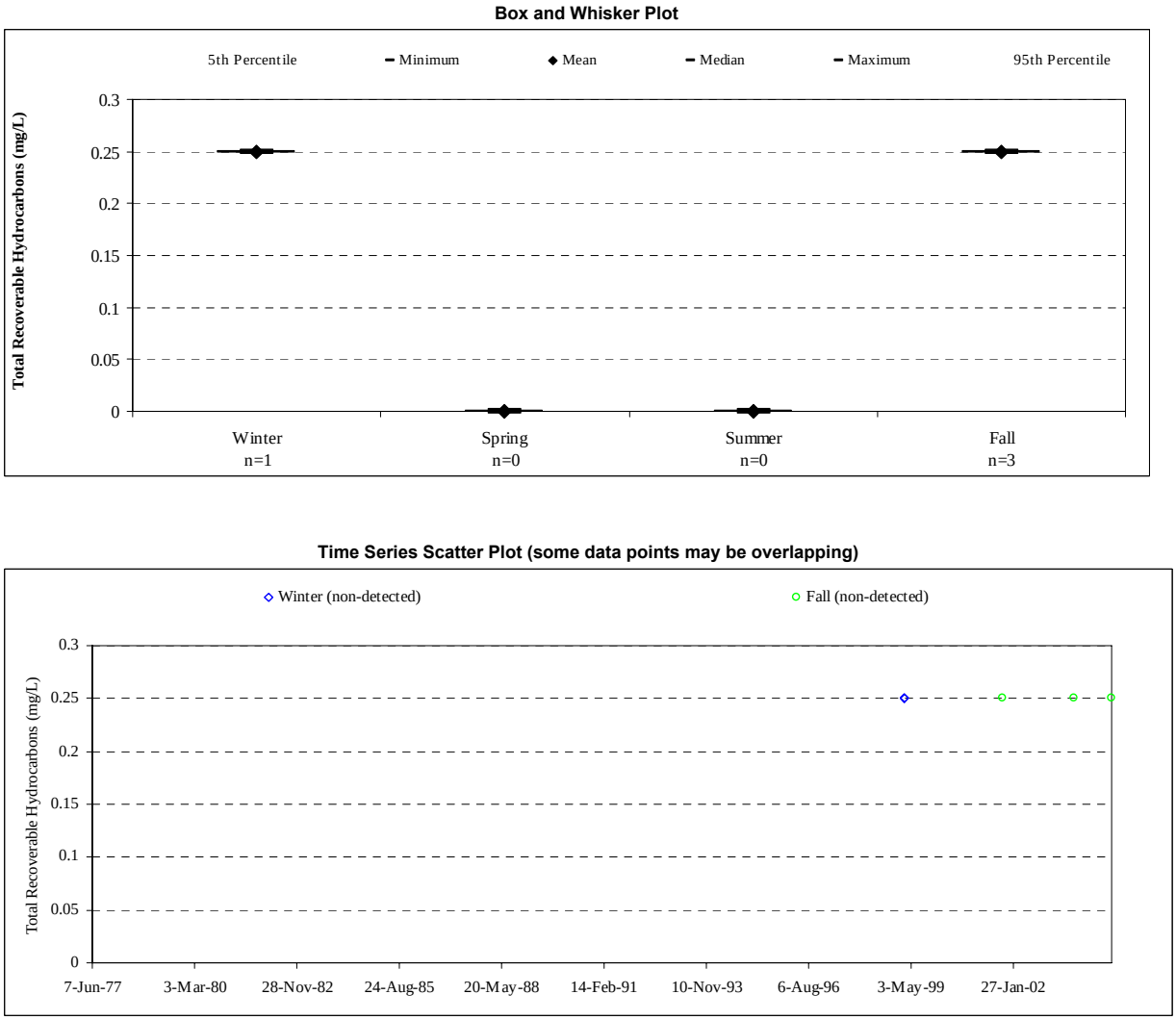


Figure G-1-3-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Lower Reach of Lower Athabasca River

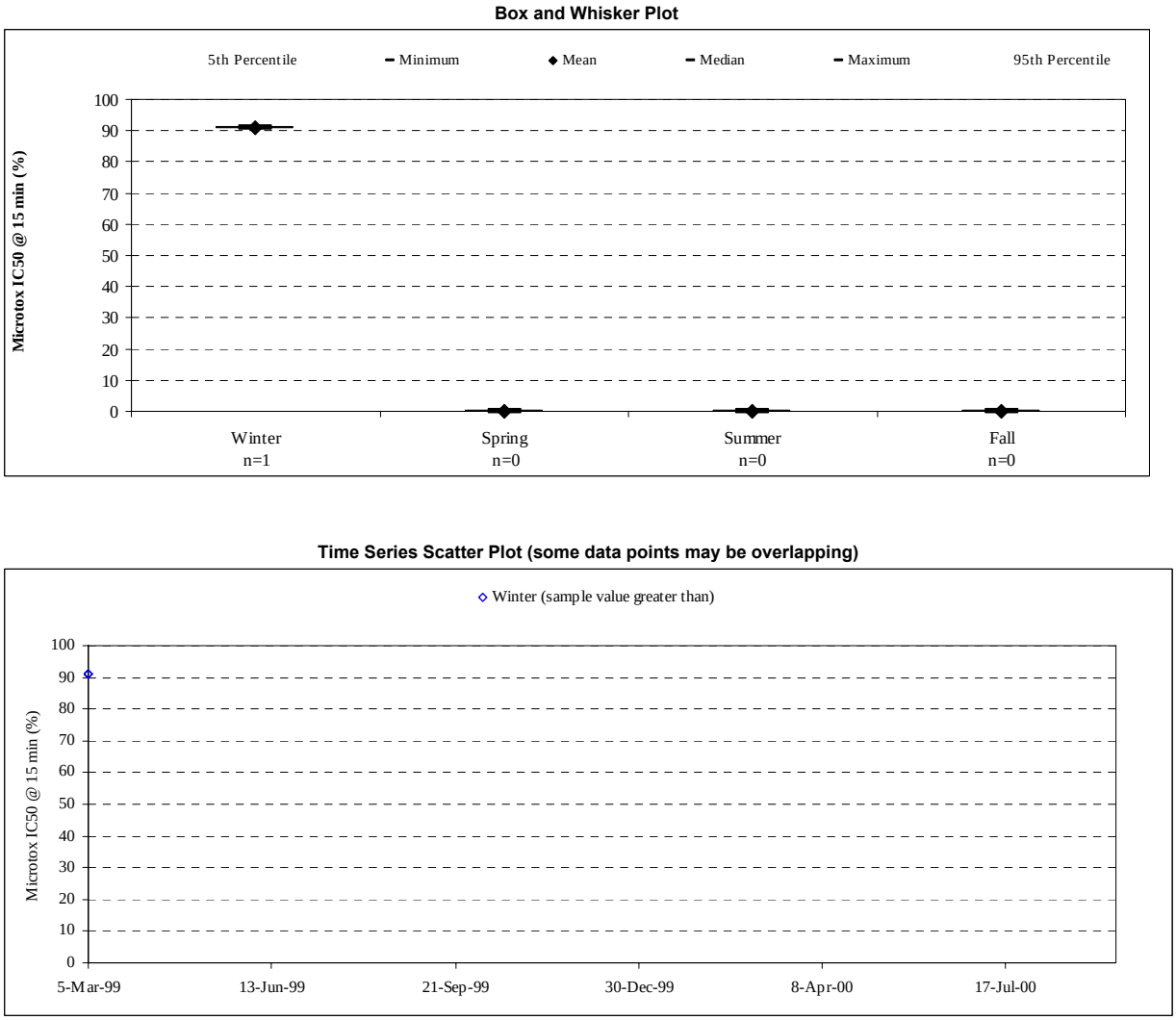
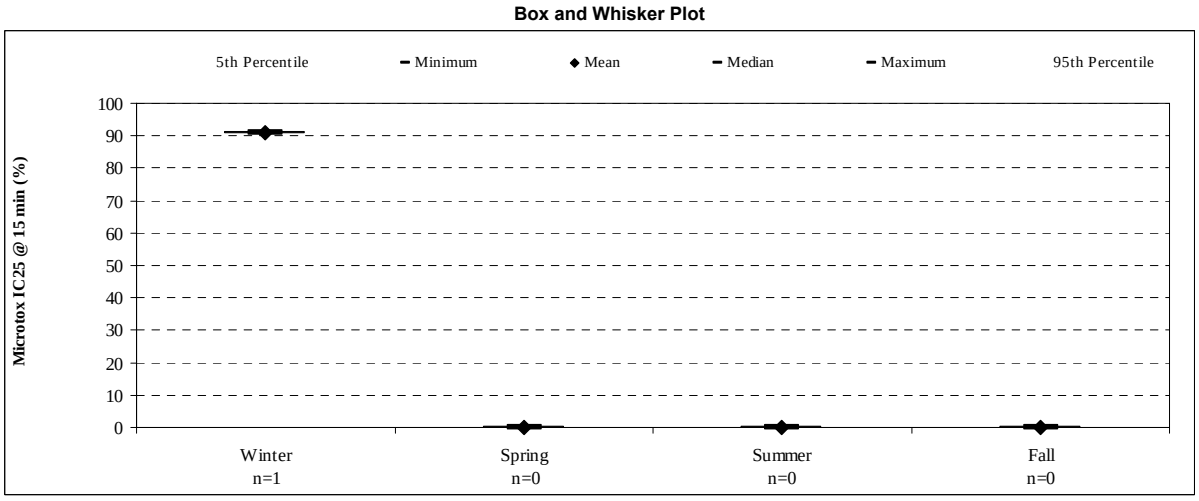


Figure G-1-3-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Lower Reach of Lower Athabasca River



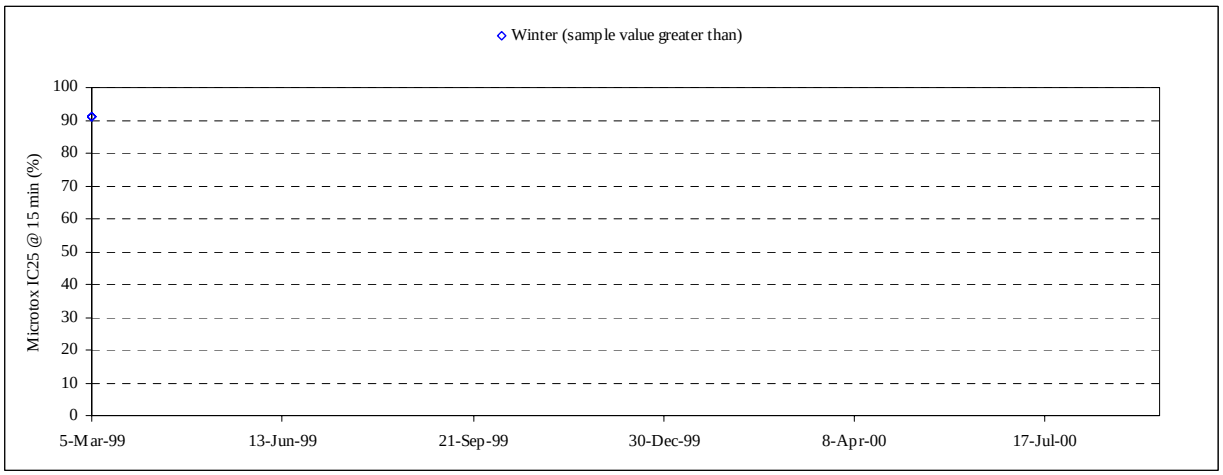


Figure G-1-3-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Lower Reach of Lower Athabasca River

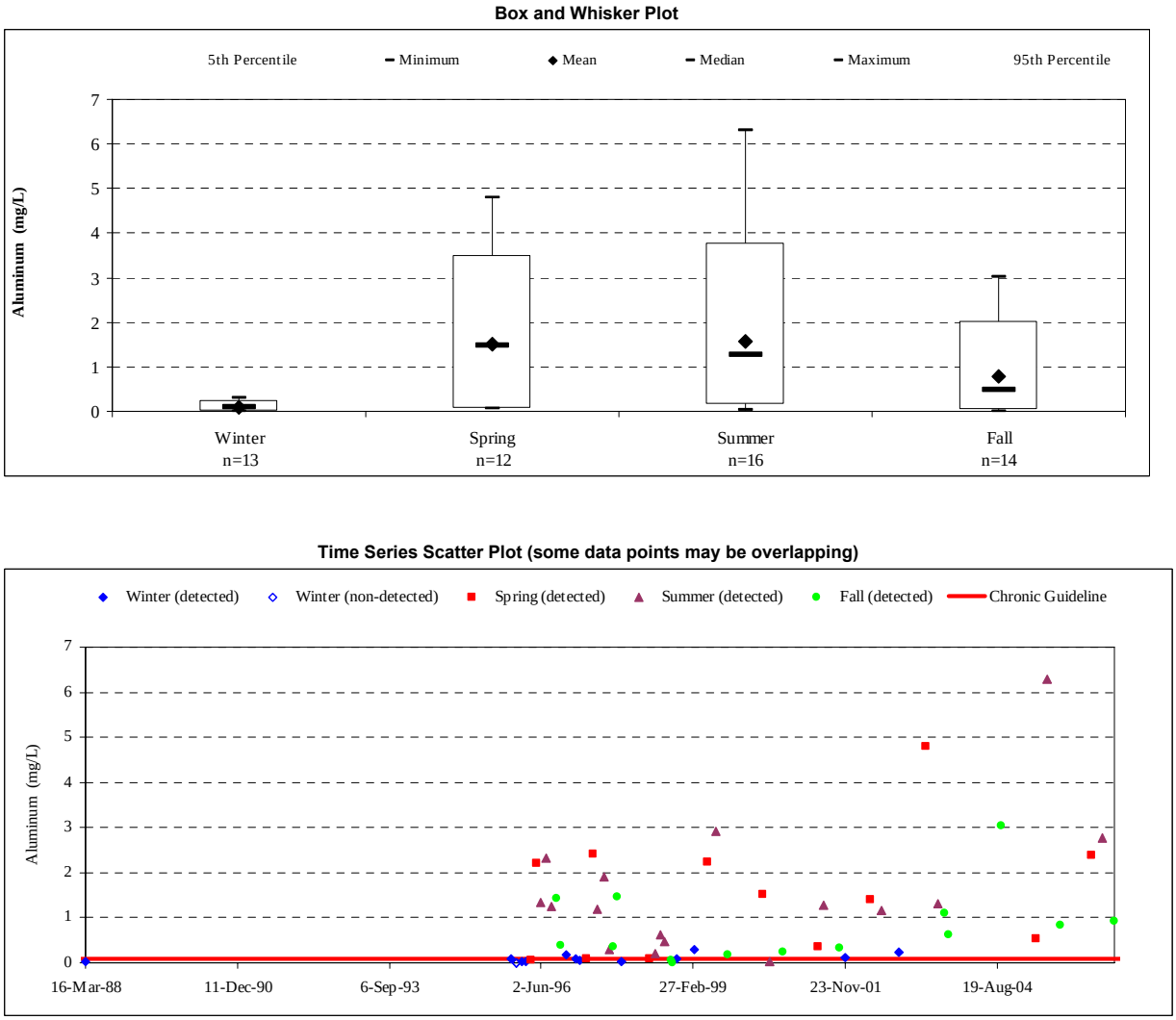
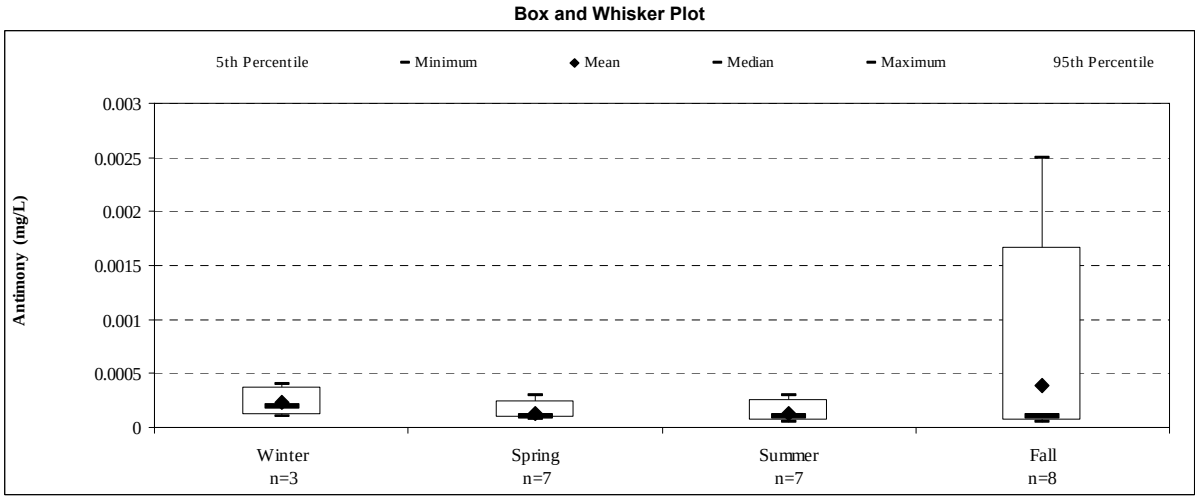


Figure G-1-3-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Lower Reach of Lower Athabasca River



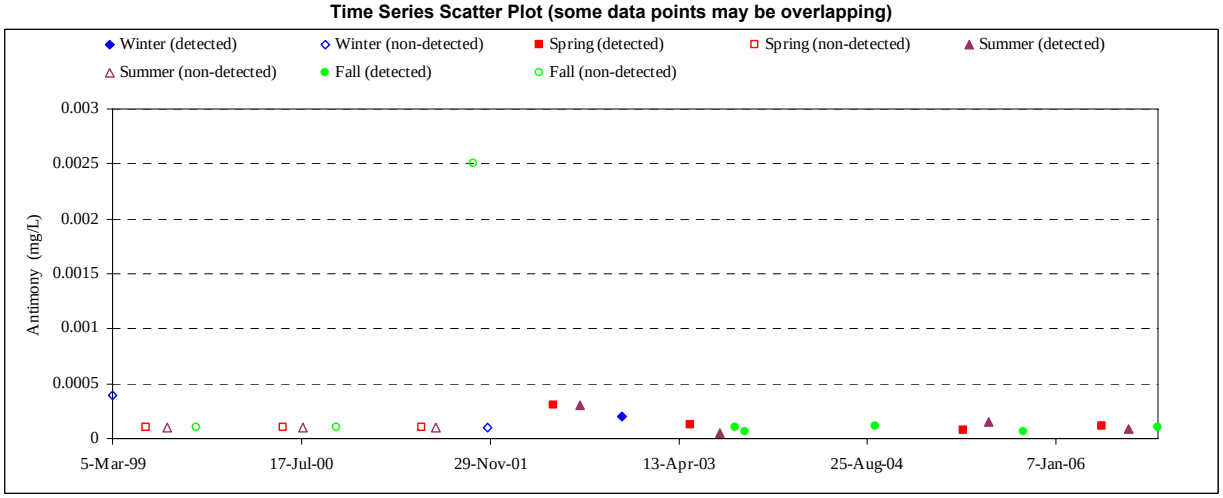


Figure G-1-3-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Lower Reach of Lower Athabasca River

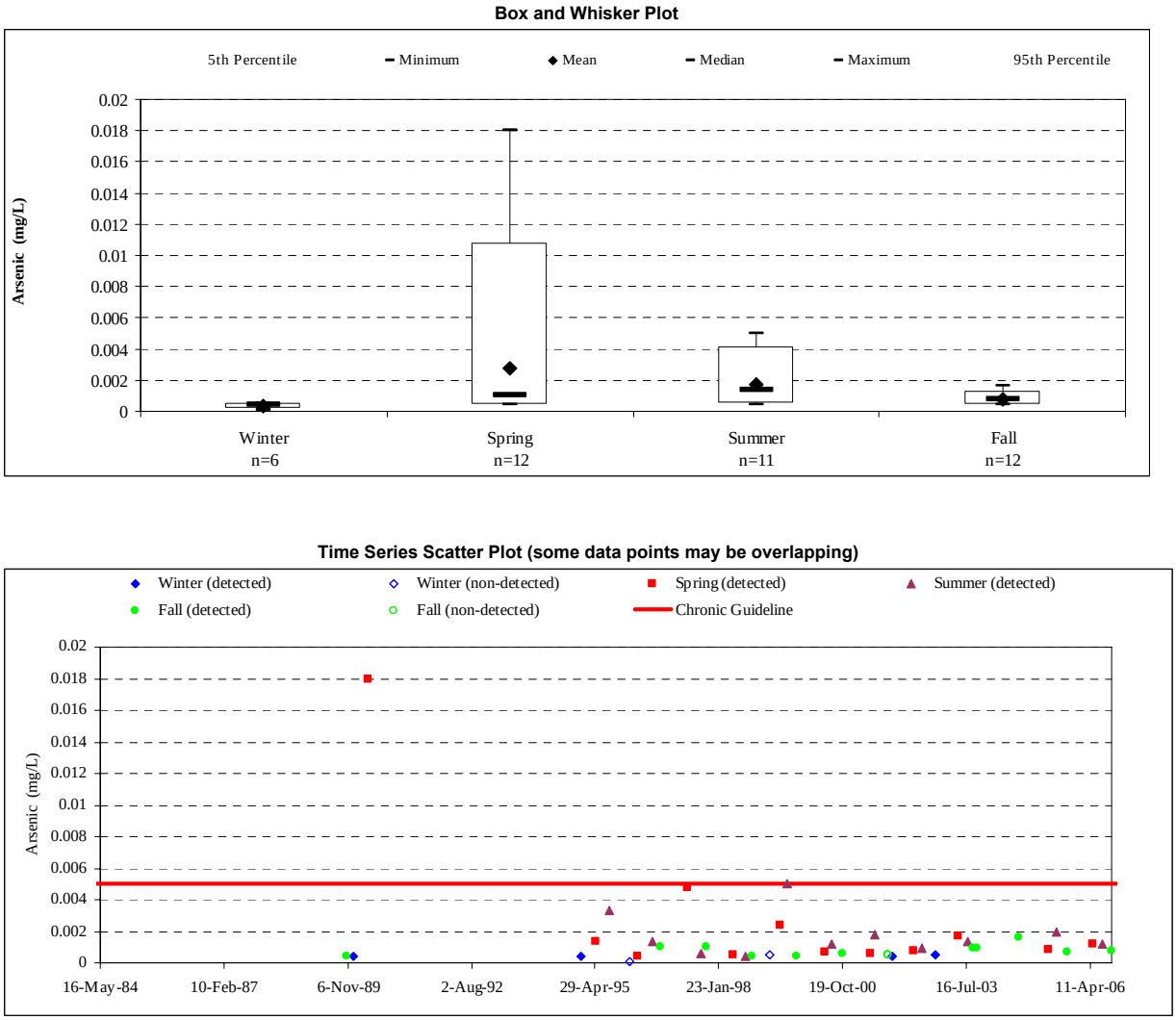
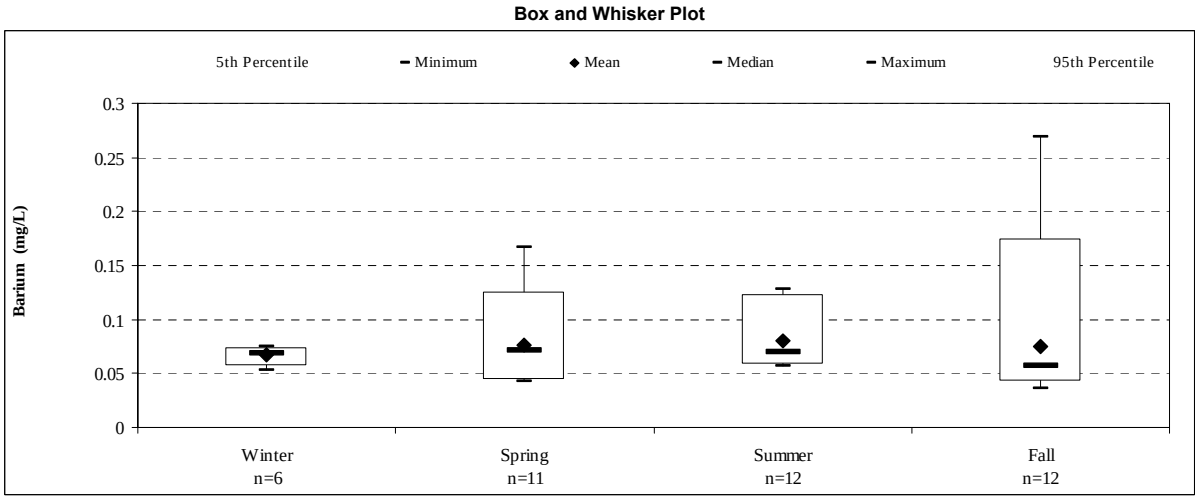


Figure G-1-3-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Lower Reach of Lower Athabasca River



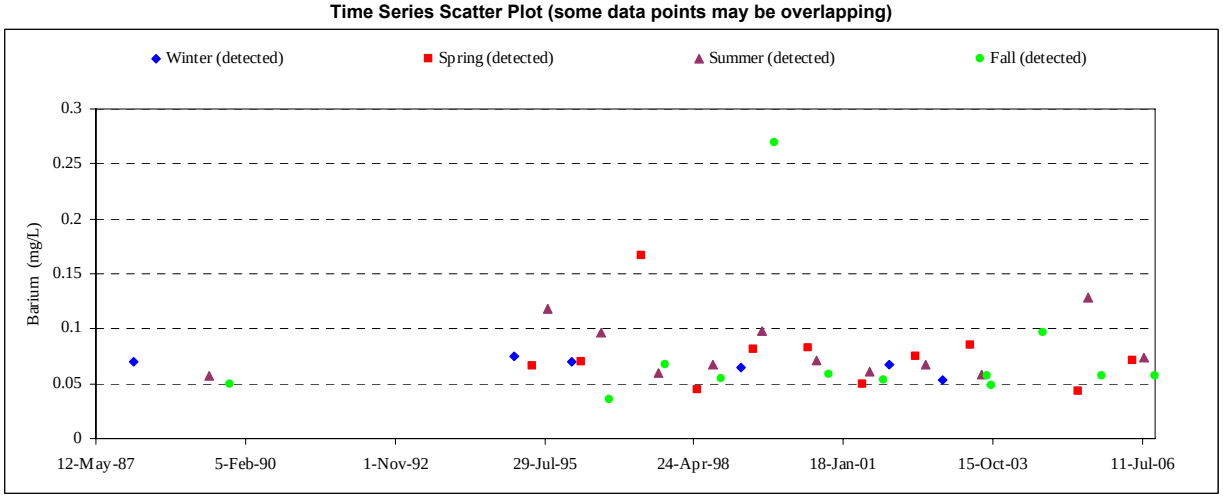


Figure G-1-3-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Lower Reach of Lower Athabasca River

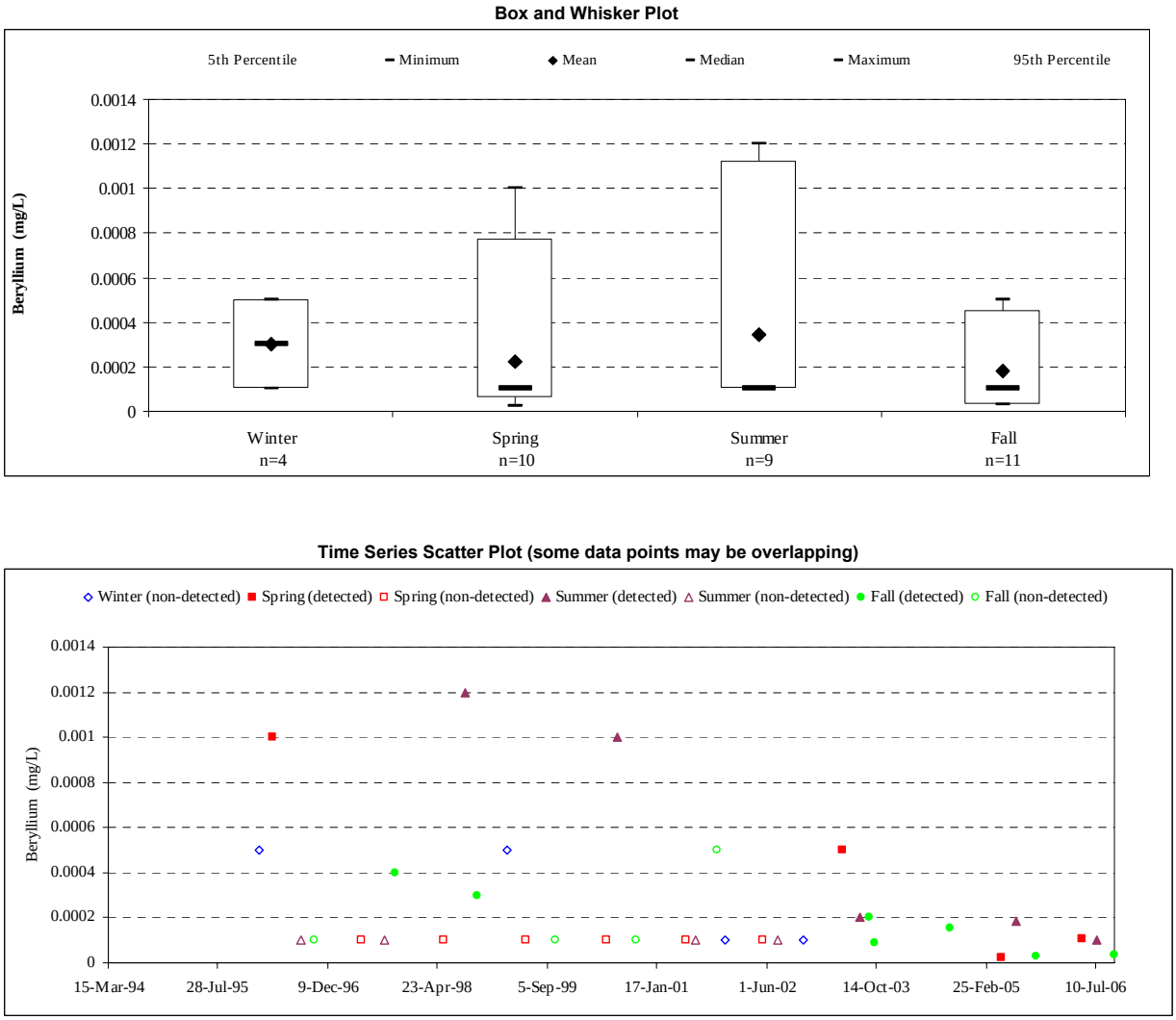
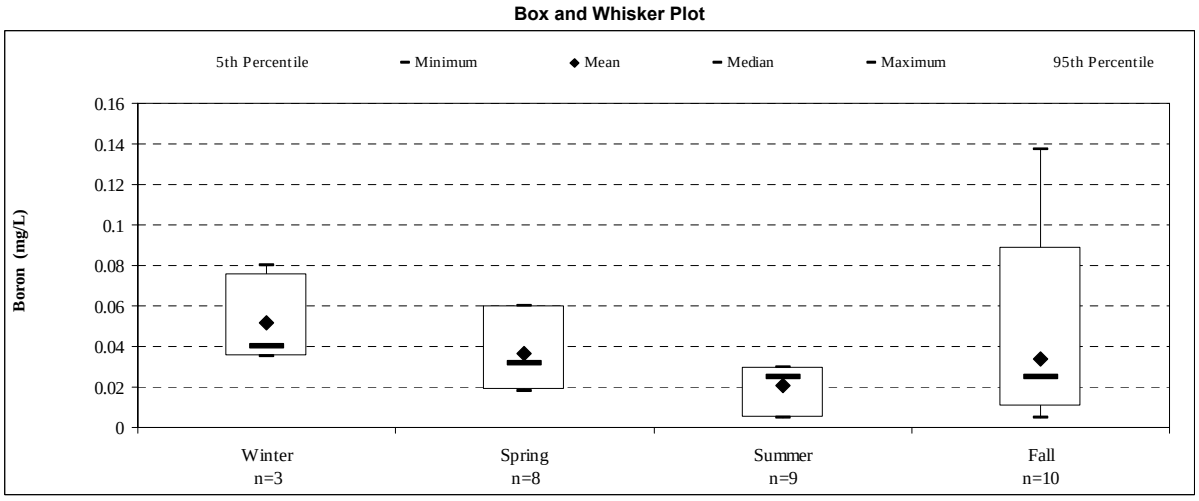


Figure G-1-3-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Lower Reach of Lower Athabasca River



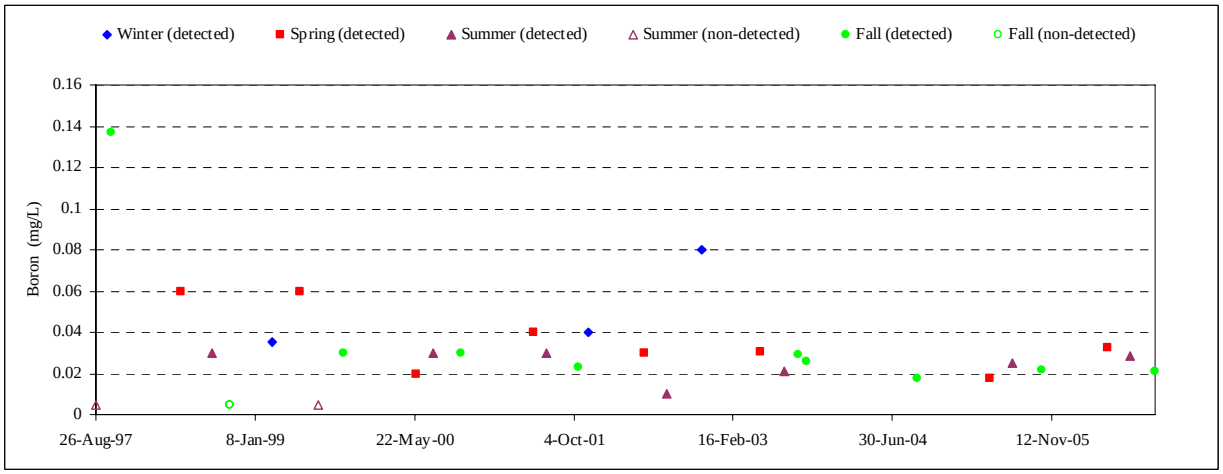
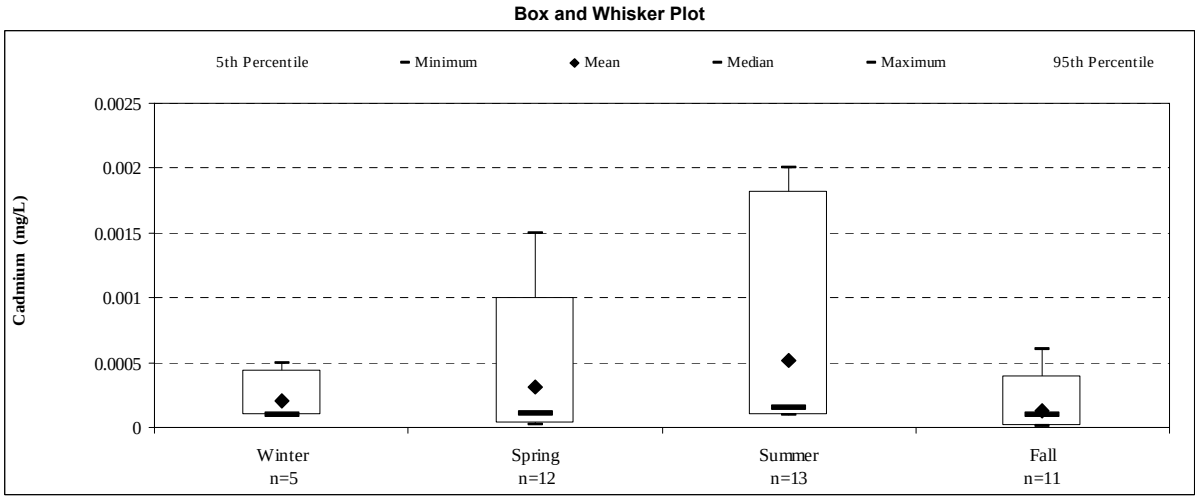


Figure G-1-3-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Lower Reach of Lower Athabasca River



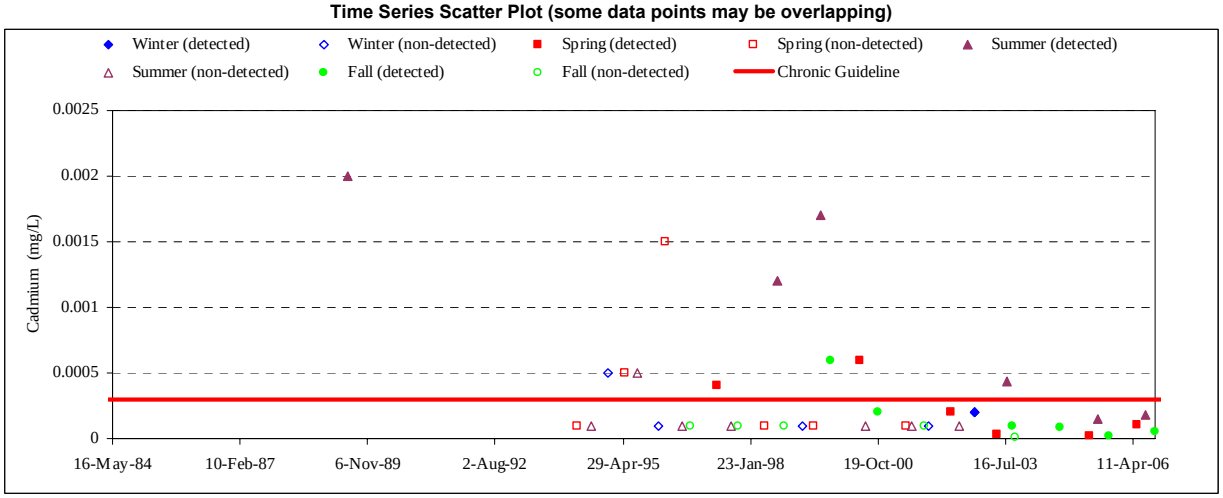
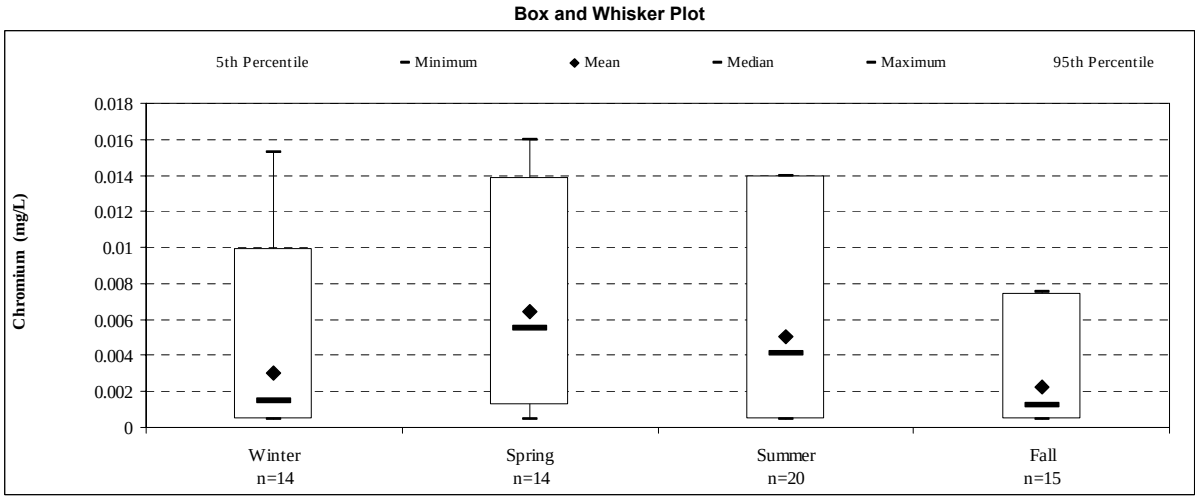


Figure G-1-3-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Lower Reach of Lower Athabasca River



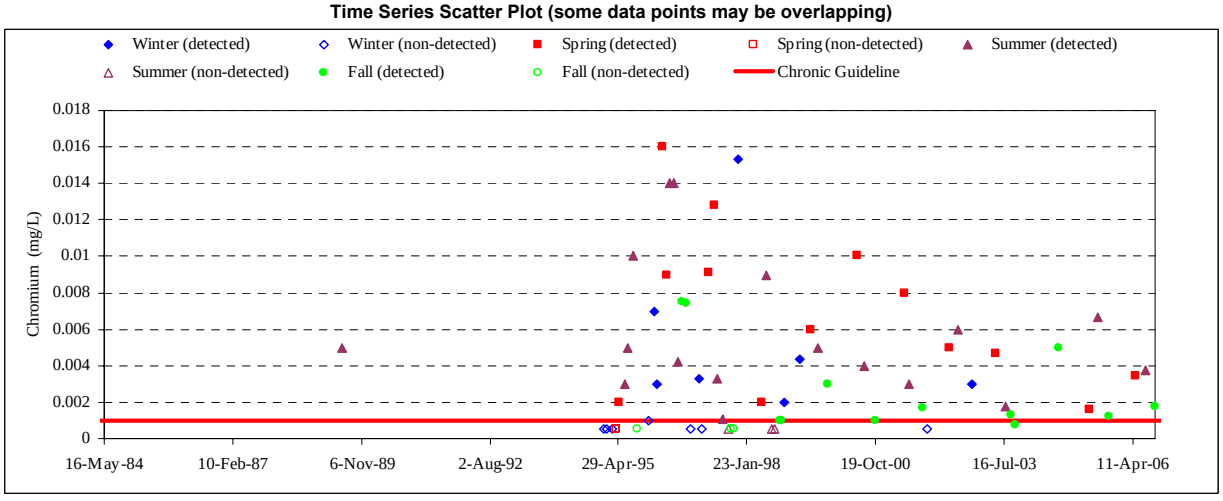
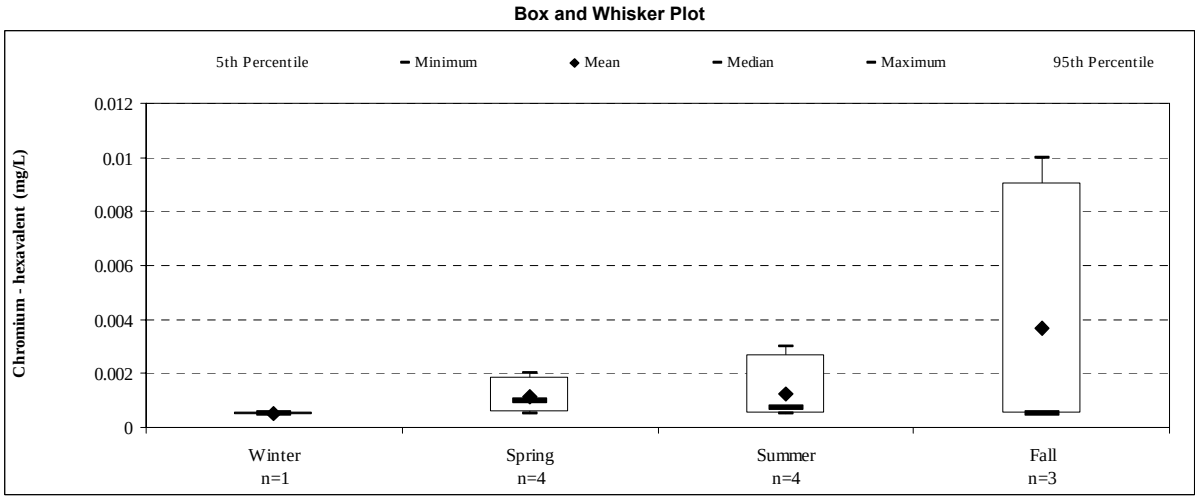


Figure G-1-3-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Lower Reach of Lower Athabasca River



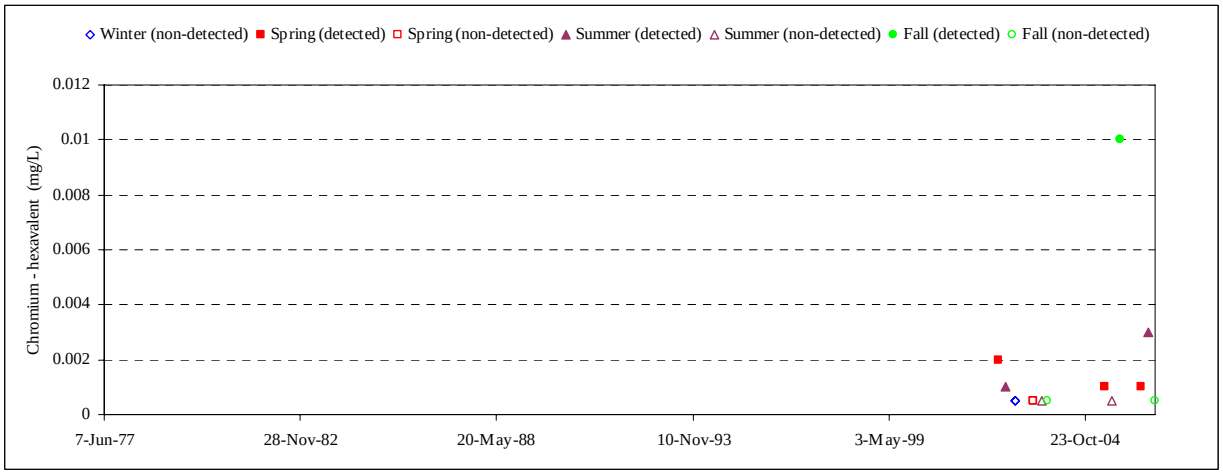


Figure G-1-3-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Lower Reach of Lower Athabasca River

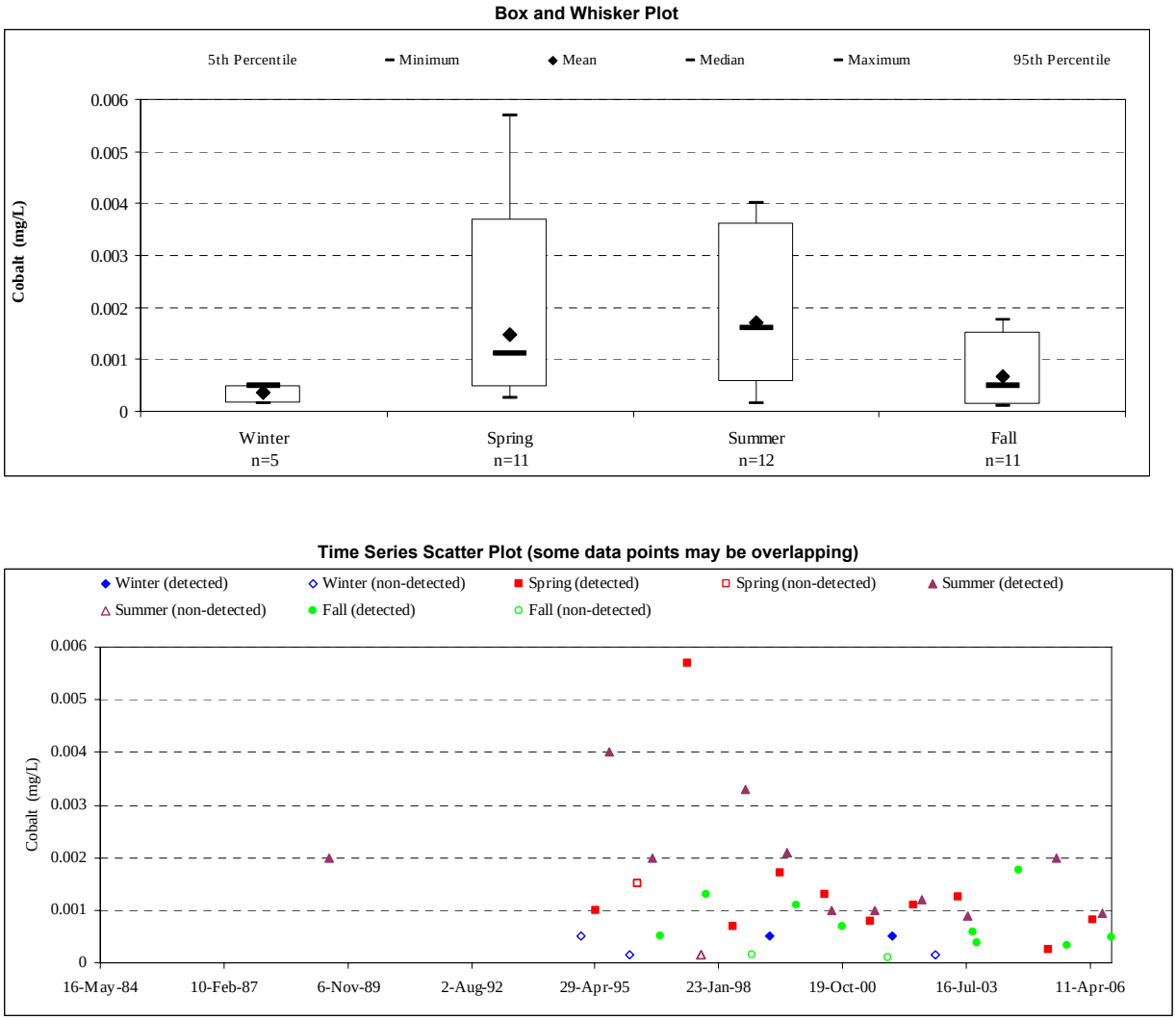


Figure G-1-3-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Lower Reach of Lower Athabasca River

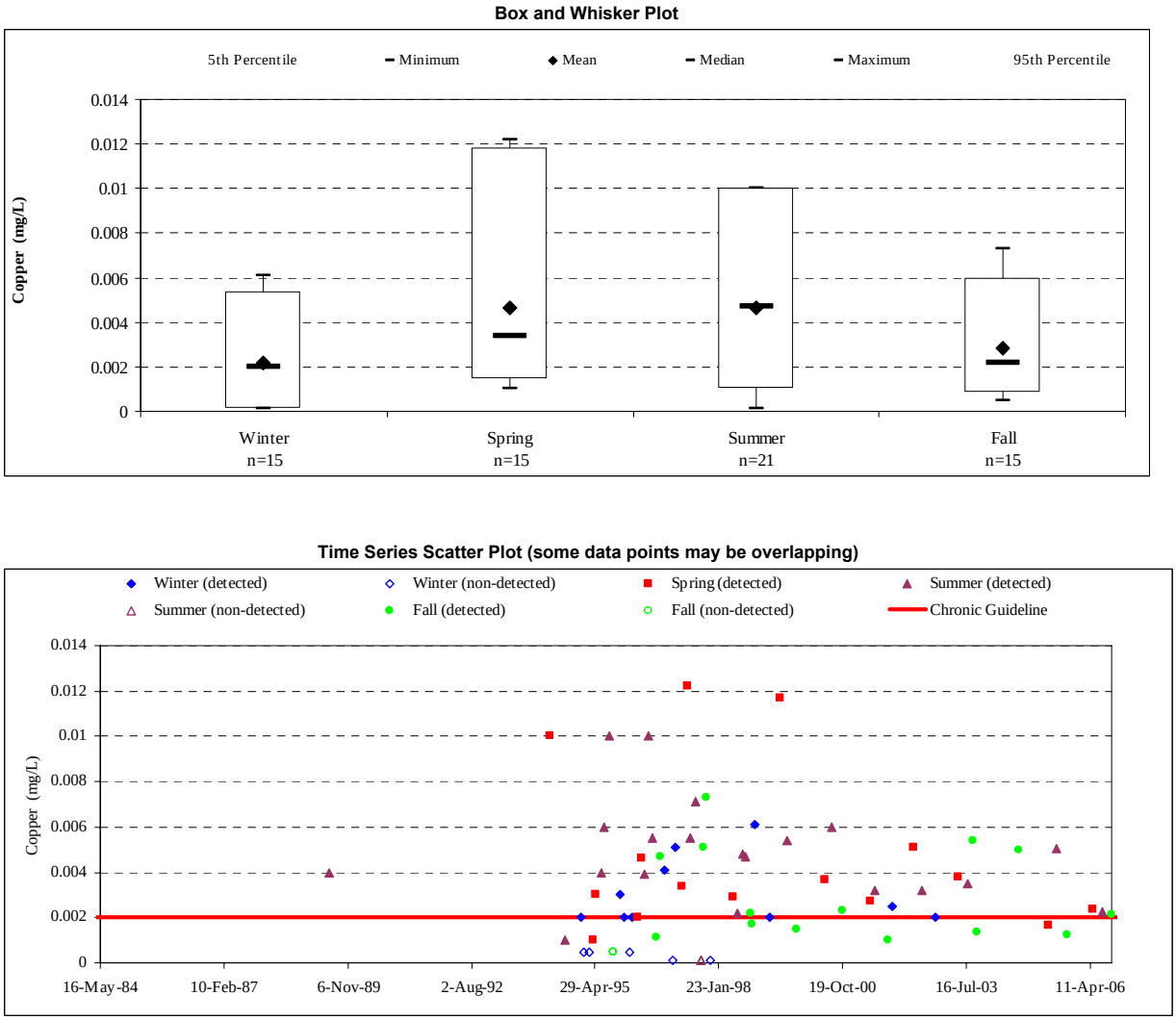


Figure G-1-3-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Lower Reach of Lower Athabasca River

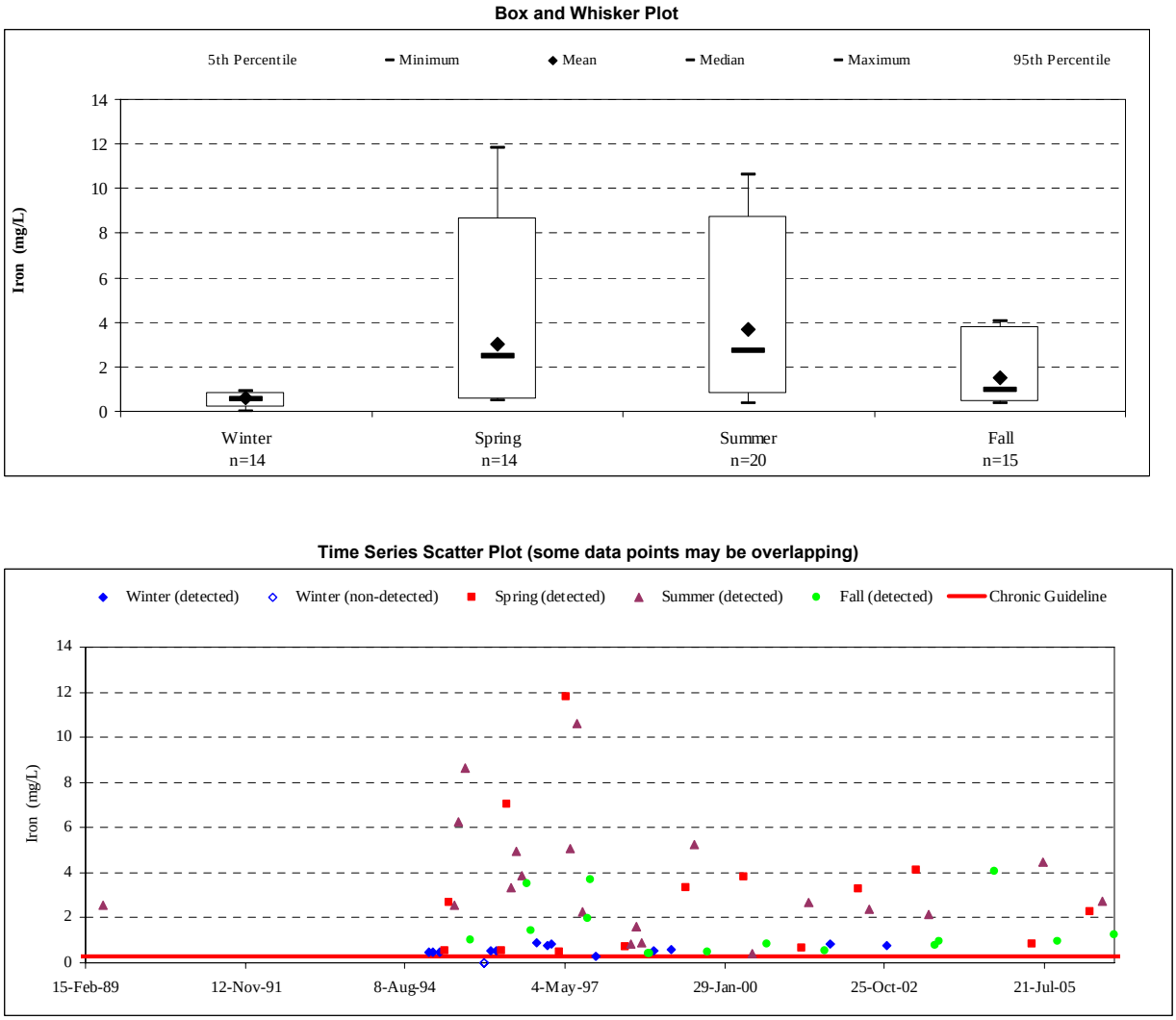
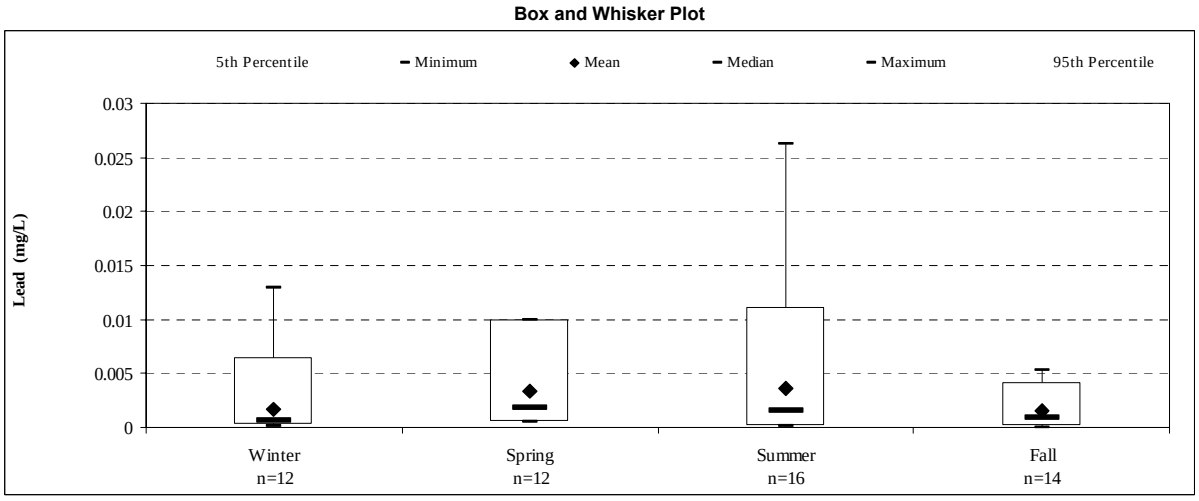


Figure G-1-3-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Lower Reach of Lower Athabasca River



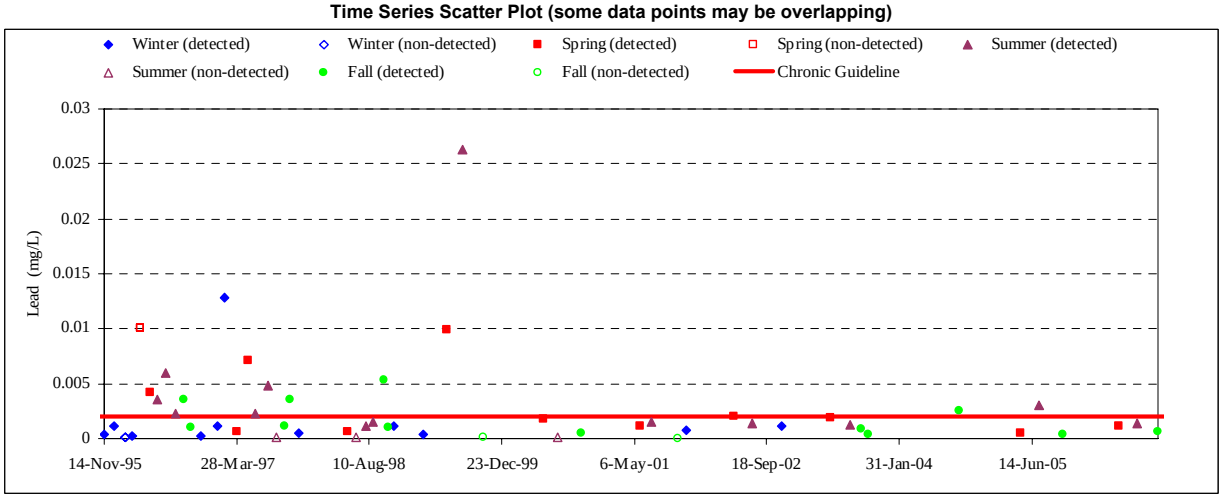


Figure G-1-3-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Lower Reach of Lower Athabasca River

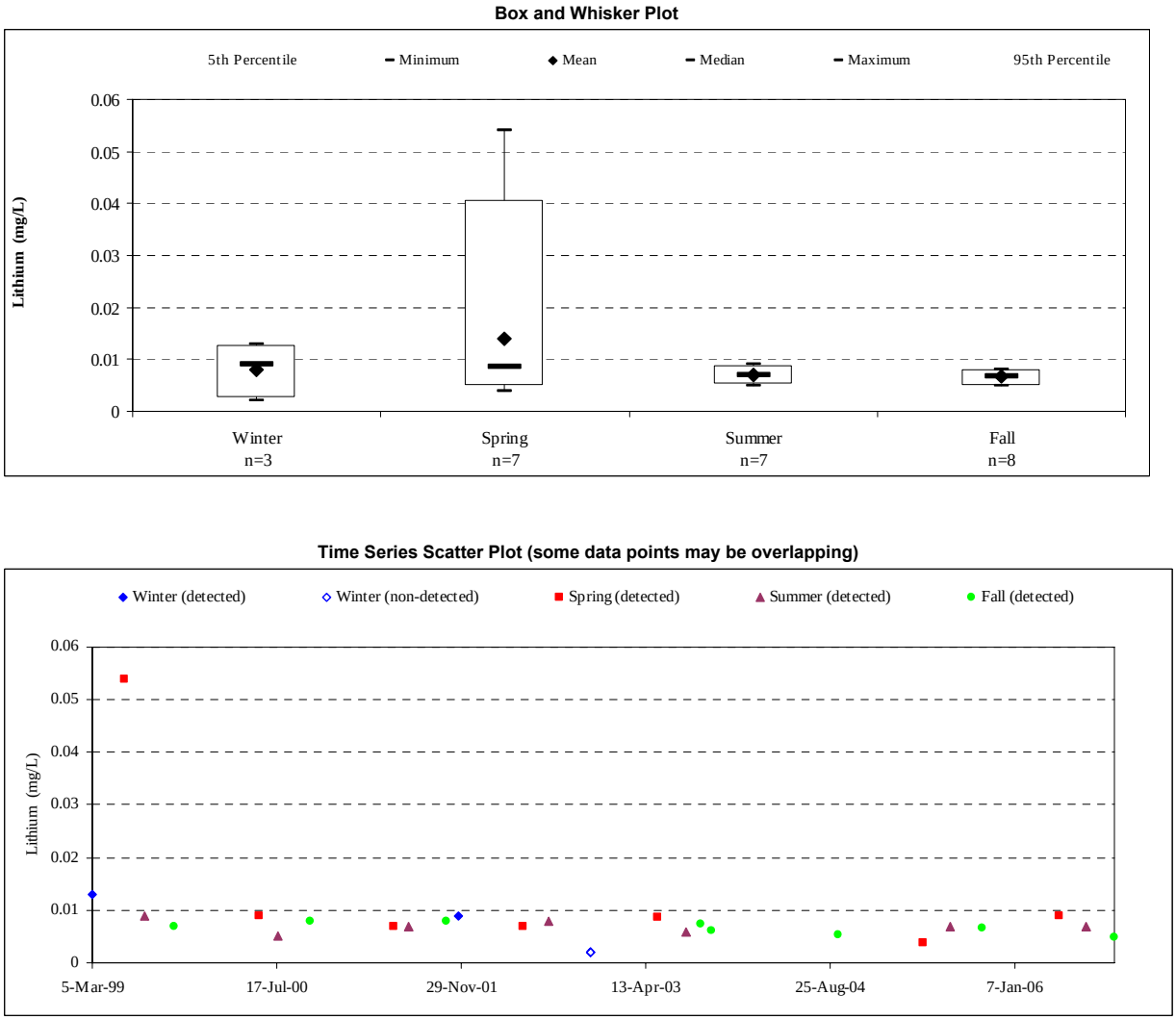
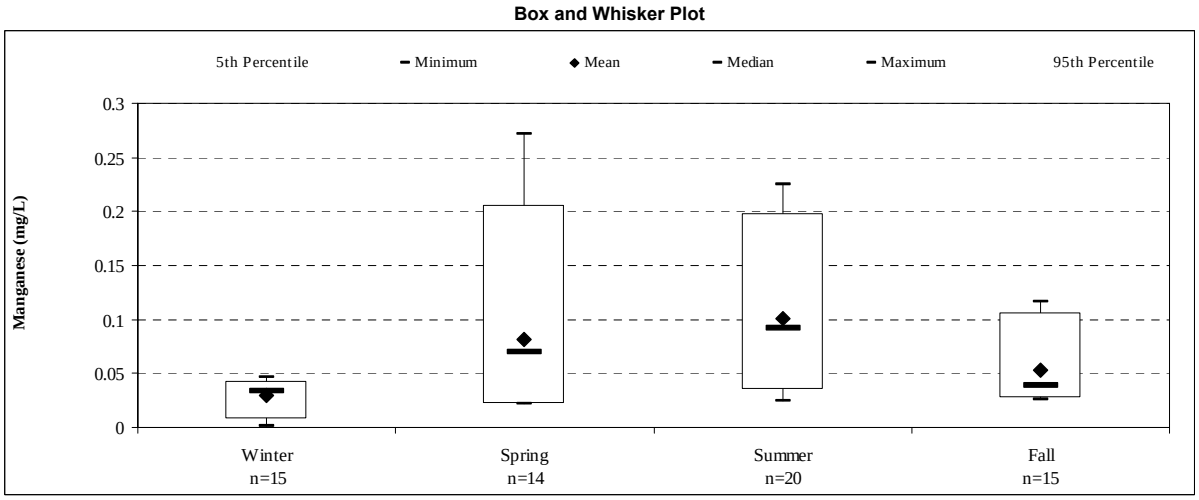


Figure G-1-3-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Lower Reach of Lower Athabasca River



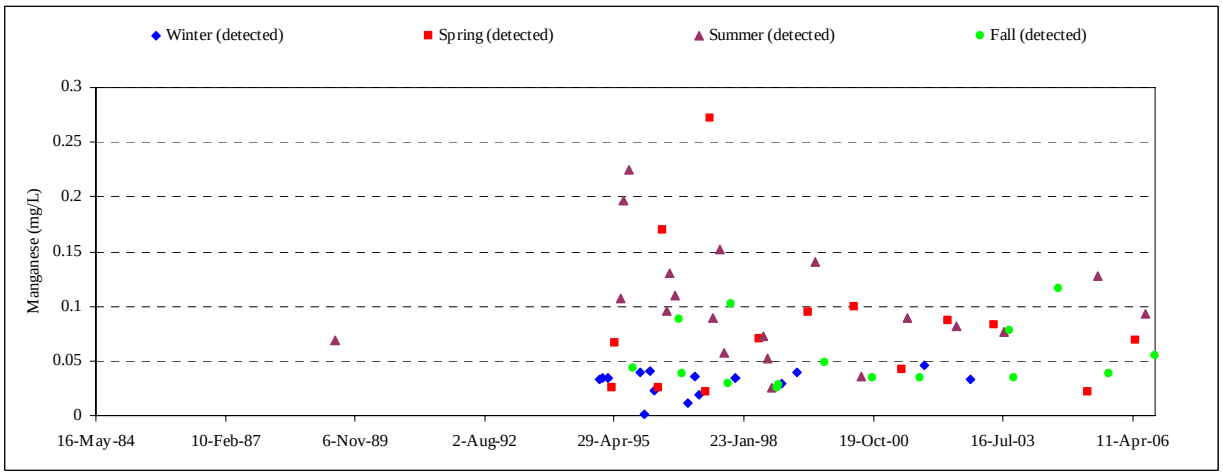
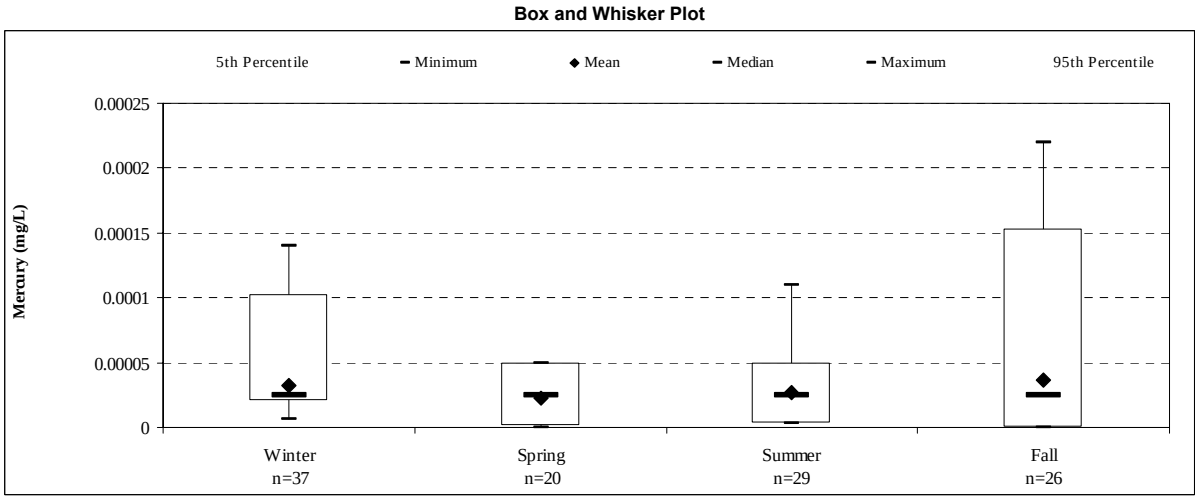


Figure G-1-3-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Lower Reach of Lower Athabasca River



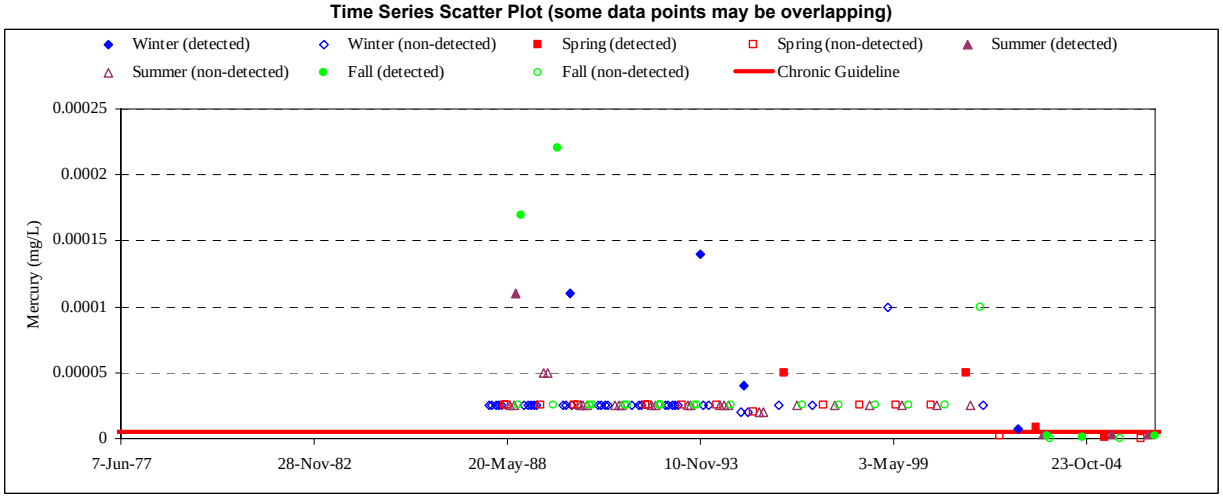
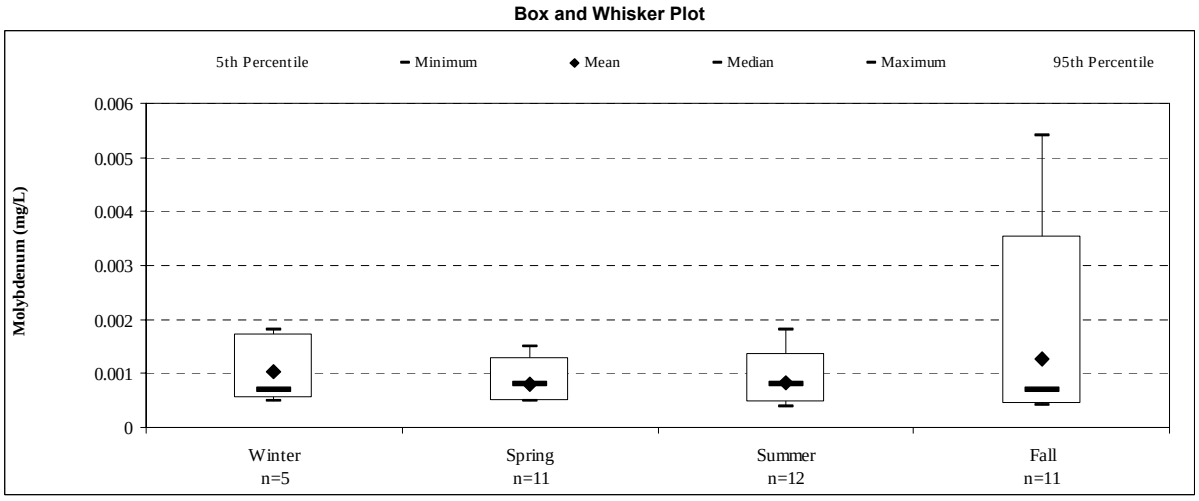


Figure G-1-3-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Lower Reach of Lower Athabasca River



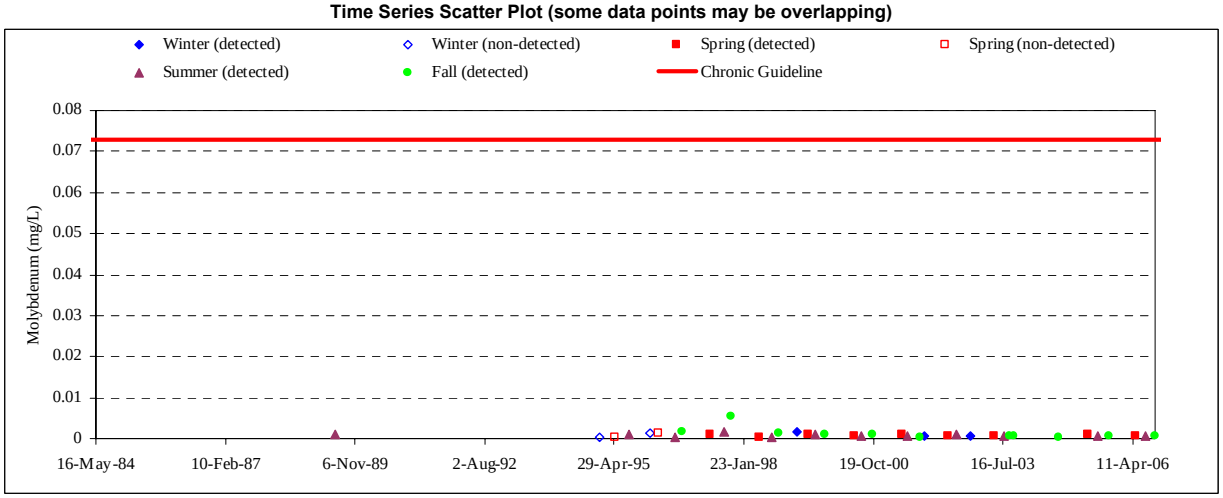


Figure G-1-3-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Lower Reach of Lower Athabasca River

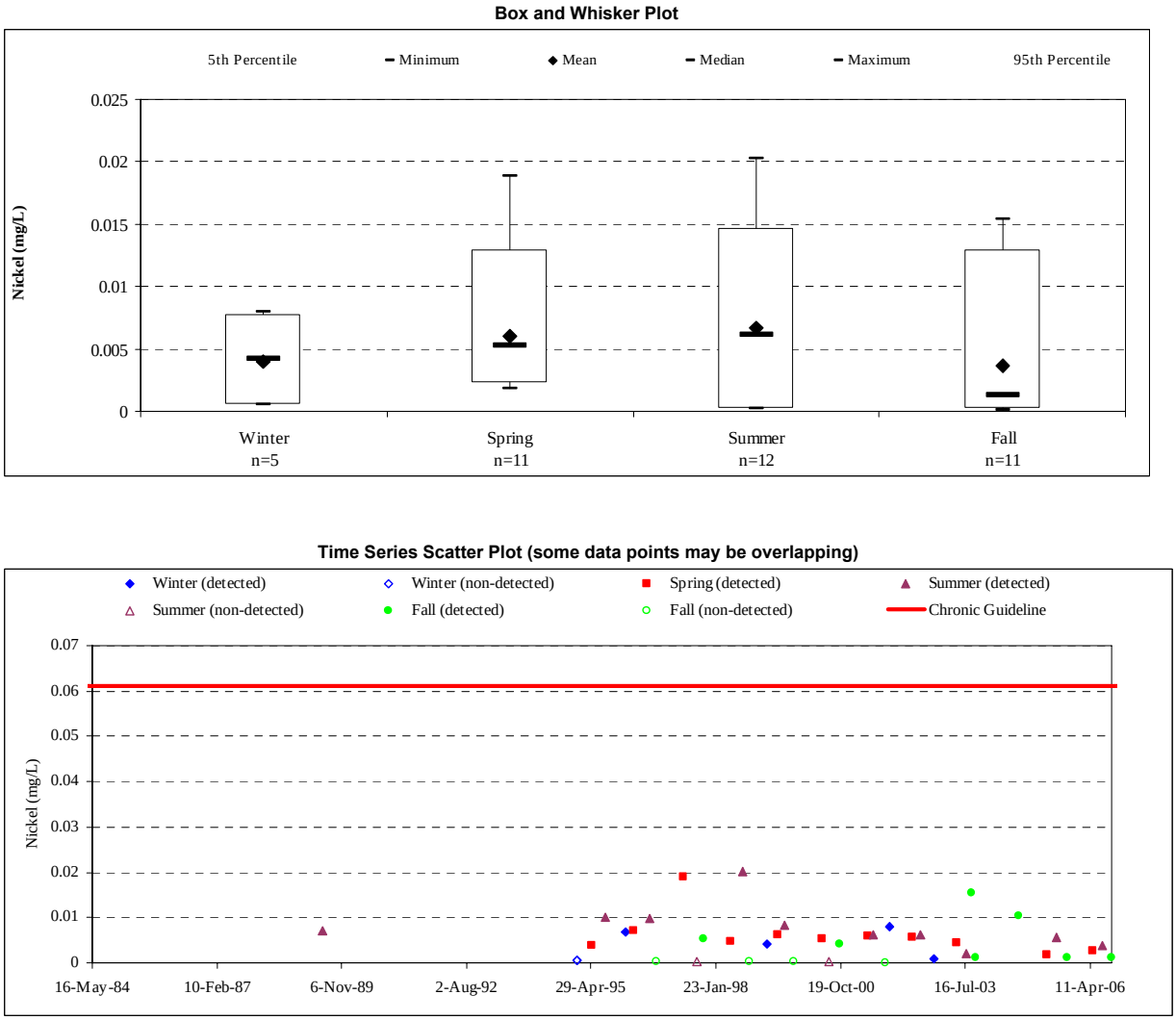
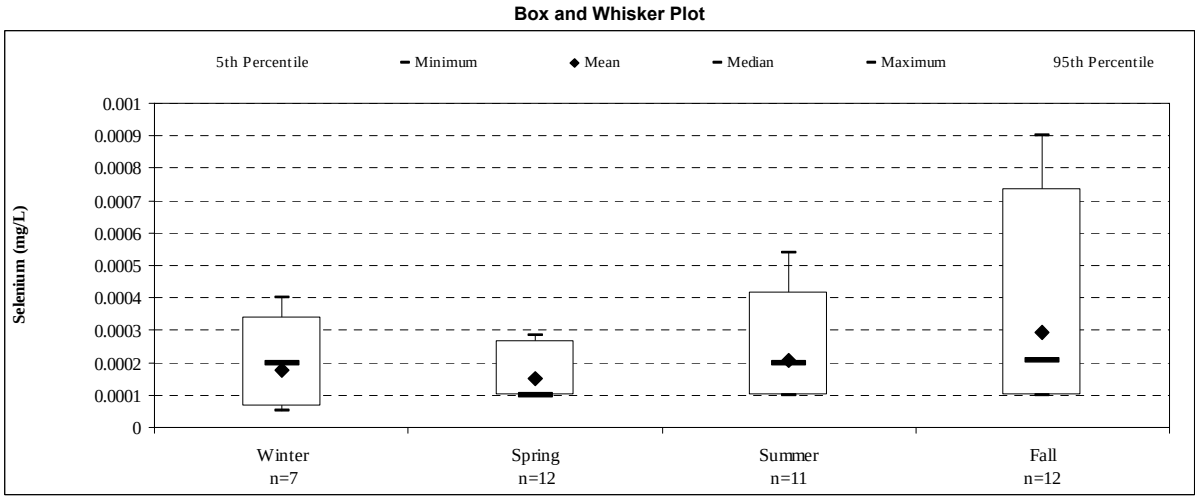


Figure G-1-3-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Lower Reach of Lower Athabasca River



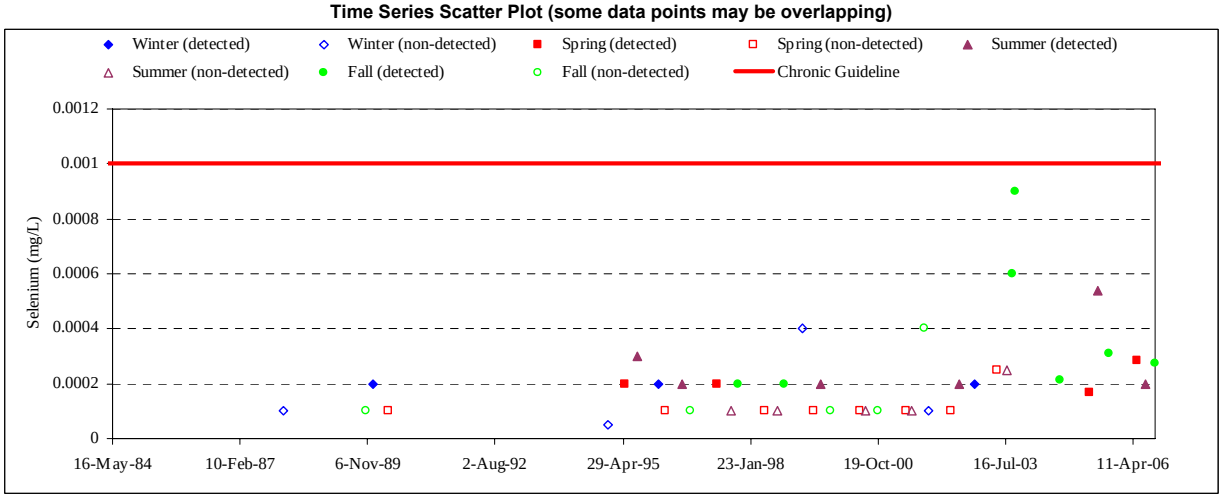


Figure G-1-3-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Lower Reach of Lower Athabasca River

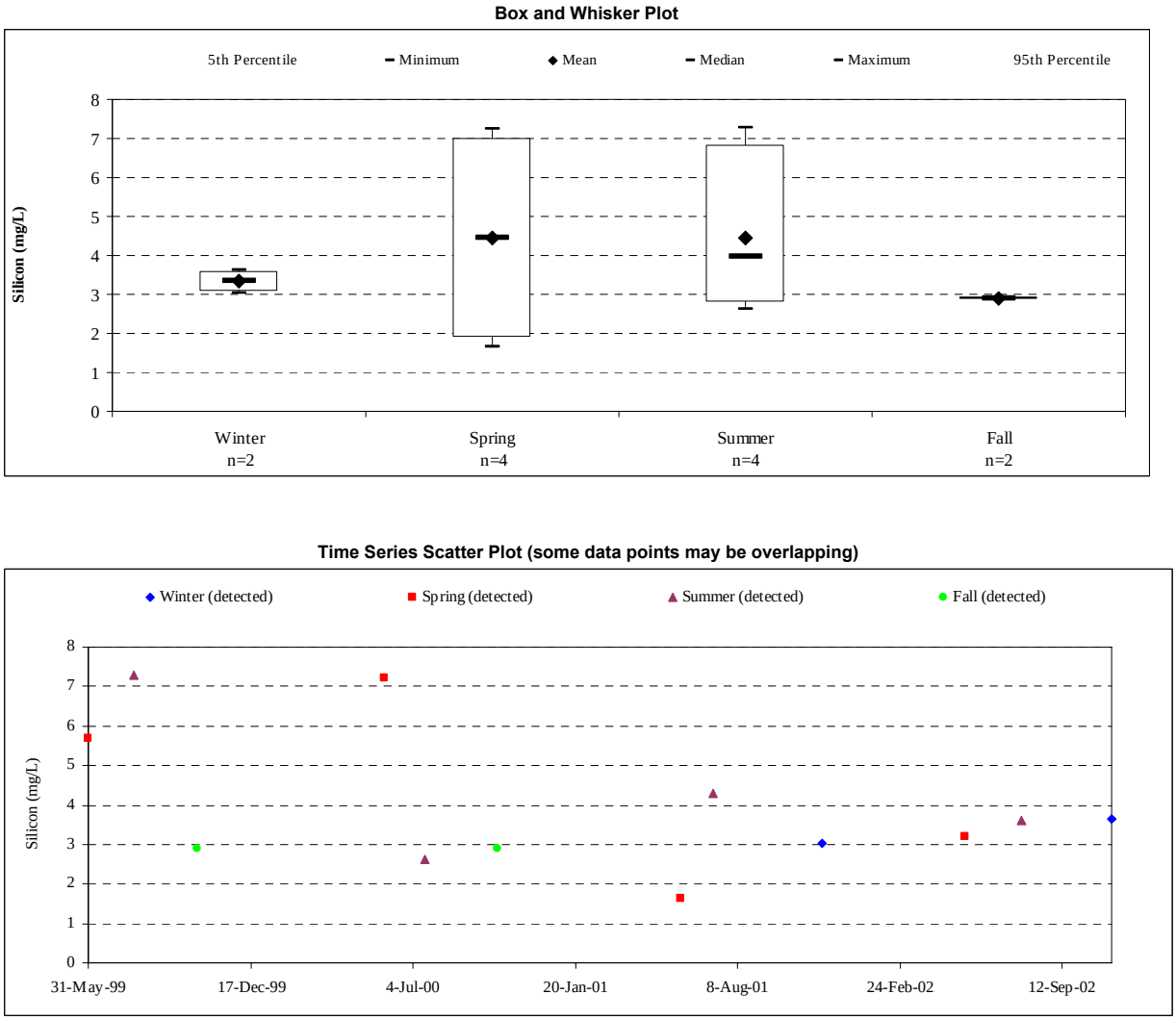
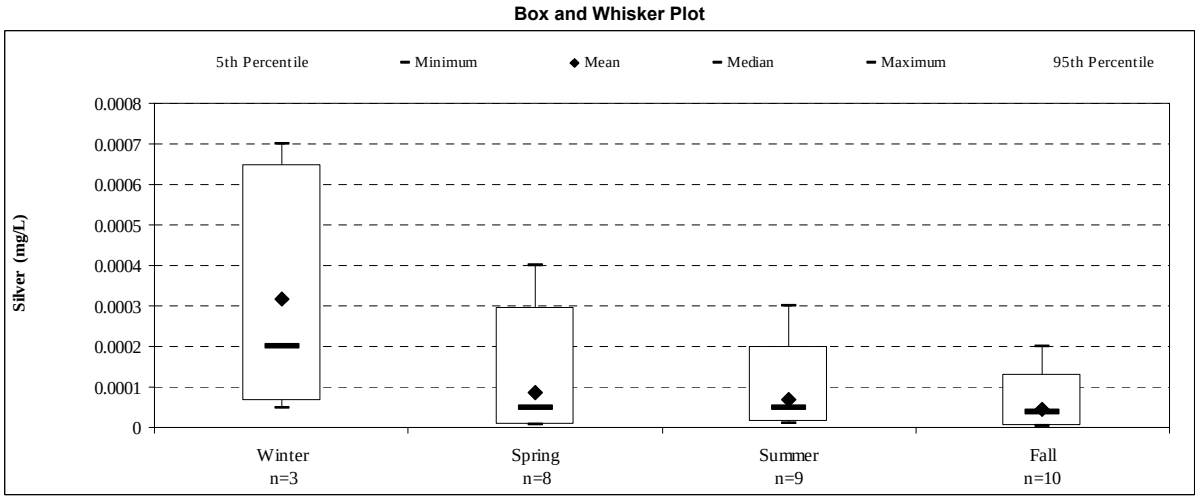


Figure G-1-3-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Lower Reach of Lower Athabasca River



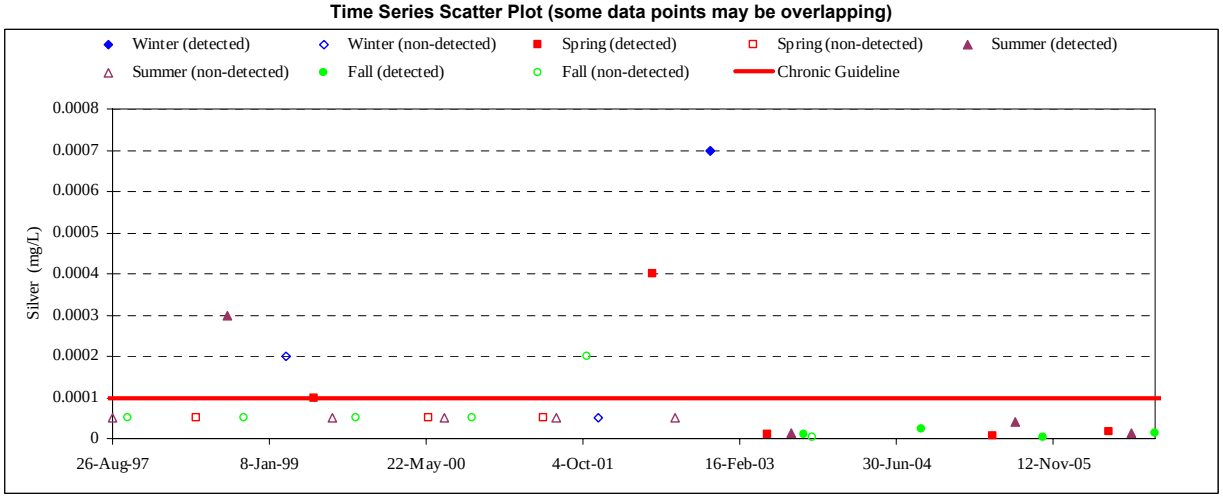
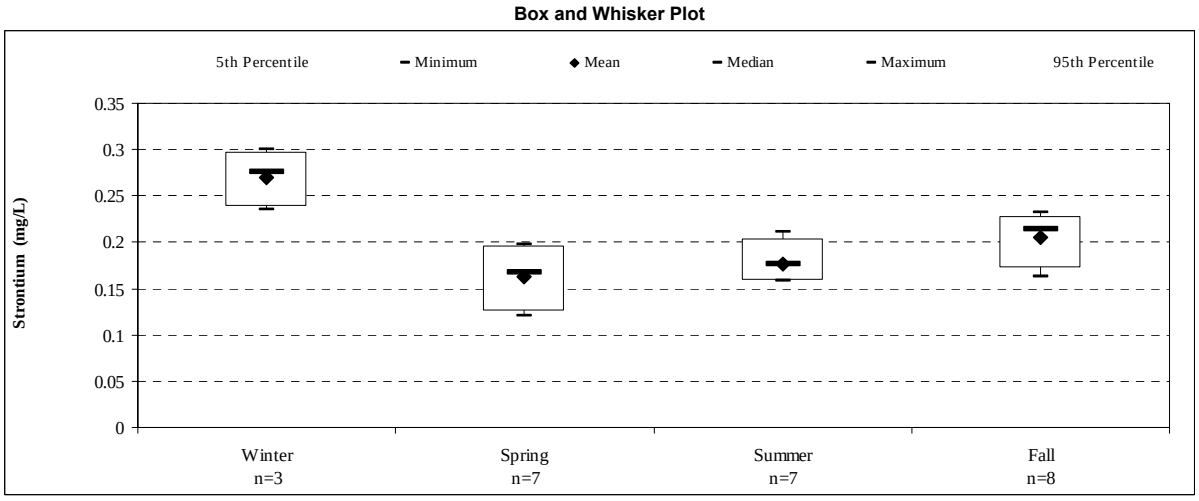


Figure G-1-3-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Lower Reach of Lower Athabasca River



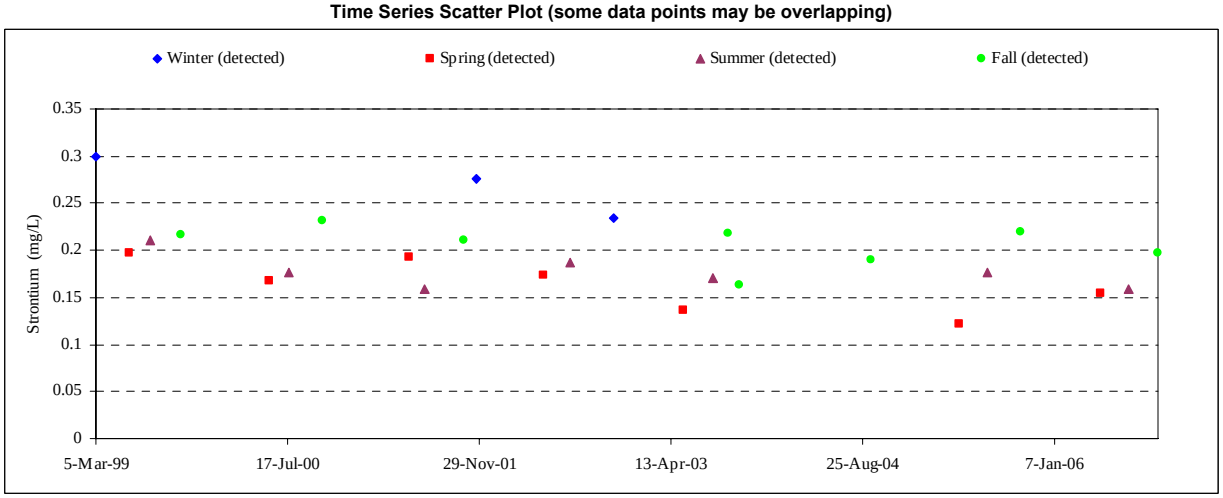


Figure G-1-3-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Lower Reach of Lower Athabasca River

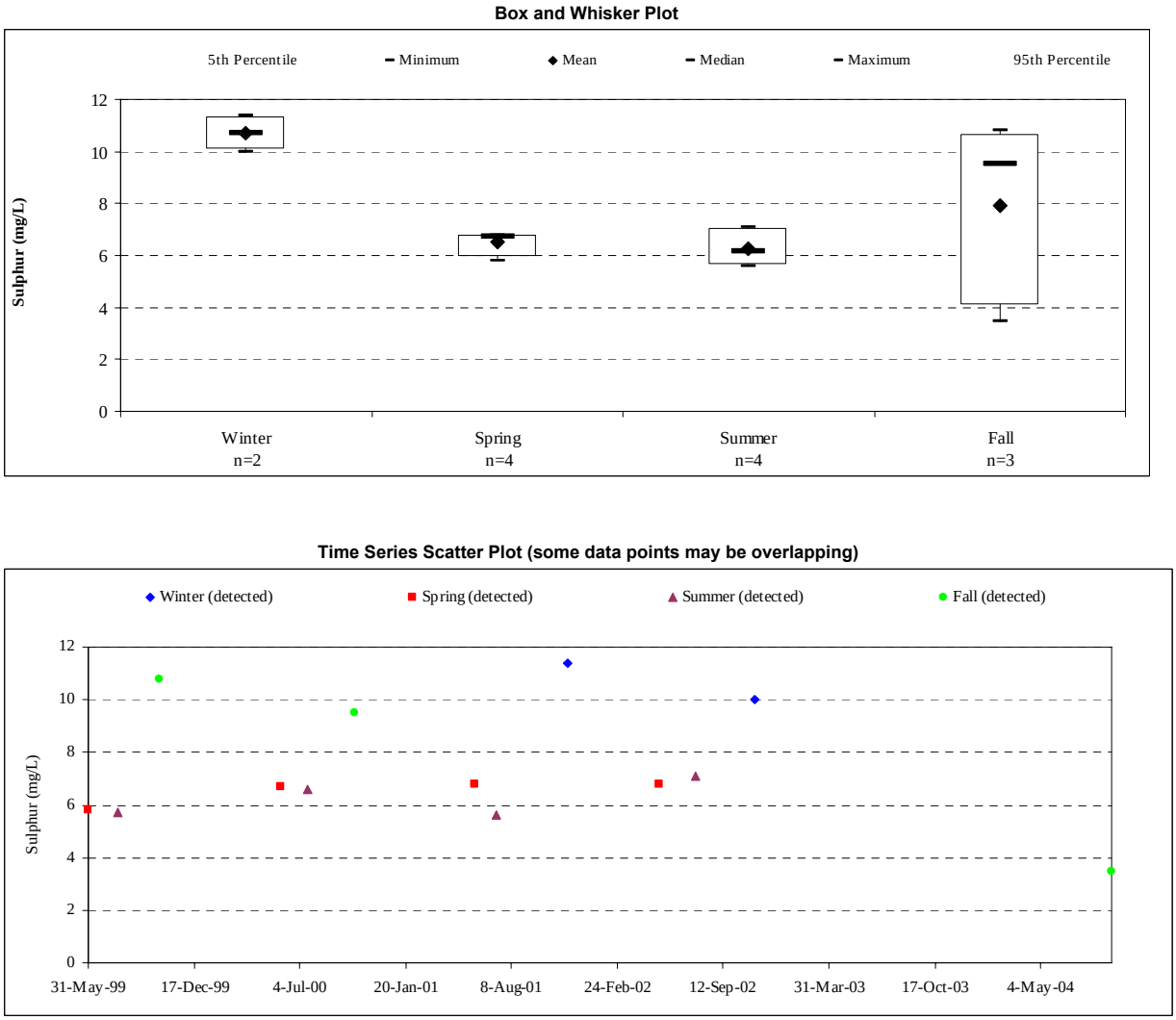
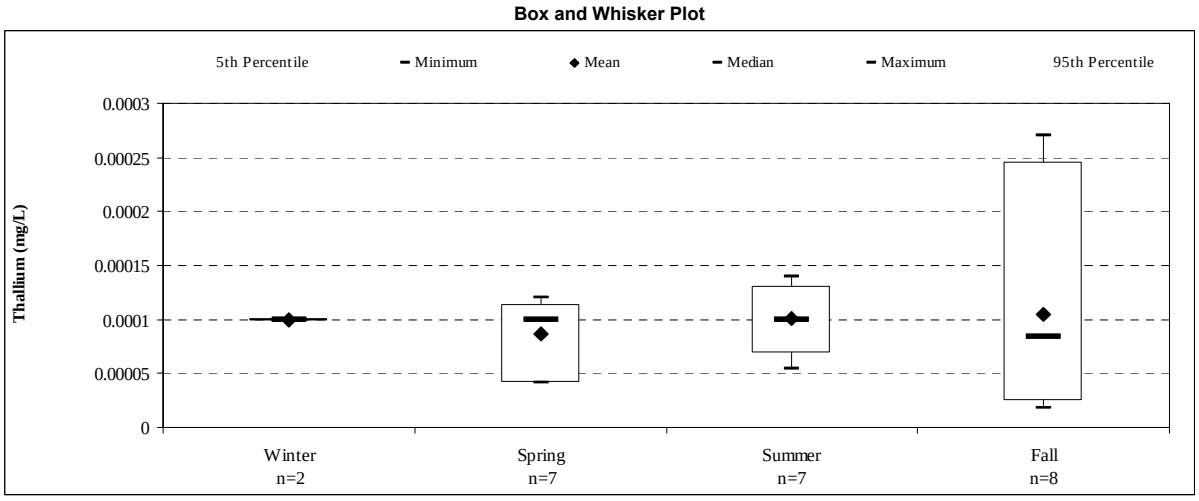


Figure G-1-3-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Lower Reach of Lower Athabasca River



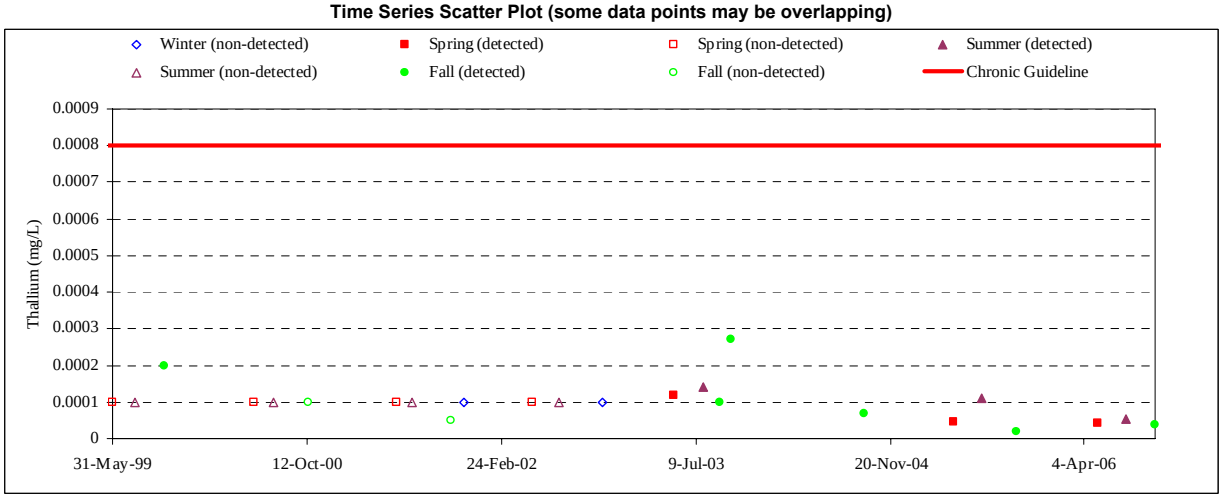


Figure G-1-3-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Lower Reach of Lower Athabasca River

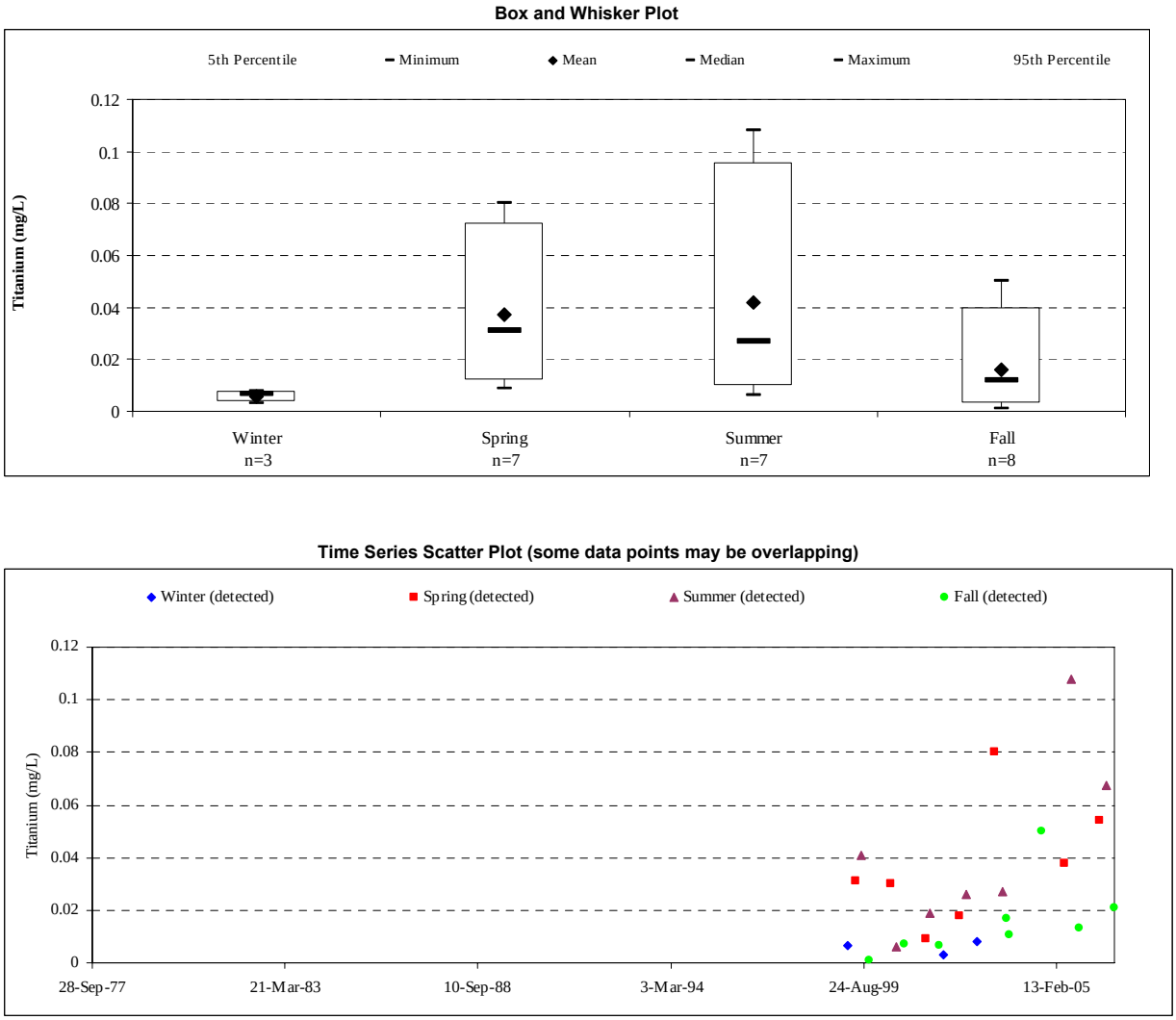


Figure G-1-3-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Lower Reach of Lower Athabasca River

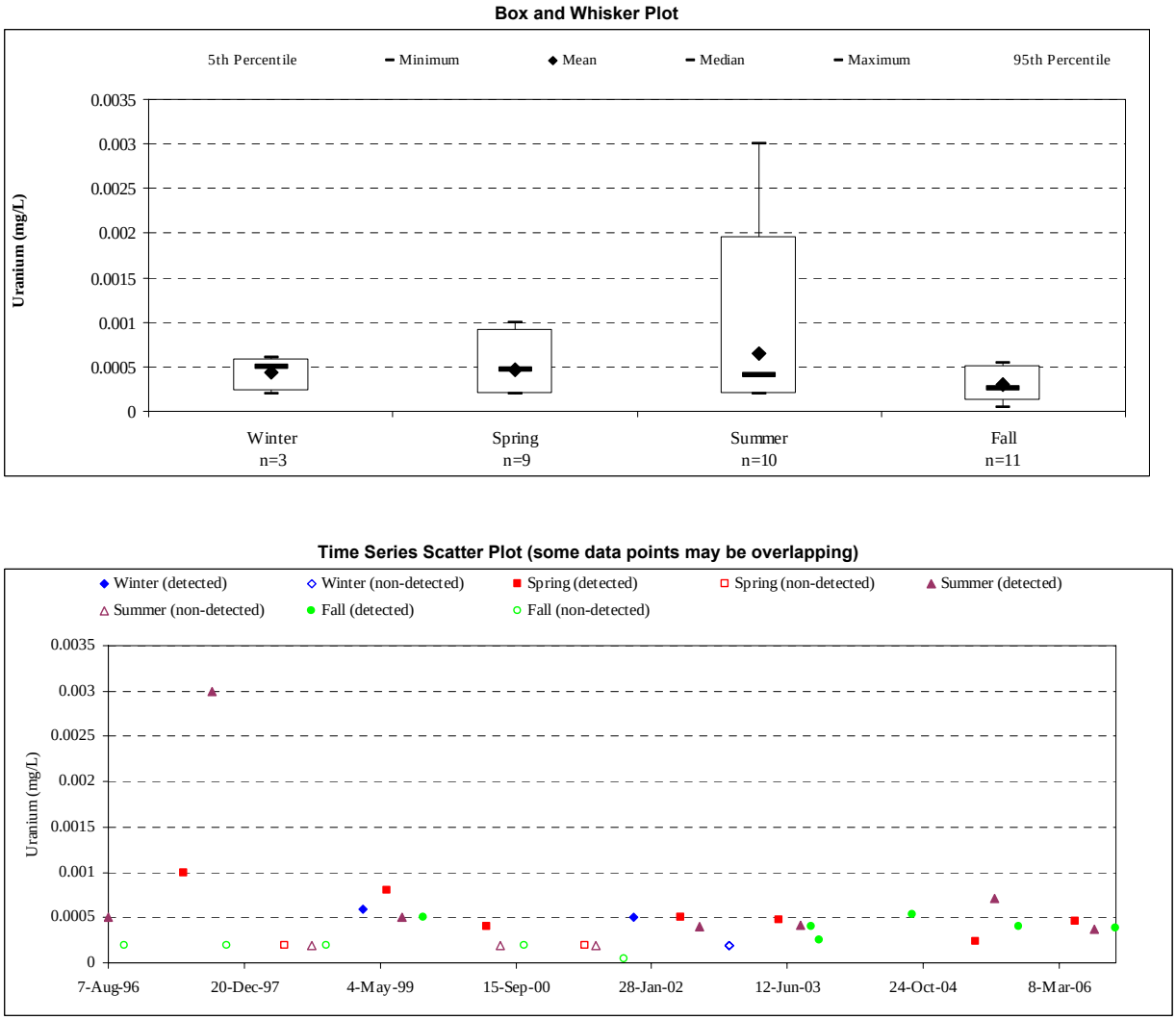
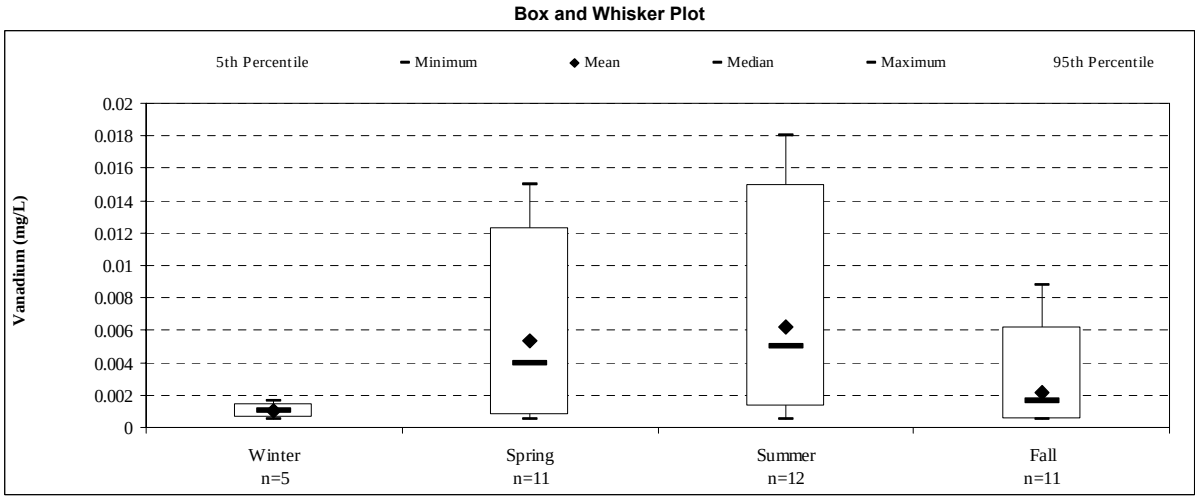


Figure G-1-3-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Lower Reach of Lower Athabasca River



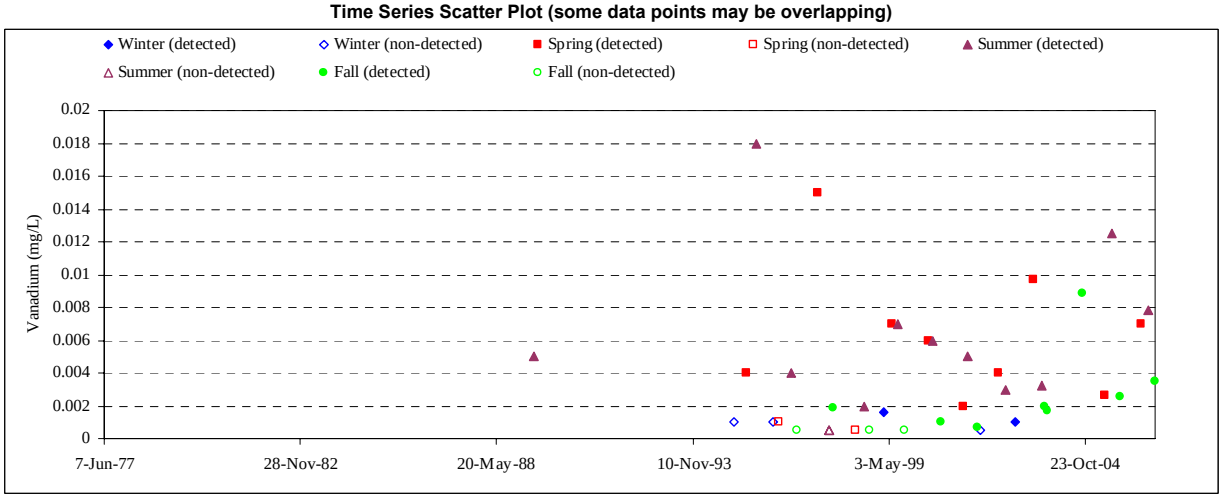


Figure G-1-3-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Lower Reach of Lower Athabasca River

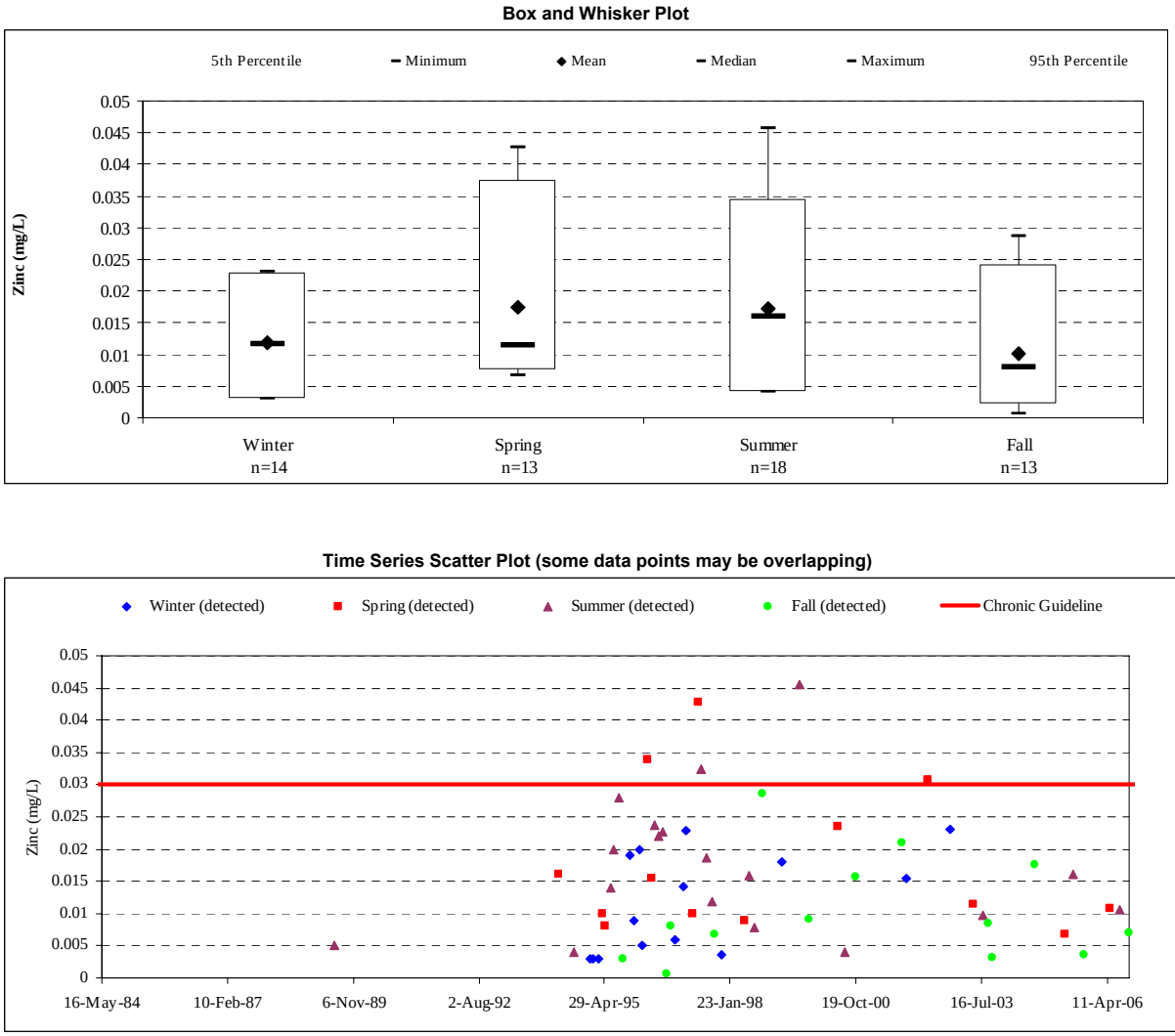
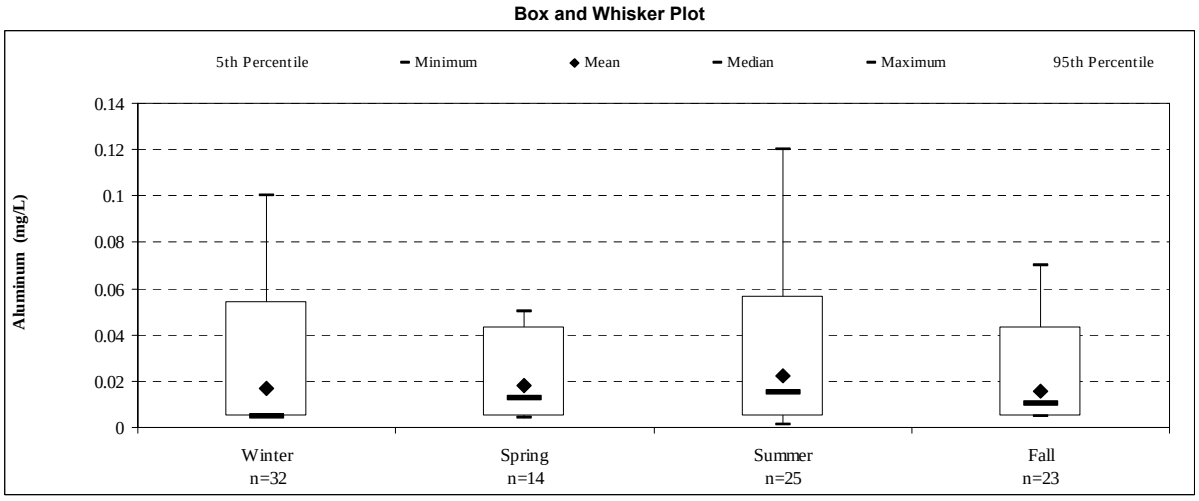


Figure G-1-3-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Lower Reach of Lower Athabasca River



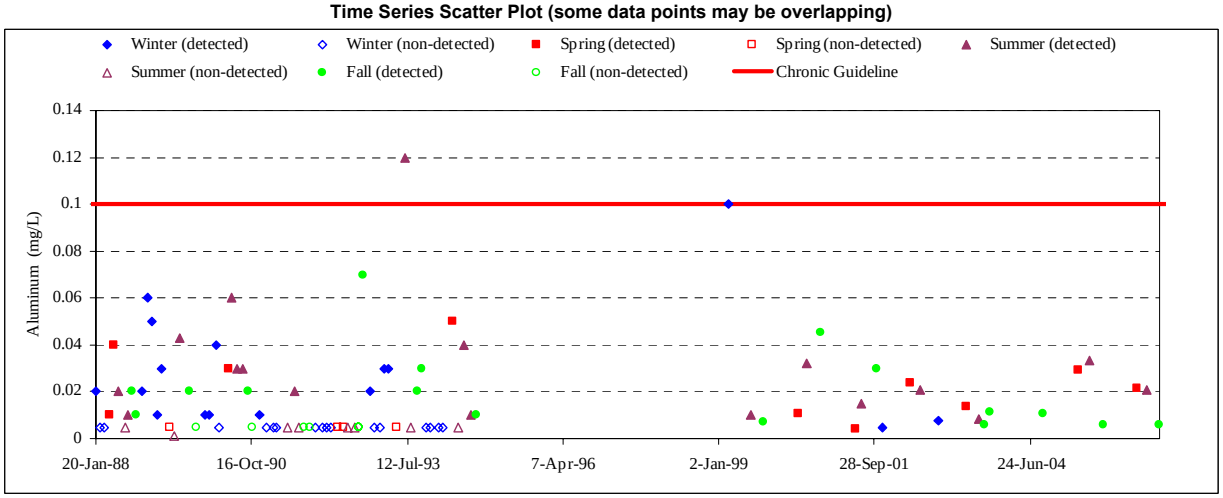


Figure G-1-3-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Lower Reach of Lower Athabasca River

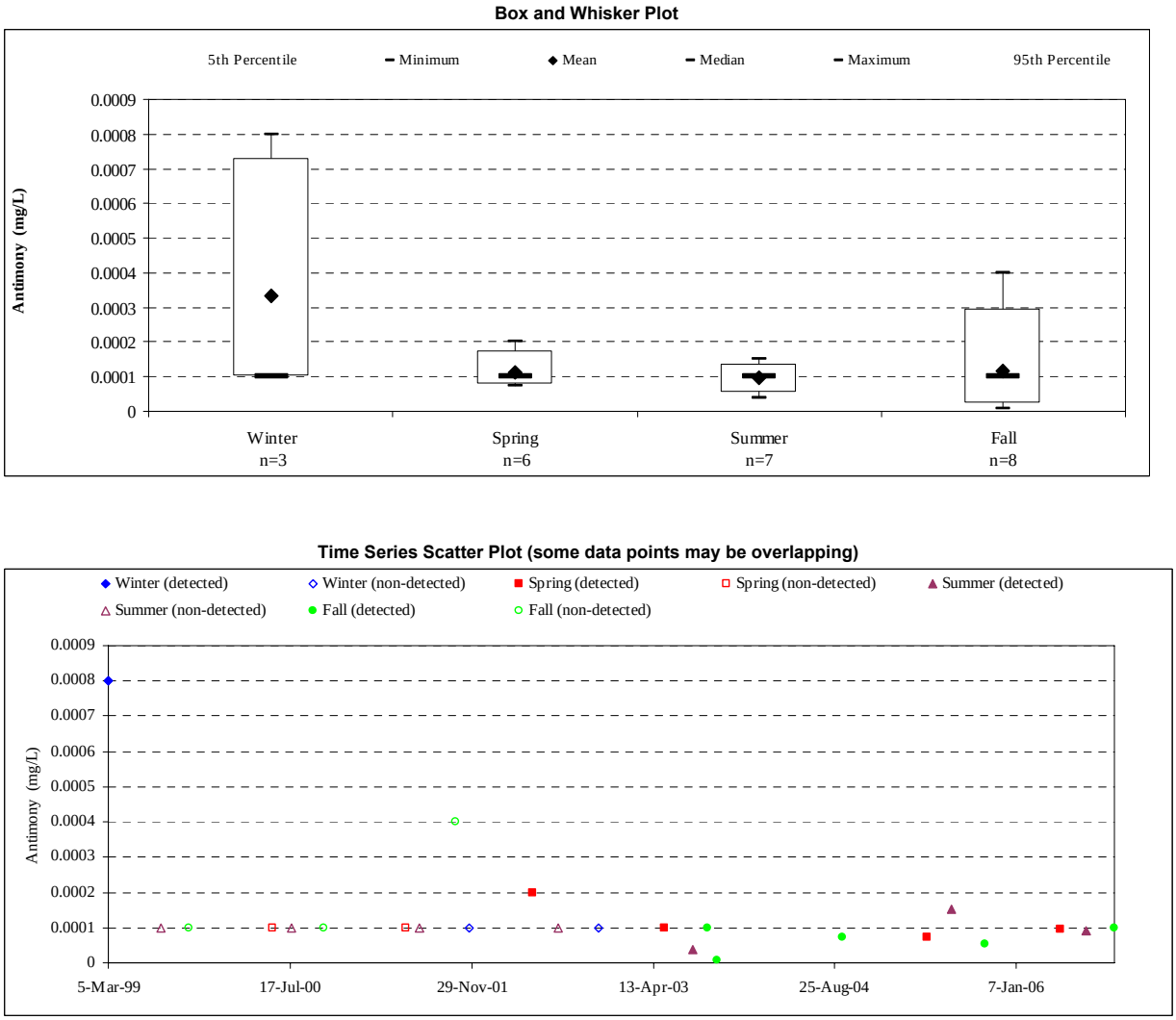
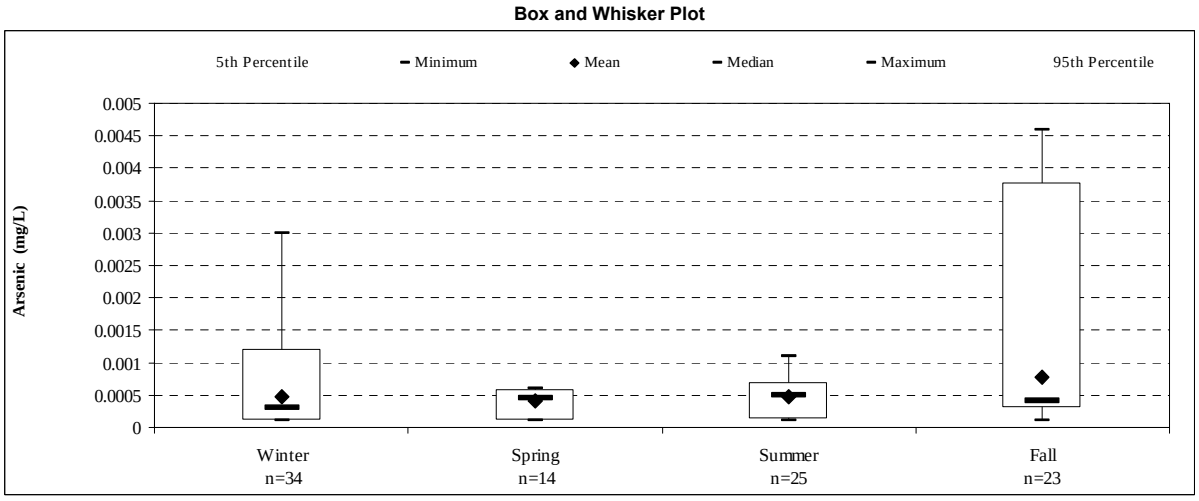


Figure G-1-3-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Lower Reach of Lower Athabasca River



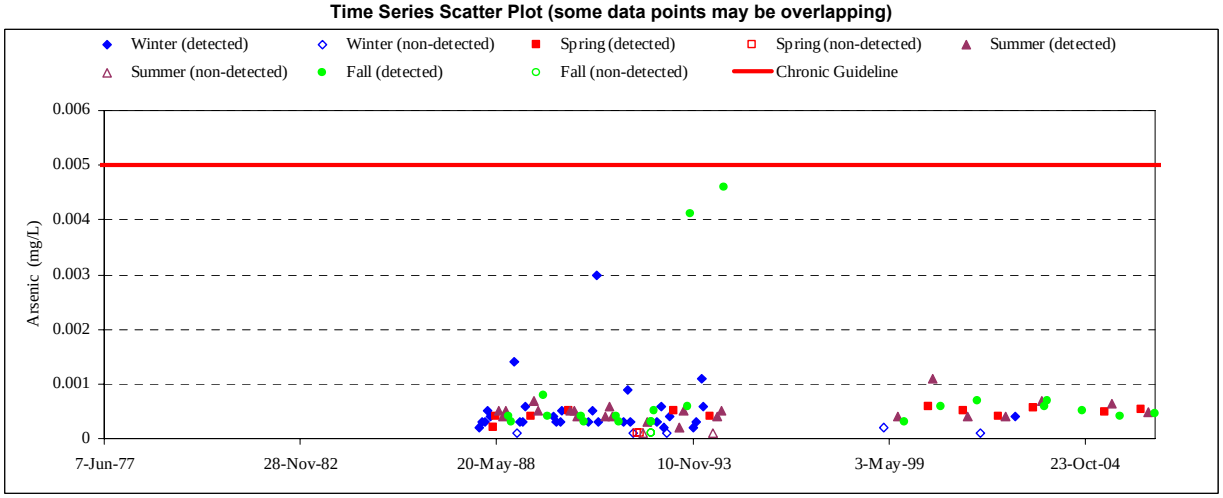


Figure G-1-3-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

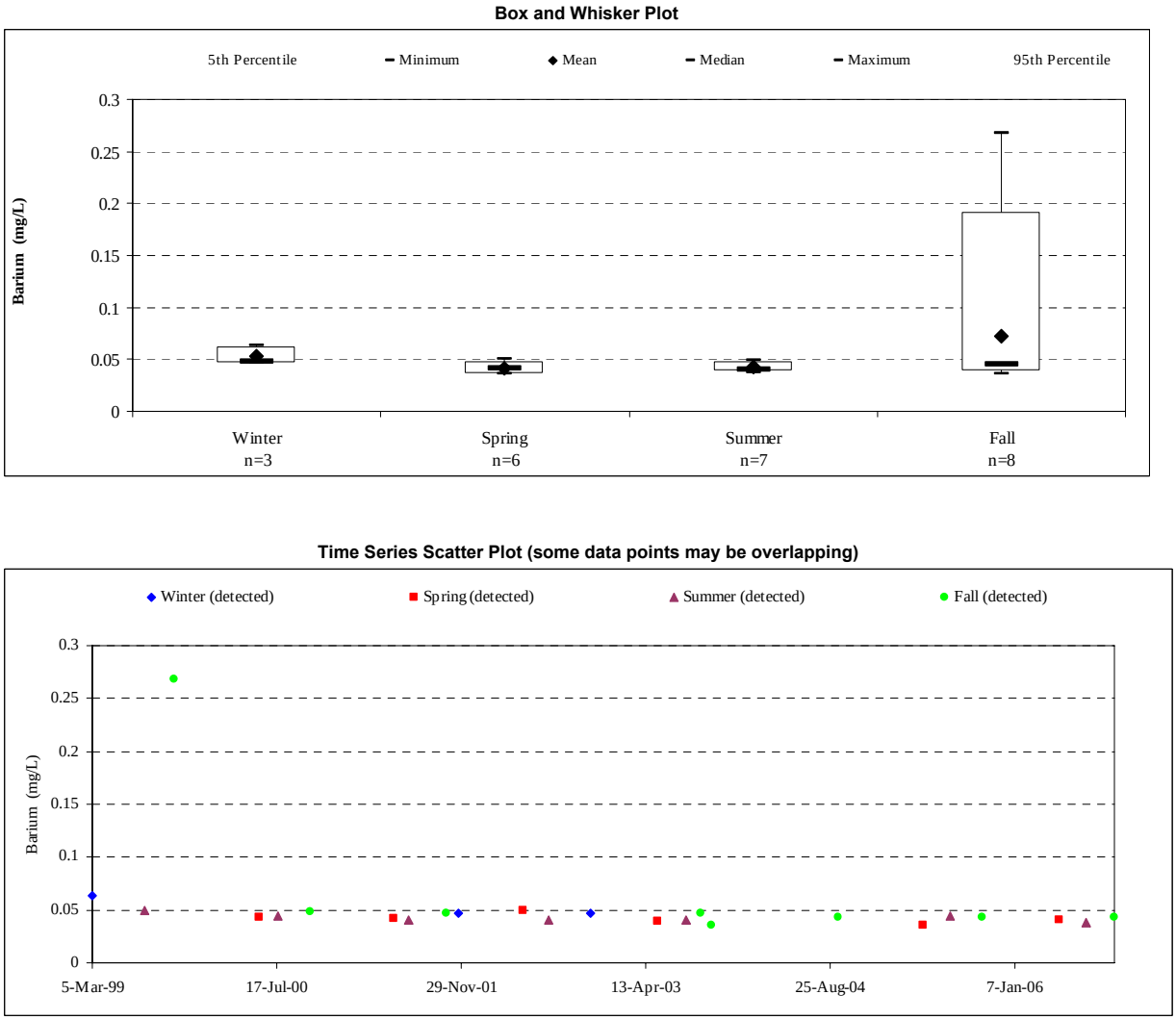


Figure G-1-3-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

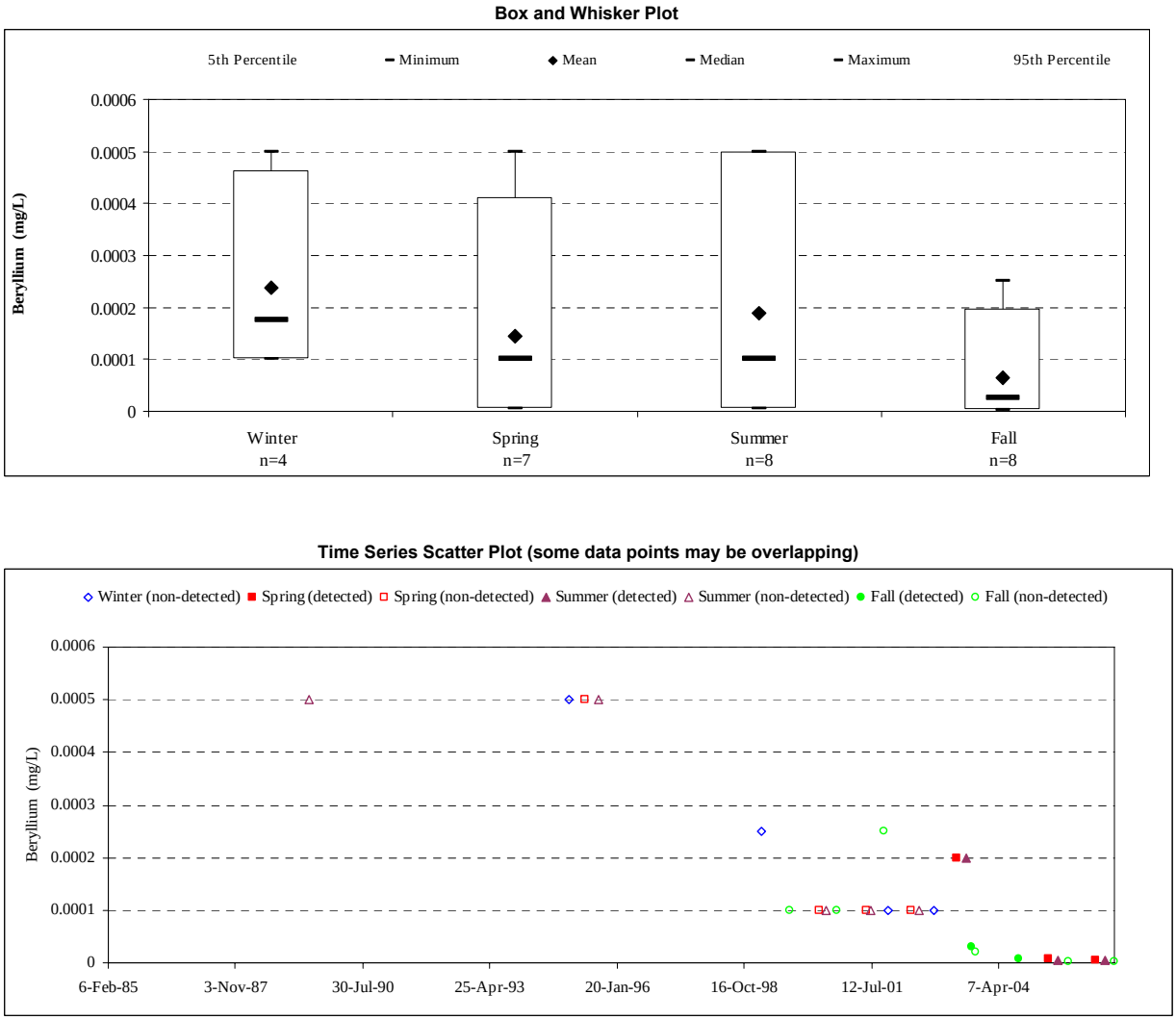
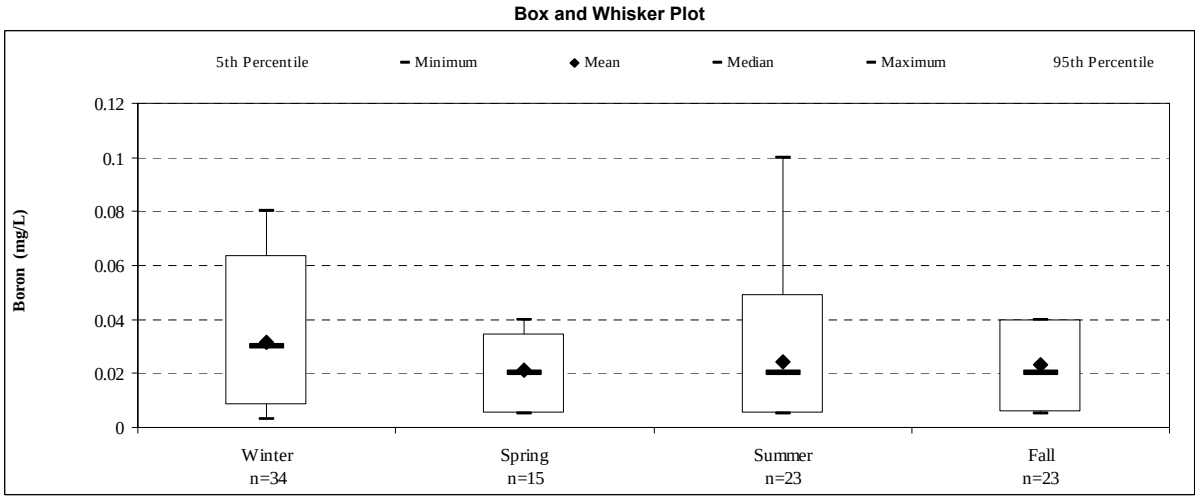


Figure G-1-3-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Lower Reach of Lower Athabasca River



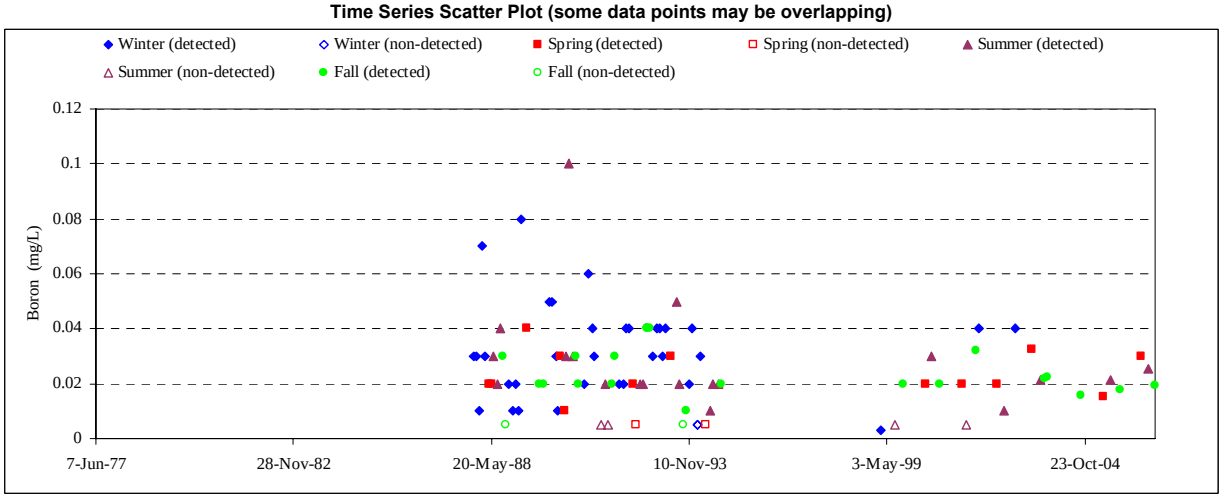


Figure G-1-3-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

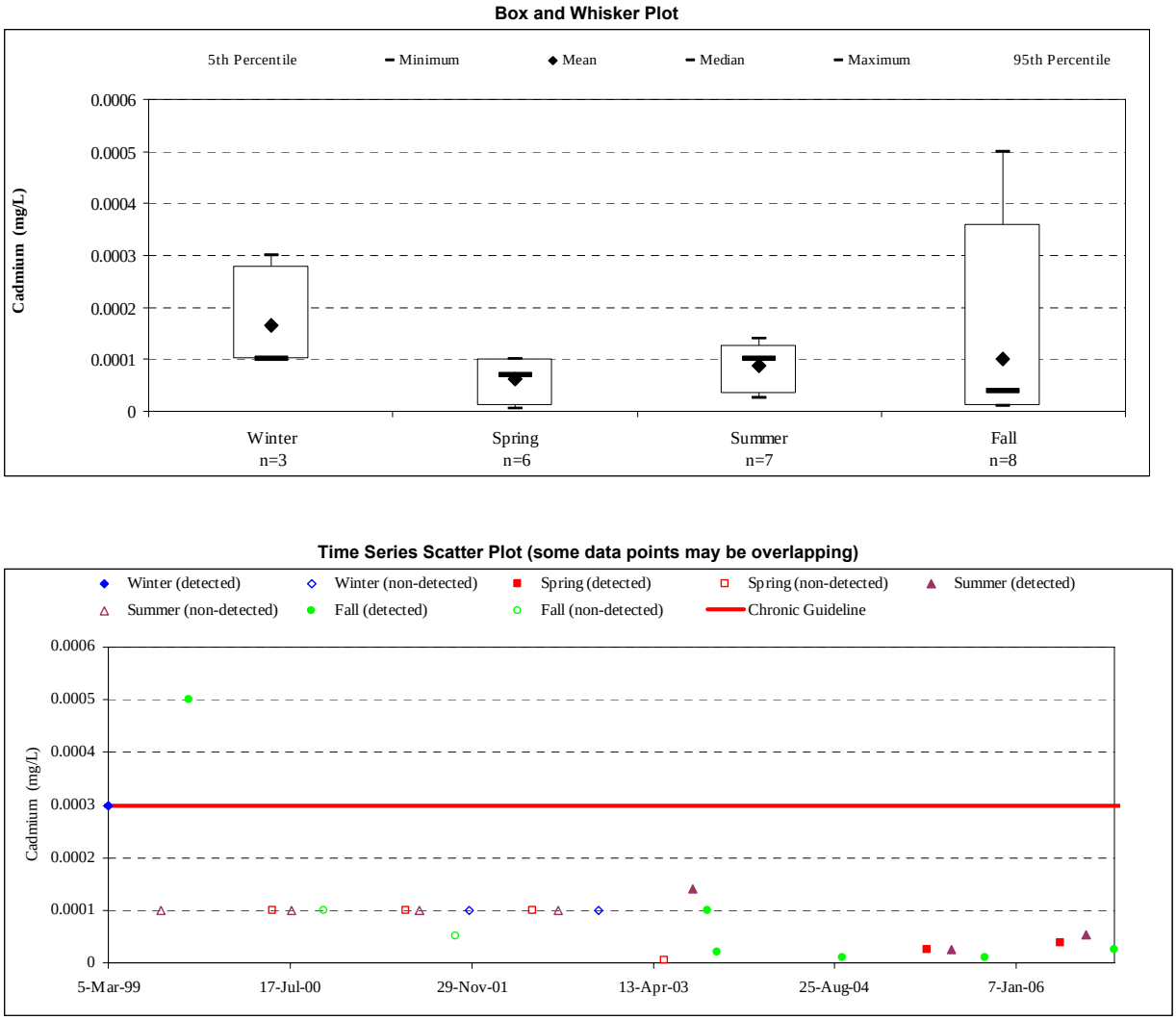


Figure G-1-3-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

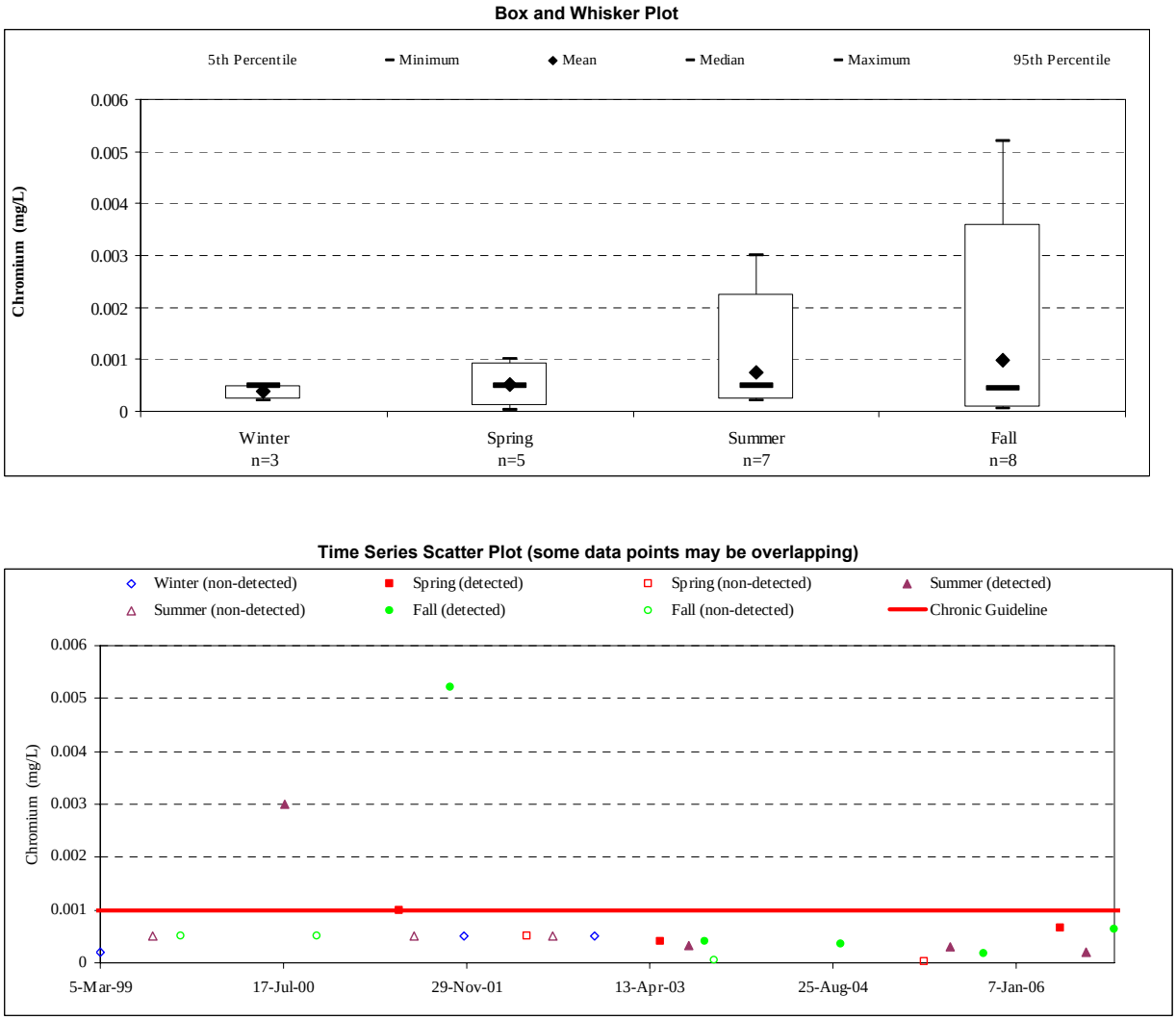
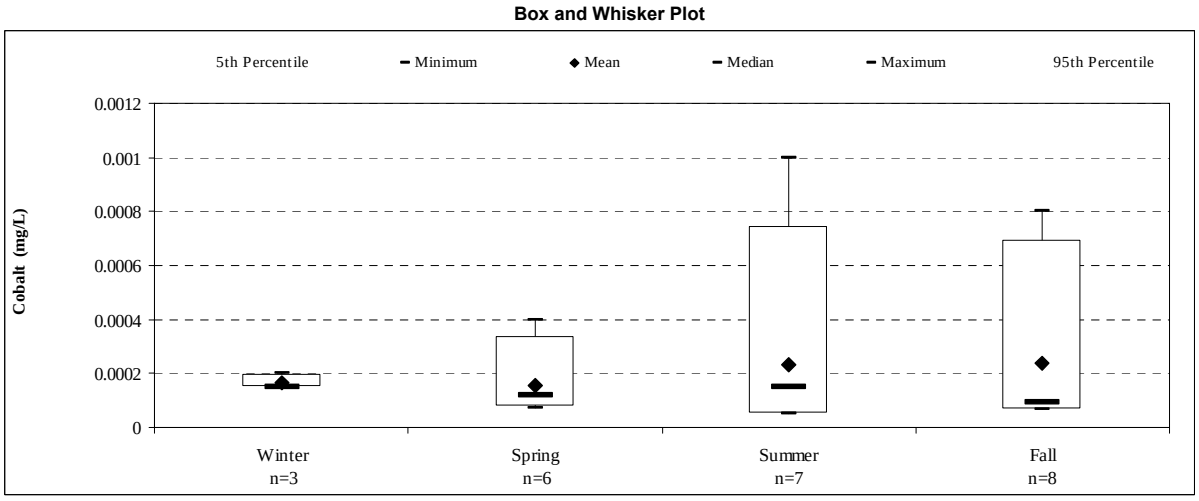


Figure G-1-3-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Lower Reach of Lower Athabasca River



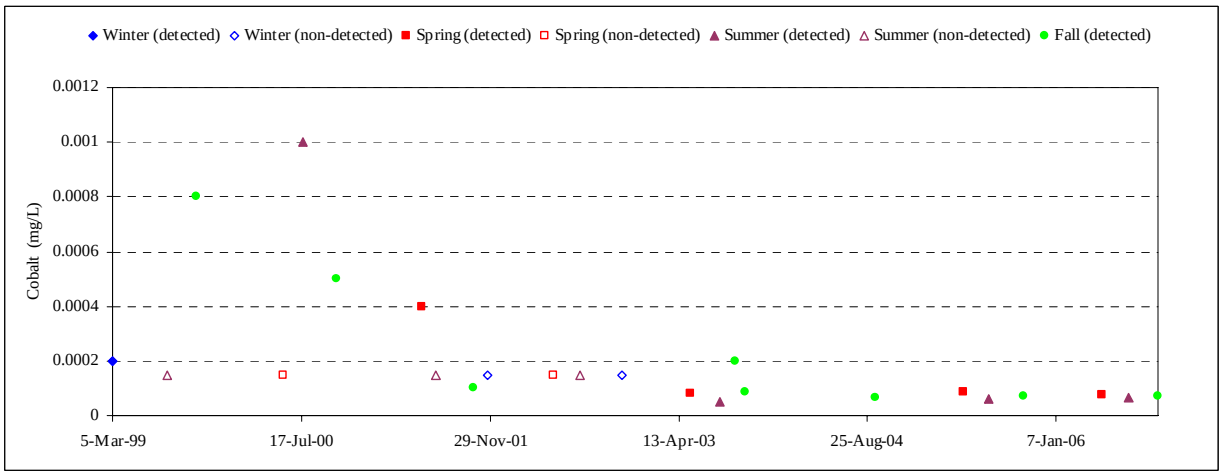
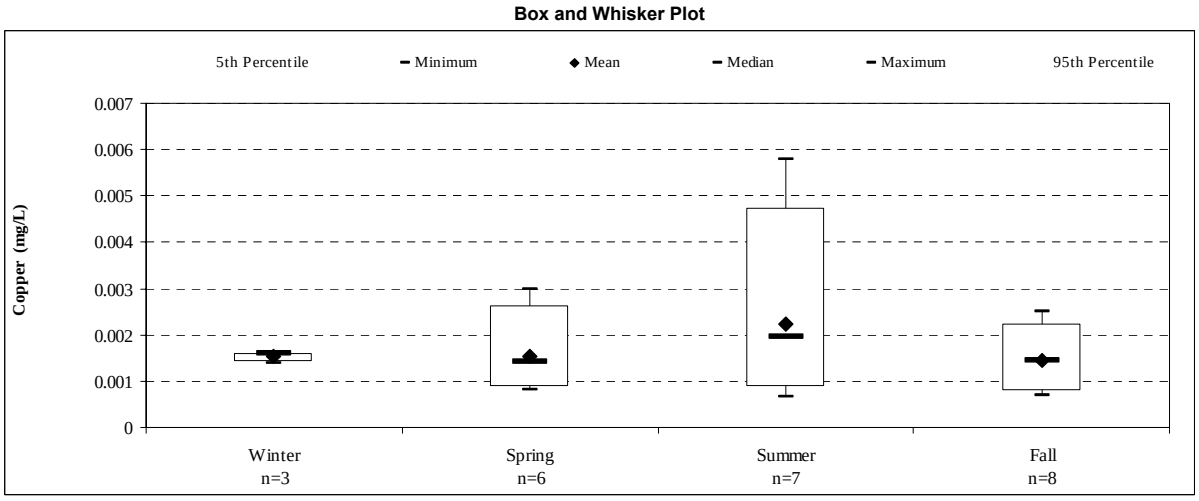


Figure G-1-3-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Lower Reach of Lower Athabasca River



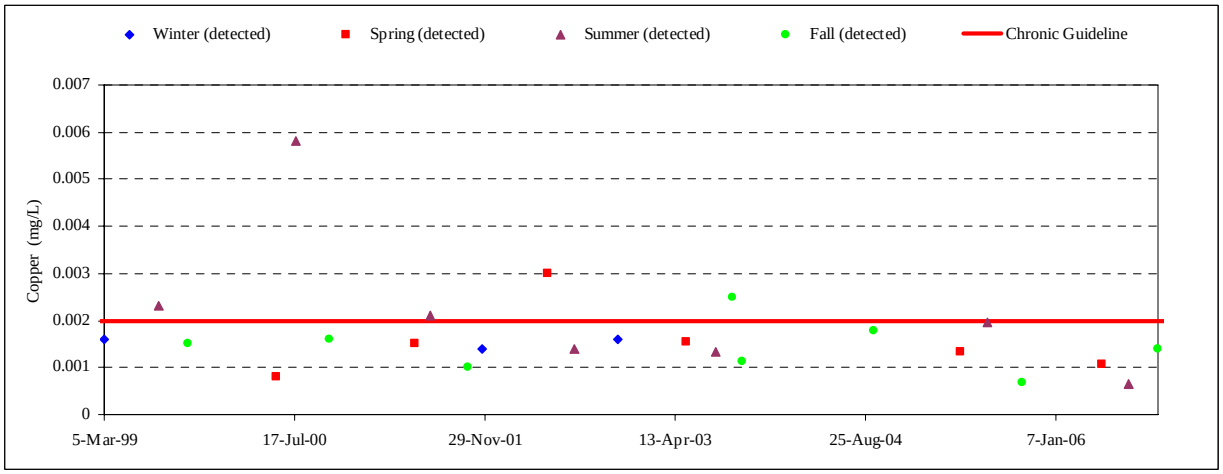


Figure G-1-3-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Lower Reach of Lower Athabasca River

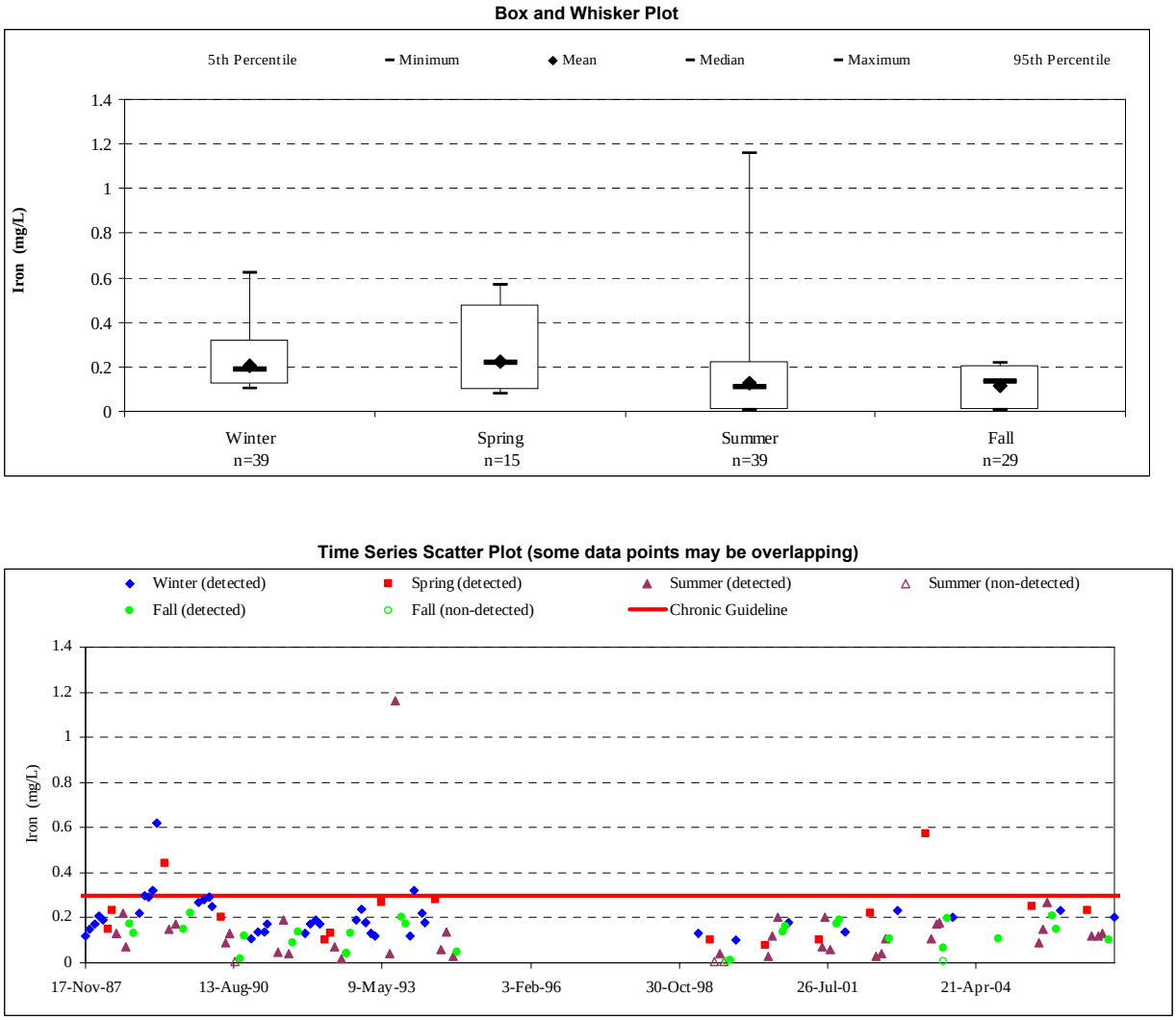
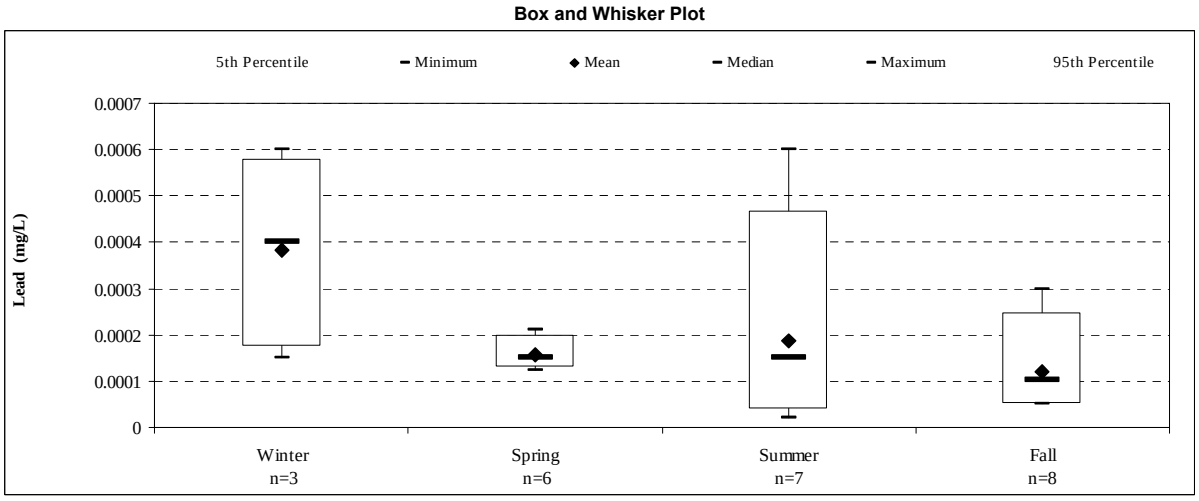


Figure G-1-3-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Lower Reach of Lower Athabasca River



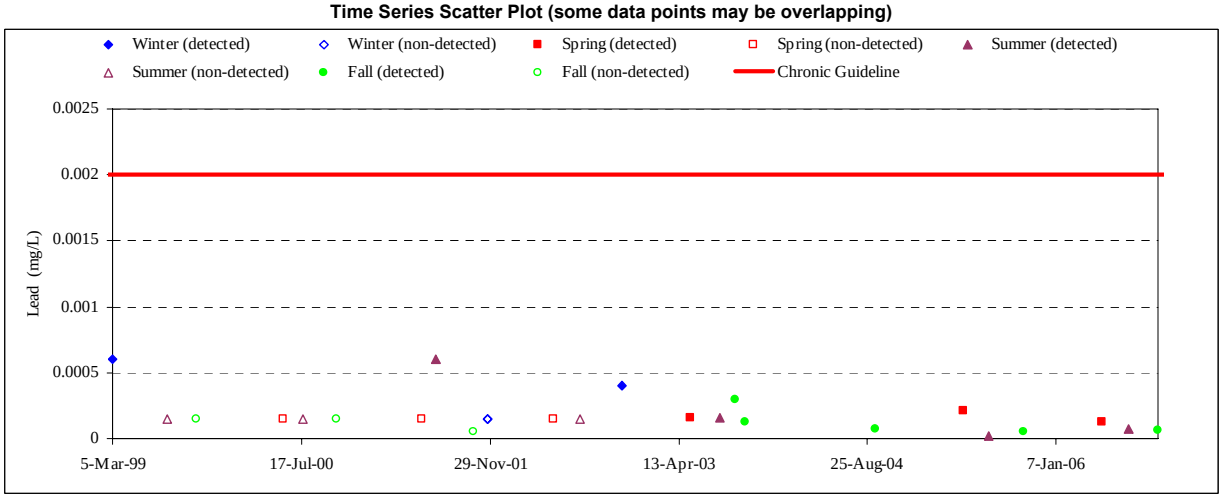


Figure G-1-3-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

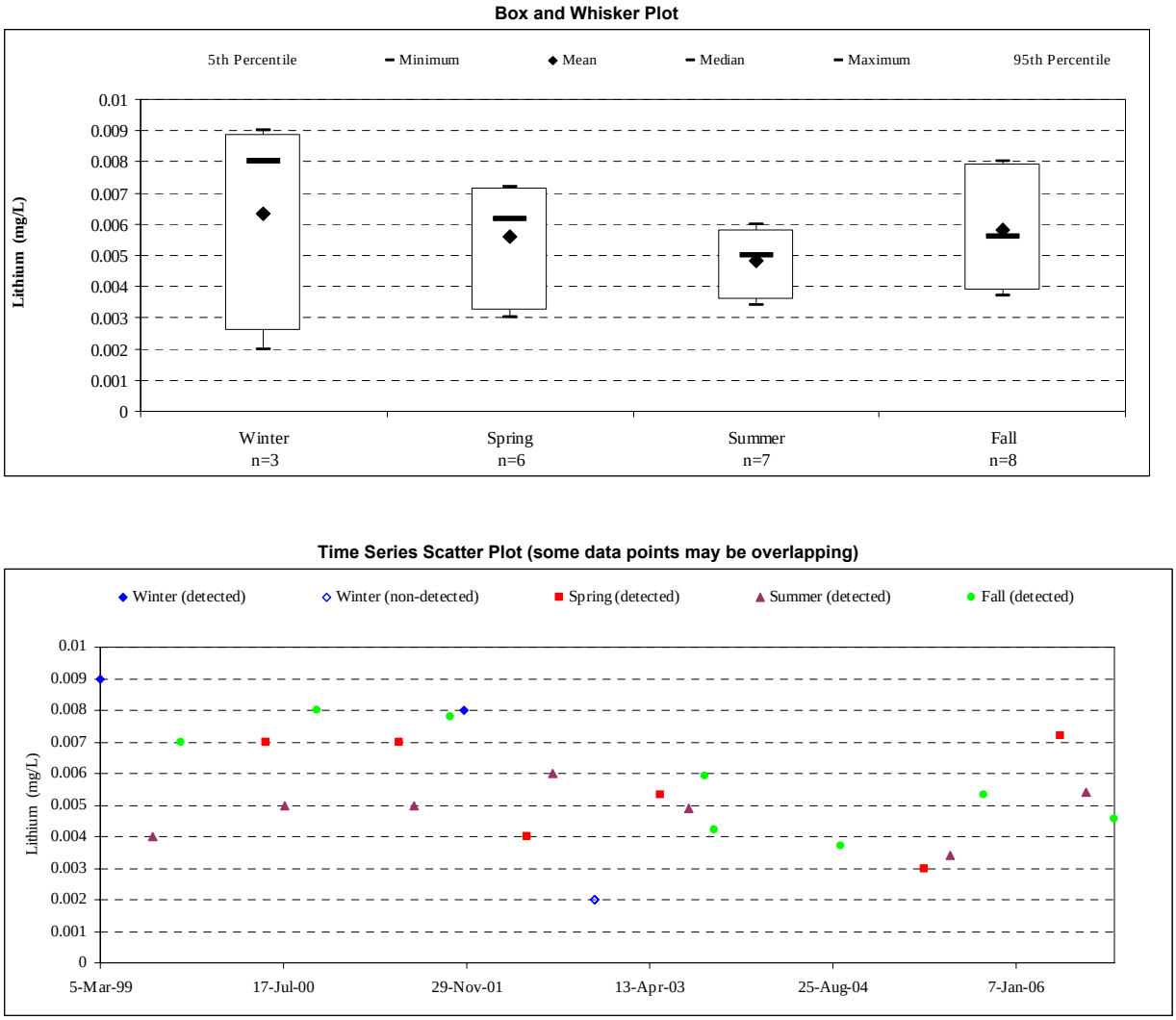
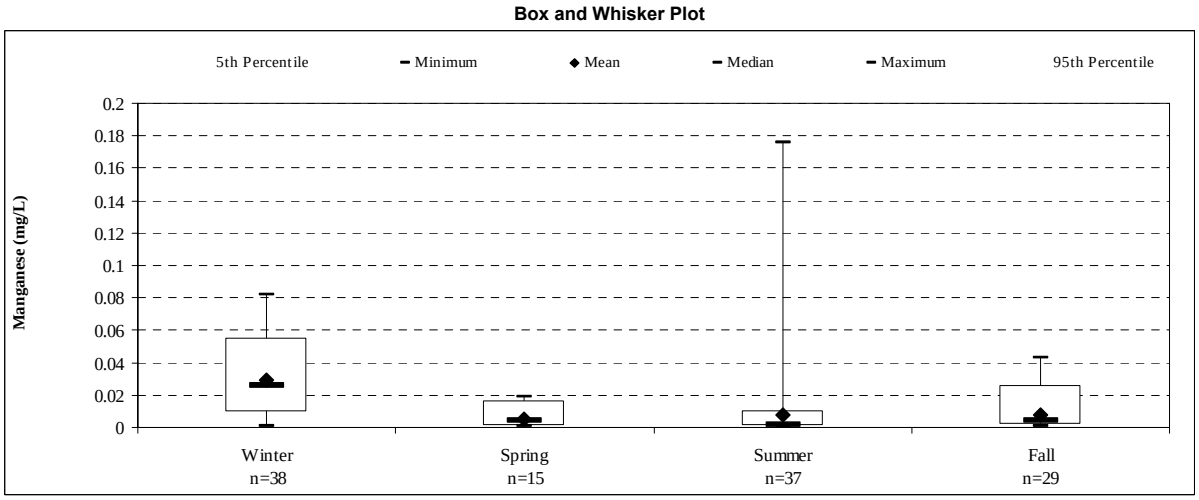


Figure G-1-3-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Lower Reach of Lower Athabasca River



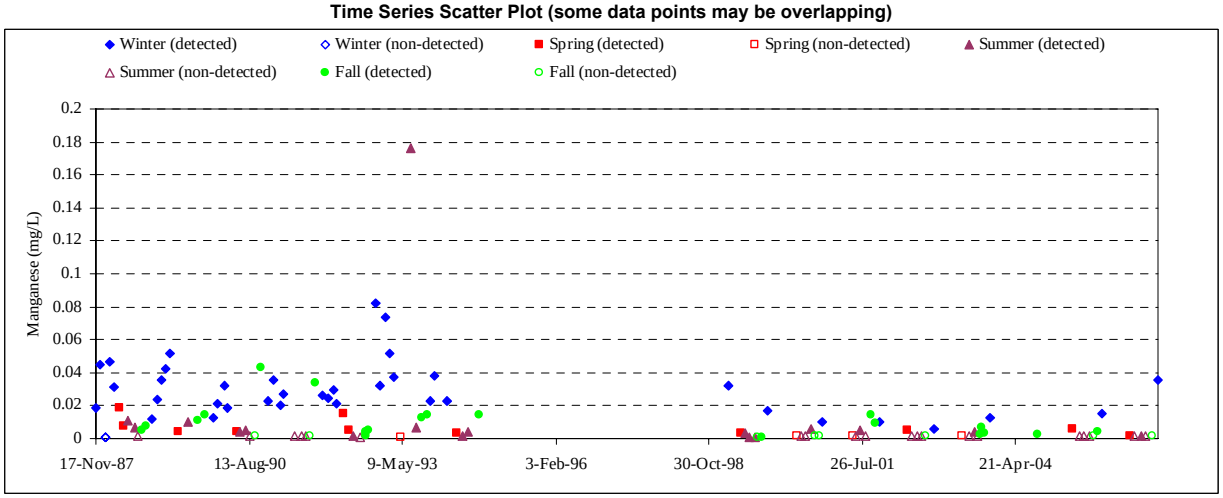
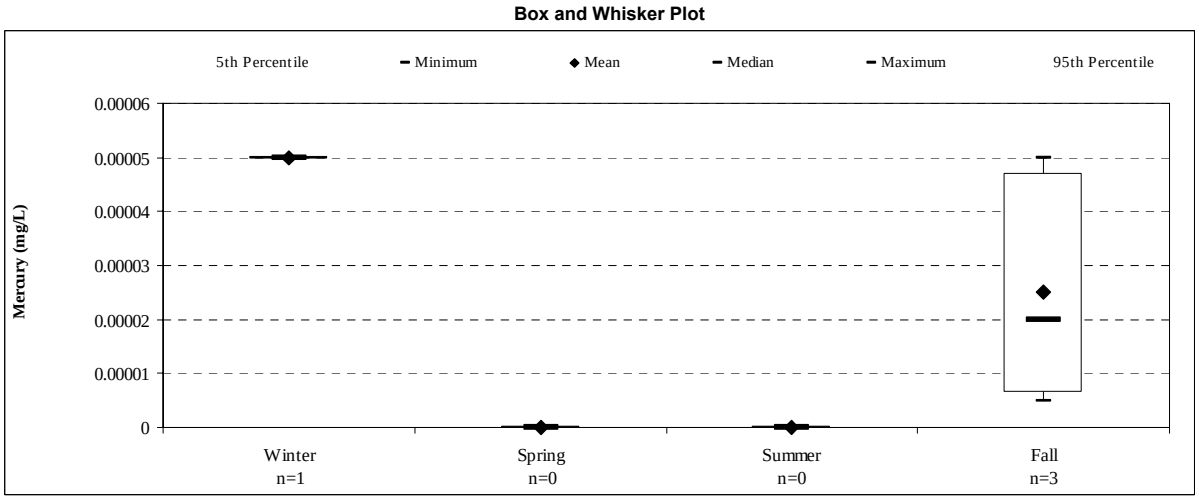


Figure G-1-3-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Lower Reach of Lower Athabasca River



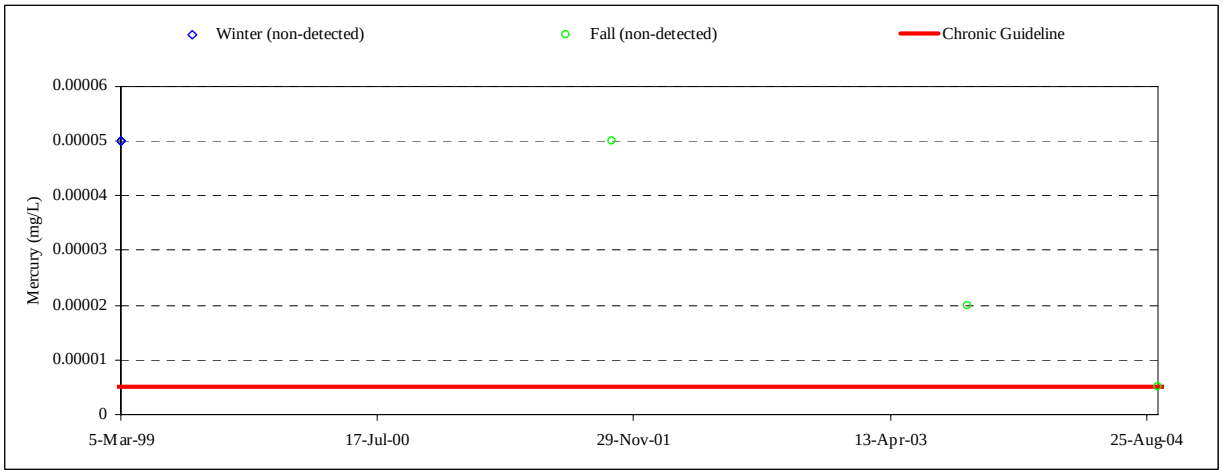


Figure G-1-3-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Lower Reach of Lower Athabasca River

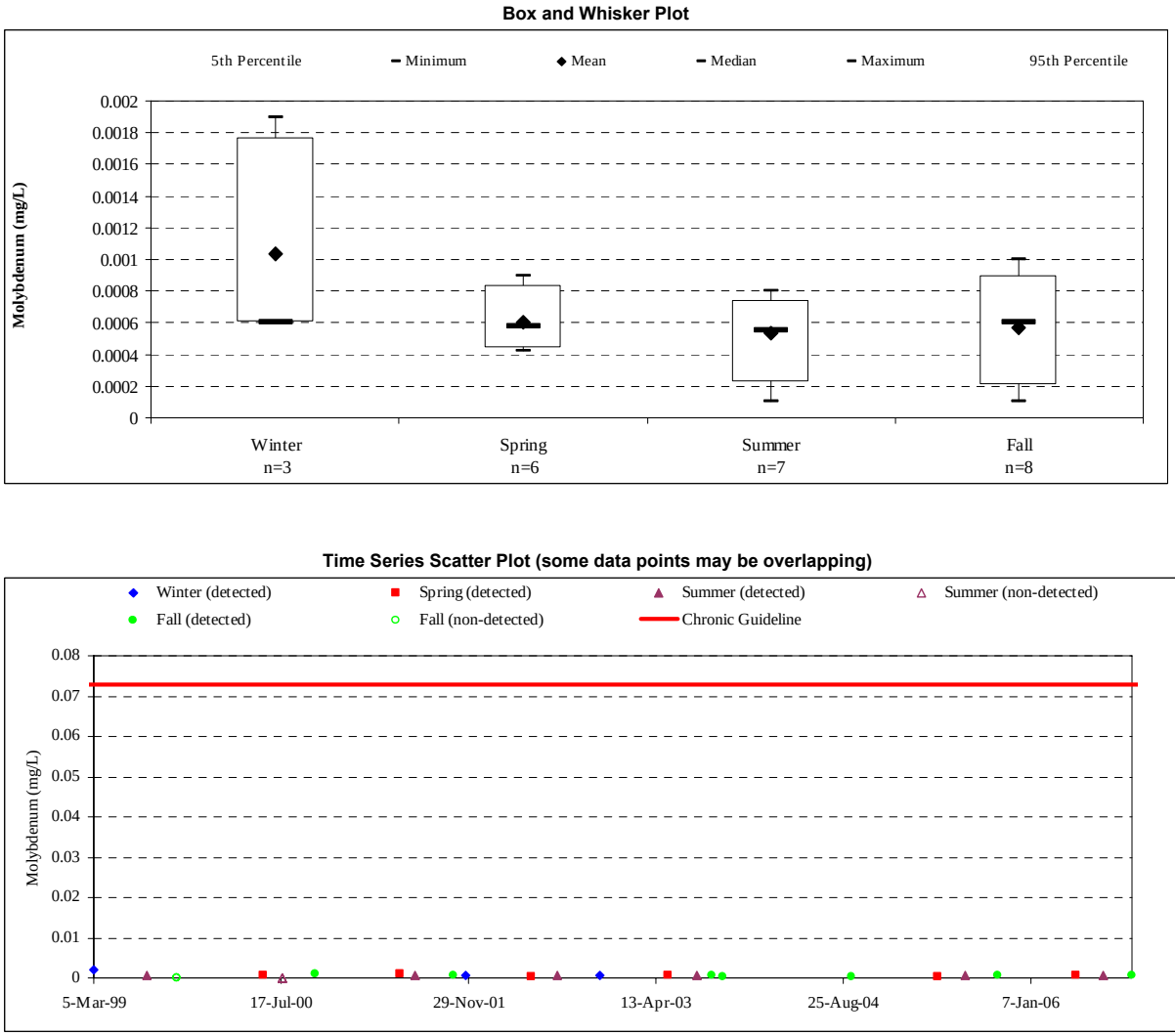


Figure G-1-3-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Lower Reach of Lower Athabasca River

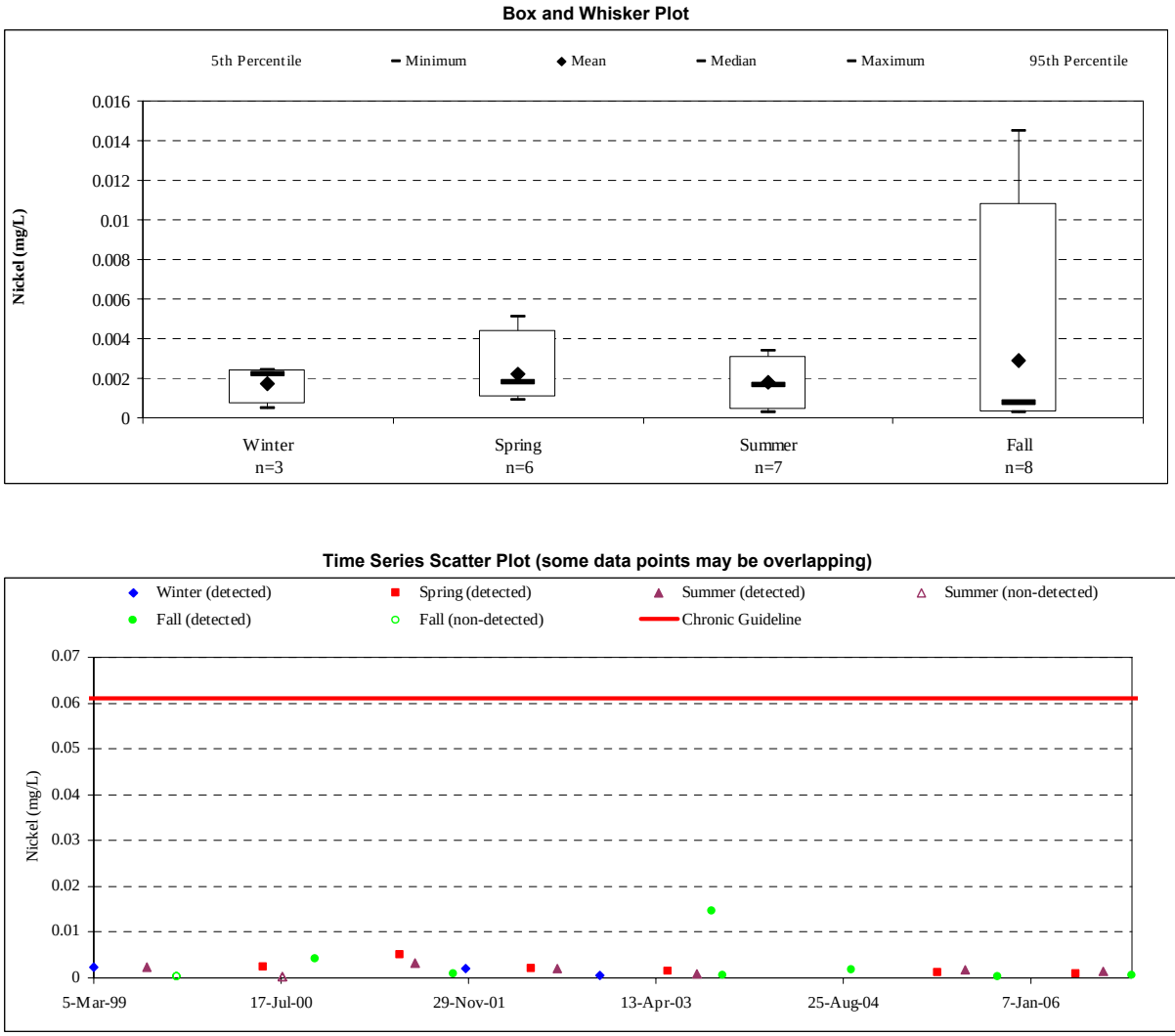
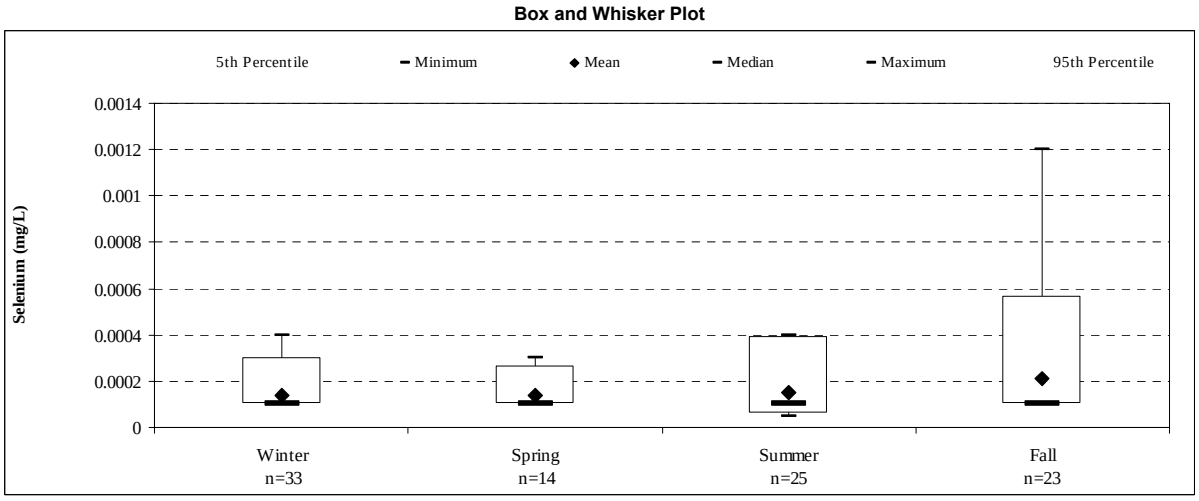


Figure G-1-3-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Lower Reach of Lower Athabasca River



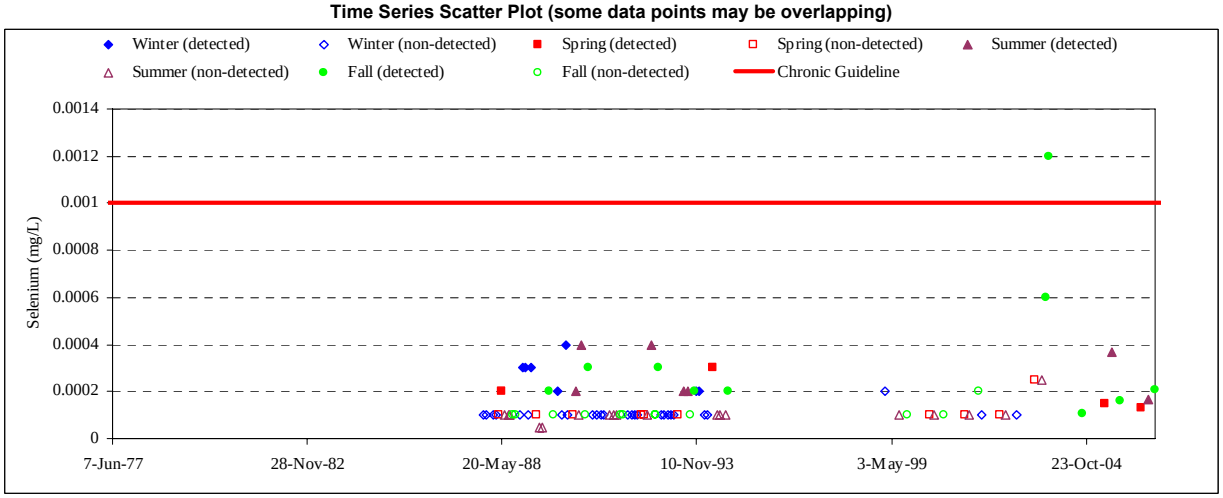
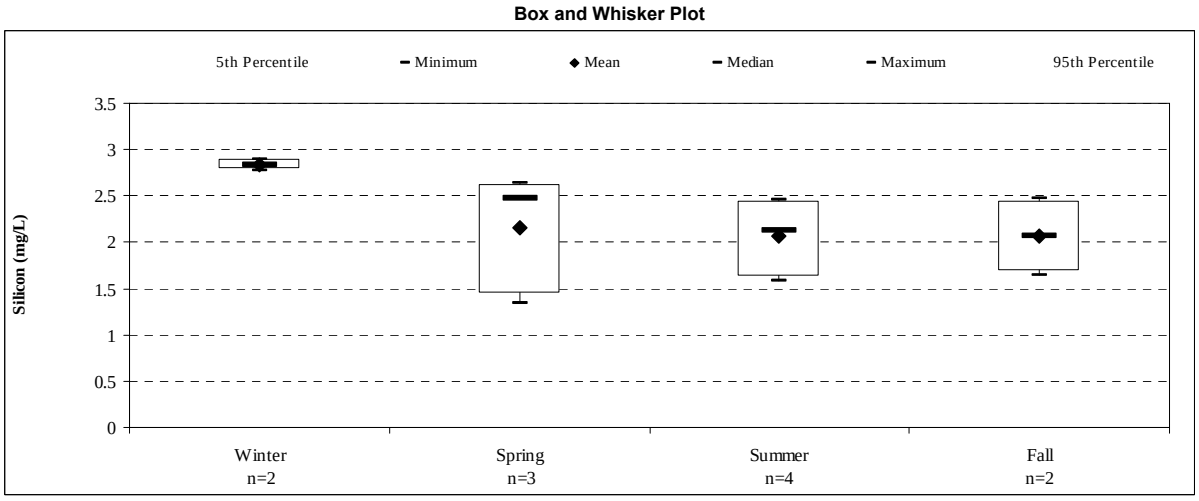


Figure G-1-3-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Lower Reach of Lower Athabasca River



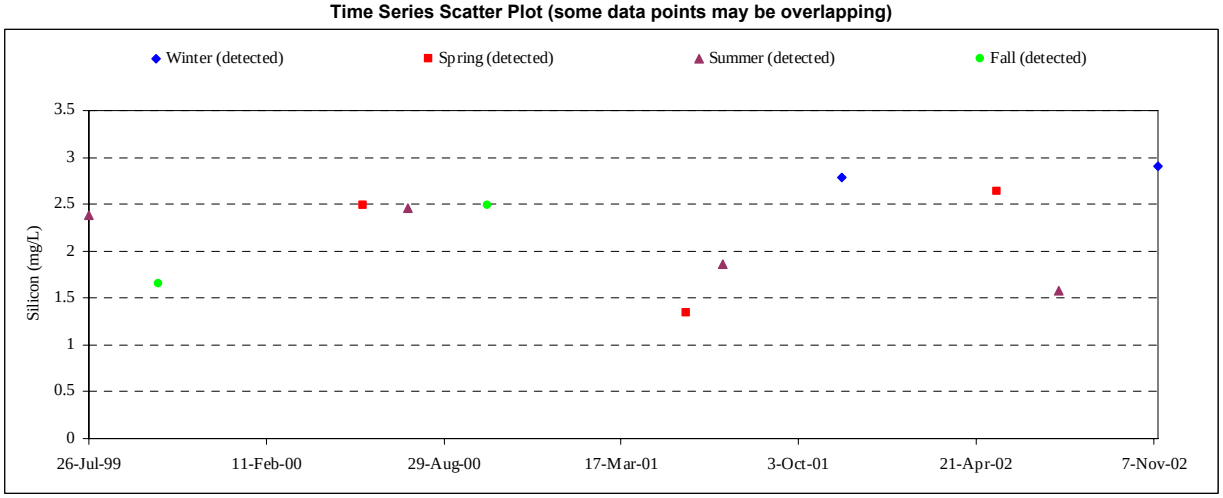


Figure G-1-3-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Lower Reach of Lower Athabasca River

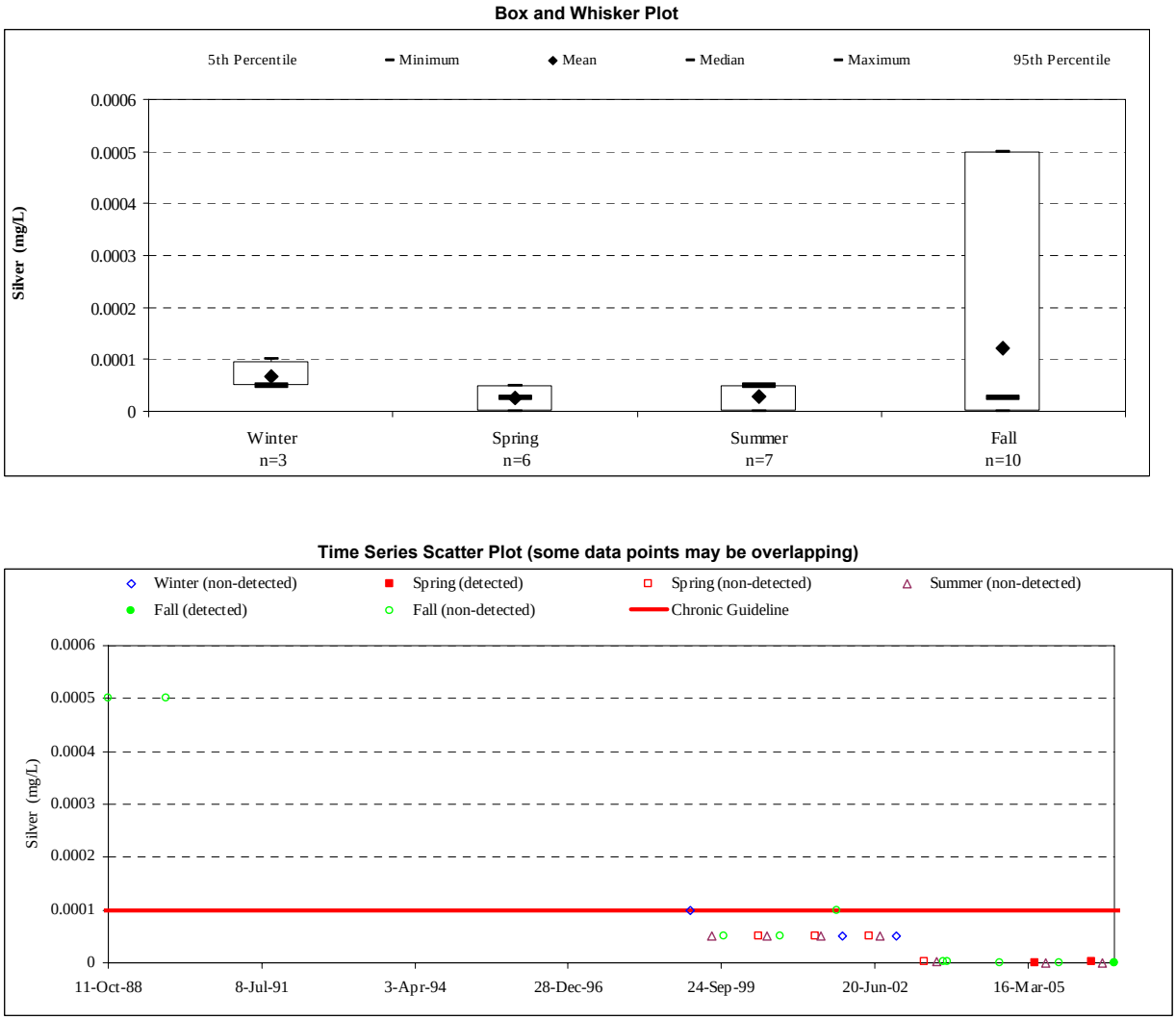


Figure G-1-3-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

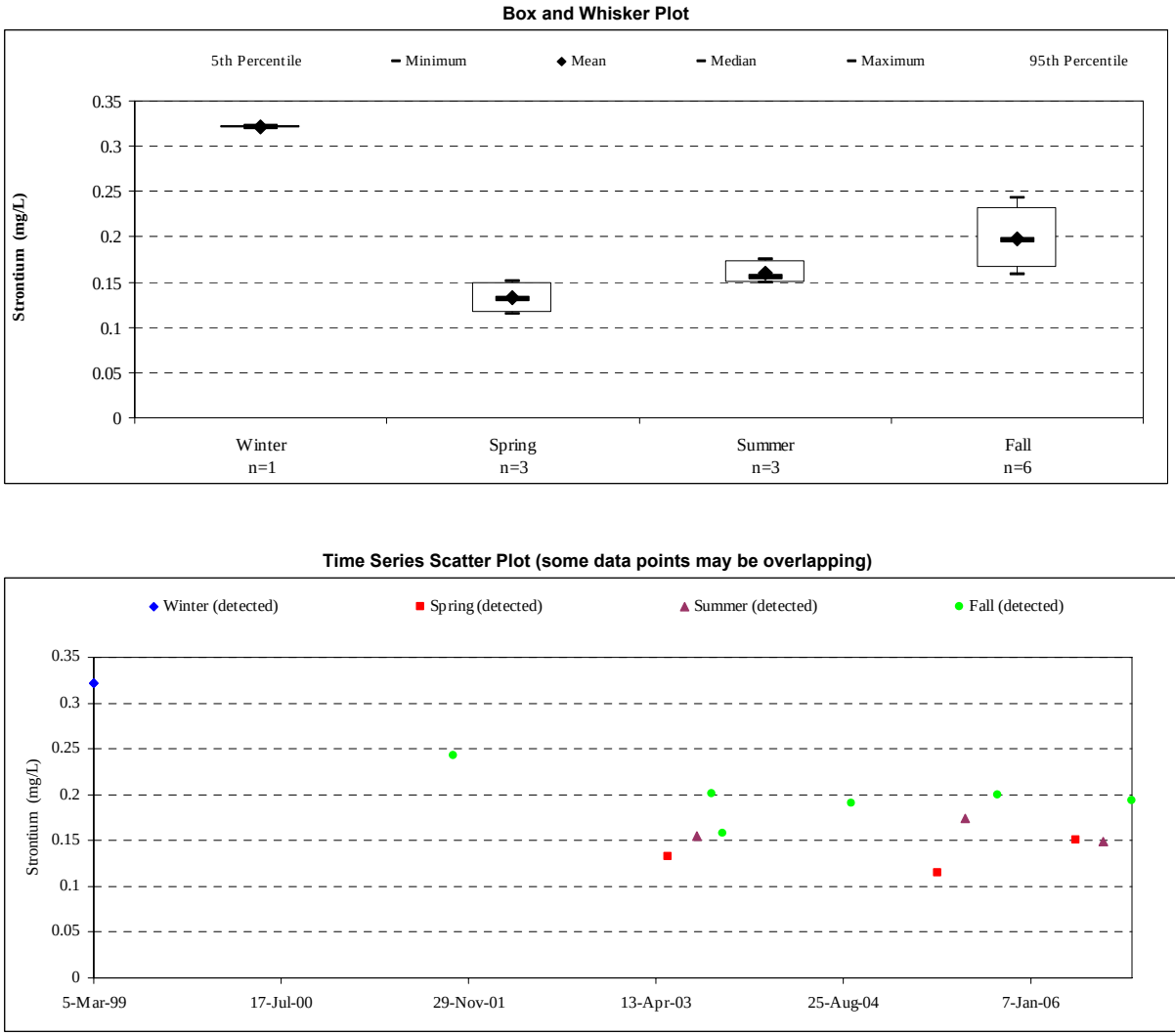


Figure G-1-3-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Lower Reach of Lower Athabasca River

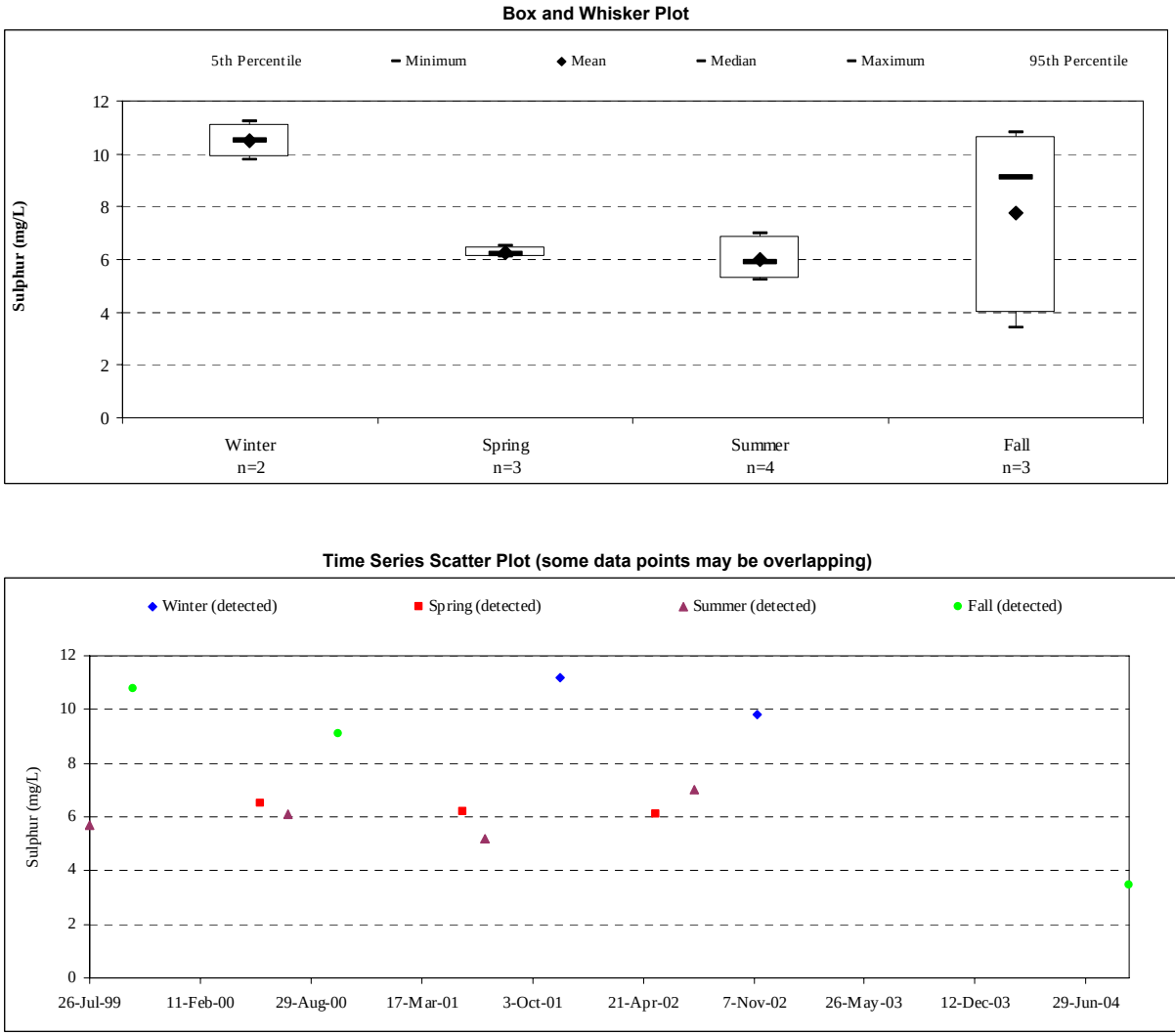


Figure G-1-3-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

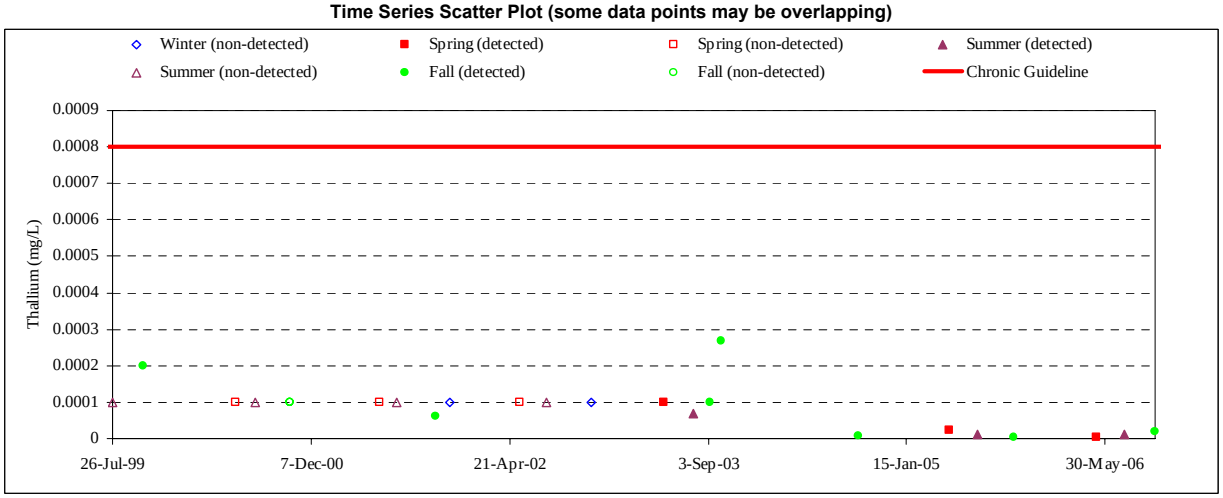
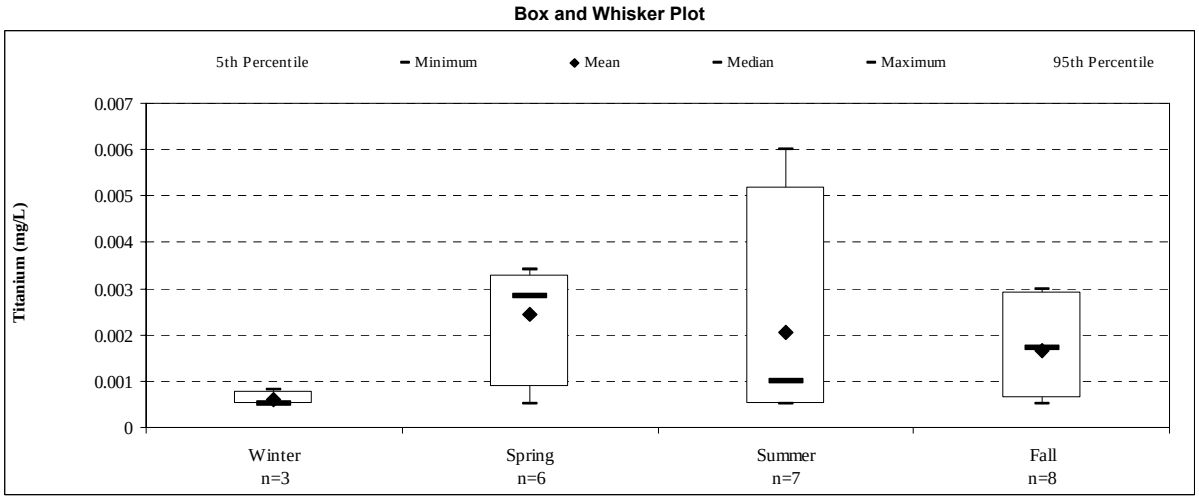


Figure G-1-3-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Lower Reach of Lower Athabasca River



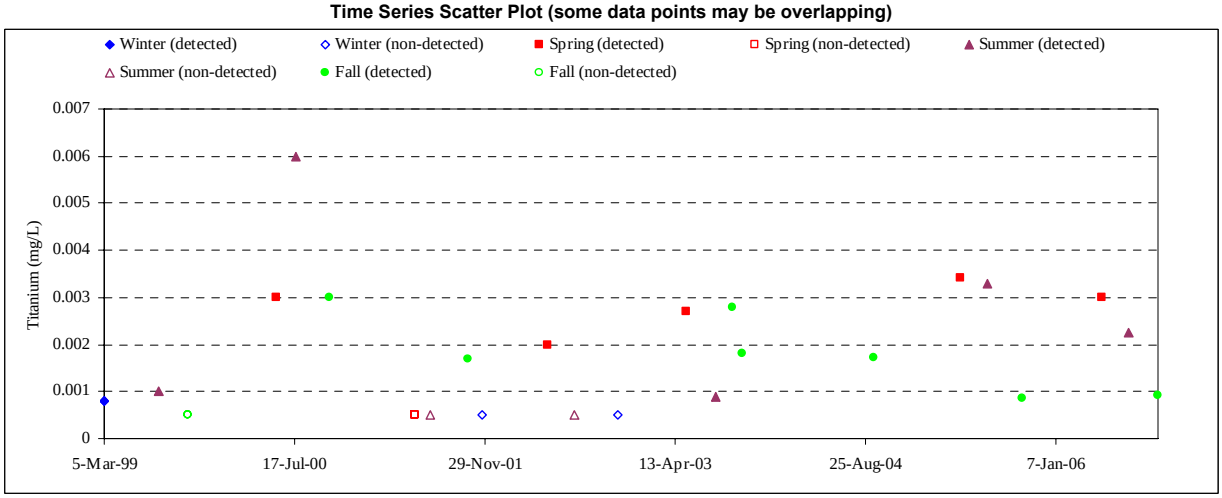


Figure G-1-3-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

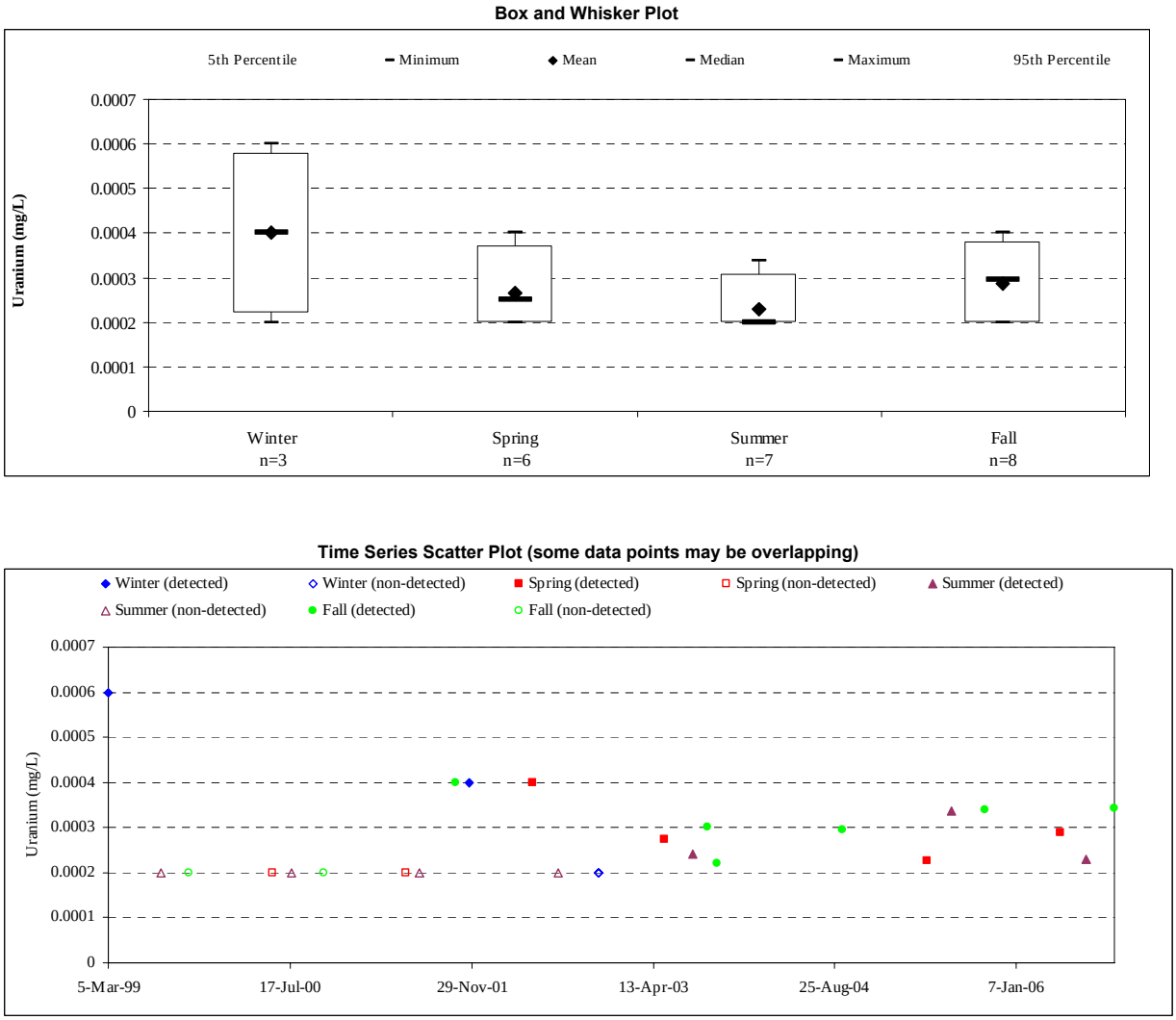


Figure G-1-3-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Lower Reach of Lower Athabasca River

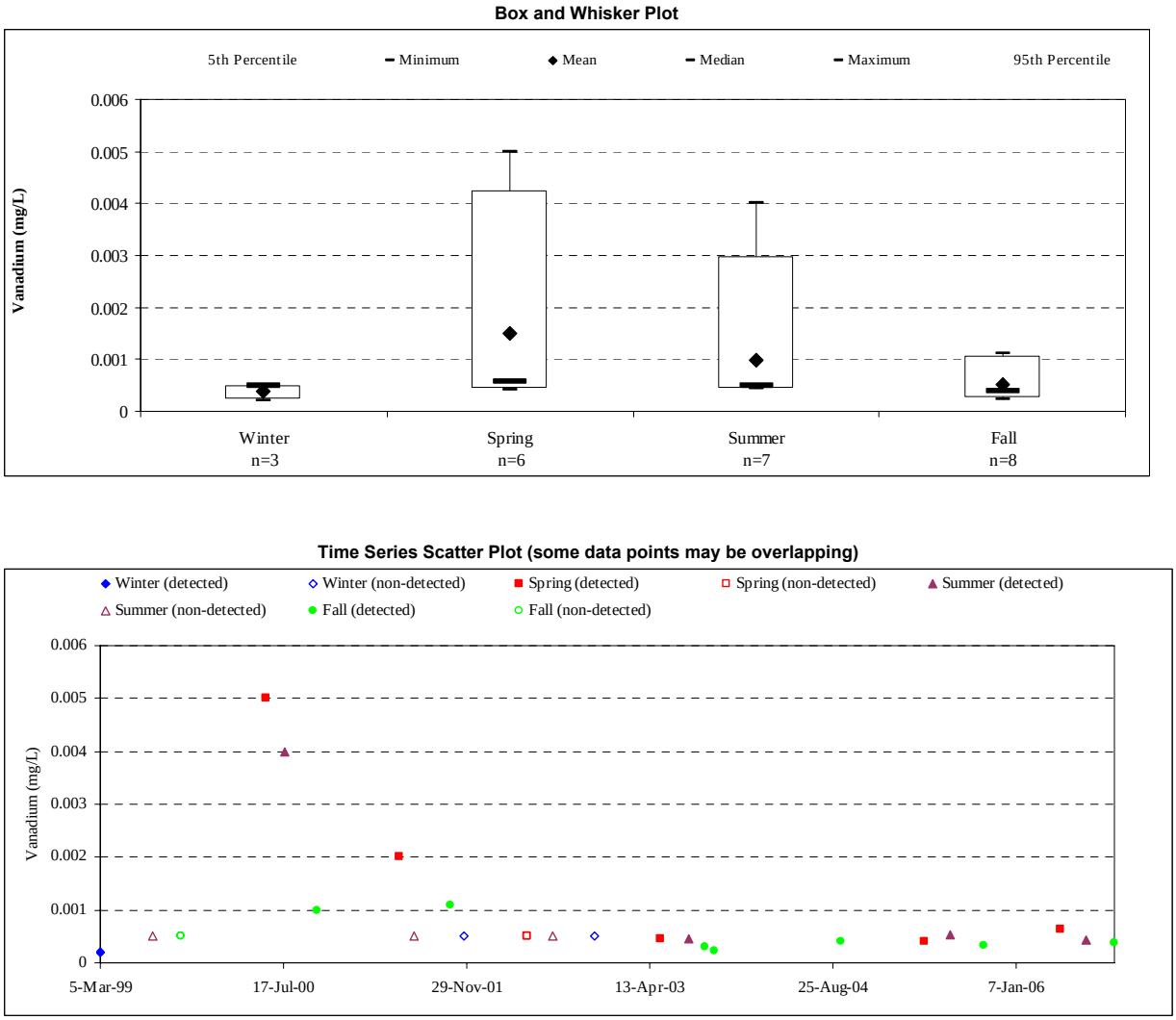


Figure G-1-3-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Lower Reach of Lower Athabasca River

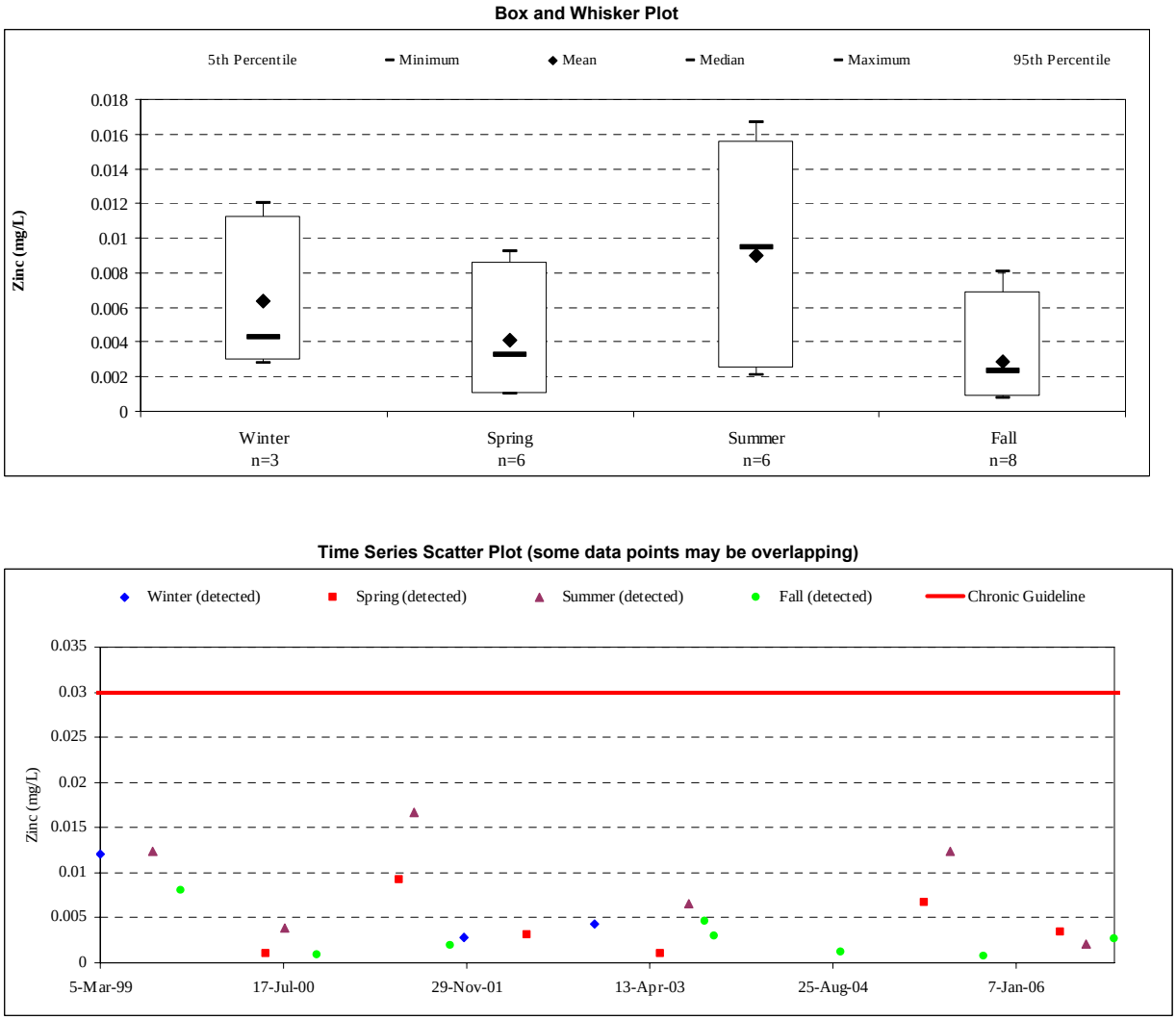
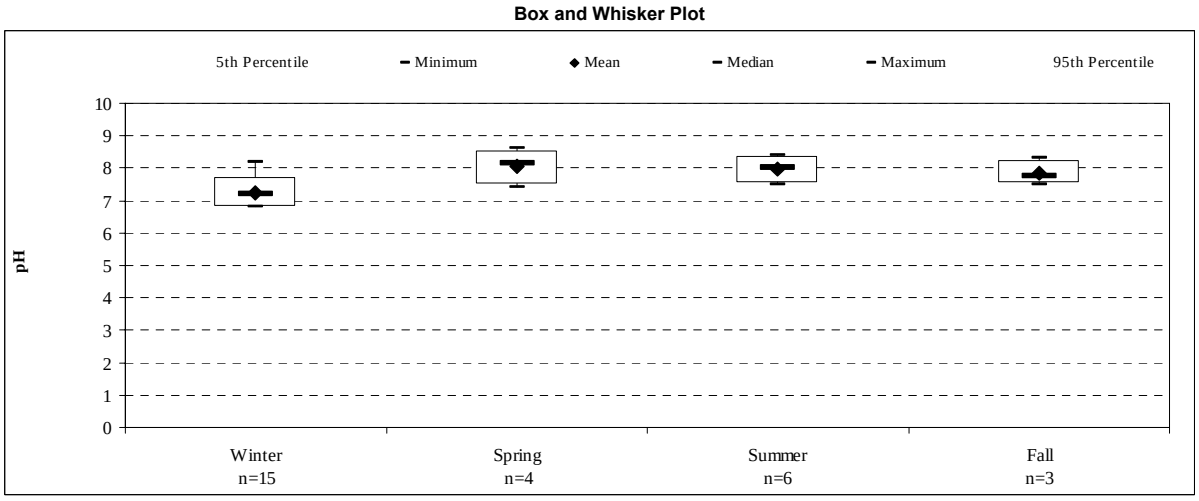


Figure G-1-4-1 Box Whisker and Time Series Scatter Plots of Observed pH in Lower Firebag River



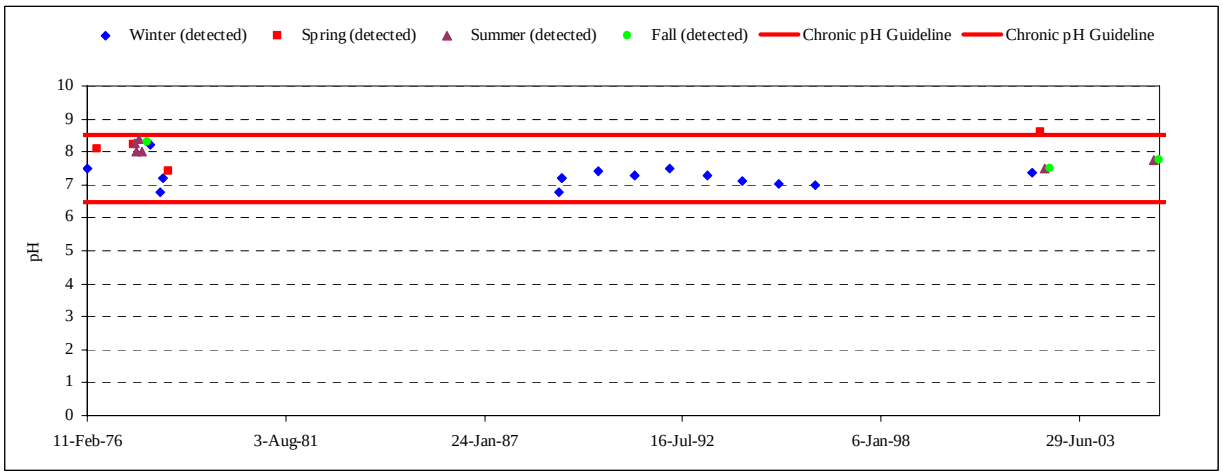
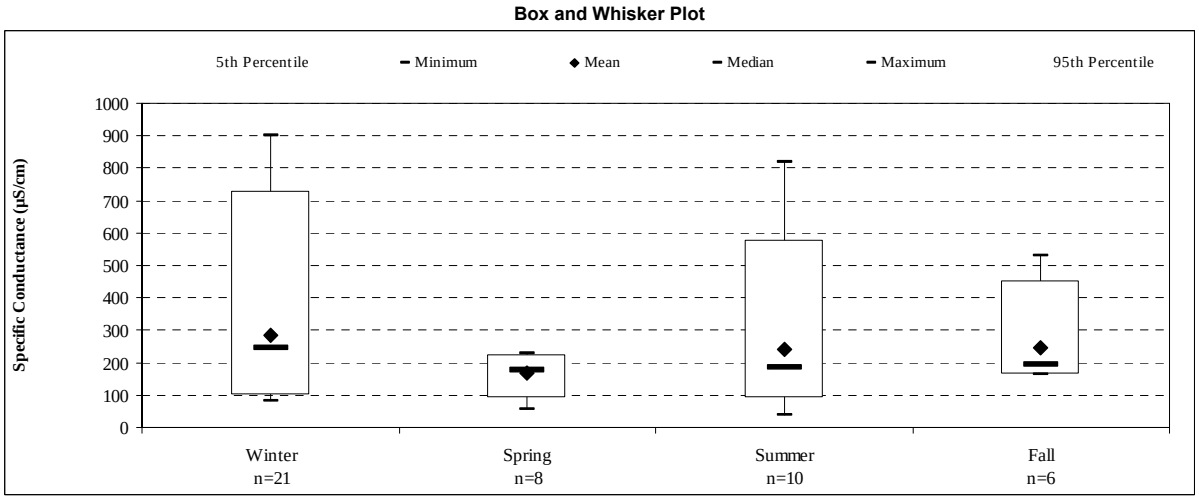


Figure G-1-4-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Lower Firebag River



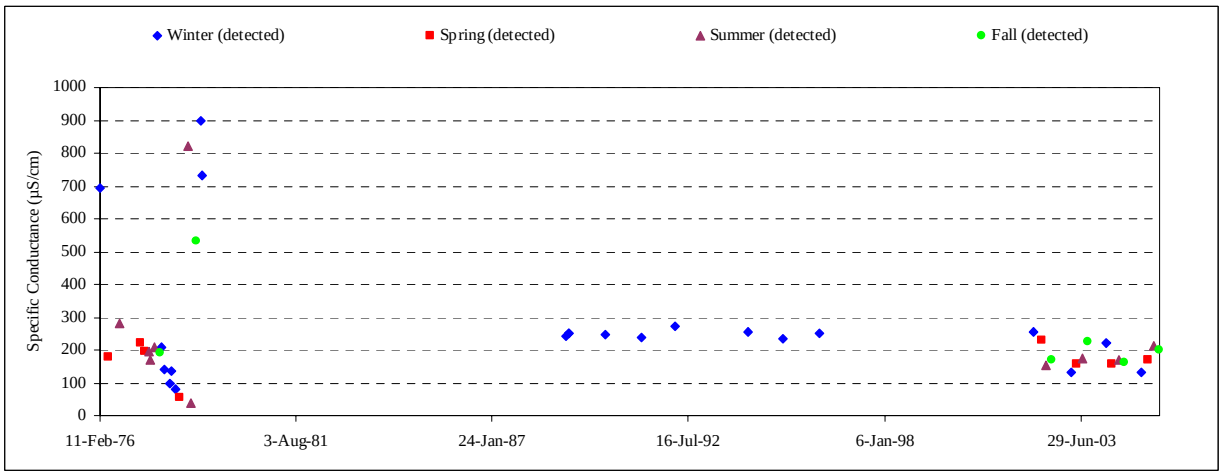
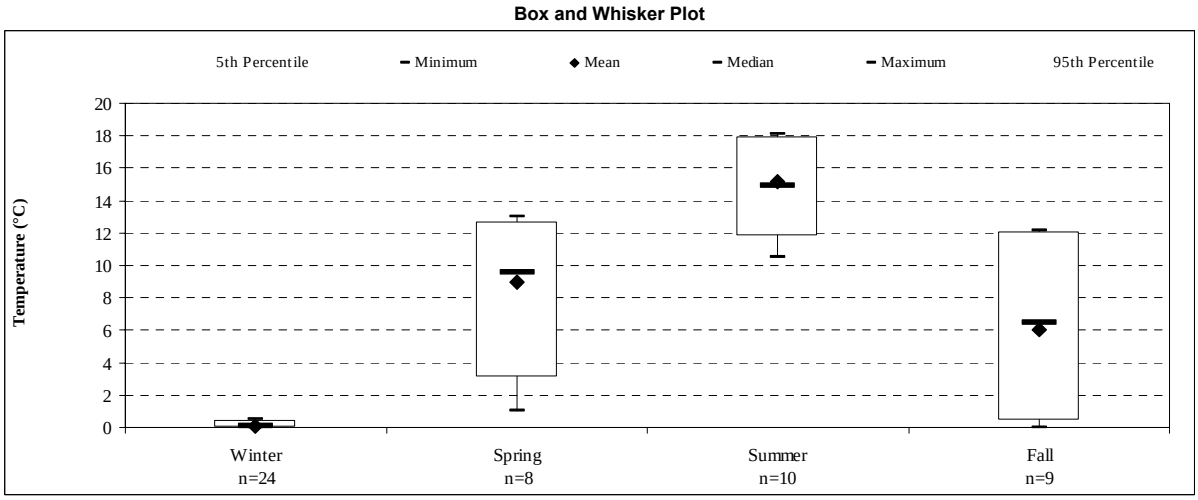


Figure G-1-4-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Lower Firebag River



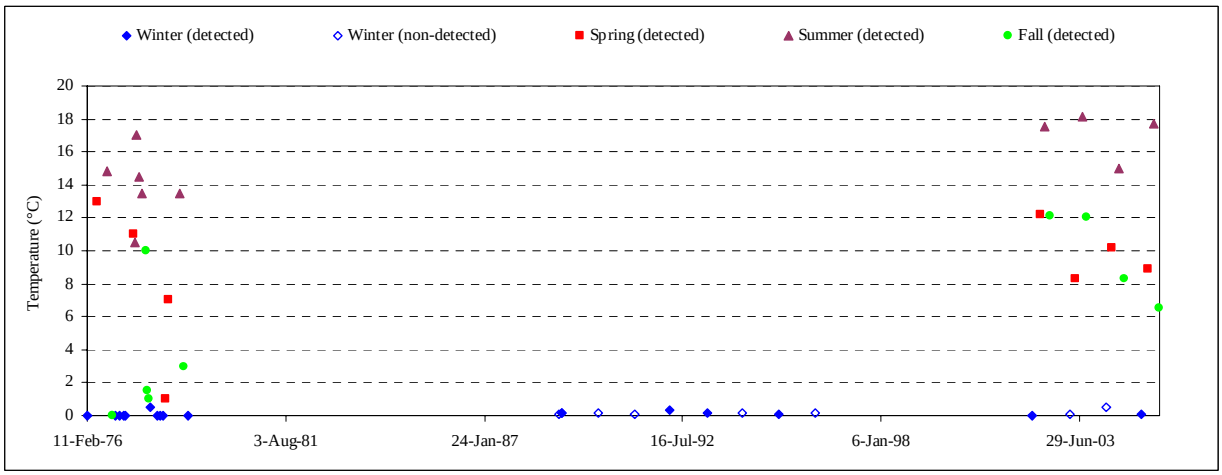
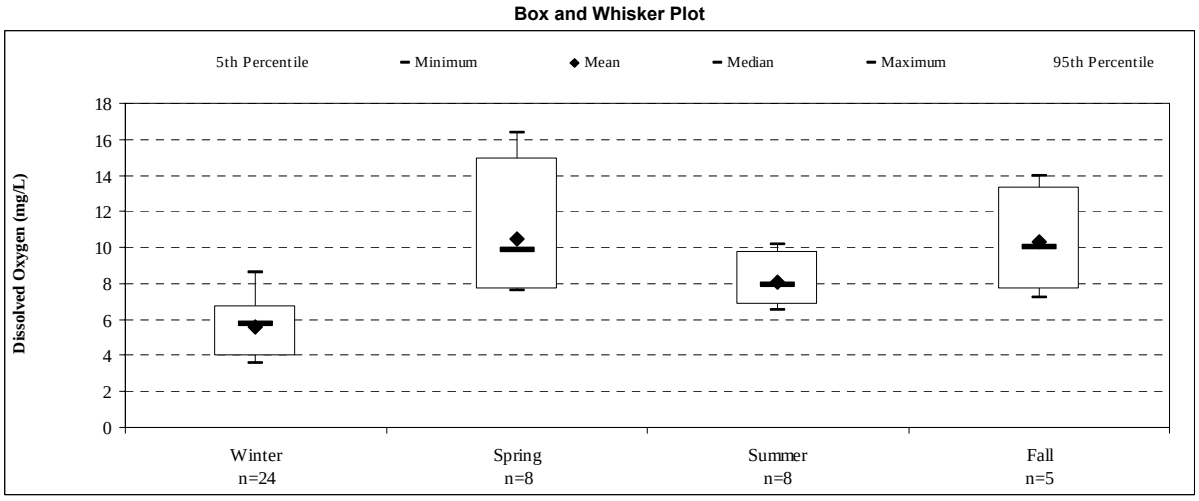


Figure G-1-4-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Lower Firebag River



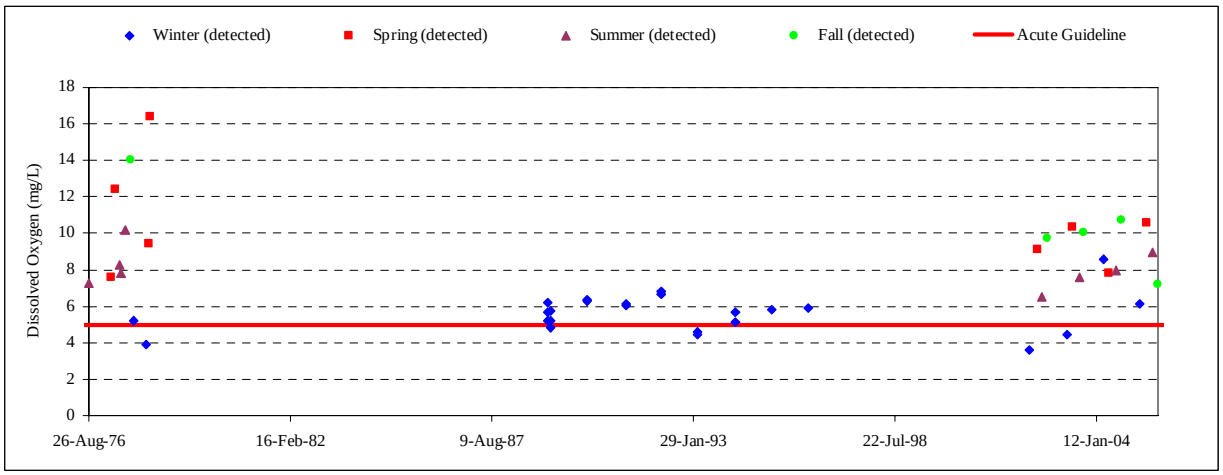
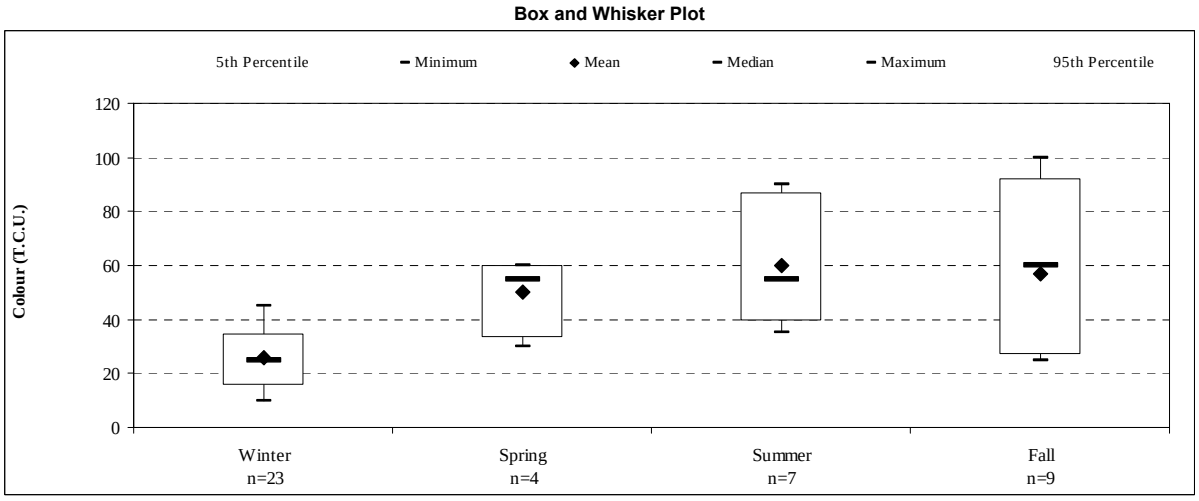


Figure G-1-4-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Lower Firebag River



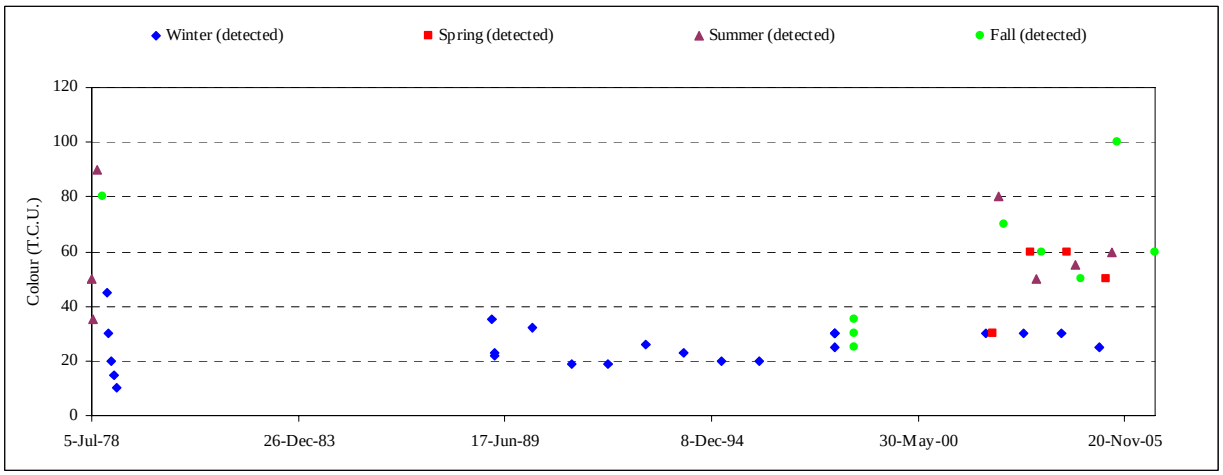
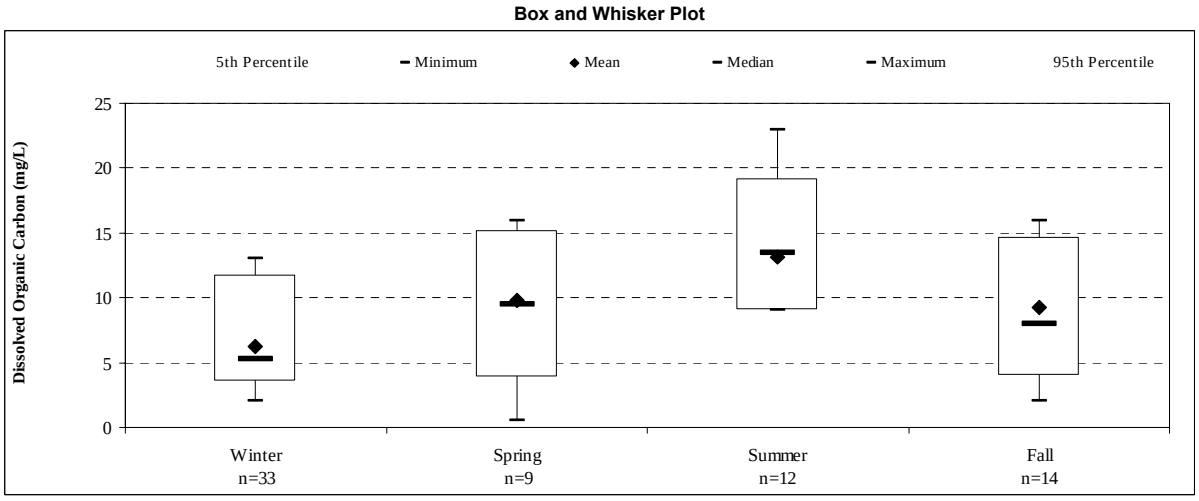


Figure G-1-4-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Lower Firebag River



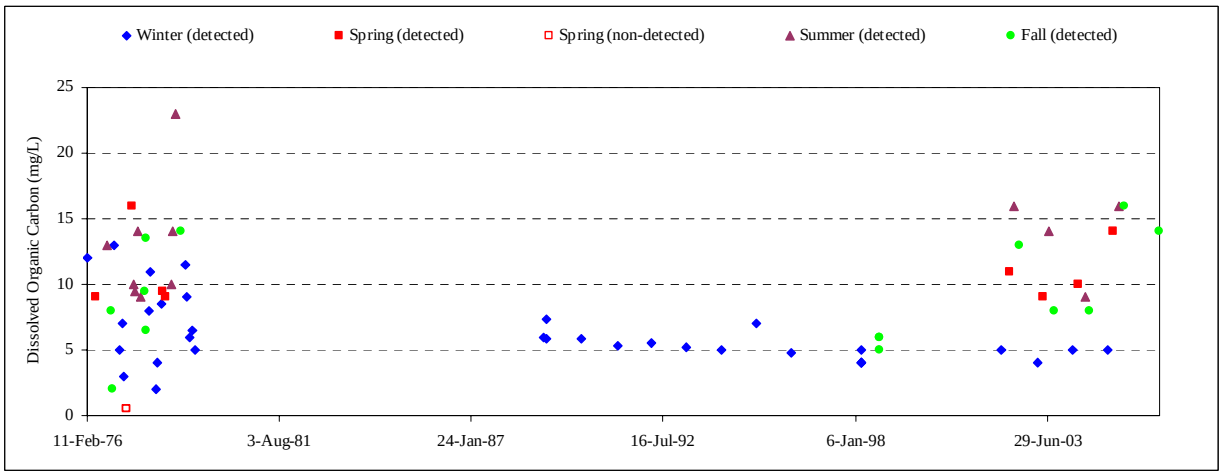


Figure G-1-4-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Lower Firebag River

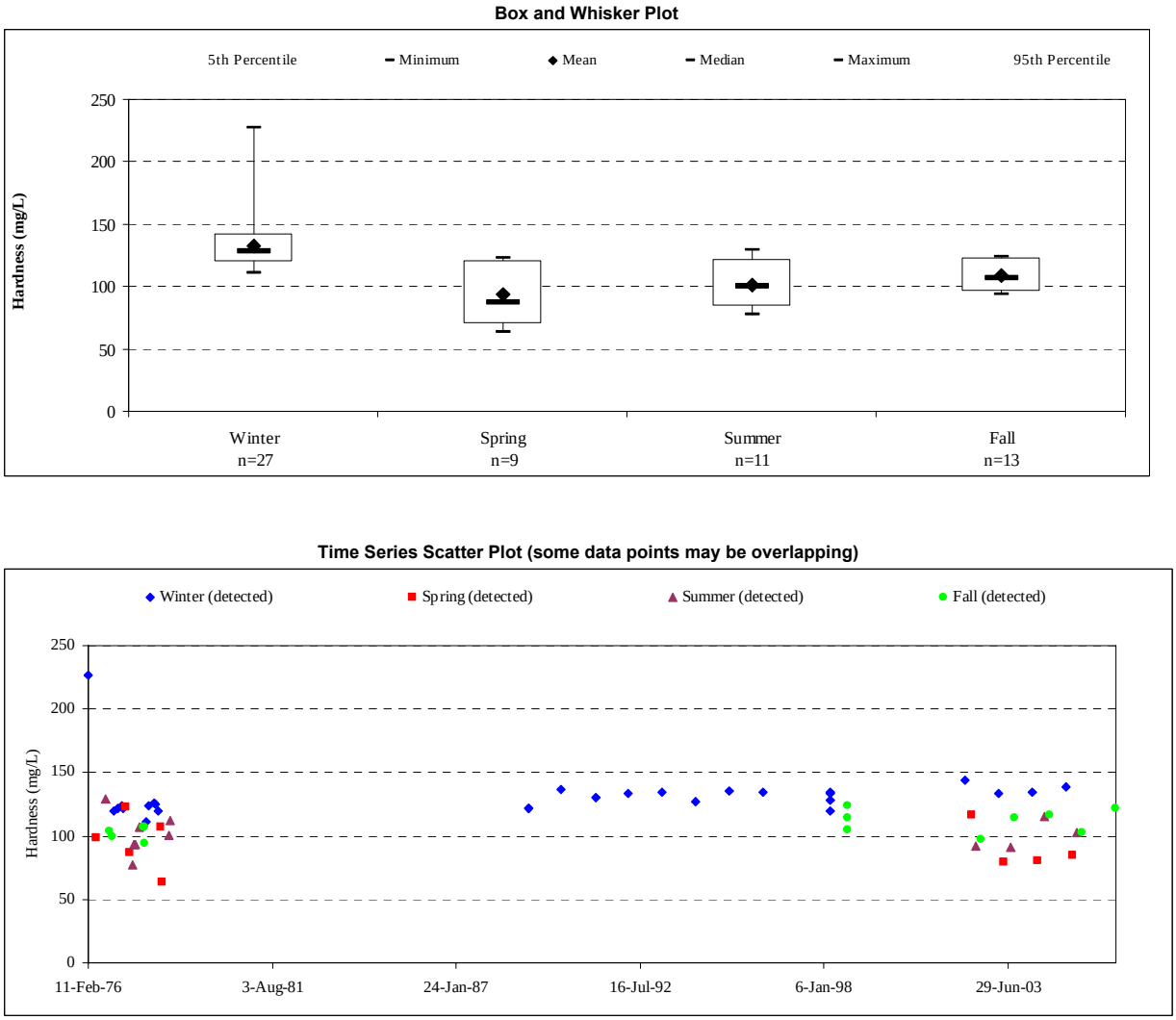
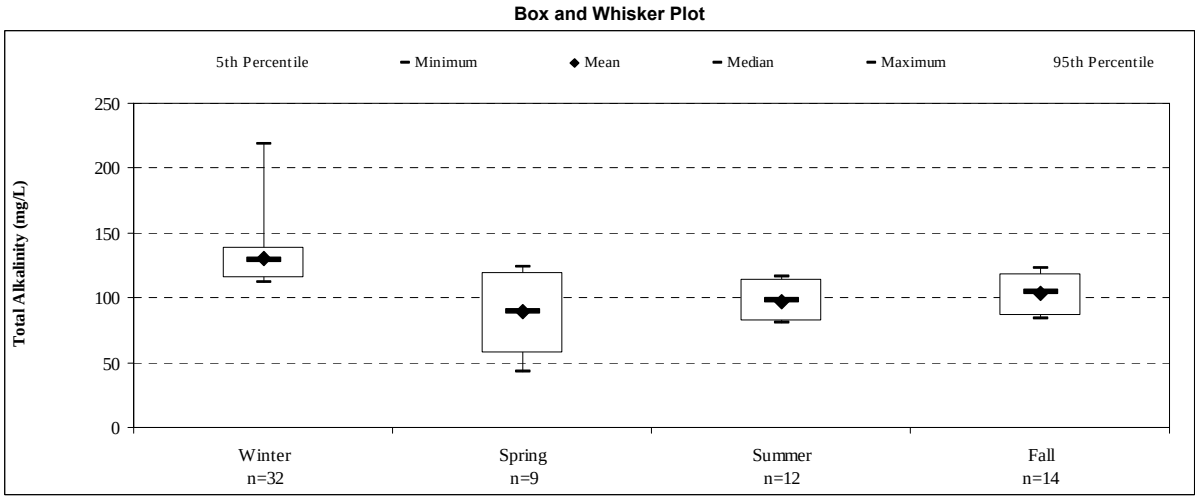


Figure G-1-4-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Lower Firebag River



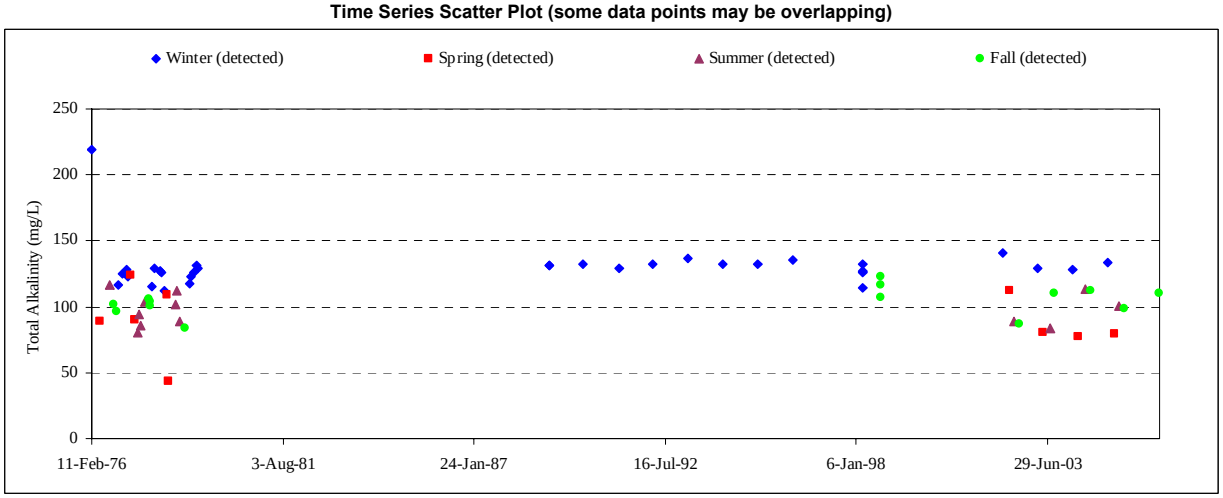


Figure G-1-4-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Lower Firebag River

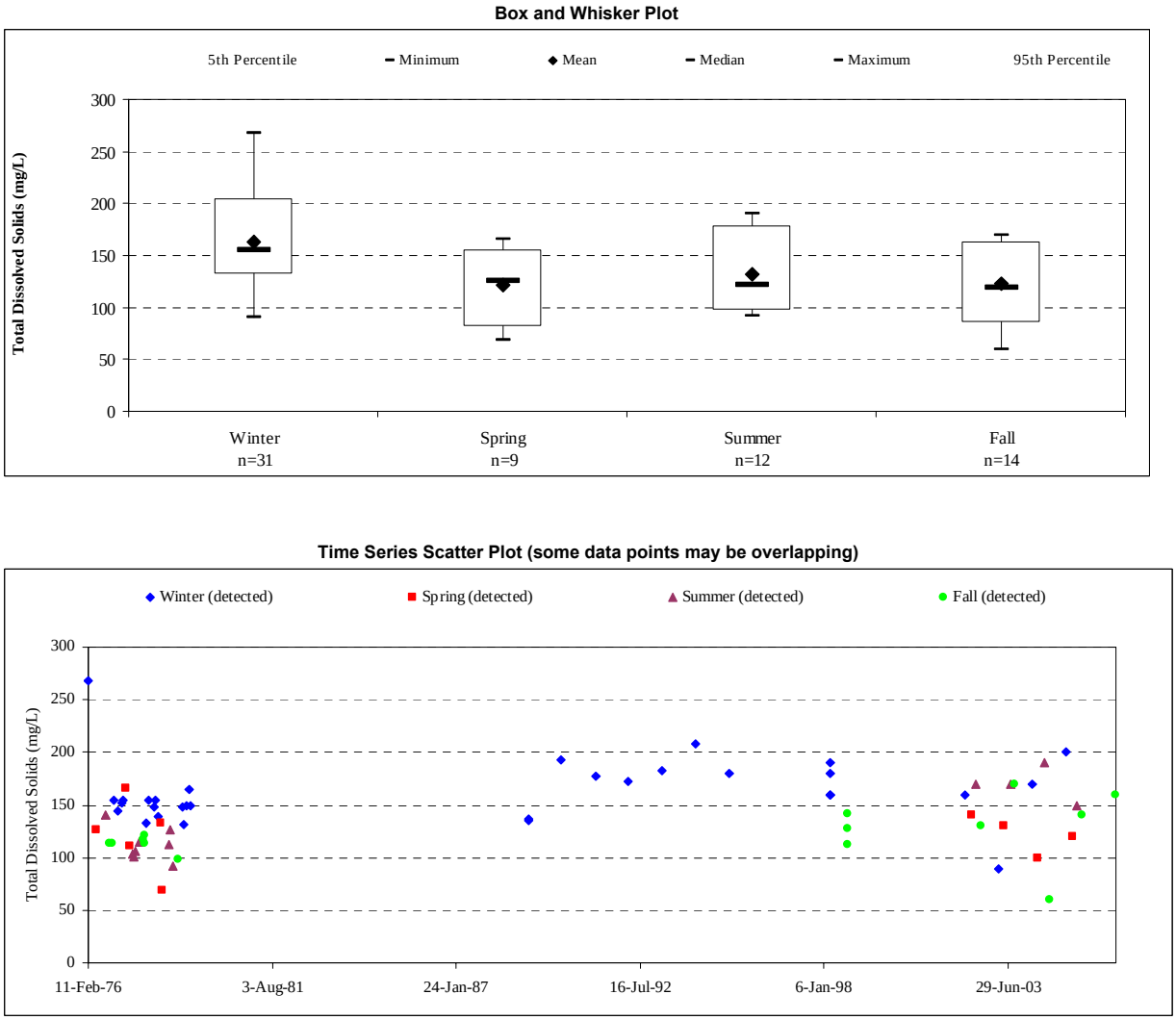
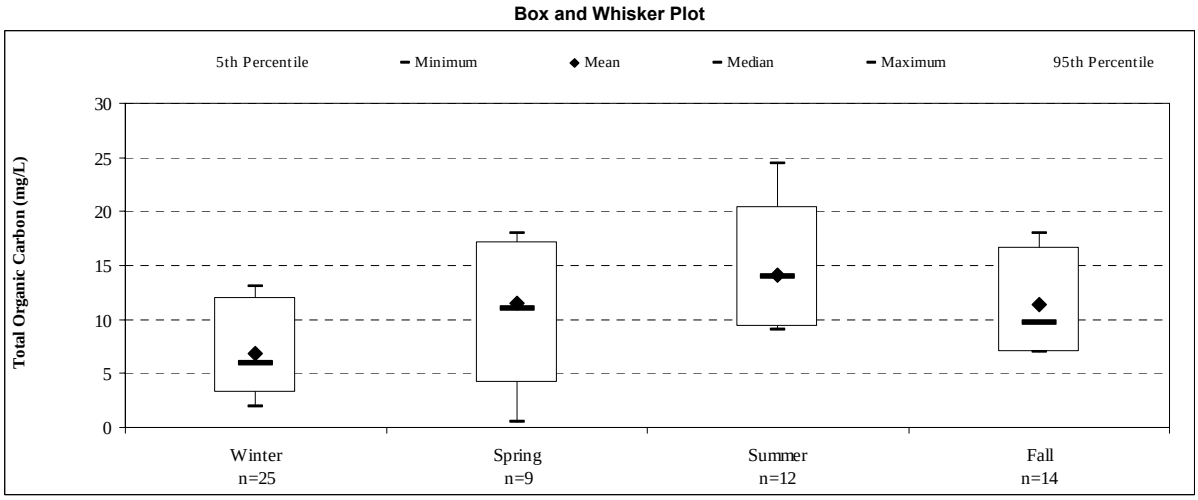


Figure G-1-4-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Lower Firebag River



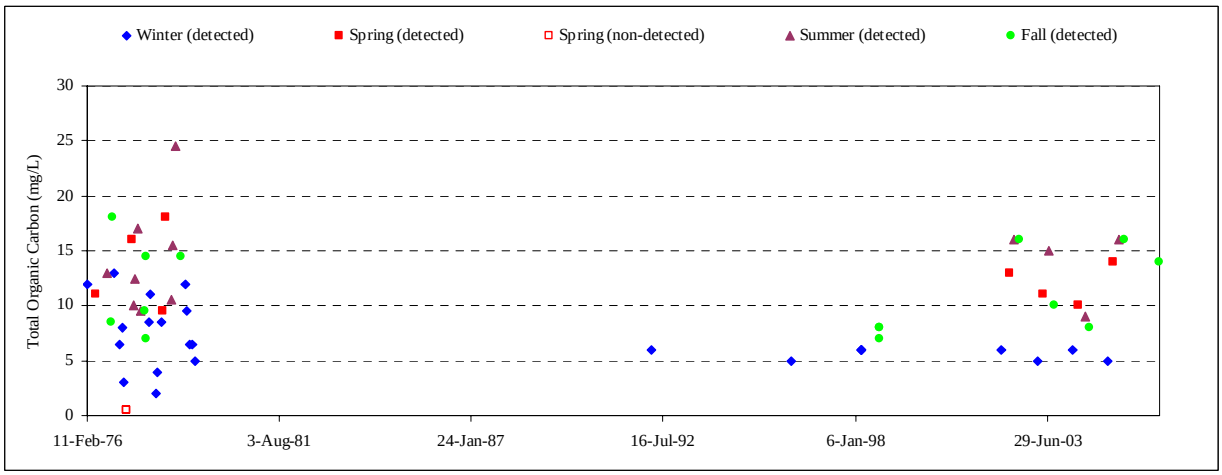
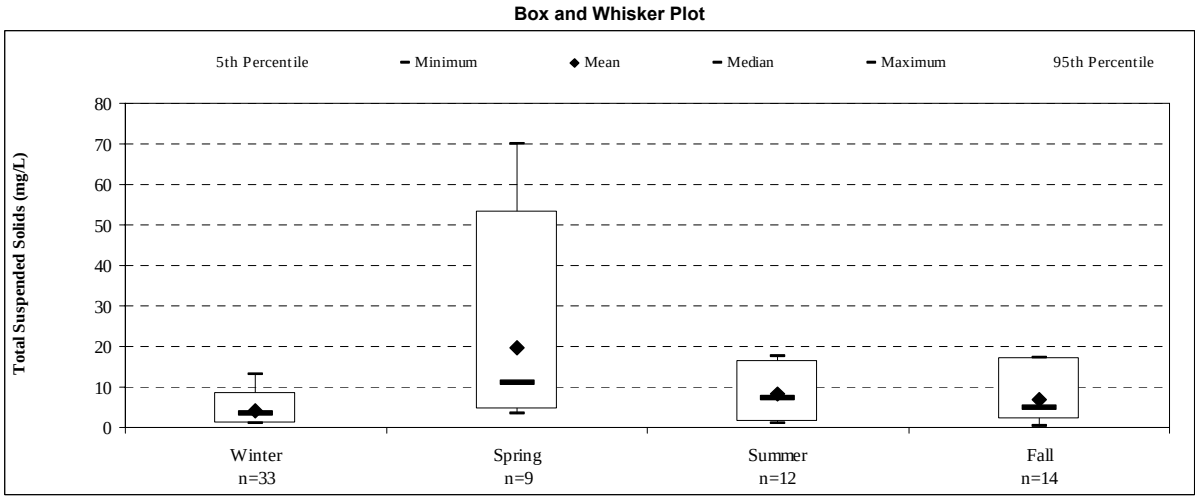


Figure G-1-4-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Lower Firebag River



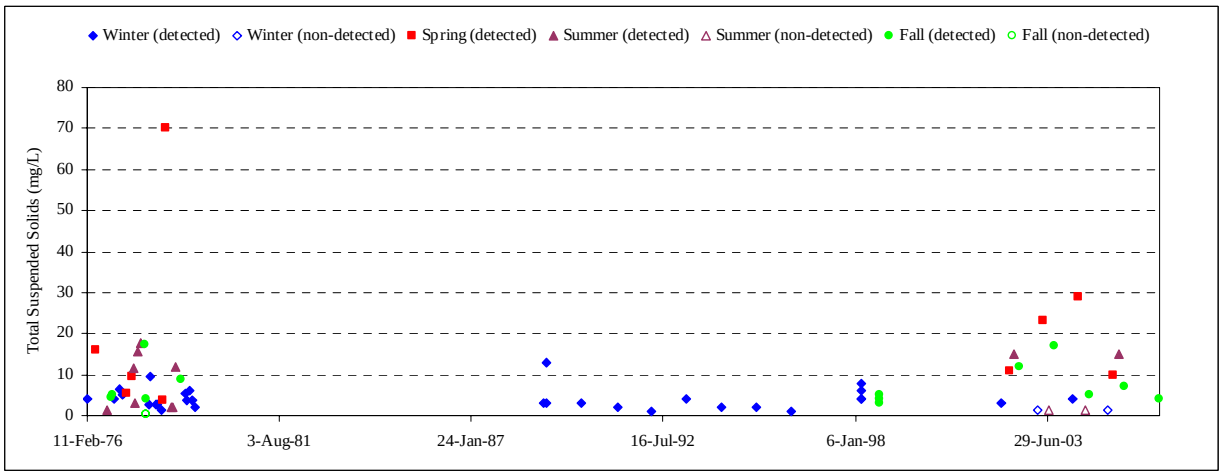
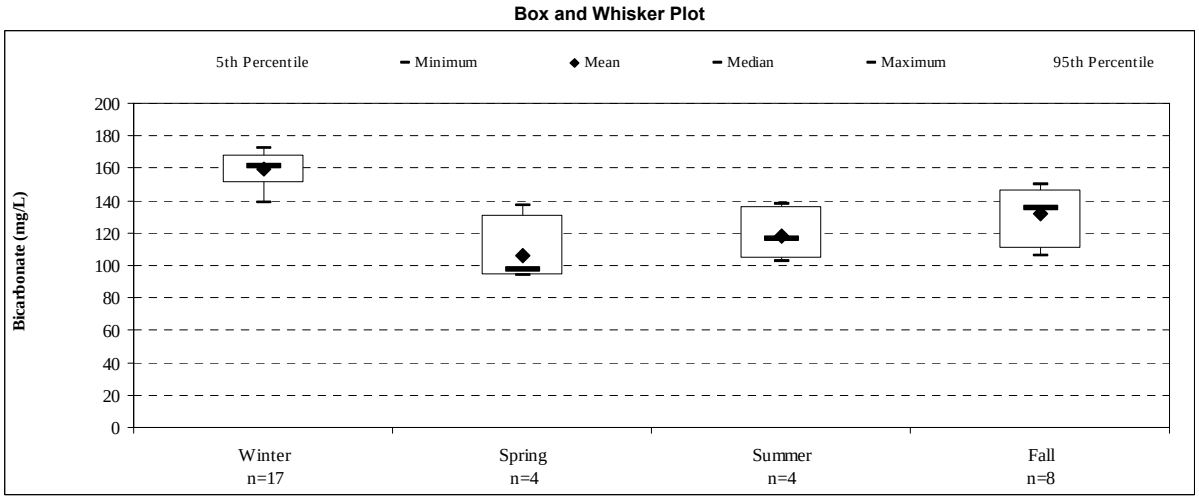


Figure G-1-4-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Lower Firebag River



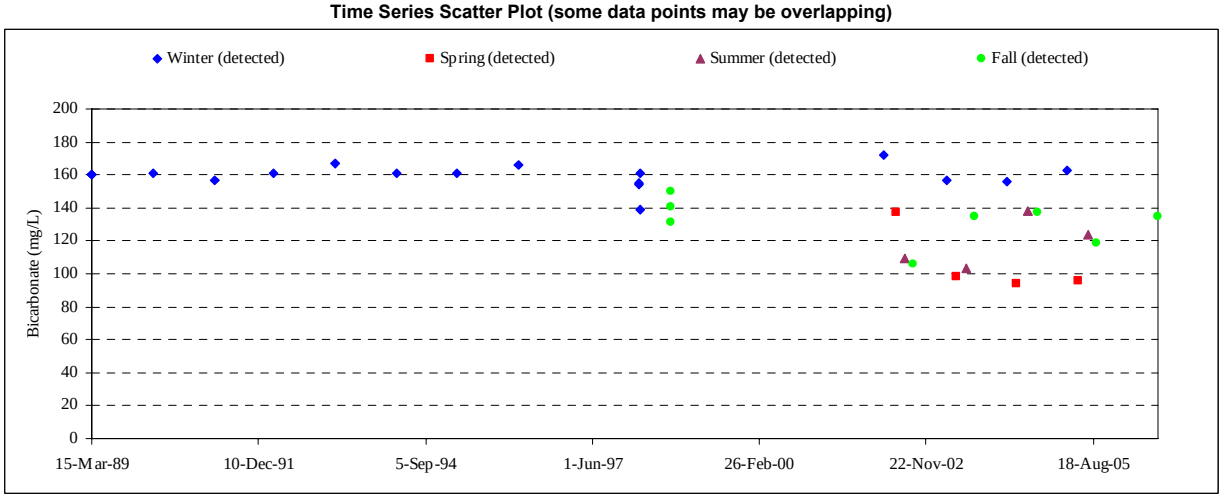


Figure G-1-4-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Lower Firebag River

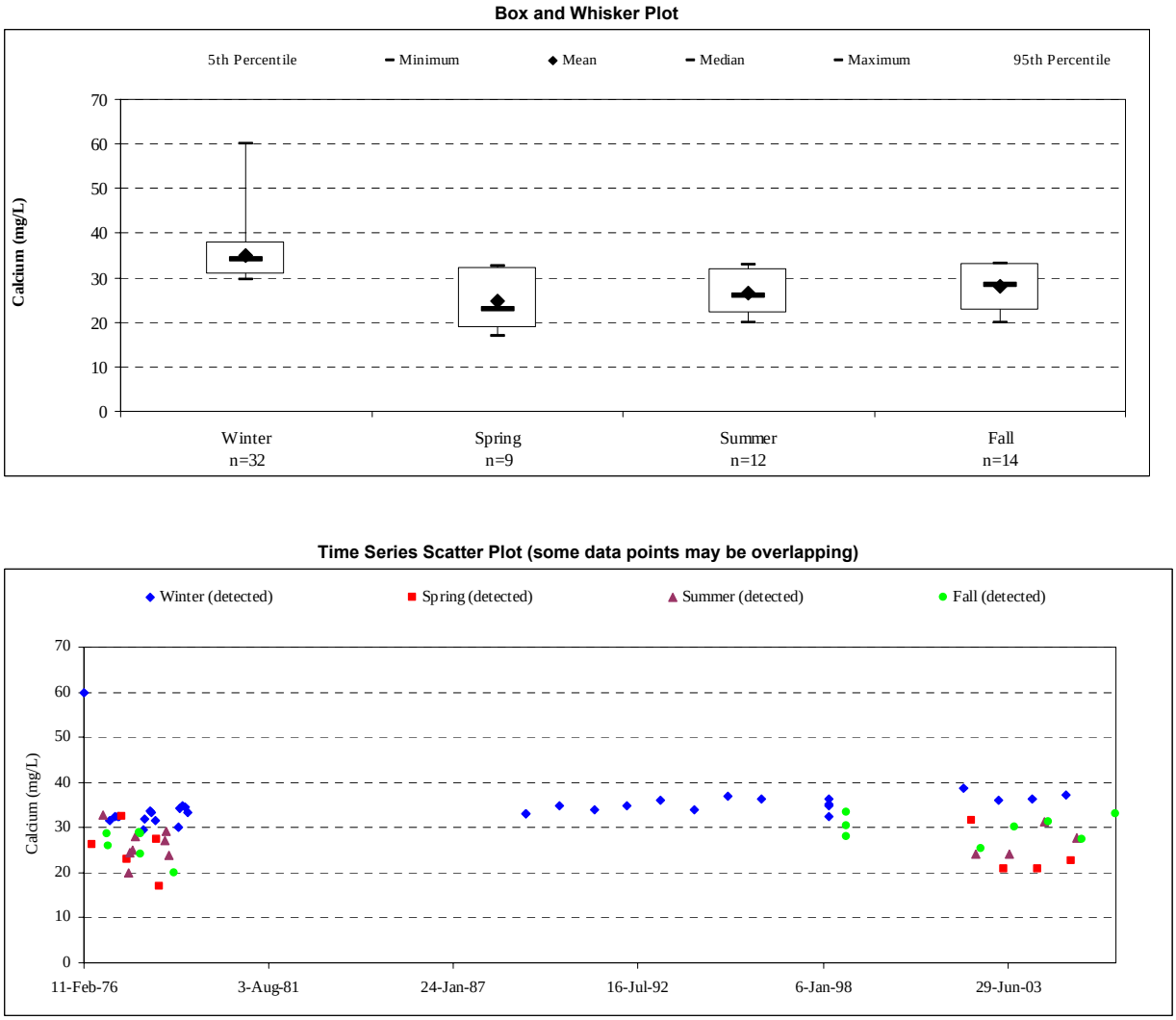
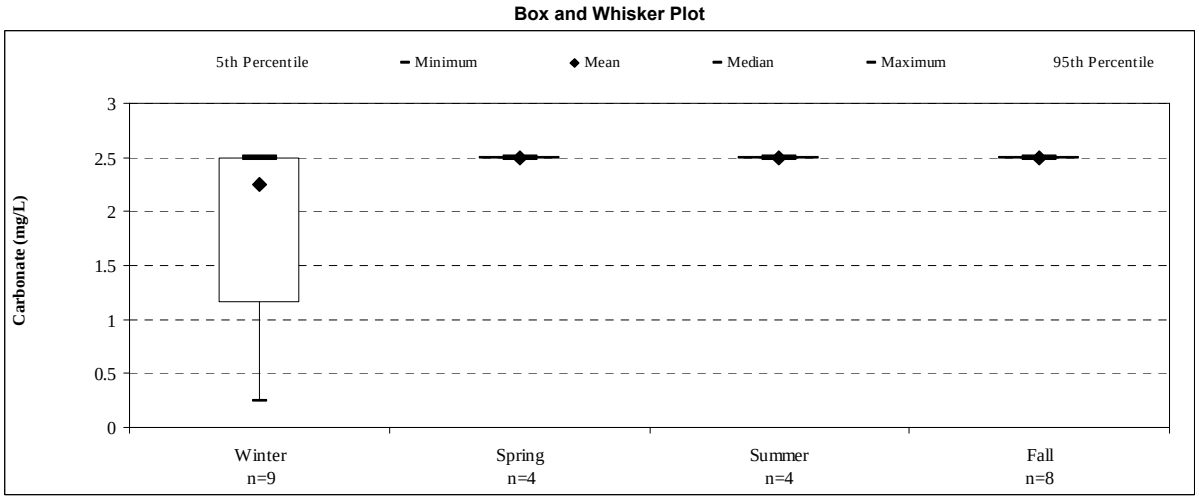


Figure G-1-4-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Lower Firebag River



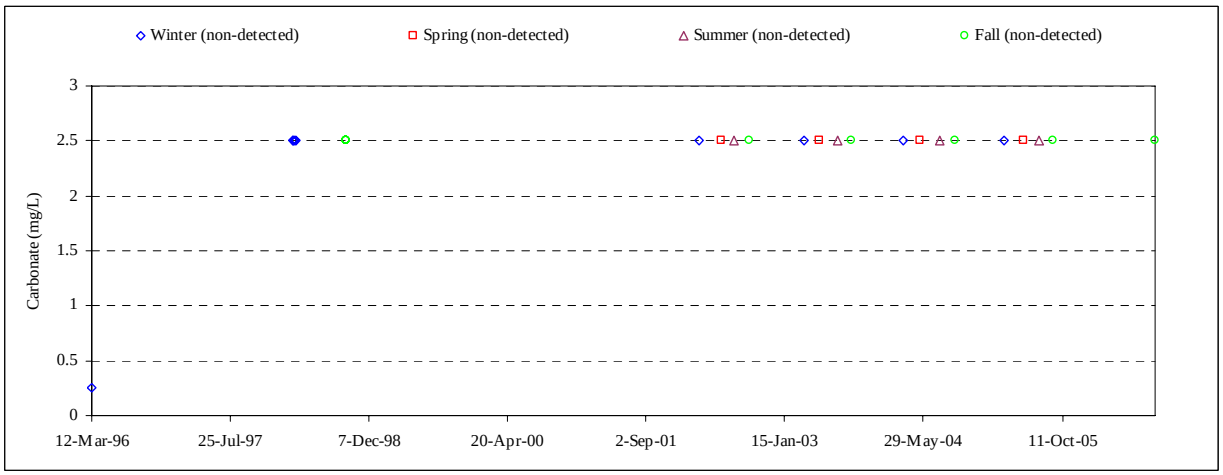
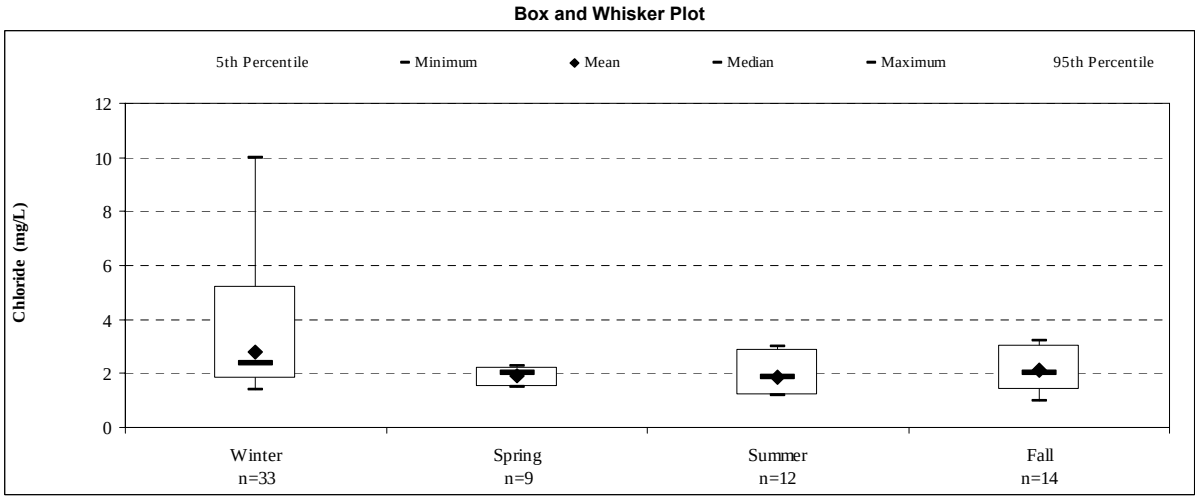


Figure G-1-4-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Lower Firebag River



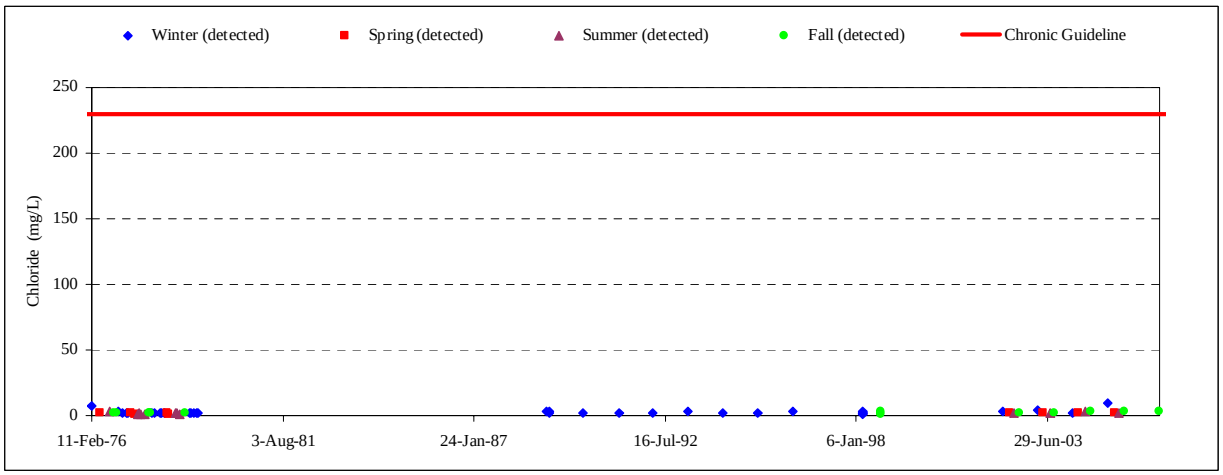
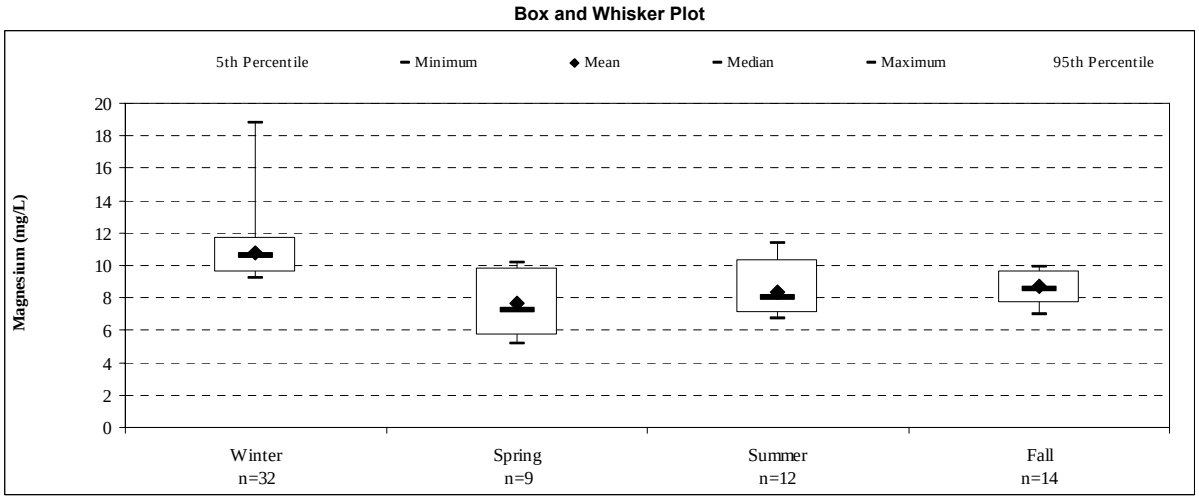


Figure G-1-4-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Lower Firebag River



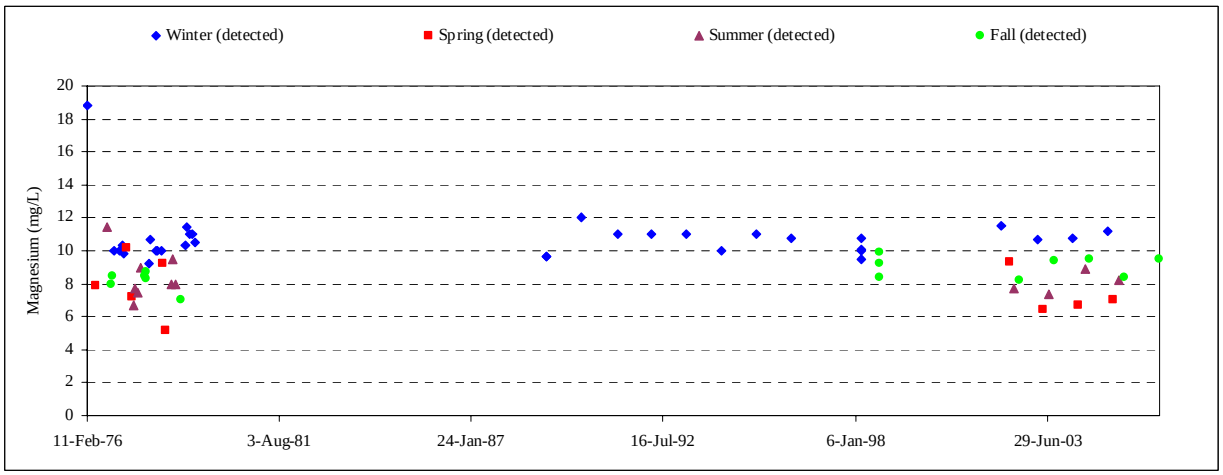
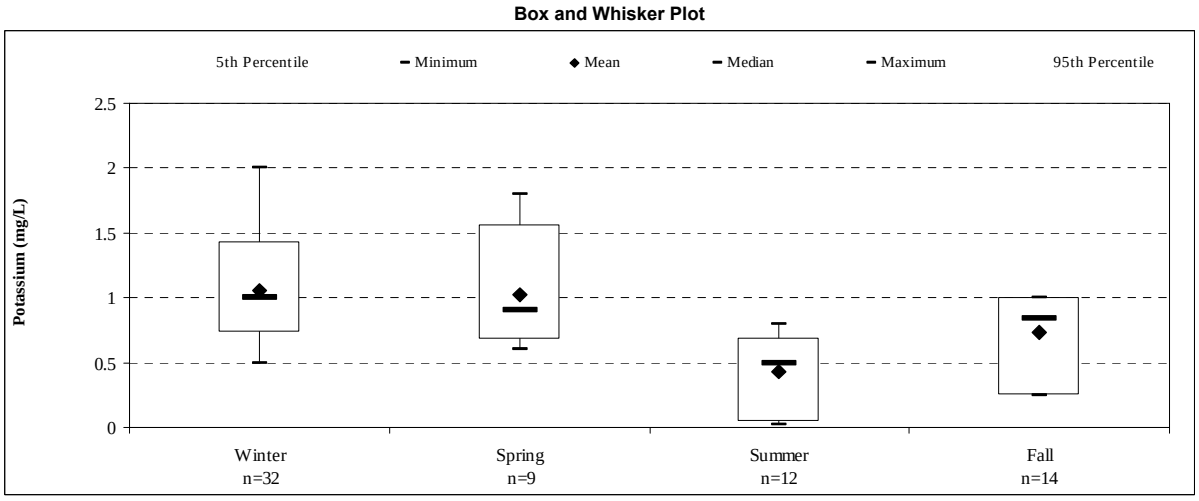


Figure G-1-4-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Lower Firebag River



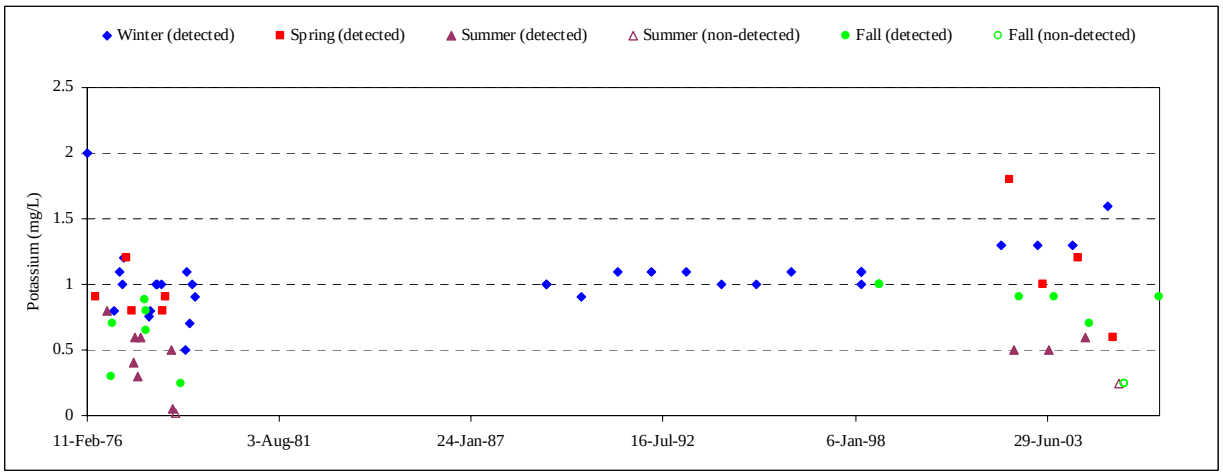
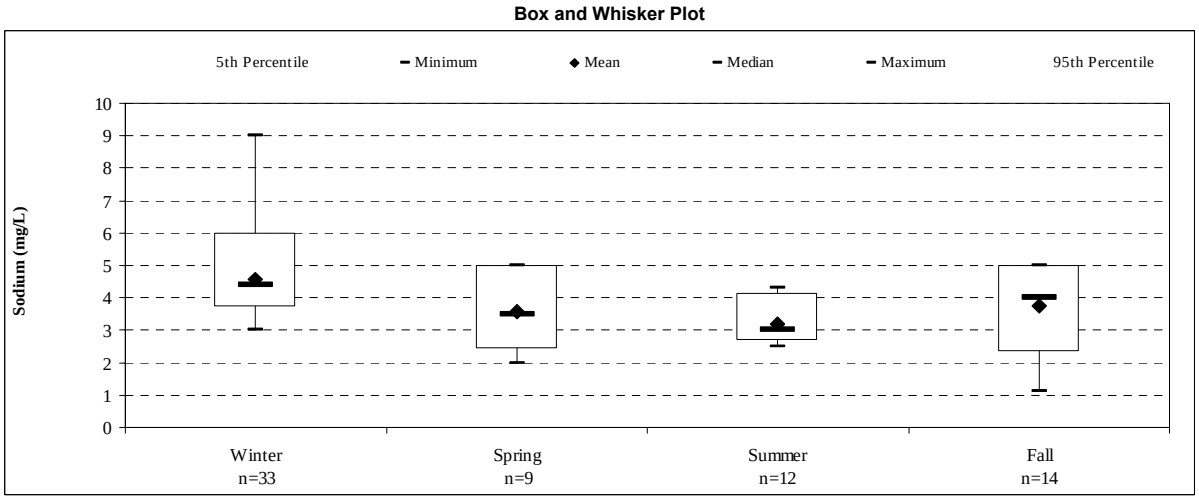


Figure G-1-4-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Lower Firebag River



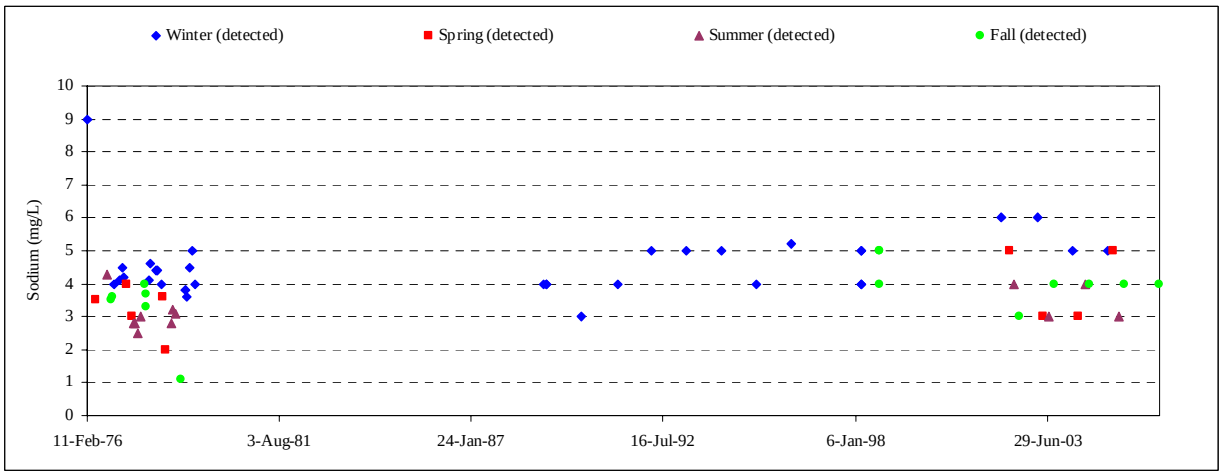
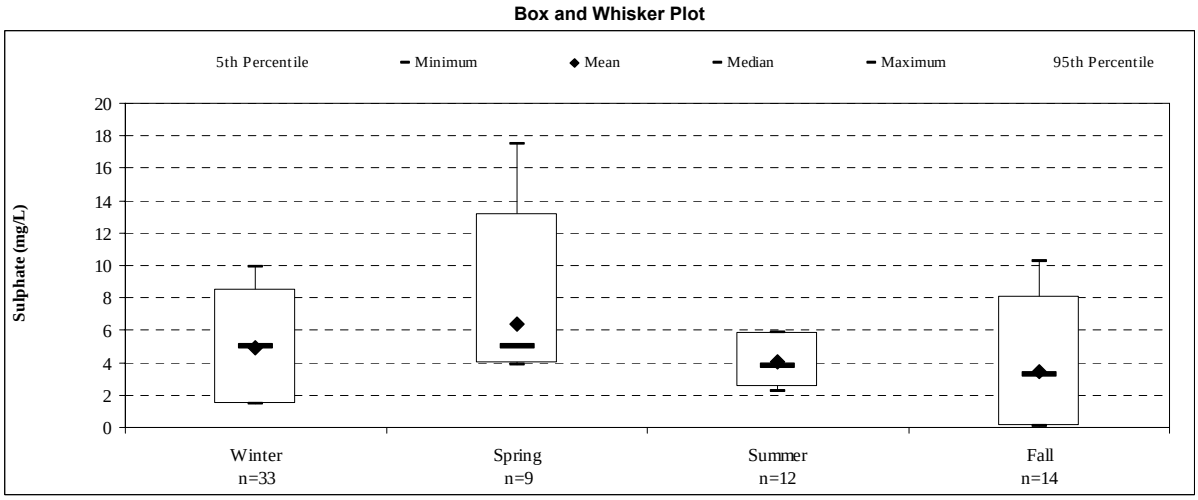


Figure G-1-4-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Lower Firebag River



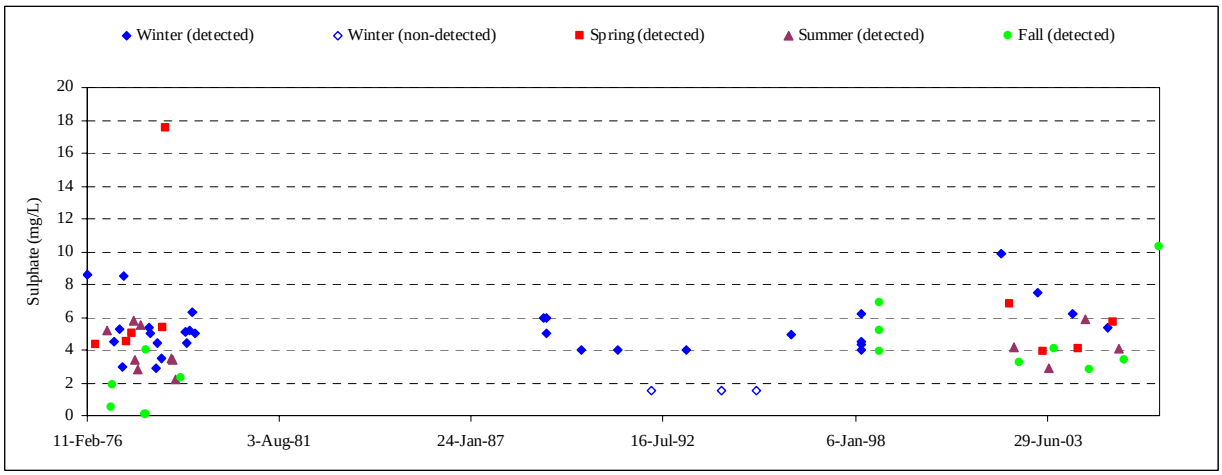
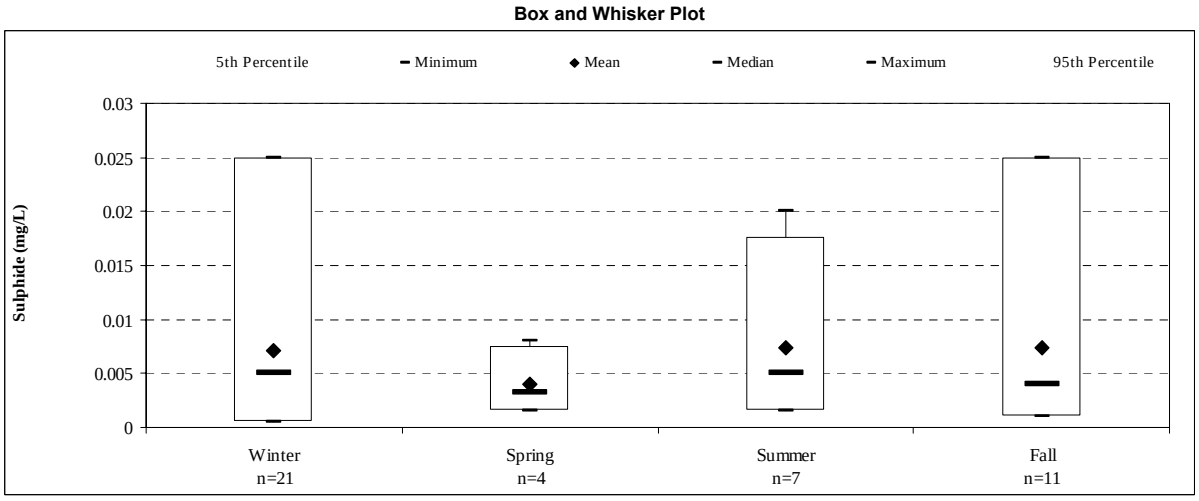


Figure G-1-4-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Lower Firebag River



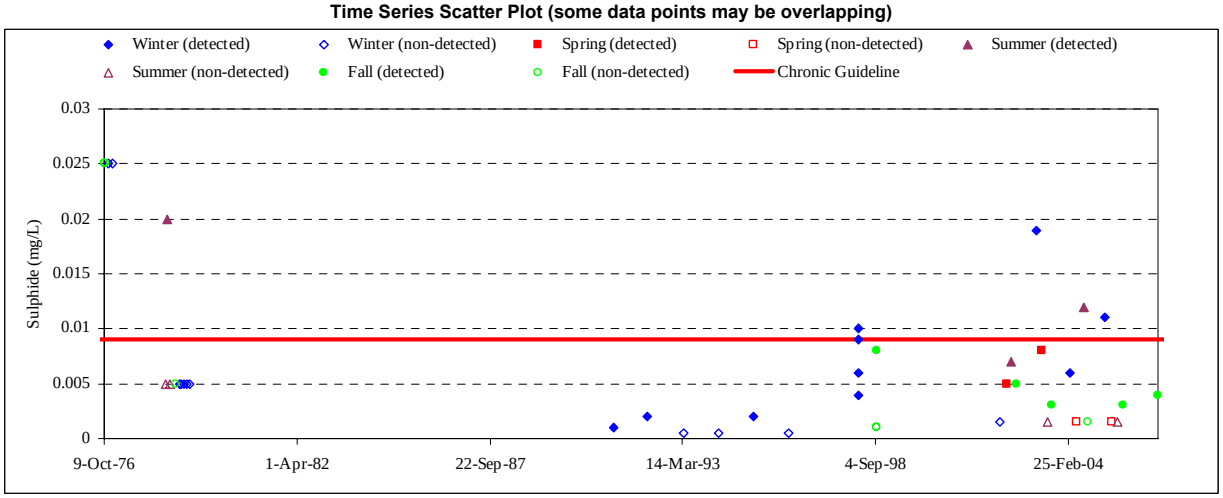
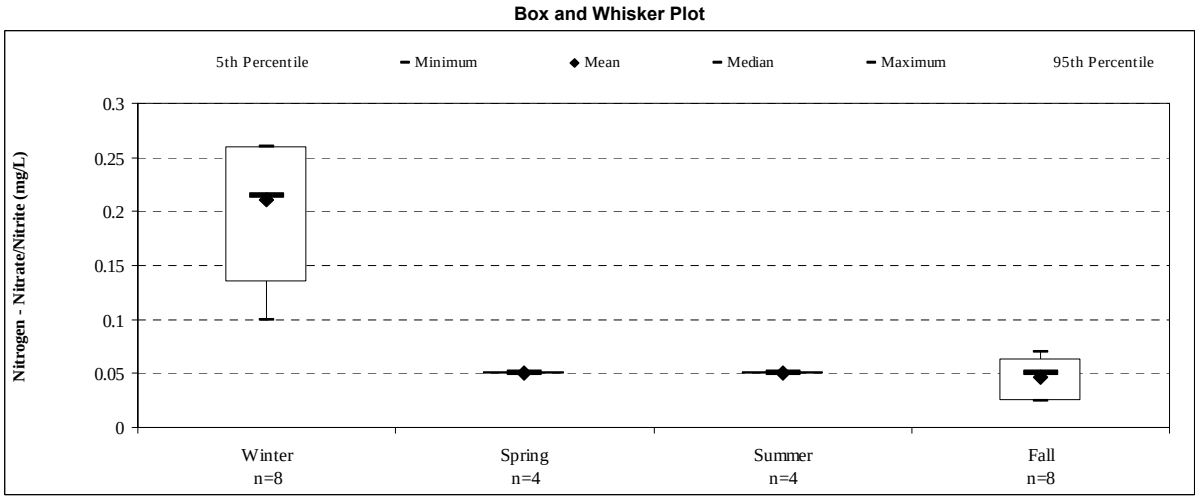


Figure G-1-4-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Lower Firebag River



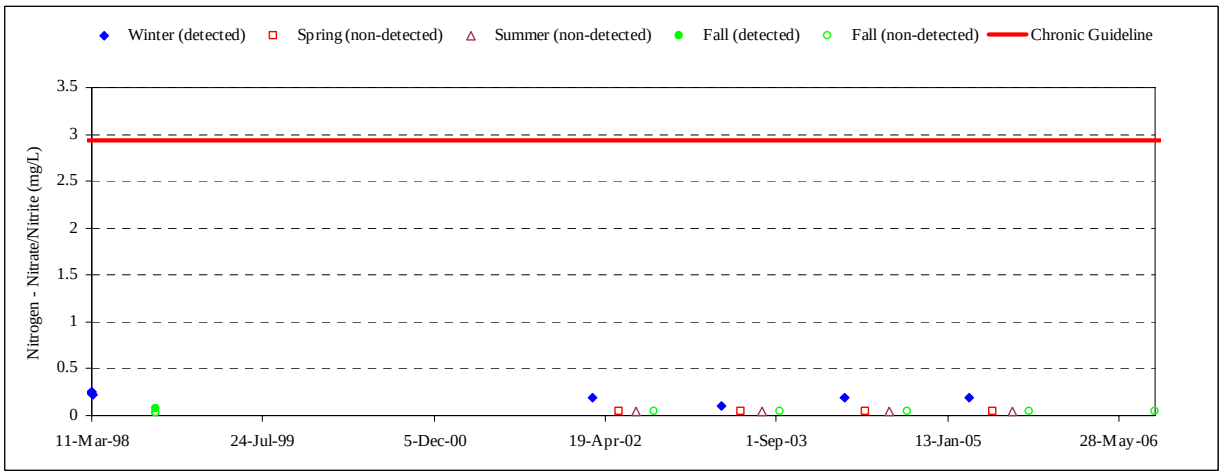
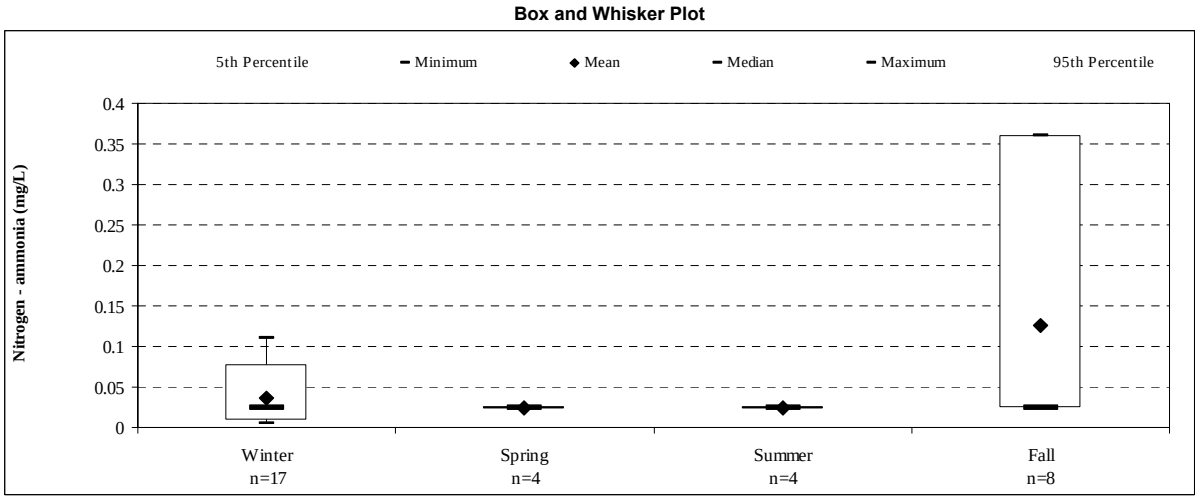


Figure G-1-4-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Lower Firebag River



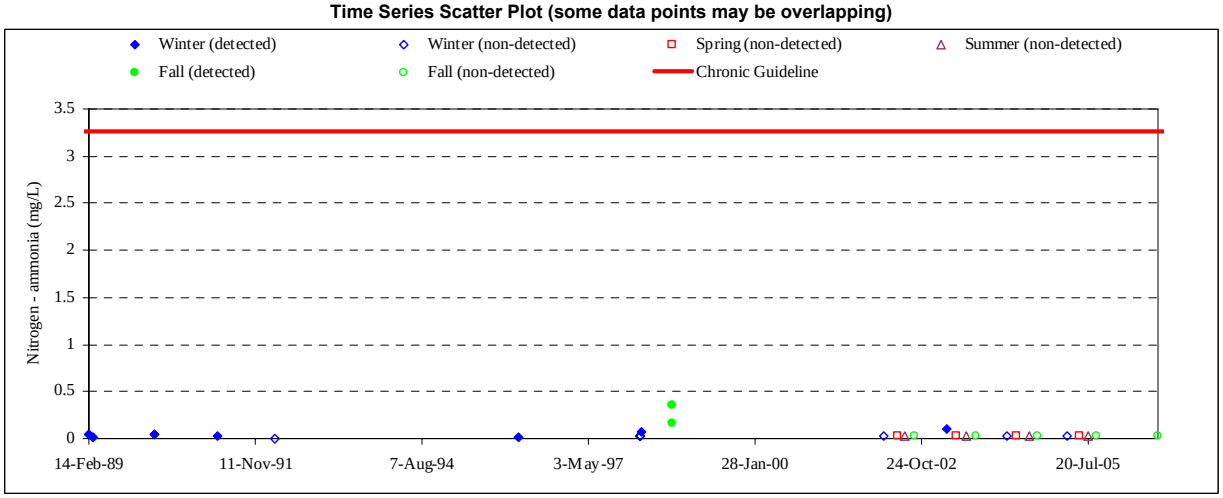
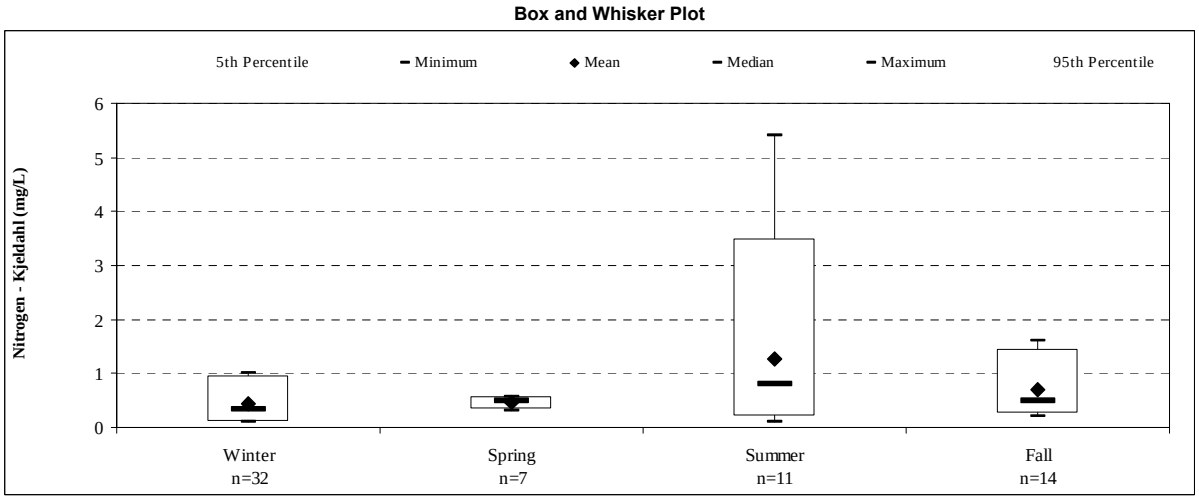


Figure G-1-4-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Lower Firebag River



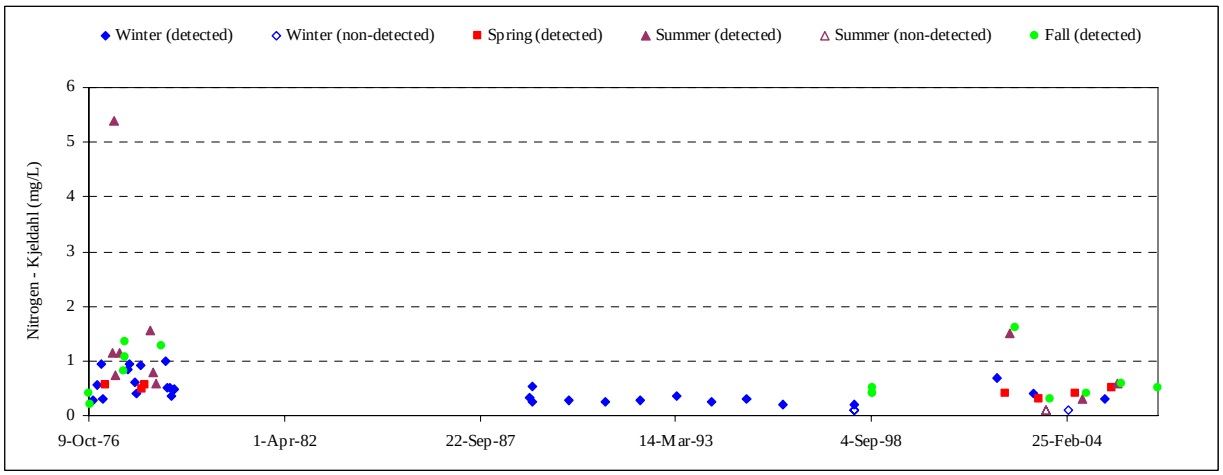
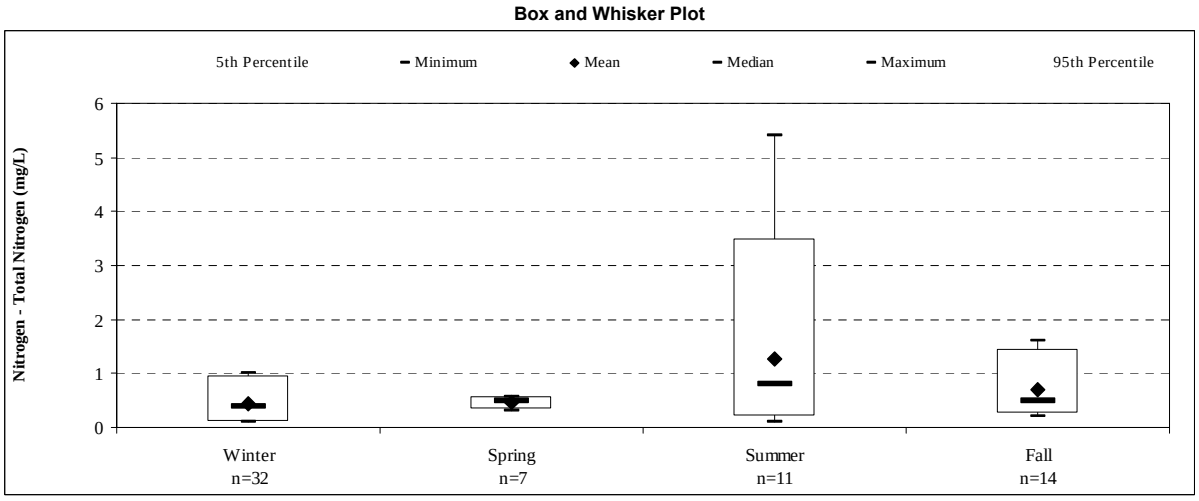


Figure G-1-4-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Lower Firebag River



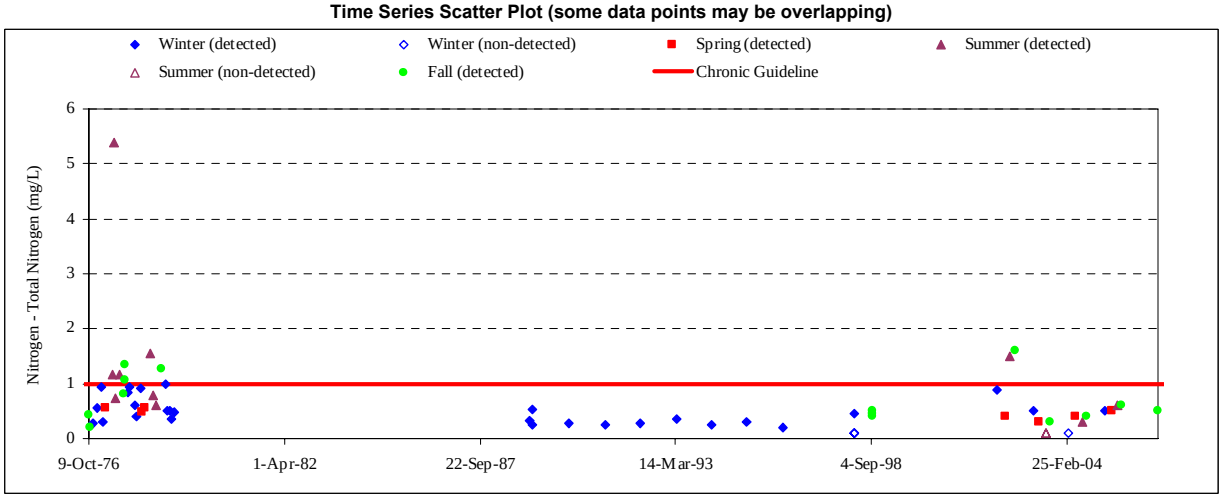
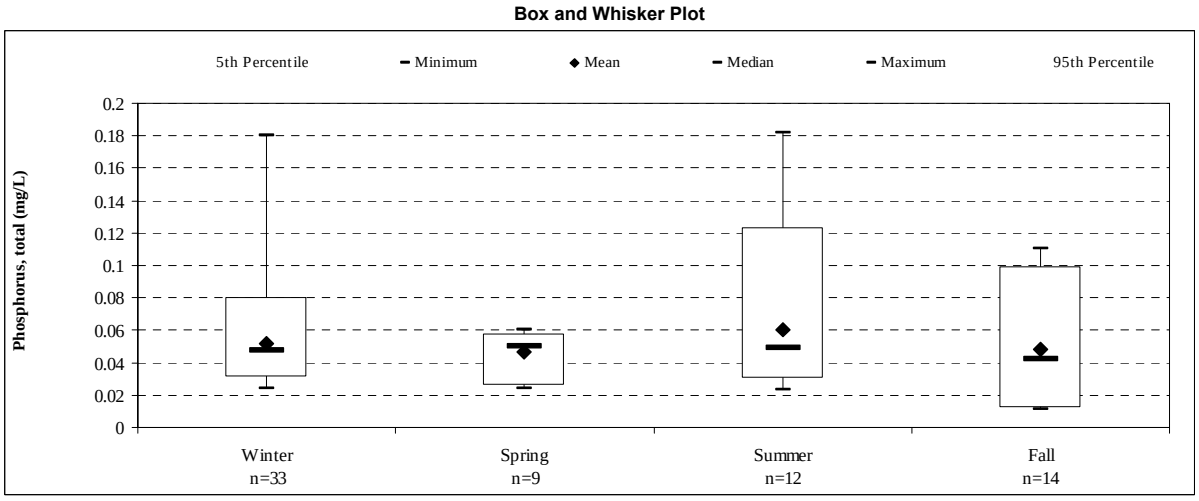


Figure G-1-4-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Lower Firebag River



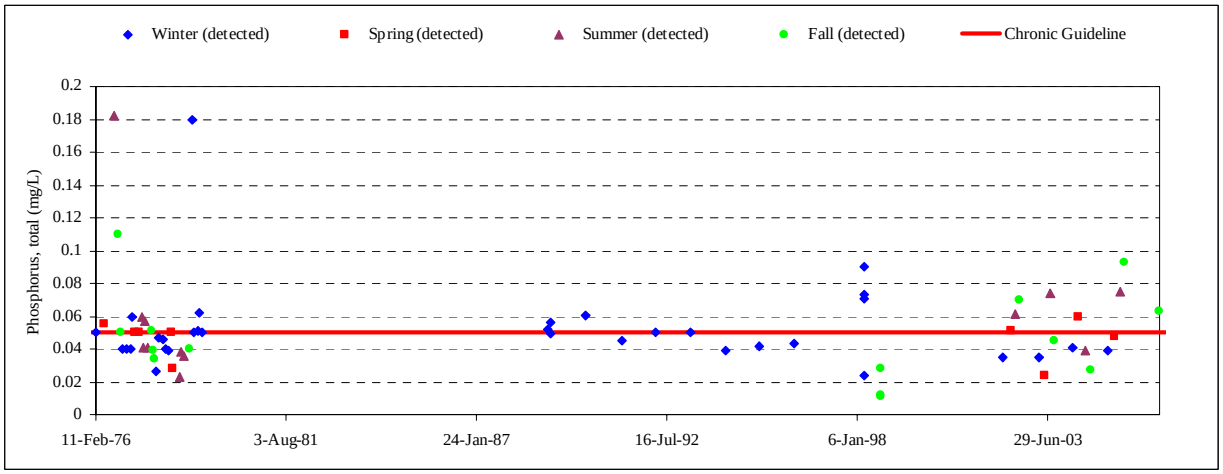
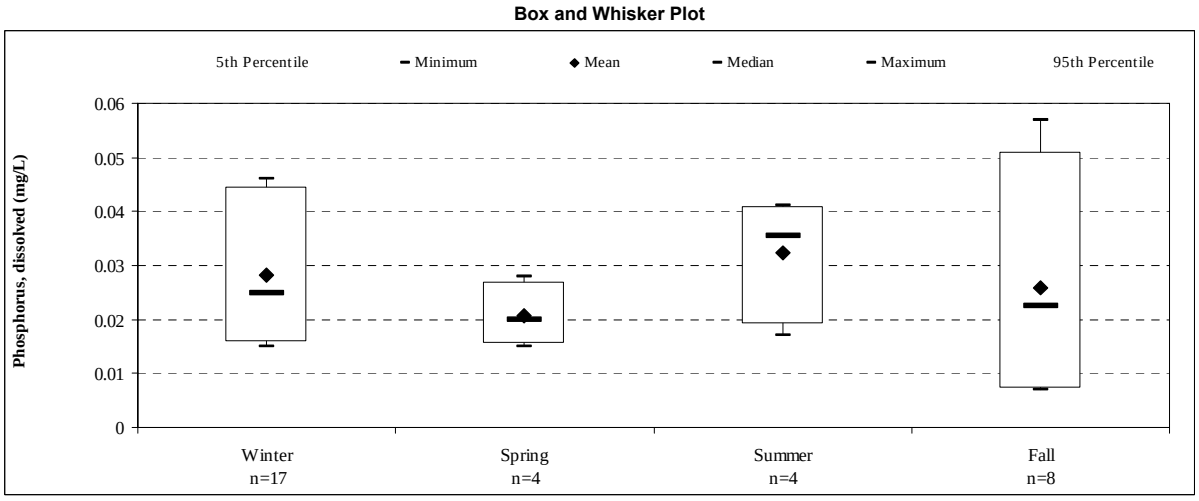


Figure G-1-4-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Lower Firebag River



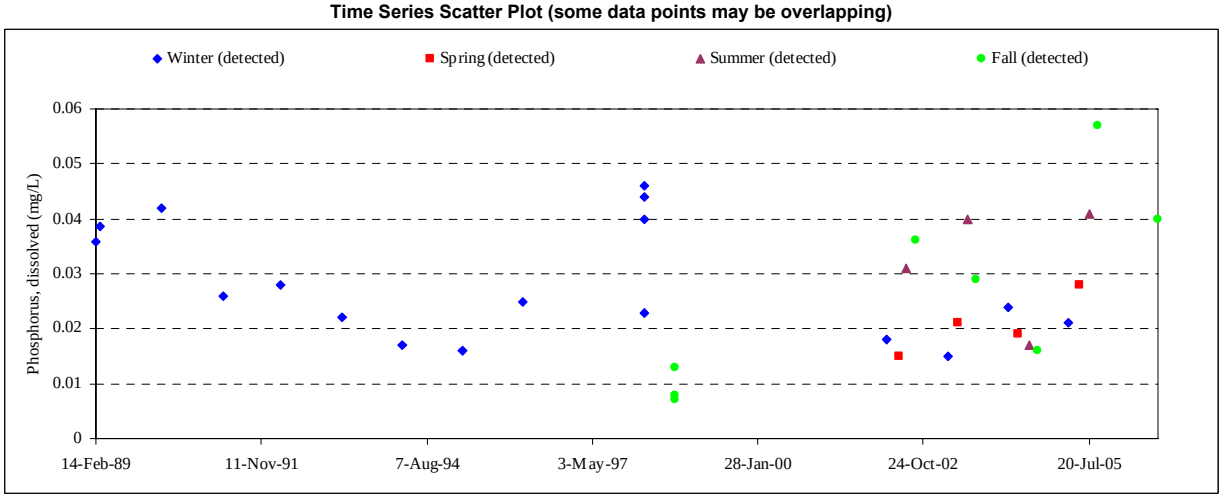
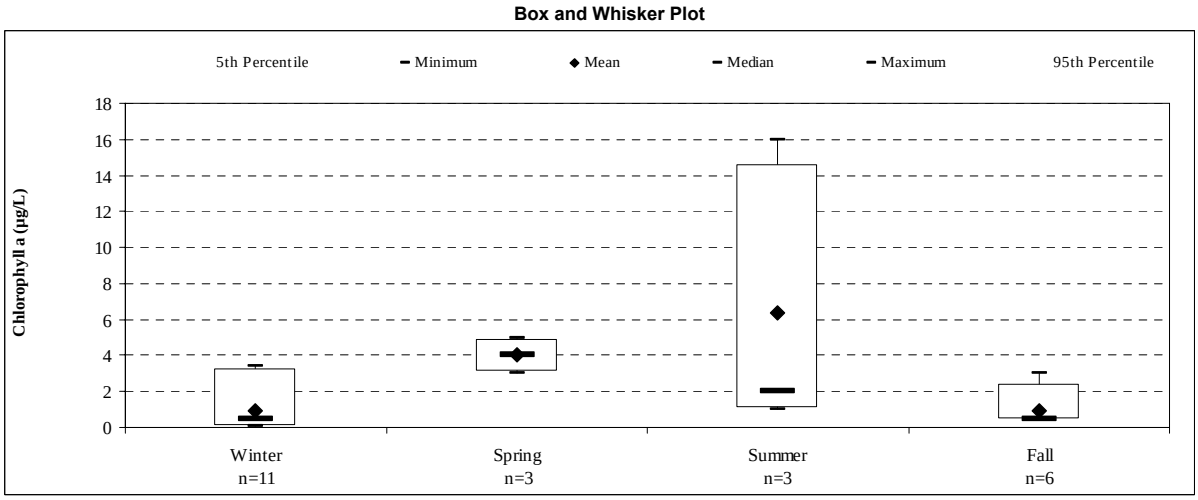


Figure G-1-4-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Lower Firebag River



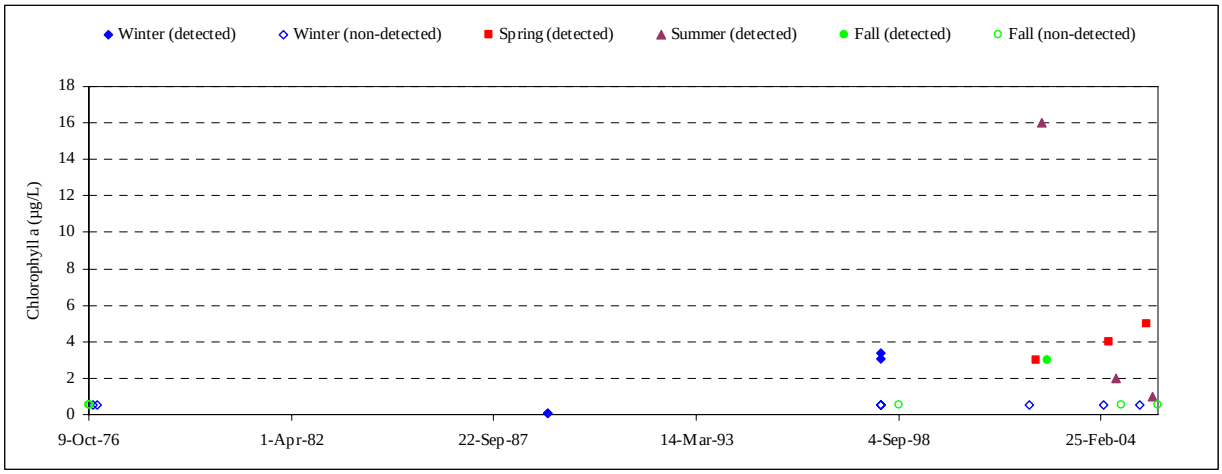
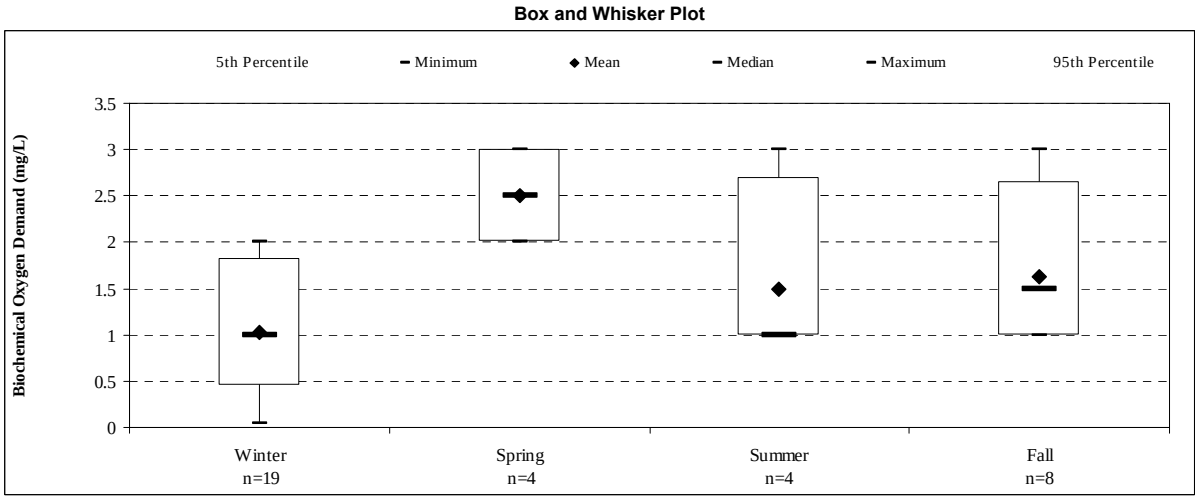


Figure G-1-4-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Lower Firebag River



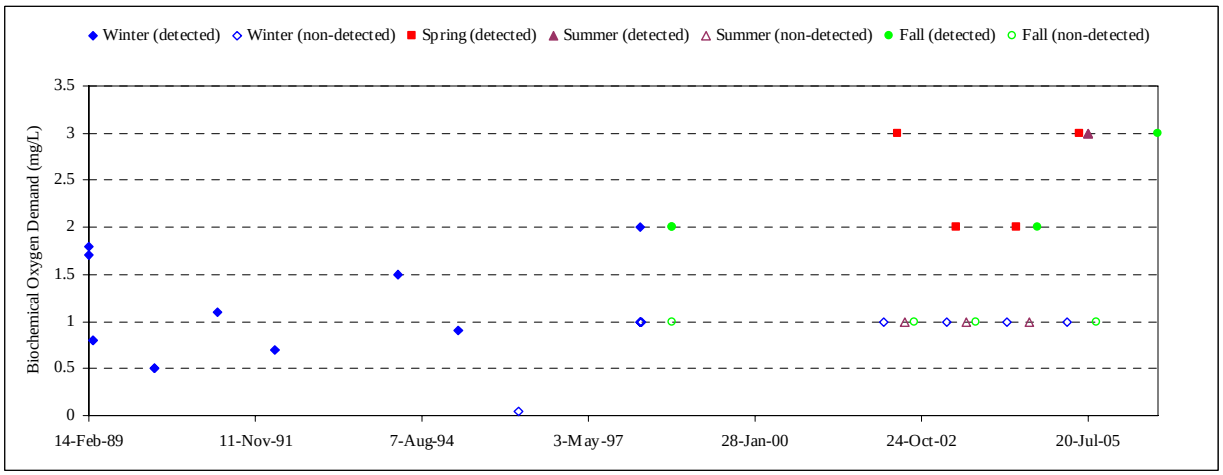
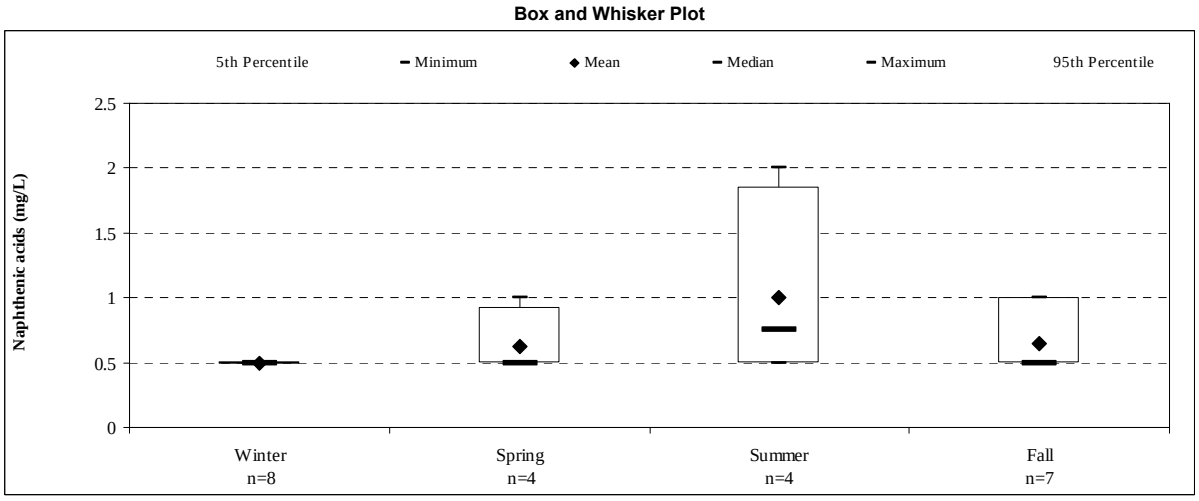


Figure G-1-4-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Lower Firebag River



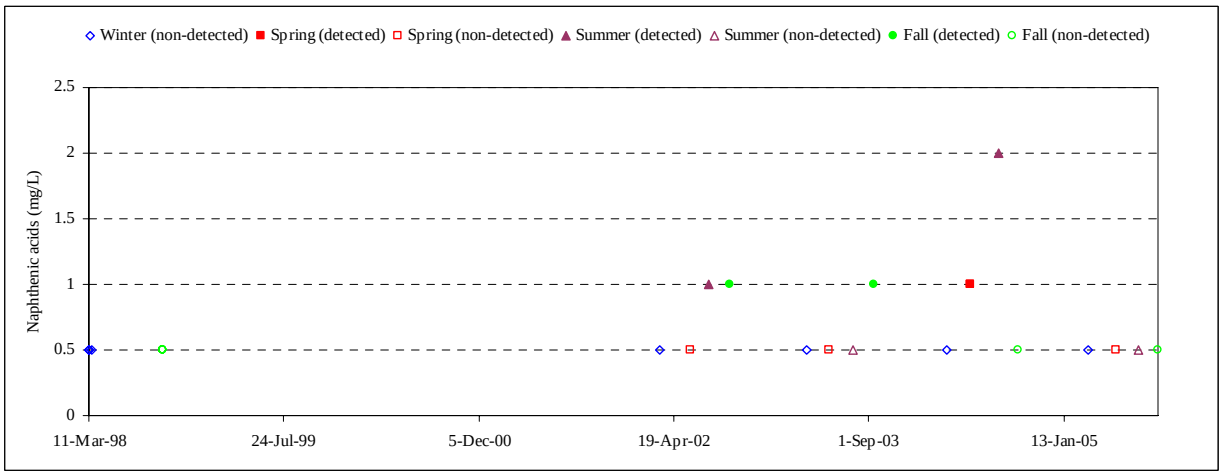
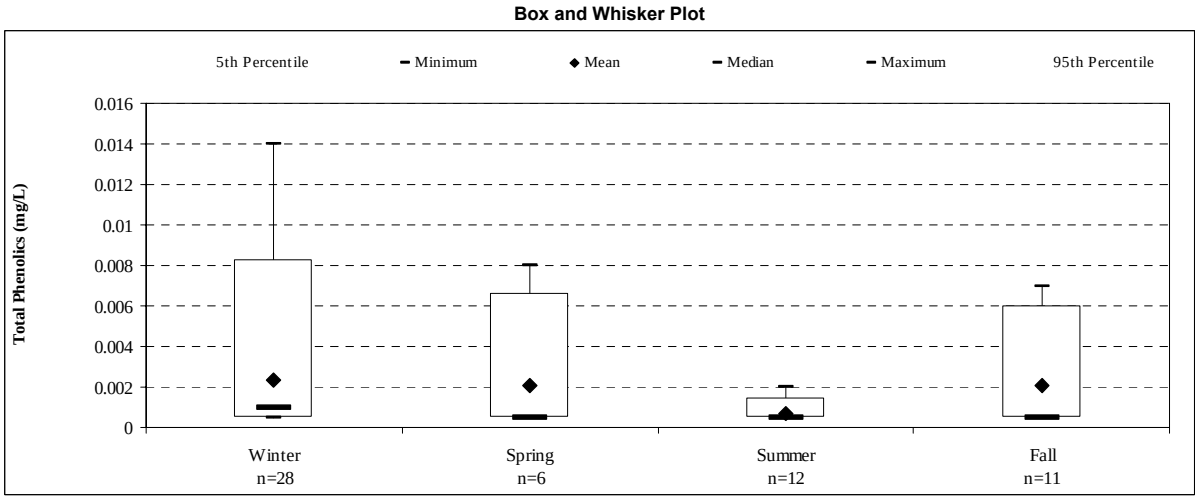


Figure G-1-4-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Lower Firebag River



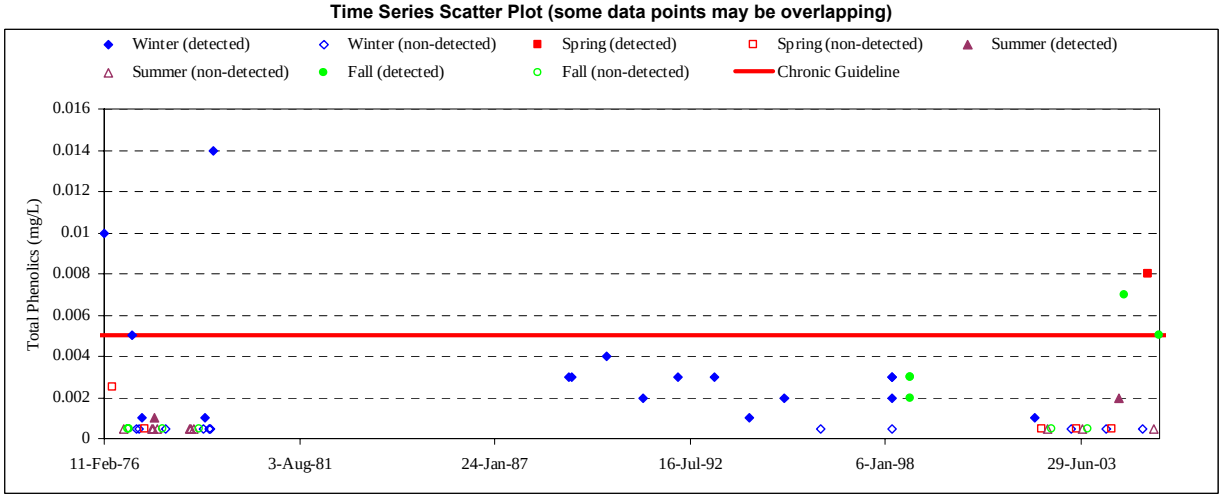


Figure G-1-4-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Lower Firebag River

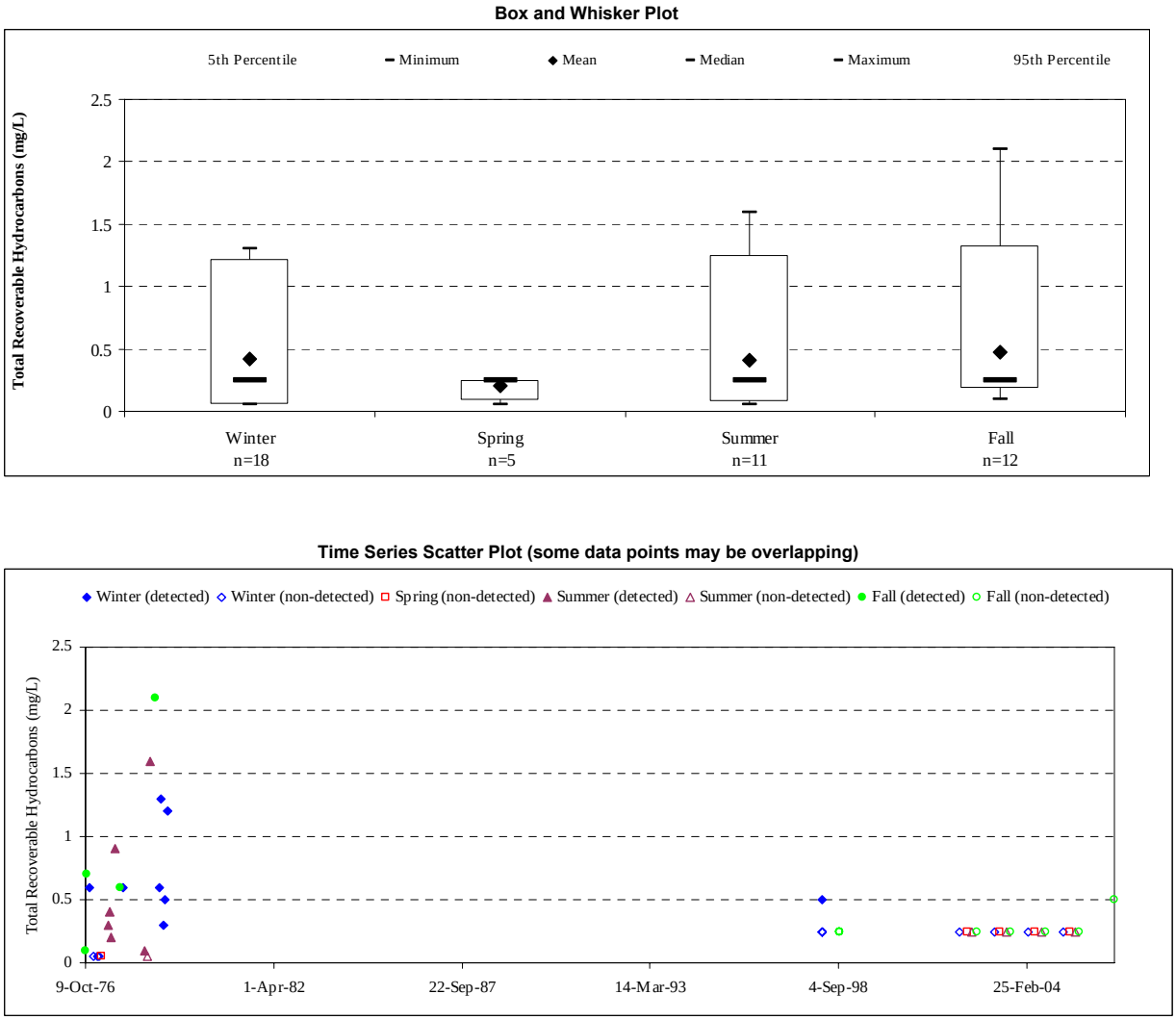
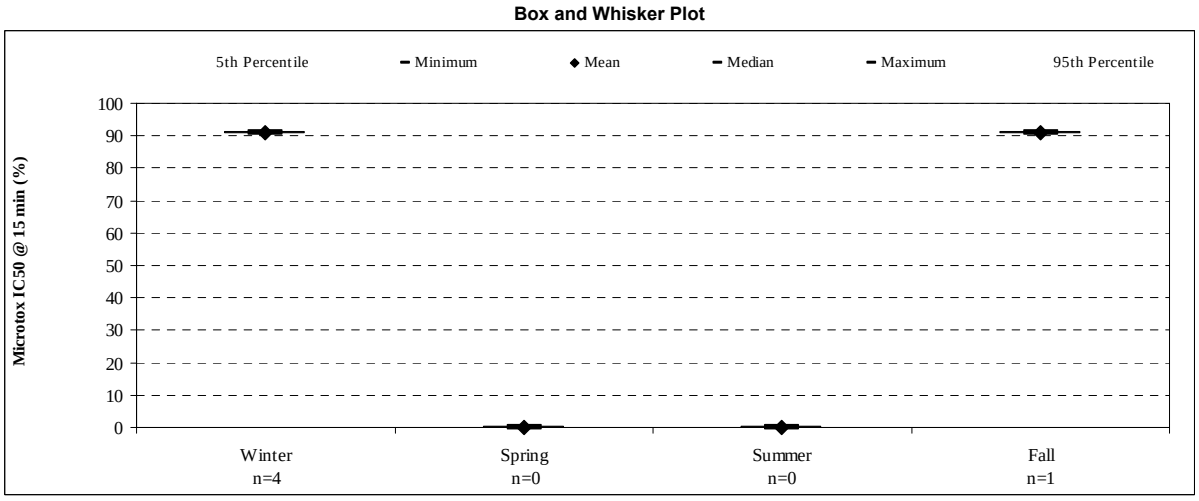


Figure G-1-4-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Lower Firebag River



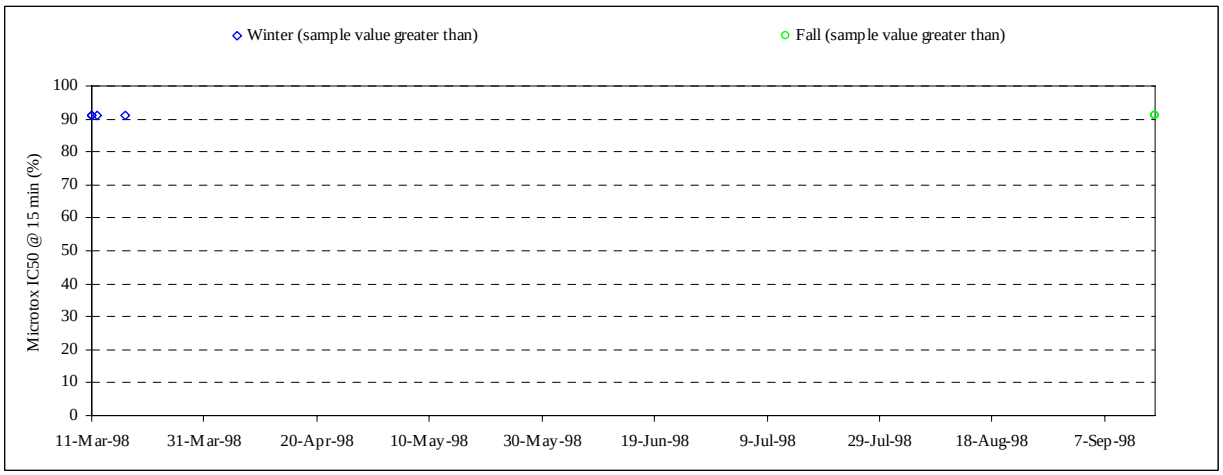
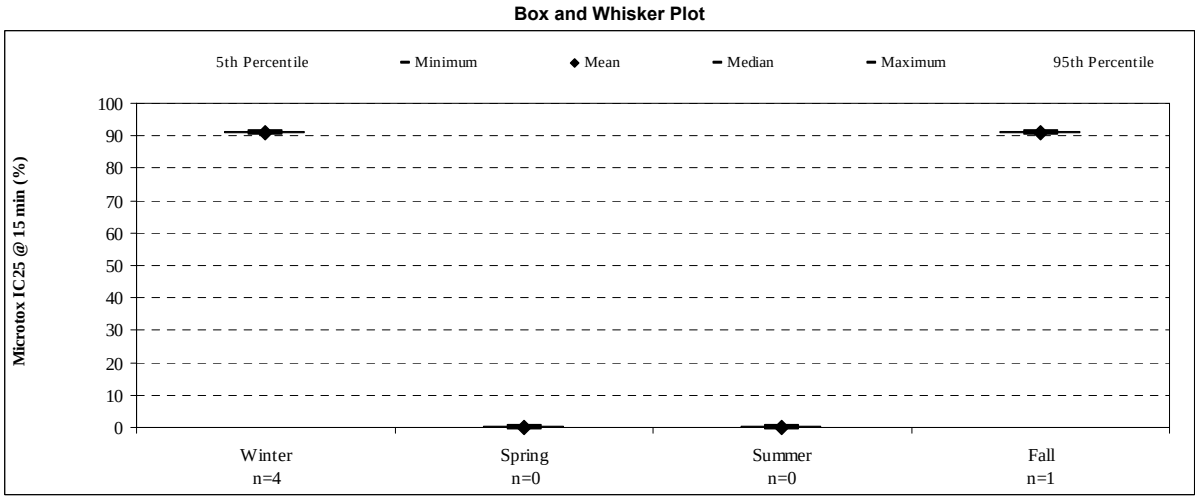


Figure G-1-4-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Lower Firebag River



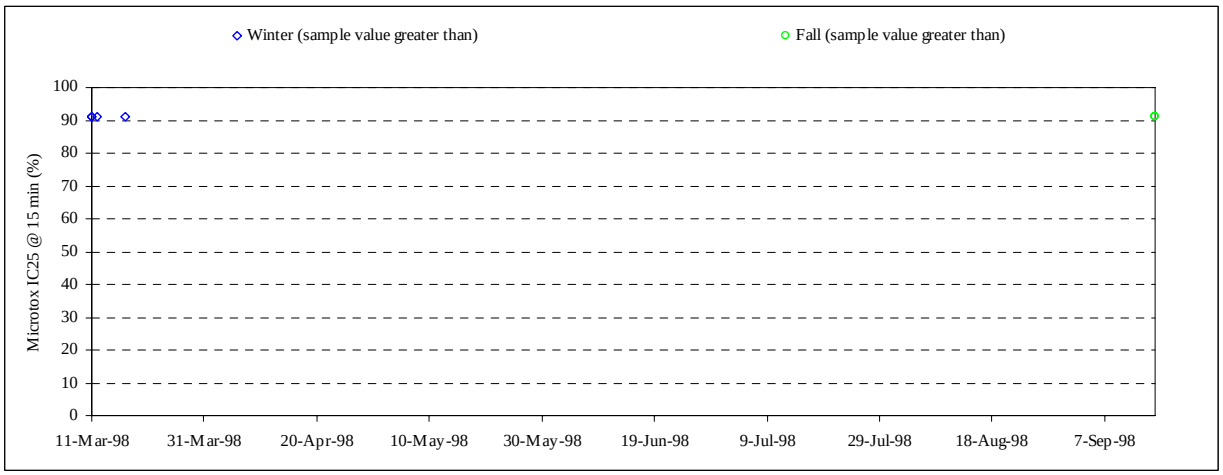
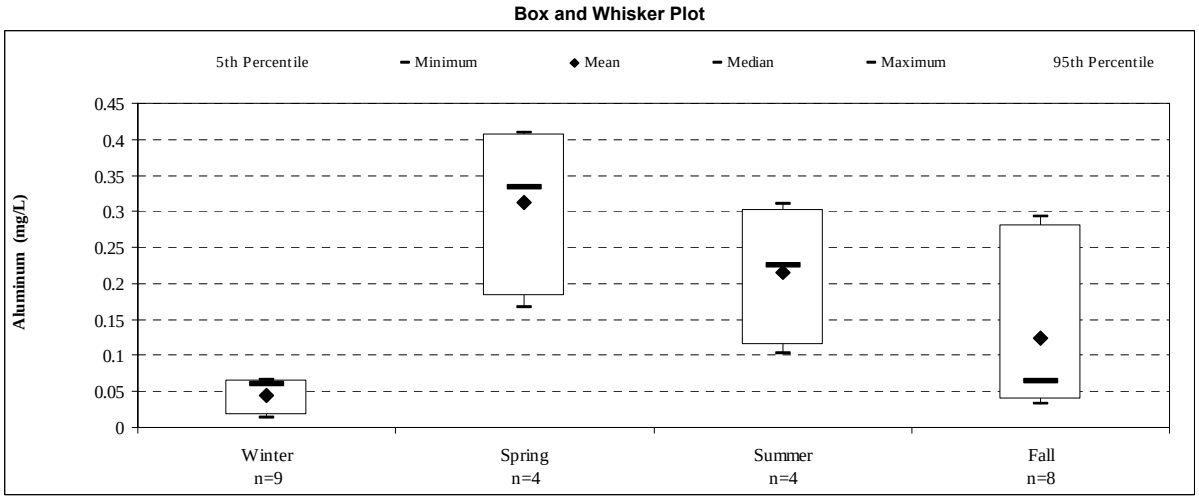


Figure G-1-4-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Lower Firebag River



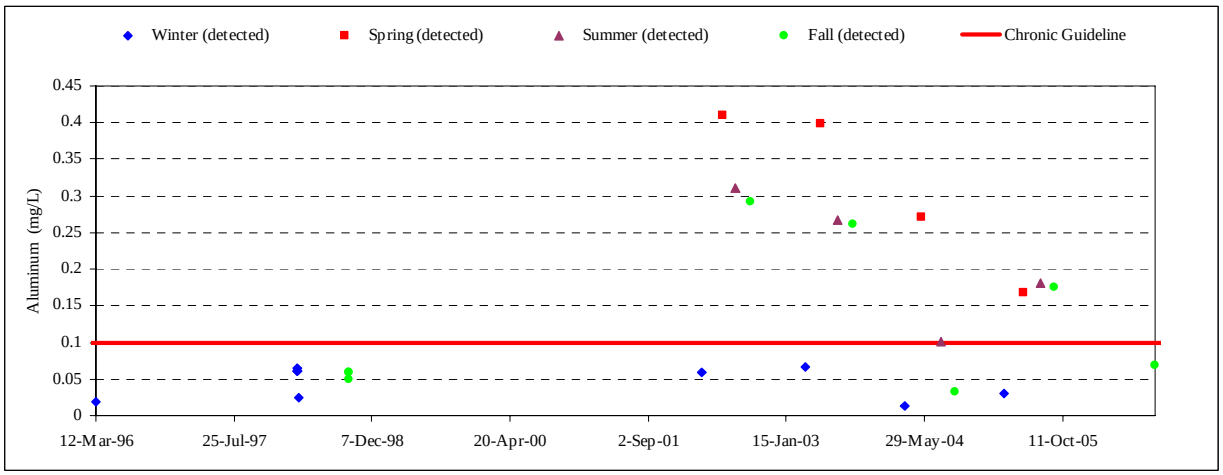
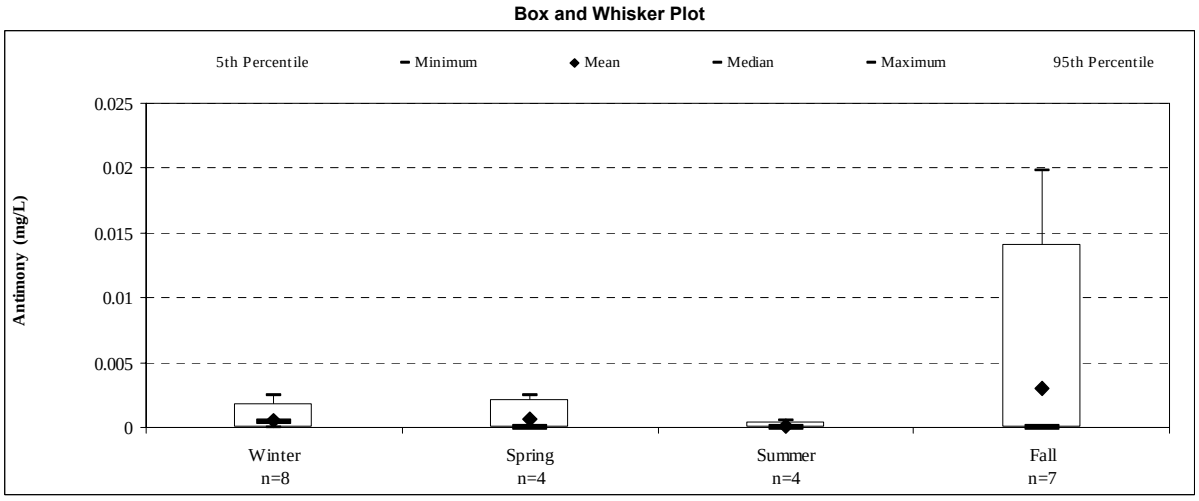


Figure G-1-4-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Lower Firebag River



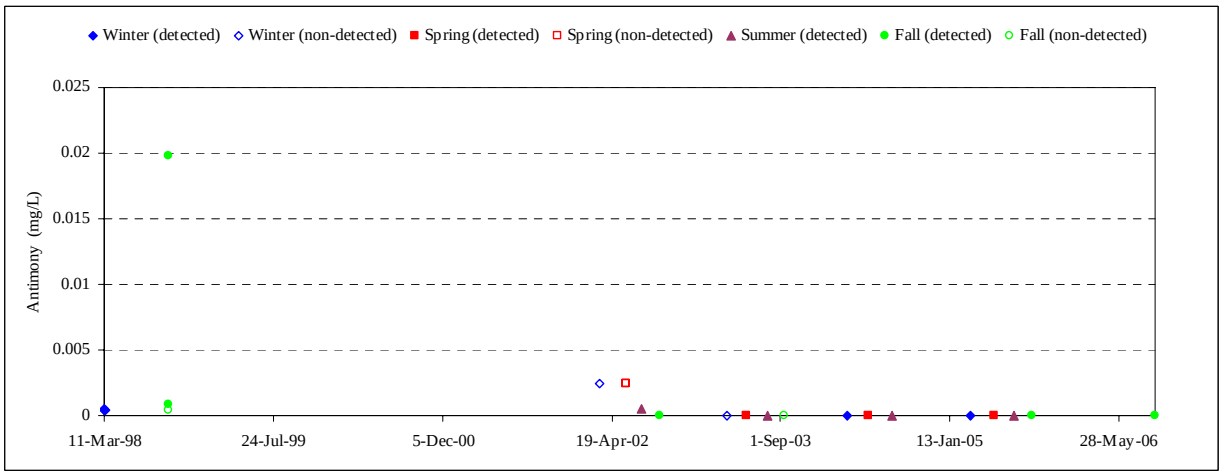
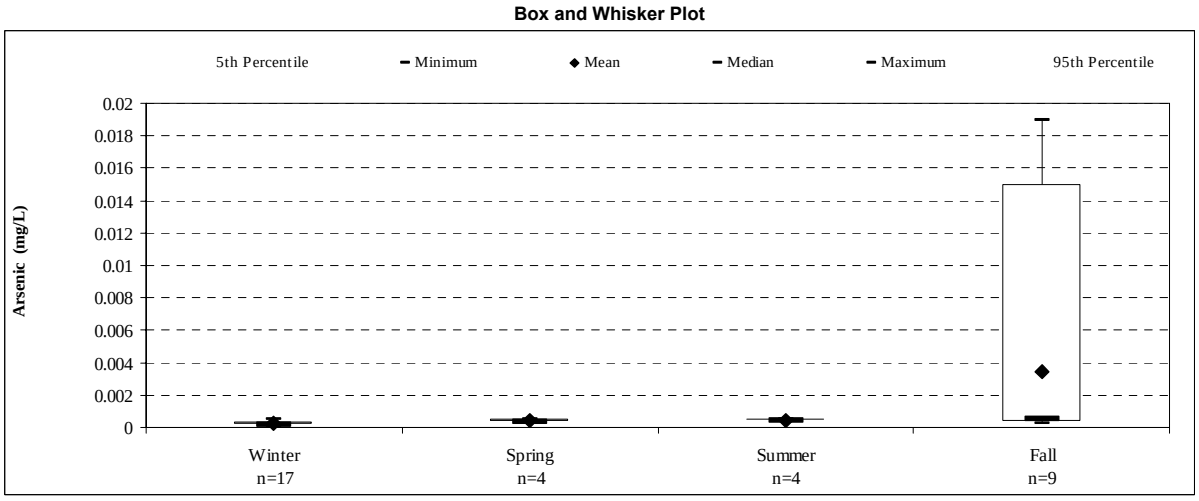


Figure G-1-4-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Lower Firebag River



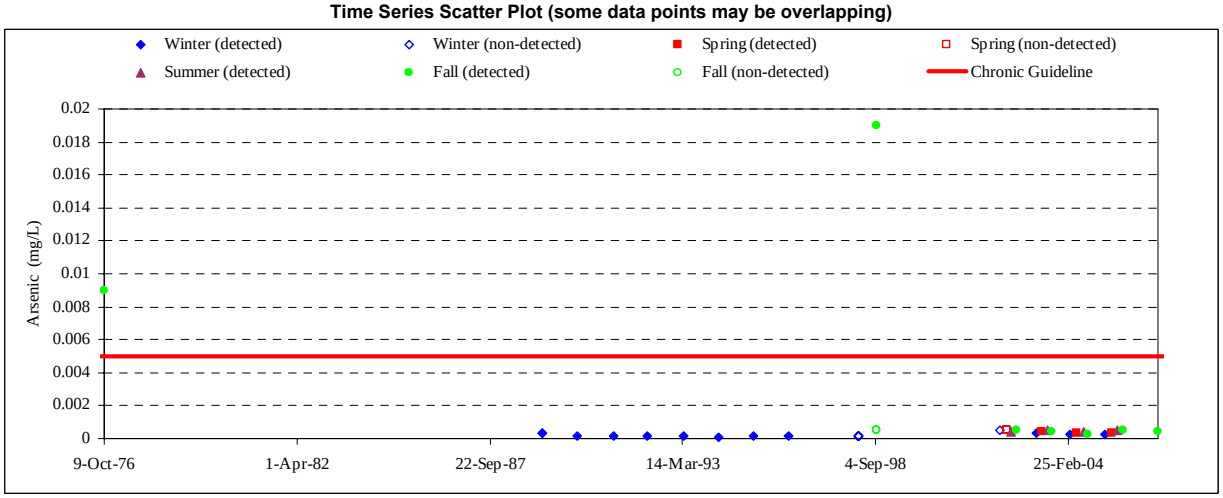
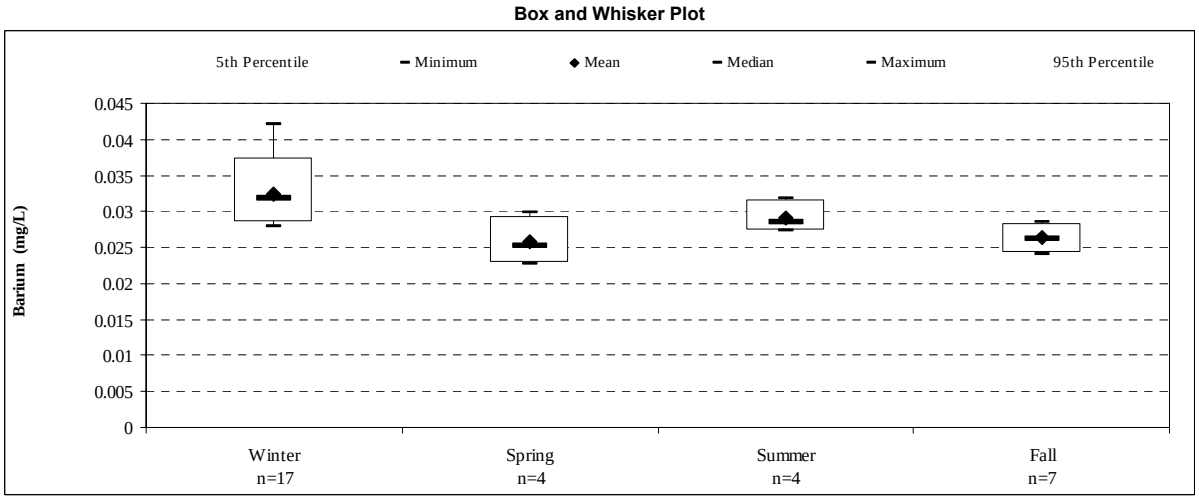


Figure G-1-4-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Lower Firebag River



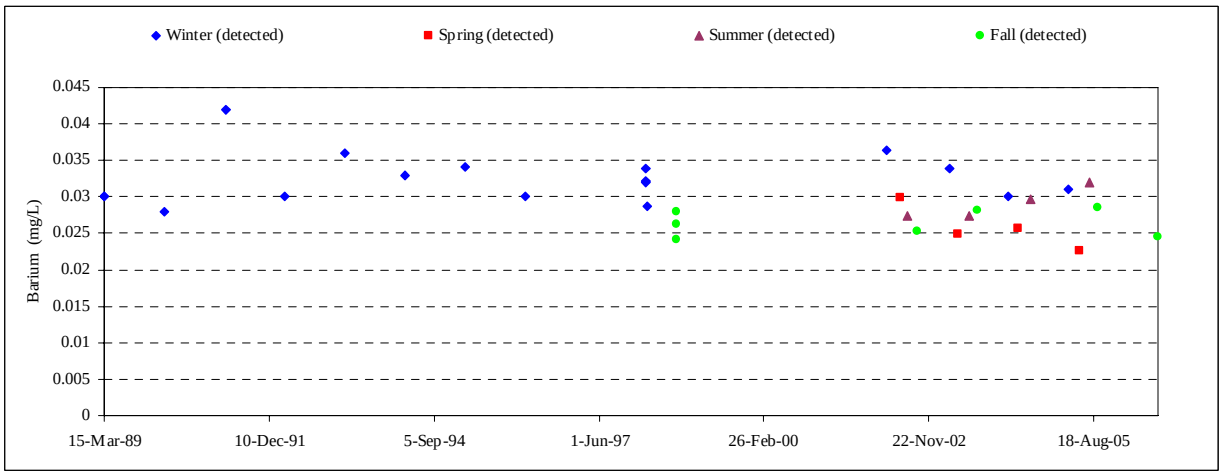


Figure G-1-4-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Lower Firebag River

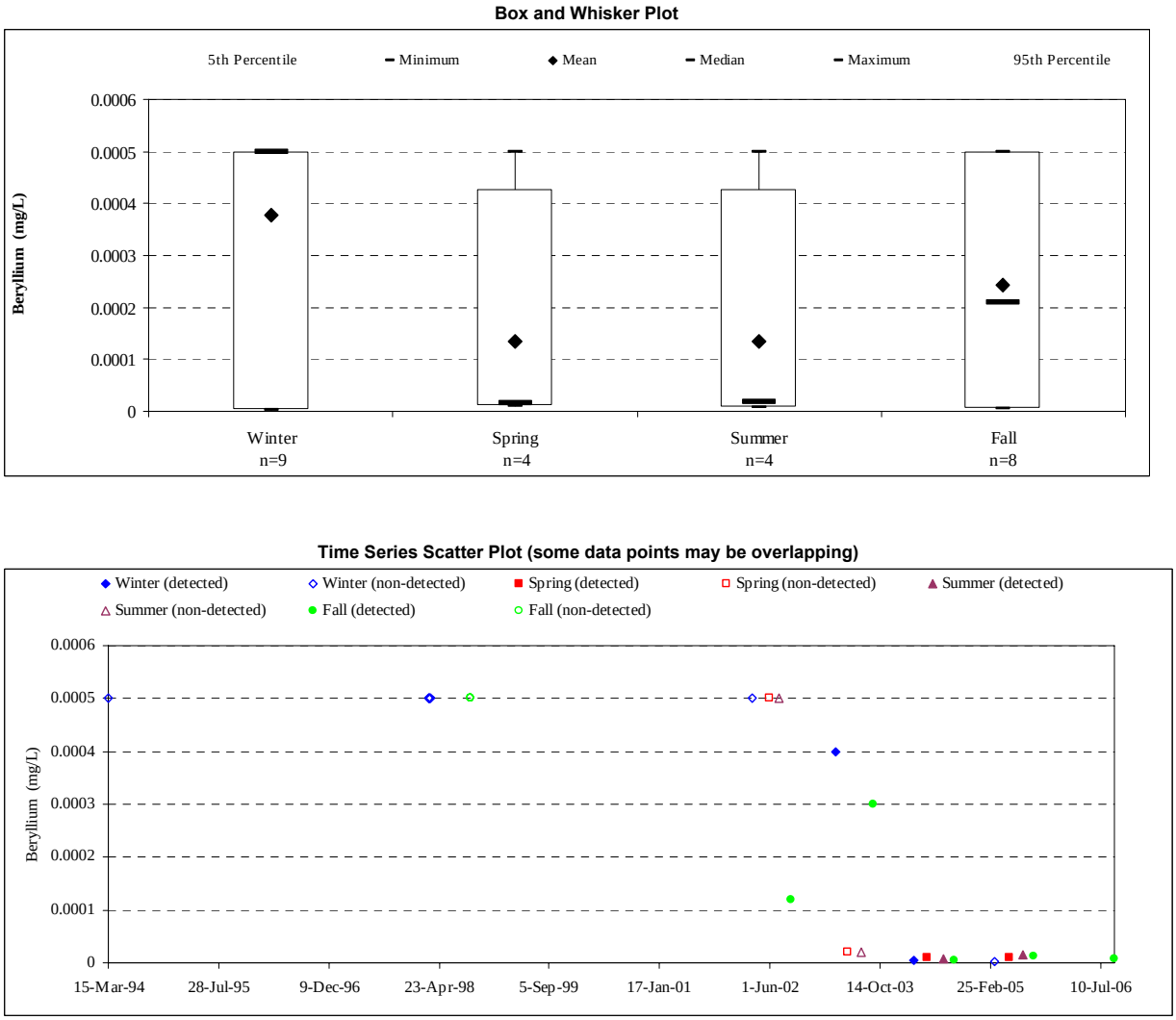
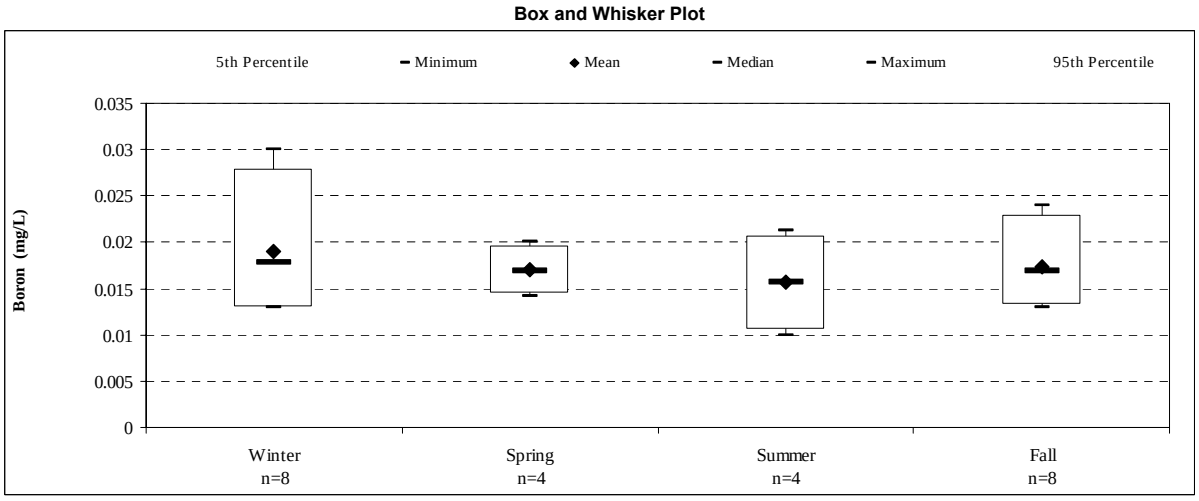


Figure G-1-4-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Lower Firebag River



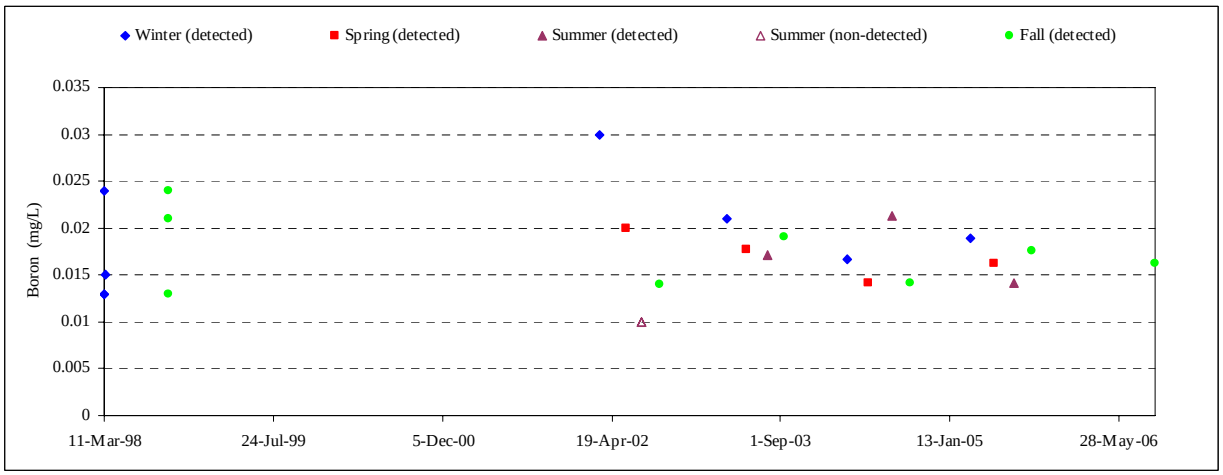


Figure G-1-4-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Lower Firebag River

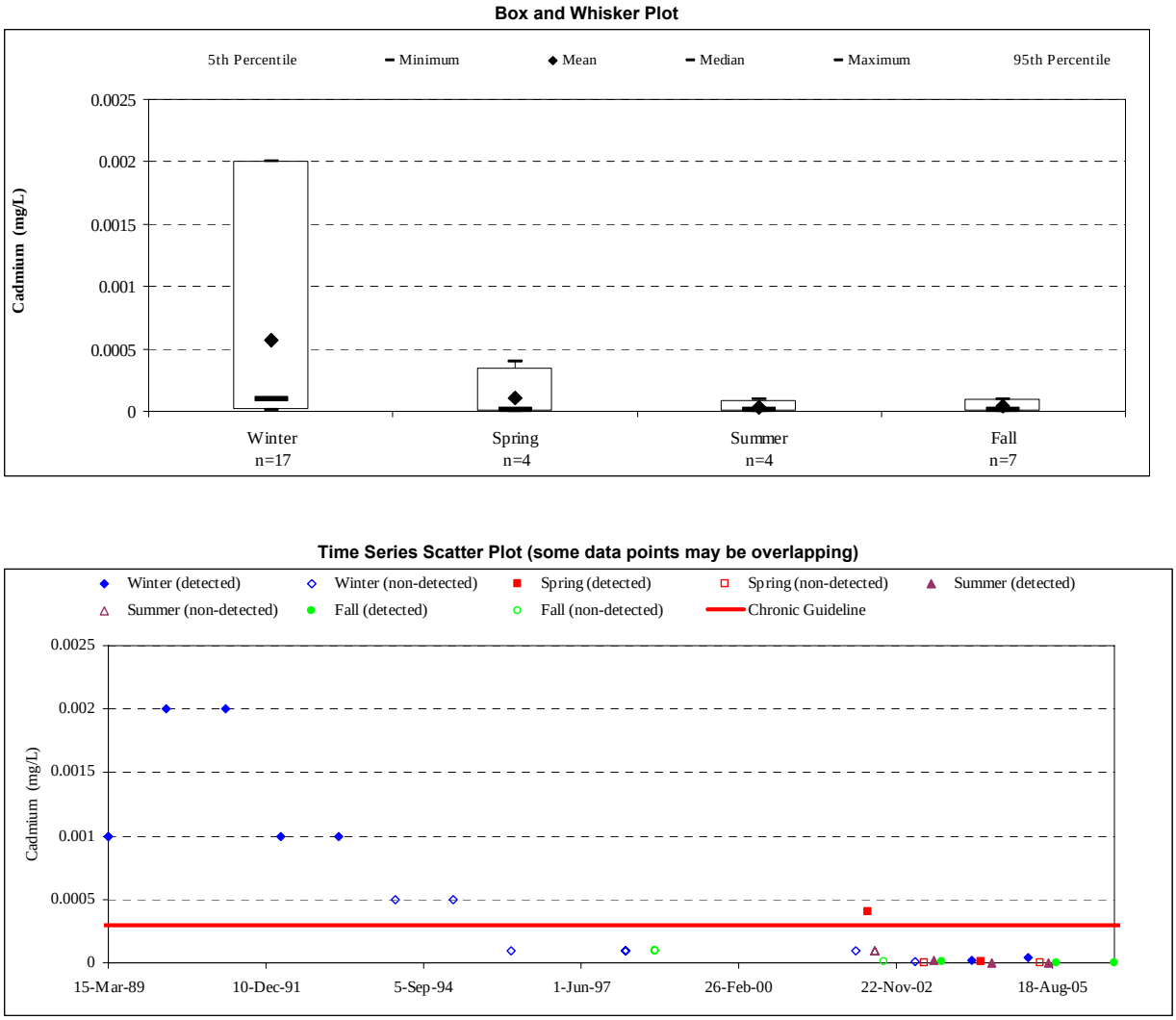
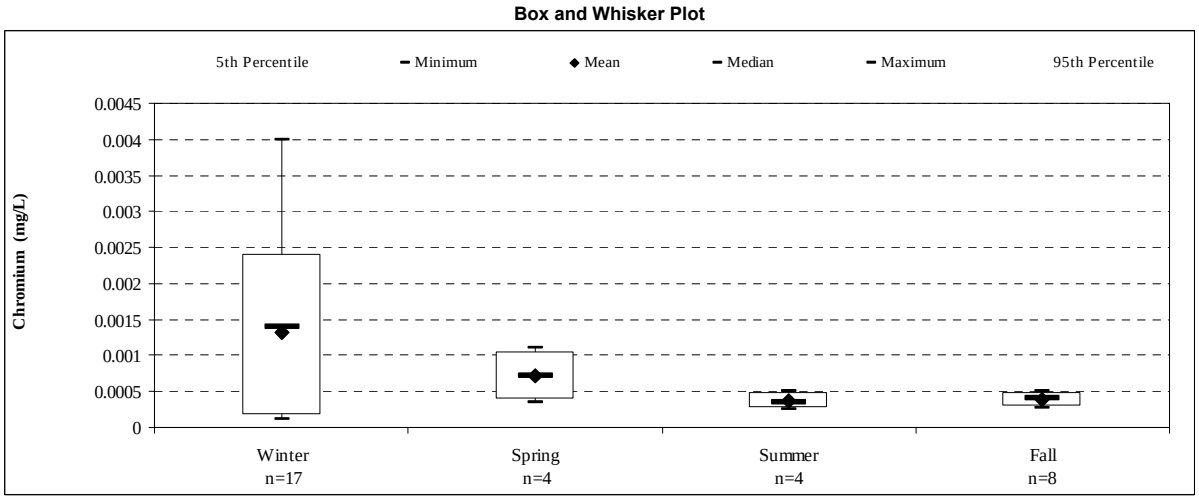


Figure G-1-4-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Lower Firebag River



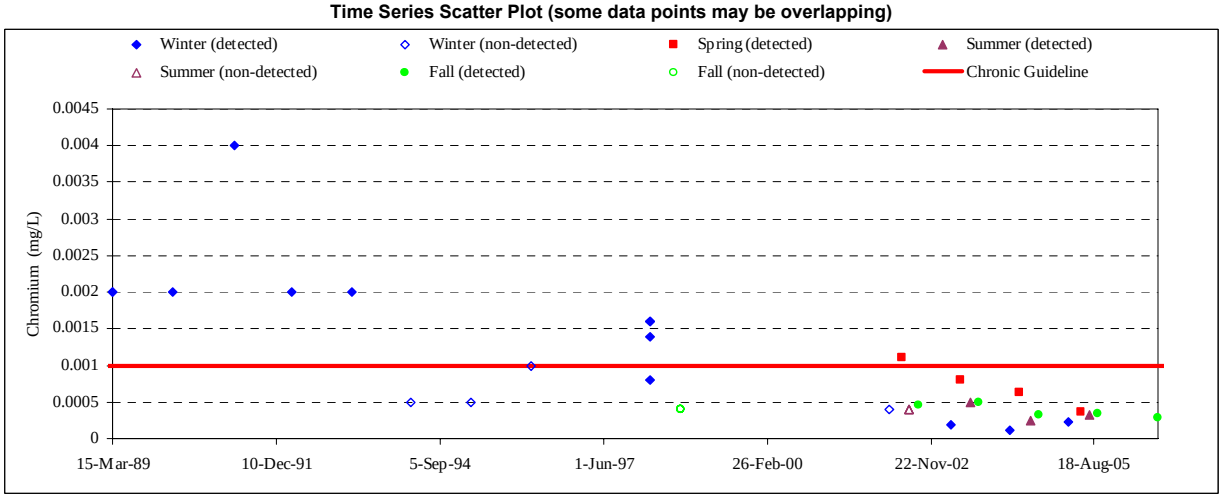


Figure G-1-4-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Lower Firebag River

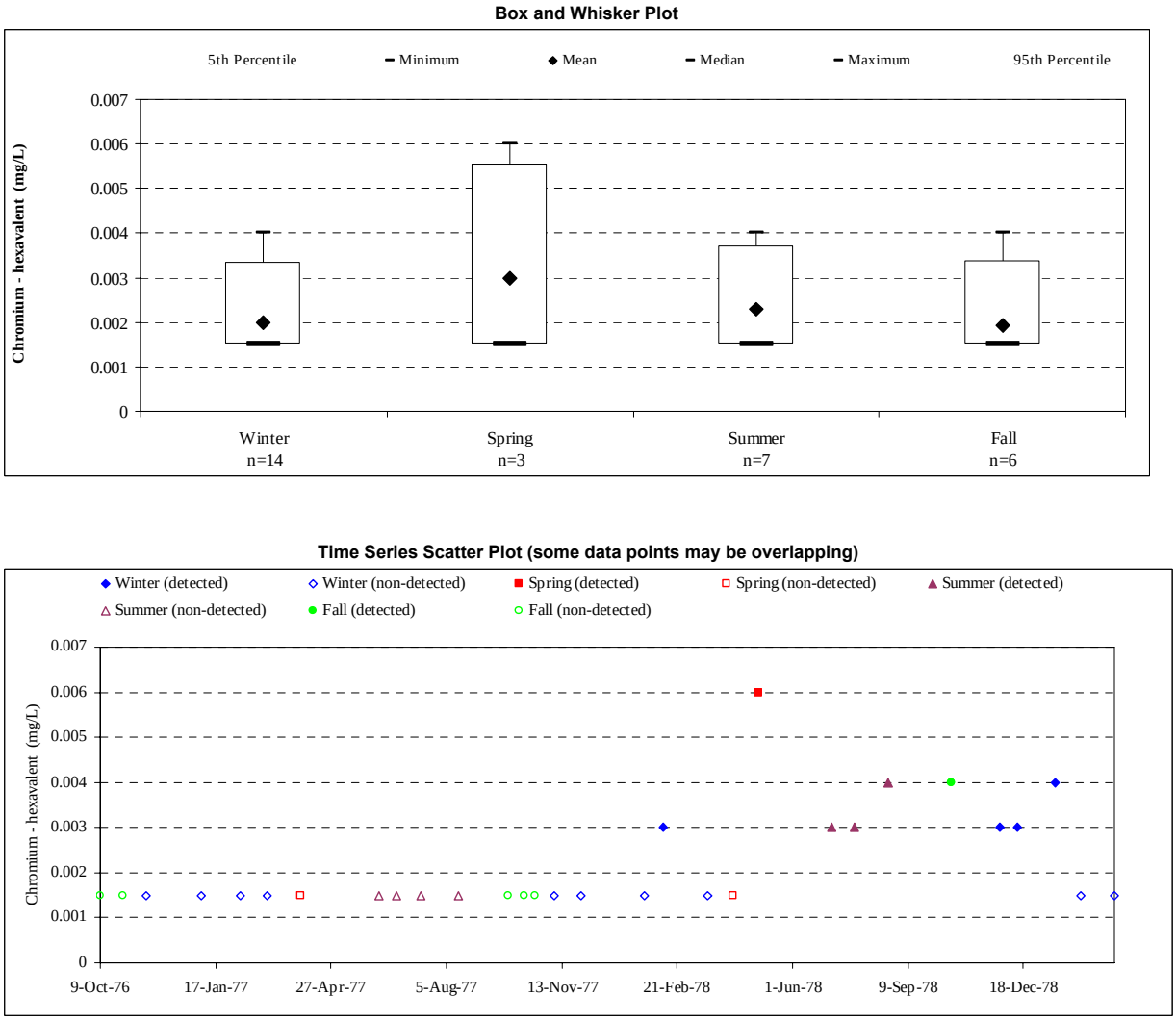
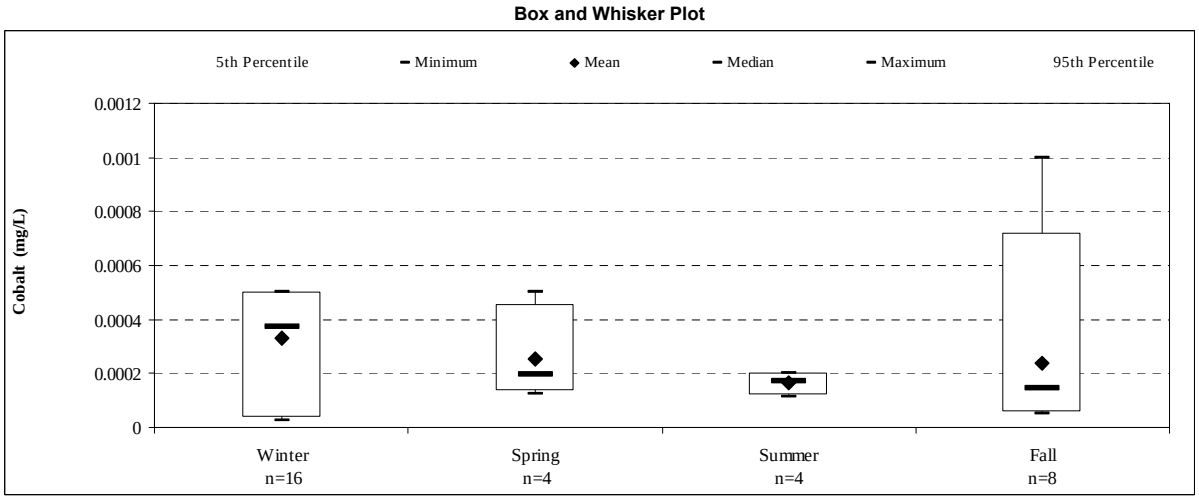


Figure G-1-4-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Lower Firebag River



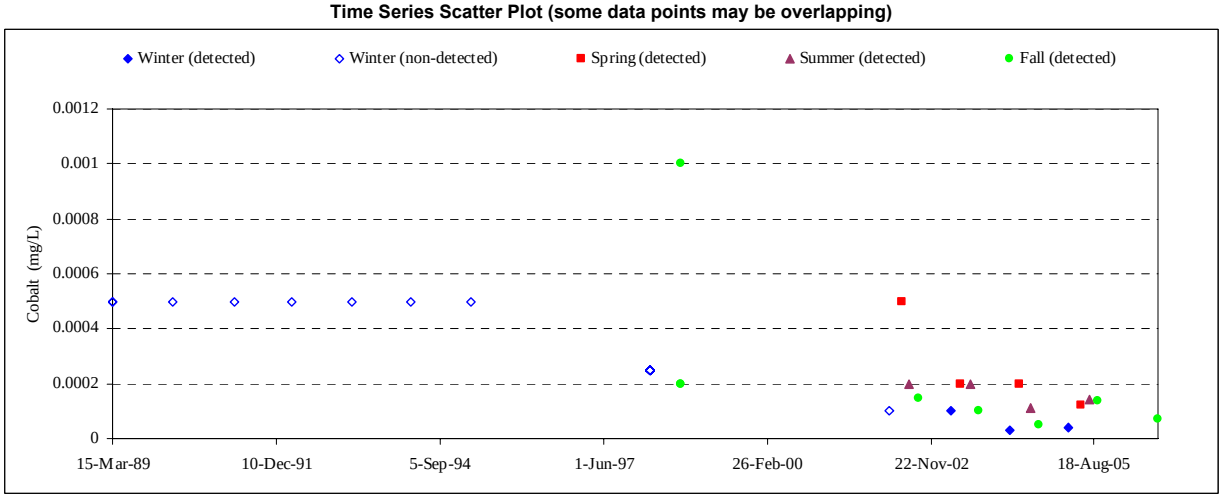
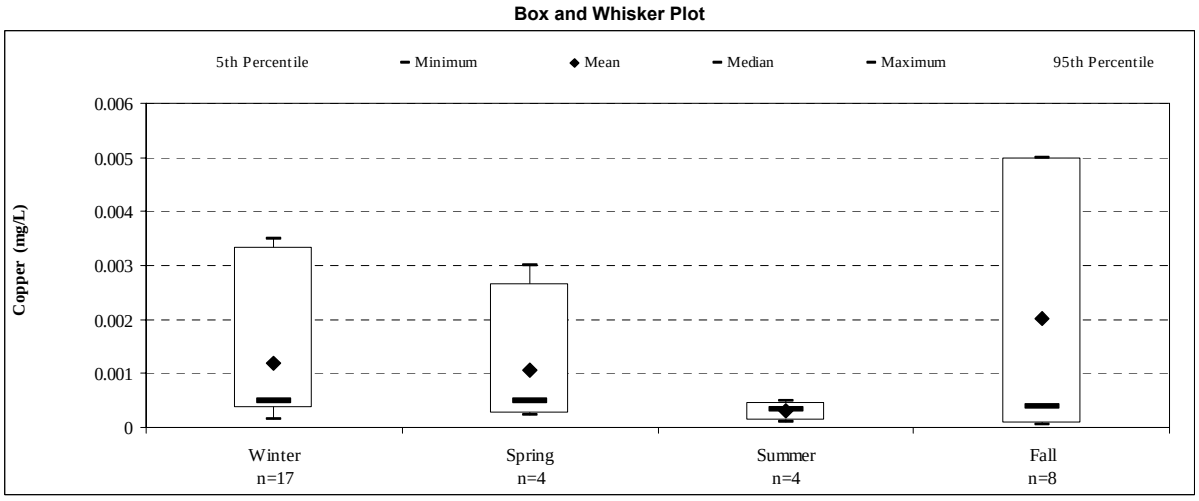


Figure G-1-4-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Lower Firebag River



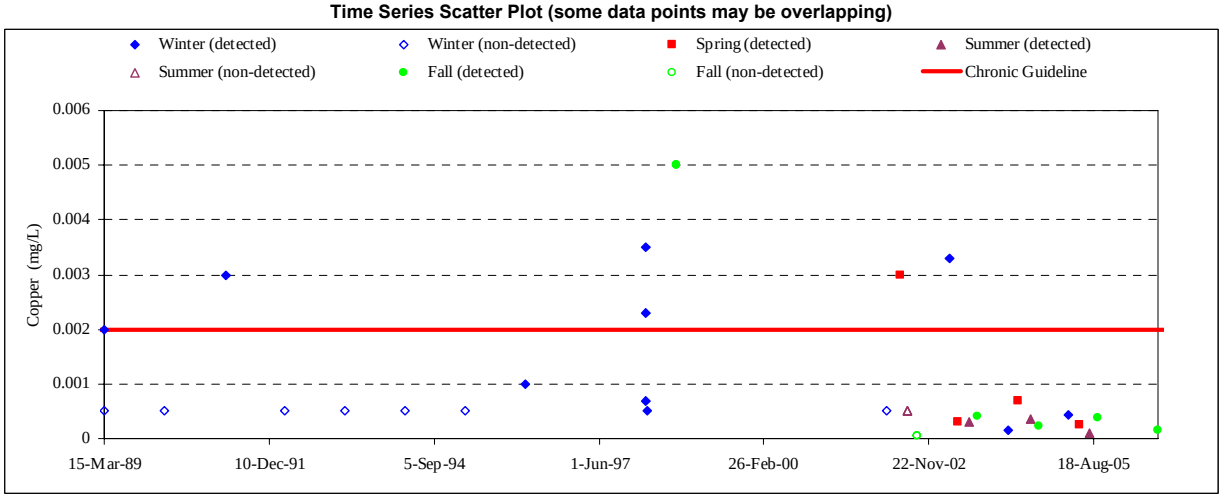
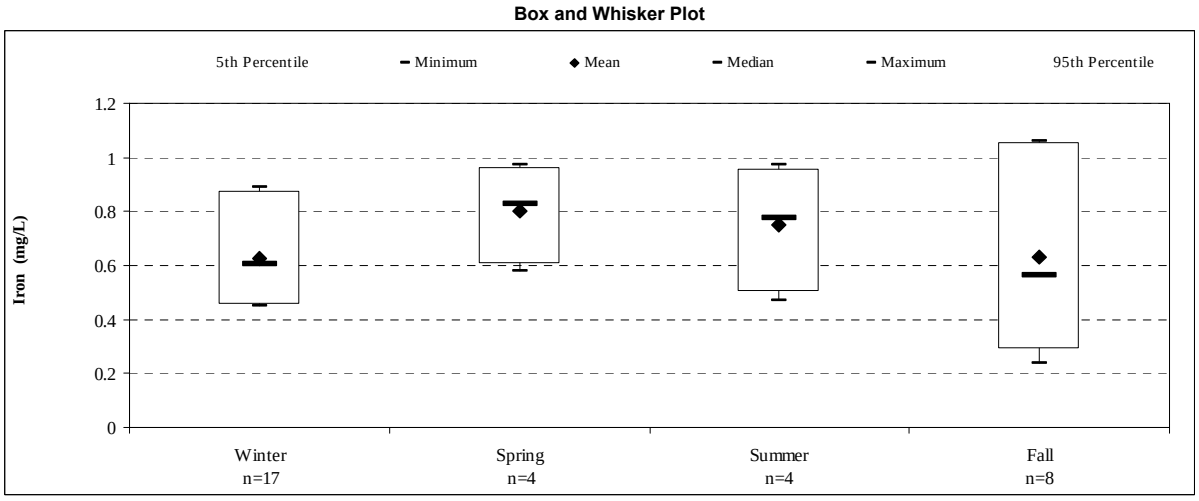


Figure G-1-4-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Lower Firebag River



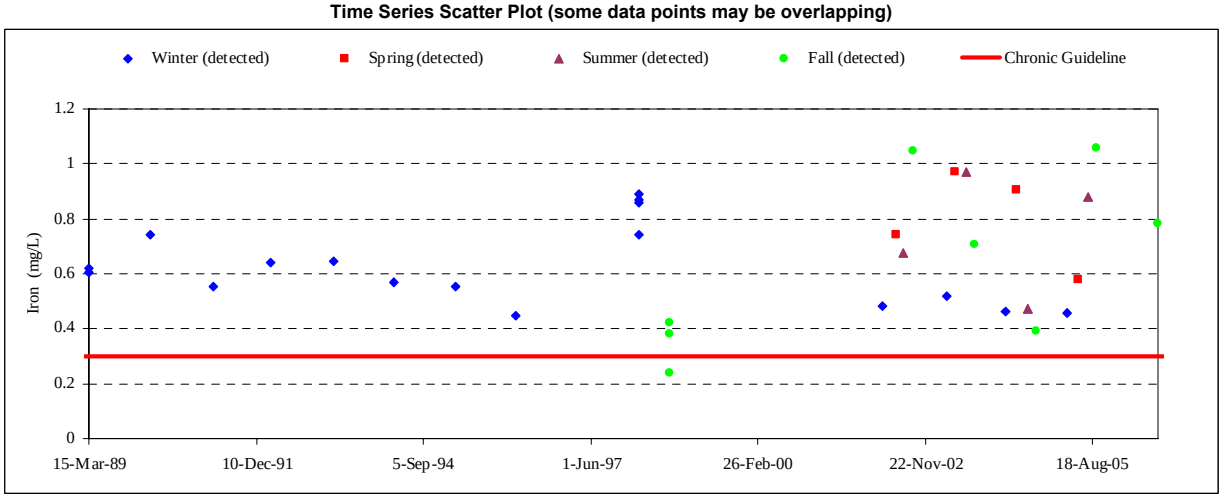
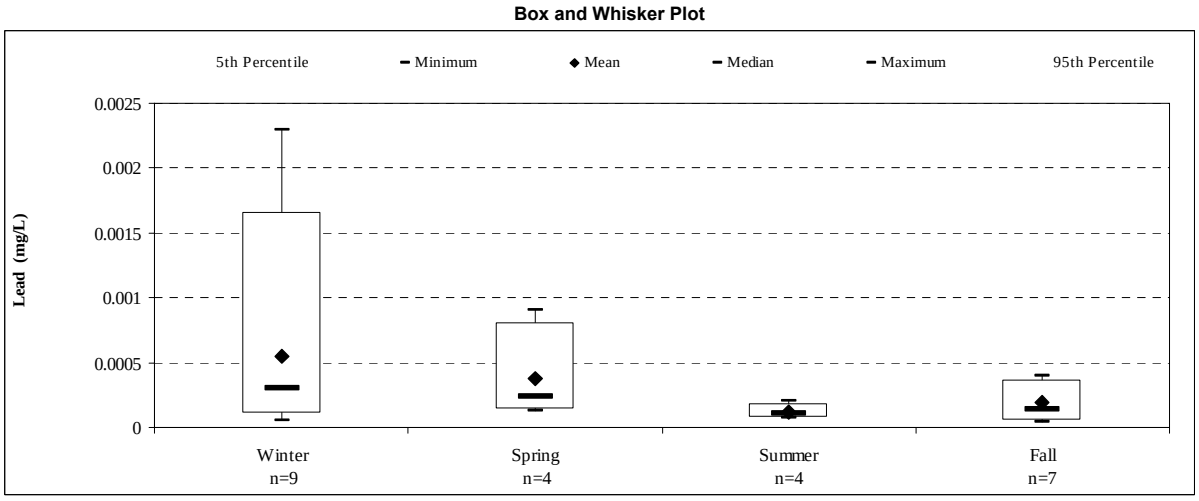


Figure G-1-4-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Lower Firebag River



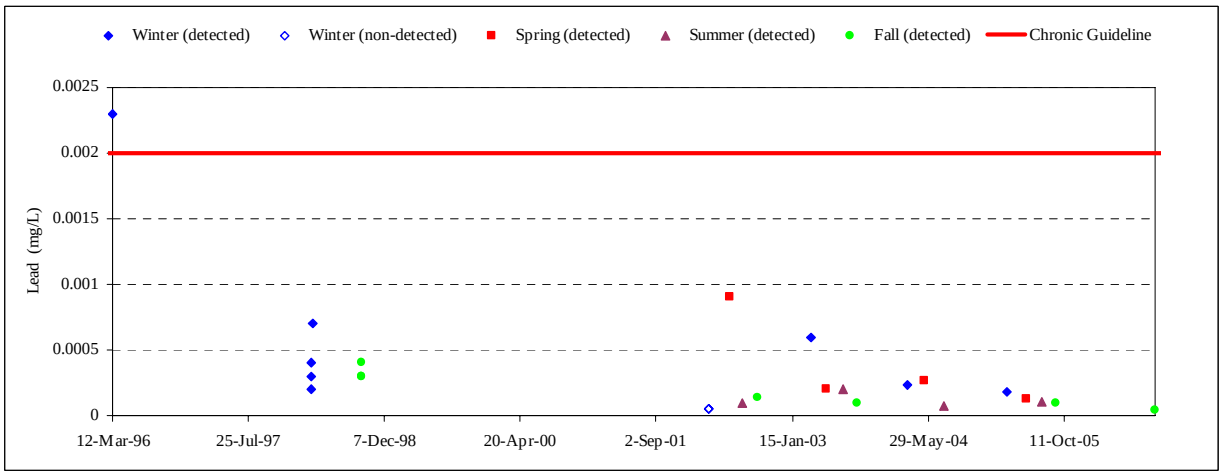
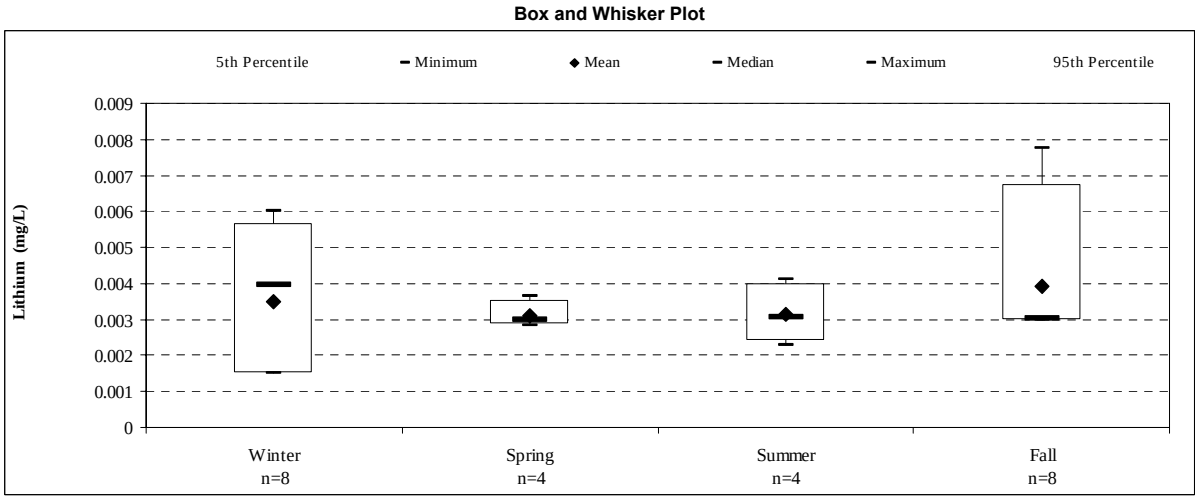


Figure G-1-4-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Lower Firebag River



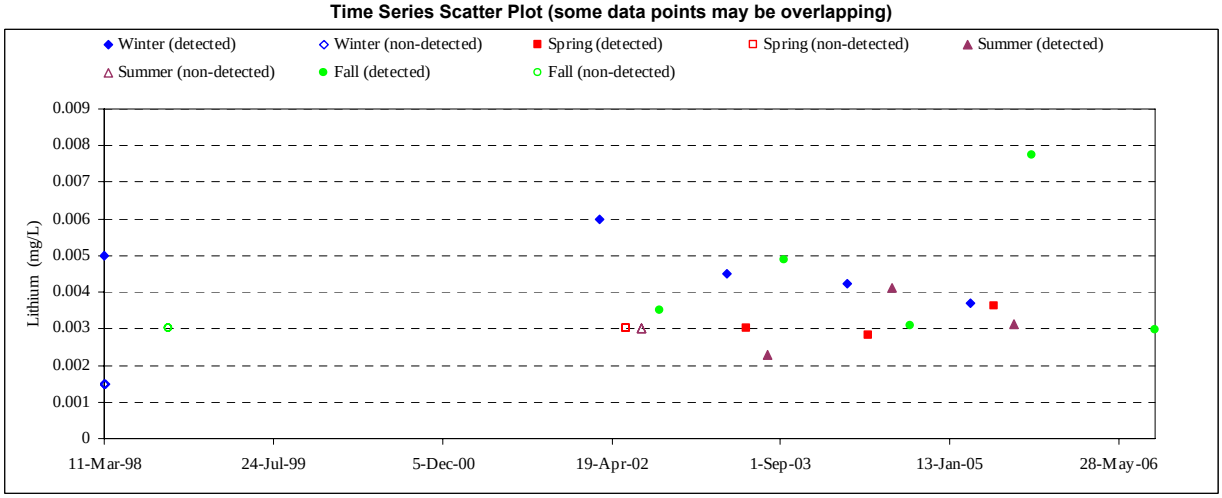
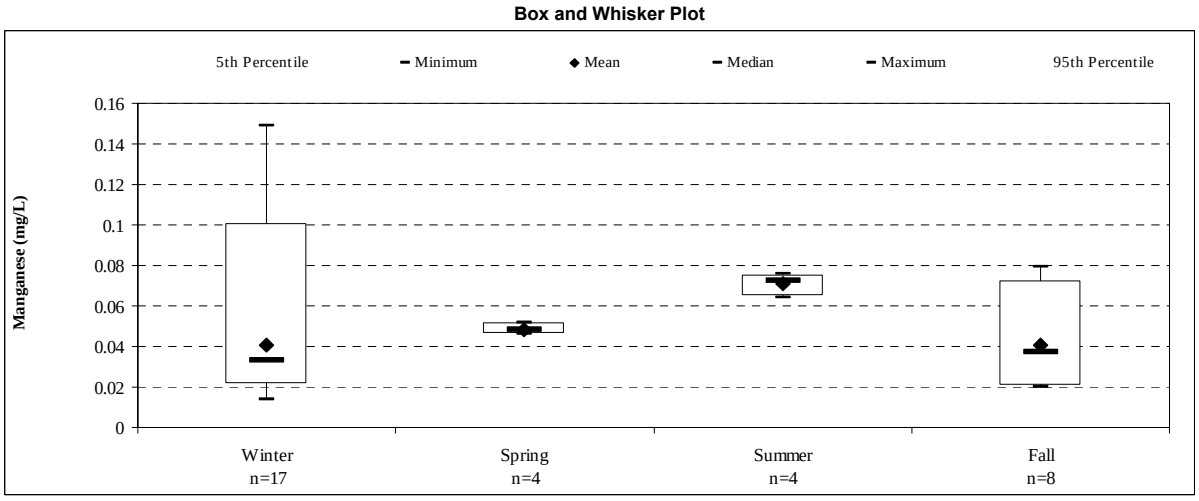


Figure G-1-4-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Lower Firebag River



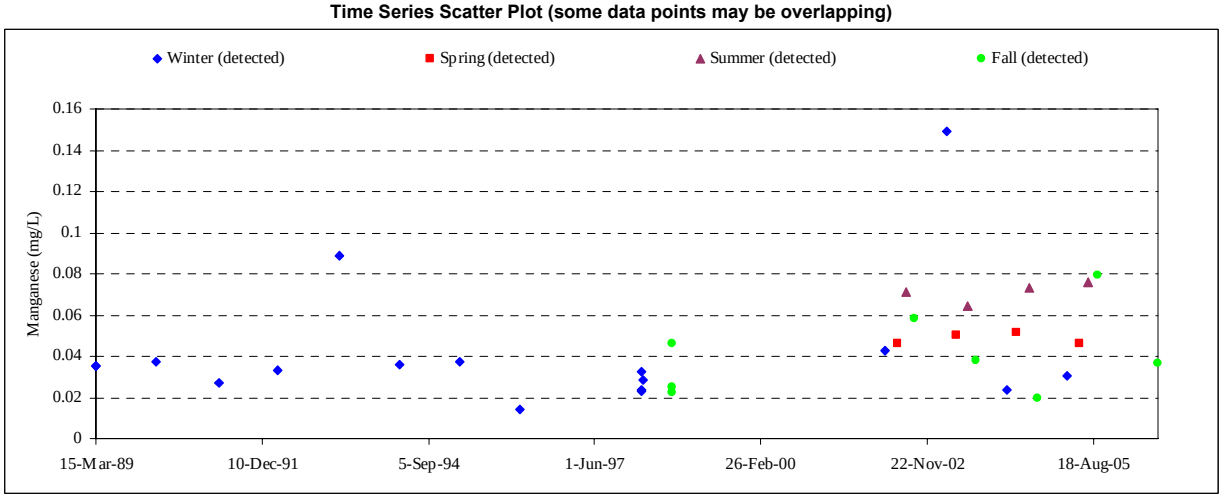
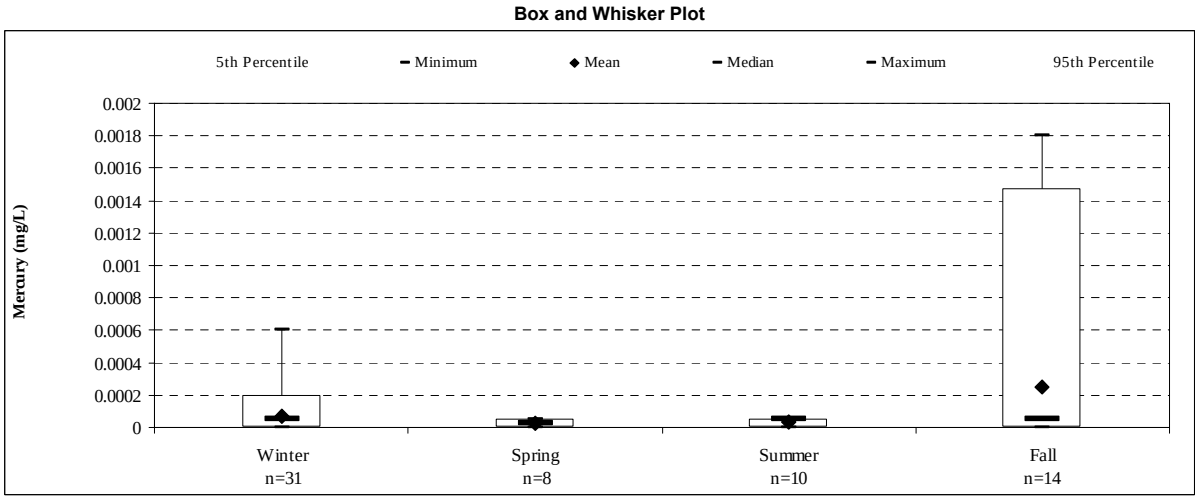


Figure G-1-4-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Lower Firebag River



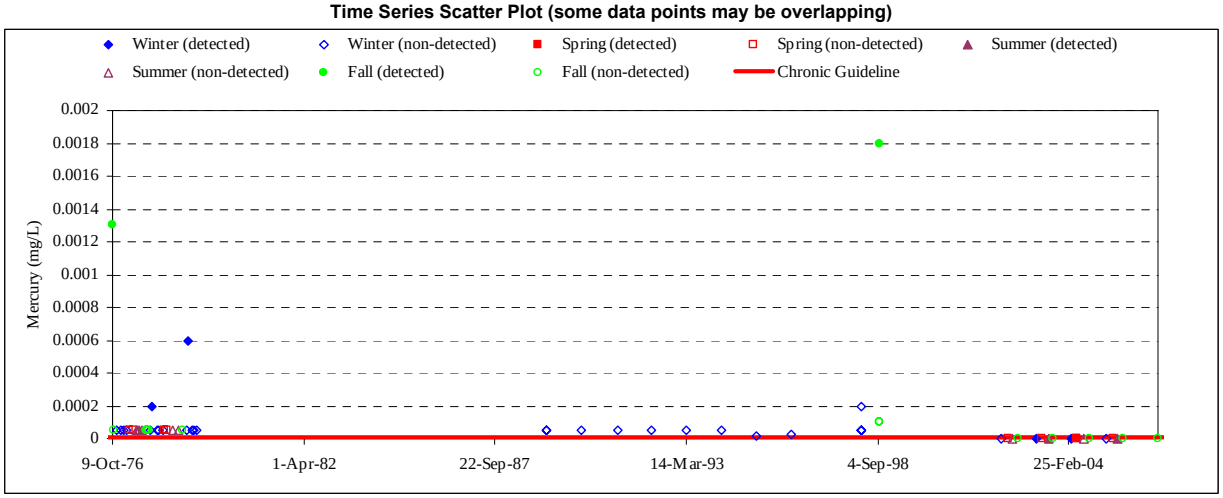
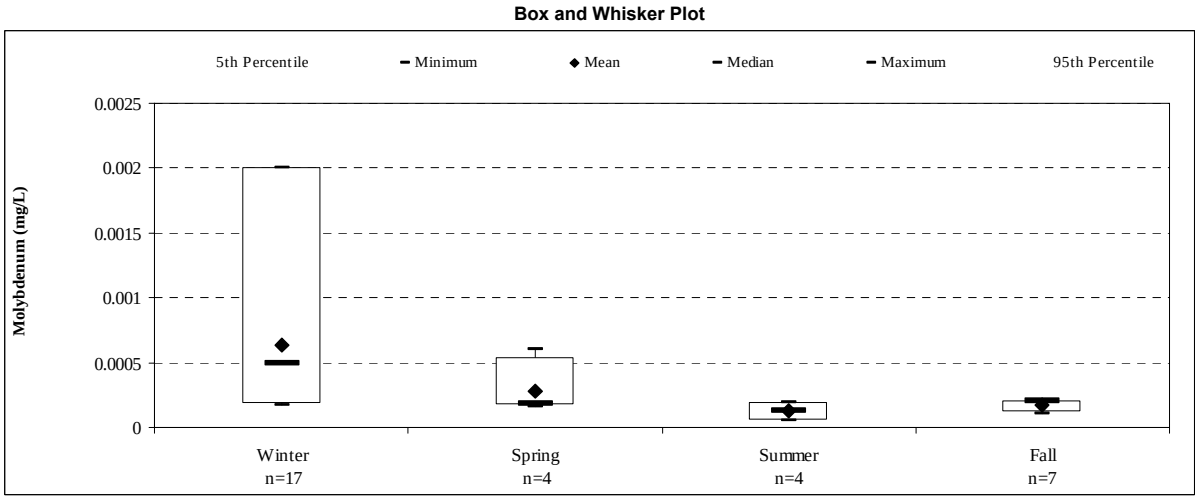


Figure G-1-4-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Lower Firebag River



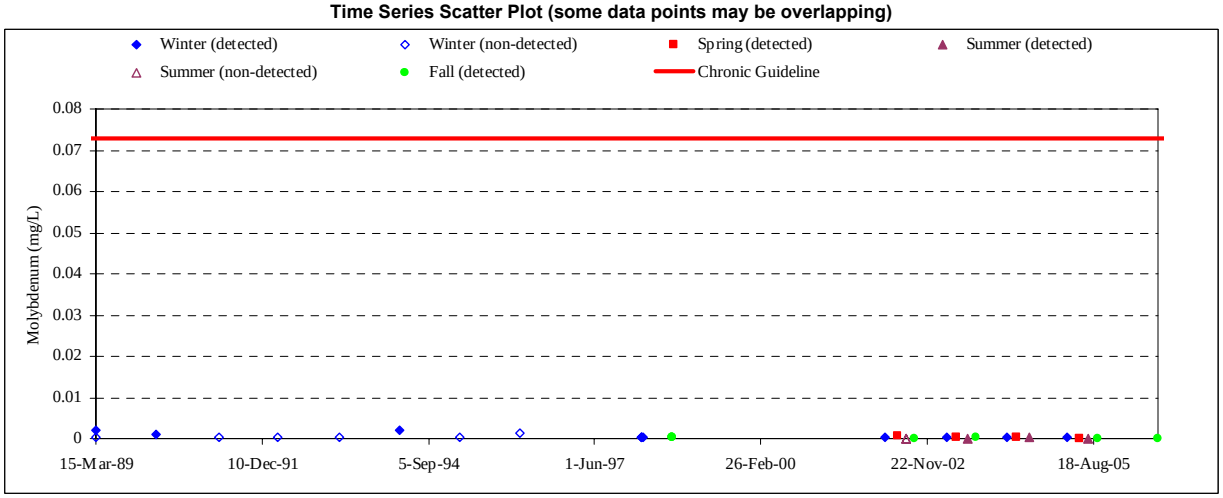
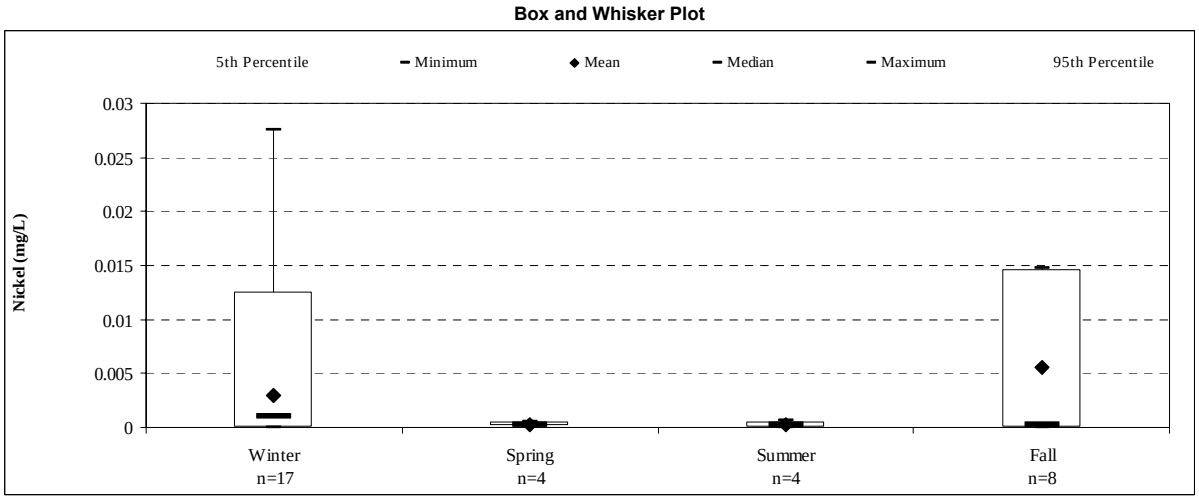


Figure G-1-4-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Lower Firebag River



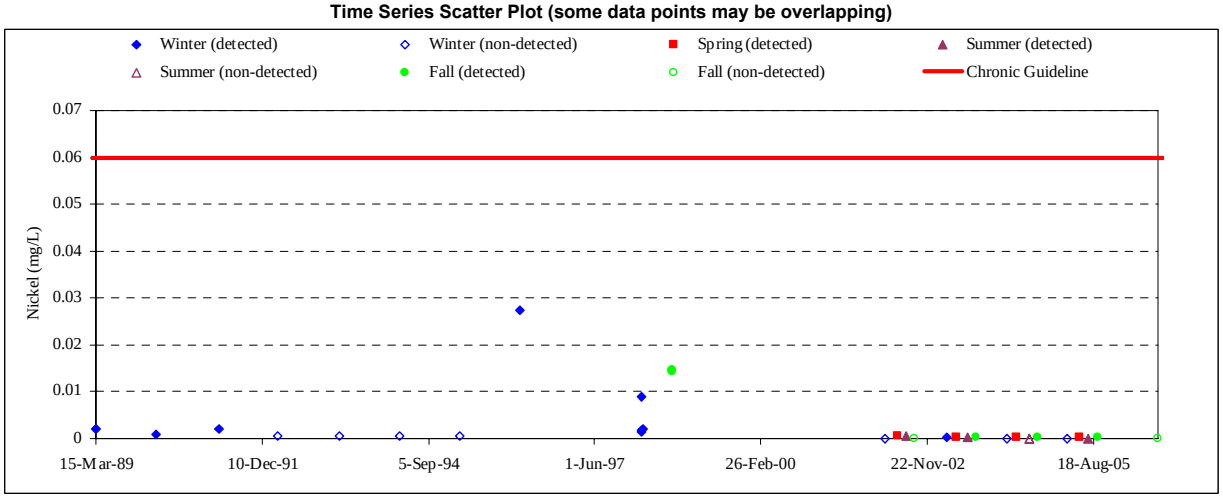
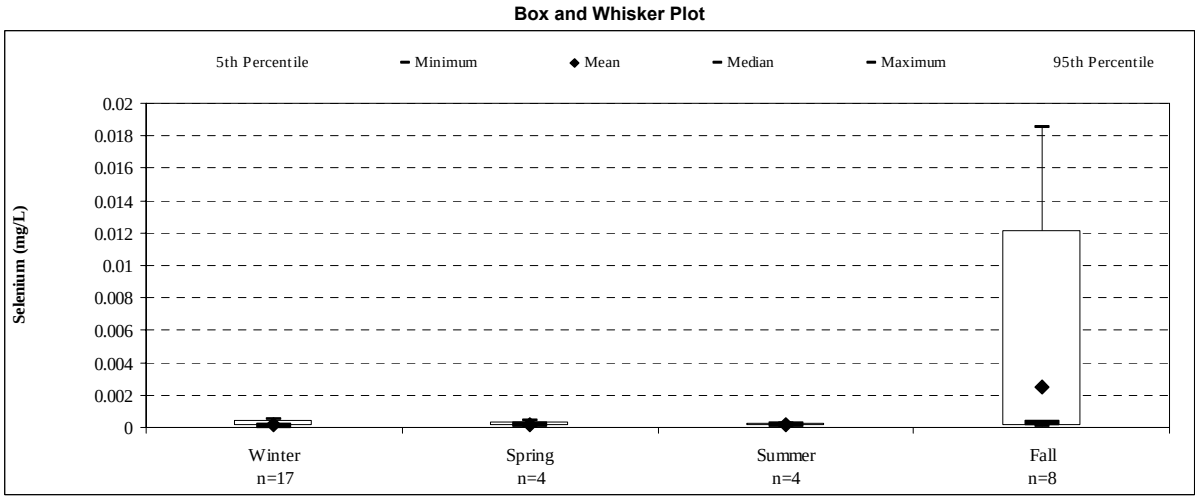


Figure G-1-4-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Lower Firebag River



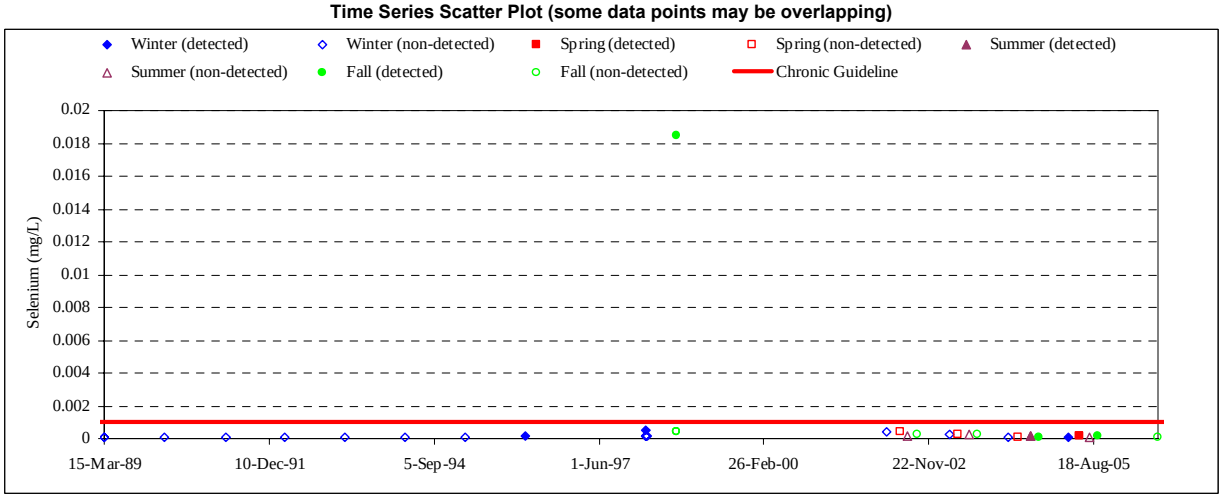
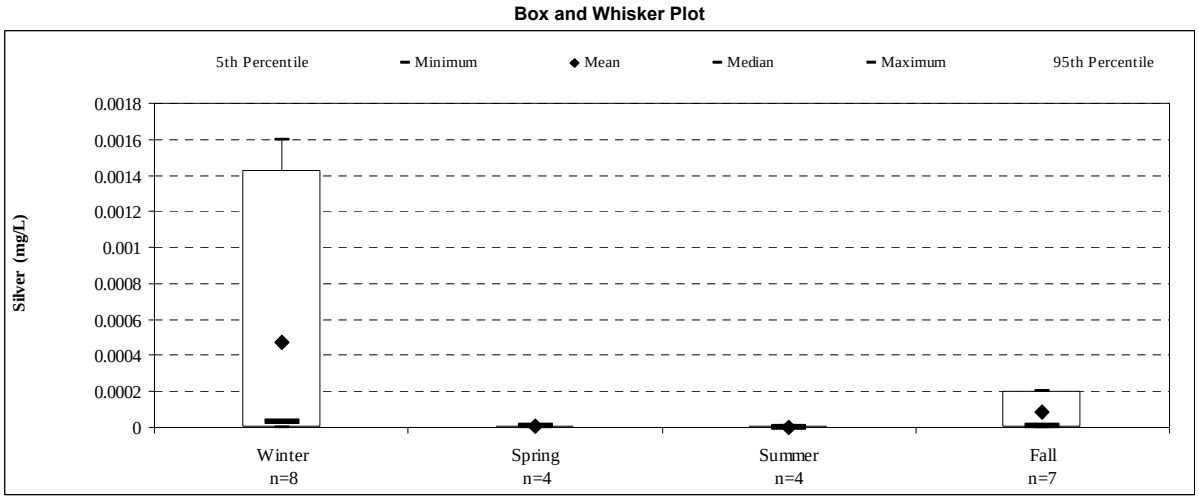


Figure G-1-4-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Lower Firebag River



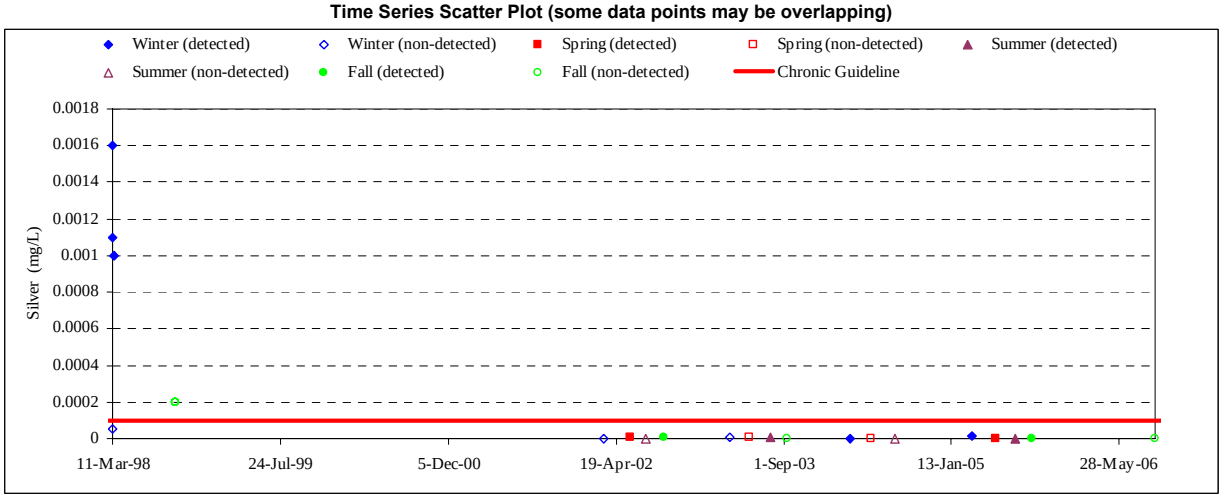
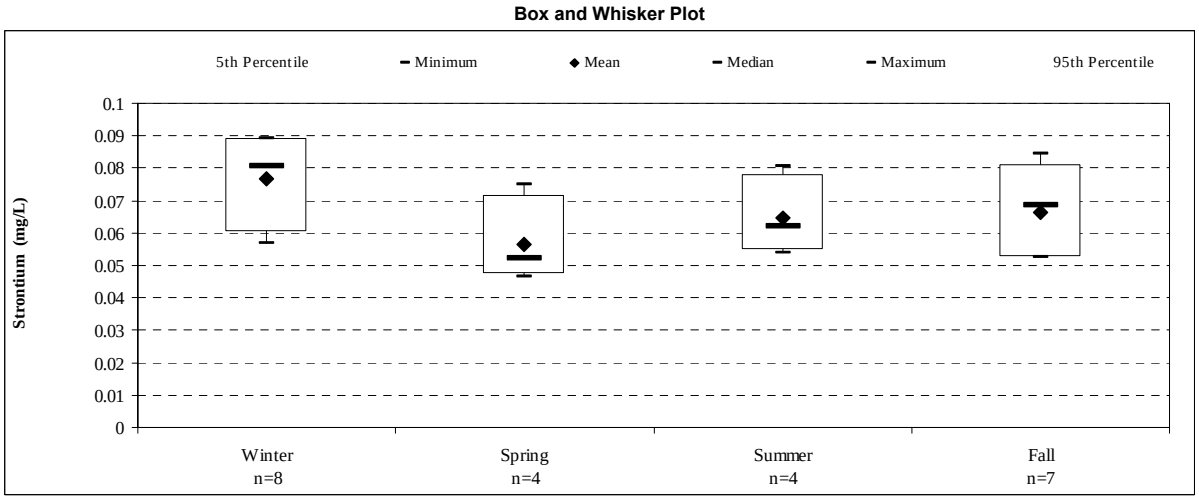


Figure G-1-4-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Lower Firebag River



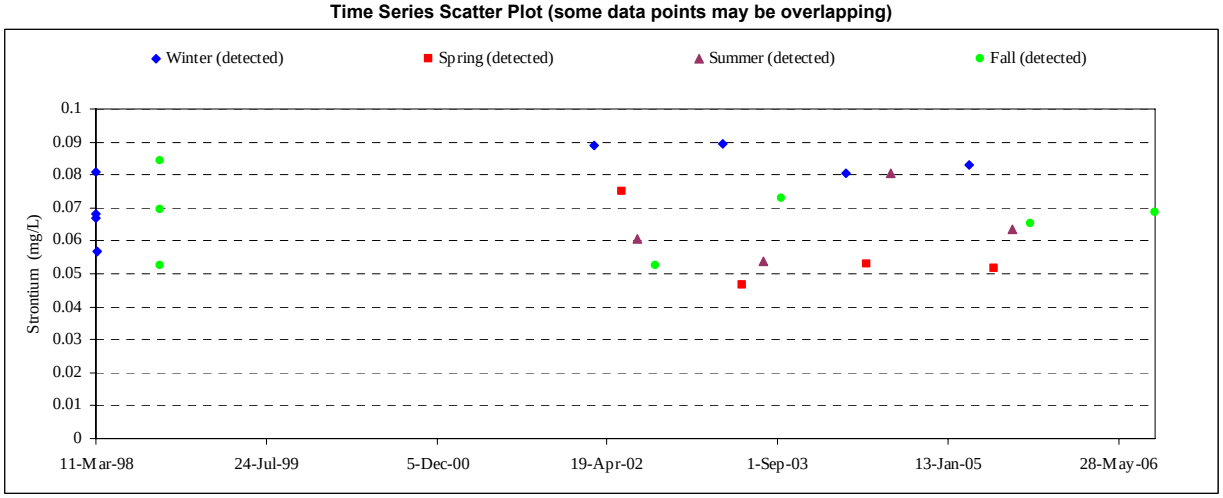
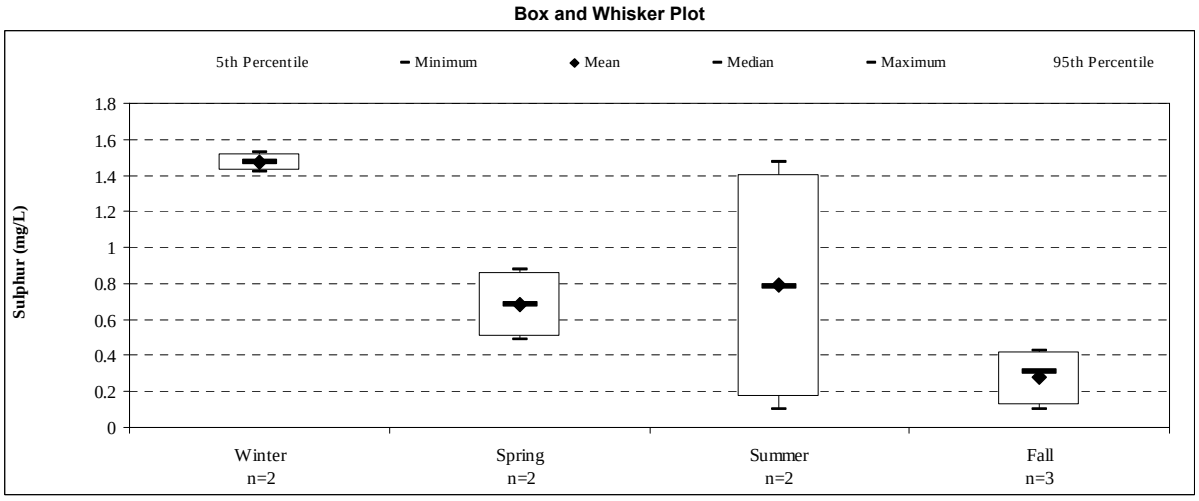


Figure G-1-4-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Lower Firebag River



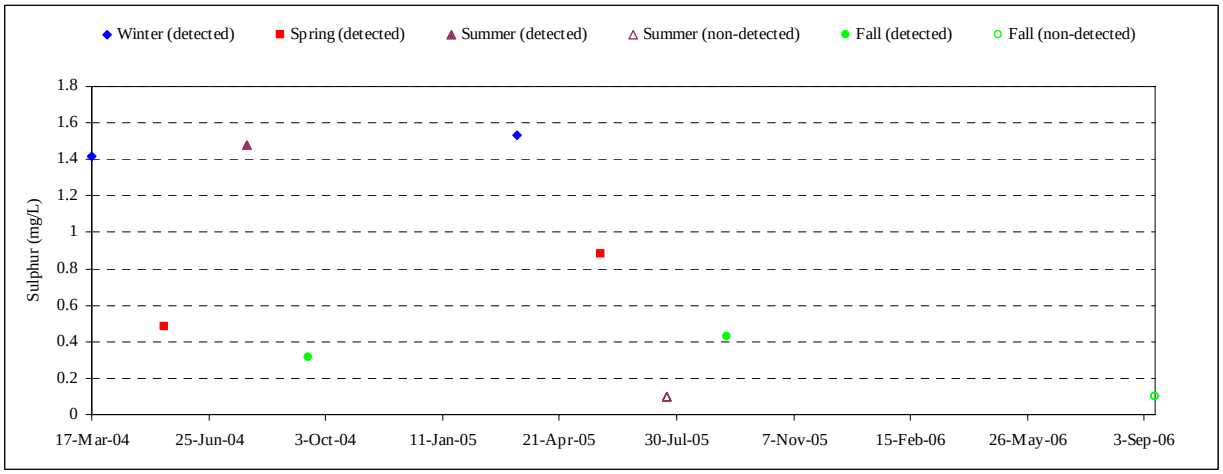
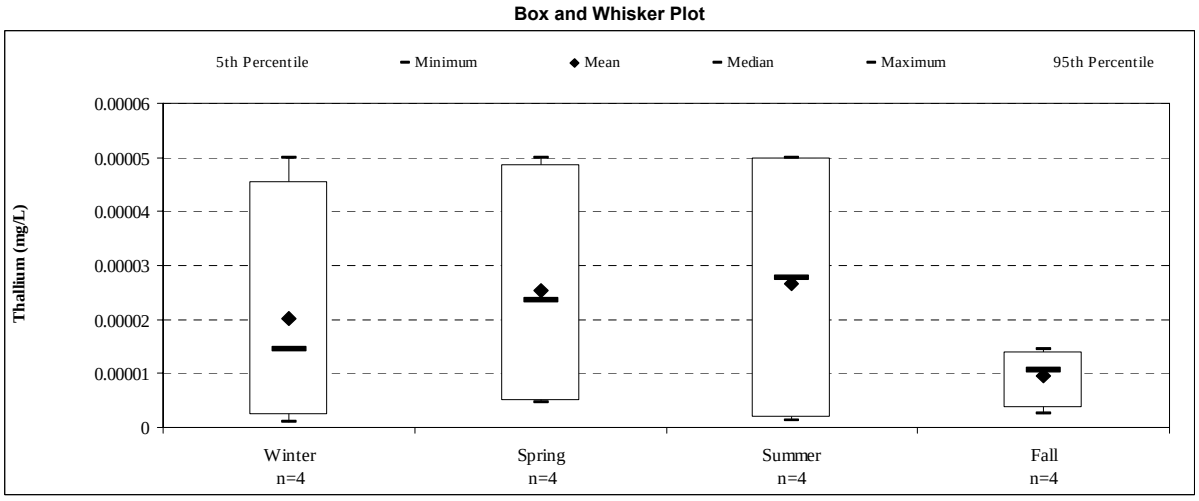


Figure G-1-4-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Lower Firebag River



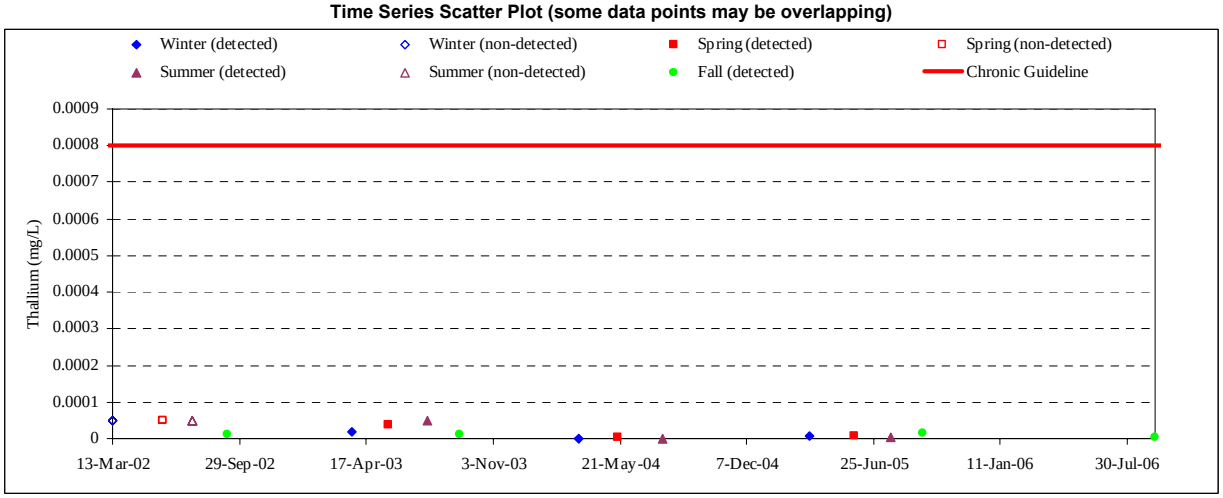
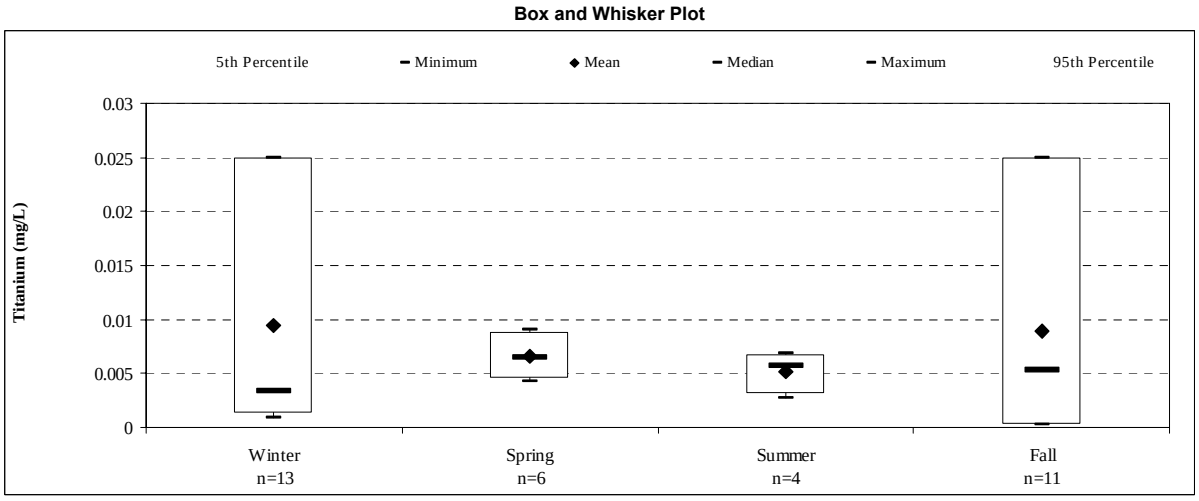


Figure G-1-4-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Lower Firebag River



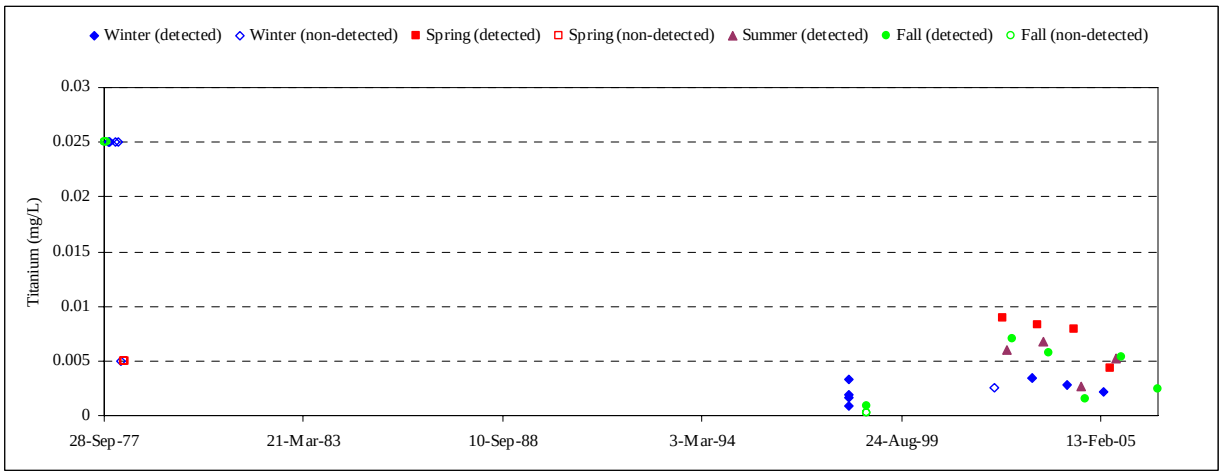
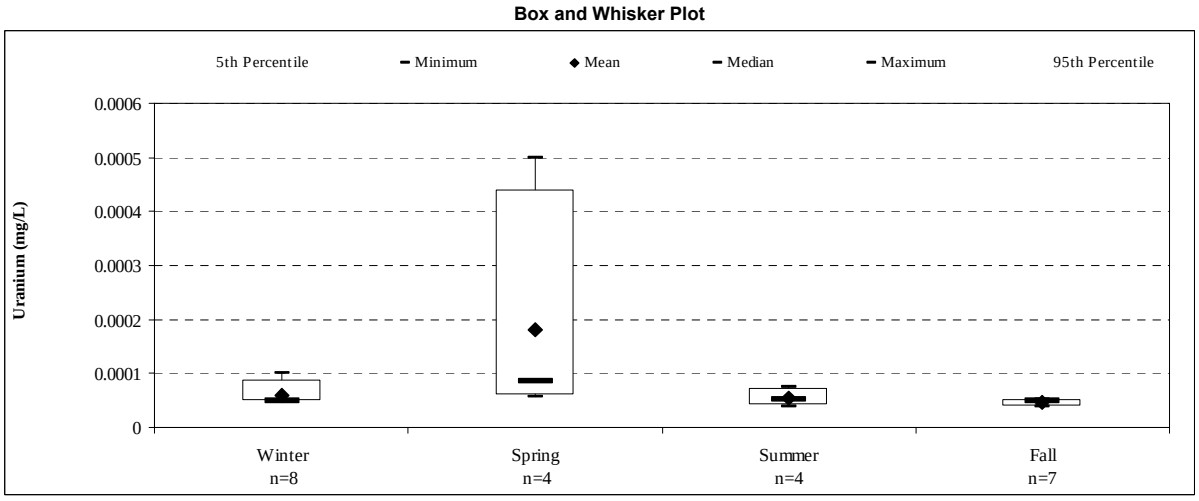


Figure G-1-4-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Lower Firebag River



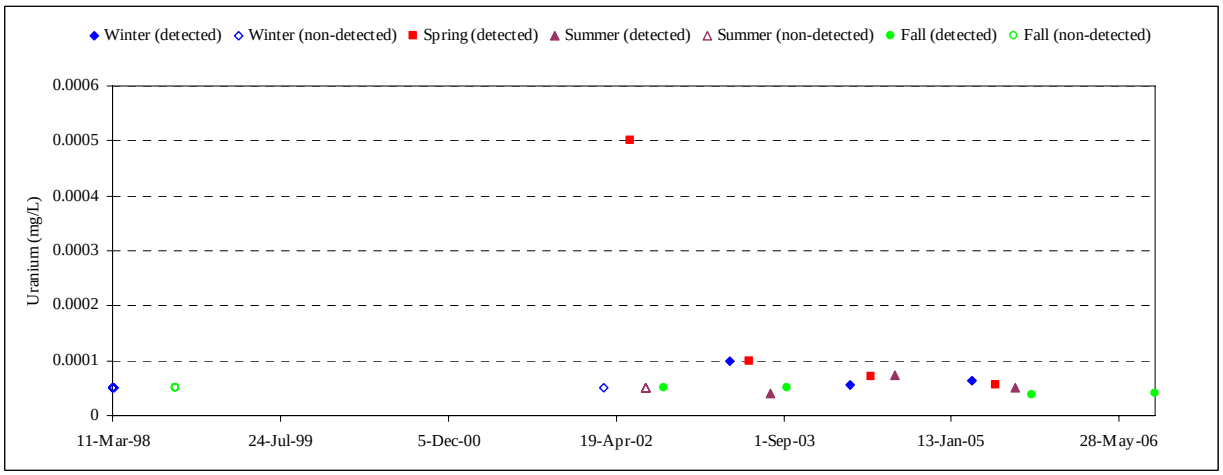
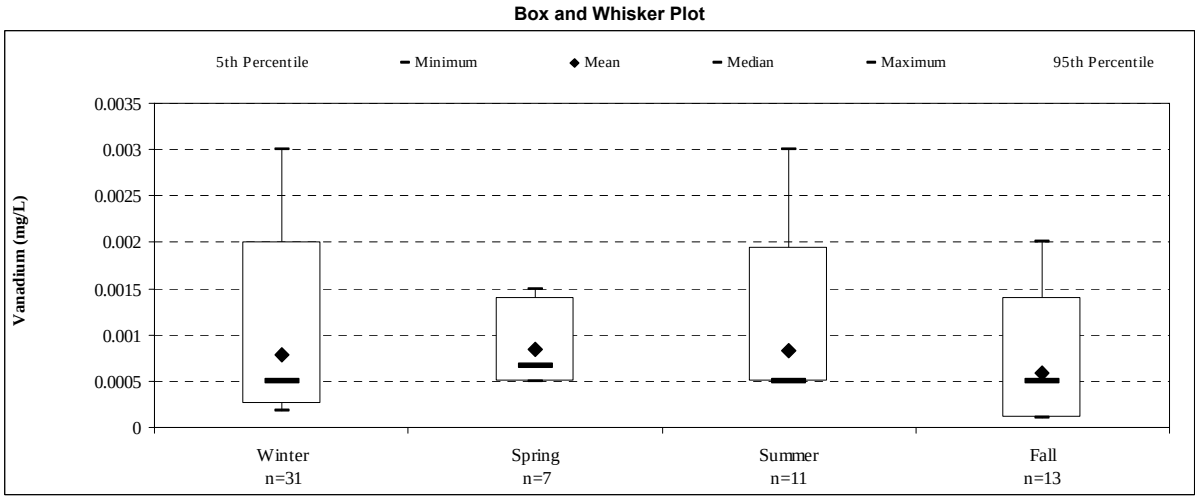


Figure G-1-4-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Lower Firebag River



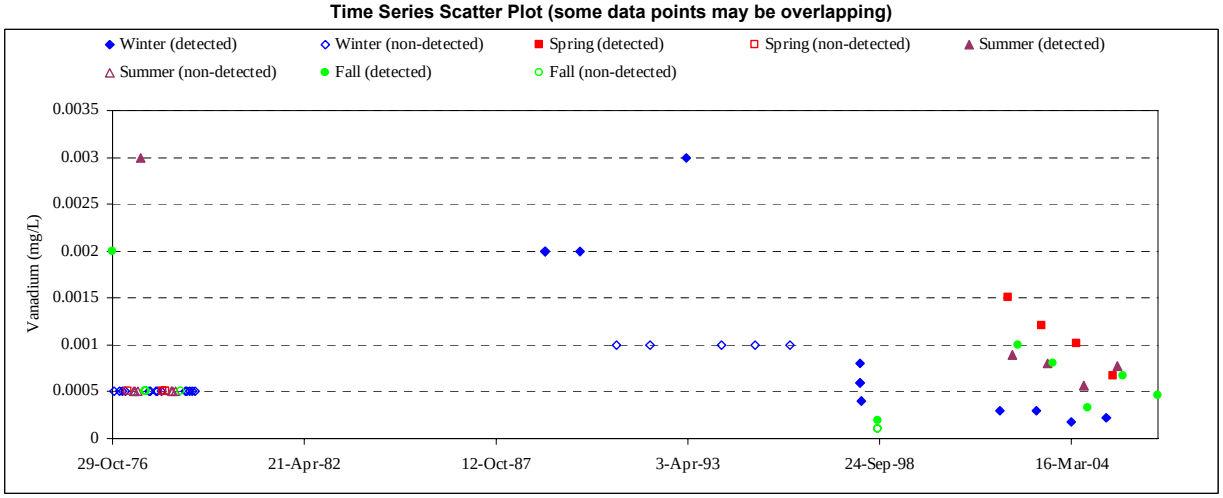
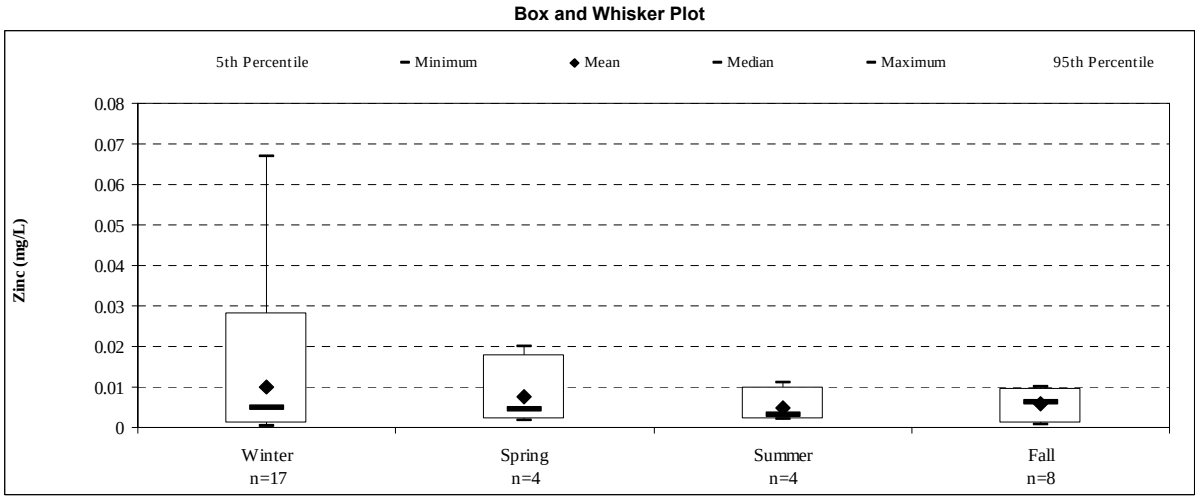


Figure G-1-4-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Lower Firebag River



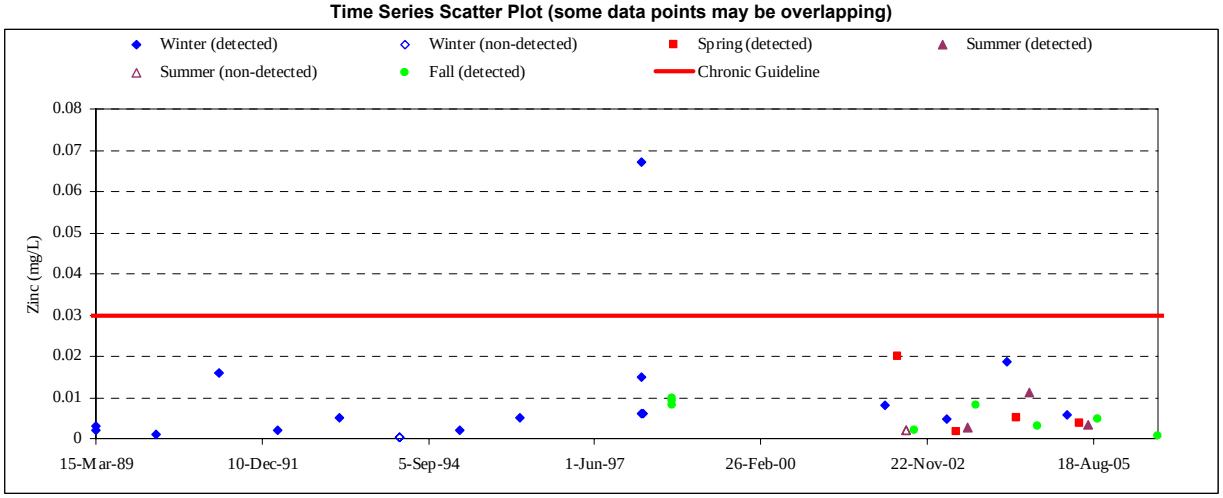
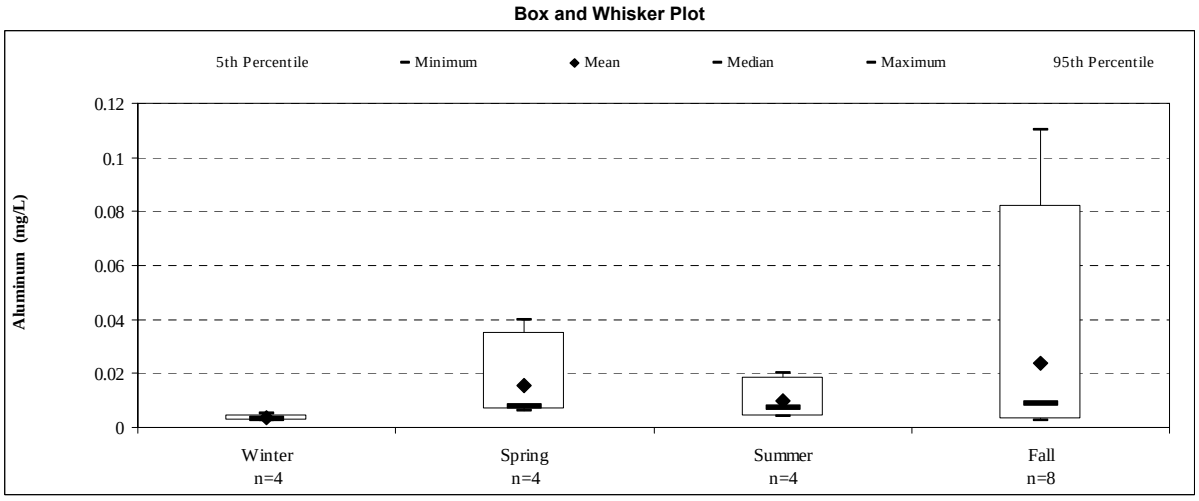


Figure G-1-4-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Lower Firebag River



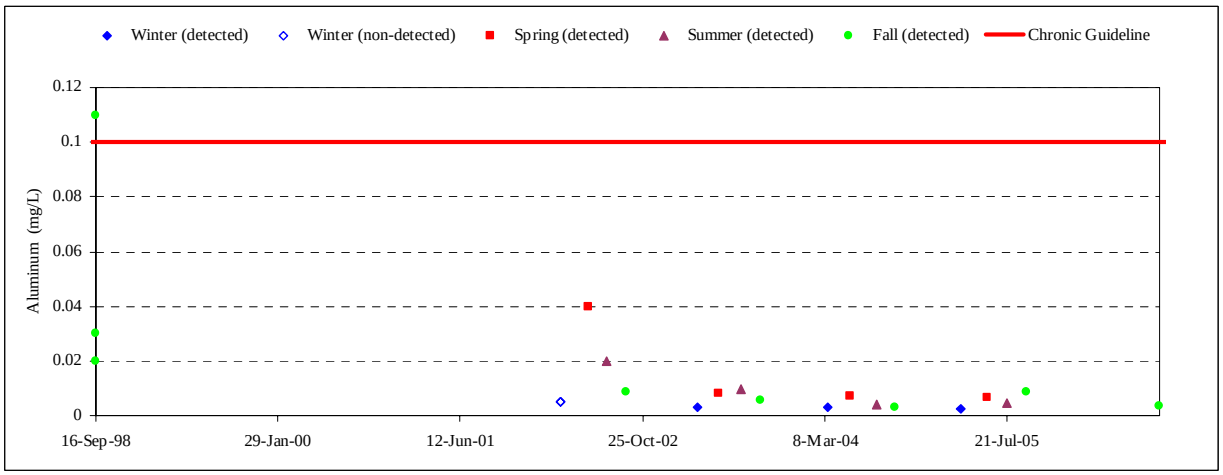
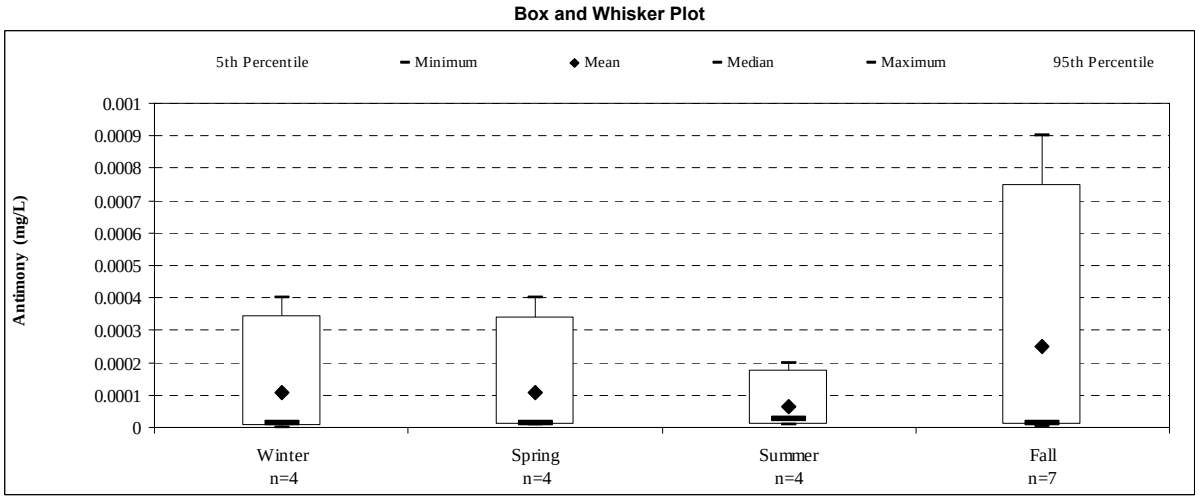


Figure G-1-4-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Lower Firebag River



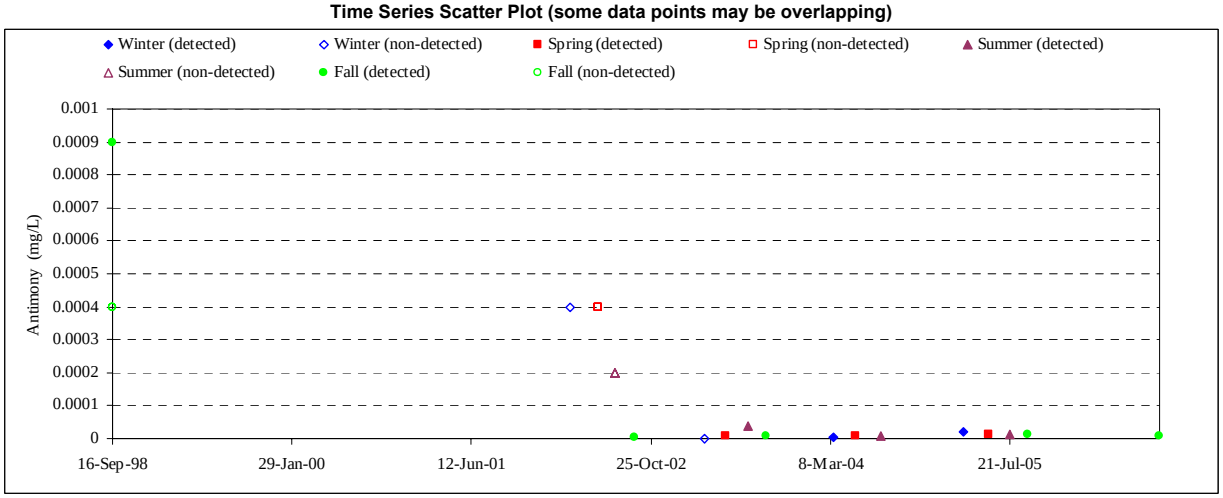
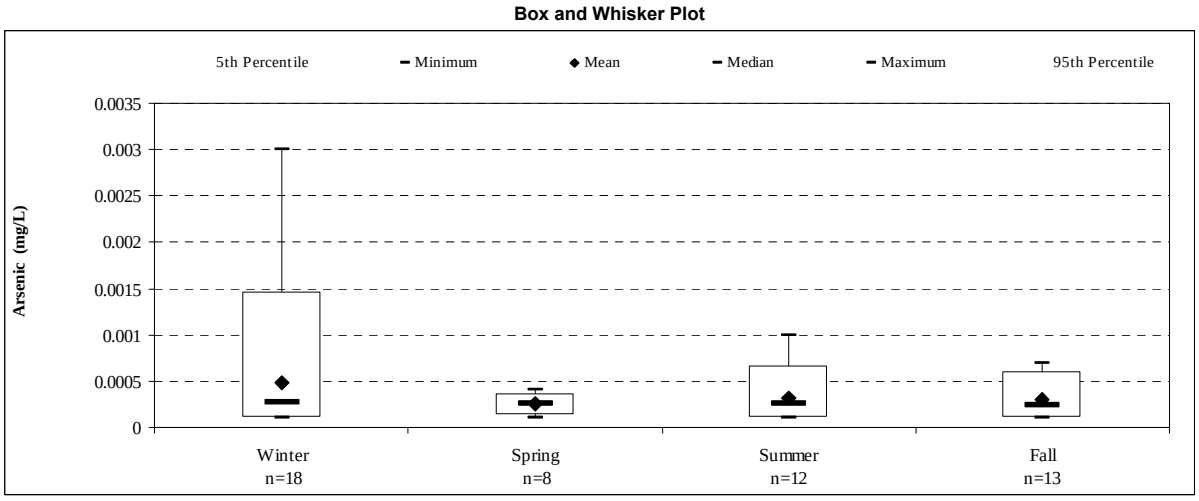


Figure G-1-4-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Lower Firebag River



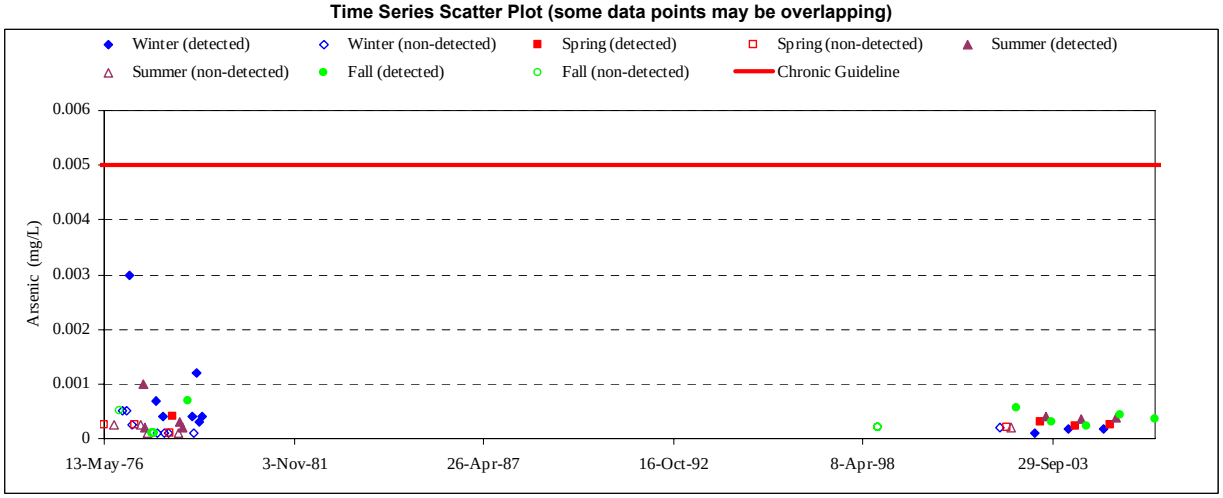
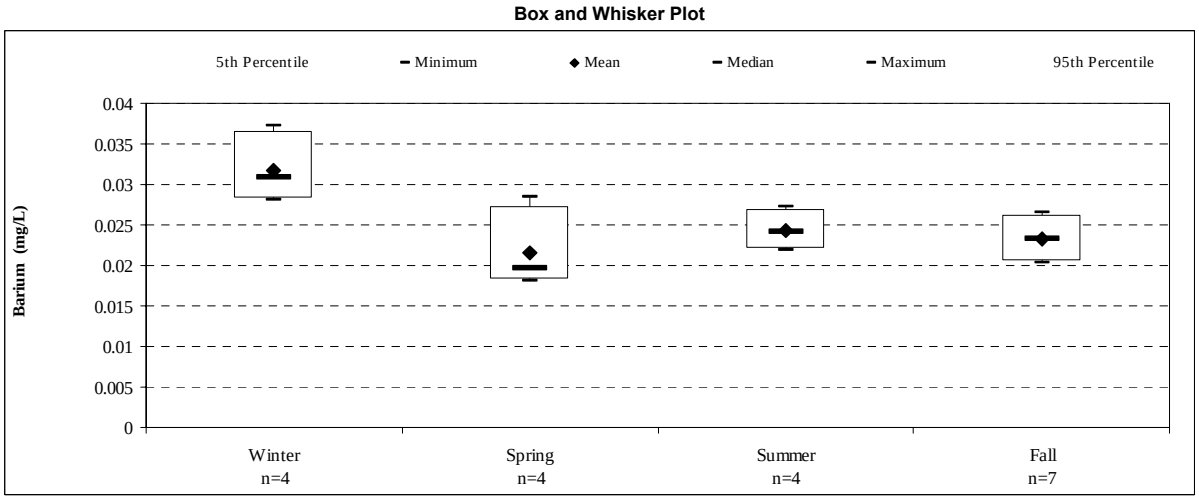


Figure G-1-4-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Lower Firebag River



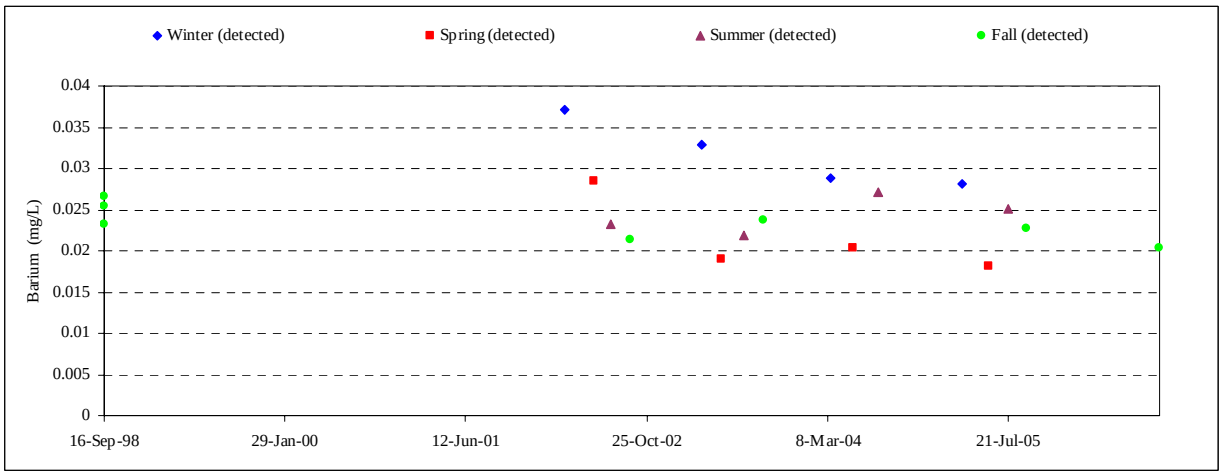
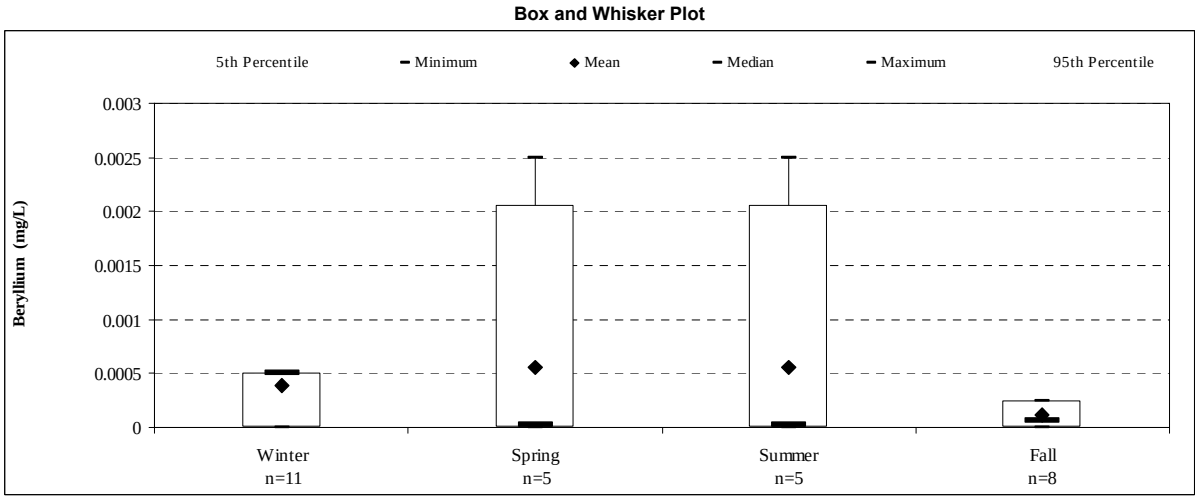


Figure G-1-4-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Lower Firebag River



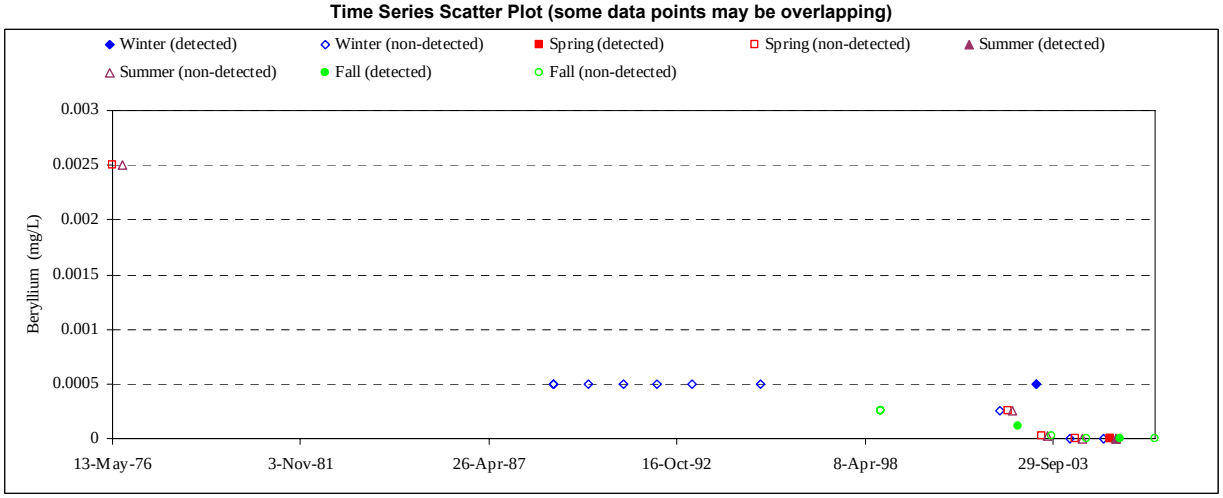
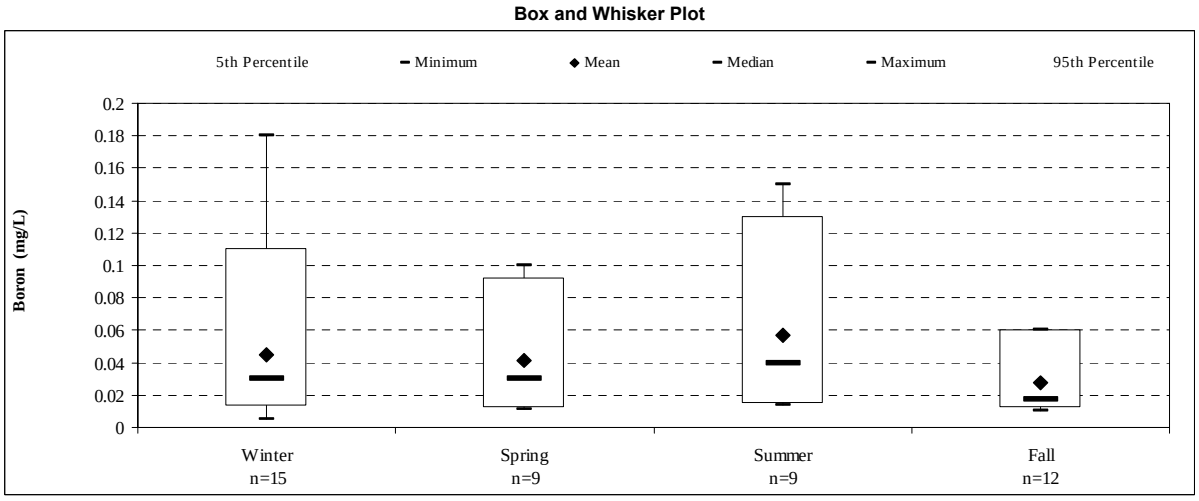


Figure G-1-4-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Lower Firebag River



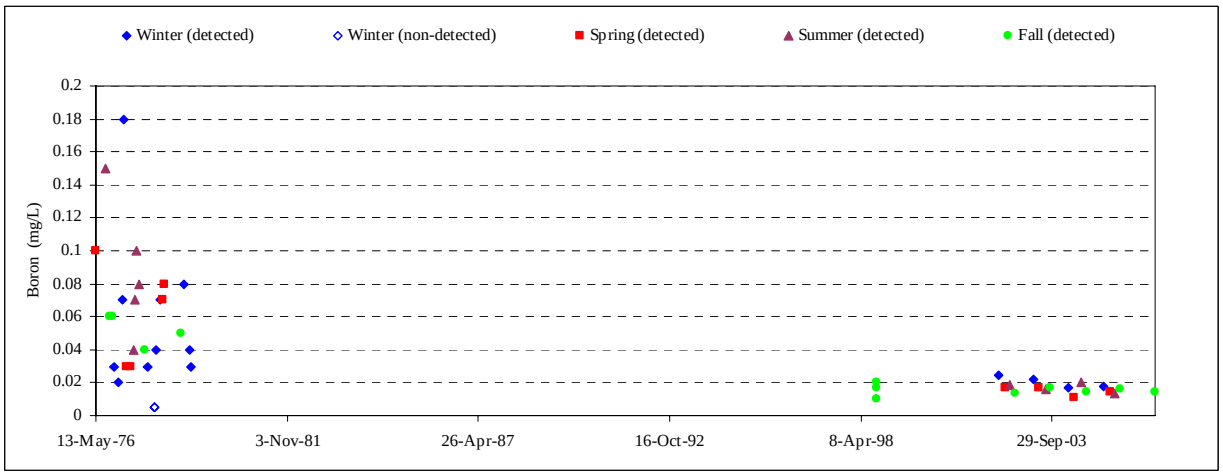
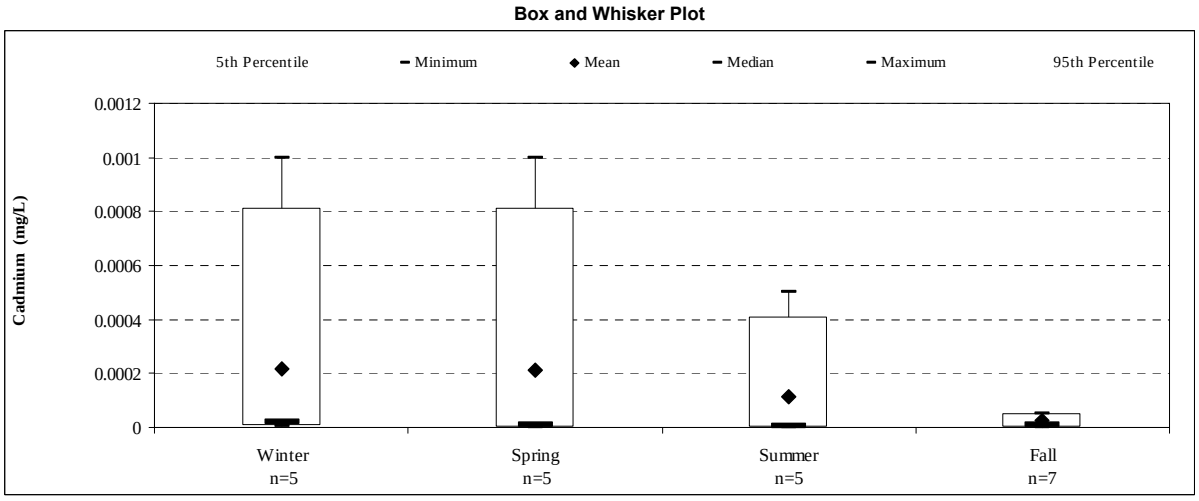


Figure G-1-4-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Lower Firebag River



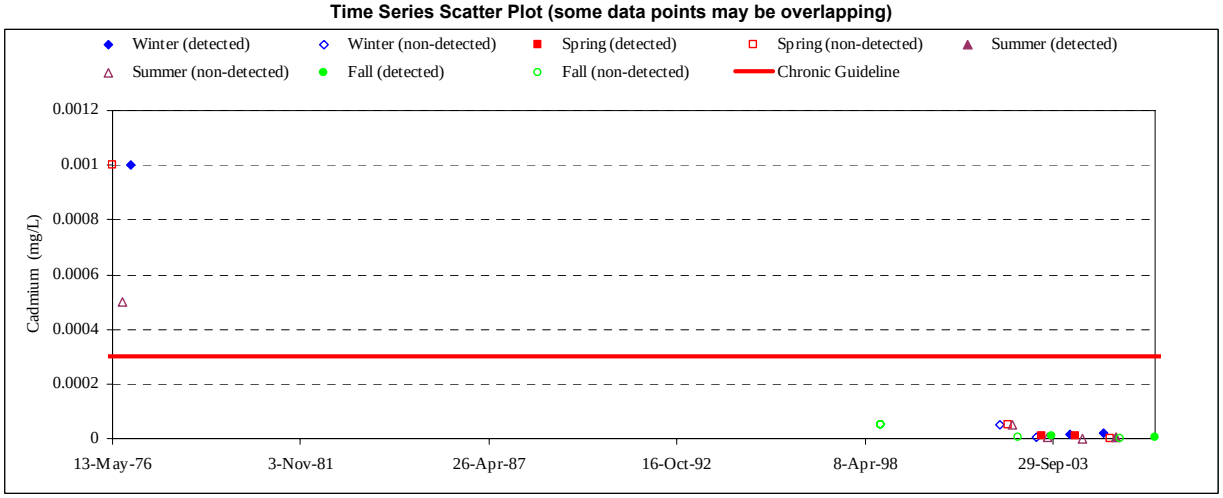
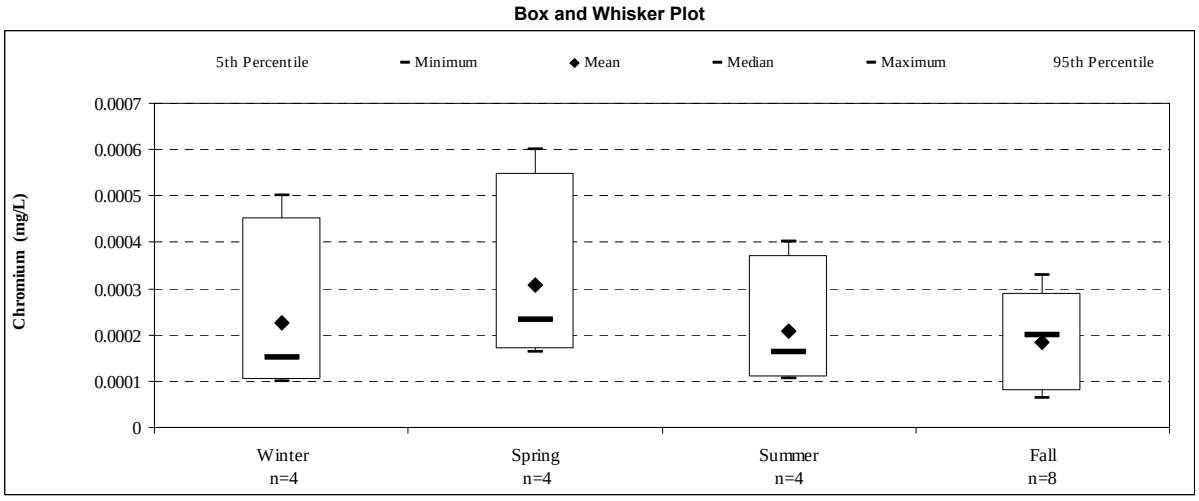


Figure G-1-4-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Lower Firebag River



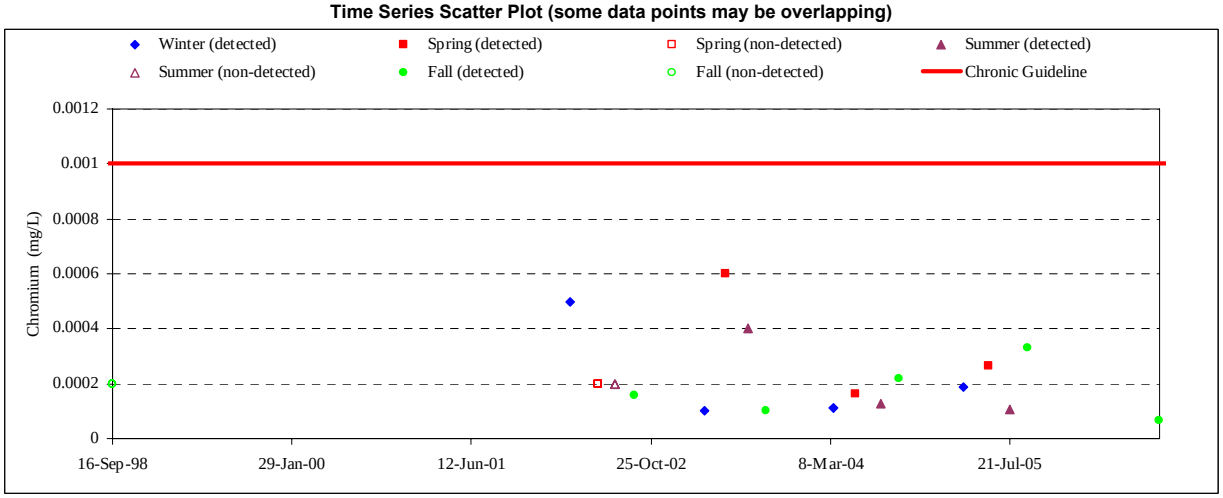
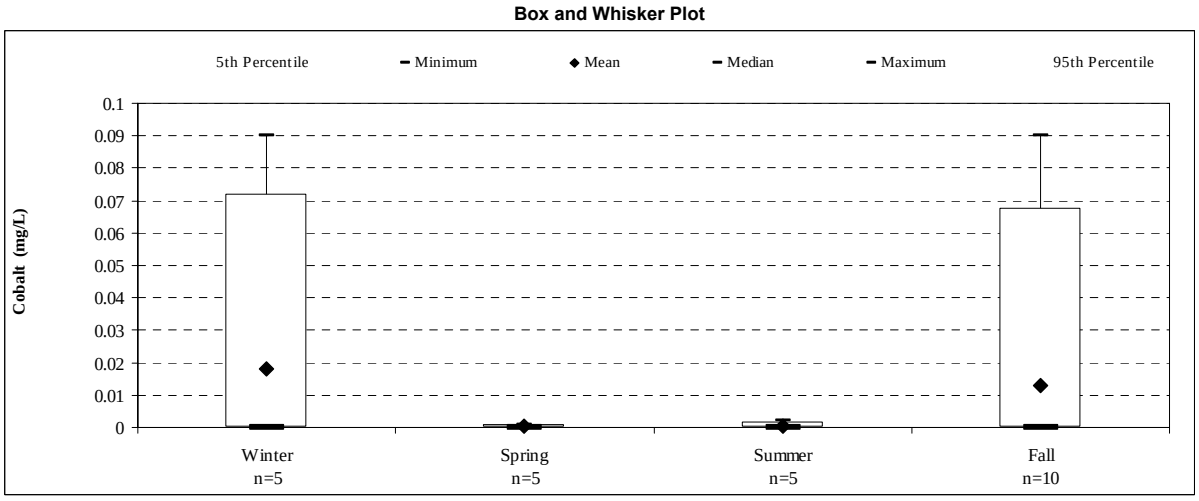


Figure G-1-4-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Lower Firebag River



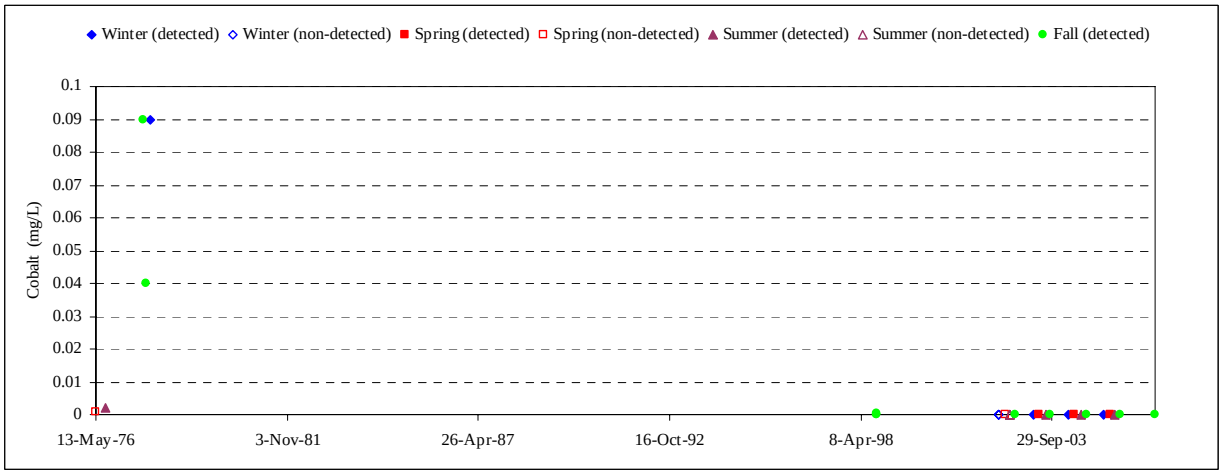
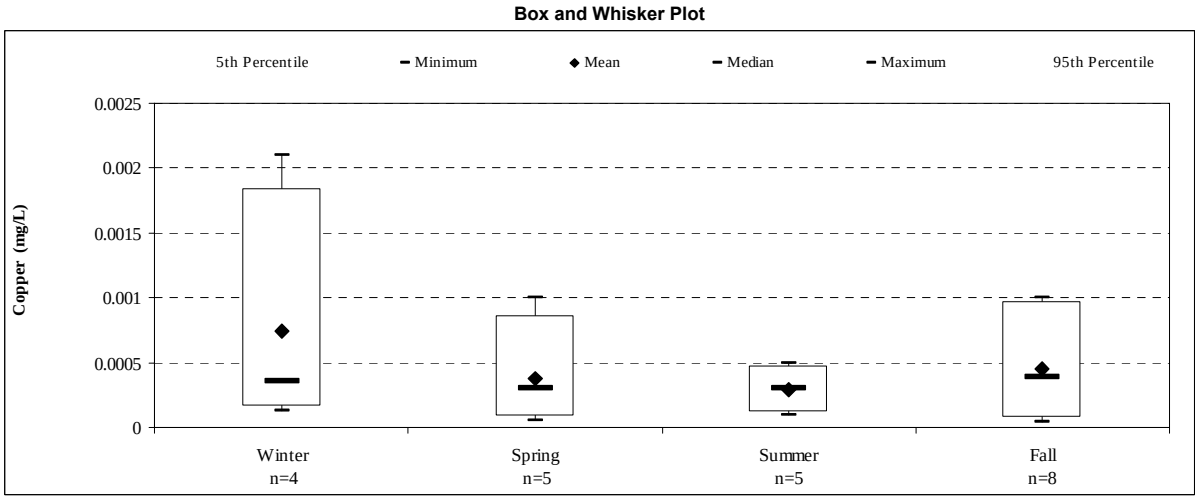


Figure G-1-4-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Lower Firebag River



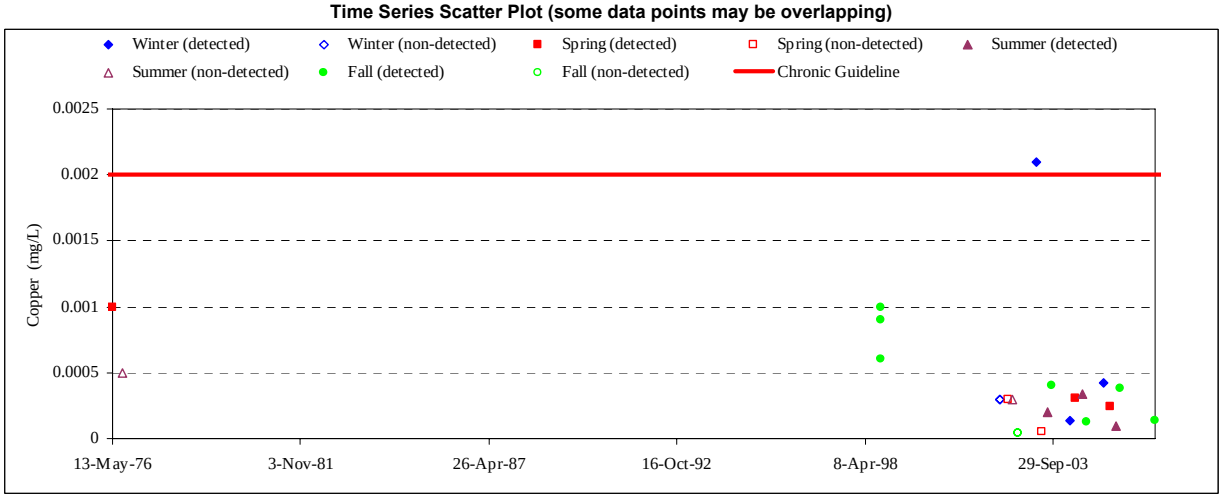
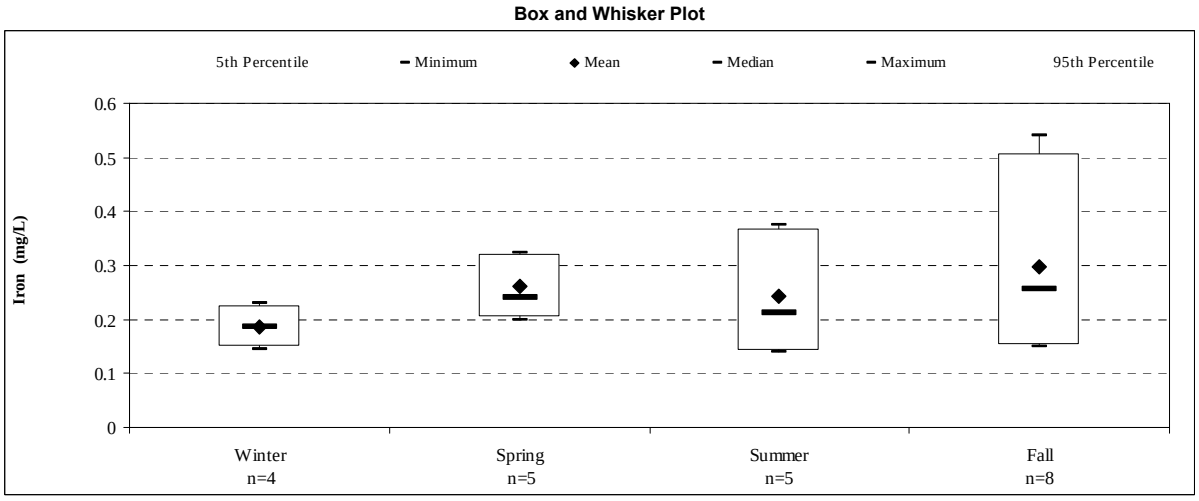


Figure G-1-4-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Lower Firebag River



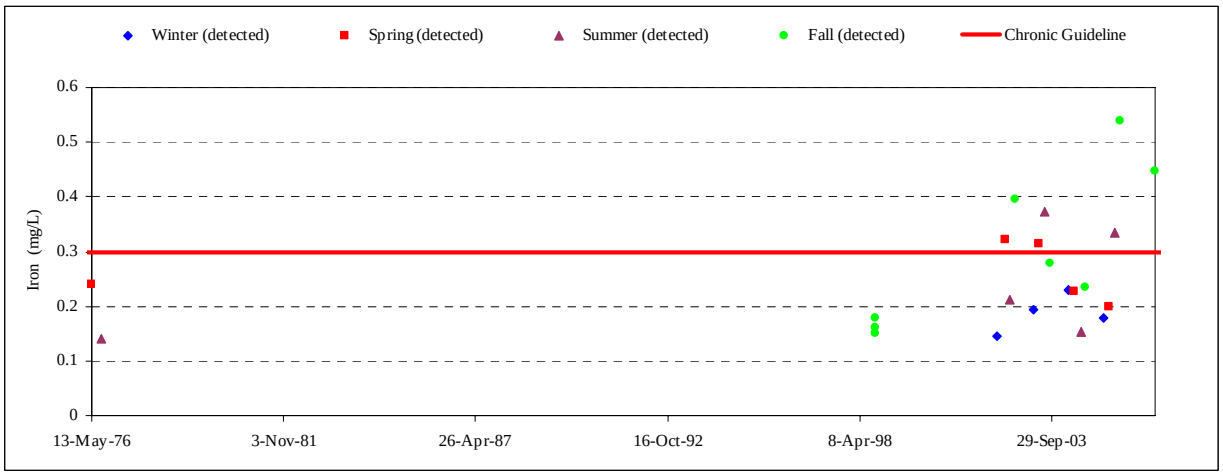
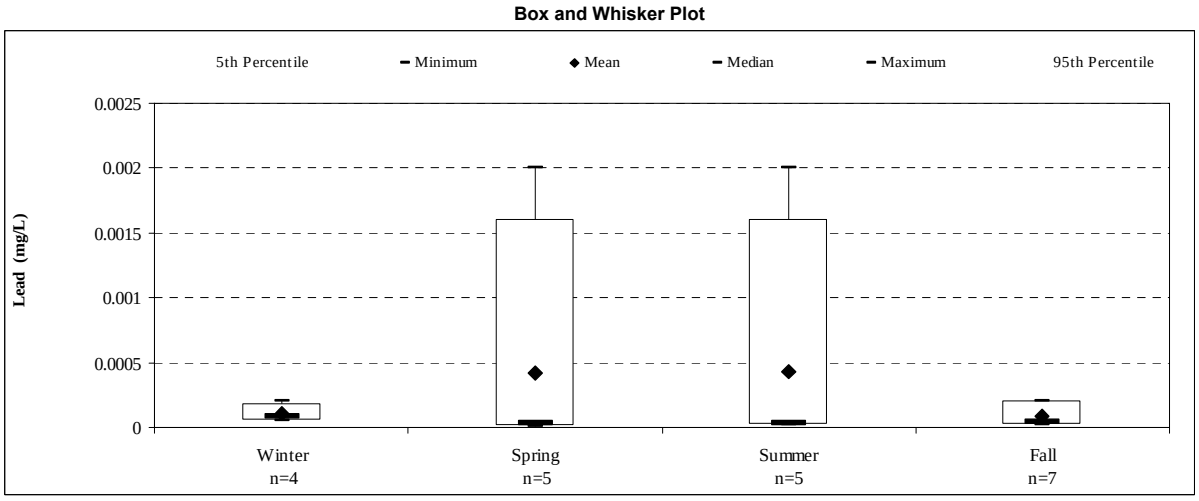


Figure G-1-4-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Lower Firebag River



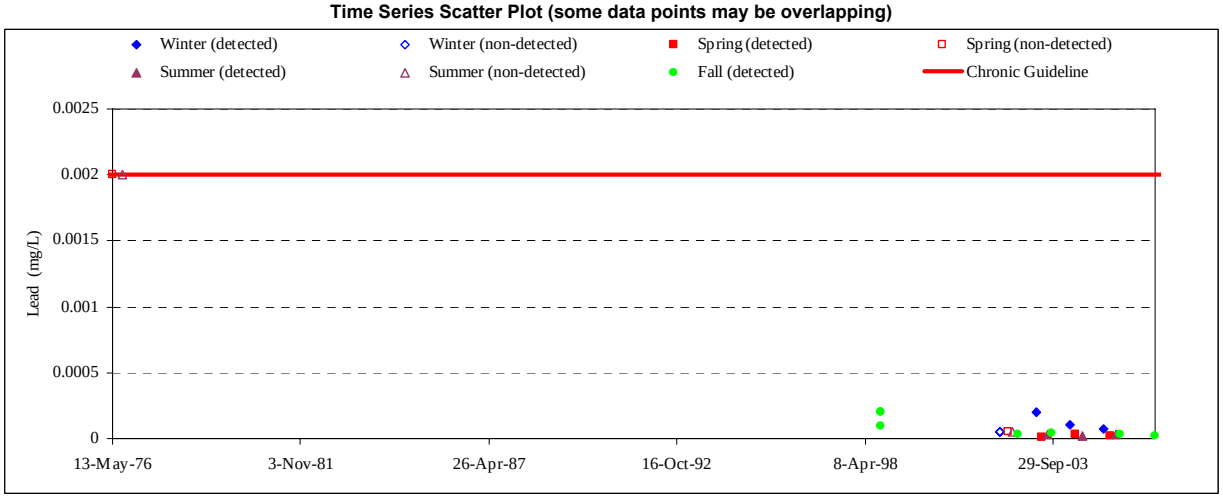
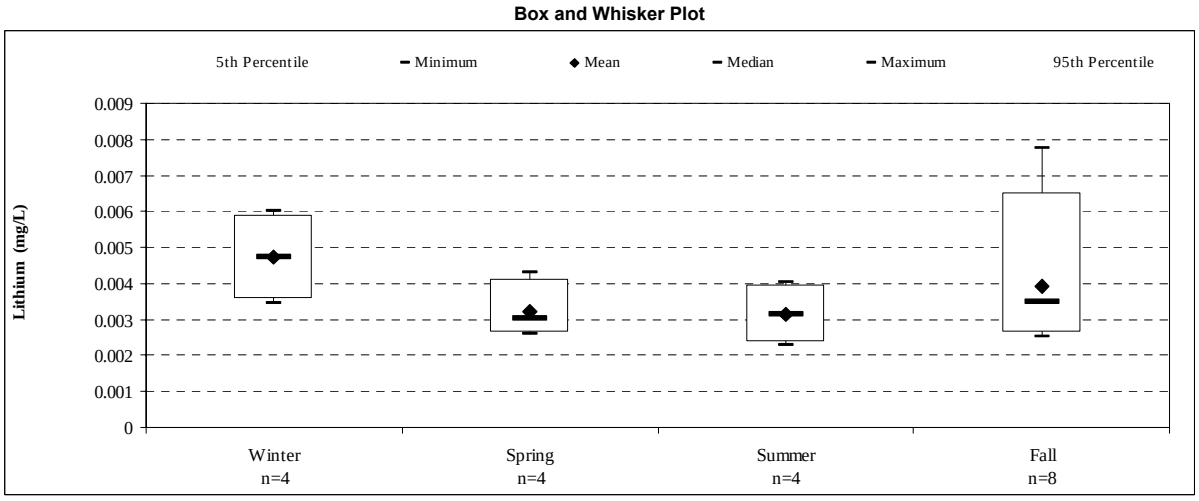


Figure G-1-4-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Lower Firebag River



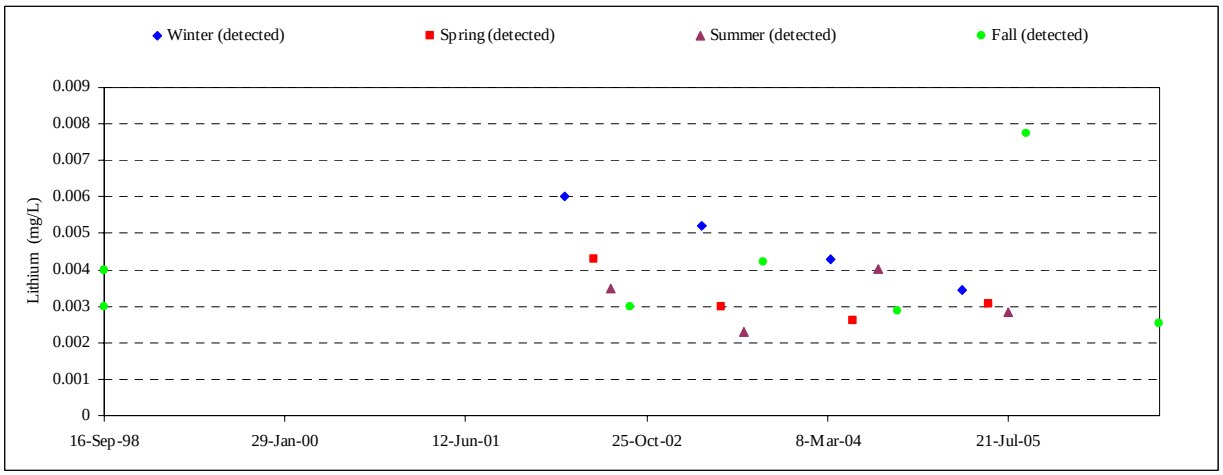
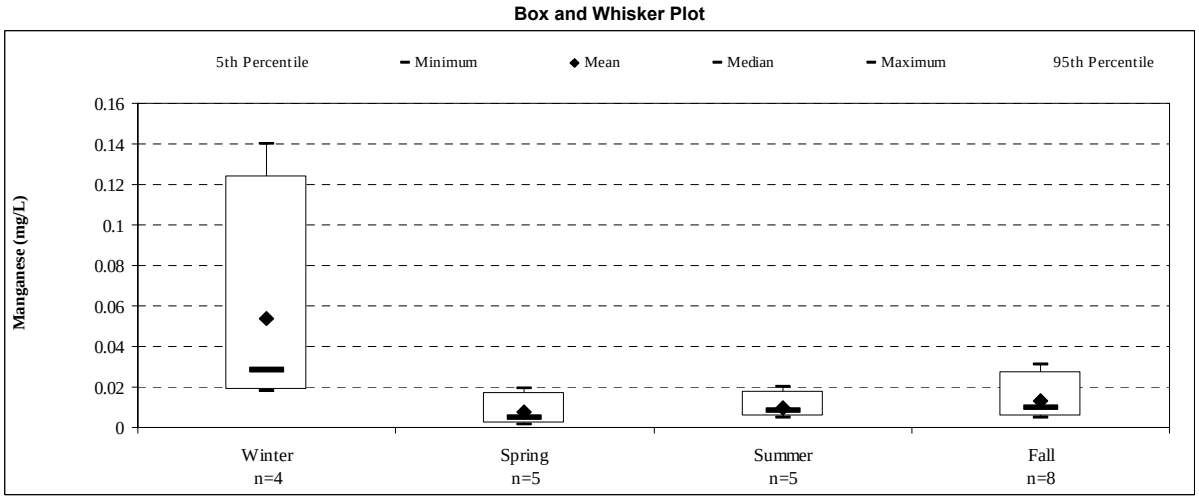


Figure G-1-4-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Lower Firebag River



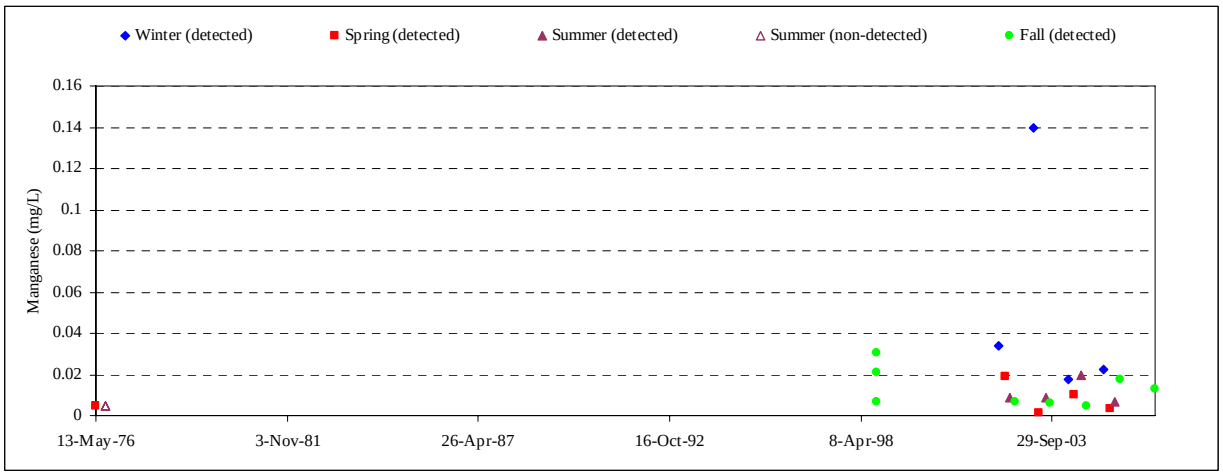
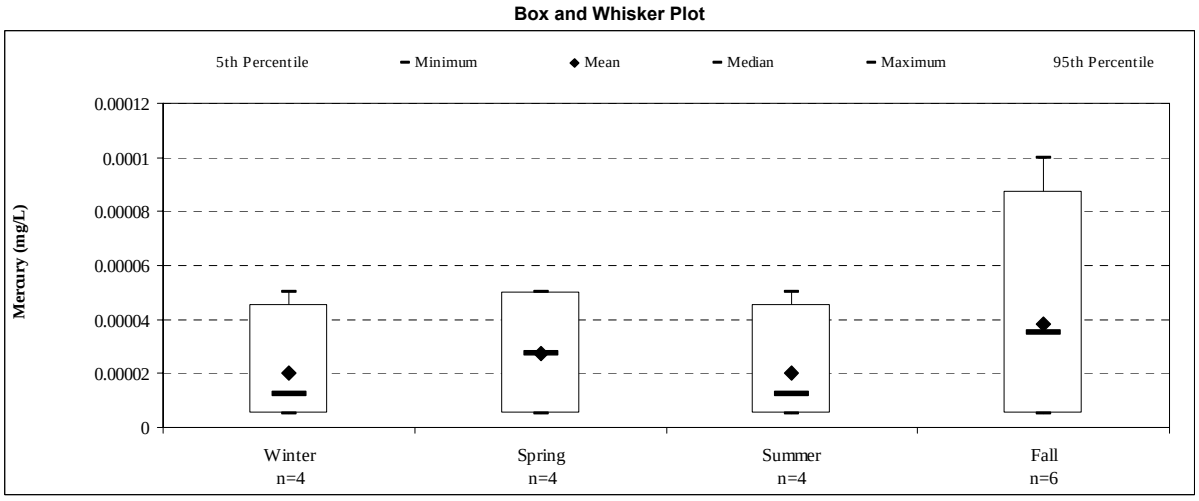


Figure G-1-4-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Lower Firebag River



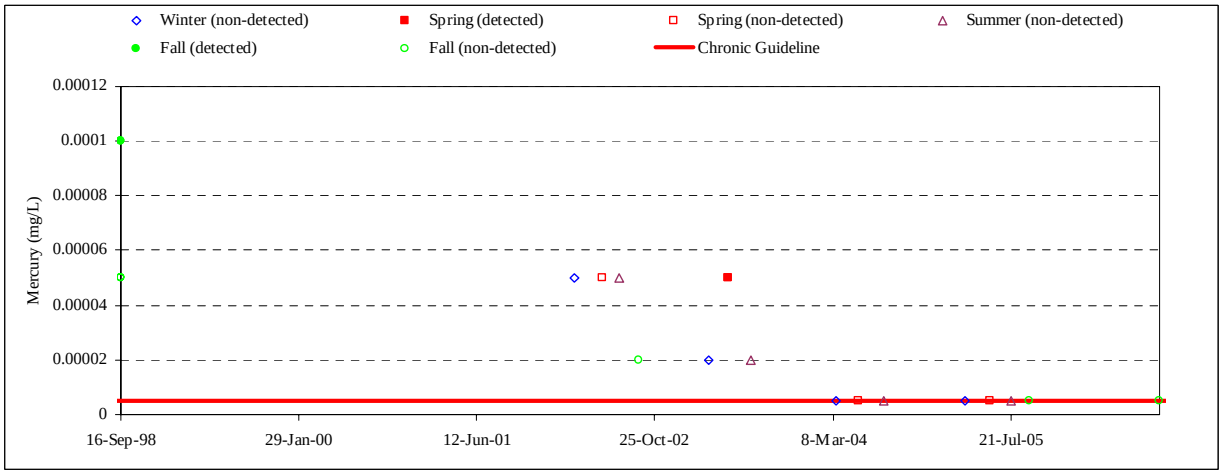
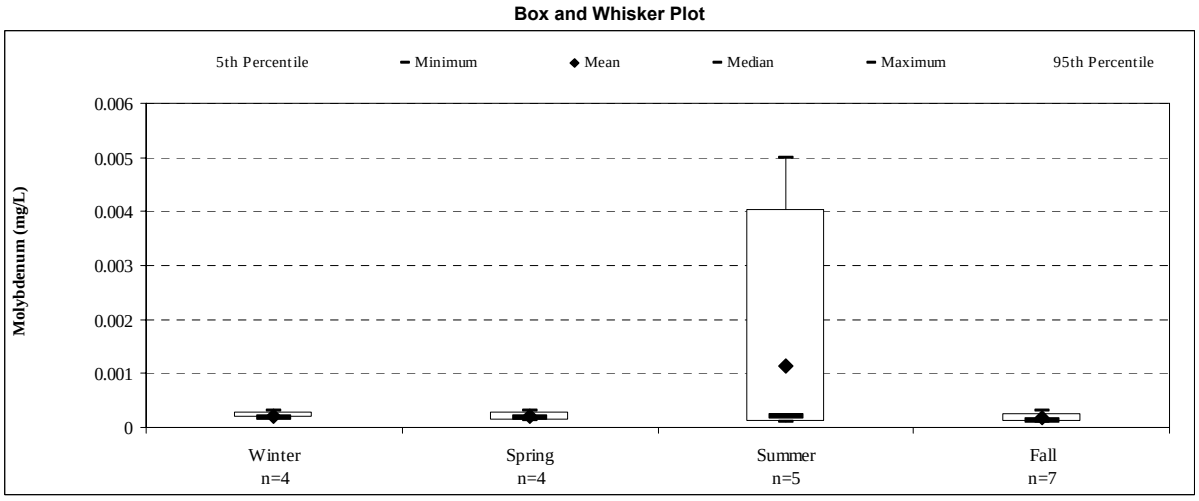


Figure G-1-4-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Lower Firebag River



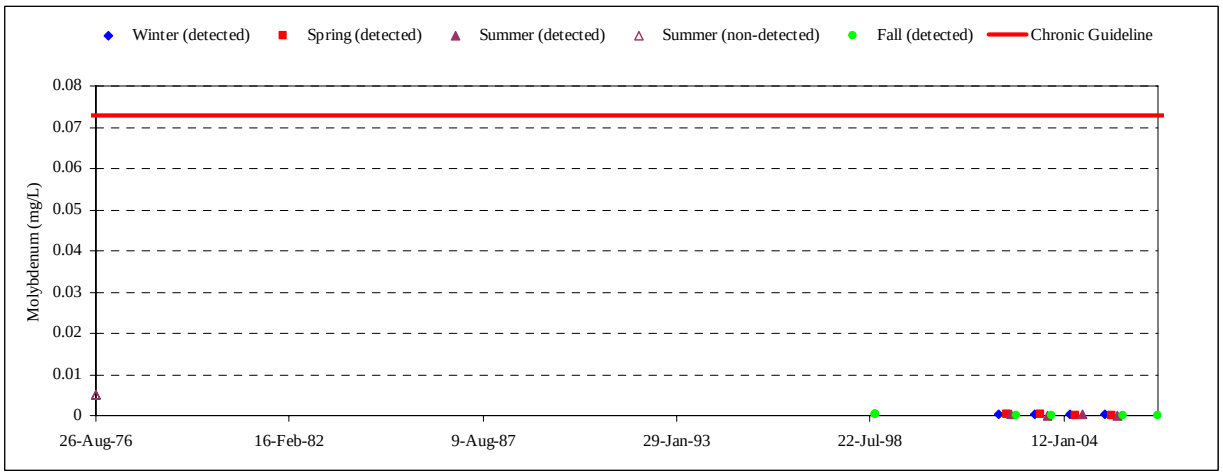
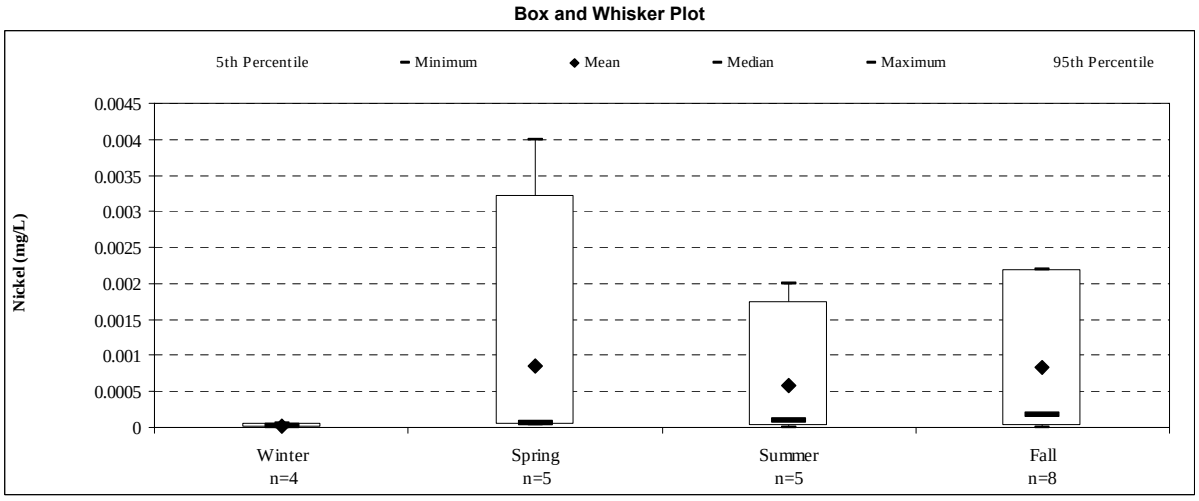


Figure G-1-4-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Lower Firebag River



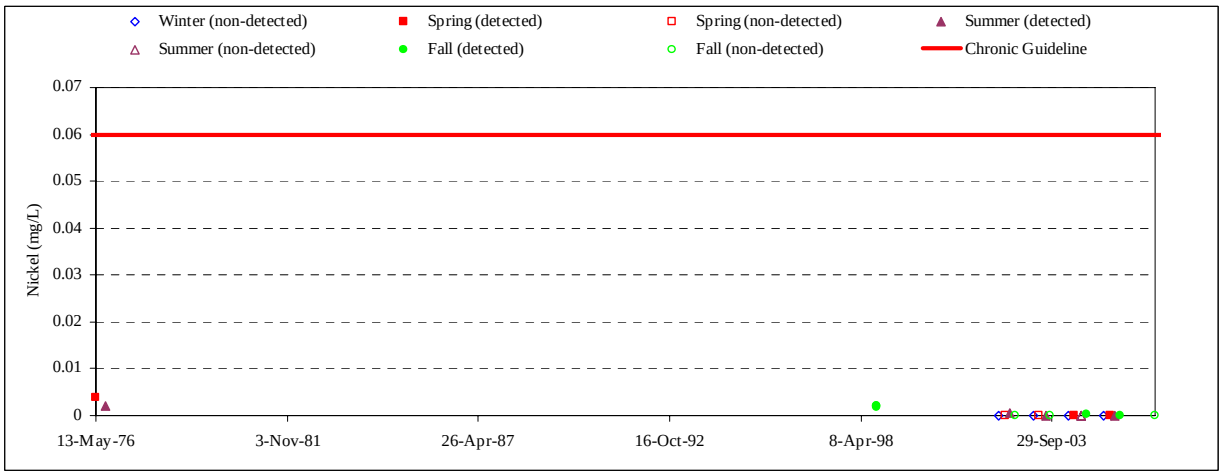
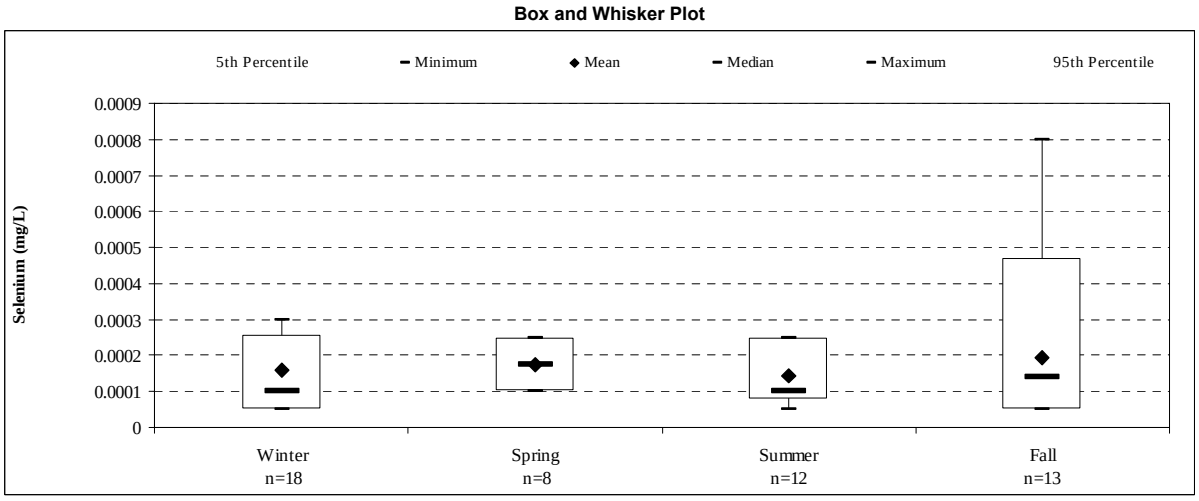


Figure G-1-4-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Lower Firebag River



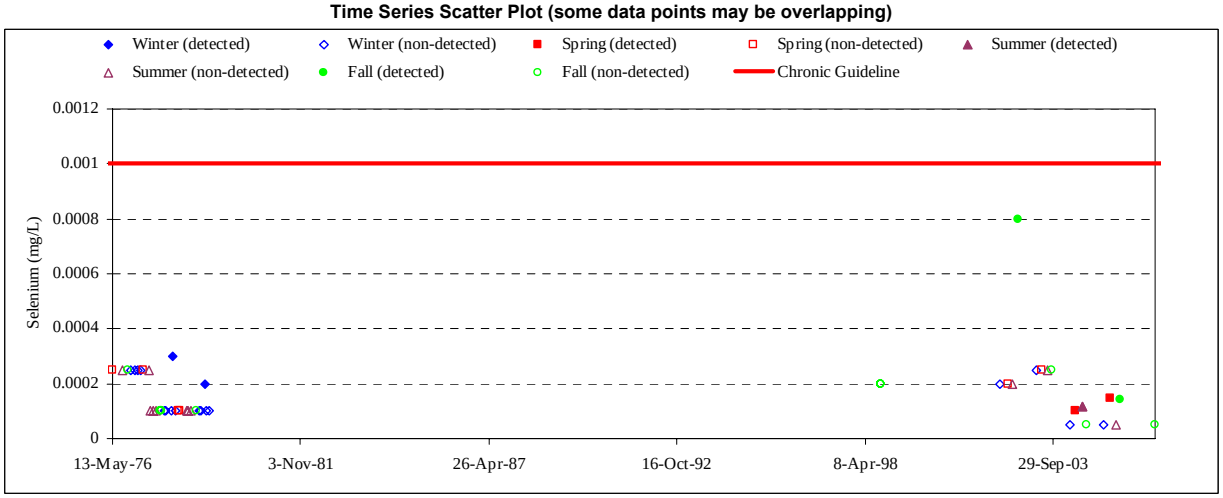


Figure G-1-4-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Lower Firebag River

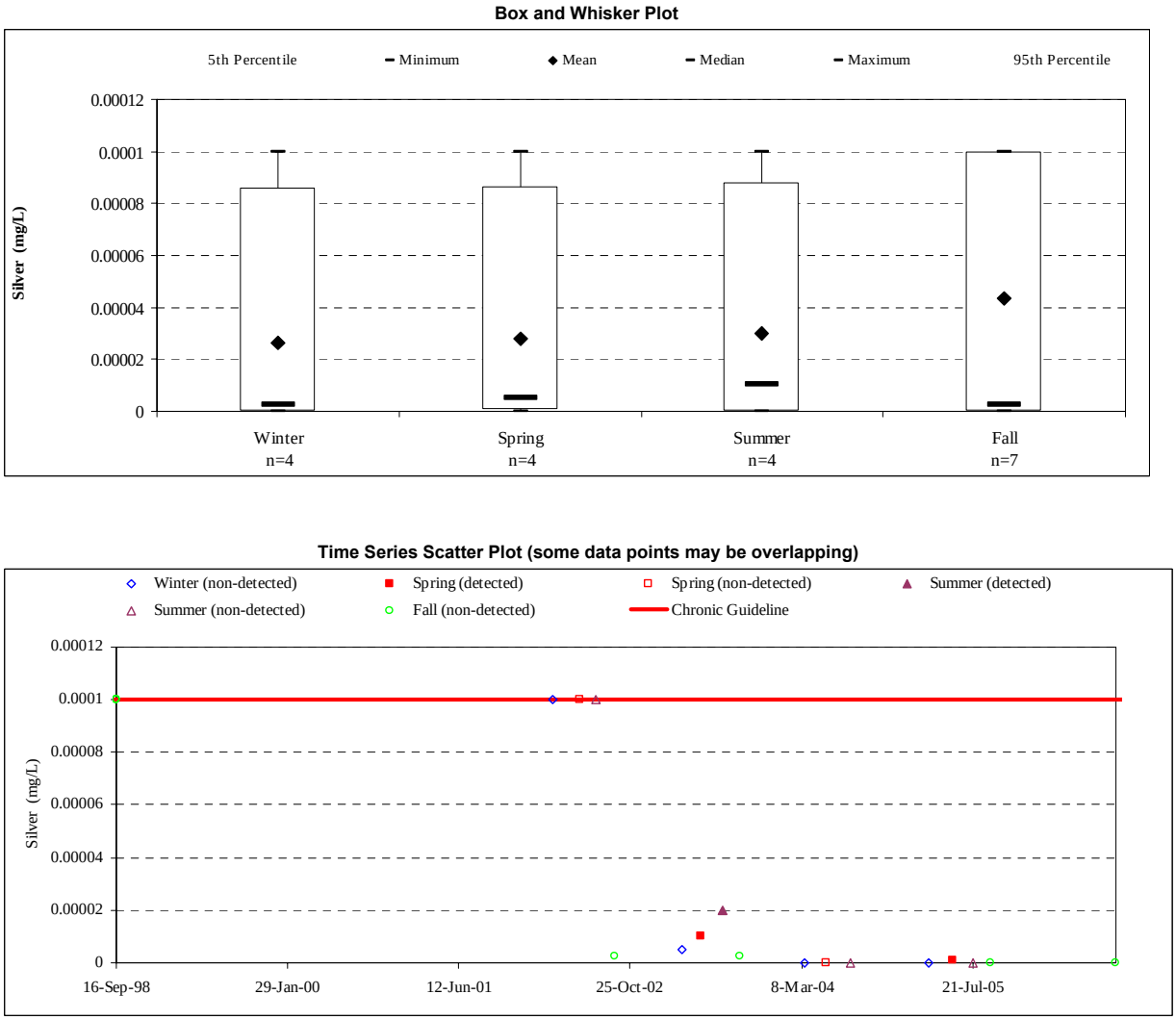
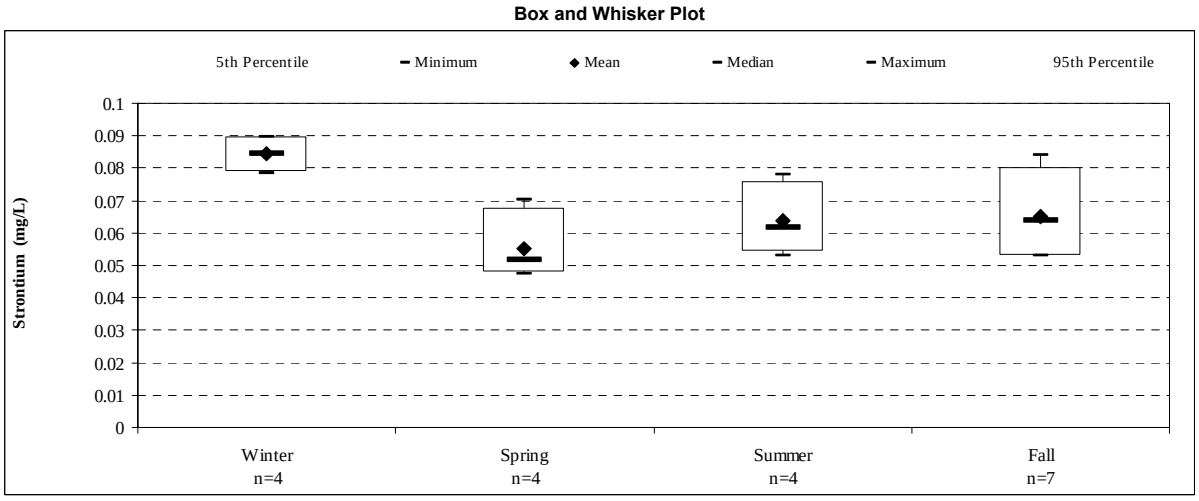


Figure G-1-4-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Lower Firebag River



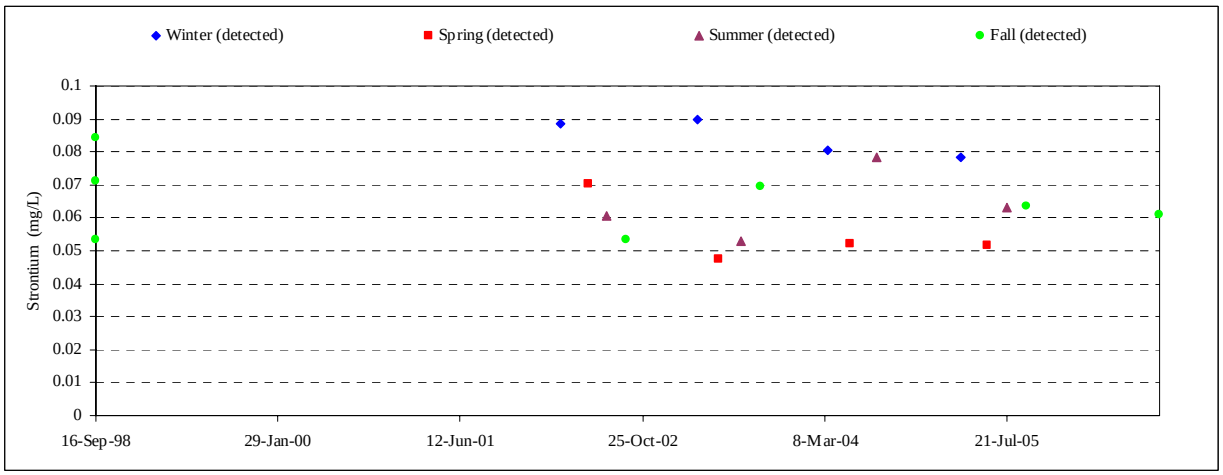
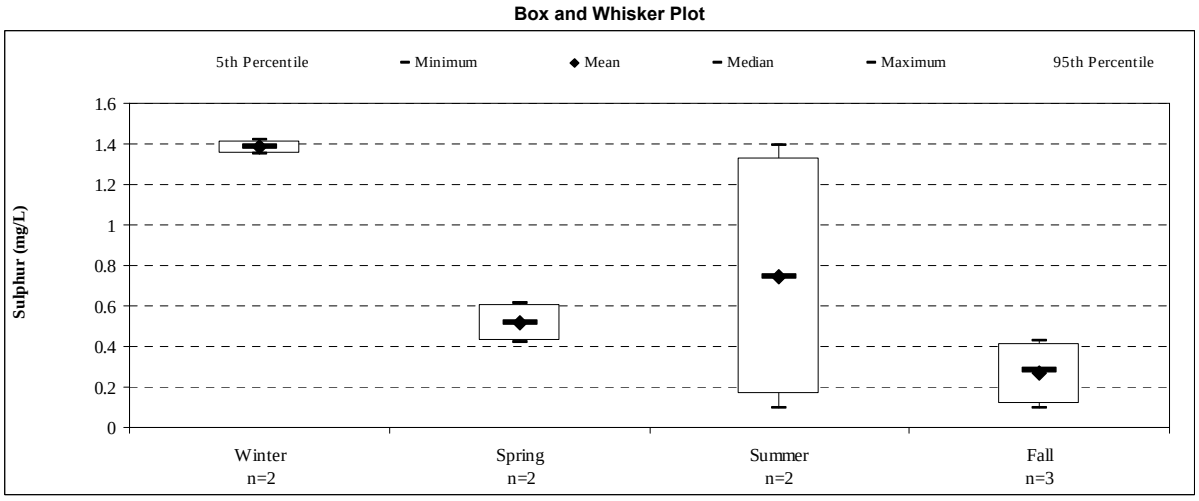


Figure G-1-4-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Lower Firebag River



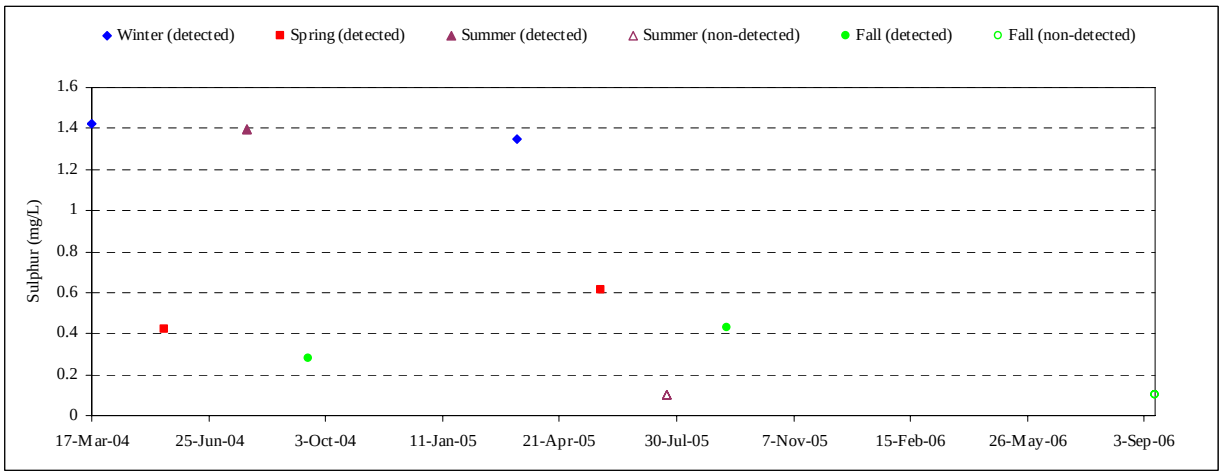
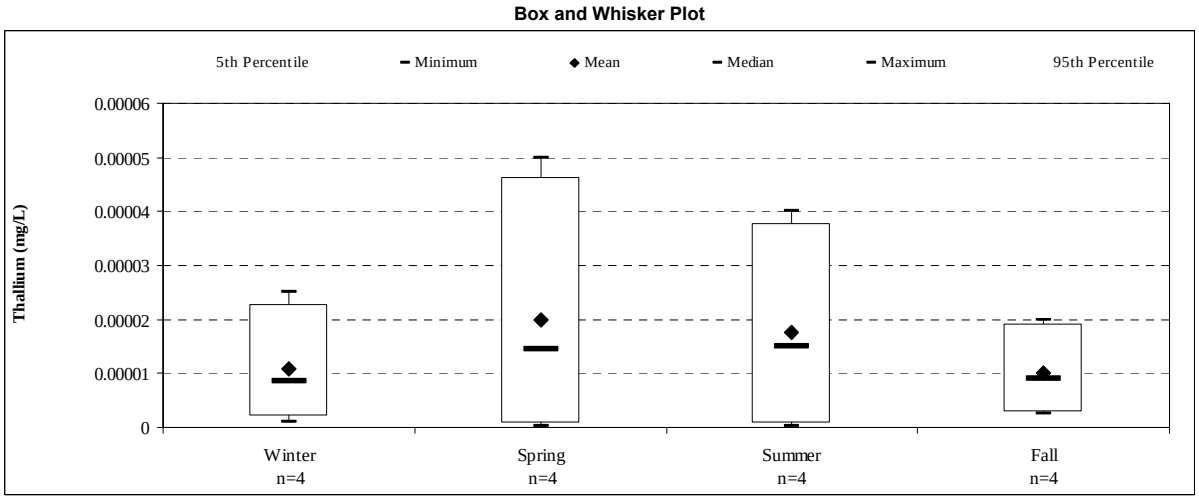


Figure G-1-4-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Lower Firebag River



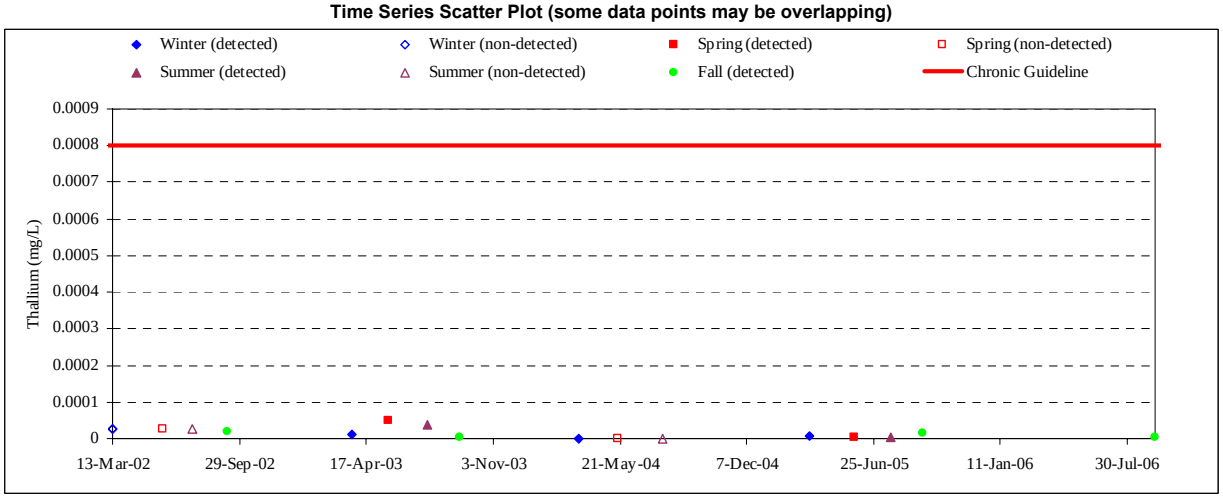
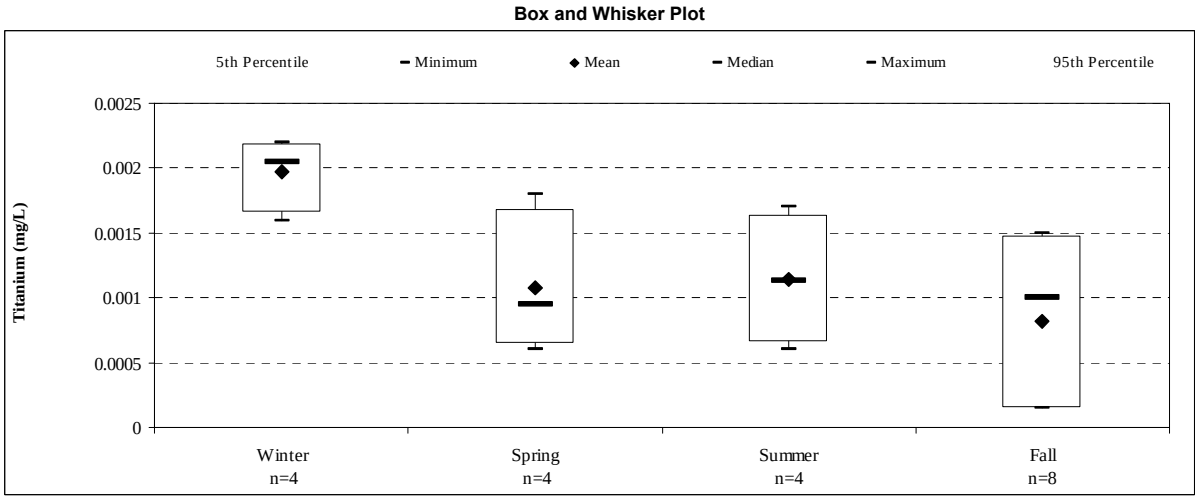


Figure G-1-4-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Lower Firebag River



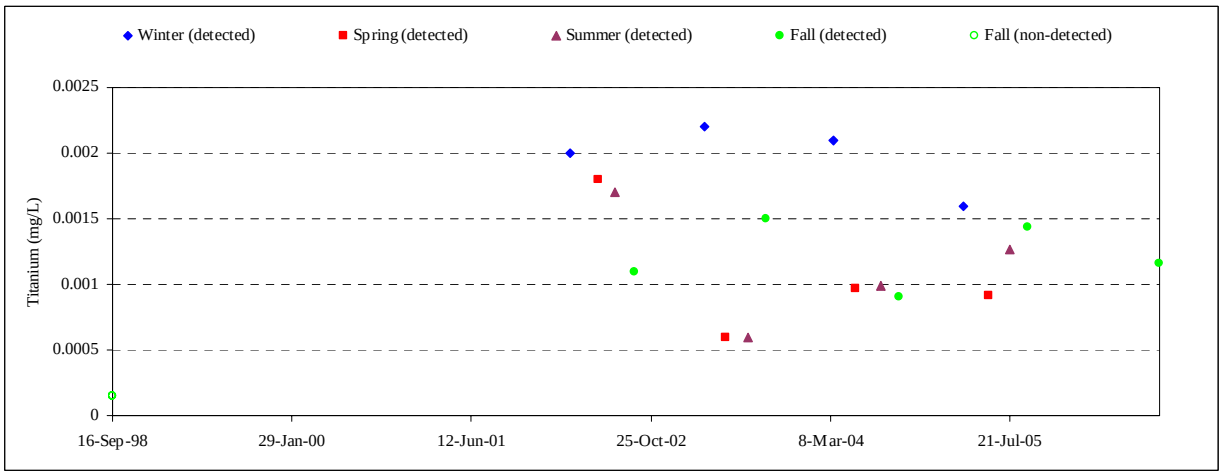
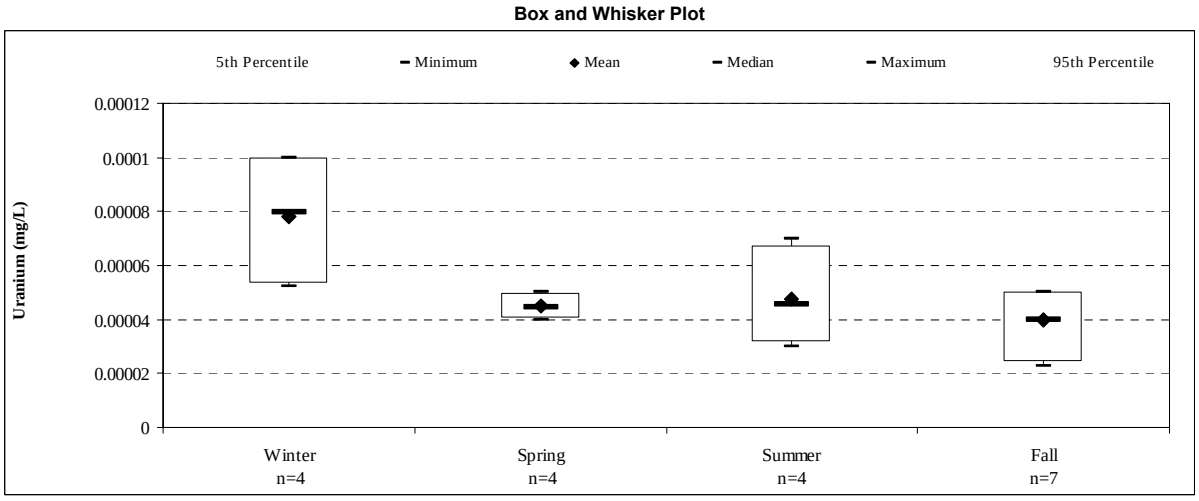


Figure G-1-4-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Lower Firebag River



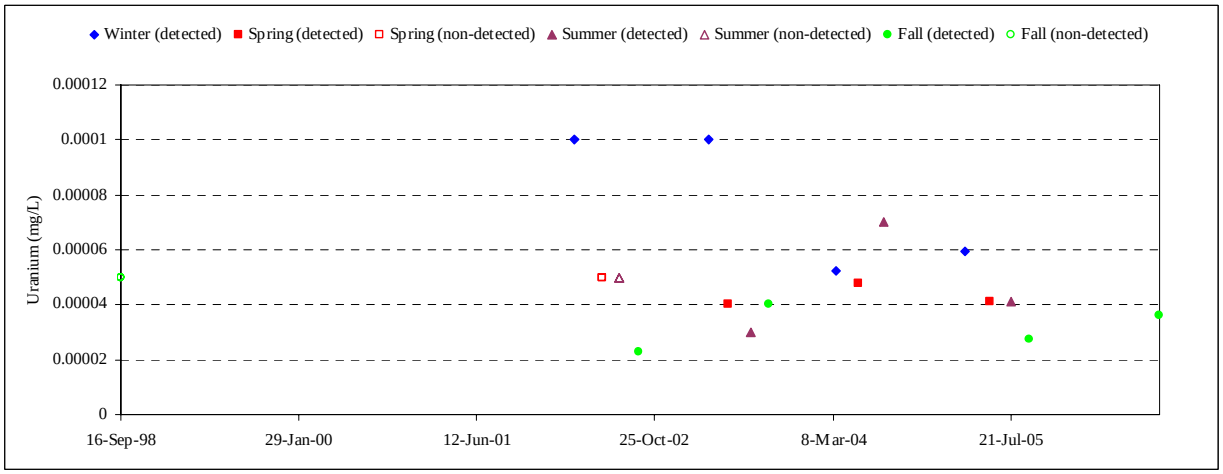
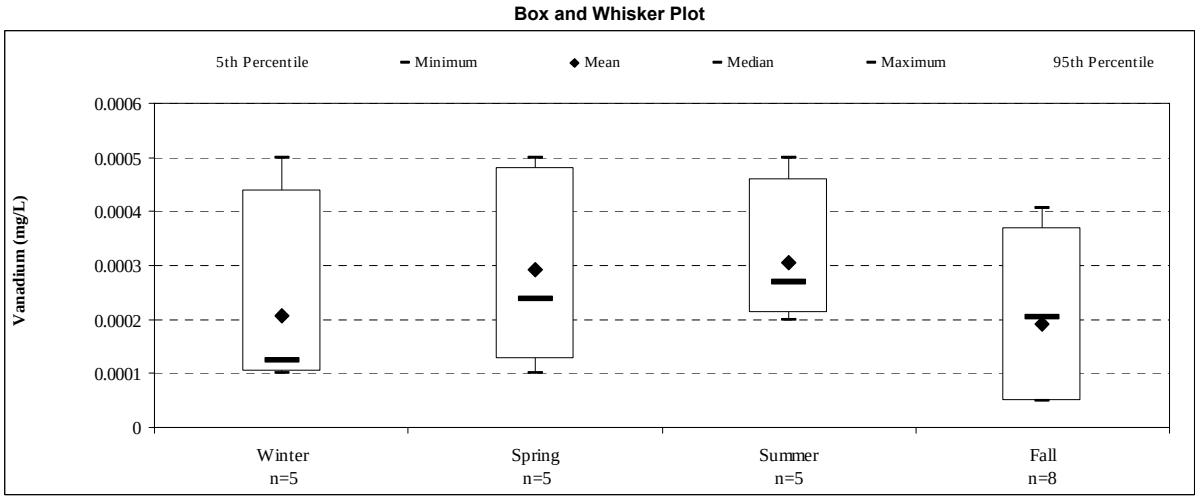


Figure G-1-4-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Lower Firebag River



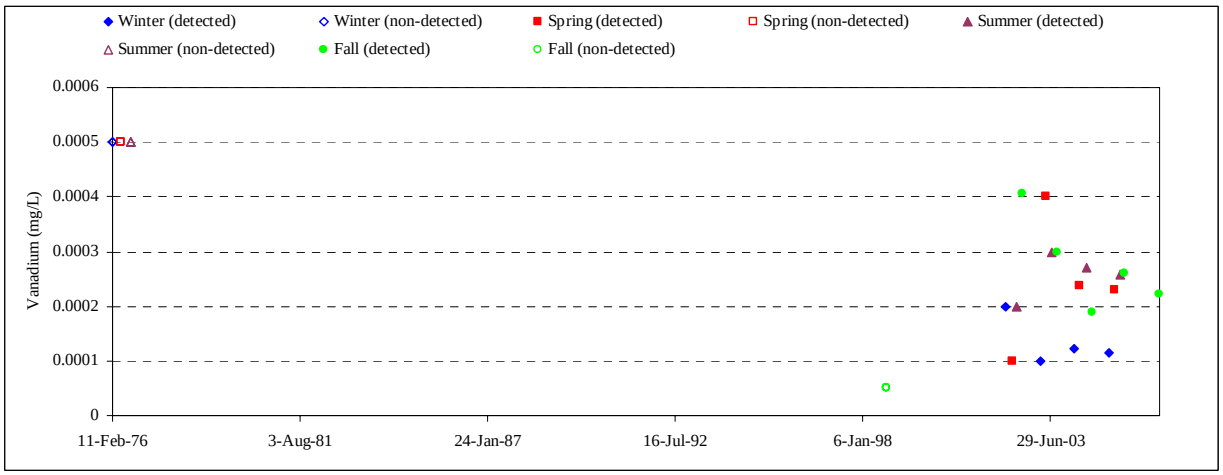
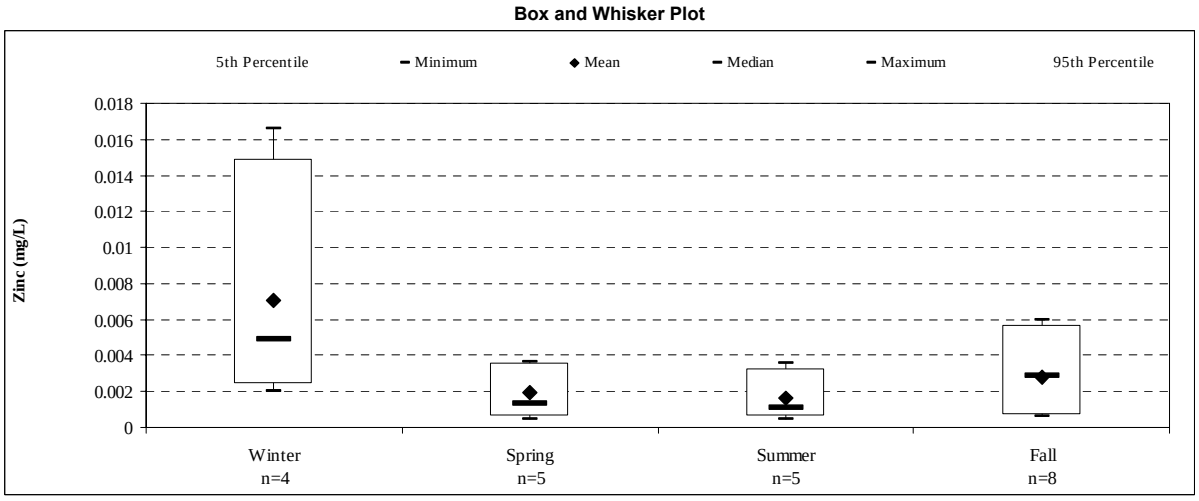


Figure G-1-4-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Lower Firebag River



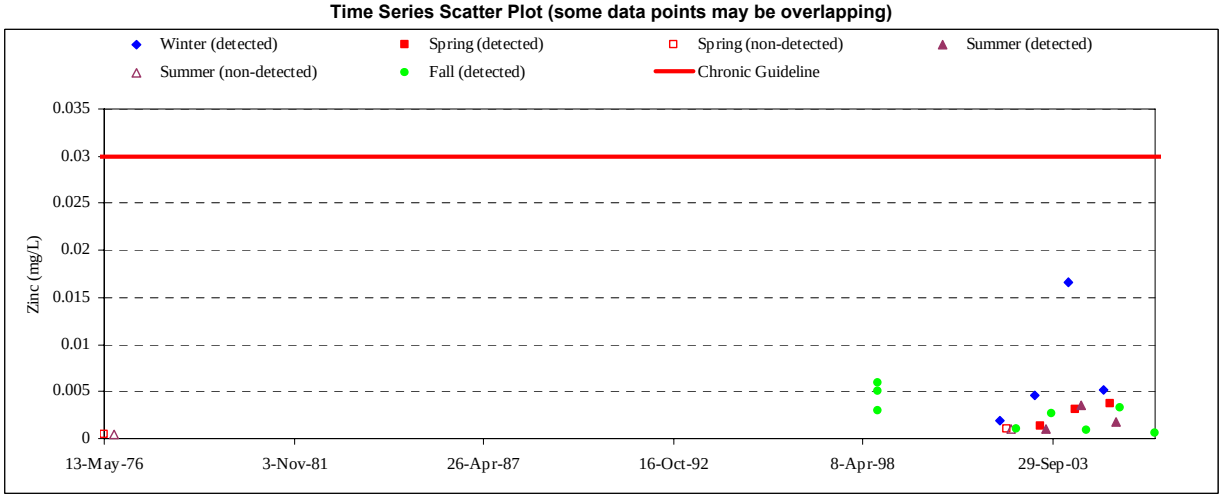
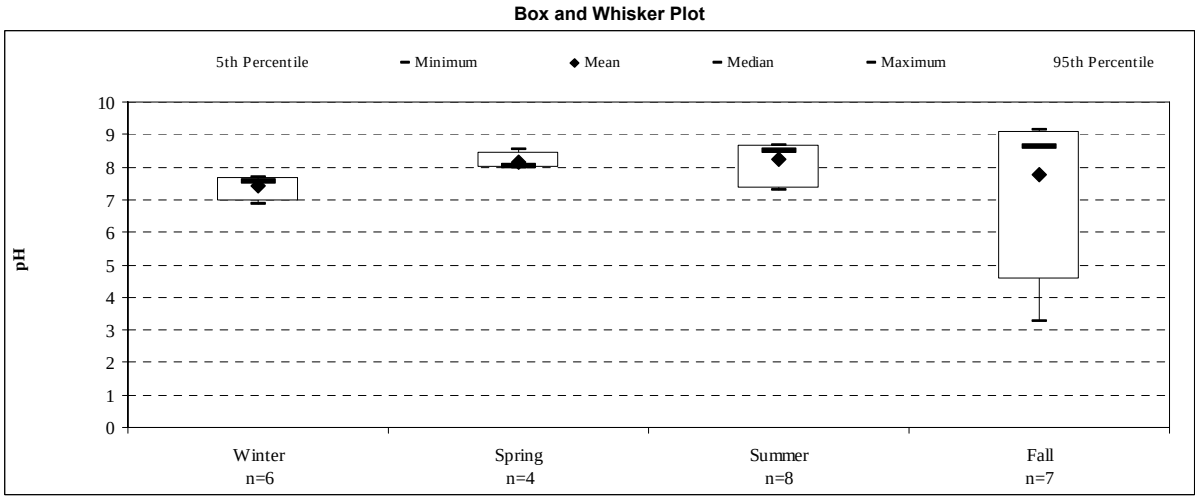


Figure G-1-5-1 Box Whisker and Time Series Scatter Plots of Observed pH in McClelland Lake



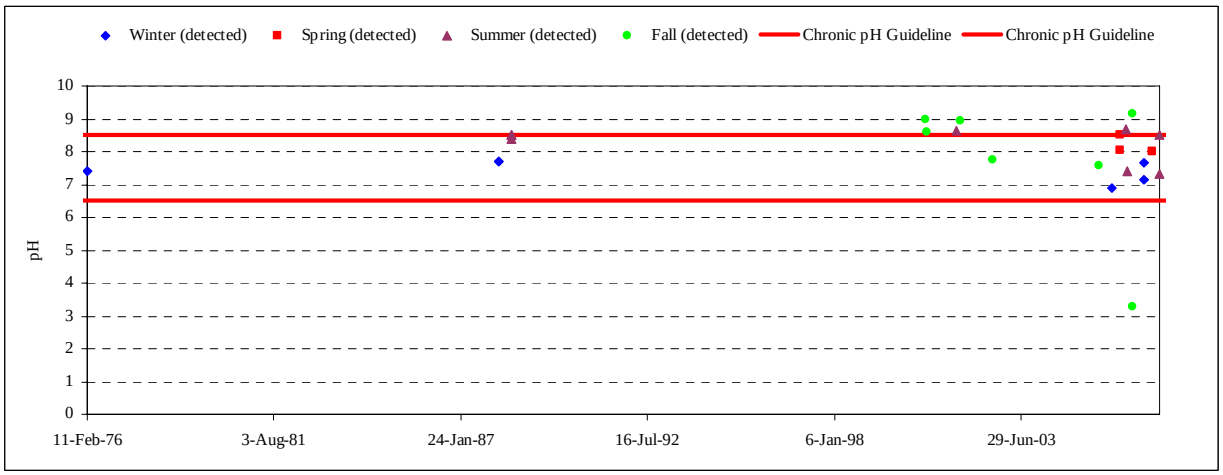
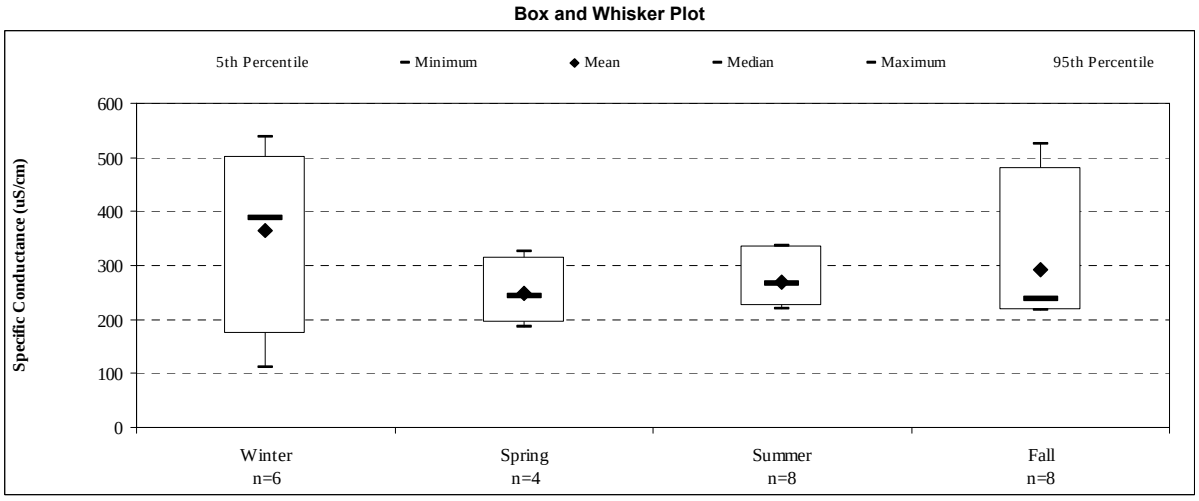


Figure G-1-5-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in McClelland Lake



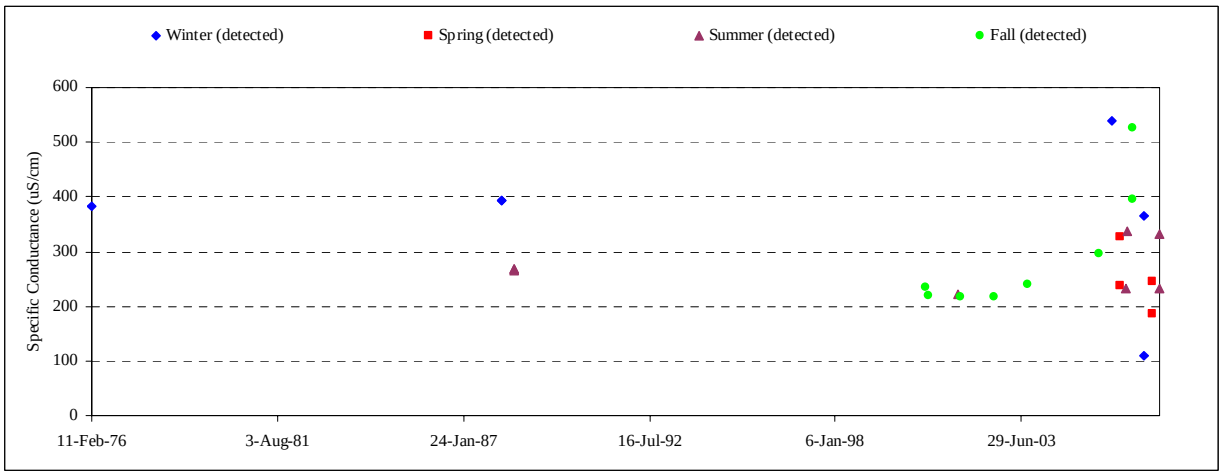
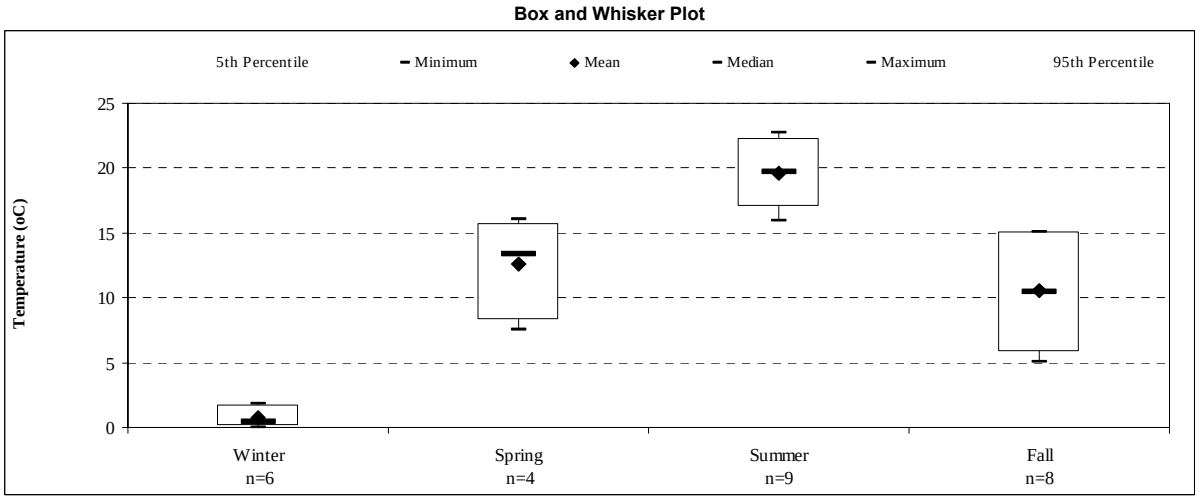


Figure G-1-5-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in McClelland Lake



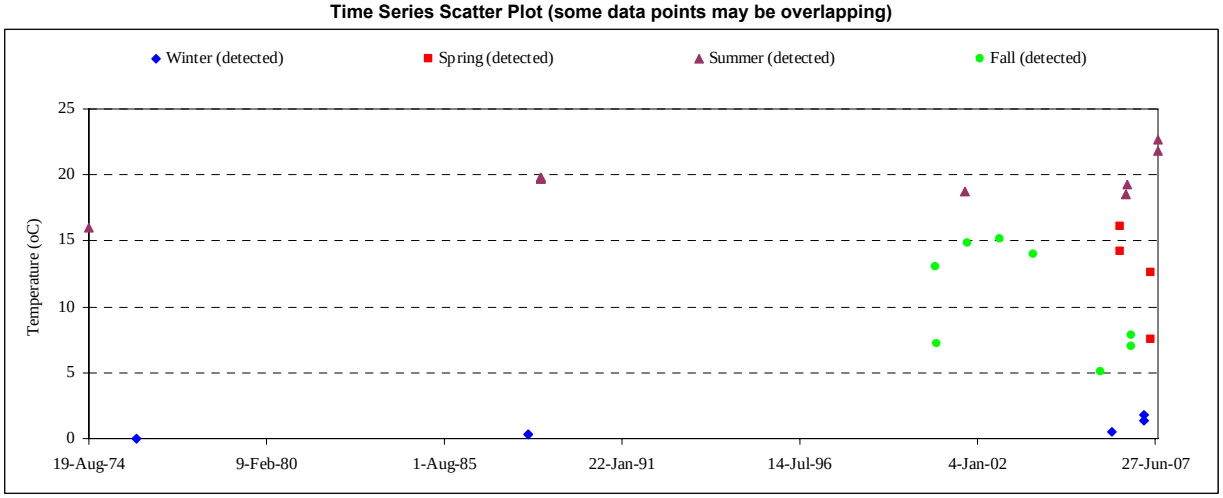
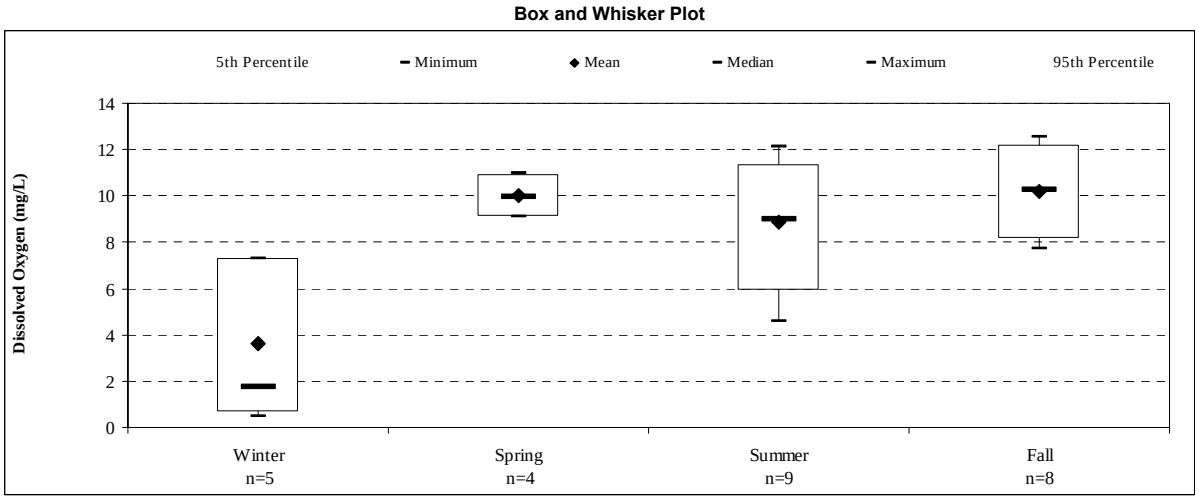


Figure G-1-5-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in McClelland Lake



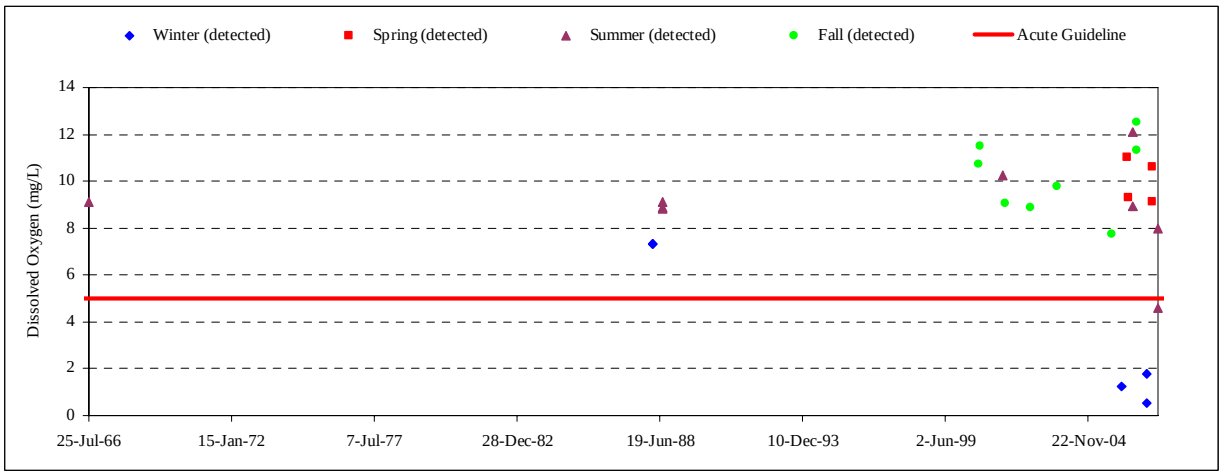
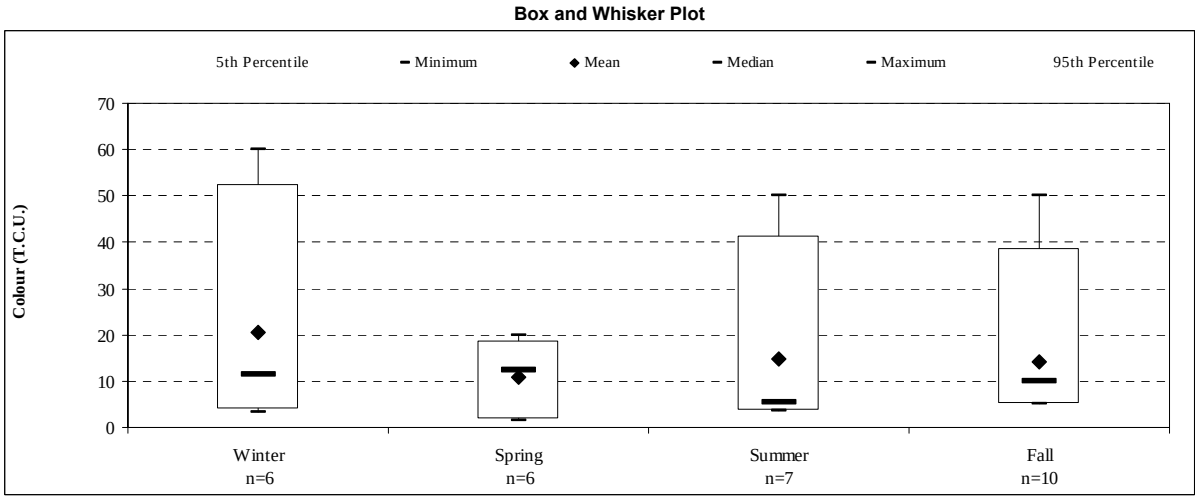


Figure G-1-5-5 Box Whisker and Time Series Scatter Plots of Observed Colour in McClelland Lake



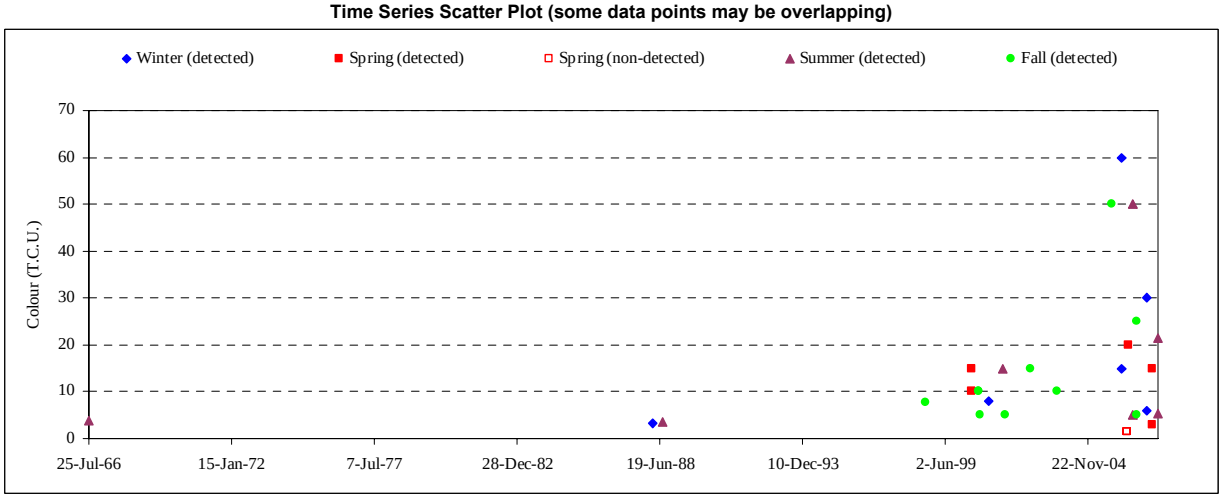
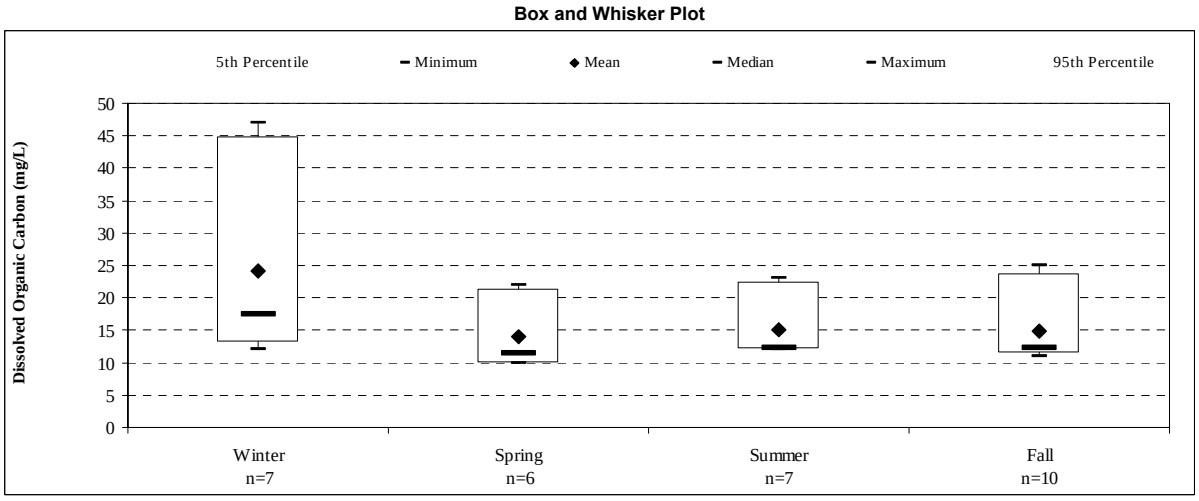


Figure G-1-5-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in McClelland Lake



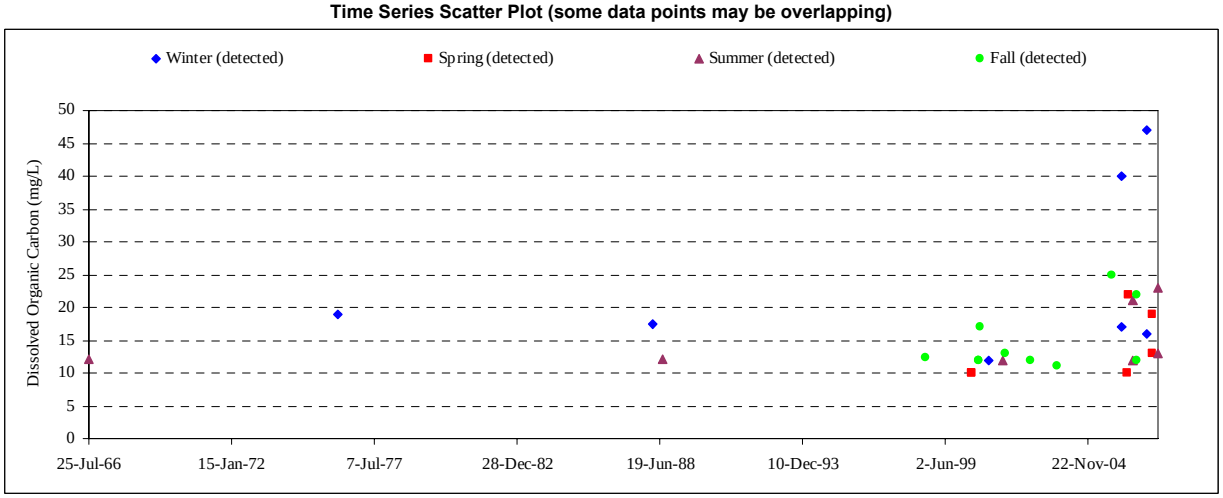
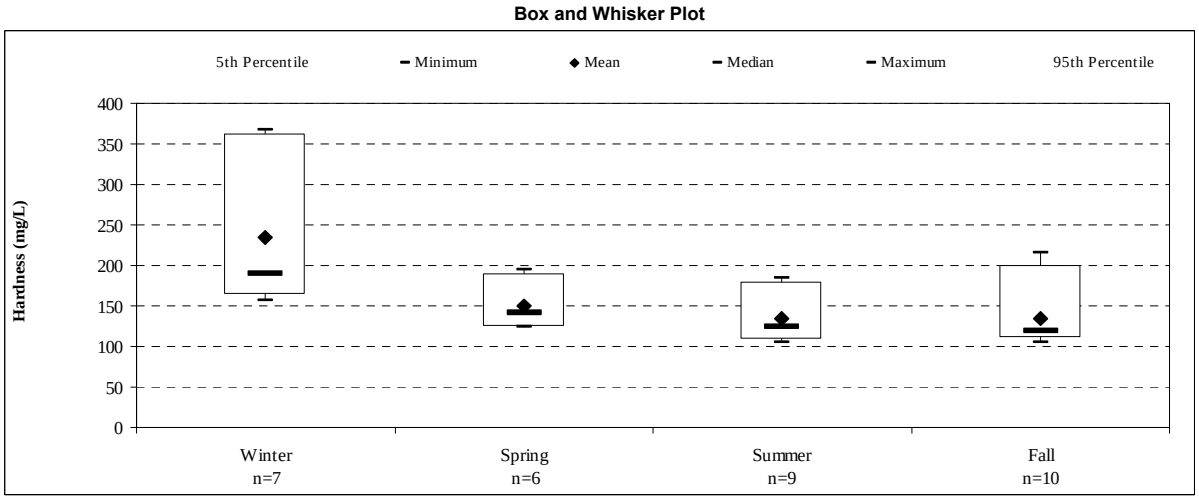


Figure G-1-5-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in McClelland Lake



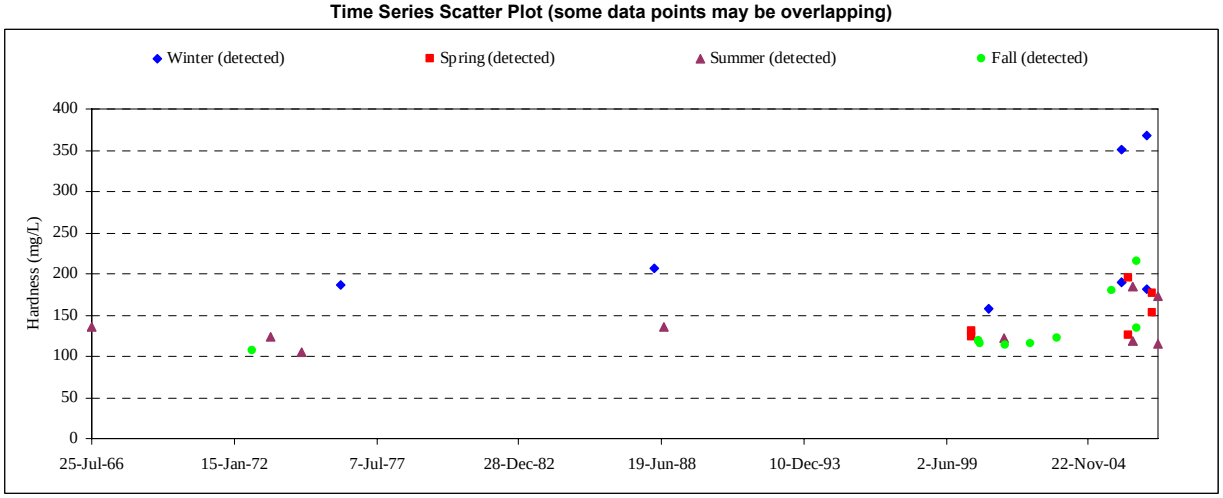
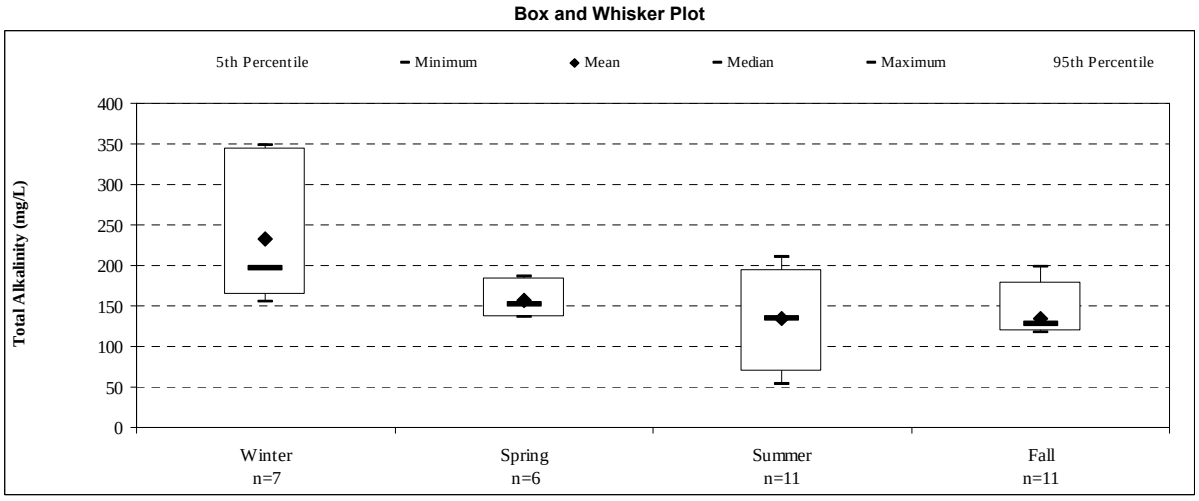


Figure G-1-5-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in McClelland Lake



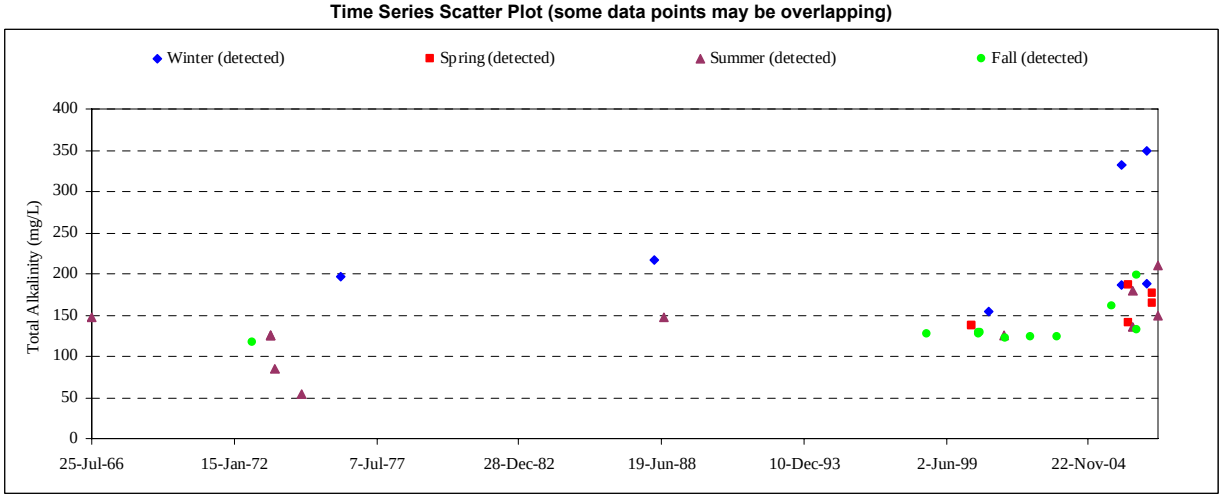
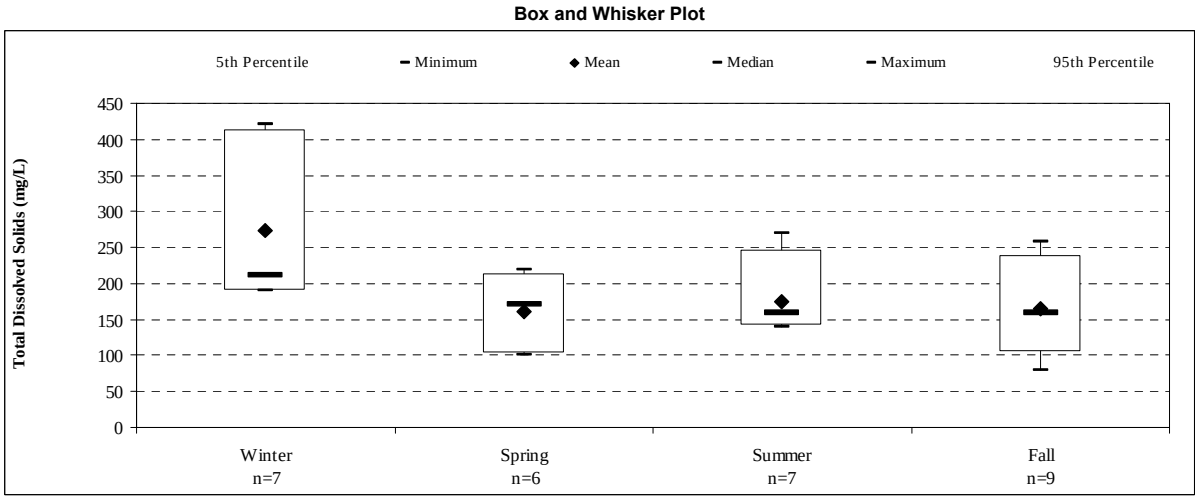


Figure G-1-5-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in McClelland Lake



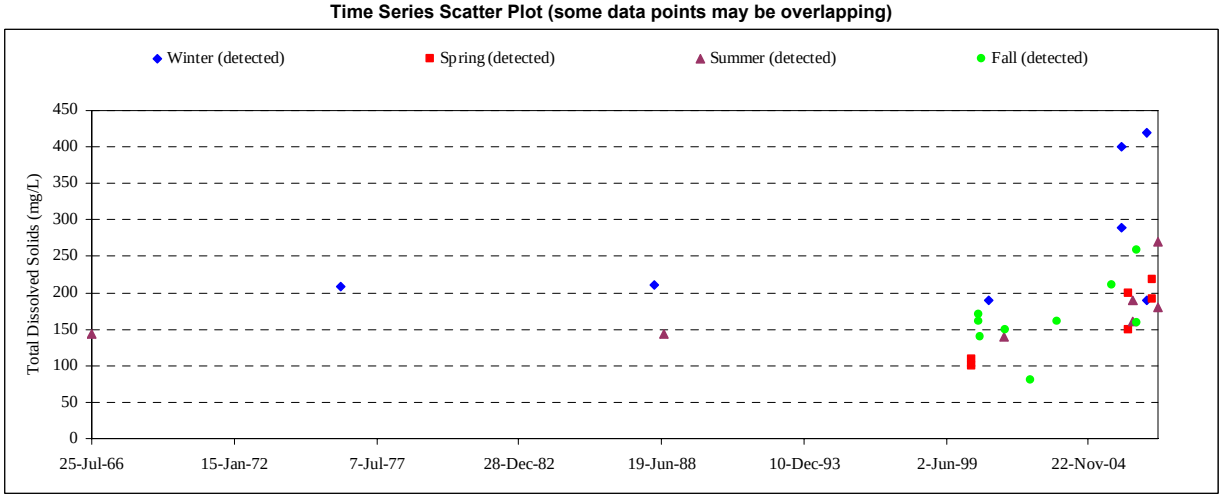
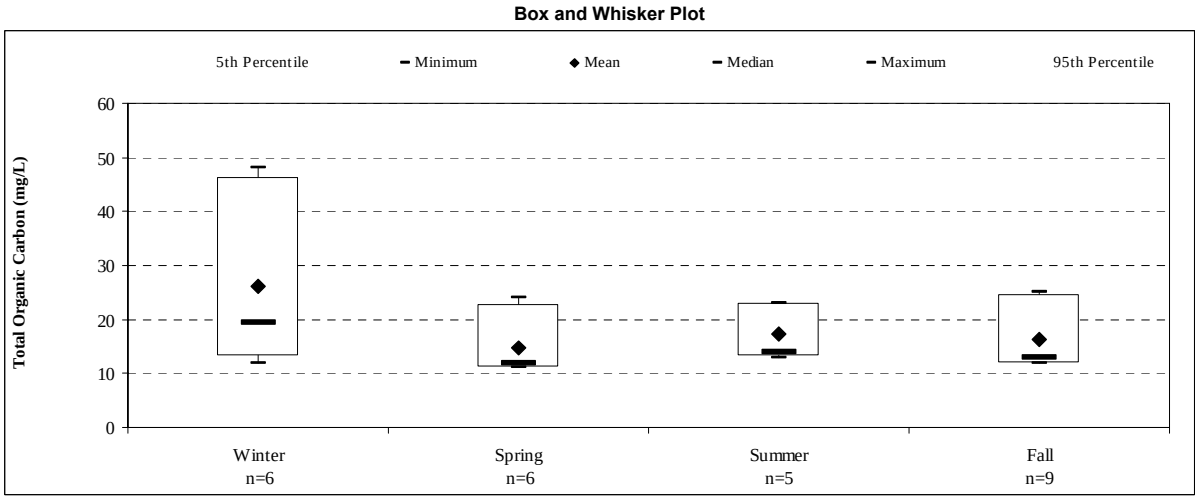


Figure G-1-5-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in McClelland Lake



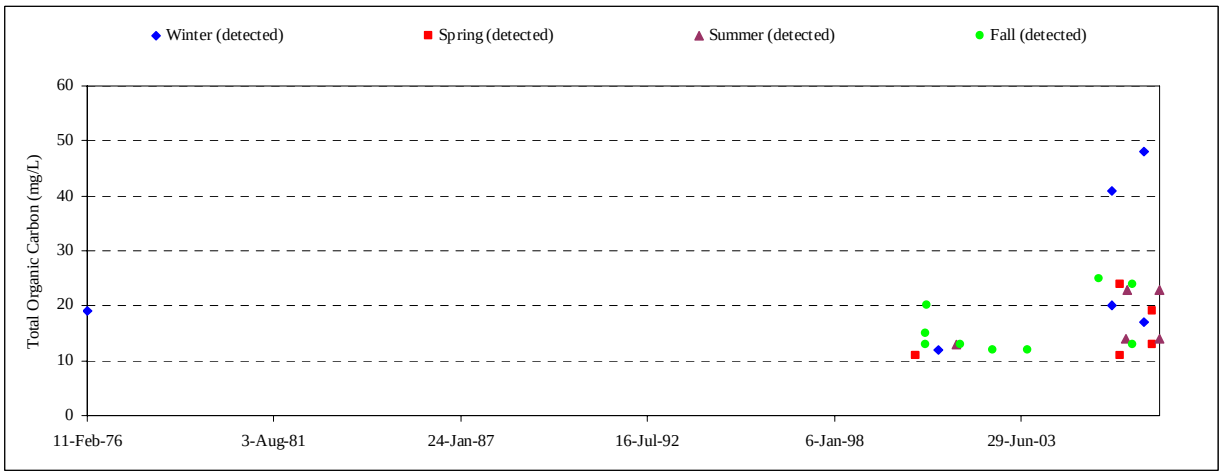
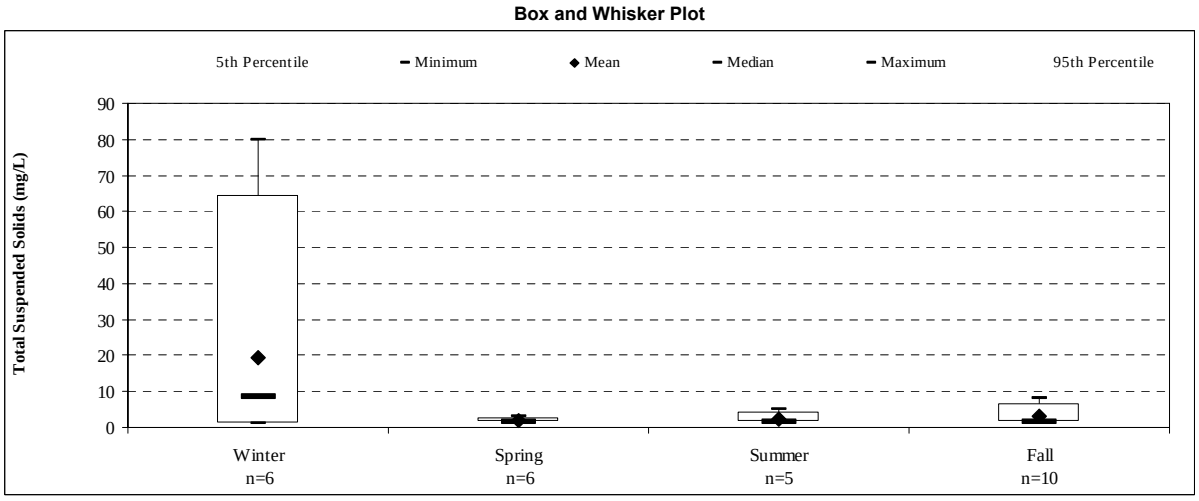


Figure G-1-5-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in McClelland Lake



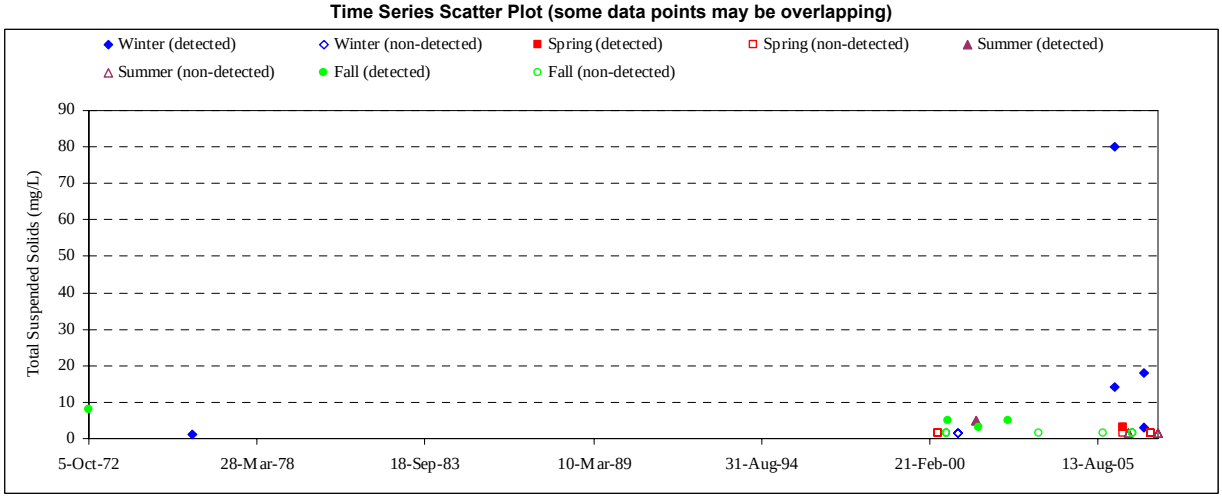
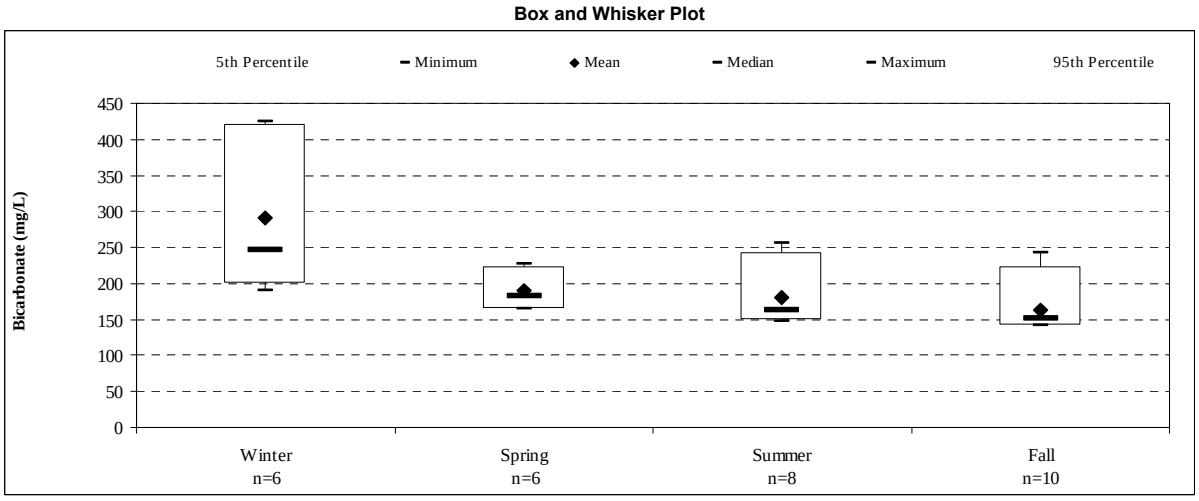


Figure G-1-5-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in McClelland Lake



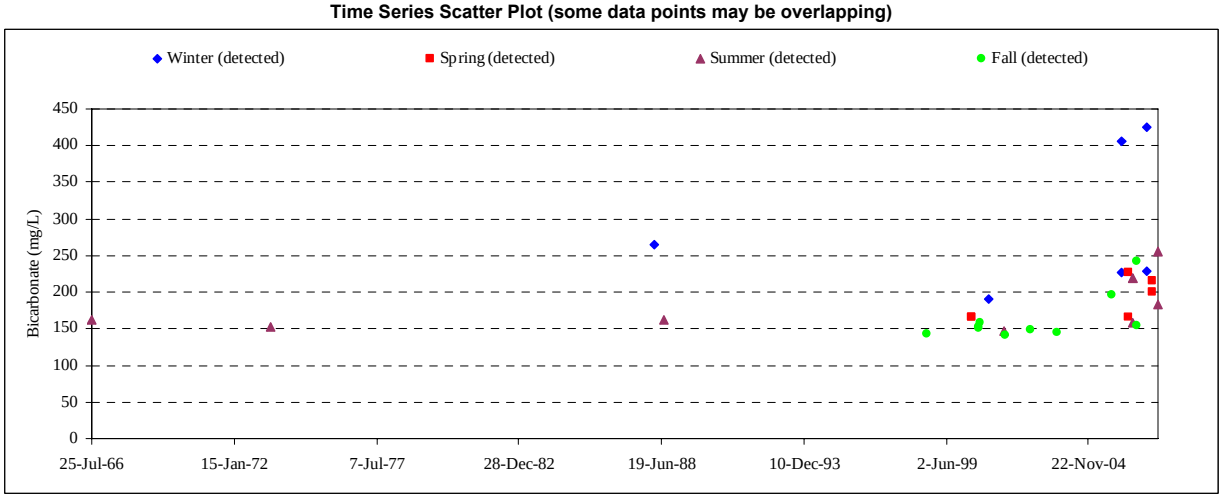
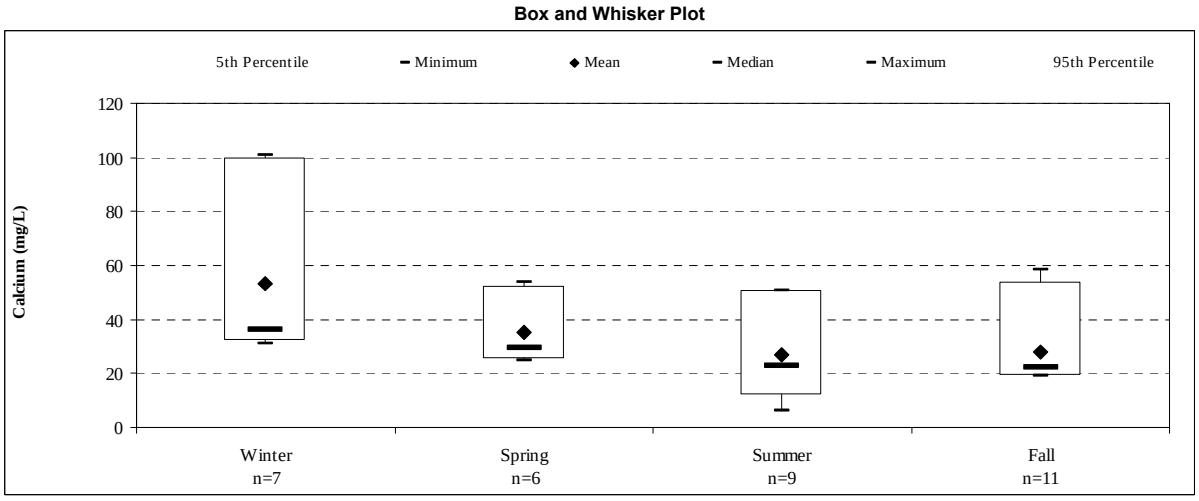


Figure G-1-5-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in McClelland Lake



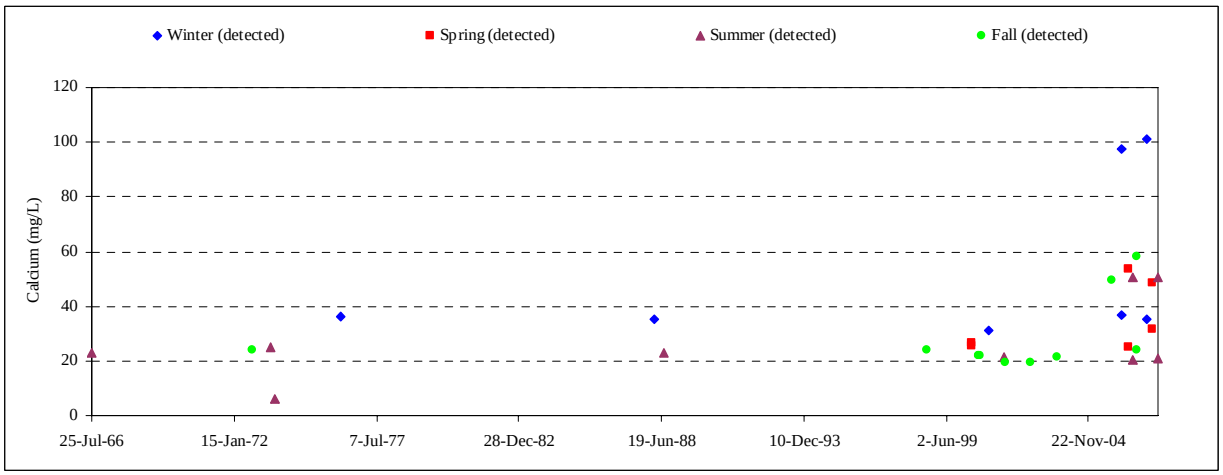
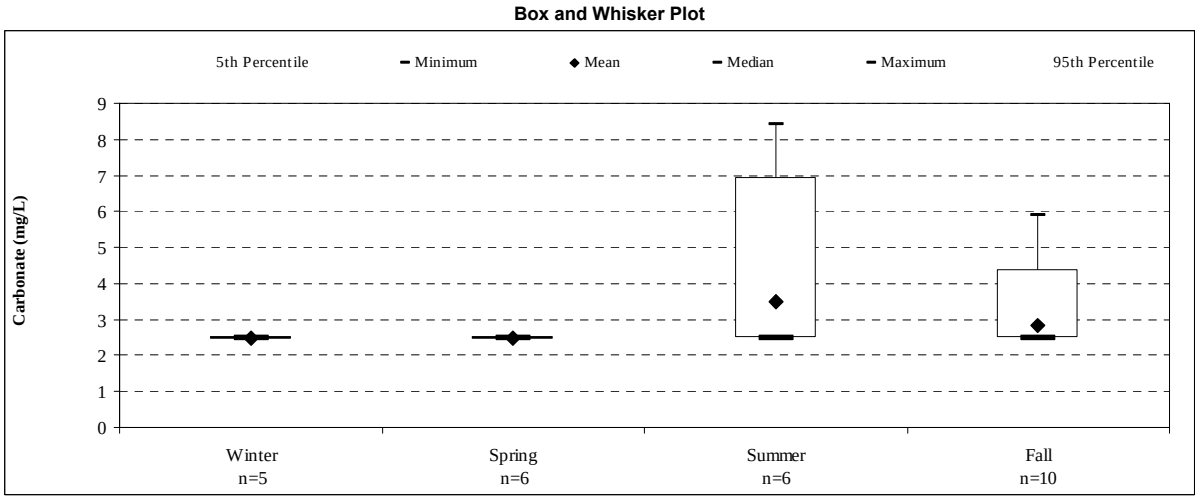


Figure G-1-5-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in McClelland Lake



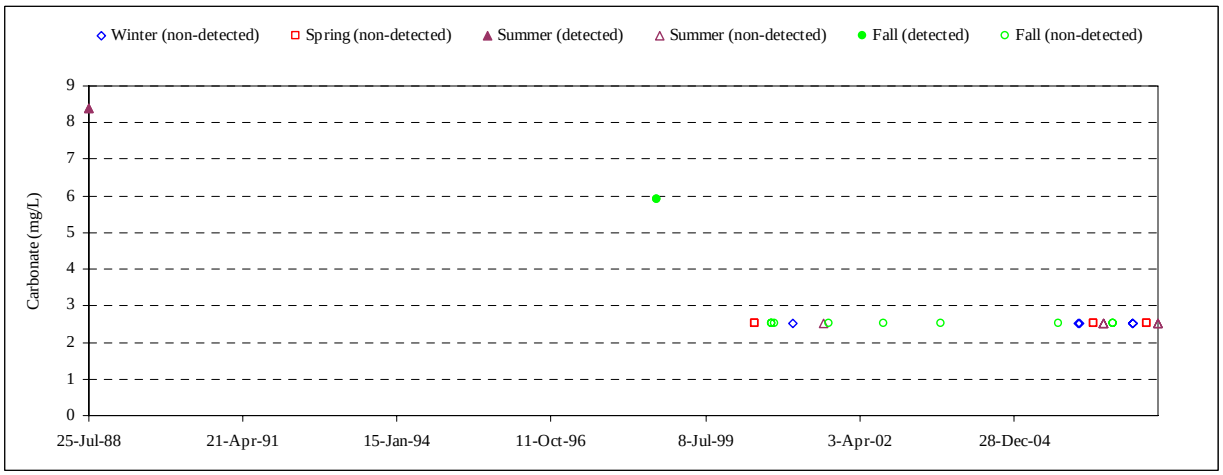
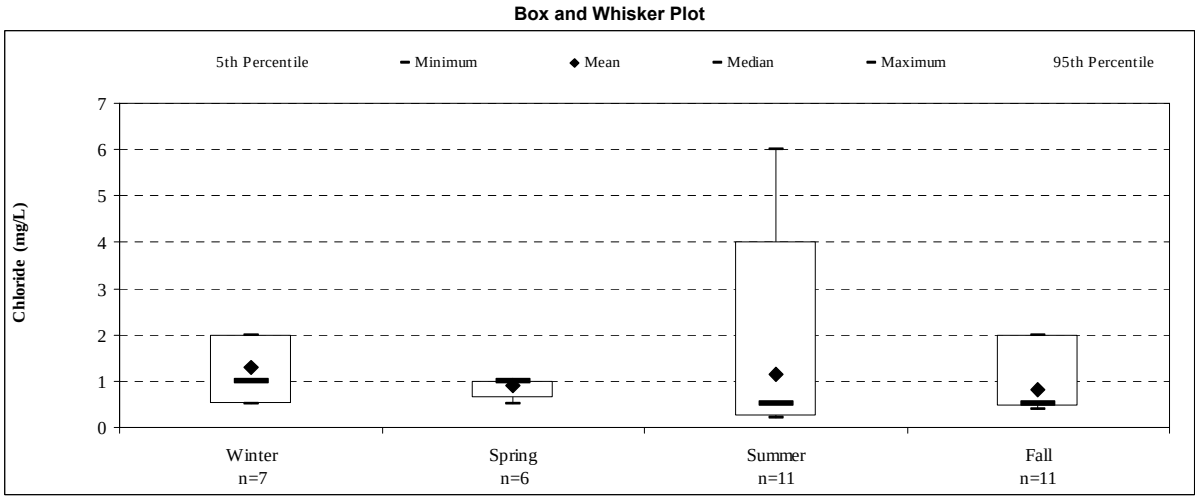


Figure G-1-5-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in McClelland Lake



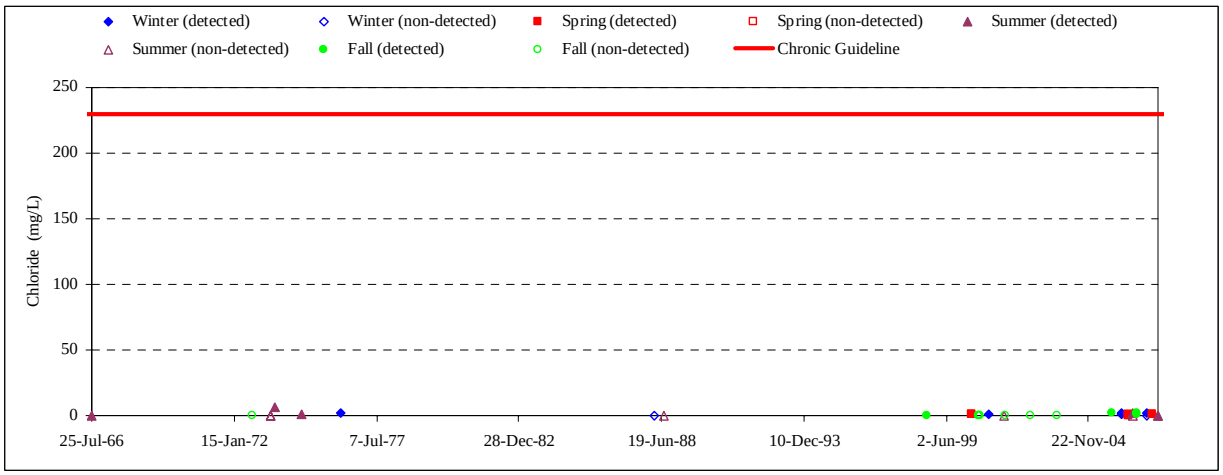
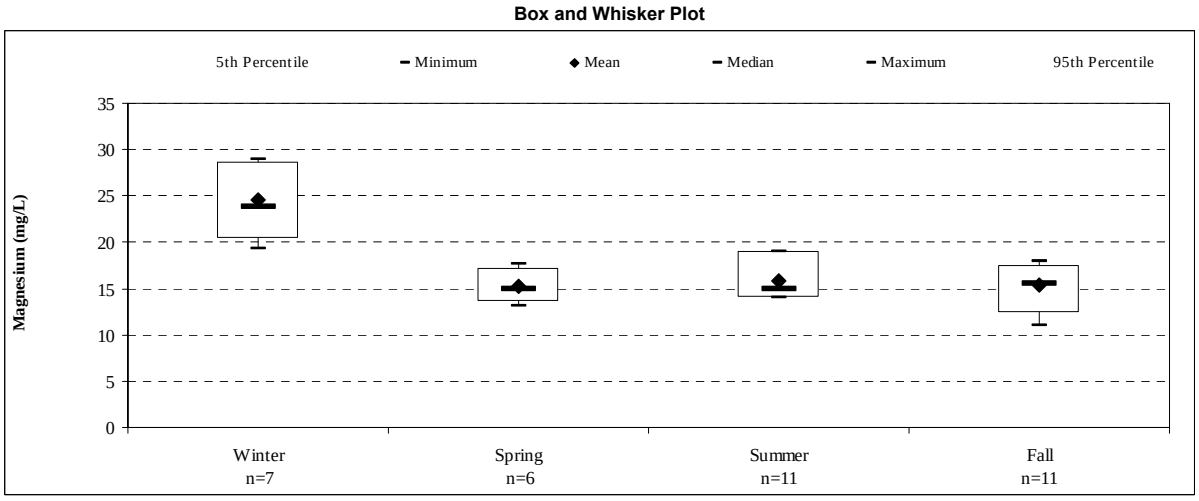


Figure G-1-5-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in McClelland Lake



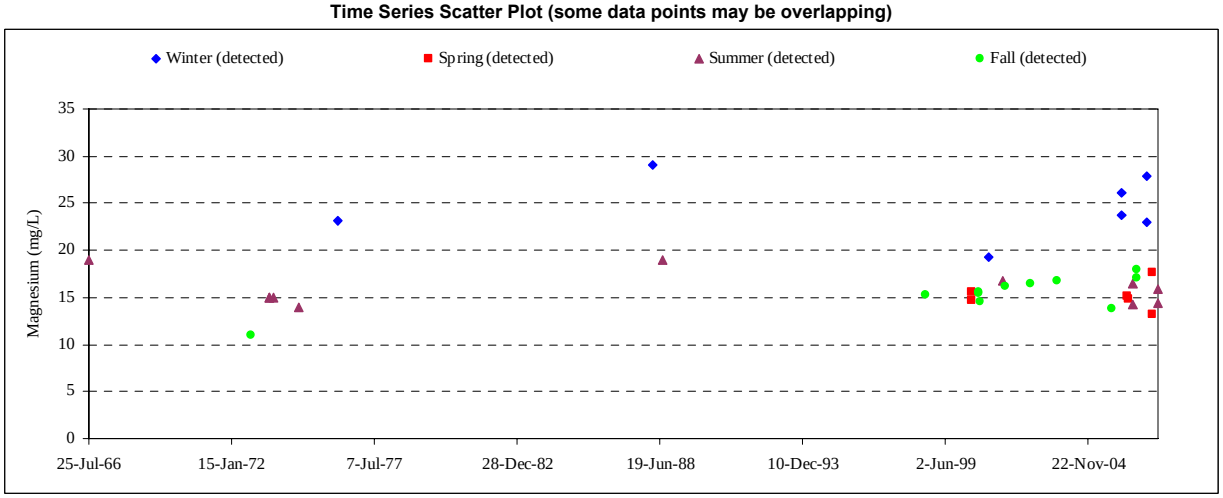
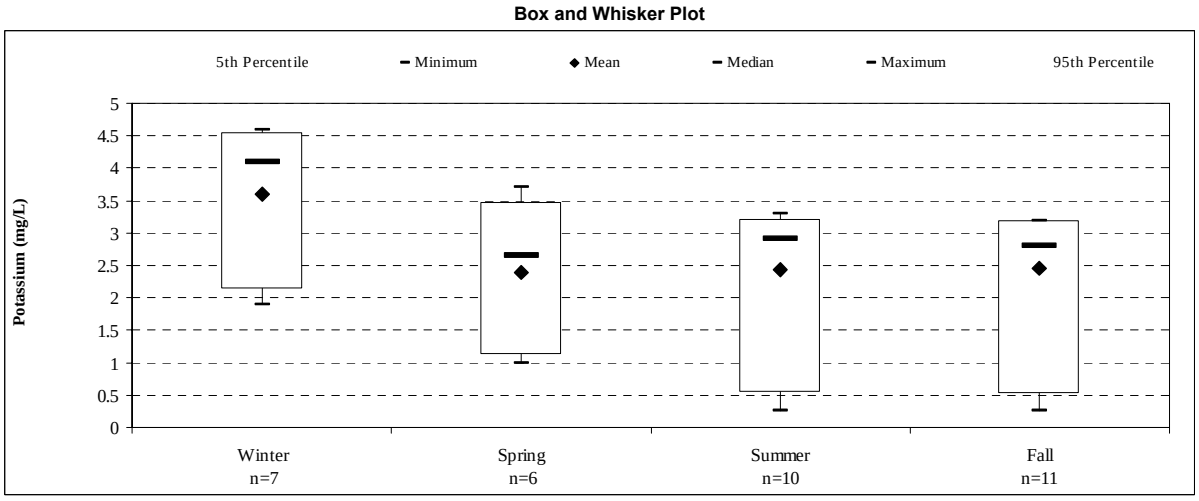


Figure G-1-5-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in McClelland Lake



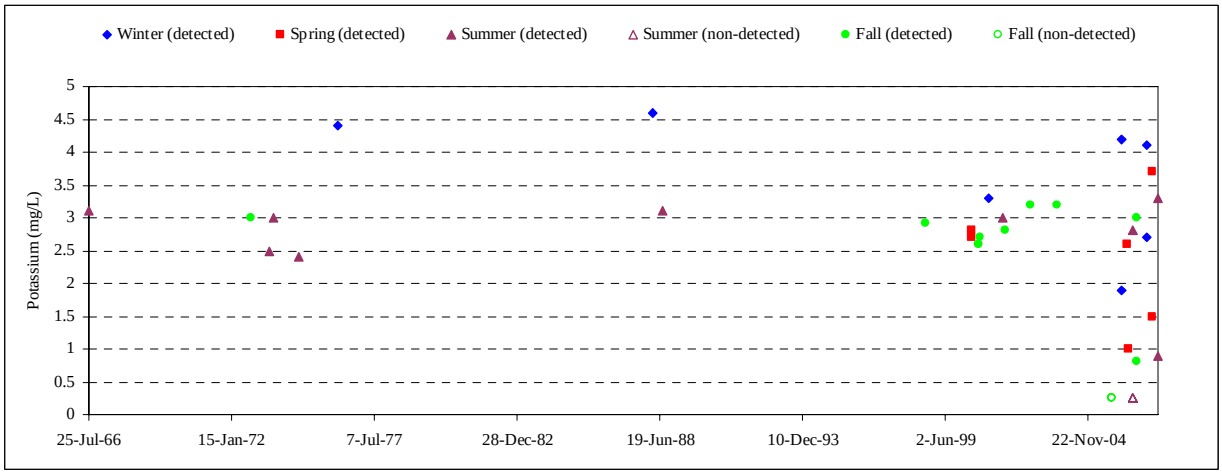
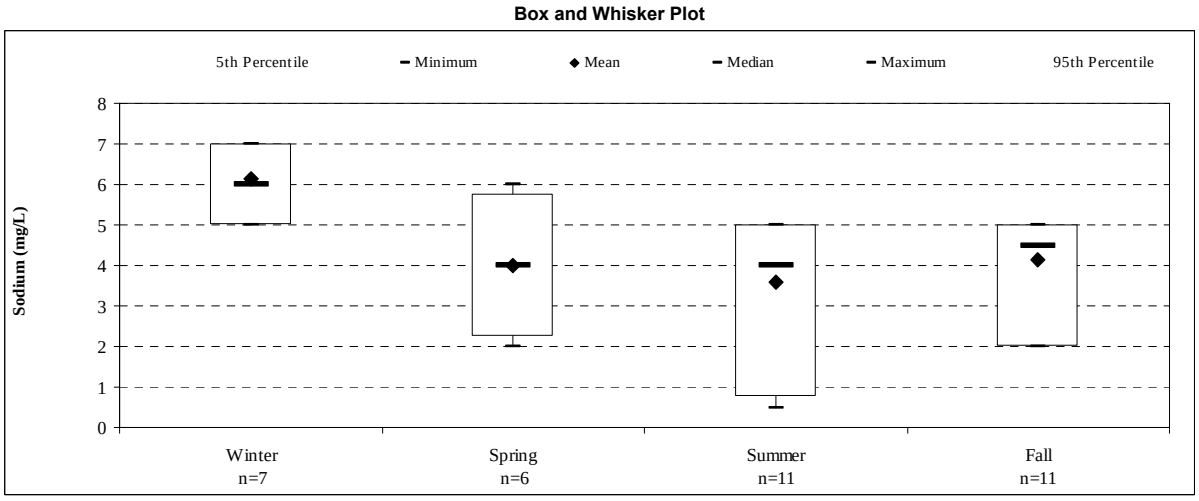


Figure G-1-5-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in McClelland Lake



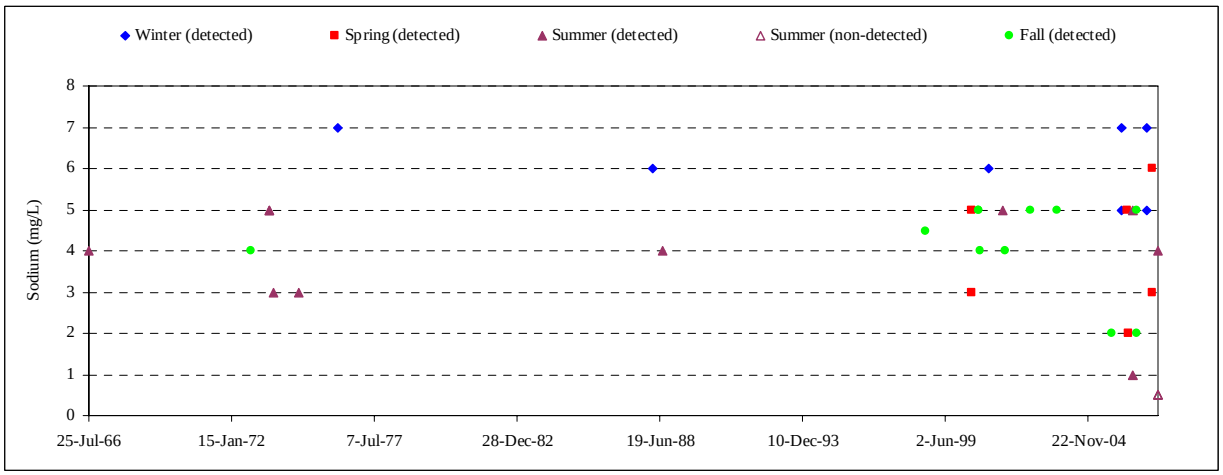
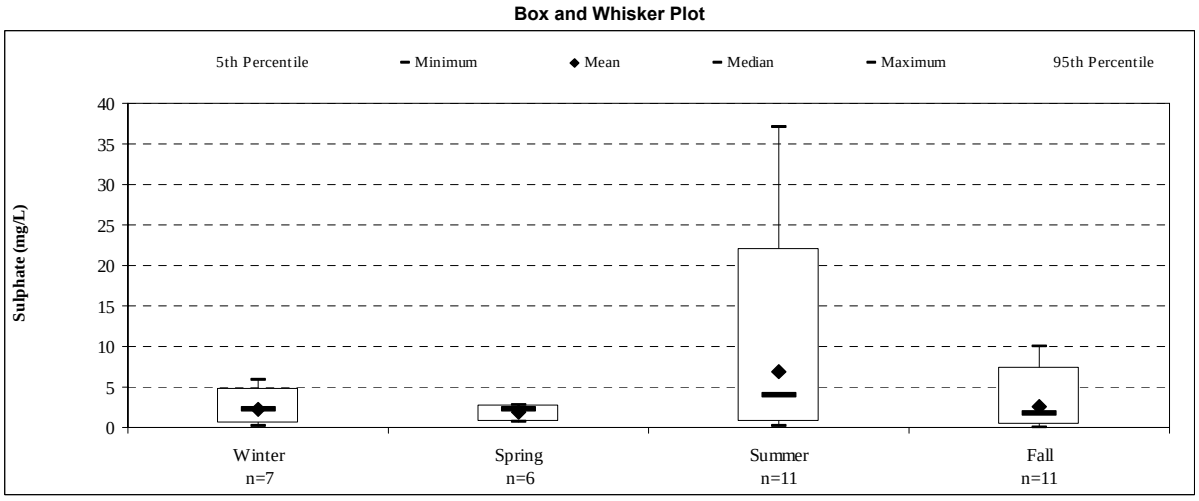


Figure G-1-5-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in McClelland Lake



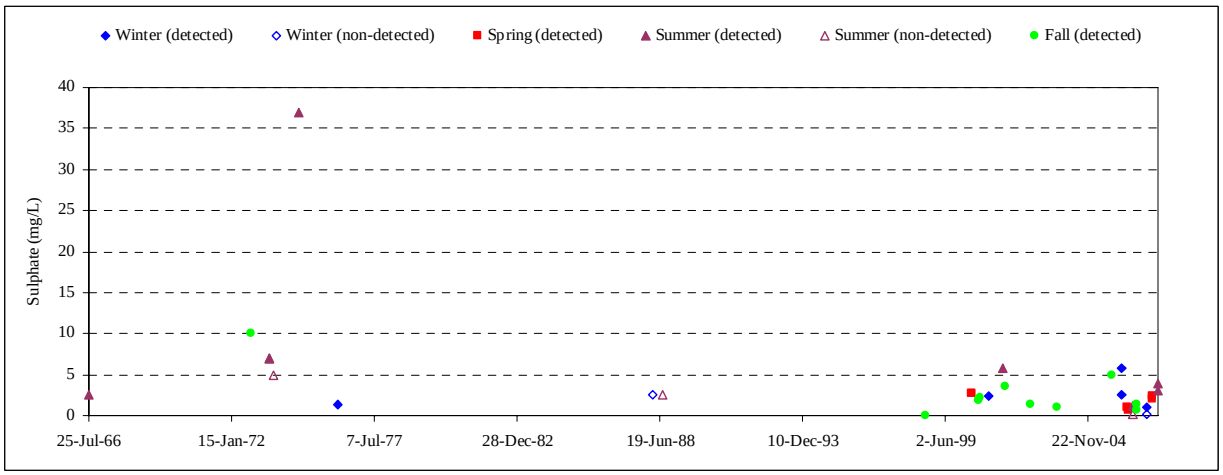
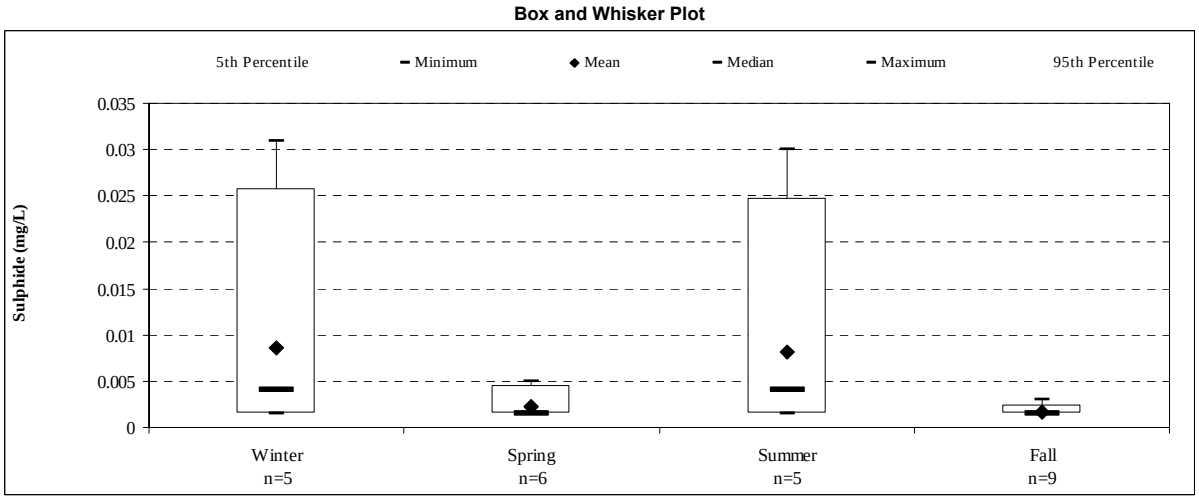


Figure G-1-5-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in McClelland Lake



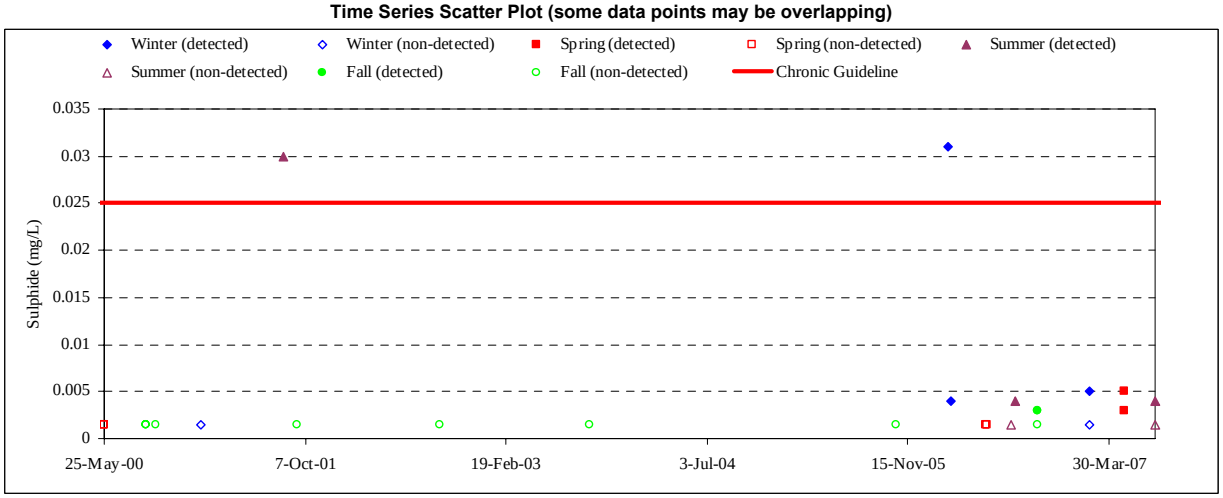
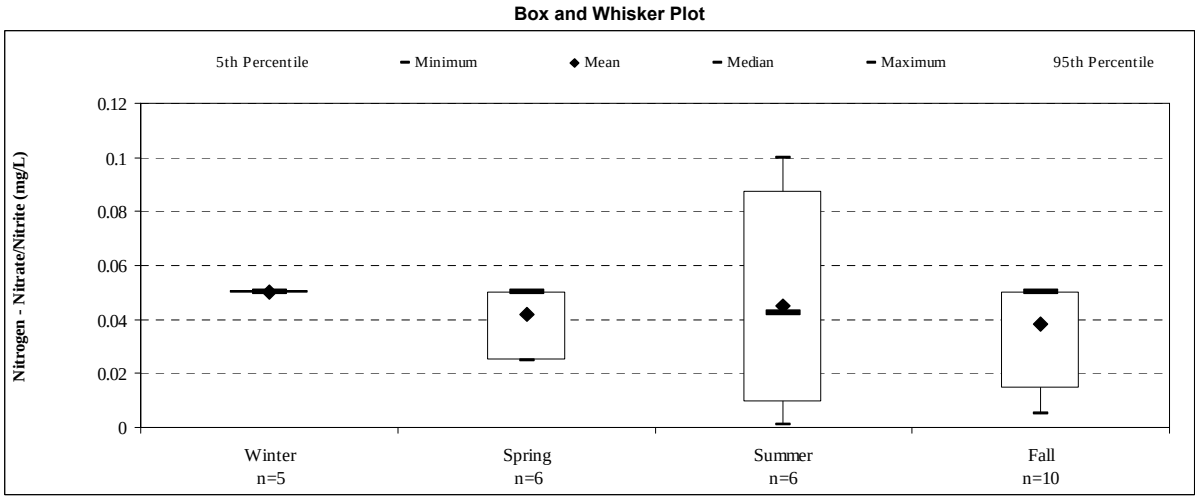


Figure G-1-5-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in McClelland Lake



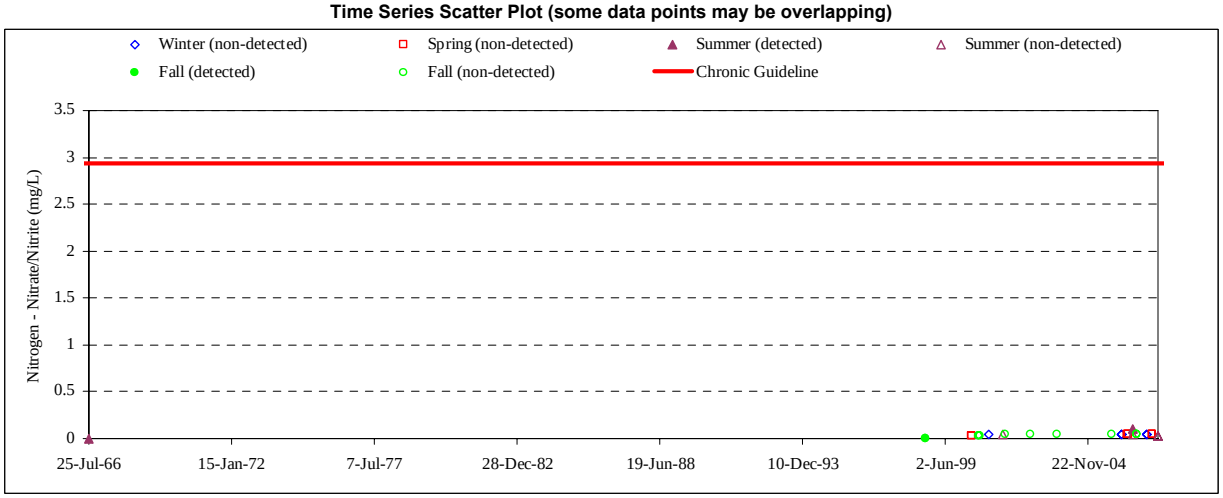
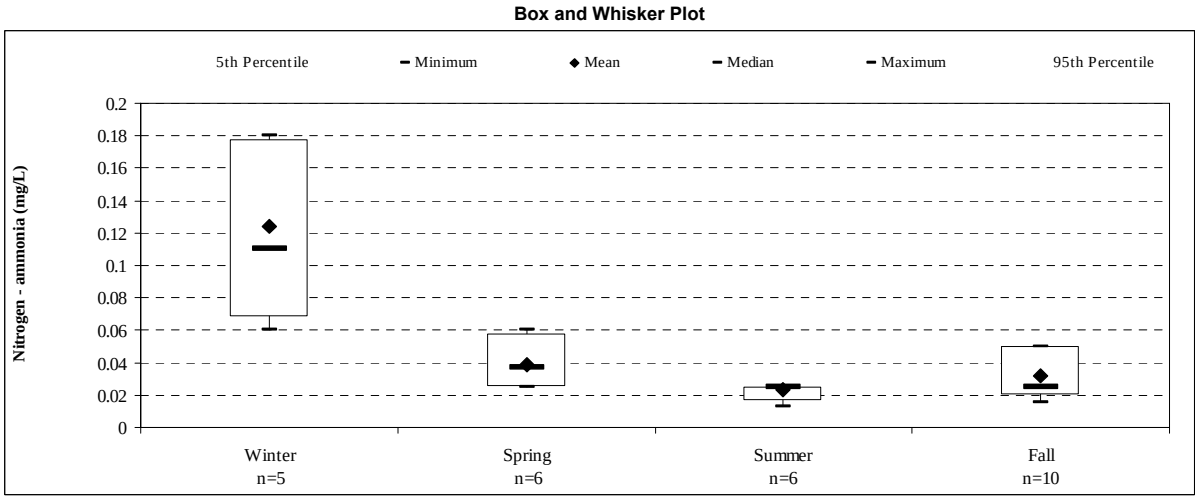


Figure G-1-5-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in McClelland Lake



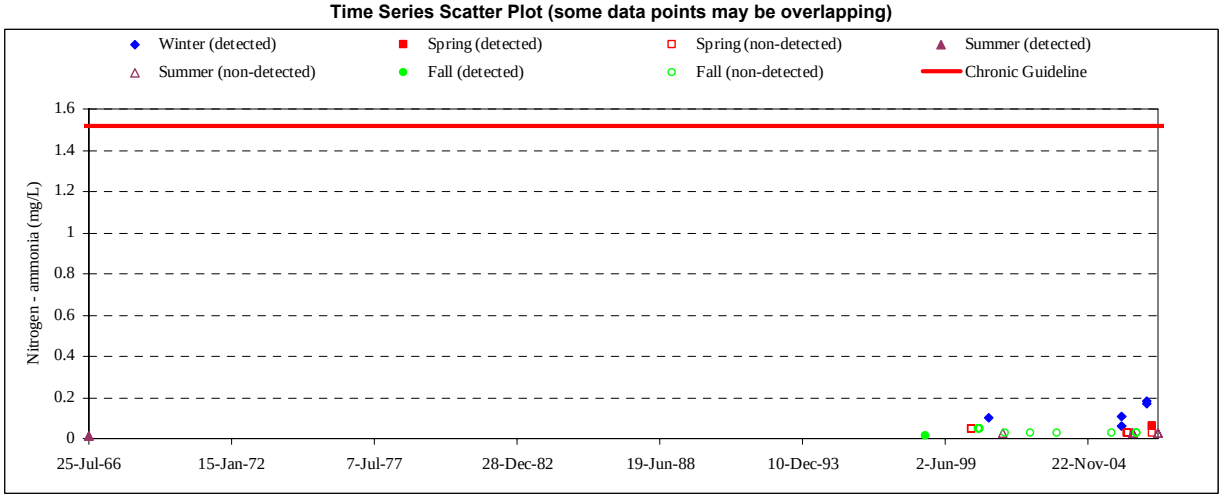
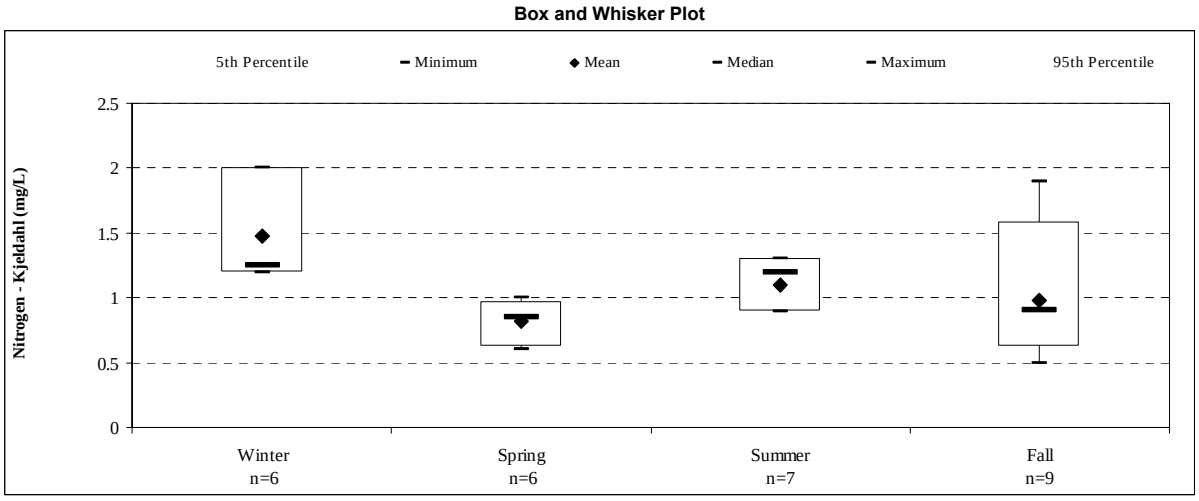


Figure G-1-5-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in McClelland Lake



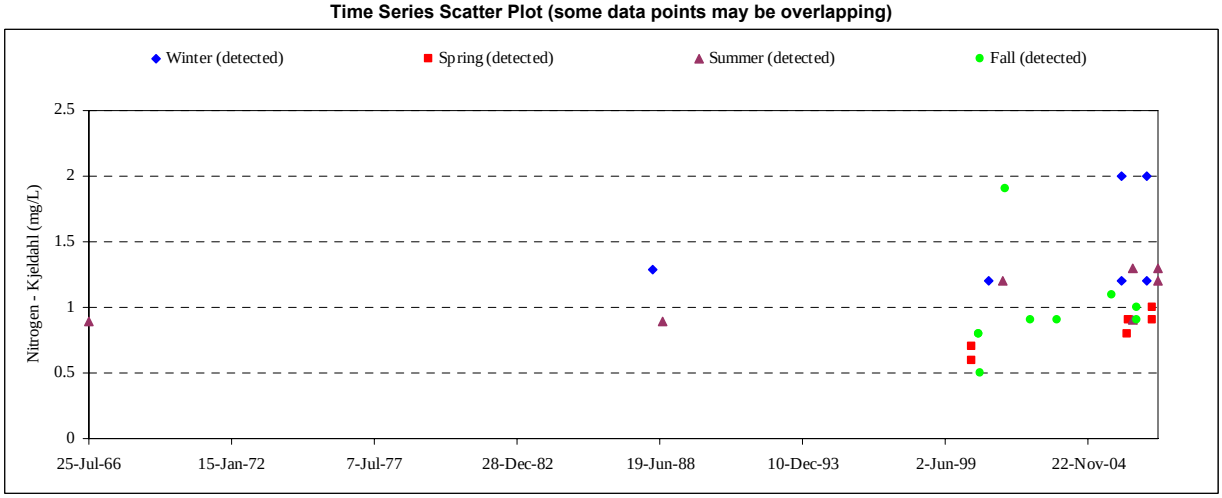
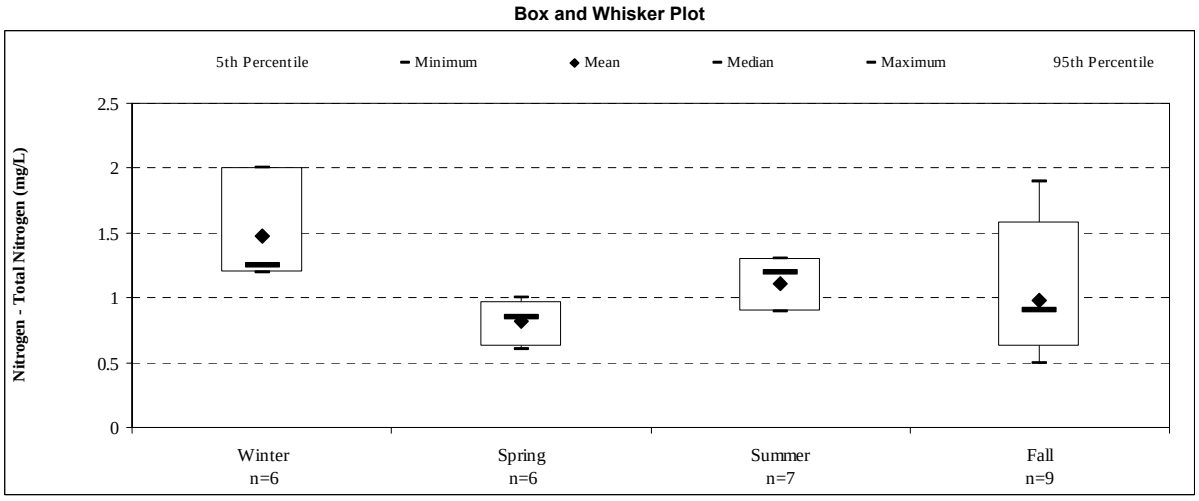


Figure G-1-5-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in McClelland Lake



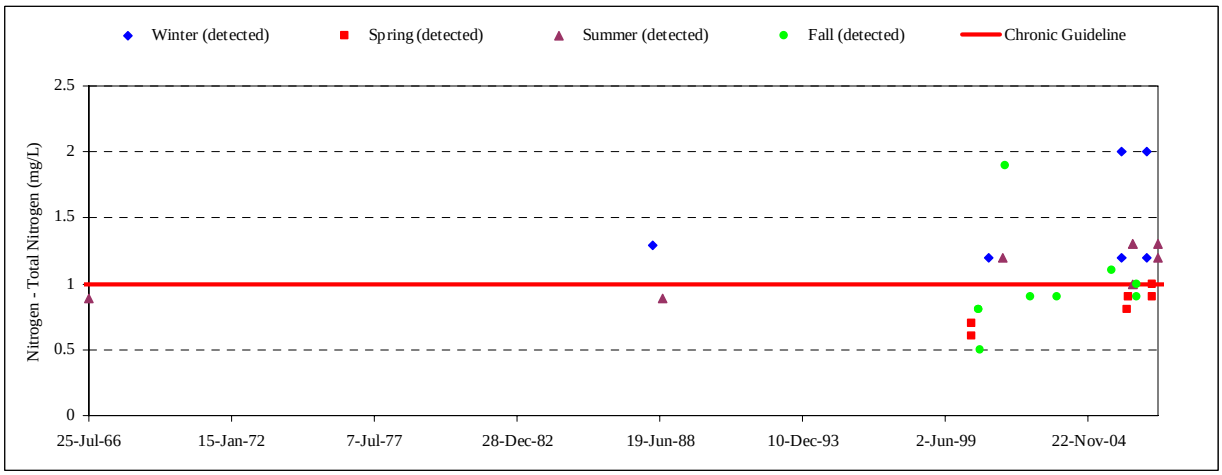
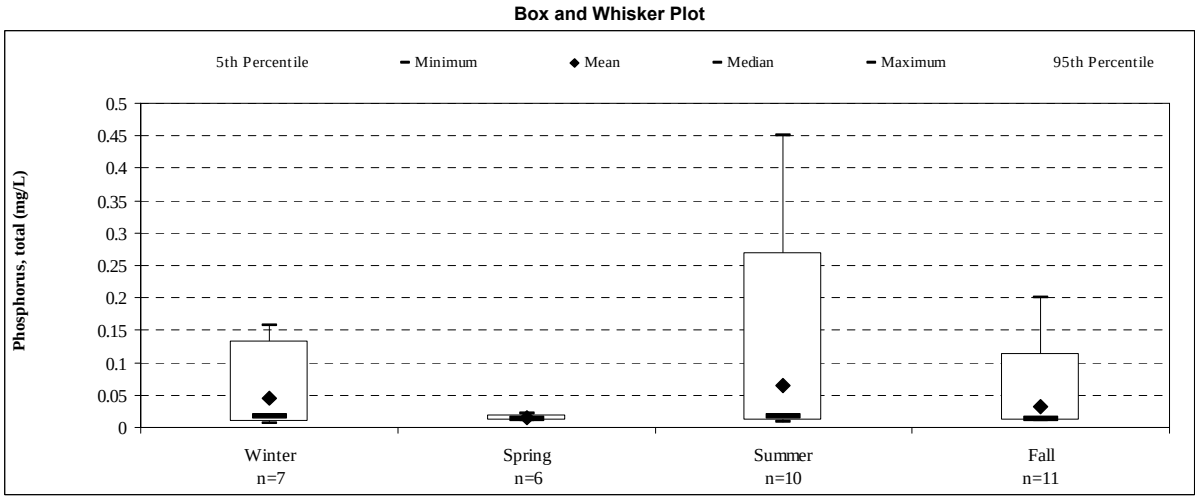


Figure G-1-5-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in McClelland Lake



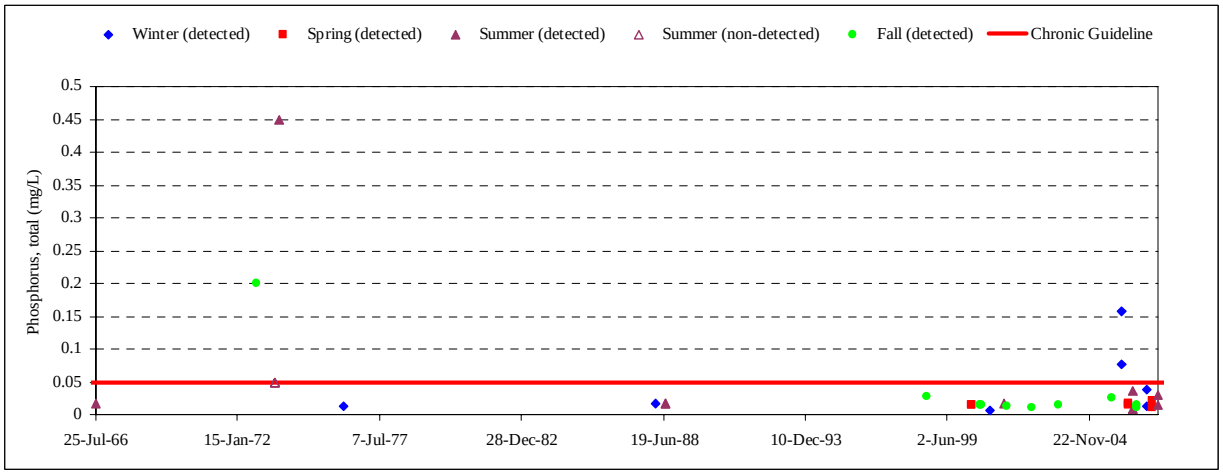
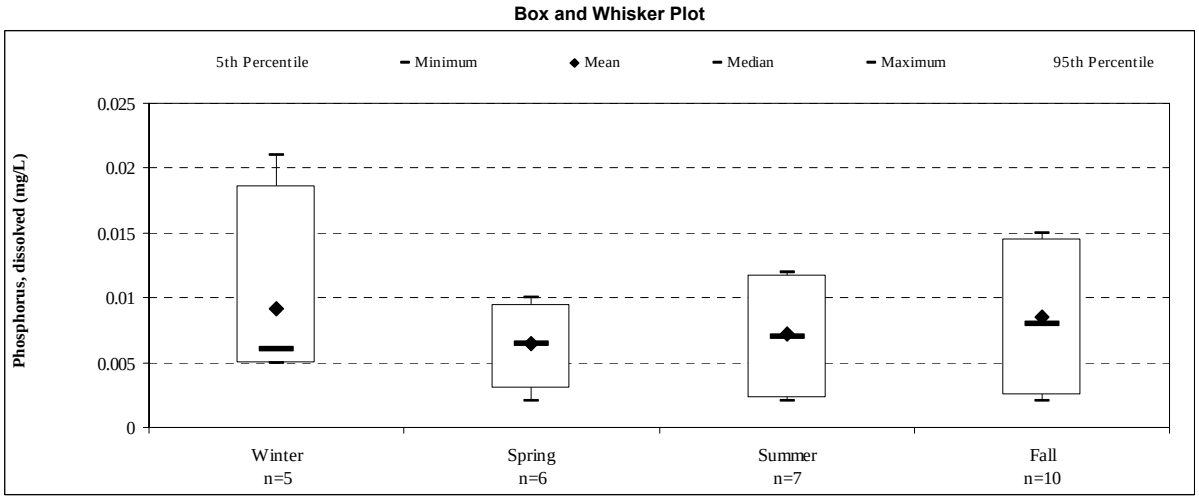


Figure G-1-5-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in McClelland Lake



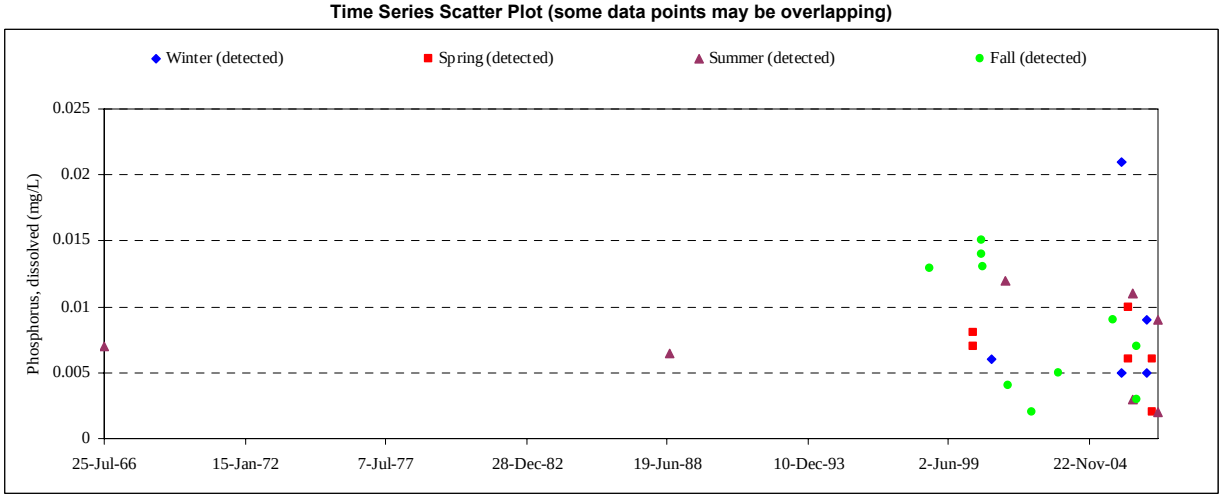
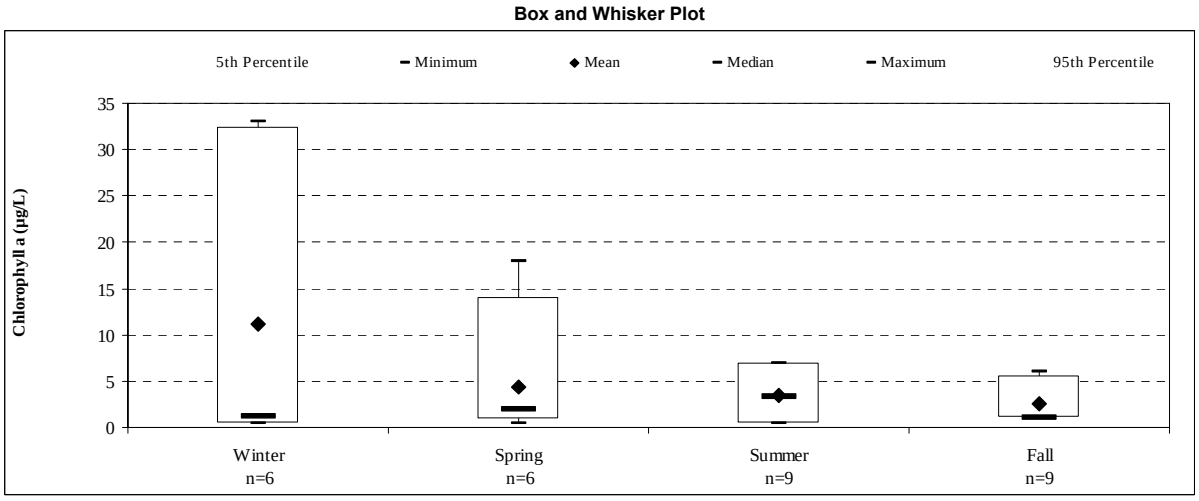


Figure G-1-5-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in McClelland Lake



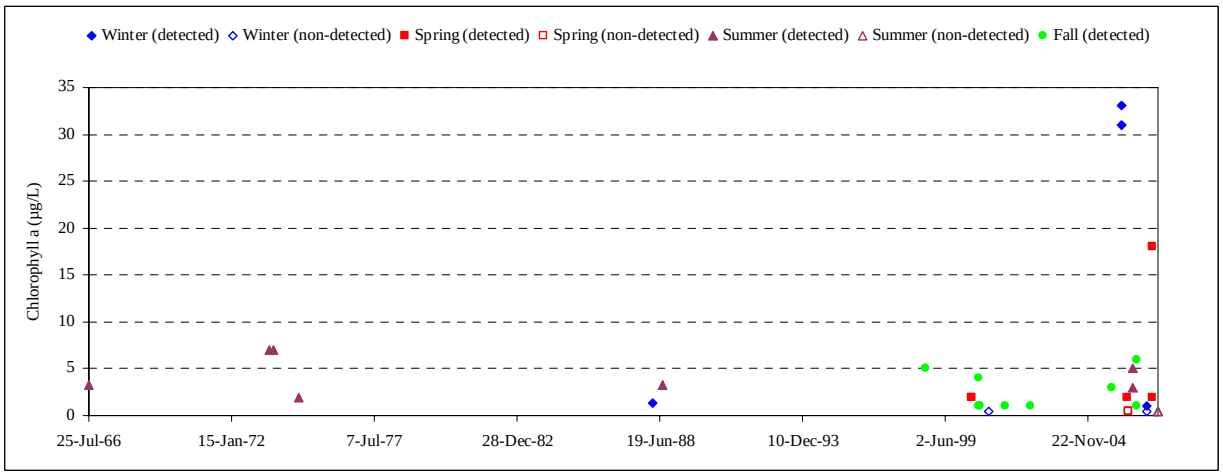
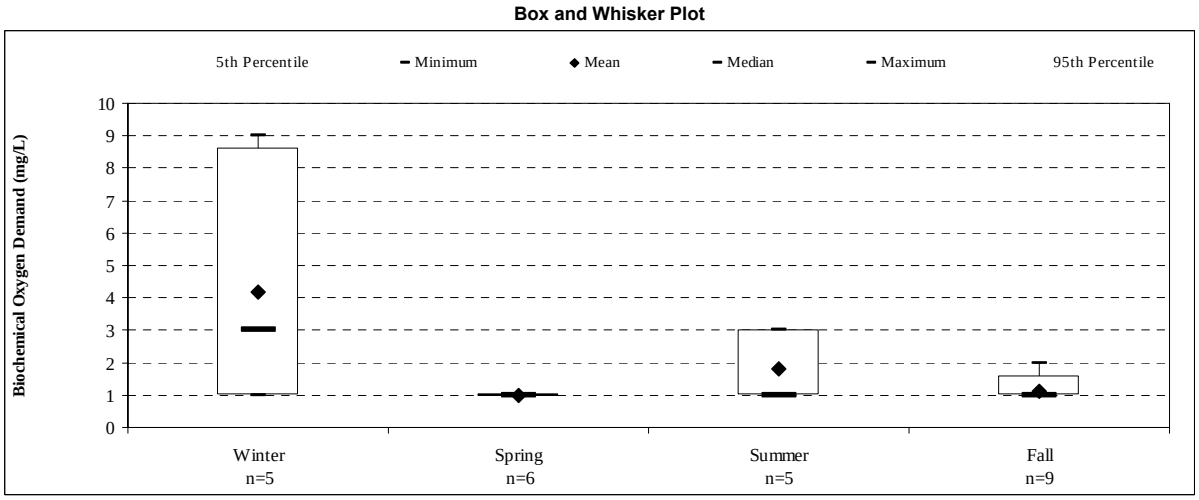


Figure G-1-5-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in McClelland Lake



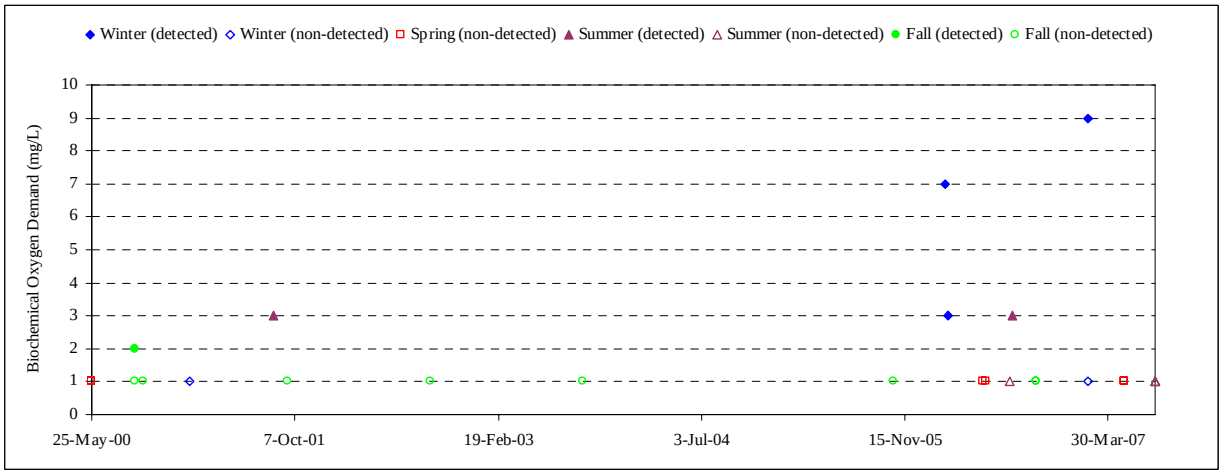
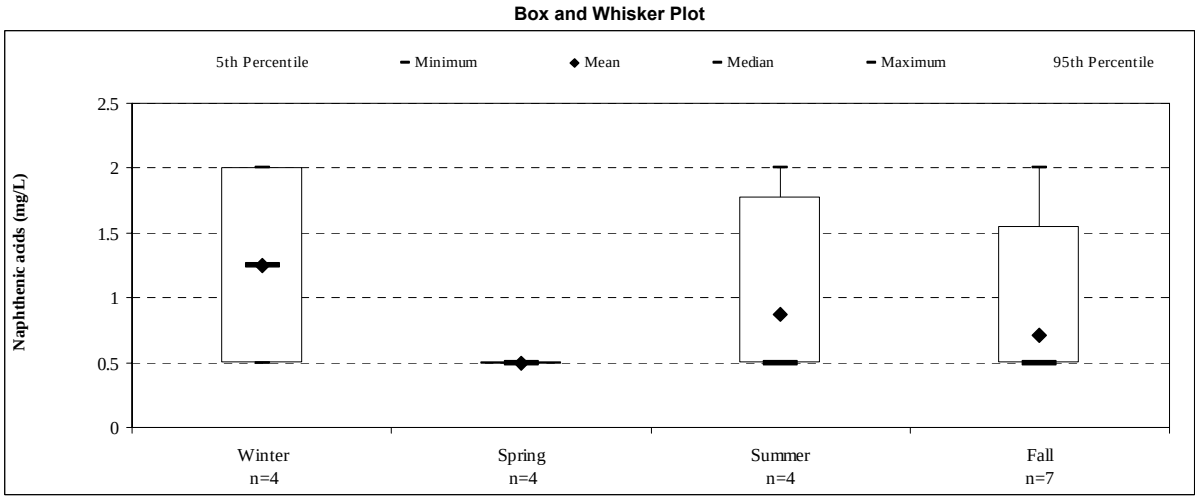


Figure G-1-5-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in McClelland Lake



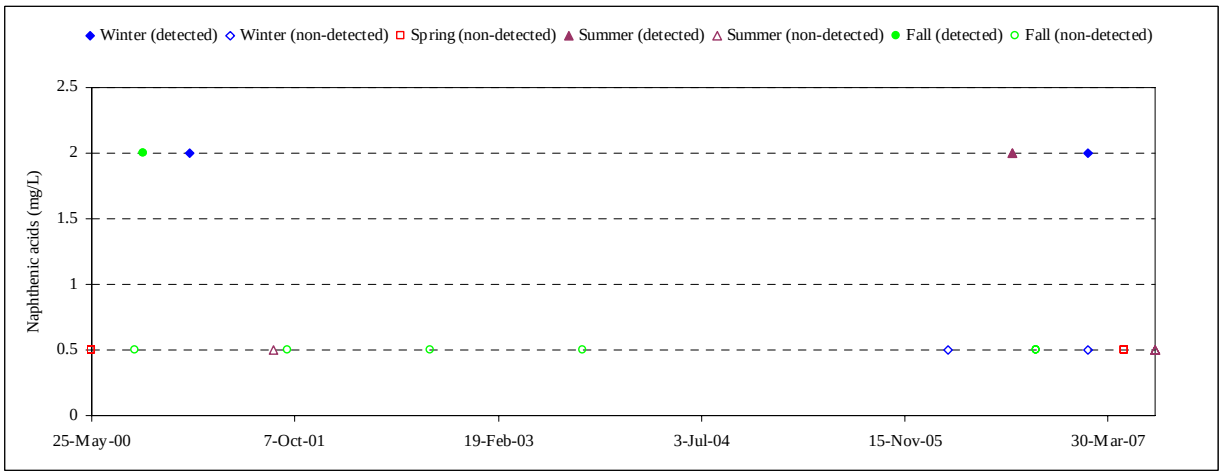
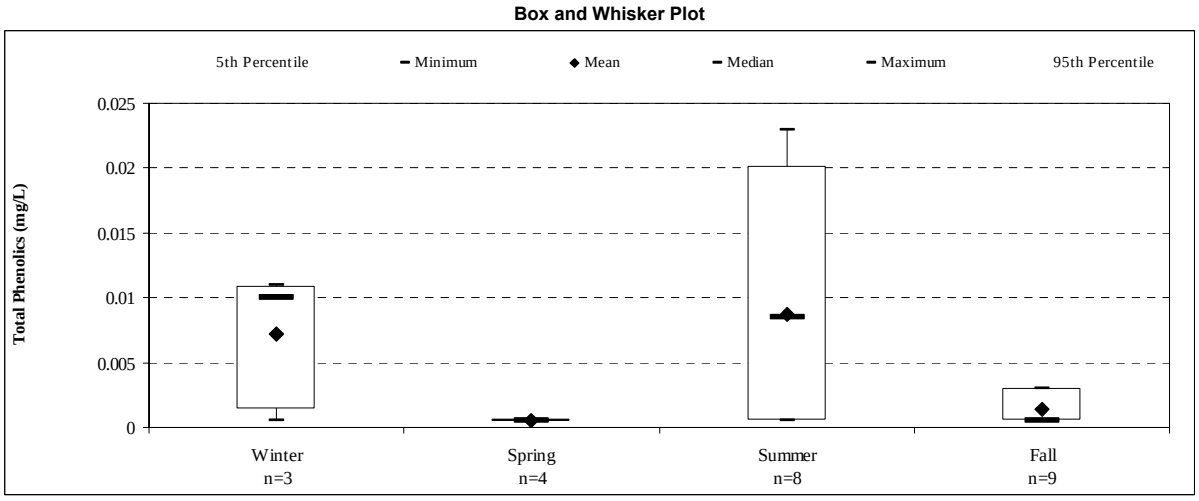


Figure G-1-5-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in McClelland Lake



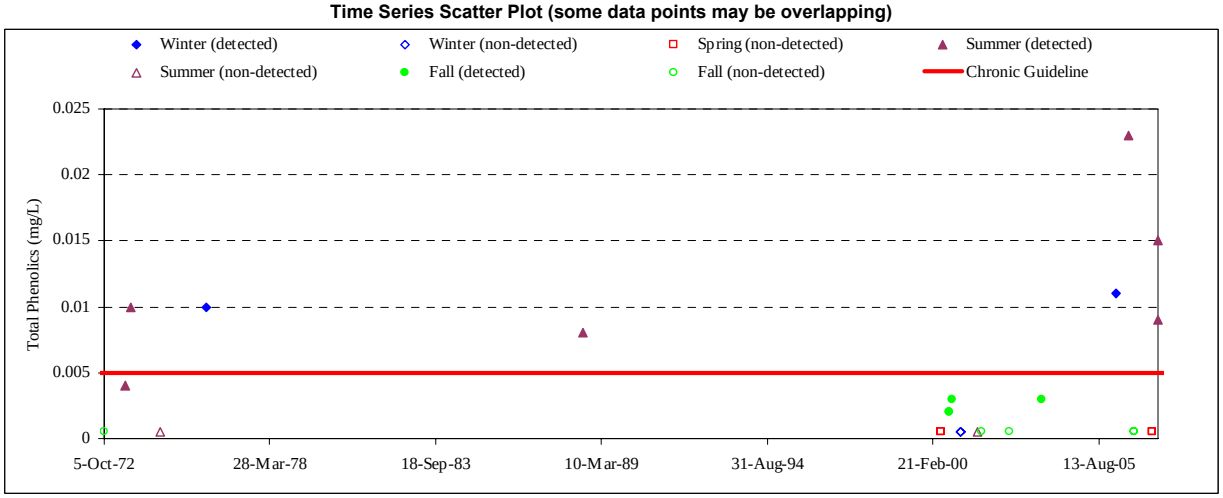


Figure G-1-5-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in McClelland Lake

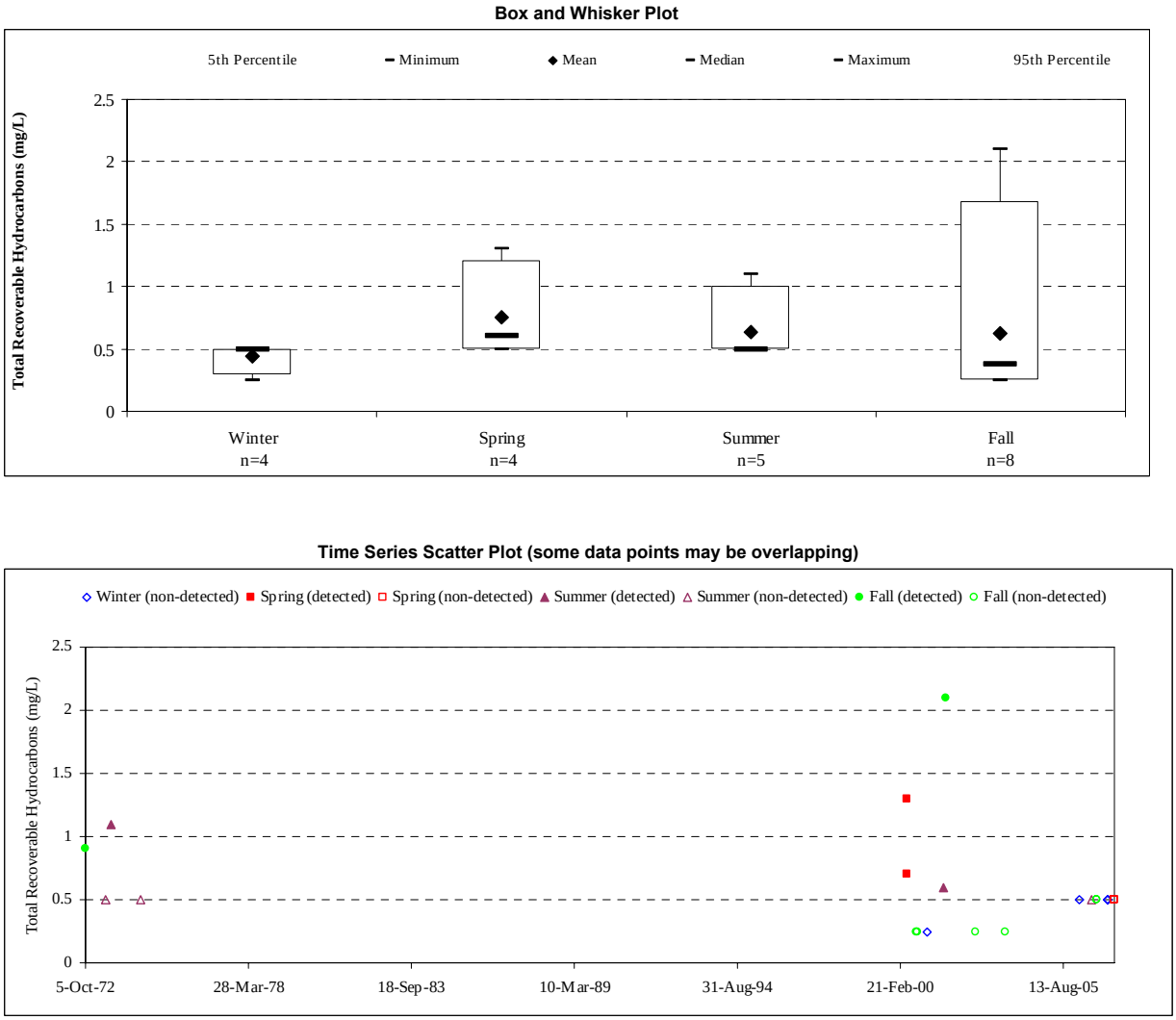
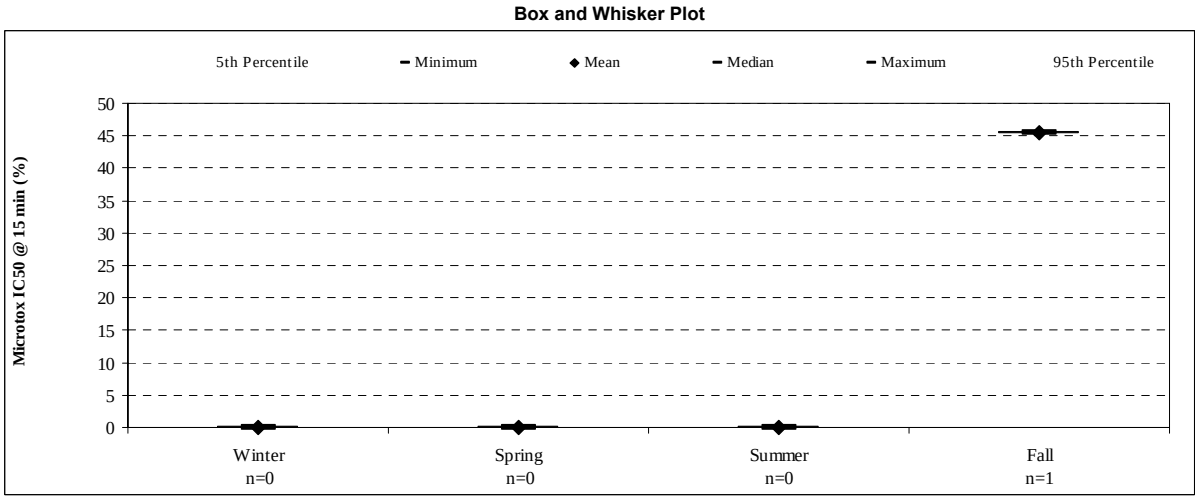


Figure G-1-5-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in McClelland Lake



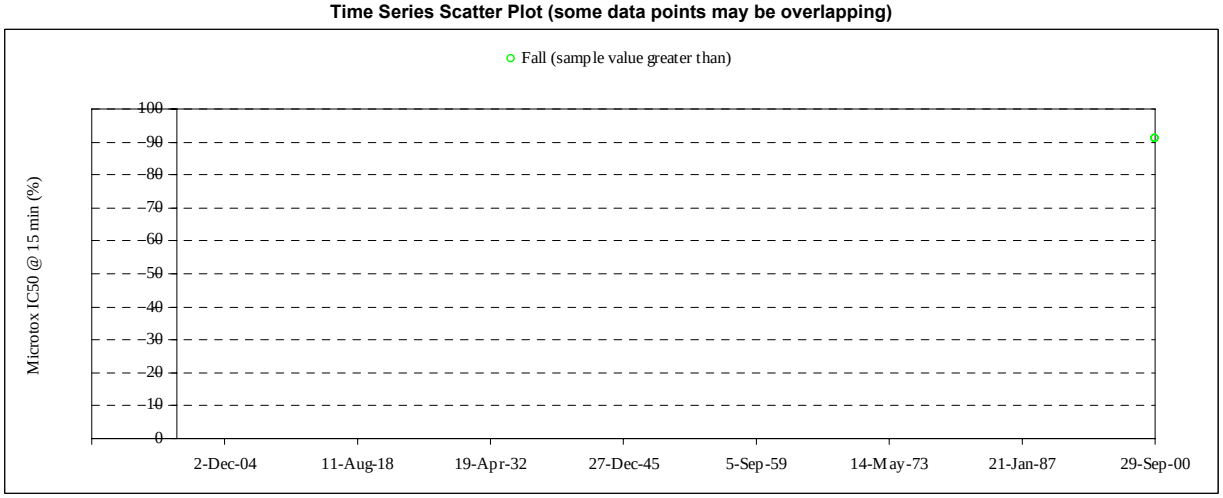
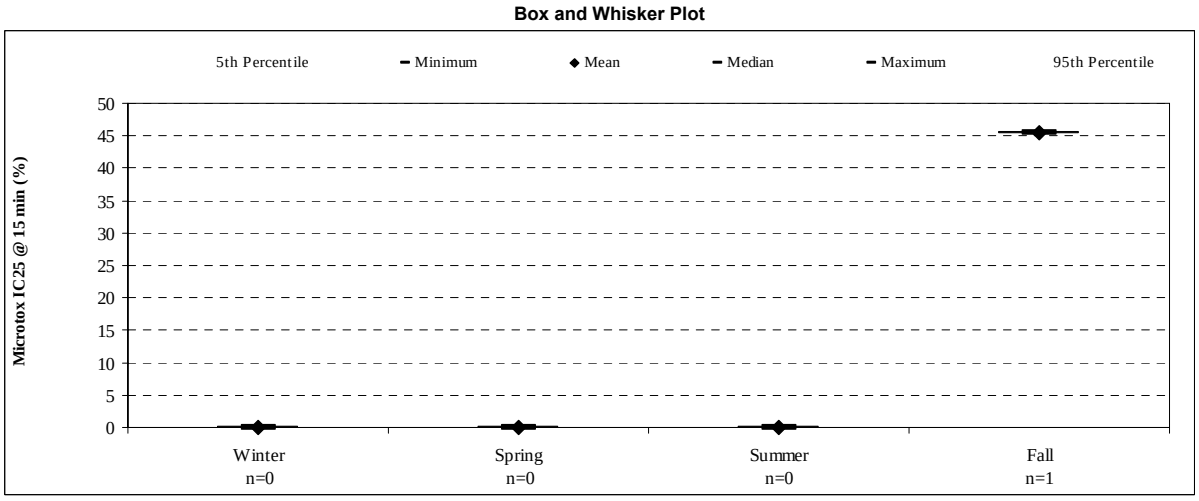


Figure G-1-5-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in McClelland Lake



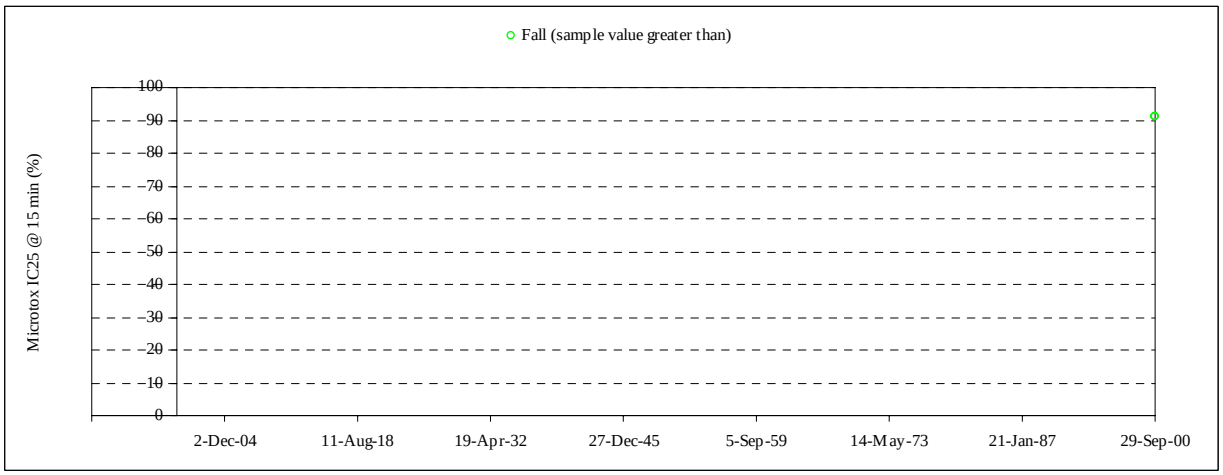
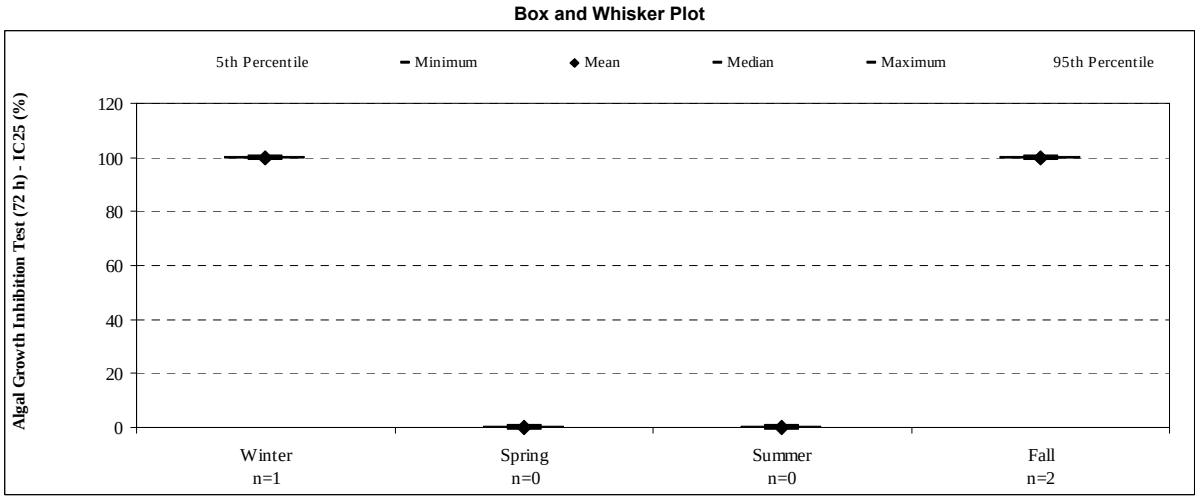


Figure G-1-5-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in McClelland Lake



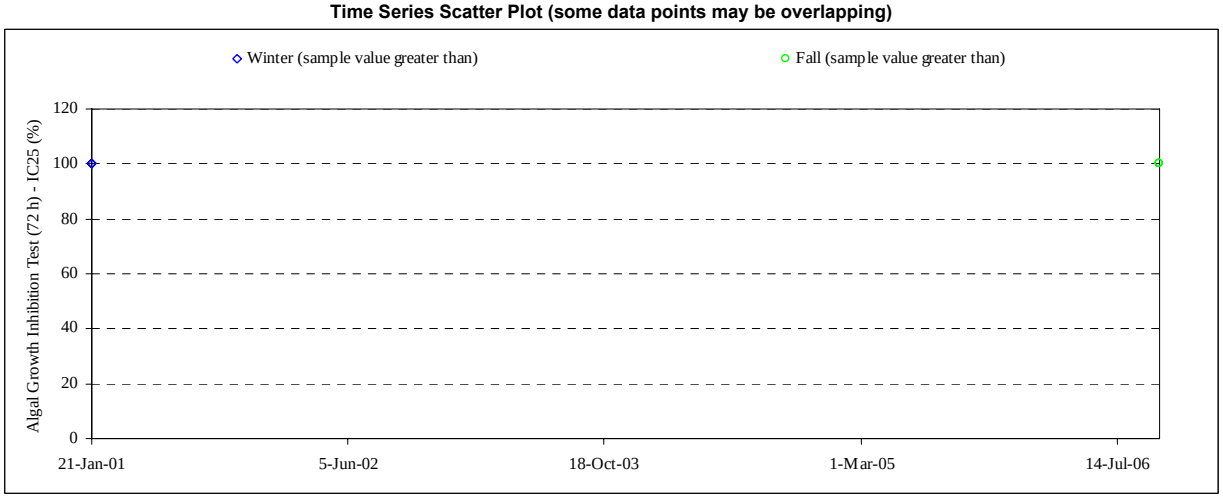
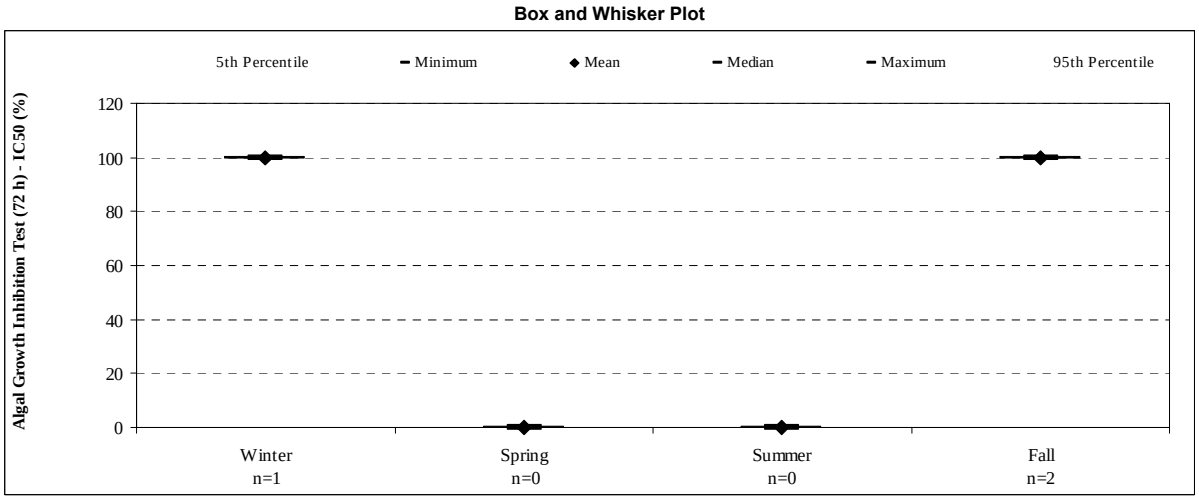


Figure G-1-5-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in McClelland Lake



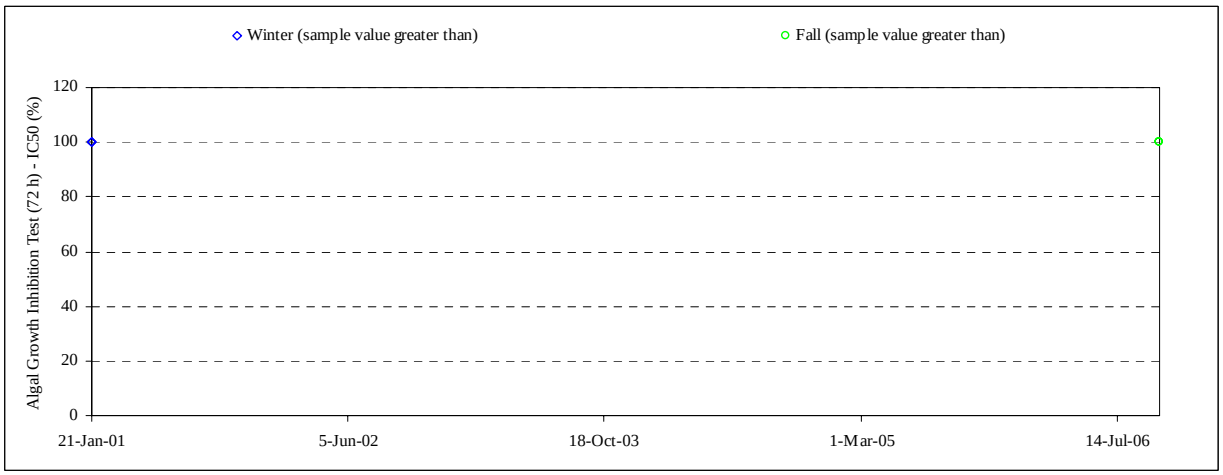
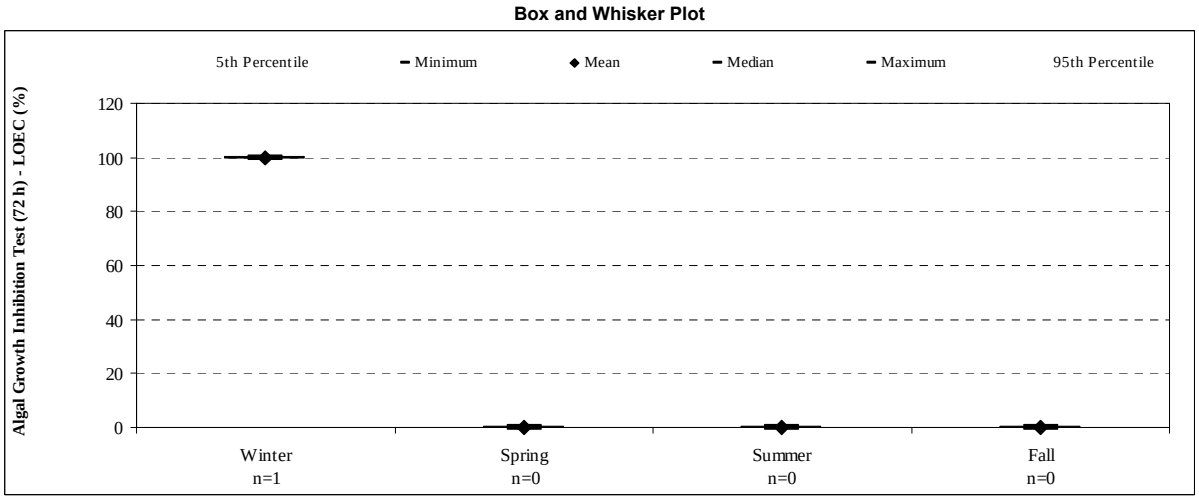


Figure G-1-5-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in McClelland Lake



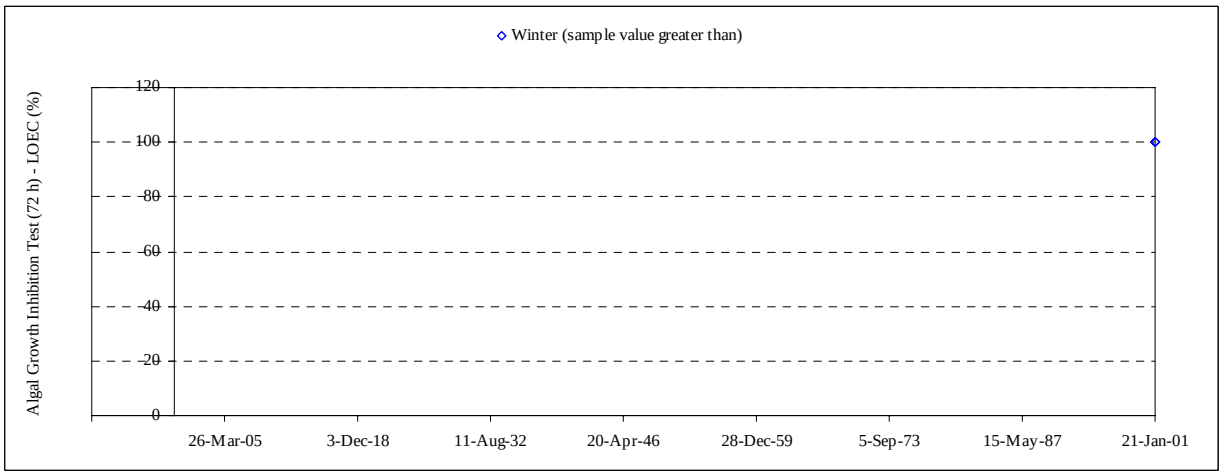
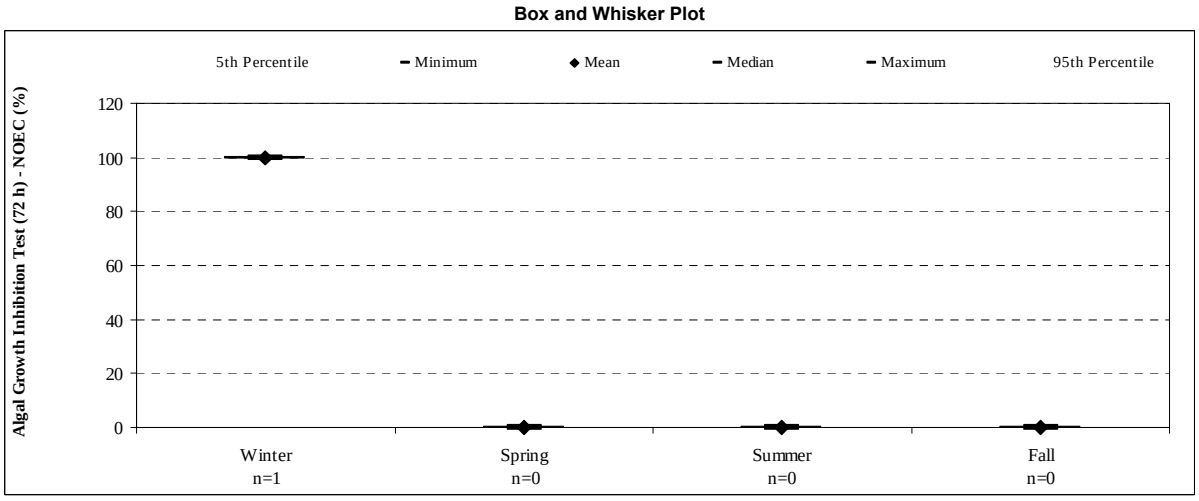


Figure G-1-5-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in McClelland Lake



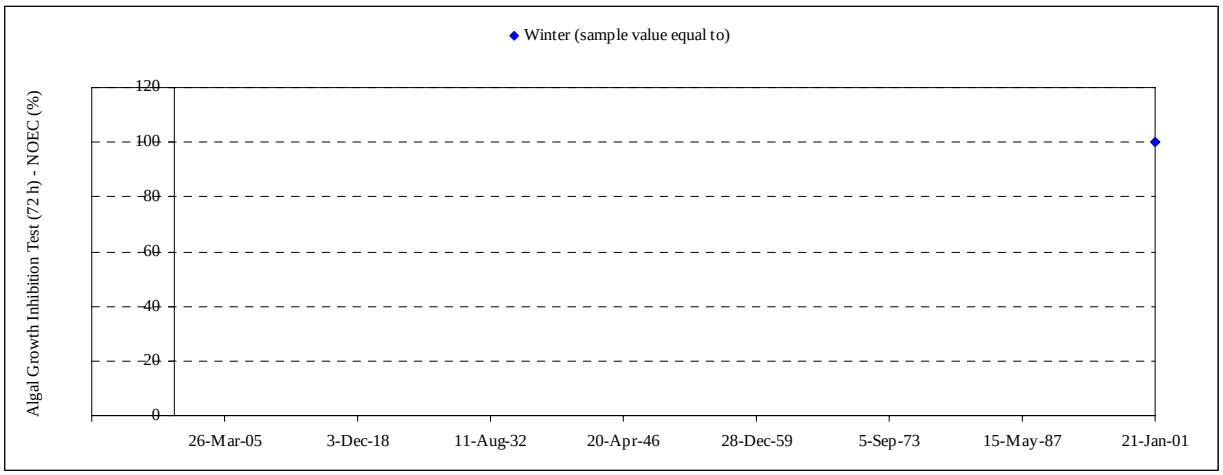
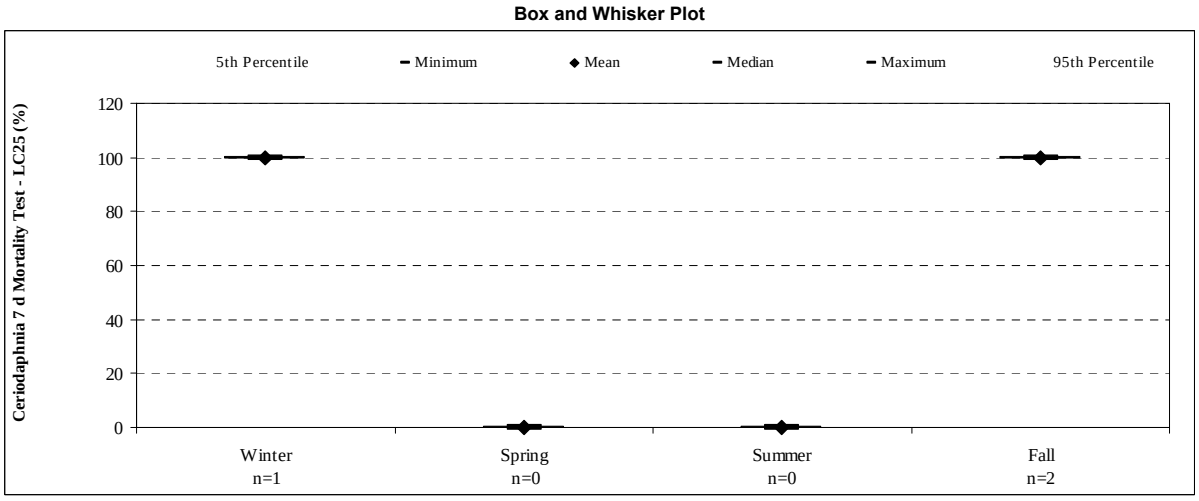


Figure G-1-5-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in McClelland Lake



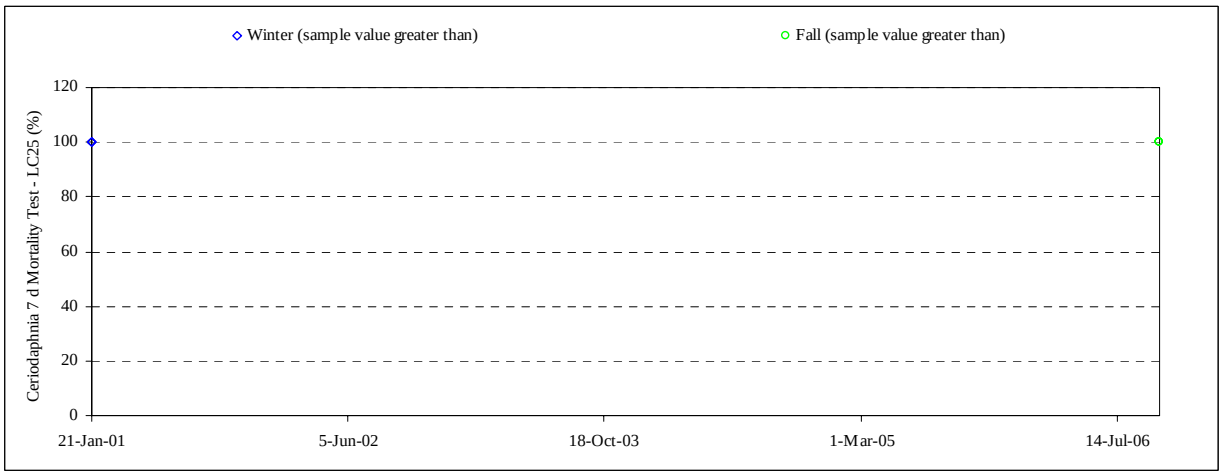
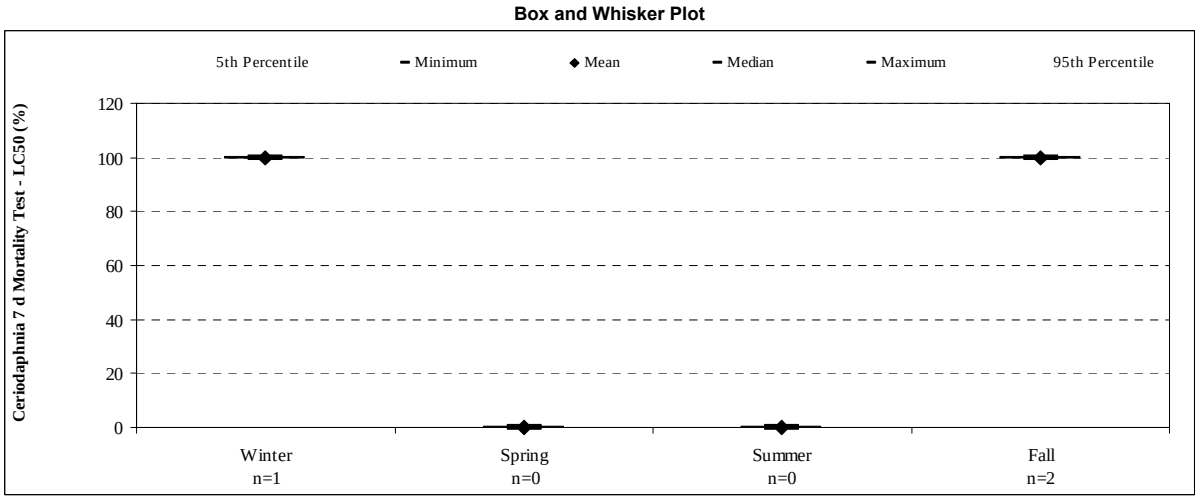


Figure G-1-5-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in McClelland Lake



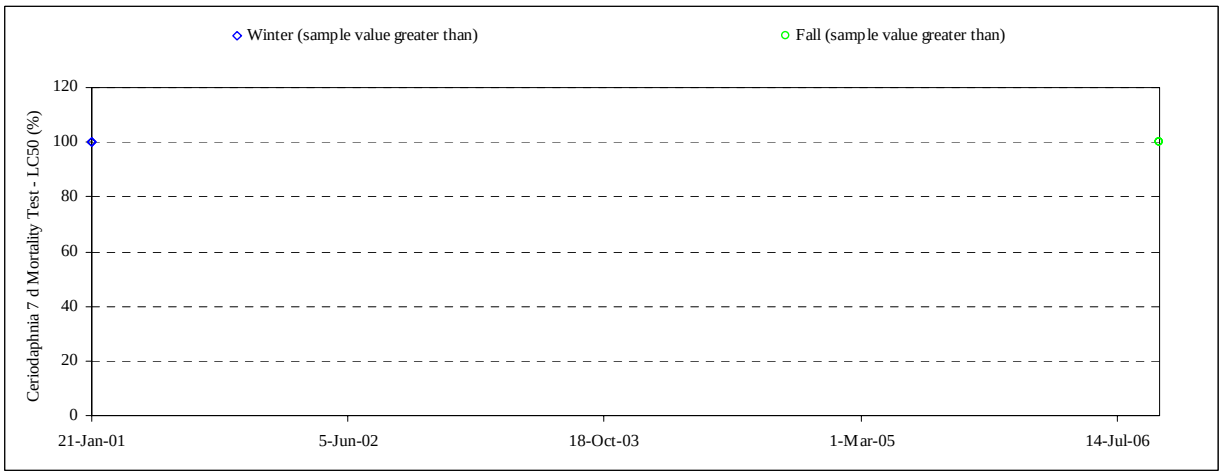


Figure G-1-5-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in McClelland Lake

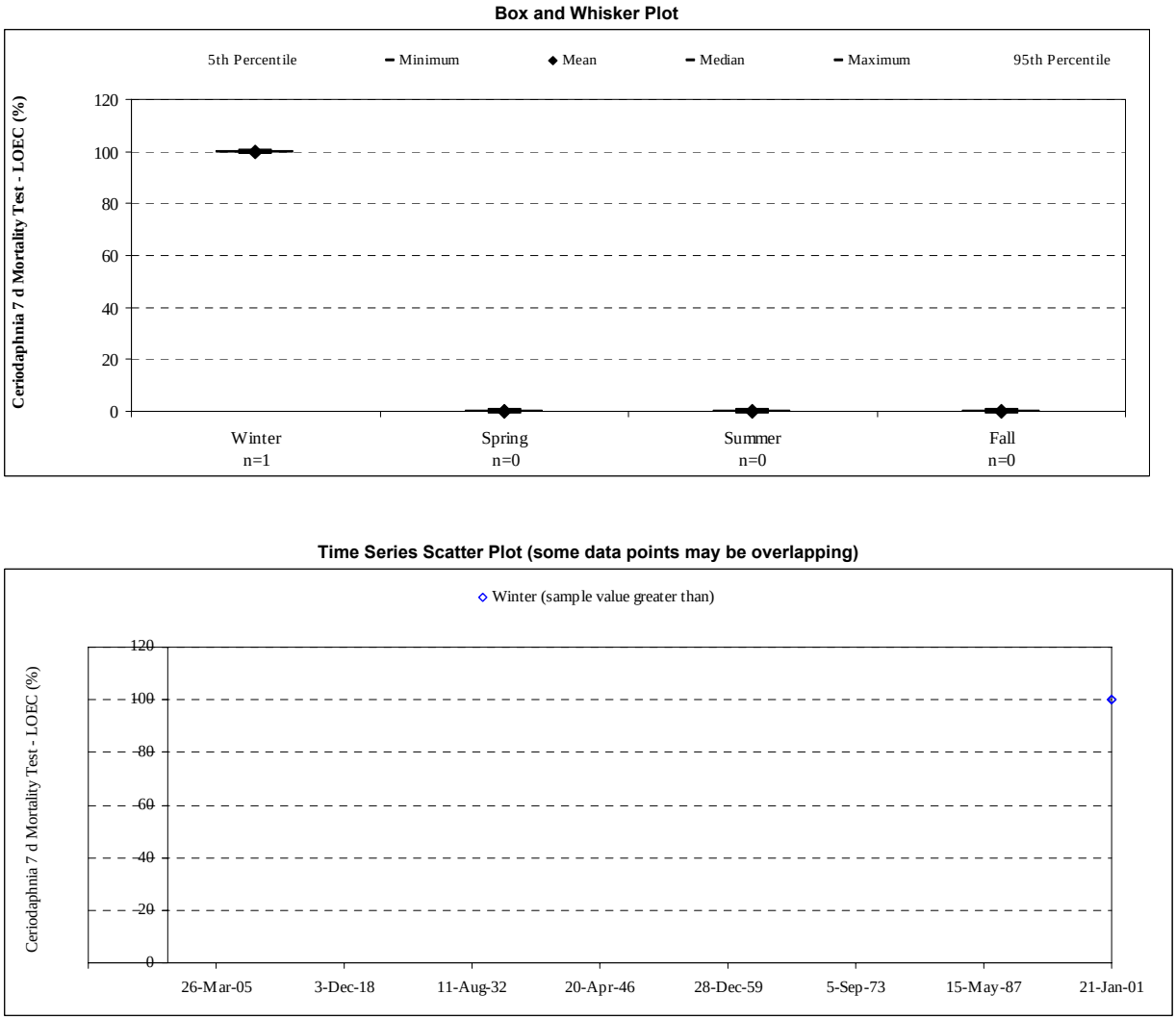
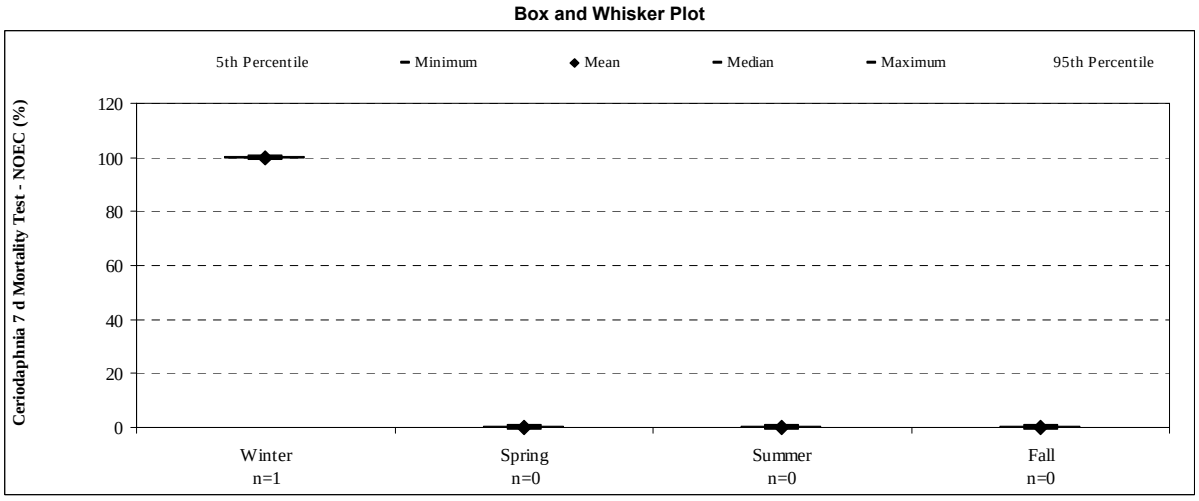


Figure G-1-5-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in McClelland Lake



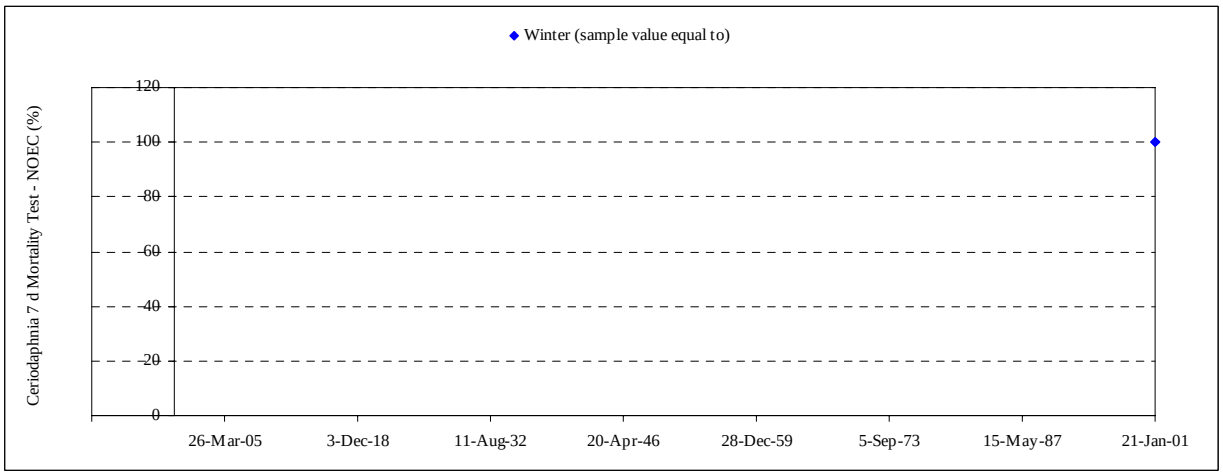
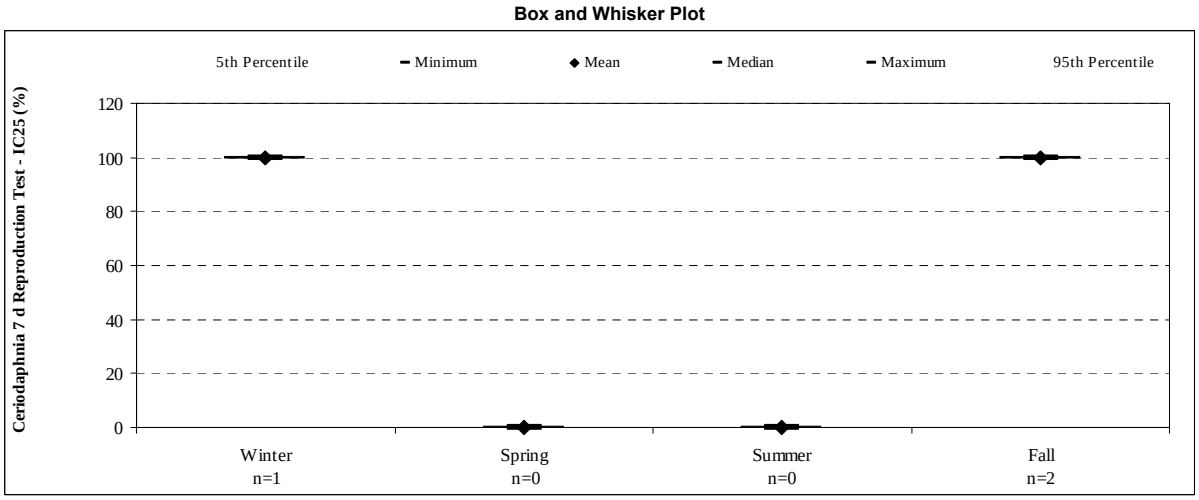


Figure G-1-5-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in McClelland Lake



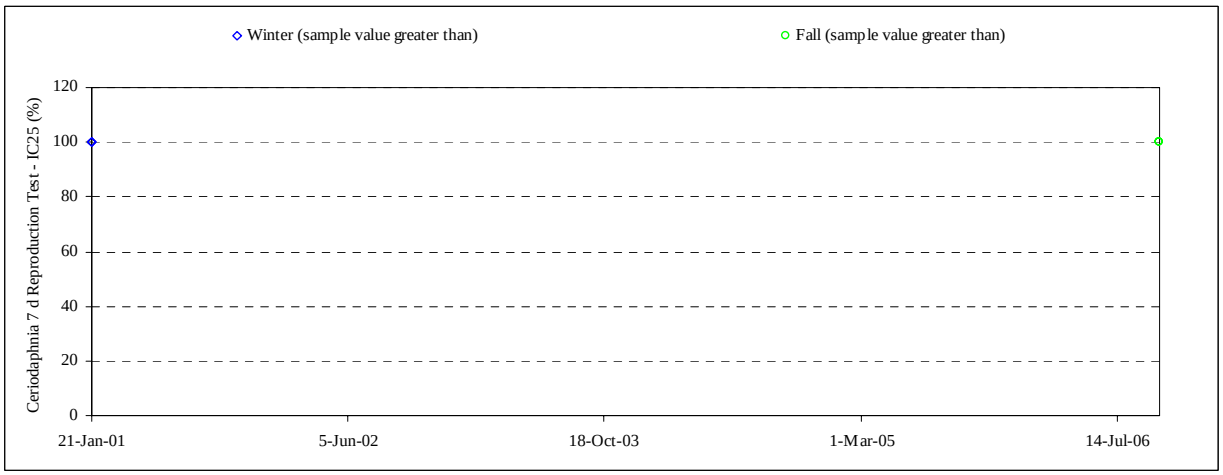
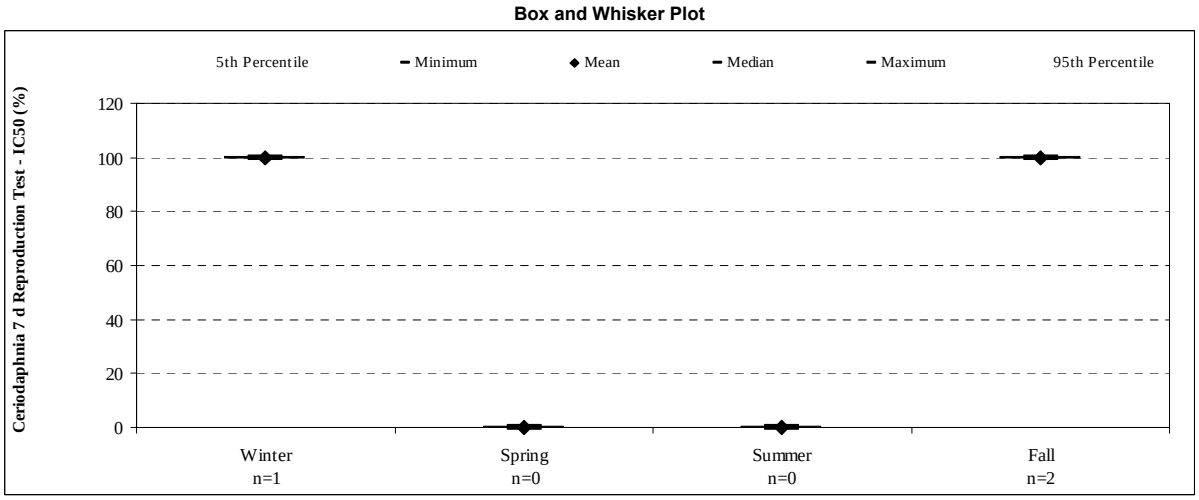


Figure G-1-5-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in McClelland Lake



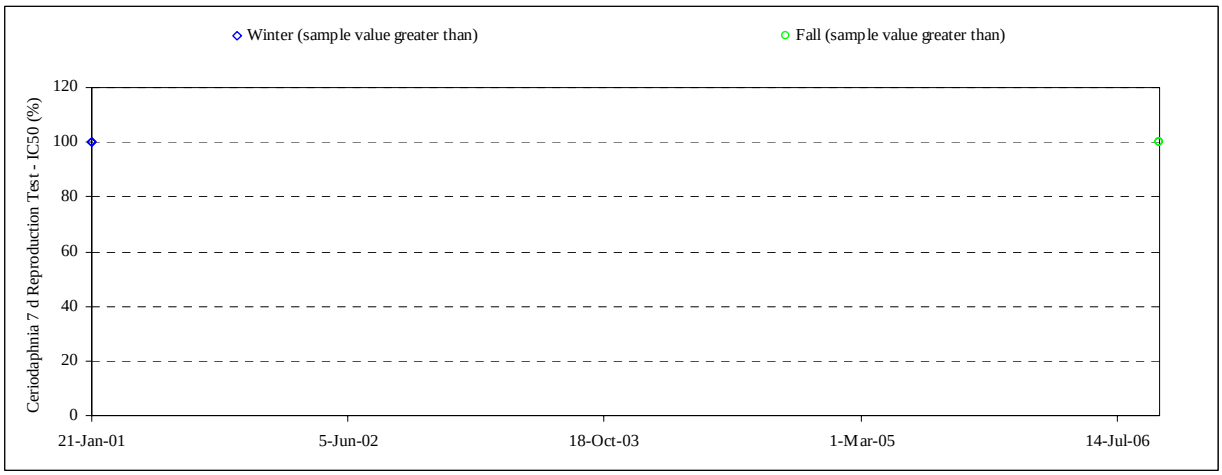
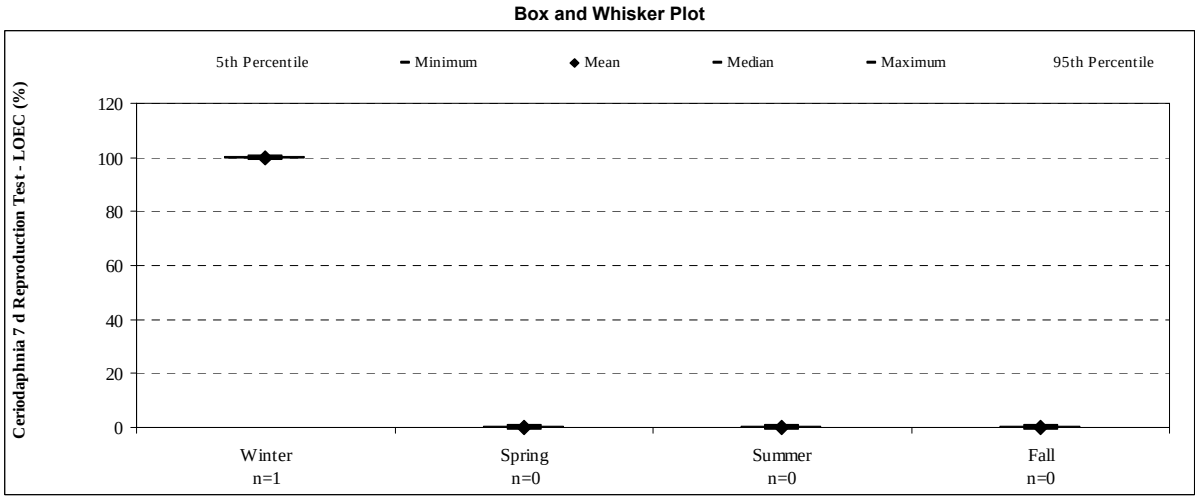


Figure G-1-5-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in McClelland Lake



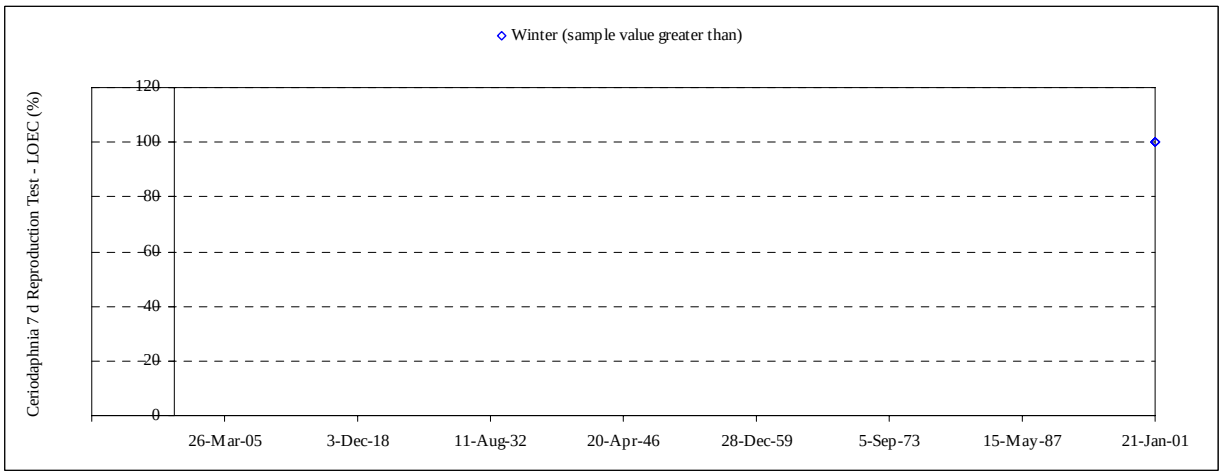
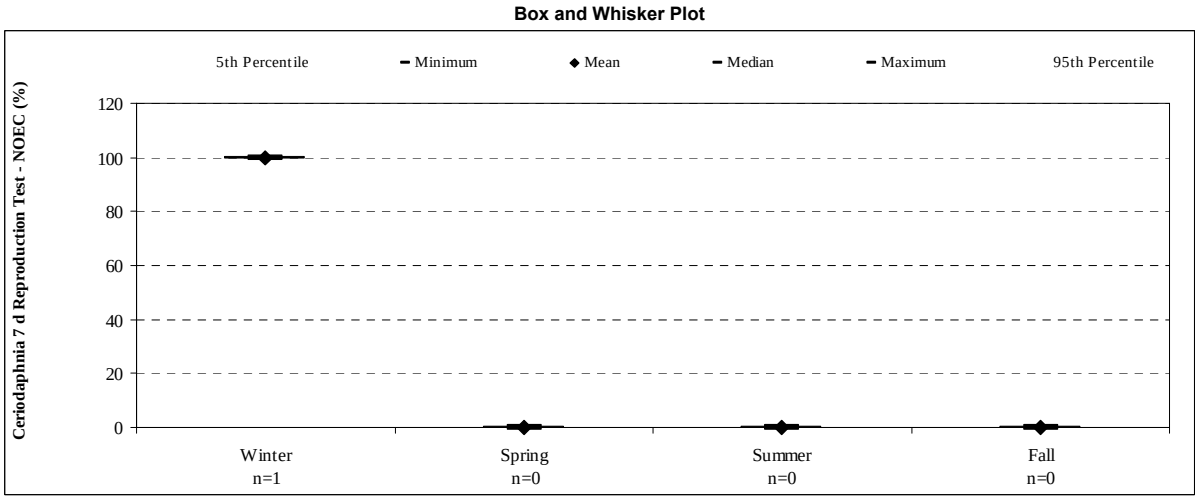


Figure G-1-5-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in McClelland Lake



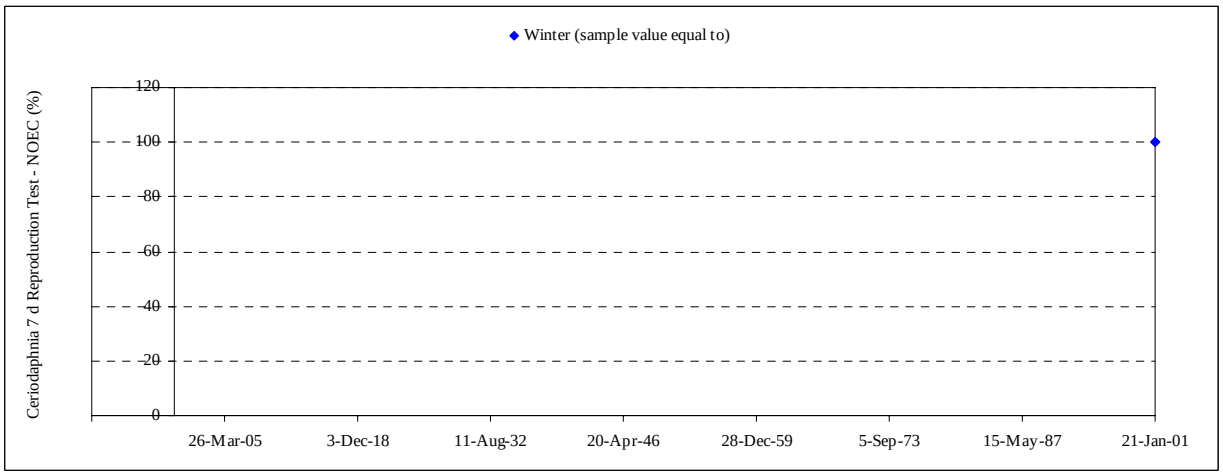
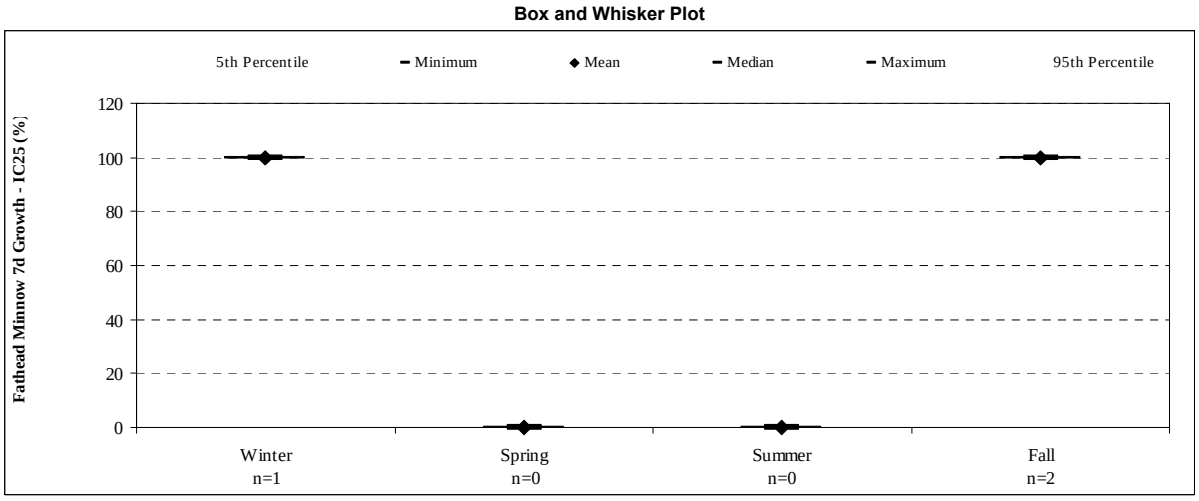


Figure G-1-5-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in McClelland Lake



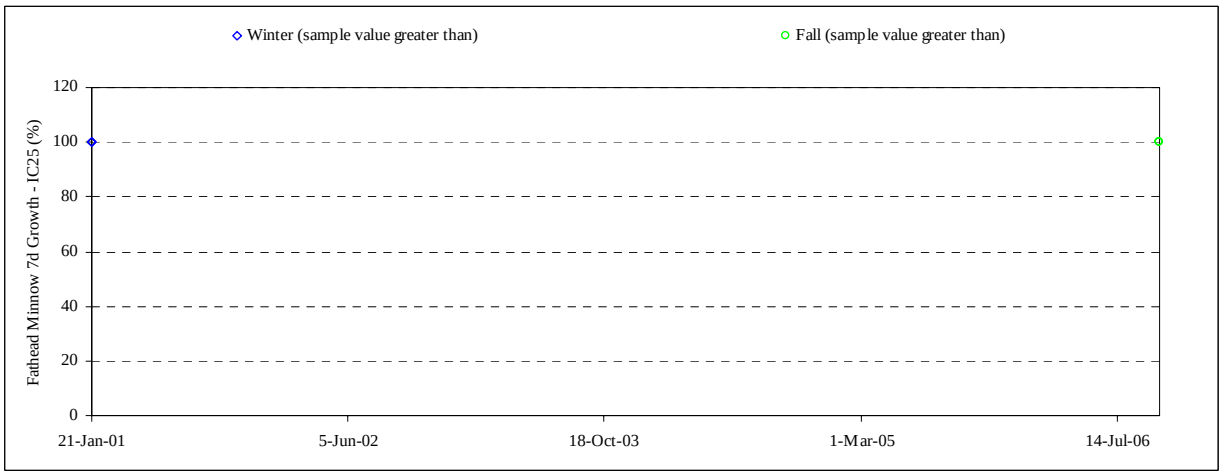
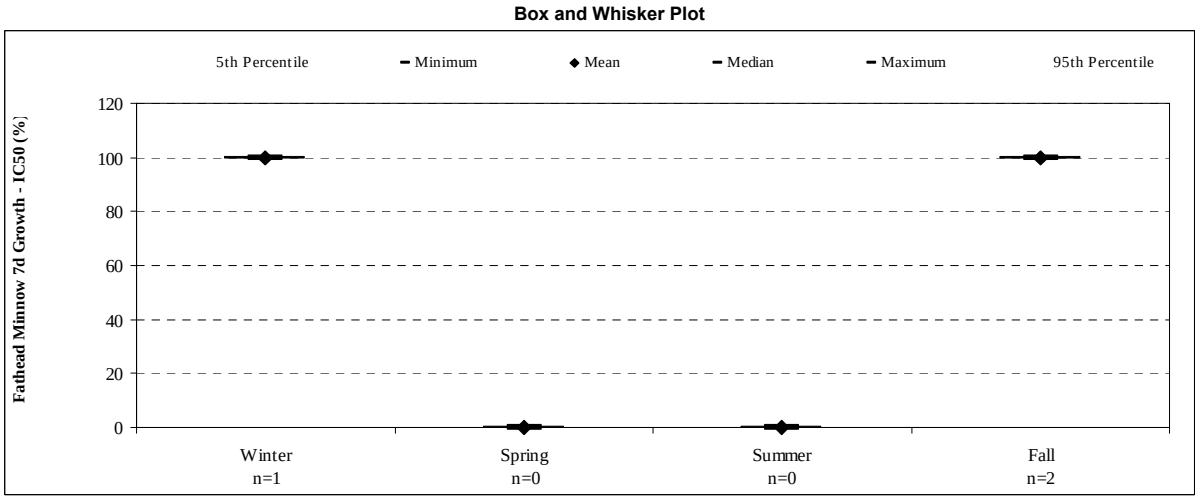


Figure G-1-5-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in McClelland Lake



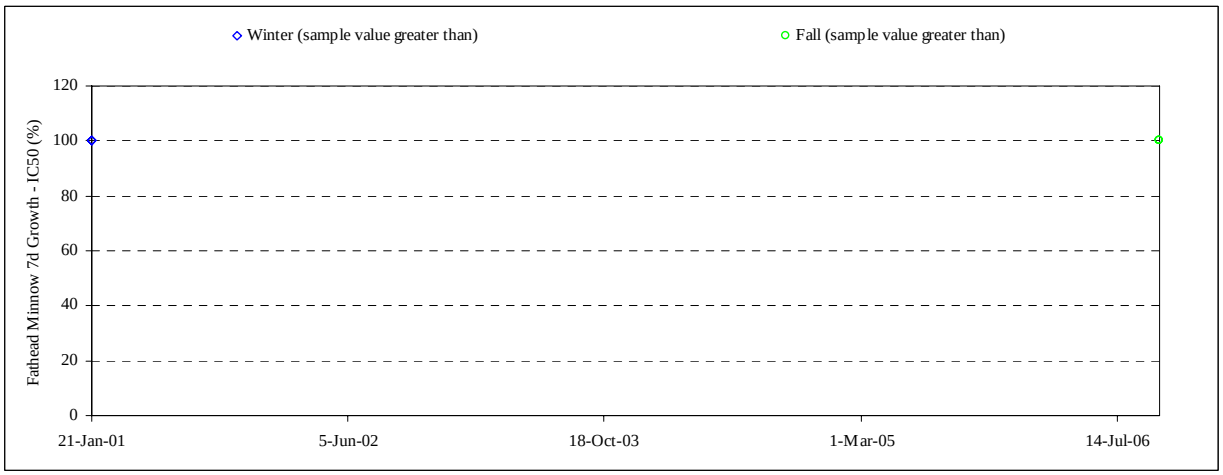
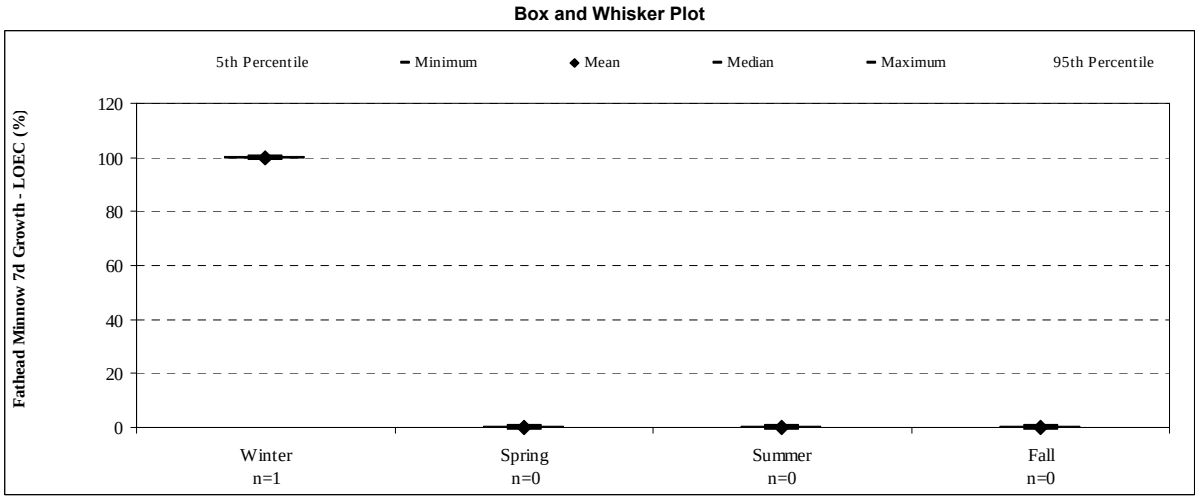


Figure G-1-5-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in McClelland Lake



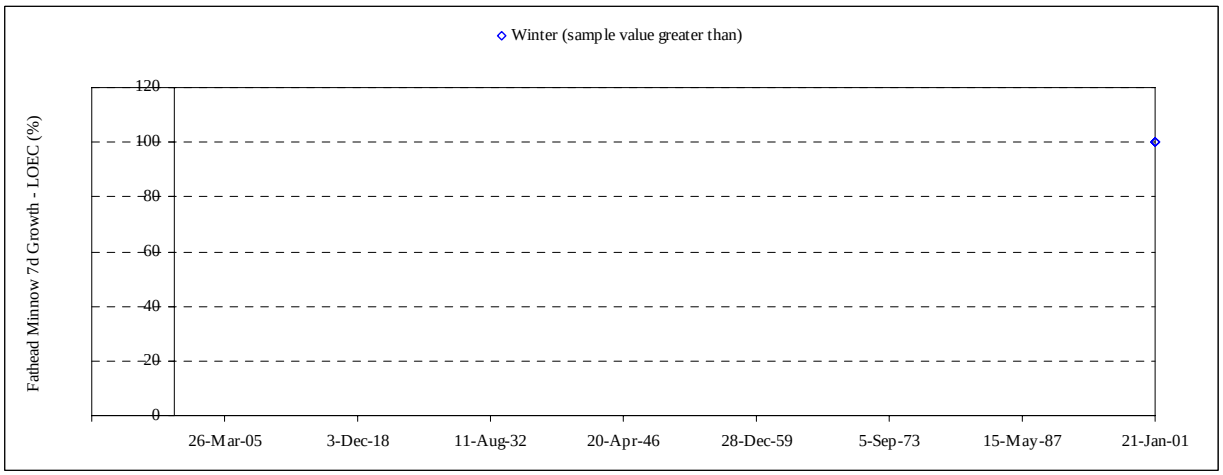
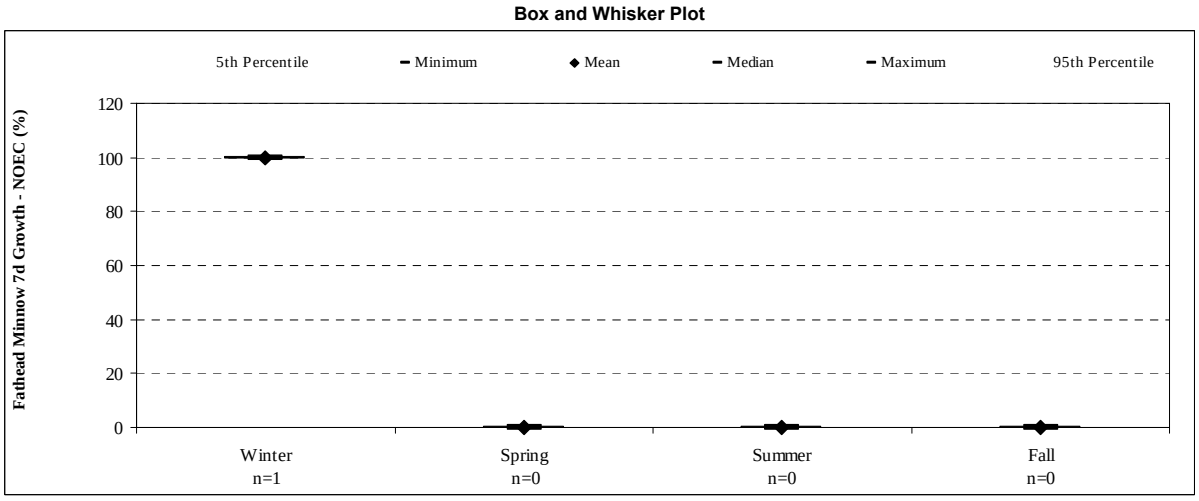


Figure G-1-5-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in McClelland Lake



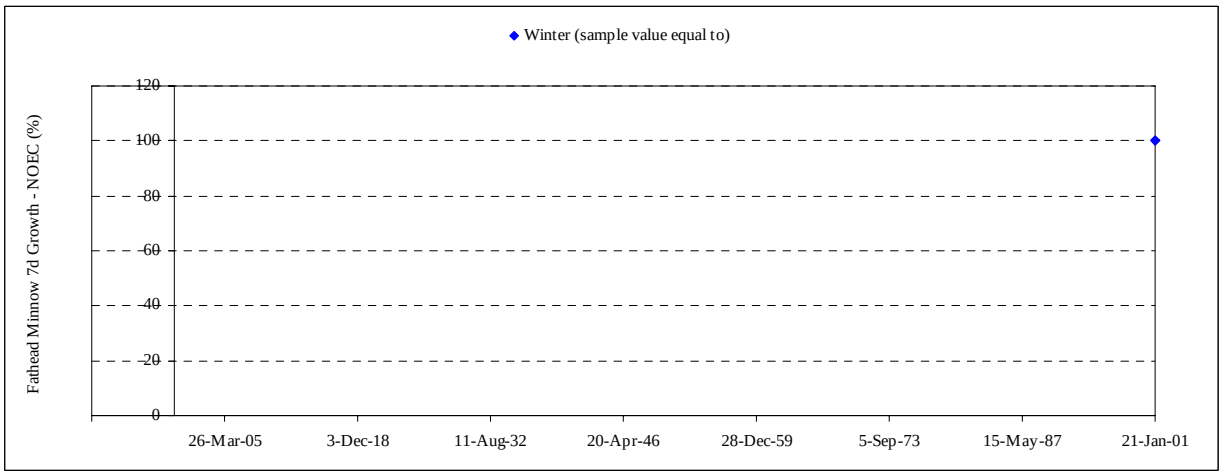
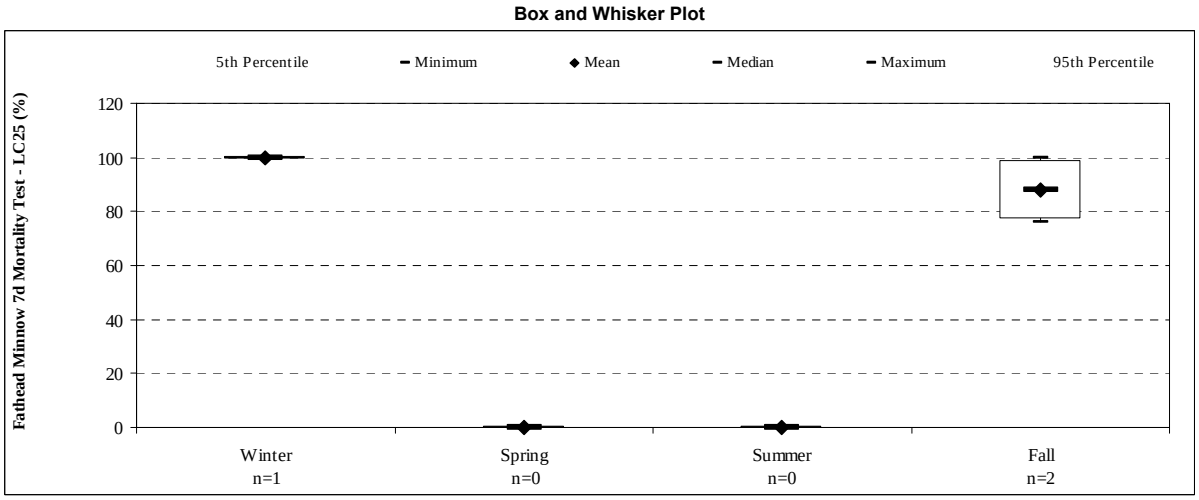


Figure G-1-5-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in McClelland Lake



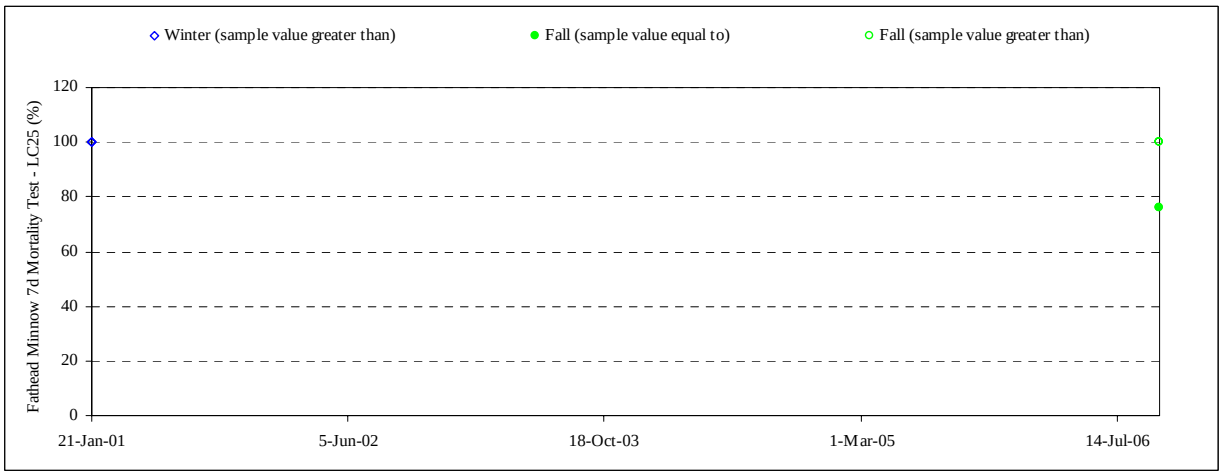
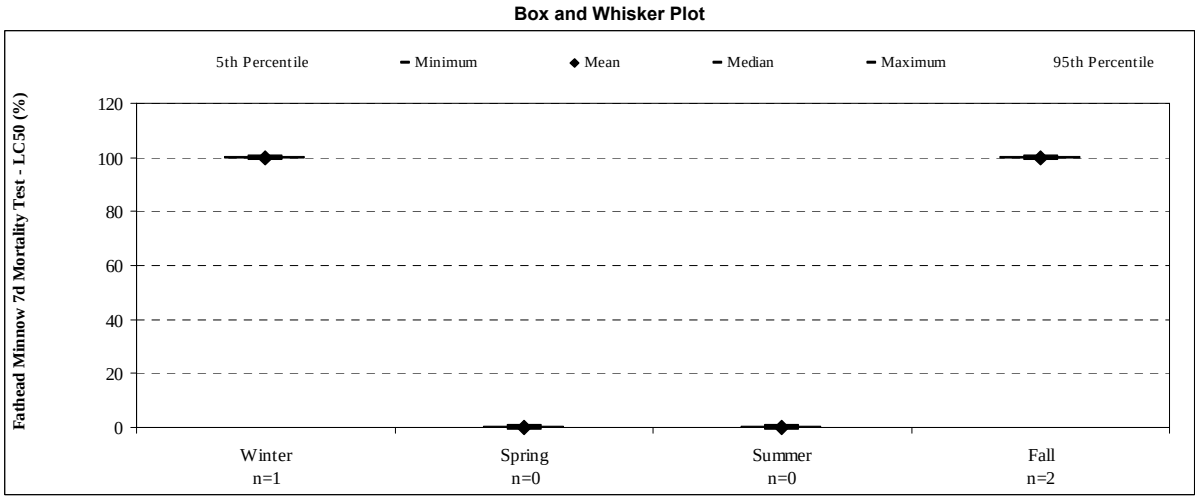


Figure G-1-5-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in McClelland Lake



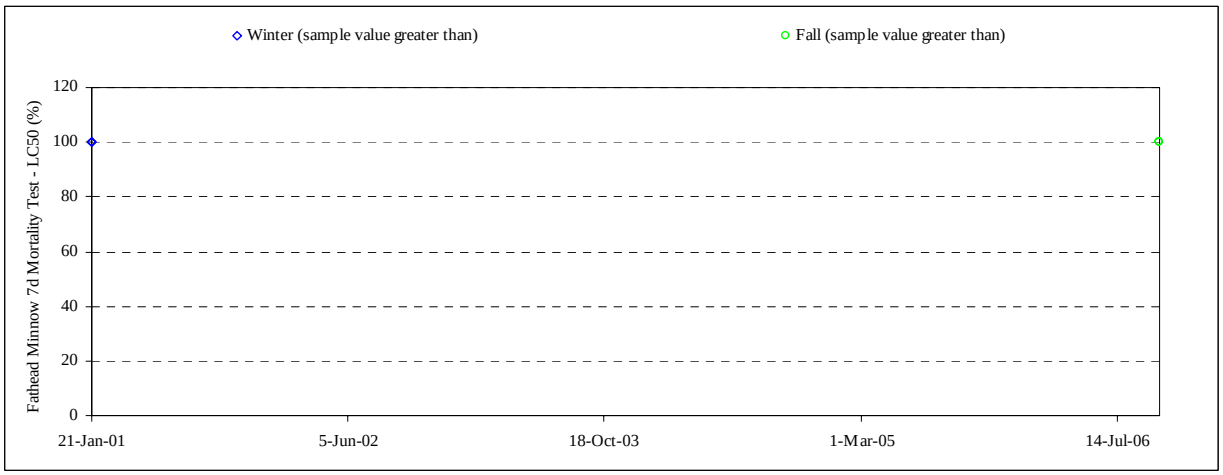
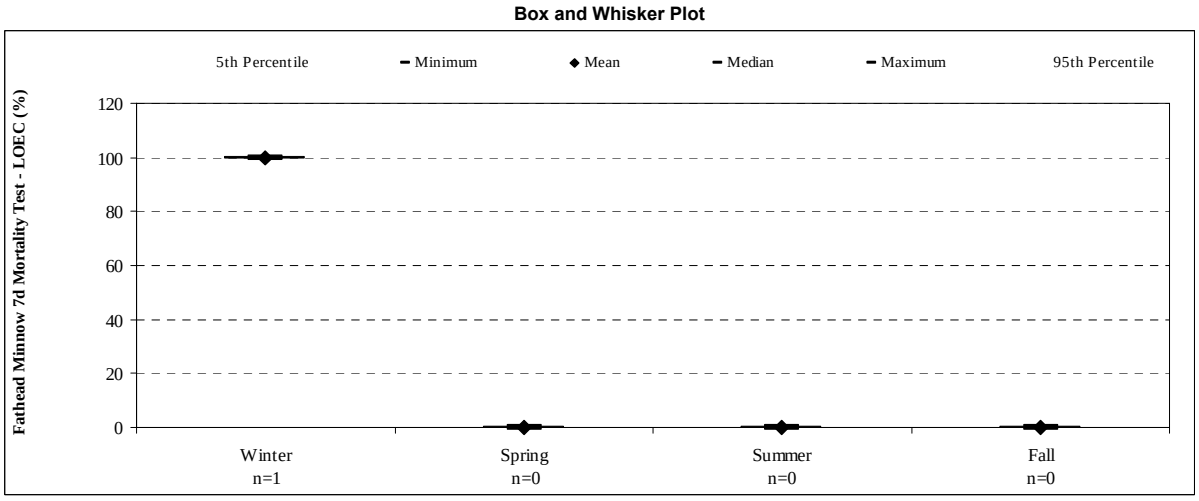


Figure G-1-5-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in McClelland Lake



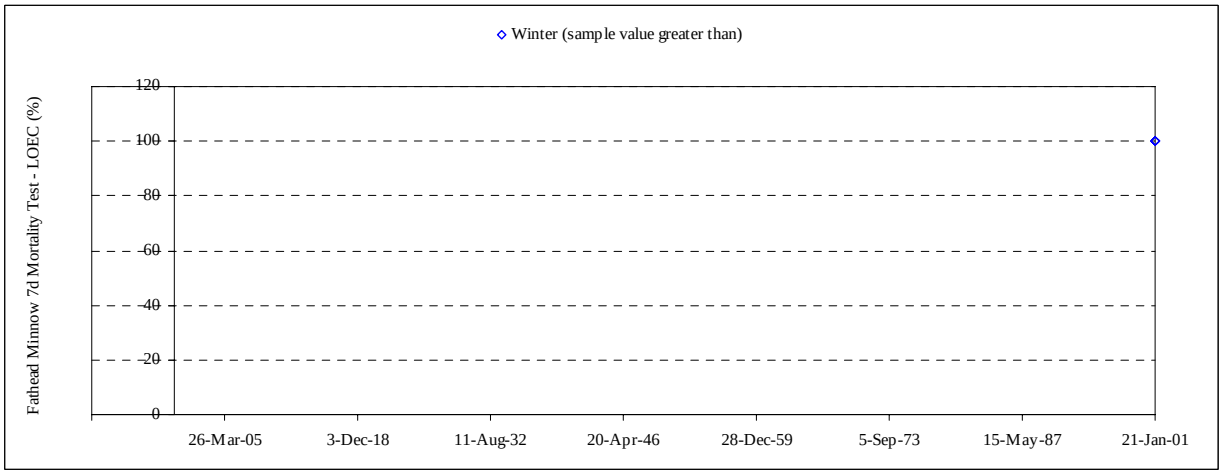
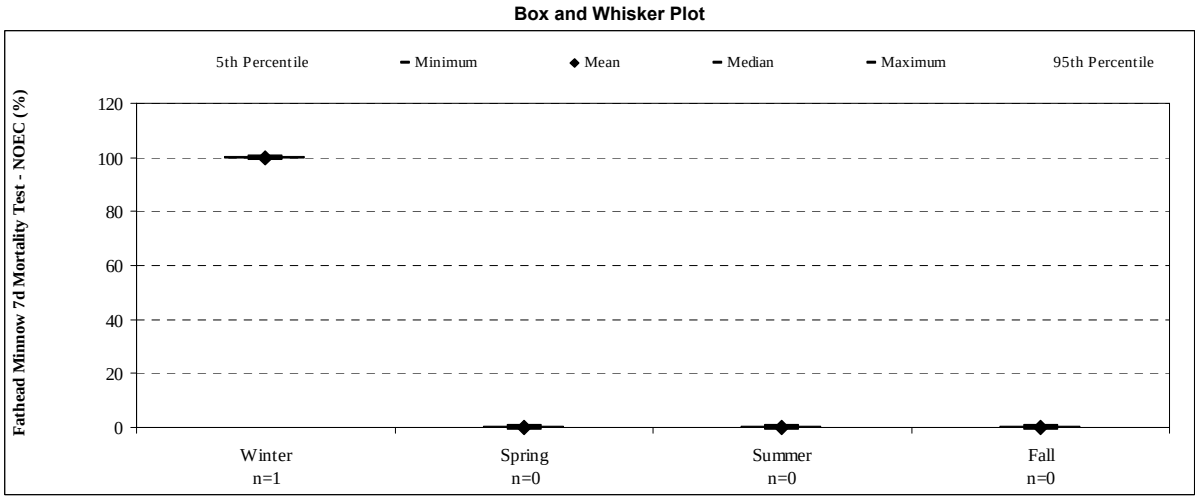


Figure G-1-5-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in McClelland Lake



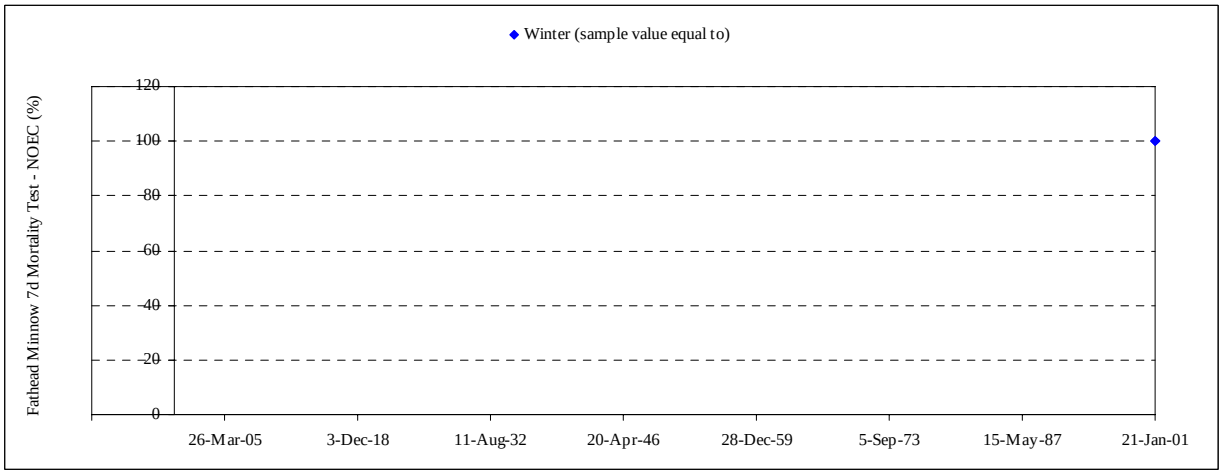
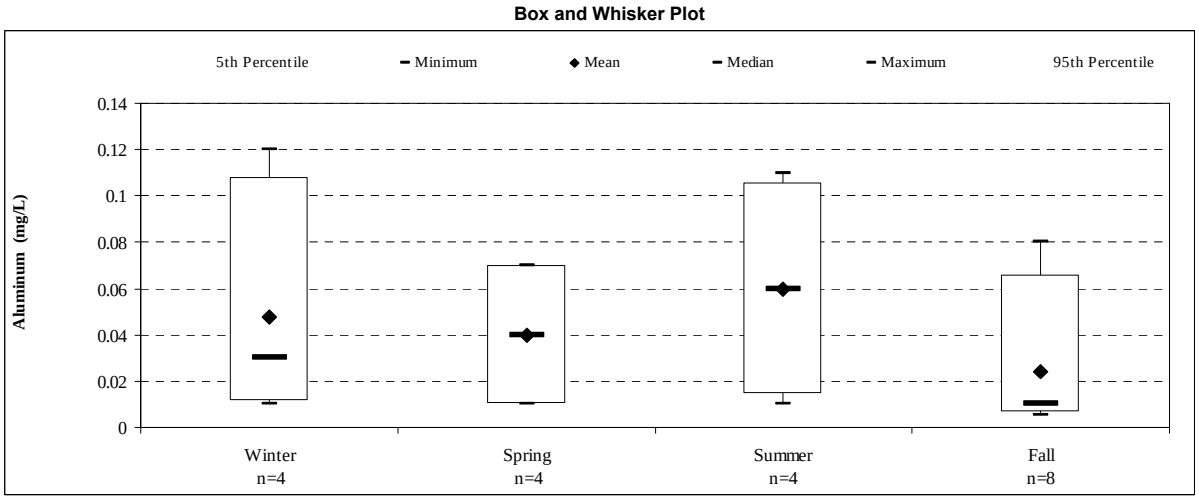


Figure G-1-5-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in McClelland Lake



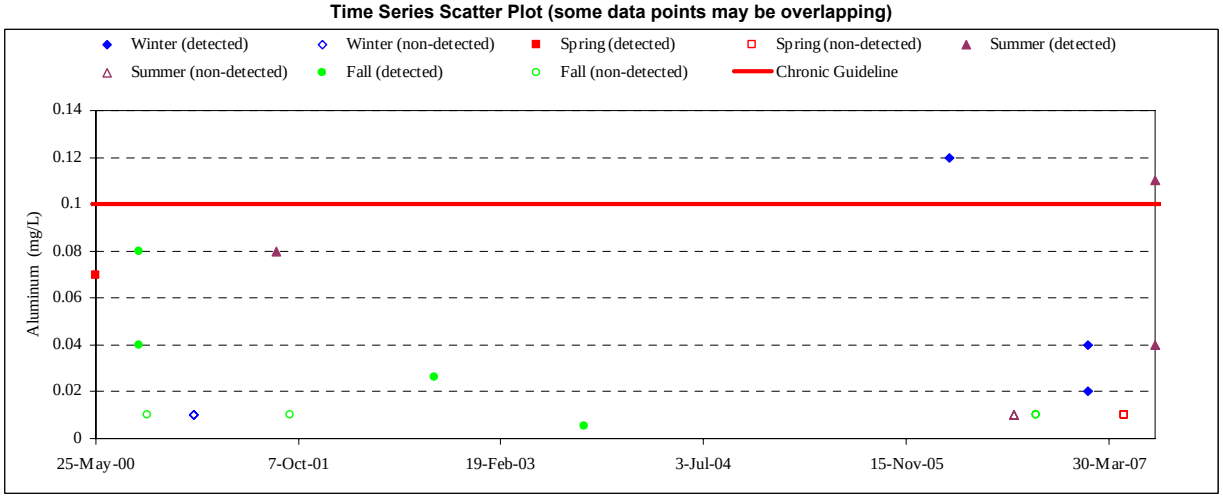
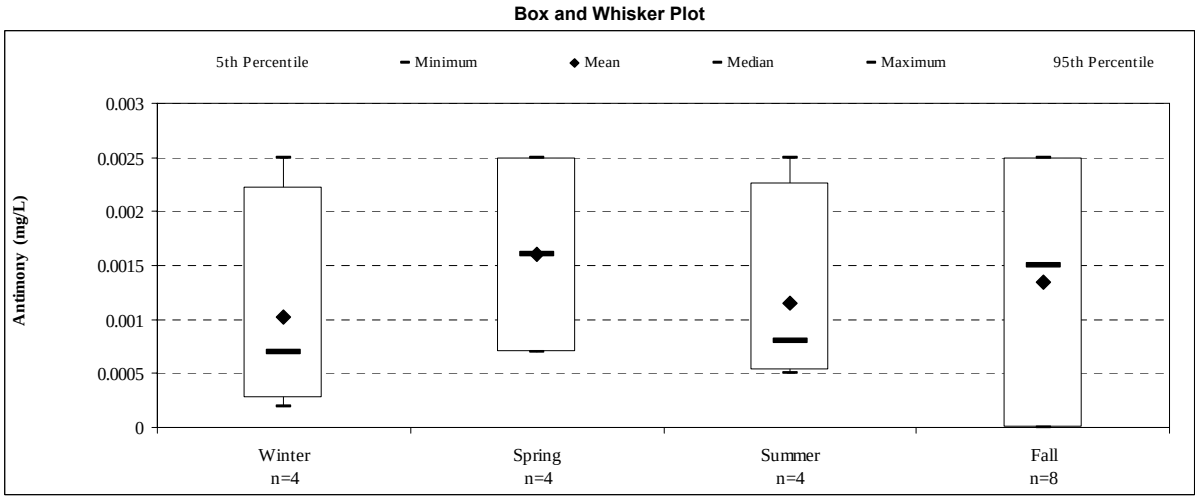


Figure G-1-5-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in McClelland Lake



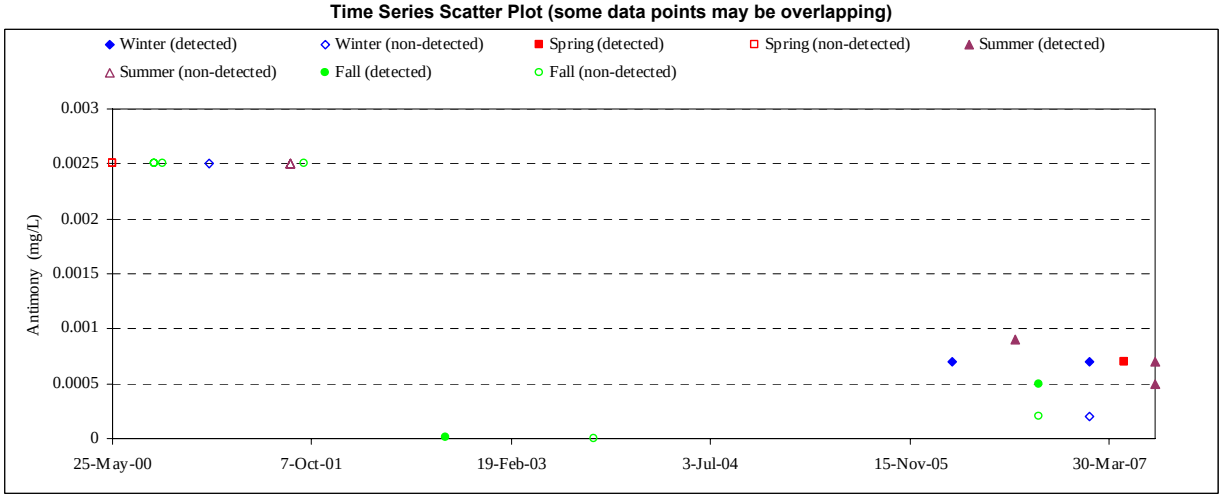
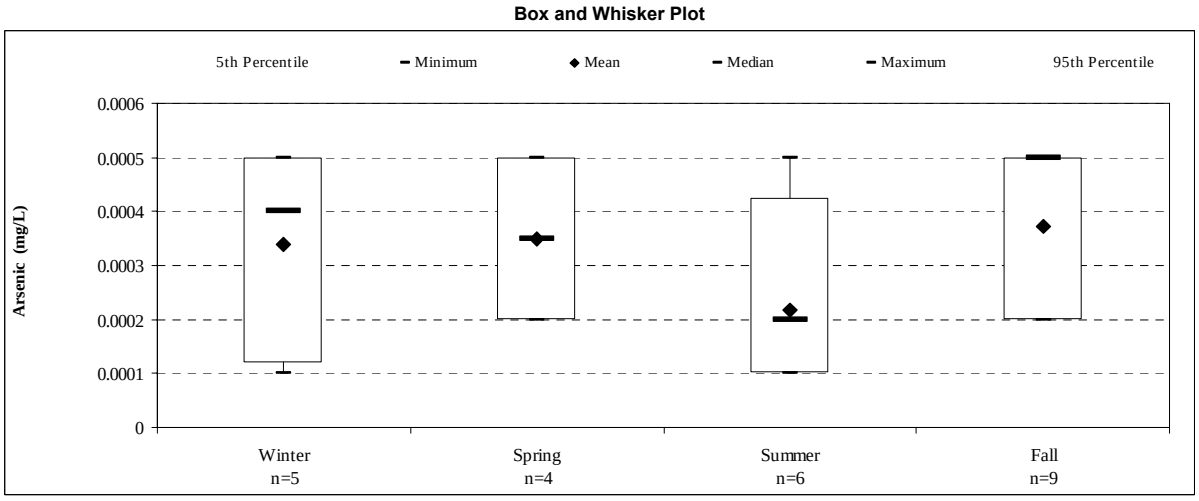


Figure G-1-5-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in McClelland Lake



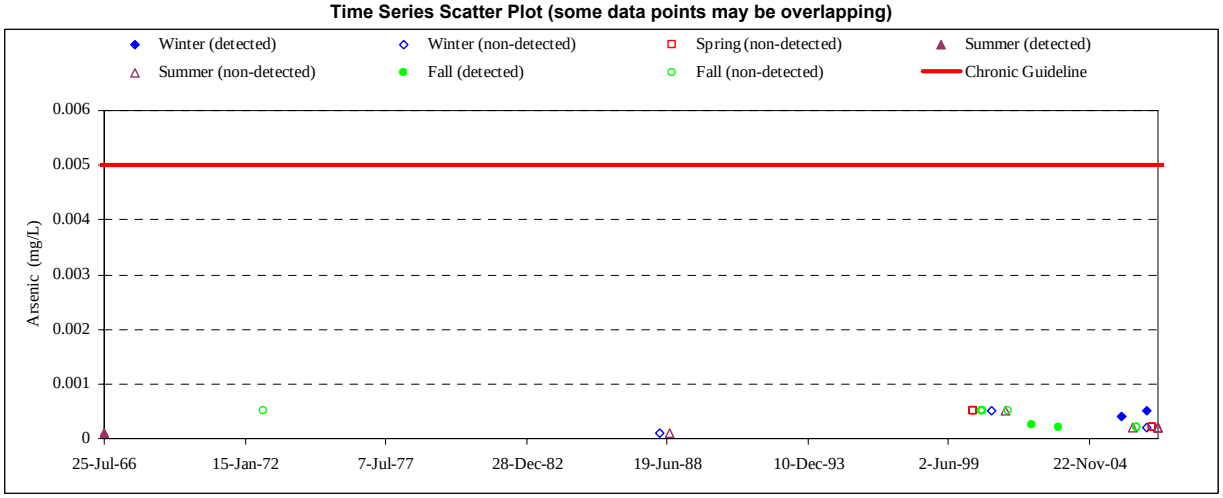
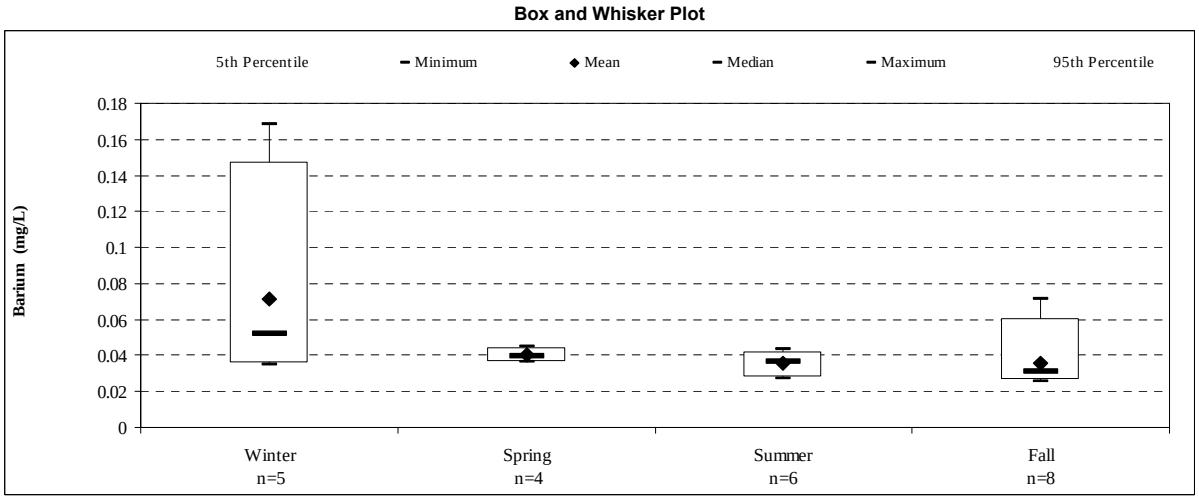


Figure G-1-5-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in McClelland Lake



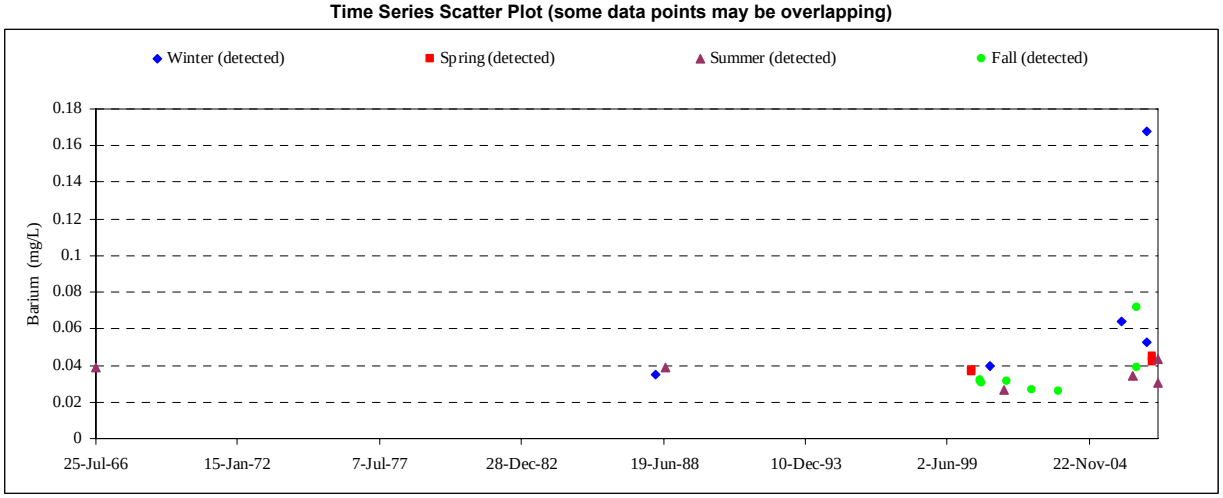
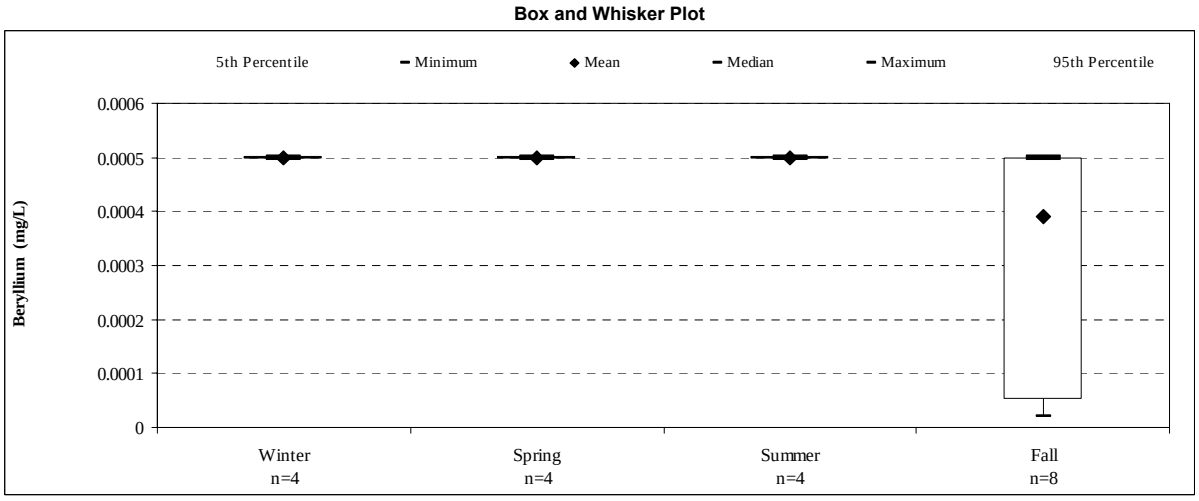


Figure G-1-5-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in McClelland Lake



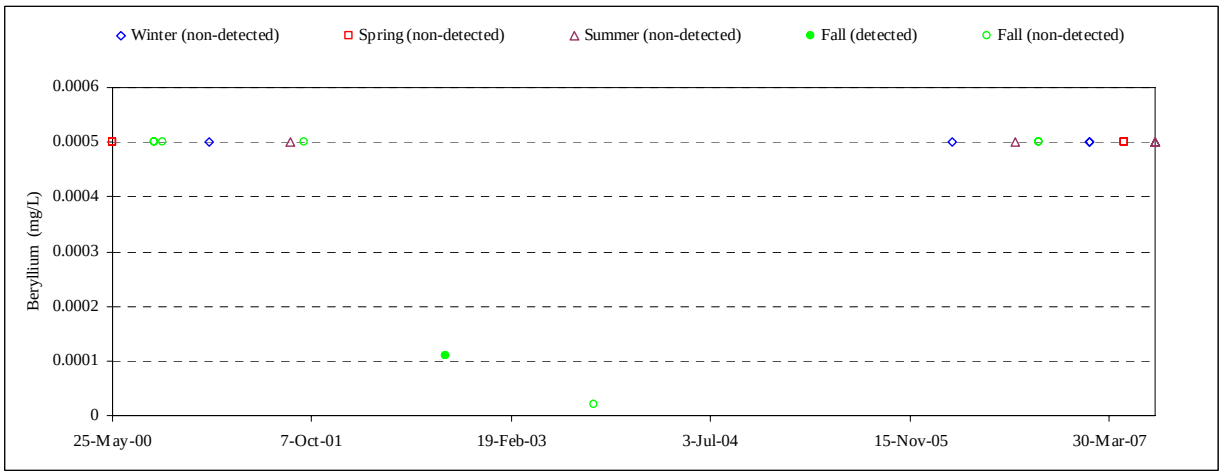
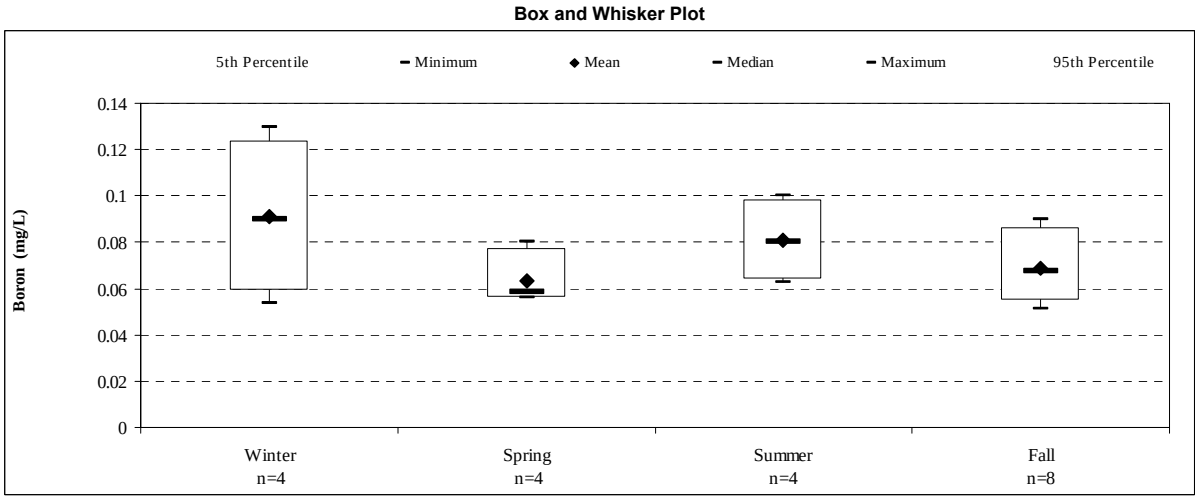


Figure G-1-5-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in McClelland Lake



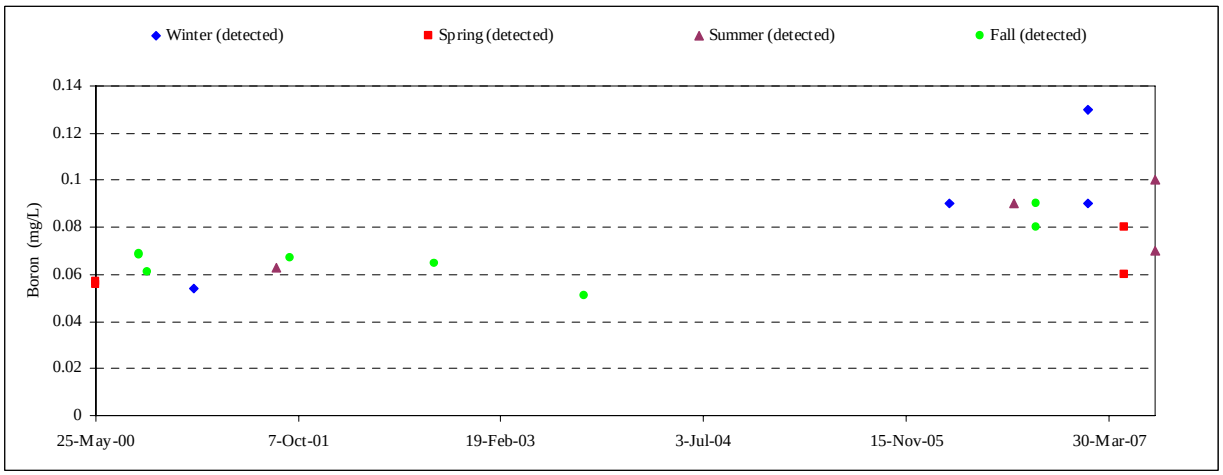
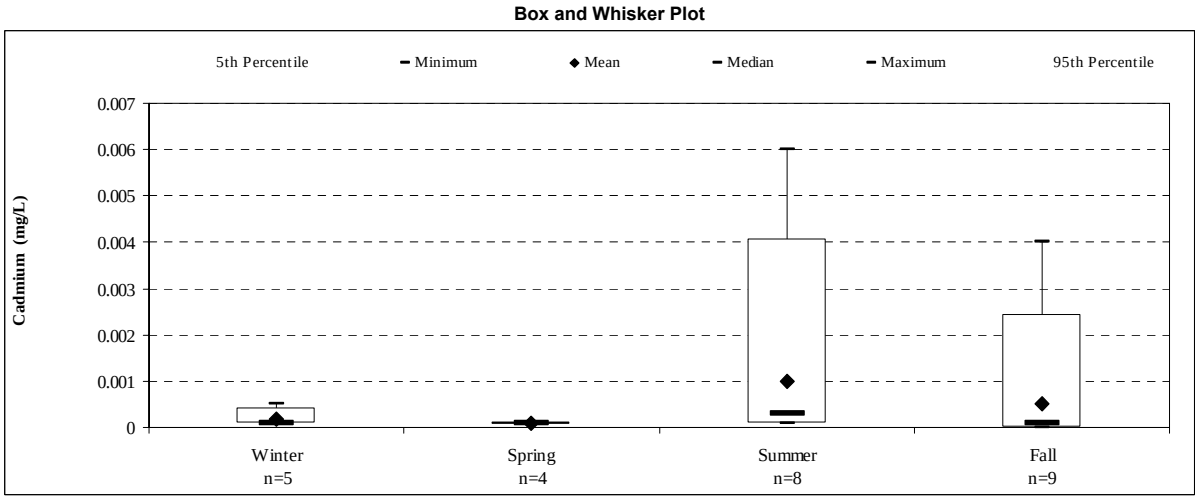


Figure G-1-5-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in McClelland Lake



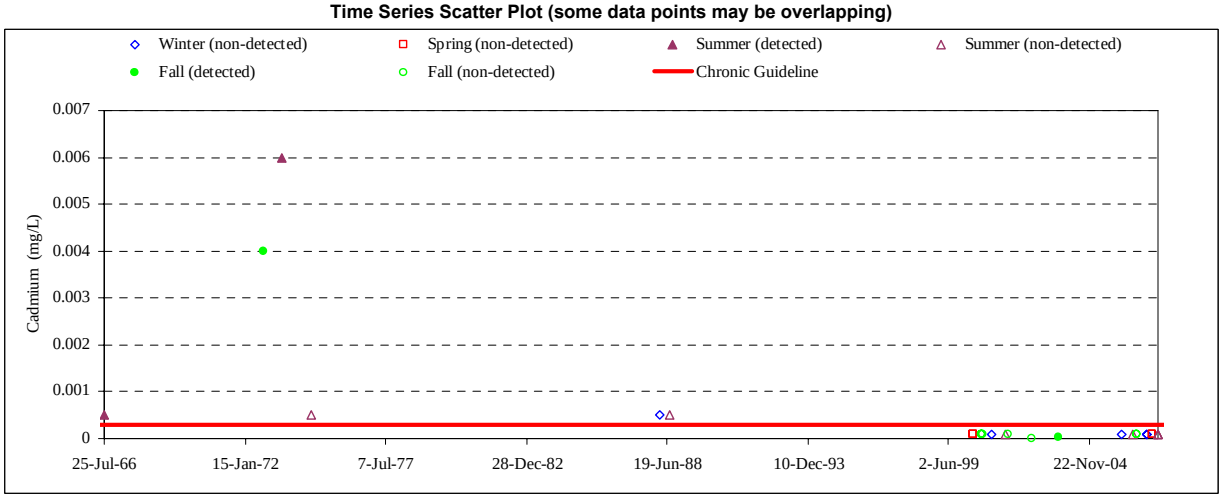
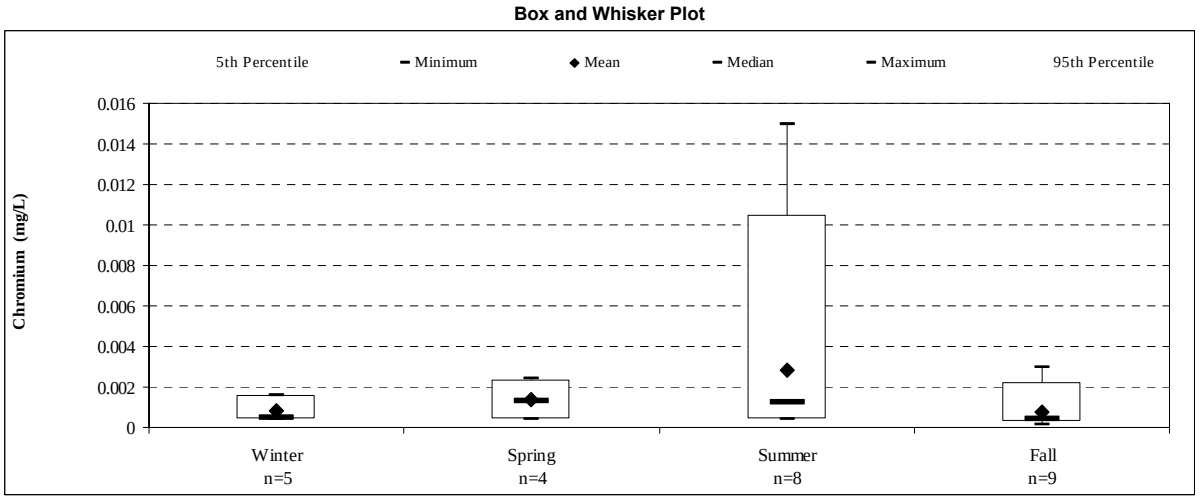


Figure G-1-5-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in McClelland Lake



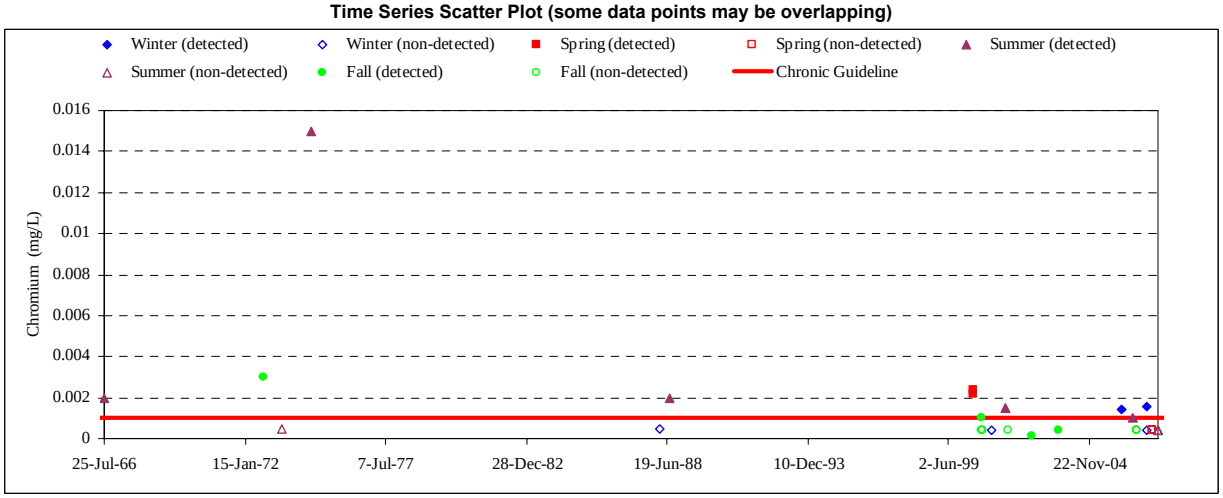
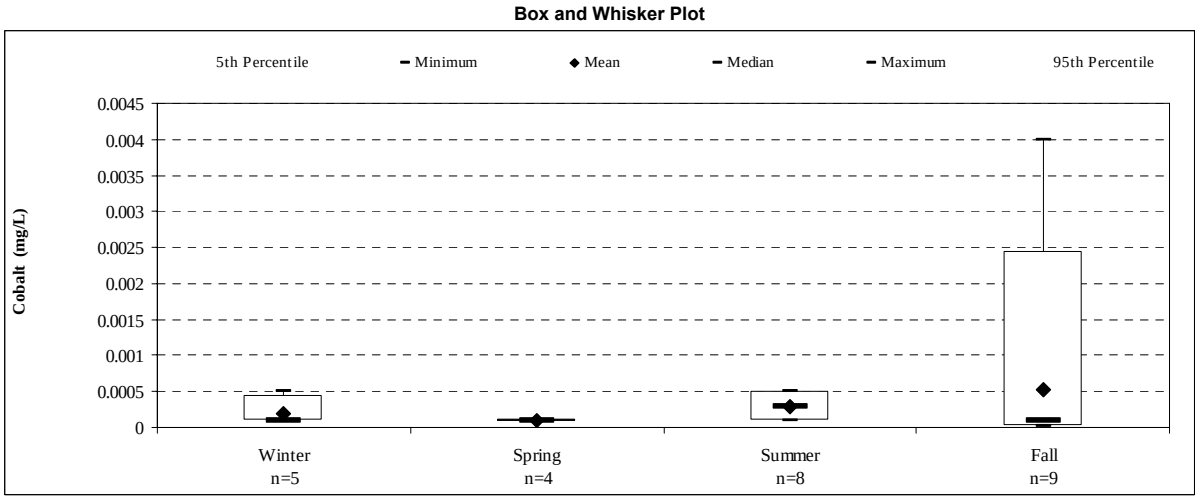


Figure G-1-5-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in McClelland Lake



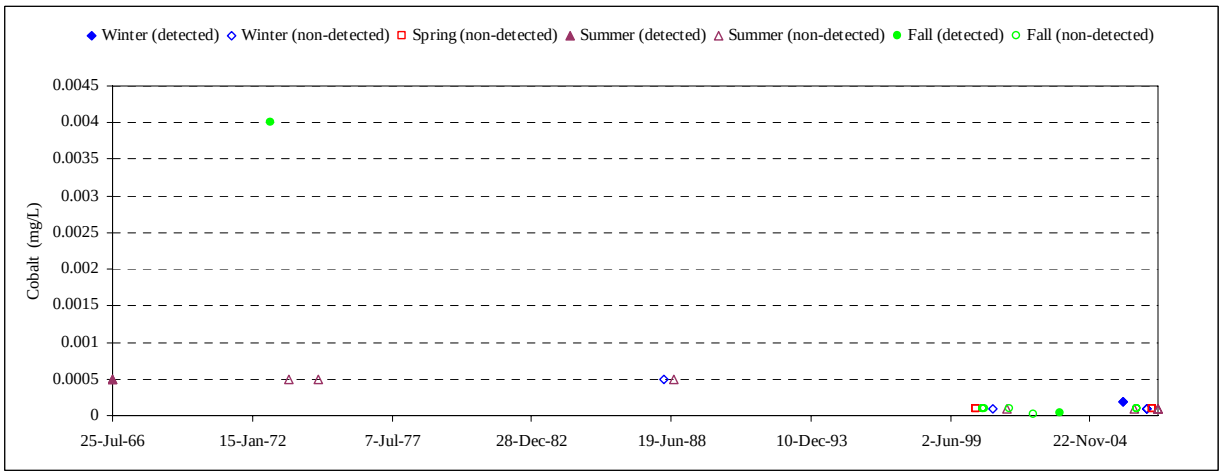
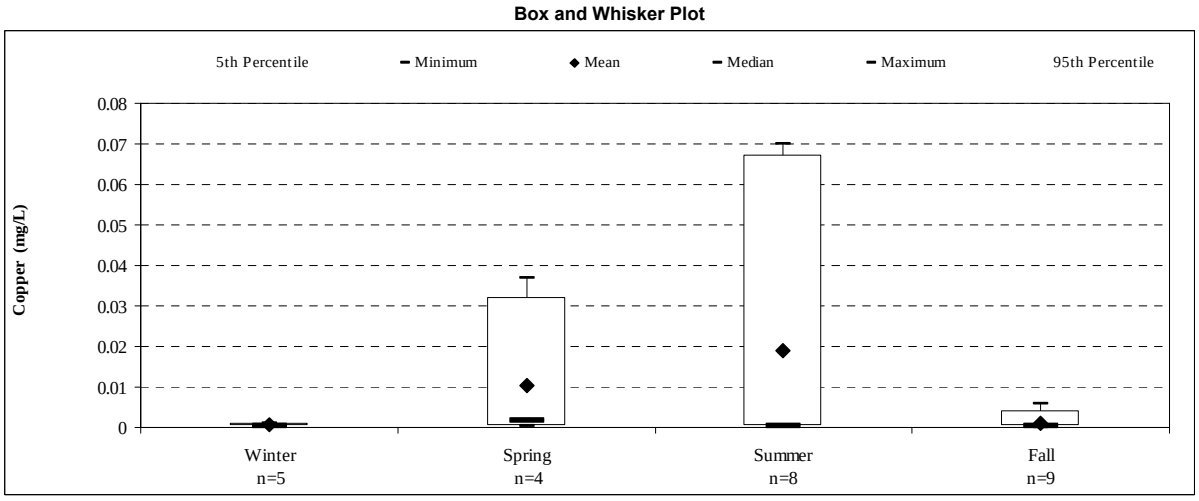


Figure G-1-5-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in McClelland Lake



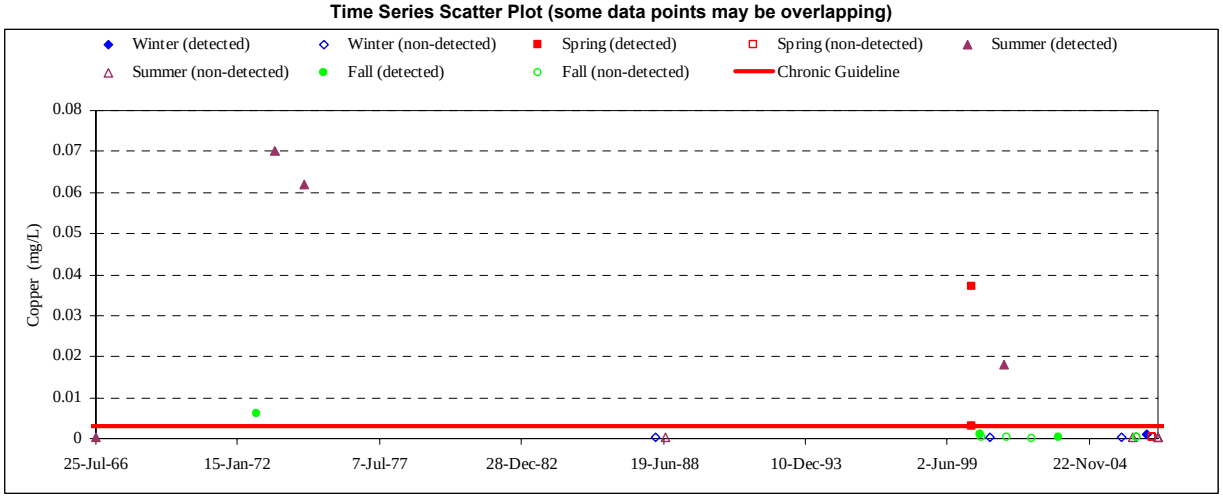
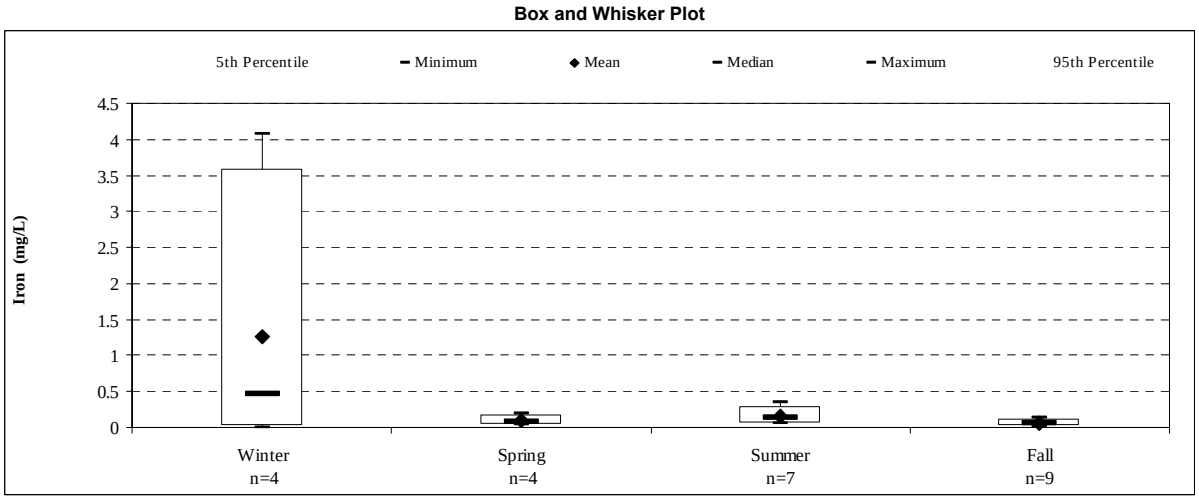


Figure G-1-5-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in McClelland Lake



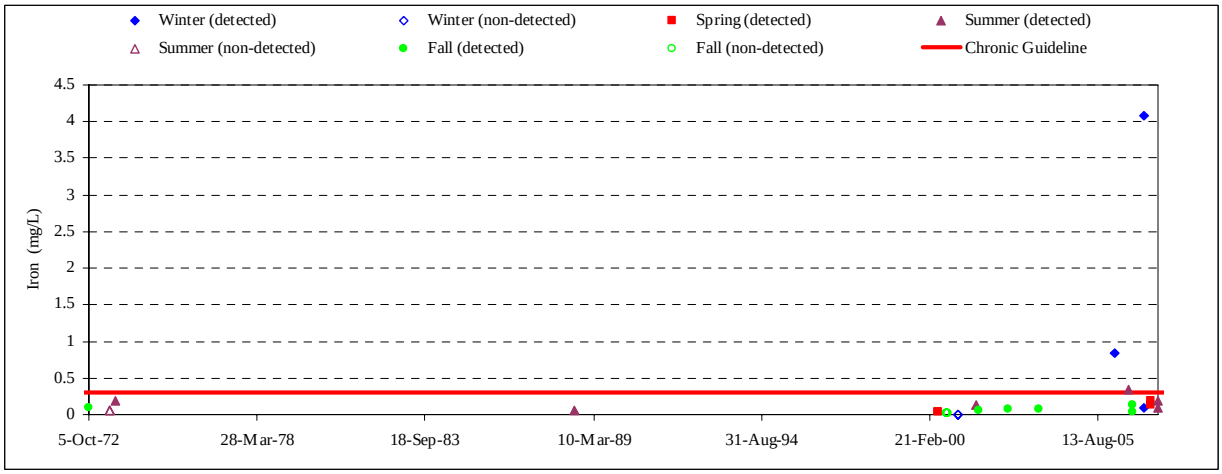
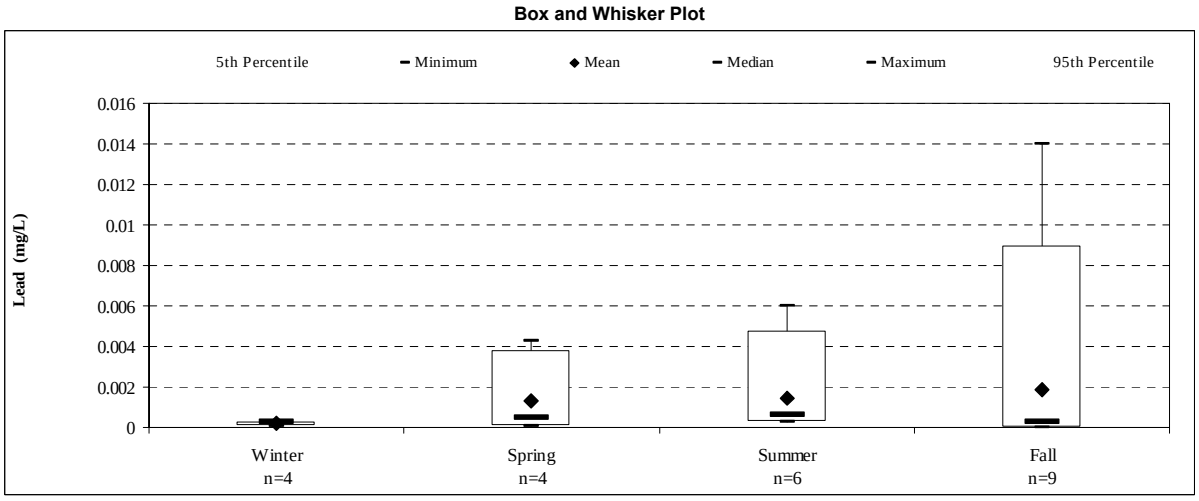


Figure G-1-5-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in McClelland Lake



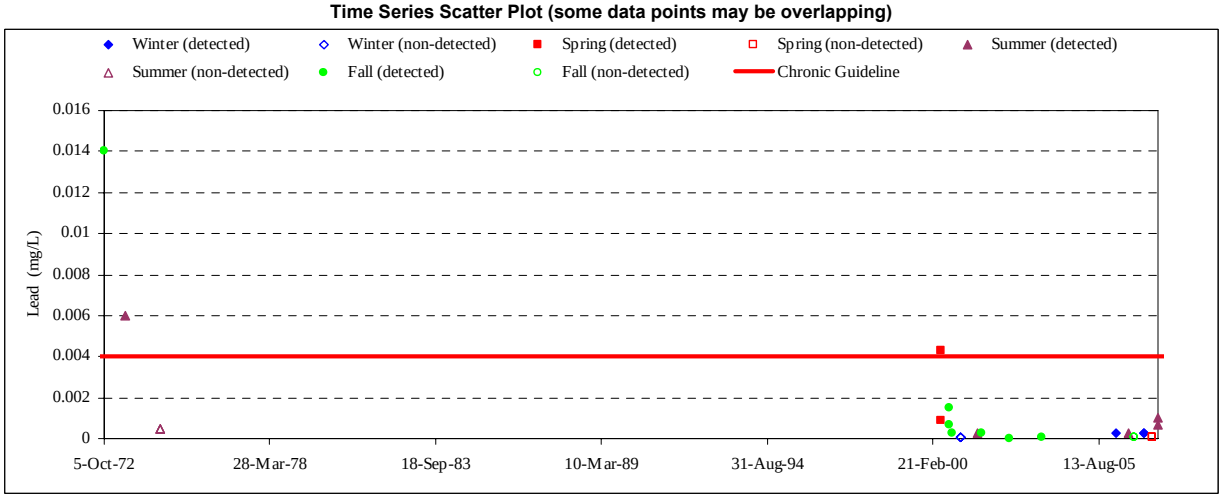
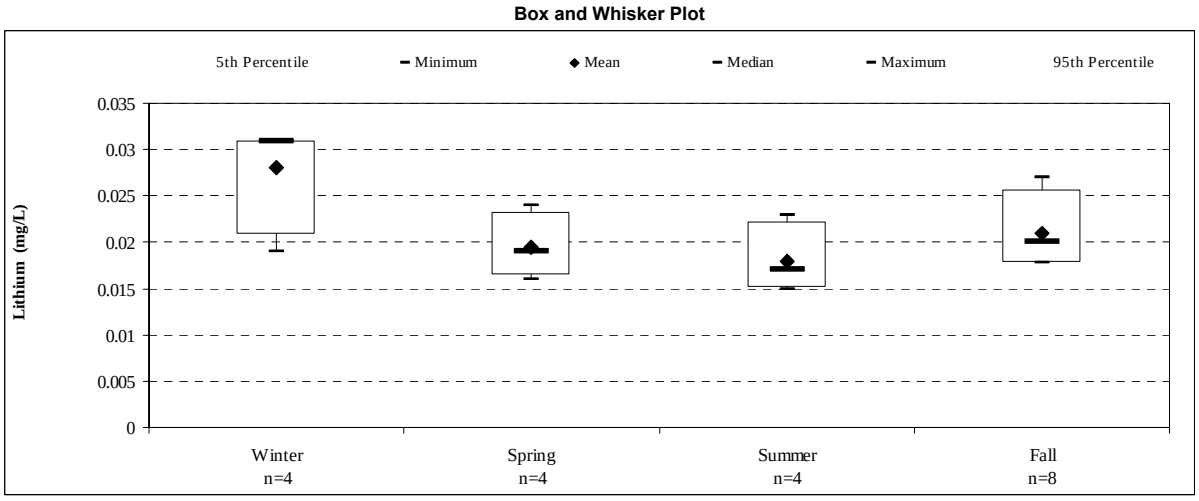


Figure G-1-5-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in McClelland Lake



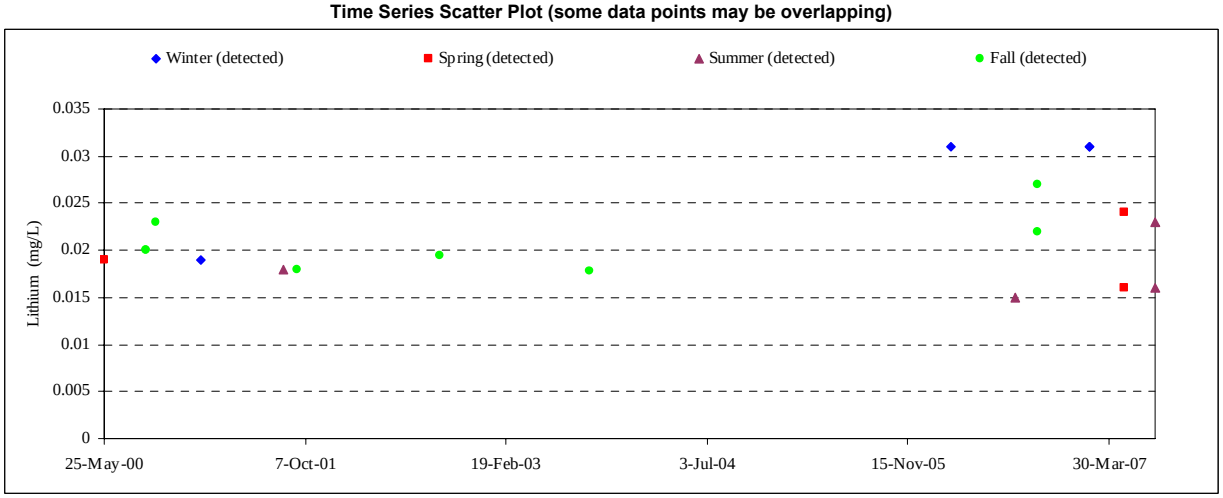


Figure G-1-5-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in McClelland Lake

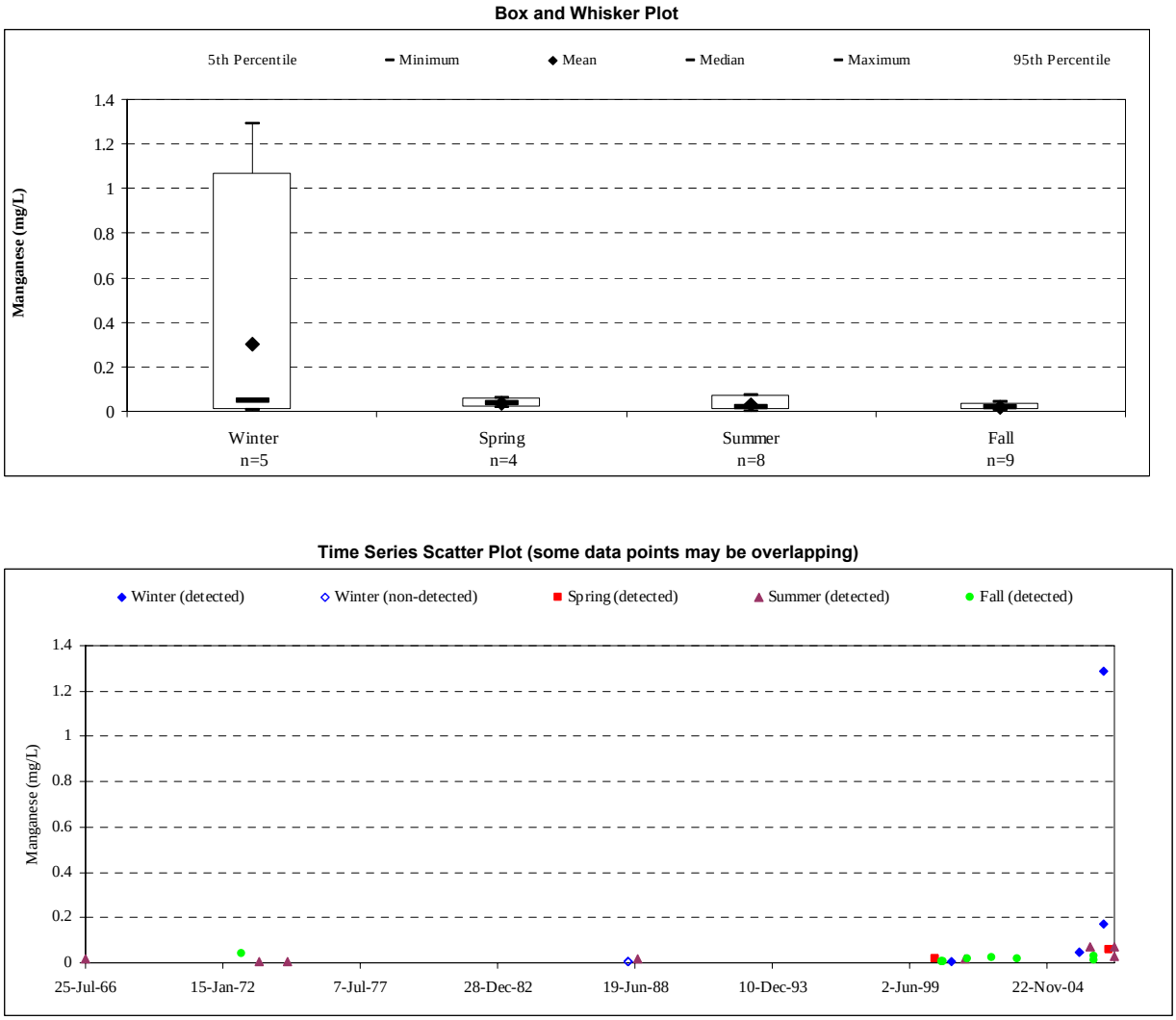
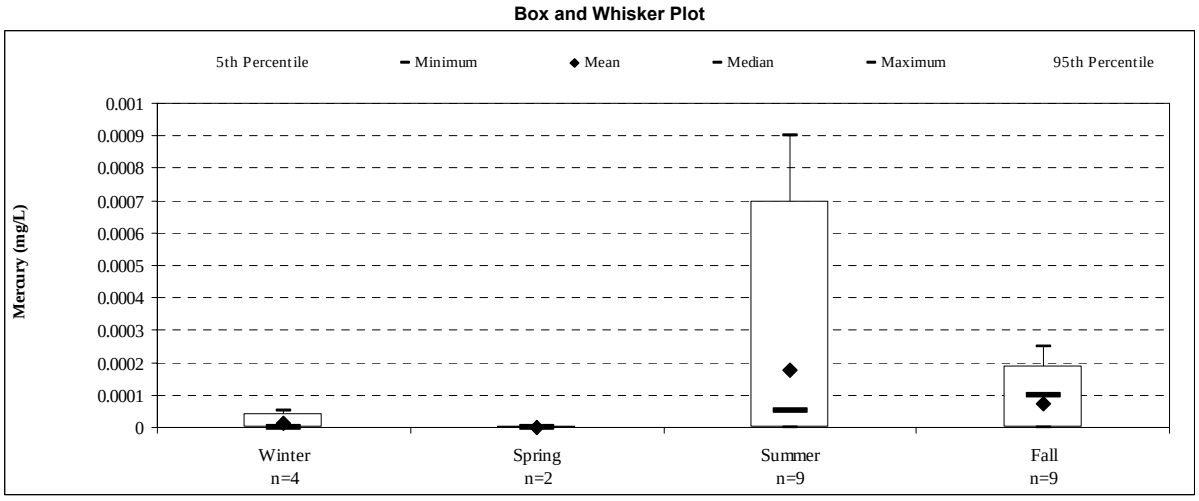


Figure G-1-5-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in McClelland Lake



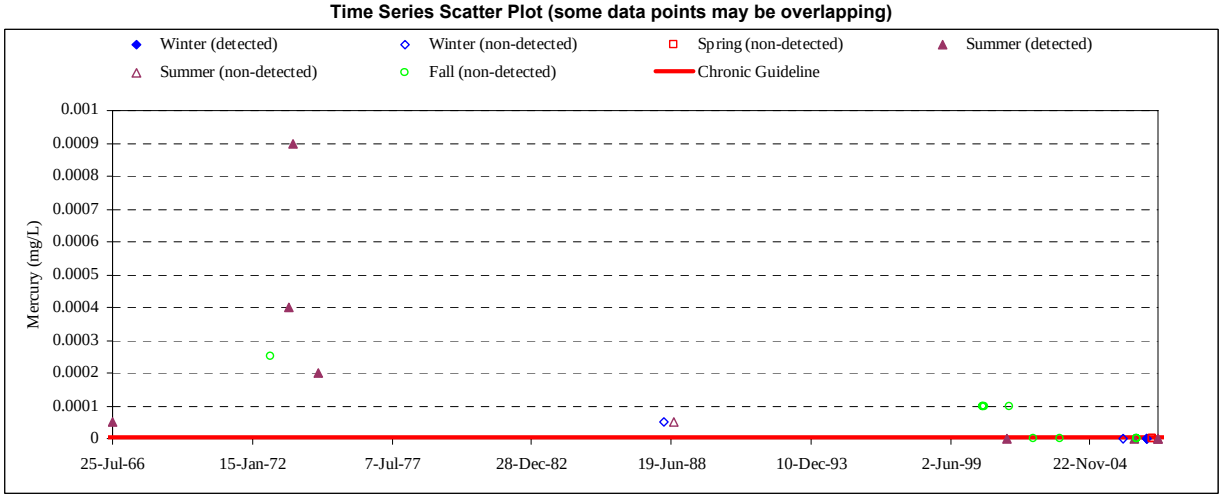
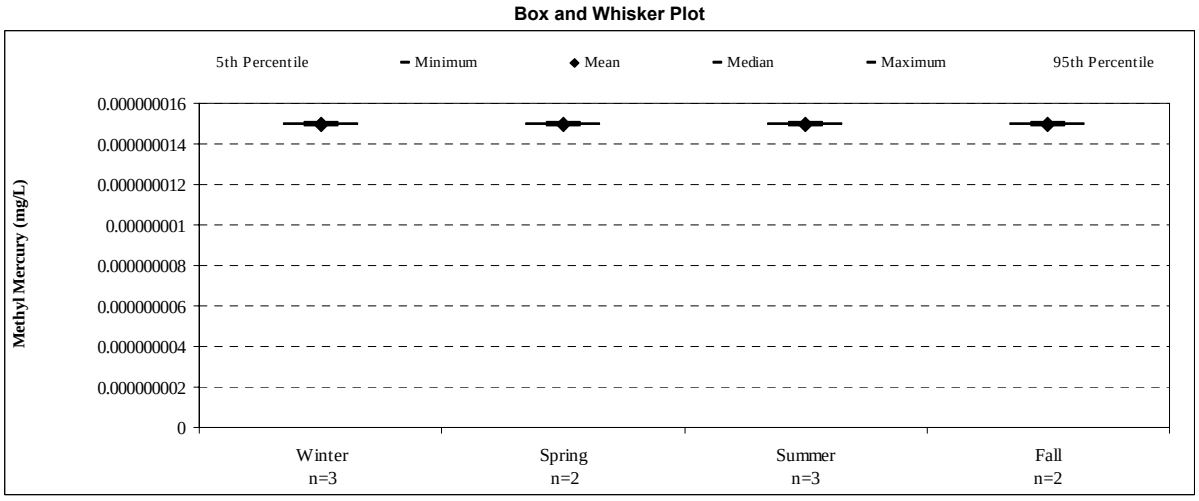


Figure G-1-5-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in McClelland Lake



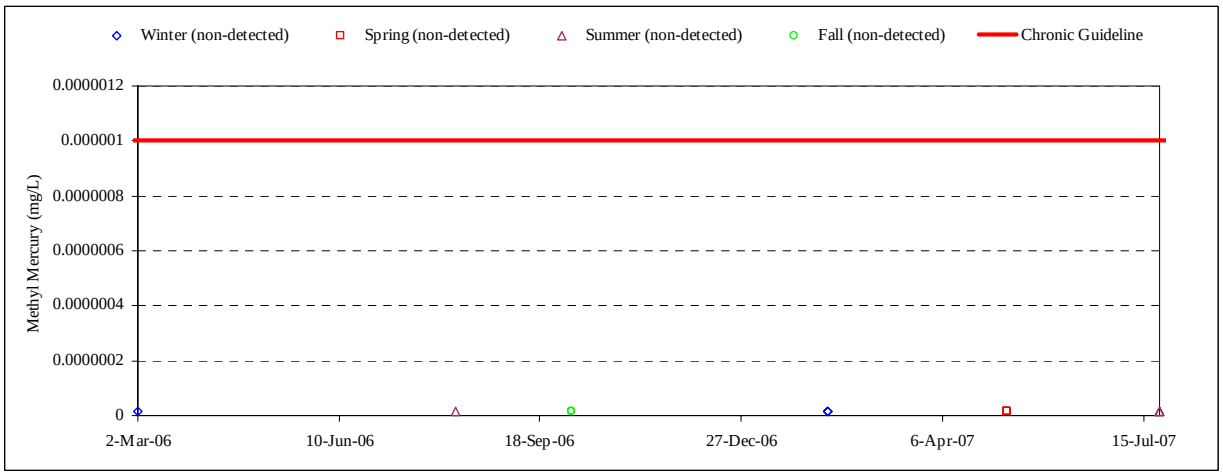
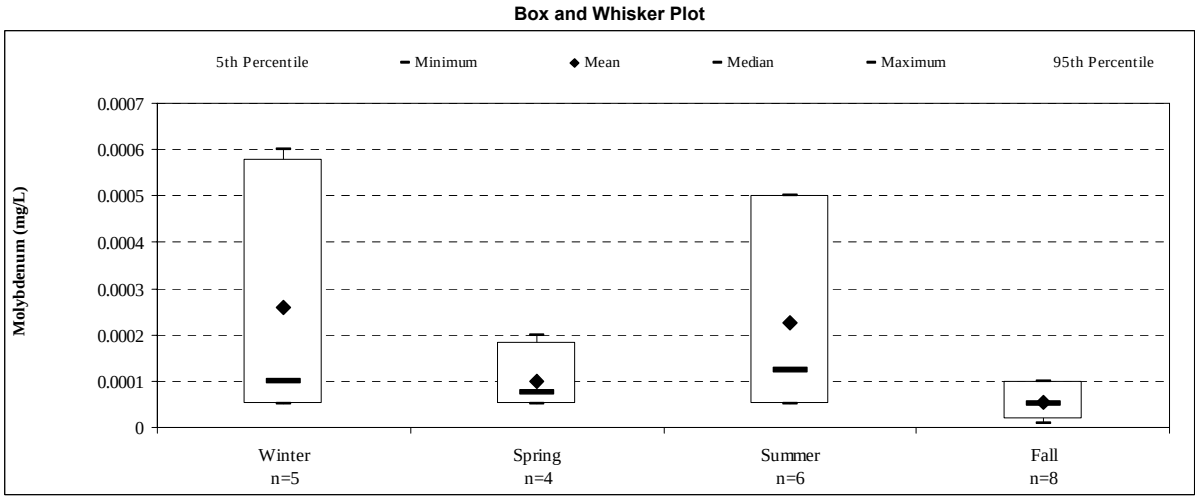


Figure G-1-5-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in McClelland Lake



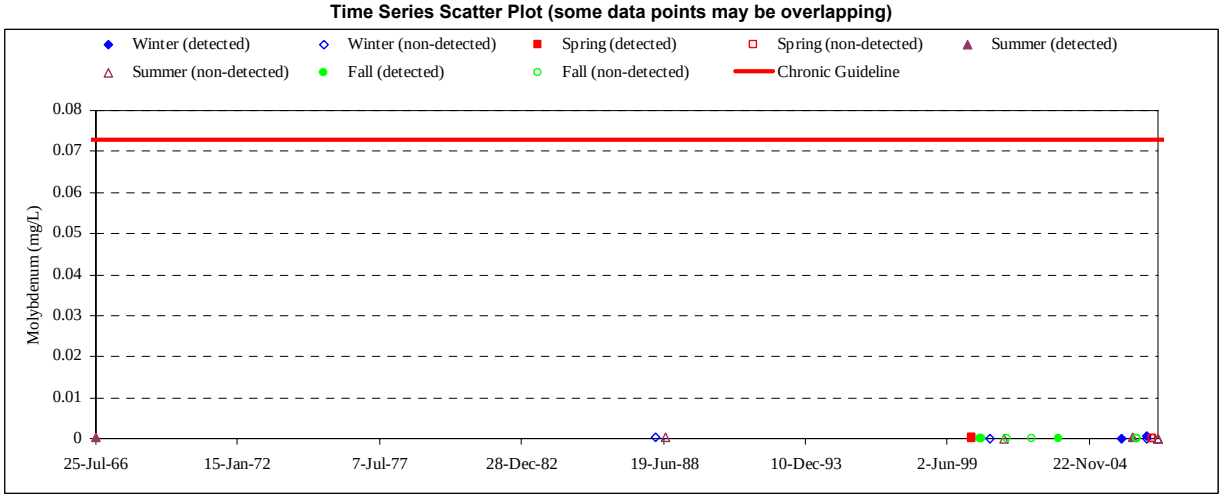
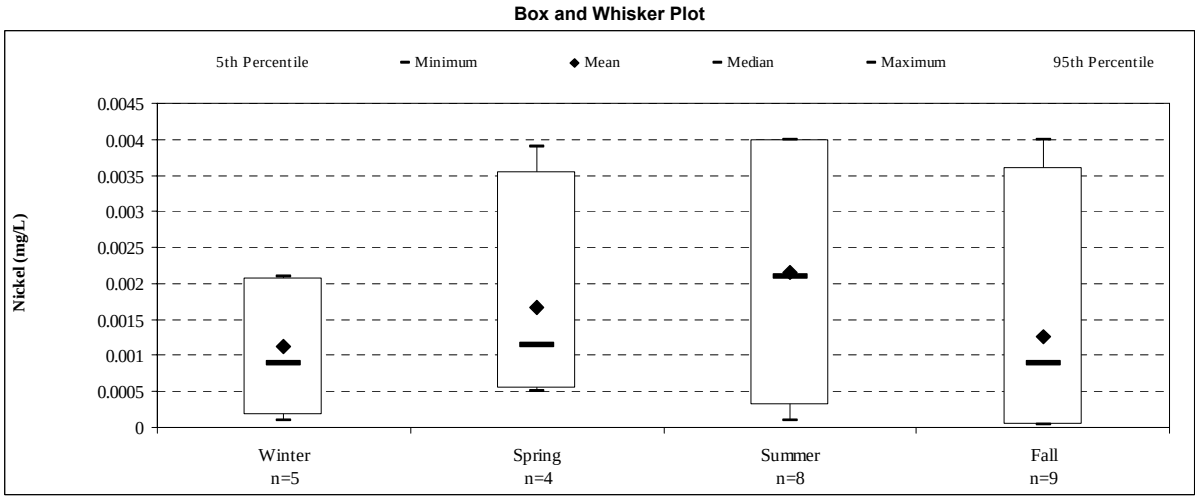


Figure G-1-5-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in McClelland Lake



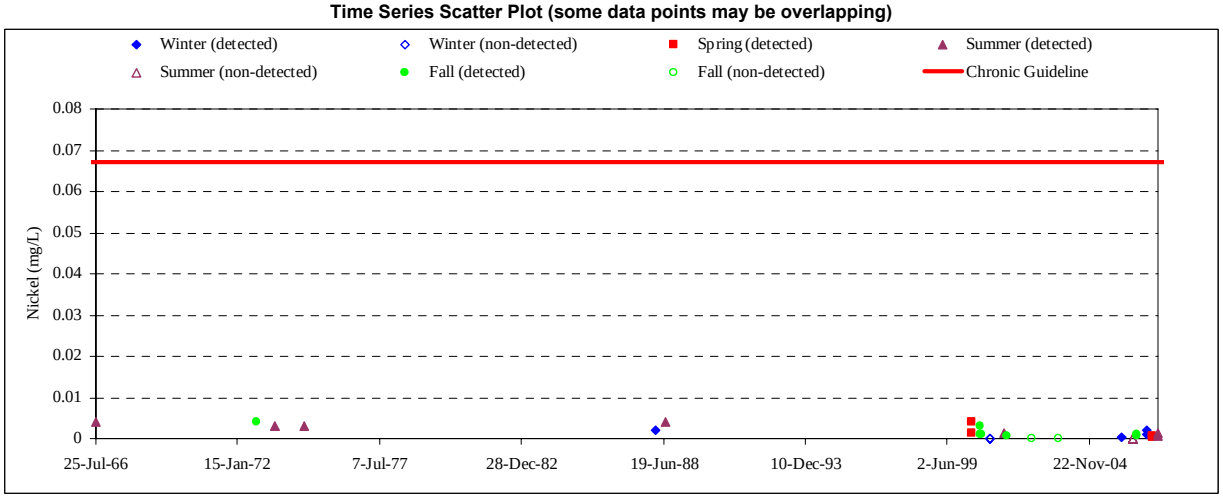
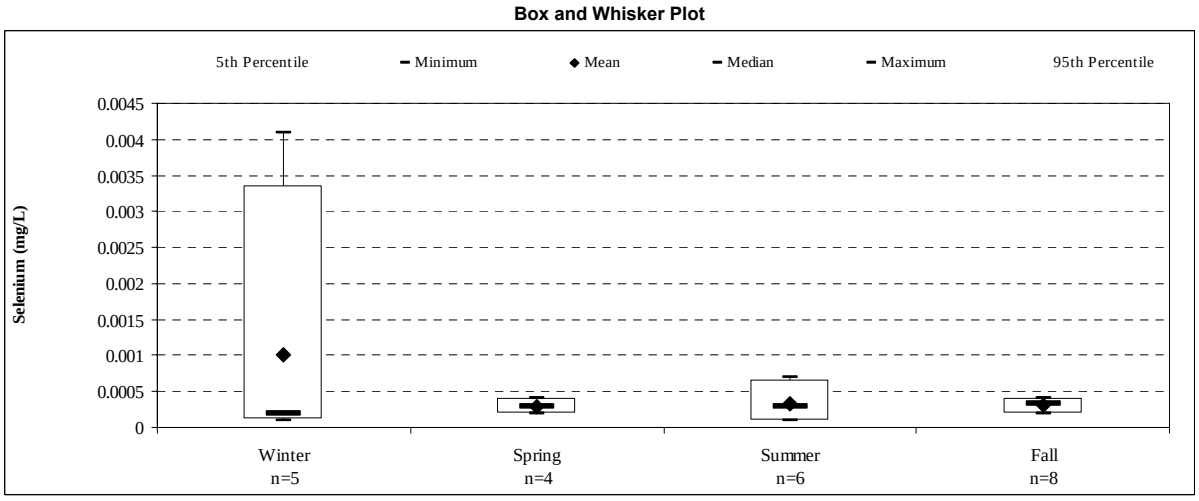


Figure G-1-5-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in McClelland Lake



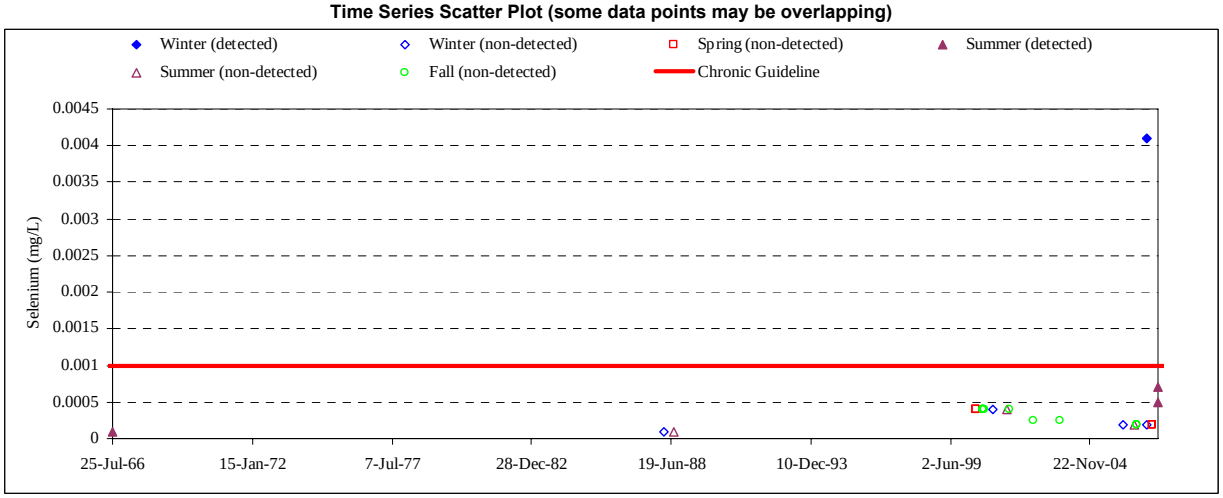
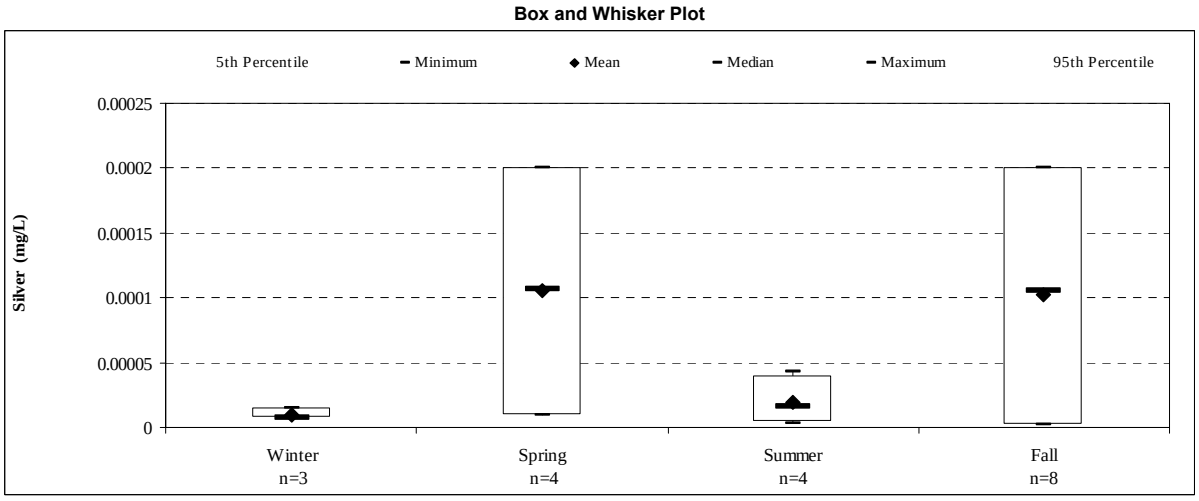


Figure G-1-5-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in McClelland Lake



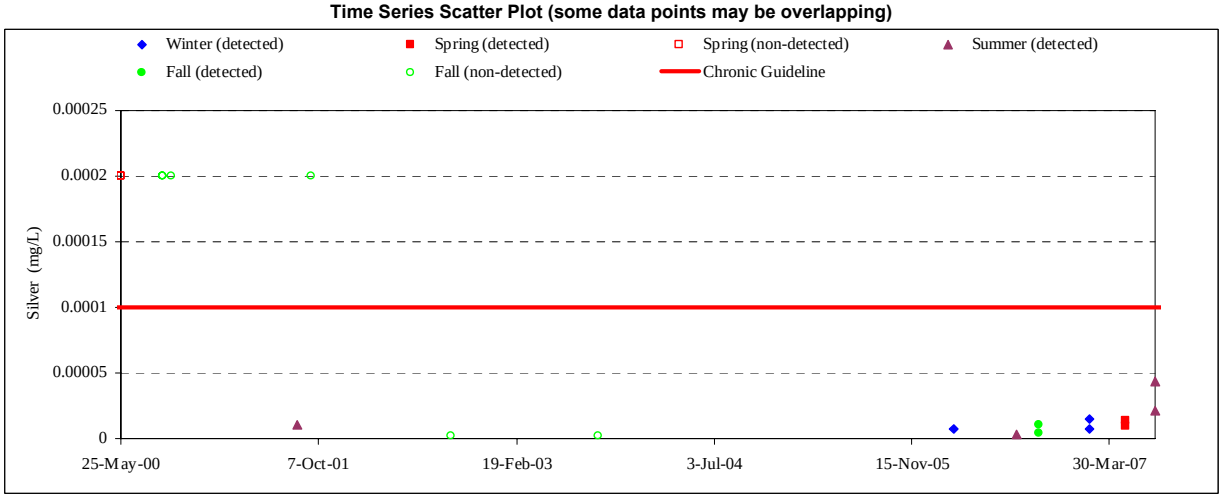
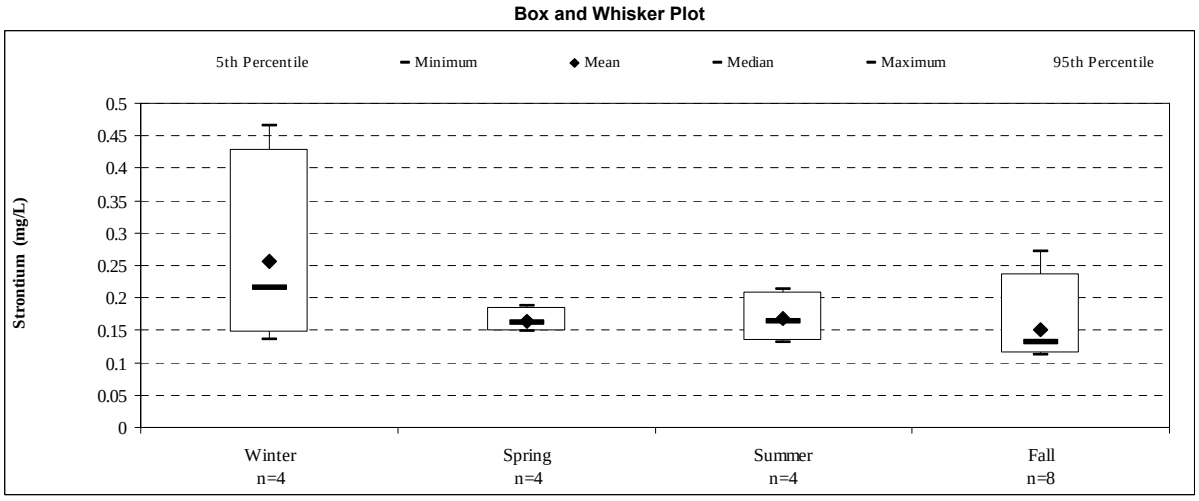


Figure G-1-5-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in McClelland Lake



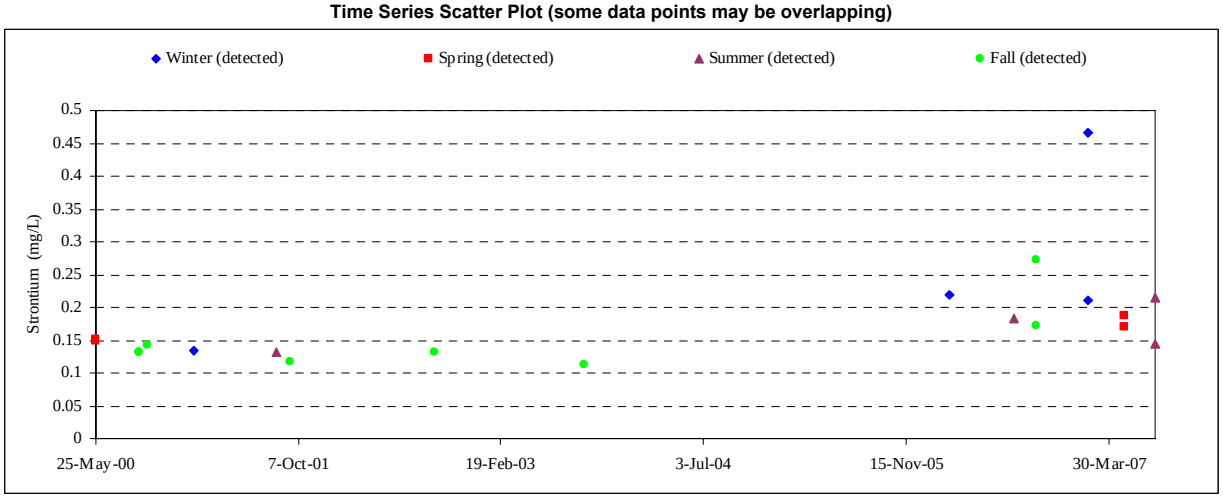


Figure G-1-5-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in McClelland Lake

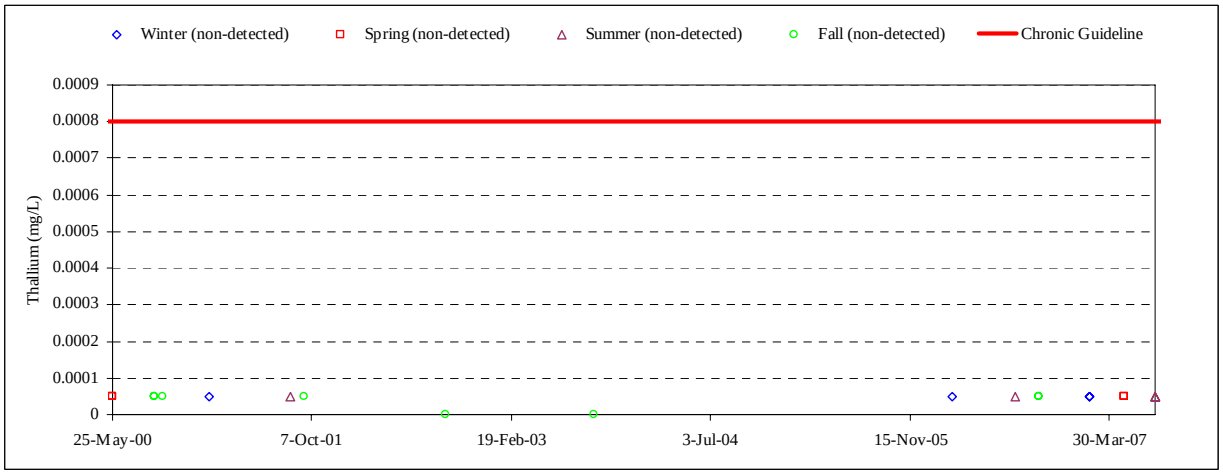


Figure G-1-5-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in McClelland Lake

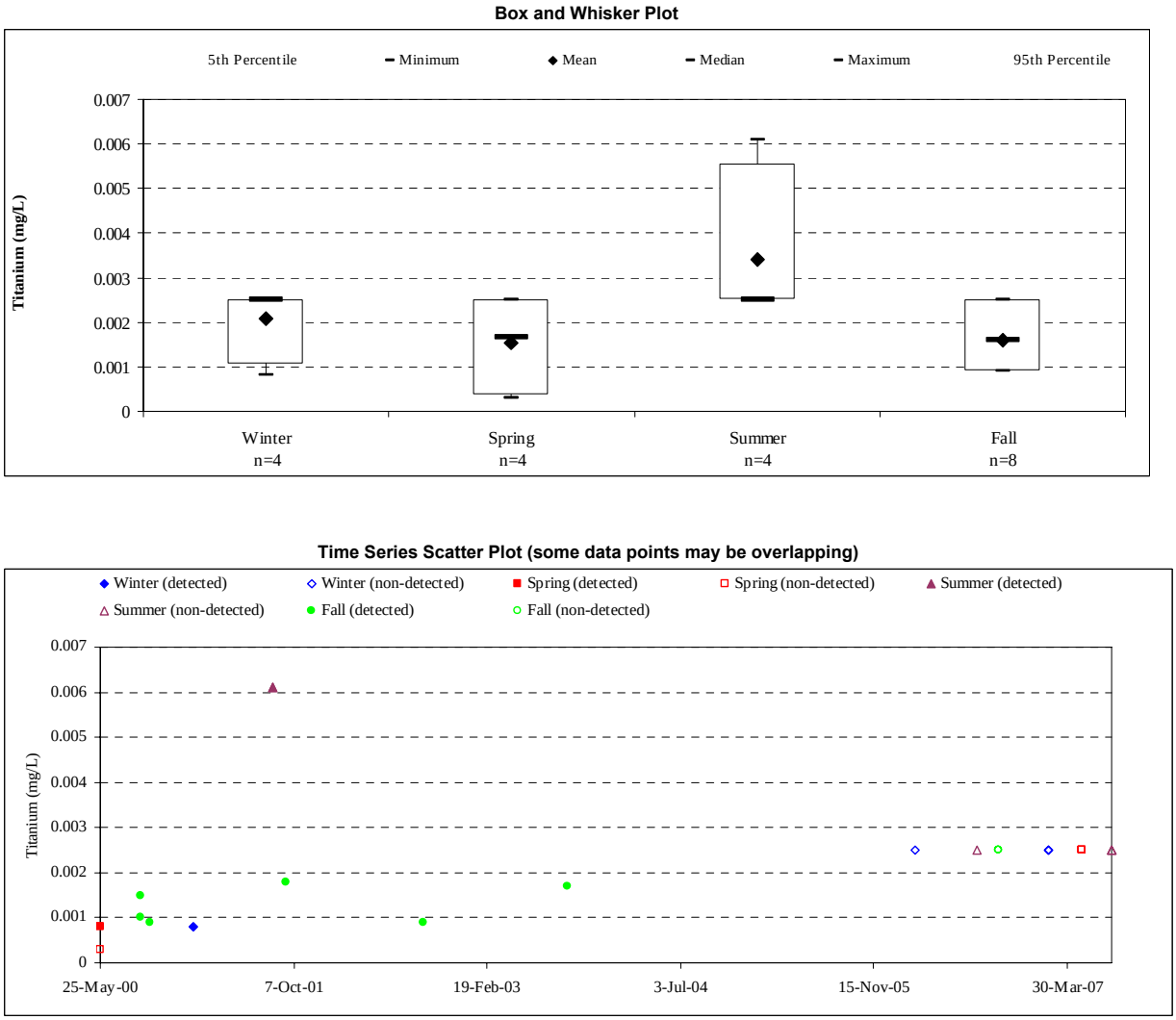
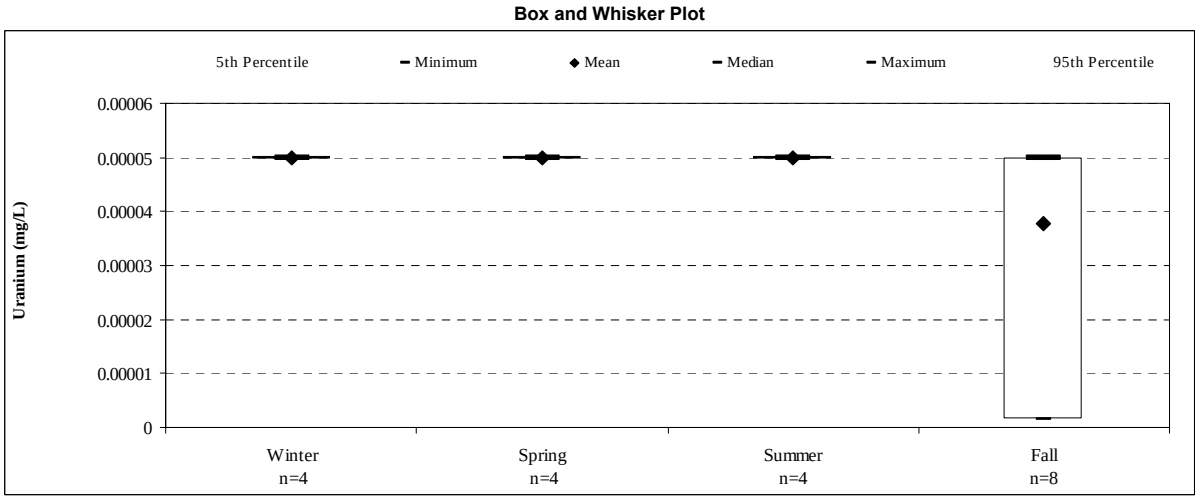


Figure G-1-5-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in McClelland Lake



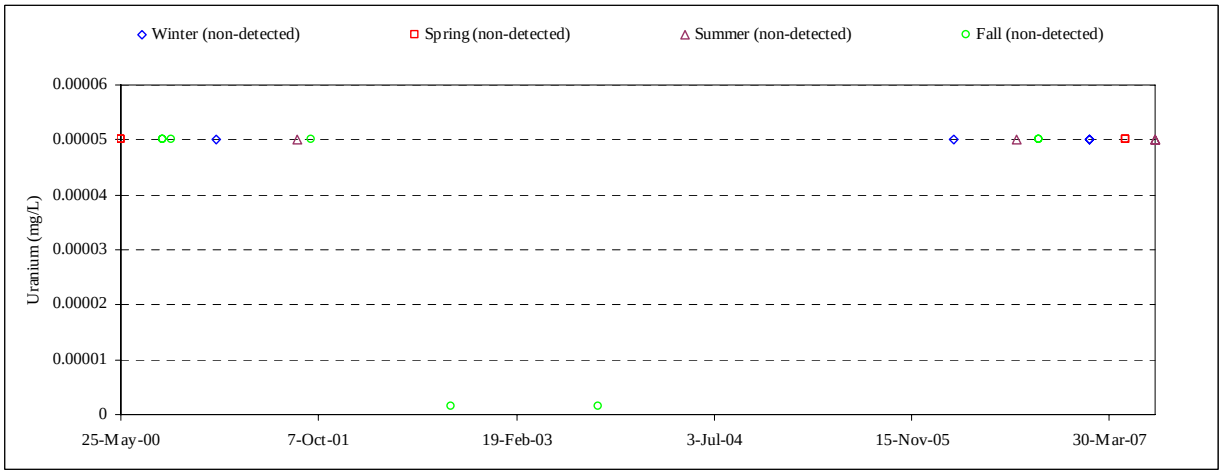
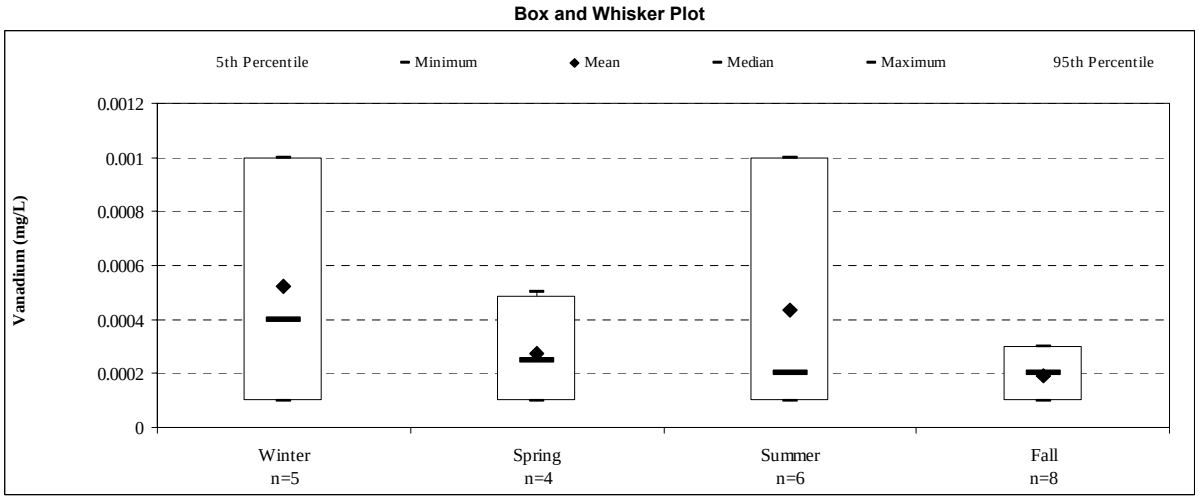


Figure G-1-5-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in McClelland Lake



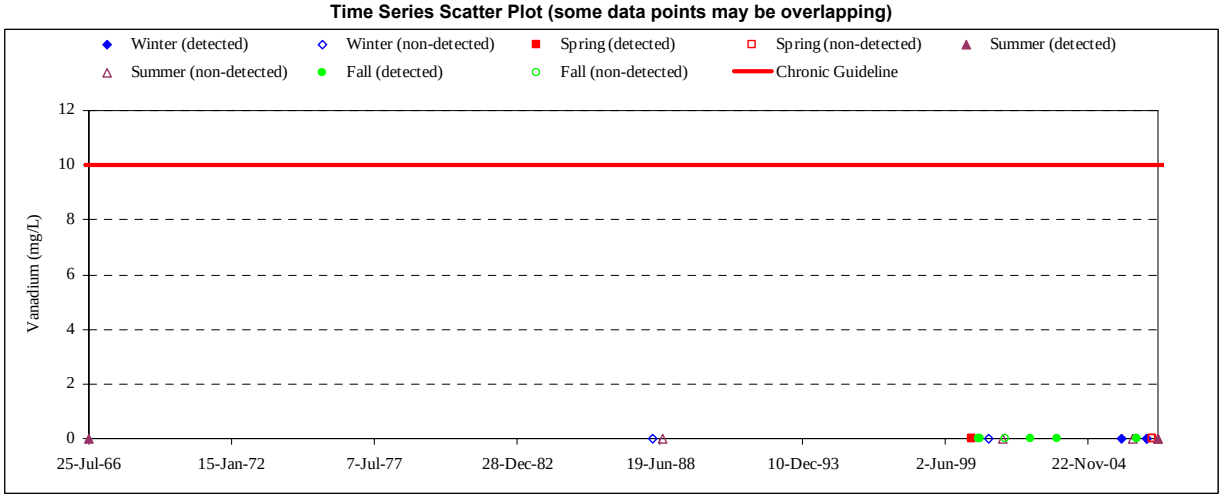
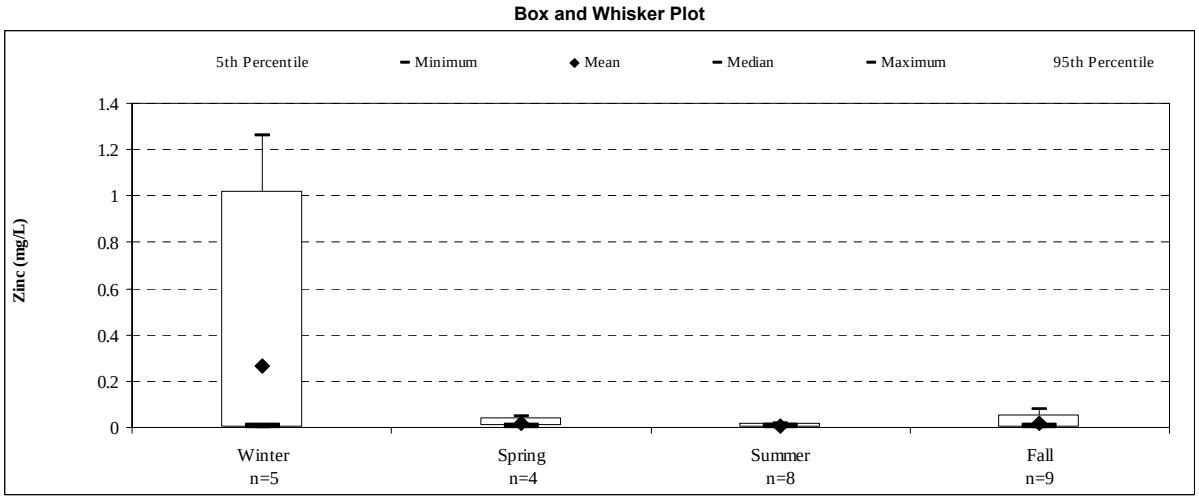


Figure G-1-5-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in McClelland Lake



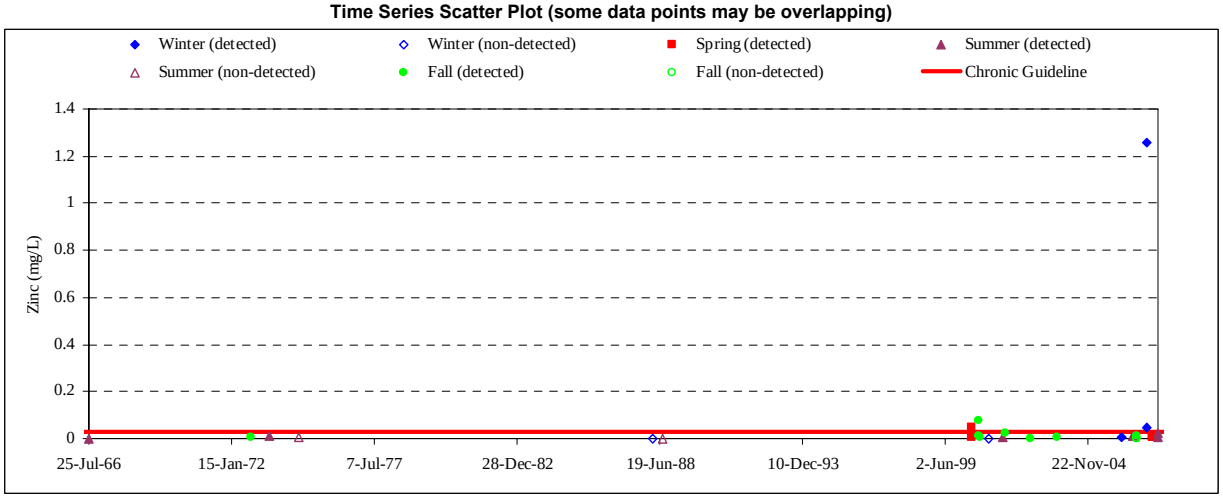
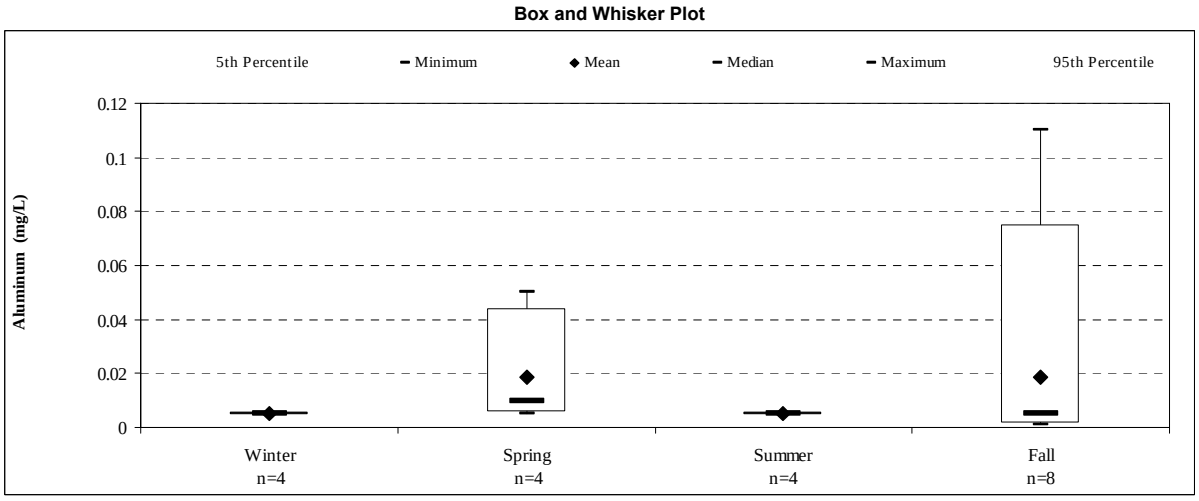


Figure G-1-5-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in McClelland Lake



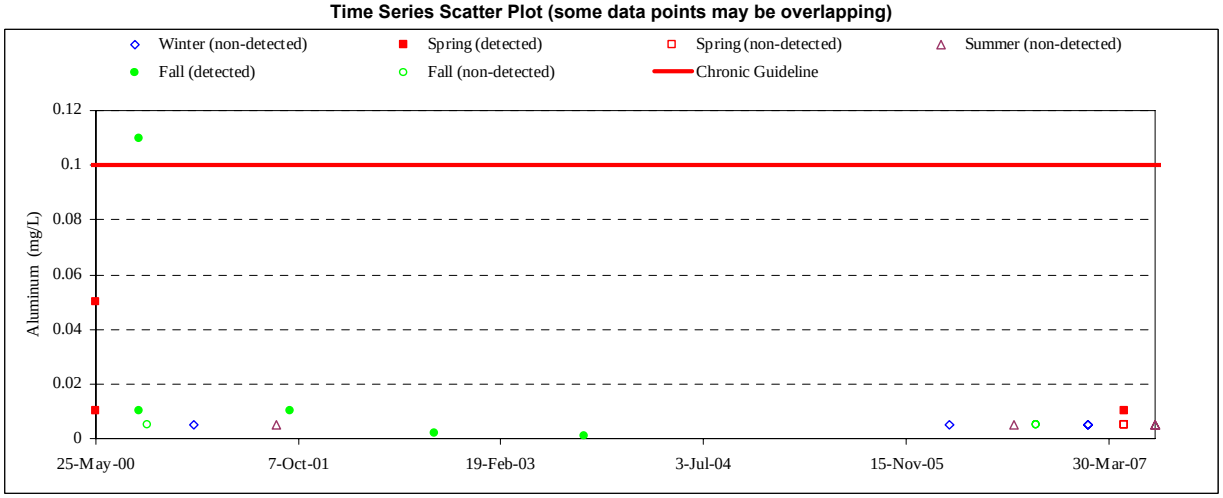
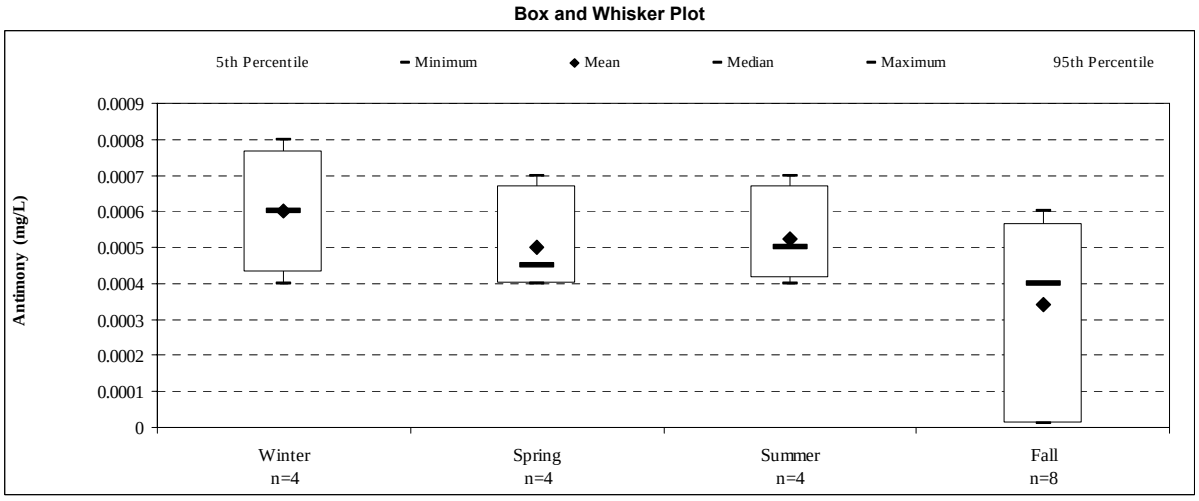


Figure G-1-5-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in McClelland Lake



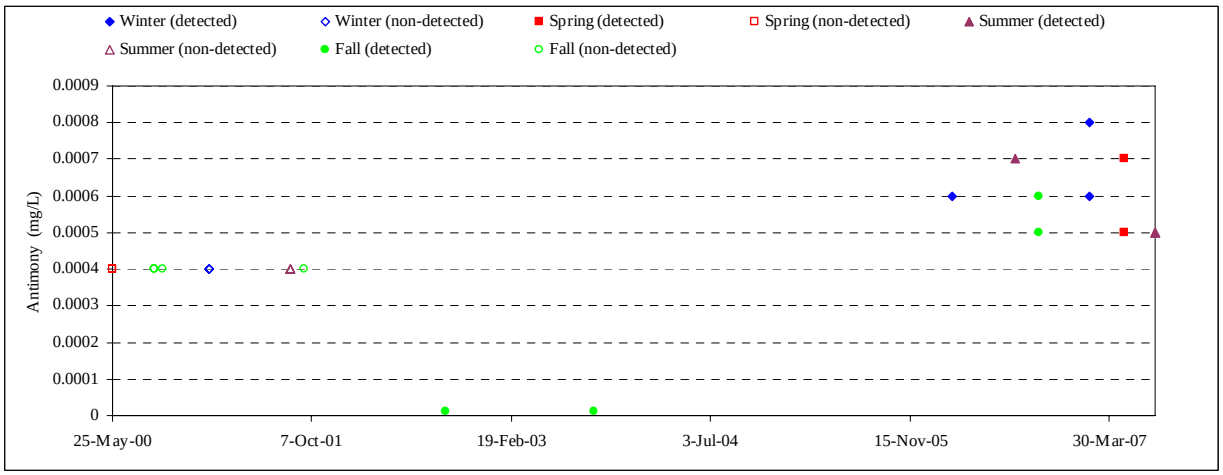
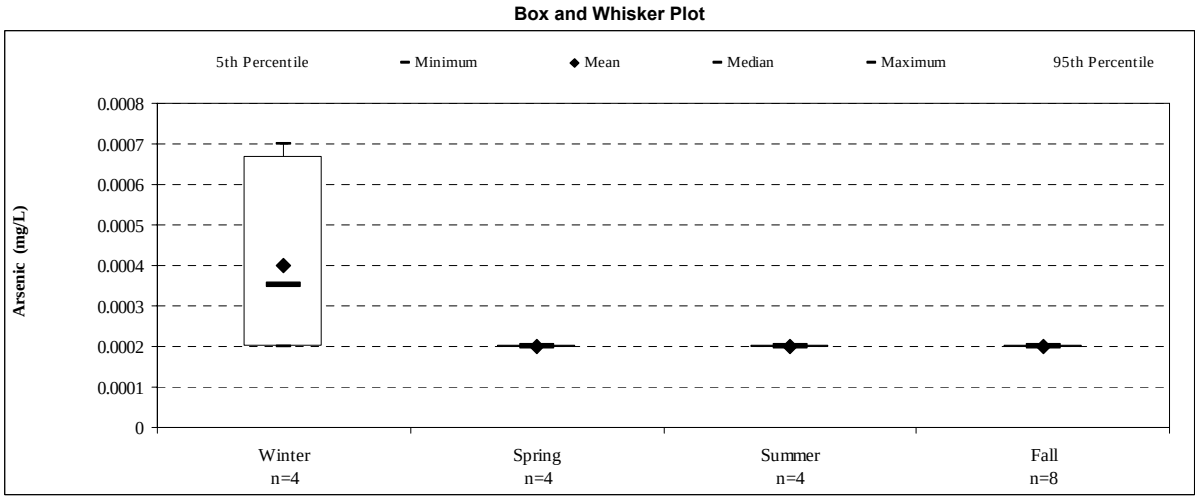


Figure G-1-5-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in McClelland Lake



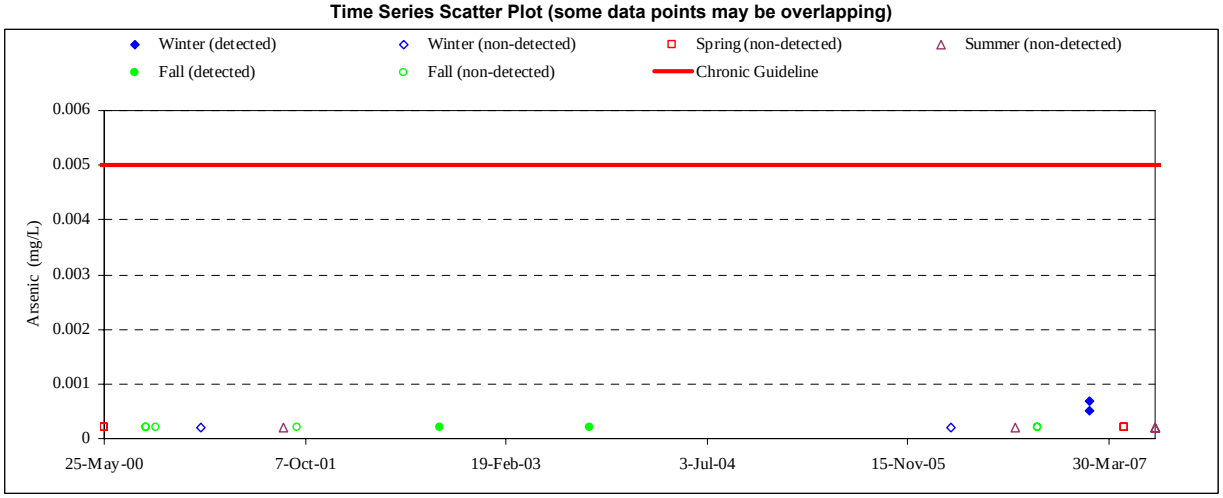
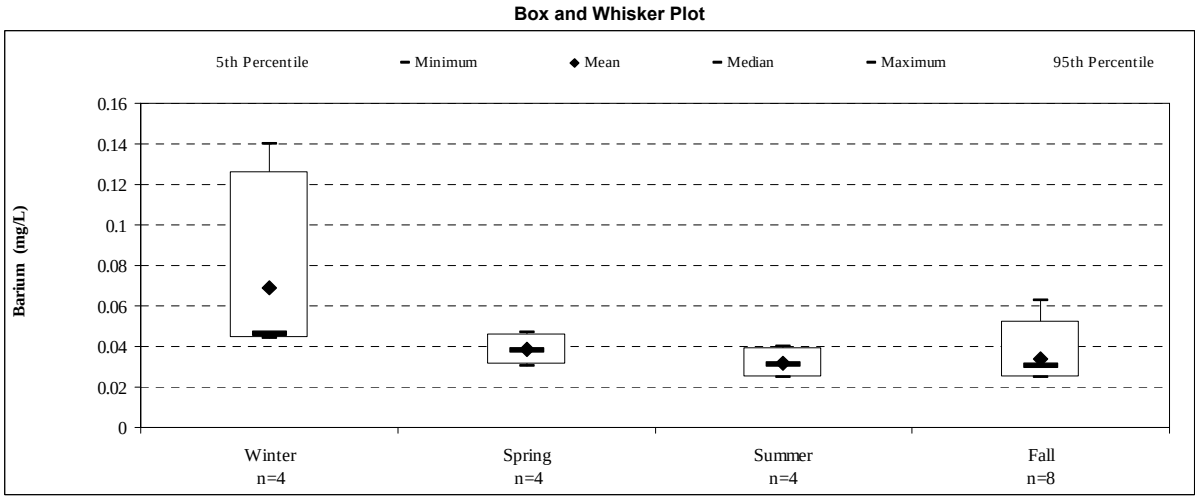


Figure G-1-5-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in McClelland Lake



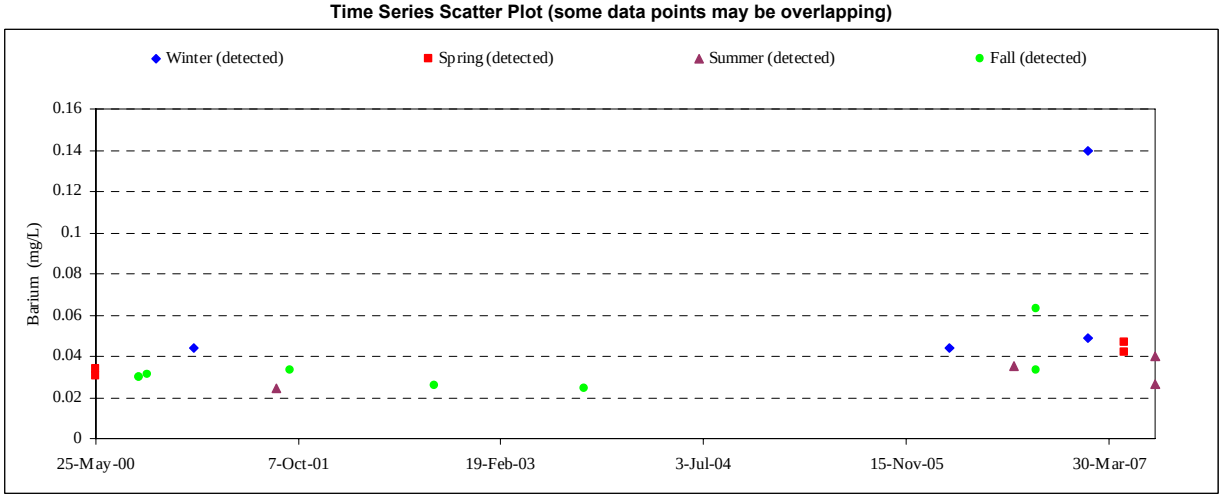
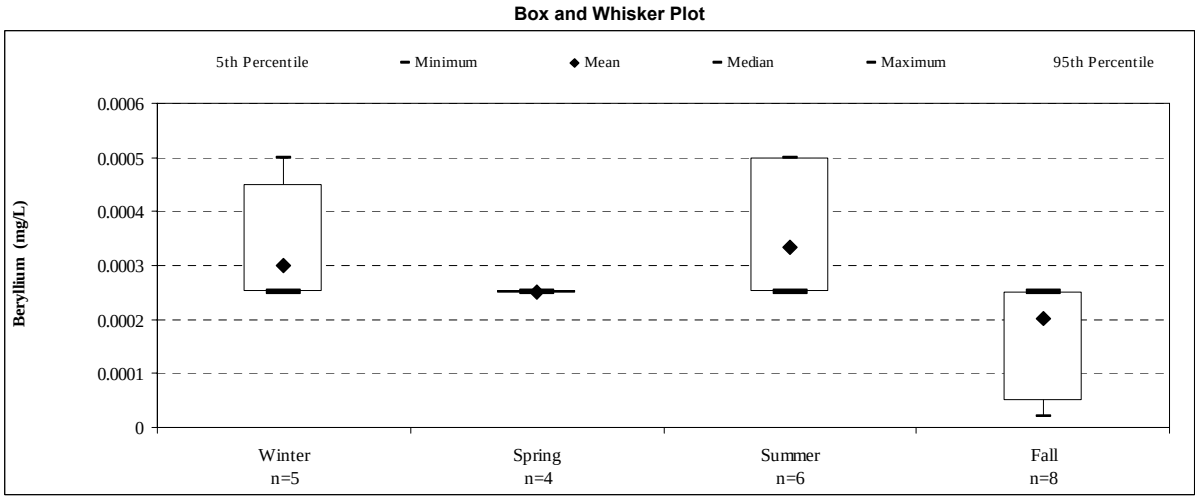


Figure G-1-5-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in McClelland Lake



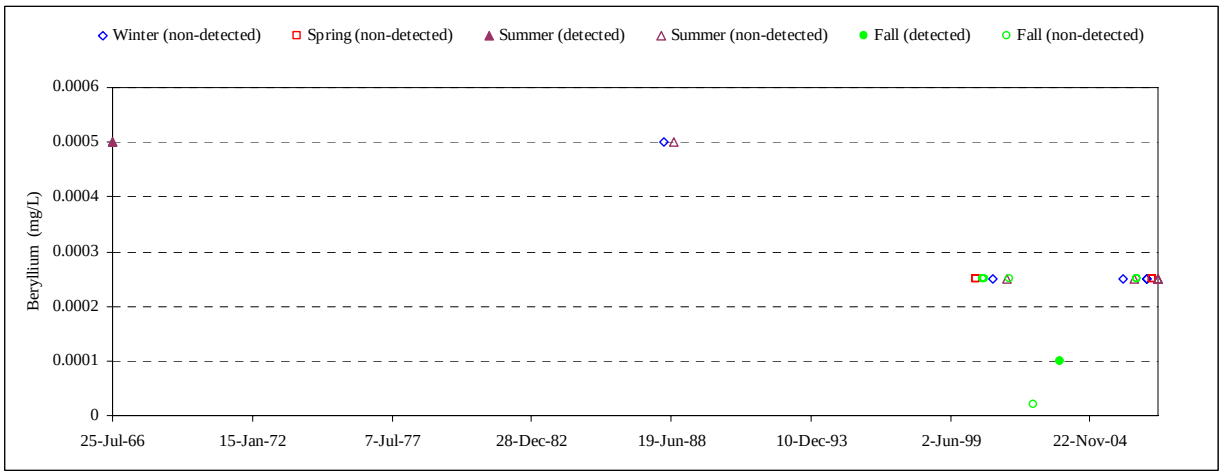
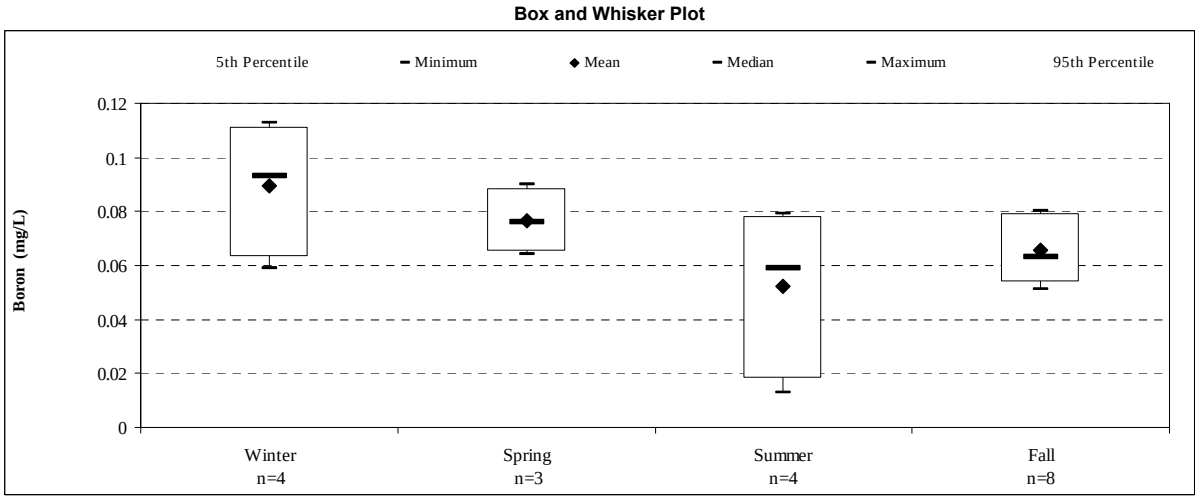


Figure G-1-5-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in McClelland Lake



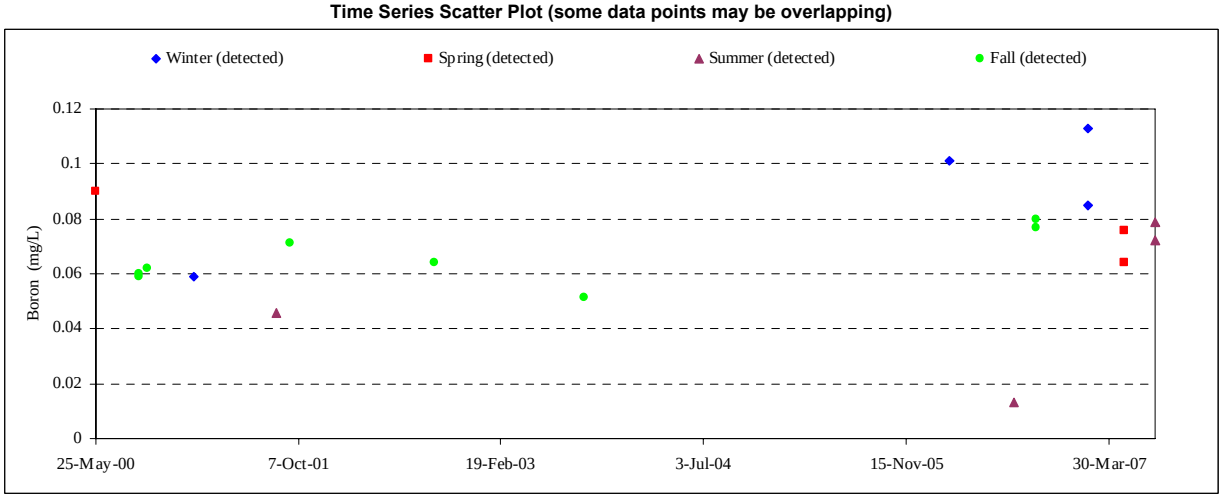
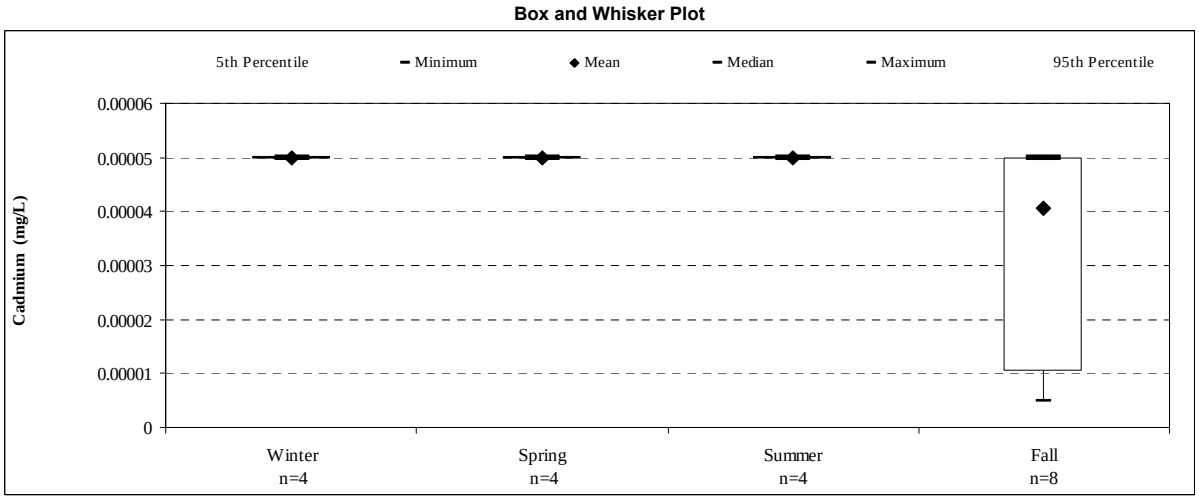


Figure G-1-5-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in McClelland Lake



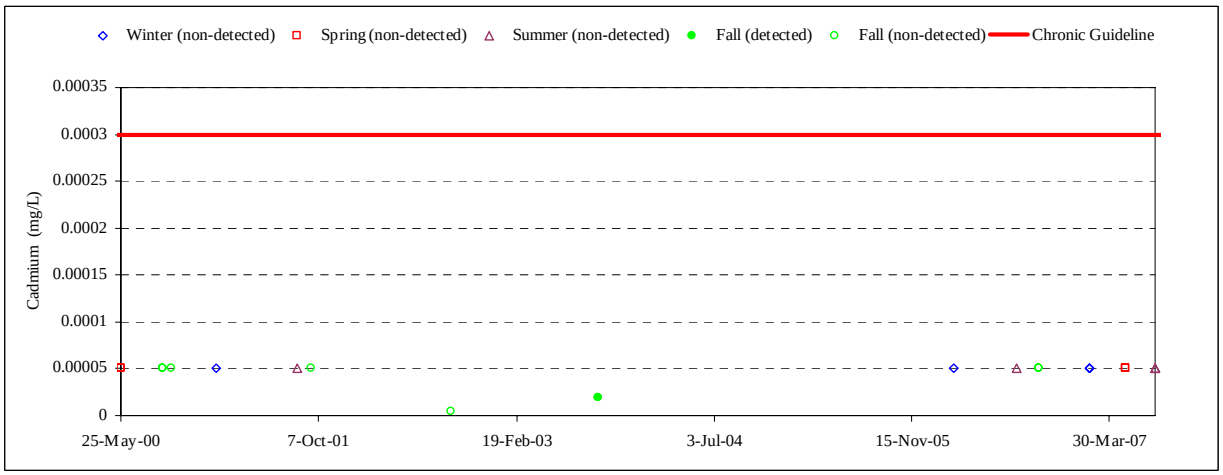


Figure G-1-5-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in McClelland Lake

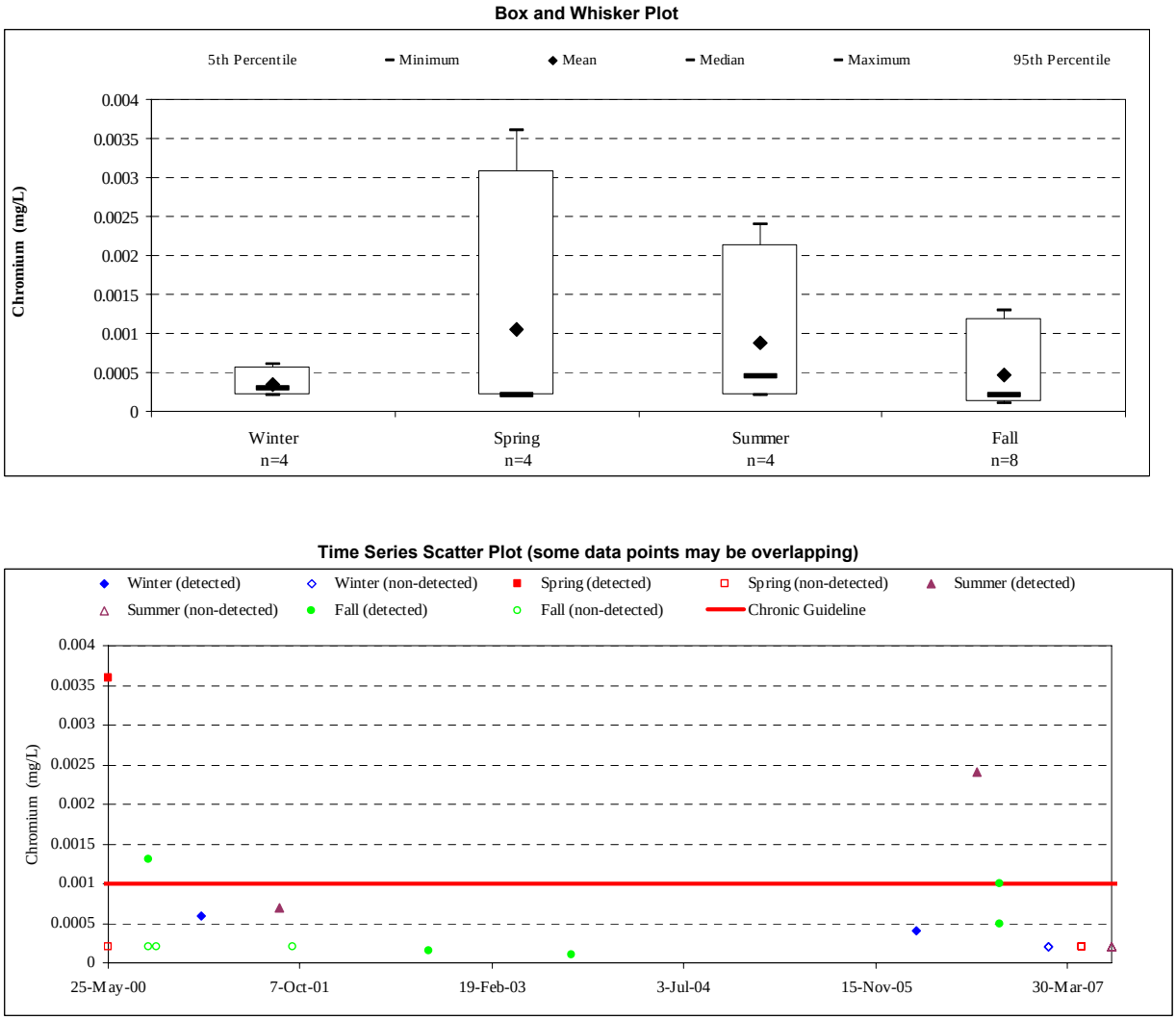
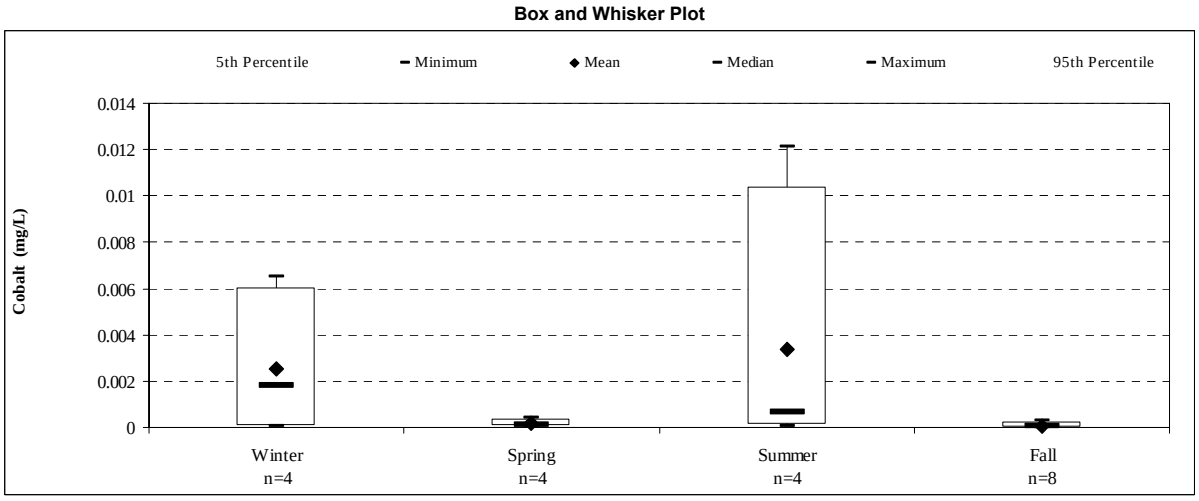


Figure G-1-5-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in McClelland Lake



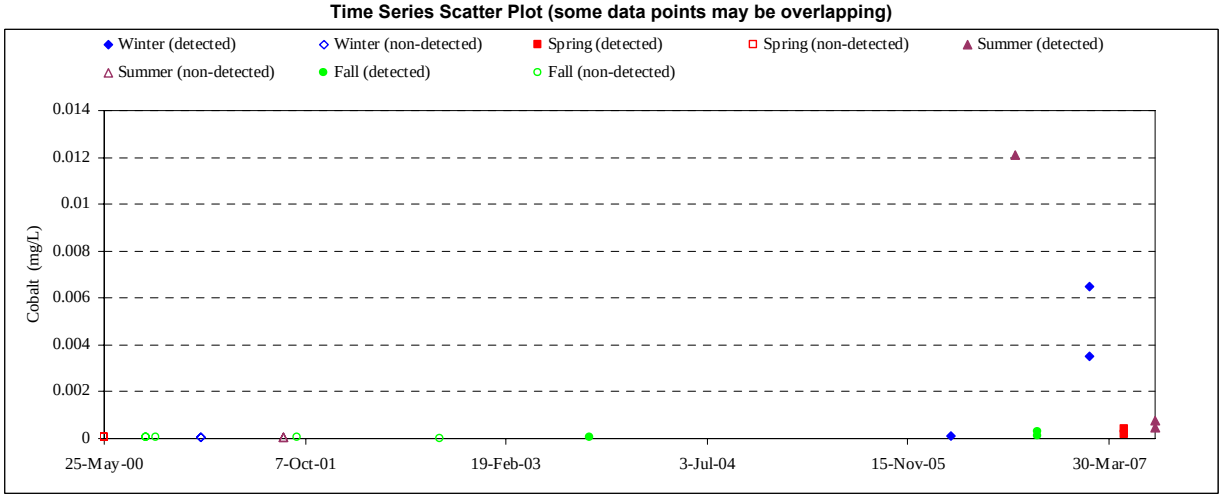
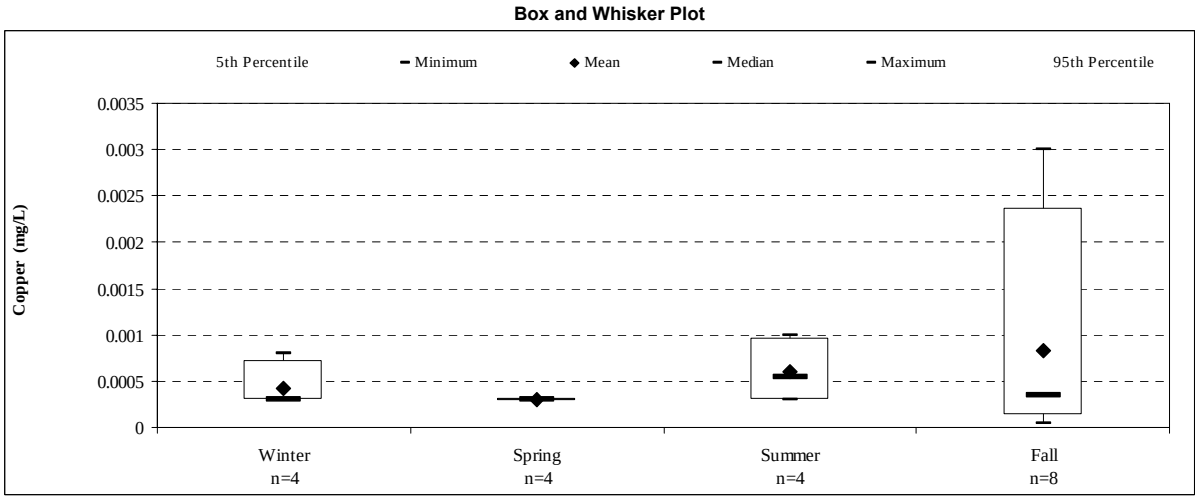


Figure G-1-5-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in McClelland Lake



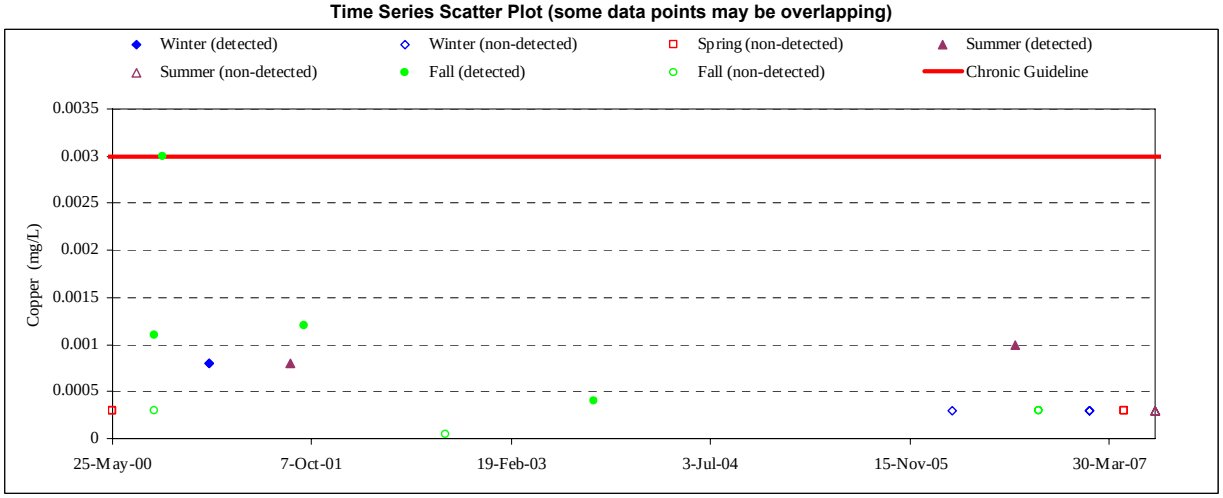
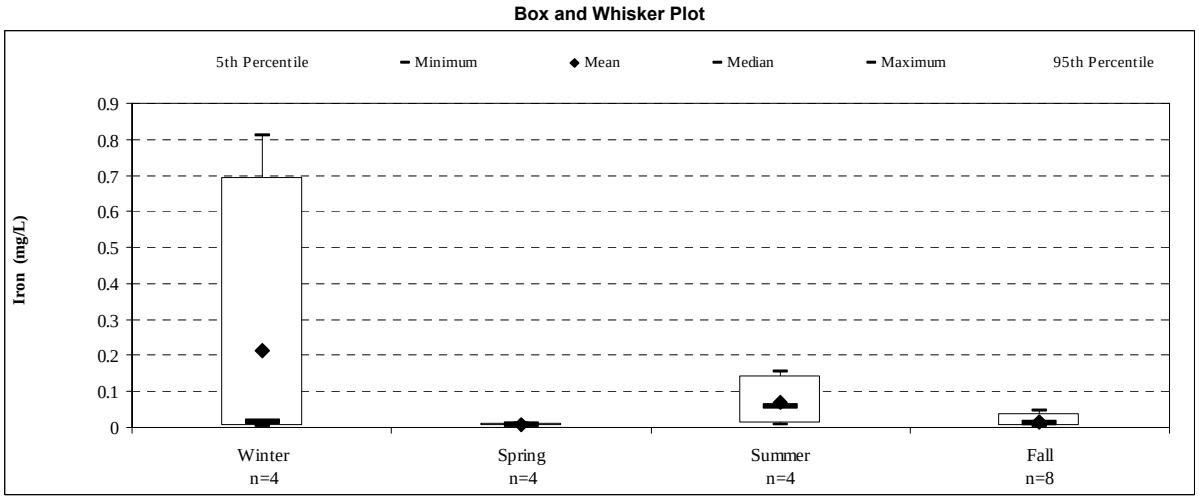


Figure G-1-5-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in McClelland Lake



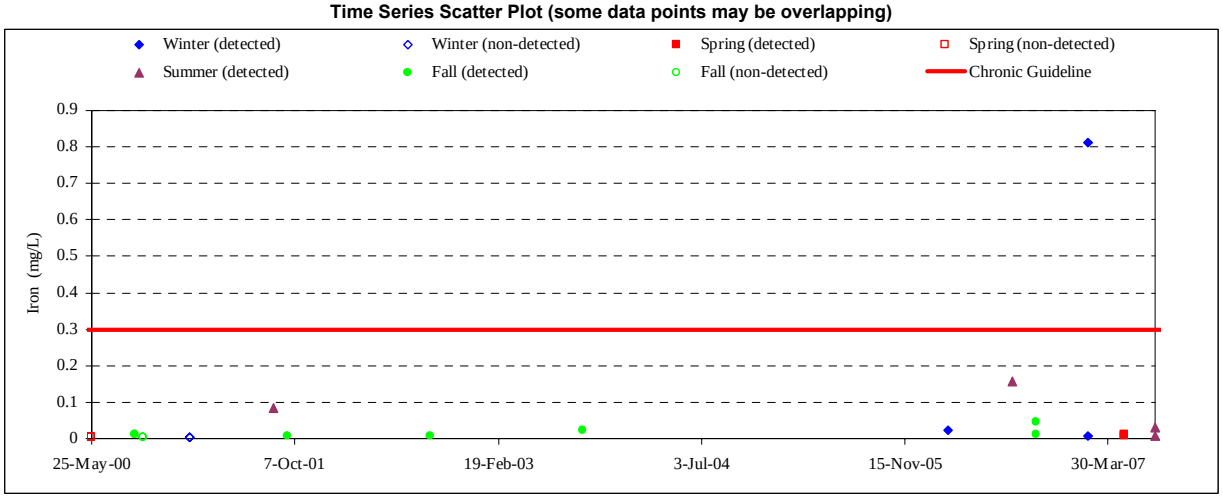
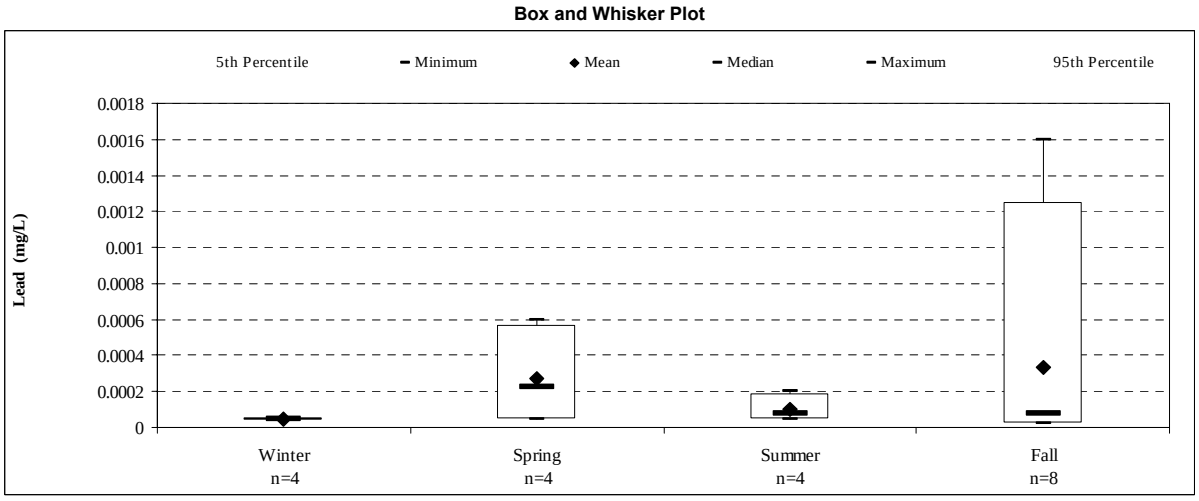


Figure G-1-5-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in McClelland Lake



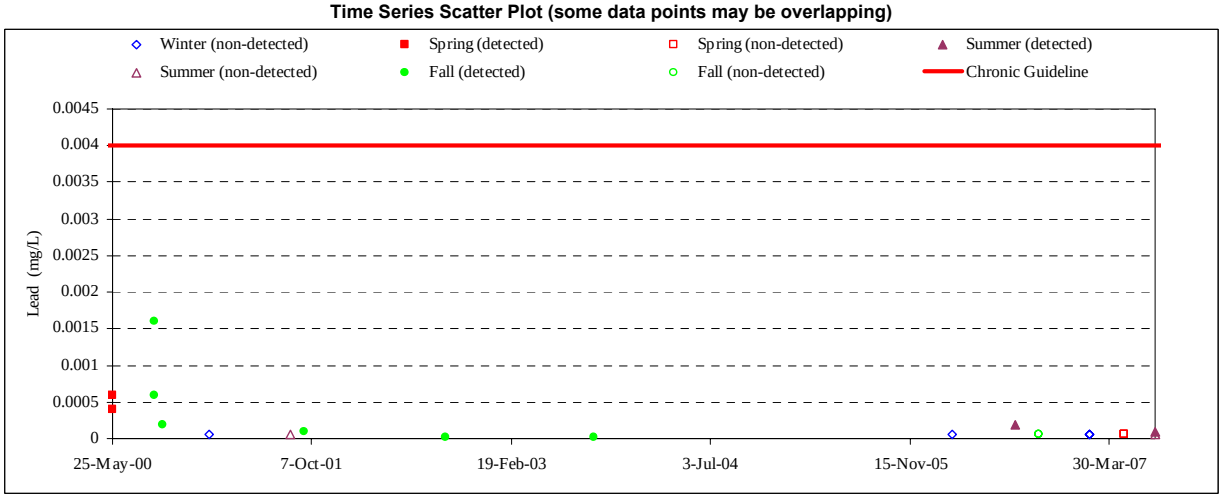
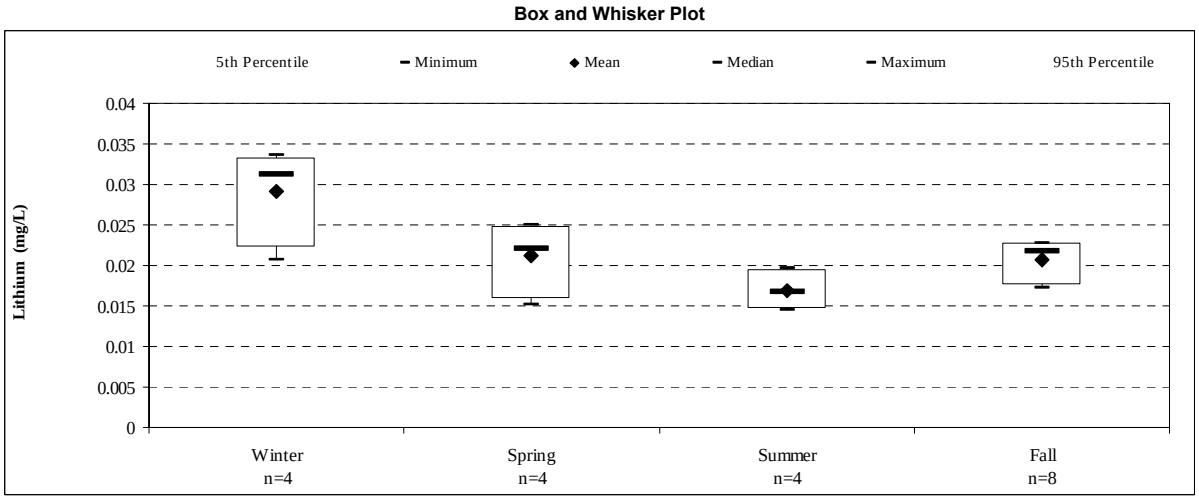


Figure G-1-5-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in McClelland Lake



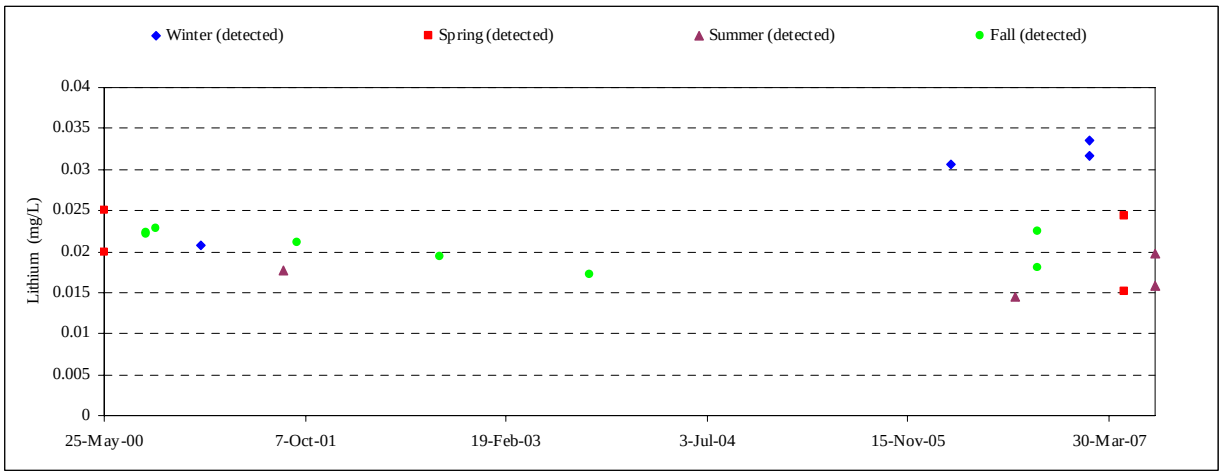
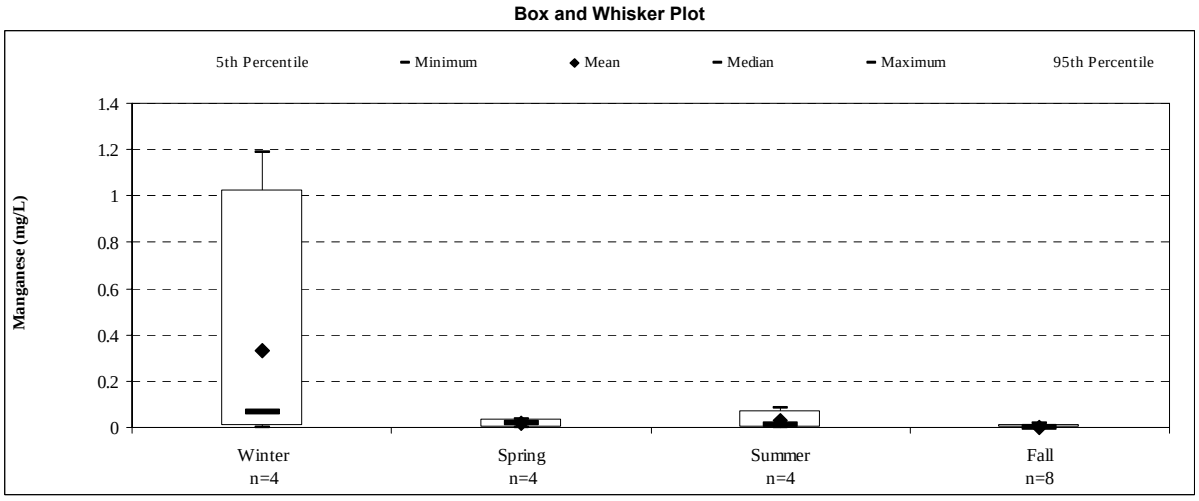


Figure G-1-5-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in McClelland Lake



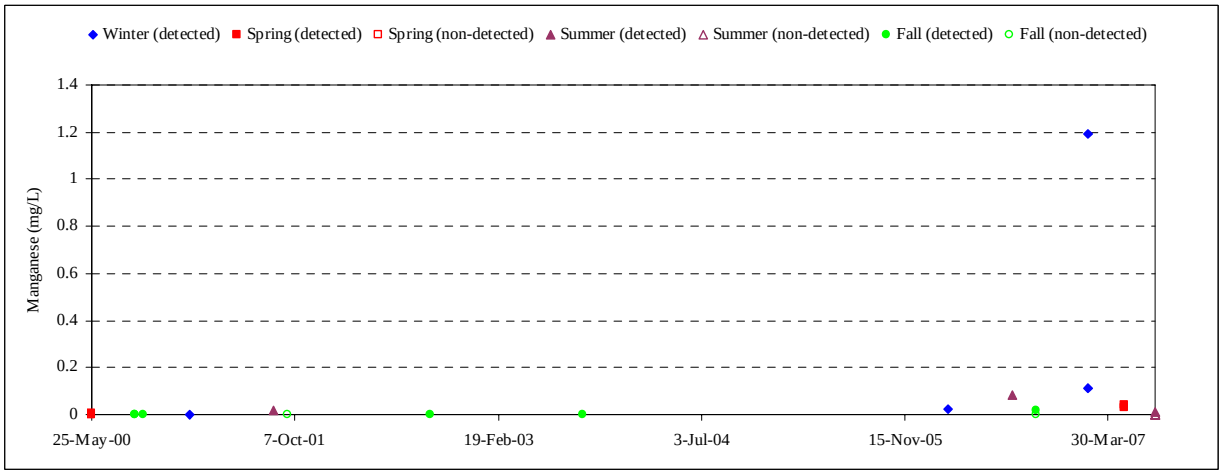
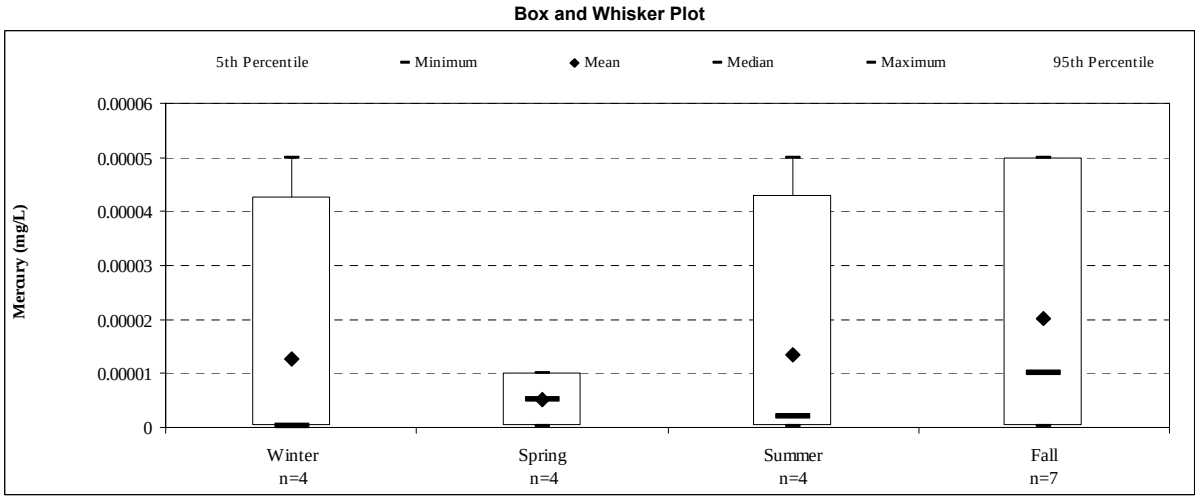


Figure G-1-5-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in McClelland Lake



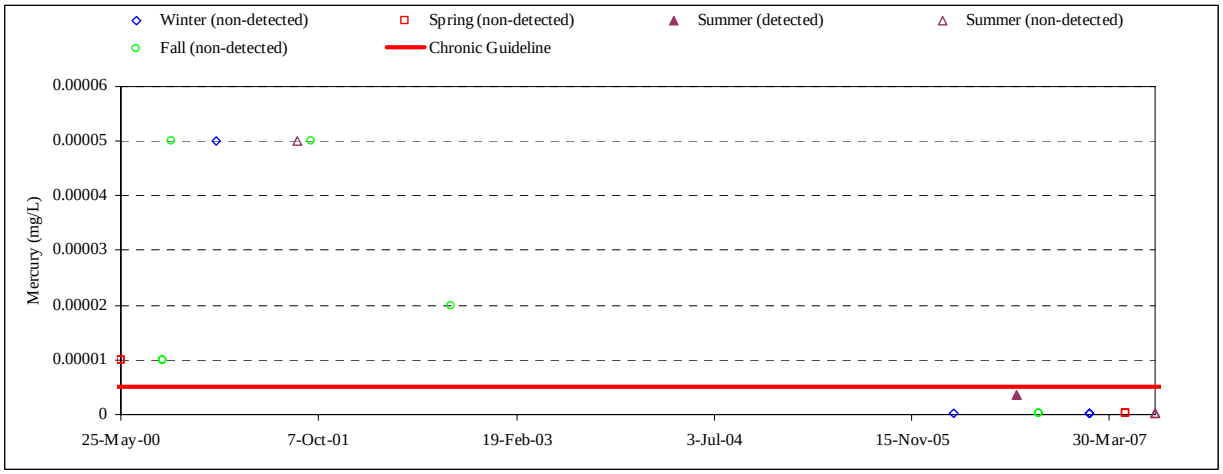
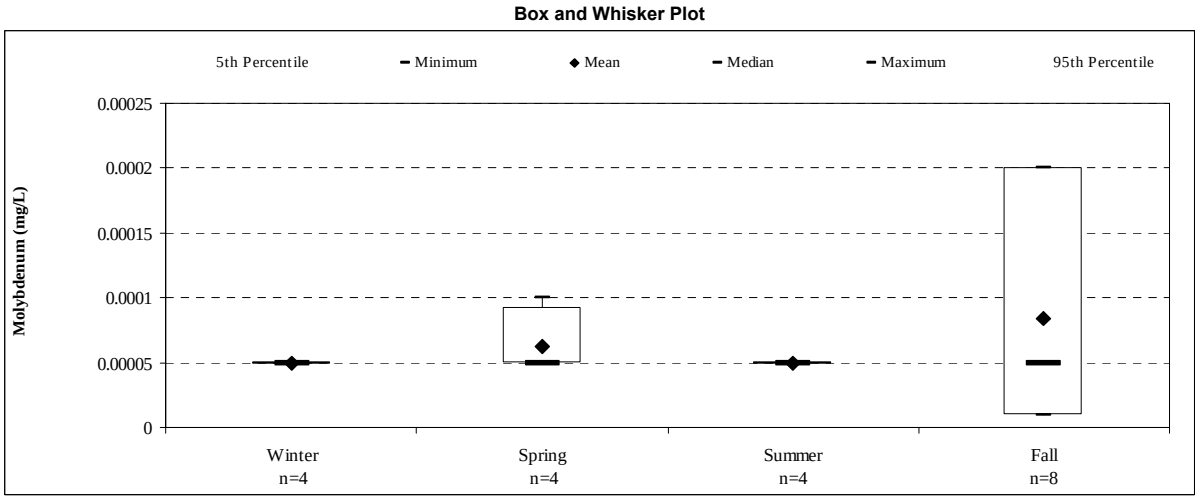


Figure G-1-5-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in McClelland Lake



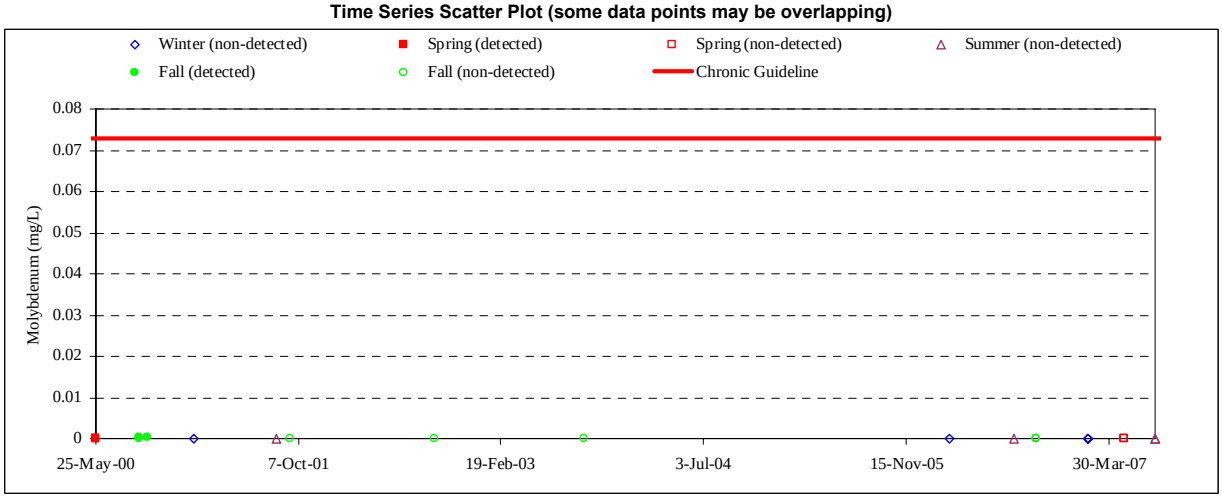


Figure G-1-5-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in McClelland Lake

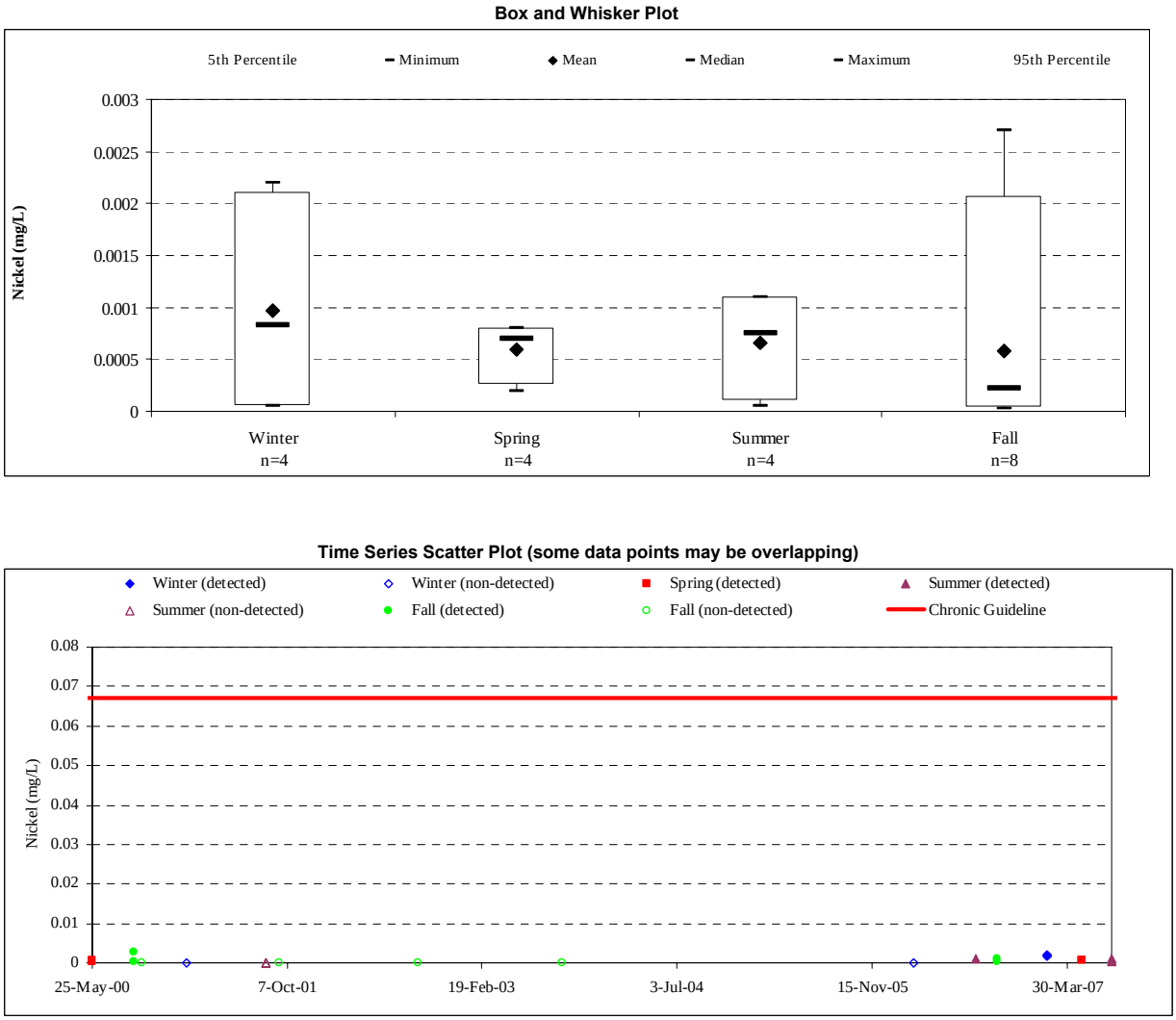
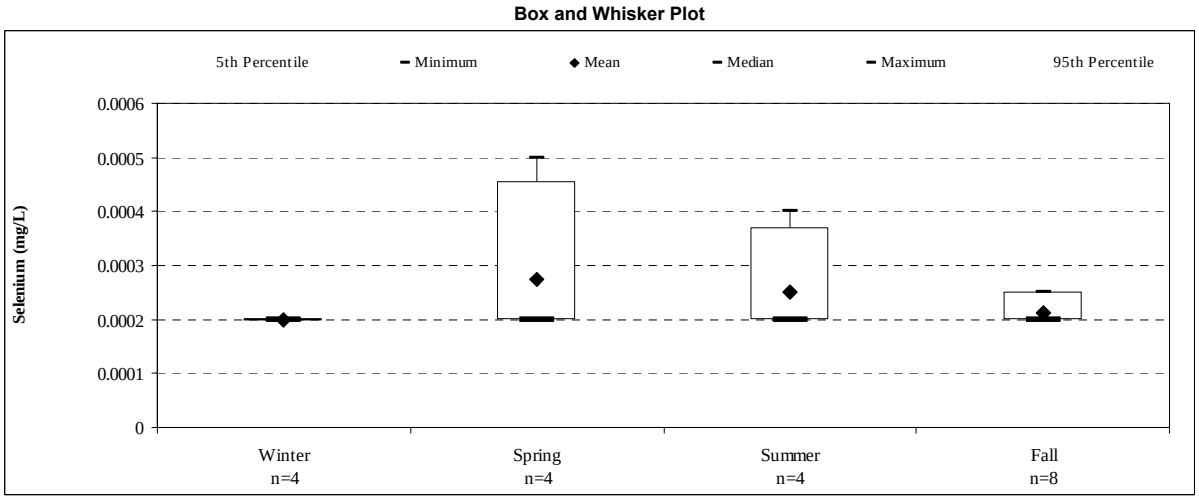


Figure G-1-5-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in McClelland Lake



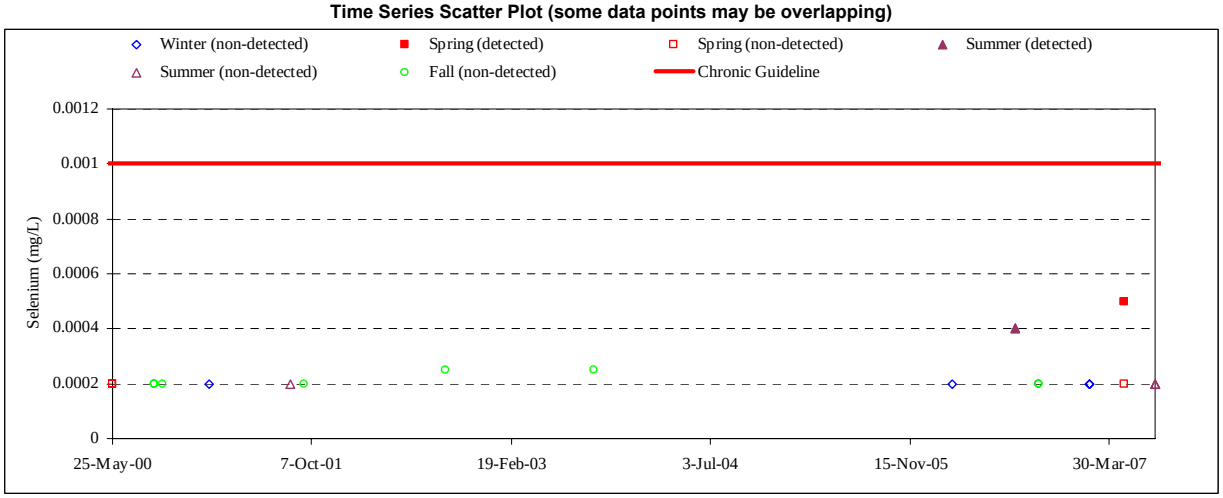
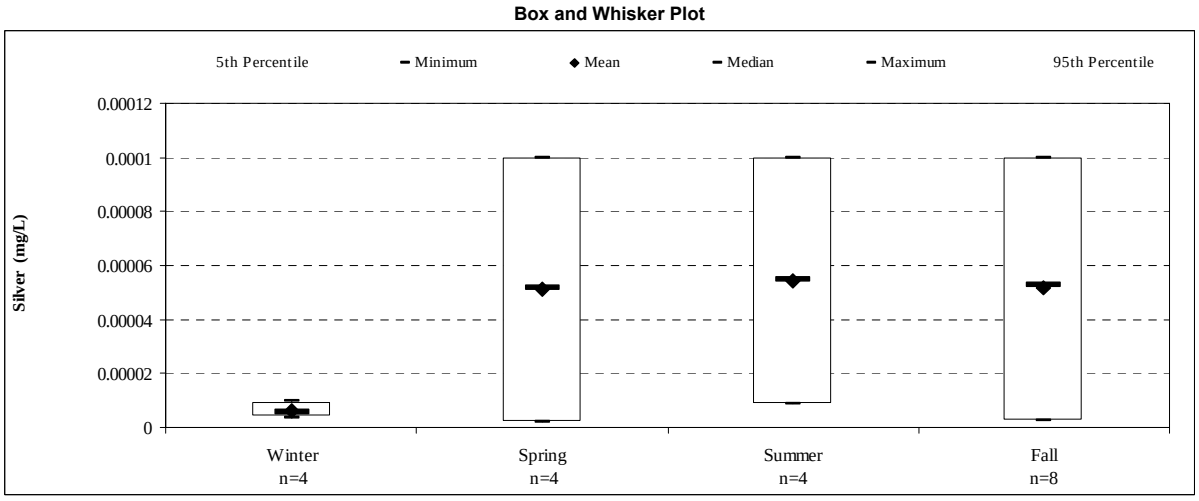


Figure G-1-5-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in McClelland Lake



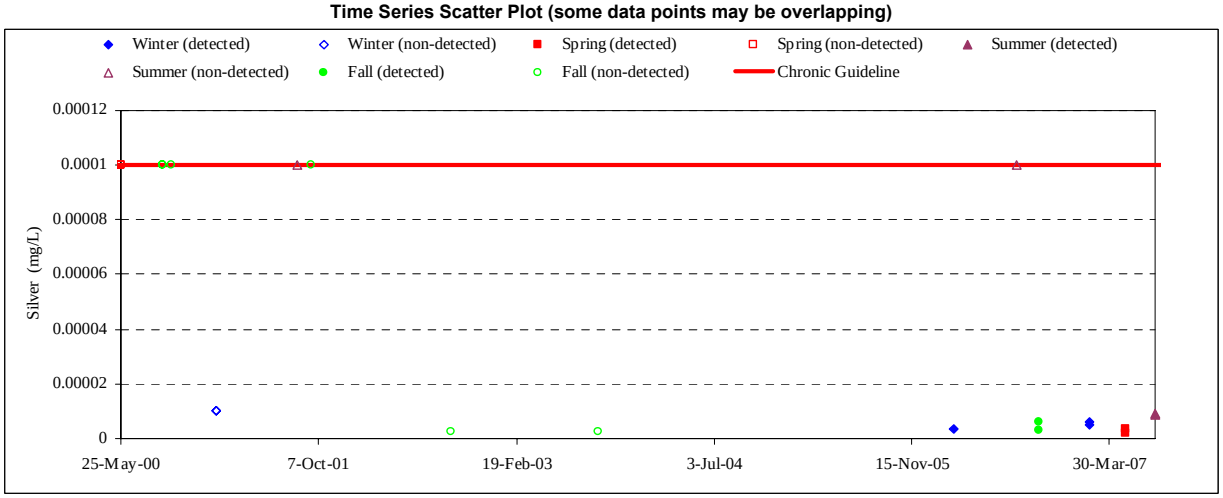
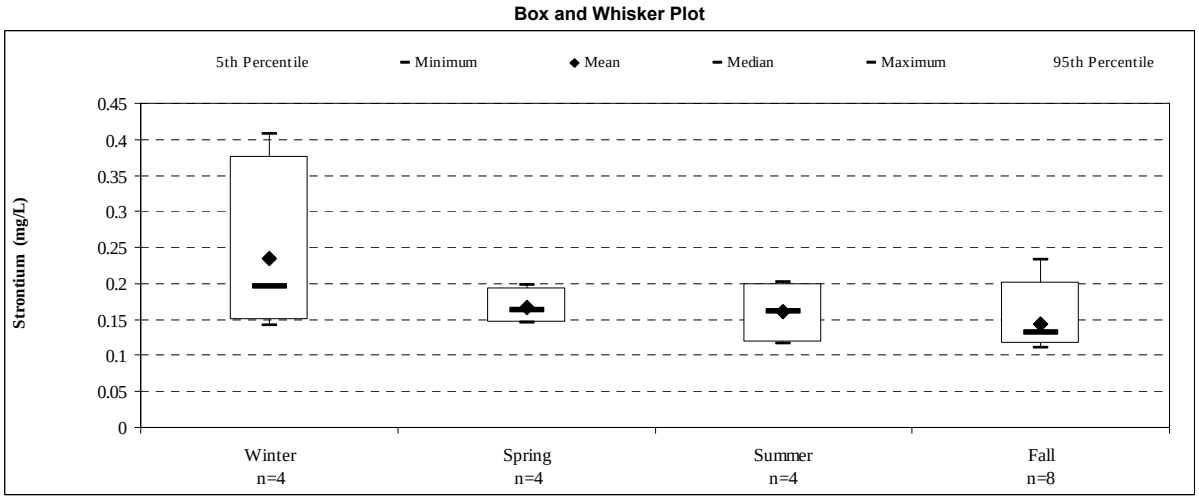


Figure G-1-5-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in McClelland Lake



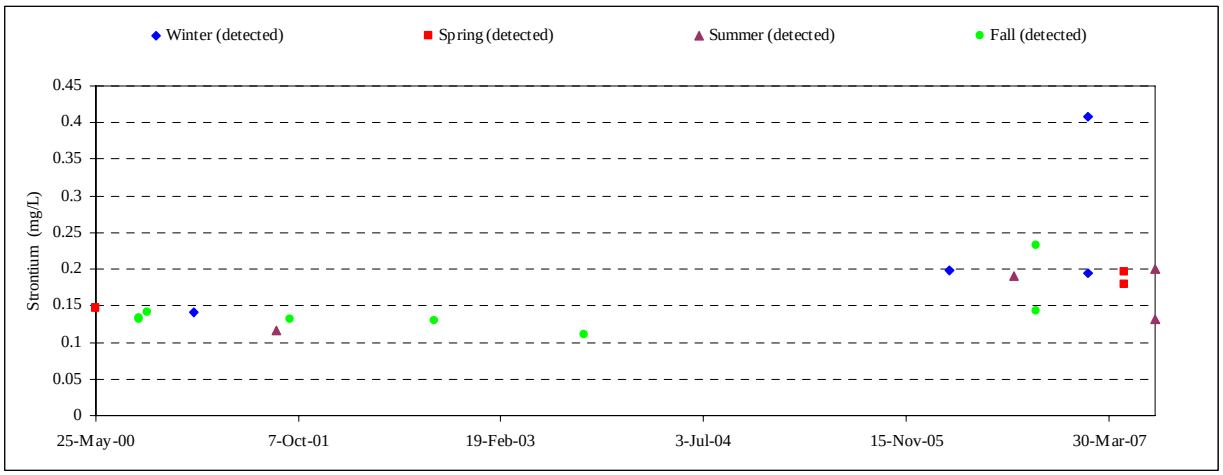


Figure G-1-5-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in McClelland Lake

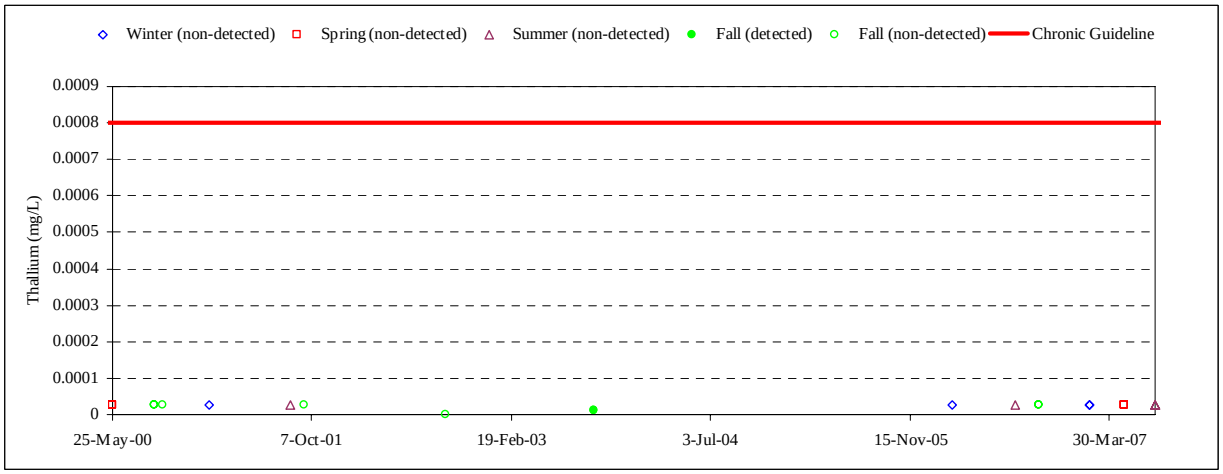
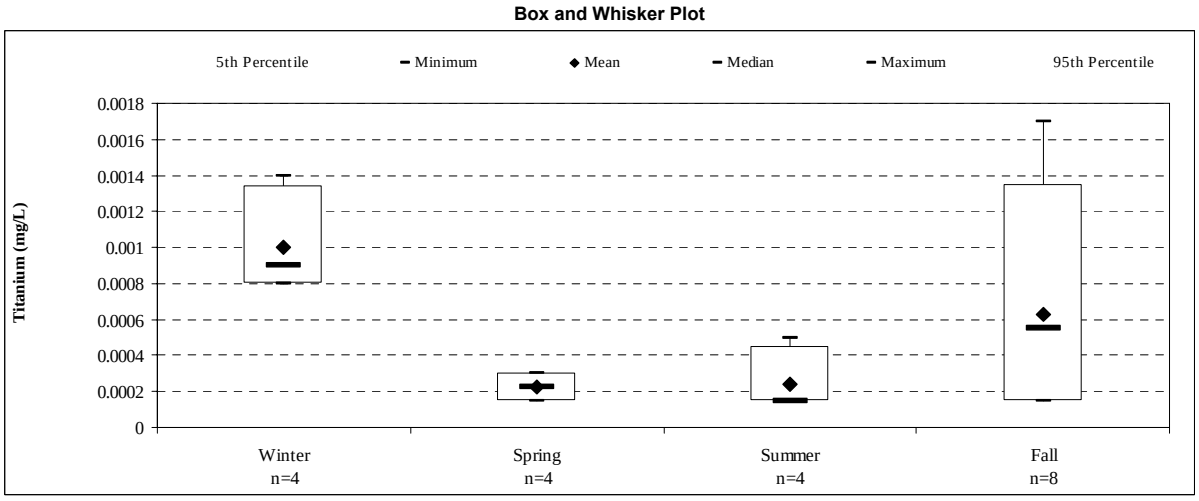


Figure G-1-5-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in McClelland Lake



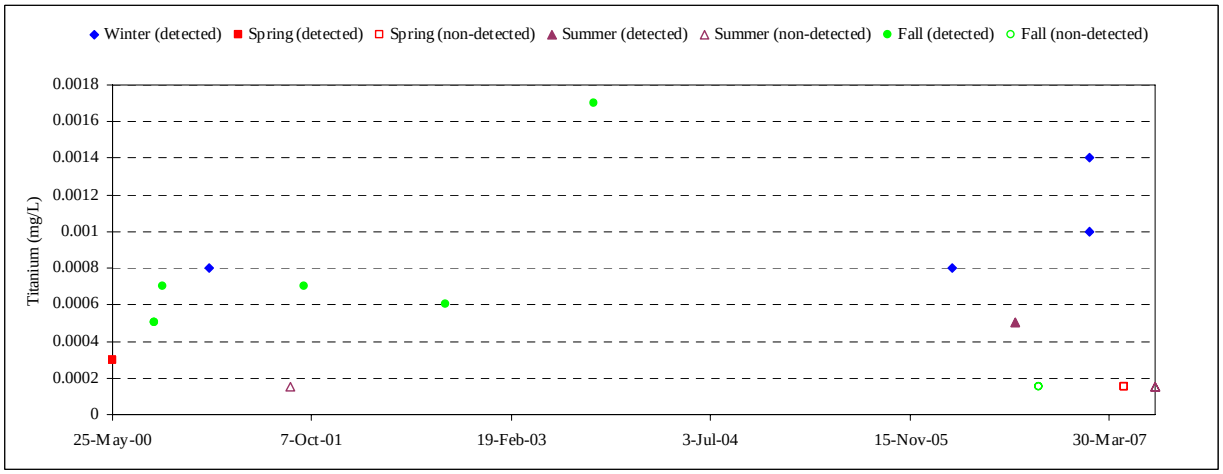
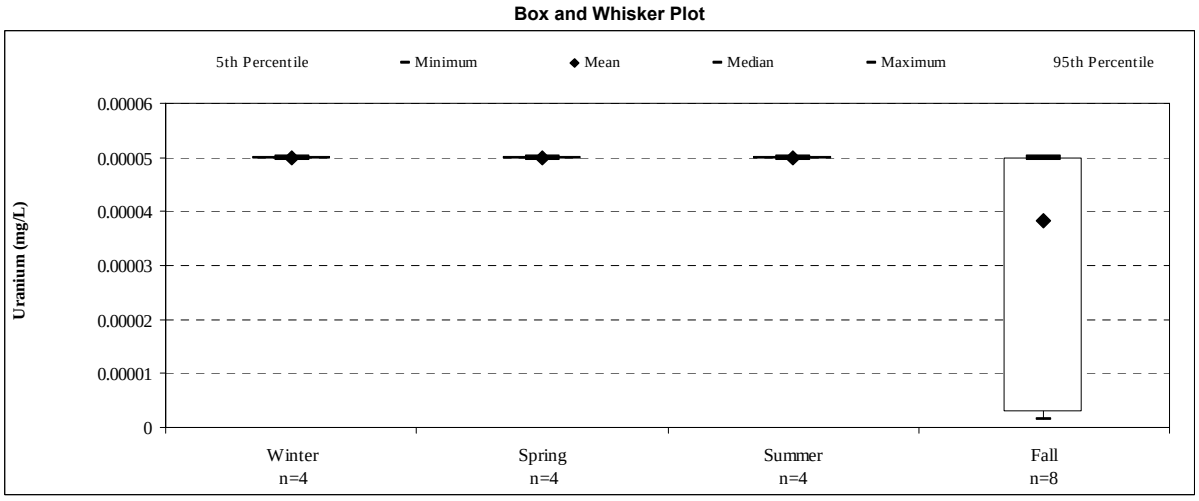


Figure G-1-5-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in McClelland Lake



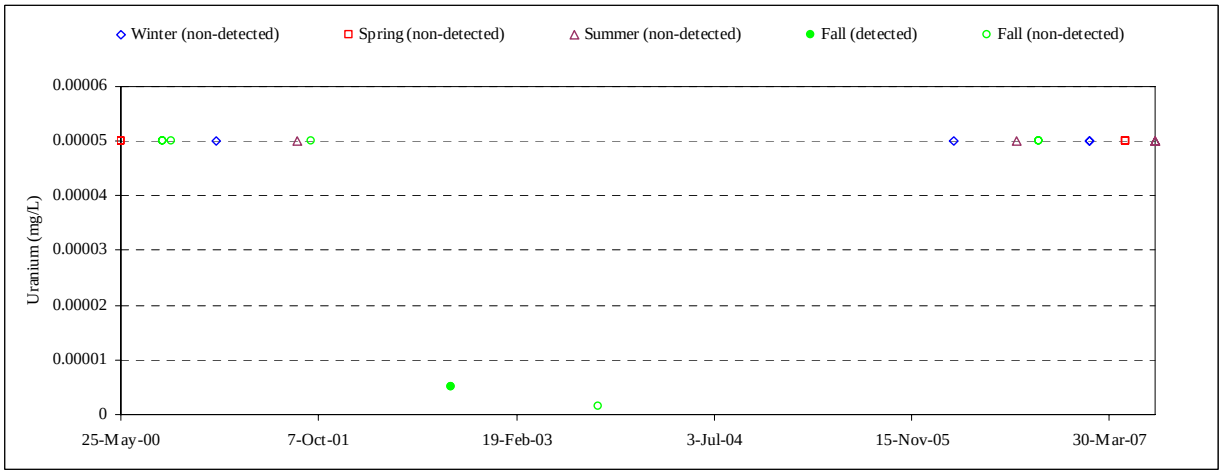
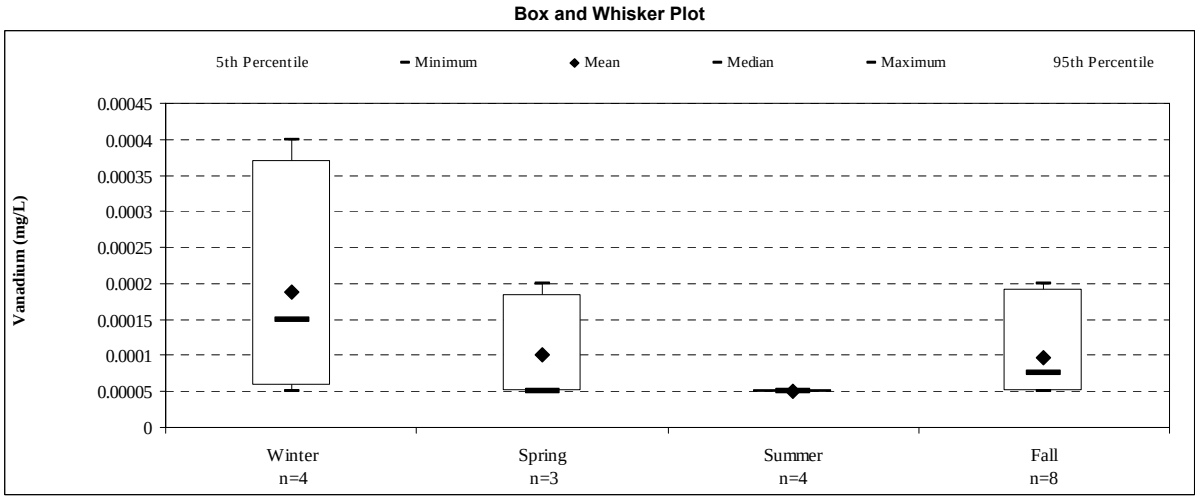


Figure G-1-5-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in McClelland Lake



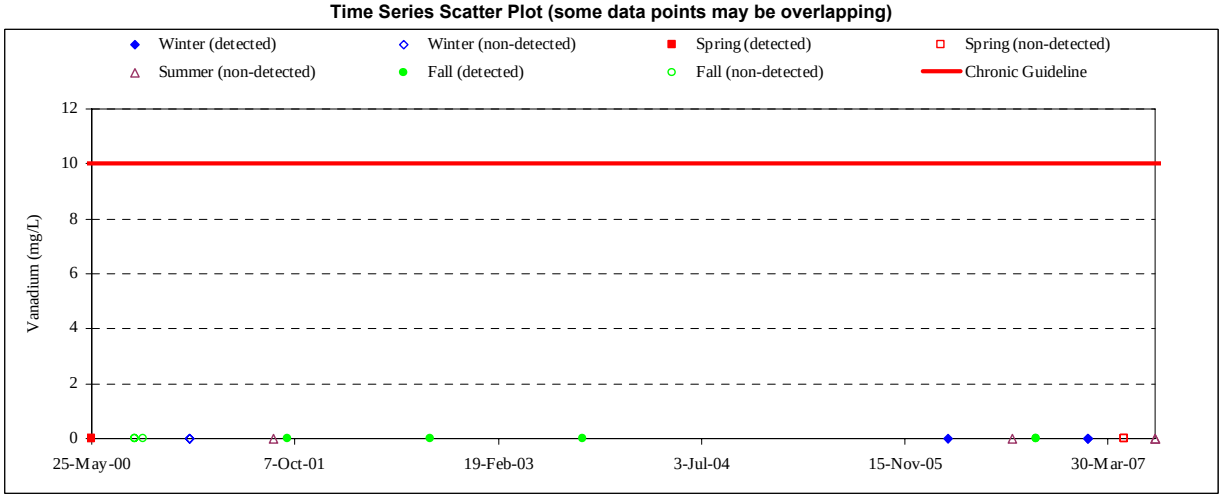
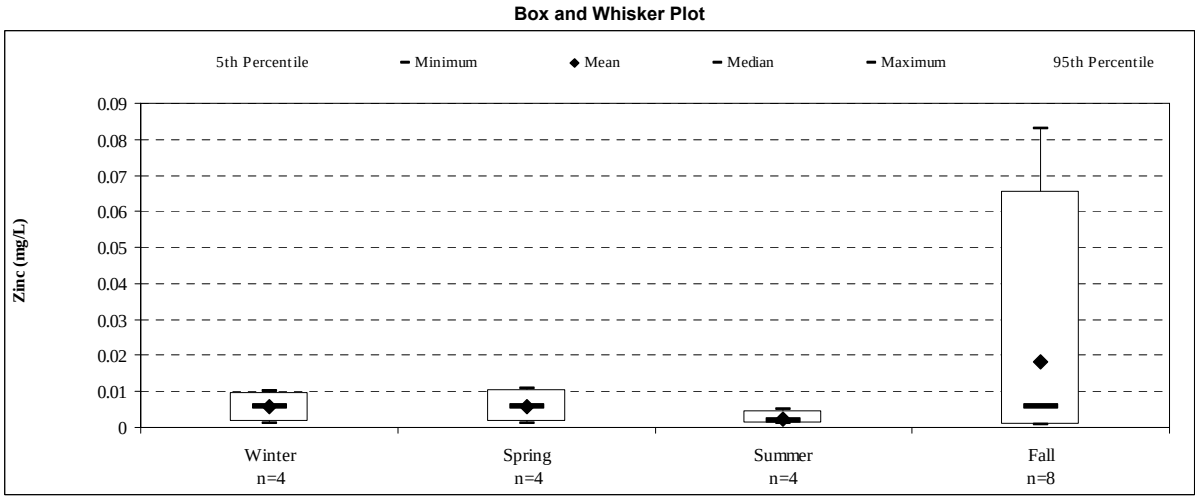


Figure G-1-5-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in McClelland Lake



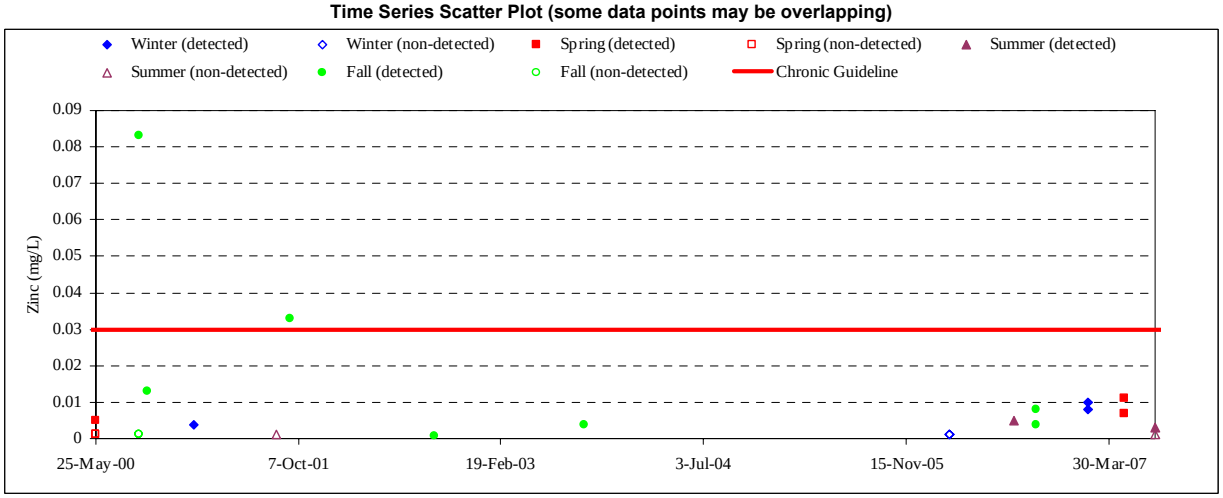
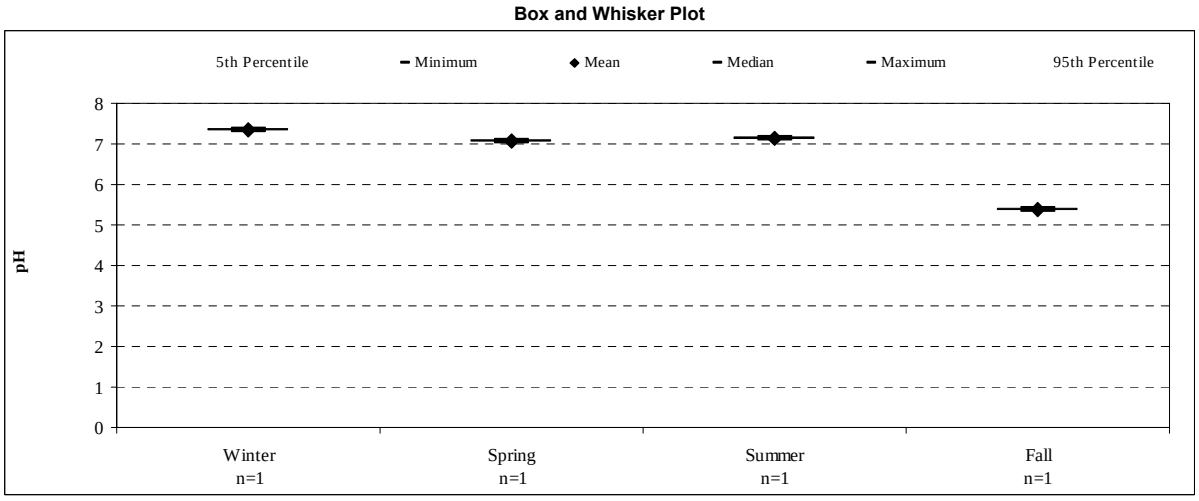


Figure G-1-6-1 Box Whisker and Time Series Scatter Plots of Observed pH in McClelland Lake Inlet



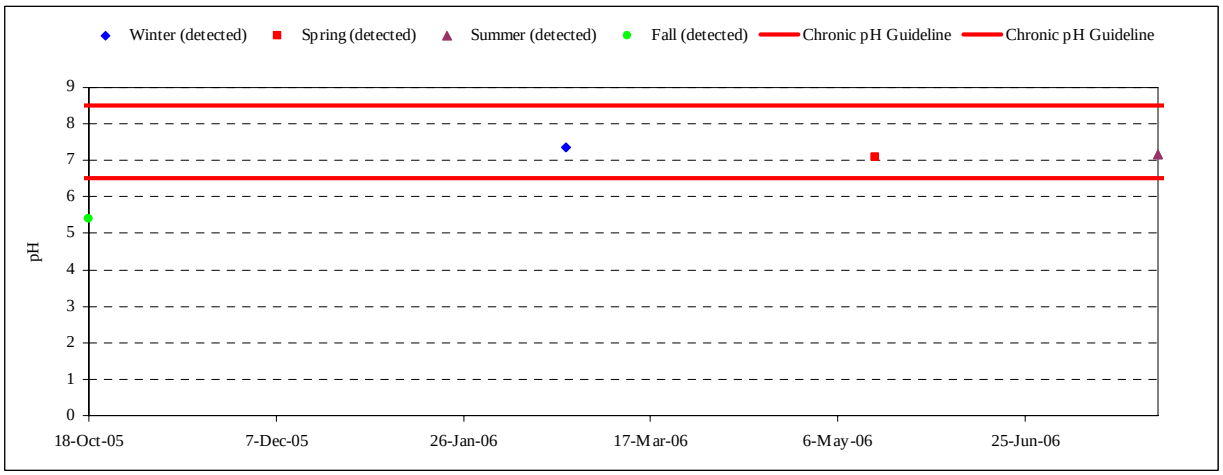
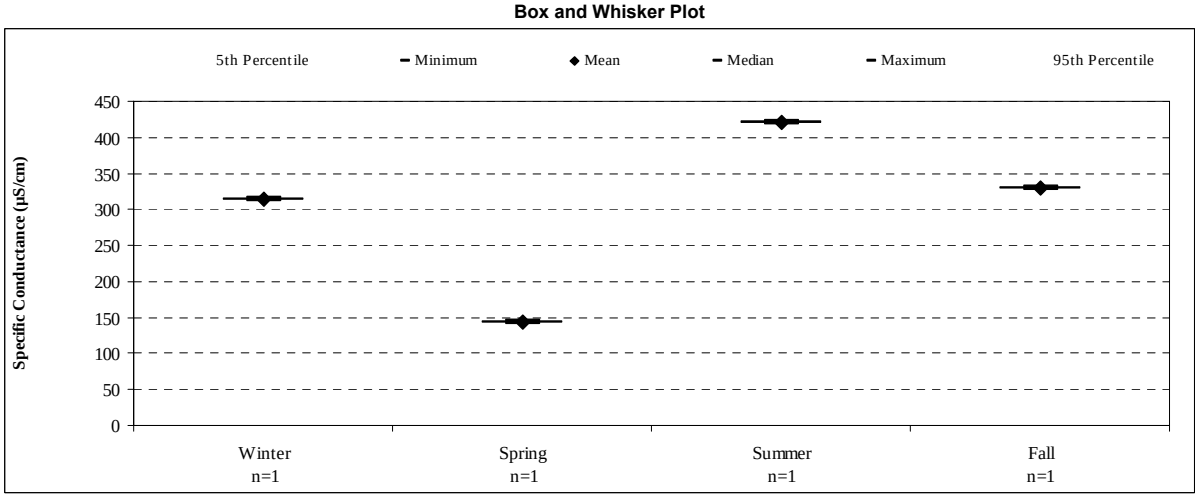


Figure G-1-6-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in McClelland Lake Inlet



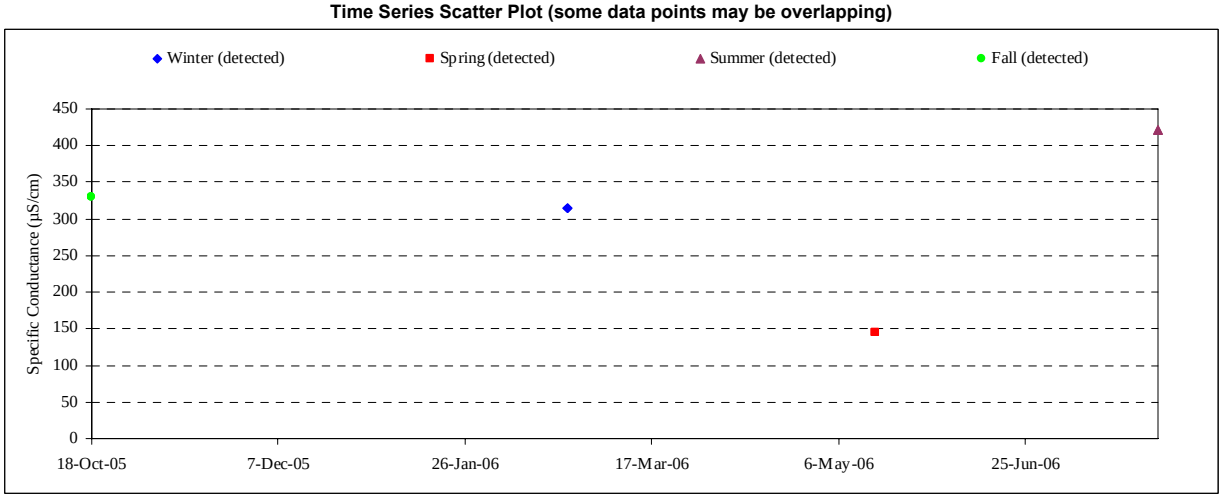
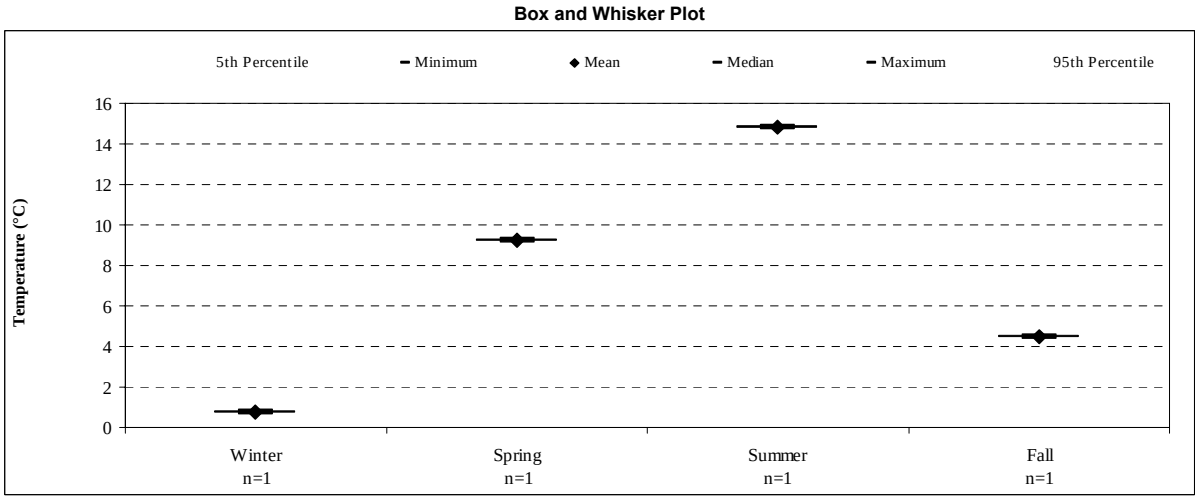


Figure G-1-6-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in McClelland Lake Inlet



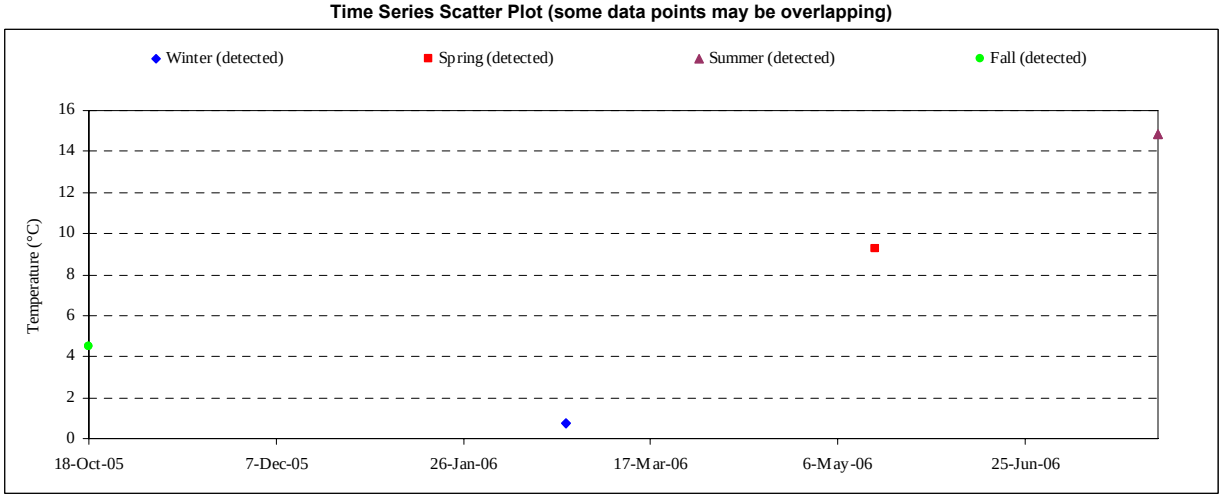
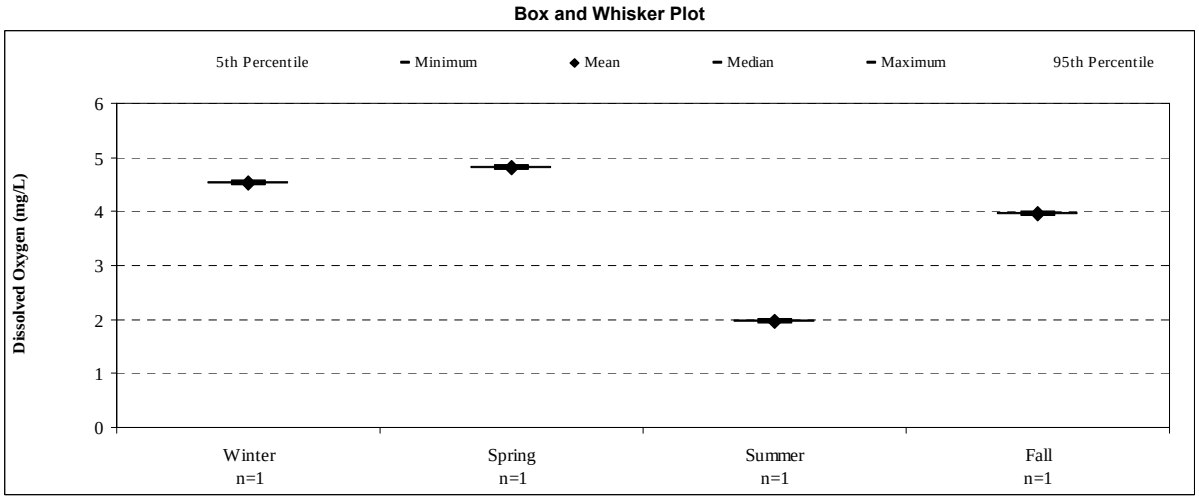


Figure G-1-6-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in McClelland Lake Inlet



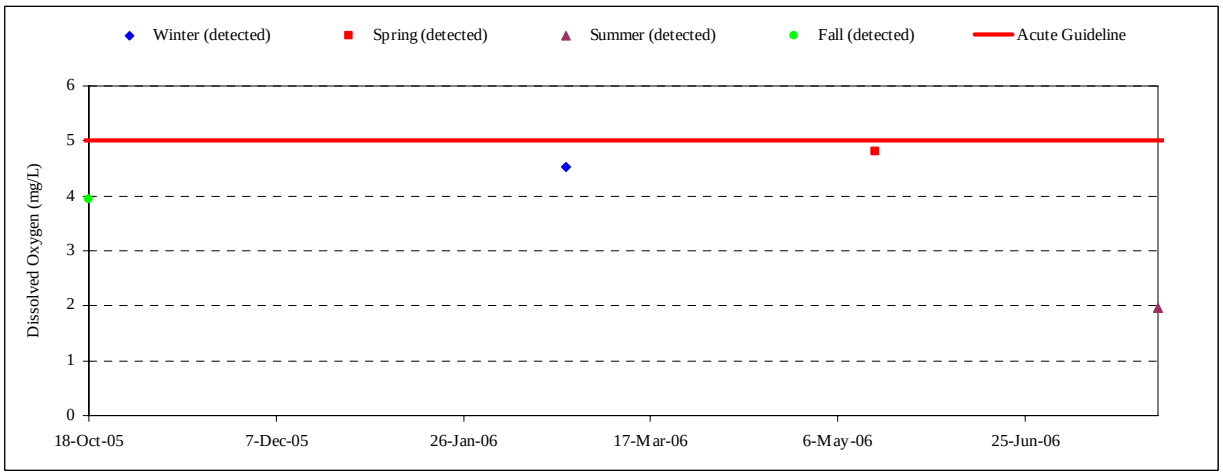
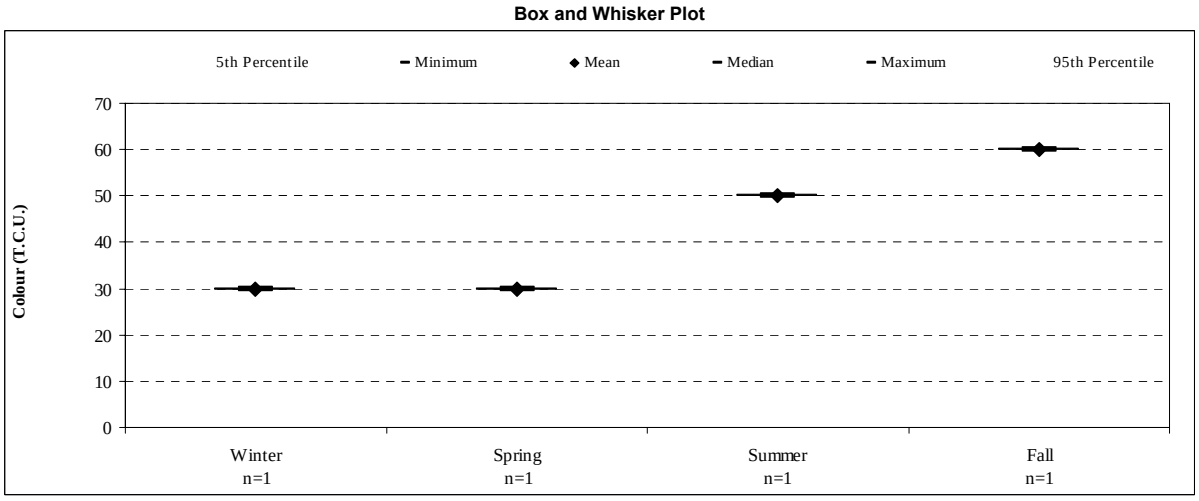


Figure G-1-6-5 Box Whisker and Time Series Scatter Plots of Observed Colour in McClelland Lake Inlet



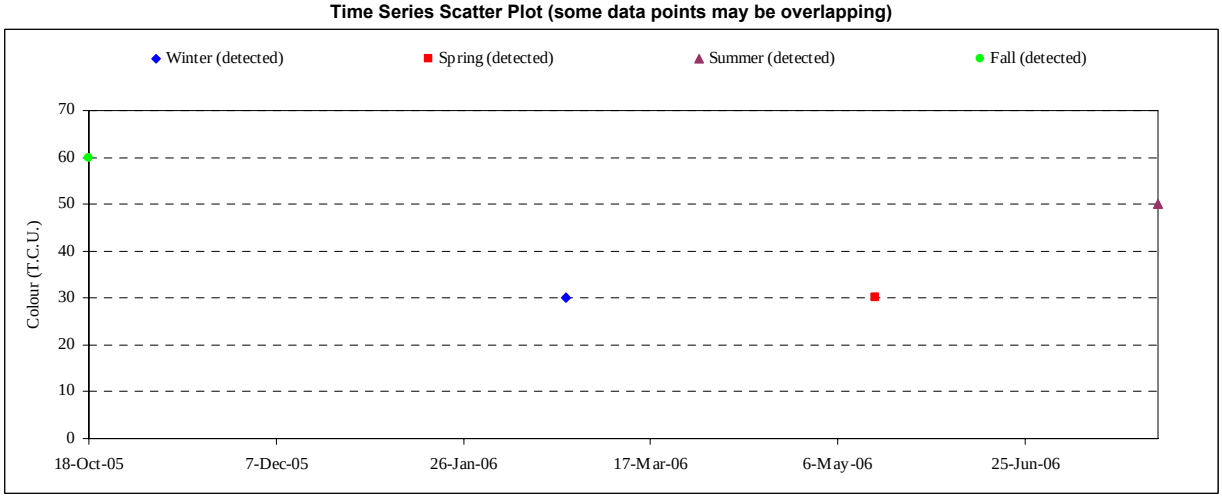
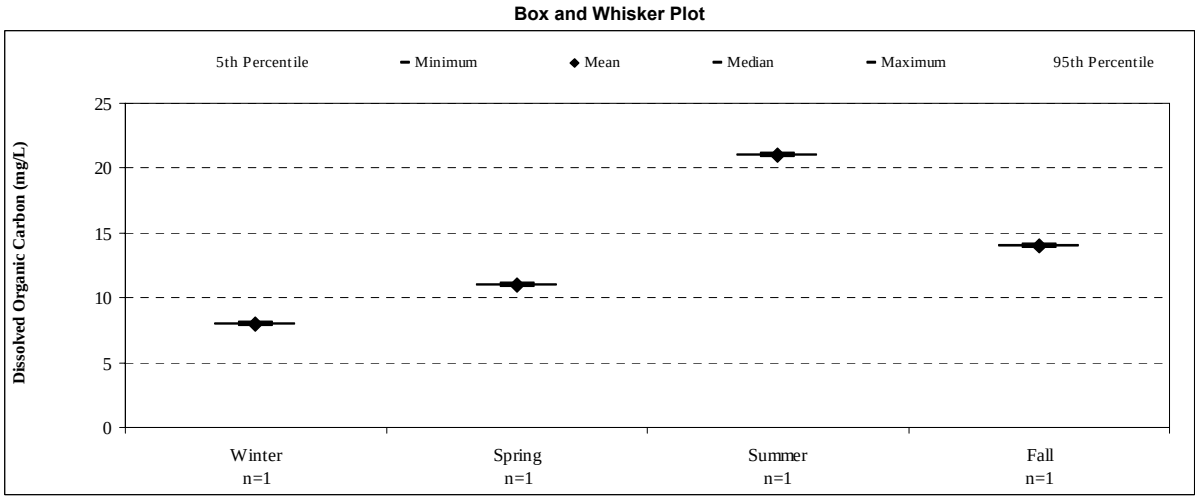


Figure G-1-6-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in McClelland Lake Inlet



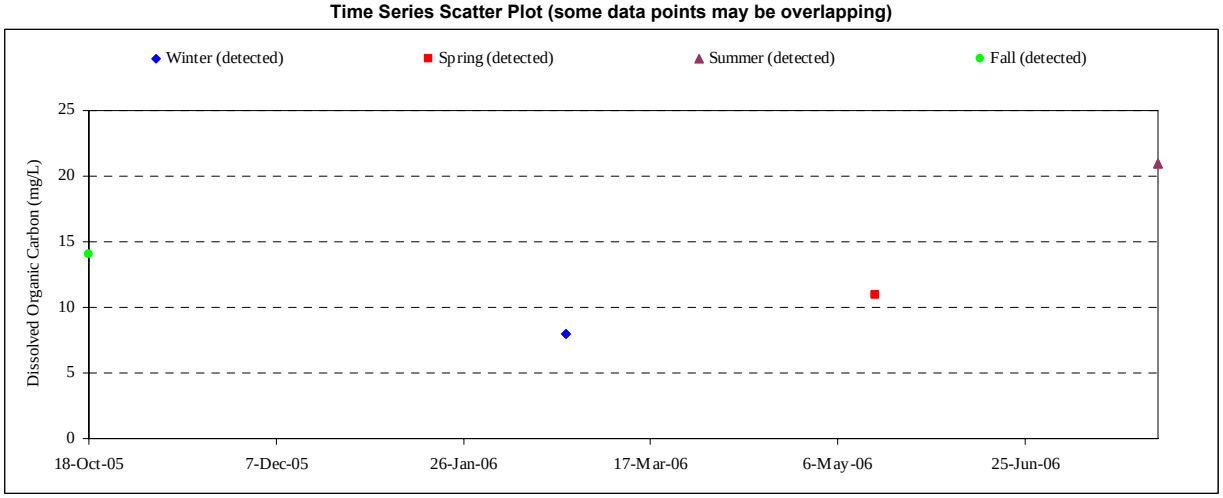
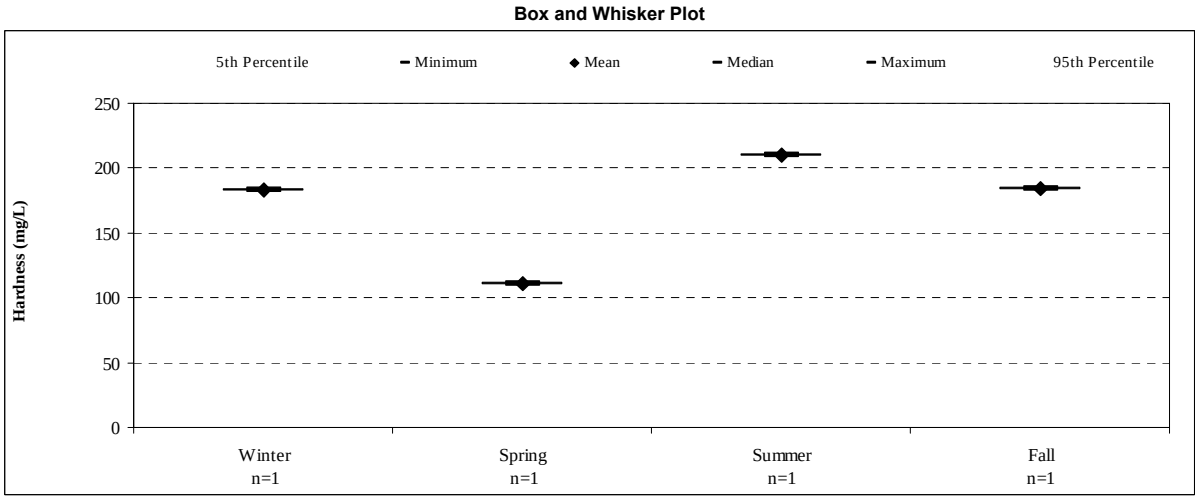


Figure G-1-6-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in McClelland Lake Inlet



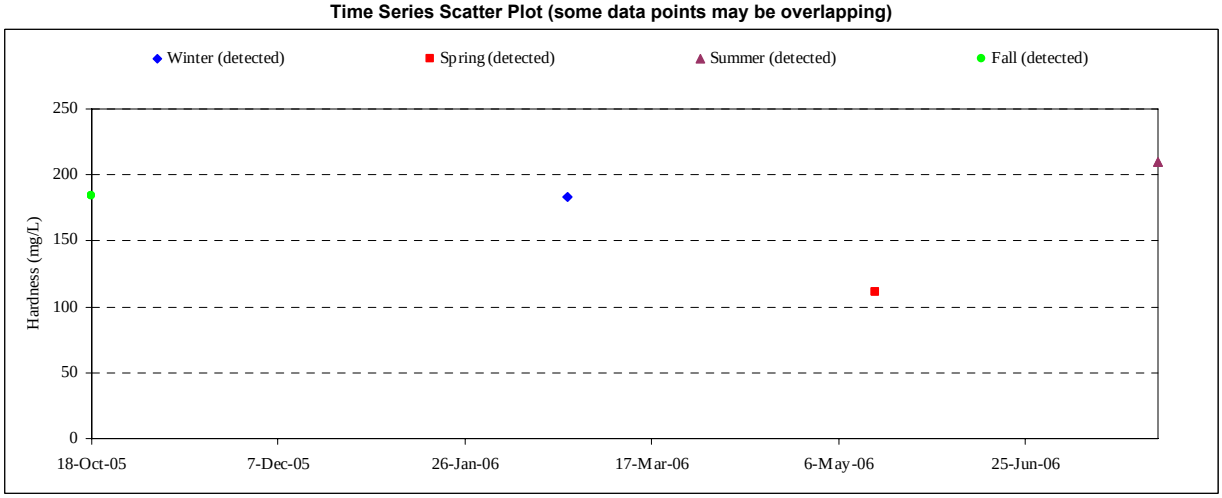
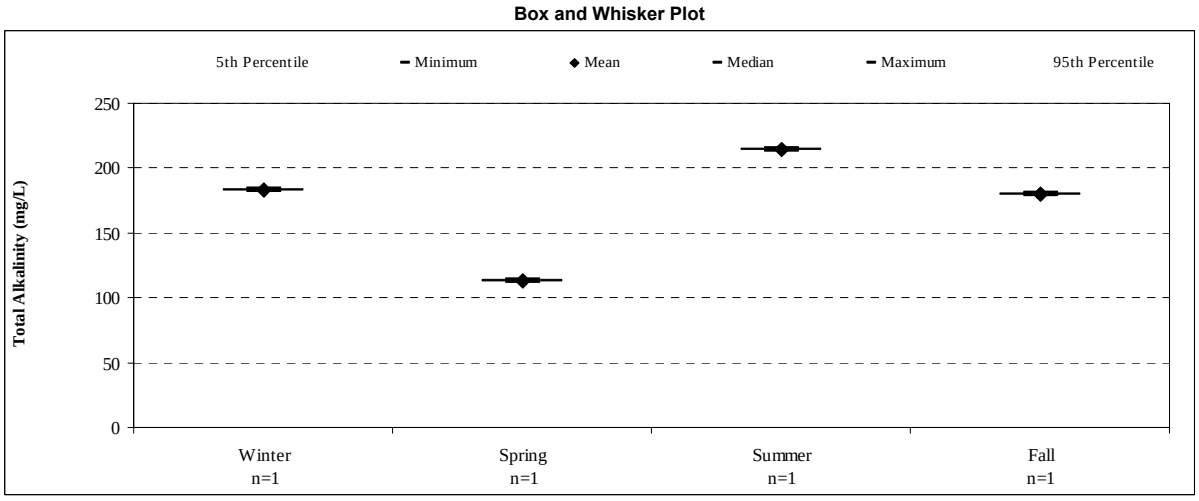


Figure G-1-6-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in McClelland Lake Inlet



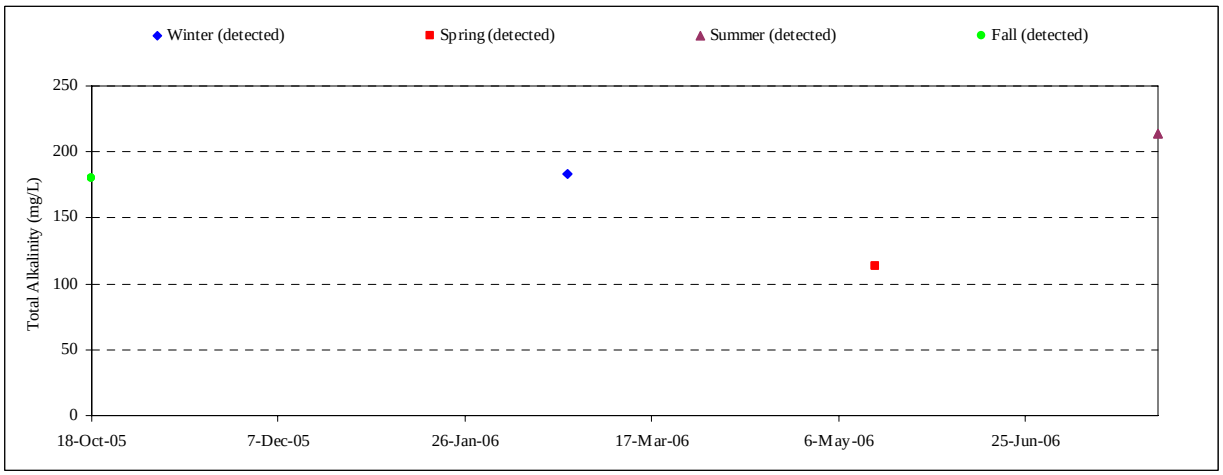
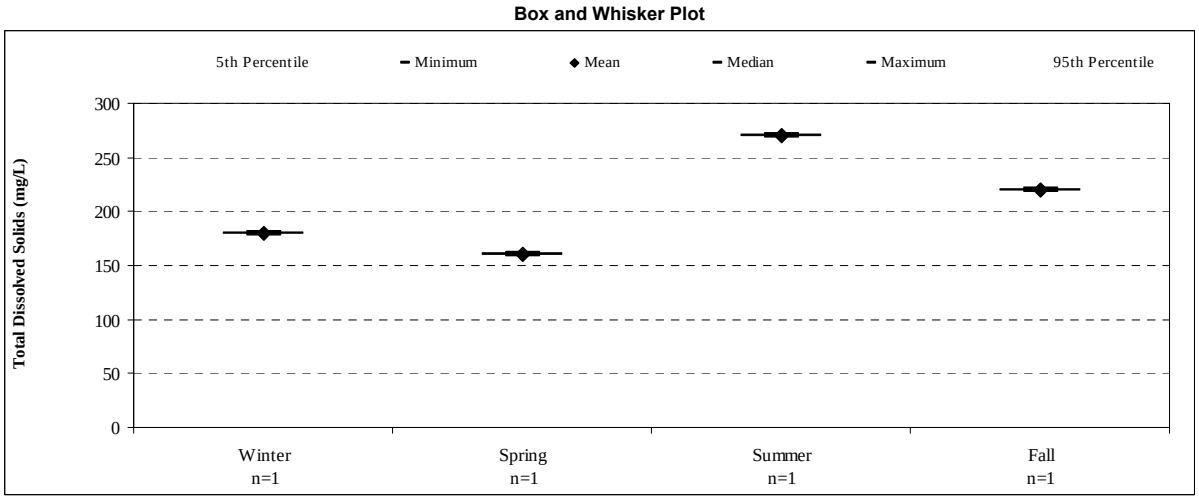


Figure G-1-6-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in McClelland Lake Inlet



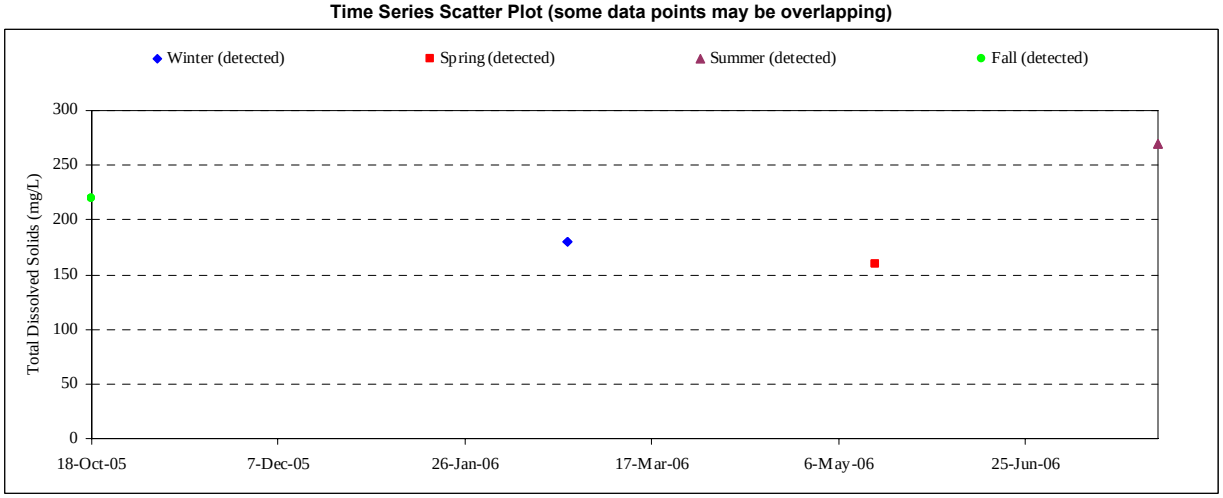
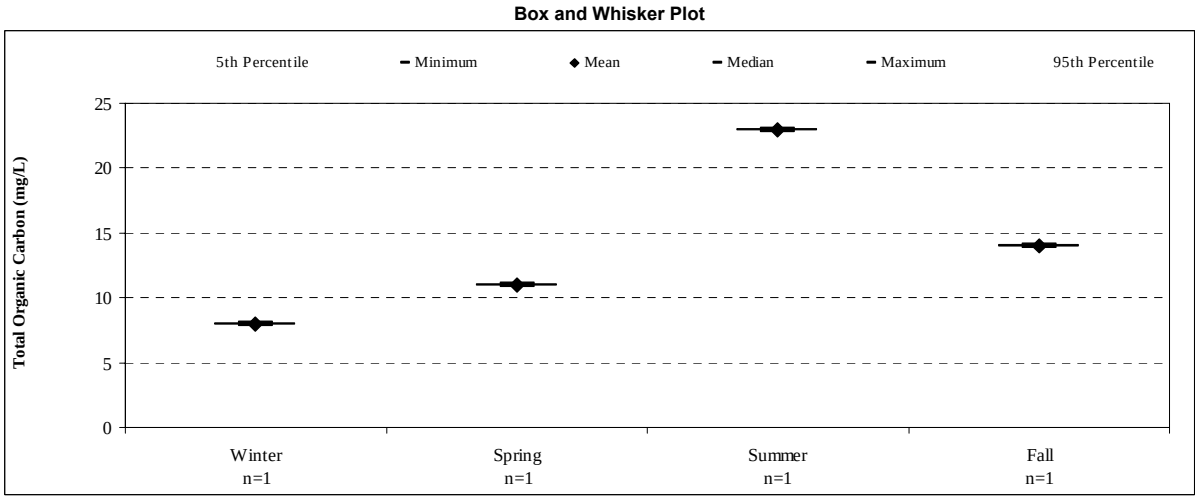


Figure G-1-6-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in McClelland Lake Inlet



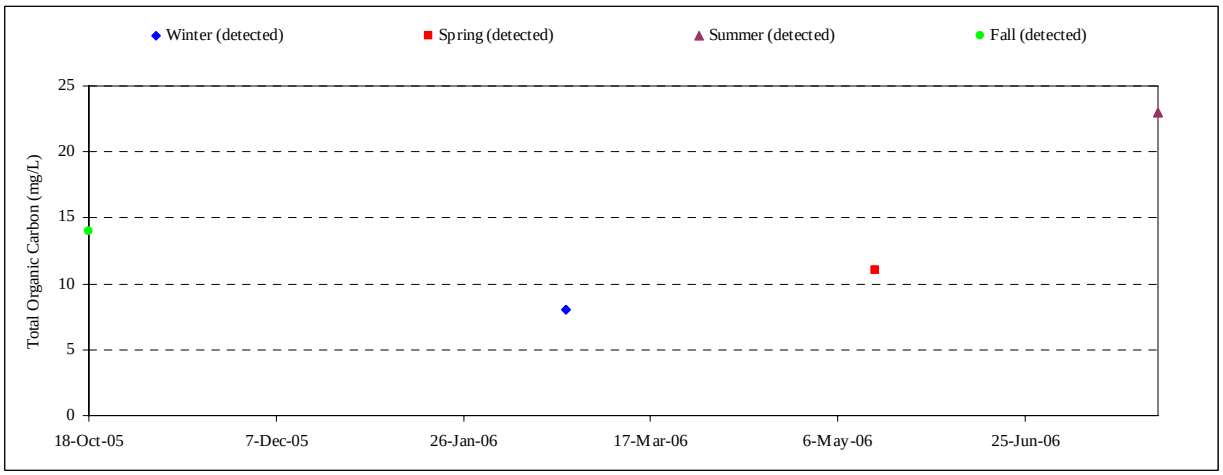
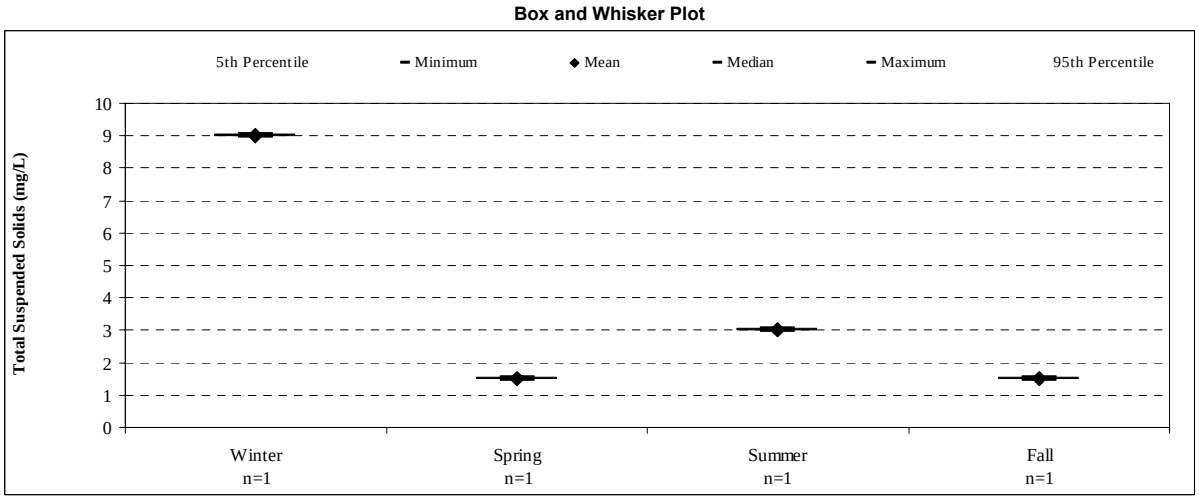


Figure G-1-6-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in McClelland Lake Inlet



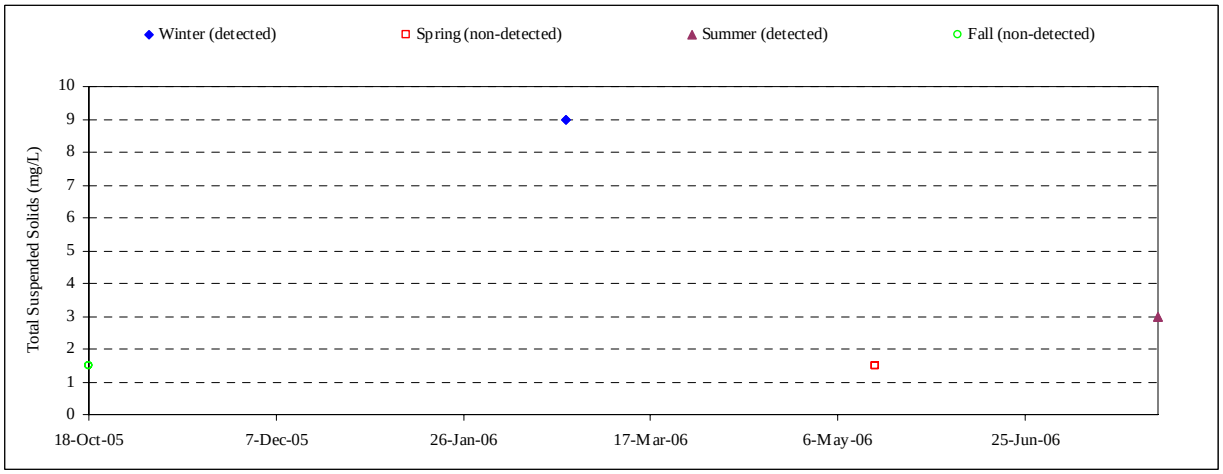
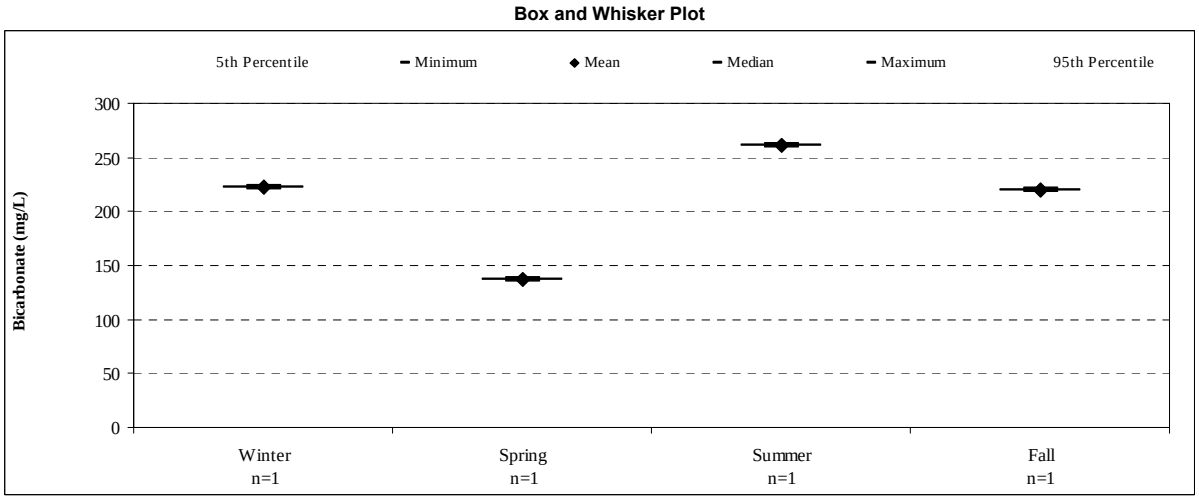


Figure G-1-6-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in McClelland Lake Inlet



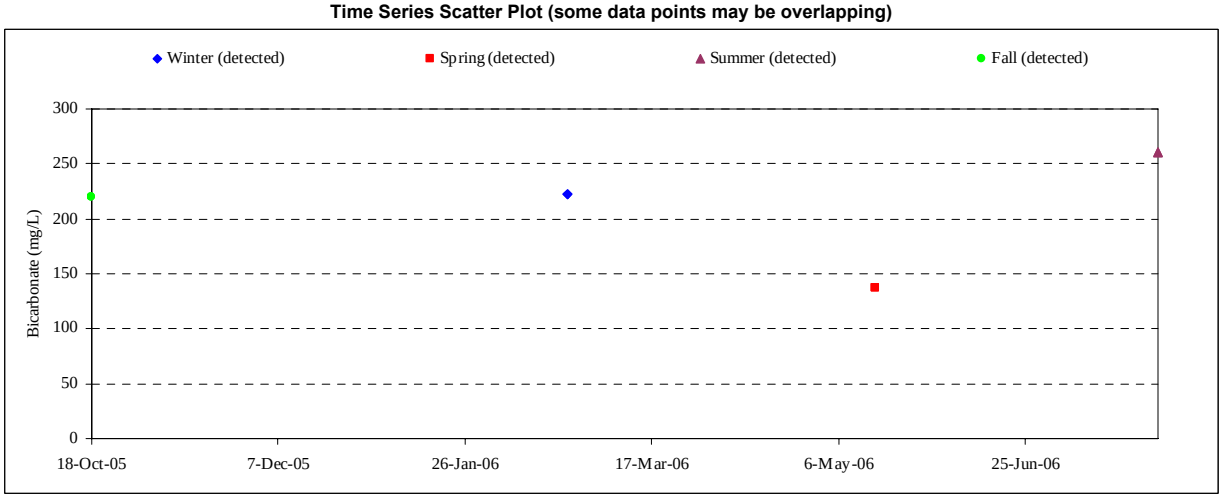
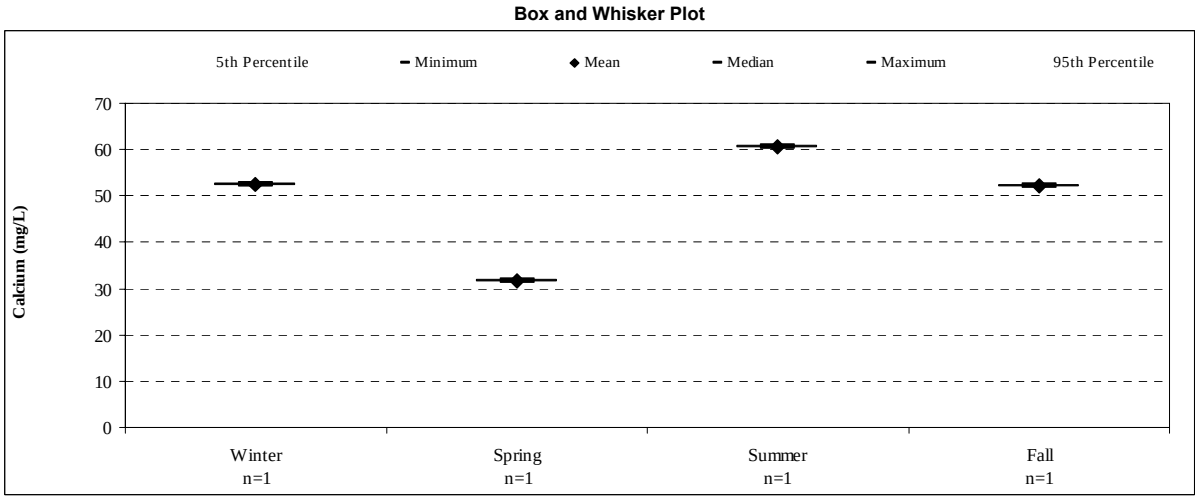


Figure G-1-6-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in McClelland Lake Inlet



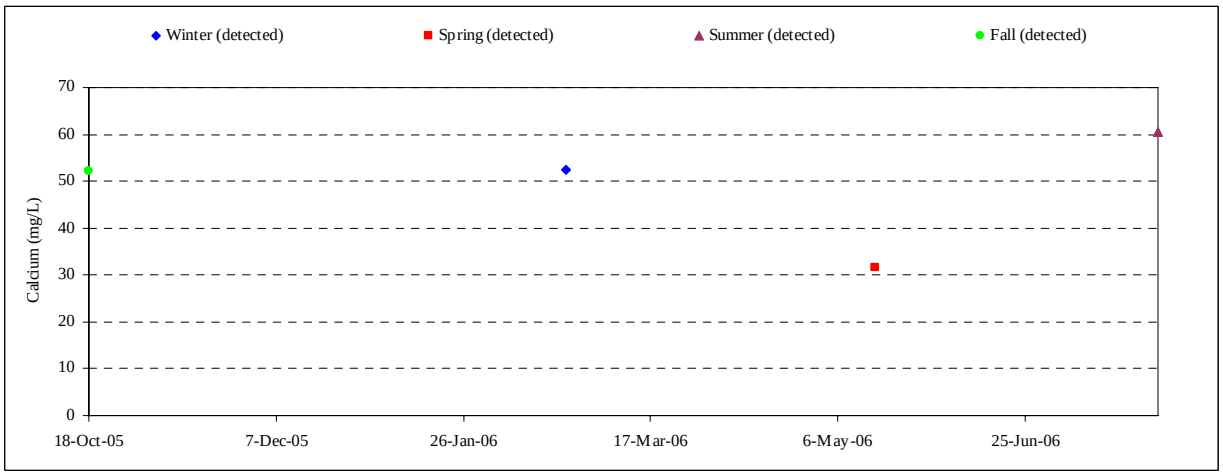
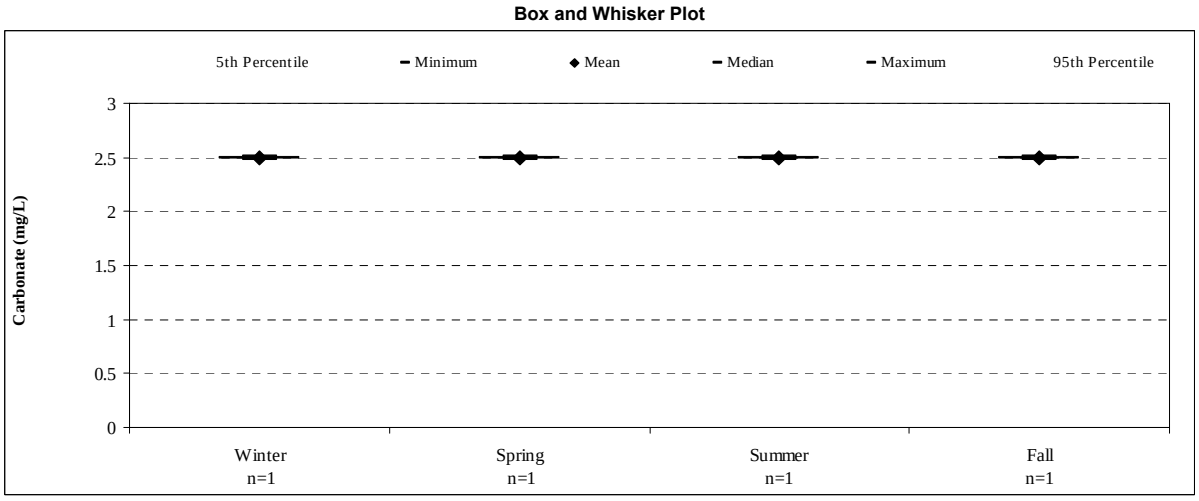


Figure G-1-6-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in McClelland Lake Inlet



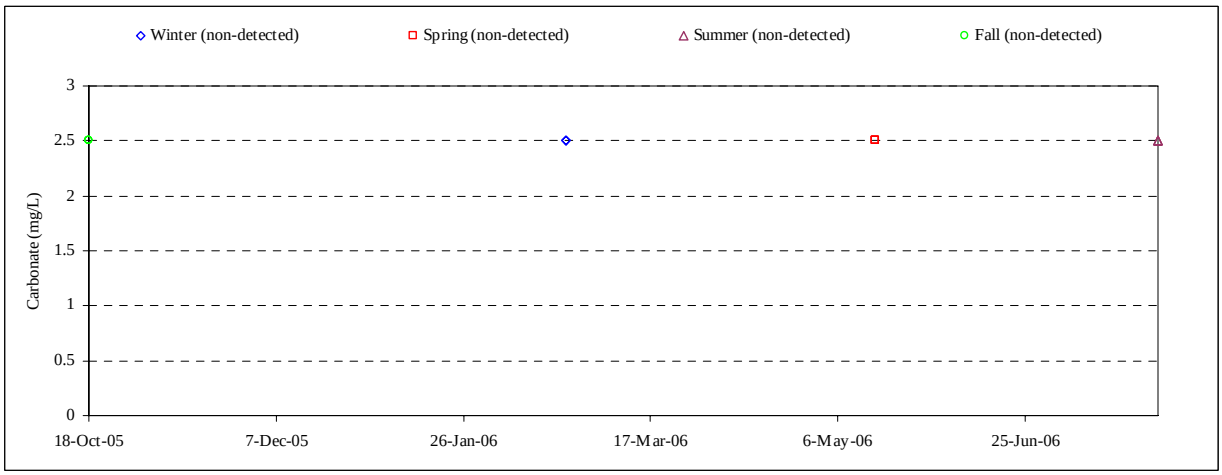
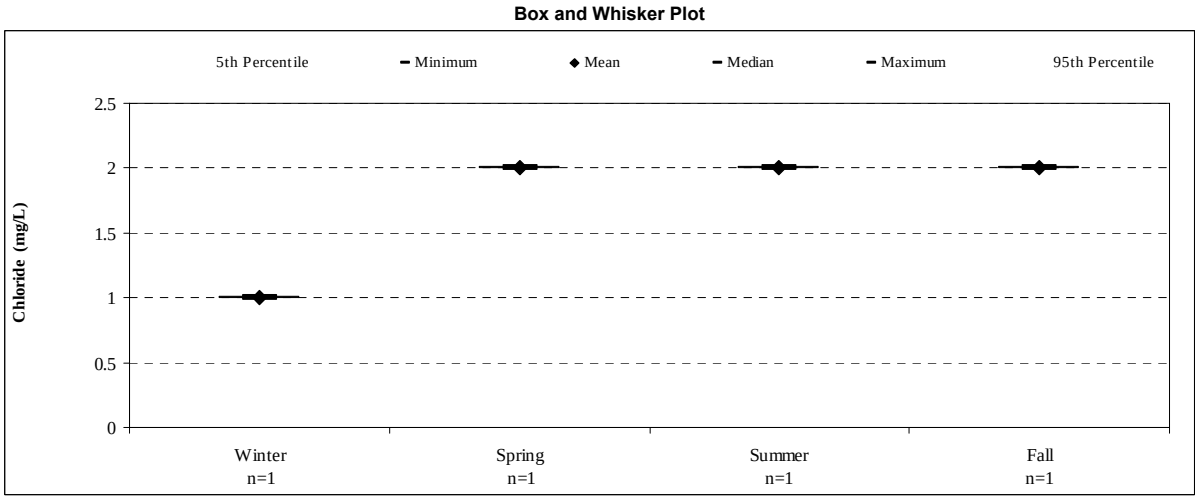


Figure G-1-6-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in McClelland Lake Inlet



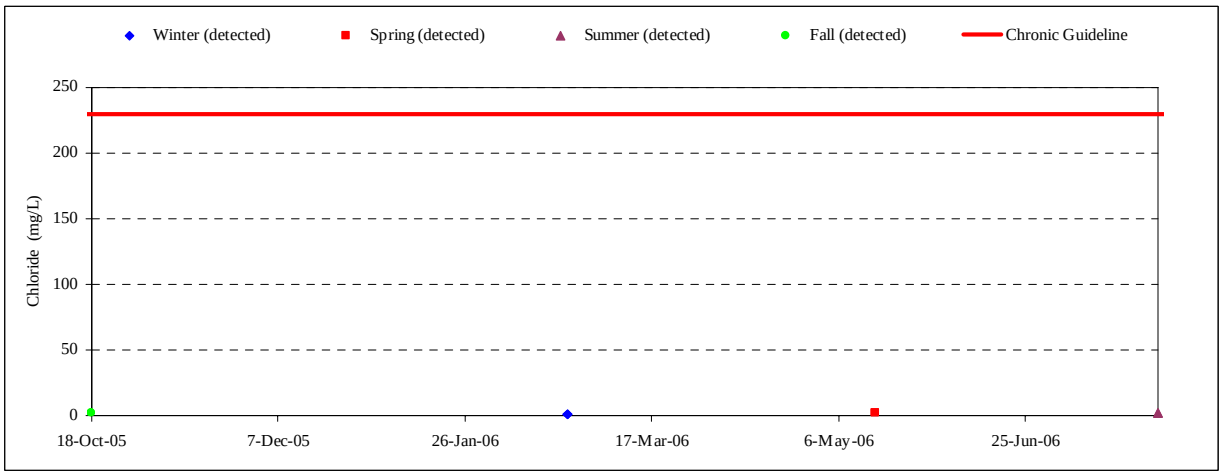
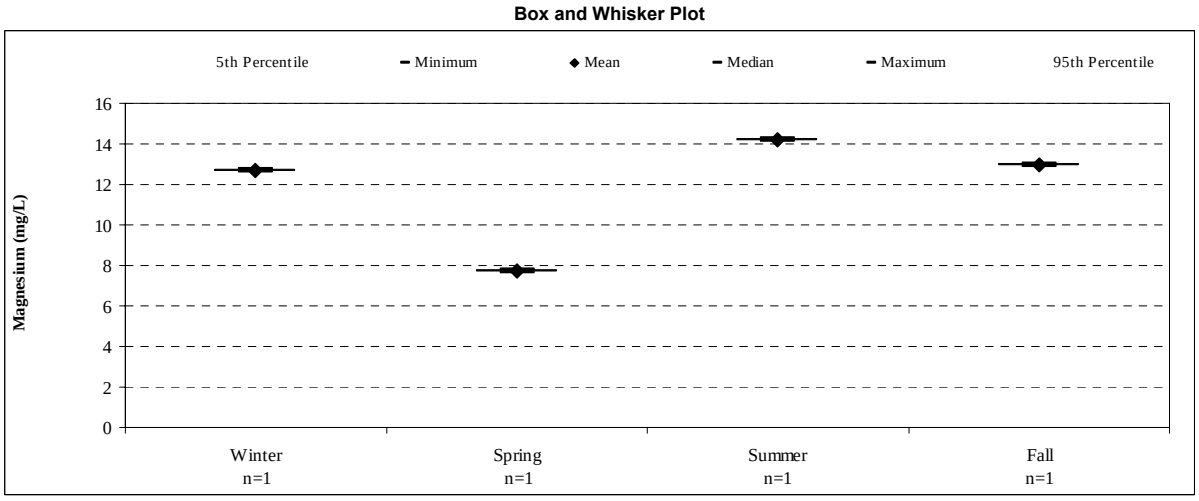


Figure G-1-6-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in McClelland Lake Inlet



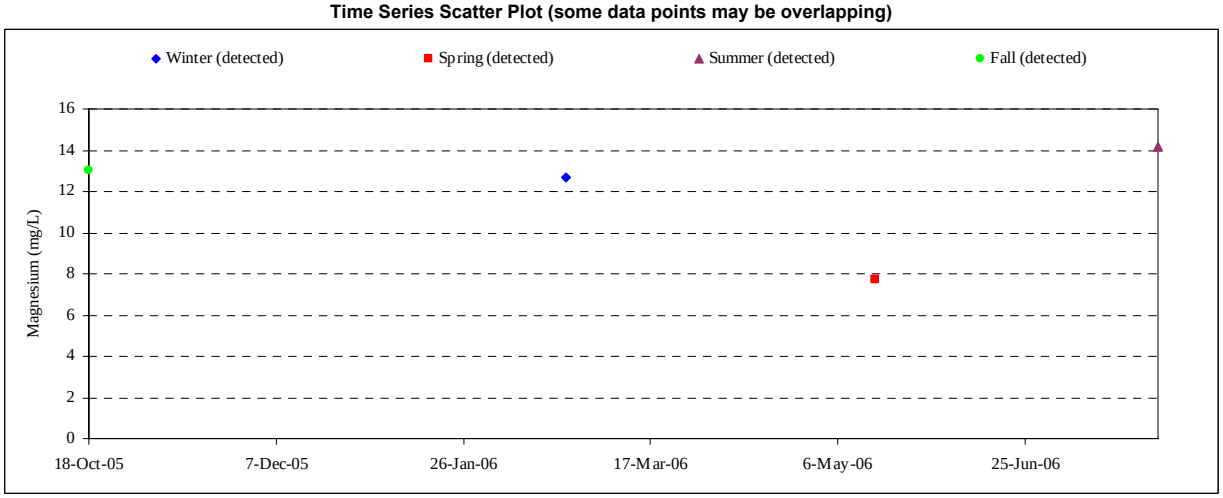
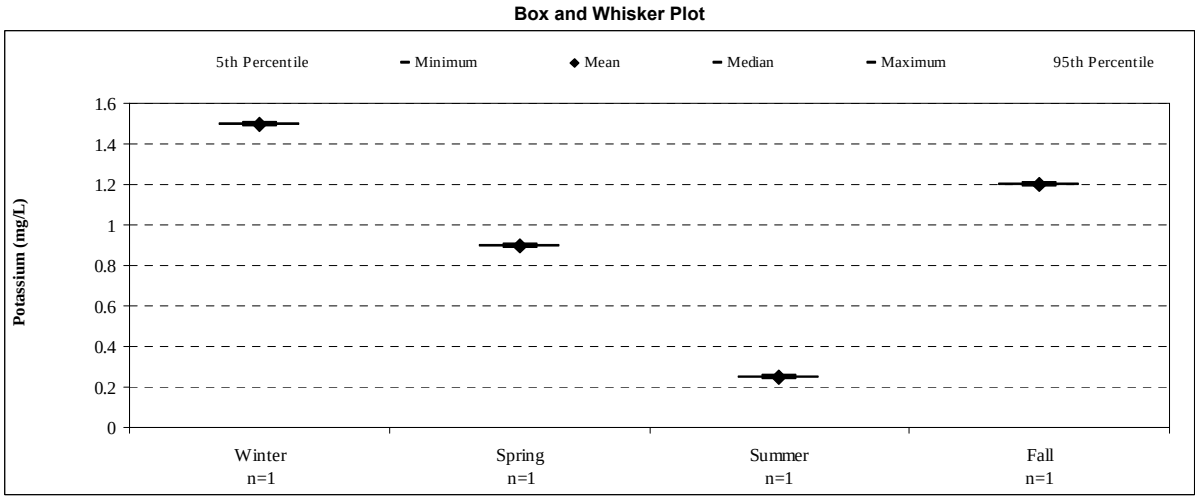


Figure G-1-6-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in McClelland Lake Inlet



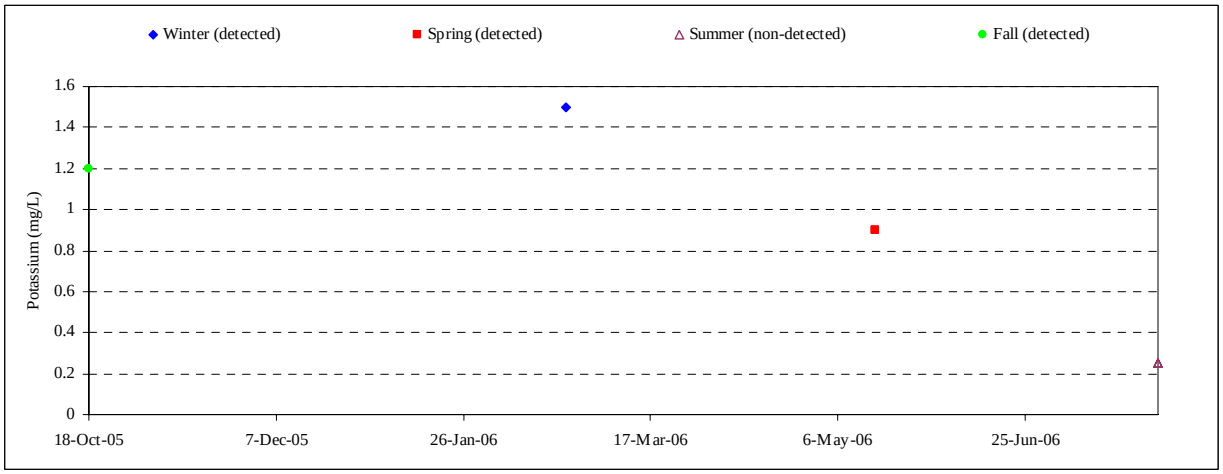
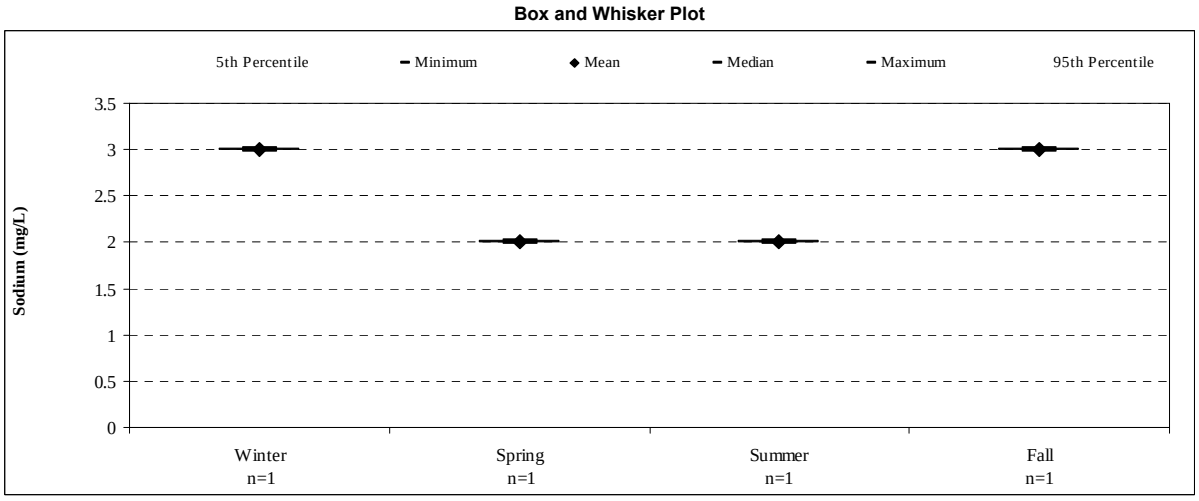


Figure G-1-6-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in McClelland Lake Inlet



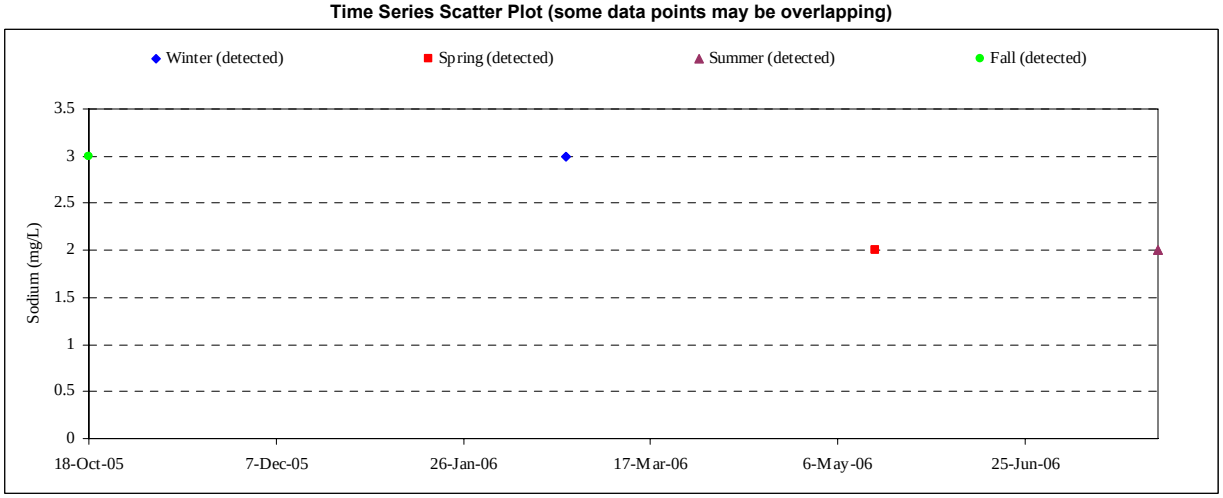
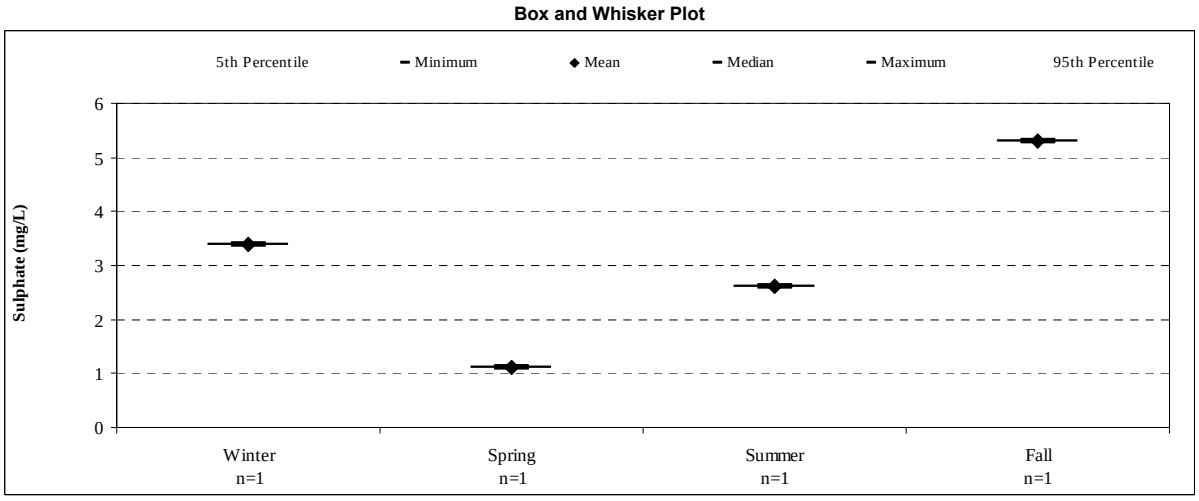


Figure G-1-6-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in McClelland Lake Inlet



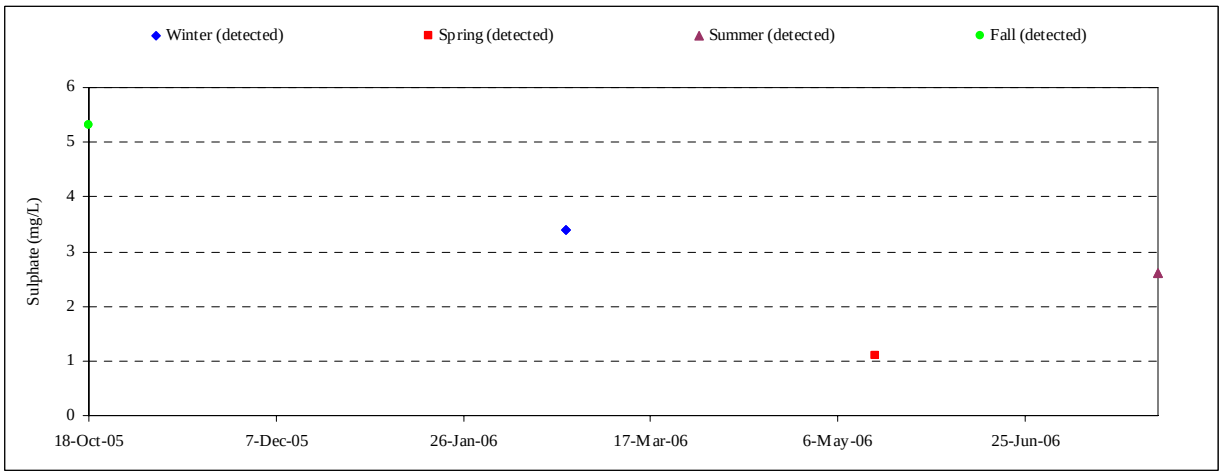
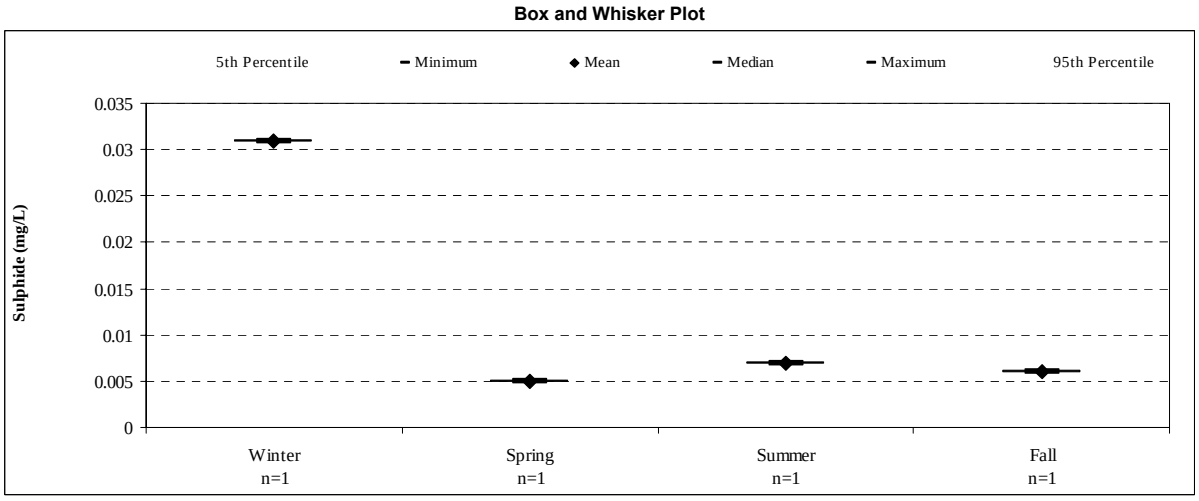


Figure G-1-6-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in McClelland Lake Inlet



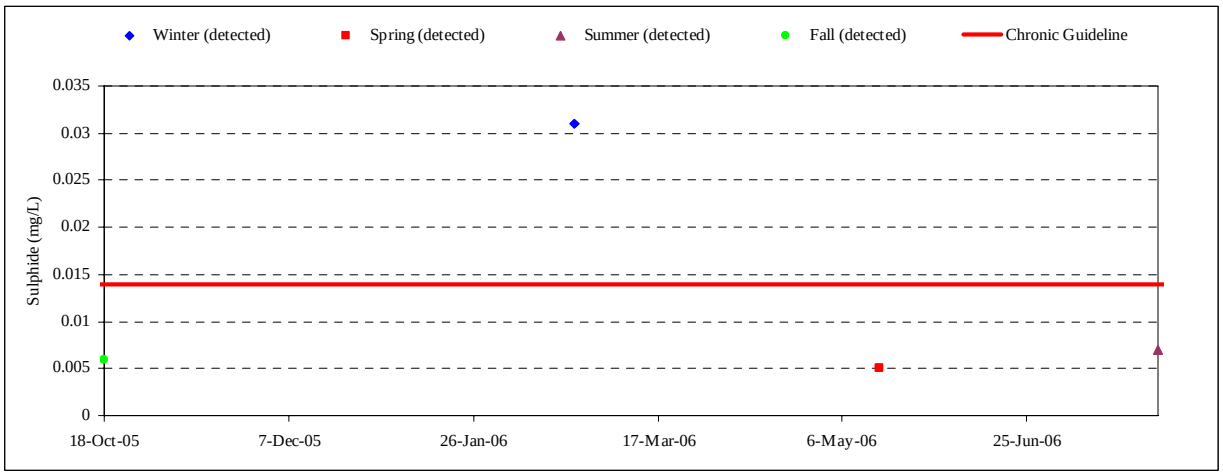
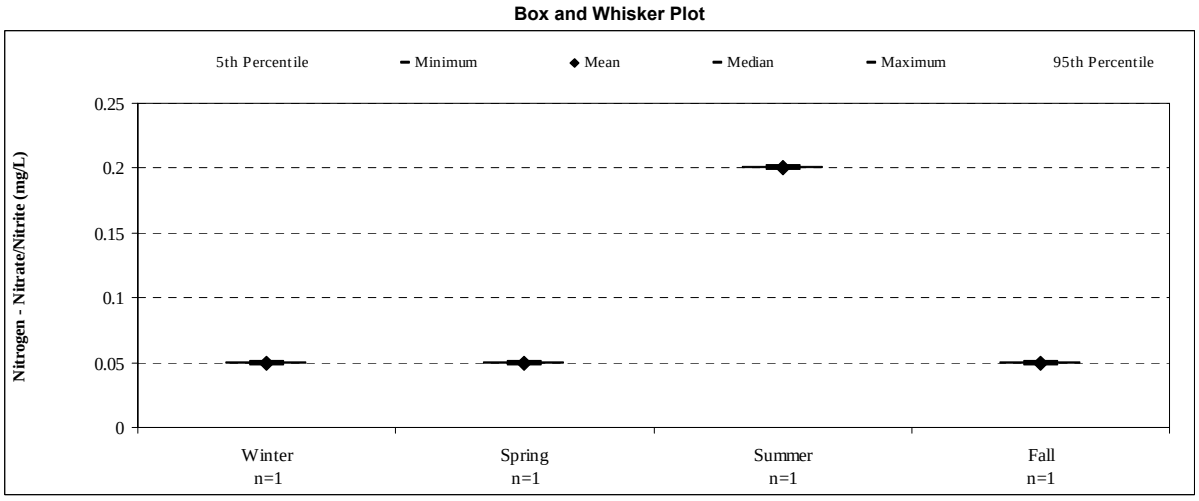


Figure G-1-6-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in McClelland Lake Inlet



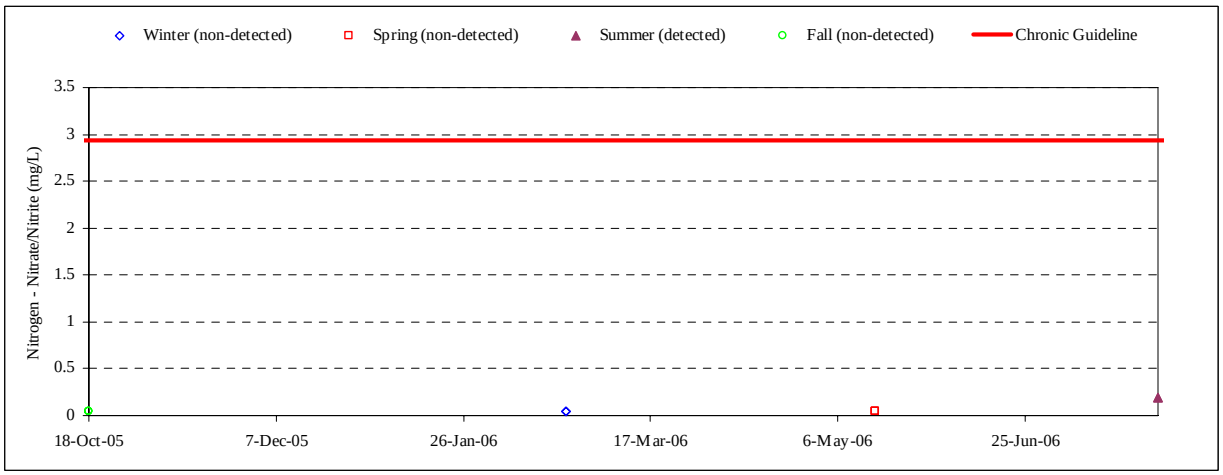
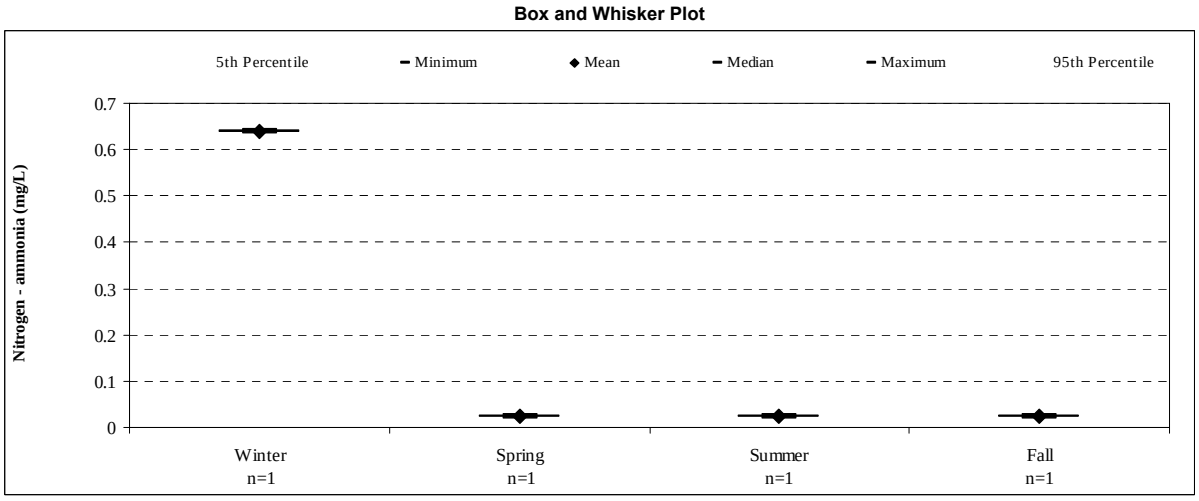


Figure G-1-6-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in McClelland Lake Inlet



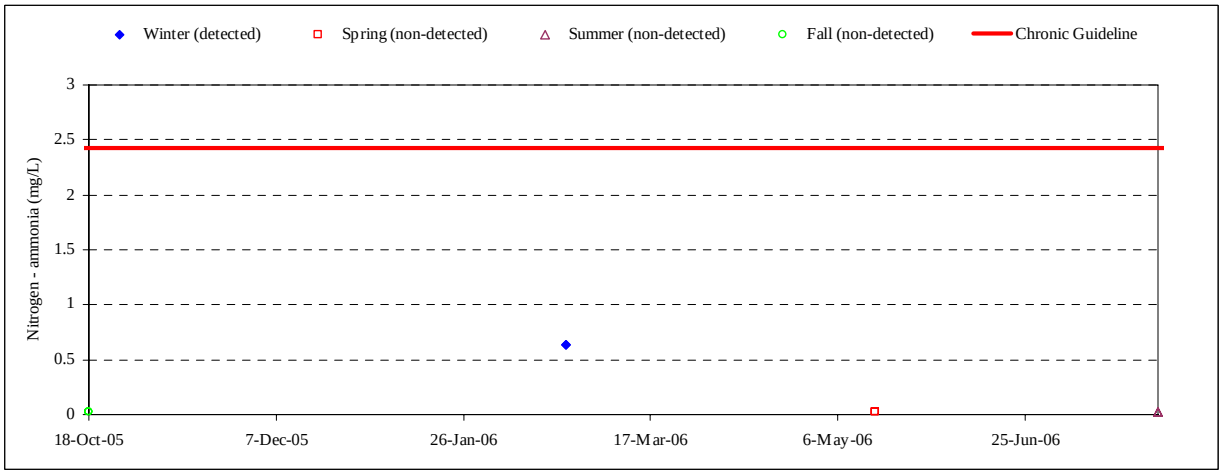
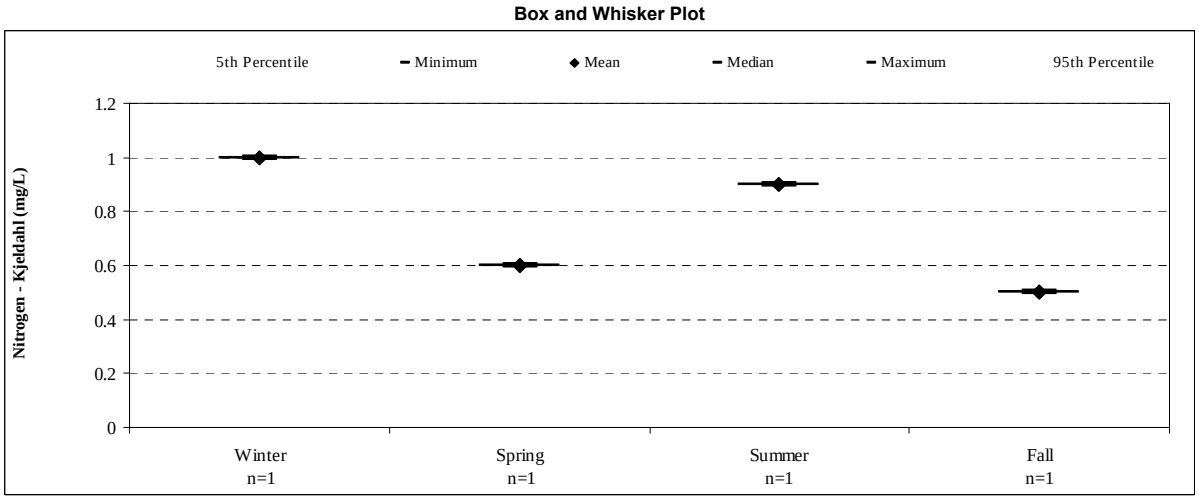


Figure G-1-6-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in McClelland Lake Inlet



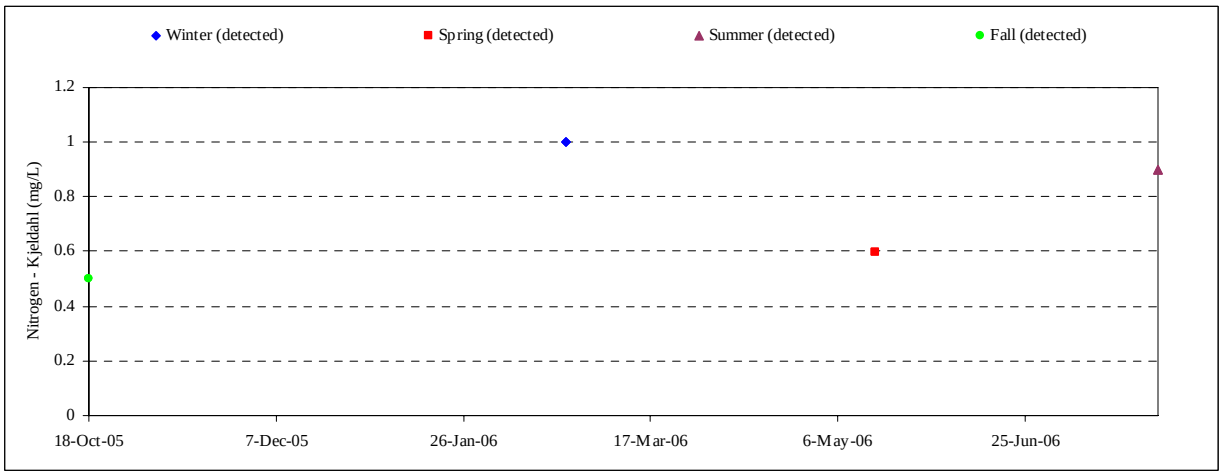
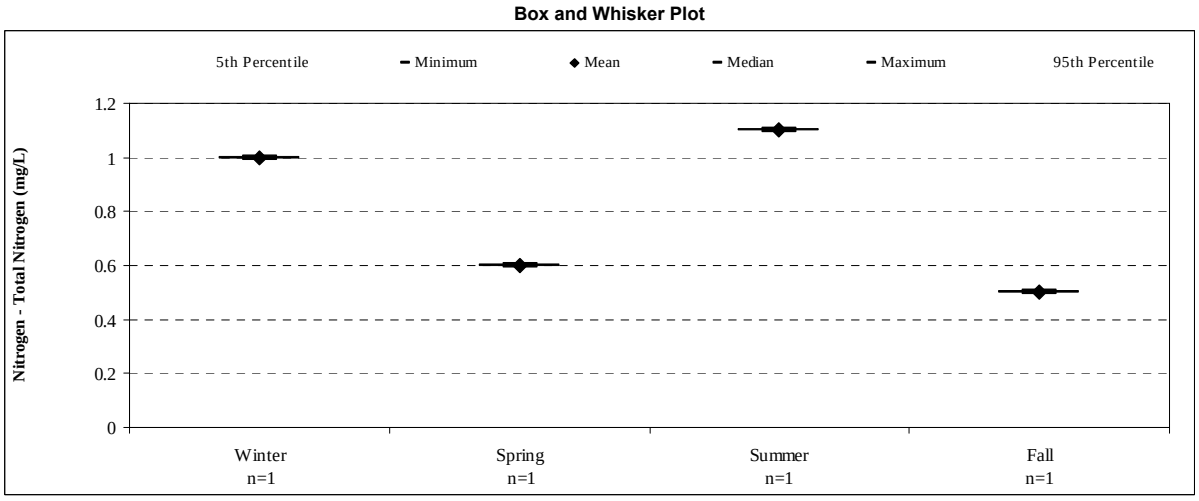


Figure G-1-6-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in McClelland Lake Inlet



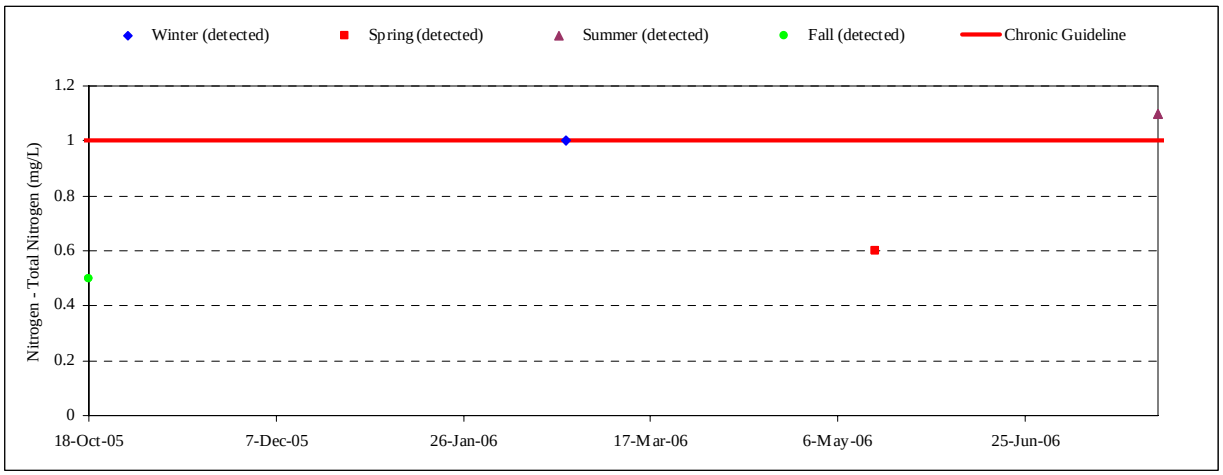
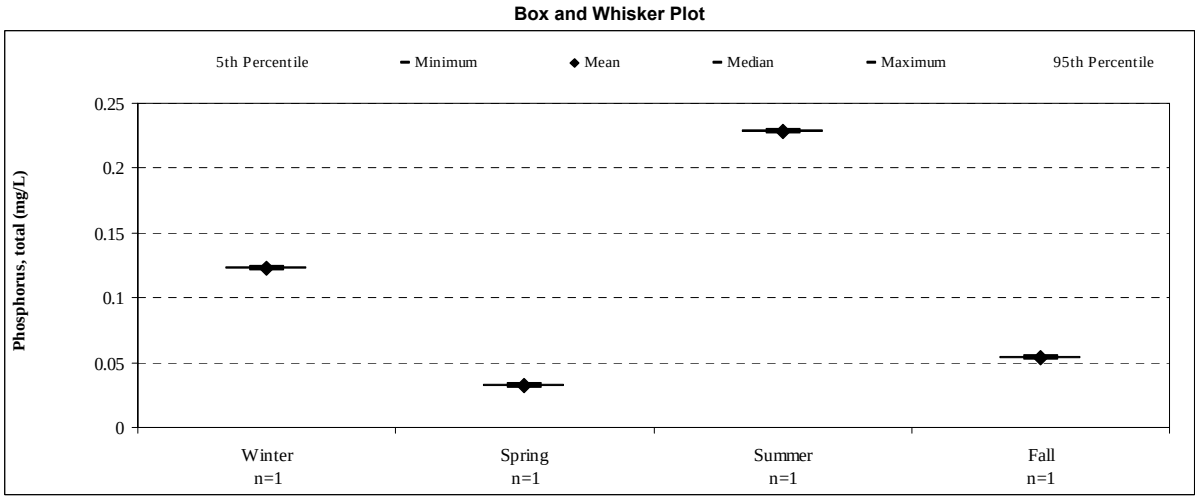


Figure G-1-6-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in McClelland Lake Inlet



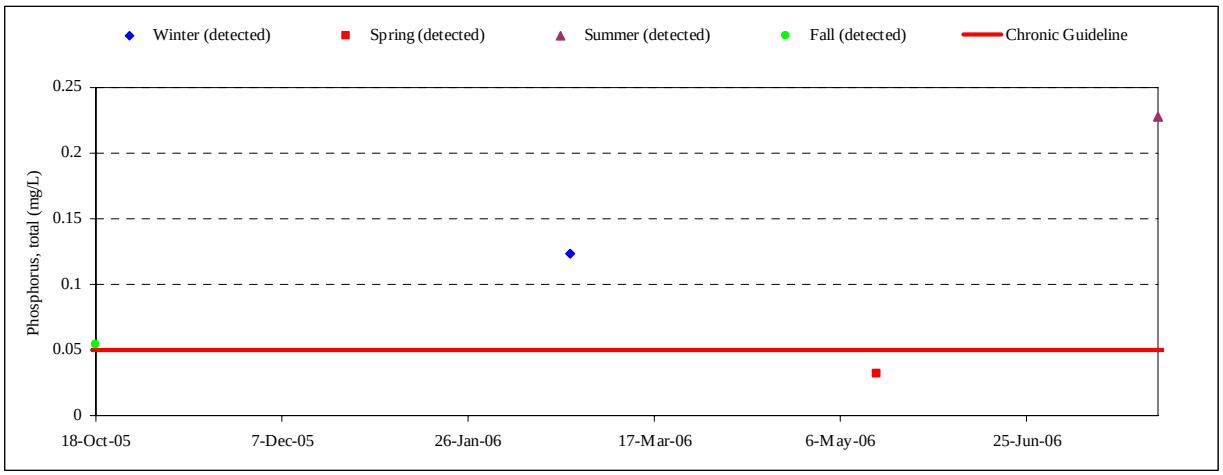
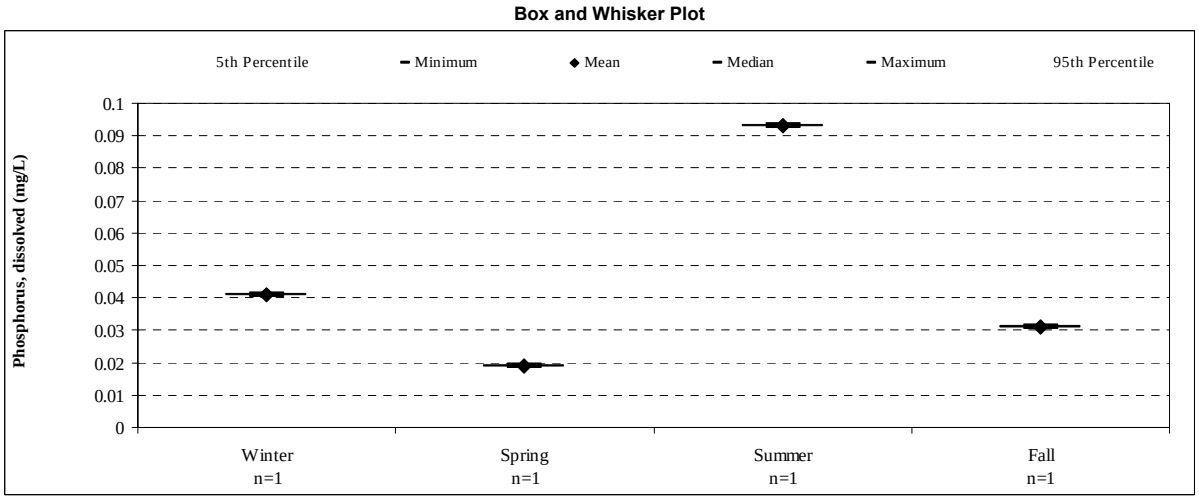


Figure G-1-6-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in McClelland Lake Inlet



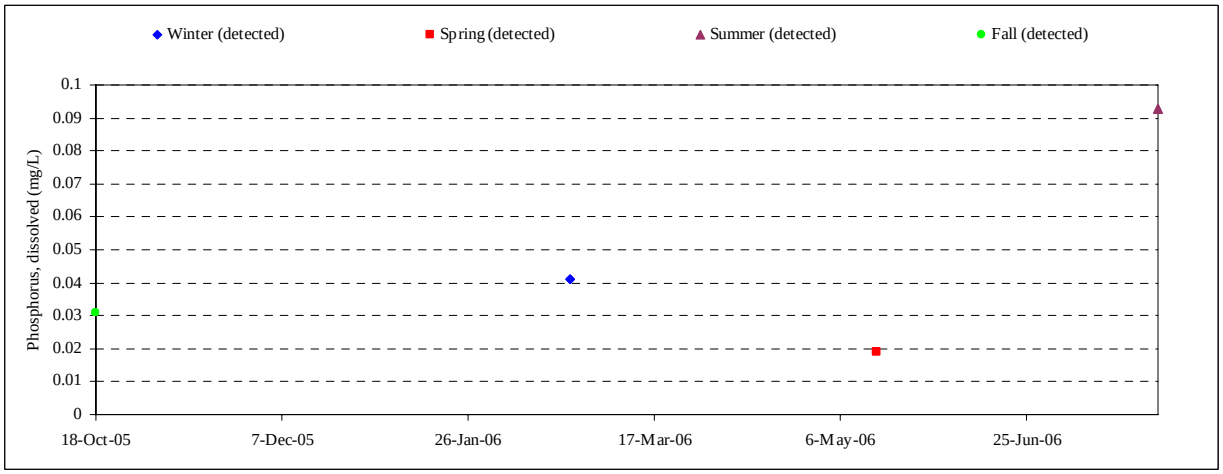
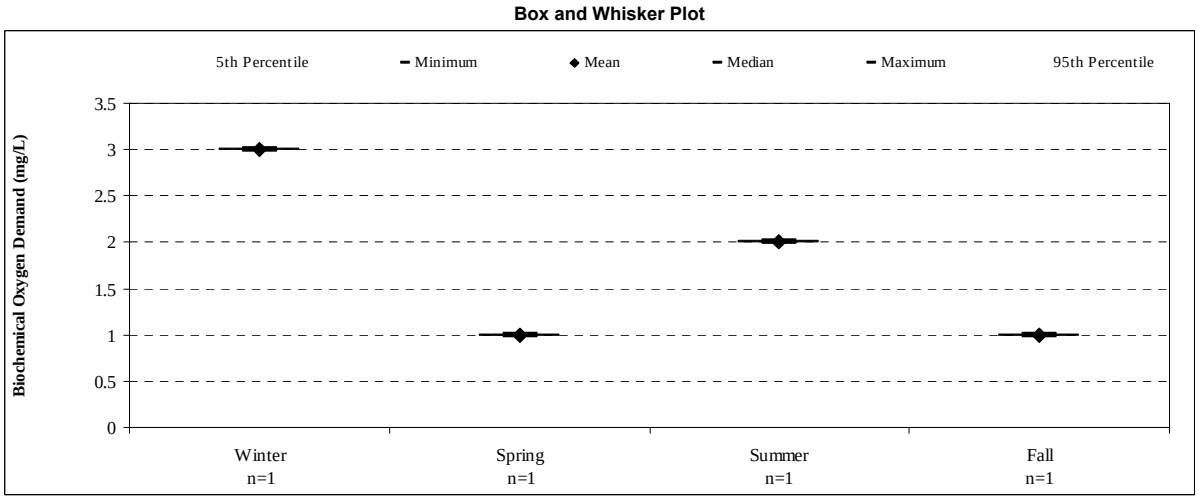


Figure G-1-6-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in McClelland Lake Inlet



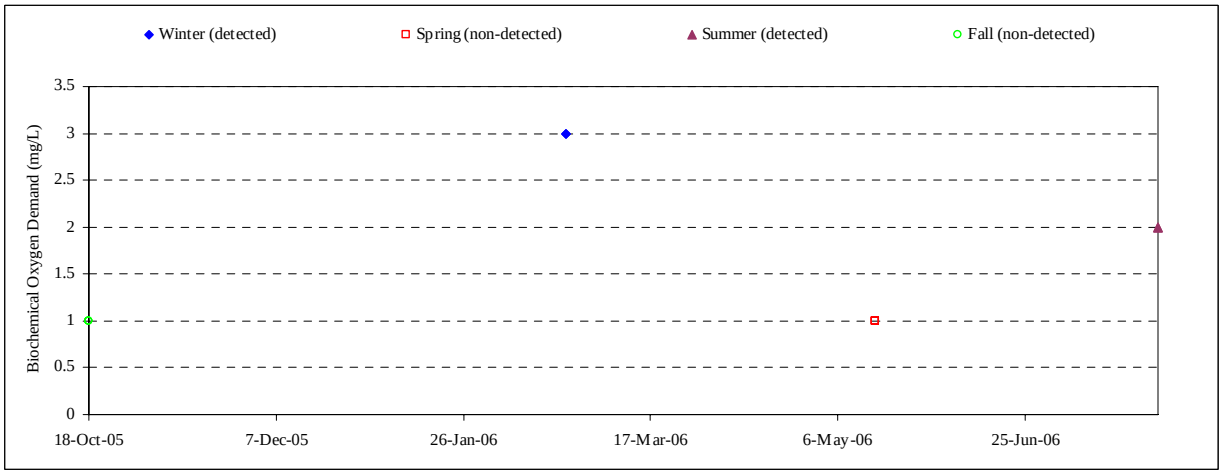
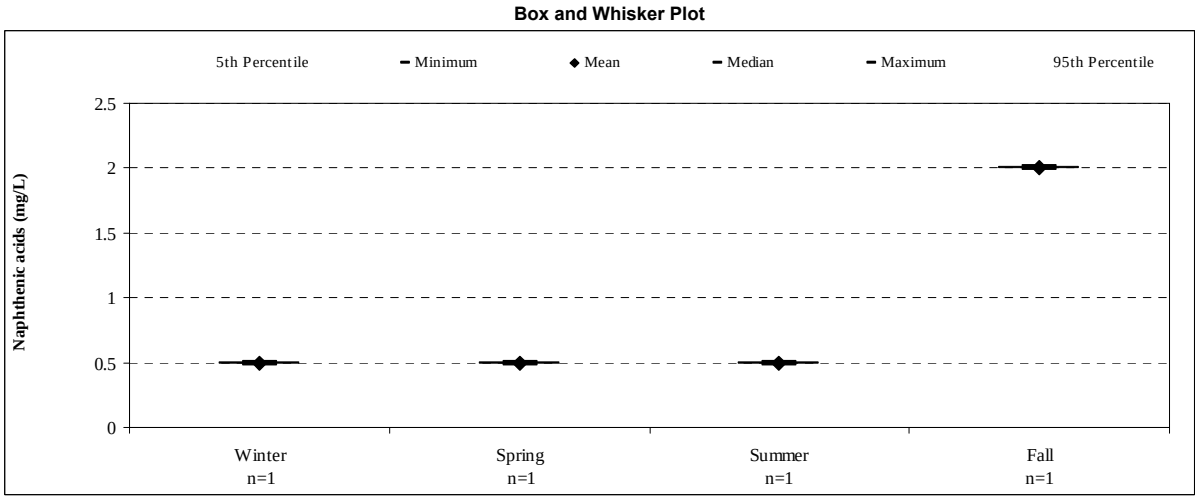


Figure G-1-6-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in McClelland Lake Inlet



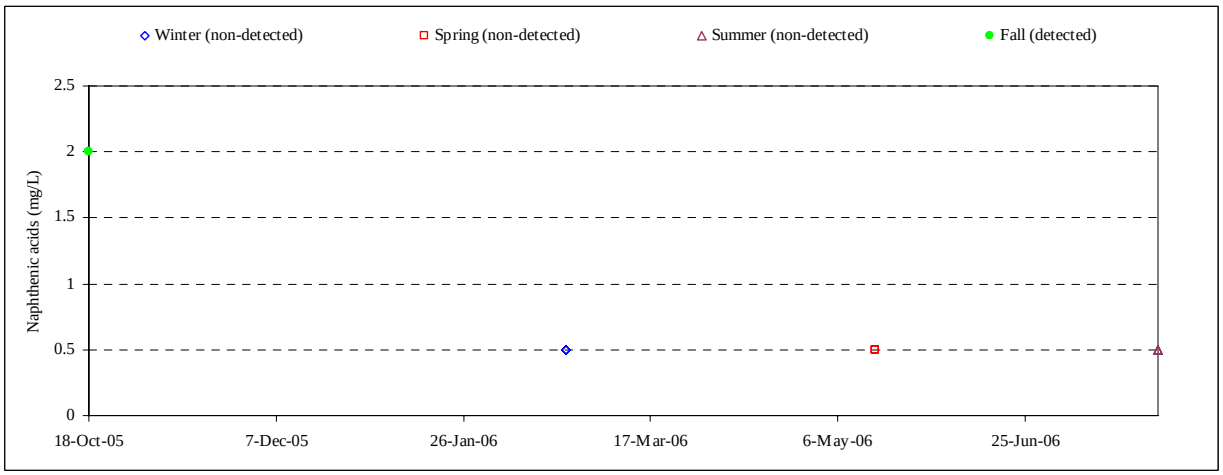


Figure G-1-6-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in McClelland Lake Inlet

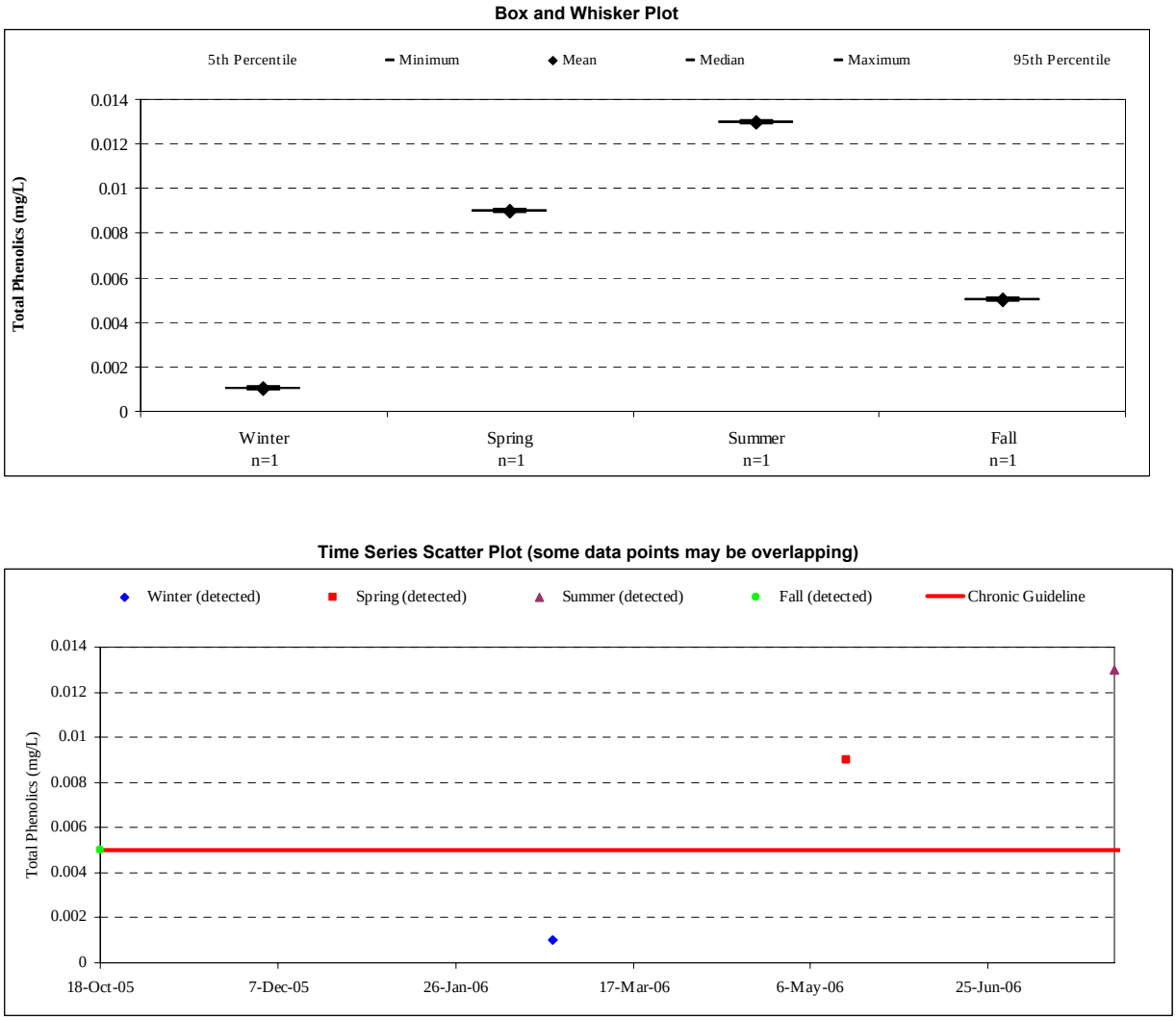


Figure G-1-6-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in McClelland Lake Inlet

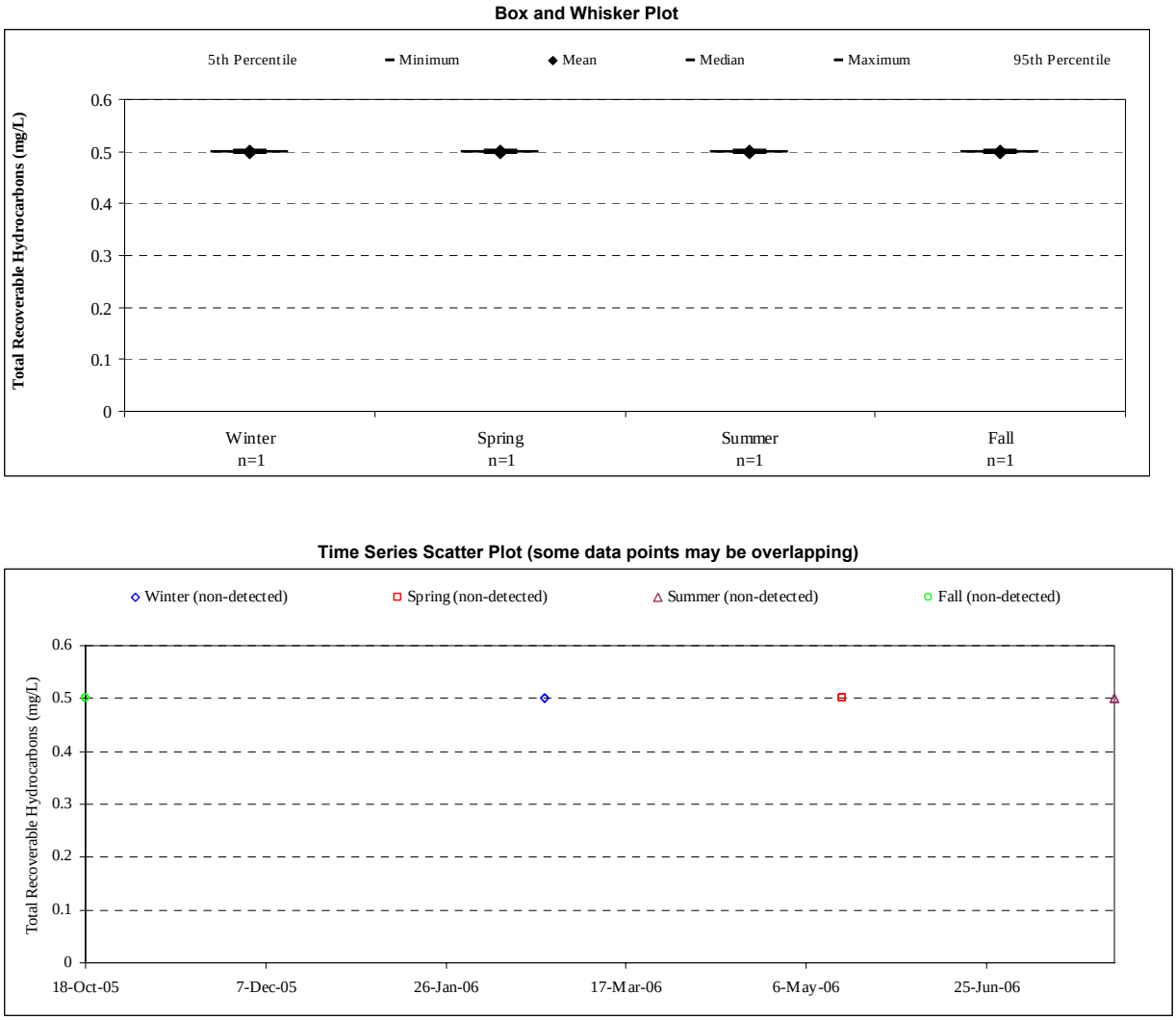
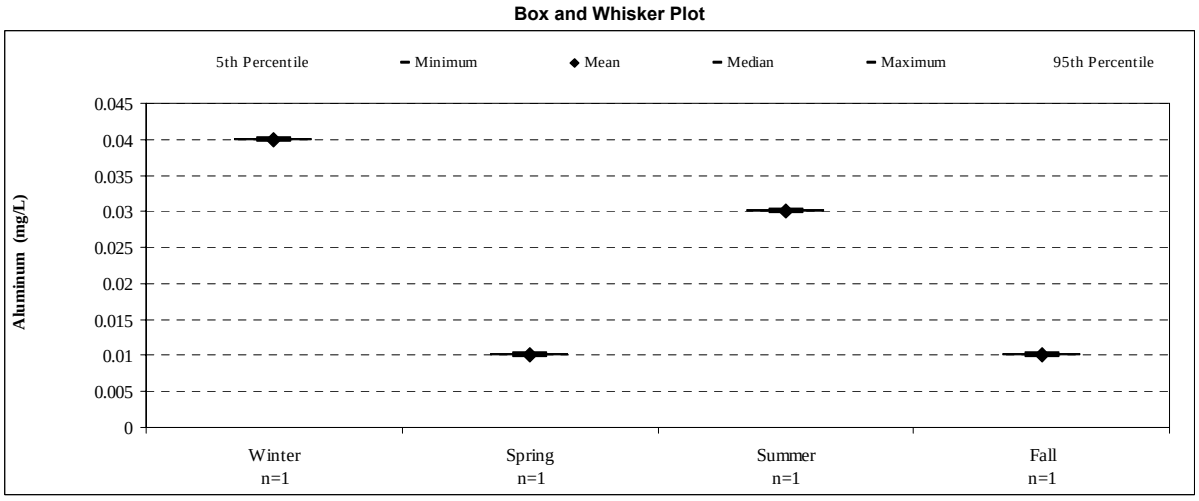


Figure G-1-6-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in McClelland Lake Inlet



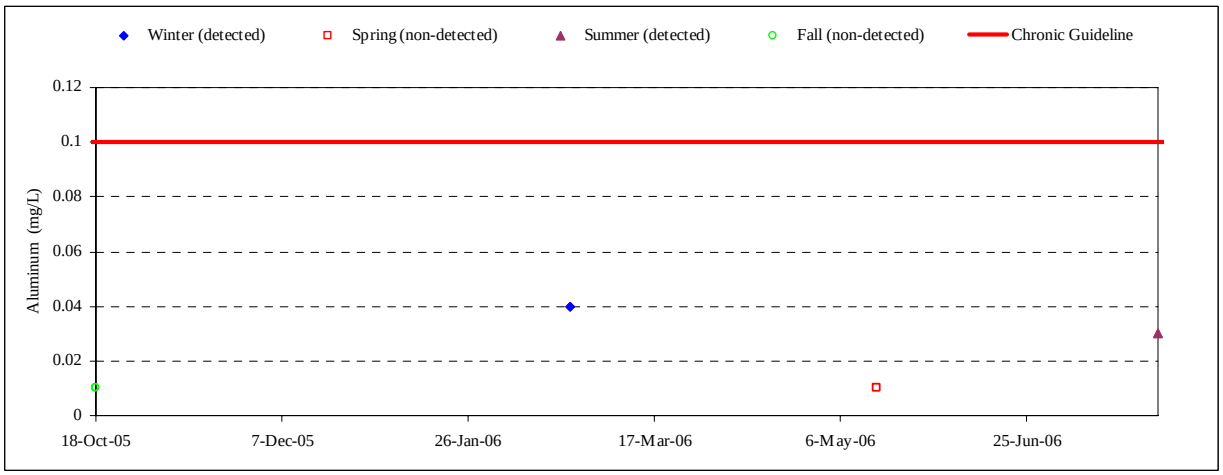
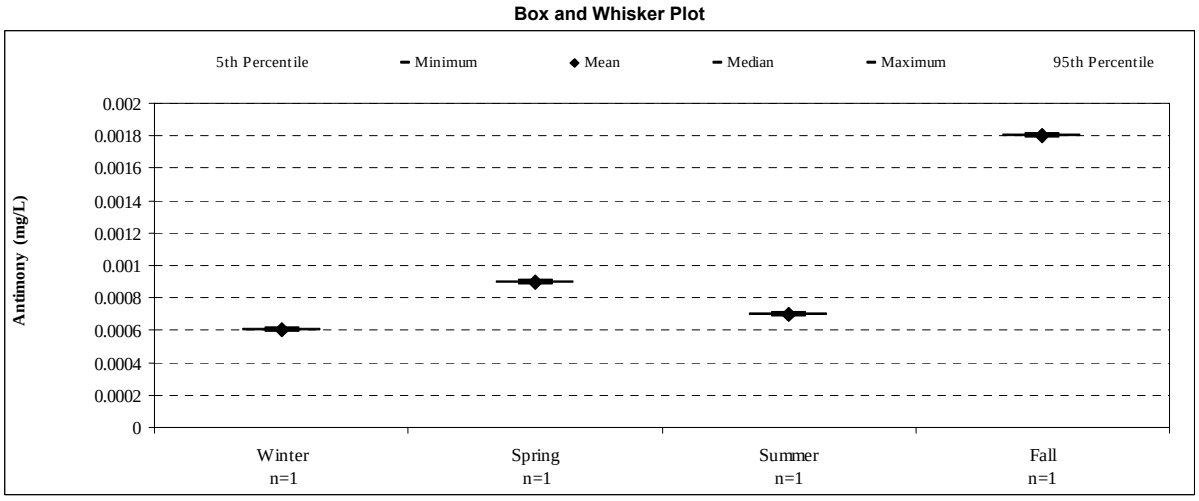


Figure G-1-6-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in McClelland Lake Inlet



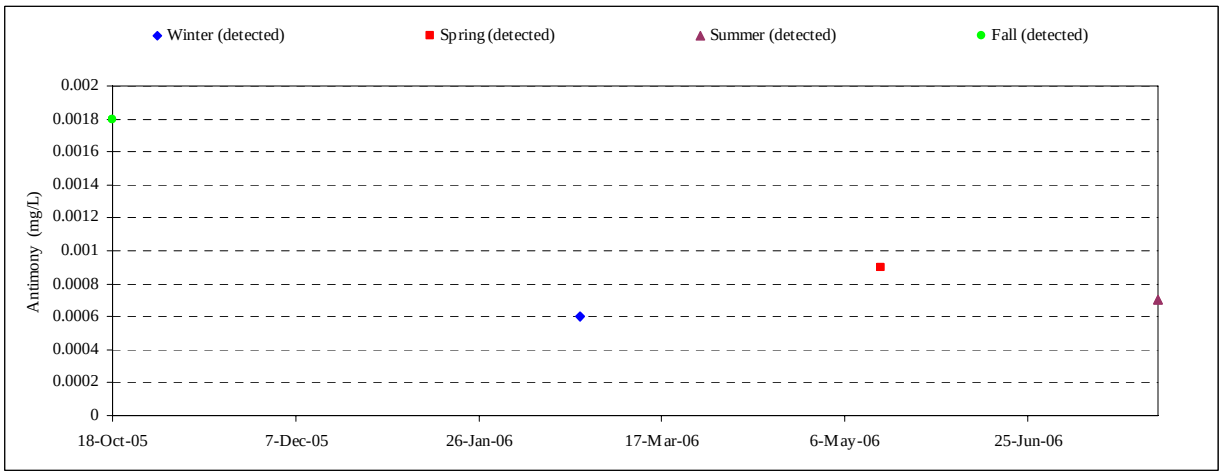
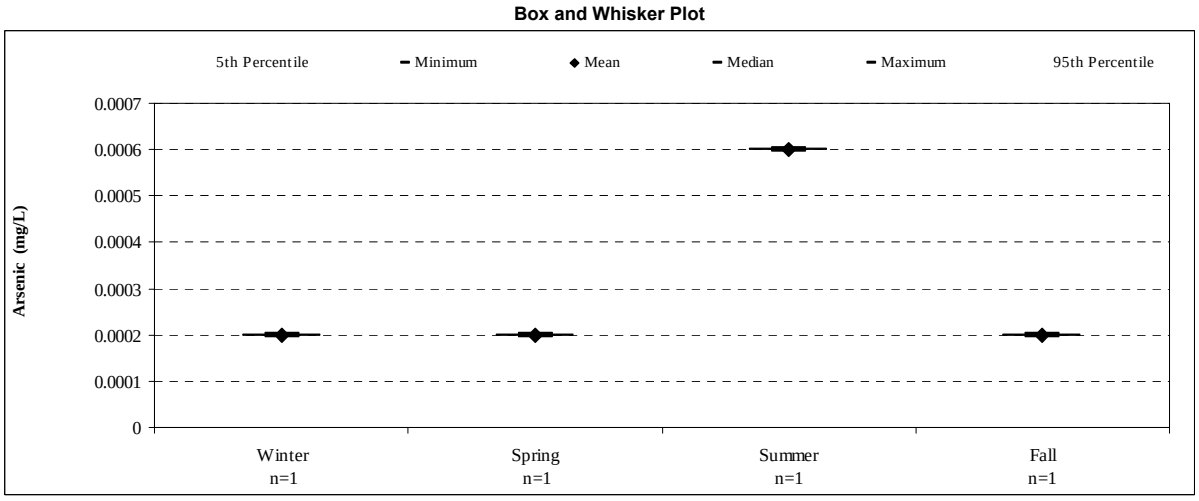


Figure G-1-6-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in McClelland Lake Inlet



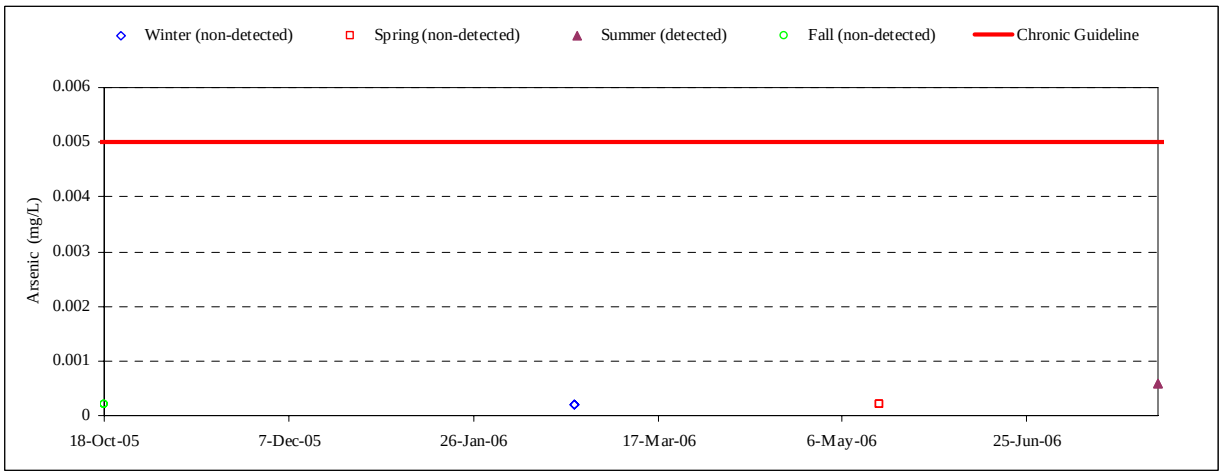
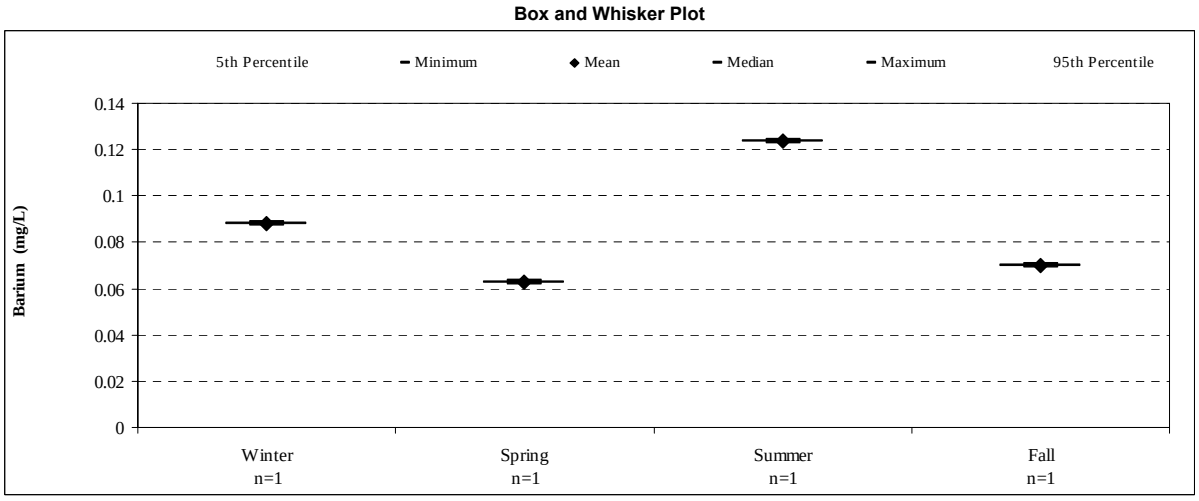


Figure G-1-6-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in McClelland Lake Inlet



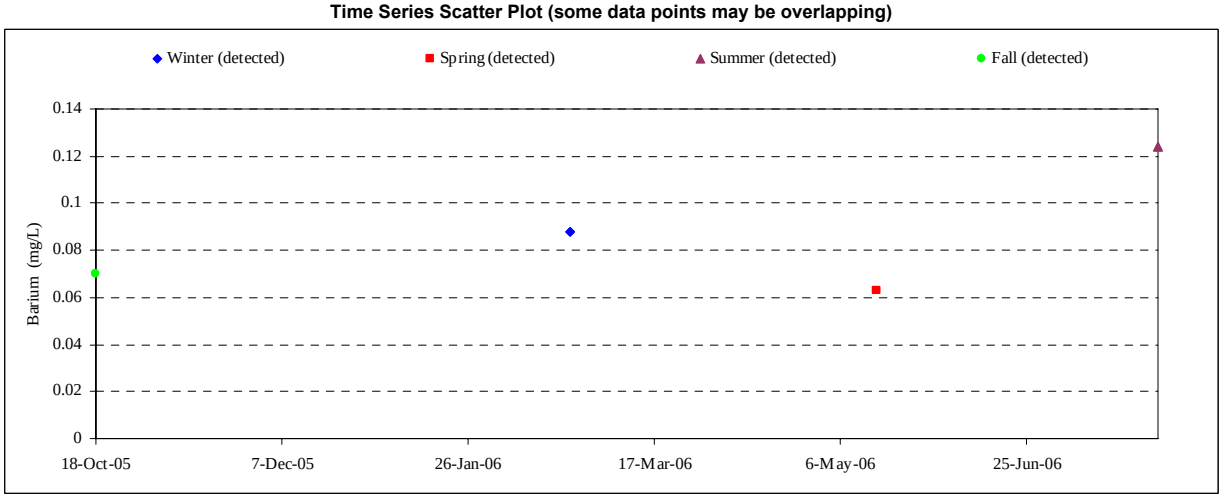
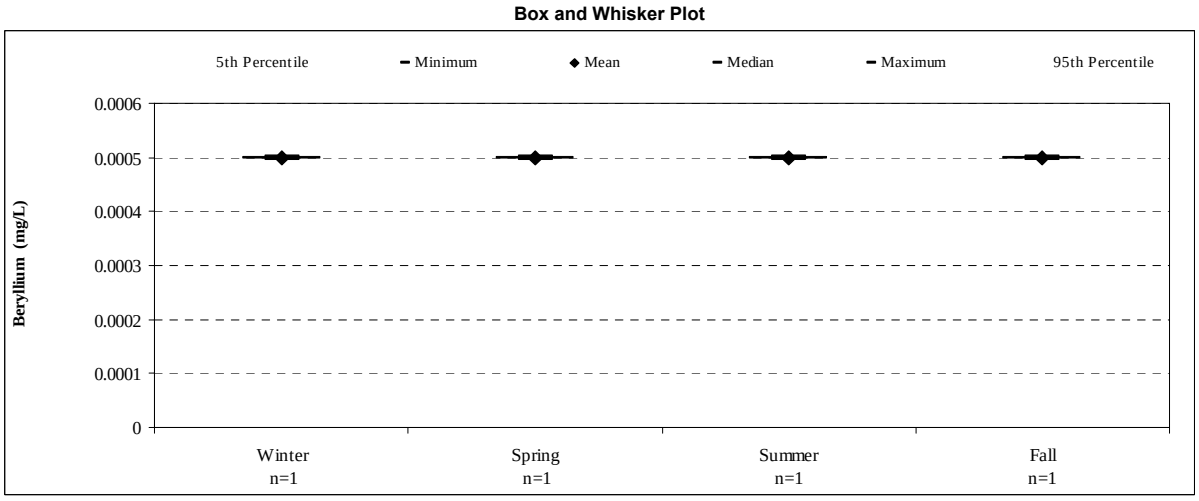


Figure G-1-6-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in McClelland Lake Inlet



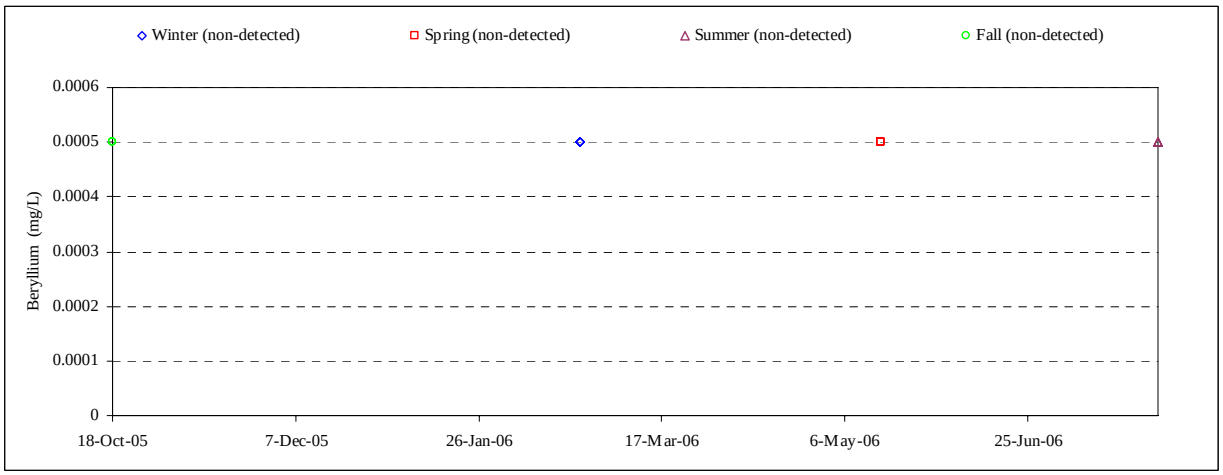
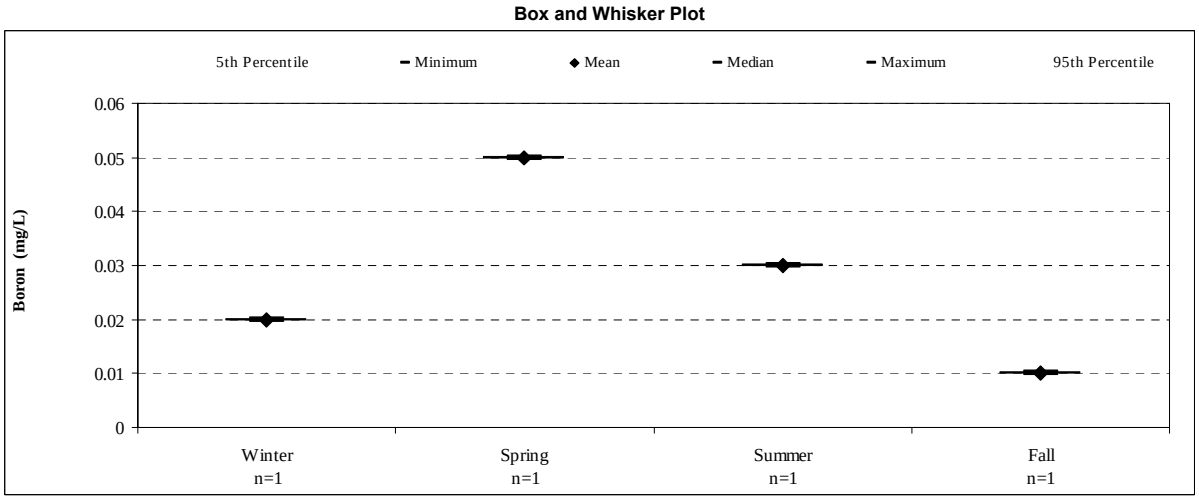


Figure G-1-6-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in McClelland Lake Inlet



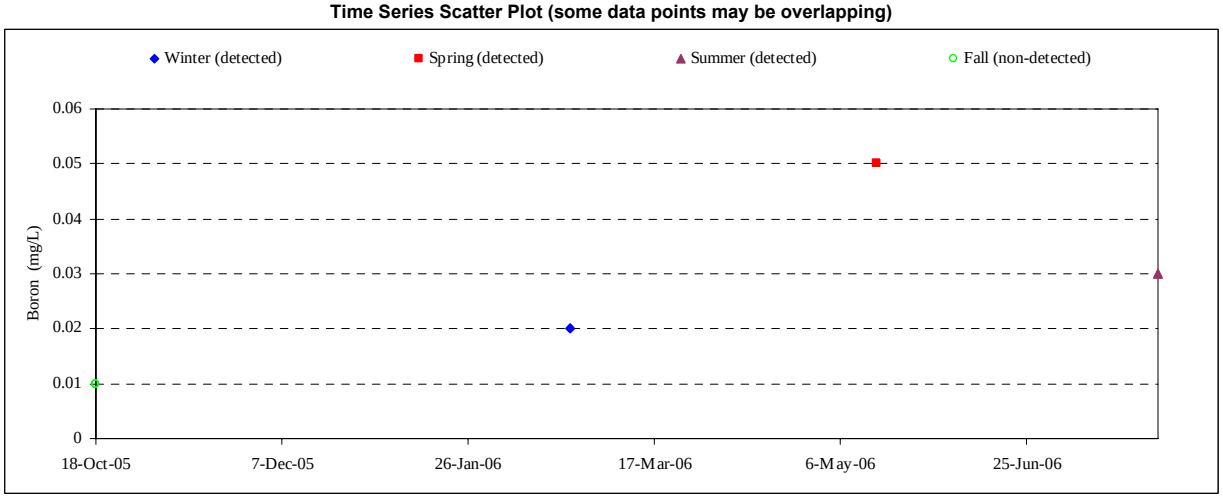
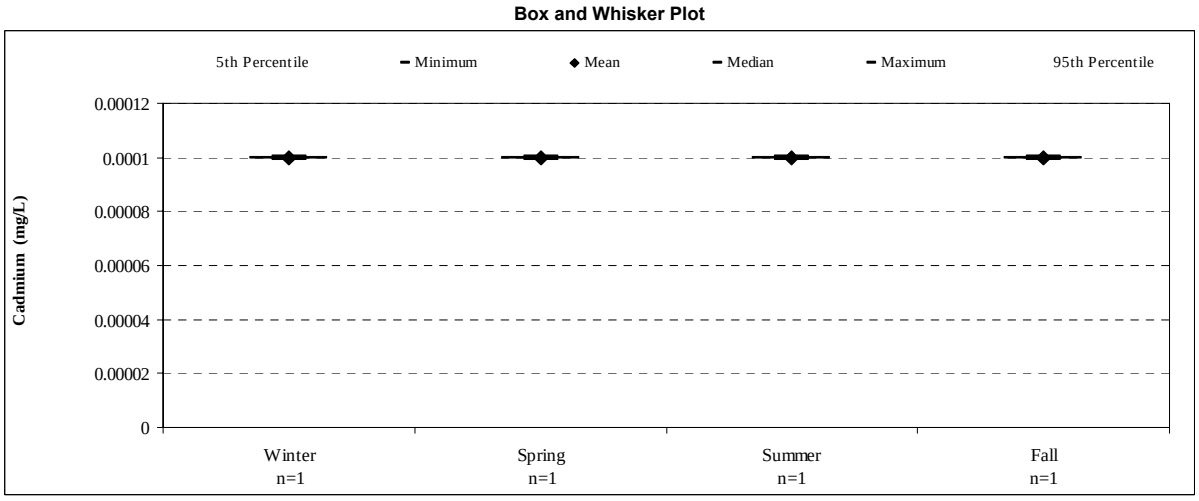


Figure G-1-6-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in McClelland Lake Inlet



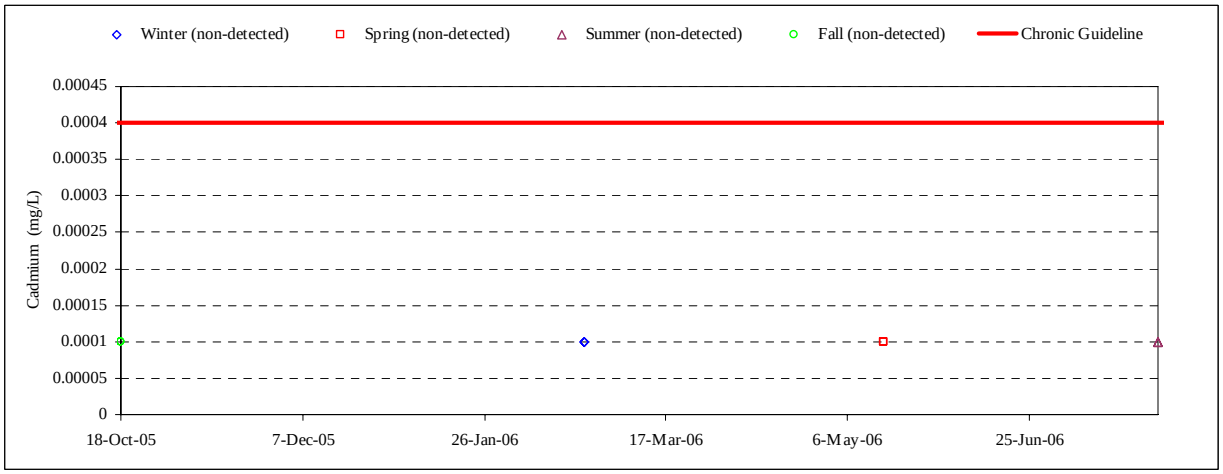
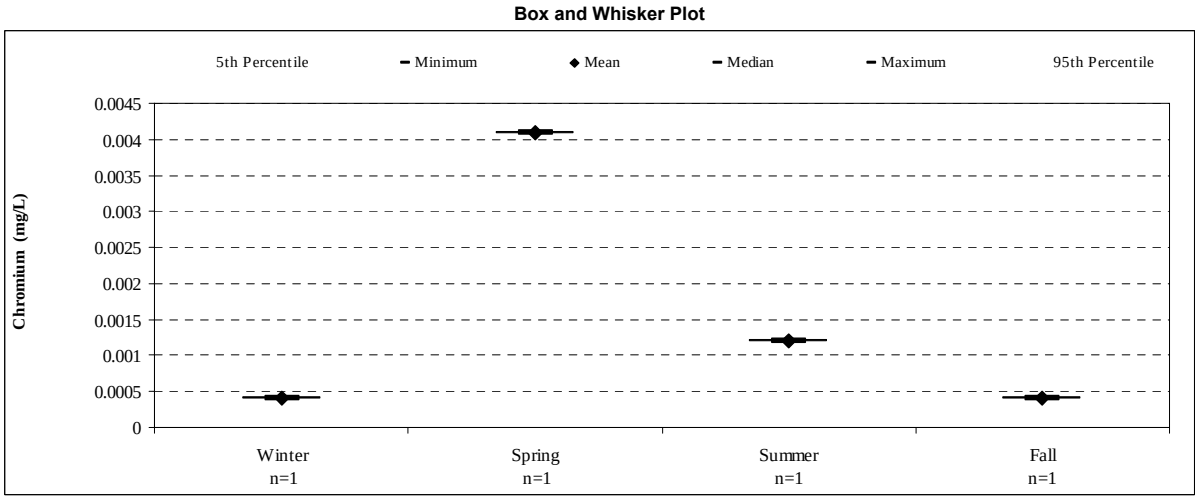


Figure G-1-6-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in McClelland Lake Inlet



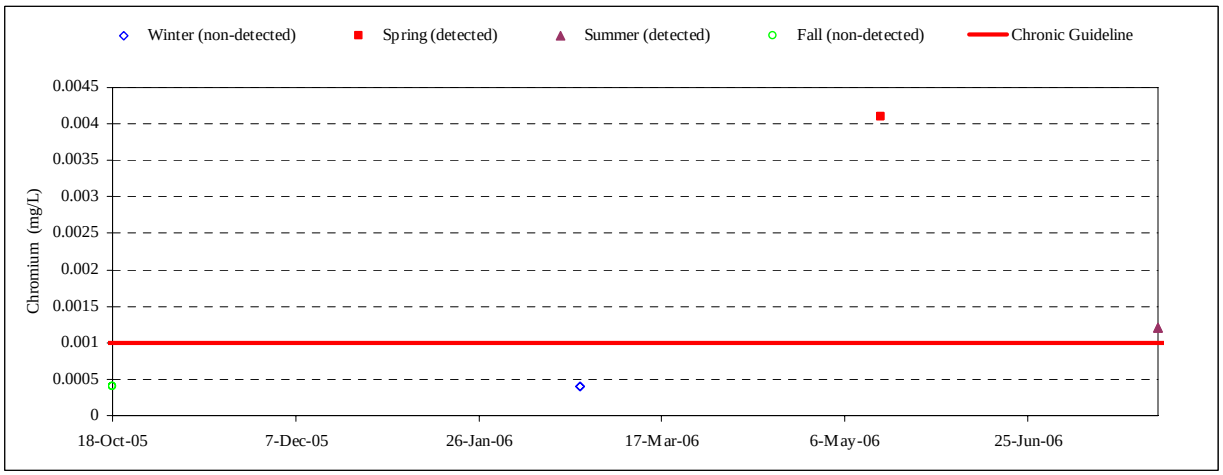
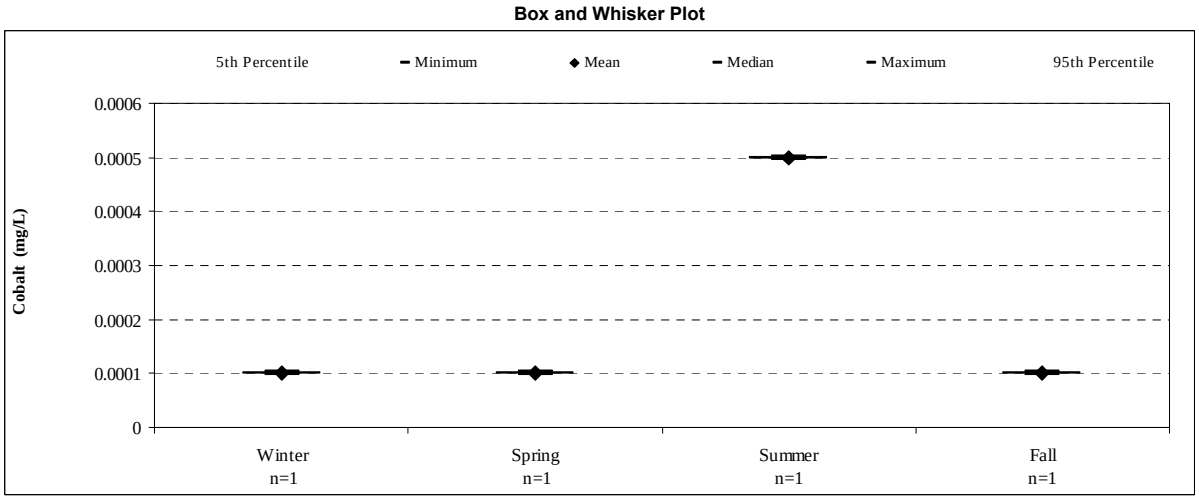


Figure G-1-6-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in McClelland Lake Inlet



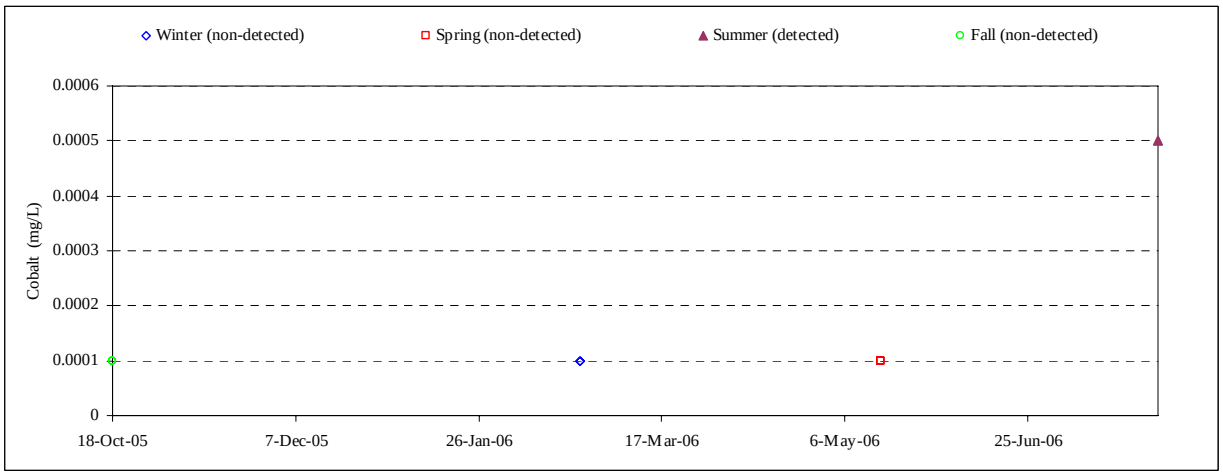
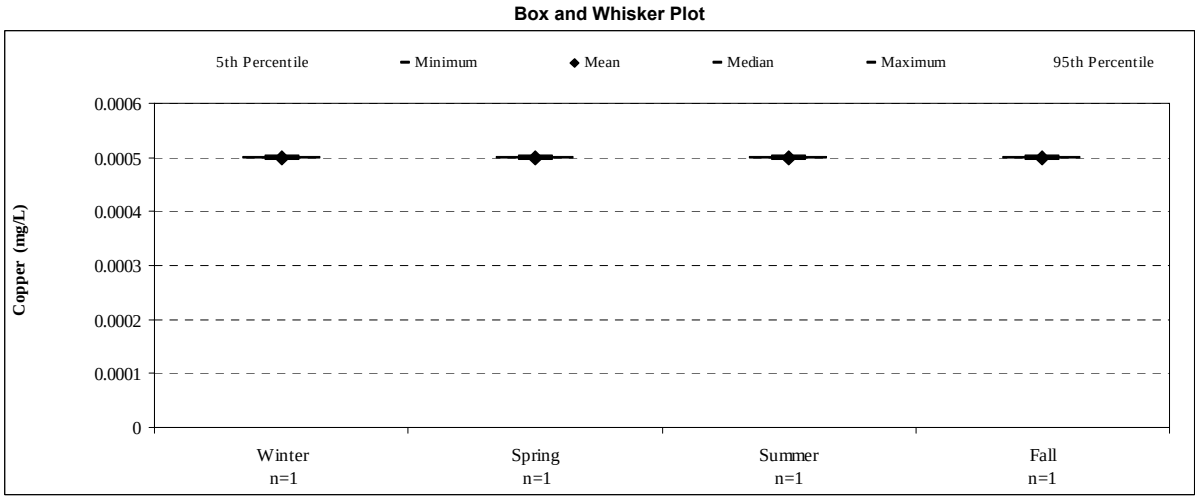


Figure G-1-6-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in McClelland Lake Inlet



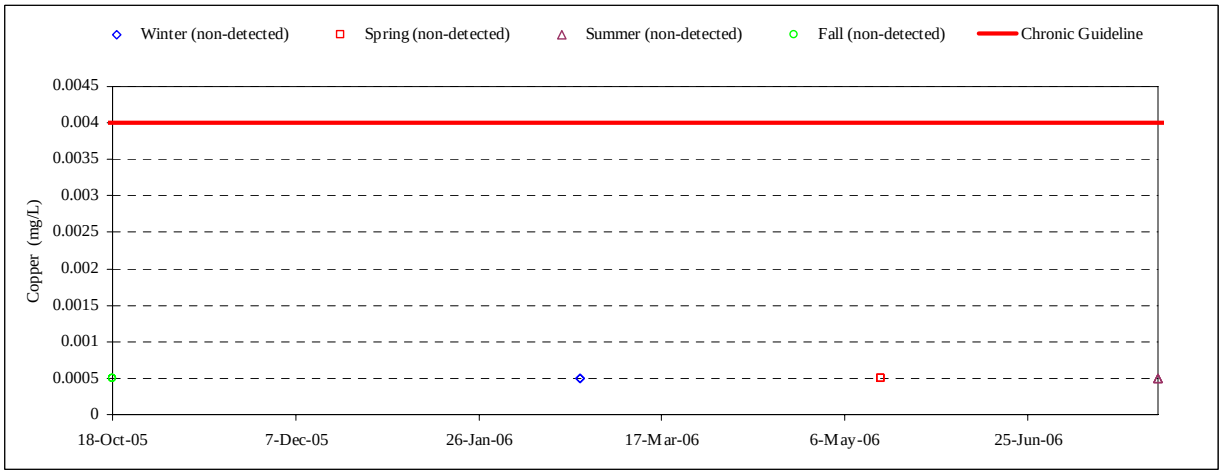
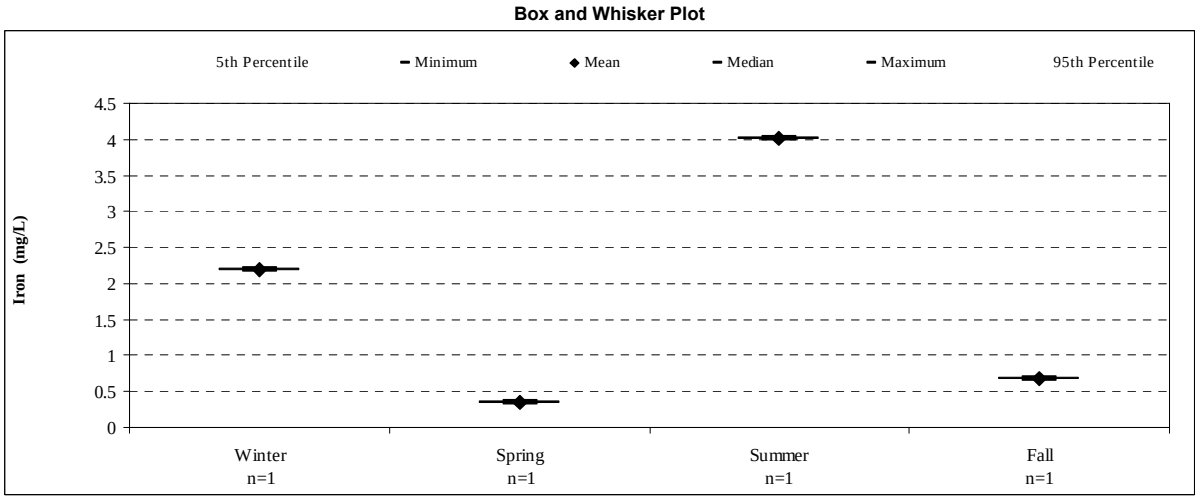


Figure G-1-6-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in McClelland Lake Inlet



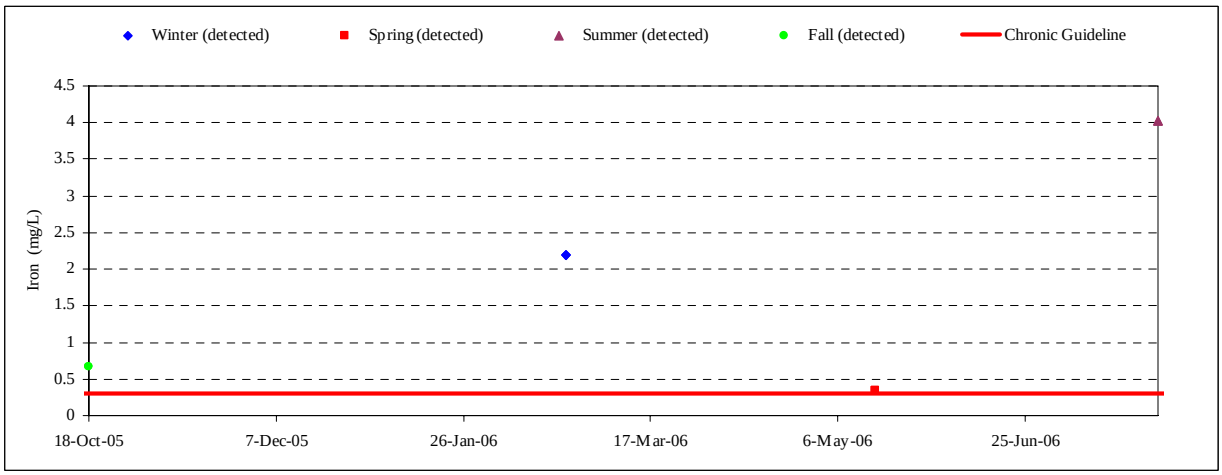
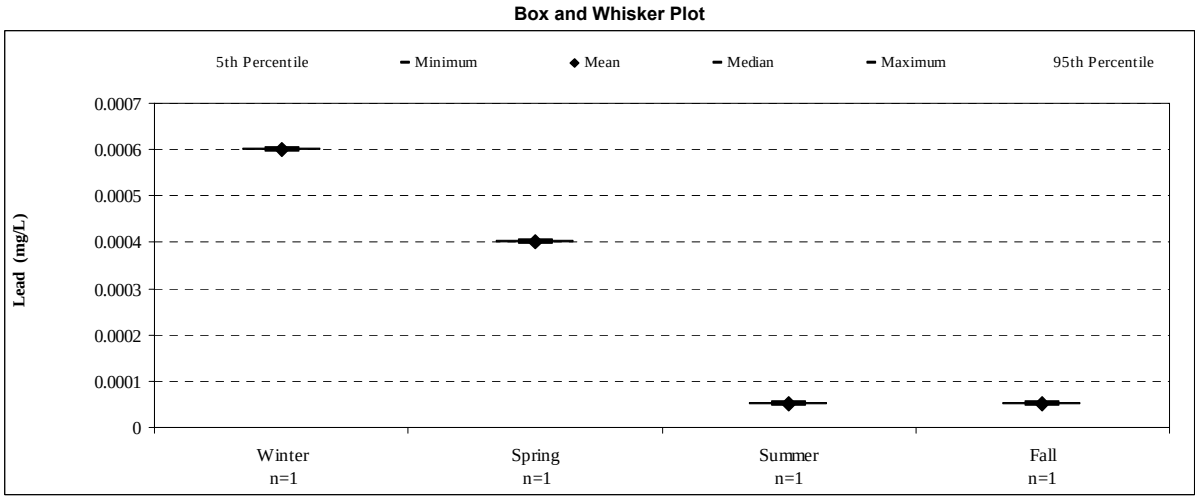


Figure G-1-6-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in McClelland Lake Inlet



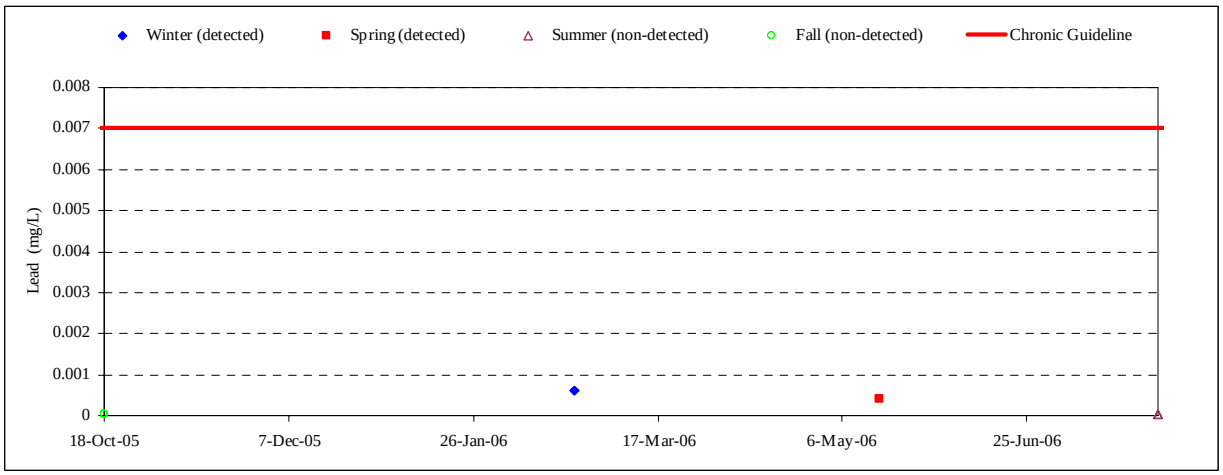
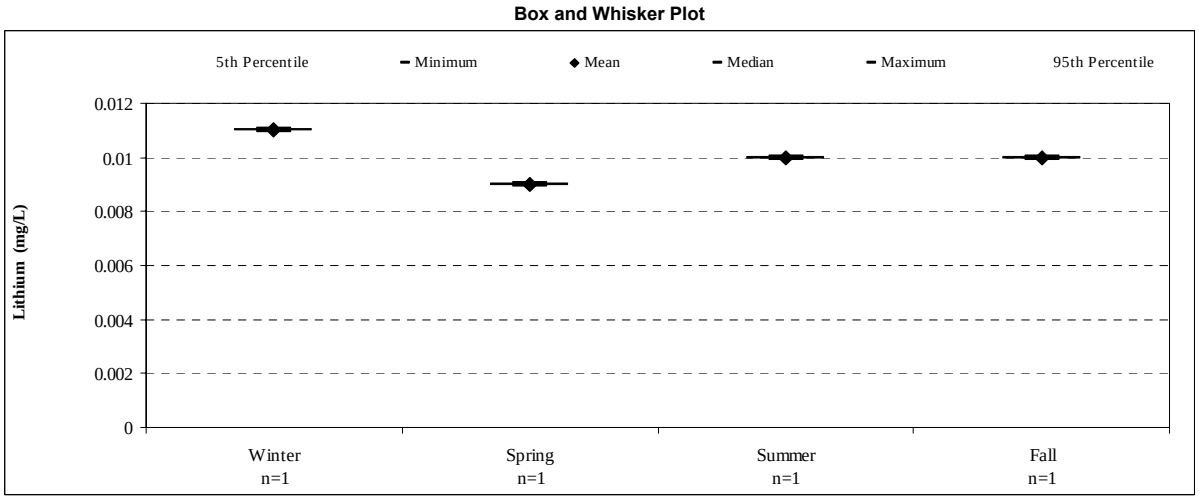


Figure G-1-6-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in McClelland Lake Inlet



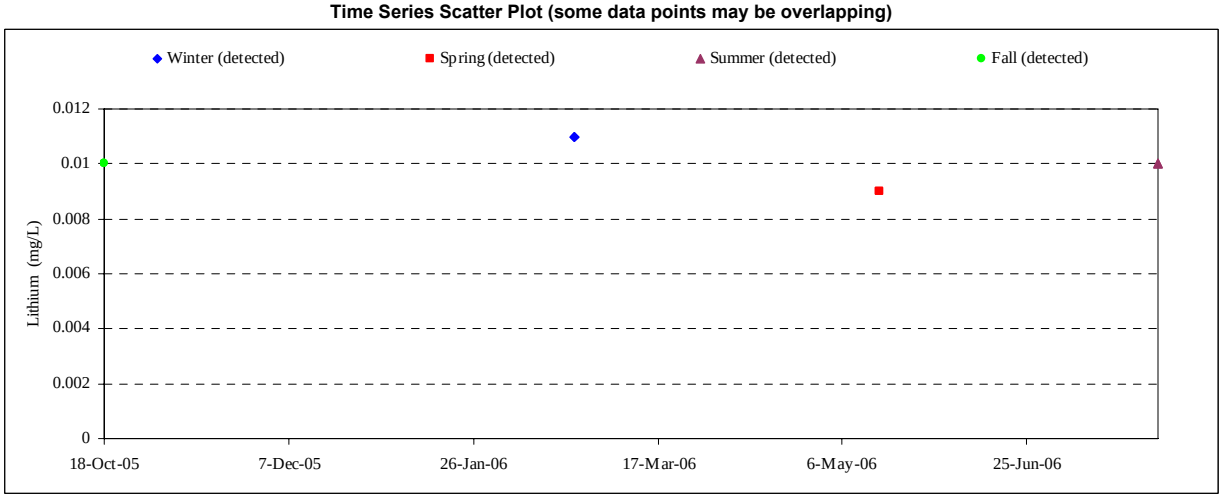
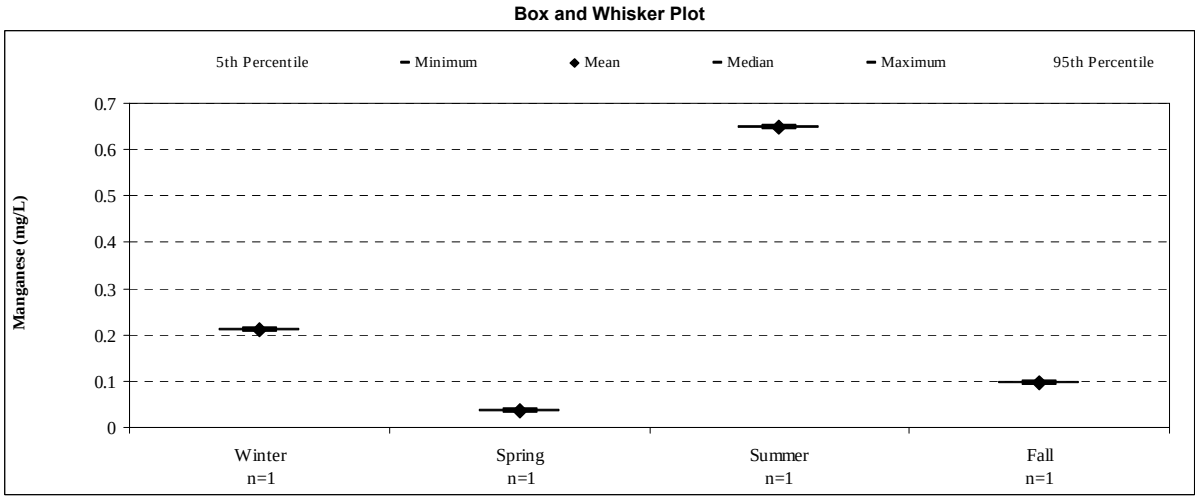


Figure G-1-6-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in McClelland Lake Inlet



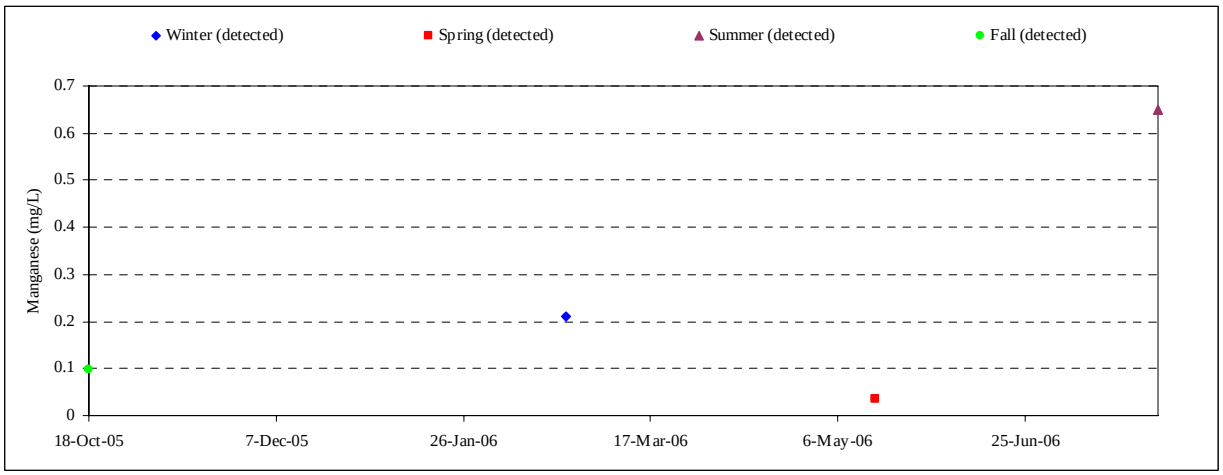
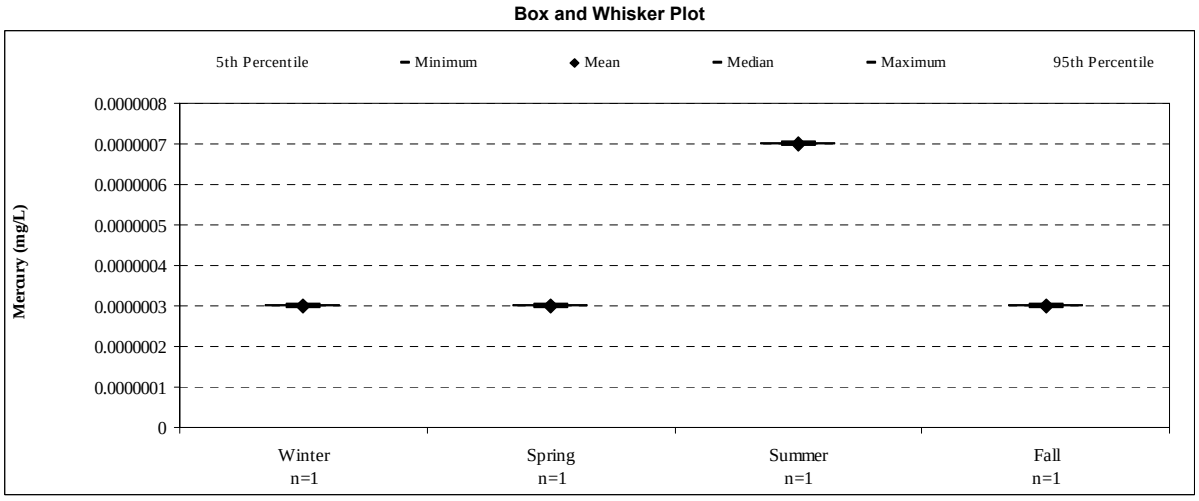


Figure G-1-6-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in McClelland Lake Inlet



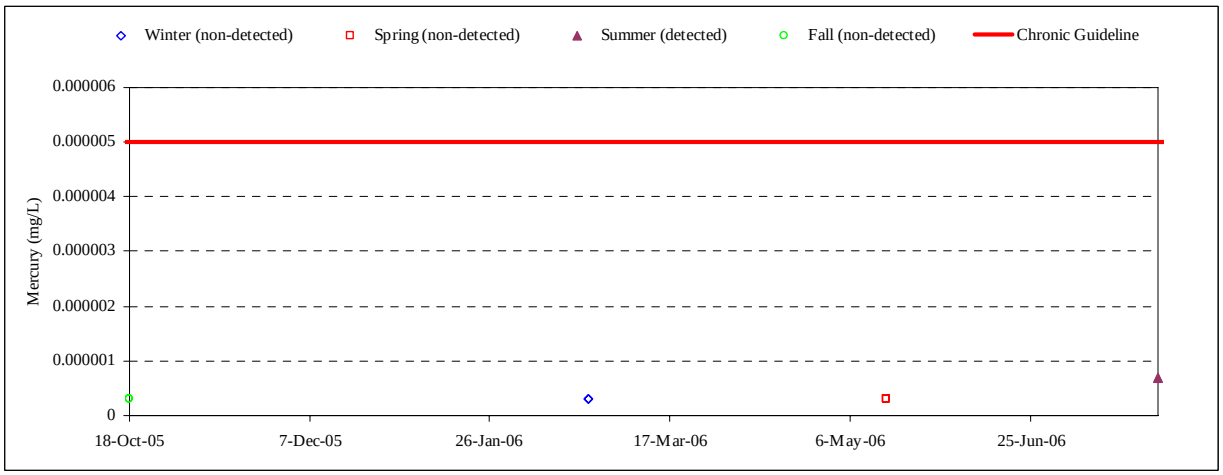
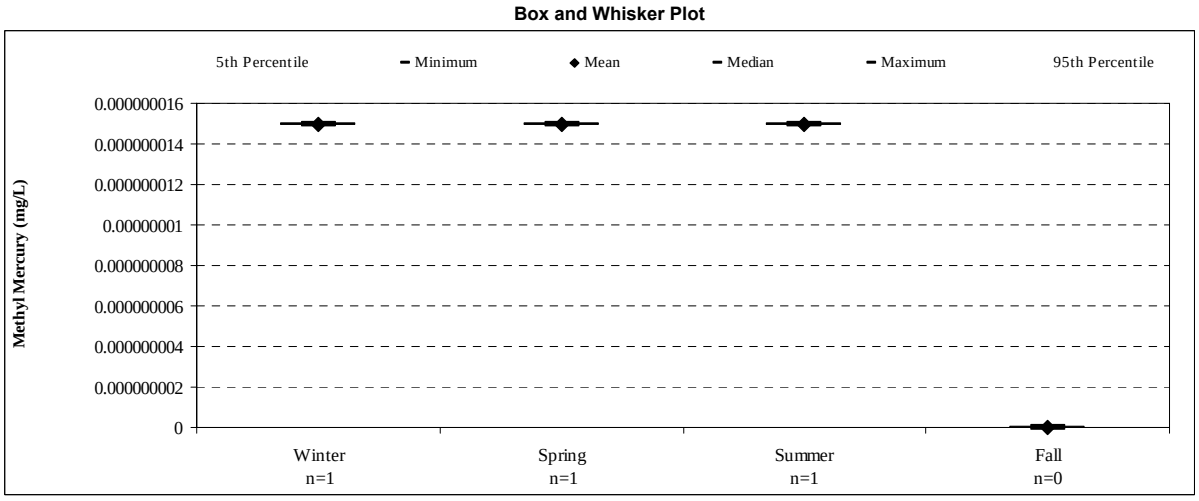


Figure G-1-6-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in McClelland Lake Inlet



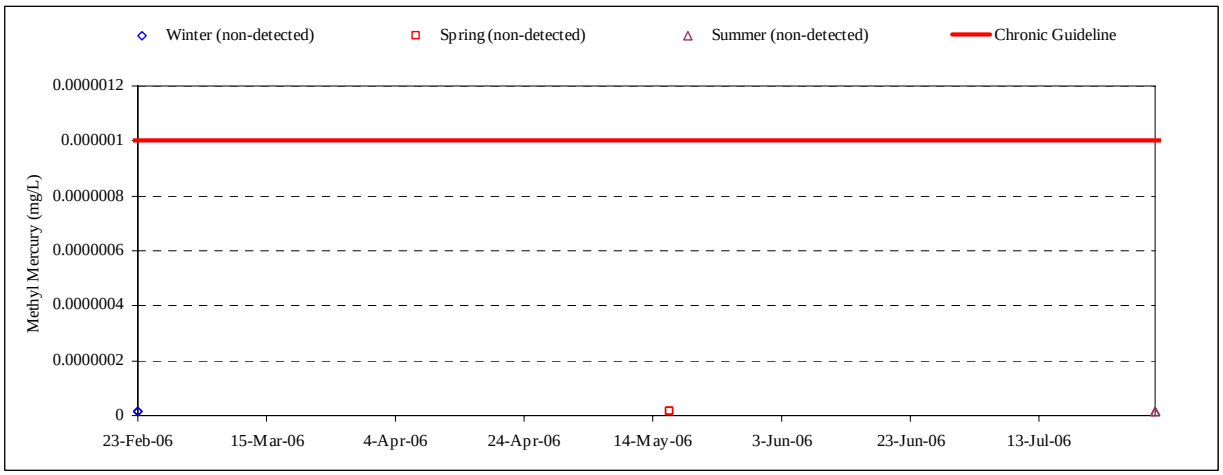
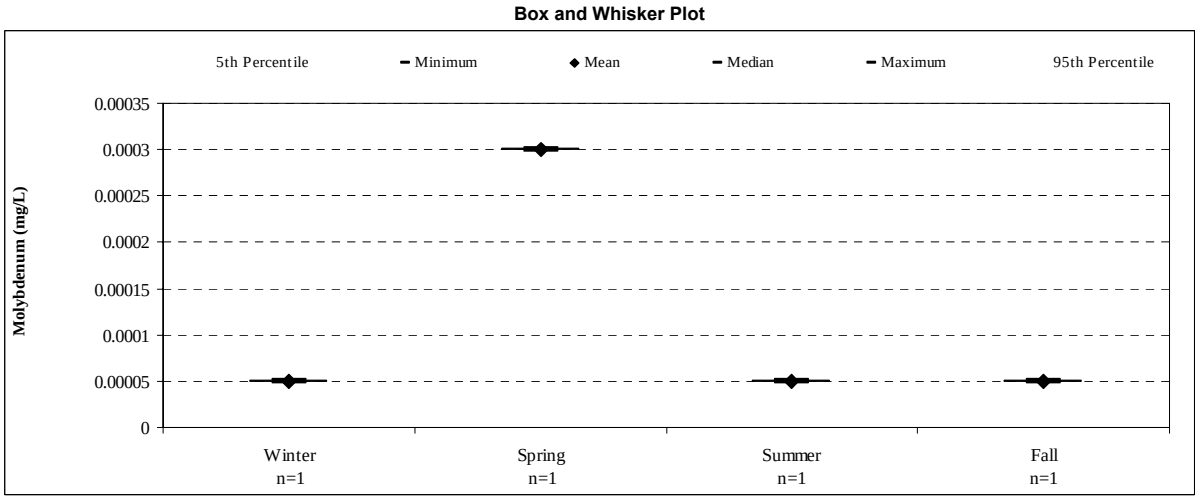


Figure G-1-6-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in McClelland Lake Inlet



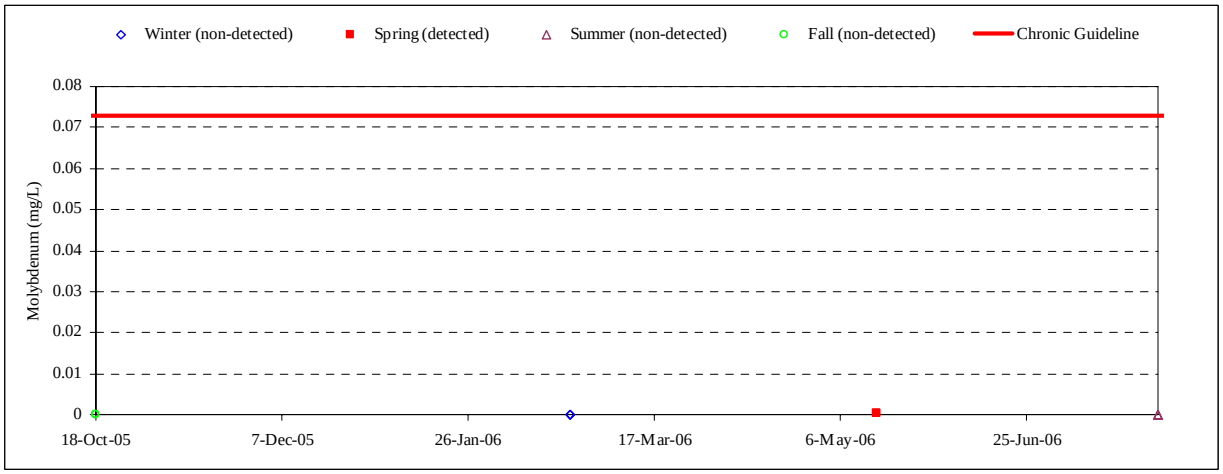
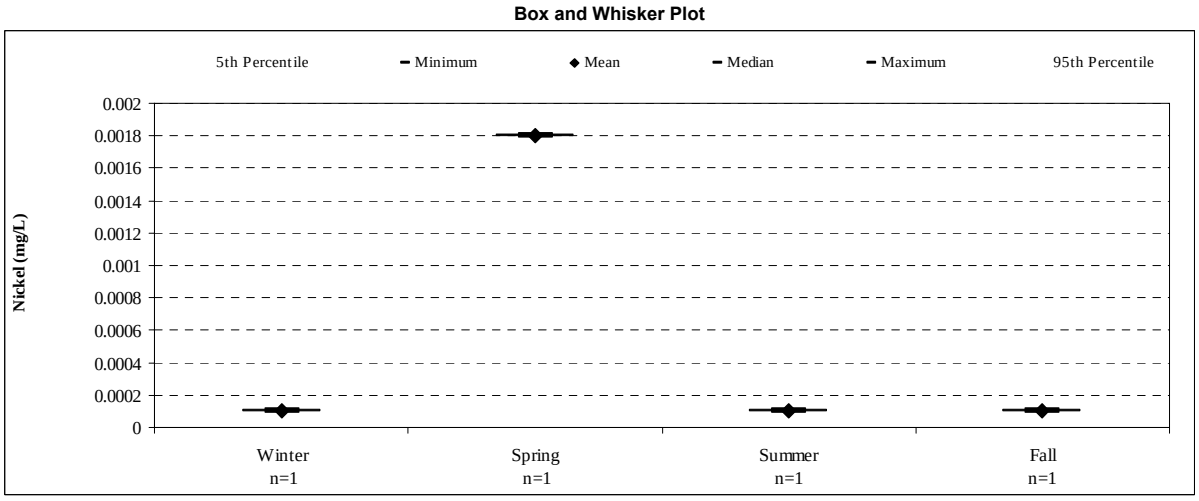


Figure G-1-6-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in McClelland Lake Inlet



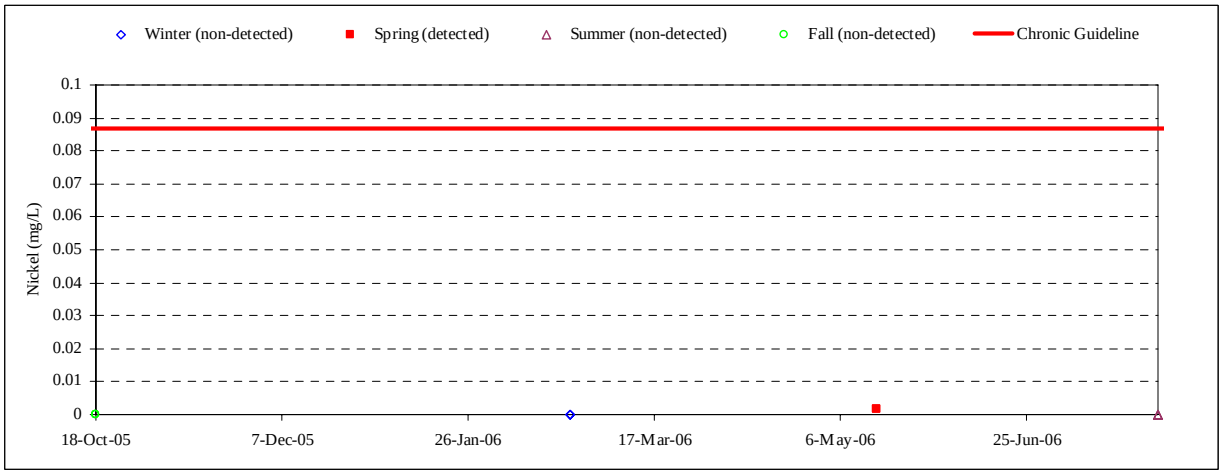
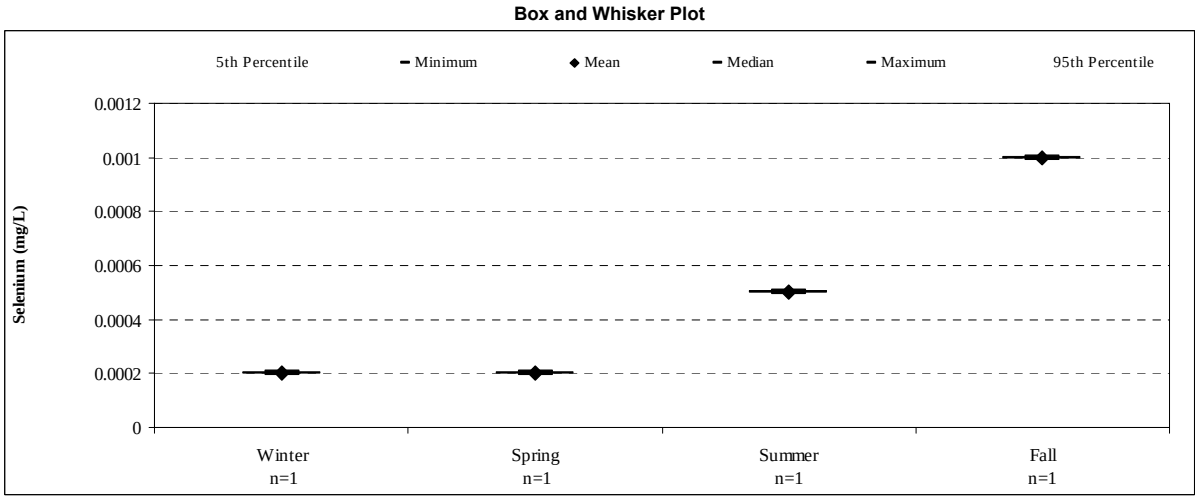


Figure G-1-6-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in McClelland Lake Inlet



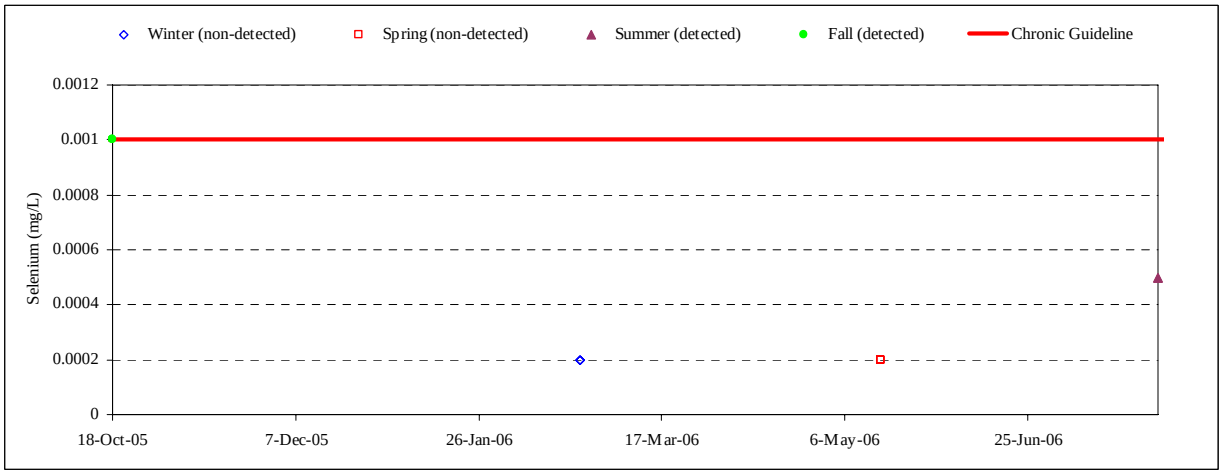
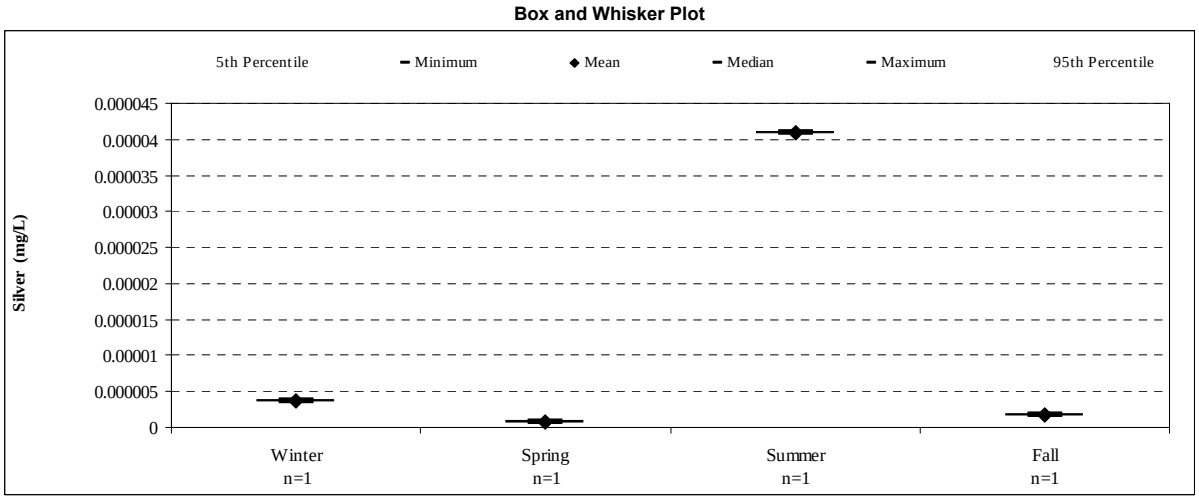


Figure G-1-6-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in McClelland Lake Inlet



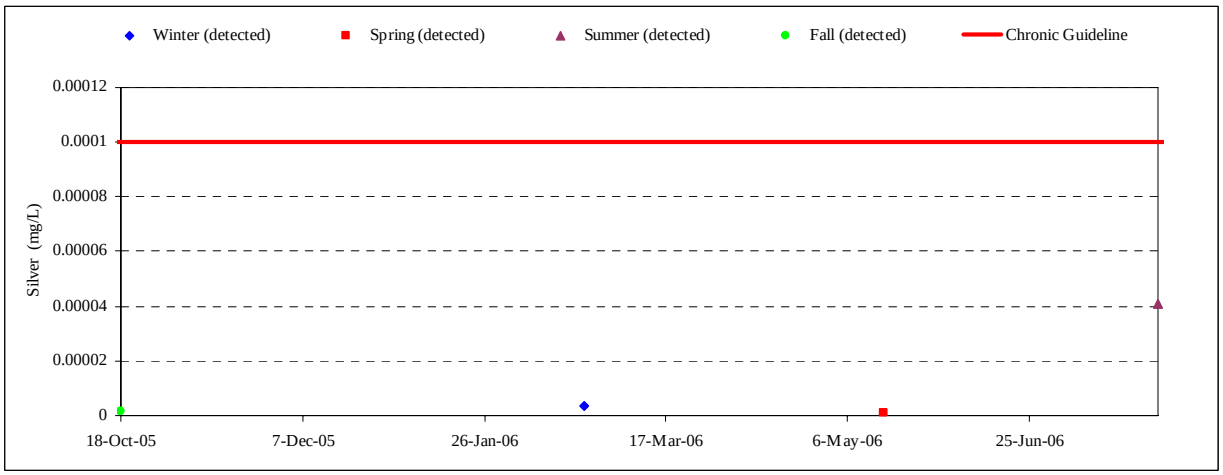
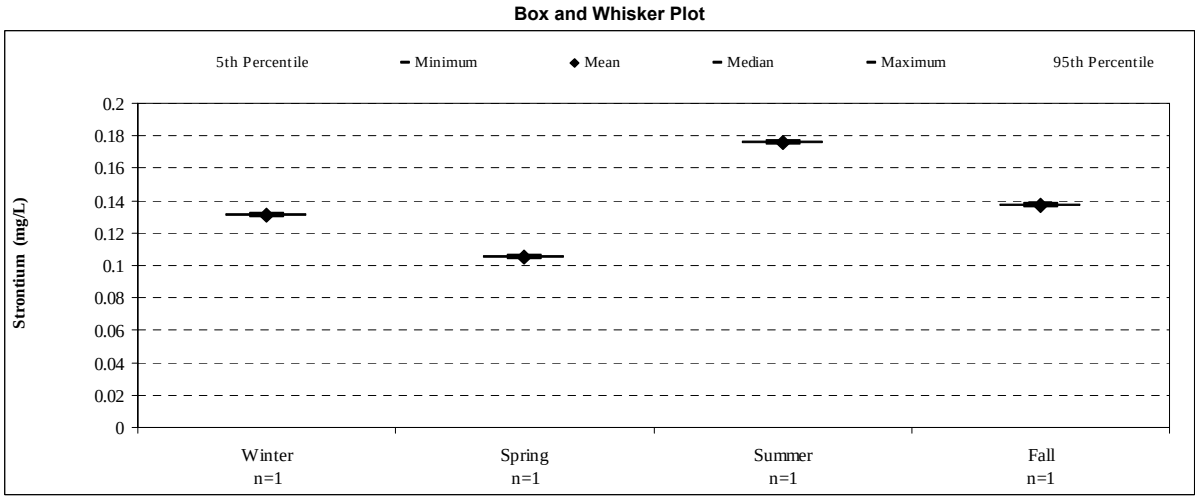


Figure G-1-6-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in McClelland Lake Inlet



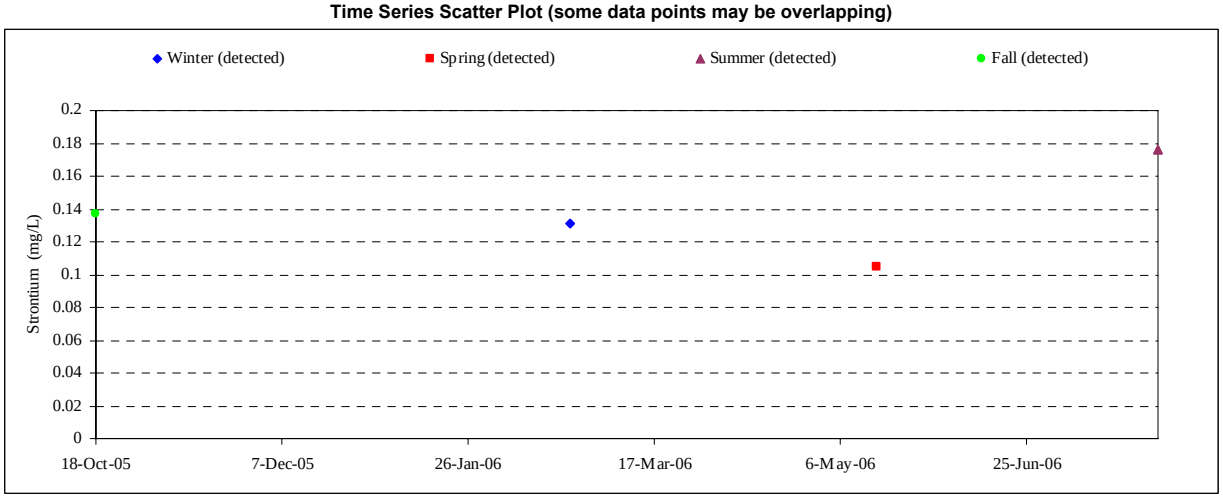
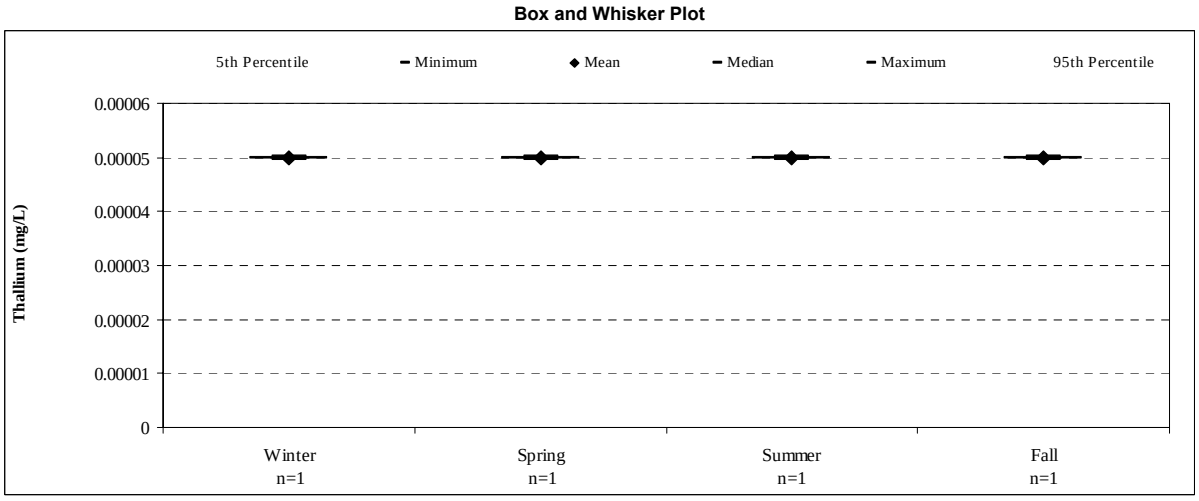


Figure G-1-6-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in McClelland Lake Inlet



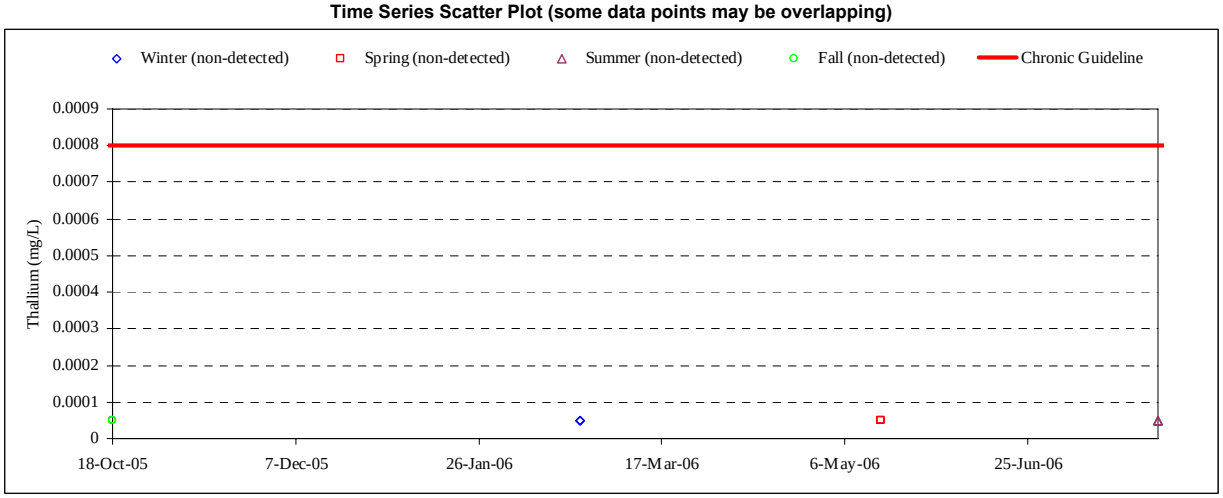
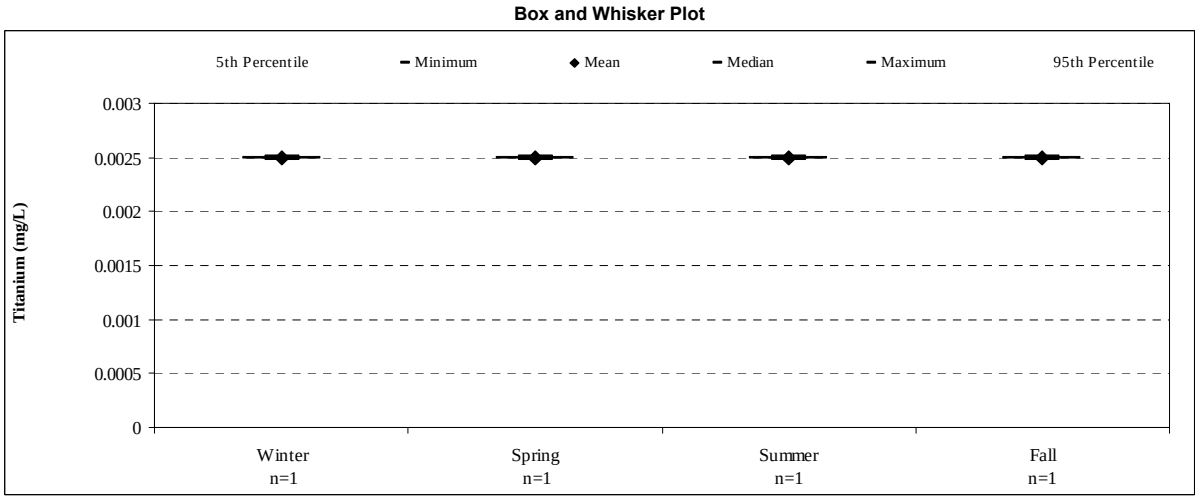


Figure G-1-6-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in McClelland Lake Inlet



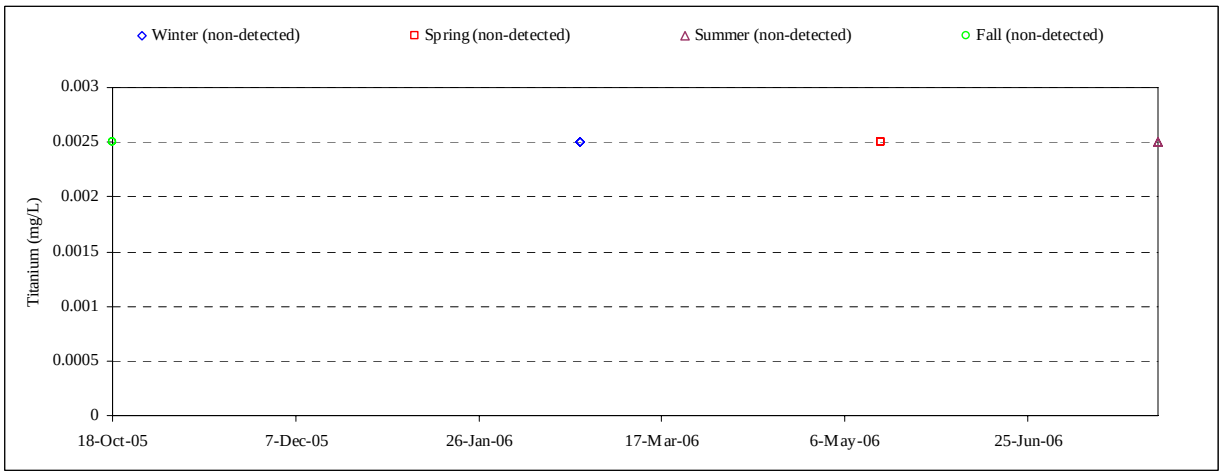
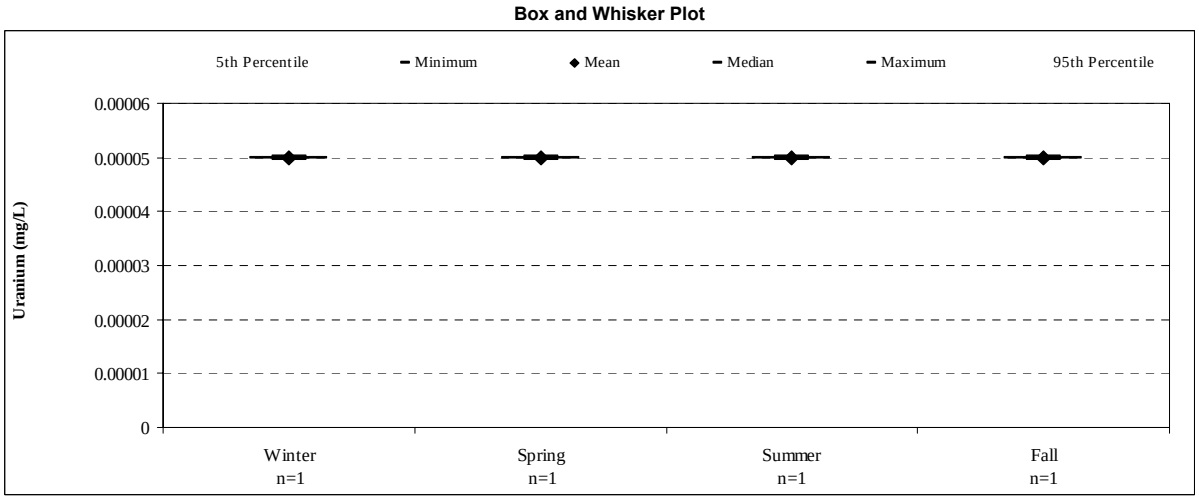


Figure G-1-6-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in McClelland Lake Inlet



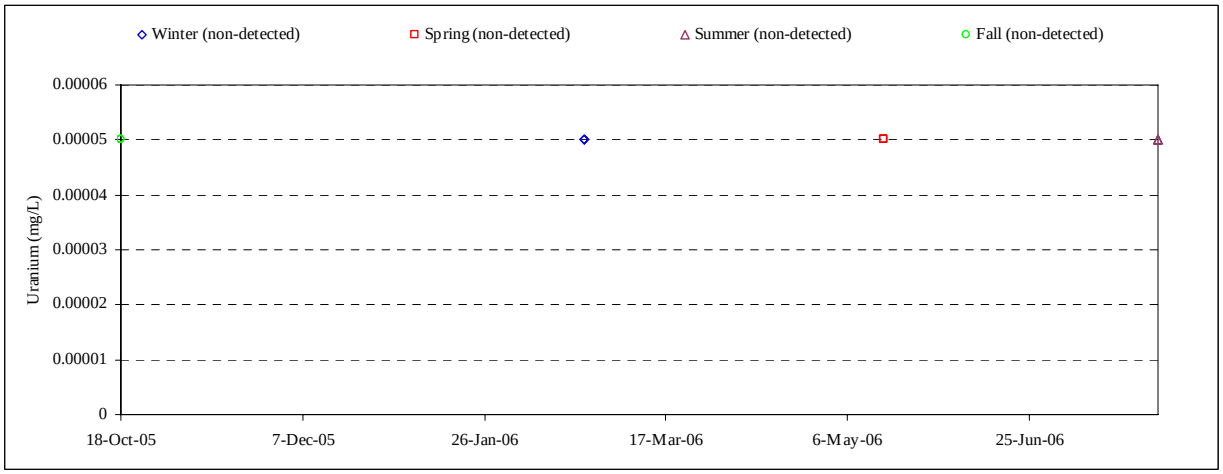
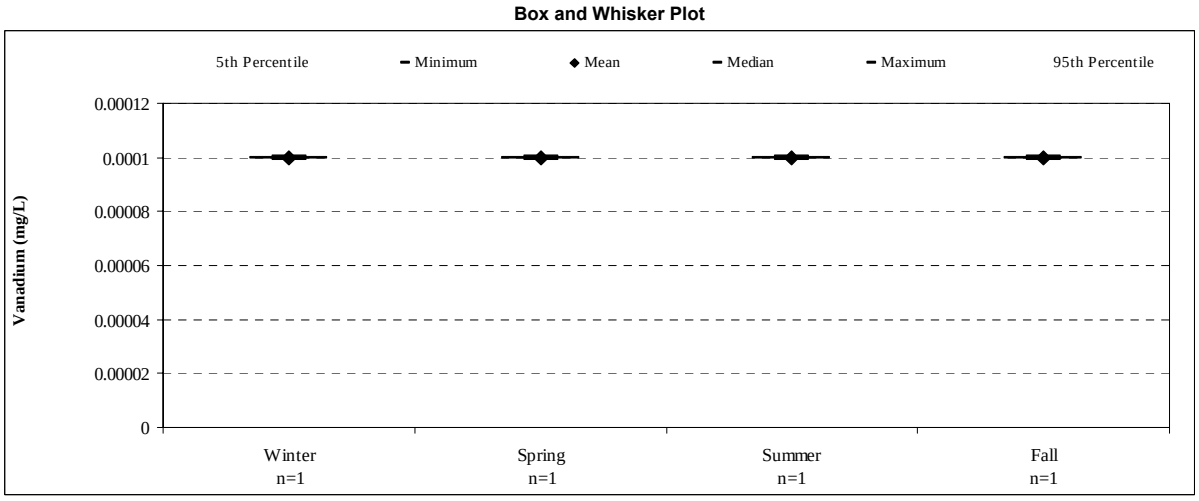


Figure G-1-6-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in McClelland Lake Inlet



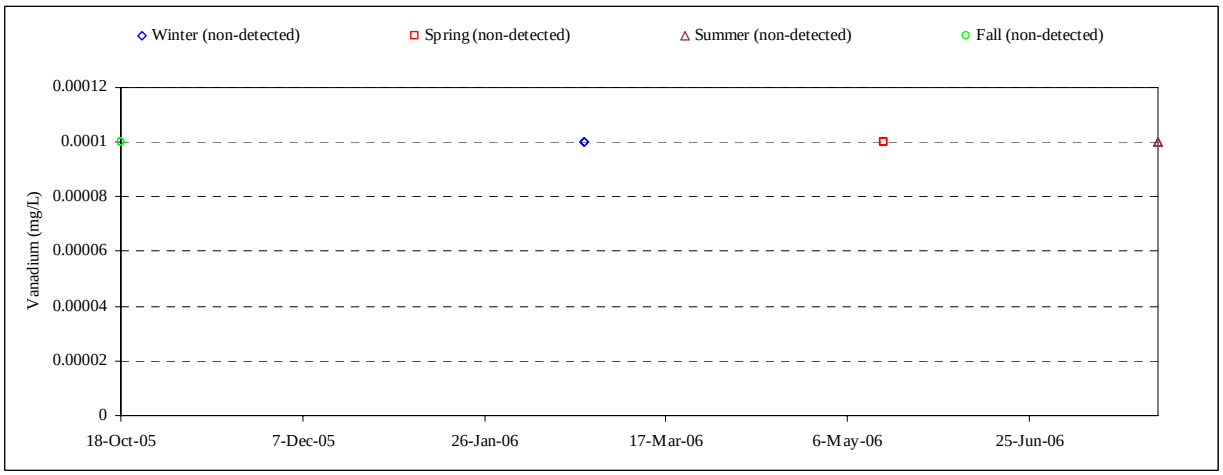
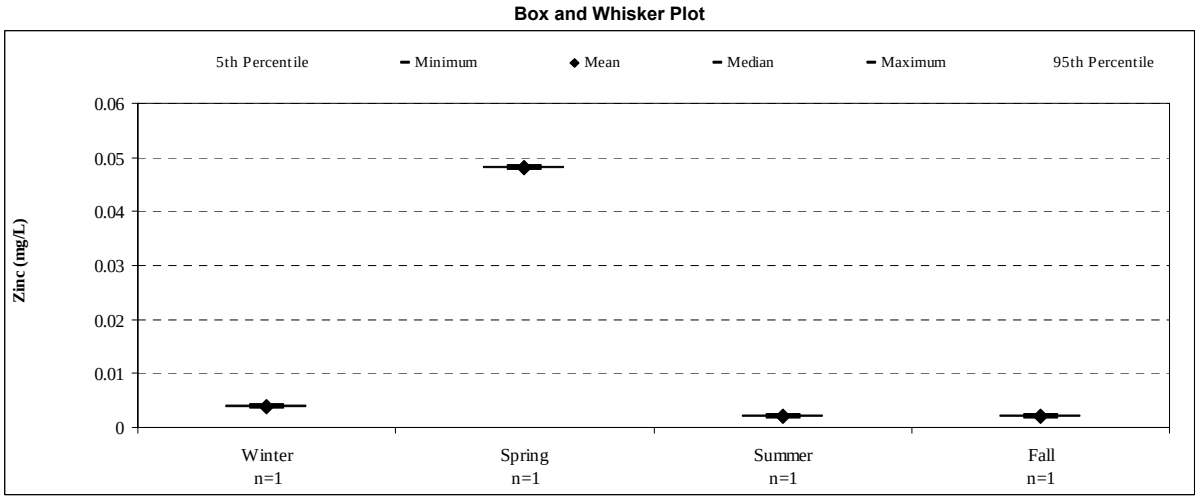


Figure G-1-6-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in McClelland Lake Inlet



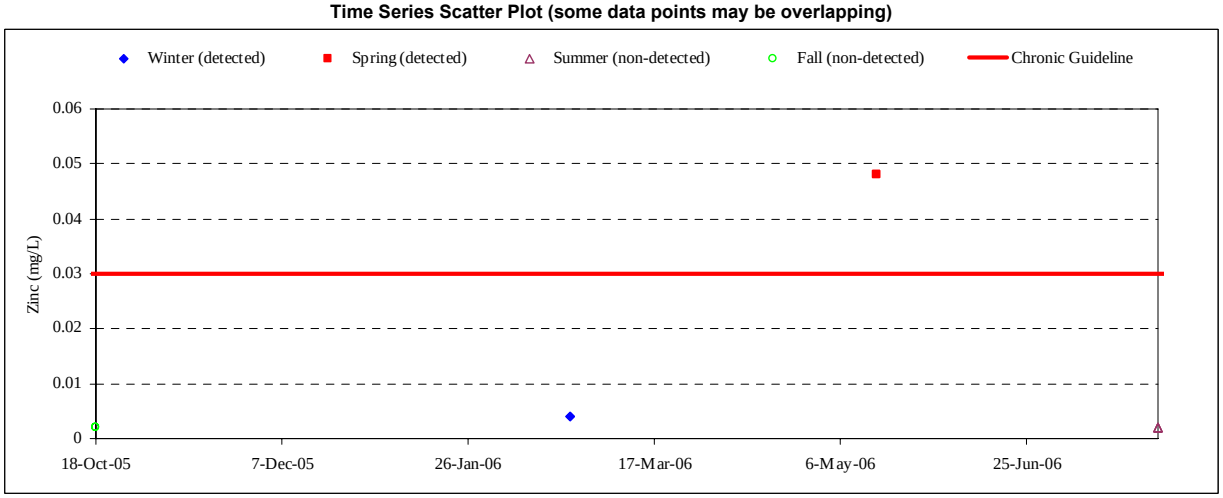
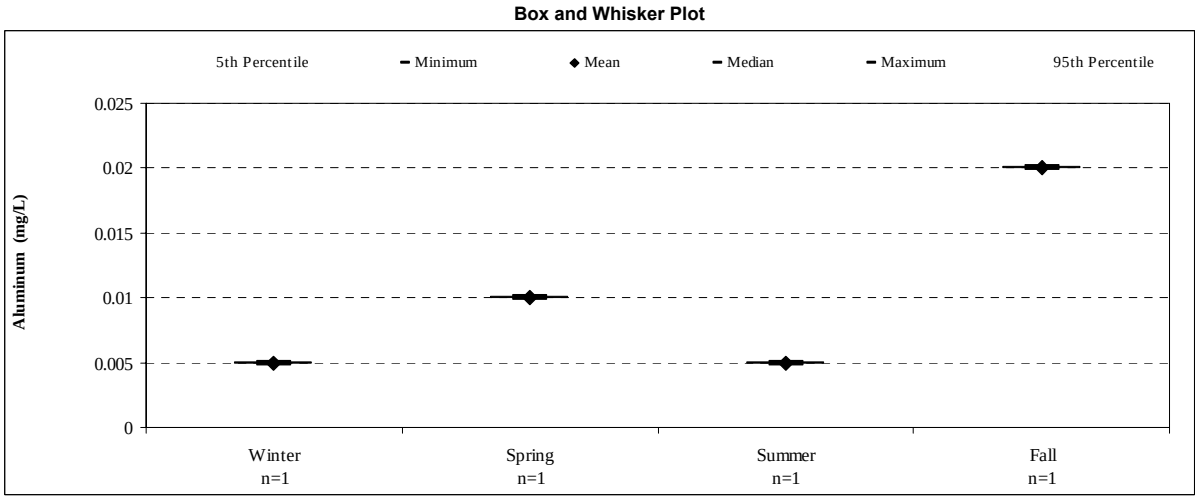


Figure G-1-6-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in McClelland Lake Inlet



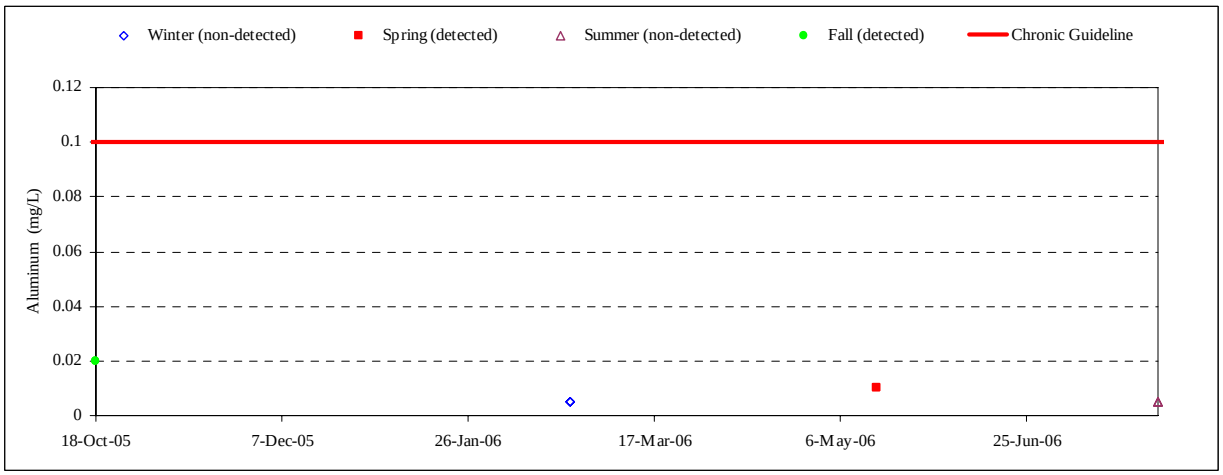
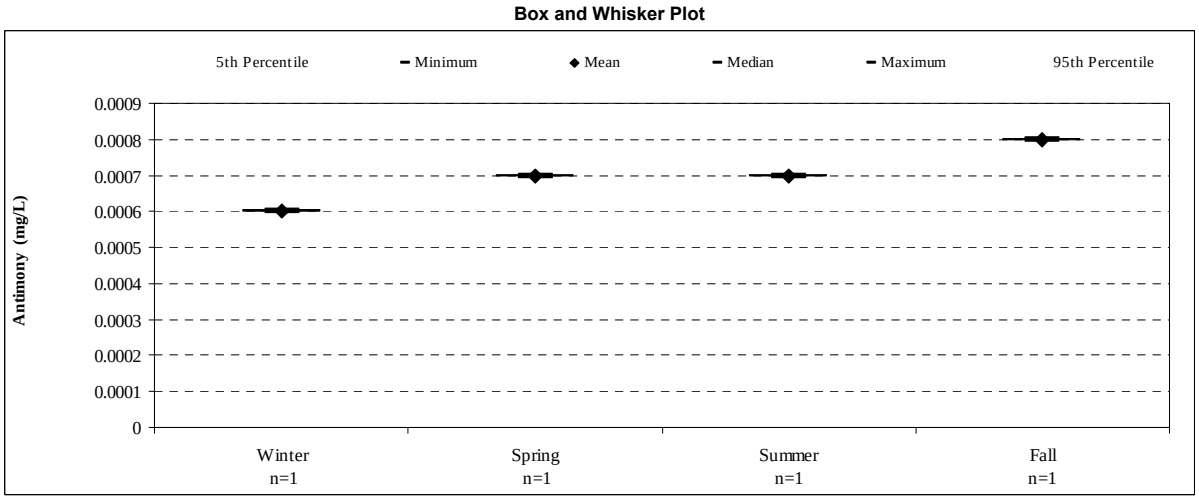


Figure G-1-6-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in McClelland Lake Inlet



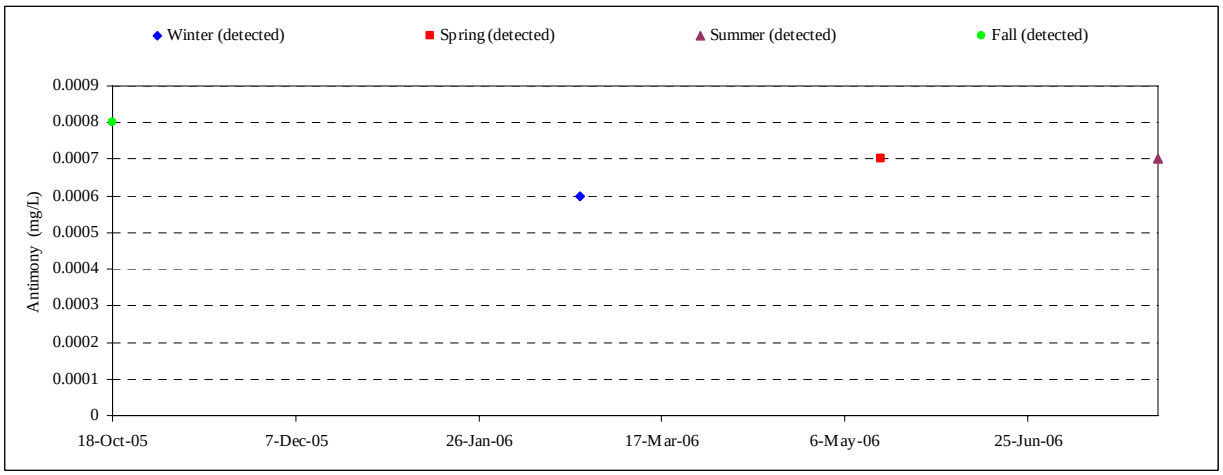
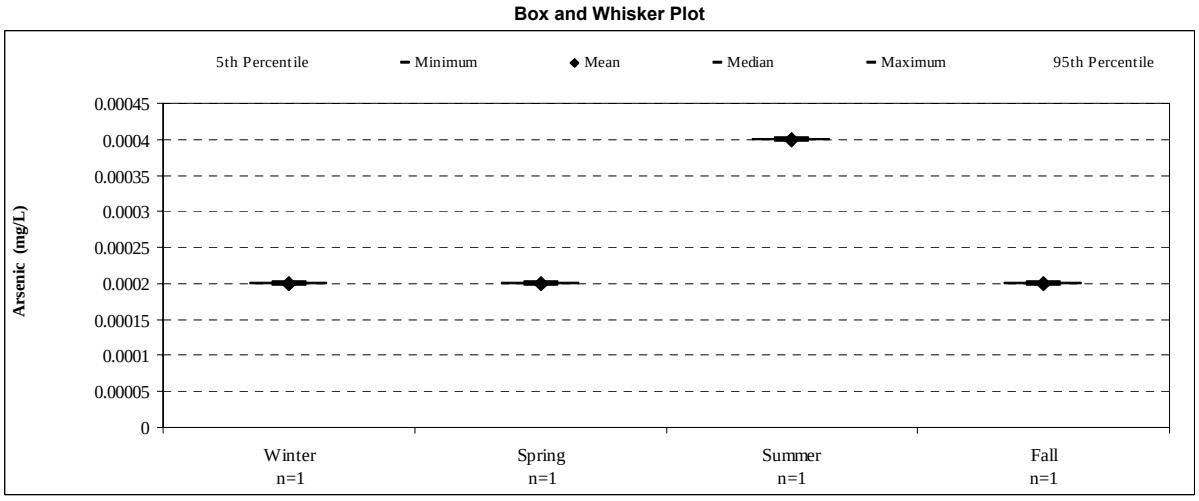


Figure G-1-6-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in McClelland Lake Inlet



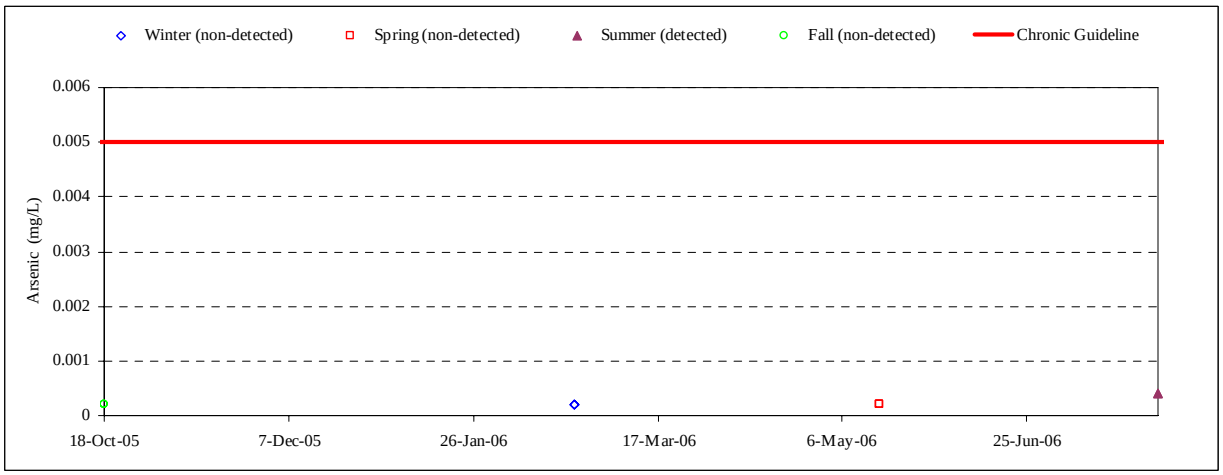
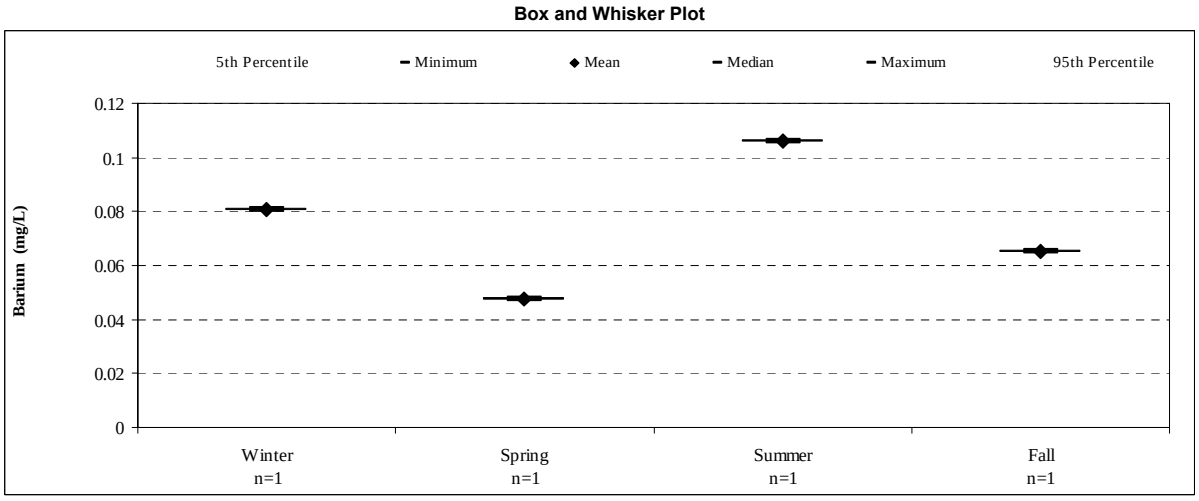


Figure G-1-6-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in McClelland Lake Inlet



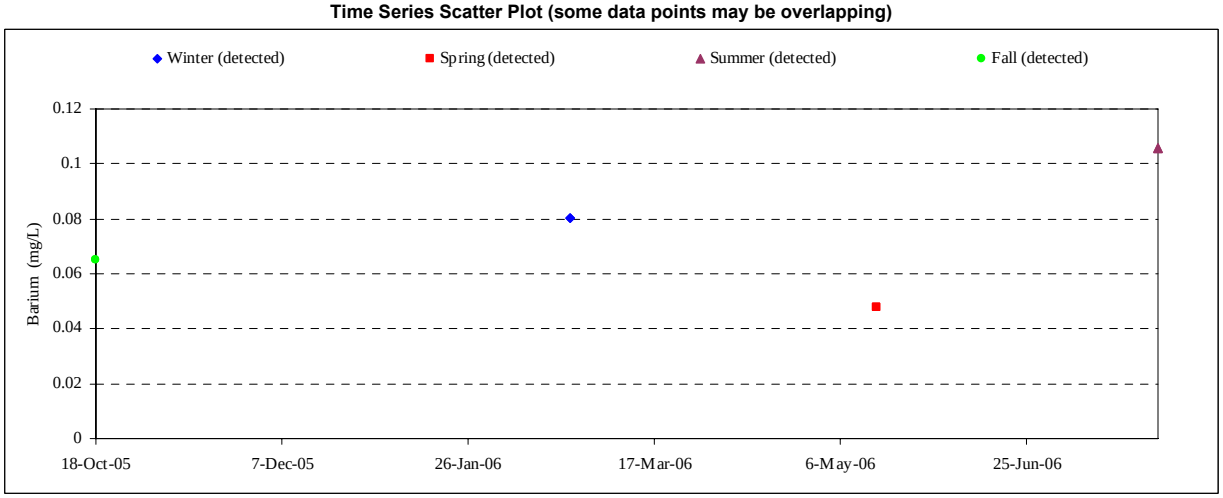
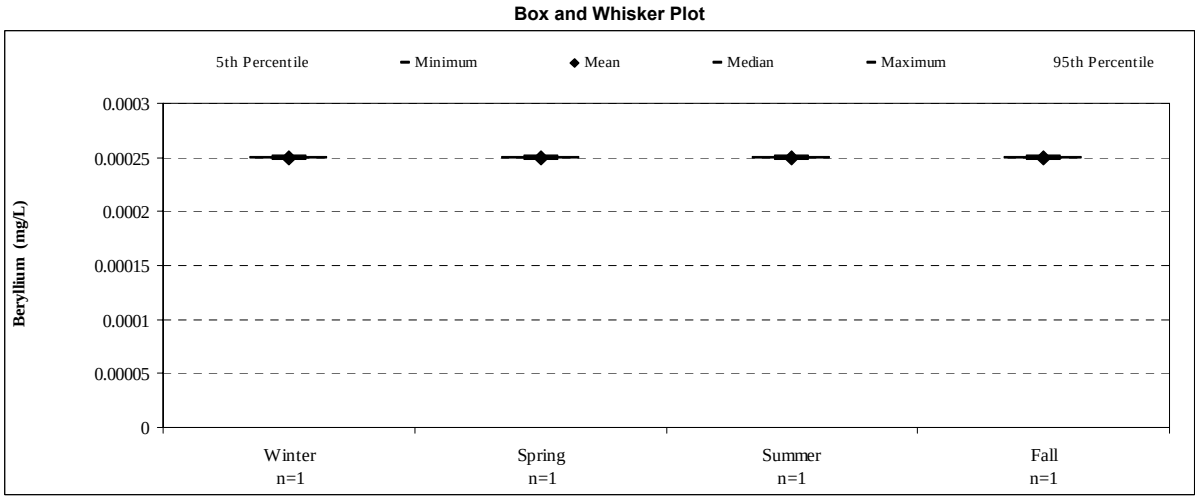


Figure G-1-6-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in McClelland Lake Inlet



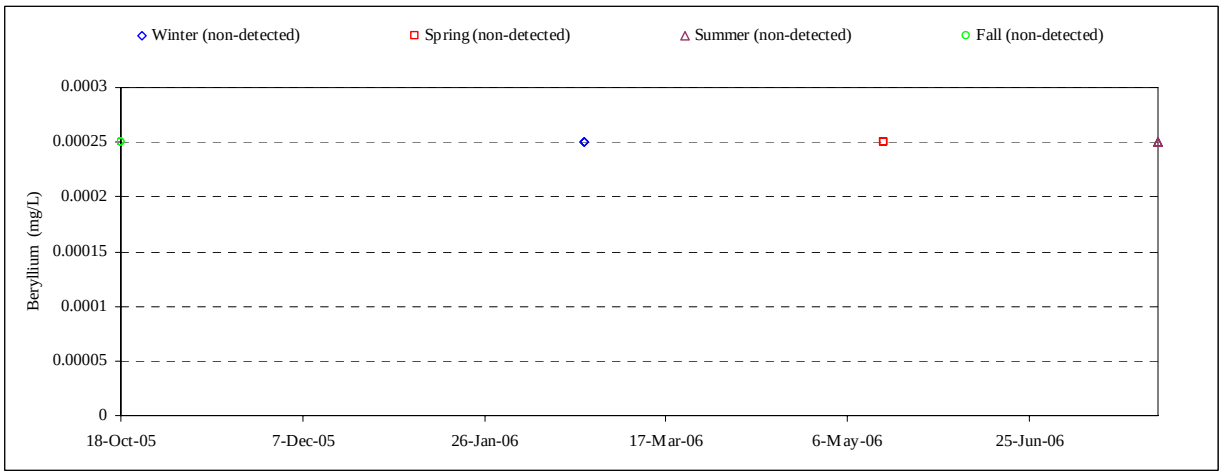
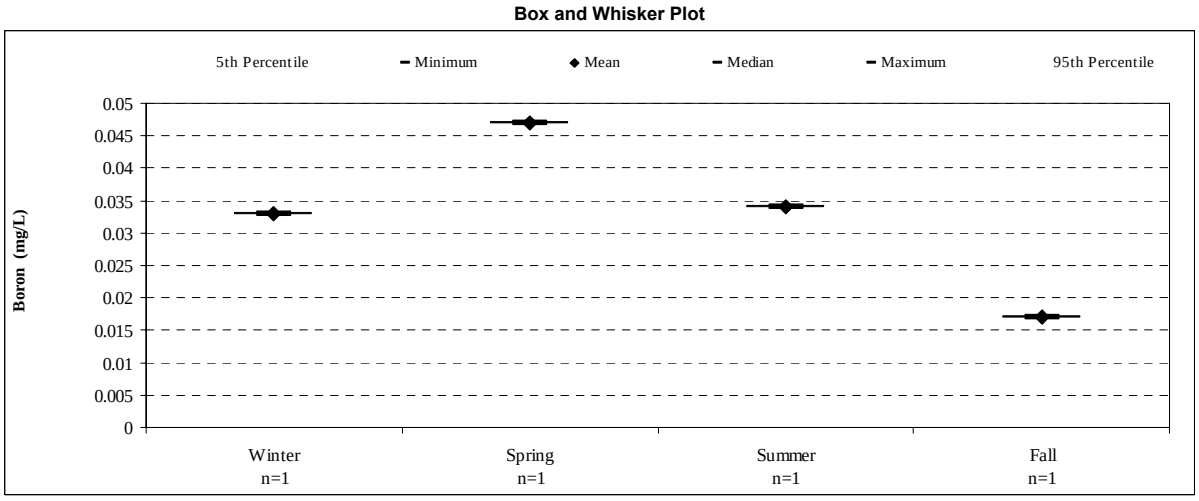


Figure G-1-6-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in McClelland Lake Inlet



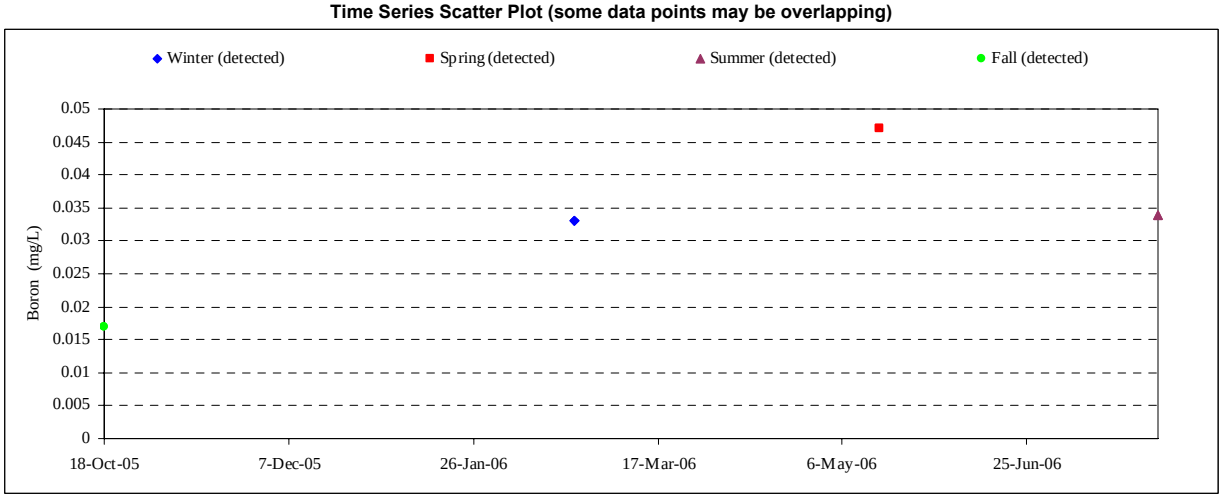
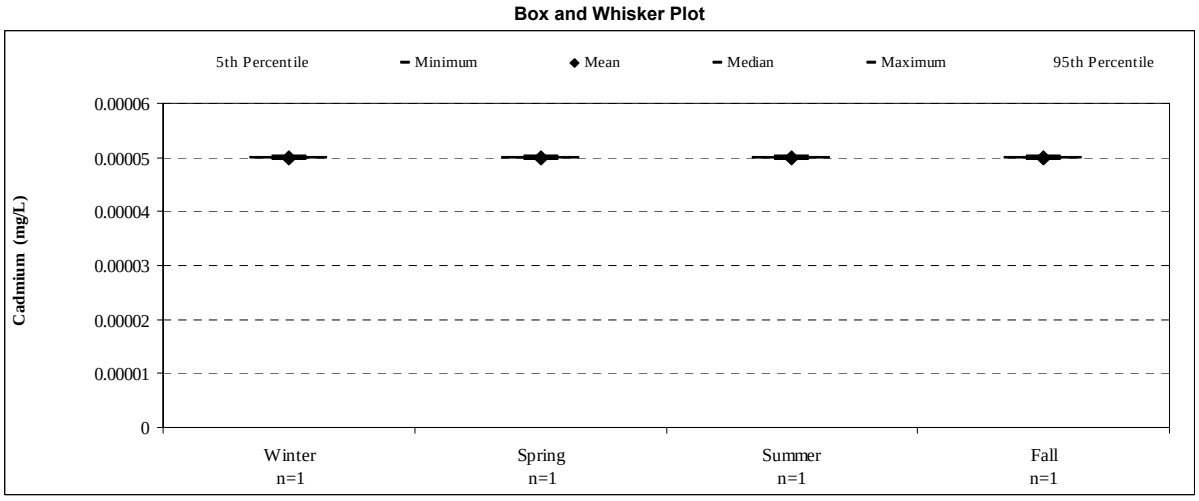


Figure G-1-6-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in McClelland Lake Inlet



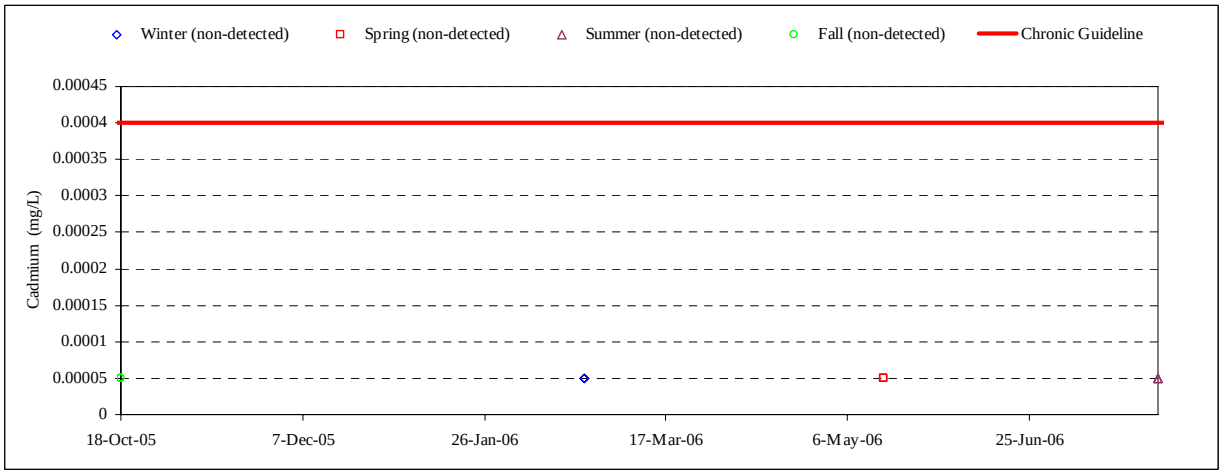
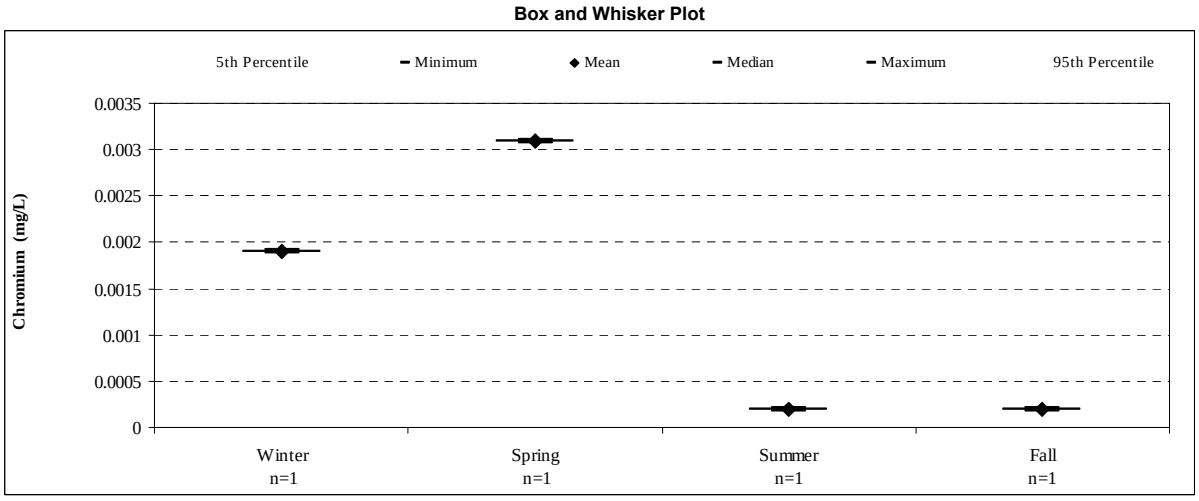


Figure G-1-6-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in McClelland Lake Inlet



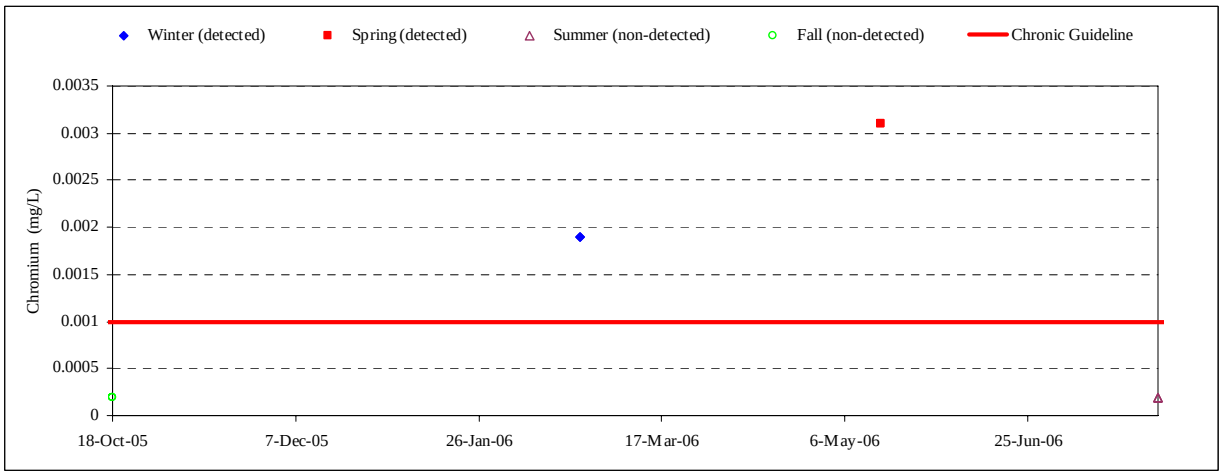
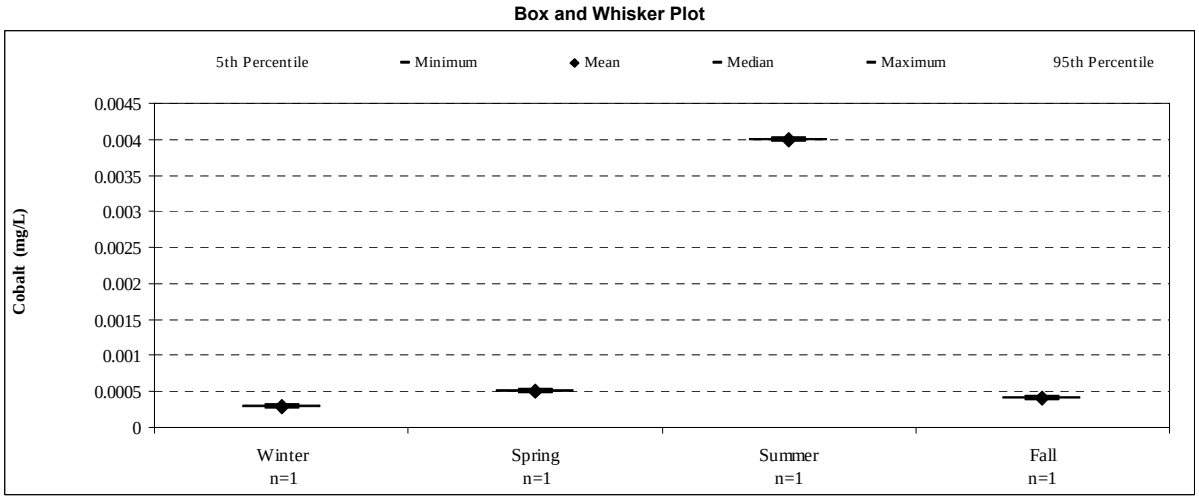


Figure G-1-6-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in McClelland Lake Inlet



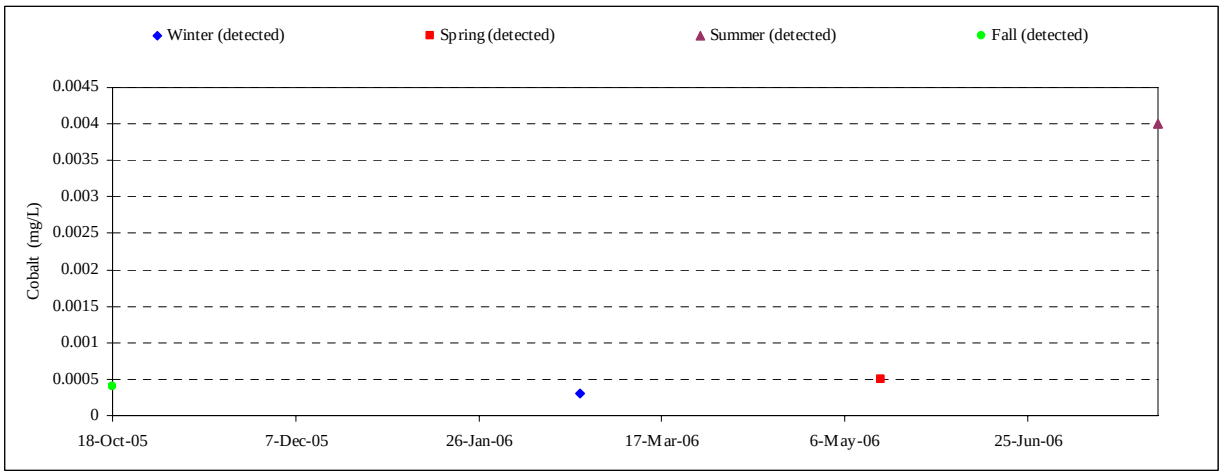
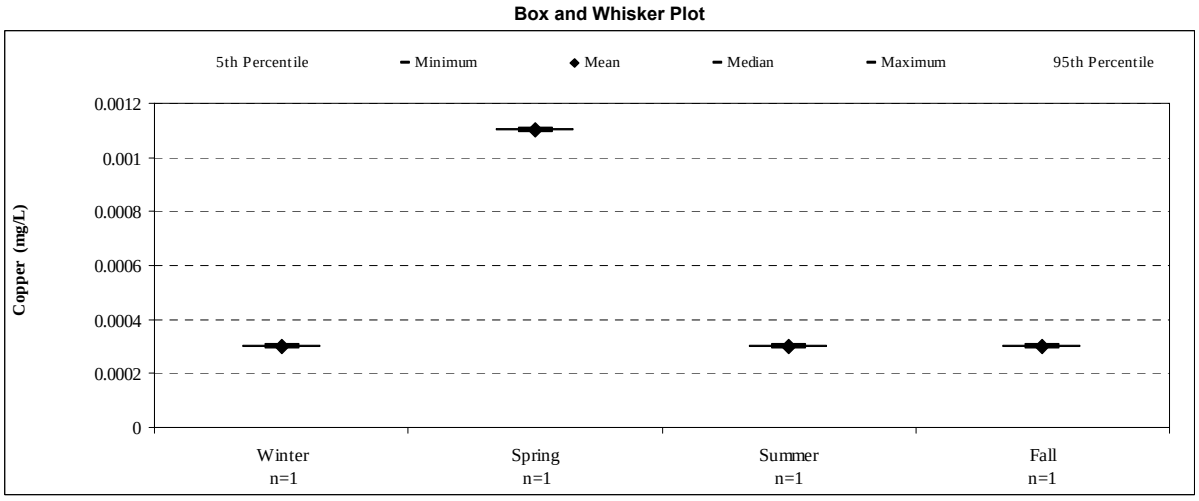


Figure G-1-6-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in McClelland Lake Inlet



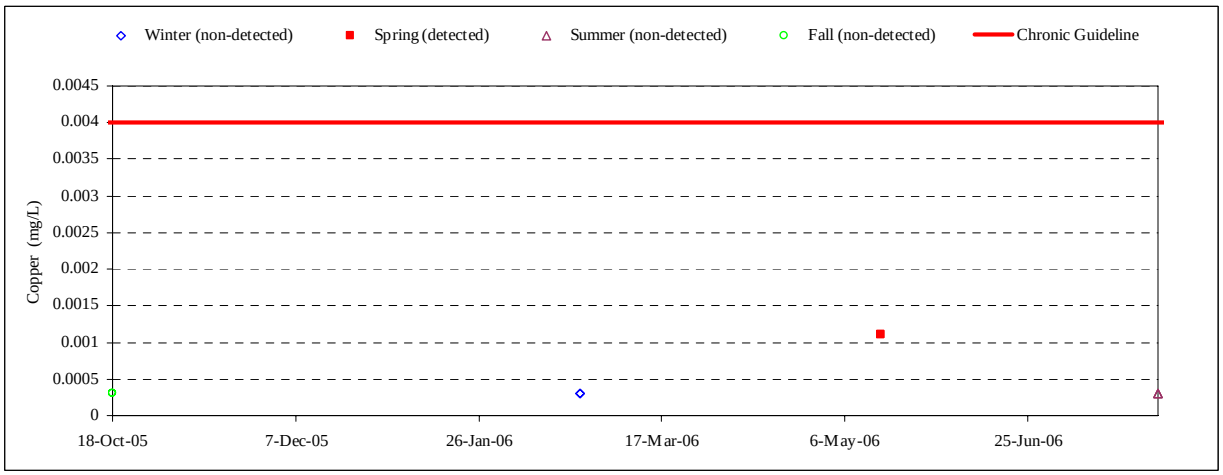
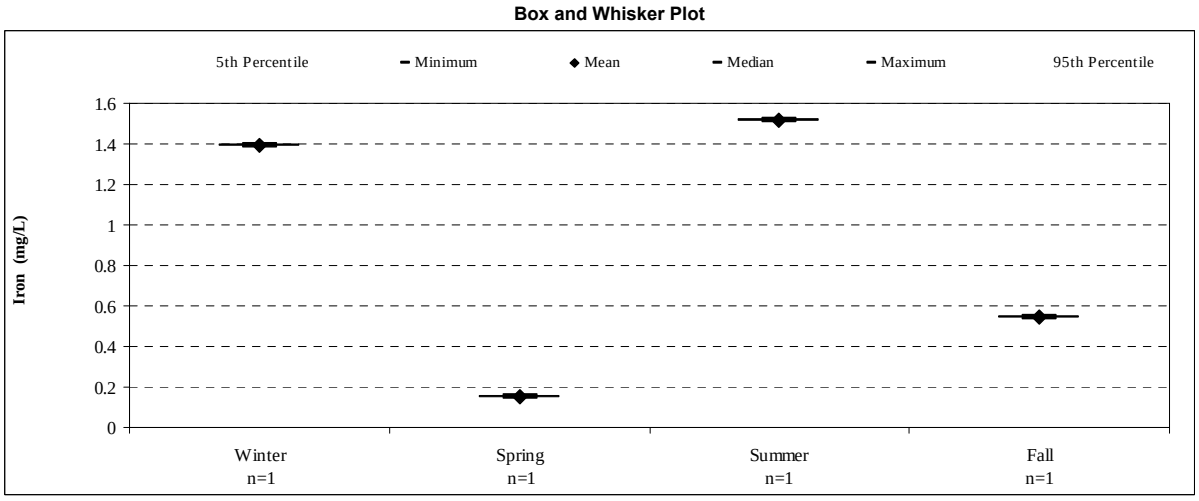


Figure G-1-6-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in McClelland Lake Inlet



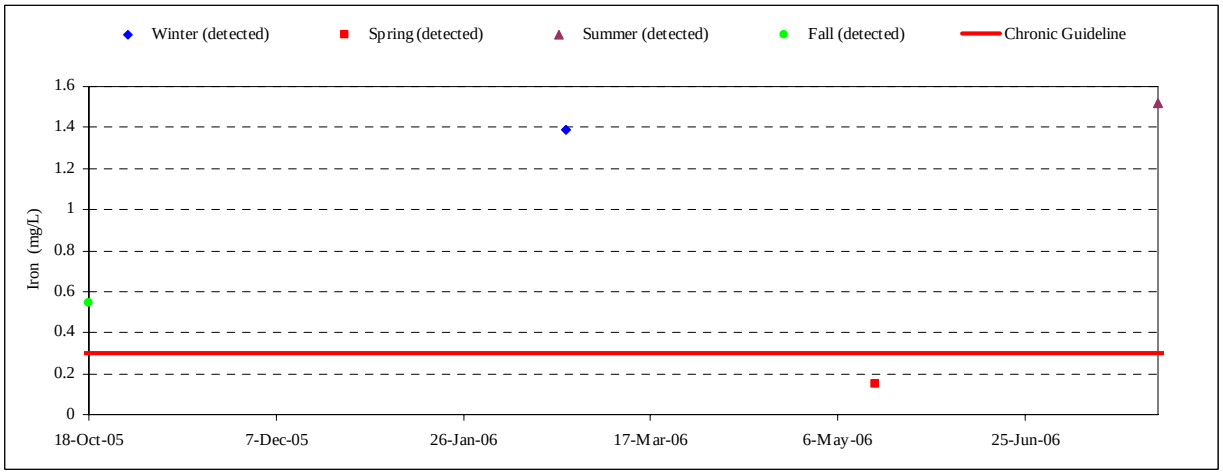
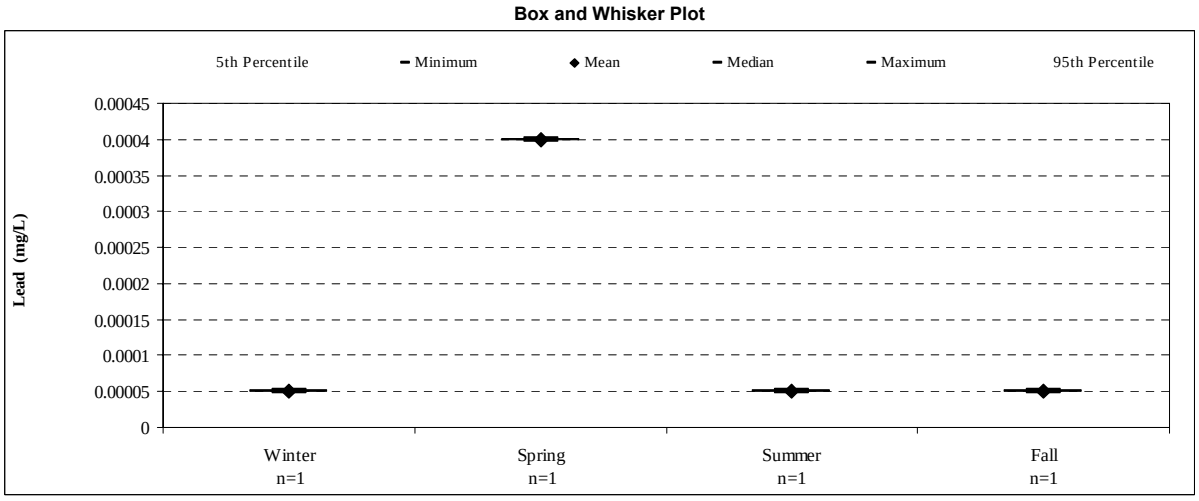


Figure G-1-6-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in McClelland Lake Inlet



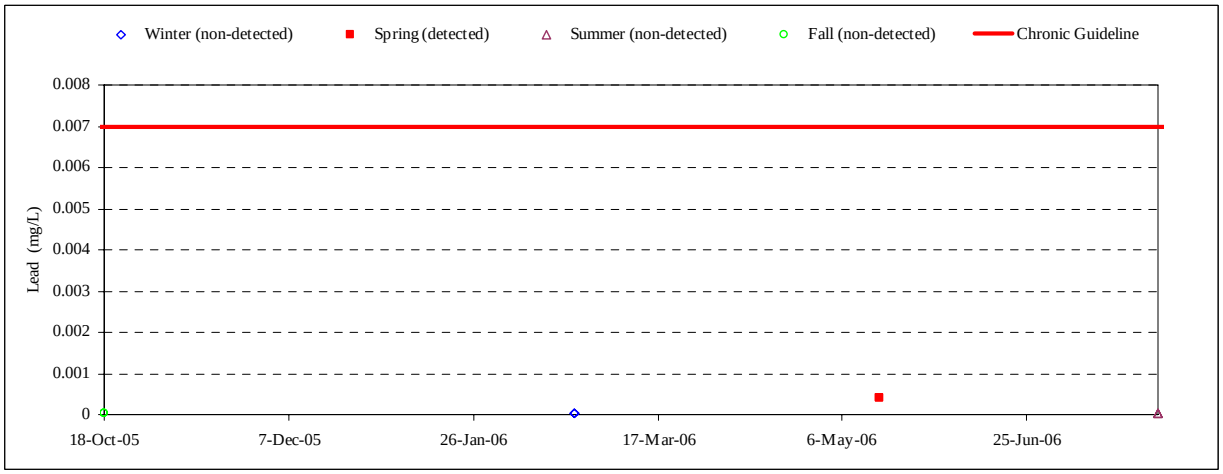
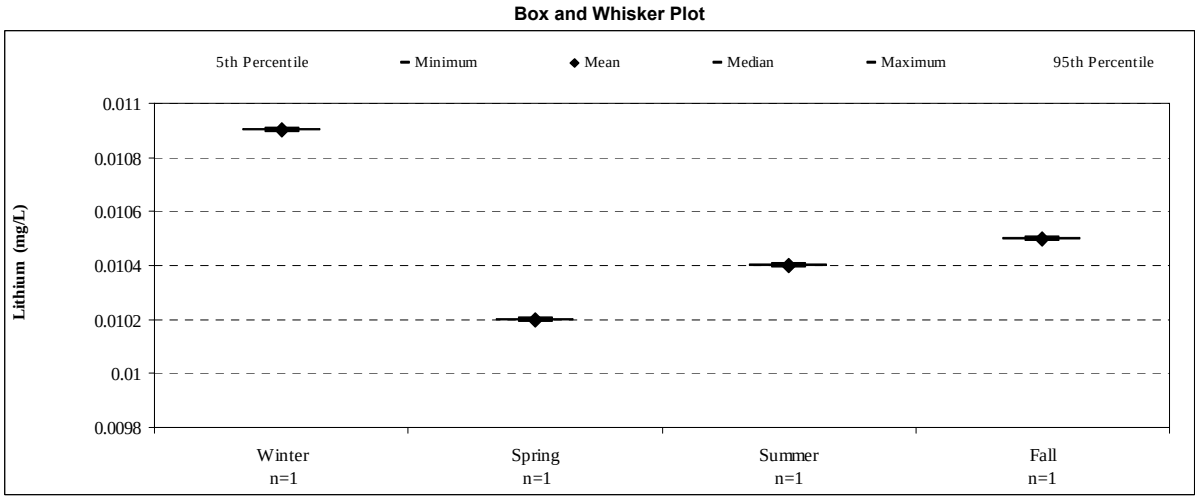


Figure G-1-6-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in McClelland Lake Inlet



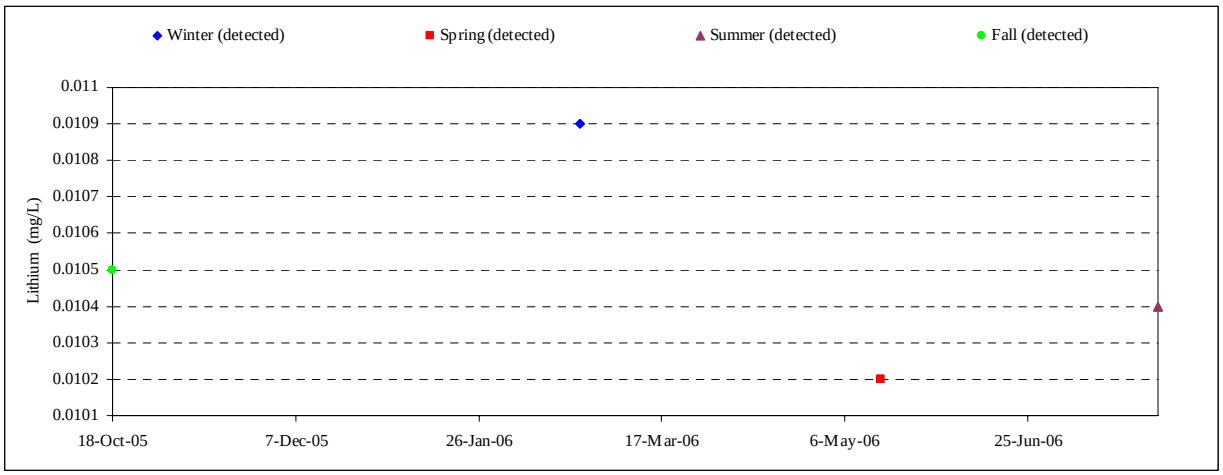
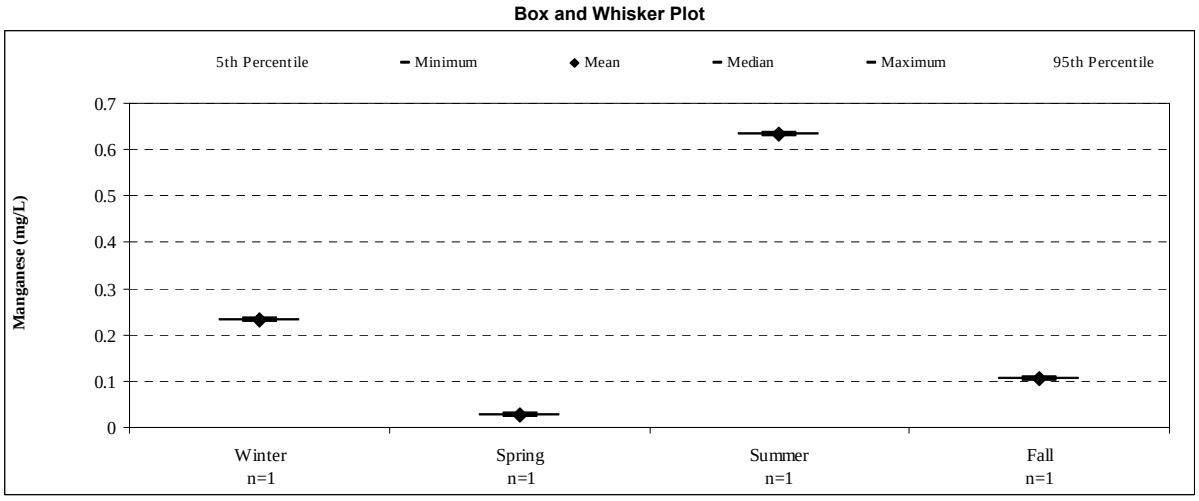


Figure G-1-6-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in McClelland Lake Inlet



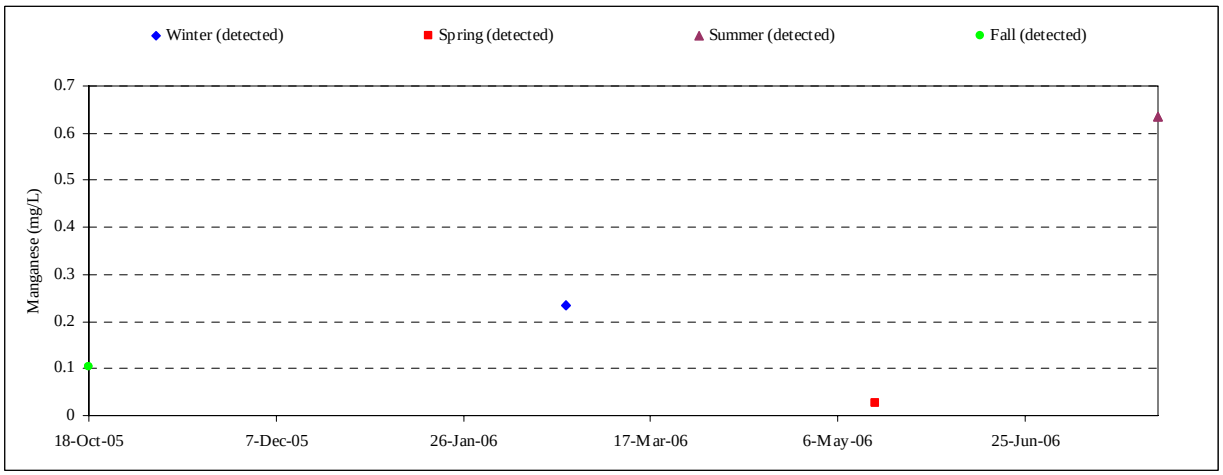
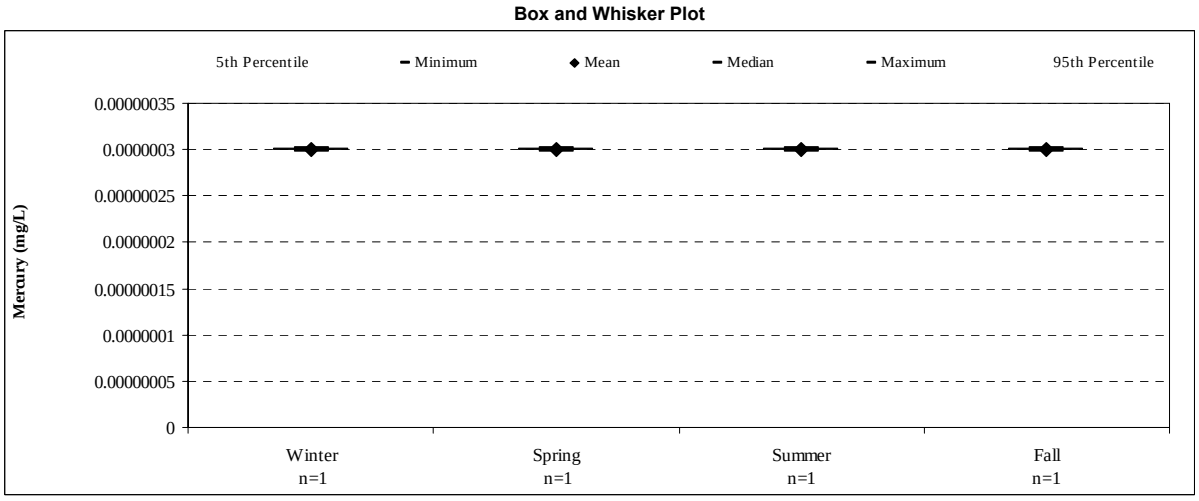


Figure G-1-6-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in McClelland Lake Inlet



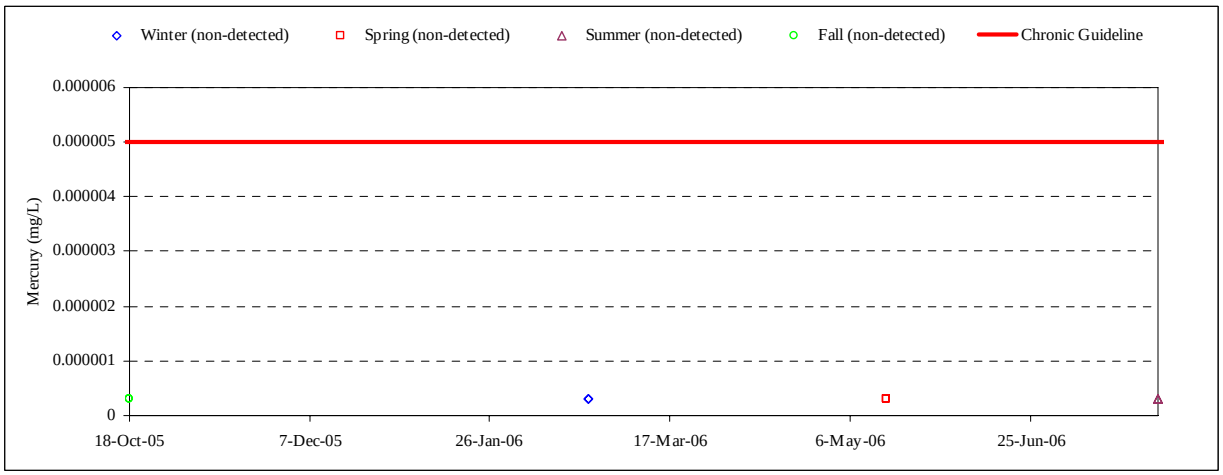
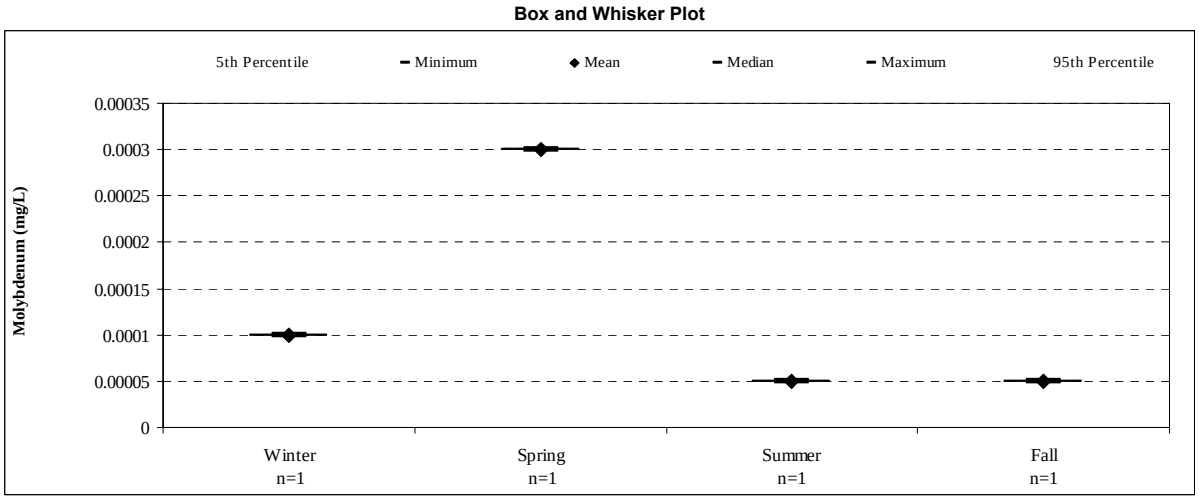


Figure G-1-6-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in McClelland Lake Inlet



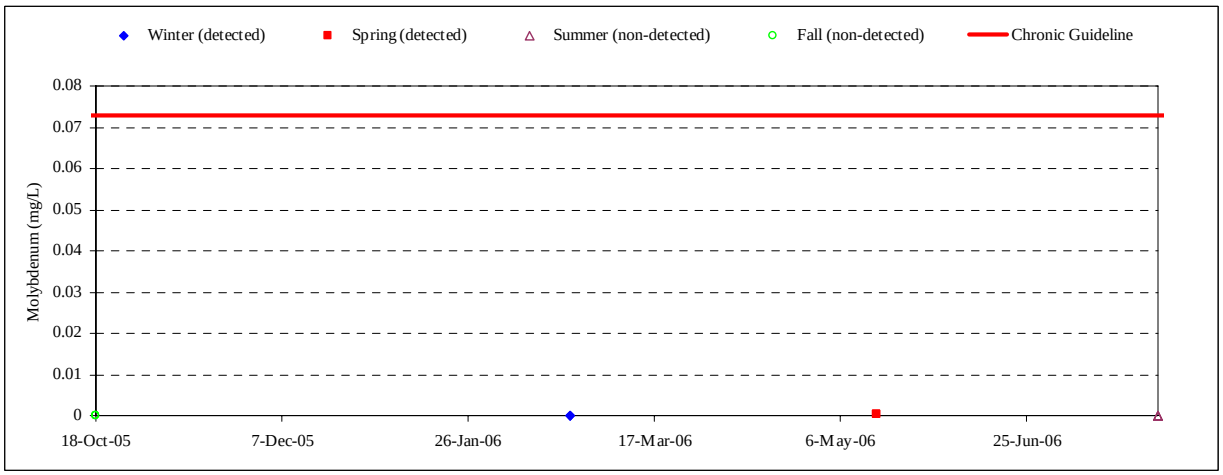
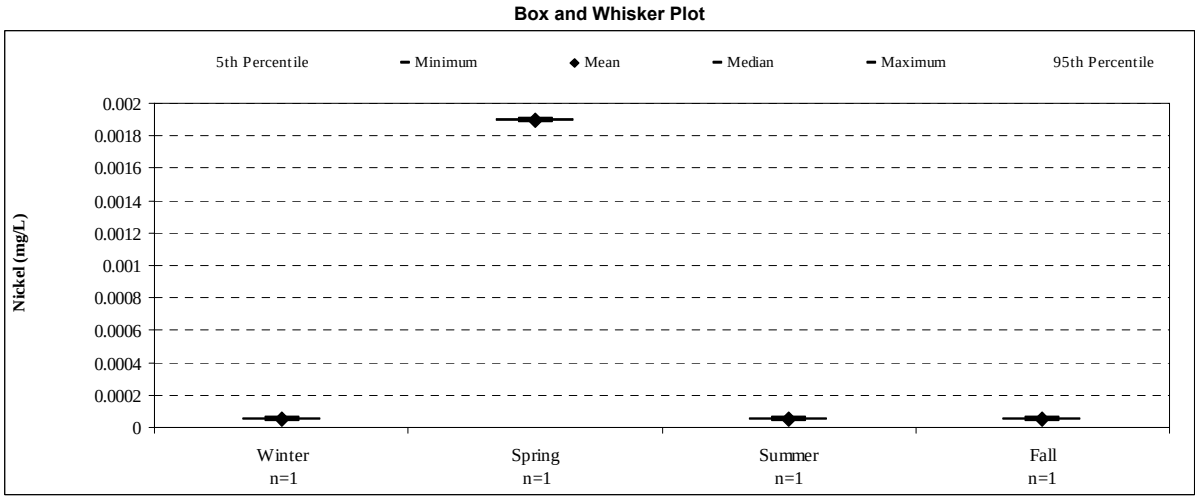


Figure G-1-6-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in McClelland Lake Inlet



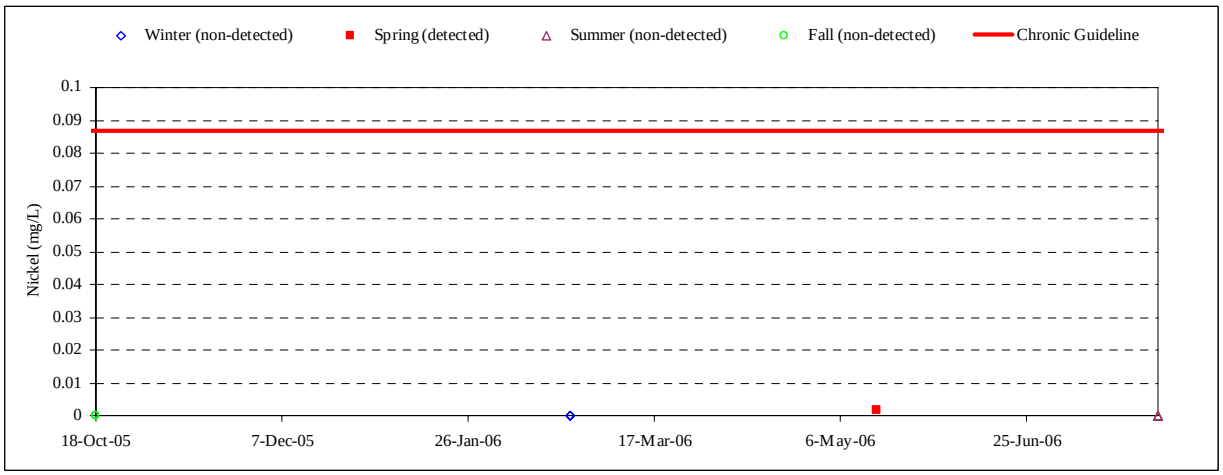
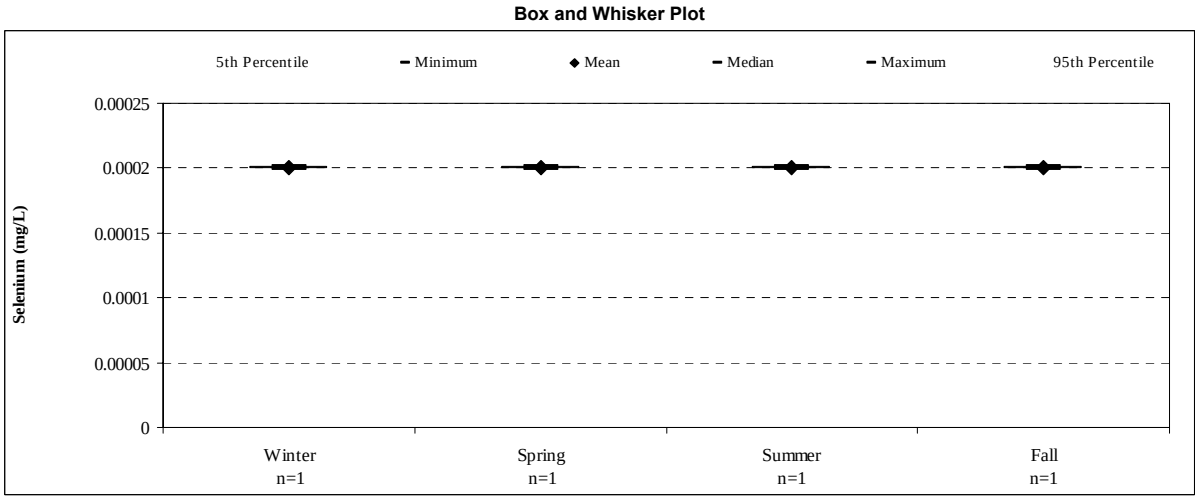


Figure G-1-6-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in McClelland Lake Inlet



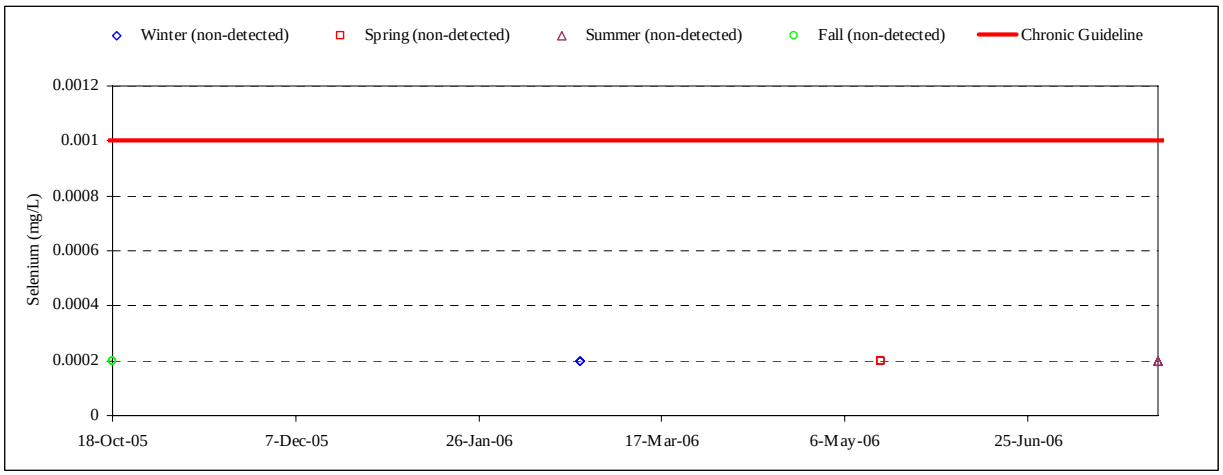
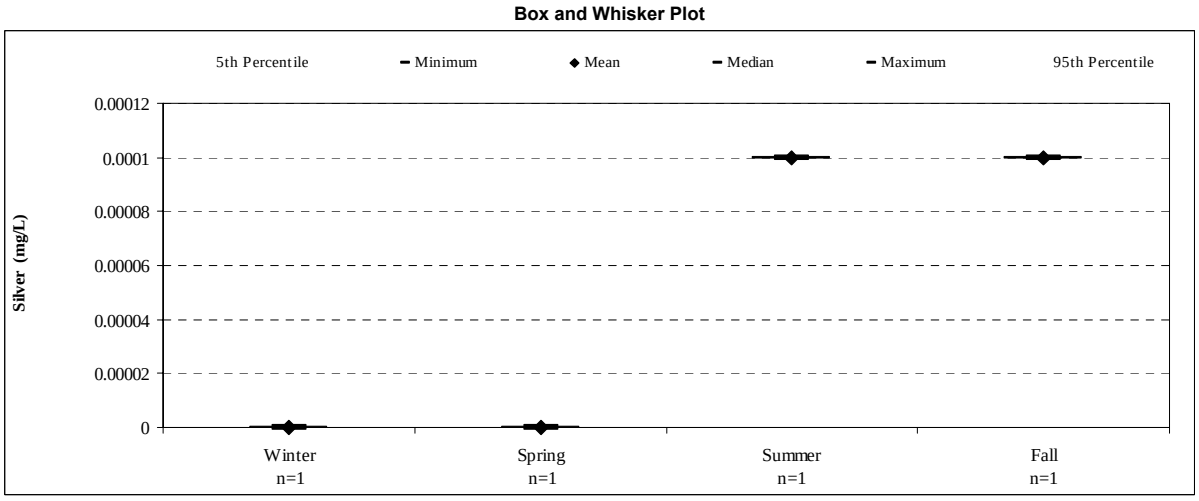


Figure G-1-6-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in McClelland Lake Inlet



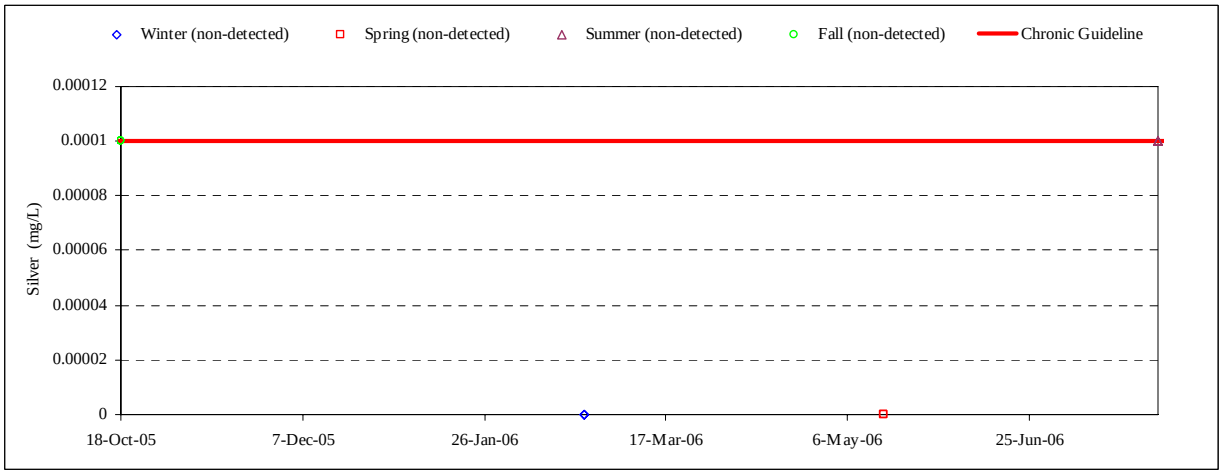
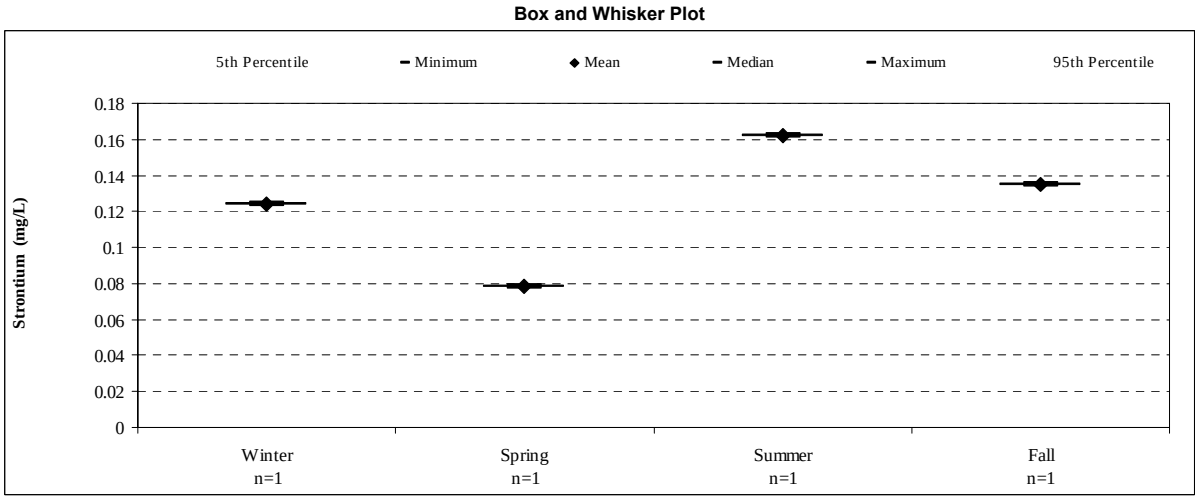


Figure G-1-6-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in McClelland Lake Inlet



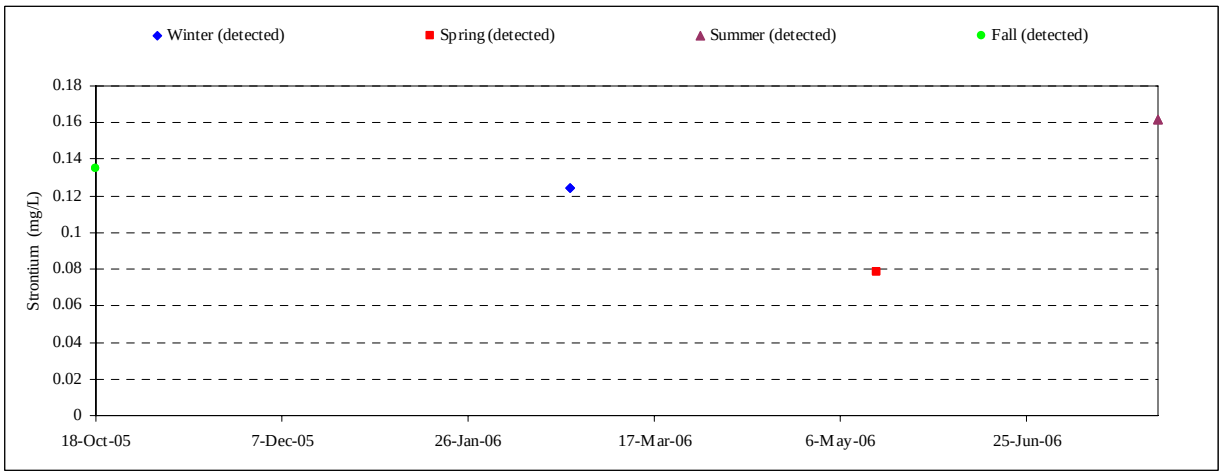
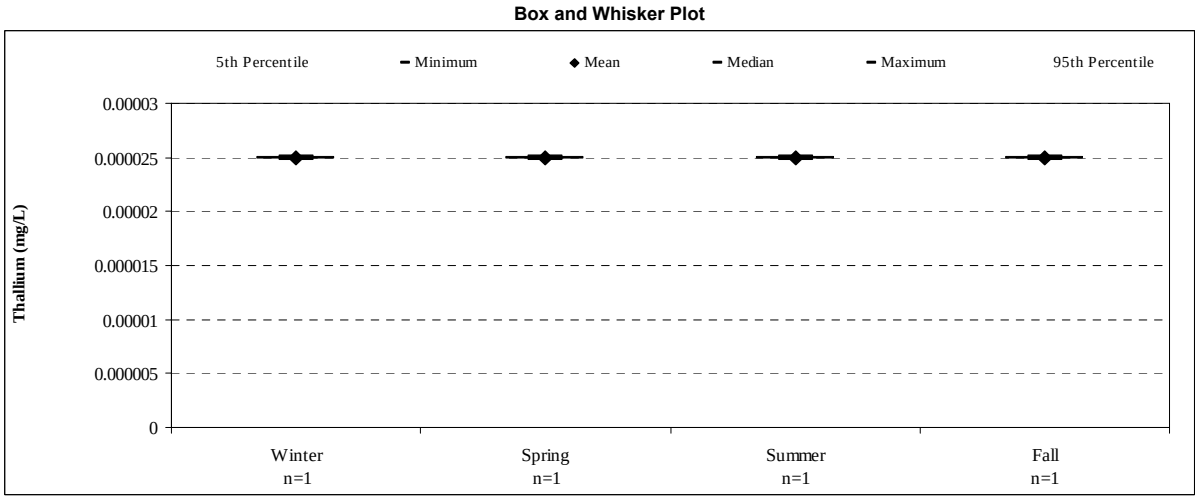


Figure G-1-6-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in McClelland Lake Inlet



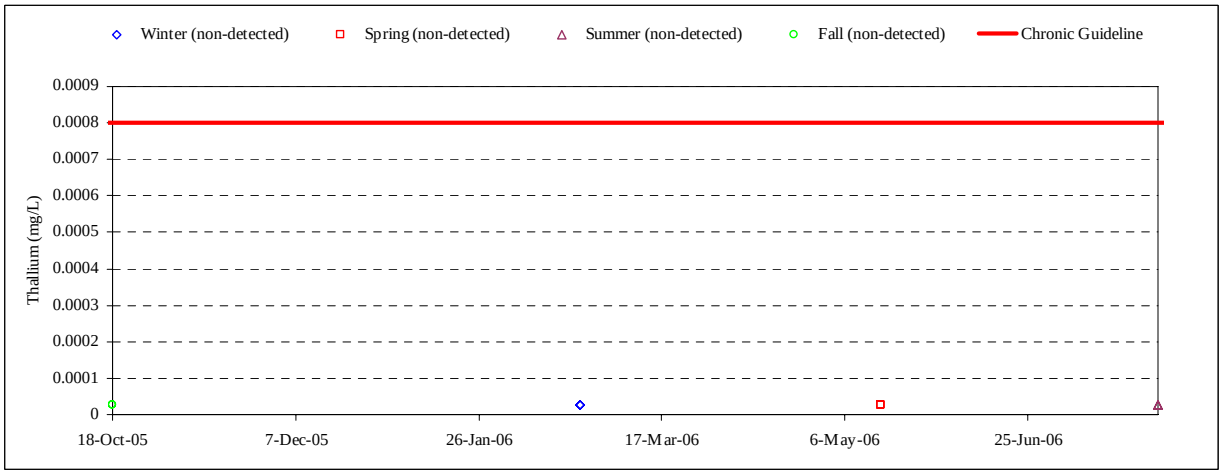
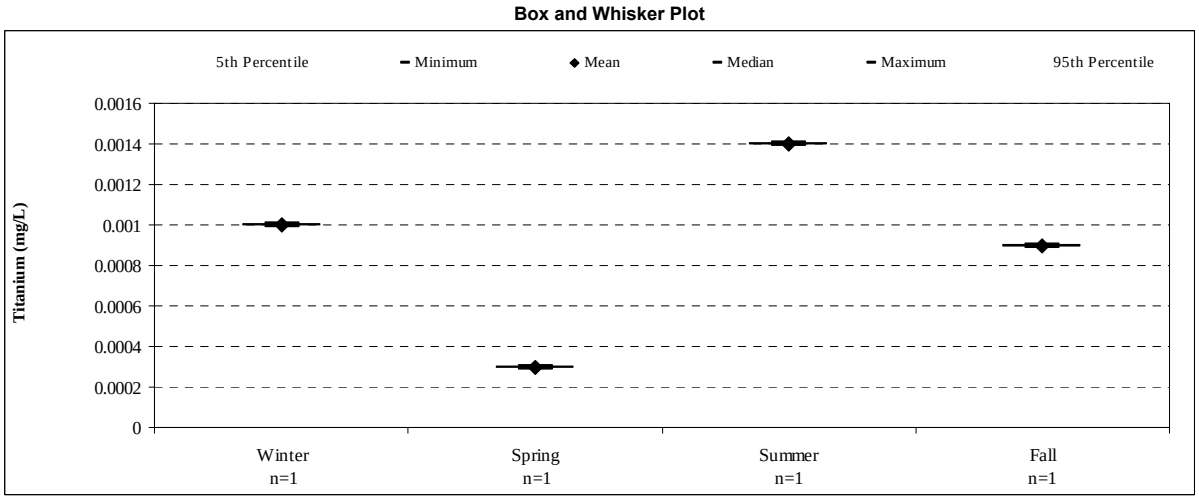


Figure G-1-6-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in McClelland Lake Inlet



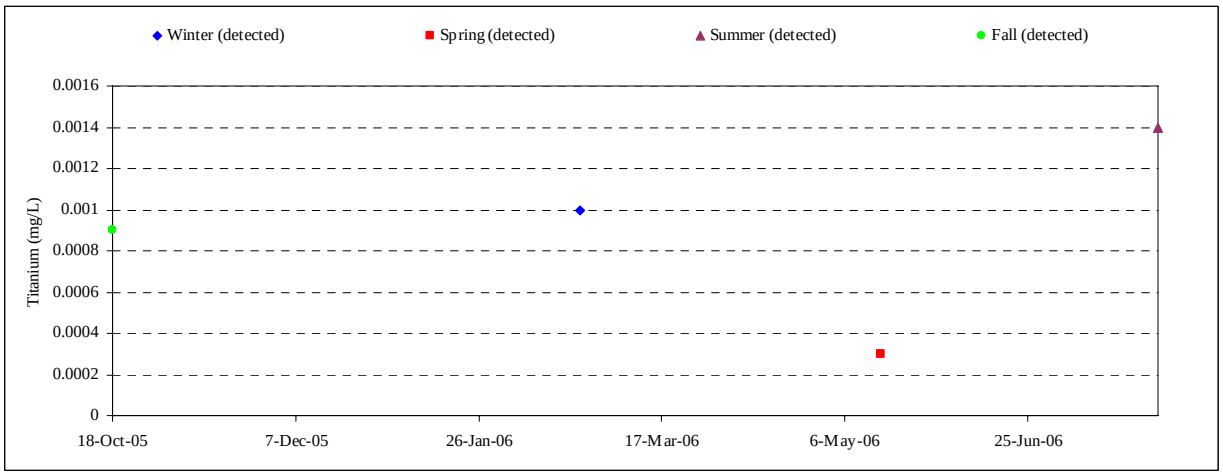
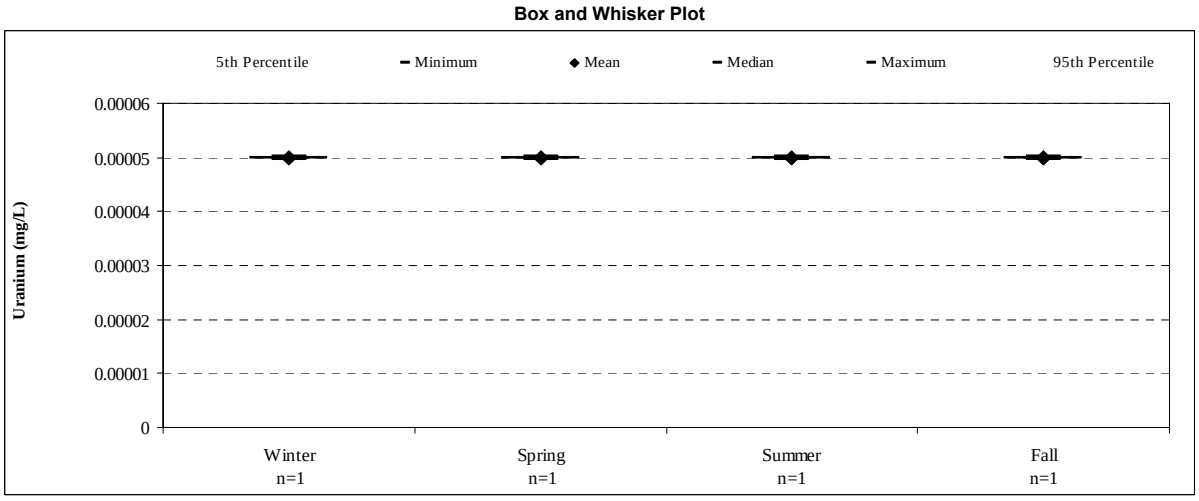


Figure G-1-6-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in McClelland Lake Inlet



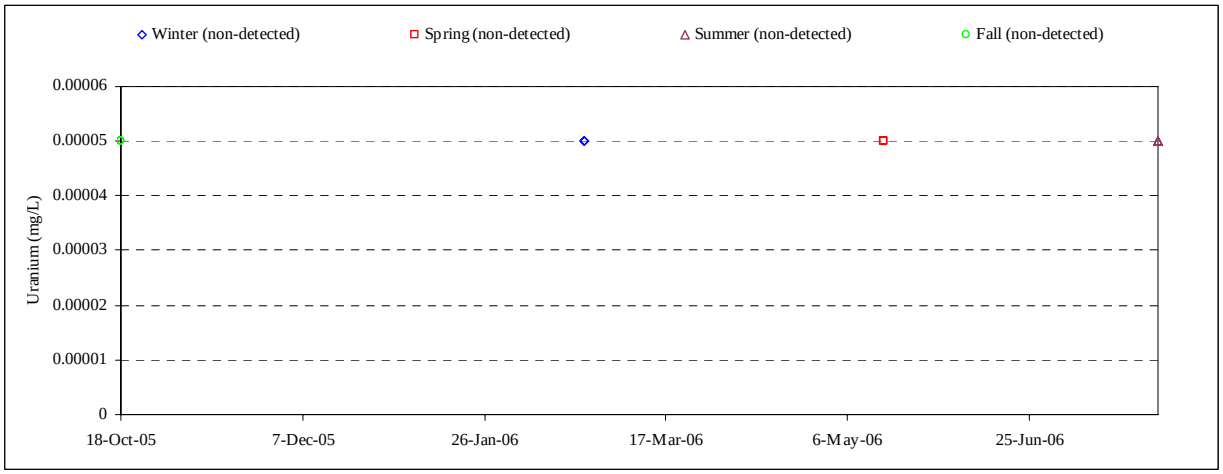
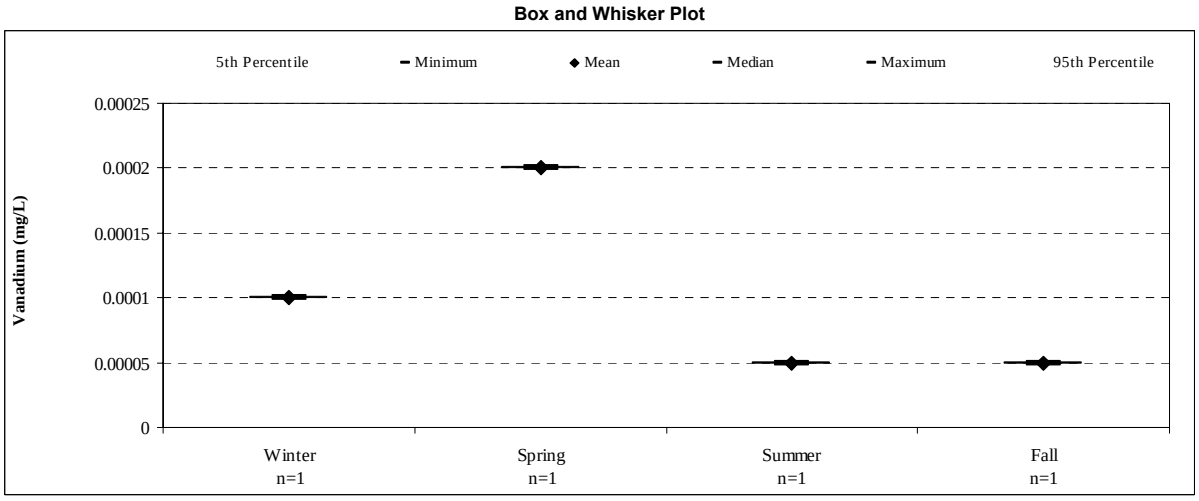


Figure G-1-6-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in McClelland Lake Inlet



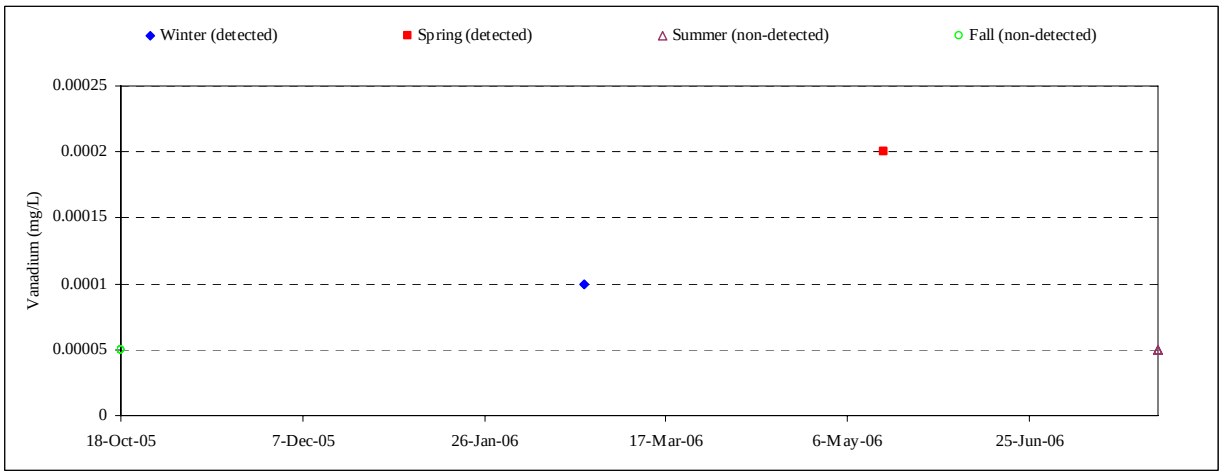
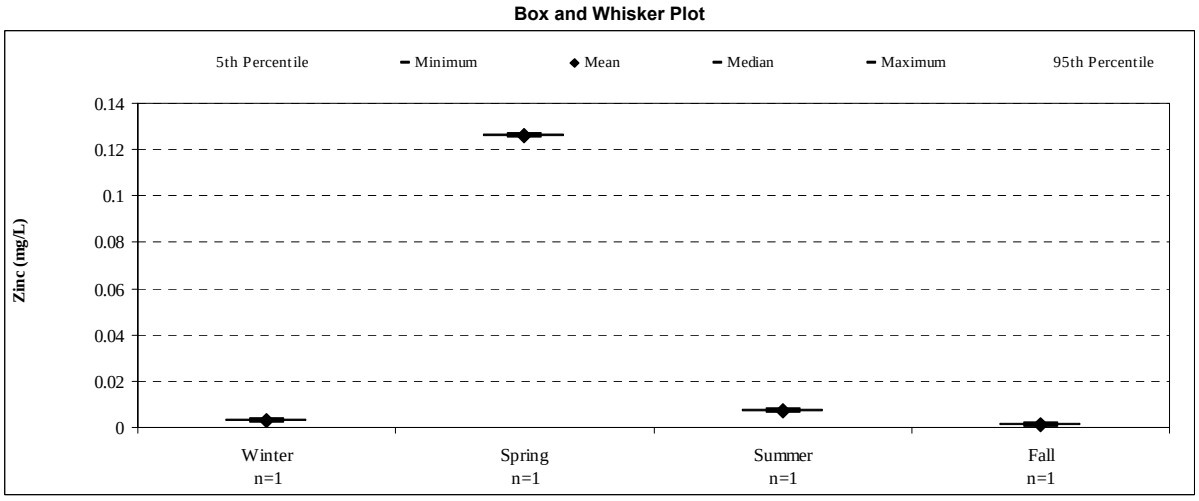


Figure G-1-6-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in McClelland Lake Inlet



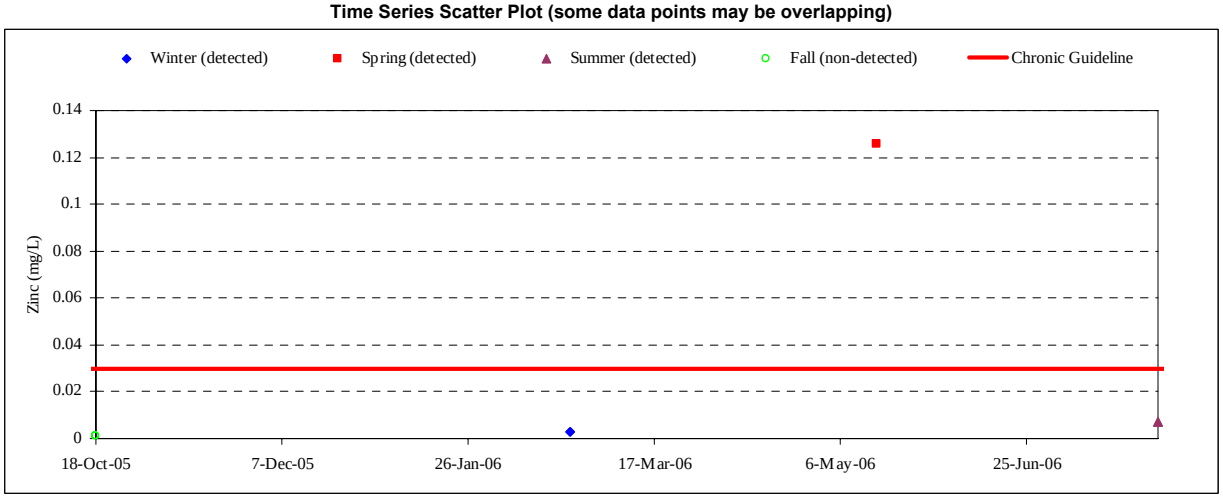
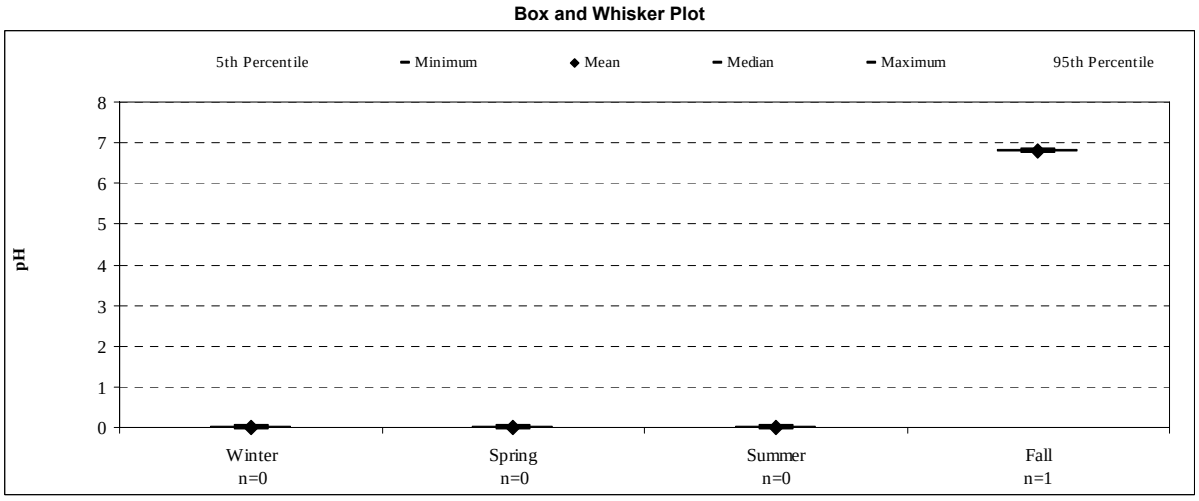


Figure G-1-7-1 Box Whisker and Time Series Scatter Plots of Observed pH in McClelland Lake Outlet



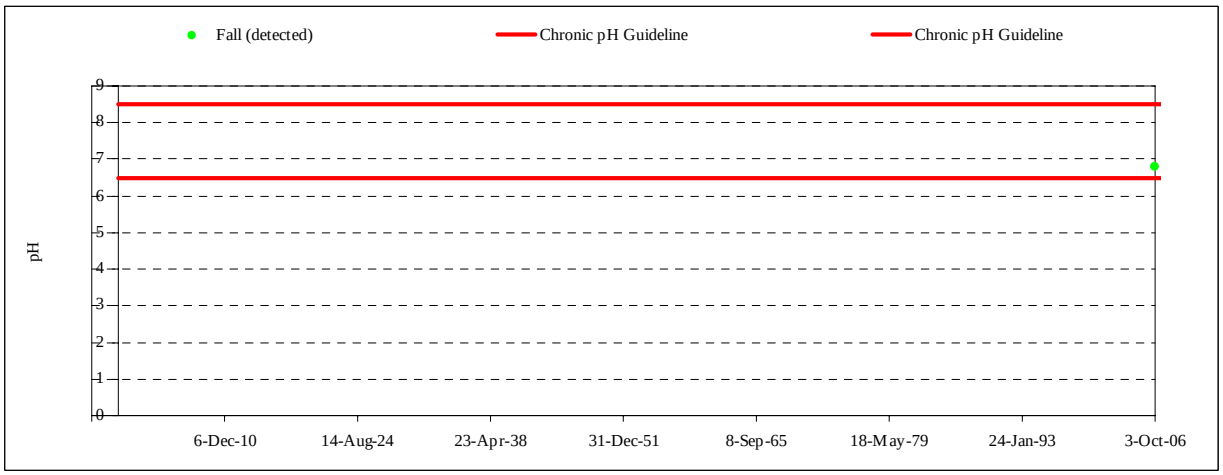
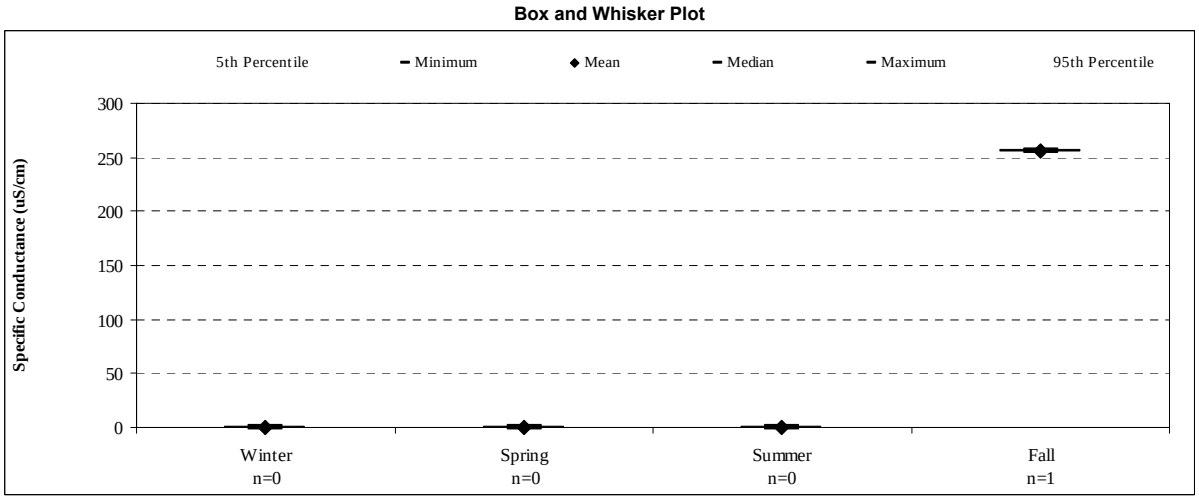


Figure G-1-7-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in McClelland Lake Outlet



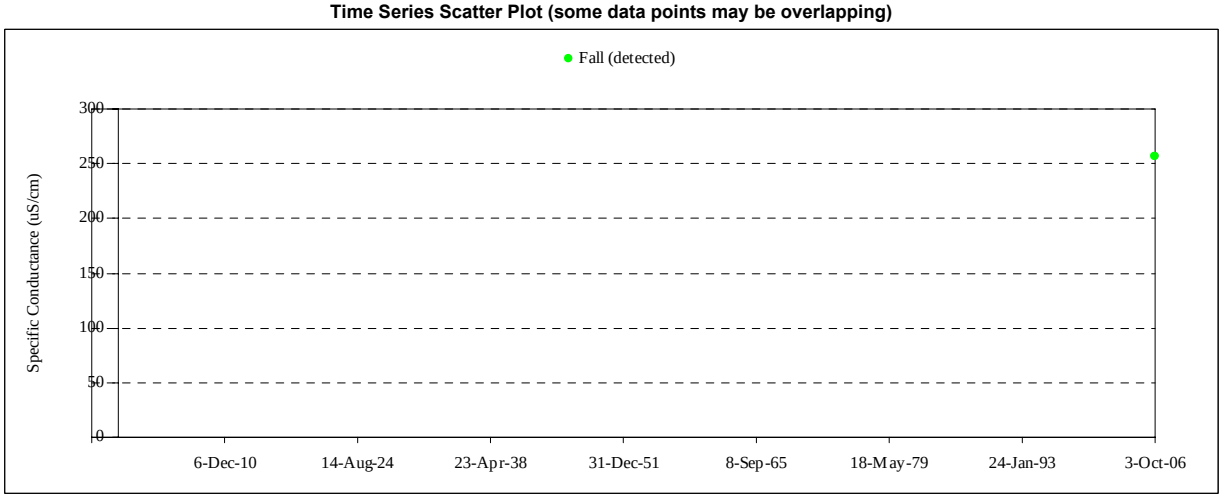
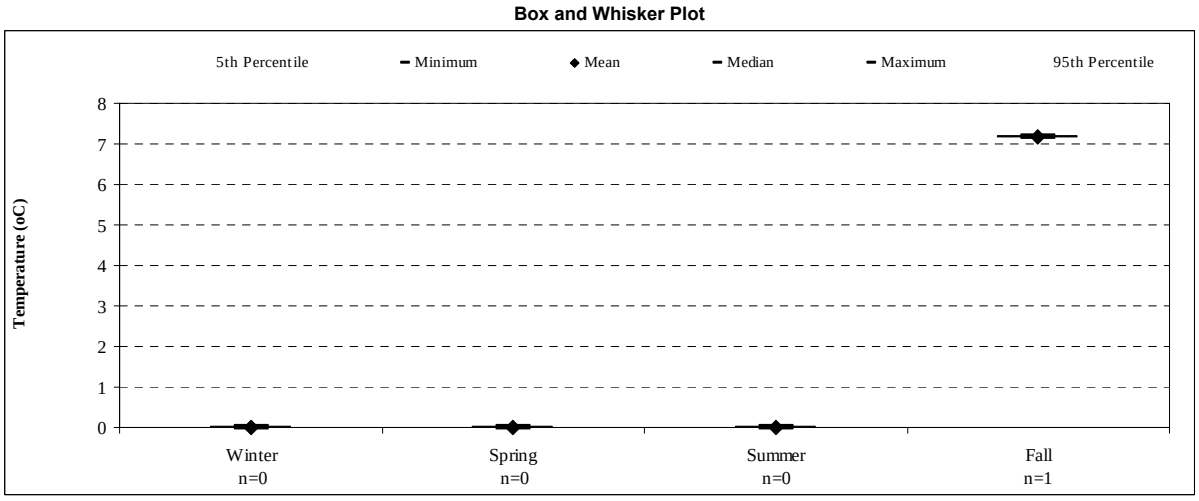


Figure G-1-7-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in McClelland Lake Outlet



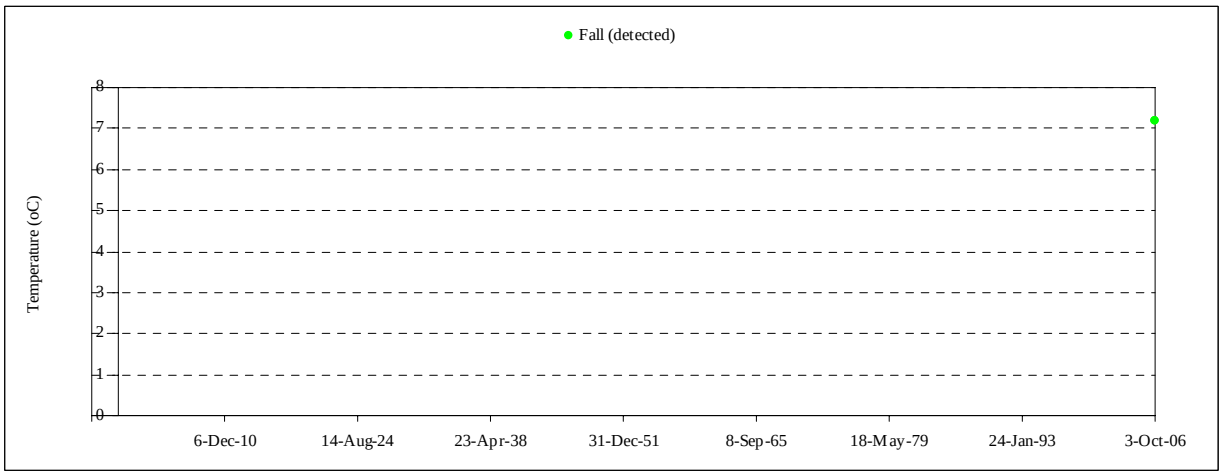
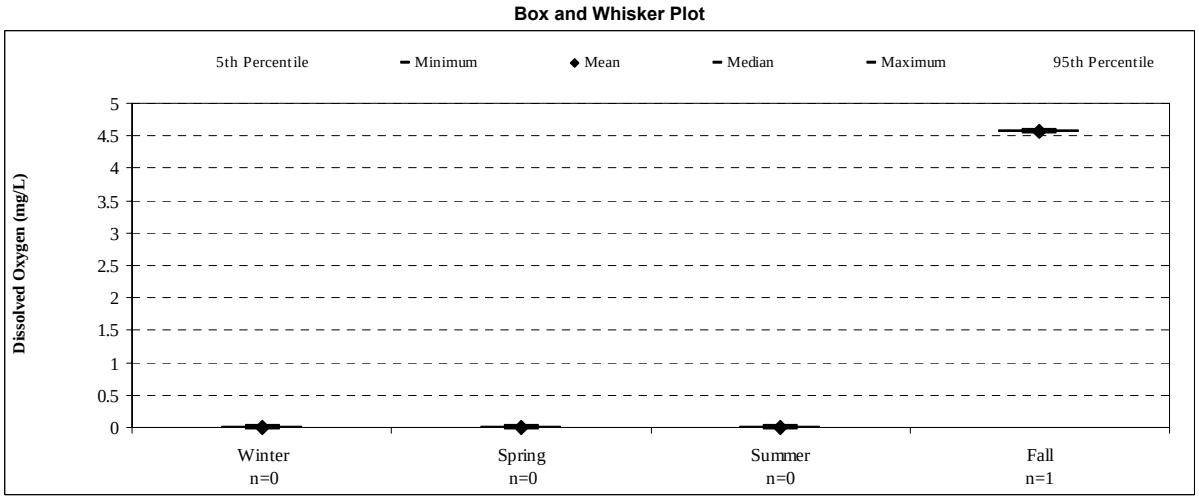


Figure G-1-7-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in McClelland Lake Outlet



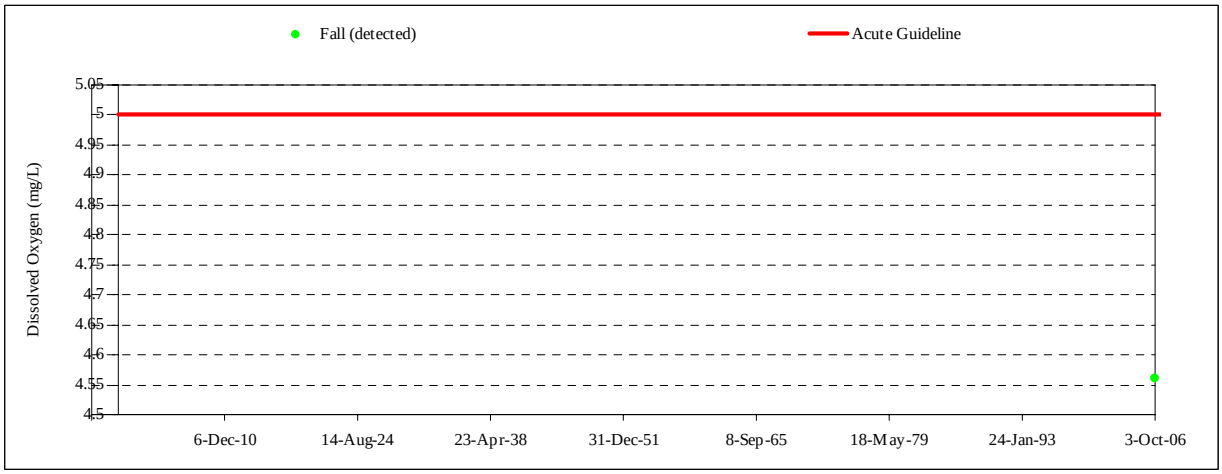
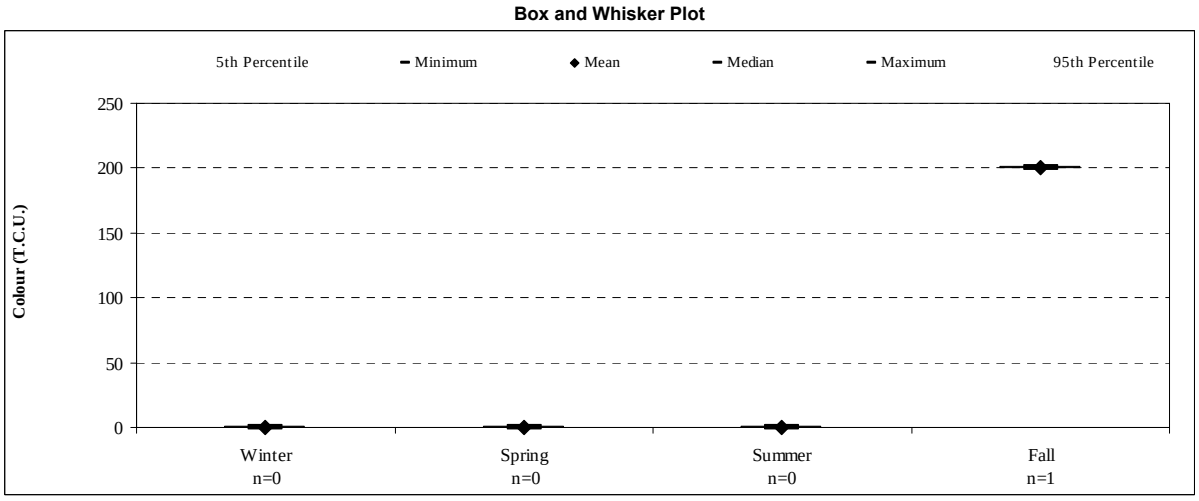


Figure G-1-7-5 Box Whisker and Time Series Scatter Plots of Observed Colour in McClelland Lake Outlet



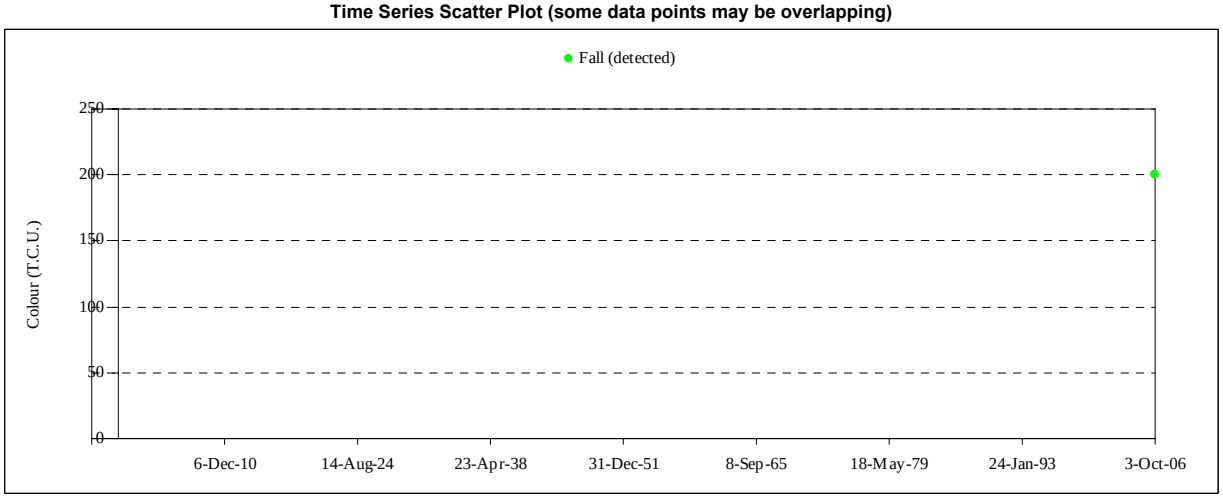
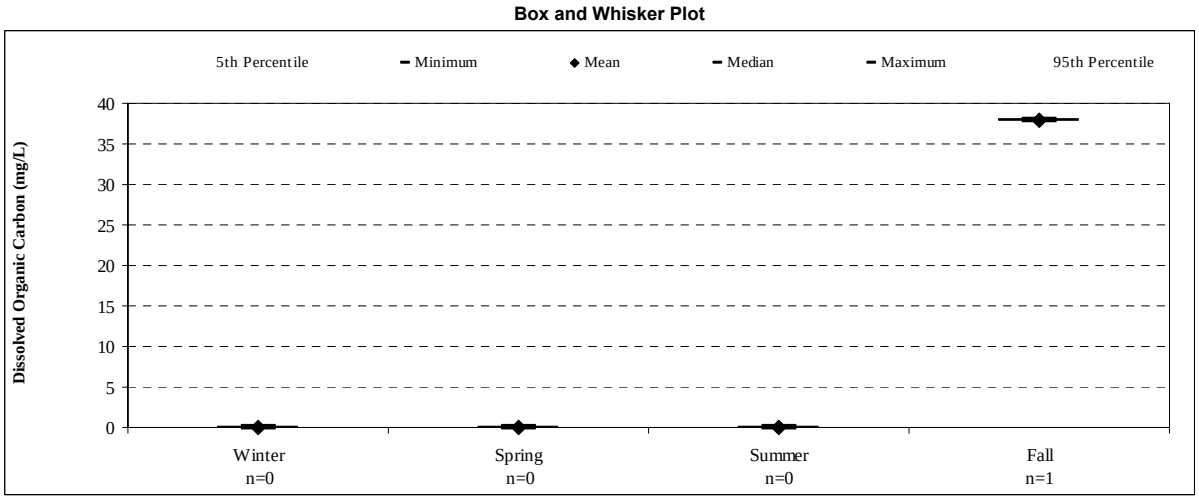


Figure G-1-7-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in McClelland Lake Outlet



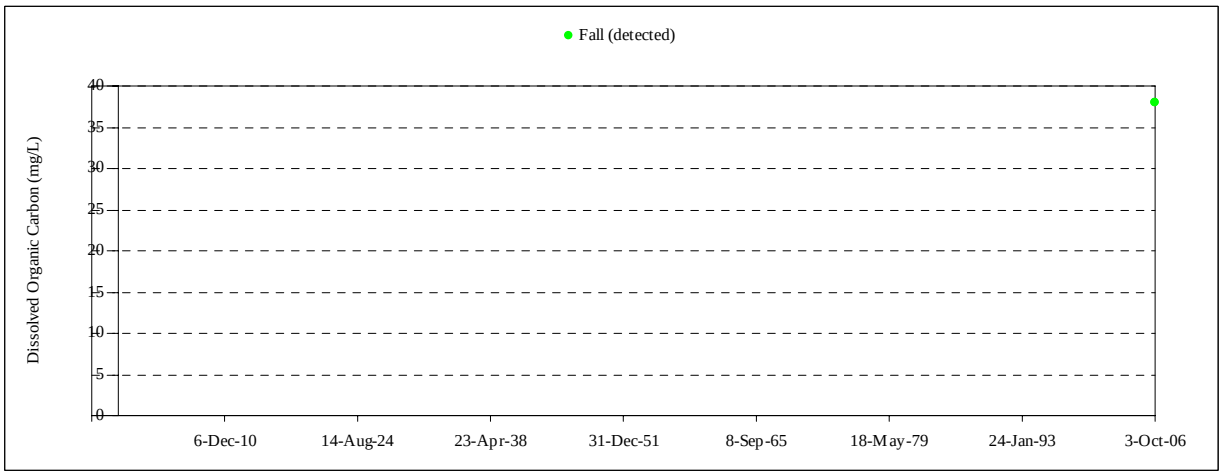


Figure G-1-7-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in McClelland Lake Outlet

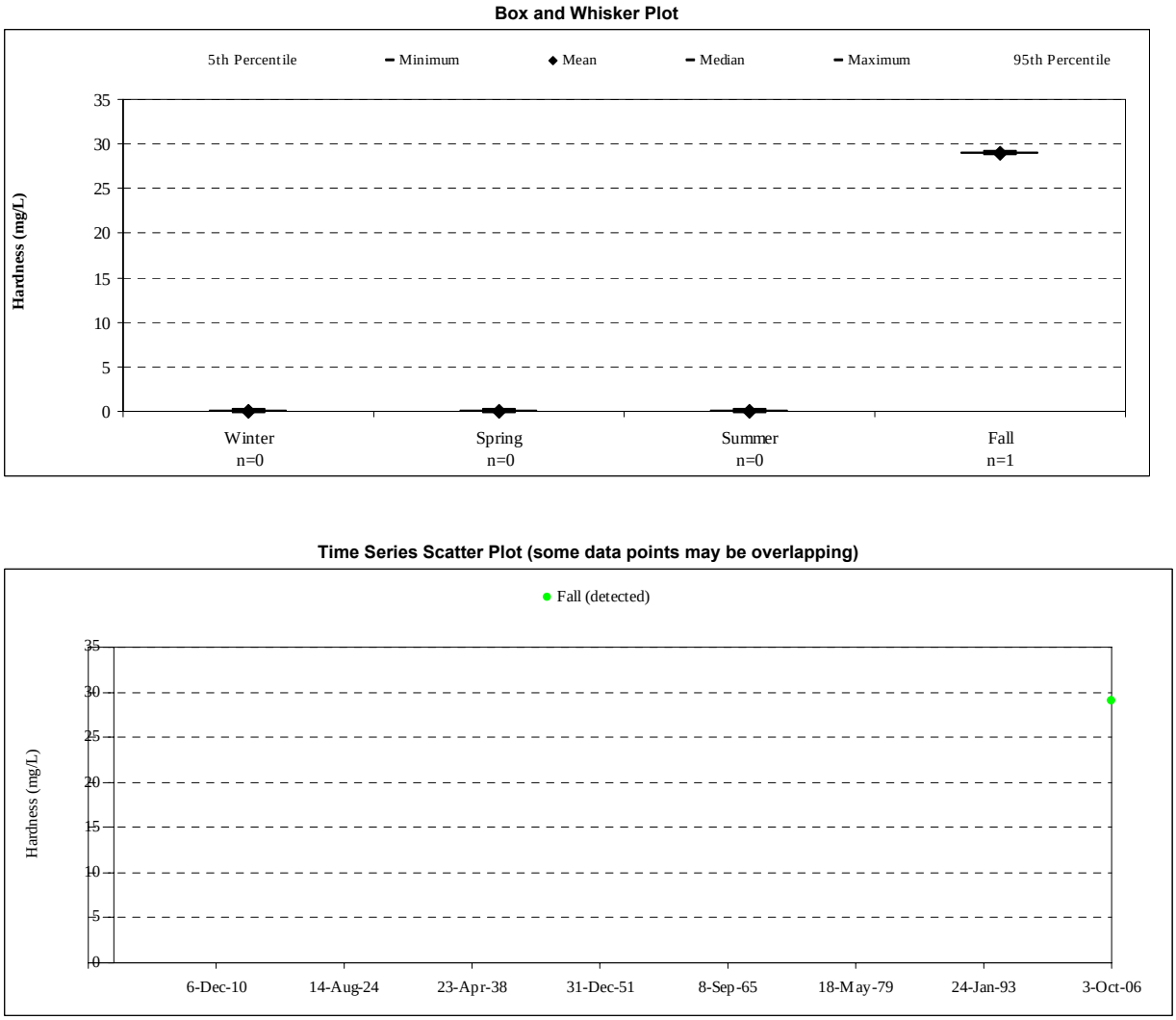
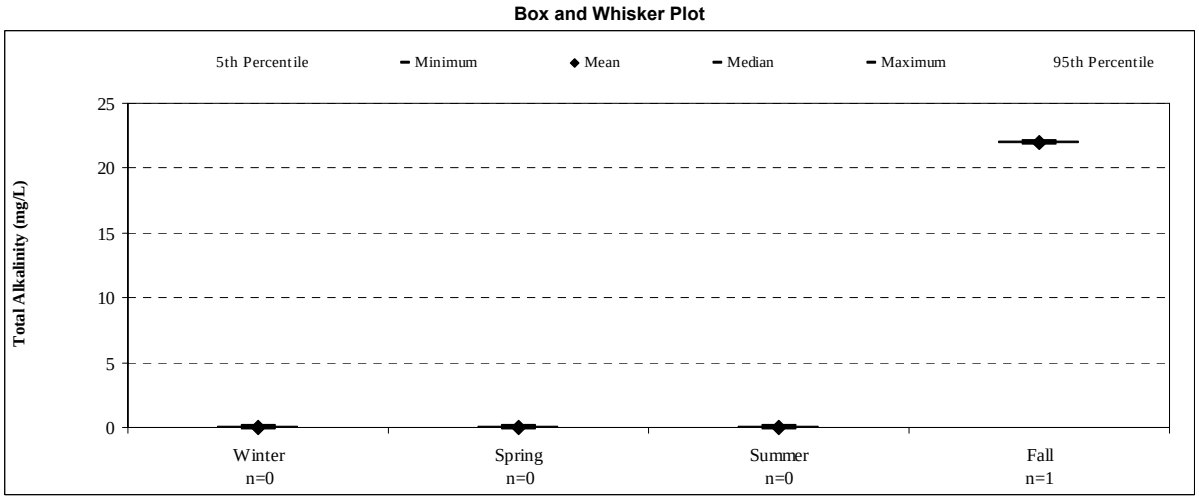


Figure G-1-7-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in McClelland Lake Outlet



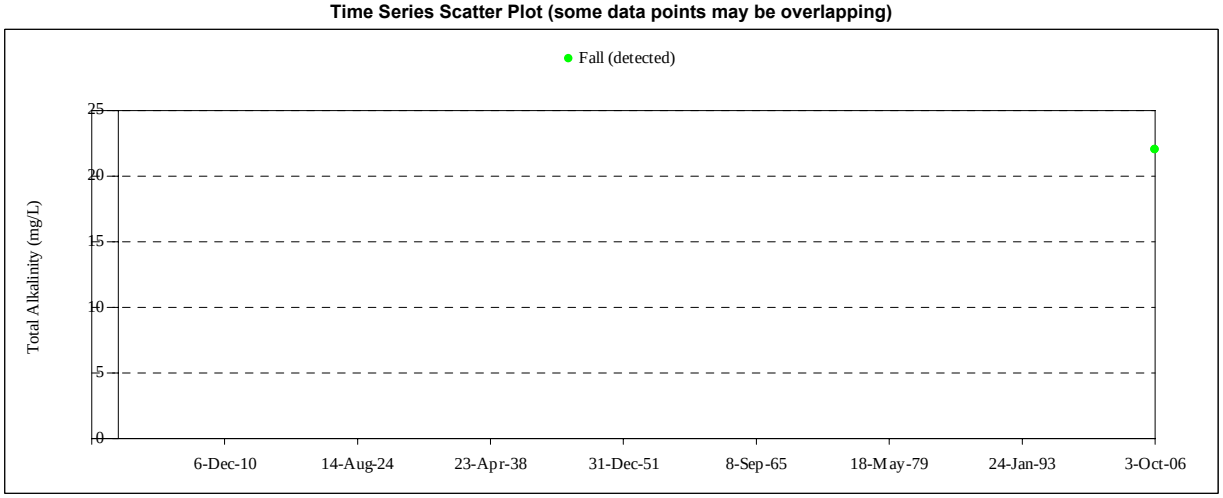


Figure G-1-7-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in McClelland Lake Outlet

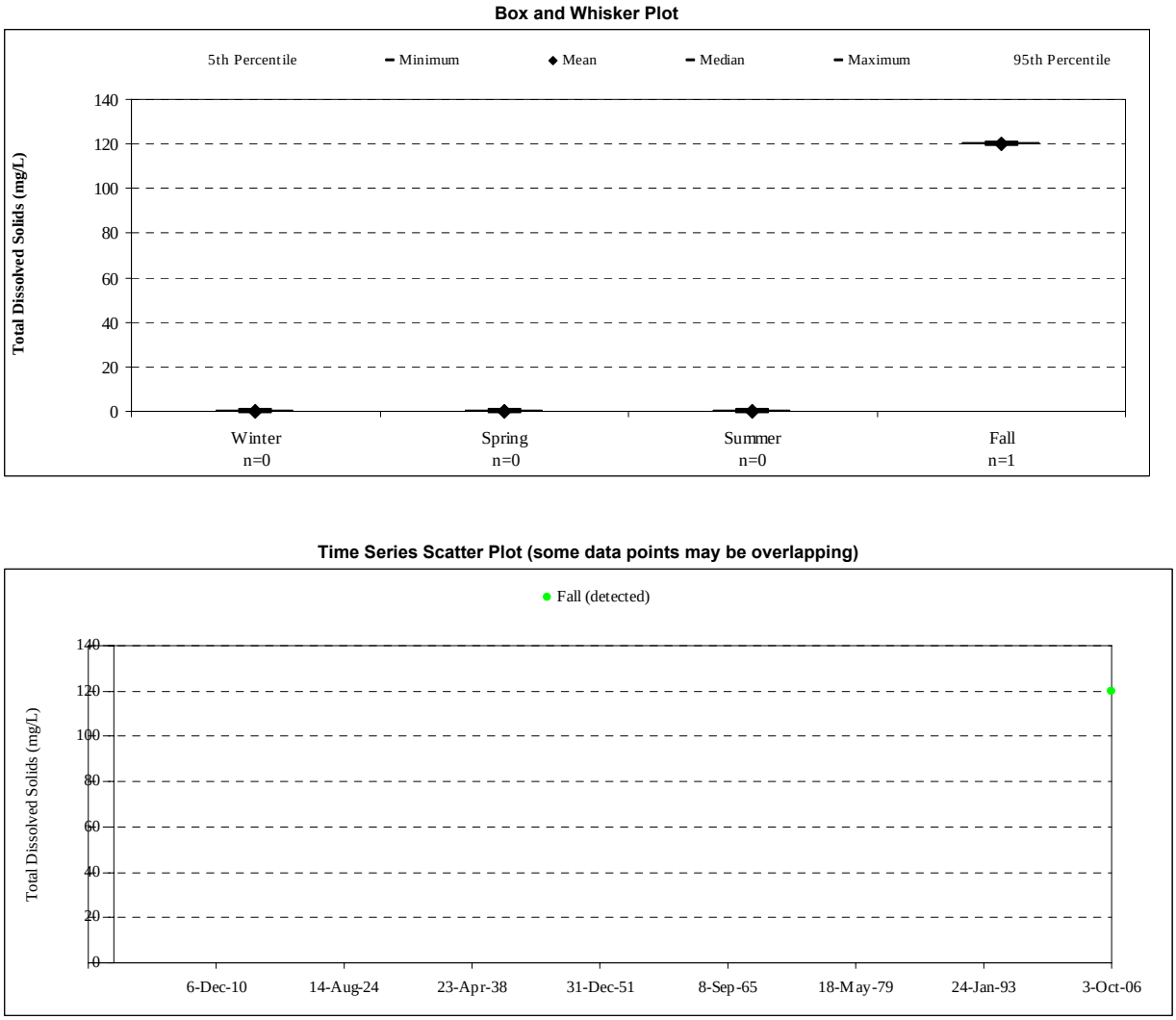


Figure G-1-7-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in McClelland Lake Outlet

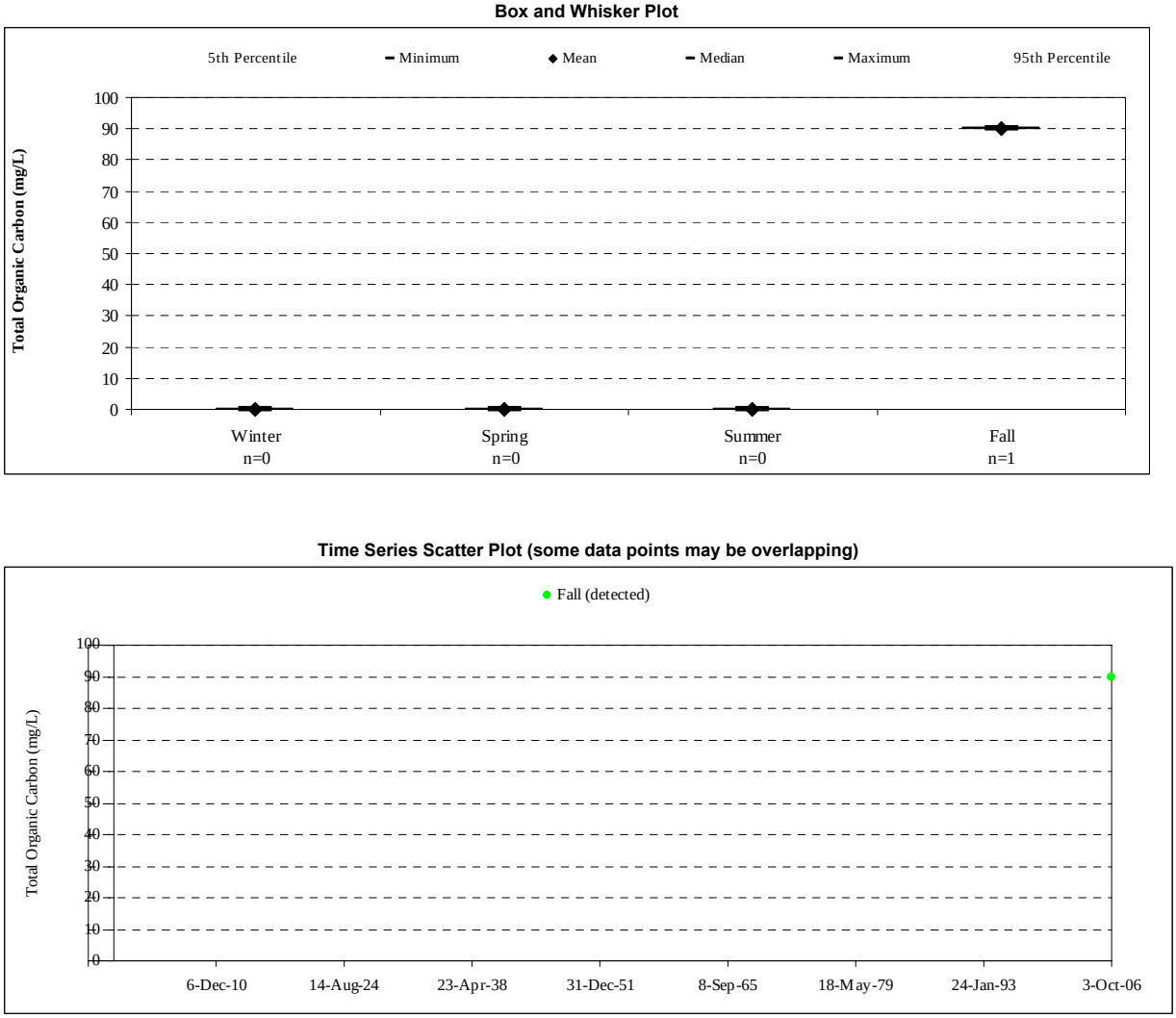


Figure G-1-7-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in McClelland Lake Outlet

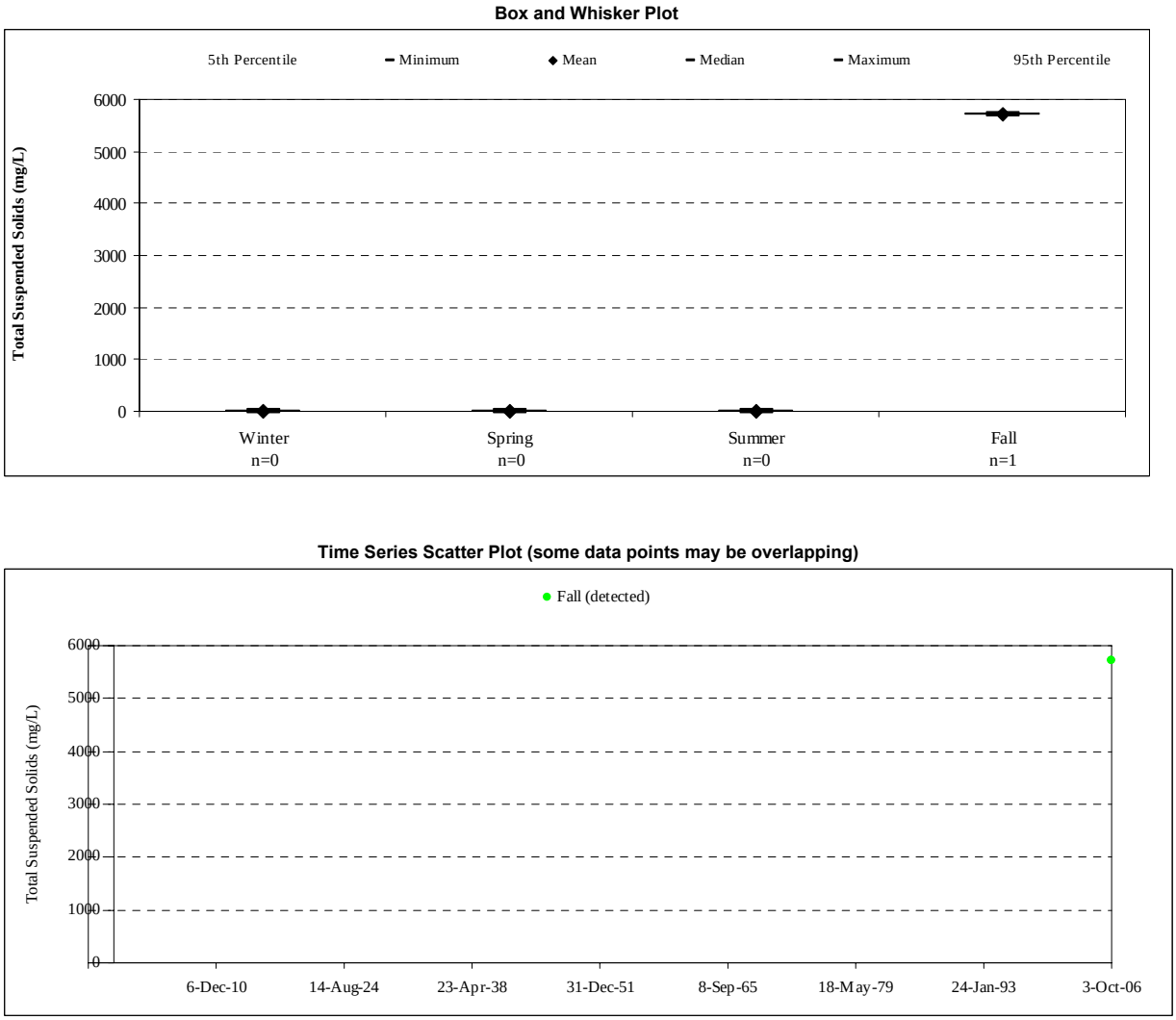
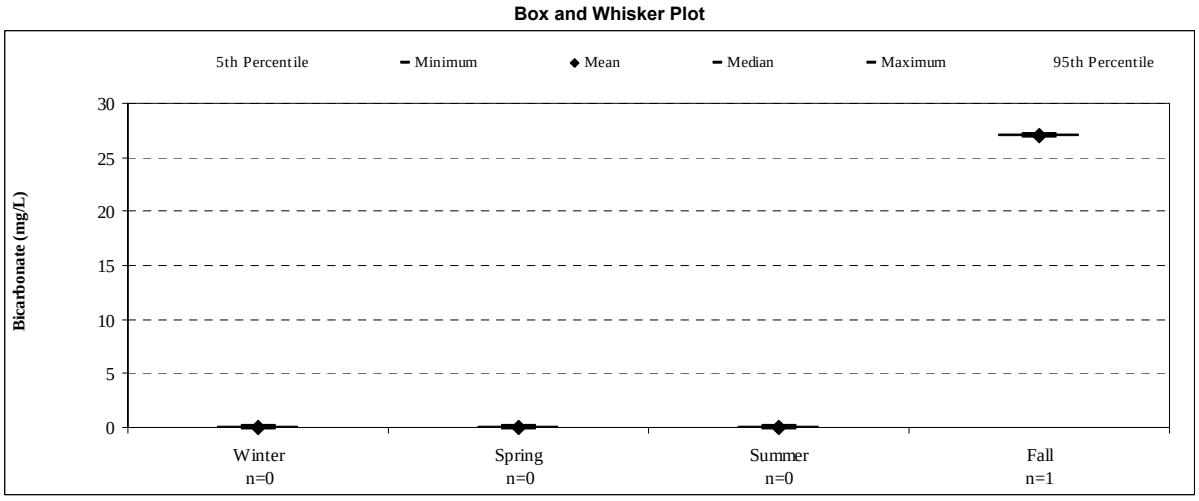


Figure G-1-7-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in McClelland Lake Outlet



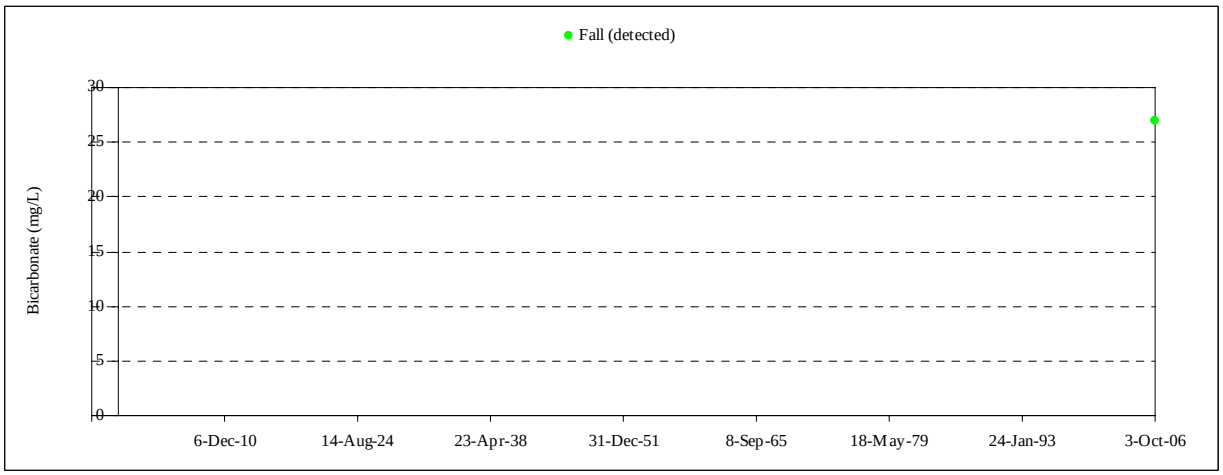


Figure G-1-7-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in McClelland Lake Outlet

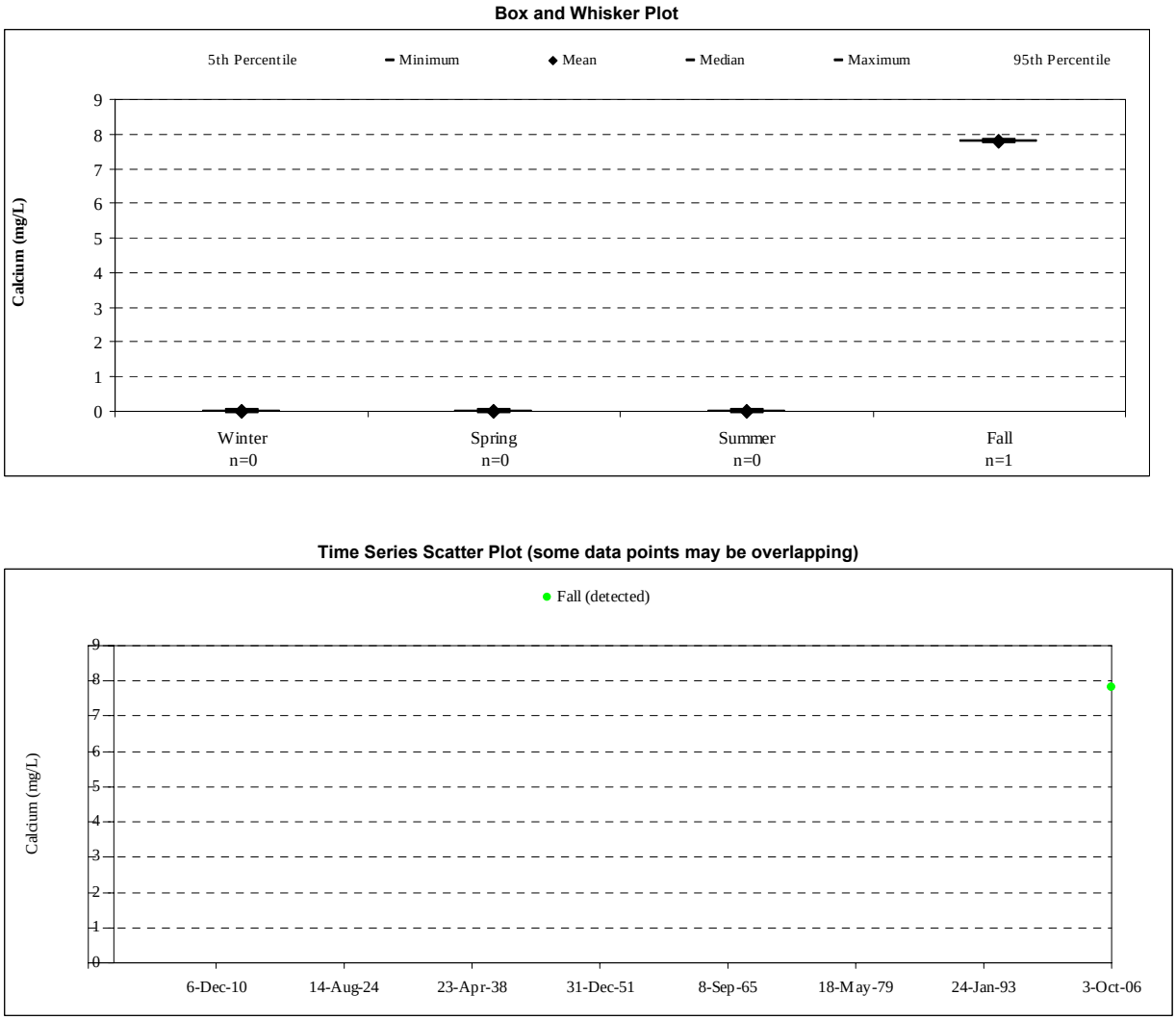
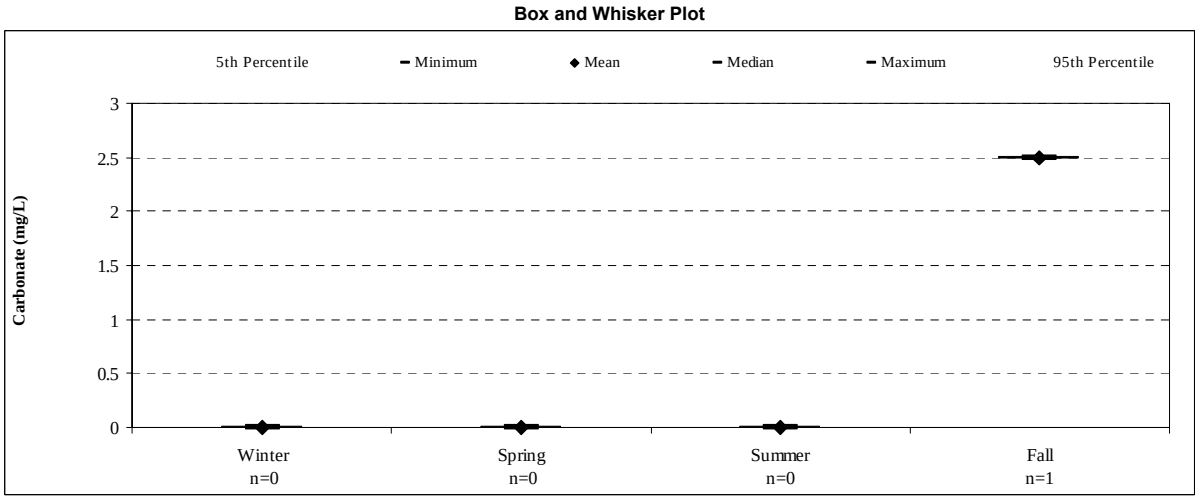


Figure G-1-7-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in McClelland Lake Outlet



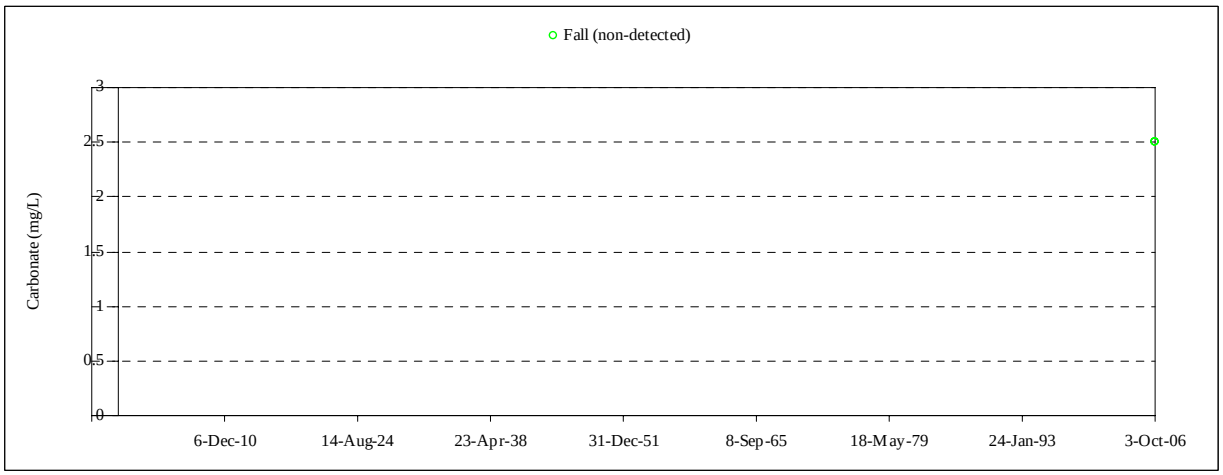
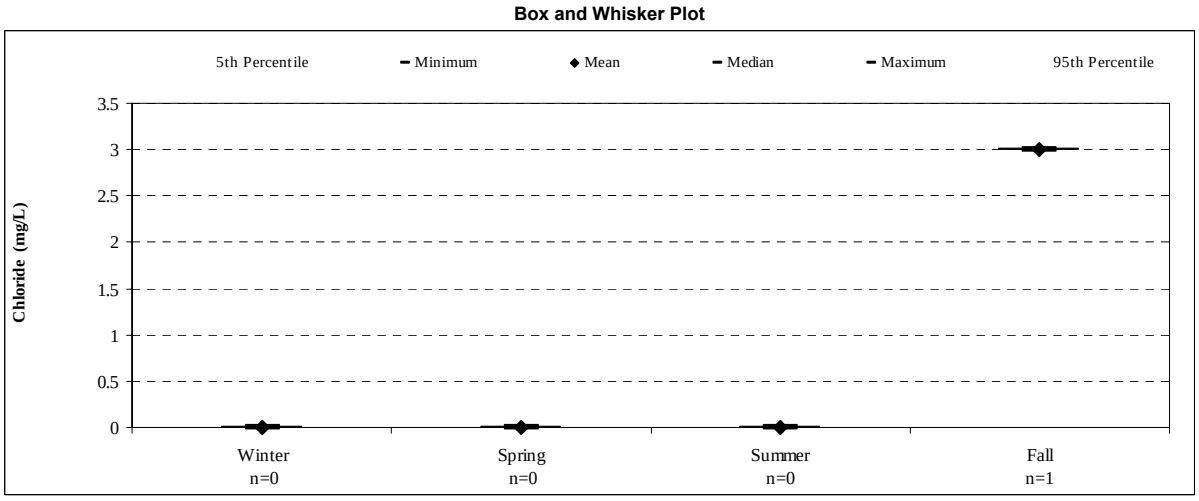


Figure G-1-7-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in McClelland Lake Outlet



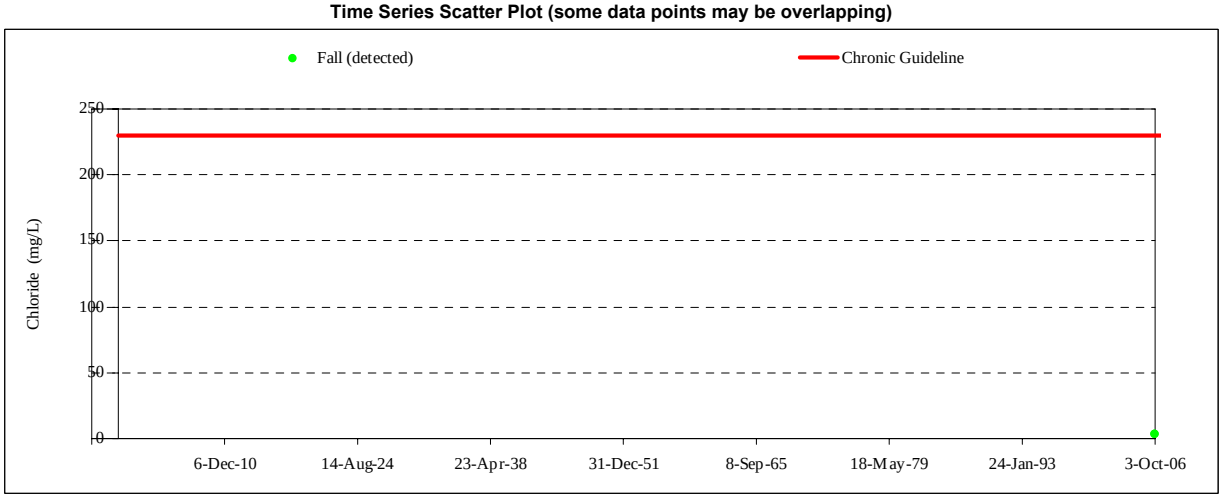
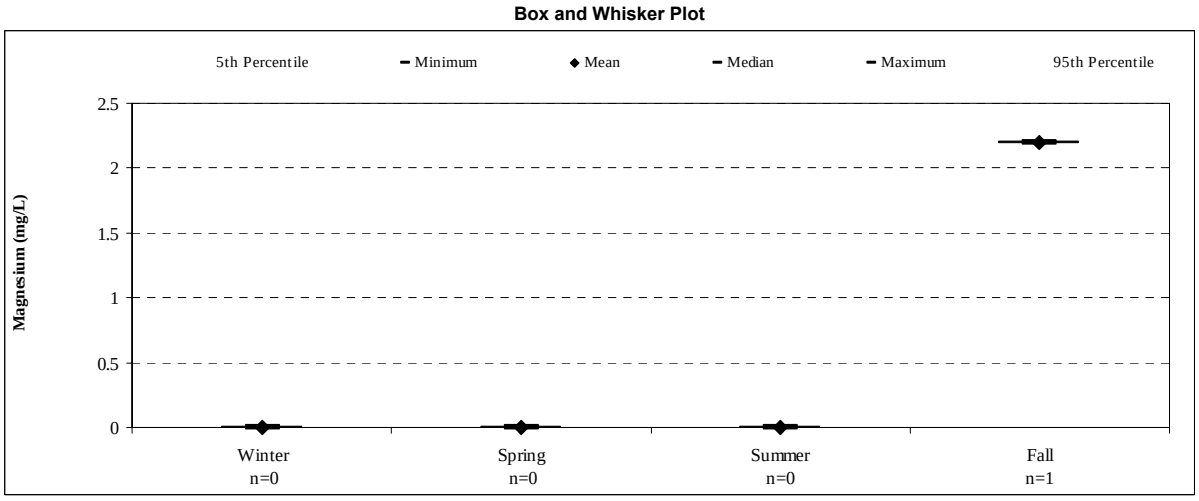


Figure G-1-7-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in McClelland Lake Outlet



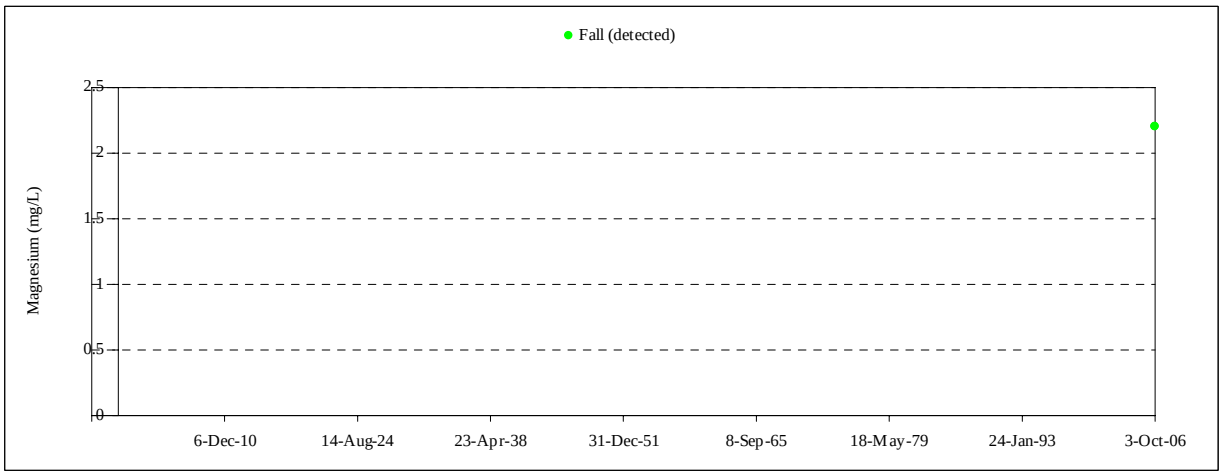
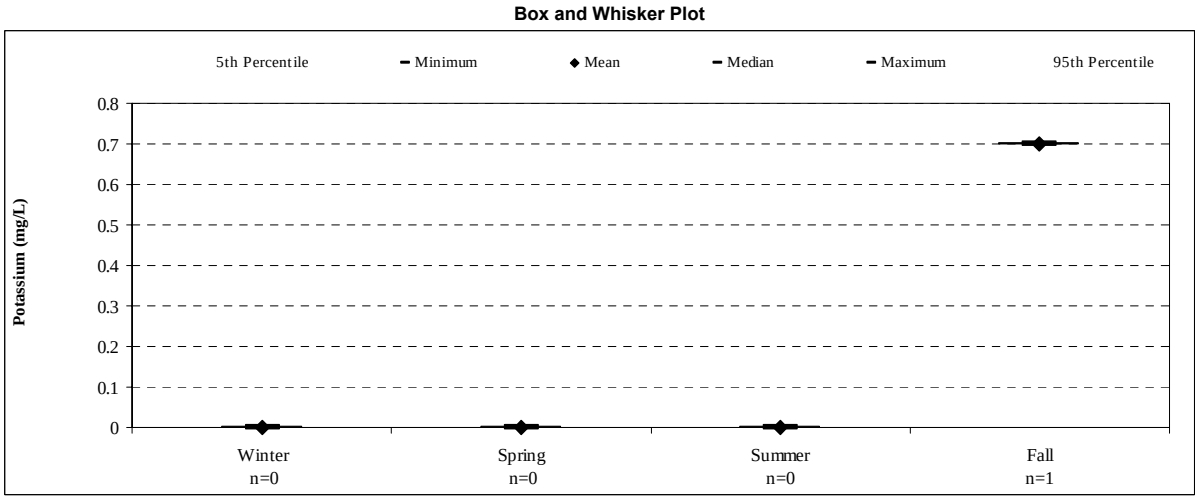


Figure G-1-7-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in McClelland Lake Outlet



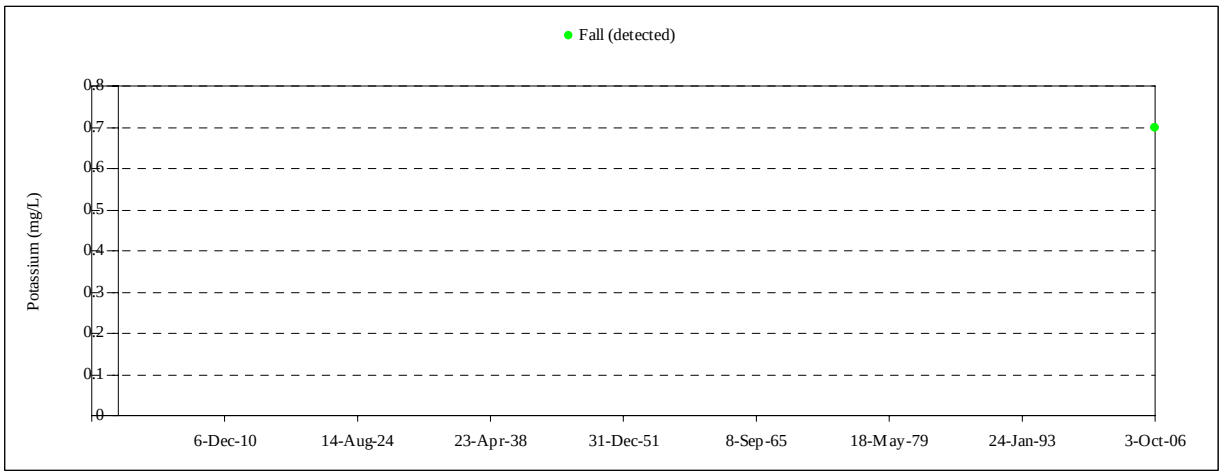
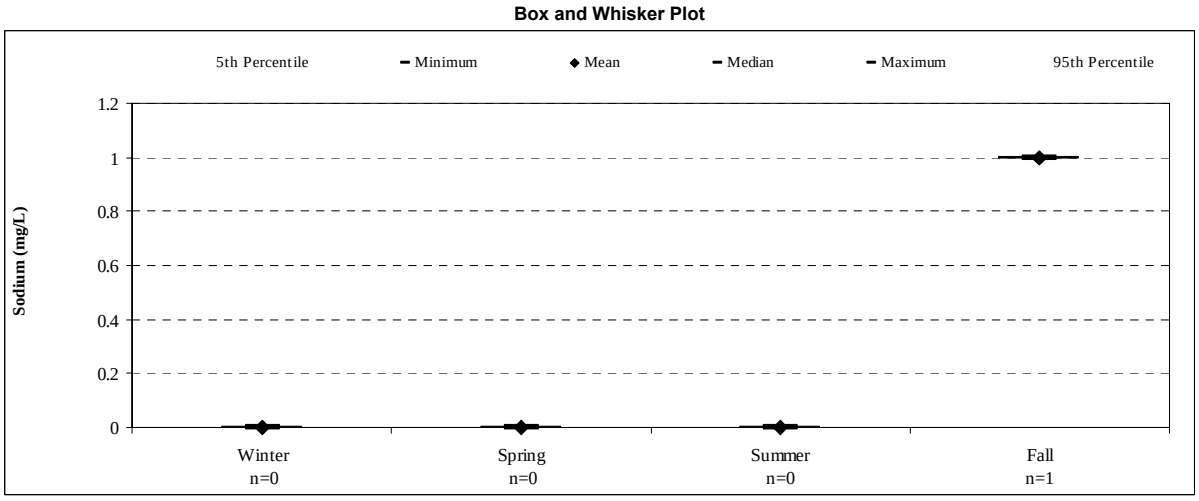


Figure G-1-7-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in McClelland Lake Outlet



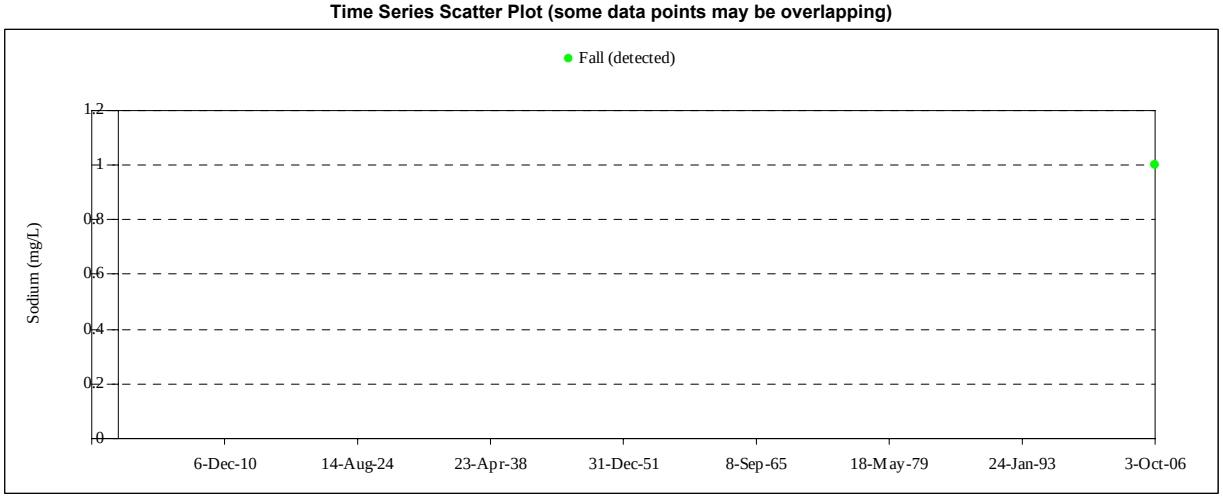
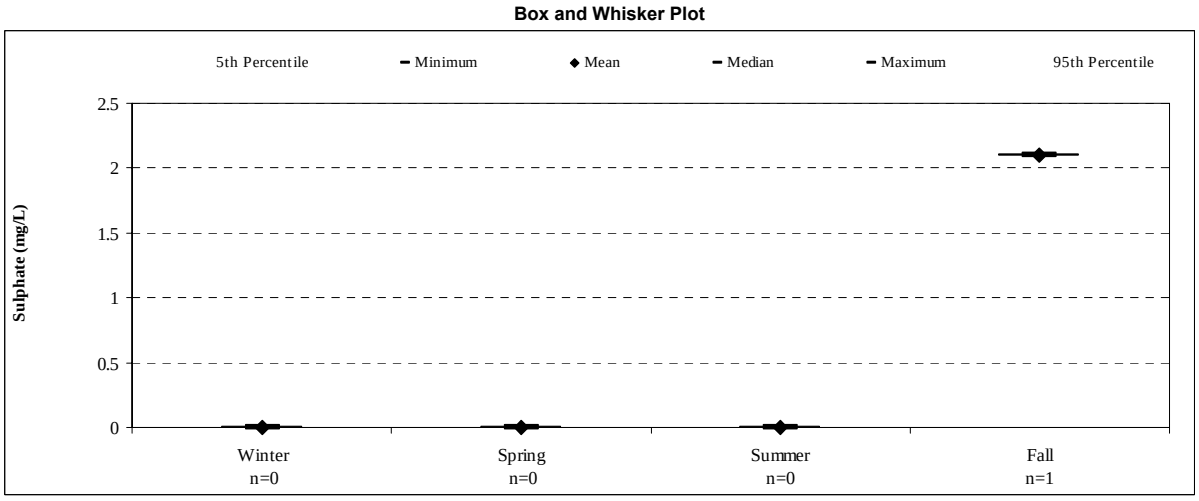


Figure G-1-7-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in McClelland Lake Outlet



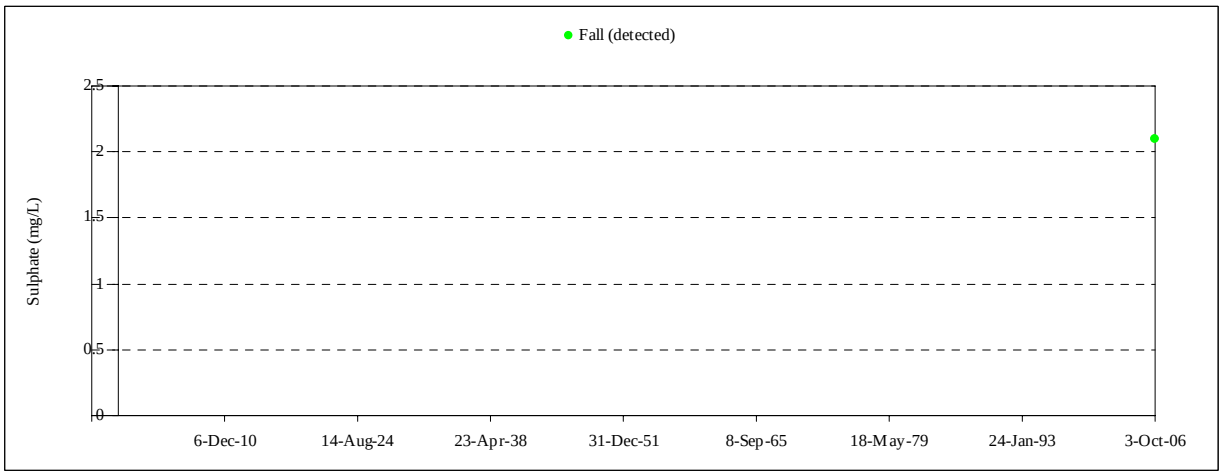
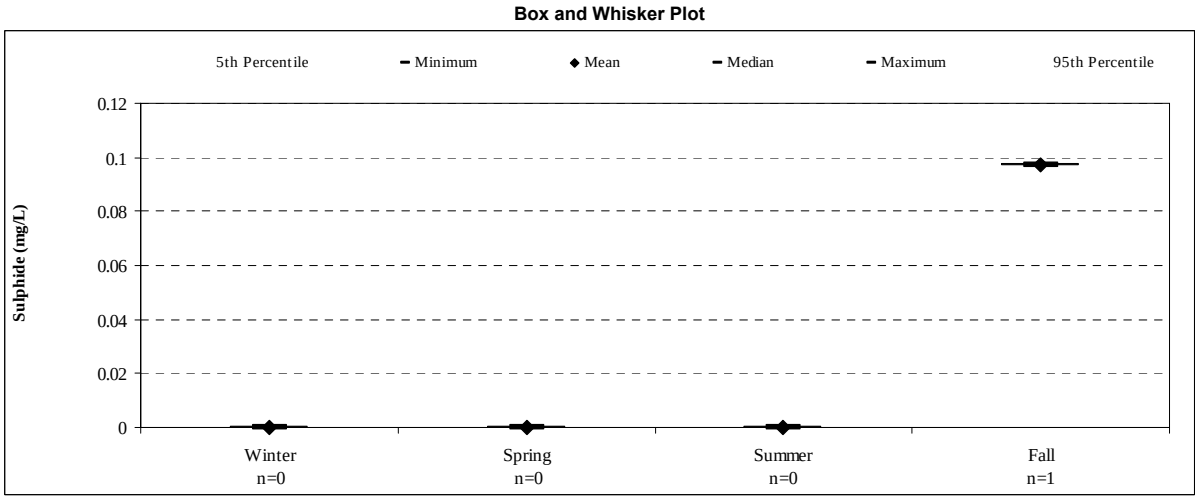


Figure G-1-7-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in McClelland Lake Outlet



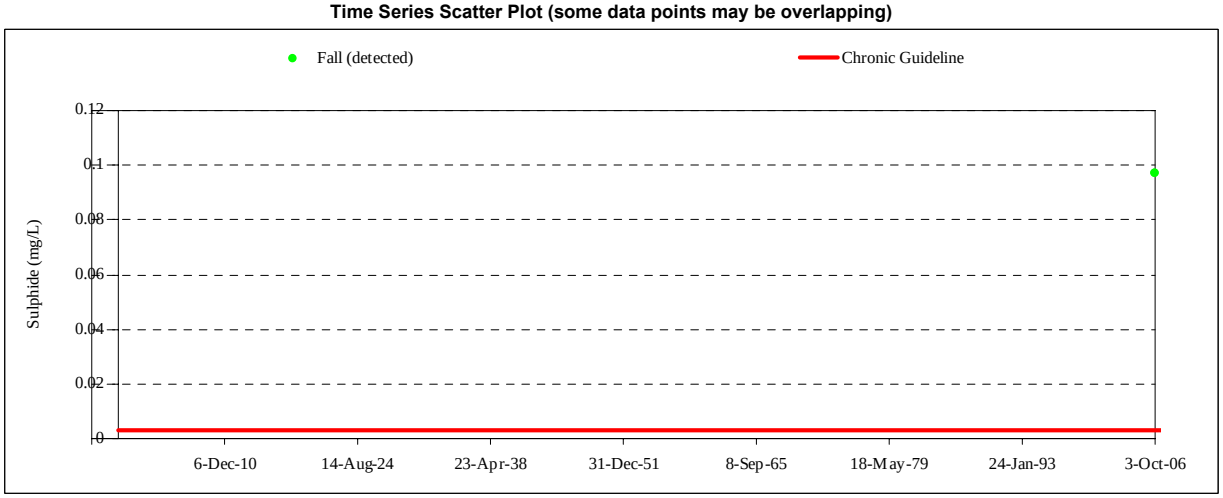
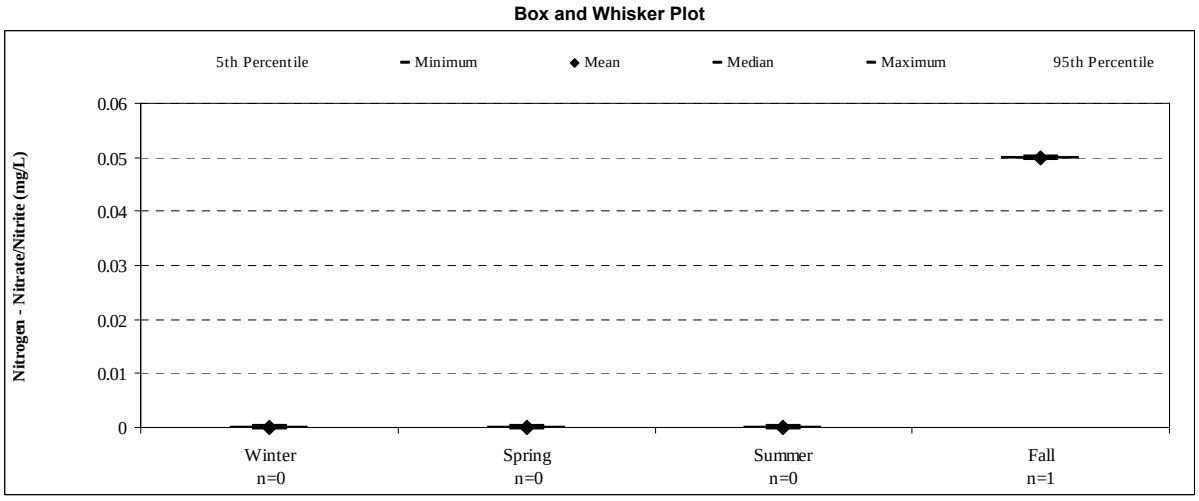


Figure G-1-7-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in McClelland Lake Outlet



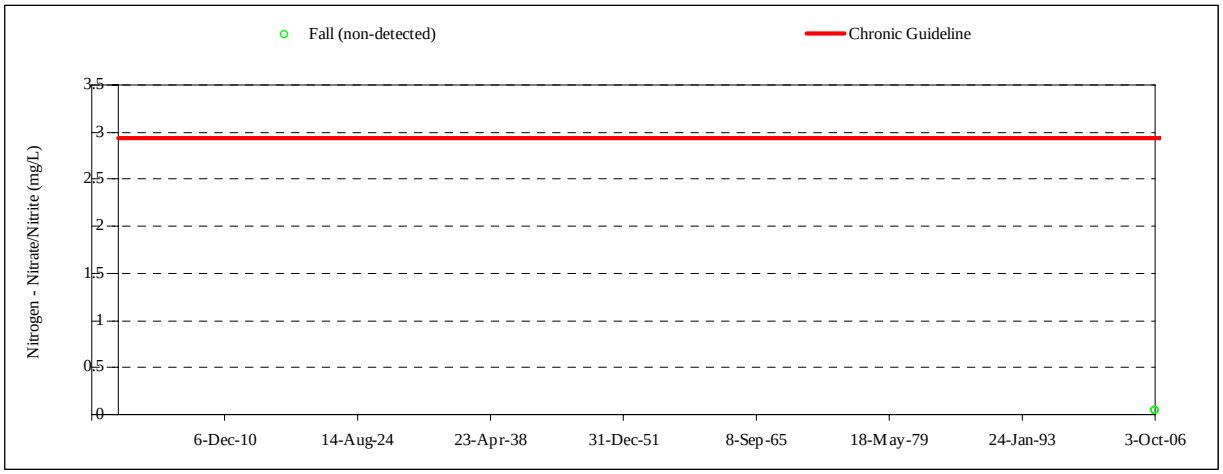
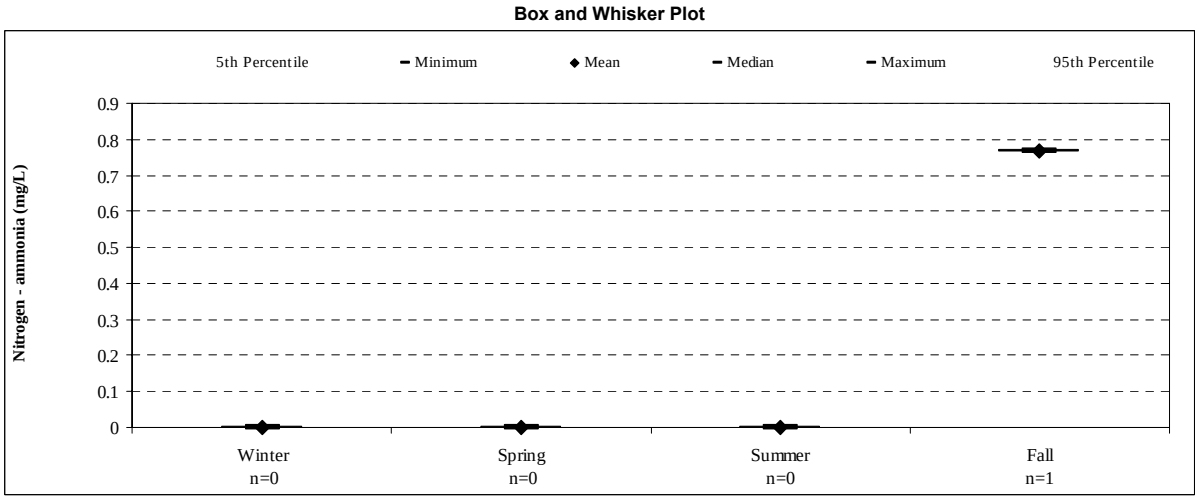


Figure G-1-7-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in McClelland Lake Outlet



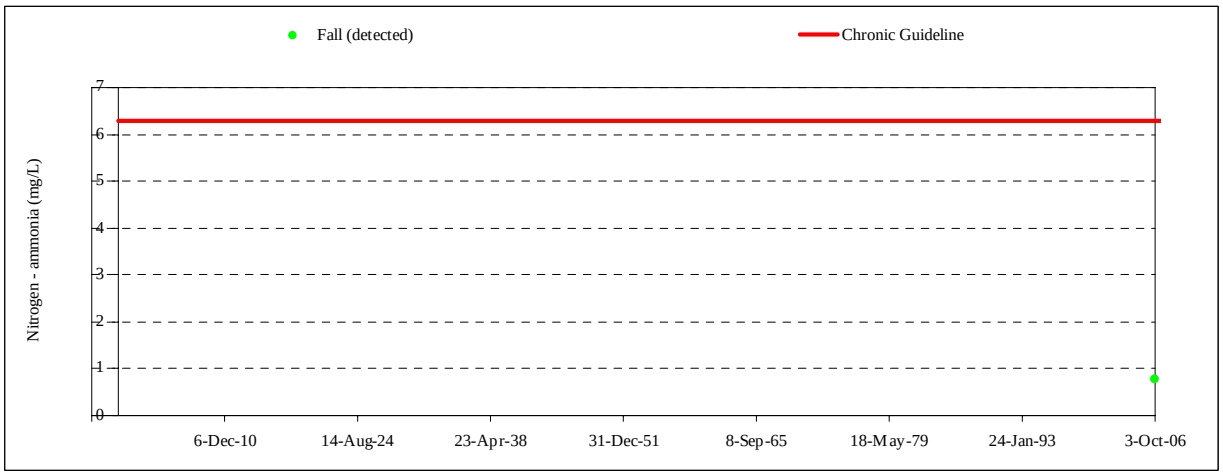
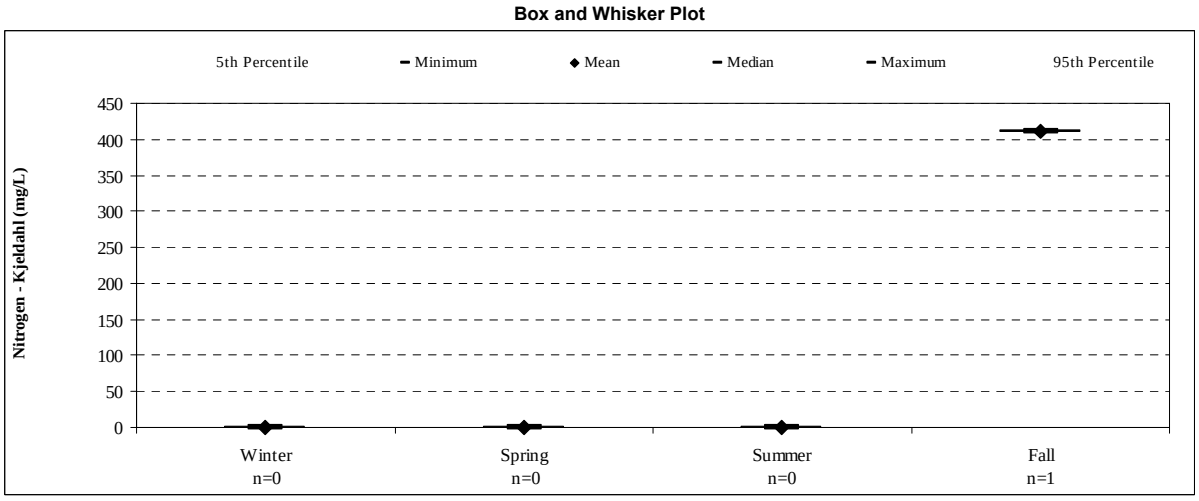


Figure G-1-7-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in McClelland Lake Outlet



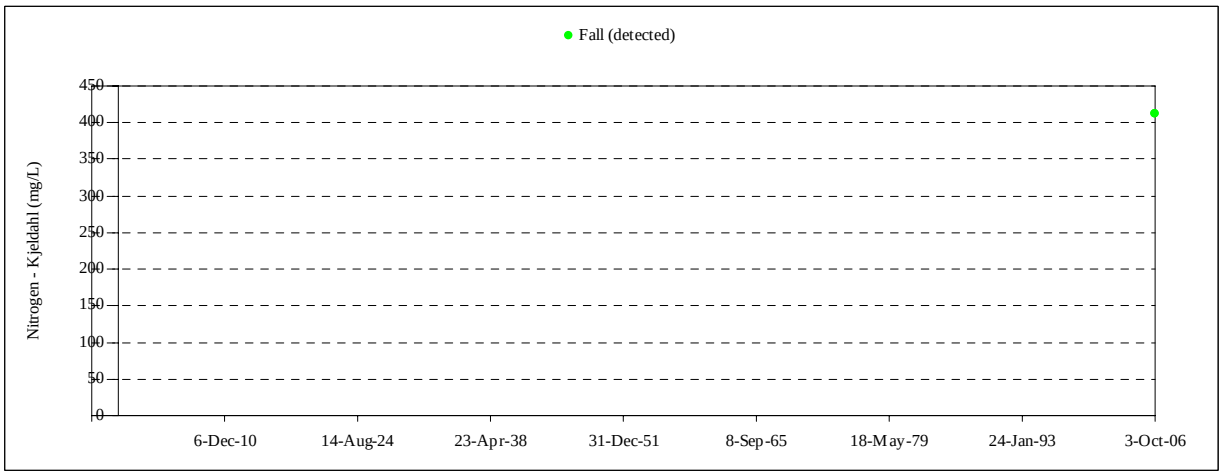
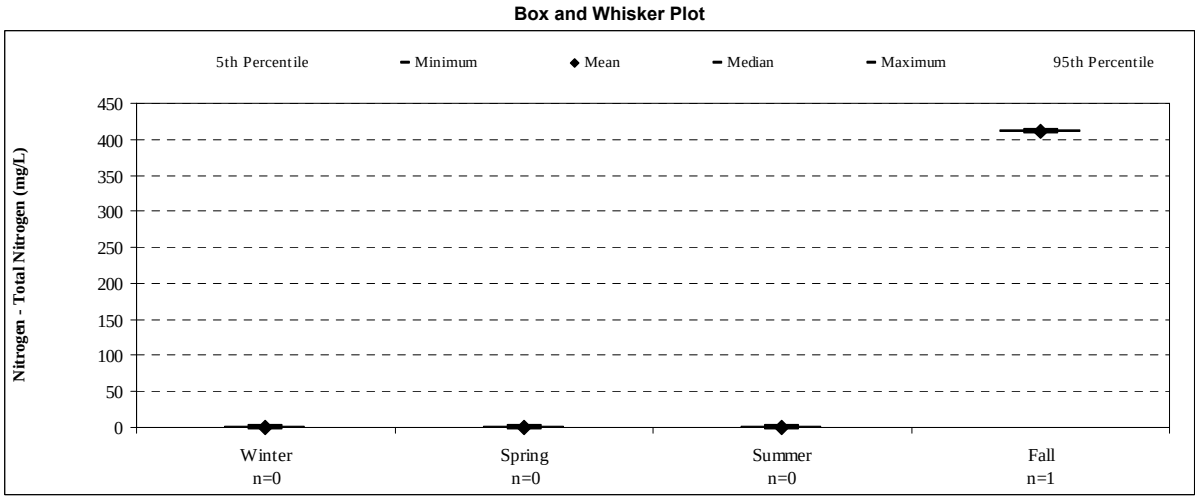


Figure G-1-7-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in McClelland Lake Outlet



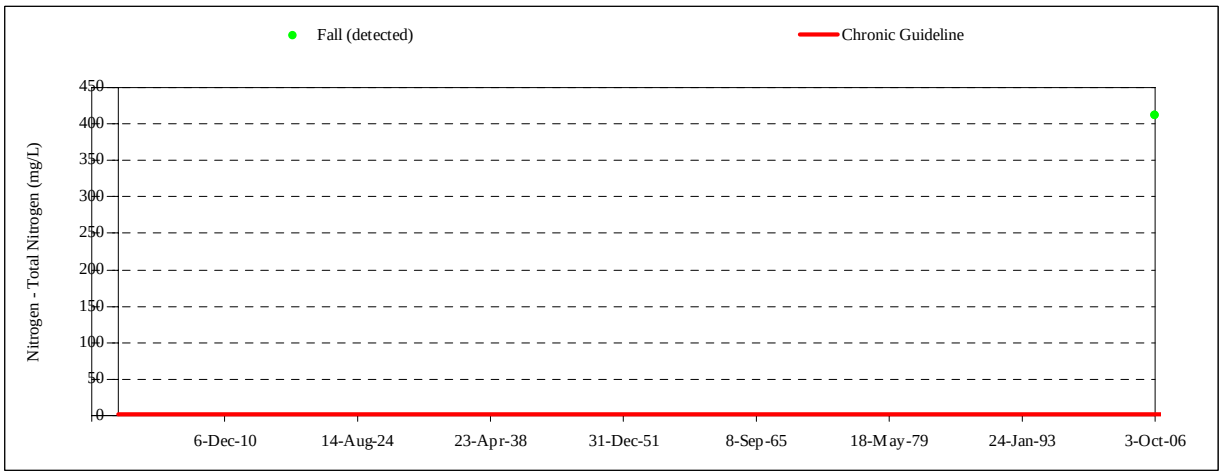
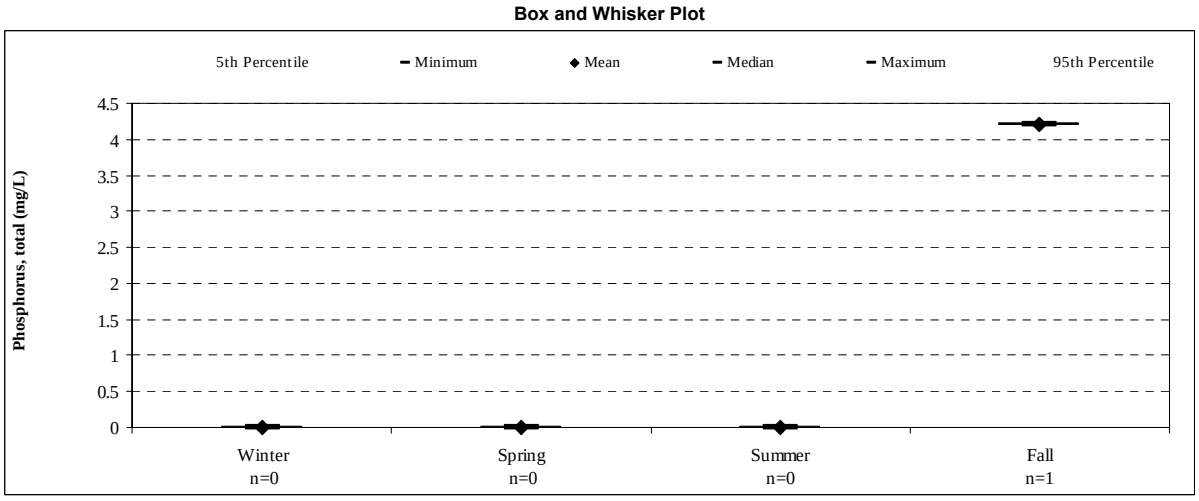


Figure G-1-7-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in McClelland Lake Outlet



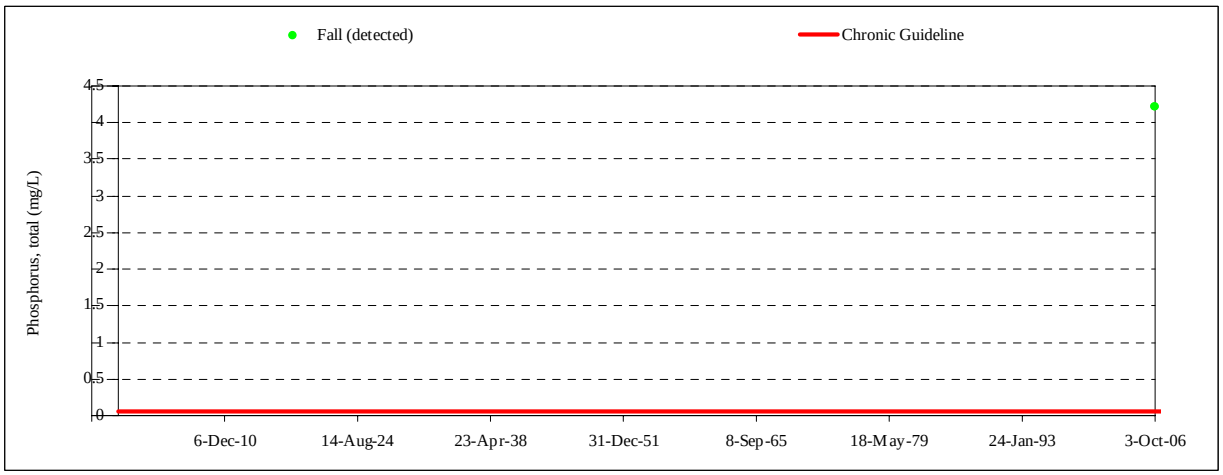
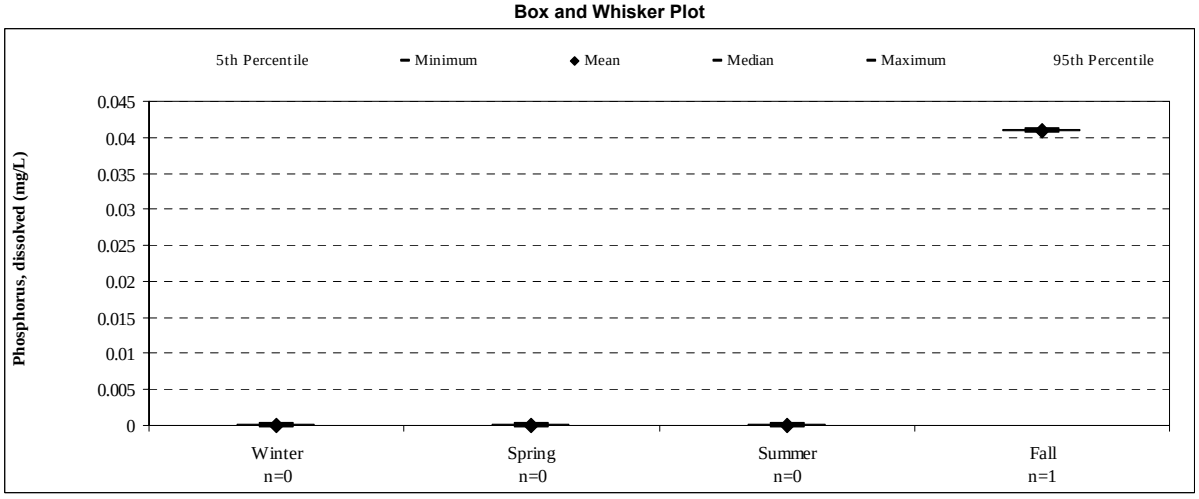


Figure G-1-7-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in McClelland Lake Outlet



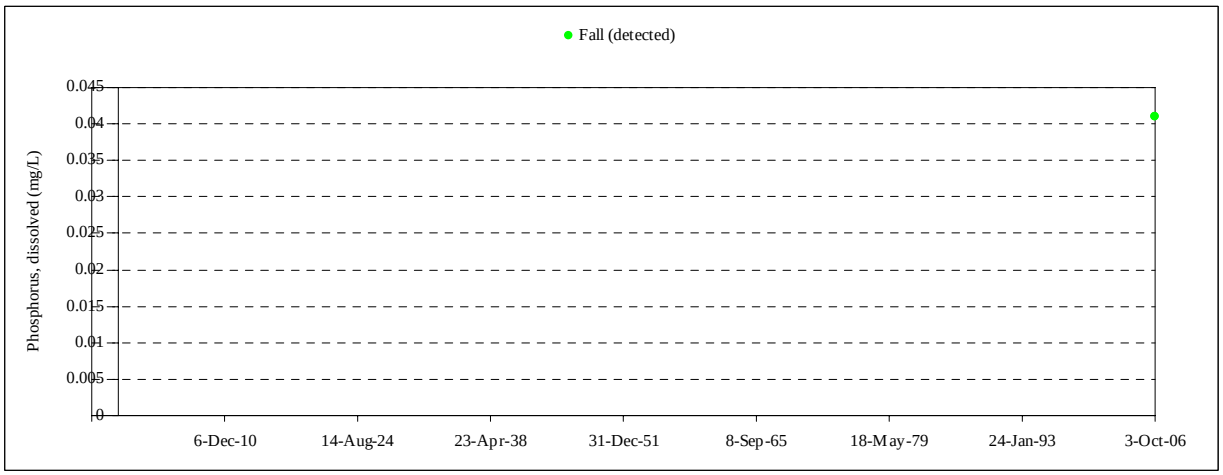
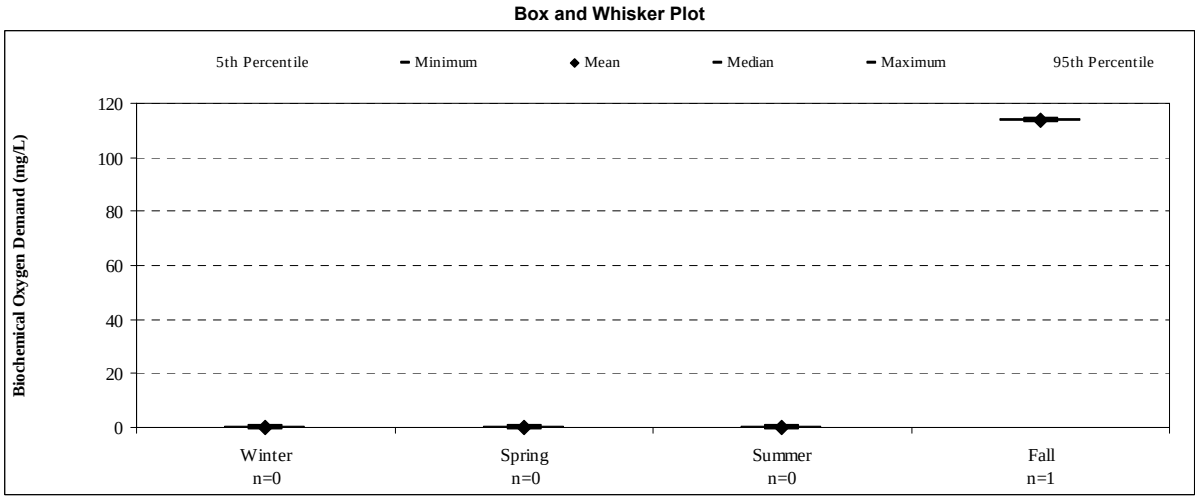


Figure G-1-7-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in McClelland Lake Outlet



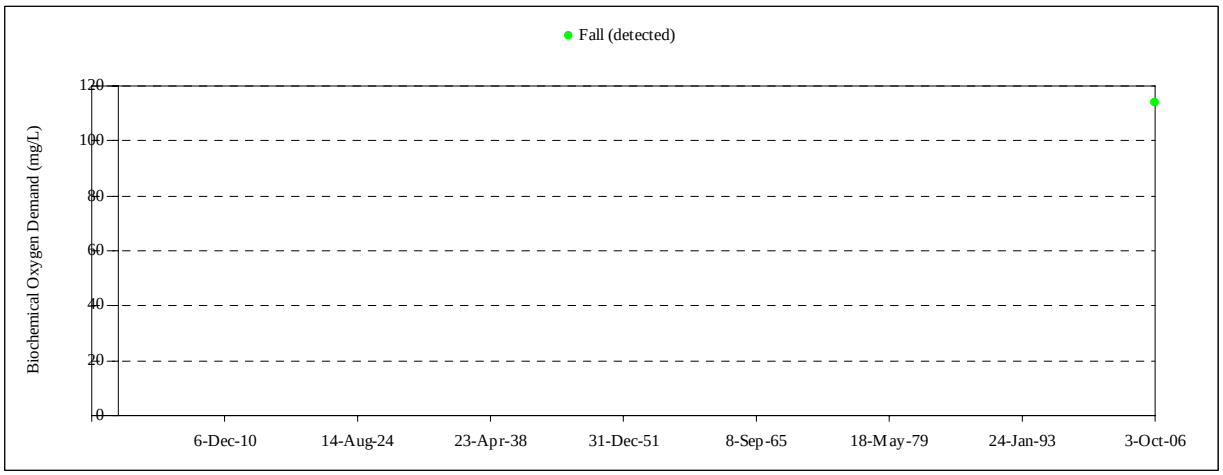
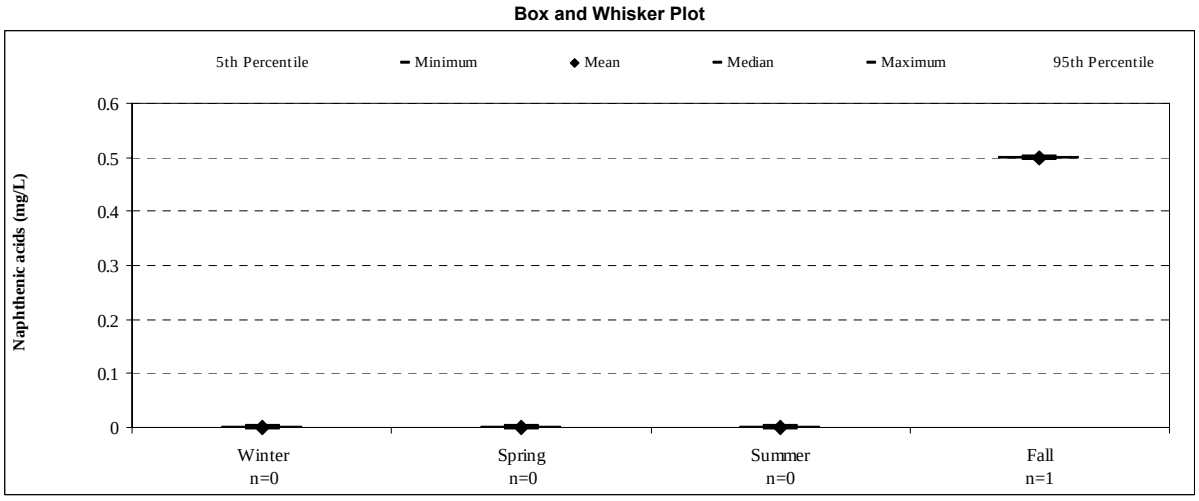


Figure G-1-7-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in McClelland Lake Outlet



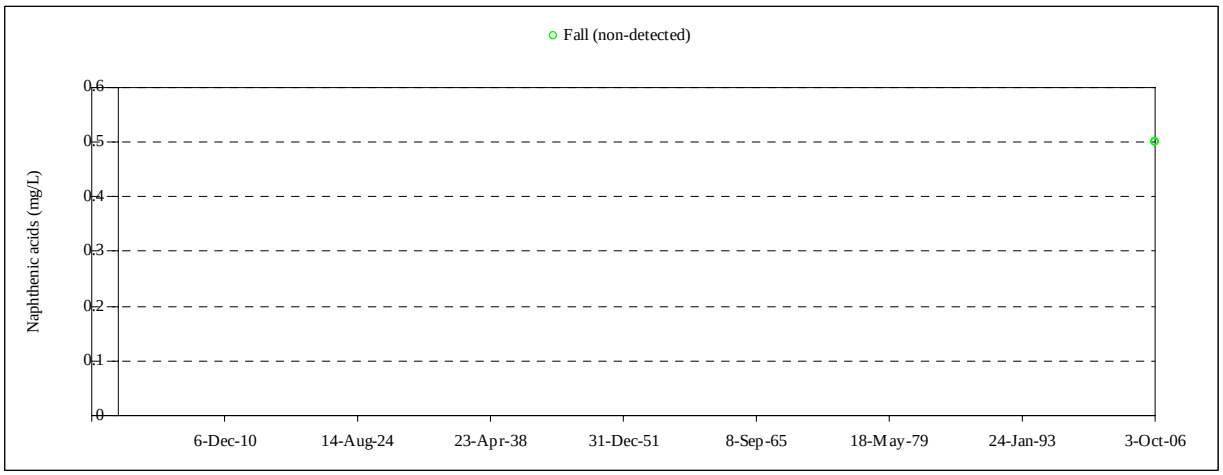
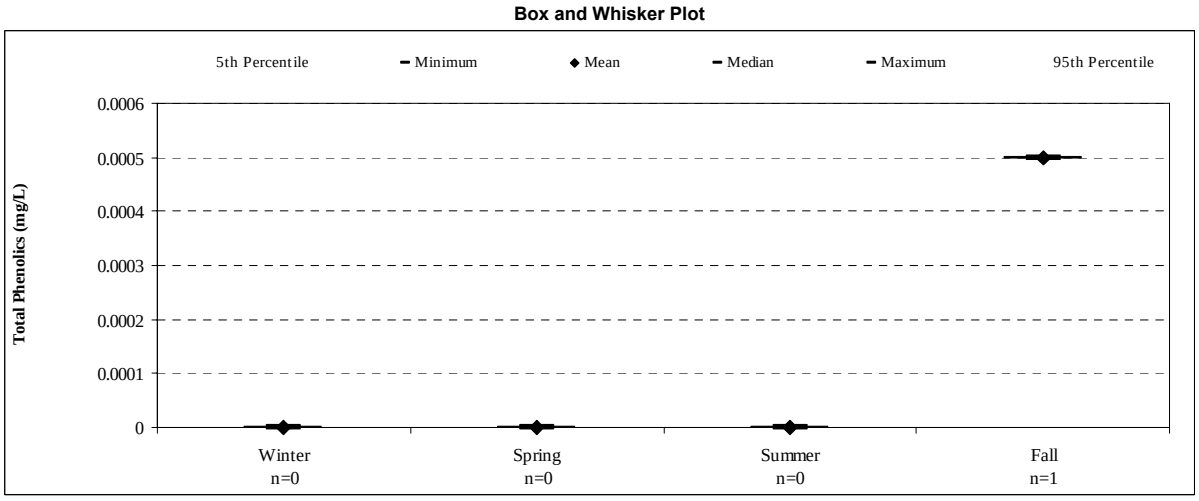


Figure G-1-7-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in McClelland Lake Outlet



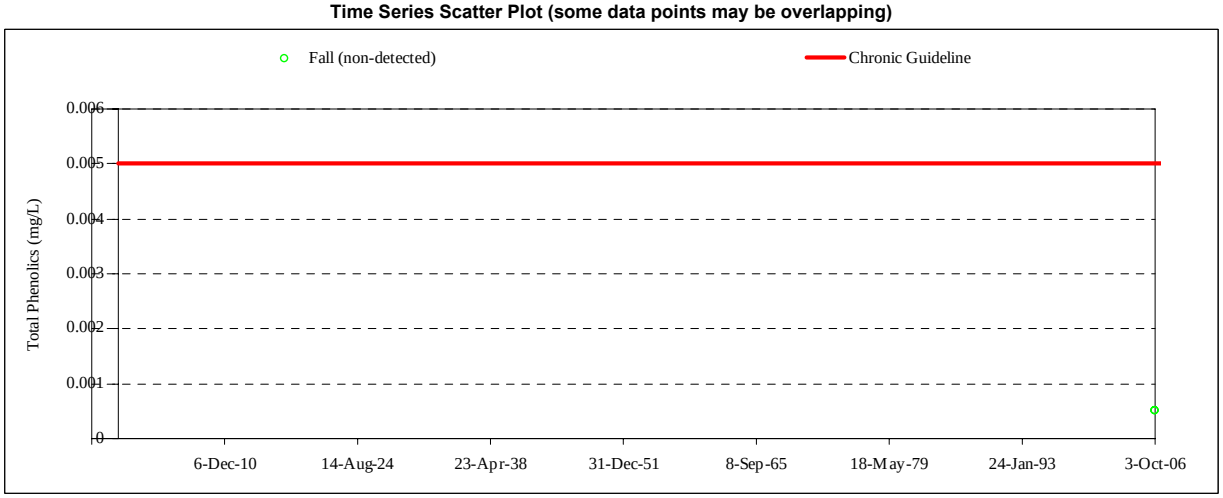
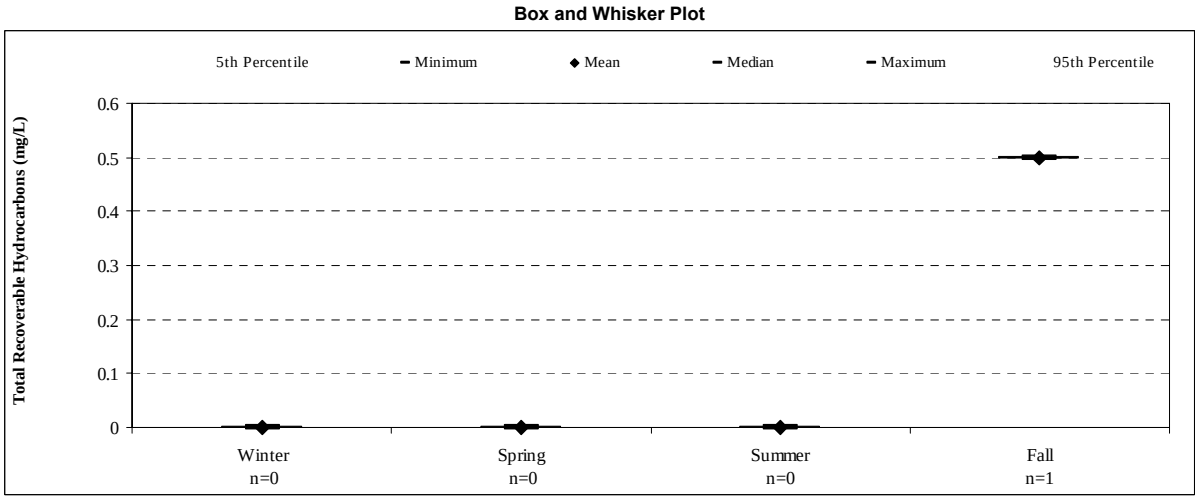


Figure G-1-7-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in McClelland Lake Outlet



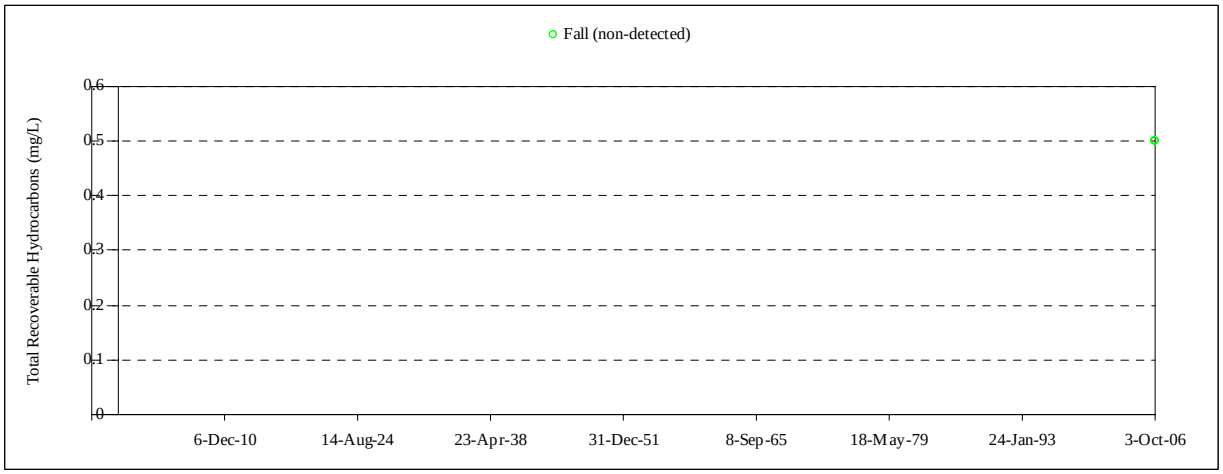
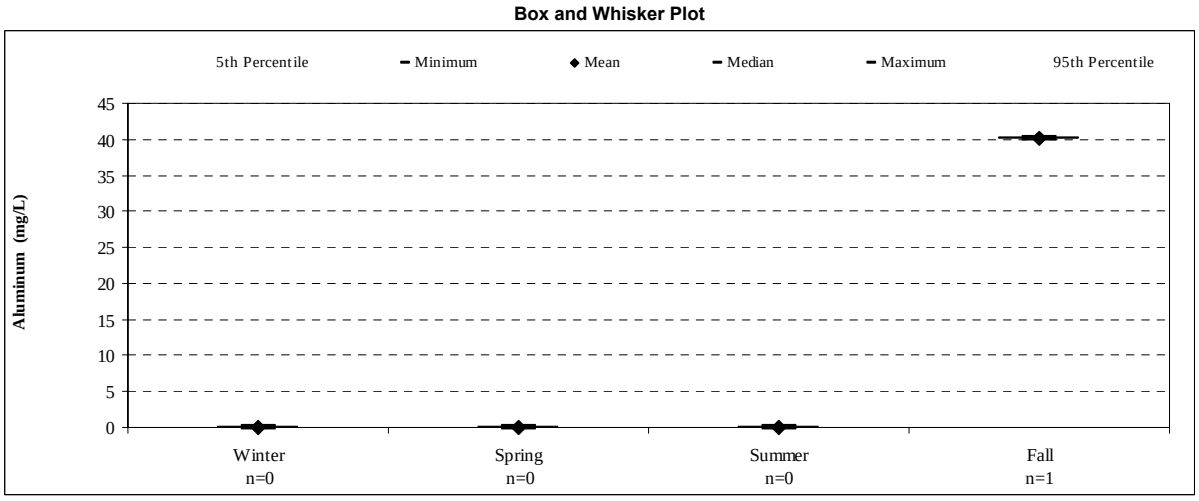


Figure G-1-7-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in McClelland Lake Outlet



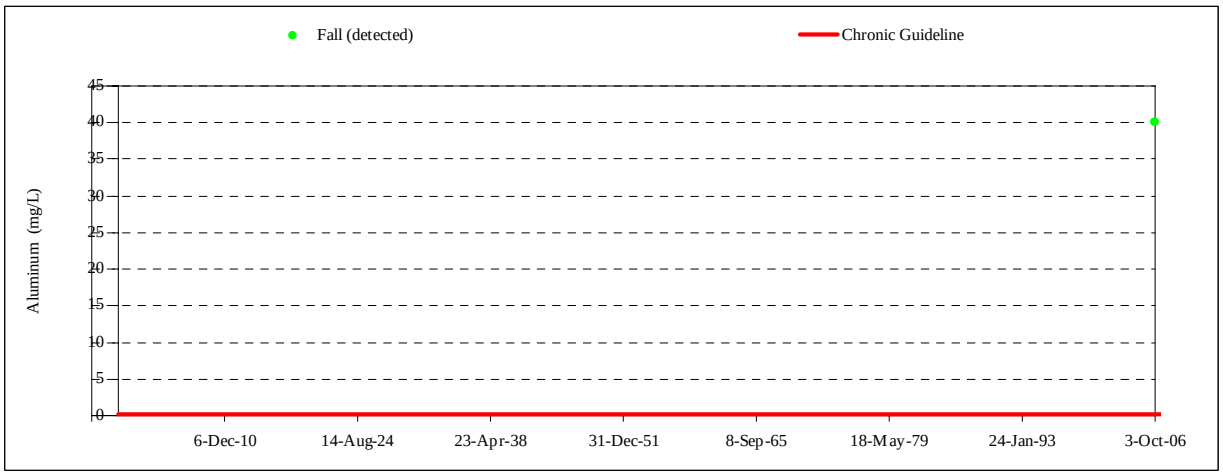
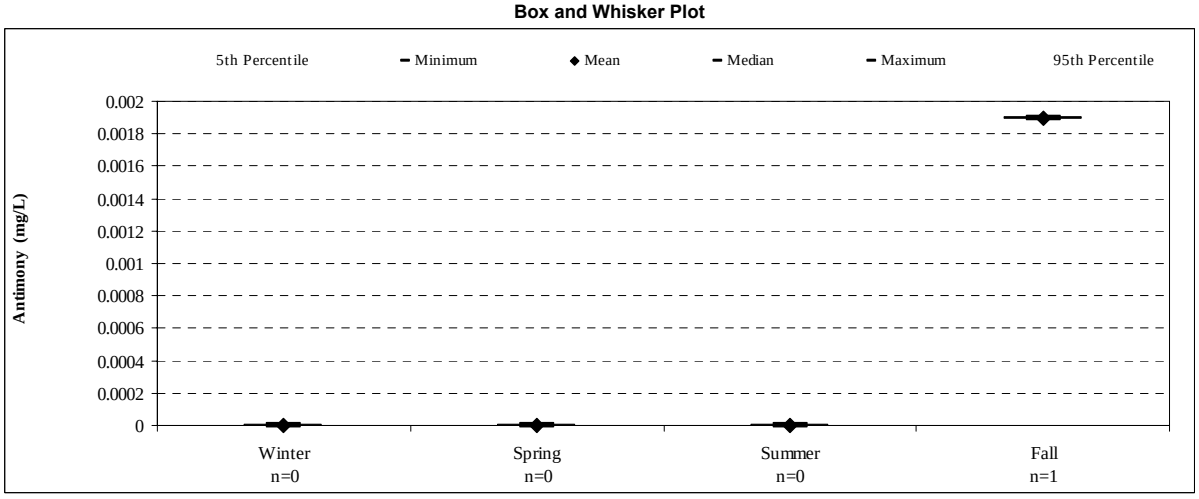


Figure G-1-7-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in McClelland Lake Outlet



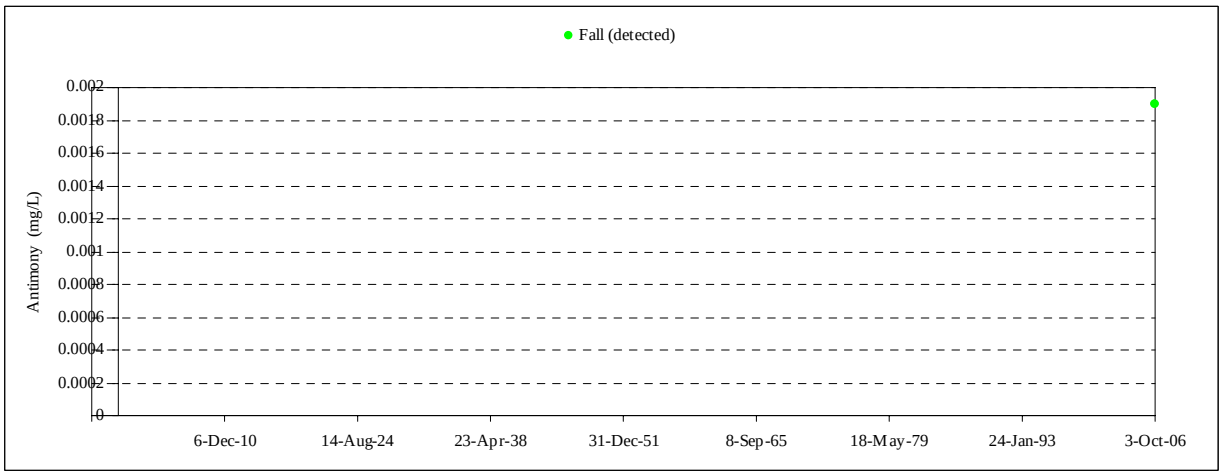
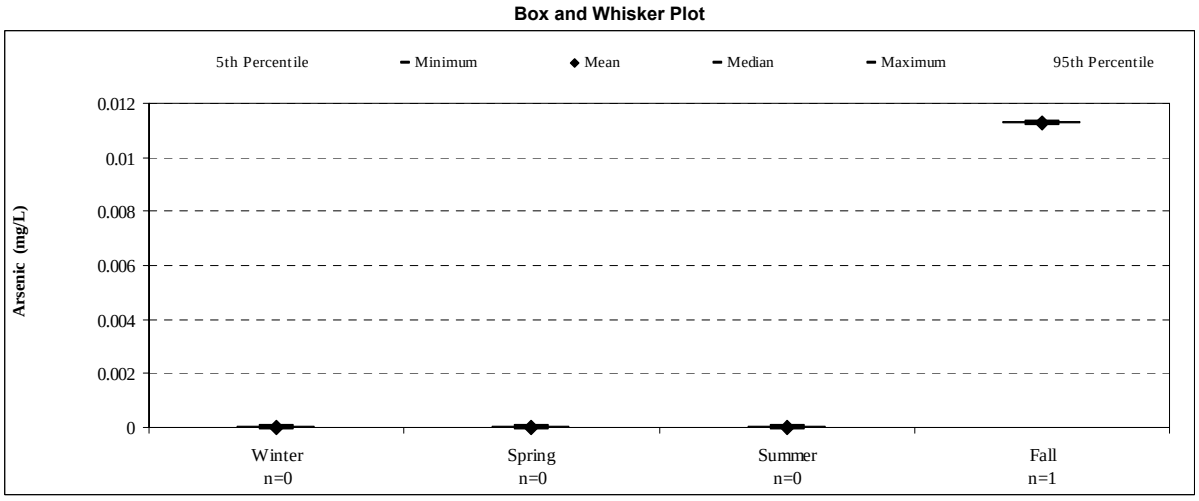


Figure G-1-7-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in McClelland Lake Outlet



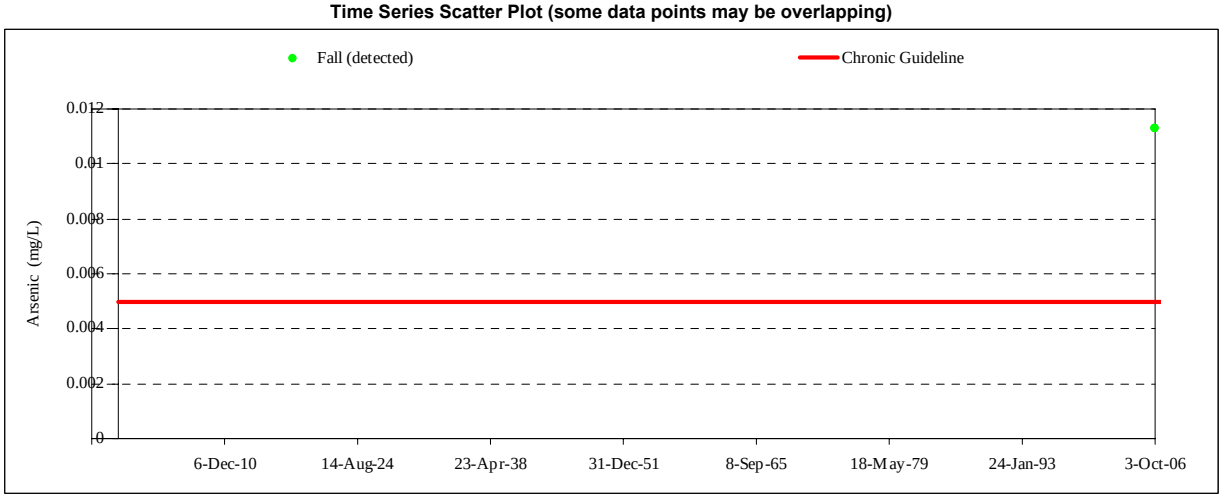
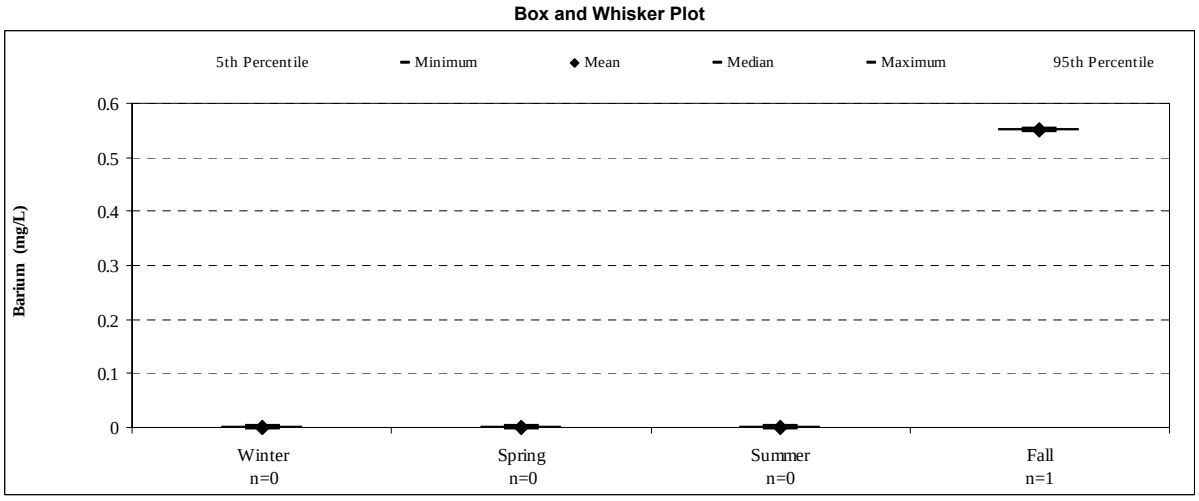


Figure G-1-7-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in McClelland Lake Outlet



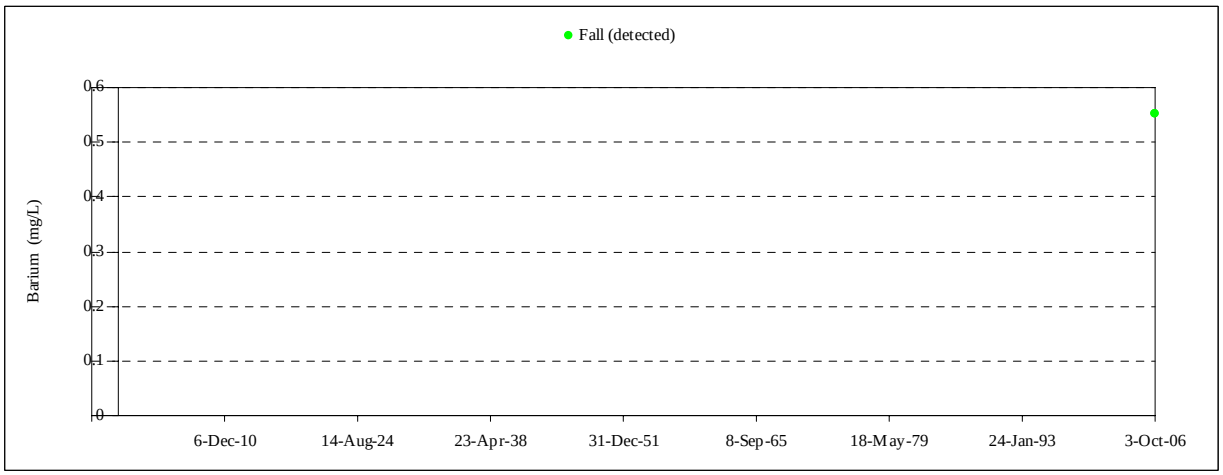
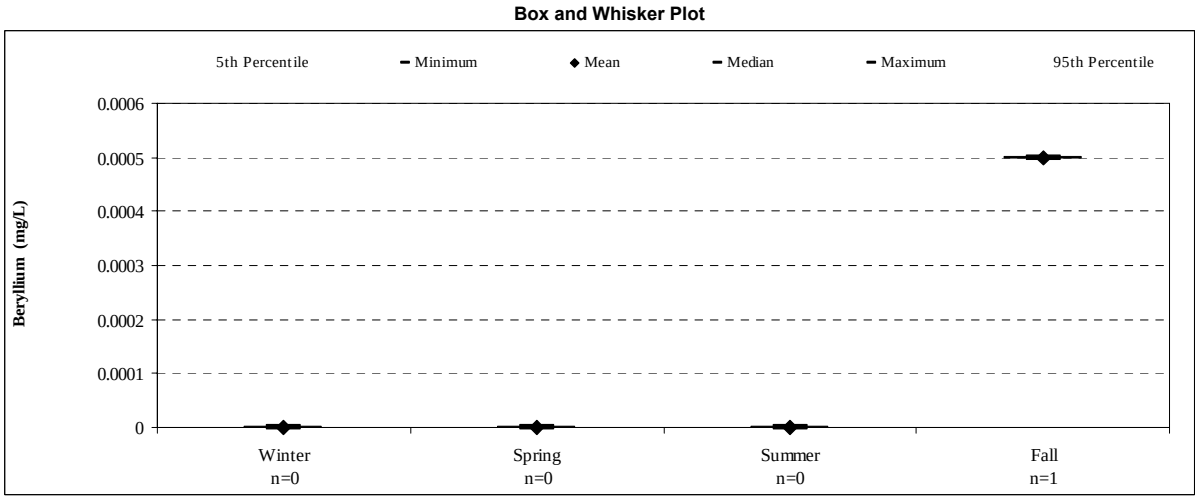


Figure G-1-7-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in McClelland Lake Outlet



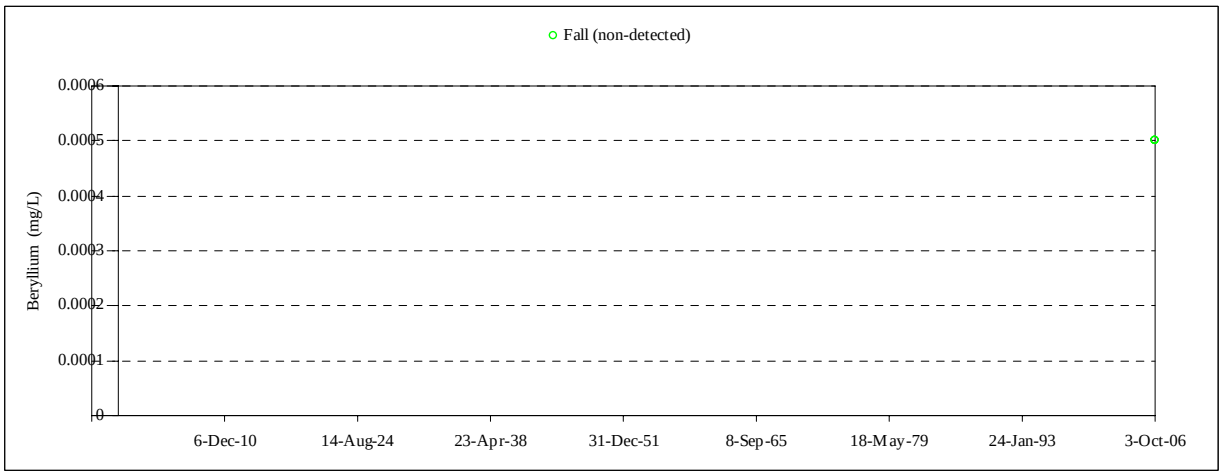
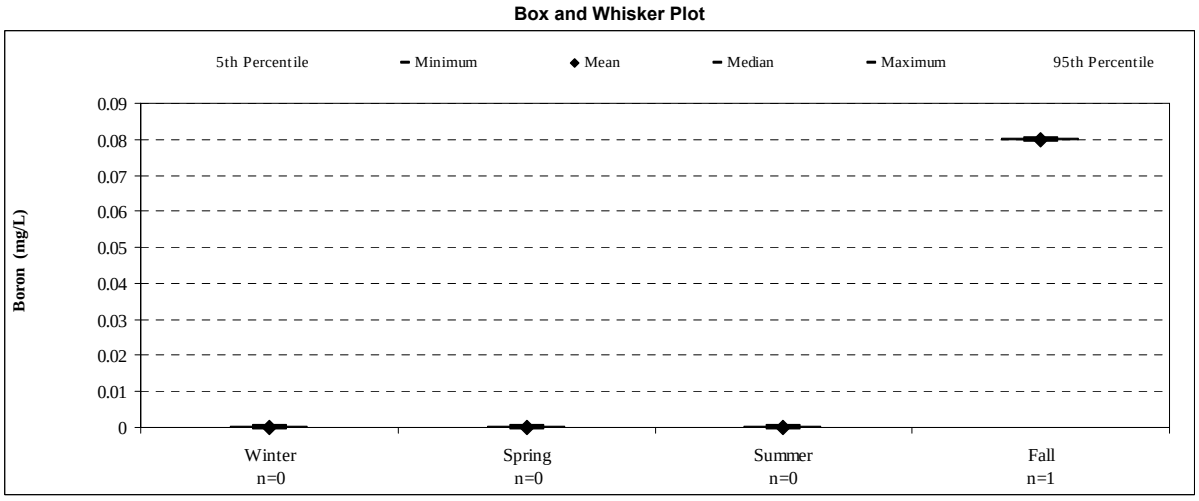


Figure G-1-7-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in McClelland Lake Outlet



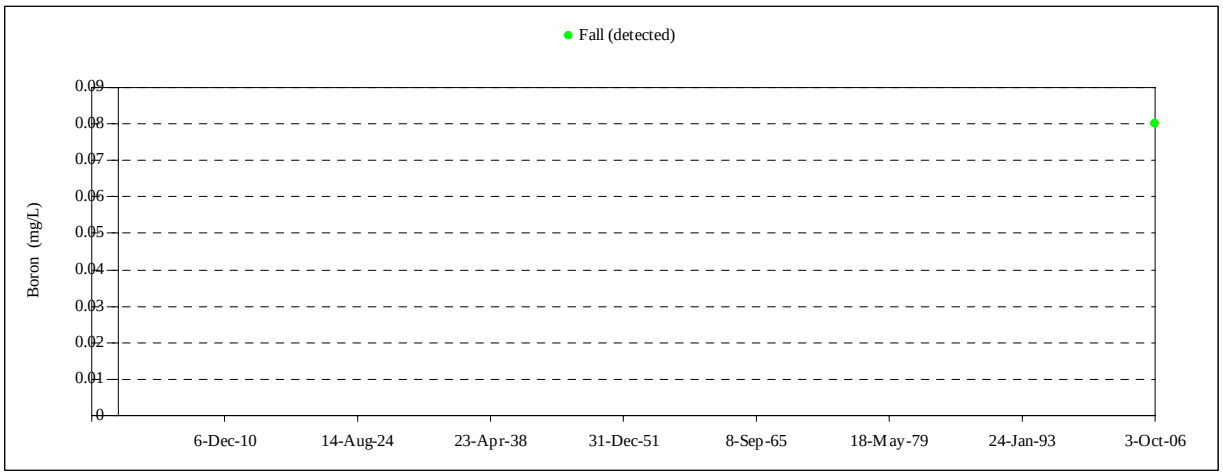
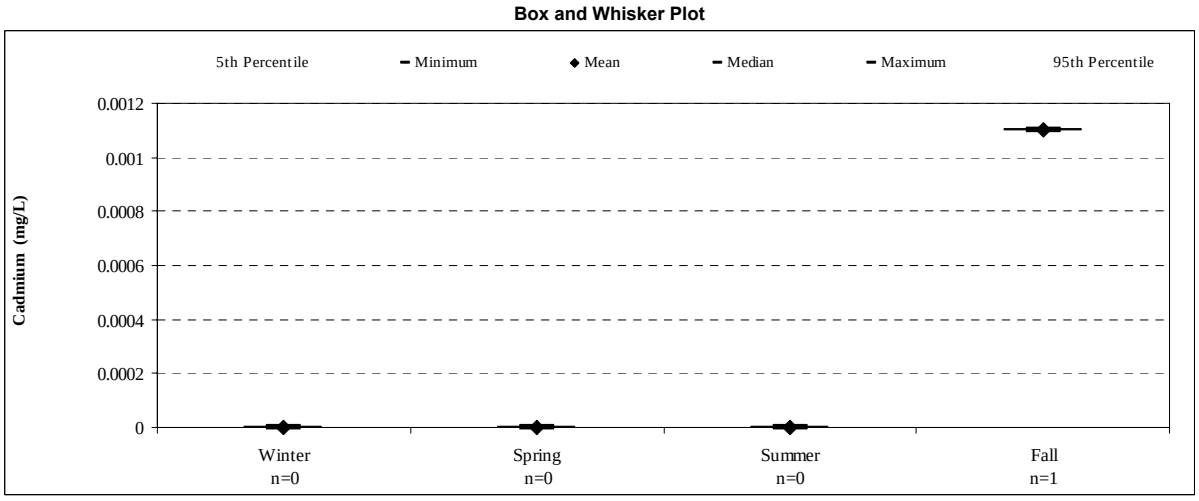


Figure G-1-7-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in McClelland Lake Outlet



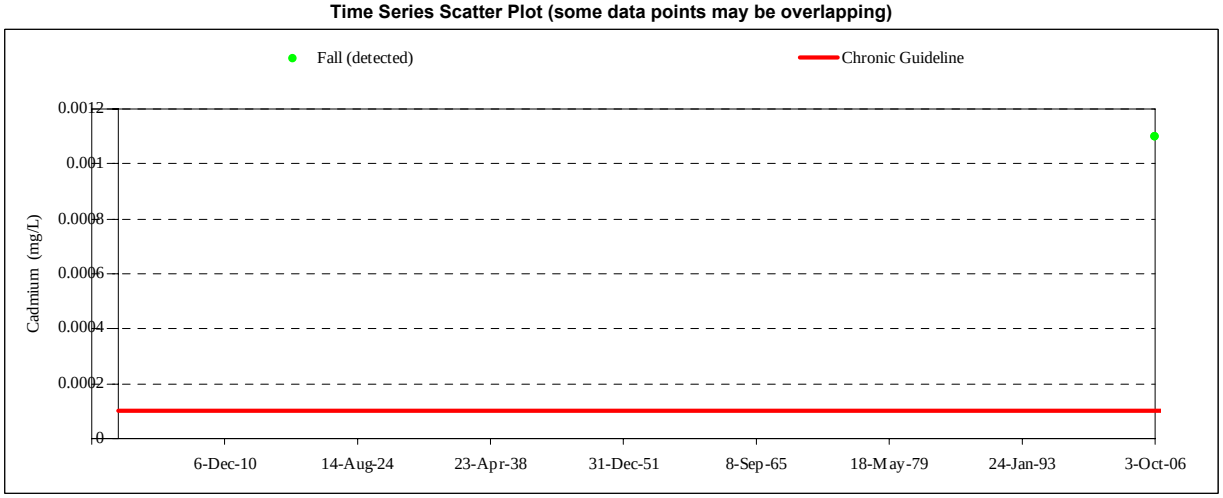
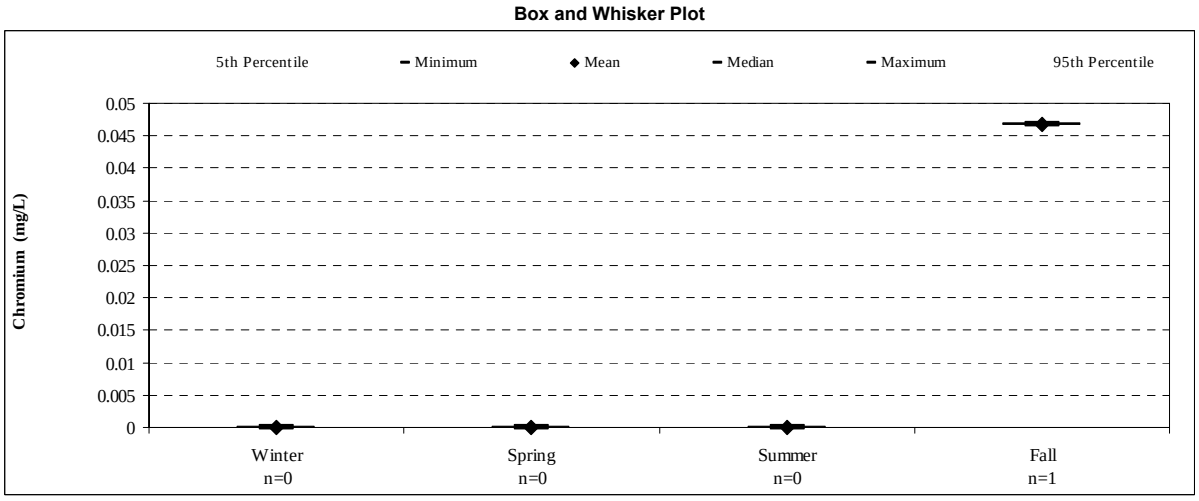


Figure G-1-7-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in McClelland Lake Outlet



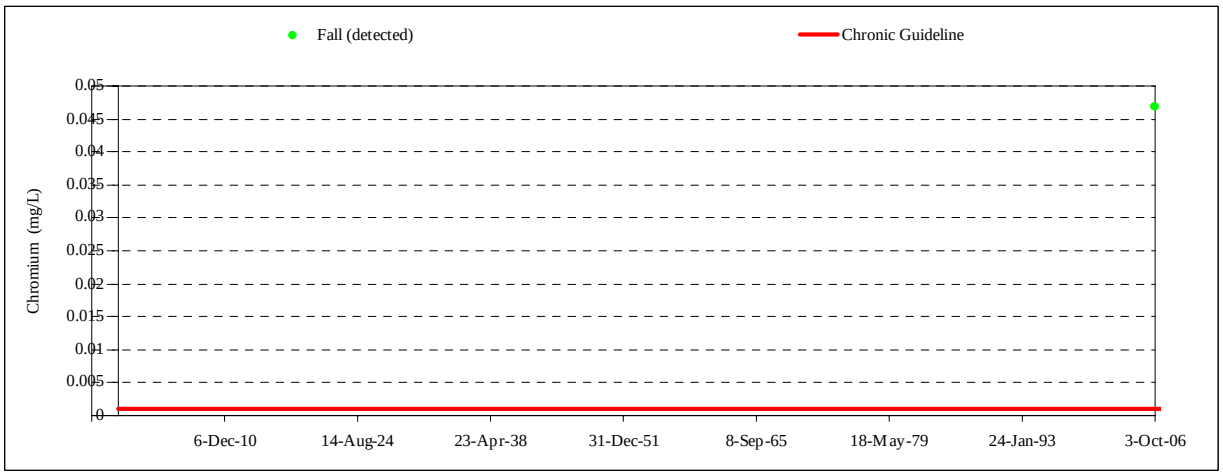
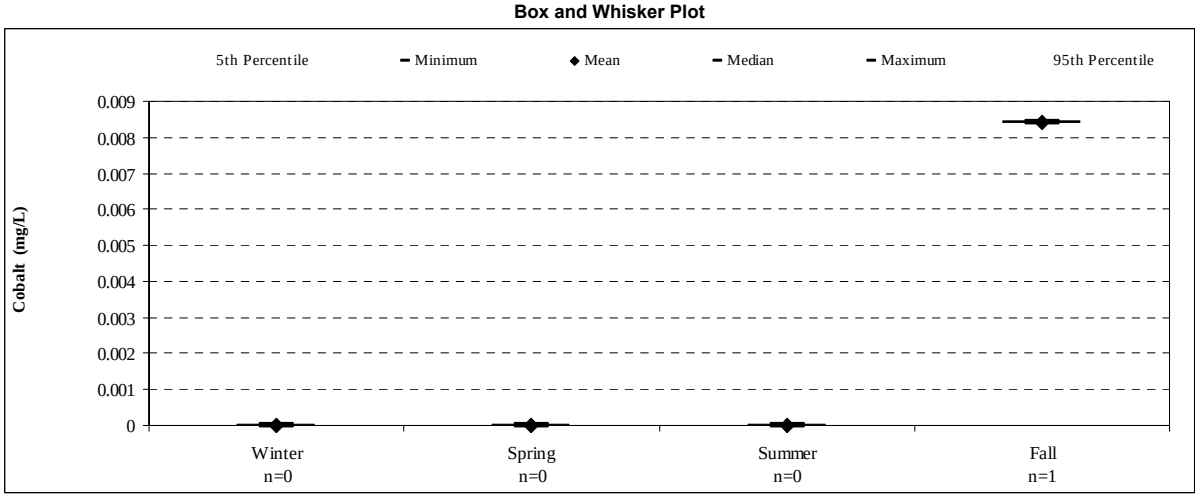


Figure G-1-7-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in McClelland Lake Outlet



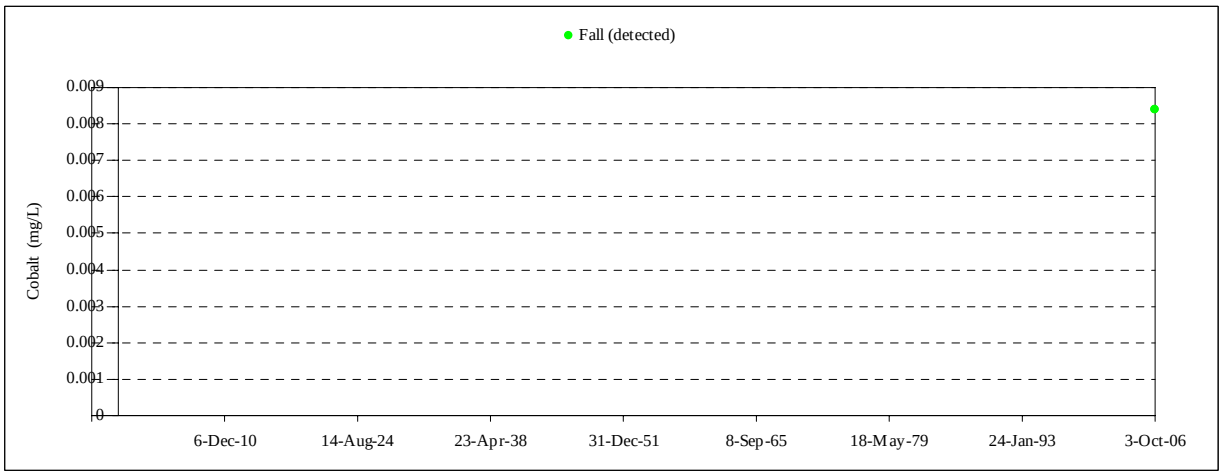
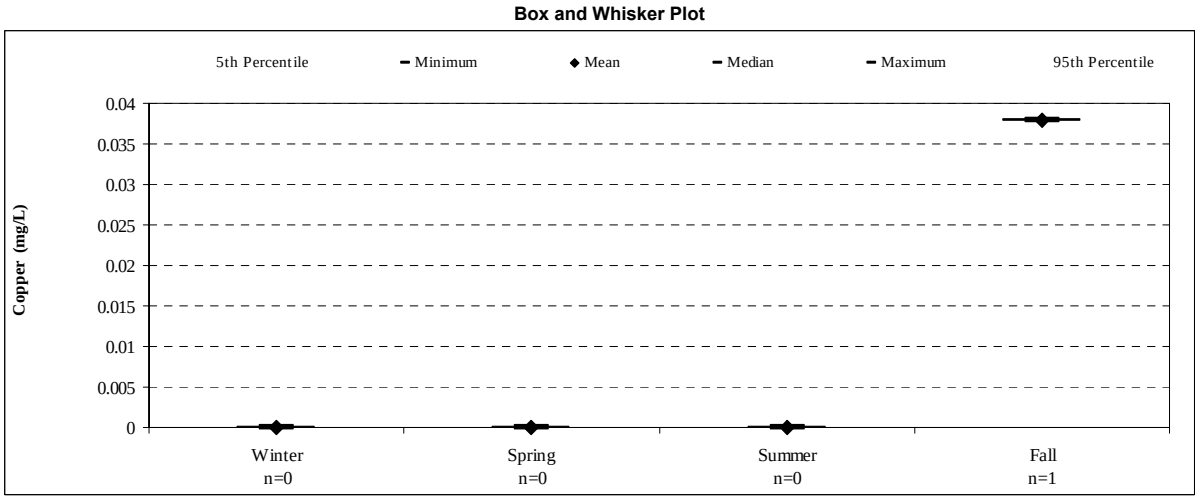


Figure G-1-7-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in McClelland Lake Outlet



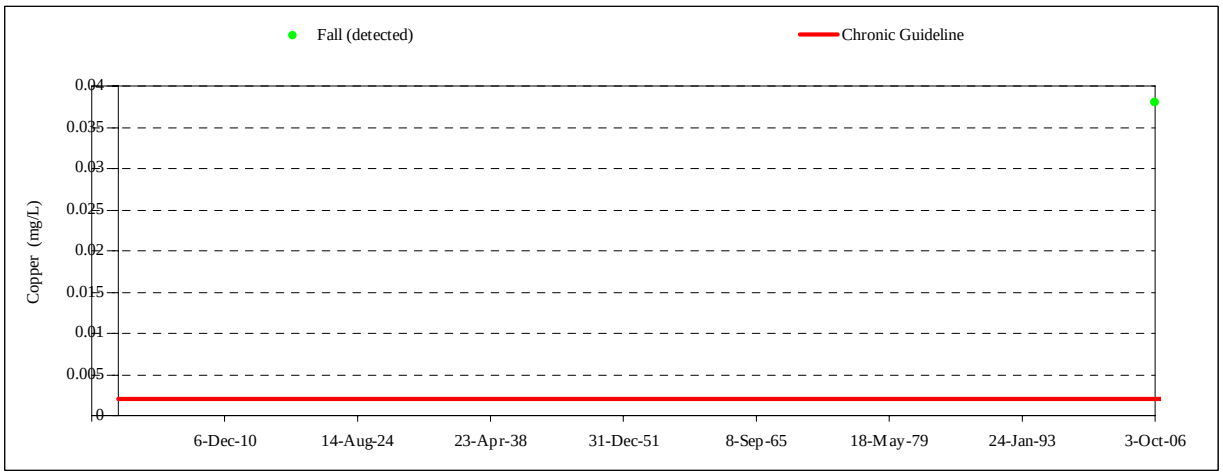
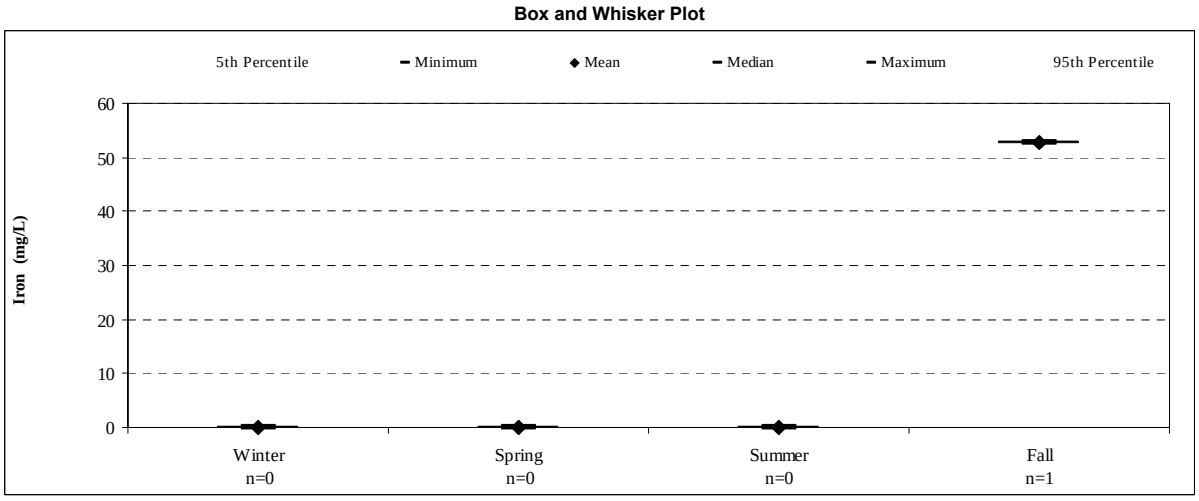


Figure G-1-7-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in McClelland Lake Outlet



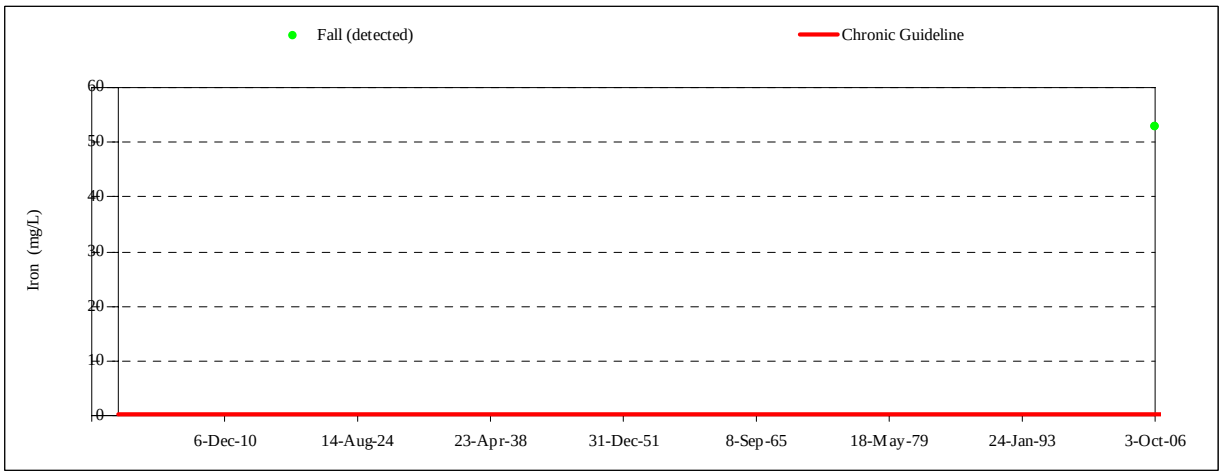
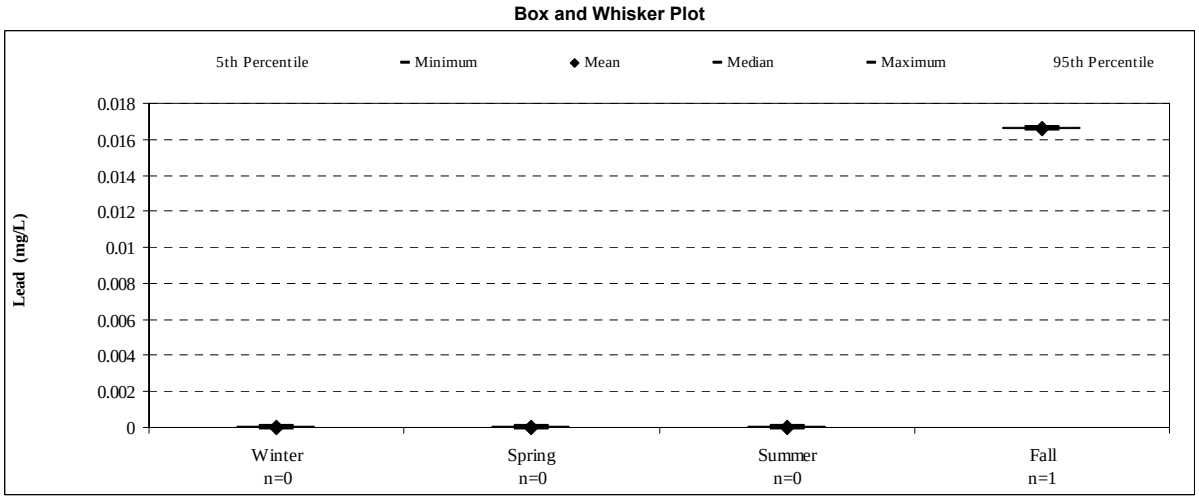


Figure G-1-7-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in McClelland Lake Outlet



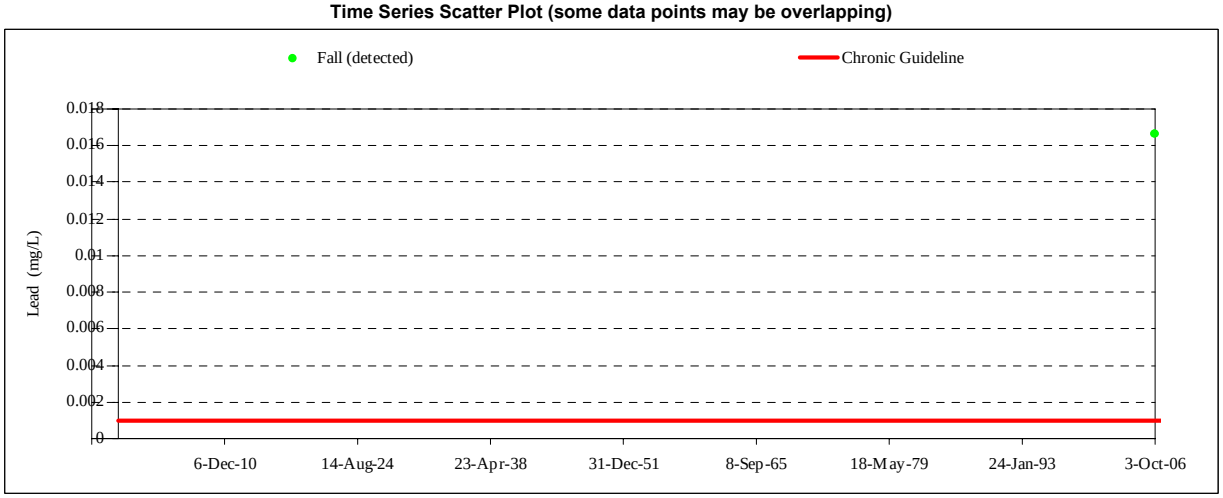
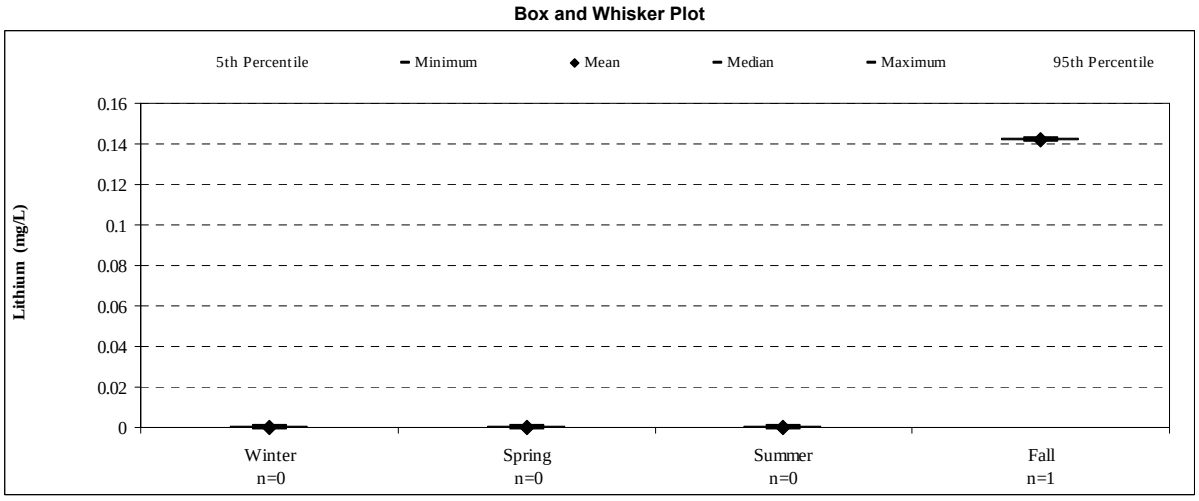


Figure G-1-7-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in McClelland Lake Outlet



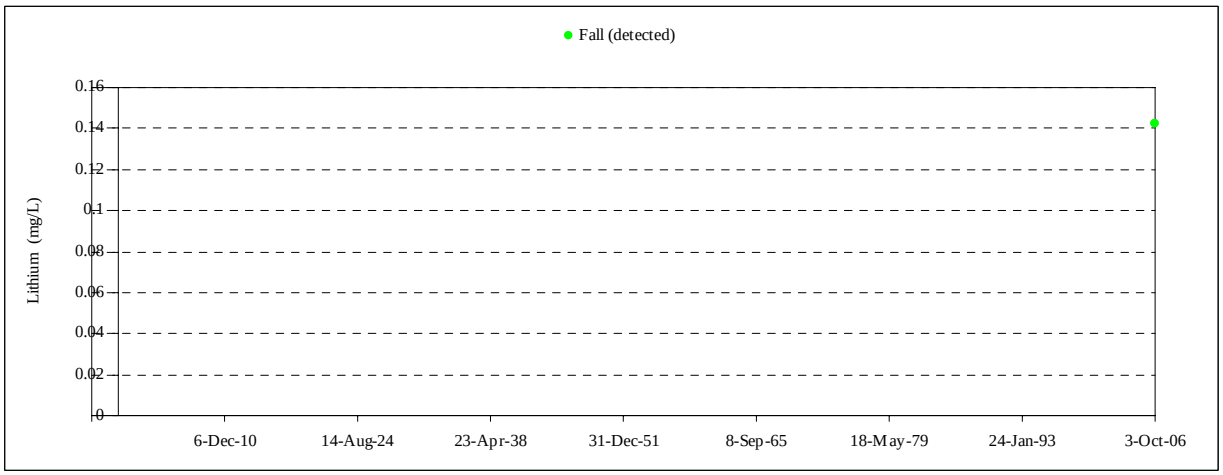
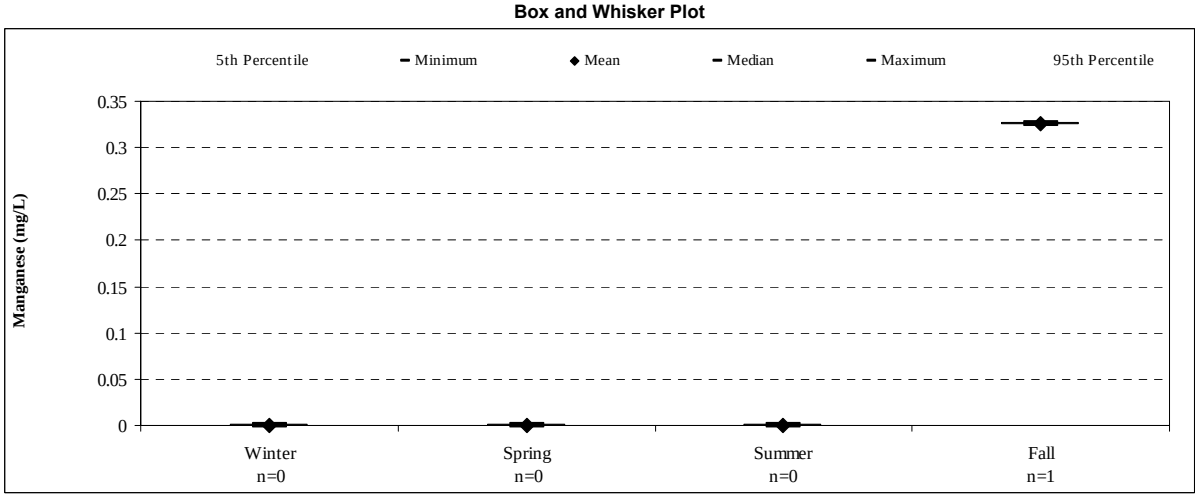


Figure G-1-7-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in McClelland Lake Outlet



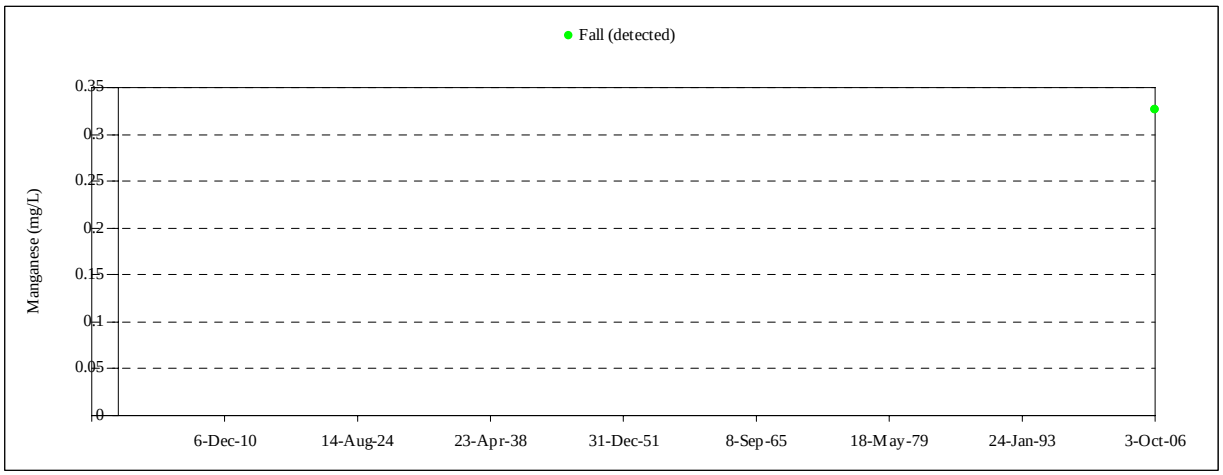
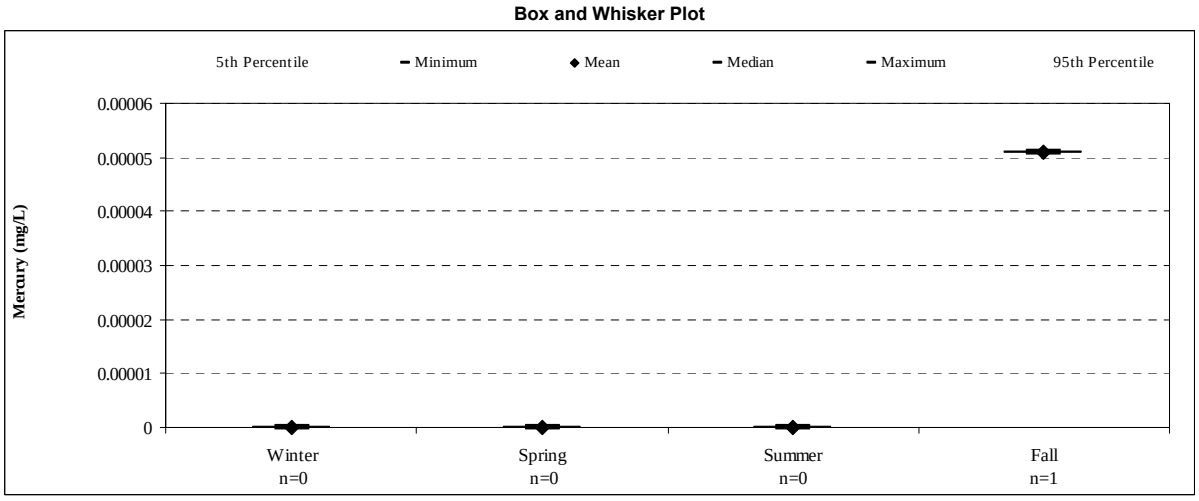


Figure G-1-7-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in McClelland Lake Outlet



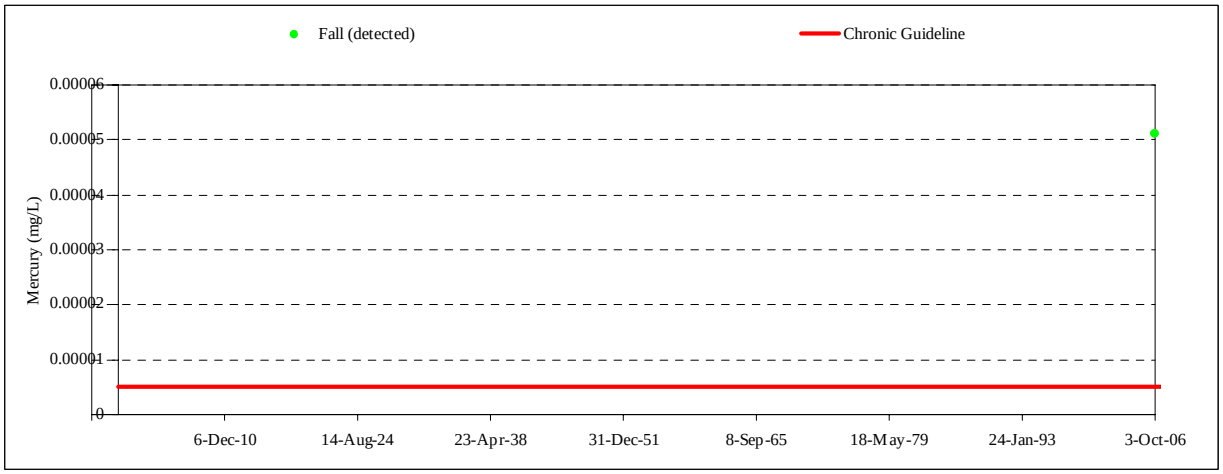
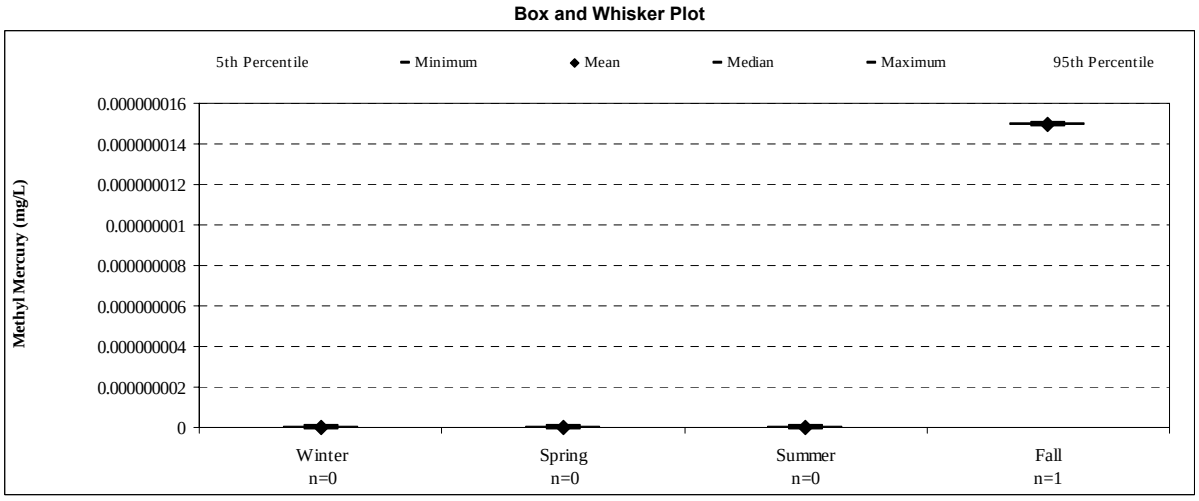


Figure G-1-7-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in McClelland Lake Outlet



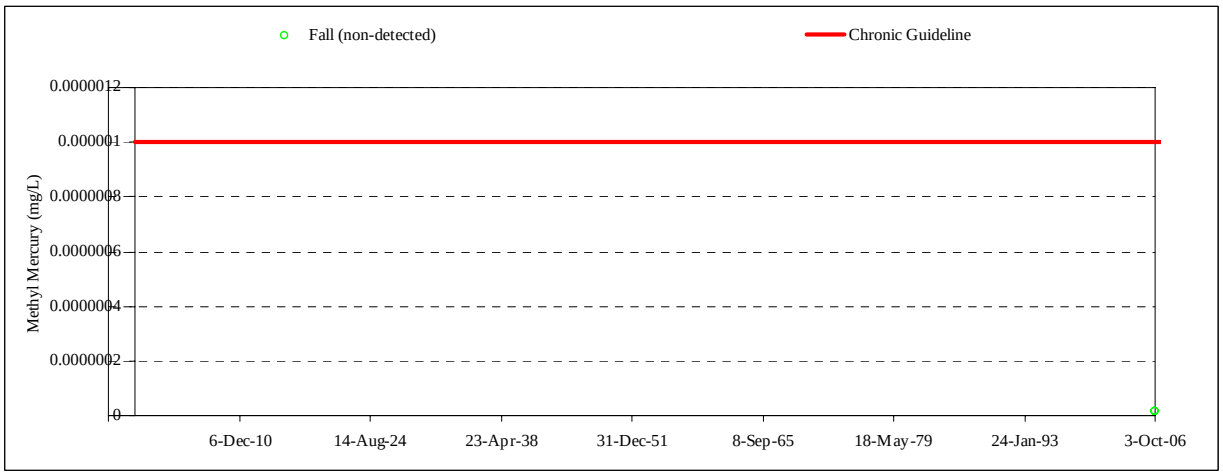
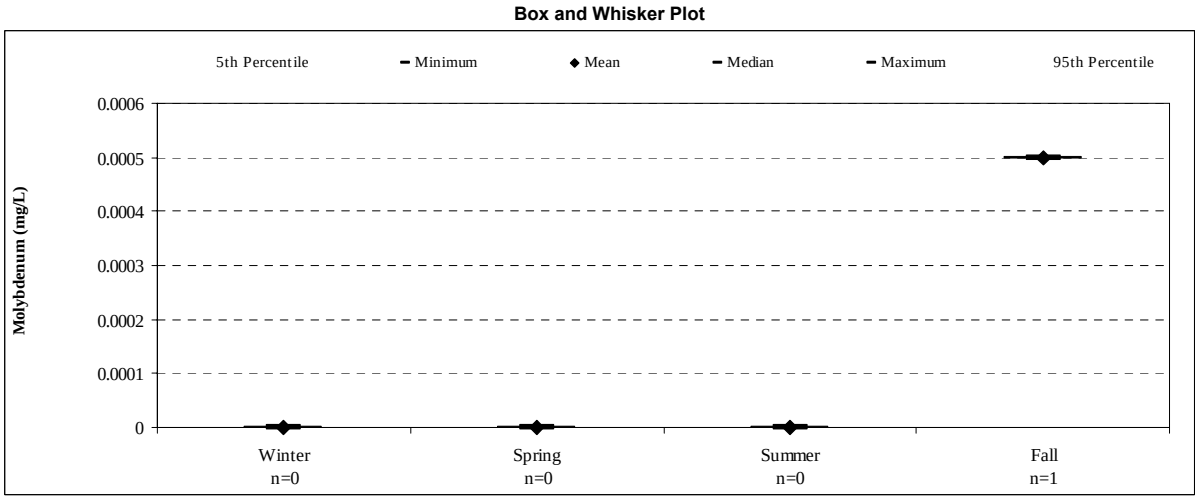


Figure G-1-7-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in McClelland Lake Outlet



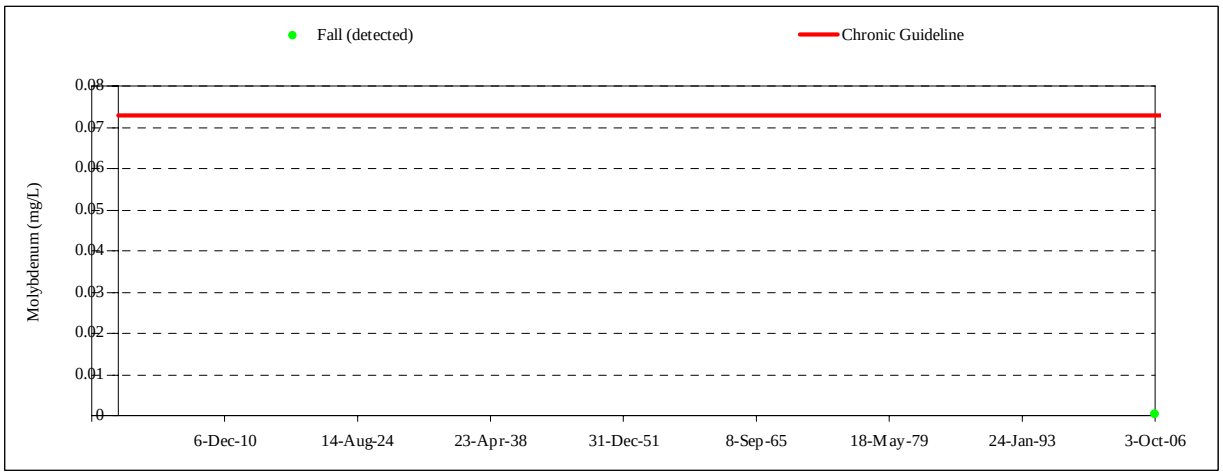
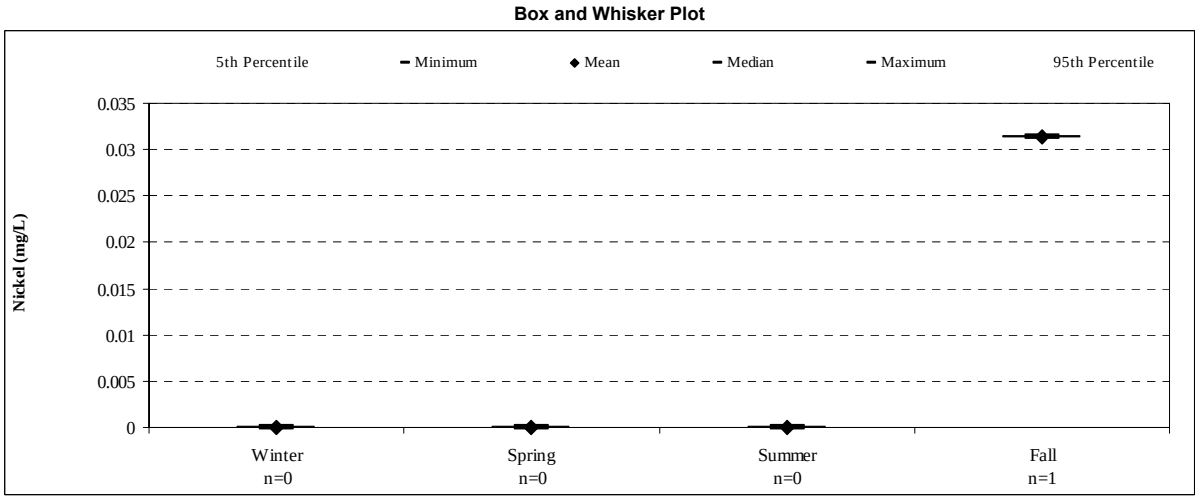


Figure G-1-7-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in McClelland Lake Outlet



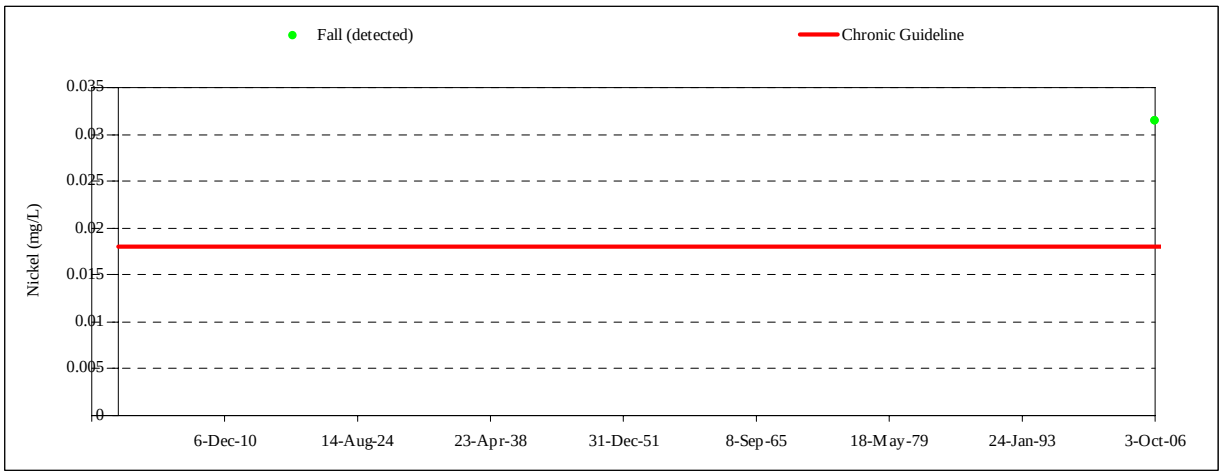
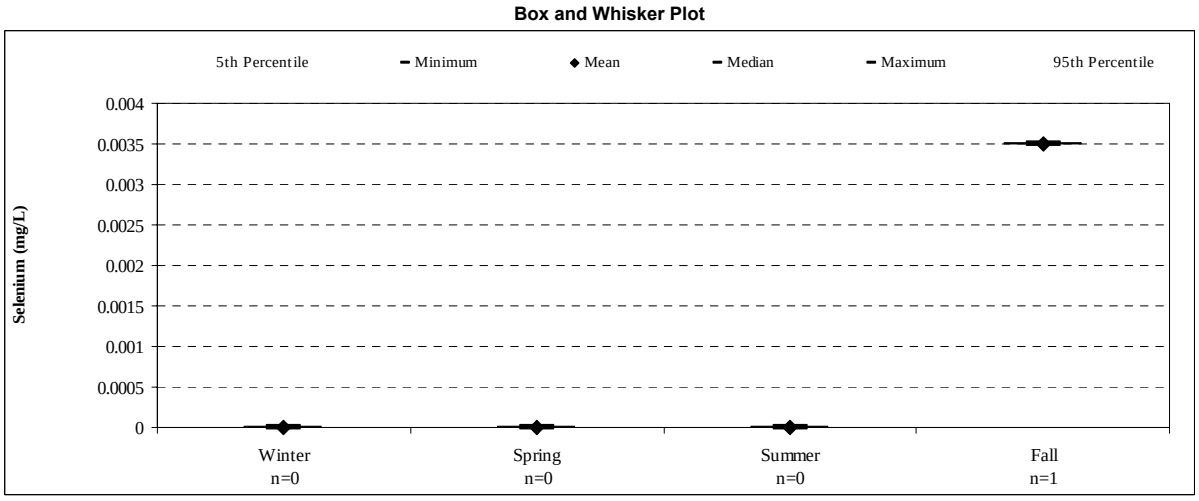


Figure G-1-7-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in McClelland Lake Outlet



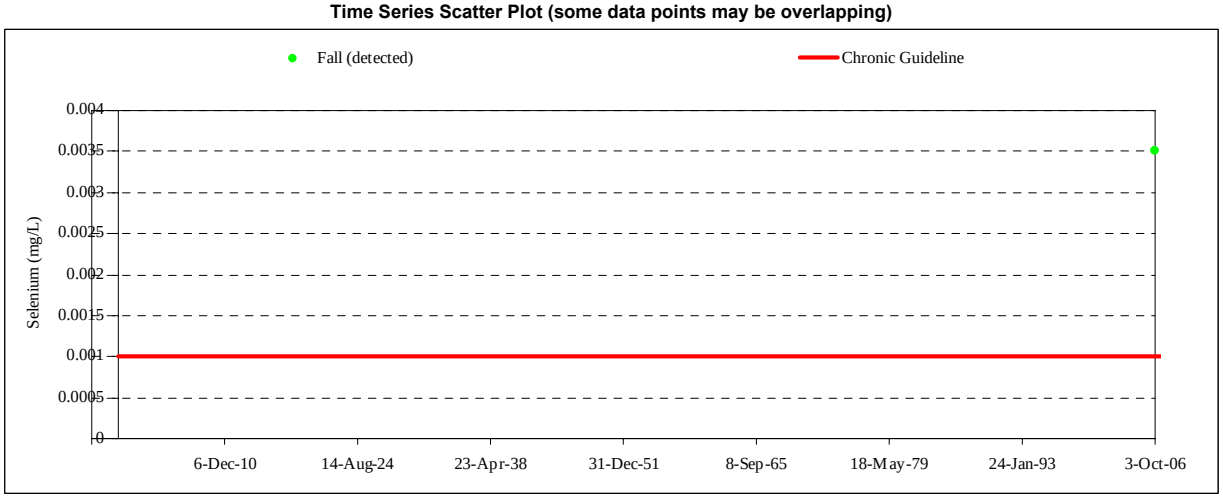
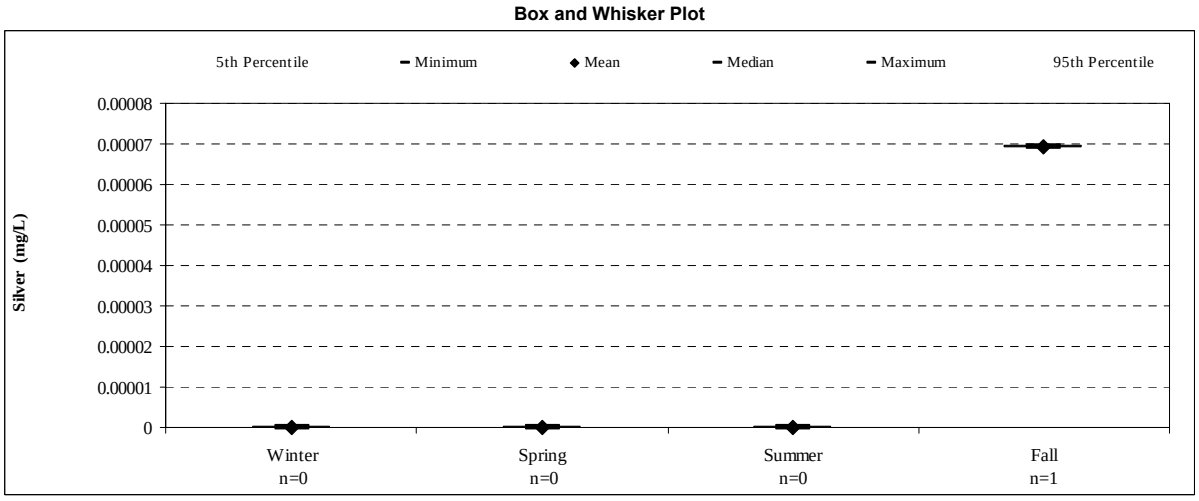


Figure G-1-7-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in McClelland Lake Outlet



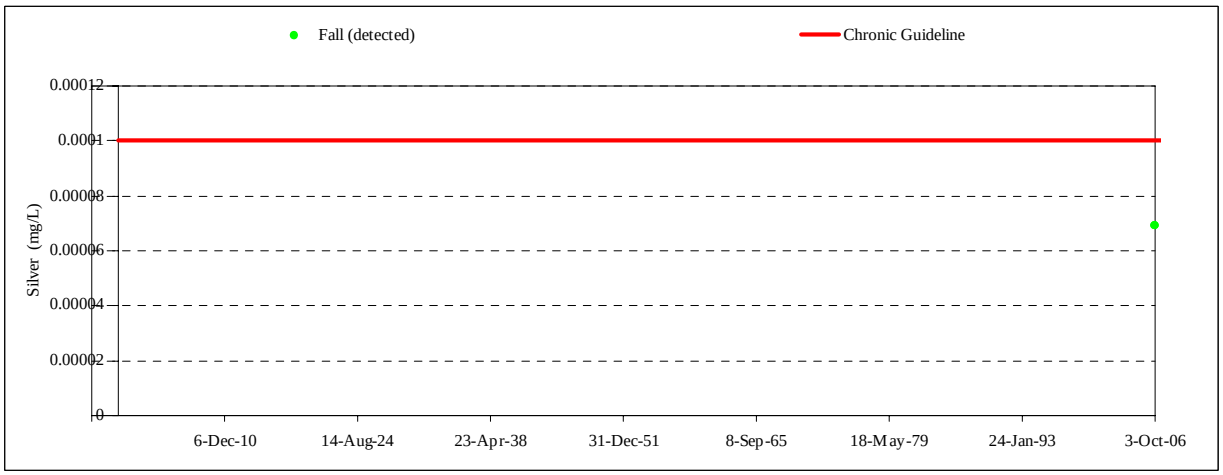
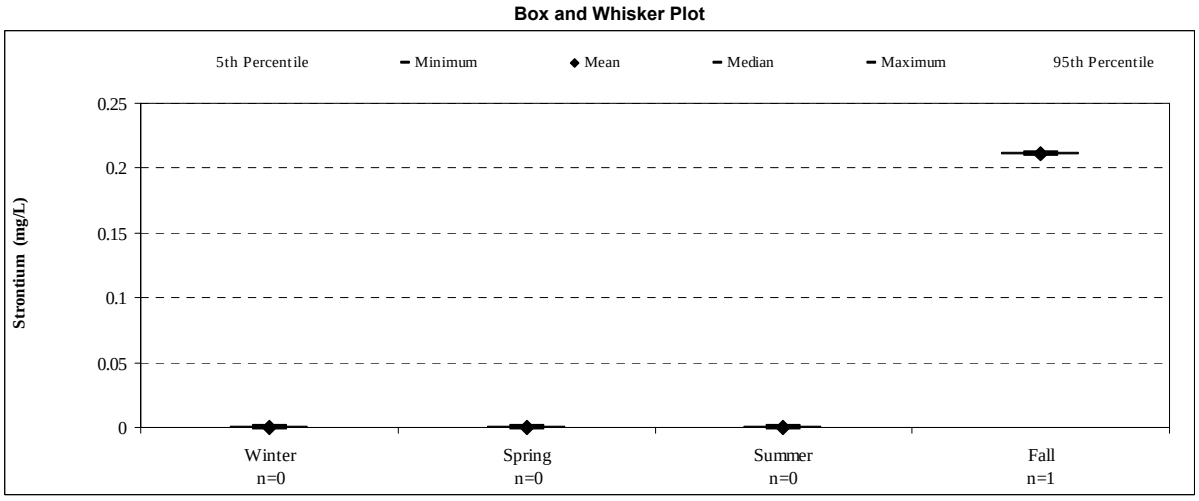


Figure G-1-7-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in McClelland Lake Outlet



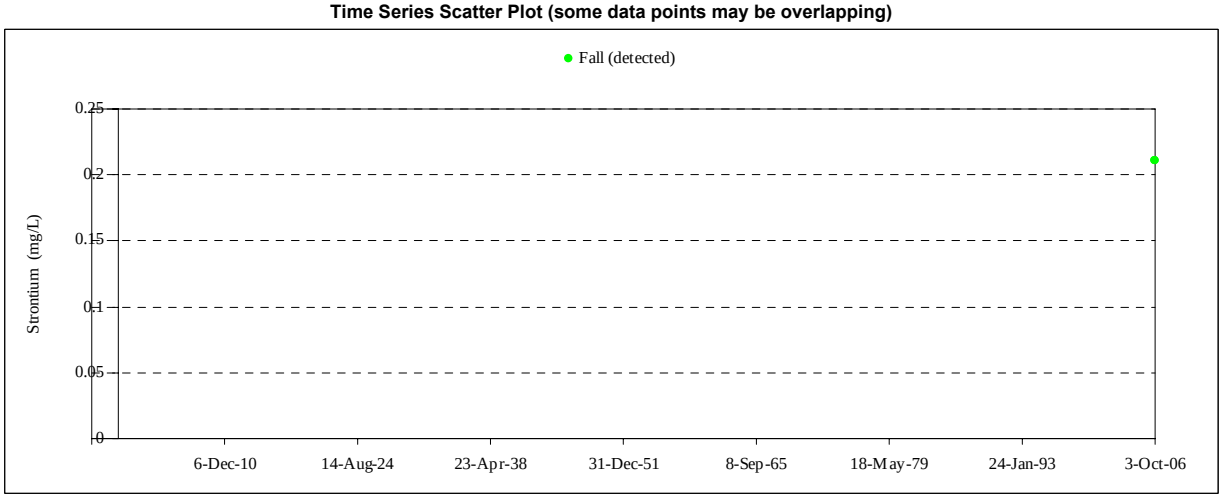
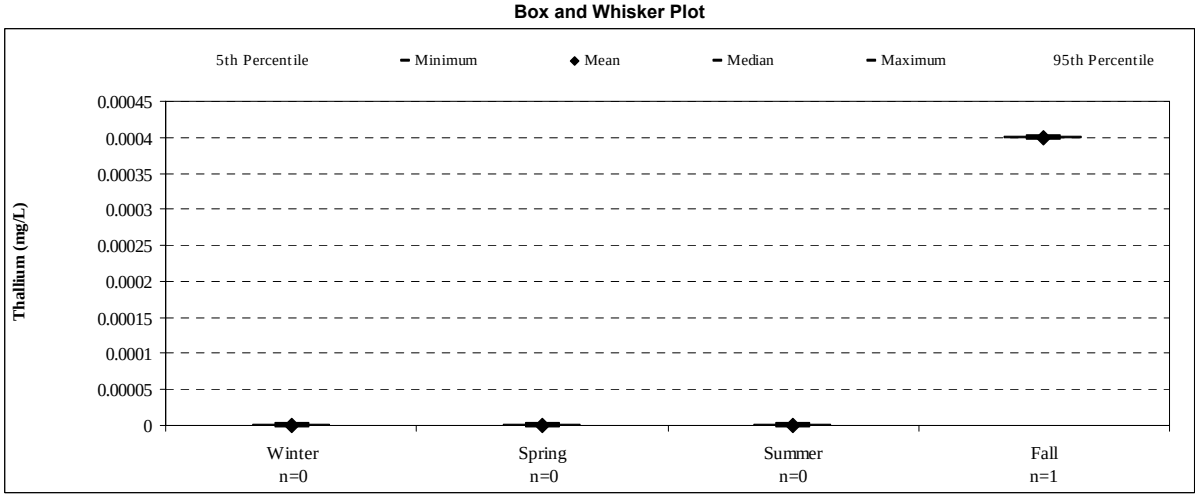


Figure G-1-7-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in McClelland Lake Outlet



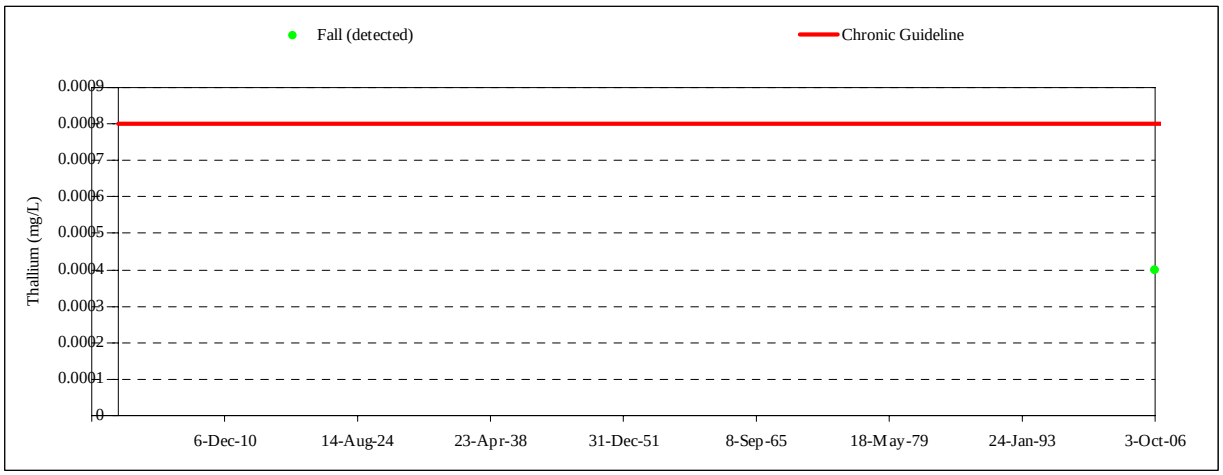
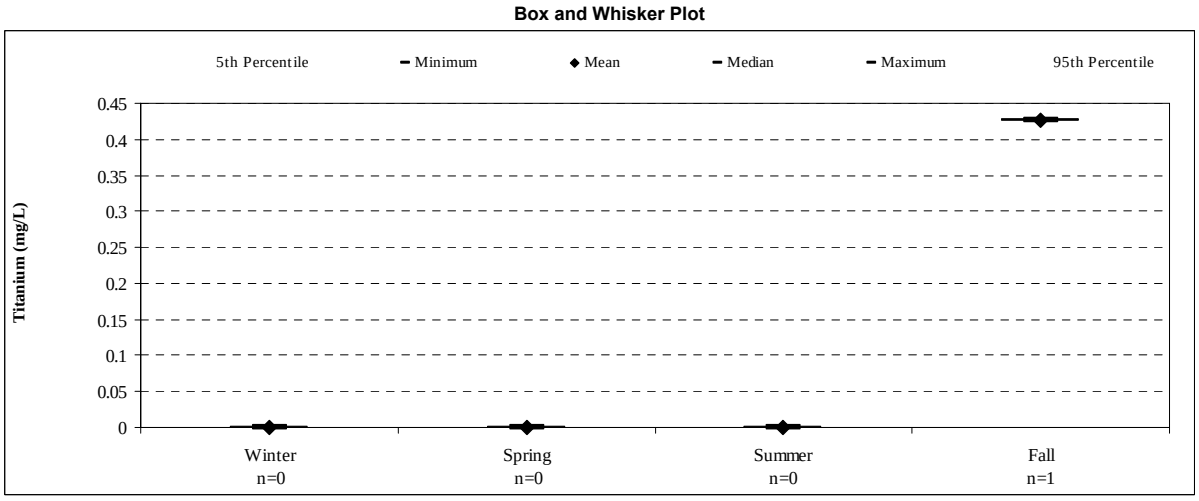


Figure G-1-7-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in McClelland Lake Outlet



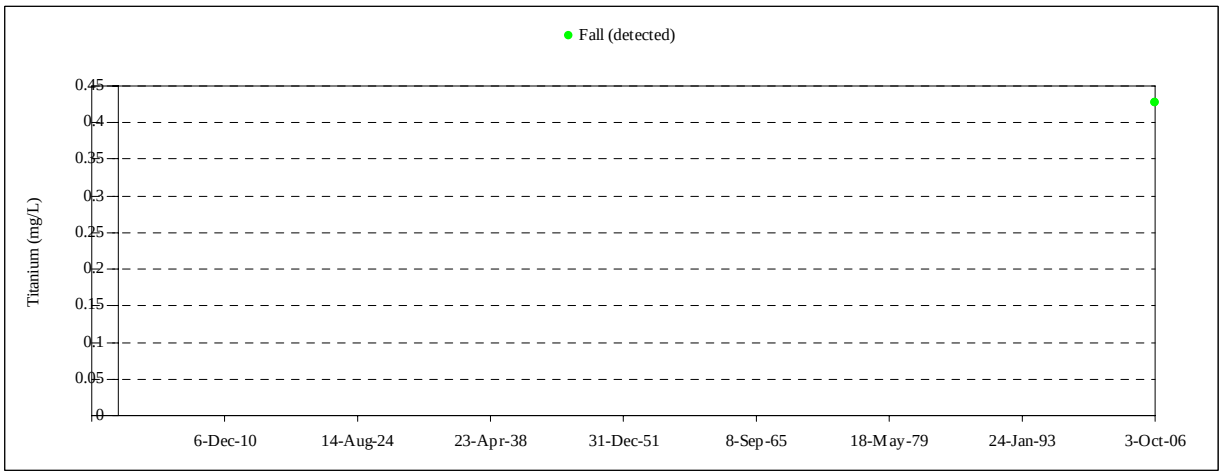
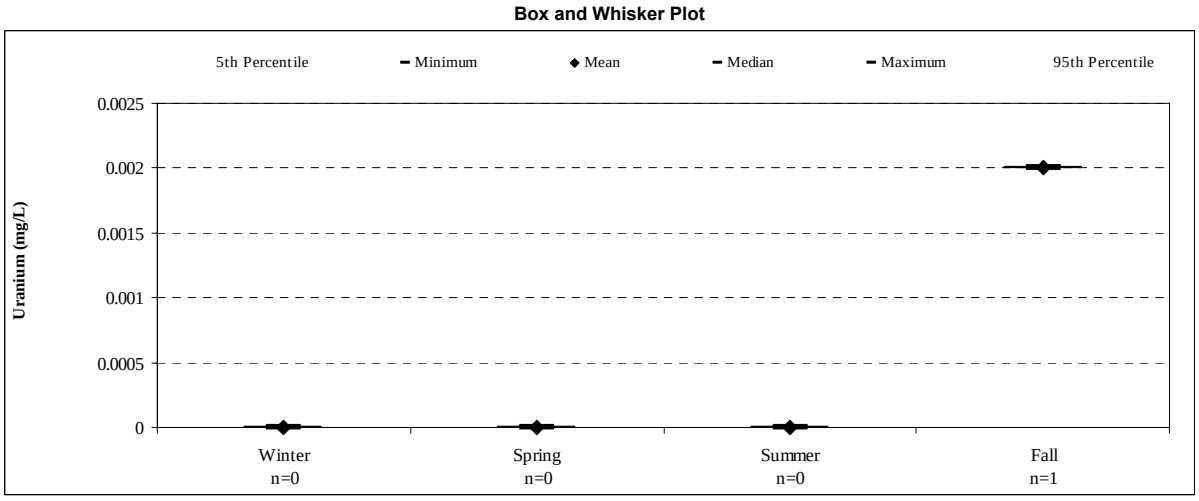


Figure G-1-7-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in McClelland Lake Outlet



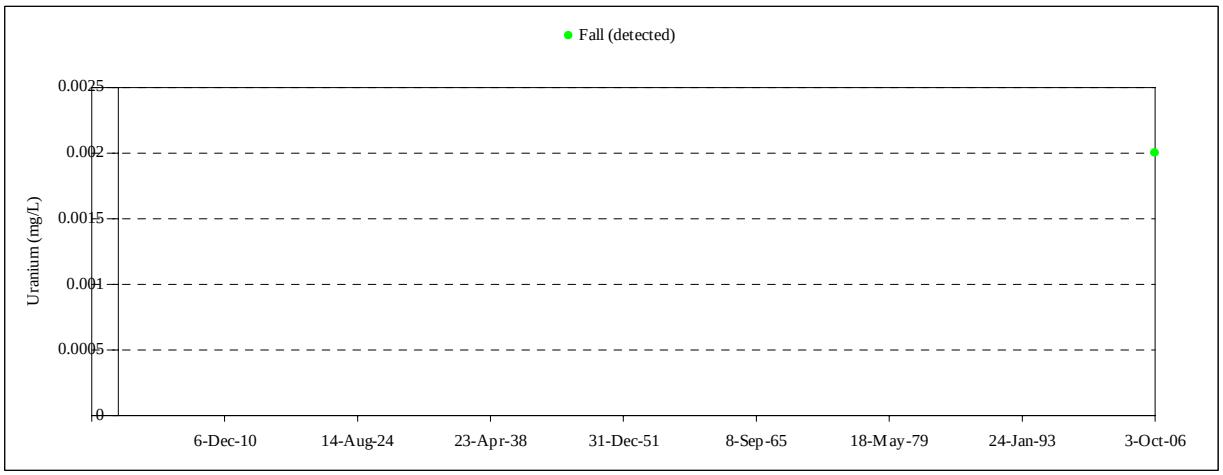
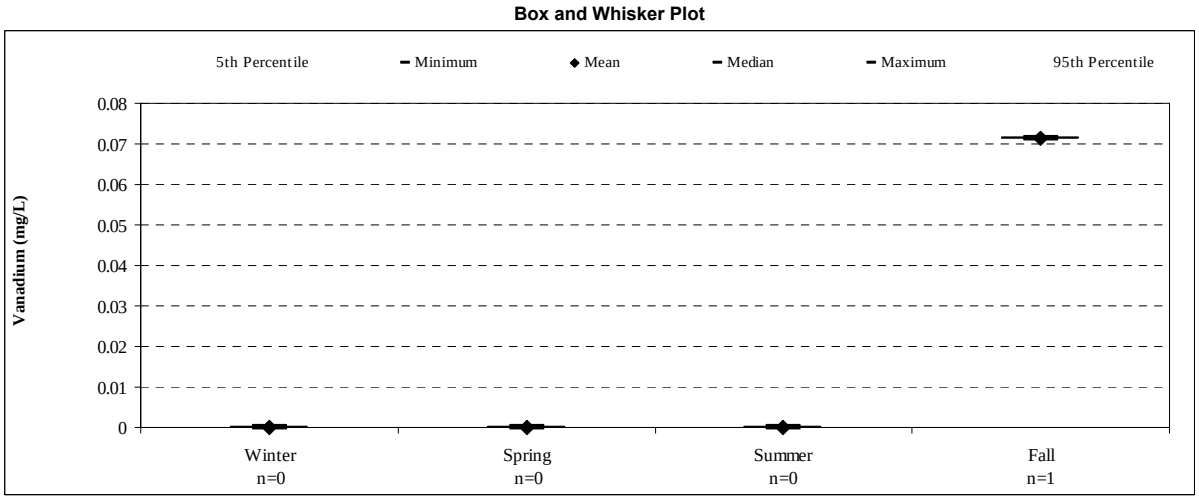


Figure G-1-7-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in McClelland Lake Outlet



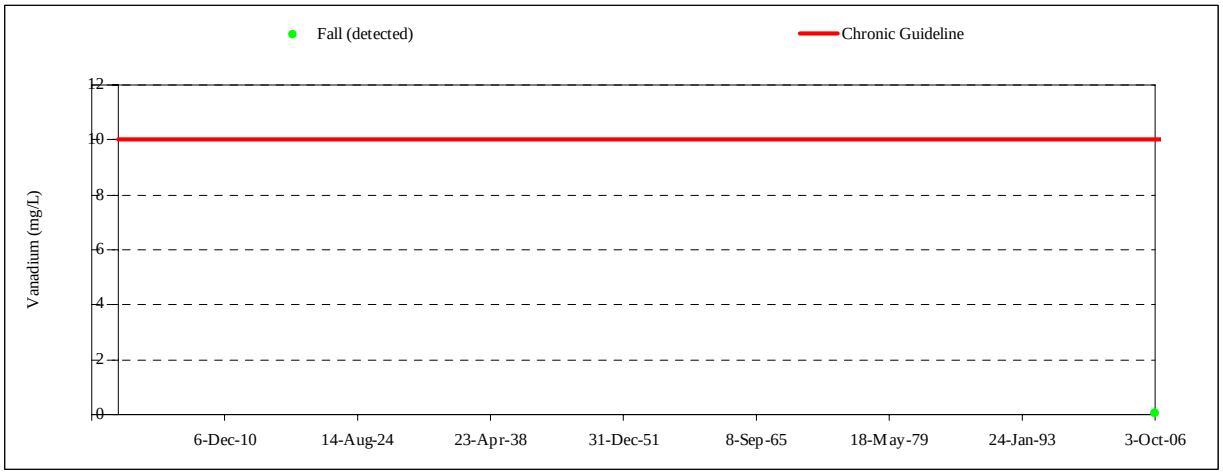
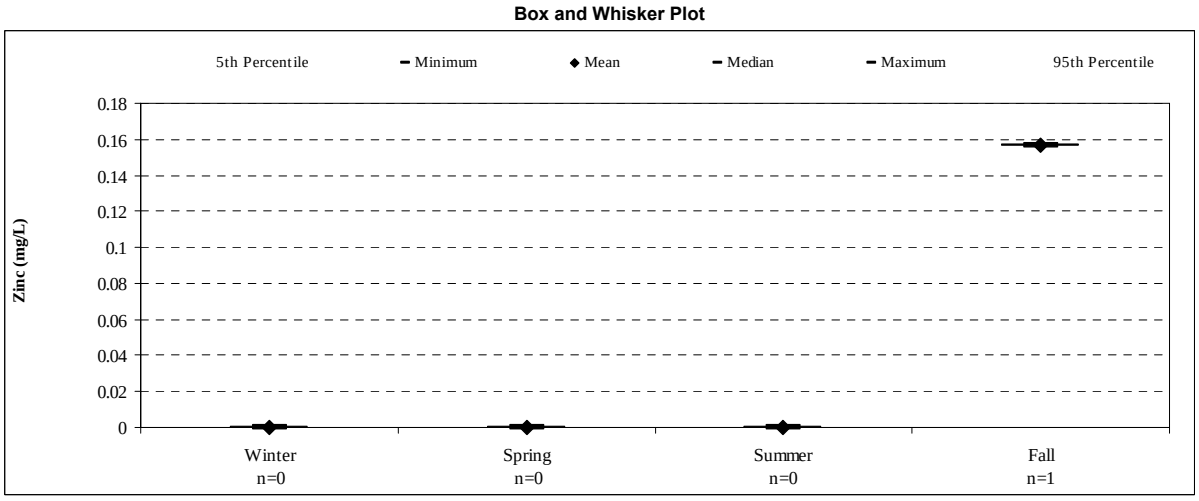


Figure G-1-7-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in McClelland Lake Outlet



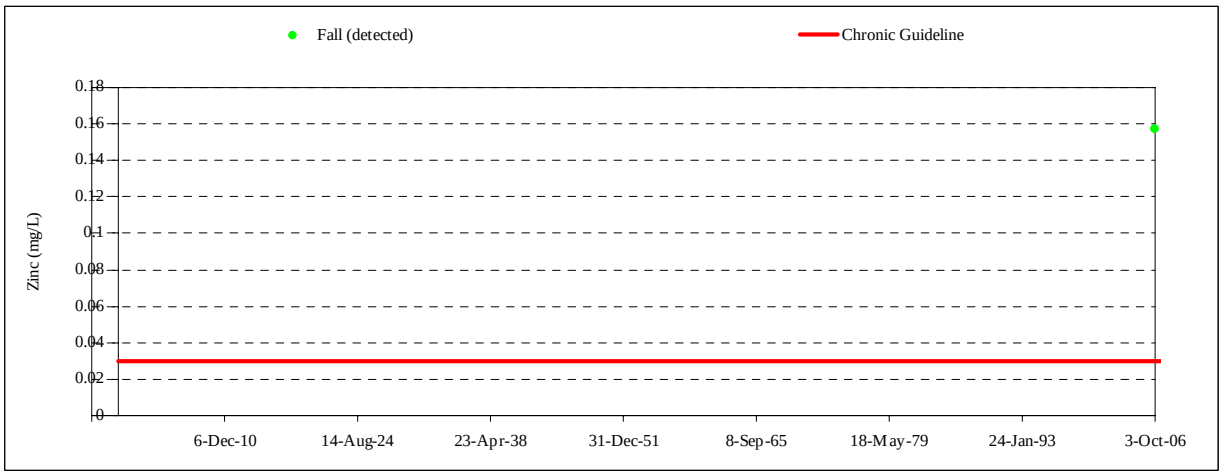
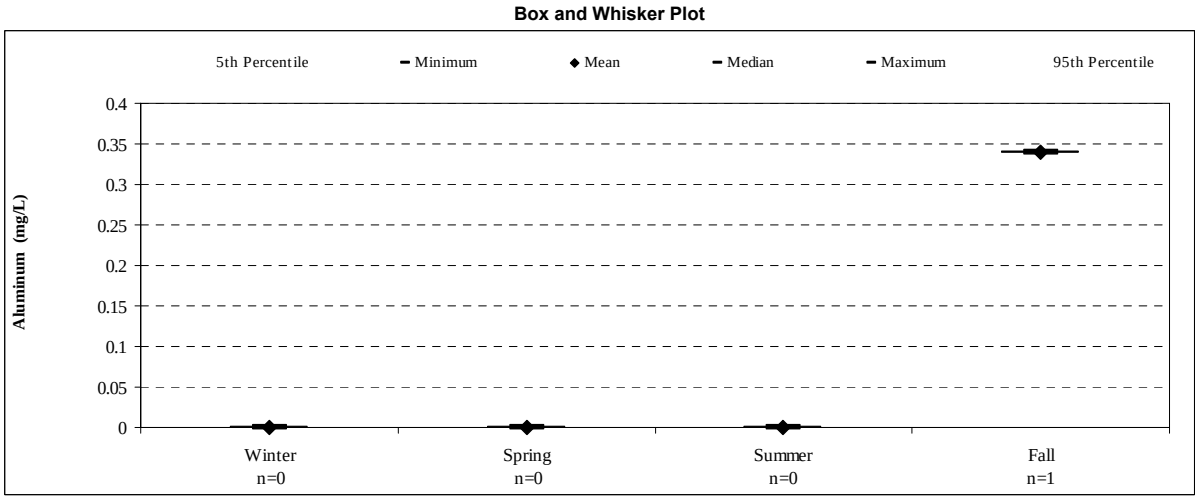


Figure G-1-7-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in McClelland Lake Outlet



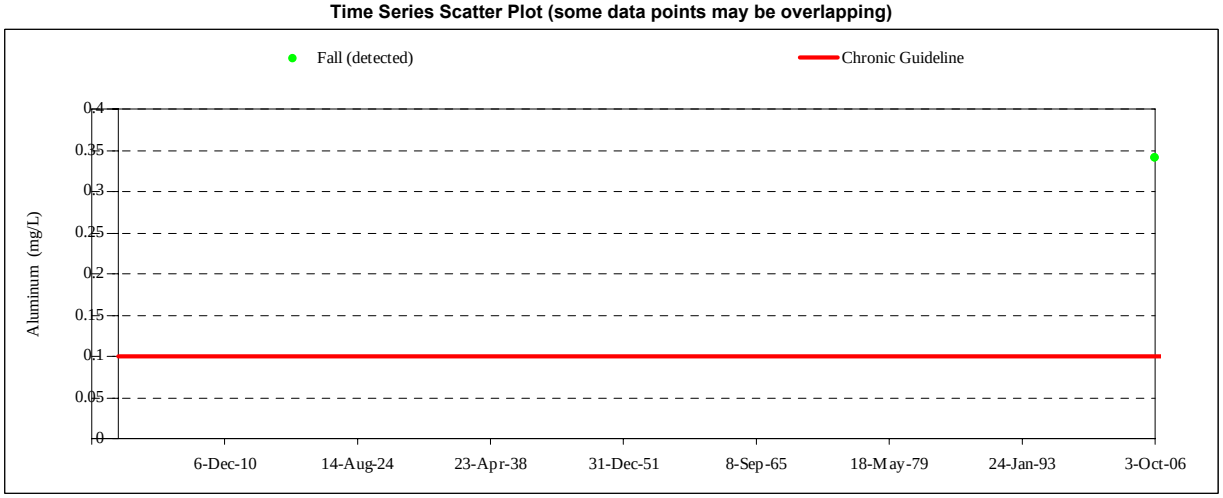
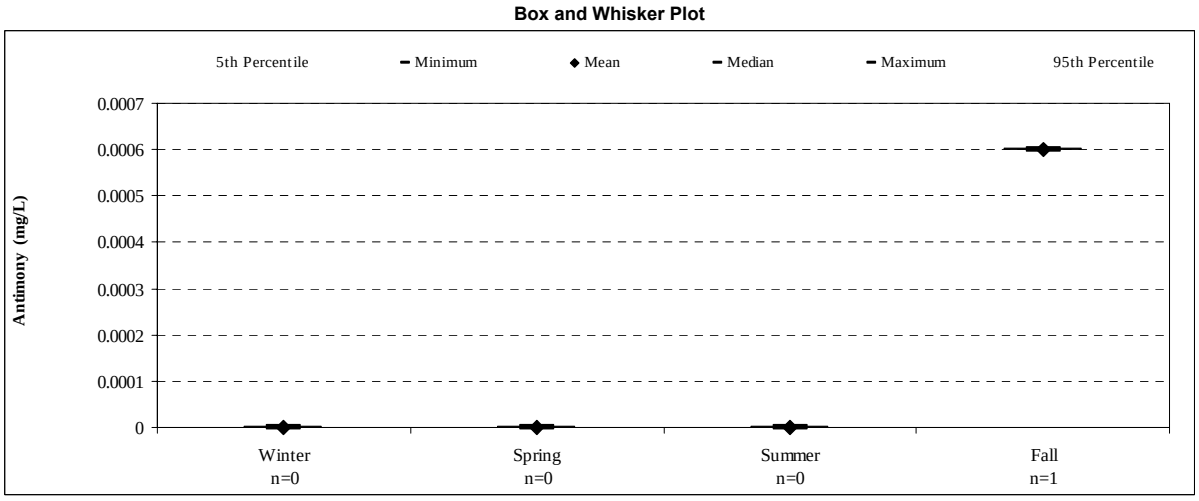


Figure G-1-7-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in McClelland Lake Outlet



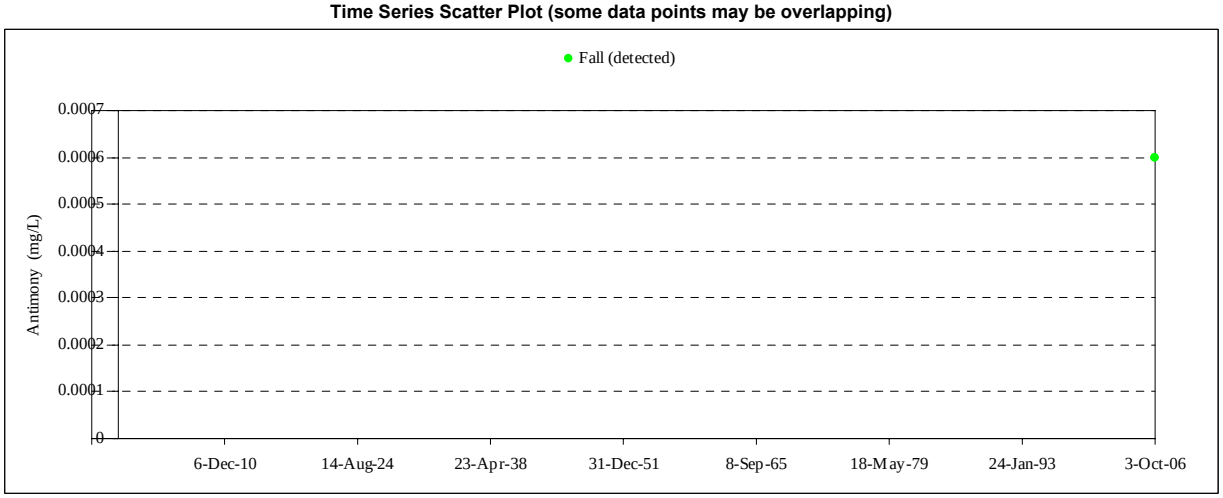
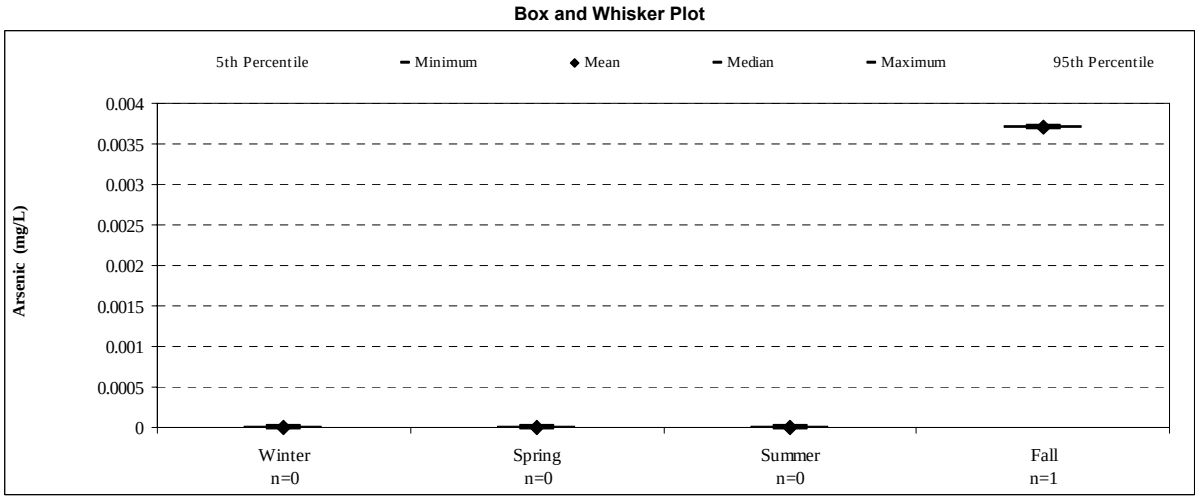


Figure G-1-7-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in McClelland Lake Outlet



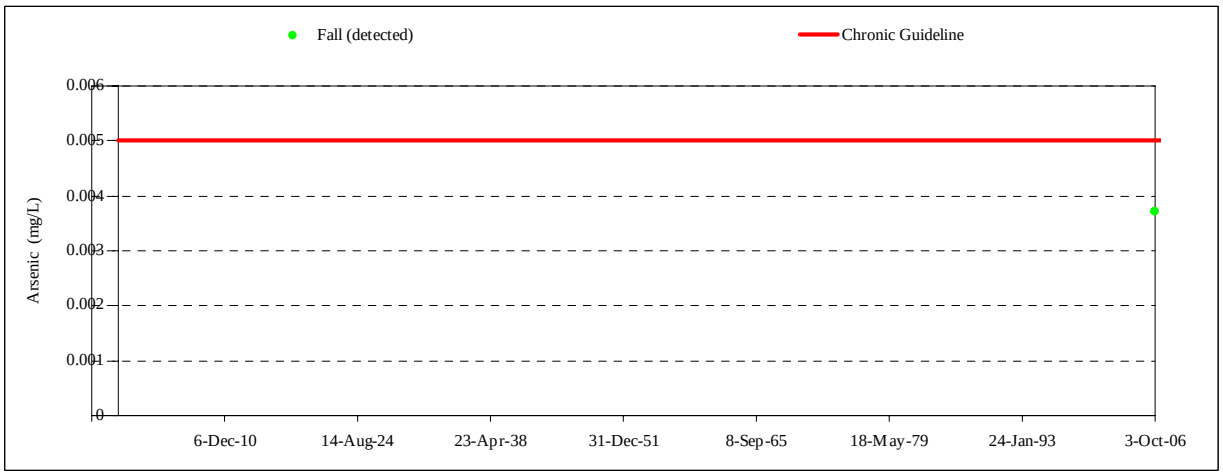
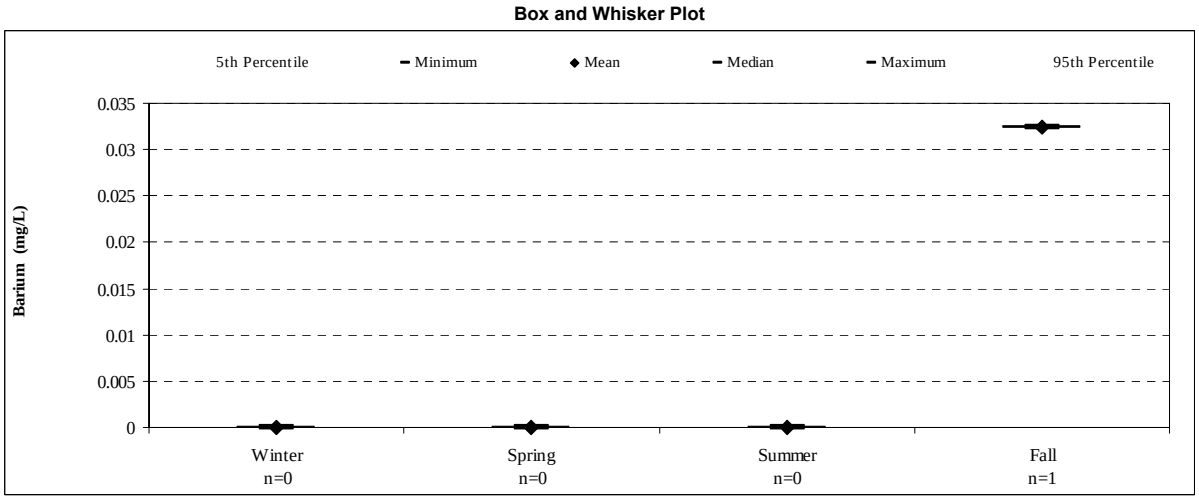


Figure G-1-7-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in McClelland Lake Outlet



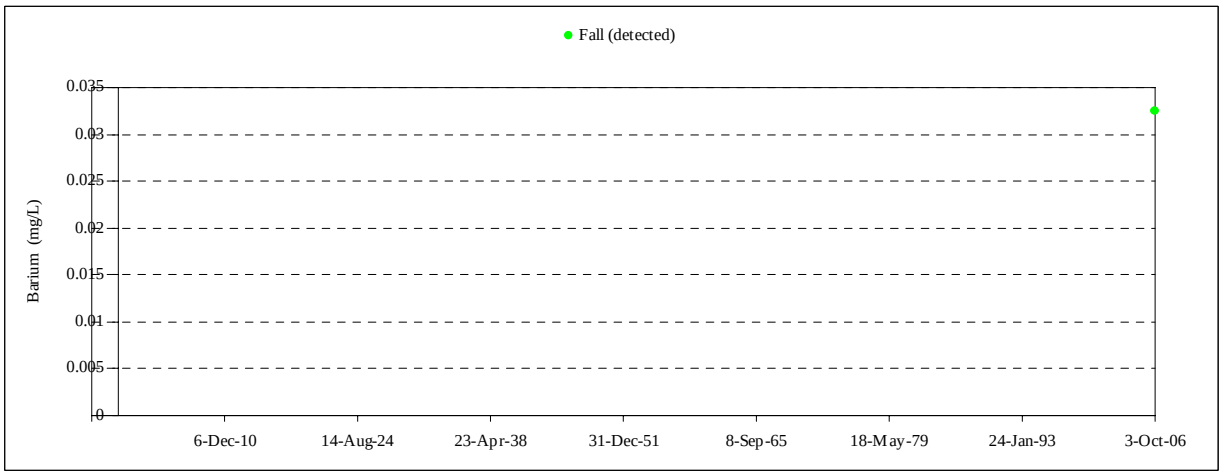
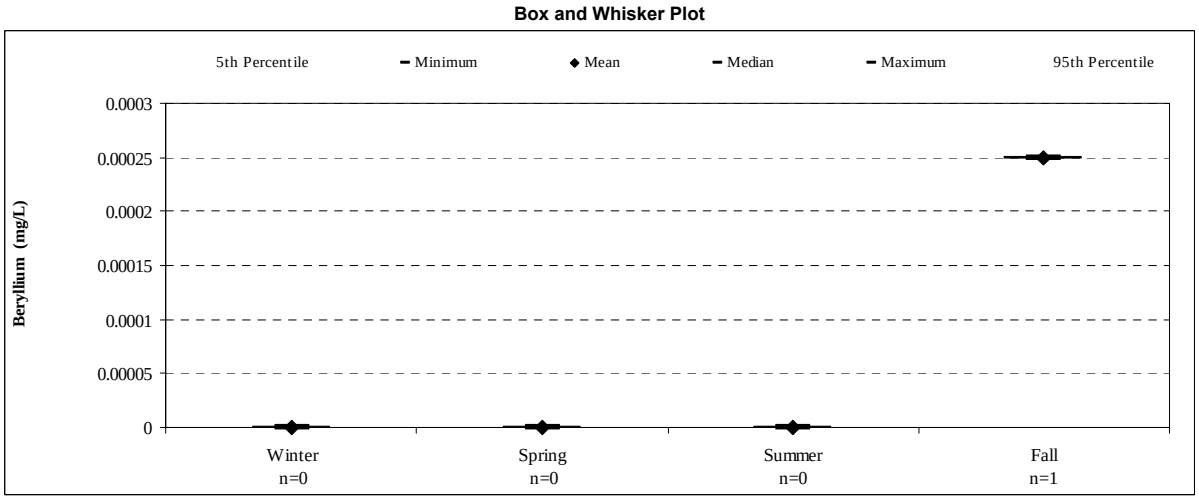


Figure G-1-7-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in McClelland Lake Outlet



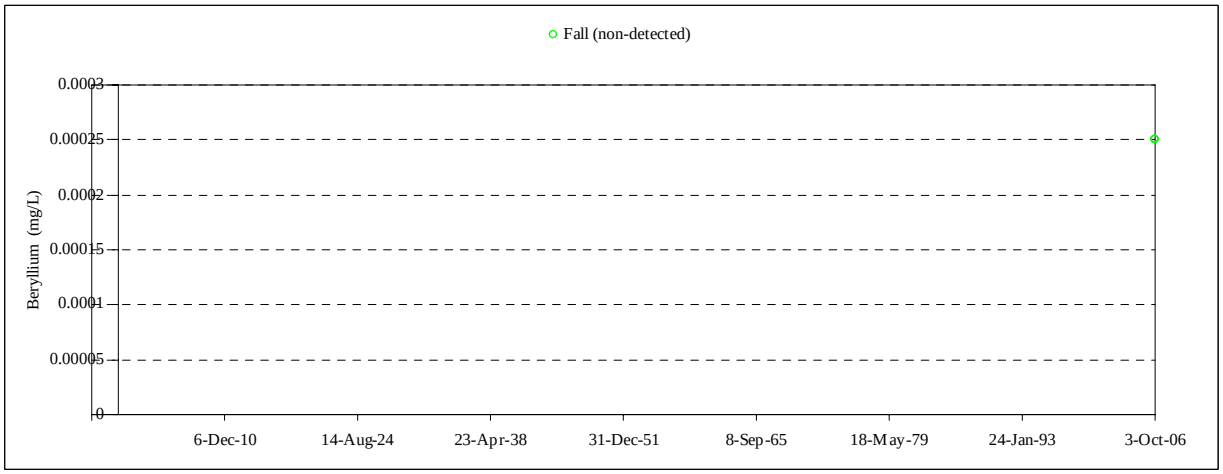
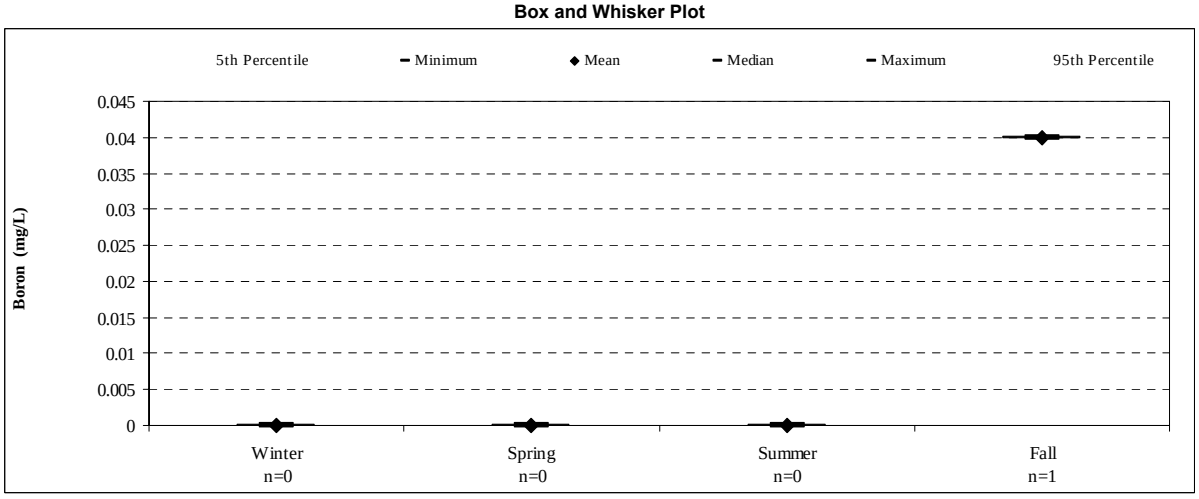


Figure G-1-7-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in McClelland Lake Outlet



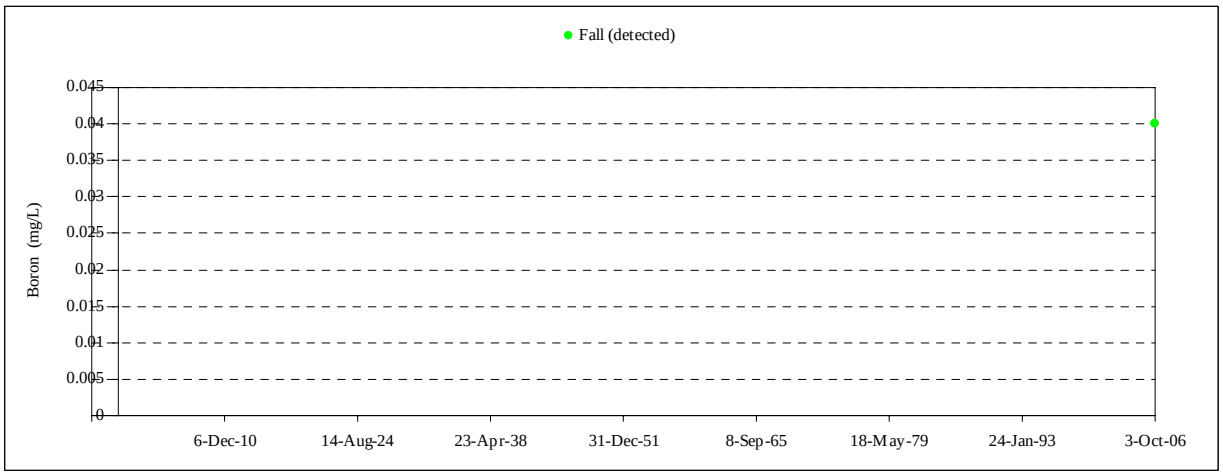
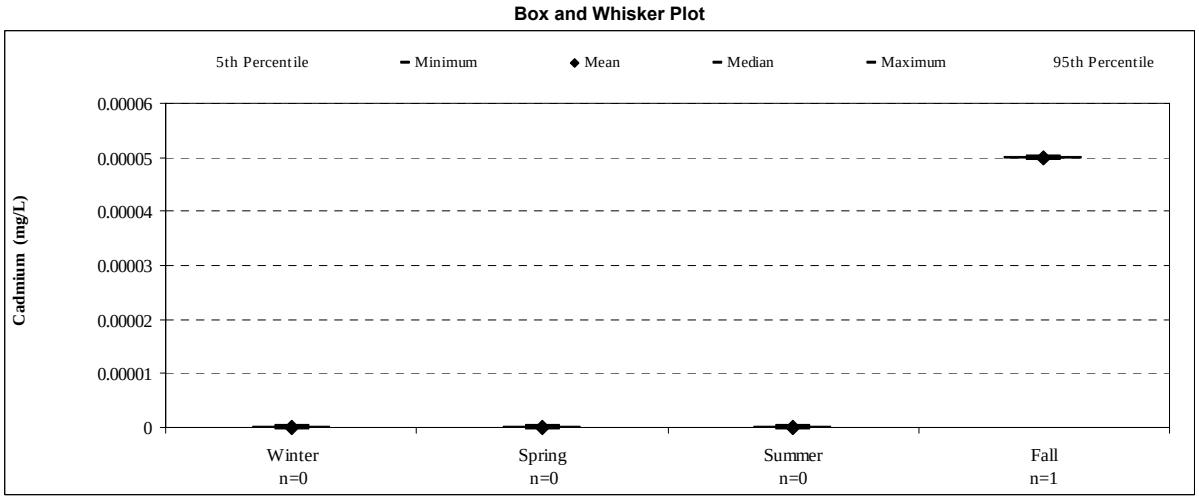


Figure G-1-7-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in McClelland Lake Outlet



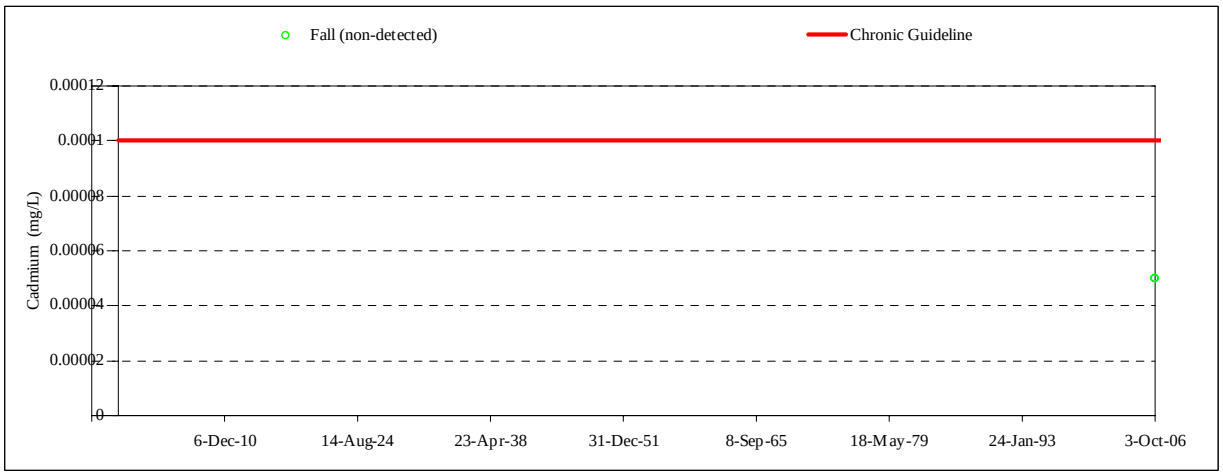
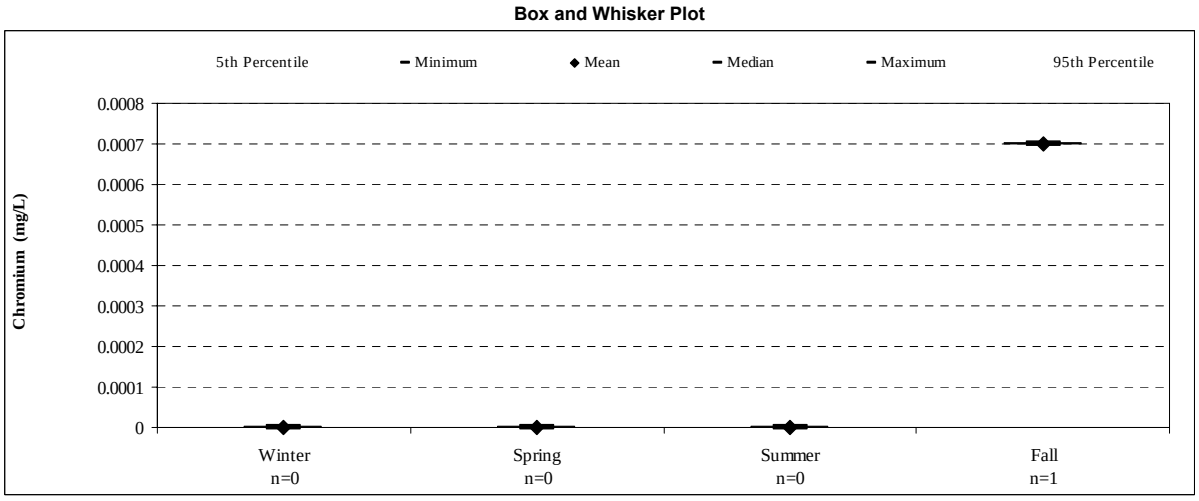


Figure G-1-7-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in McClelland Lake Outlet



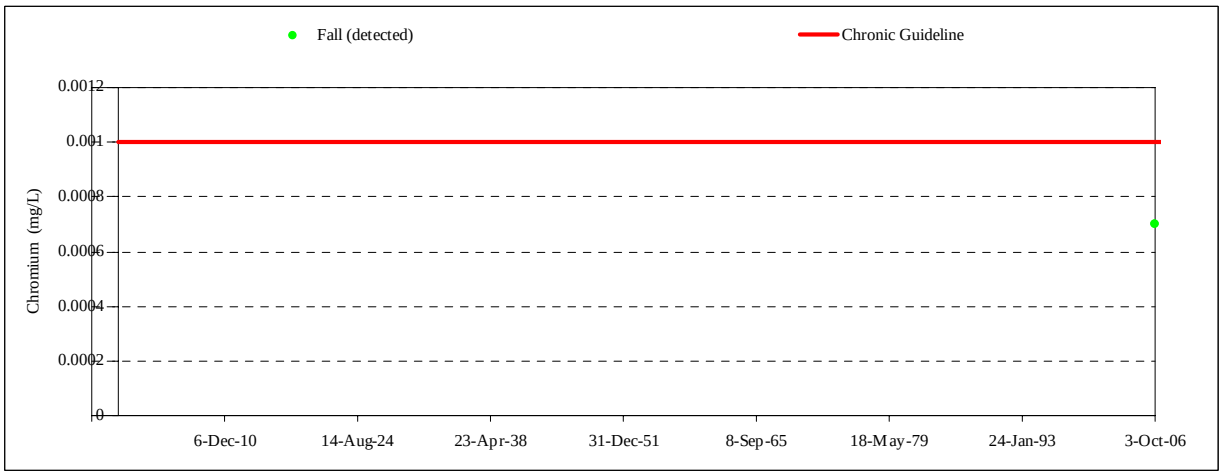
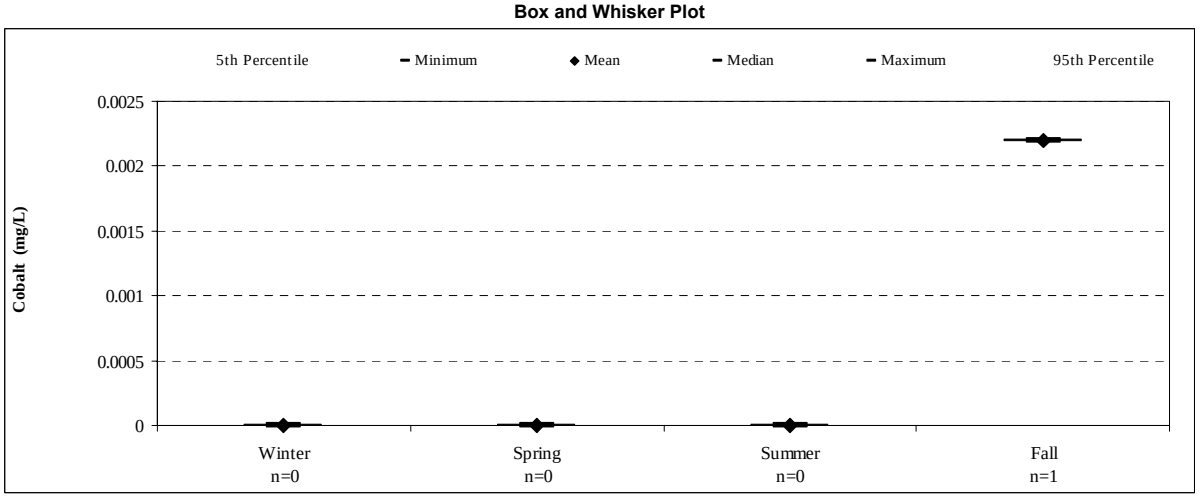


Figure G-1-7-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in McClelland Lake Outlet



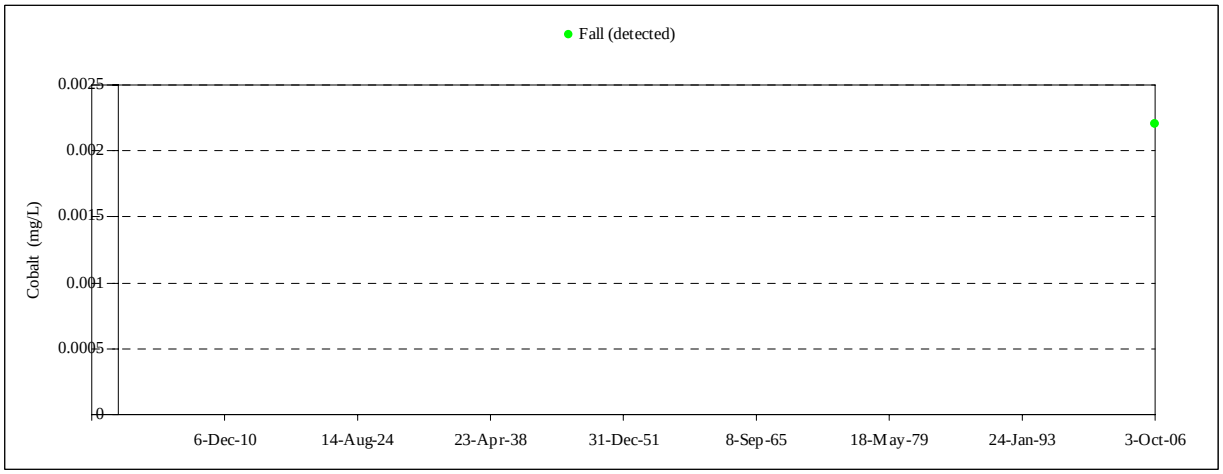
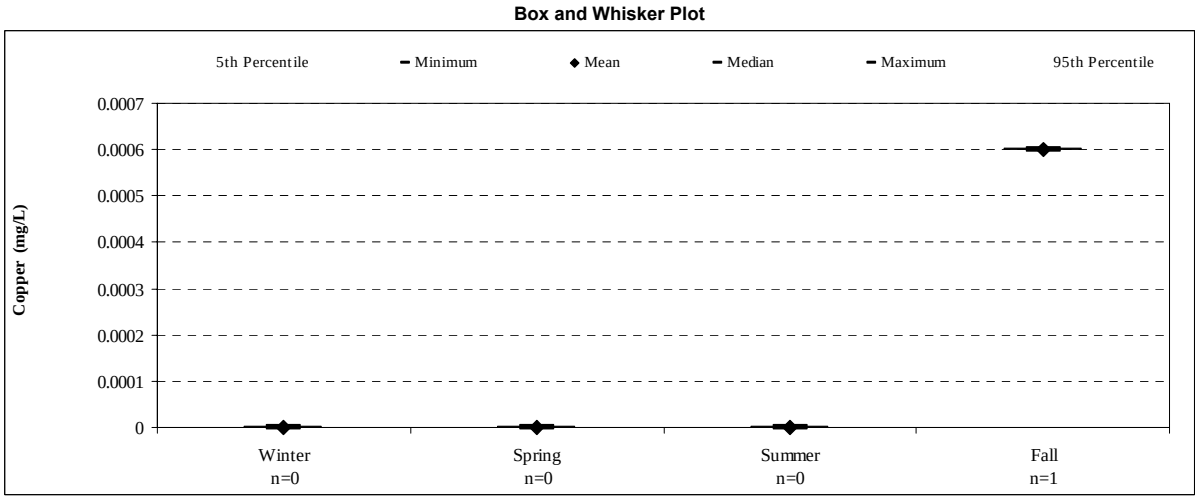


Figure G-1-7-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in McClelland Lake Outlet



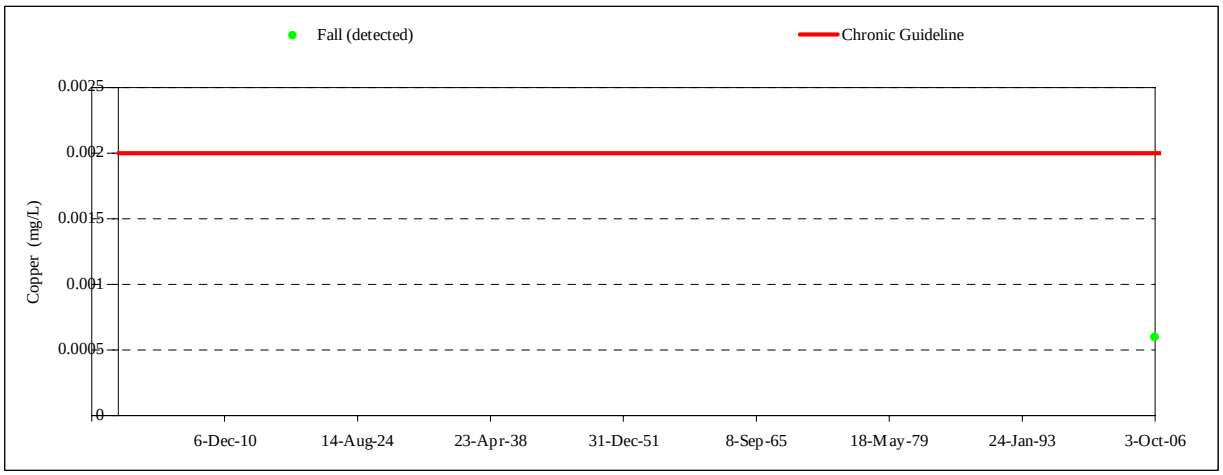
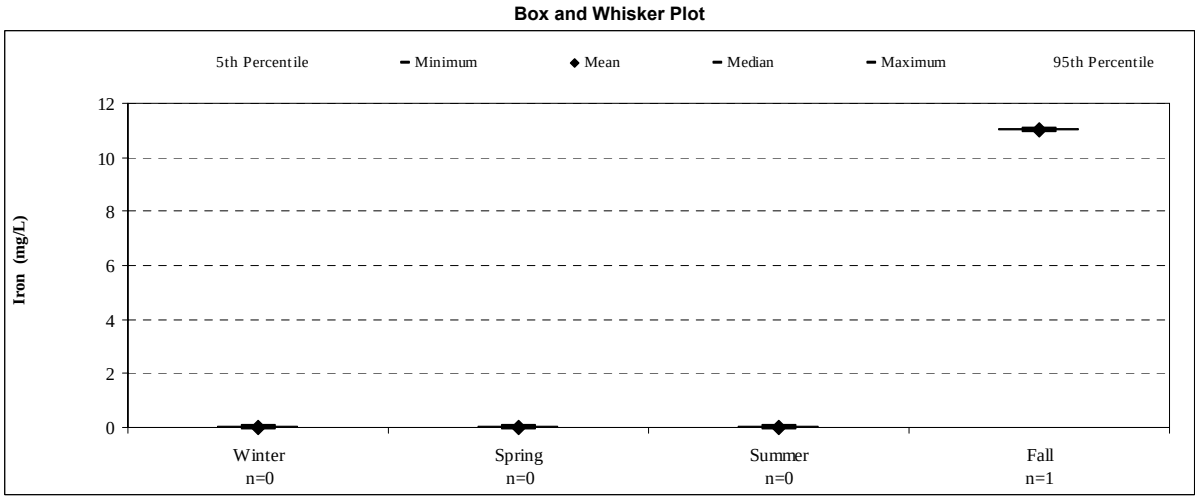


Figure G-1-7-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in McClelland Lake Outlet



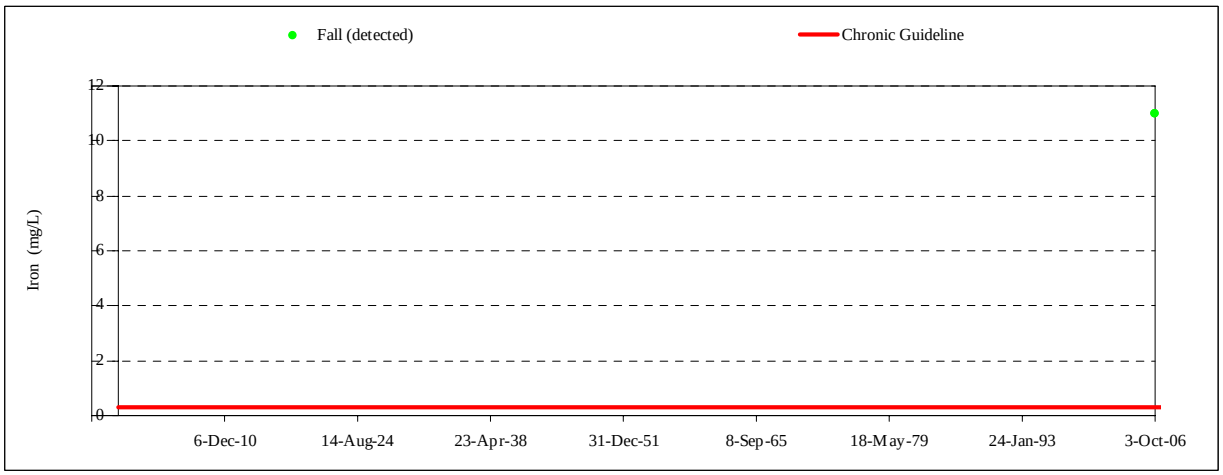
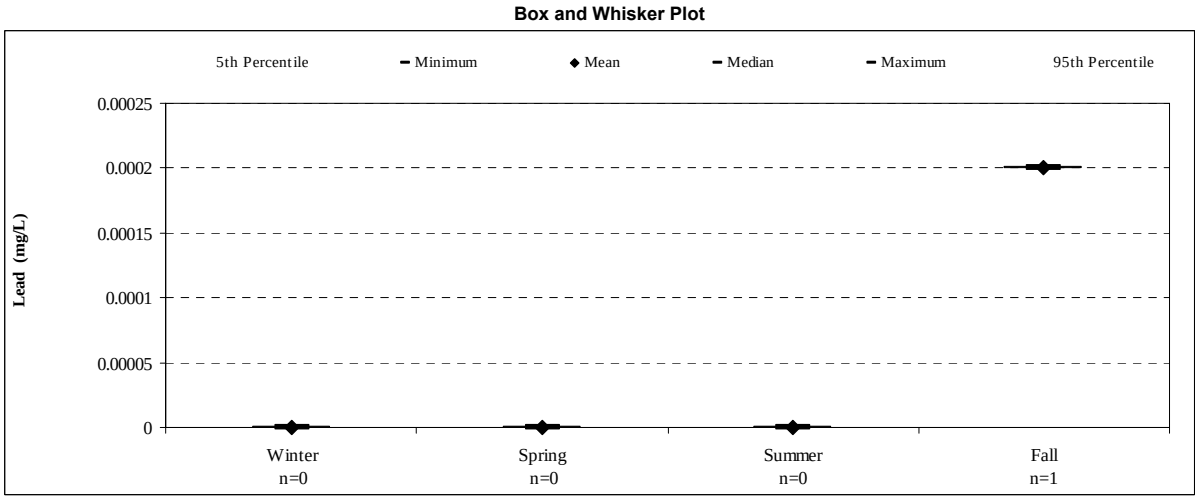


Figure G-1-7-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in McClelland Lake Outlet



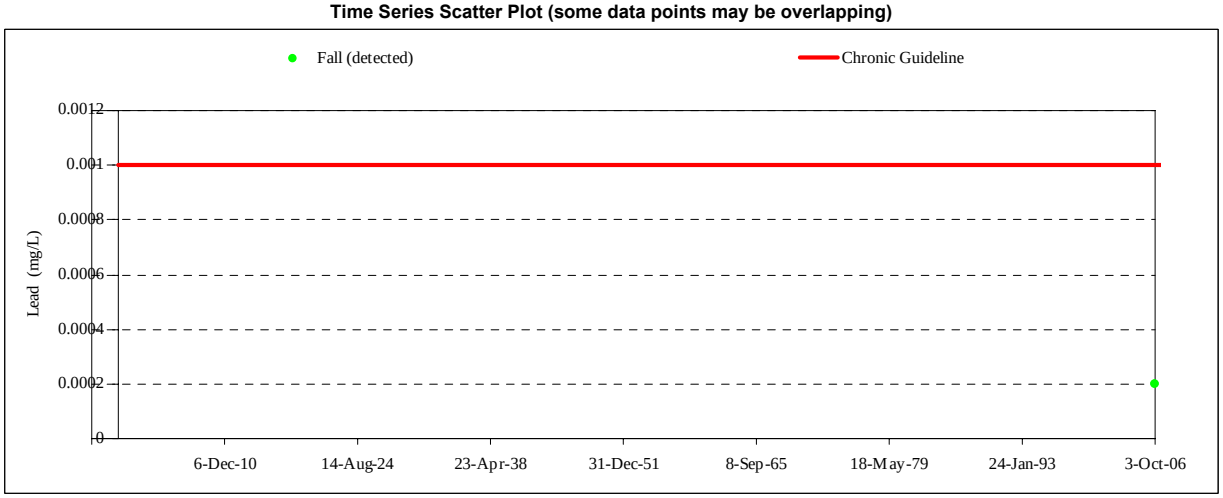
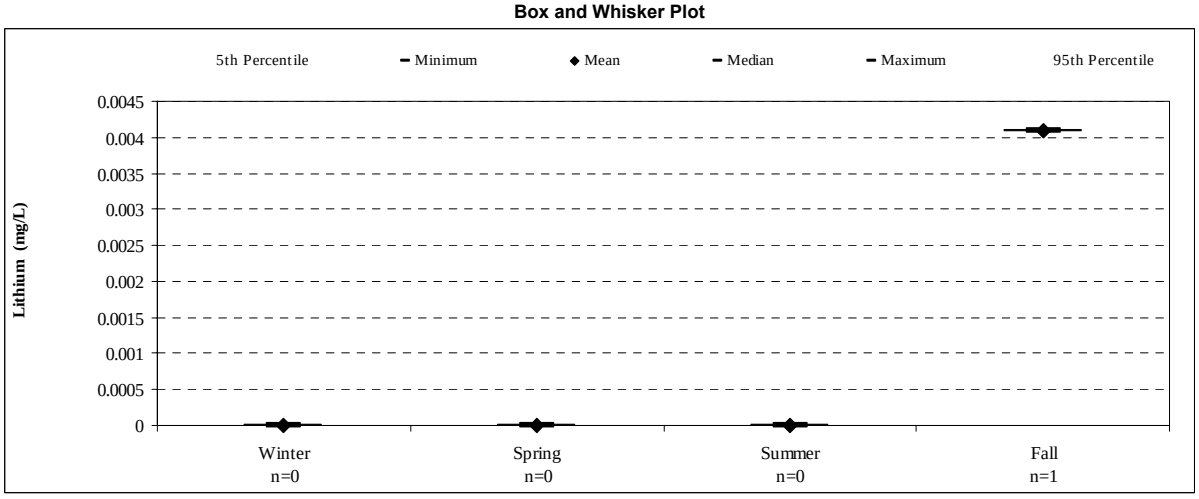


Figure G-1-7-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in McClelland Lake Outlet



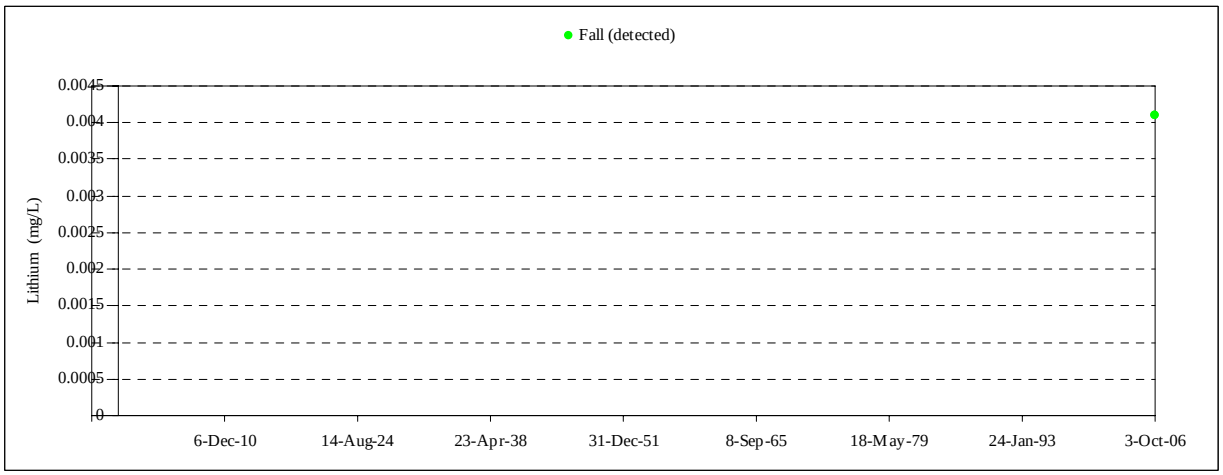


Figure G-1-7-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in McClelland Lake Outlet

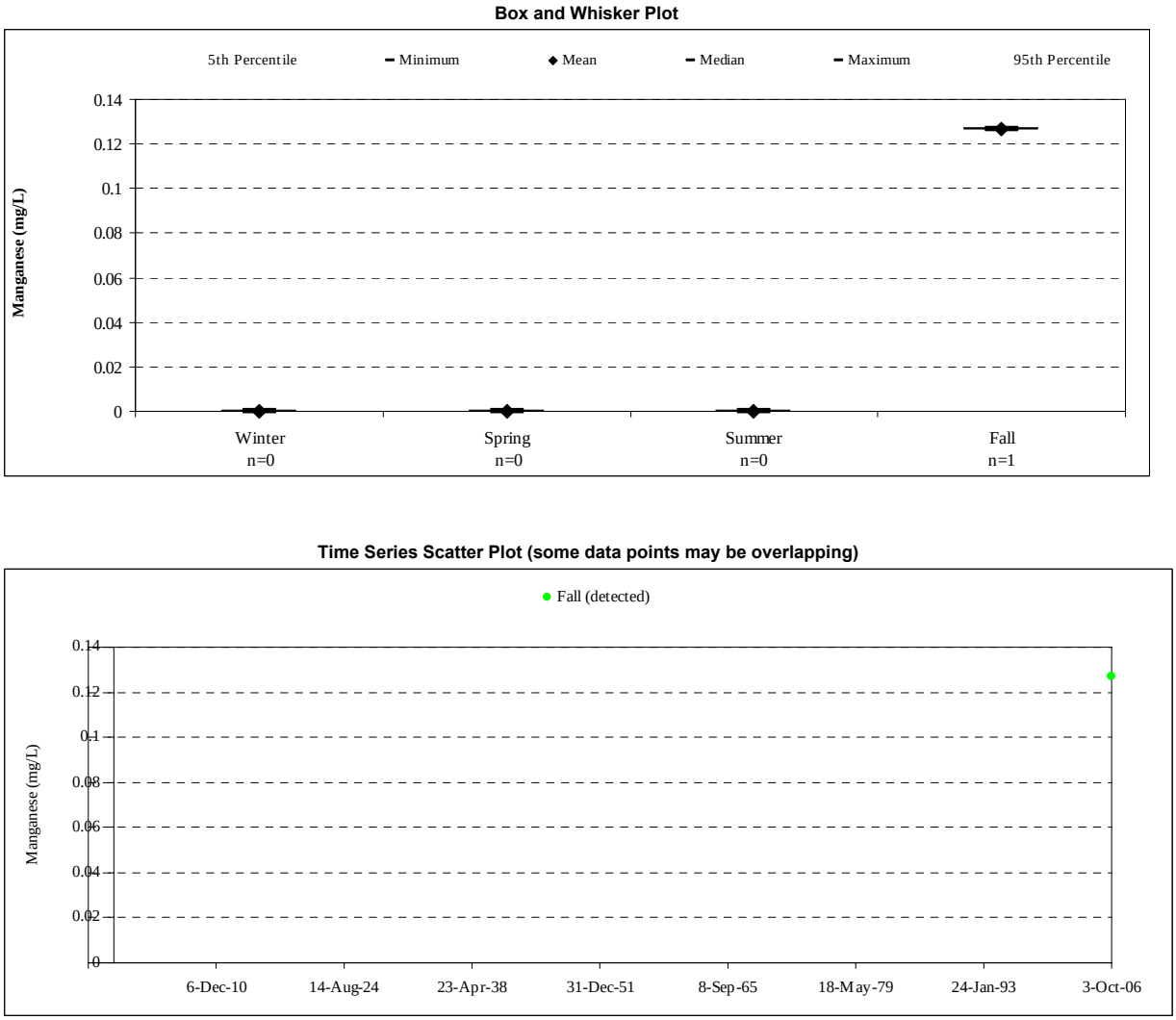
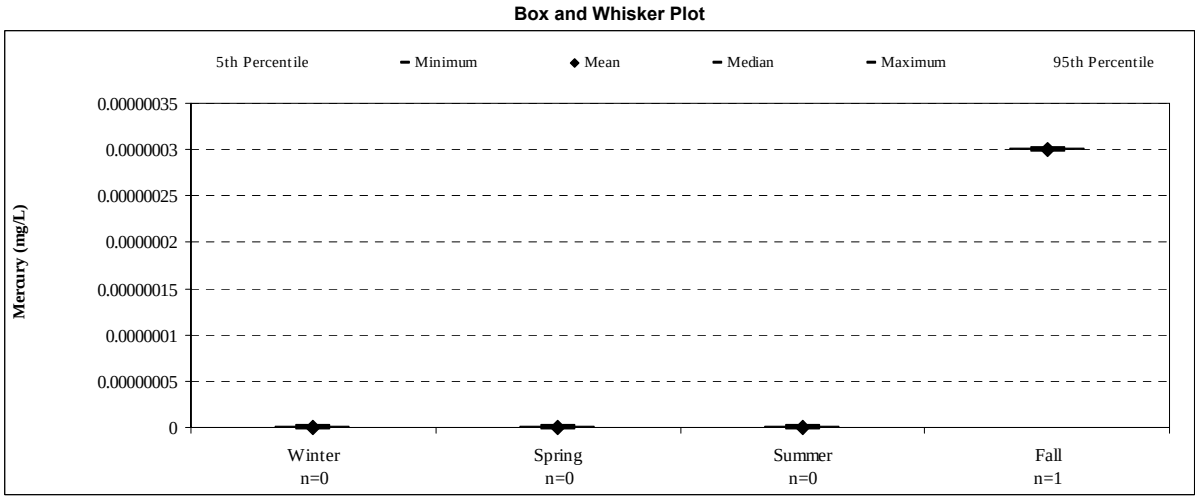


Figure G-1-7-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in McClelland Lake Outlet



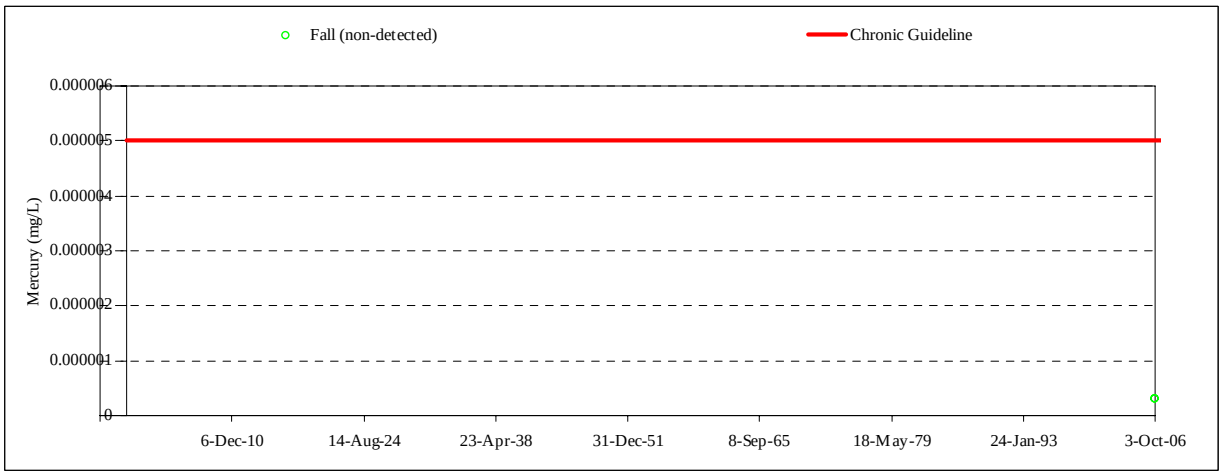
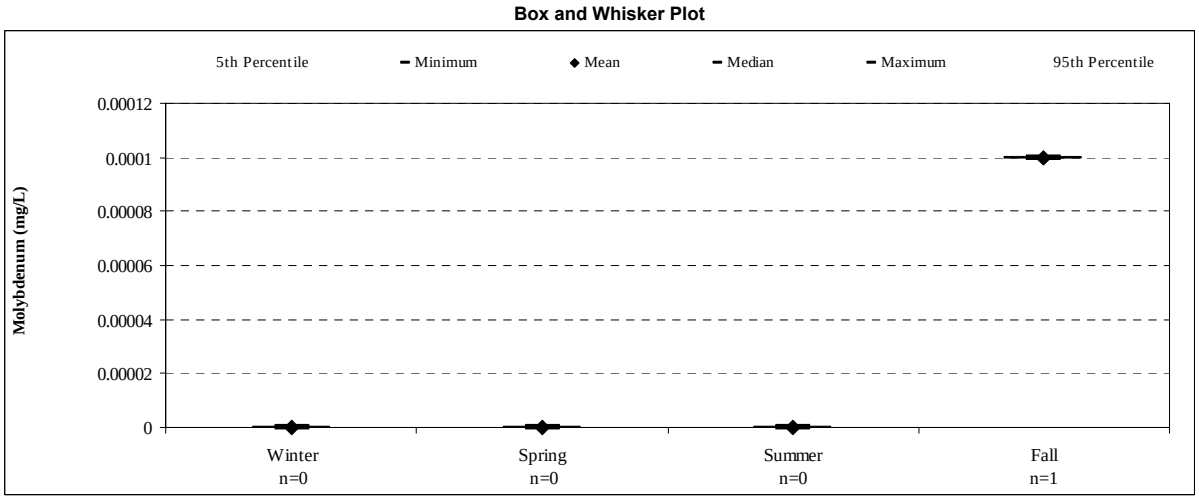


Figure G-1-7-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in McClelland Lake Outlet



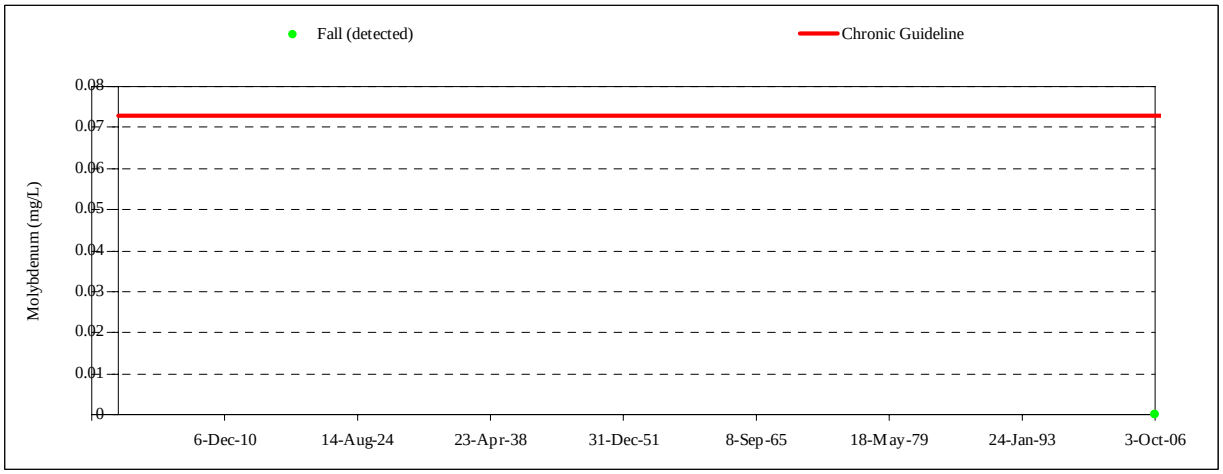
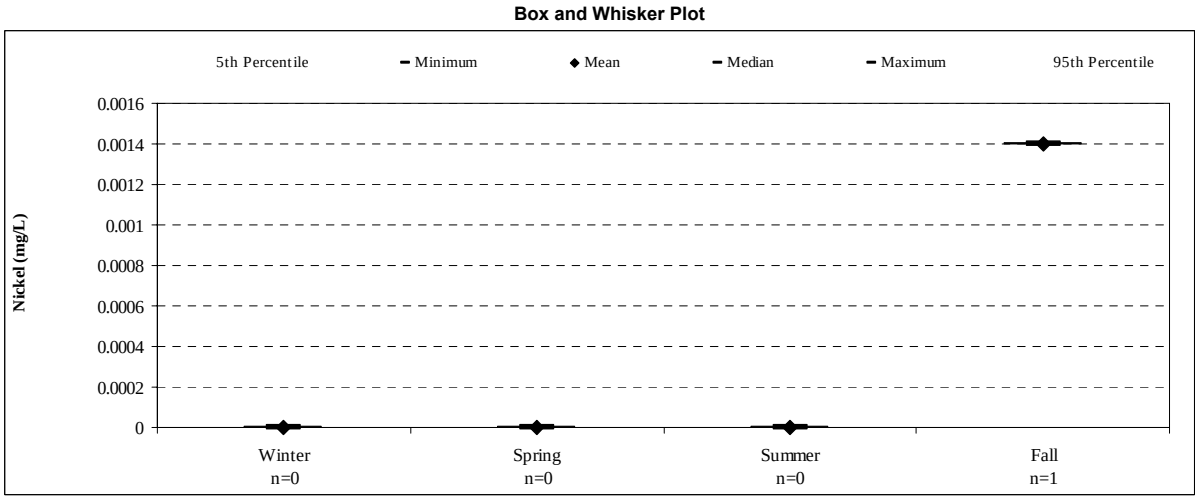


Figure G-1-7-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in McClelland Lake Outlet



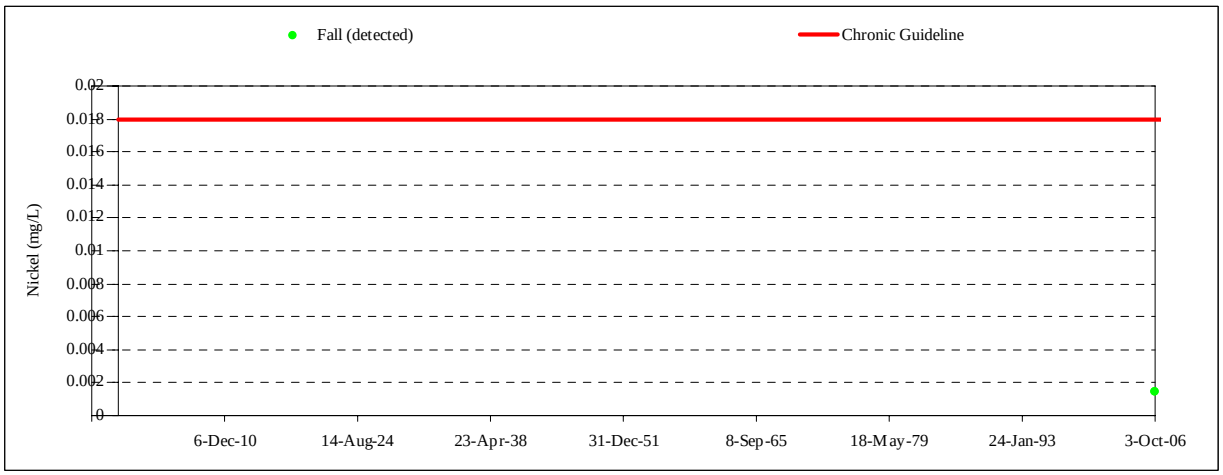
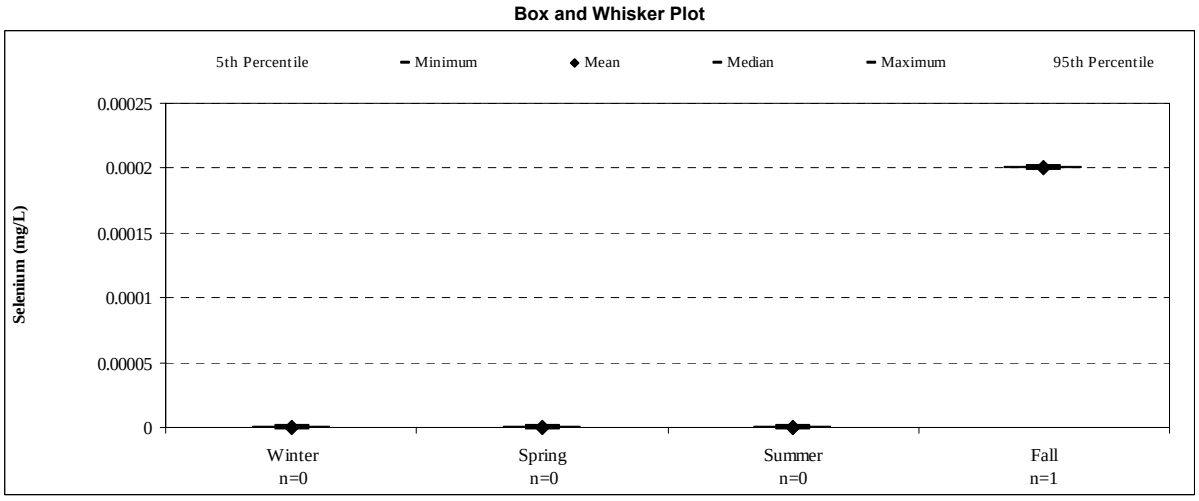


Figure G-1-7-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in McClelland Lake Outlet



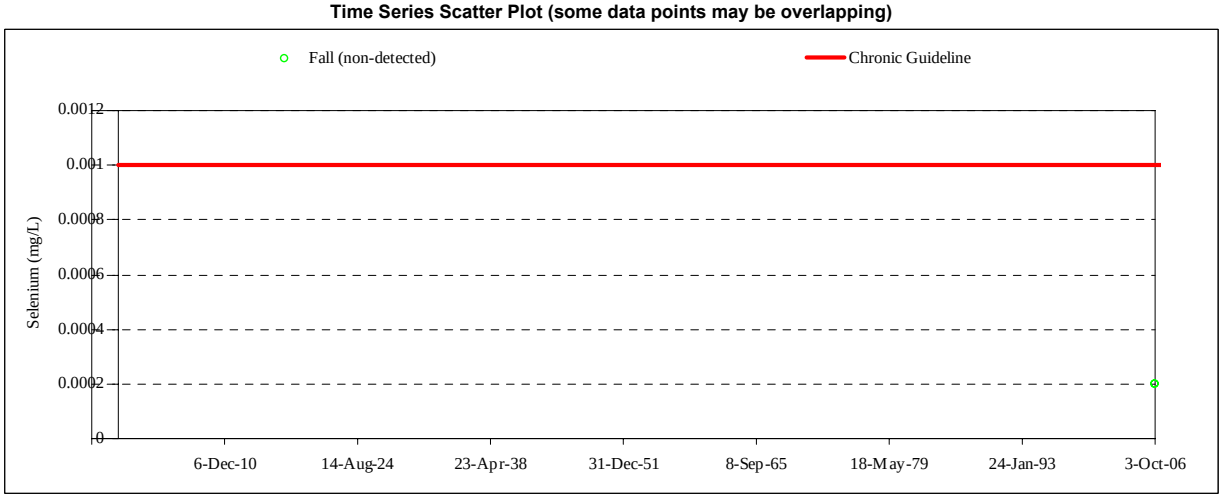
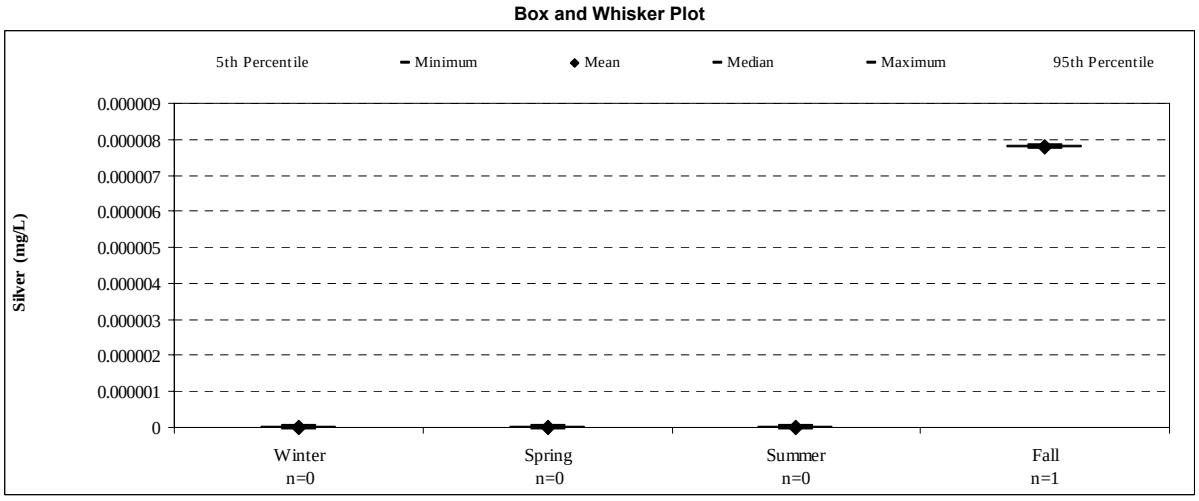


Figure G-1-7-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in McClelland Lake Outlet



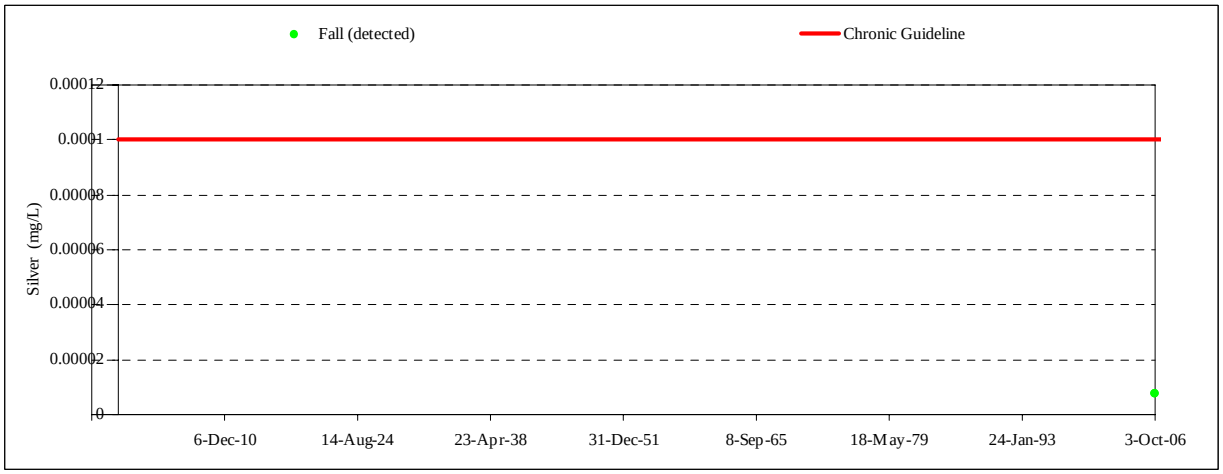


Figure G-1-7-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in McClelland Lake Outlet

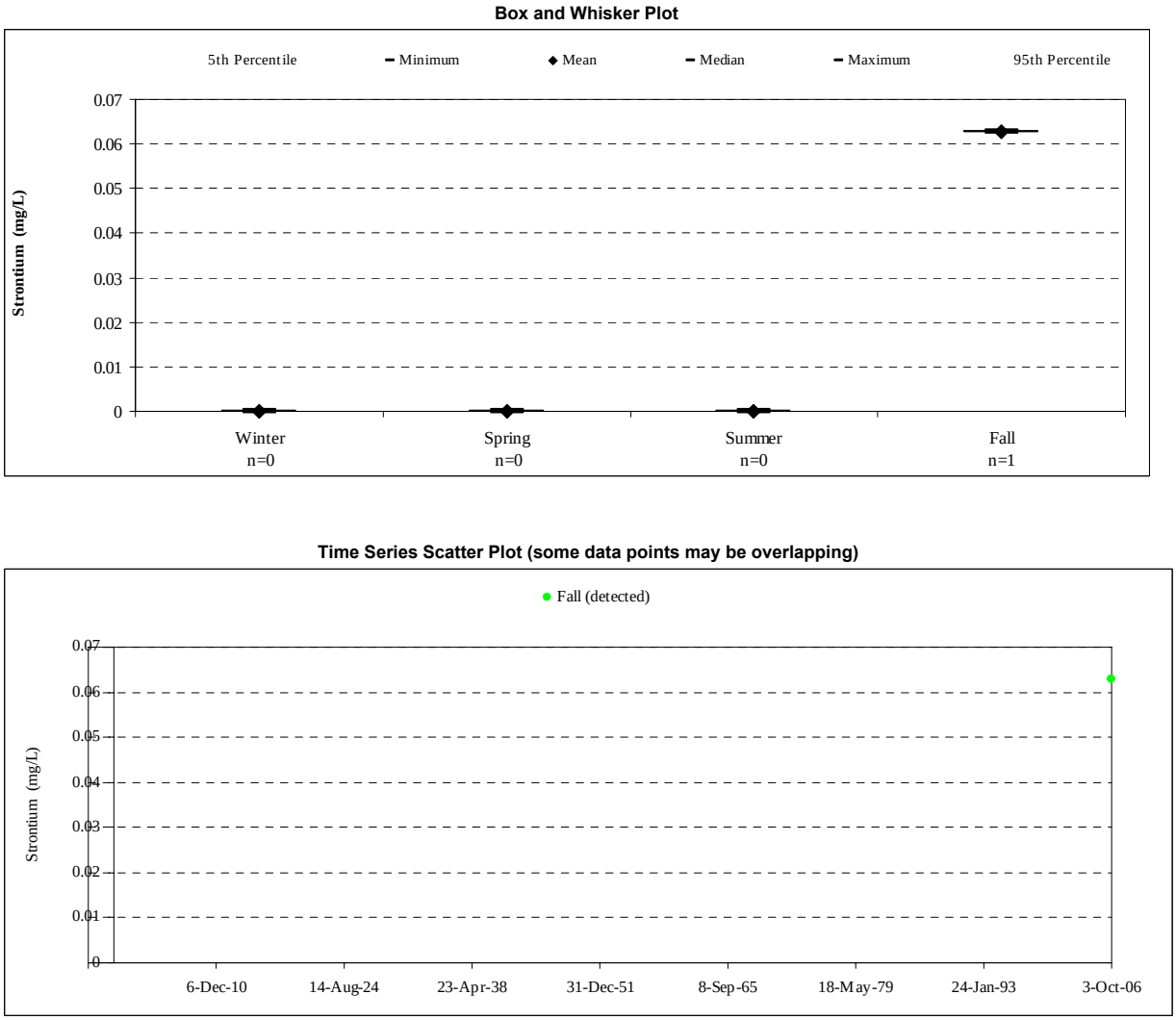
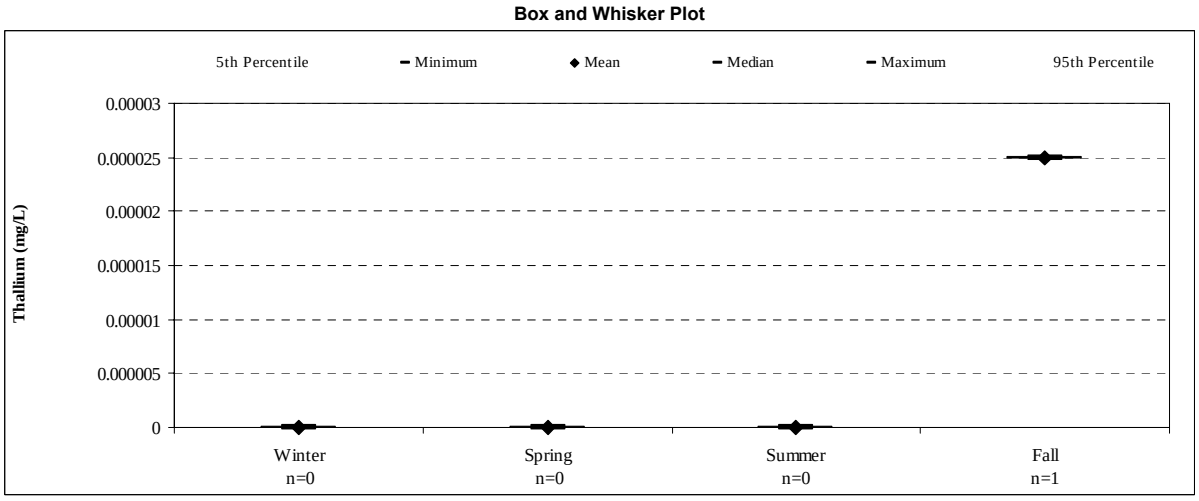


Figure G-1-7-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in McClelland Lake Outlet



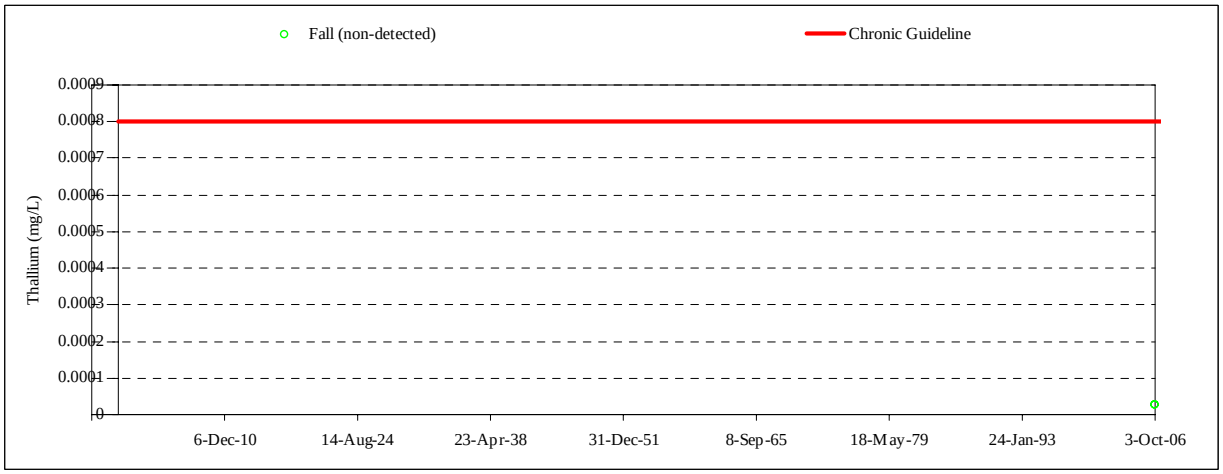


Figure G-1-7-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in McClelland Lake Outlet

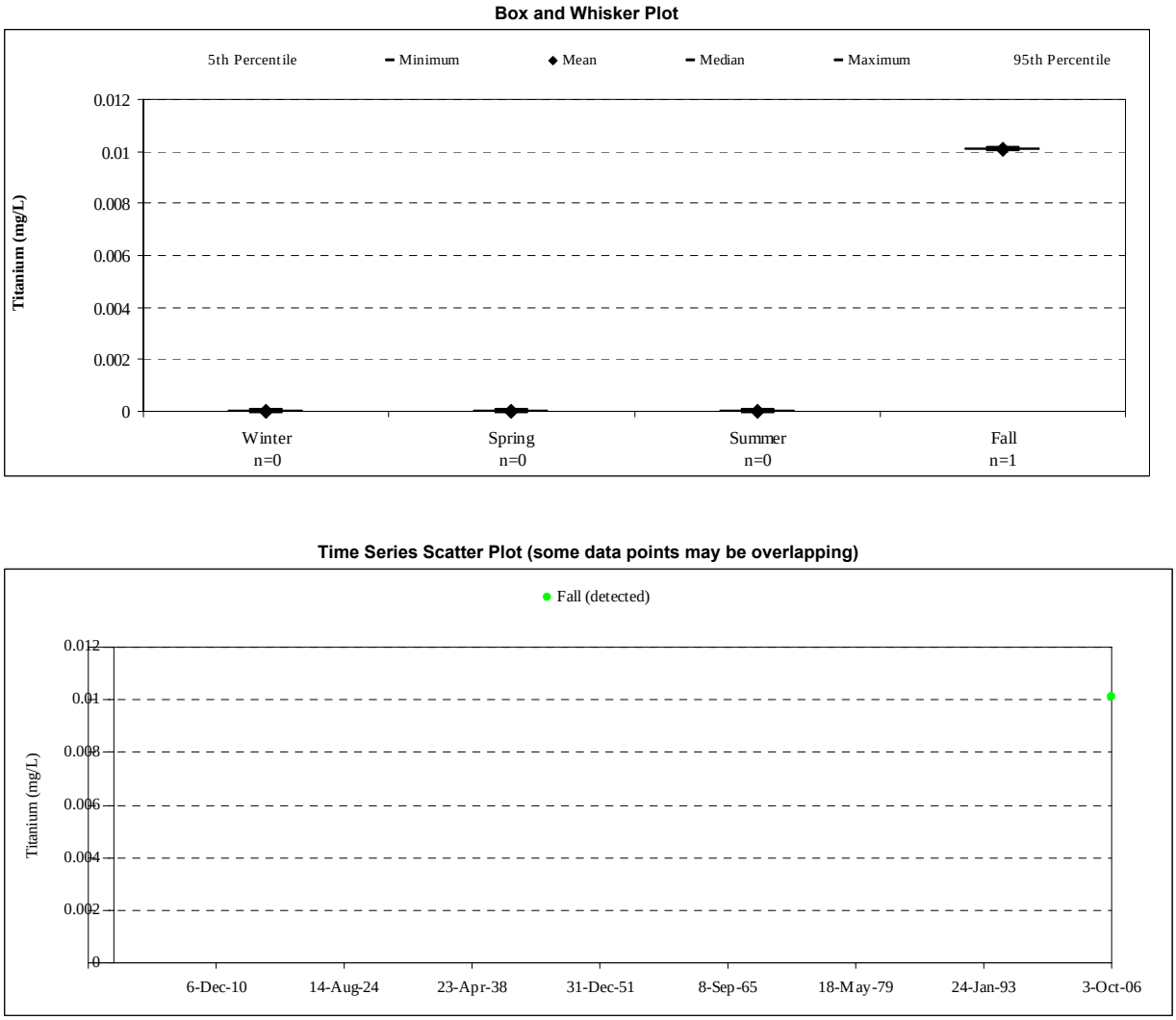
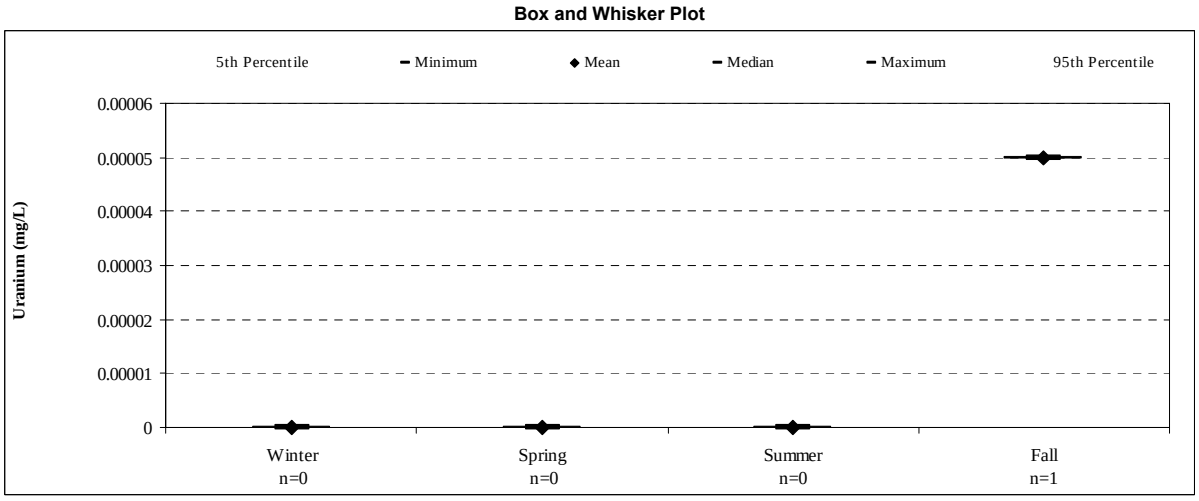


Figure G-1-7-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in McClelland Lake Outlet



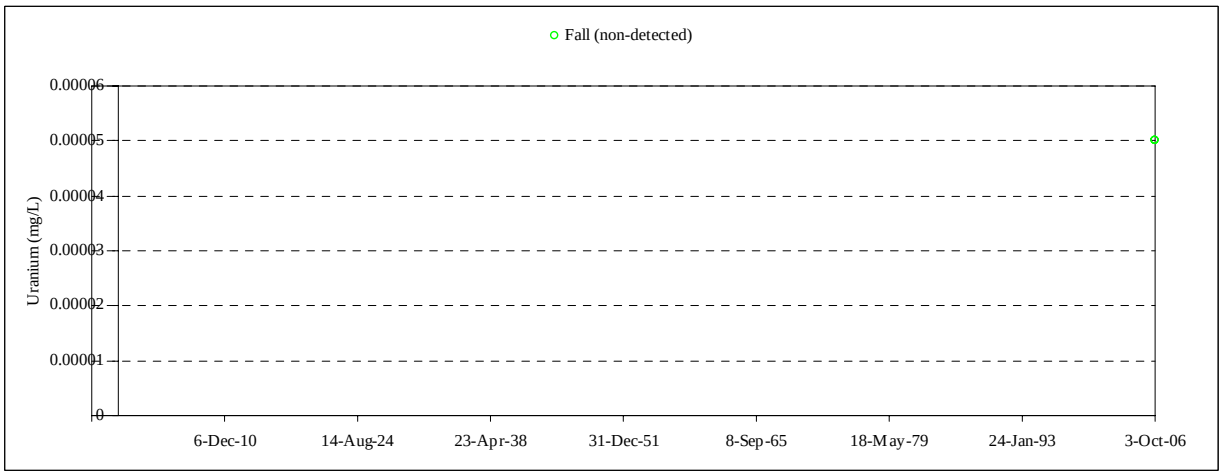
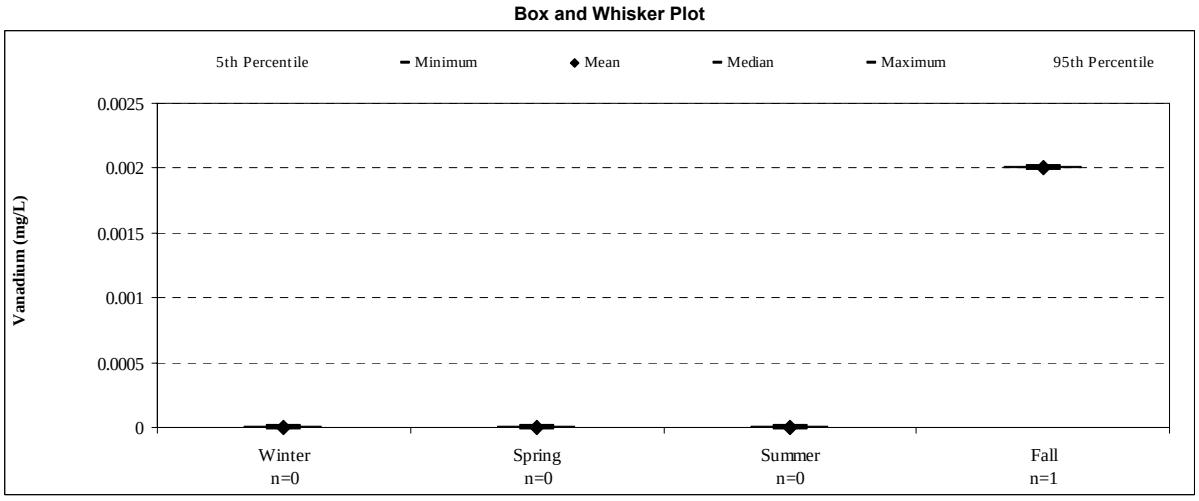


Figure G-1-7-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in McClelland Lake Outlet



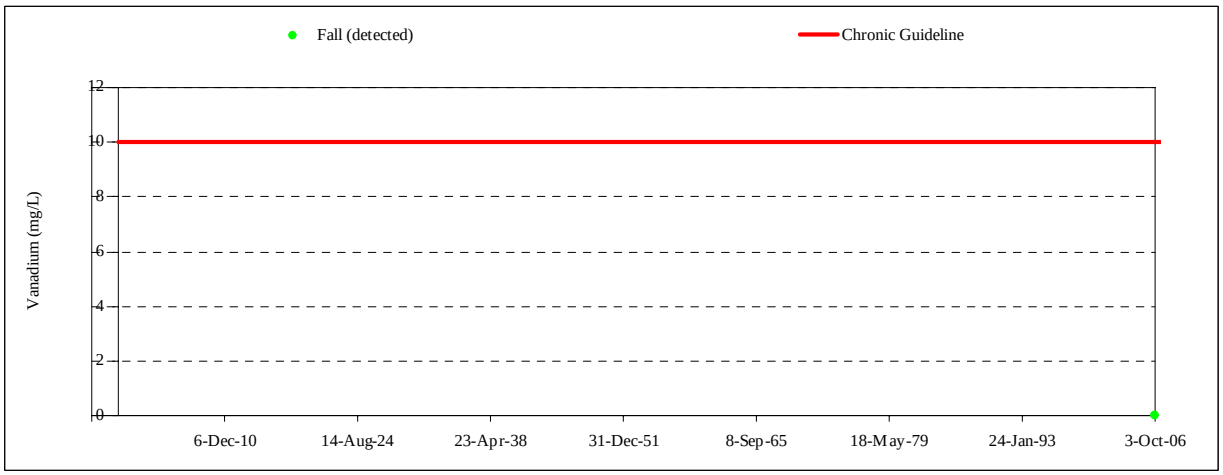
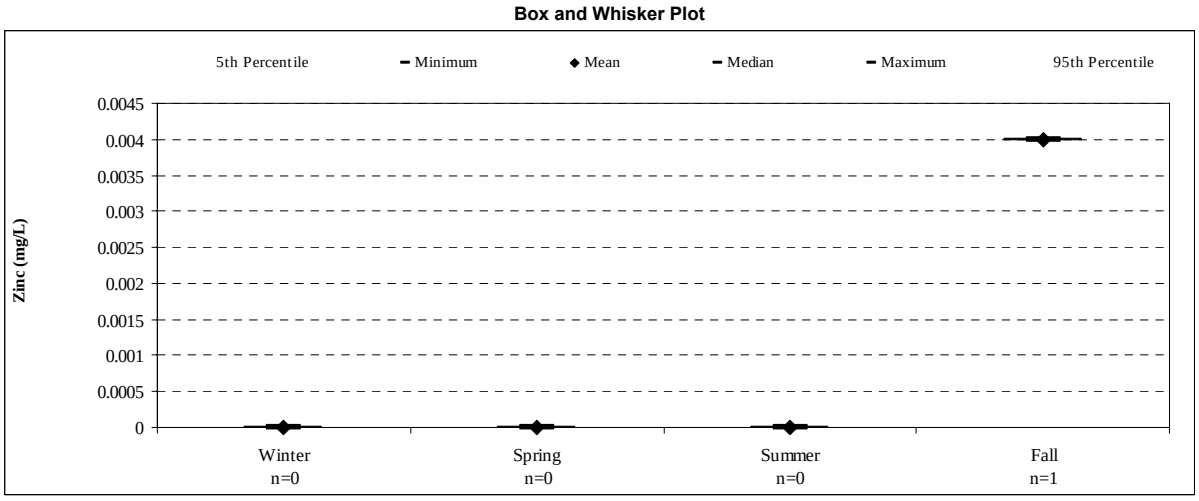


Figure G-1-7-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in McClelland Lake Outlet



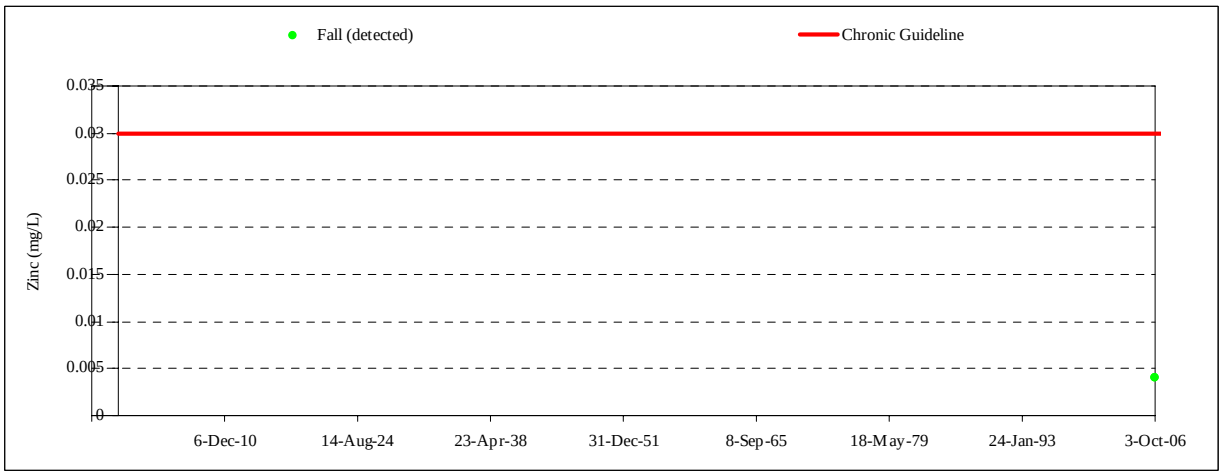
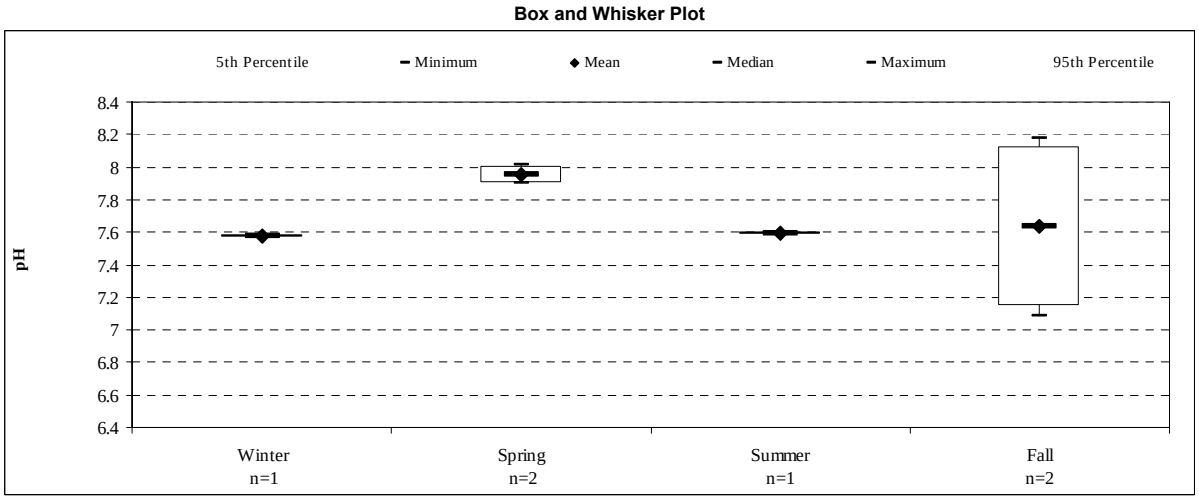


Figure G-1-8-1 Box Whisker and Time Series Scatter Plots of Observed pH in Unnamed Creek 3



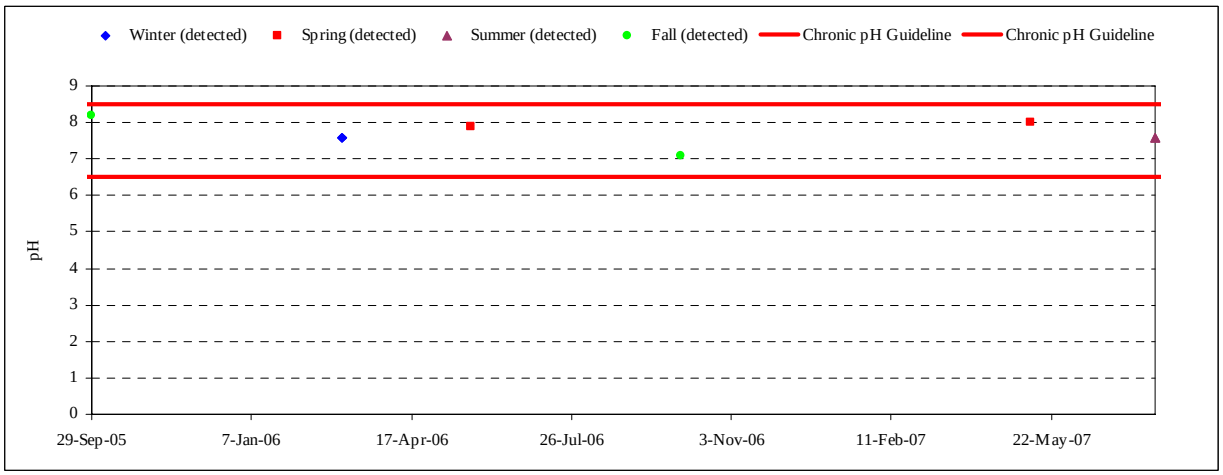
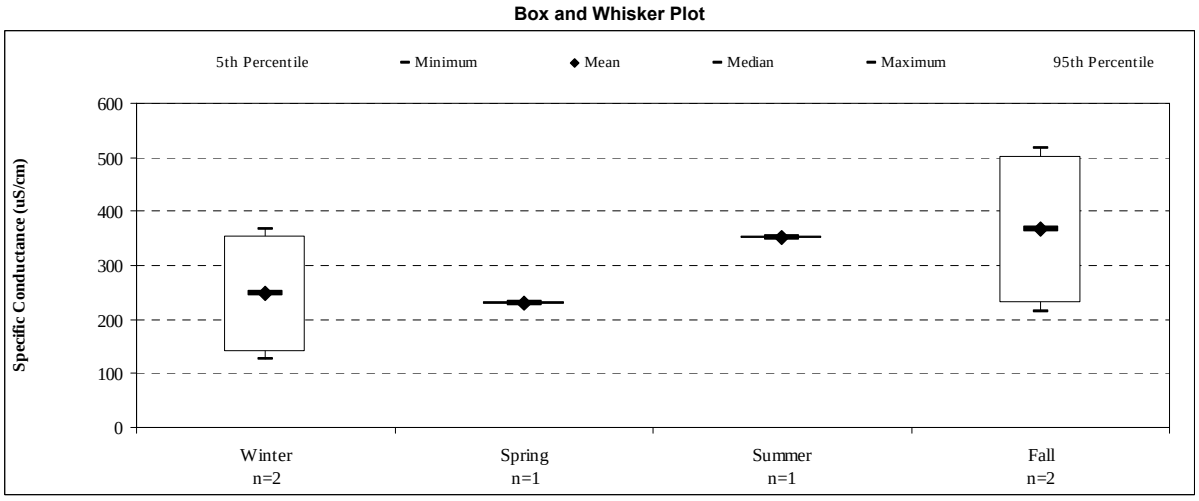


Figure G-1-8-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Unnamed Creek 3



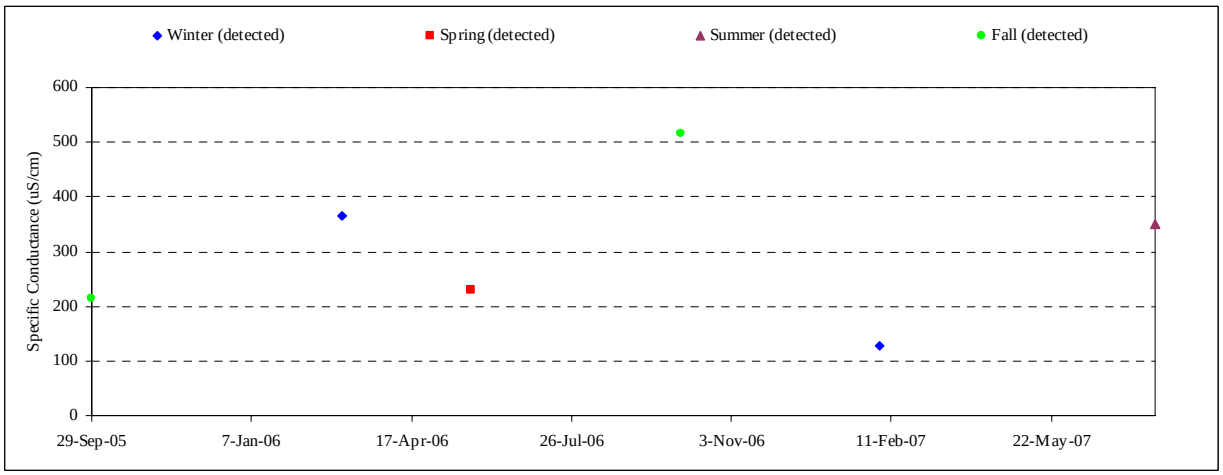
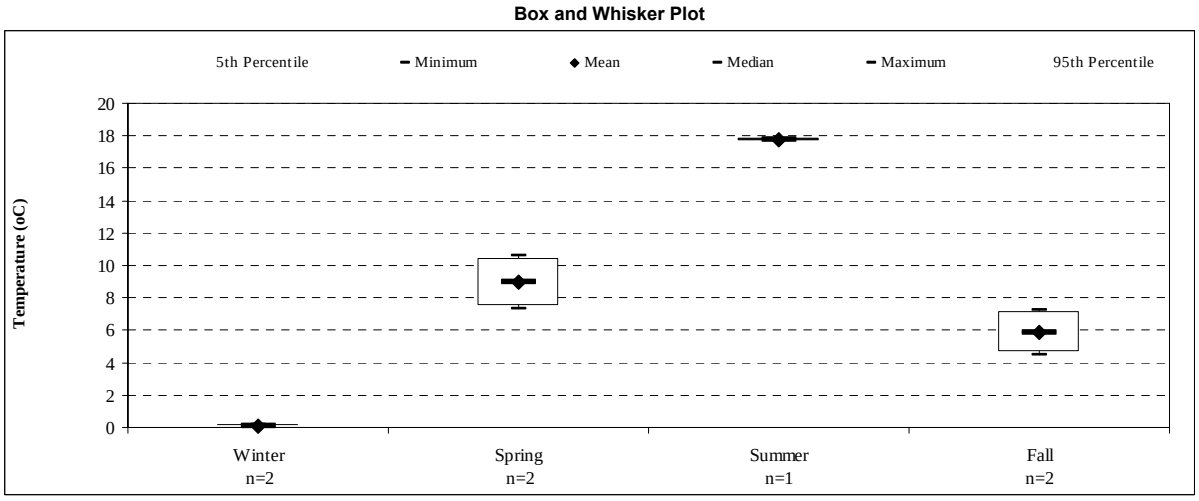


Figure G-1-8-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Unnamed Creek 3



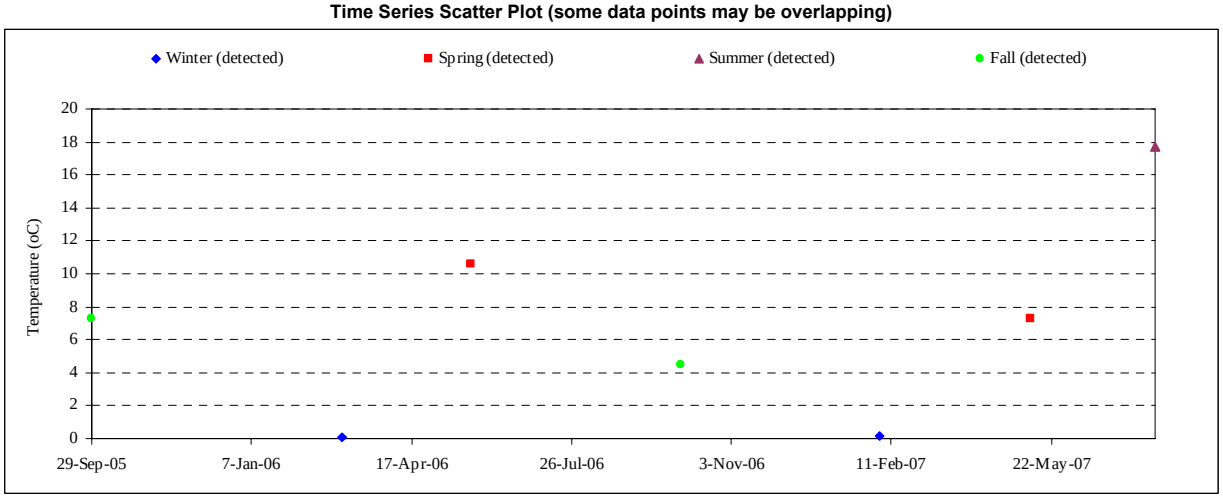
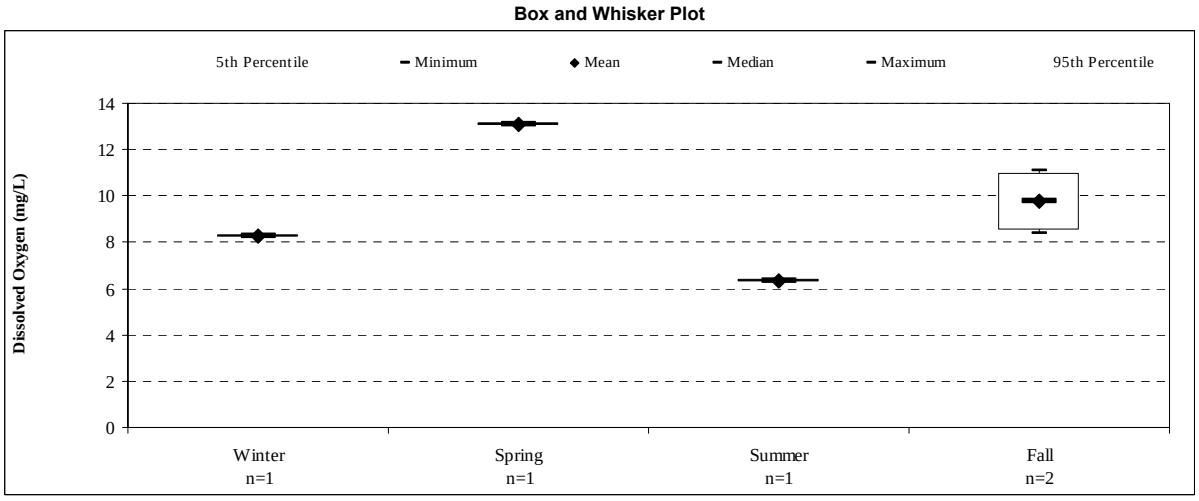


Figure G-1-8-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Unnamed Creek 3



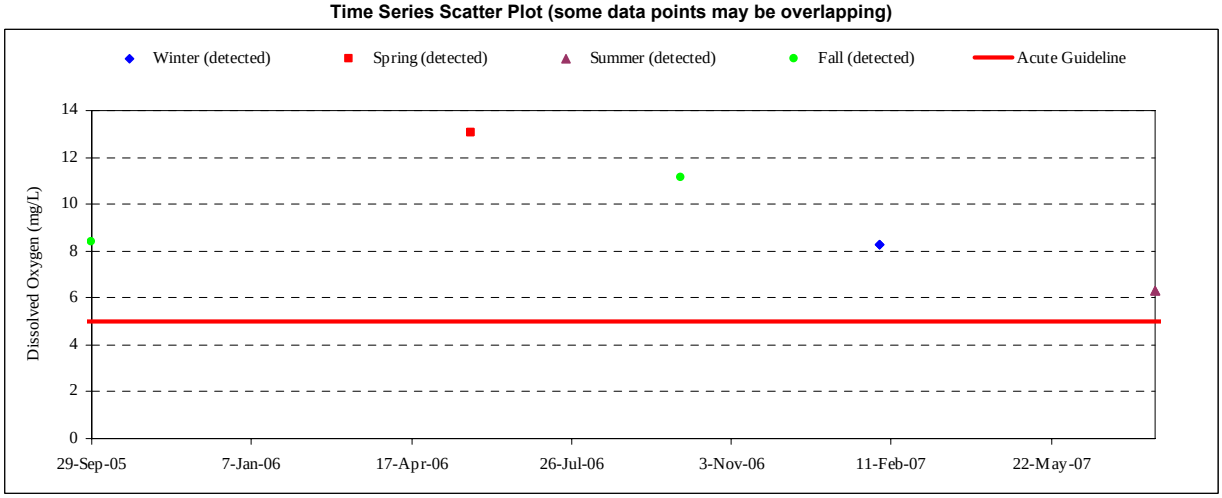
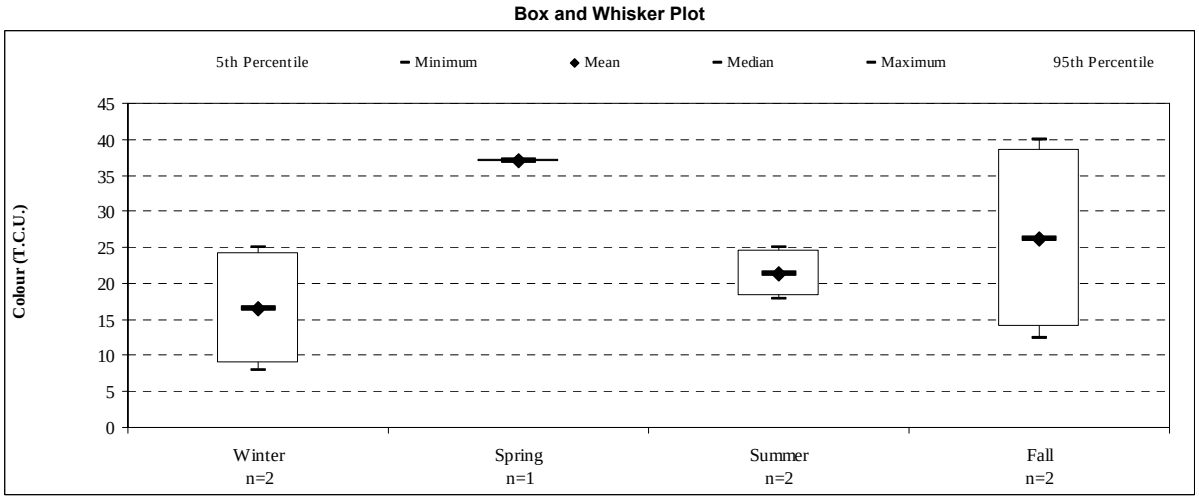


Figure G-1-8-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Unnamed Creek 3



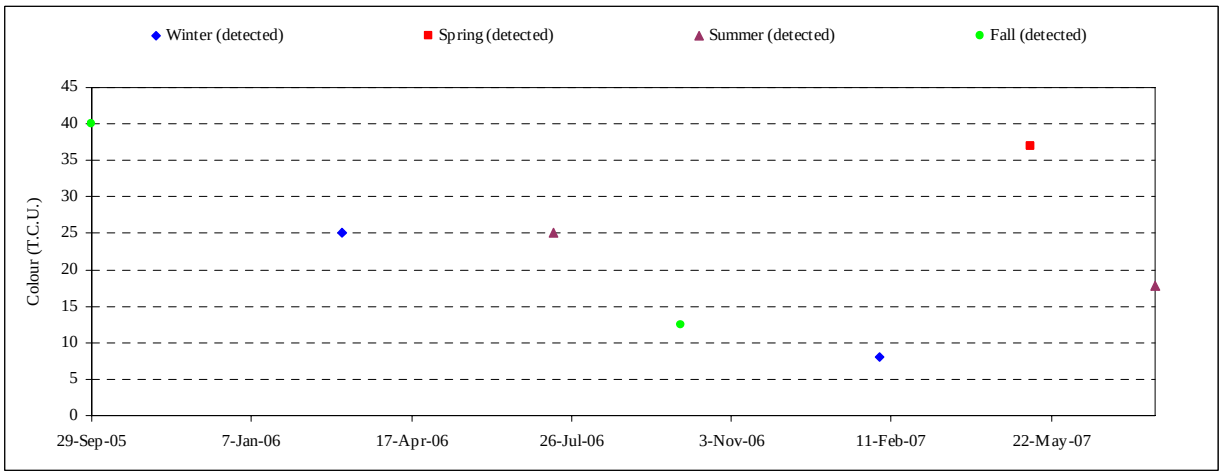
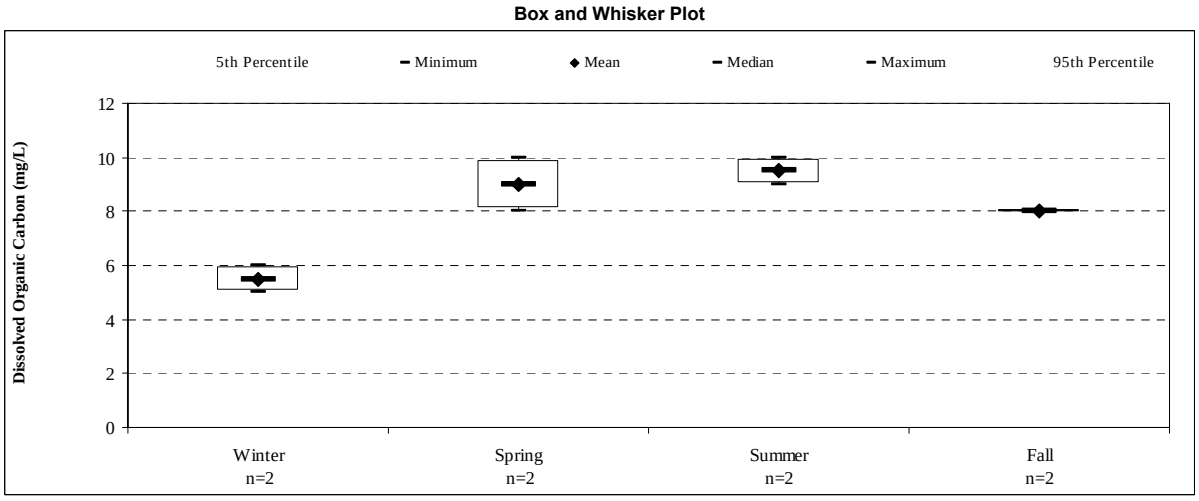


Figure G-1-8-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Unnamed Creek 3



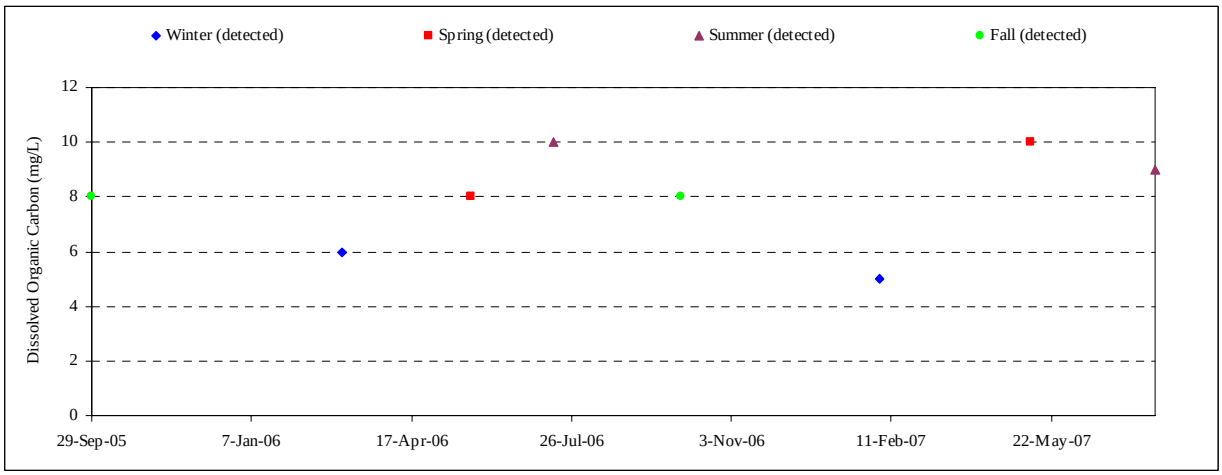
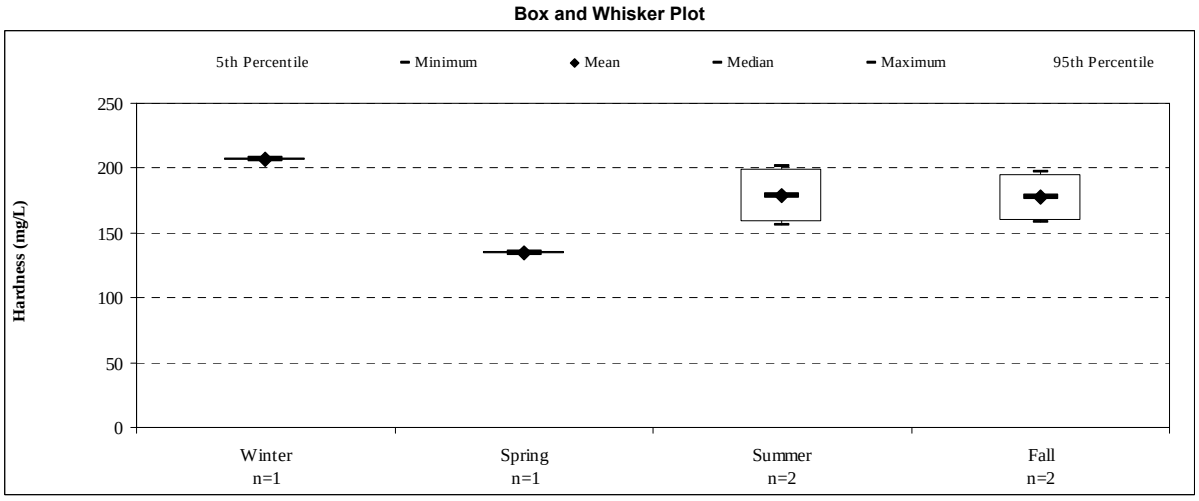


Figure G-1-8-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Unnamed Creek 3



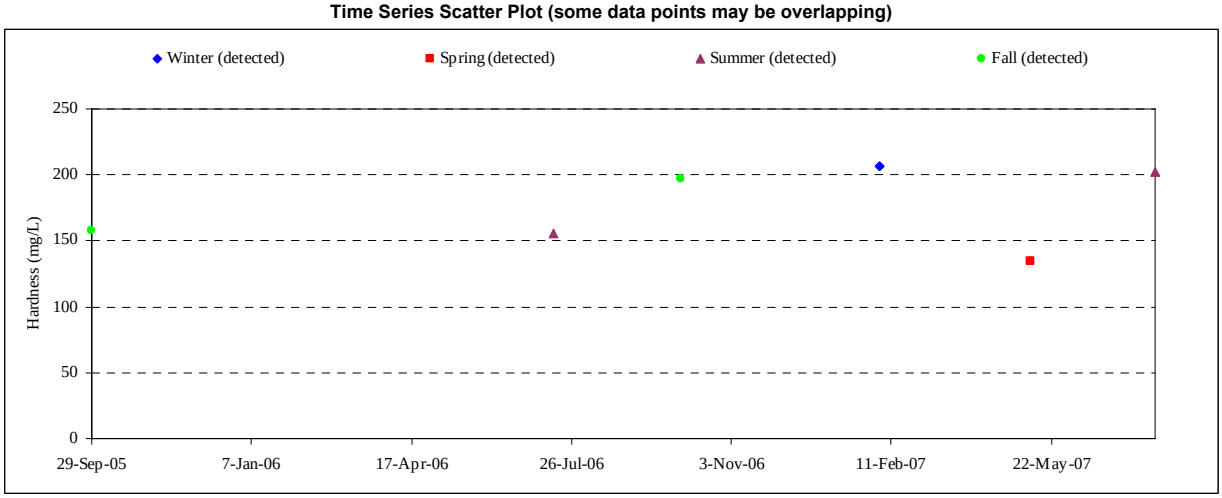
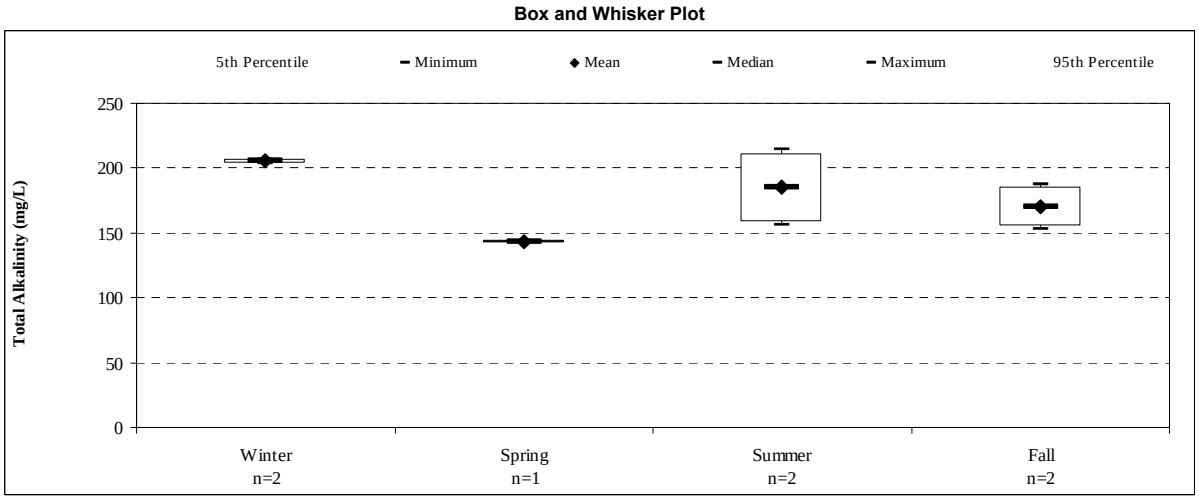


Figure G-1-8-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Unnamed Creek 3



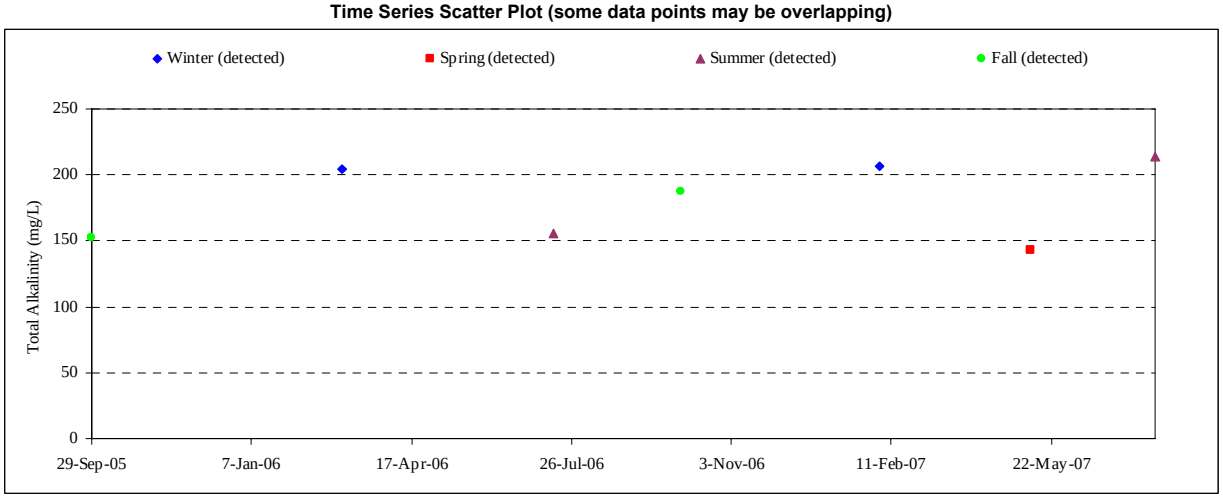
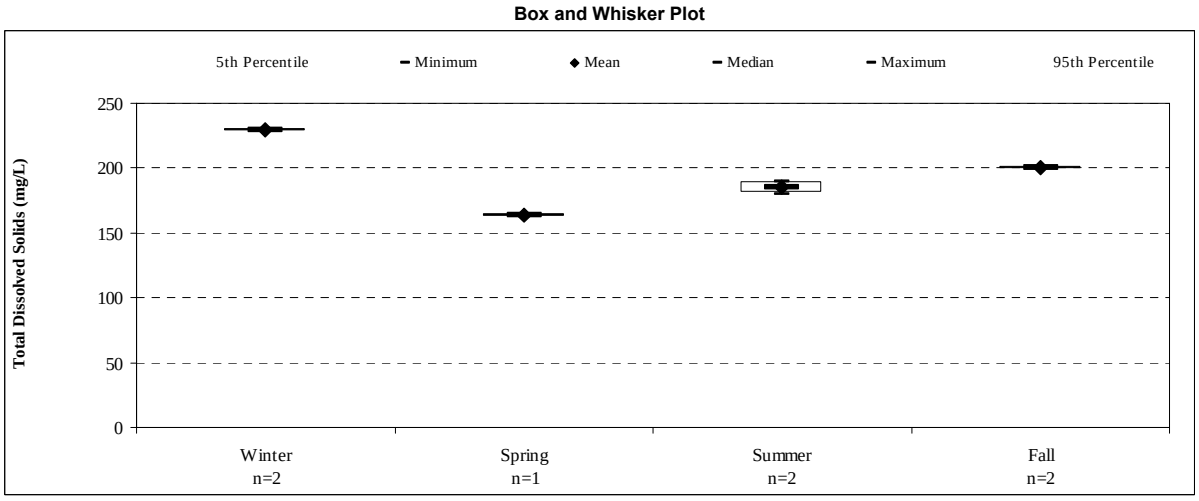


Figure G-1-8-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Unnamed Creek 3



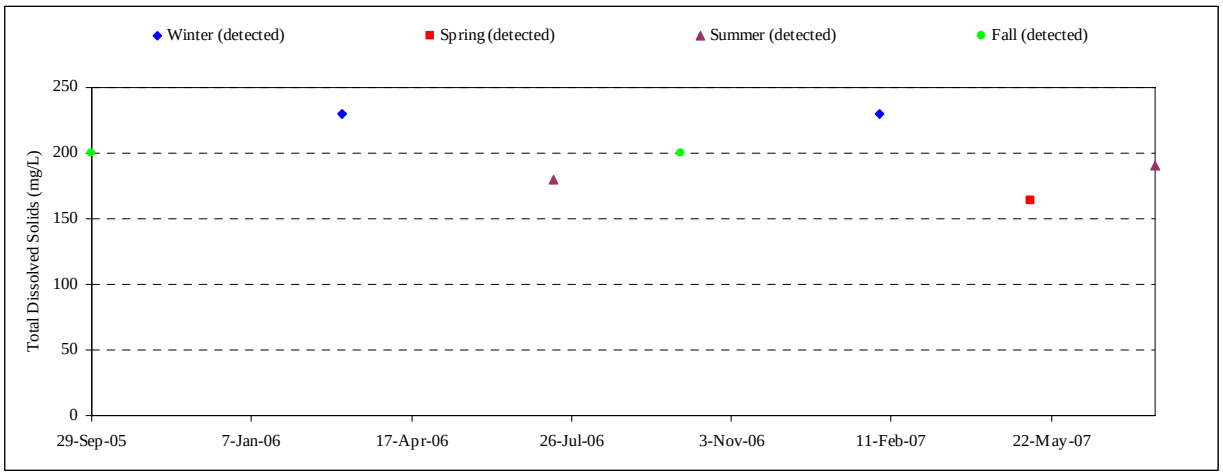
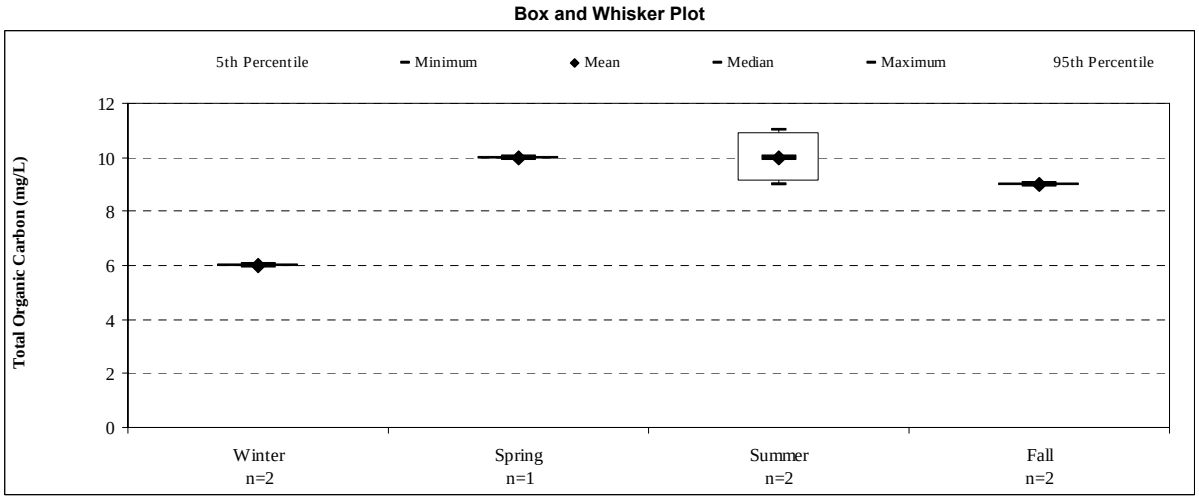


Figure G-1-8-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Unnamed Creek 3



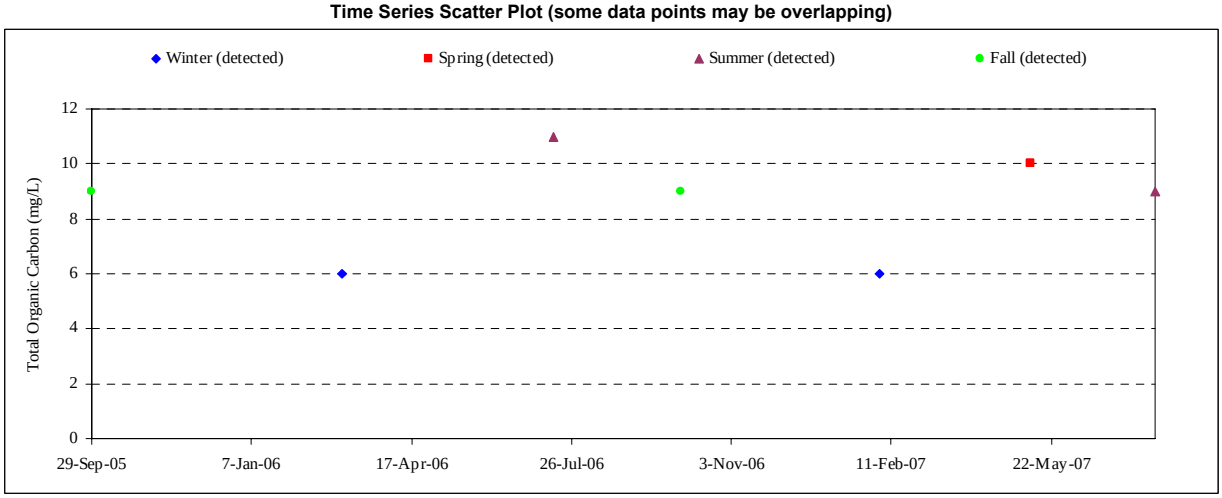
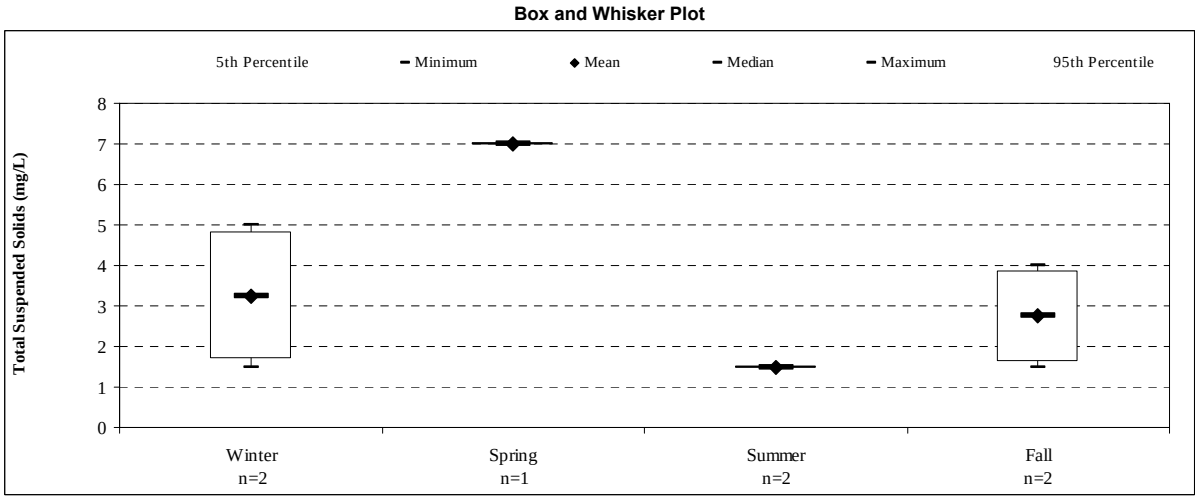


Figure G-1-8-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Unnamed Creek 3



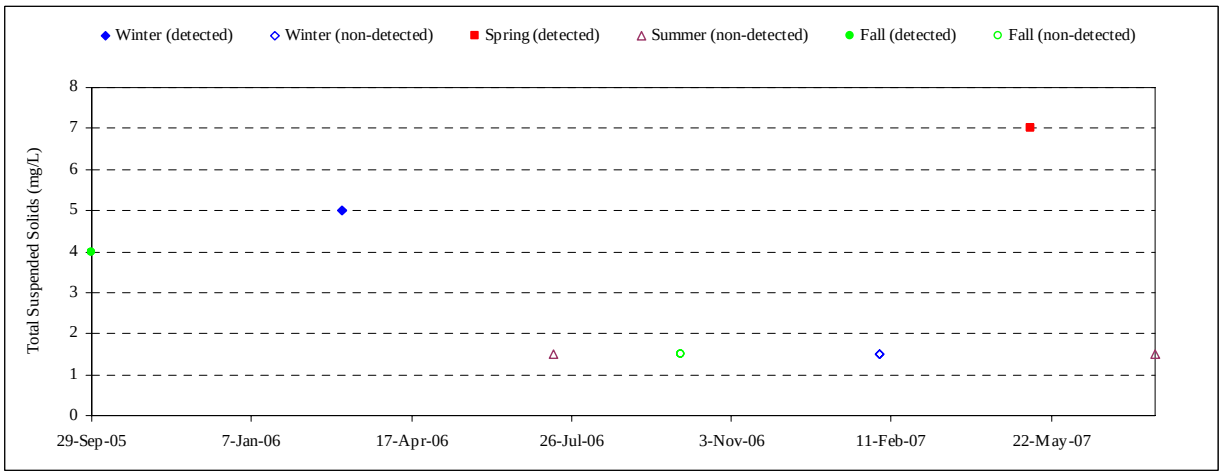
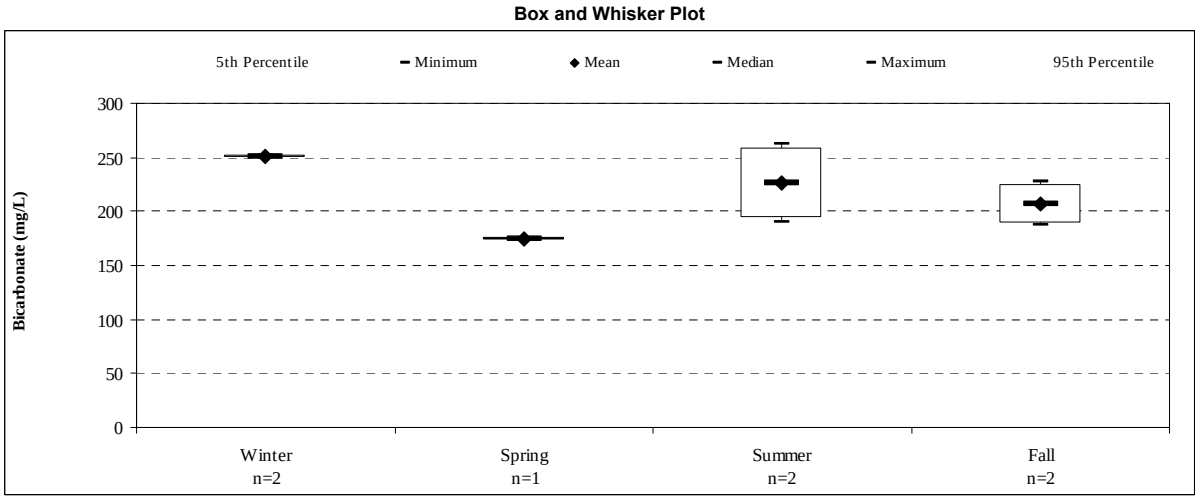


Figure G-1-8-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Unnamed Creek 3



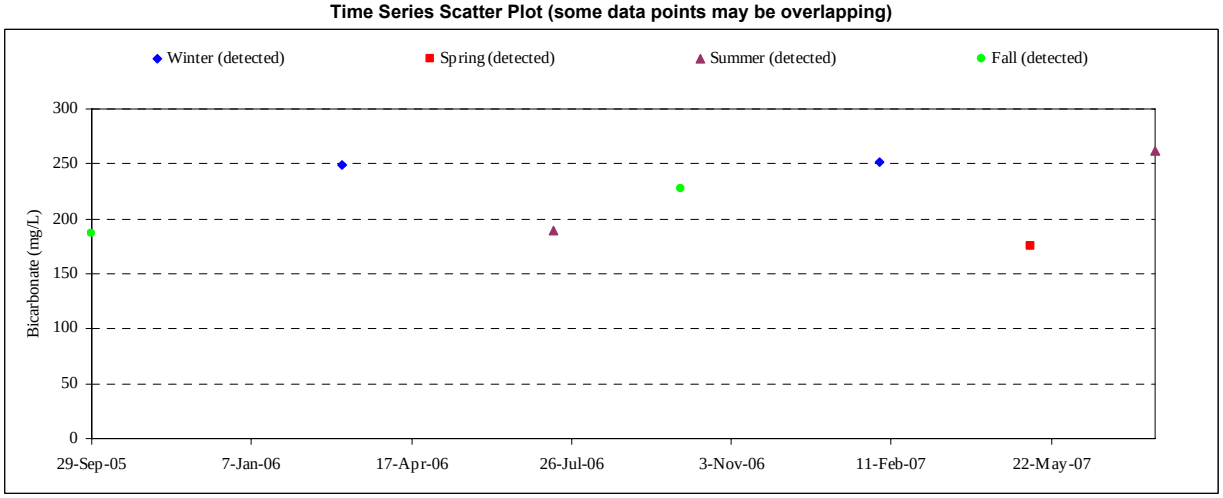
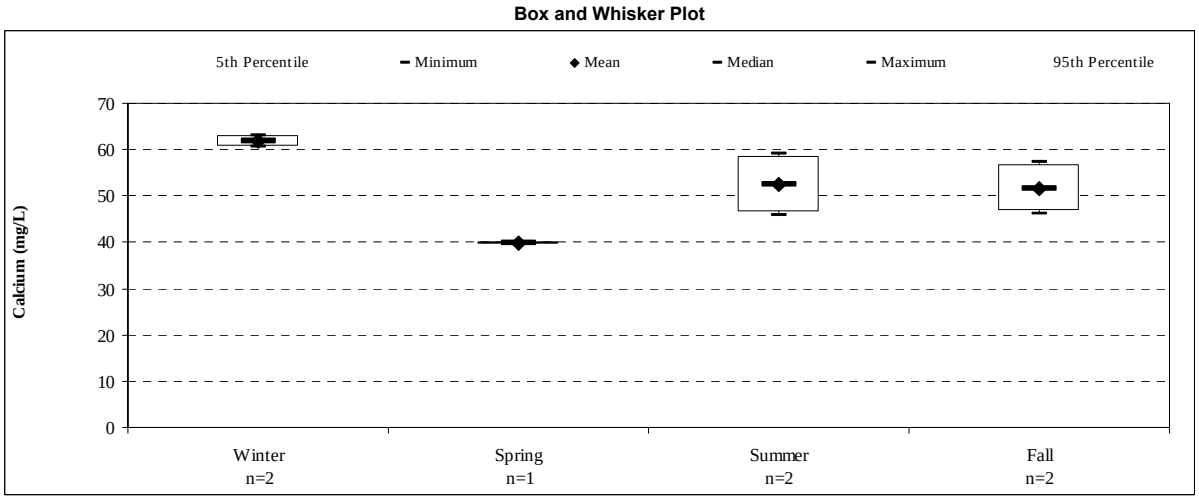


Figure G-1-8-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Unnamed Creek 3



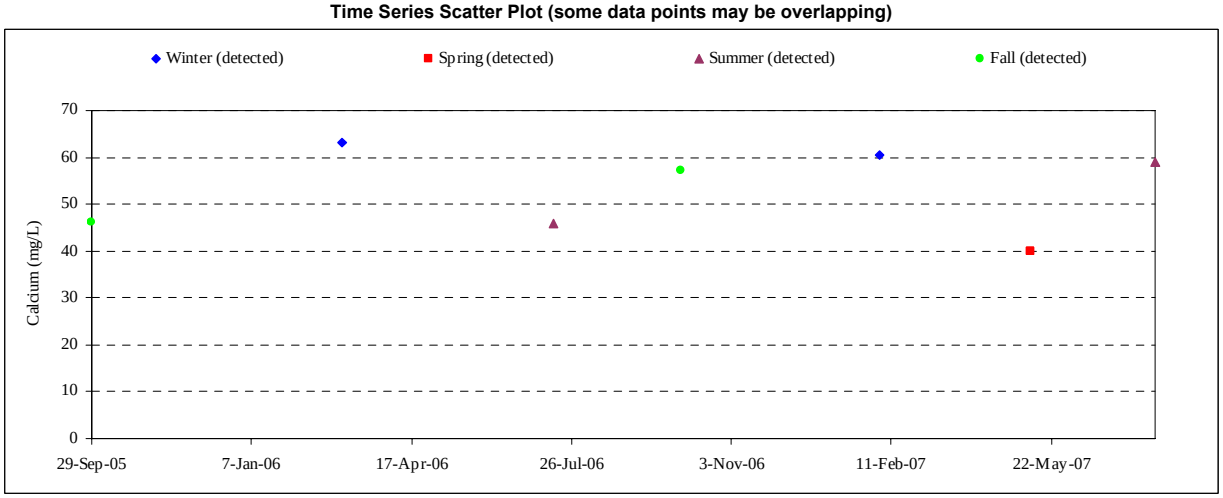
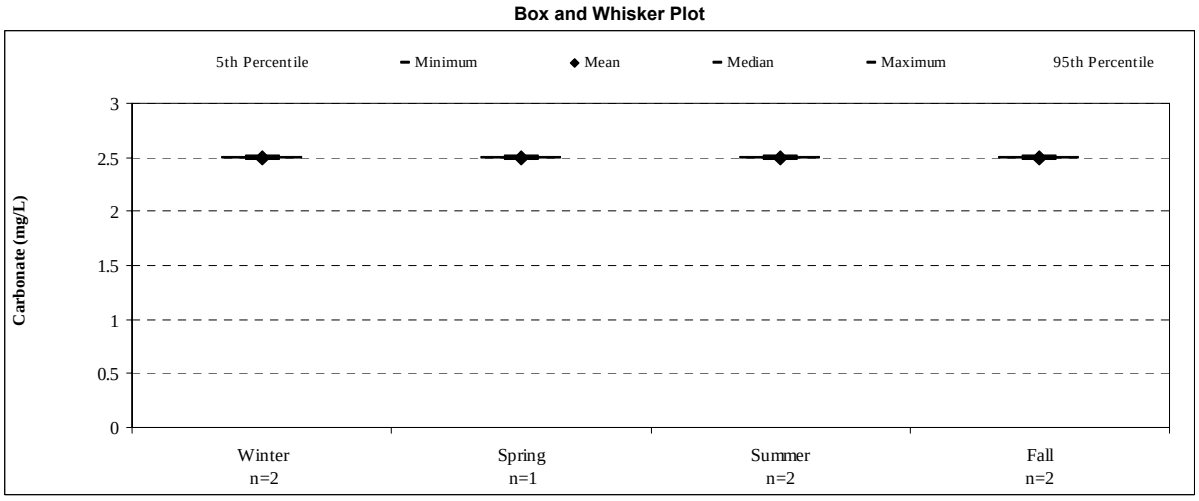


Figure G-1-8-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Unnamed Creek 3



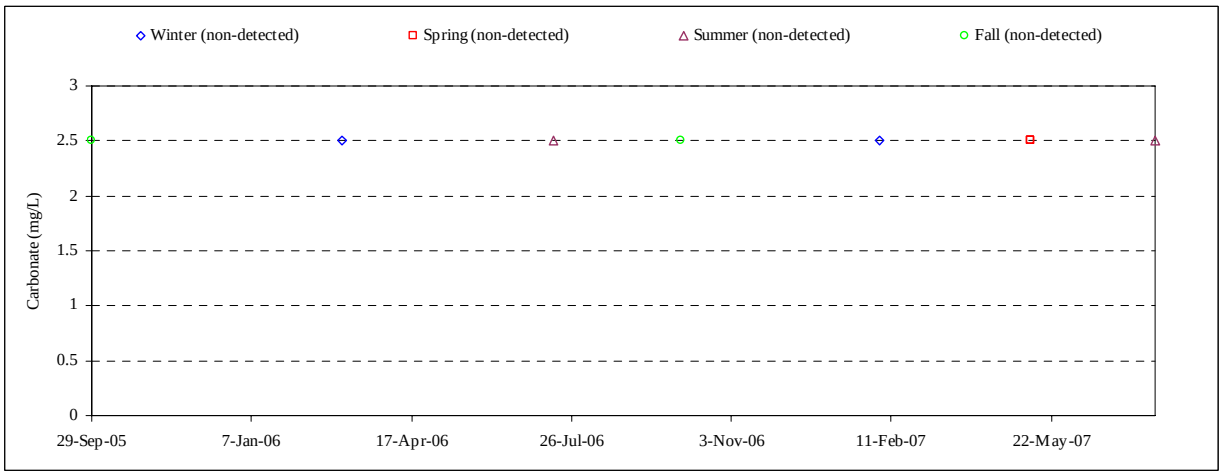
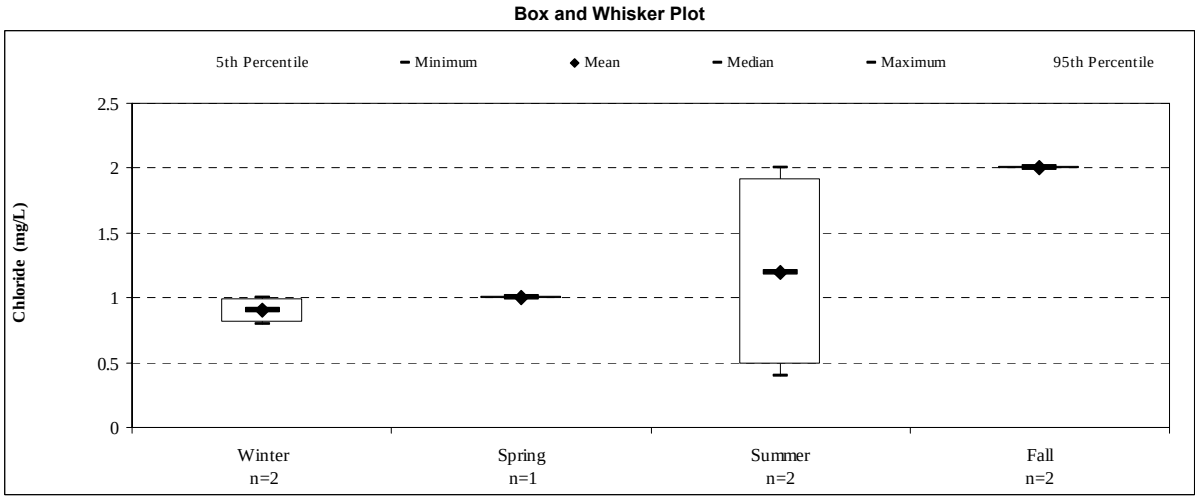


Figure G-1-8-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Unnamed Creek 3



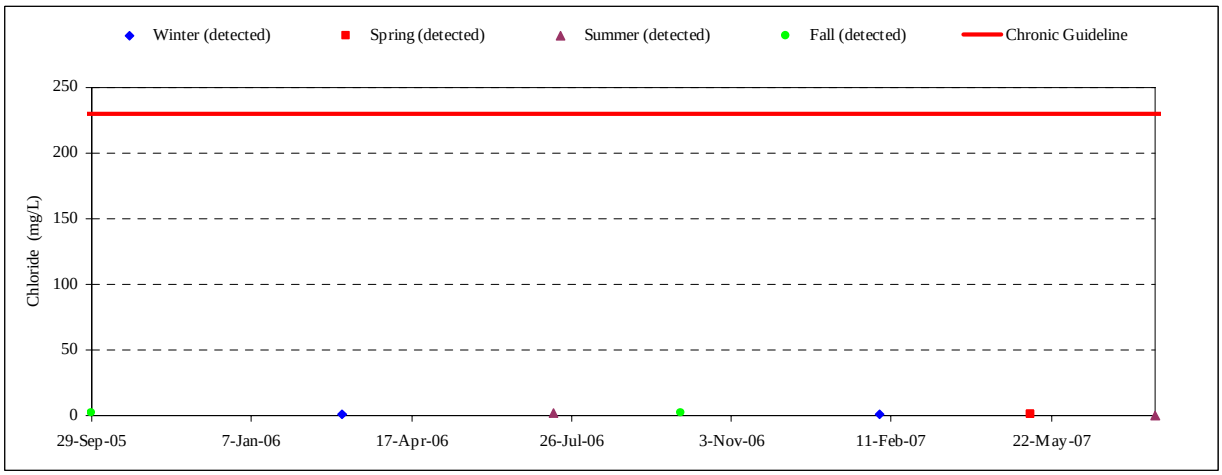
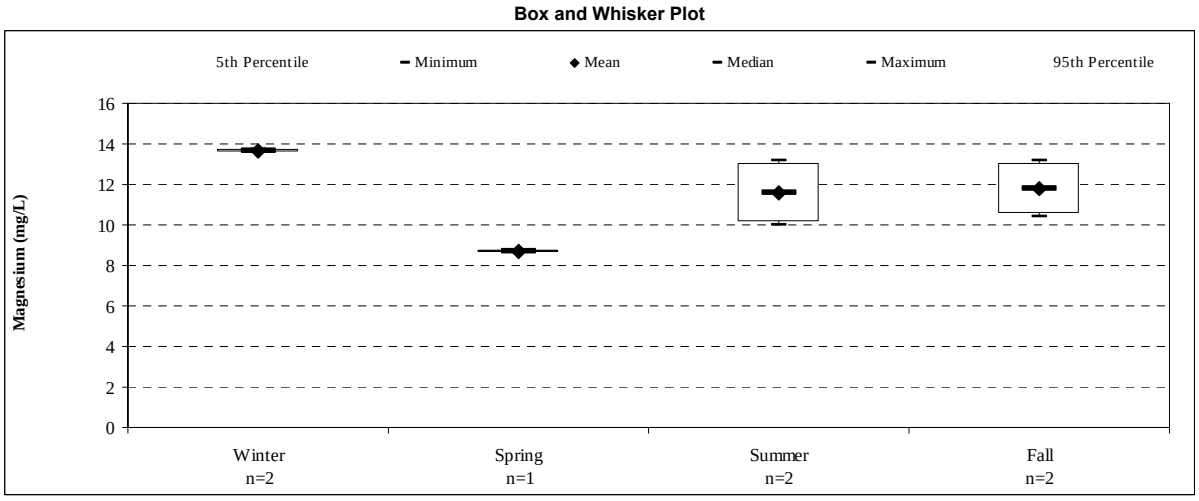


Figure G-1-8-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Unnamed Creek 3



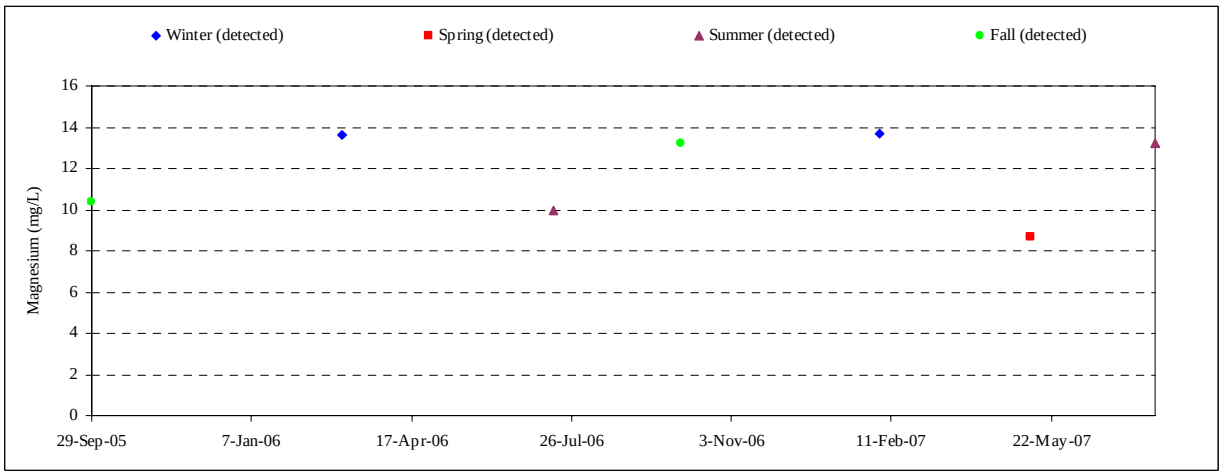
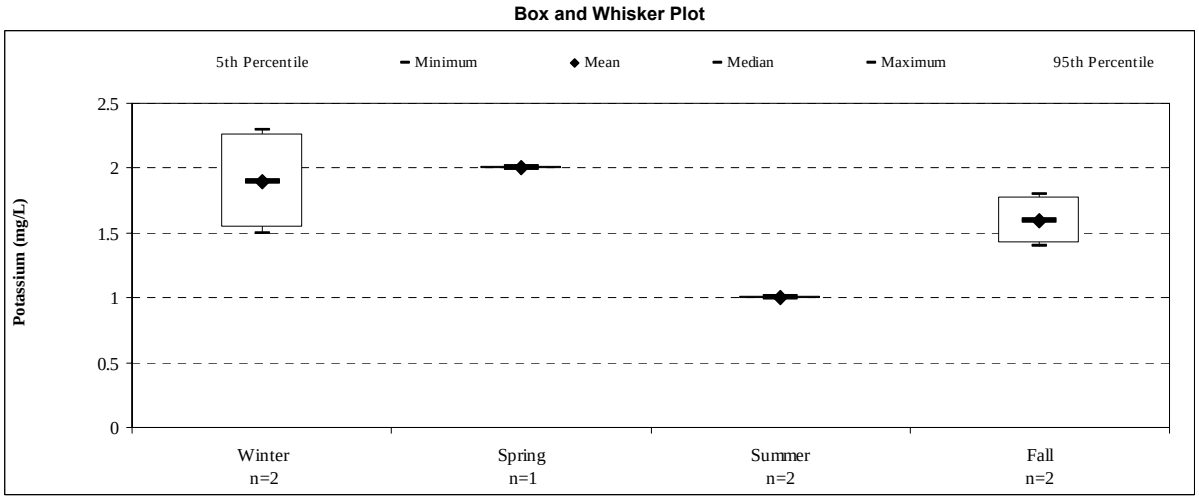


Figure G-1-8-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Unnamed Creek 3



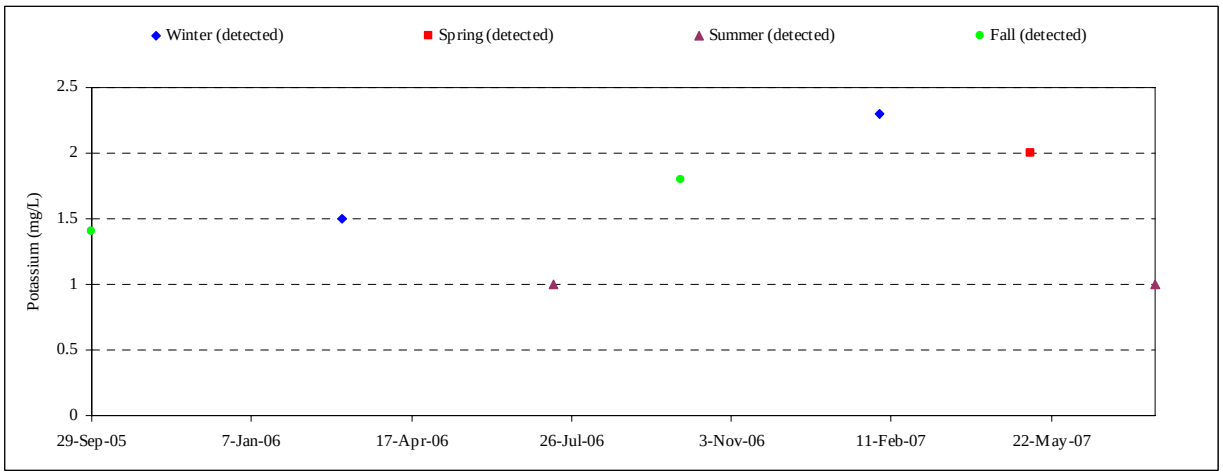
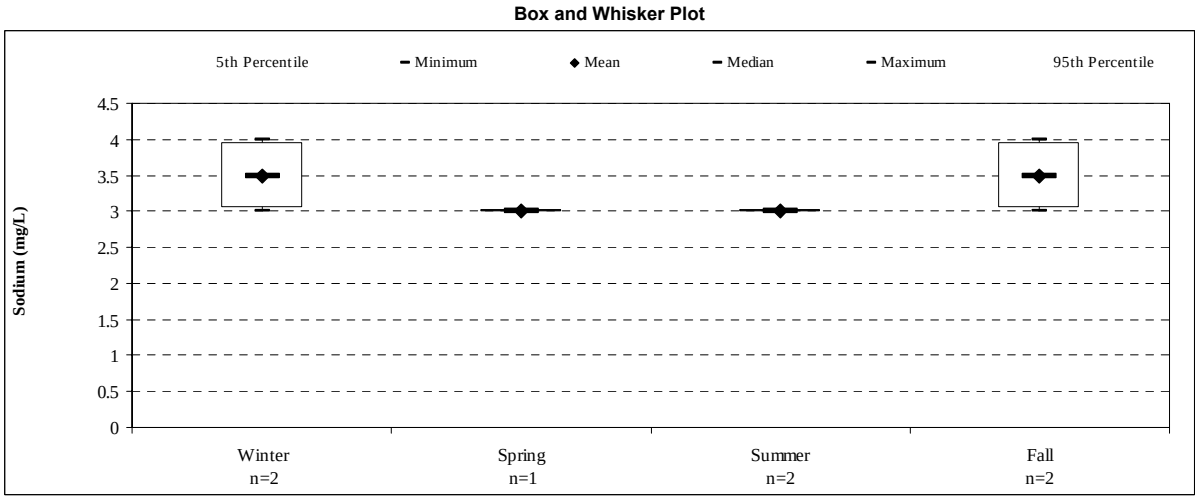


Figure G-1-8-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Unnamed Creek 3



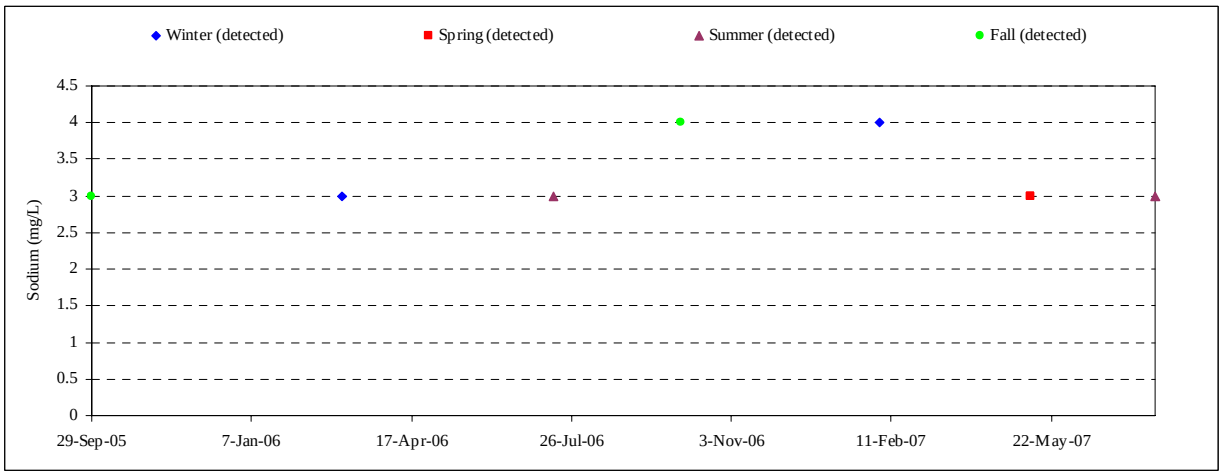
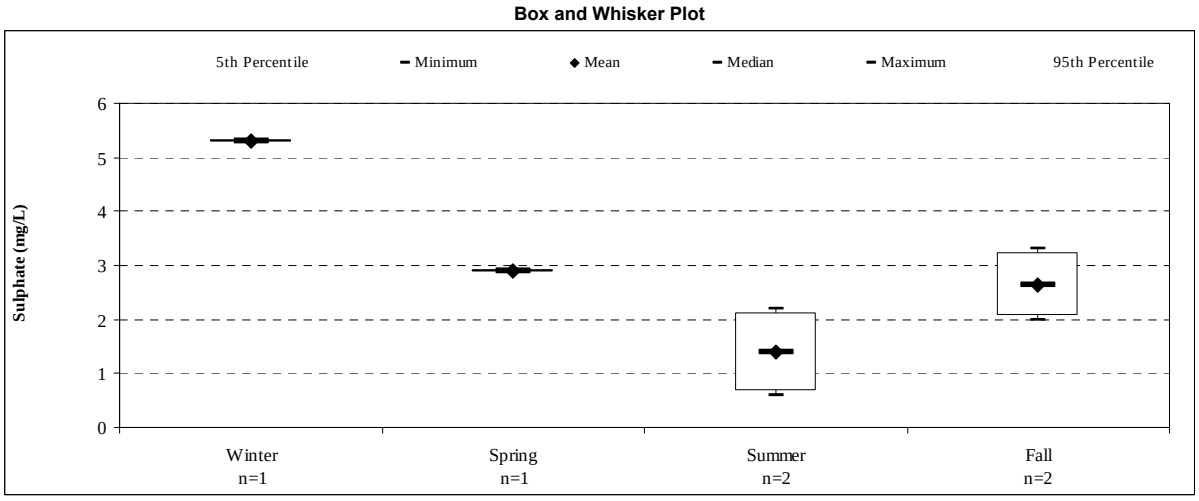


Figure G-1-8-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Unnamed Creek 3



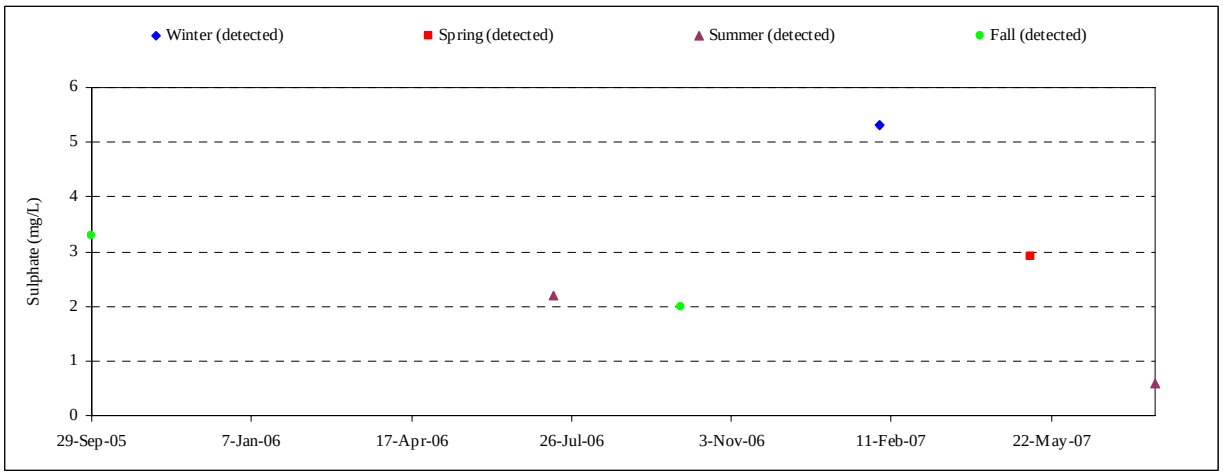
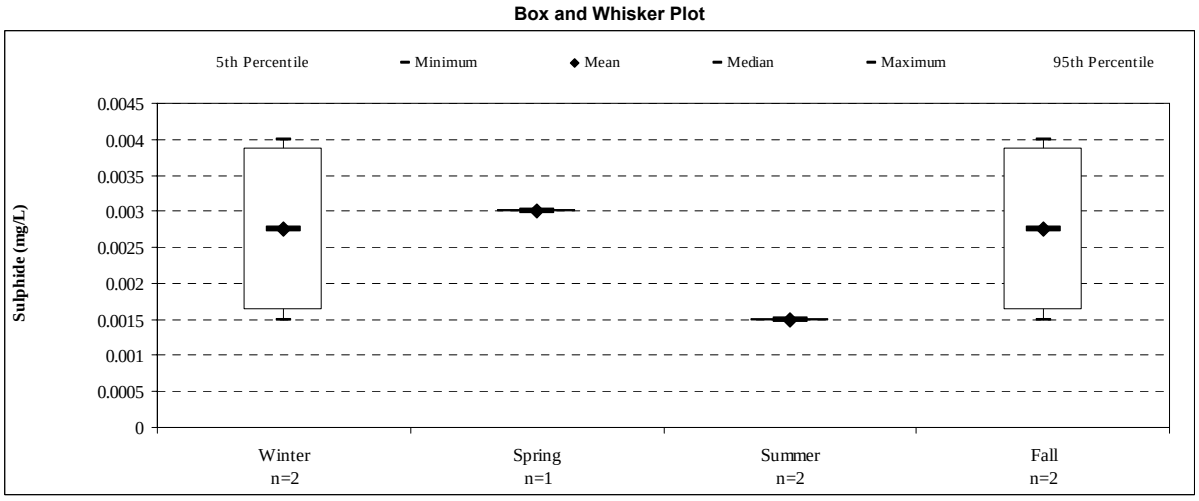


Figure G-1-8-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Unnamed Creek 3



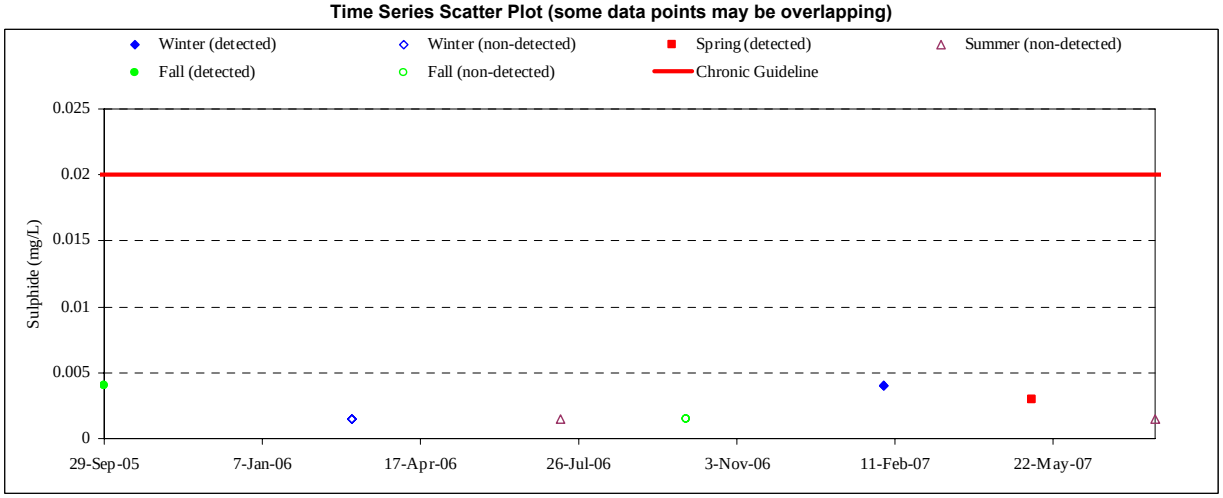
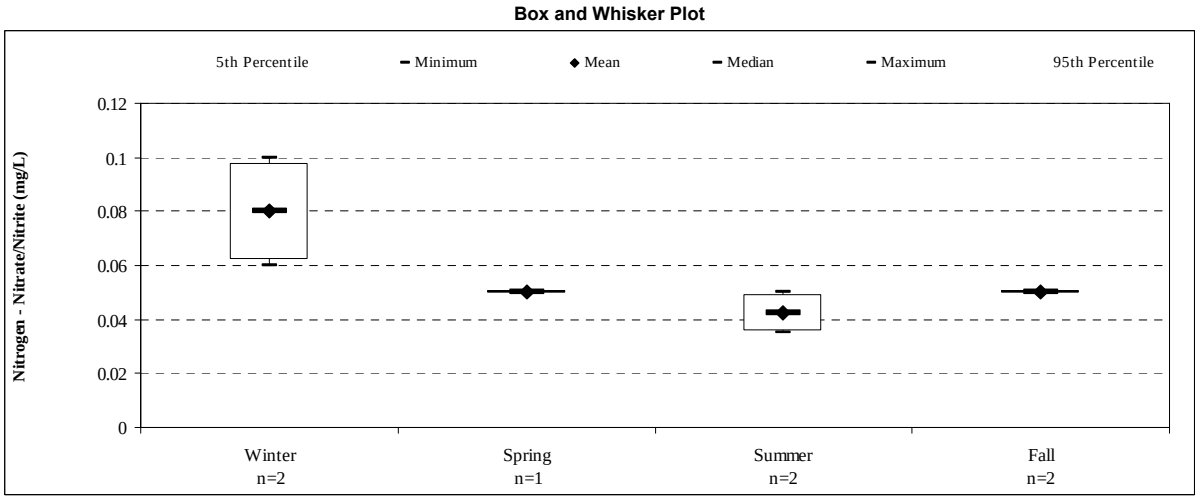


Figure G-1-8-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Unnamed Creek 3



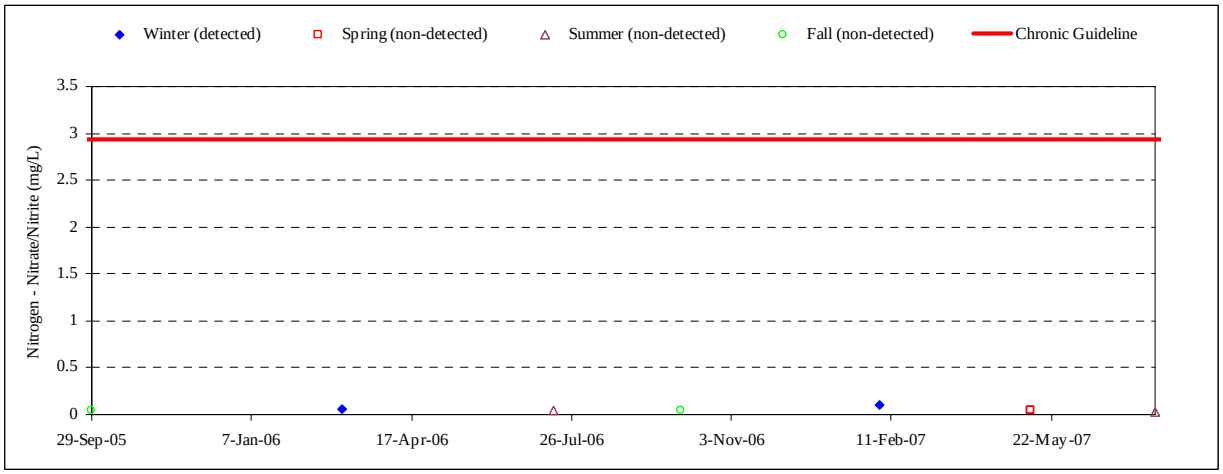
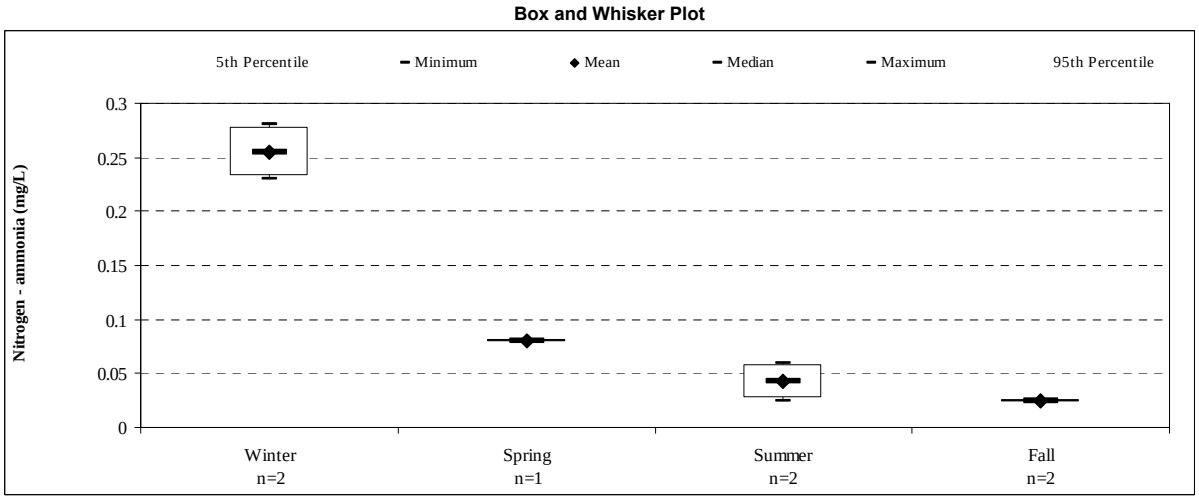


Figure G-1-8-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Unnamed Creek 3



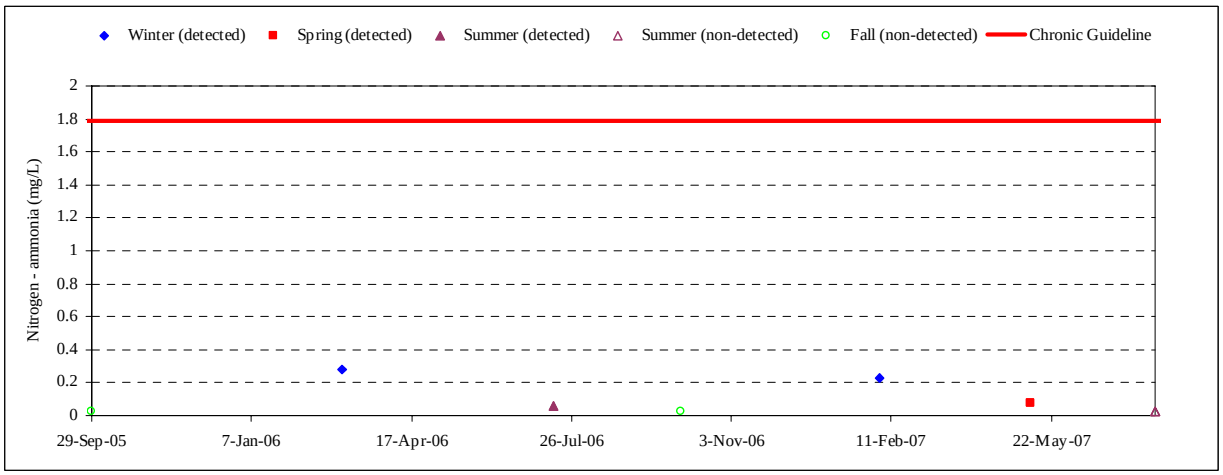
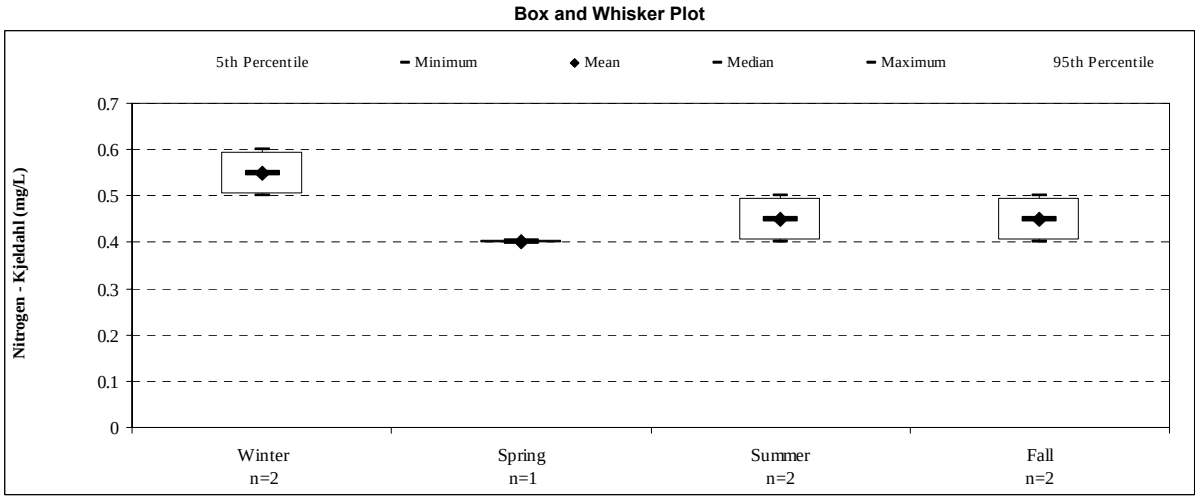


Figure G-1-8-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Unnamed Creek 3



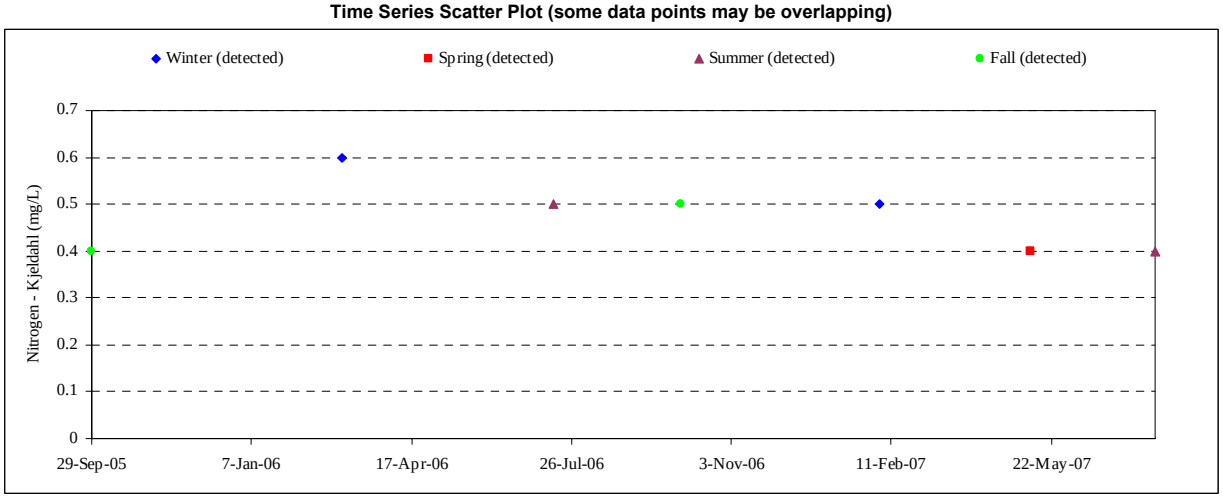
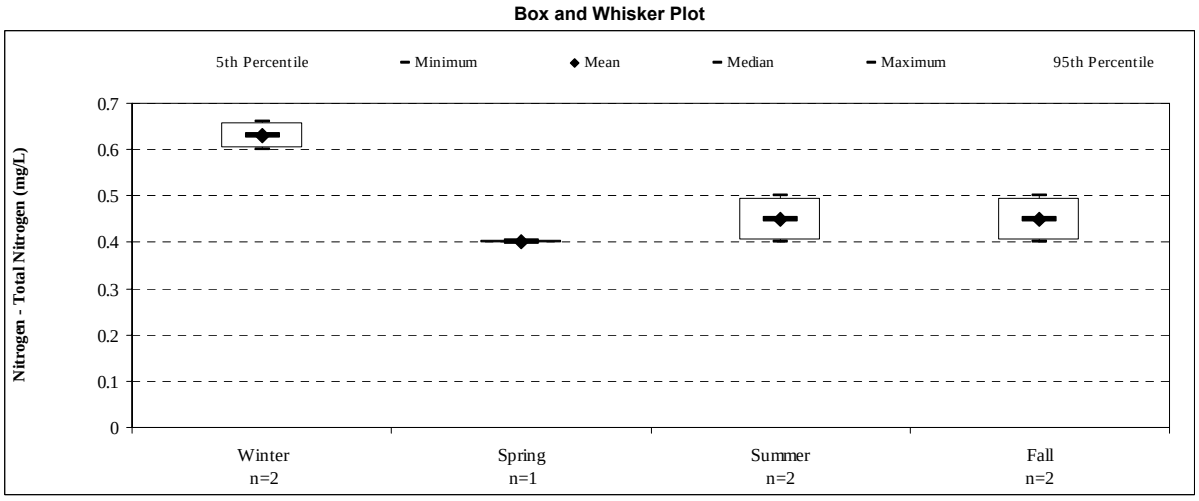


Figure G-1-8-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Unnamed Creek 3



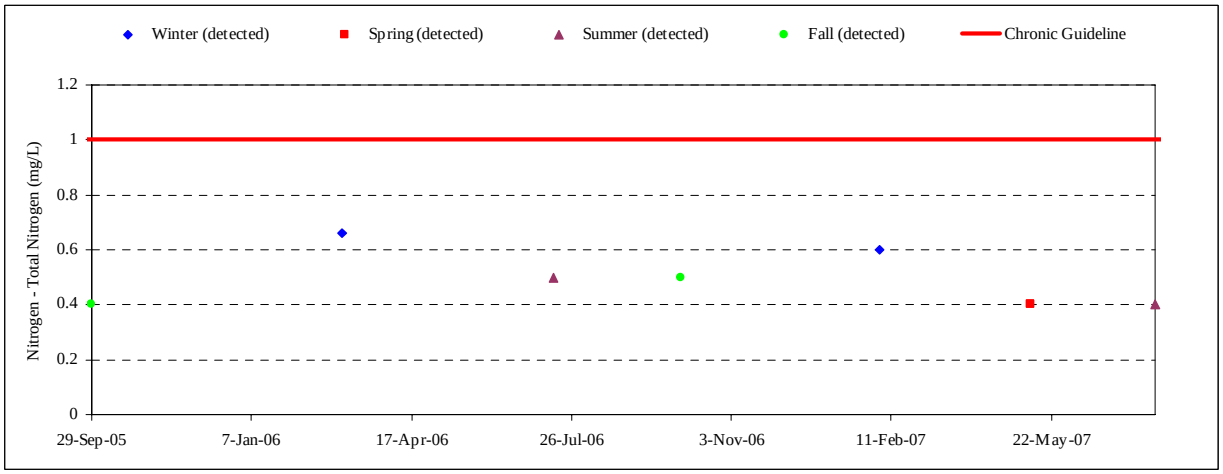
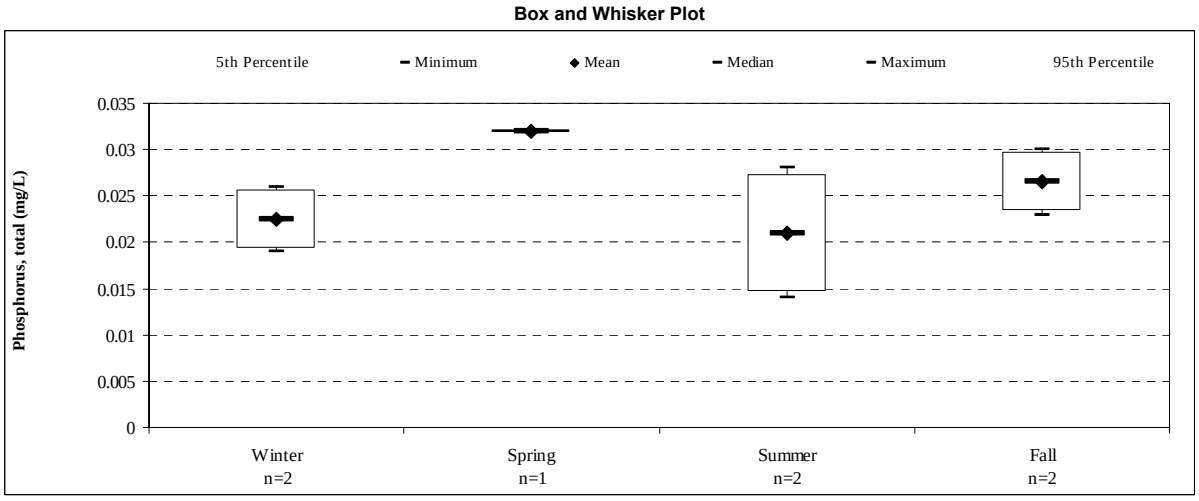


Figure G-1-8-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Unnamed Creek 3



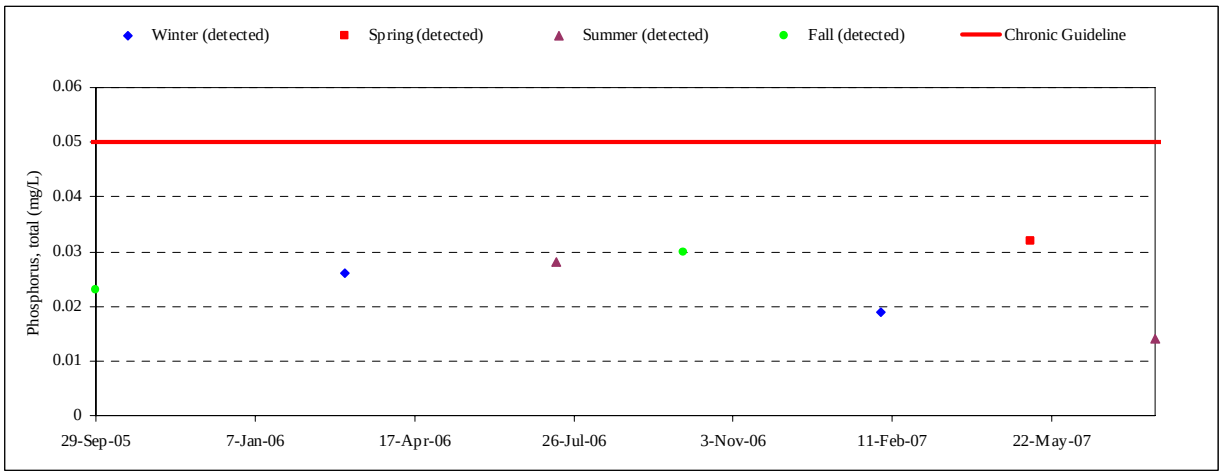
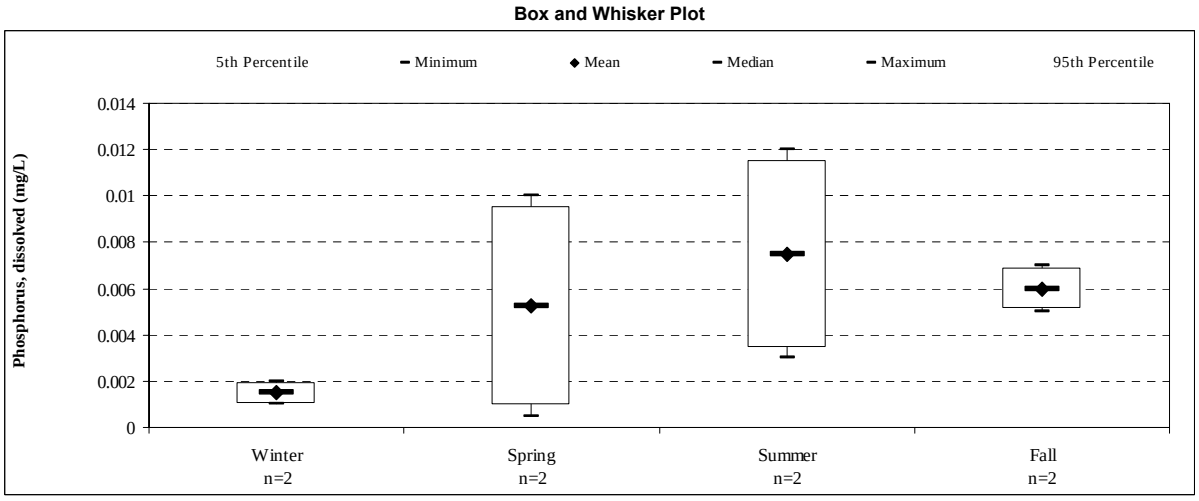


Figure G-1-8-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Unnamed Creek 3



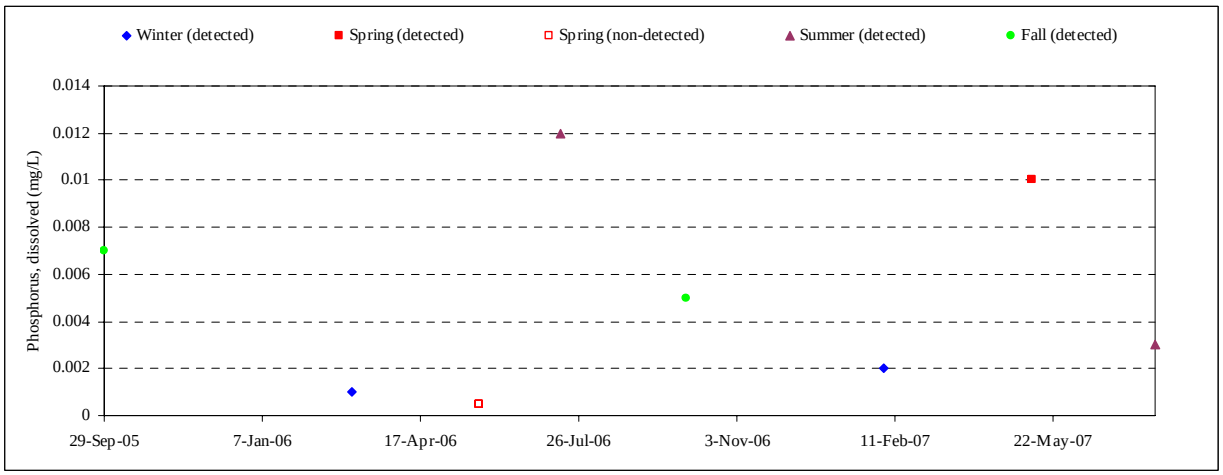
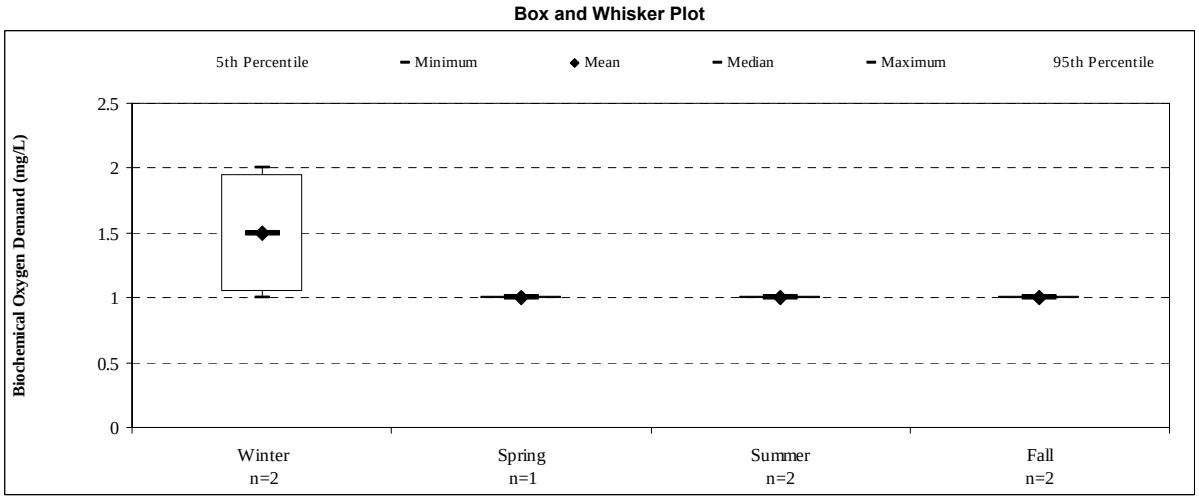


Figure G-1-8-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Unnamed Creek 3



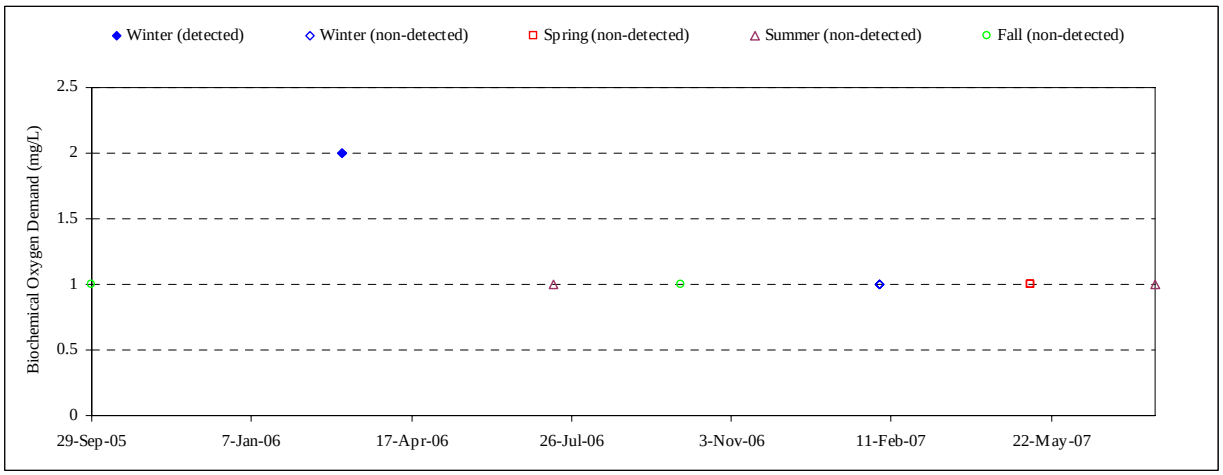
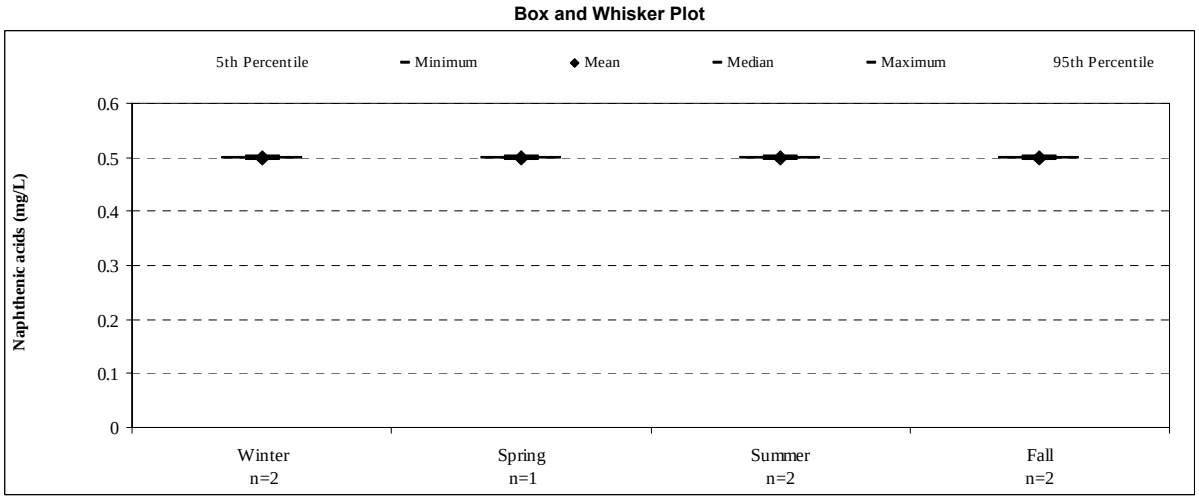


Figure G-1-8-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Unnamed Creek 3



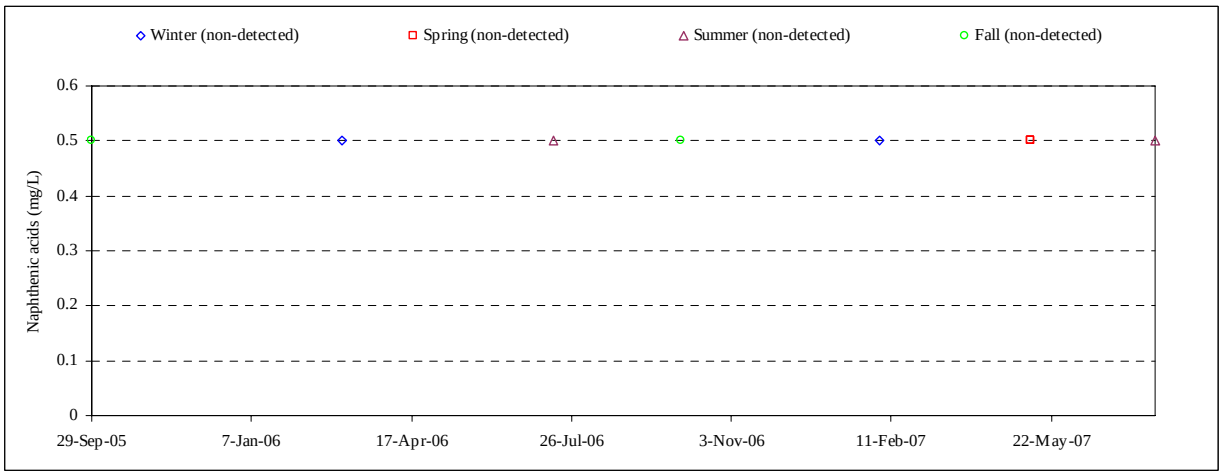
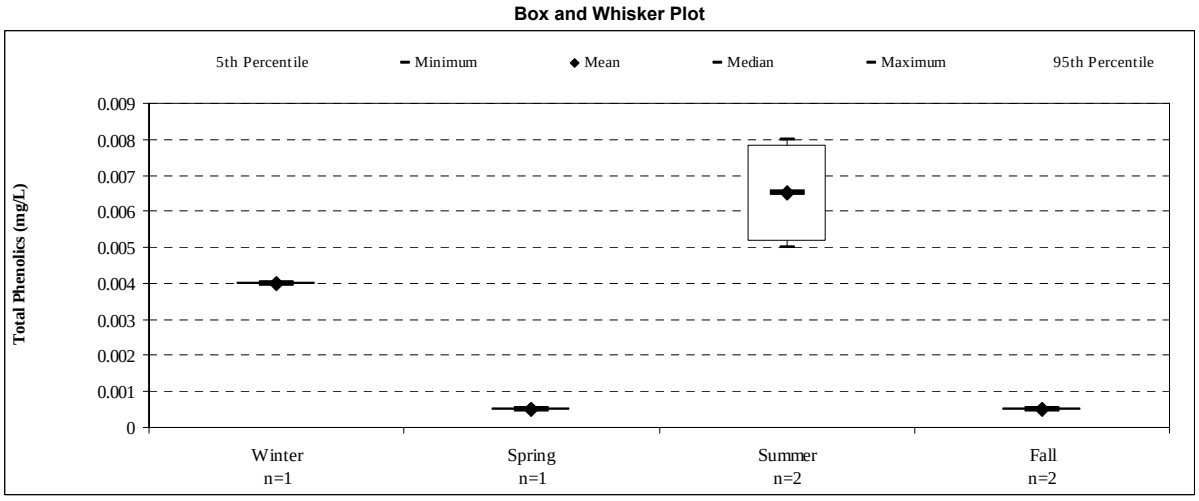


Figure G-1-8-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Unnamed Creek 3



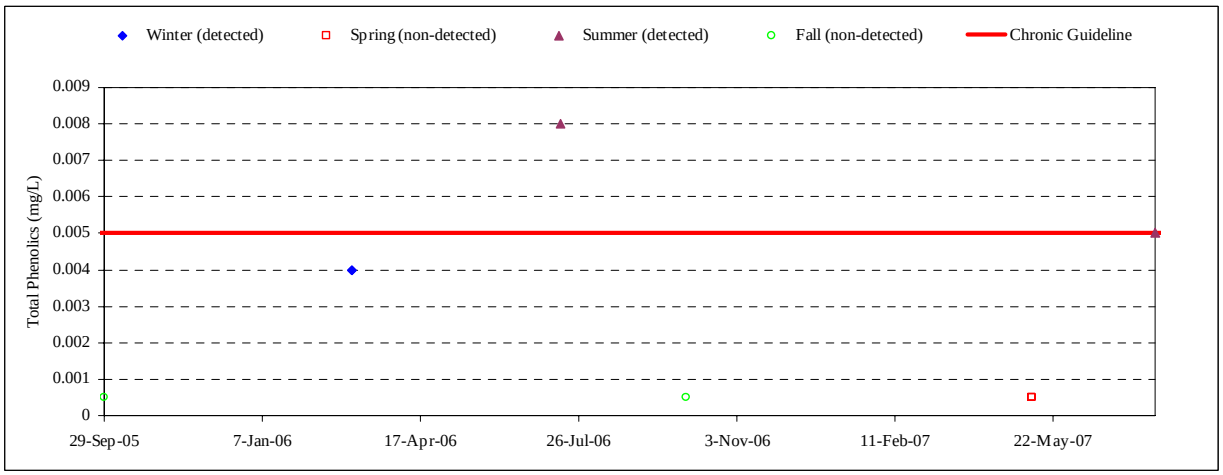
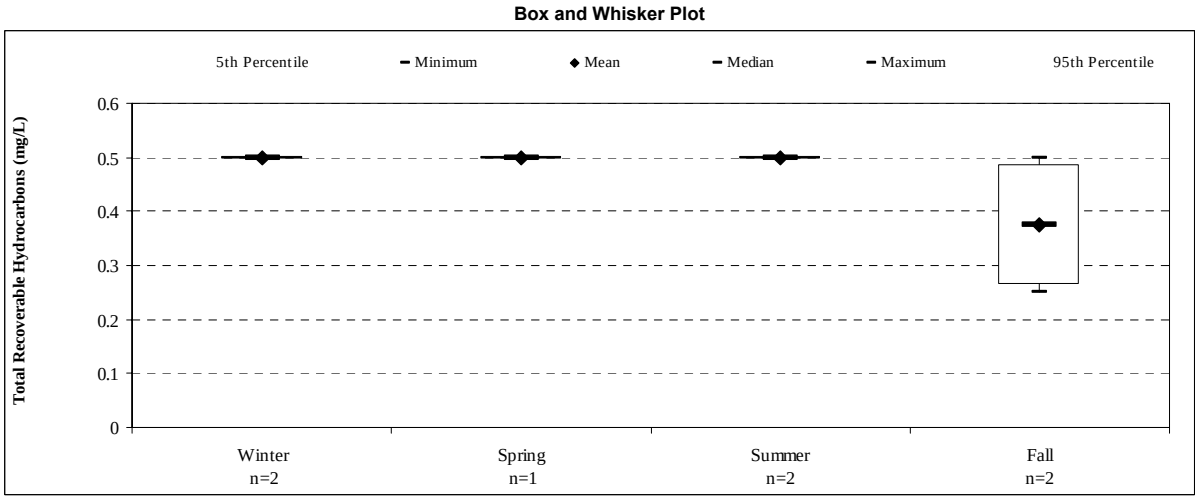


Figure G-1-8-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Unnamed Creek 3



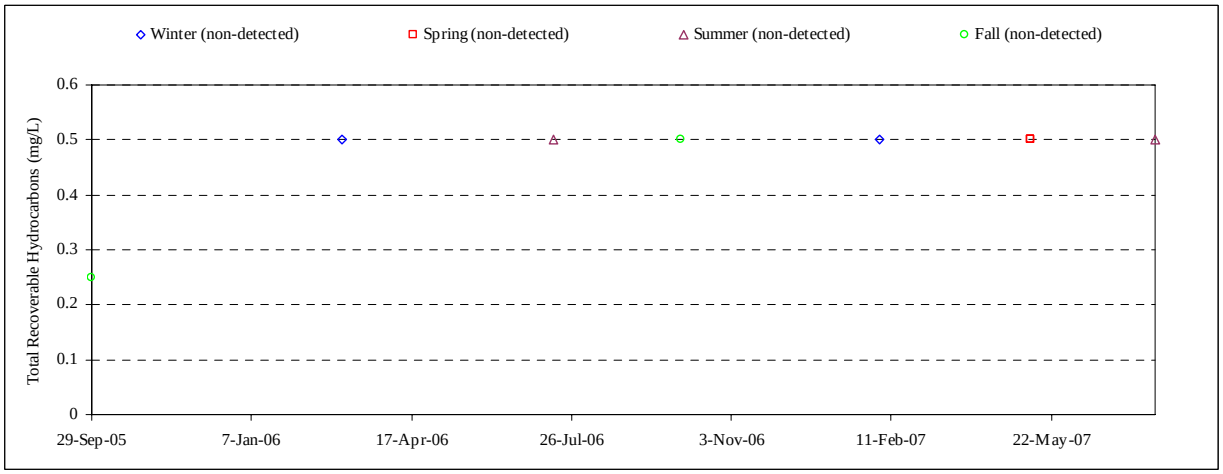
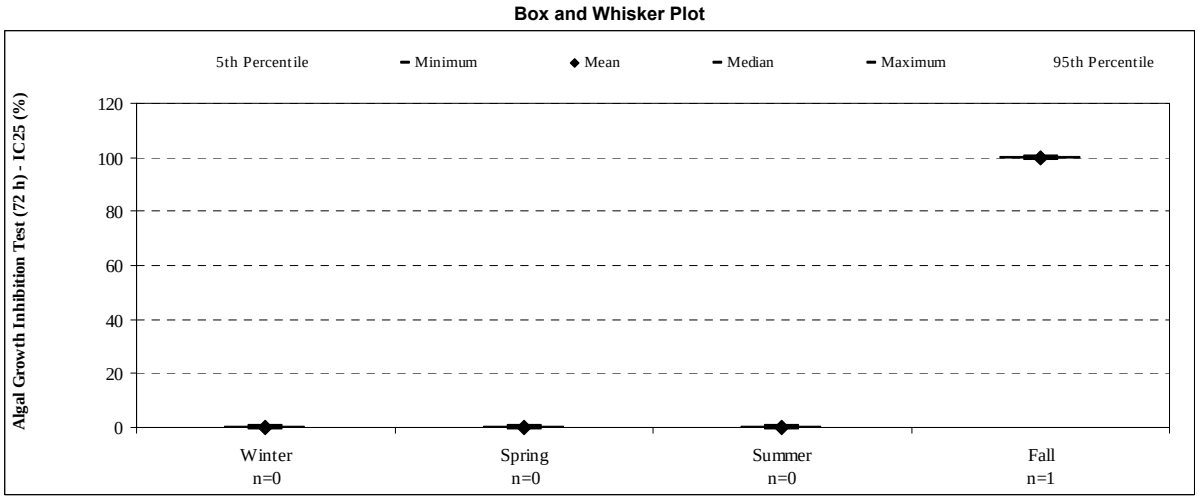


Figure G-1-8-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Unnamed Creek 3



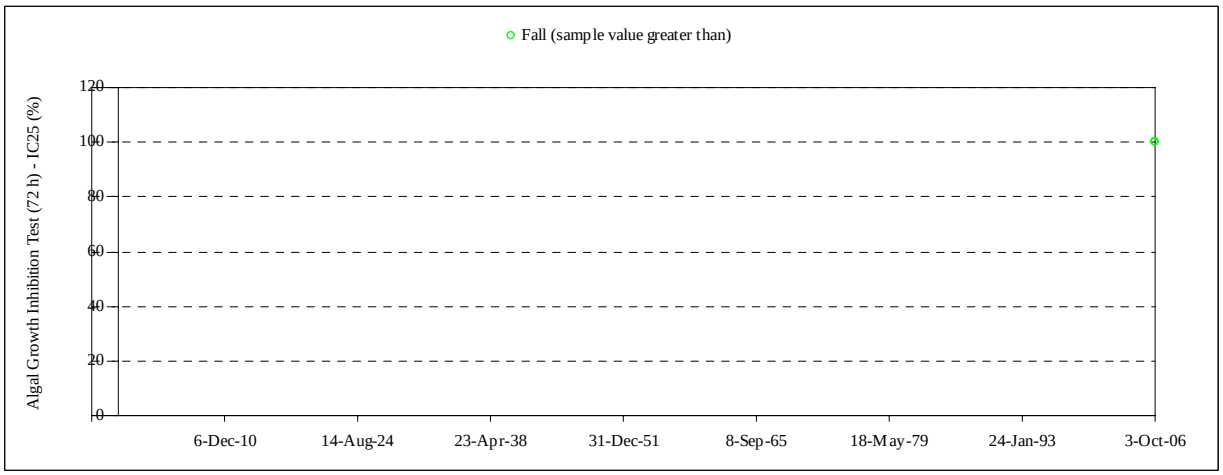
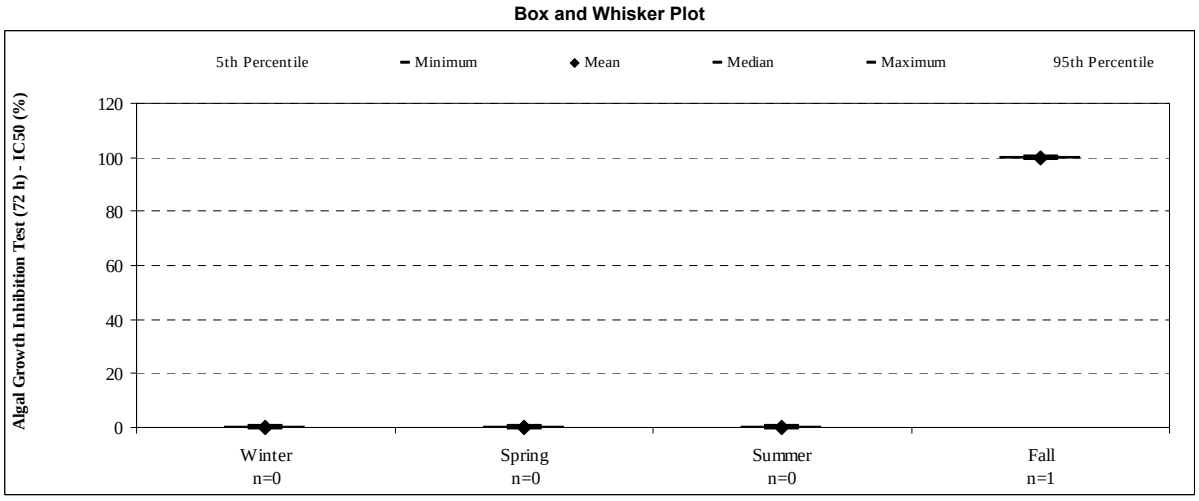


Figure G-1-8-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Unnamed Creek 3



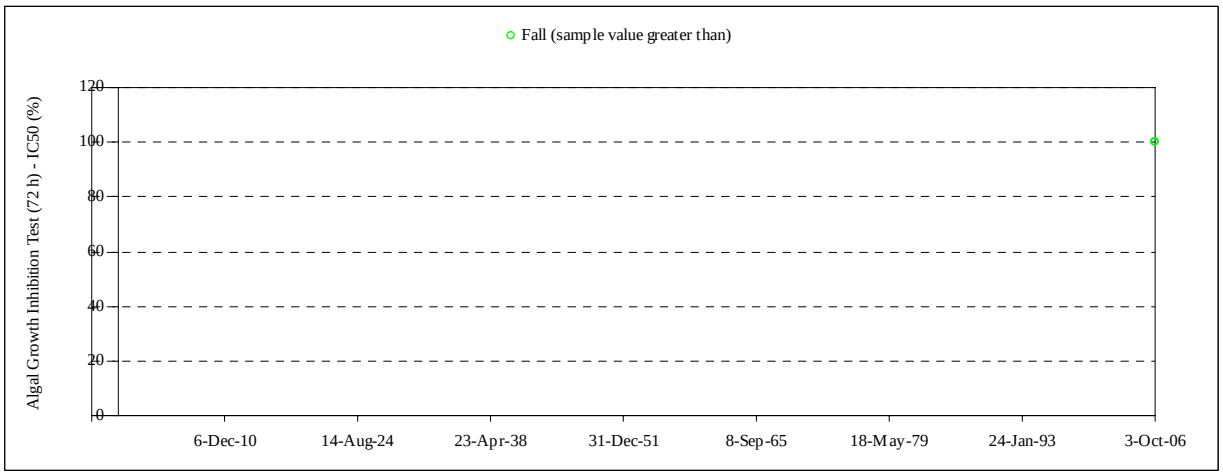
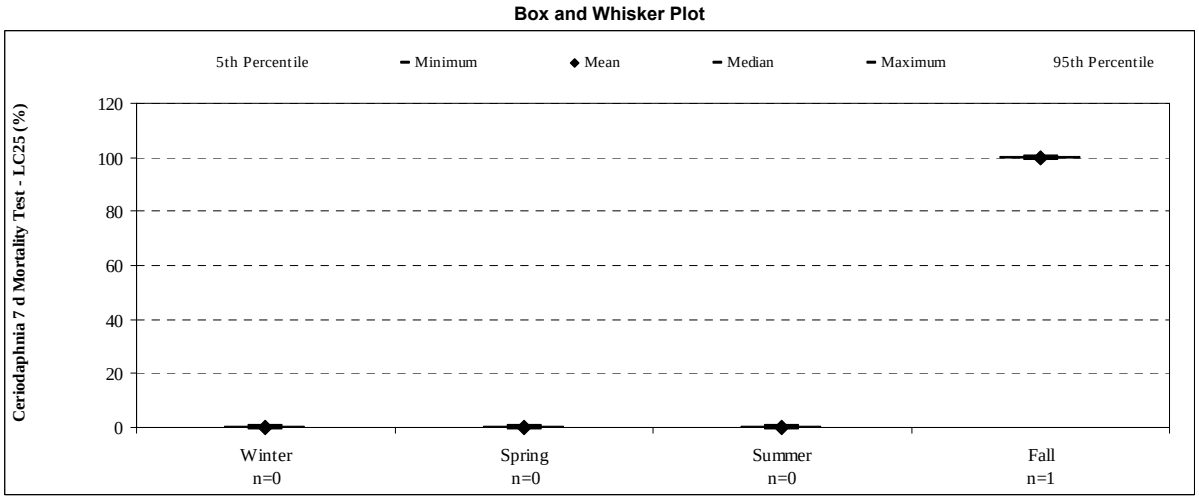


Figure G-1-8-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Unnamed Creek 3



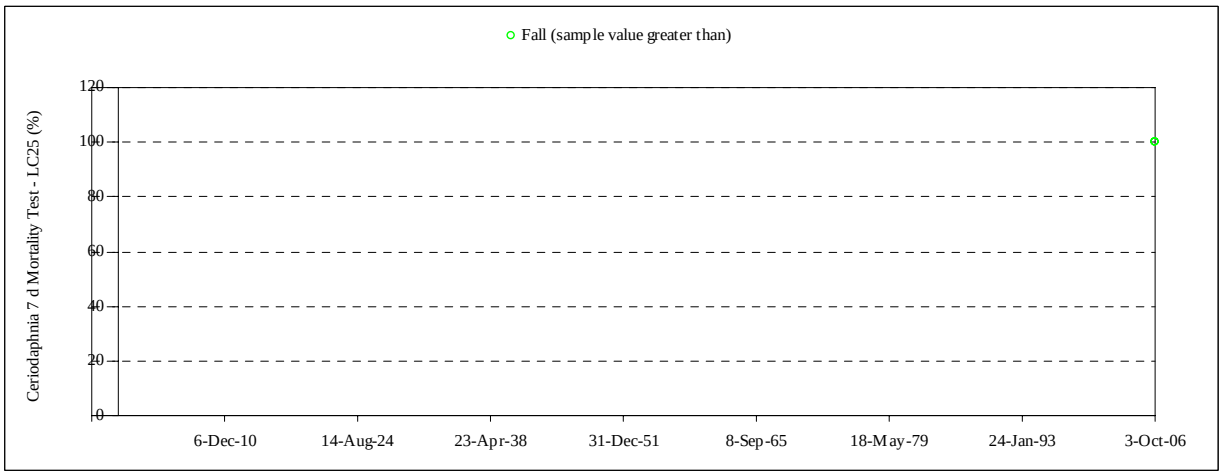
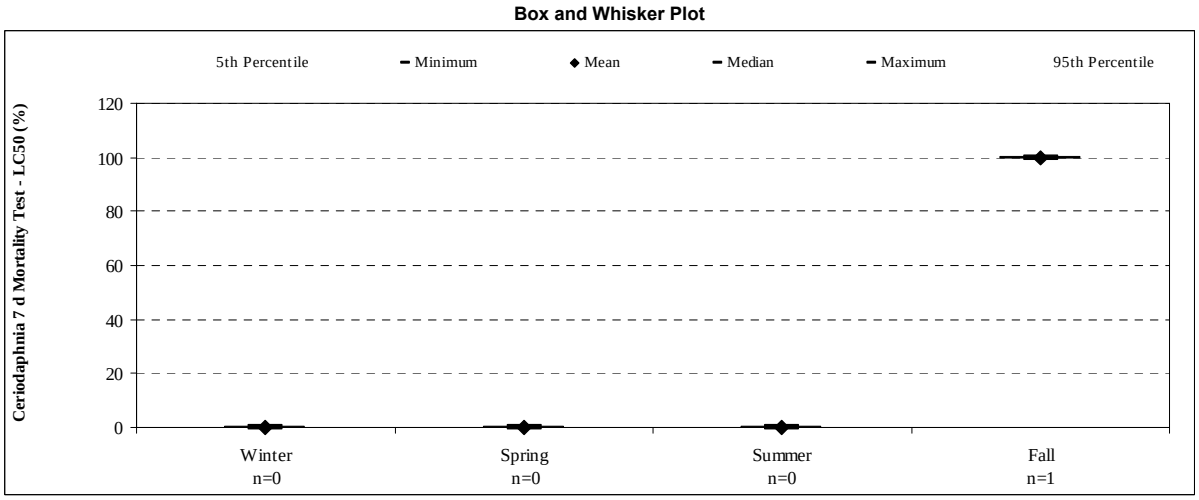


Figure G-1-8-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Unnamed Creek 3



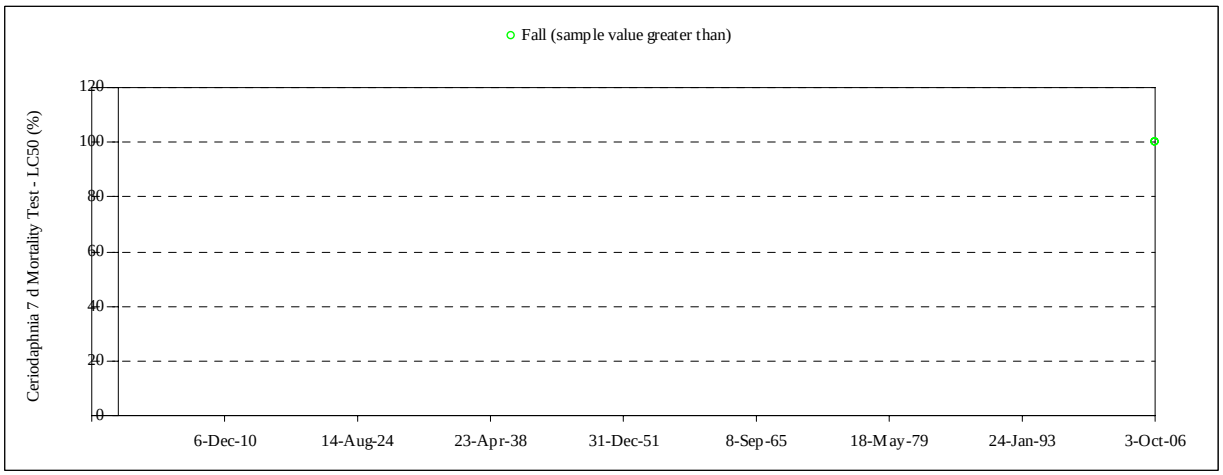
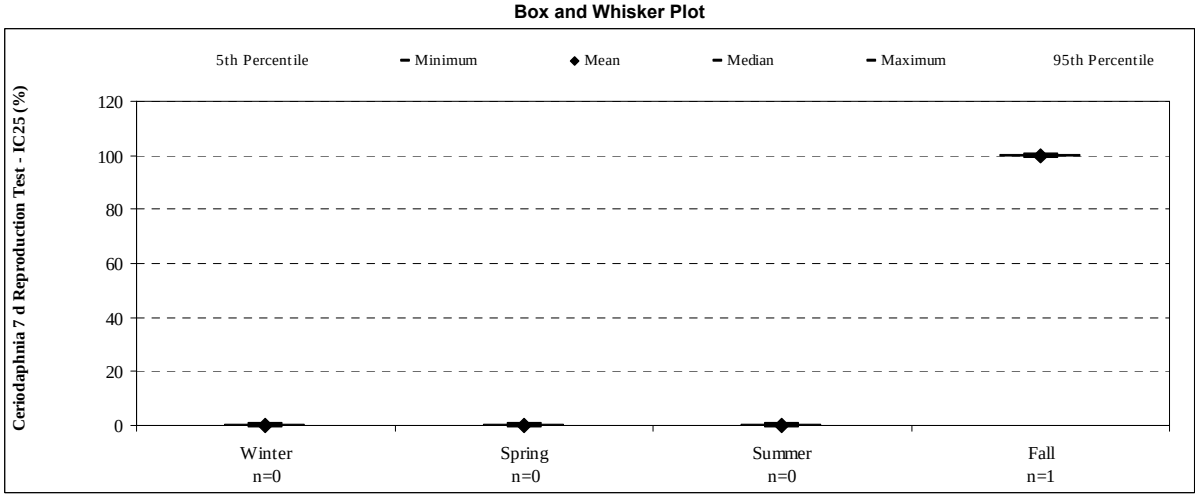


Figure G-1-8-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Unnamed Creek 3



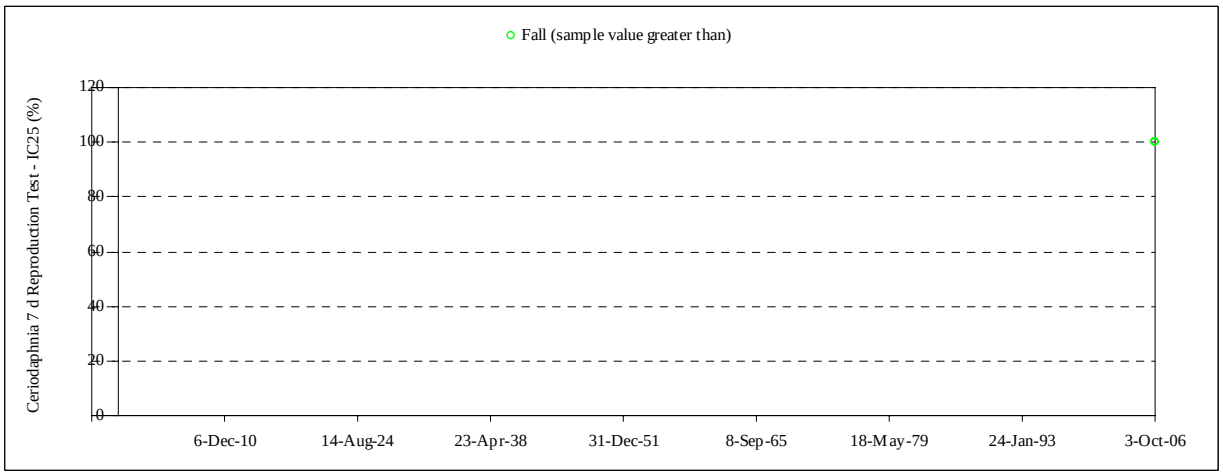
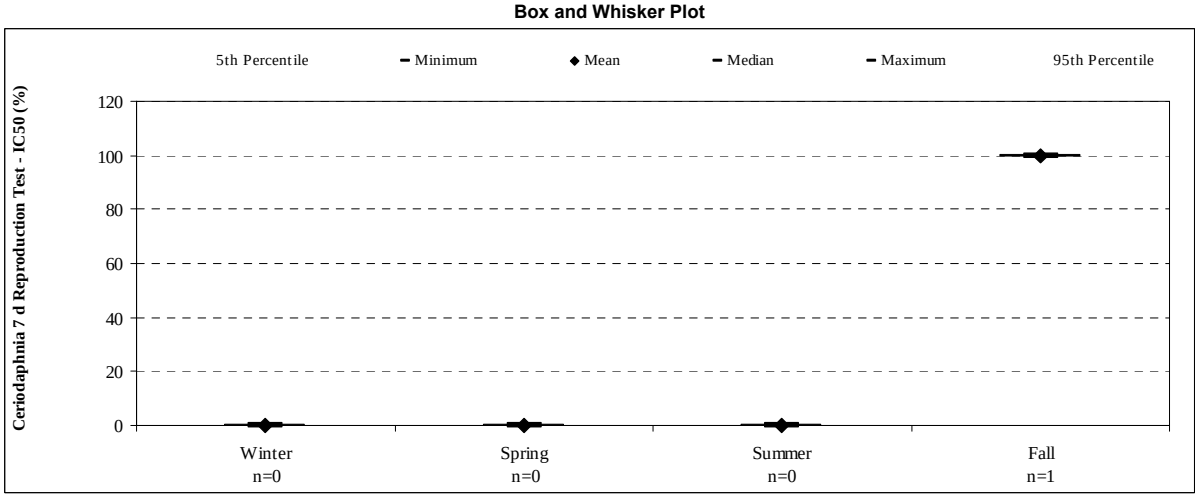


Figure G-1-8-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Unnamed Creek 3



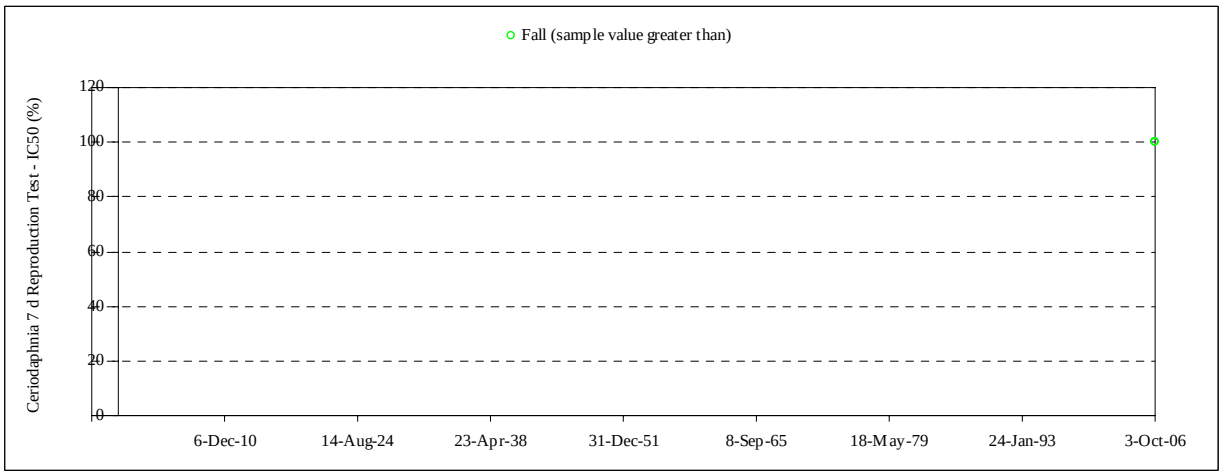
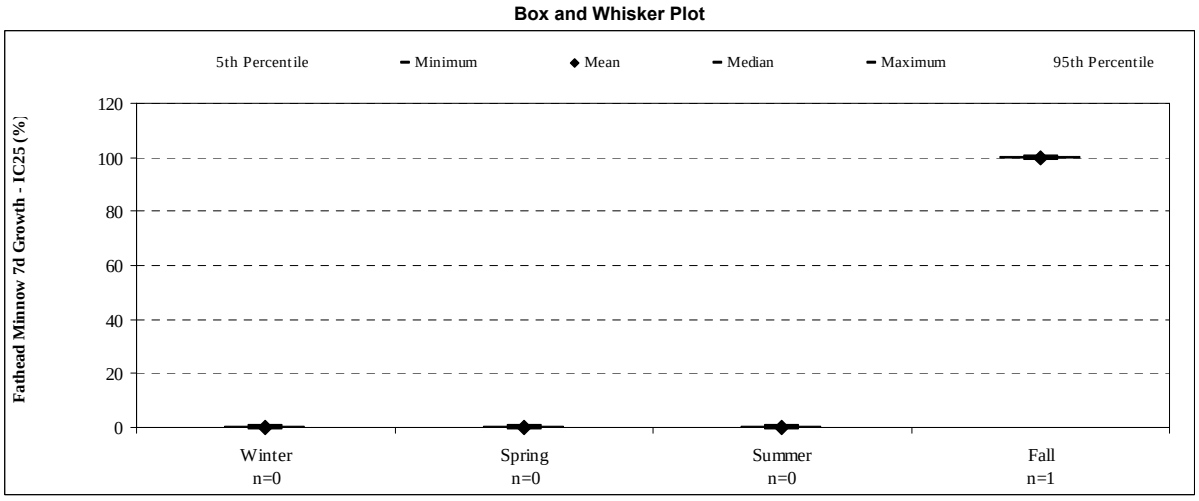


Figure G-1-8-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Unnamed Creek 3



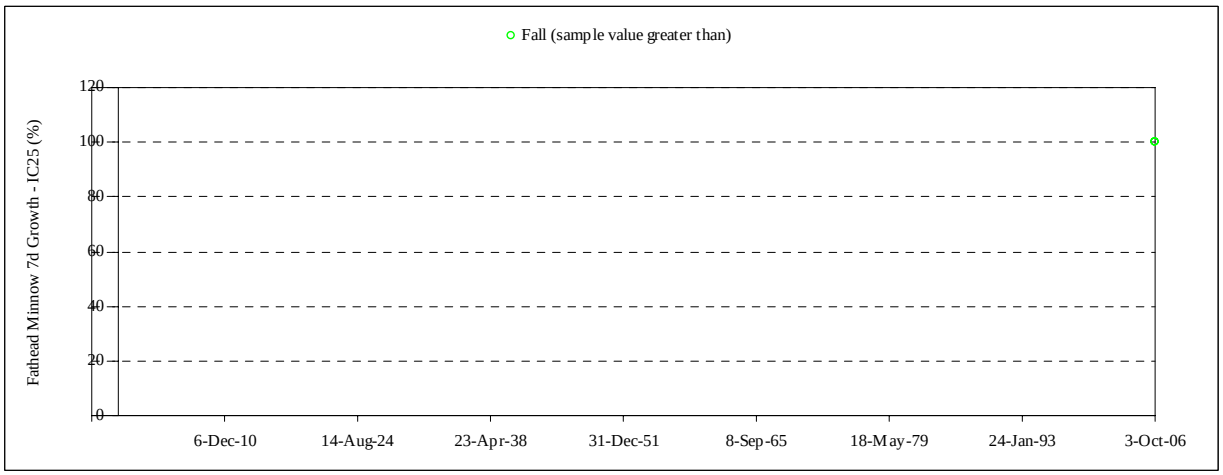
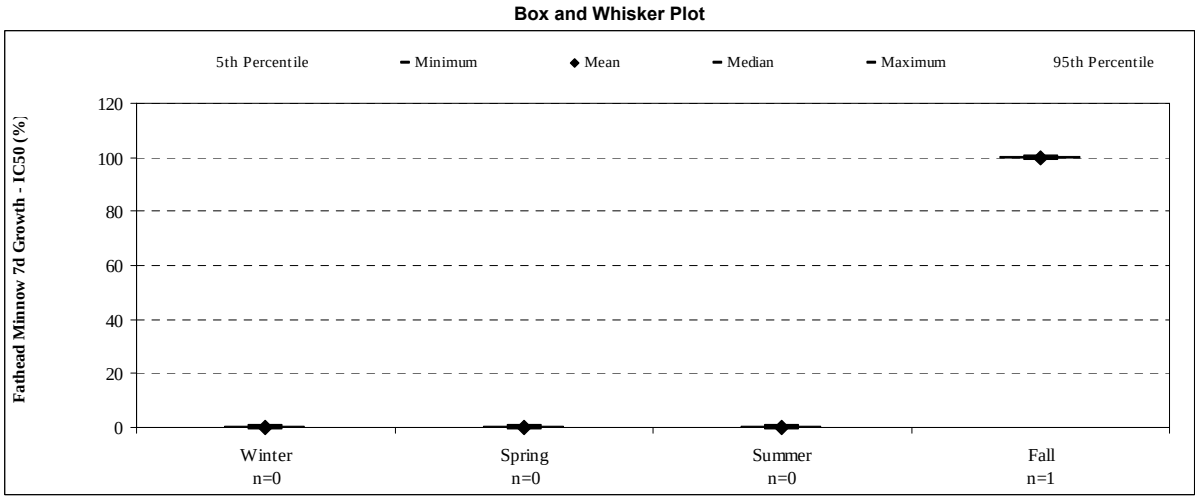


Figure G-1-8-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Unnamed Creek 3



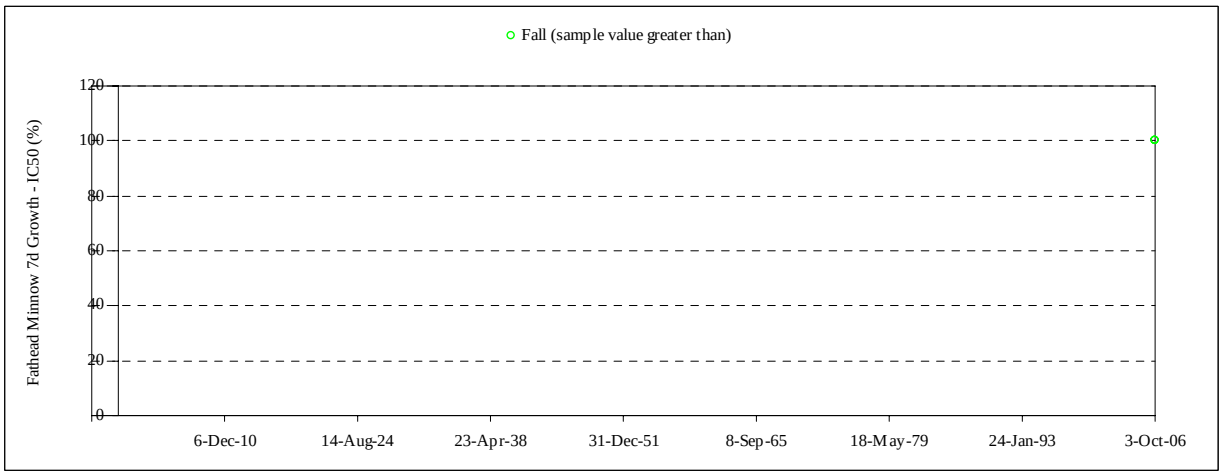
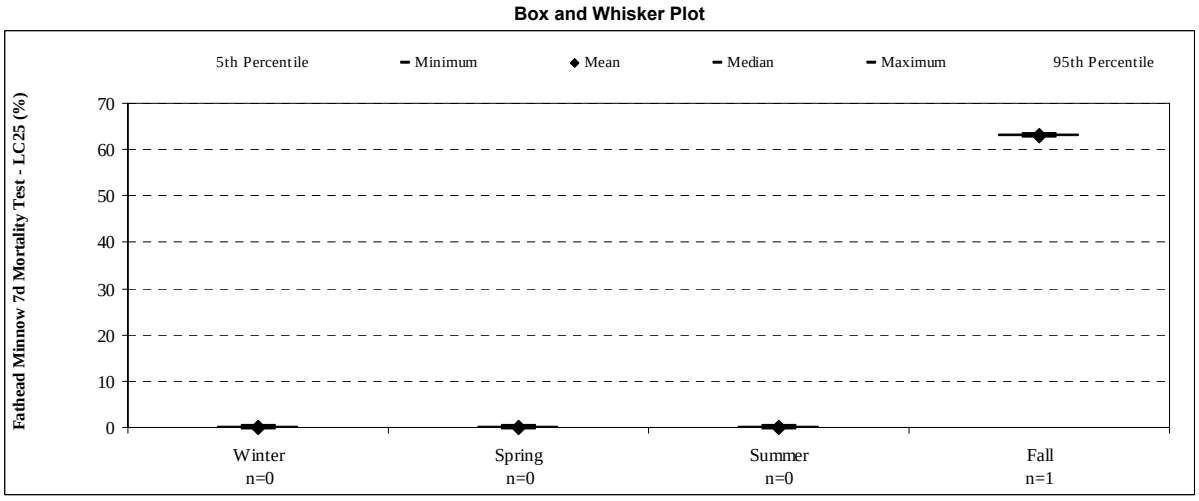


Figure G-1-8-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Unnamed Creek 3



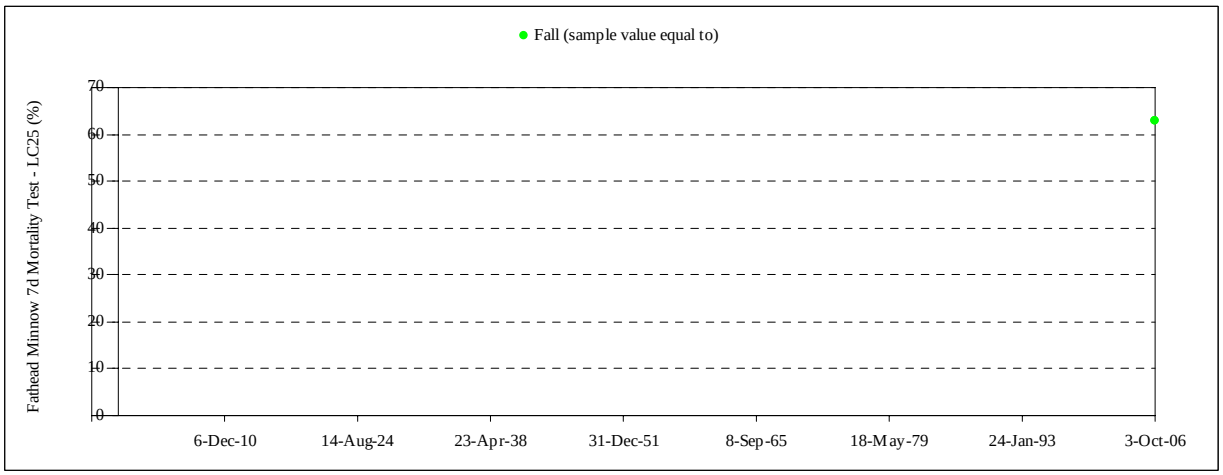
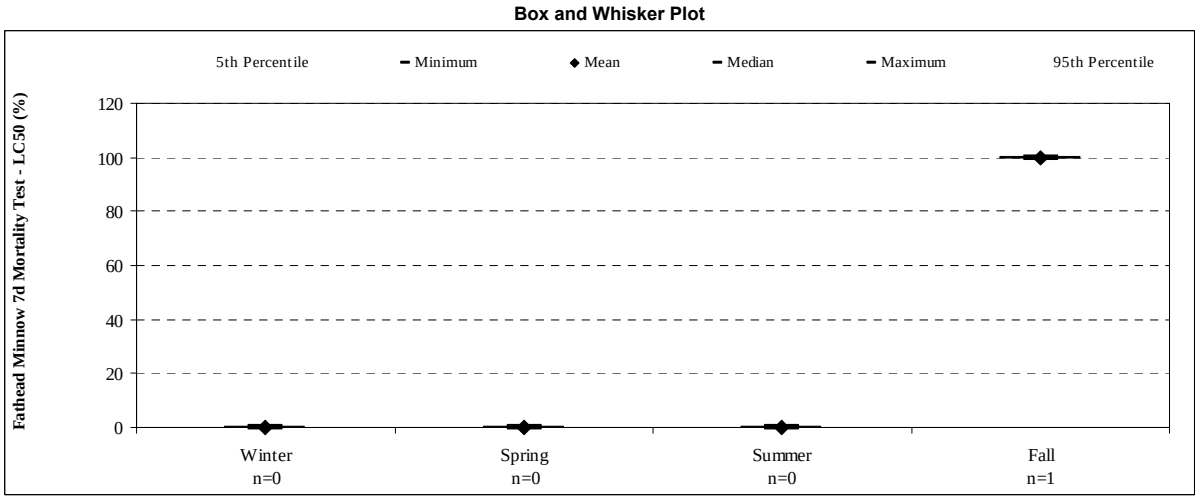


Figure G-1-8-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Unnamed Creek 3



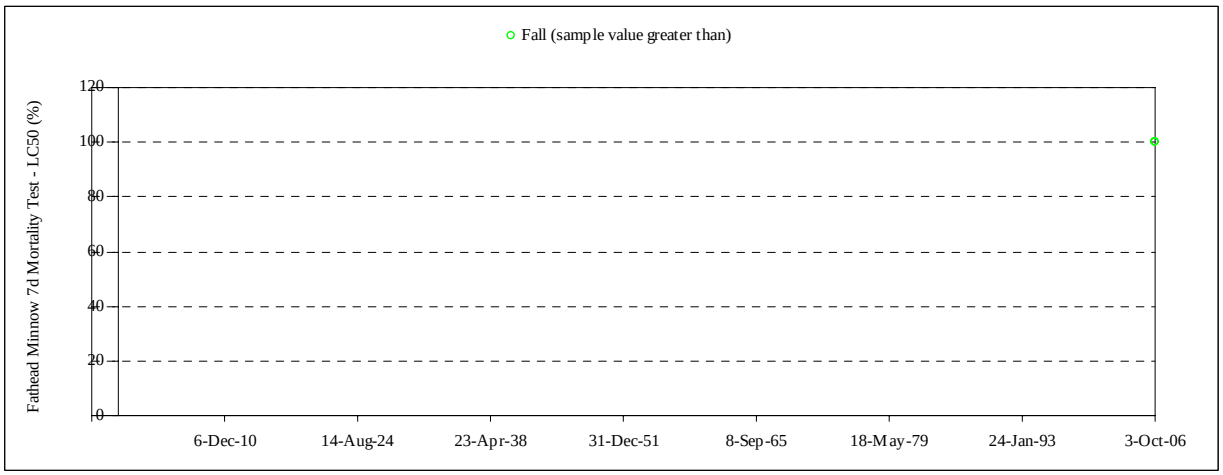
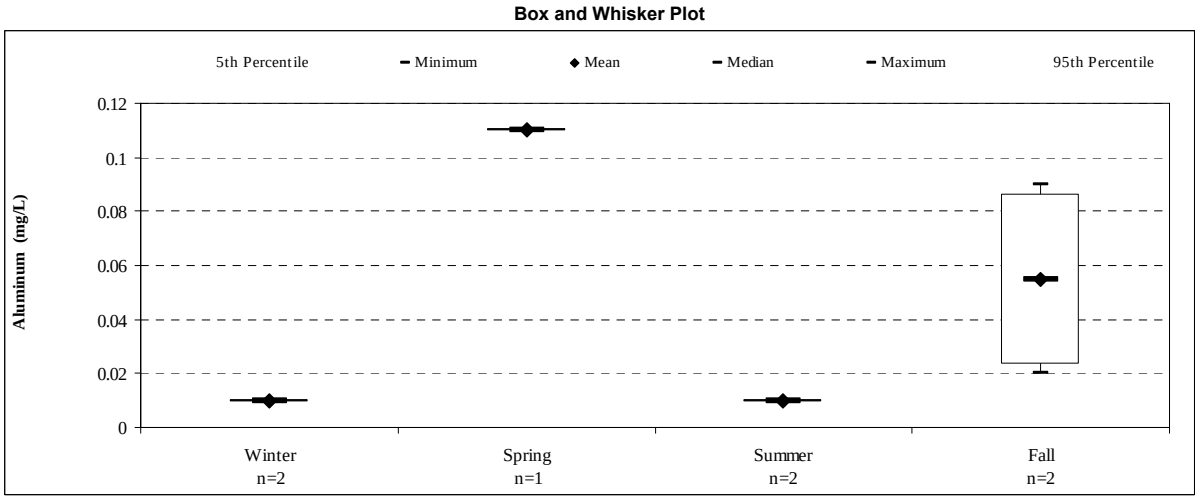


Figure G-1-8-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Unnamed Creek 3



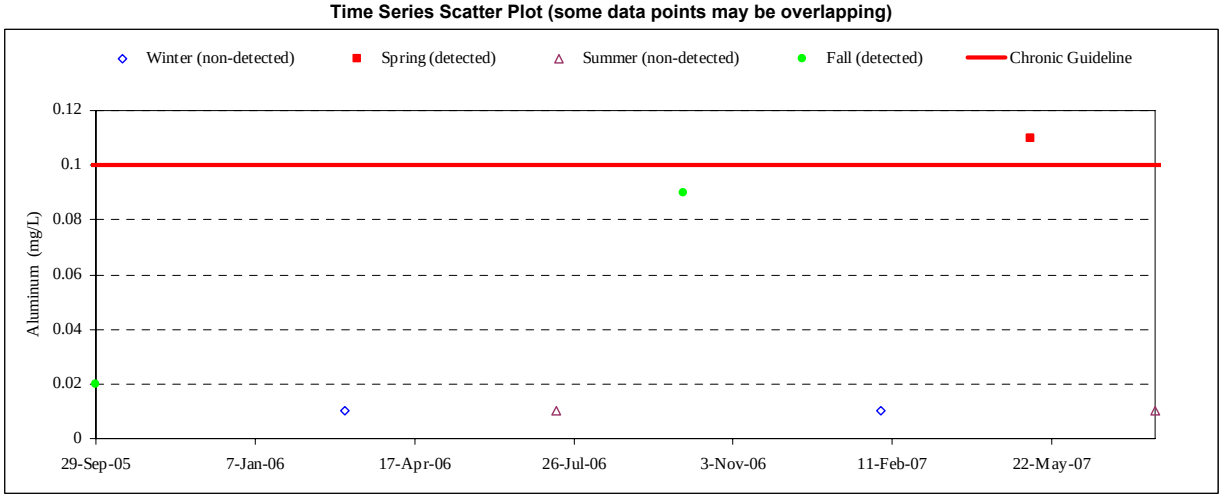
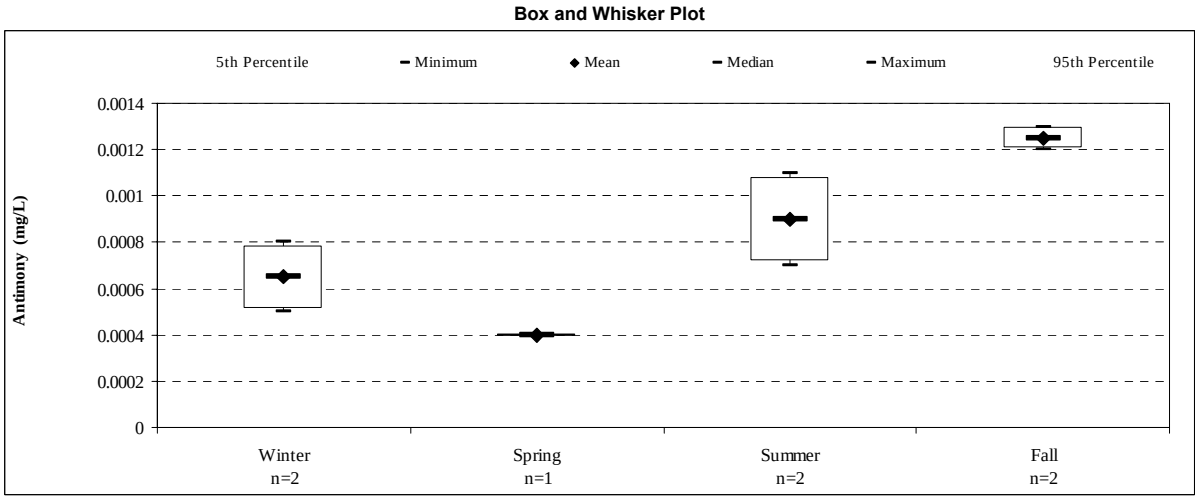


Figure G-1-8-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Unnamed Creek 3



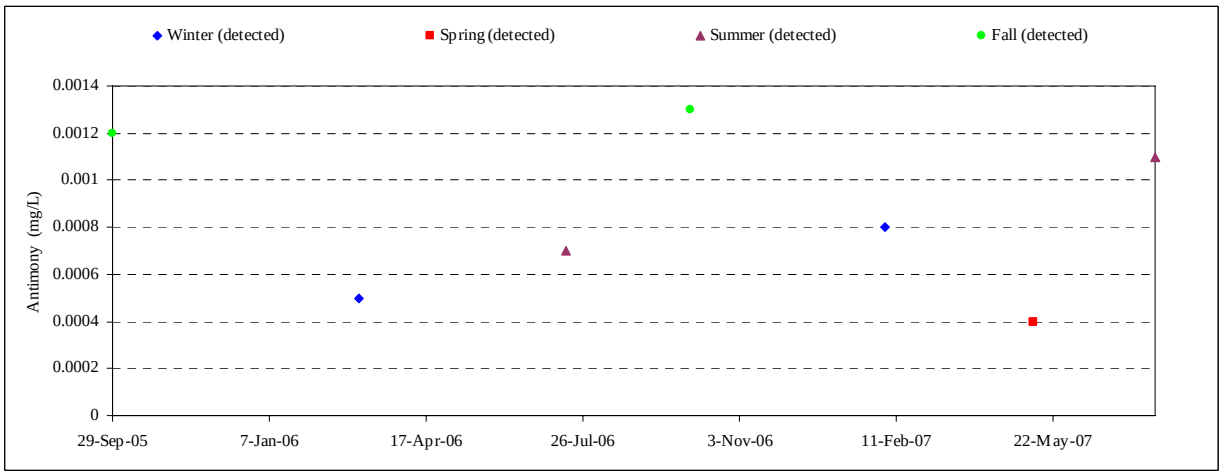
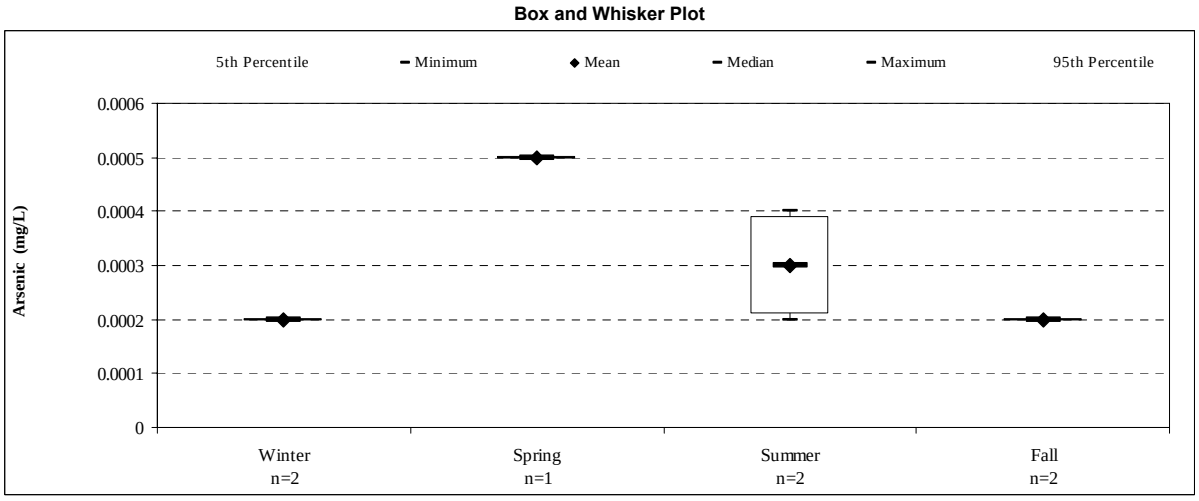


Figure G-1-8-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Unnamed Creek 3



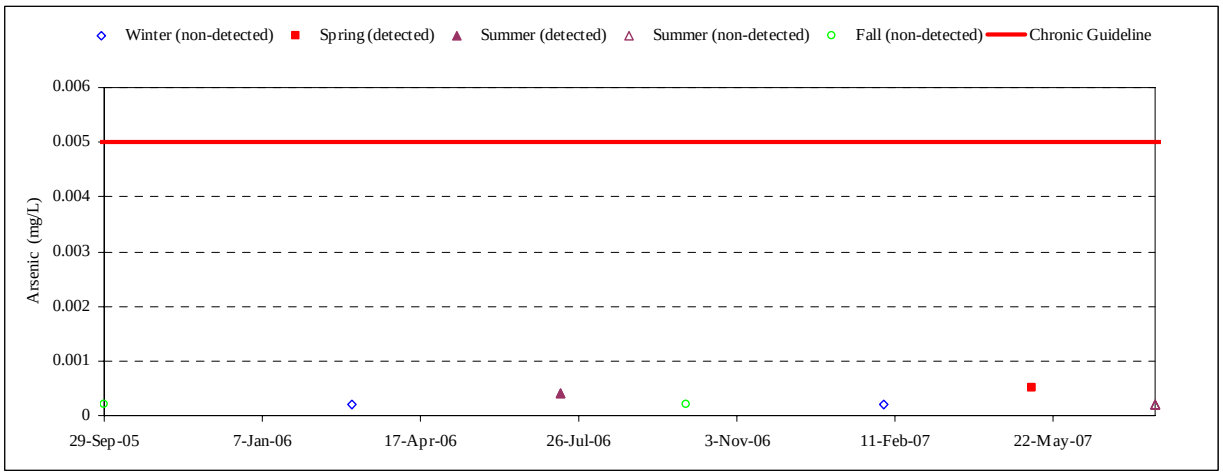
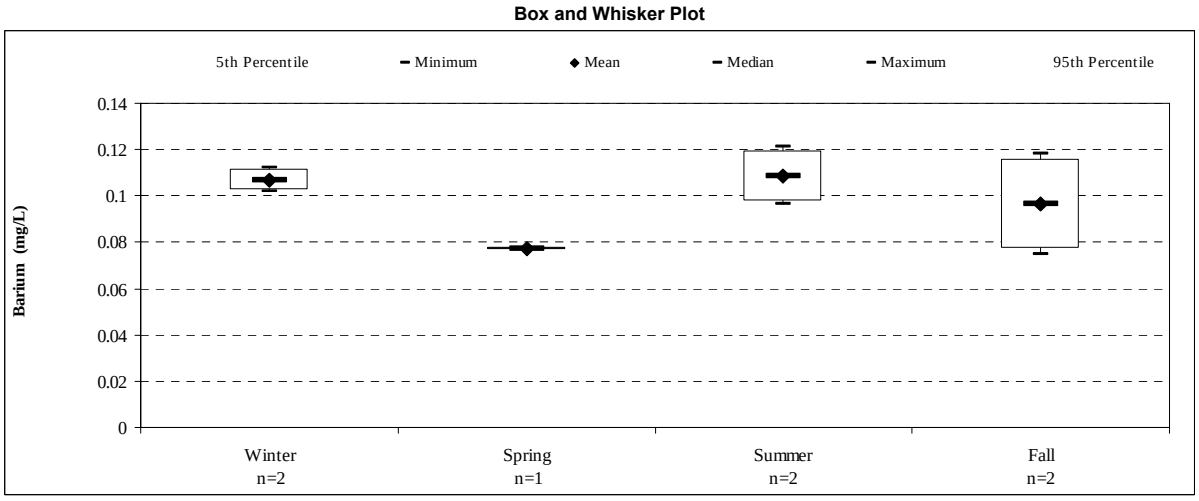


Figure G-1-8-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Unnamed Creek 3



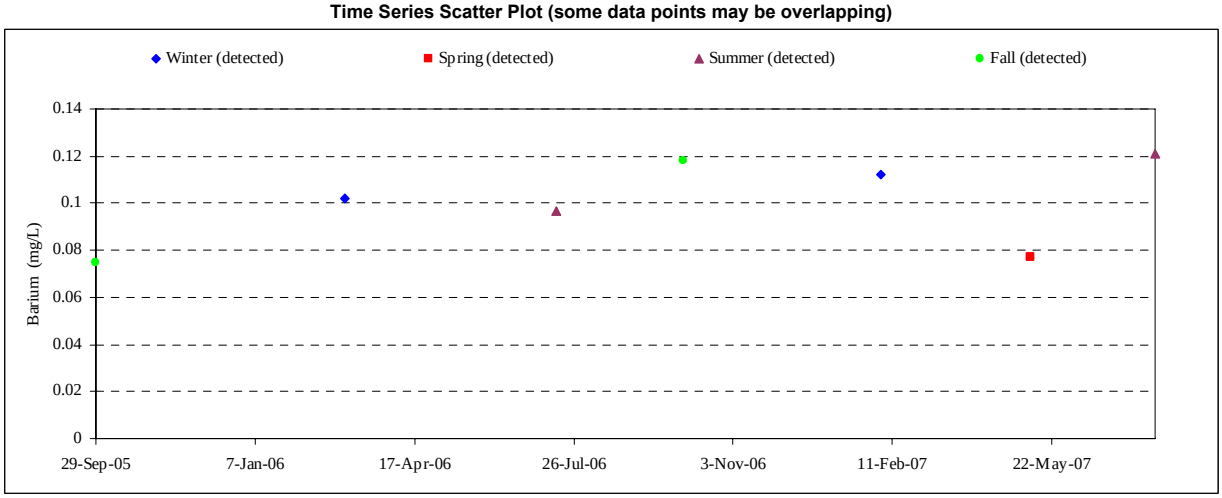
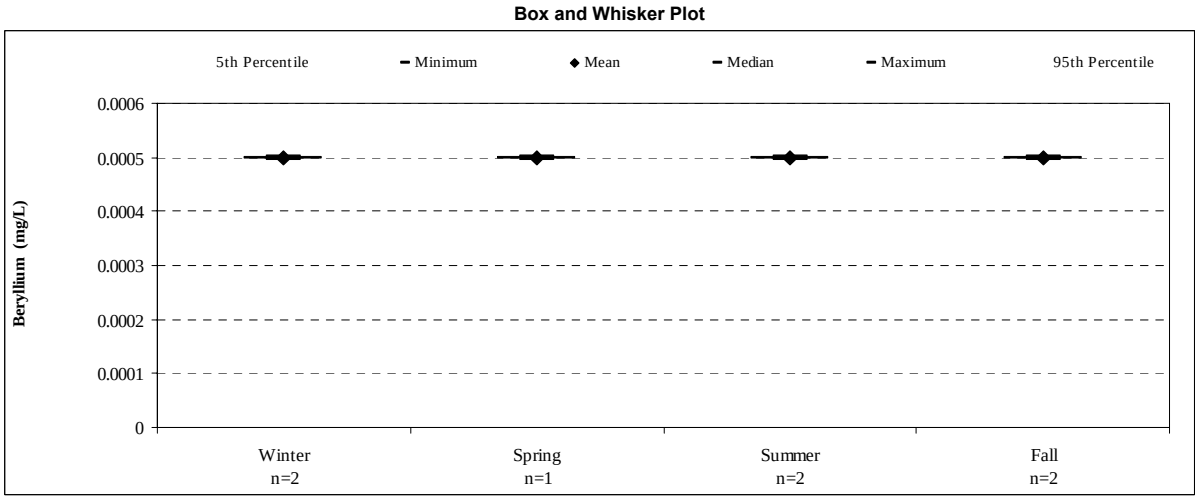


Figure G-1-8-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Unnamed Creek 3



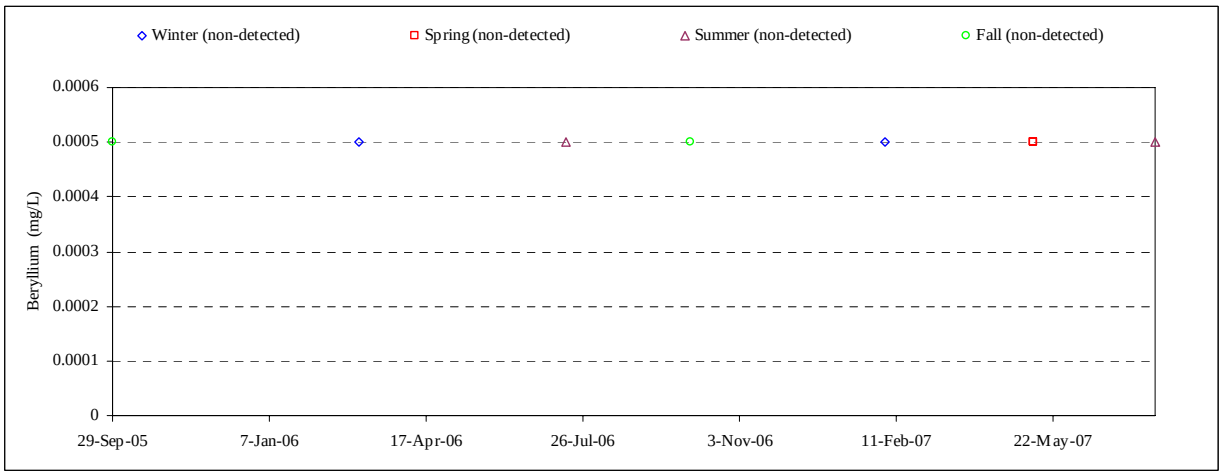
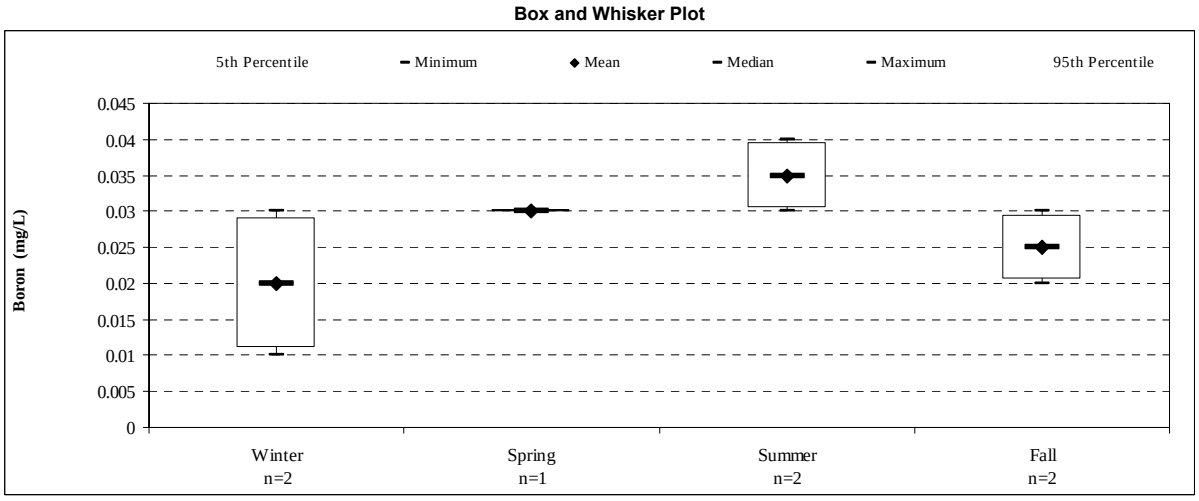


Figure G-1-8-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Unnamed Creek 3



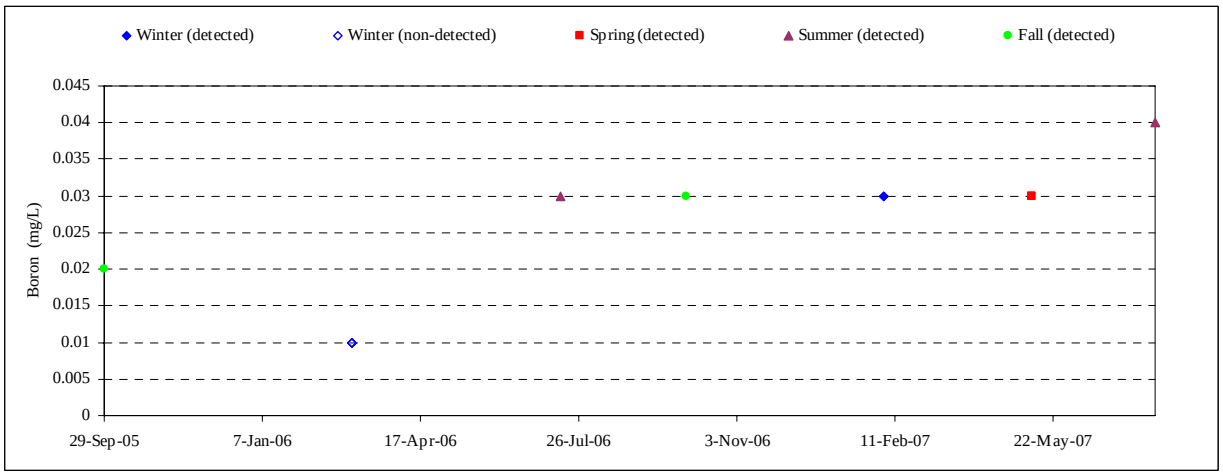
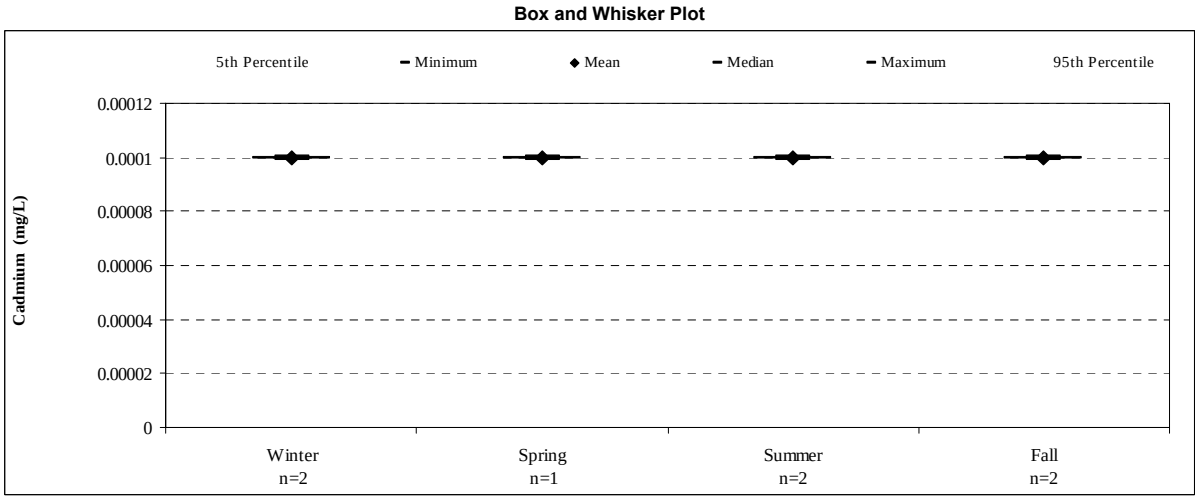


Figure G-1-8-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Unnamed Creek 3



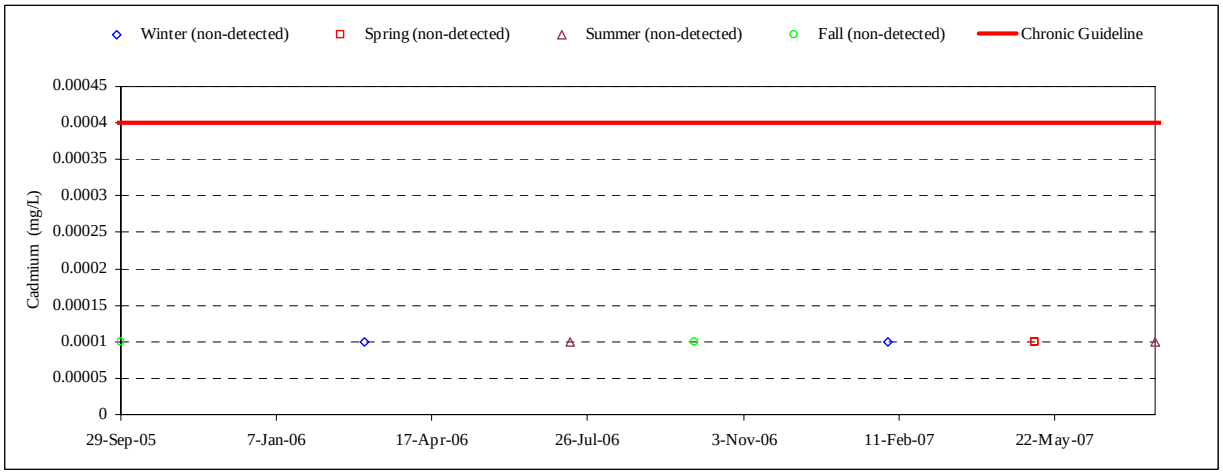
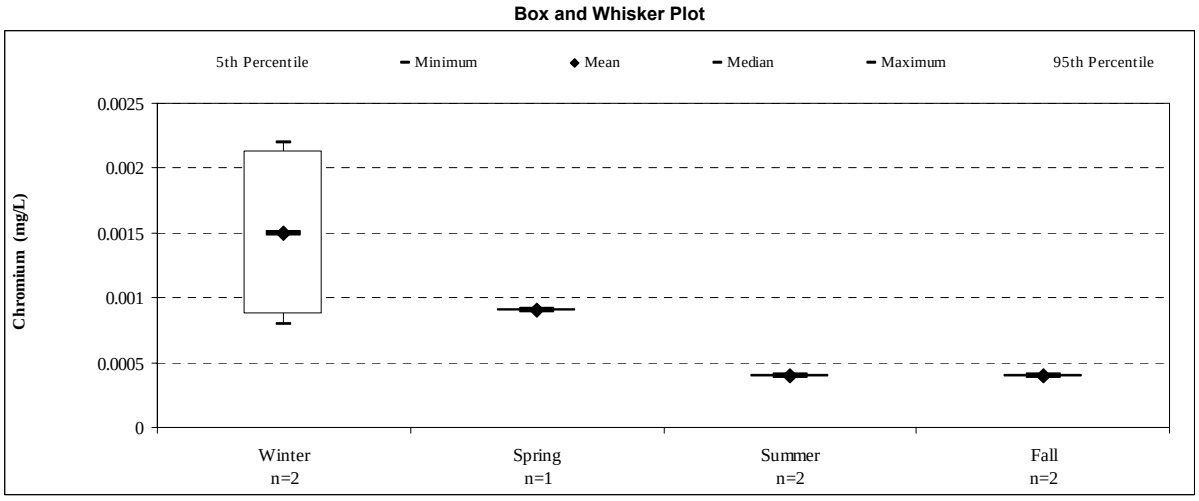


Figure G-1-8-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Unnamed Creek 3



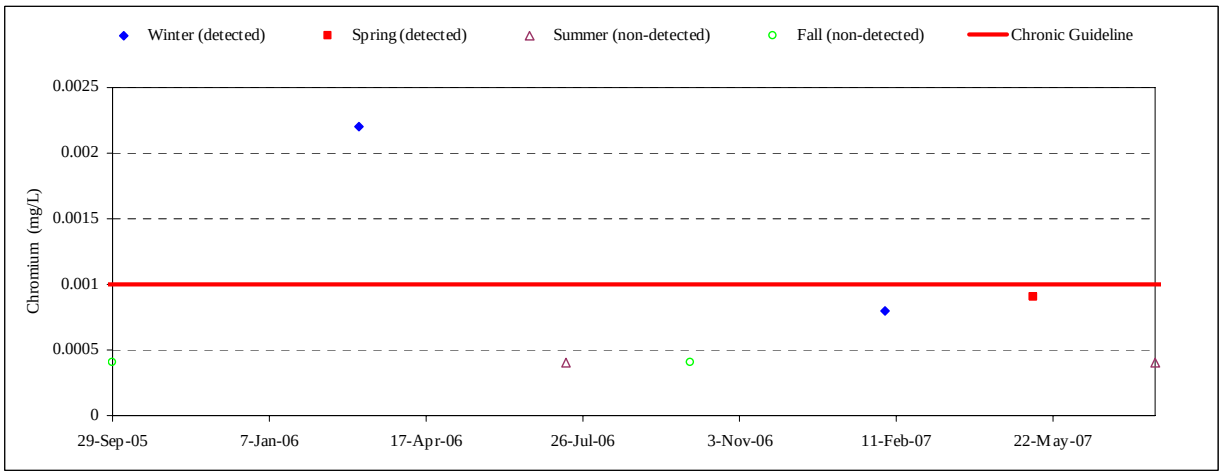
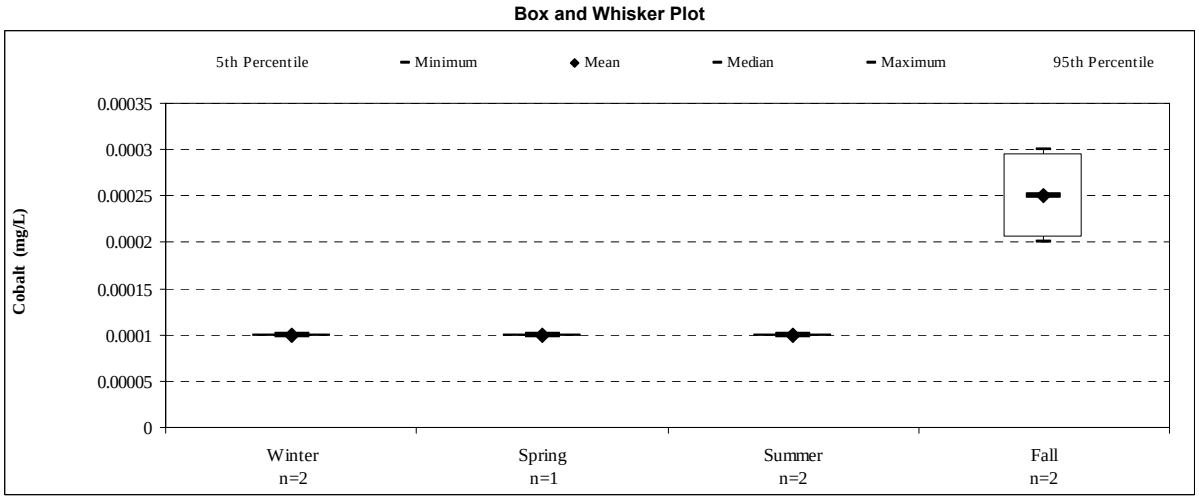


Figure G-1-8-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Unnamed Creek 3



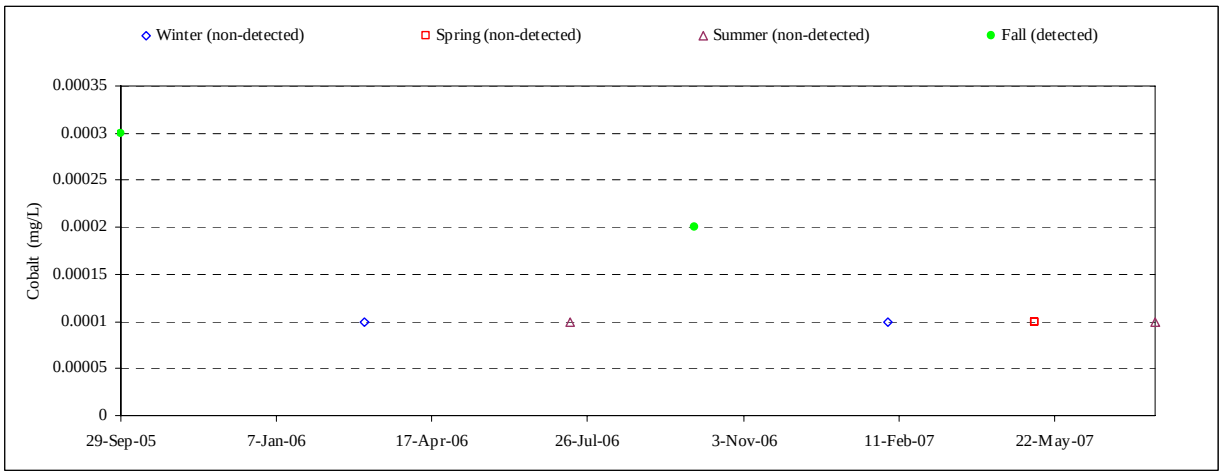
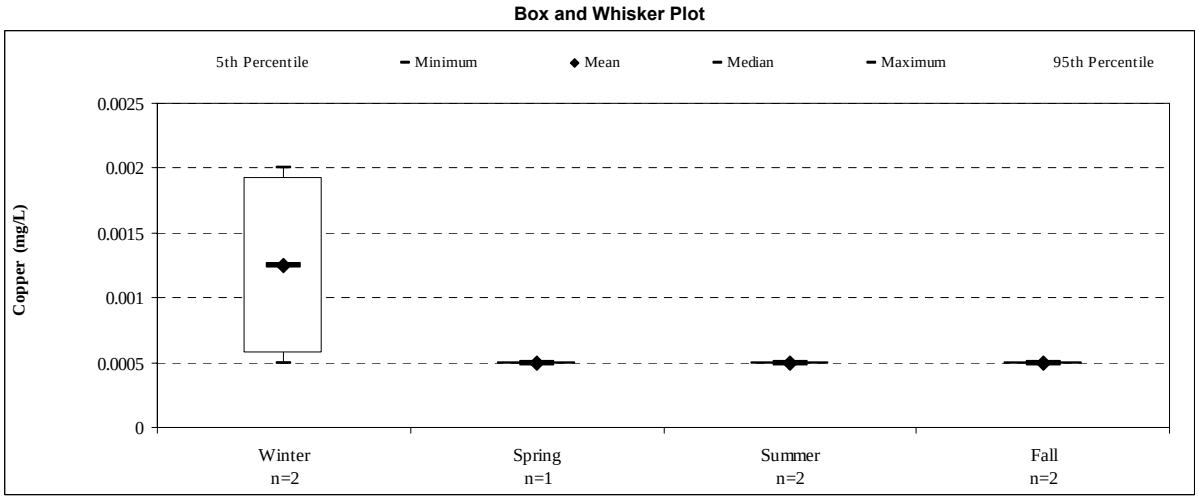


Figure G-1-8-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Unnamed Creek 3



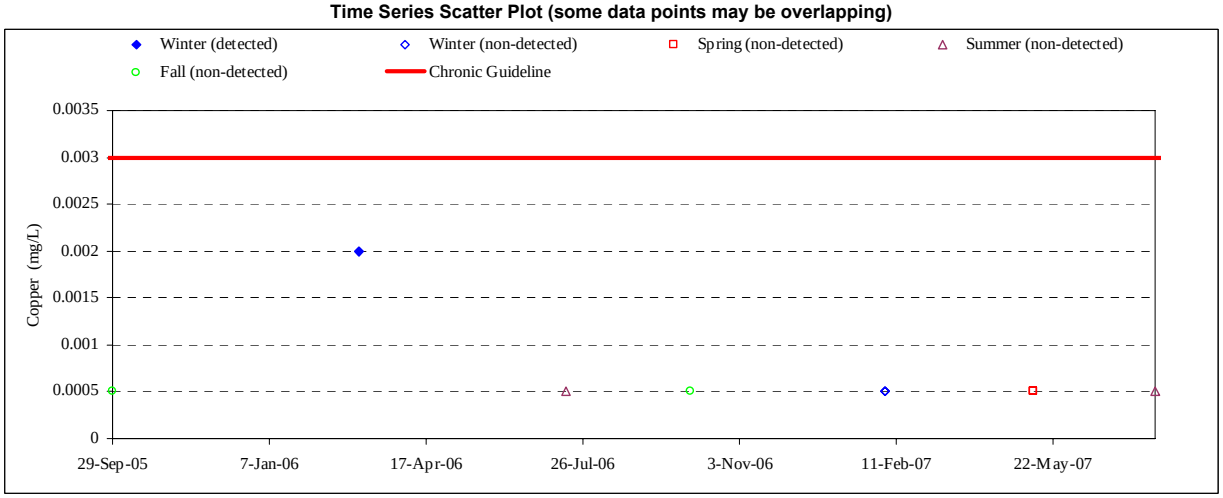
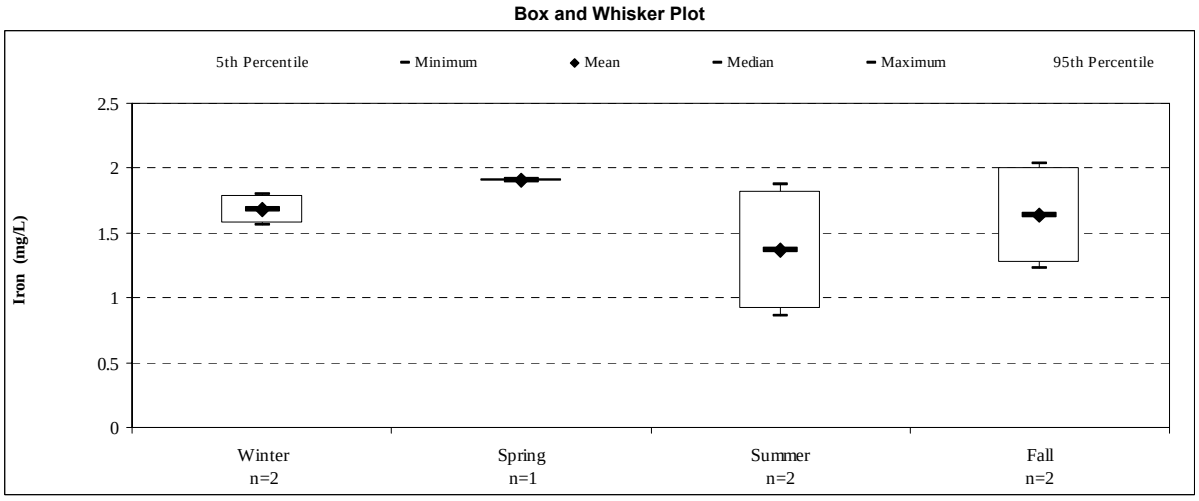


Figure G-1-8-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Unnamed Creek 3



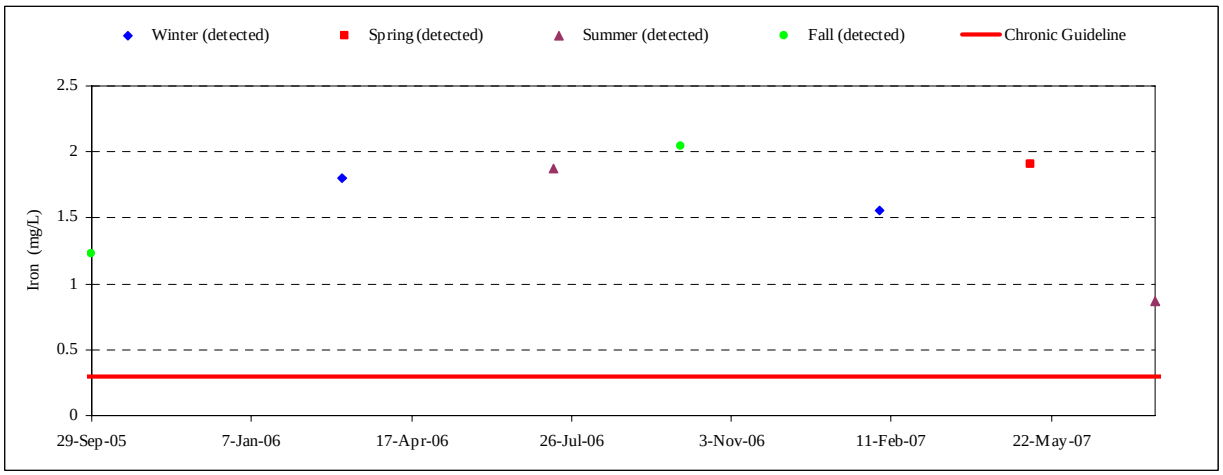
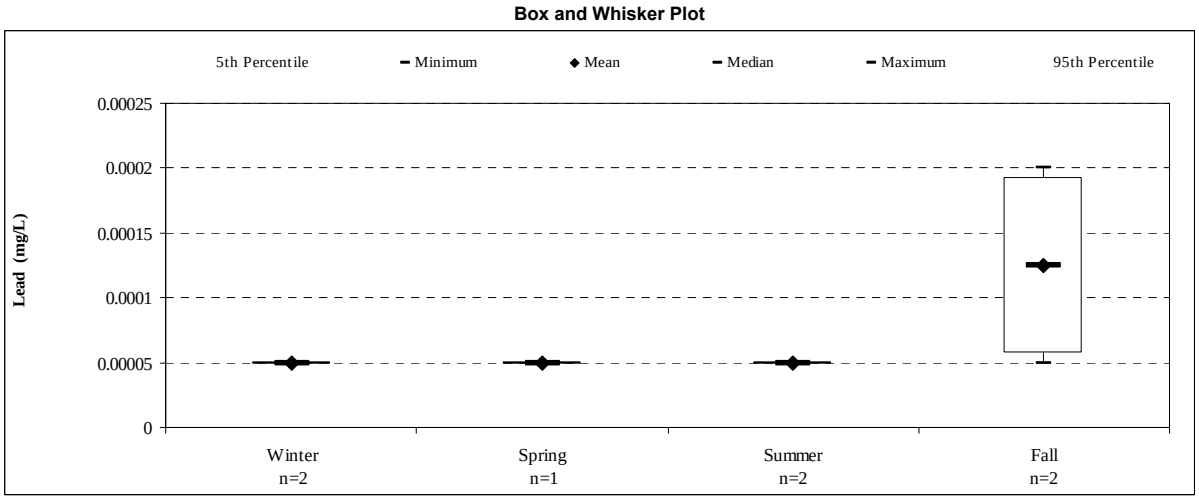


Figure G-1-8-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Unnamed Creek 3



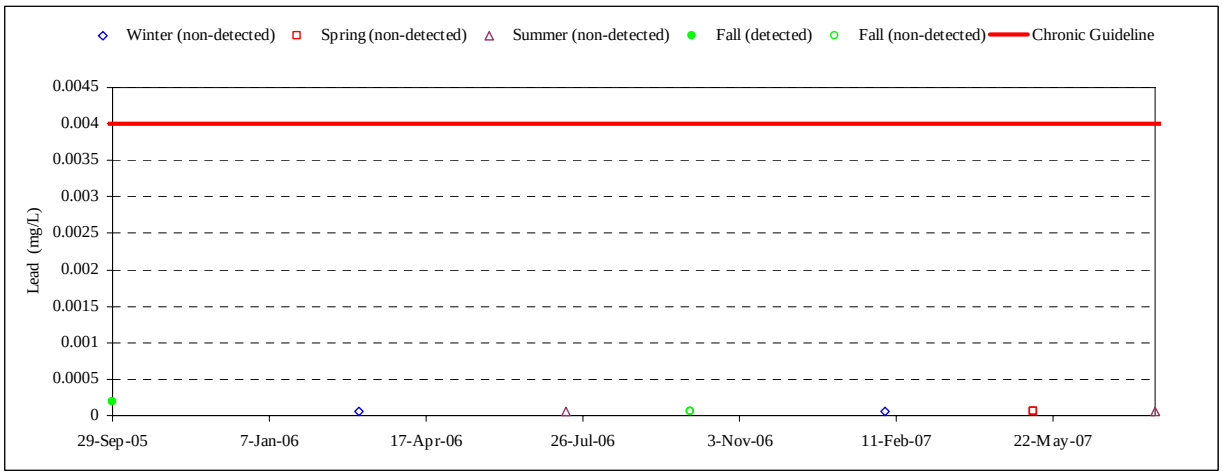
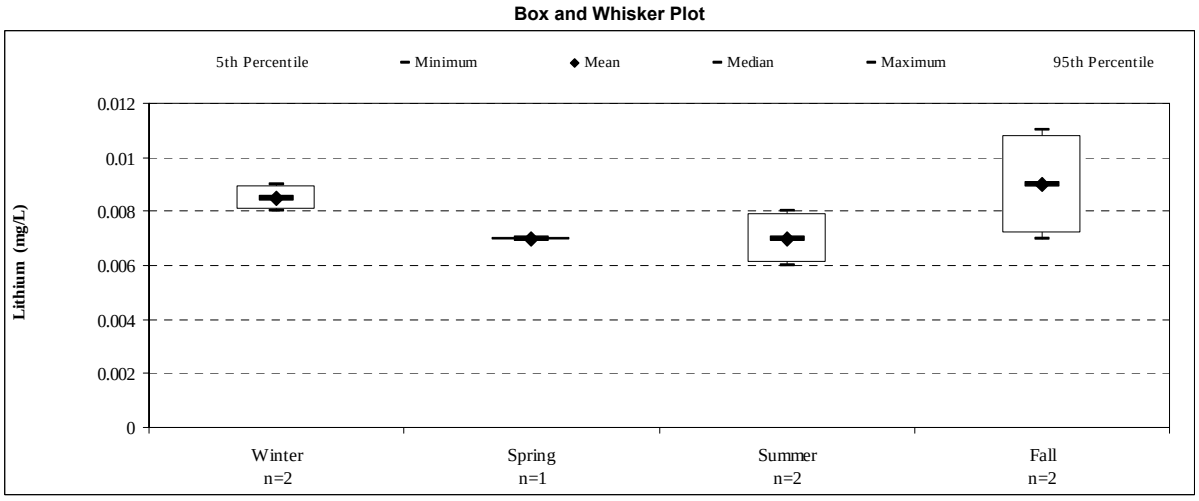


Figure G-1-8-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Unnamed Creek 3



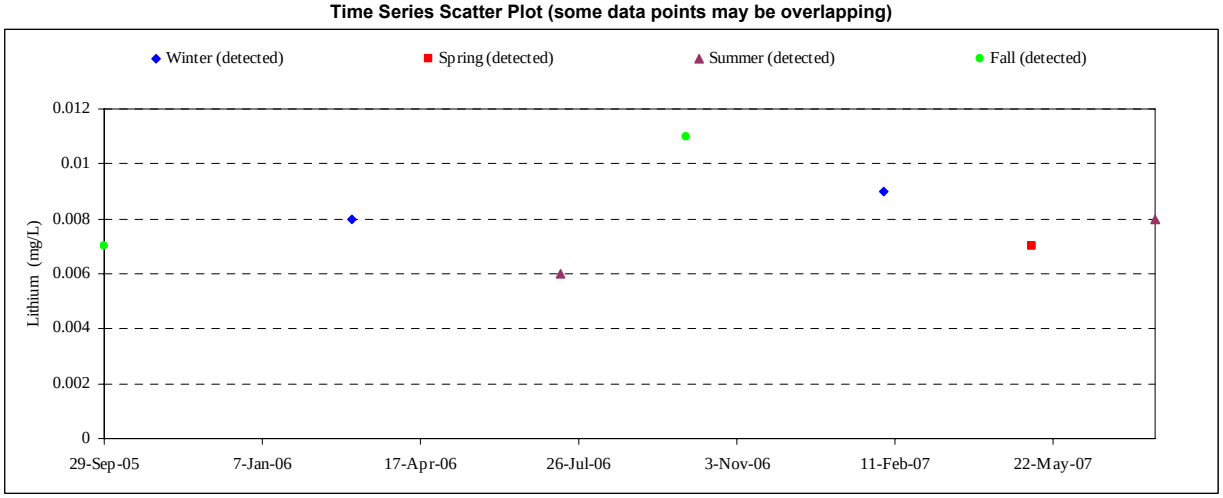
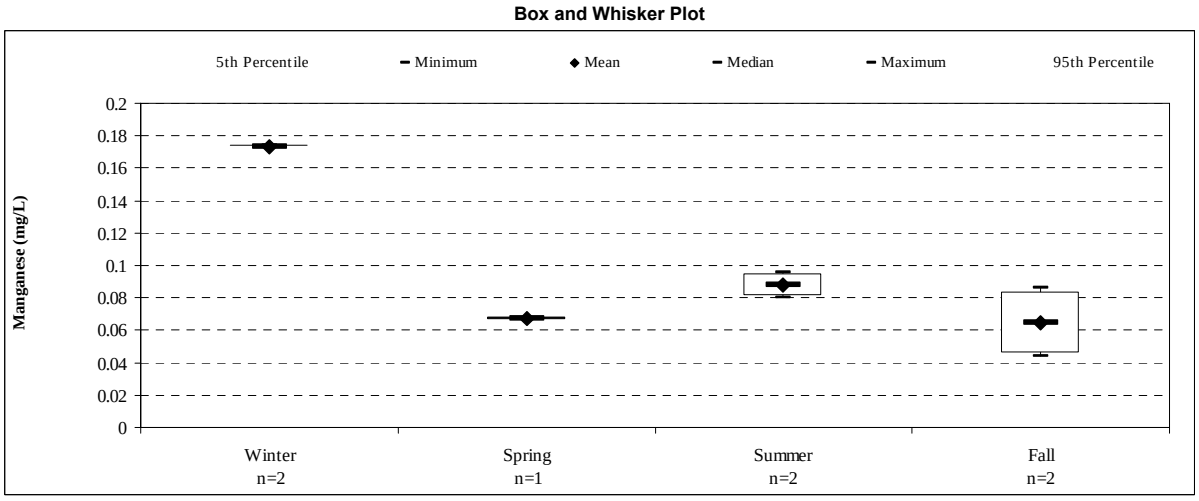


Figure G-1-8-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Unnamed Creek 3



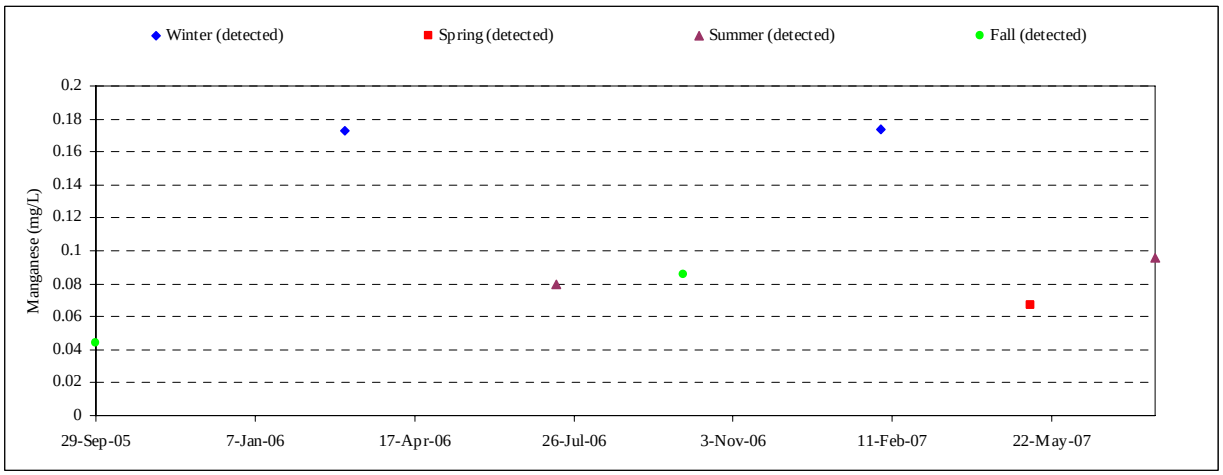
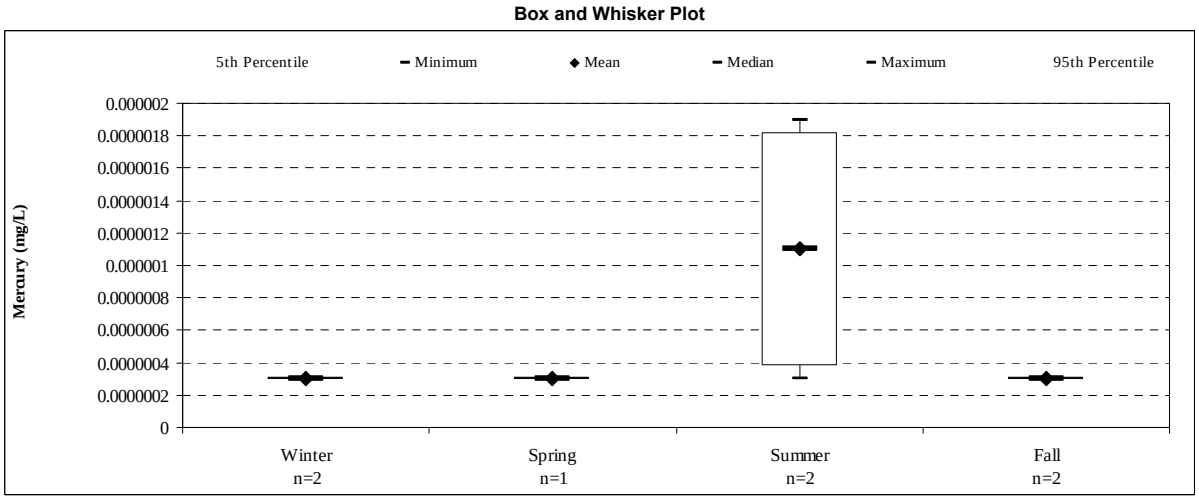


Figure G-1-8-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Unnamed Creek 3



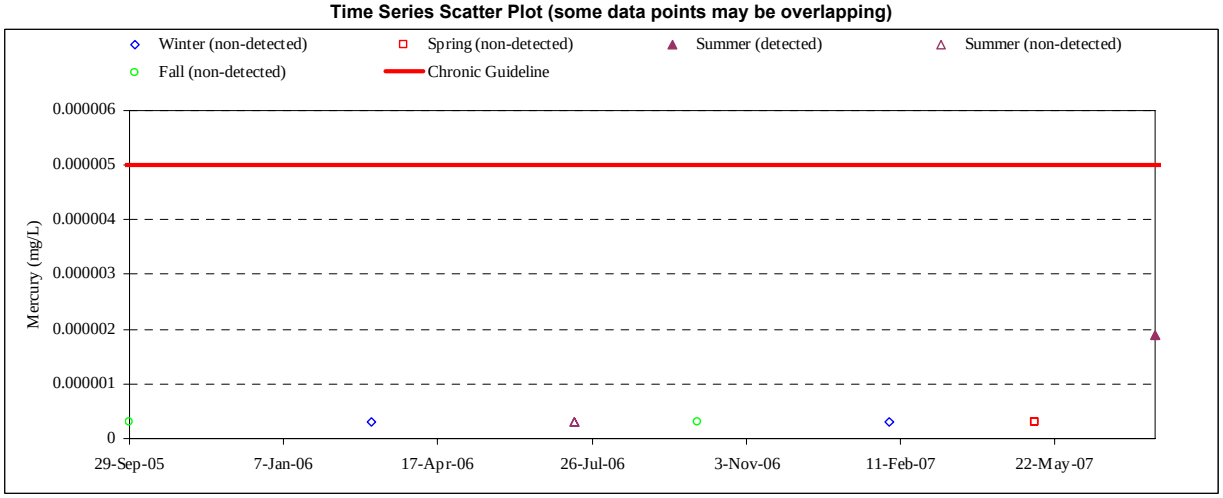
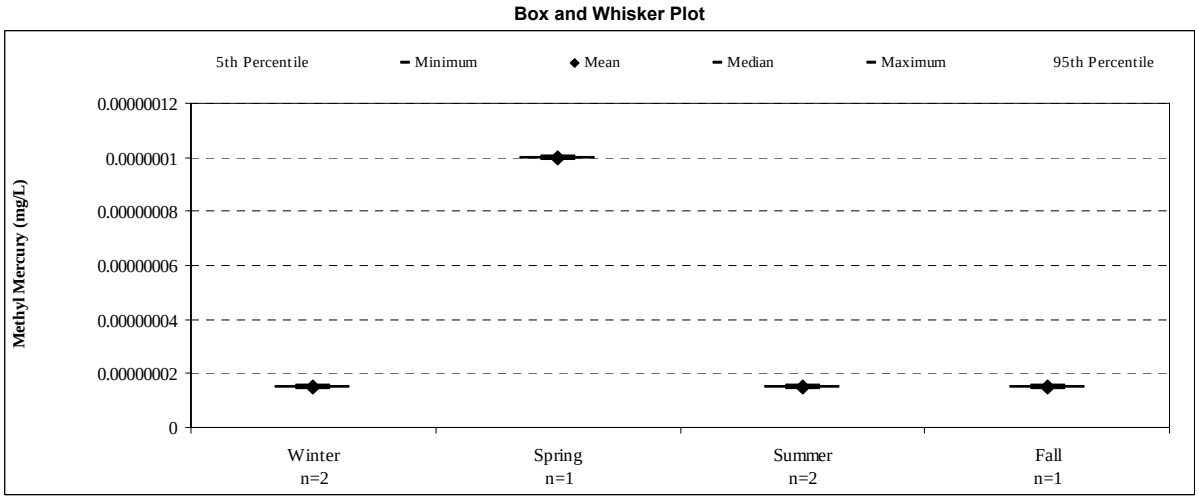


Figure G-1-8-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Unnamed Creek 3



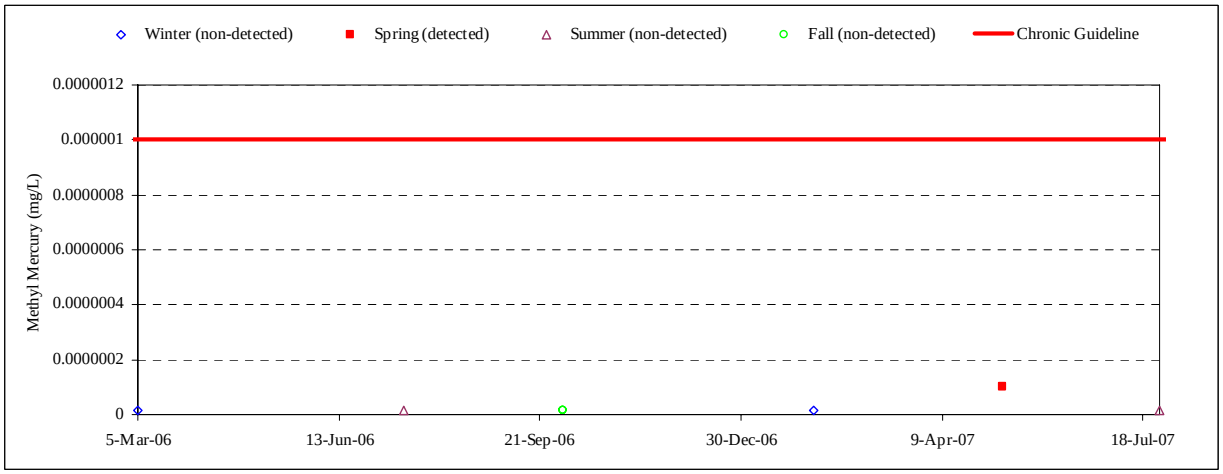
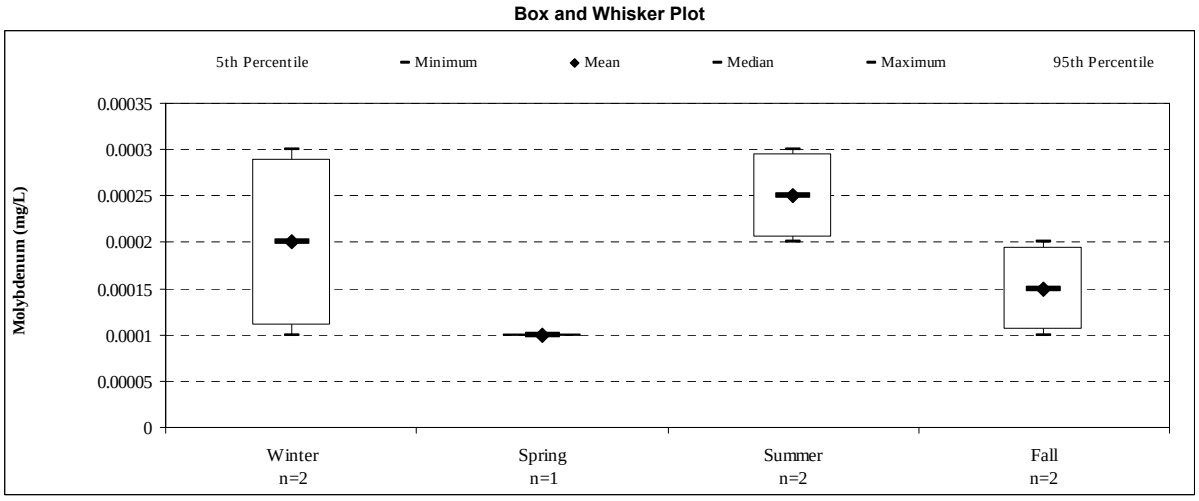


Figure G-1-8-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Unnamed Creek 3



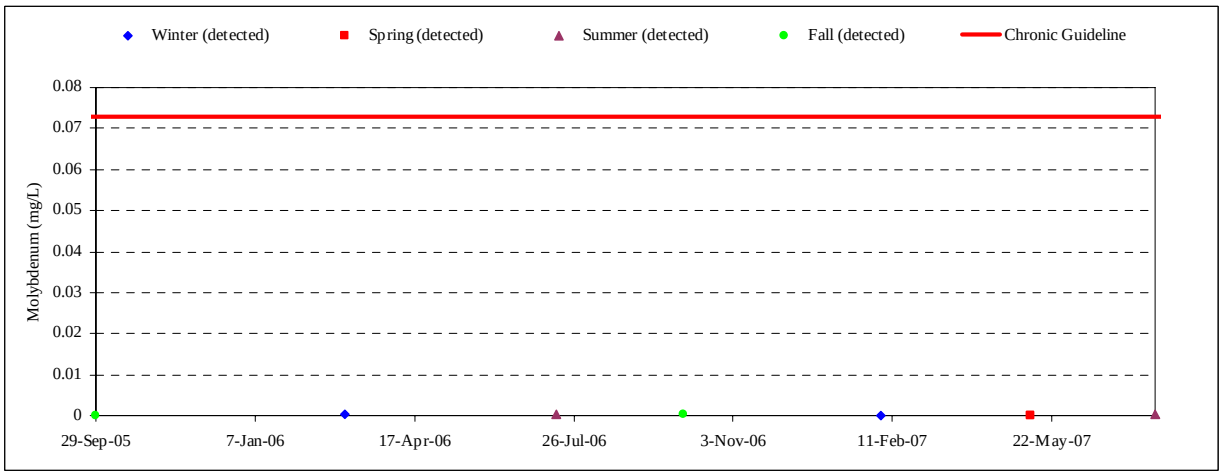
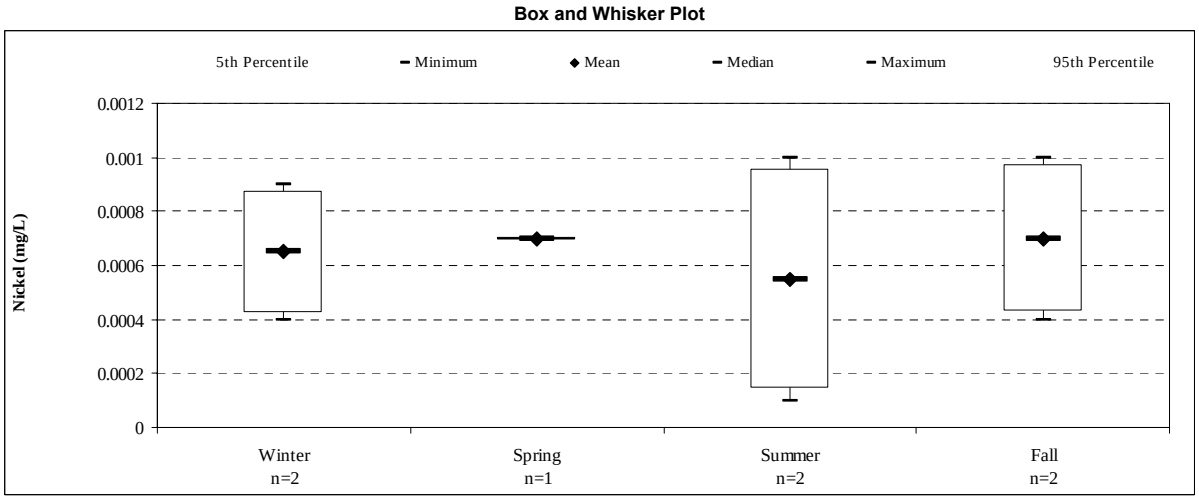


Figure G-1-8-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Unnamed Creek 3



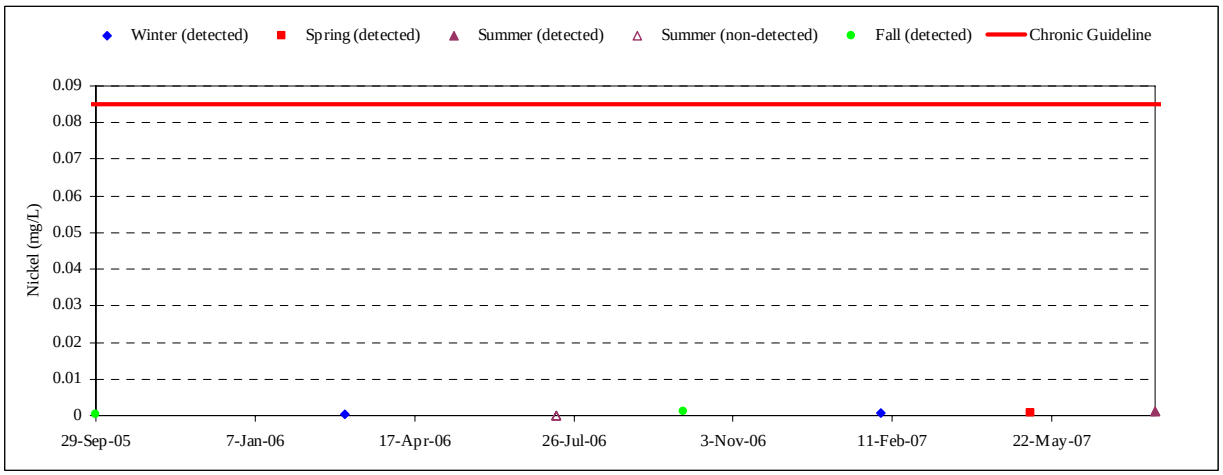
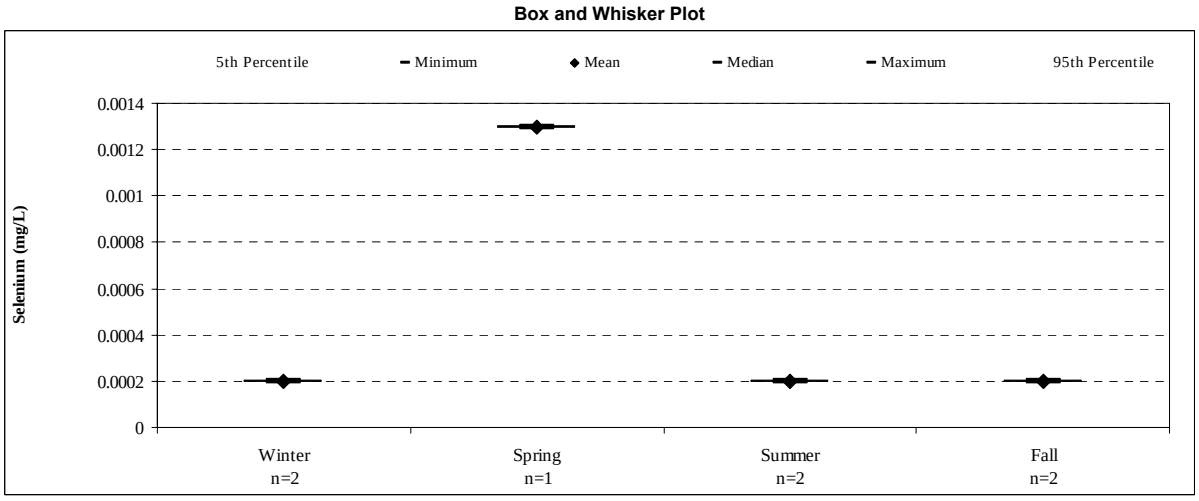


Figure G-1-8-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Unnamed Creek 3



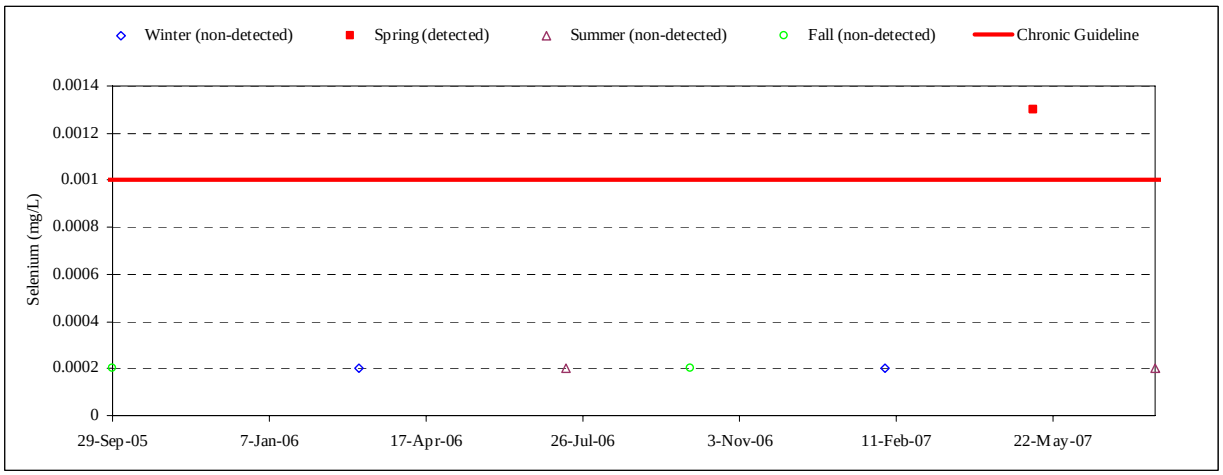
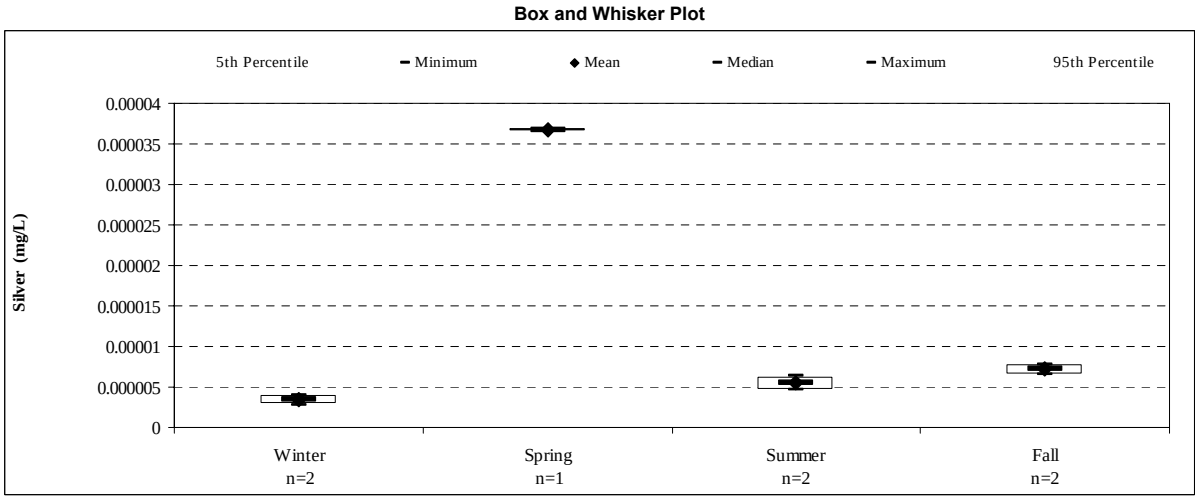


Figure G-1-8-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Unnamed Creek 3



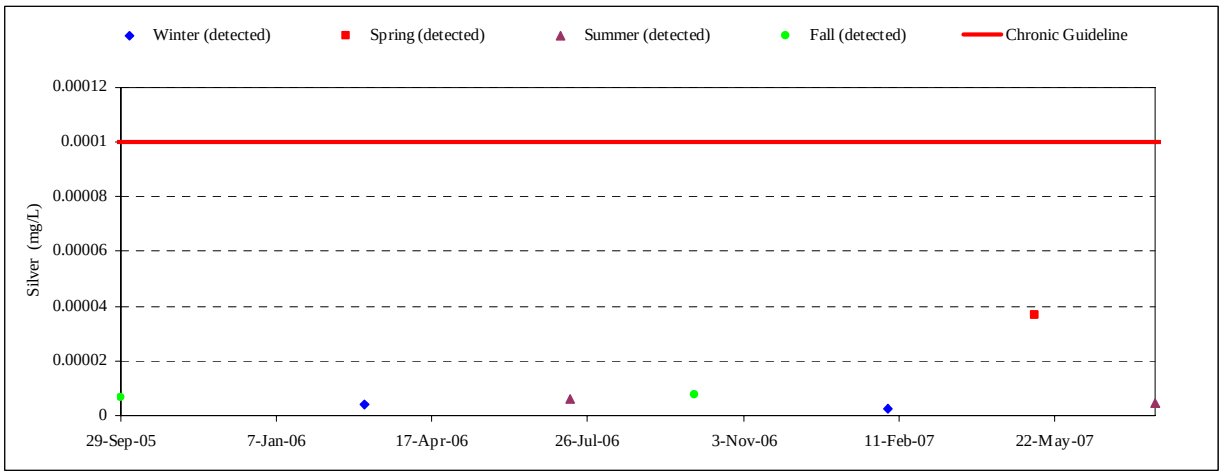
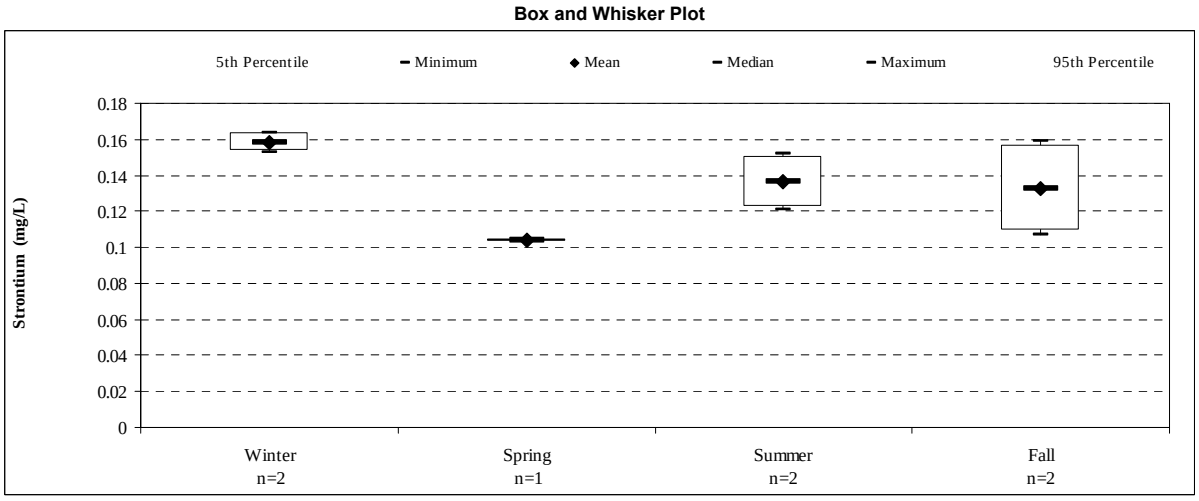


Figure G-1-8-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Unnamed Creek 3



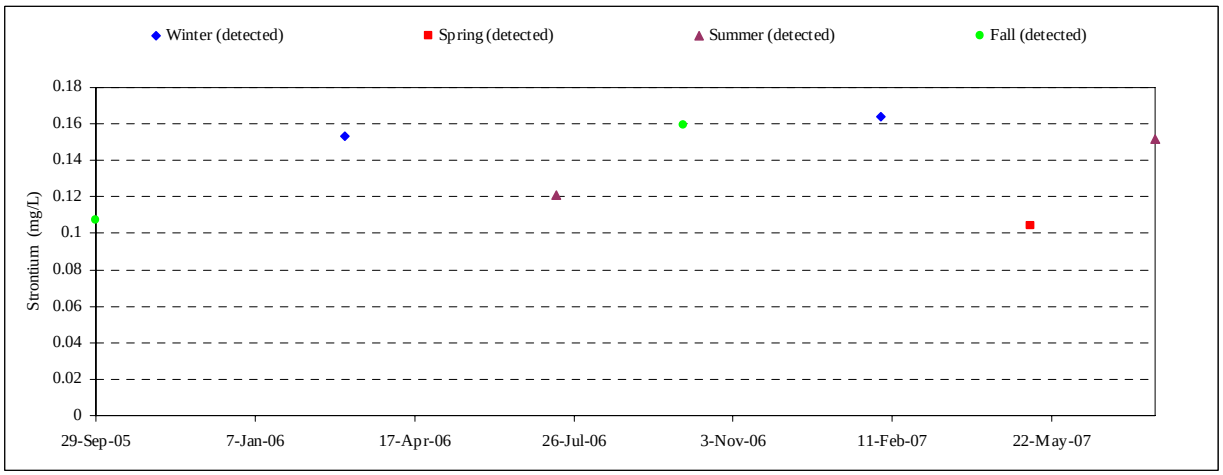
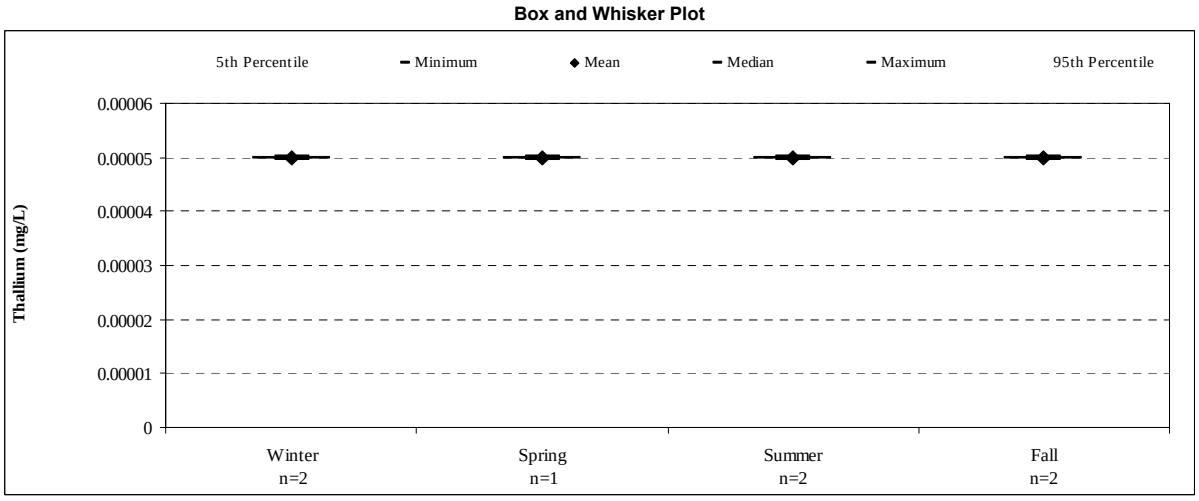


Figure G-1-8-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Unnamed Creek 3



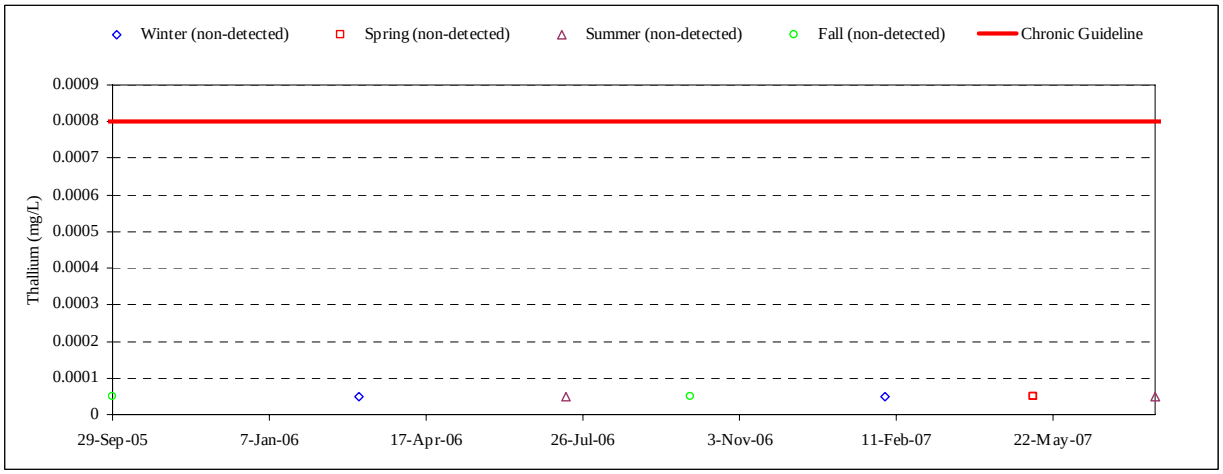
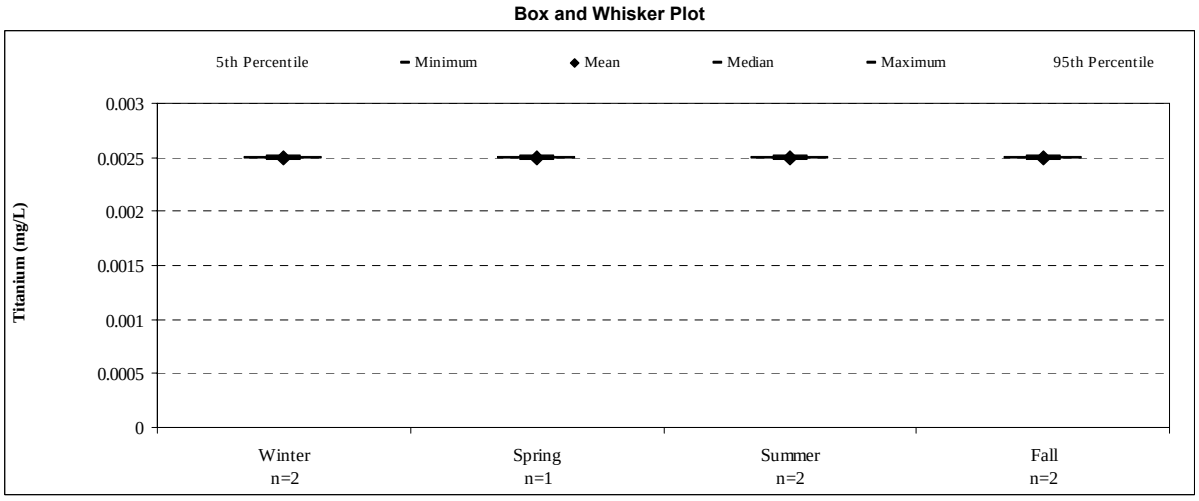


Figure G-1-8-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Unnamed Creek 3



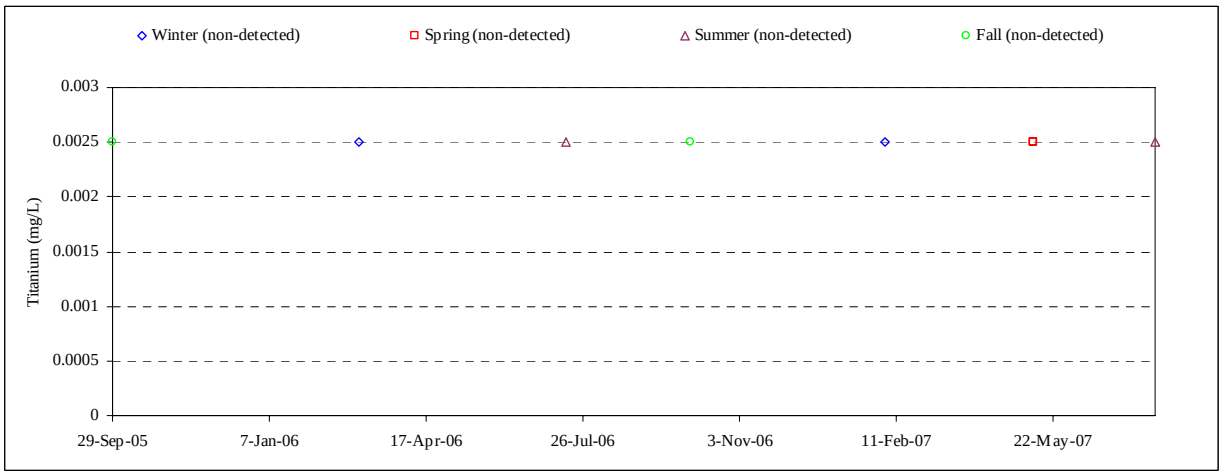
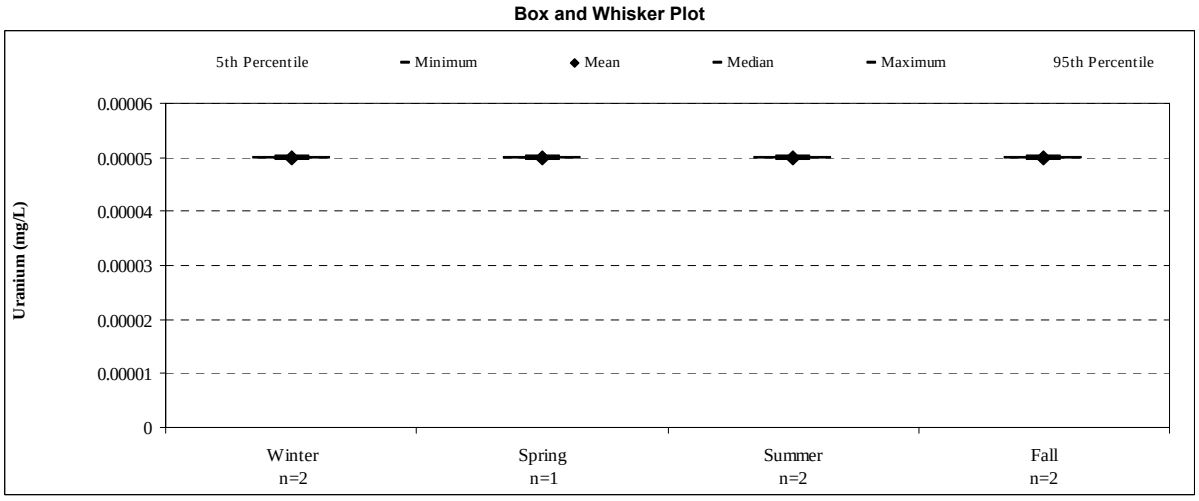


Figure G-1-8-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Unnamed Creek 3



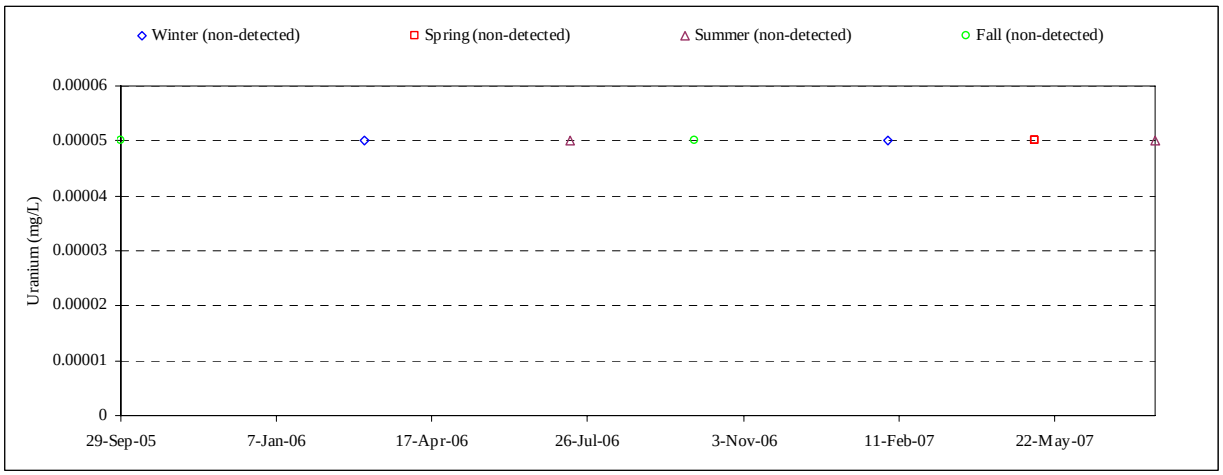
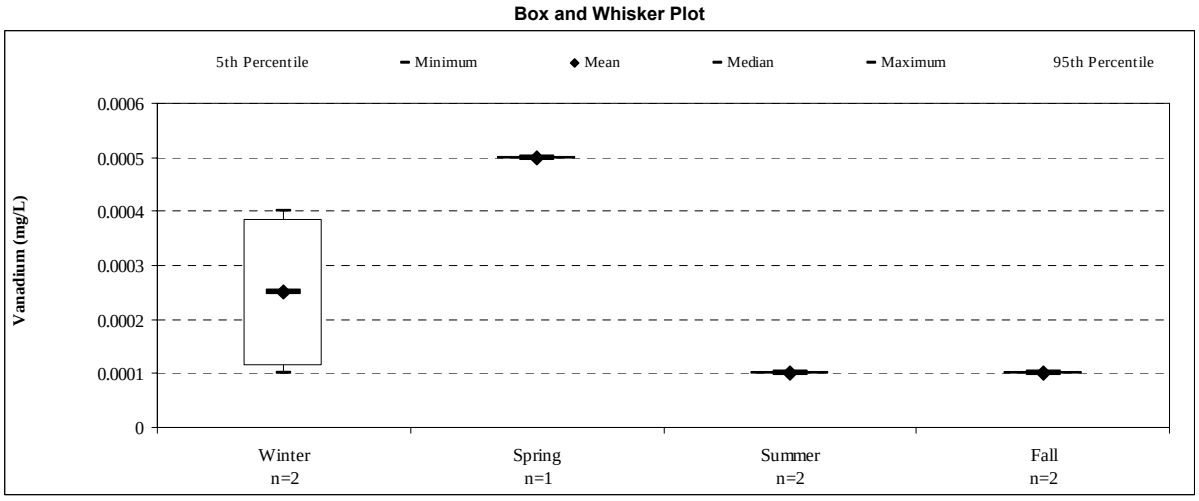


Figure G-1-8-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Unnamed Creek 3



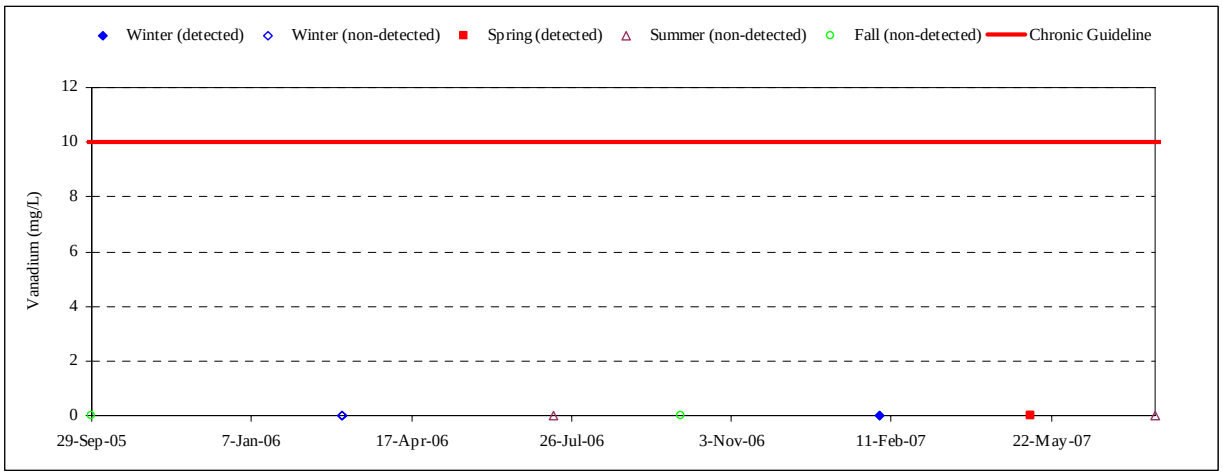
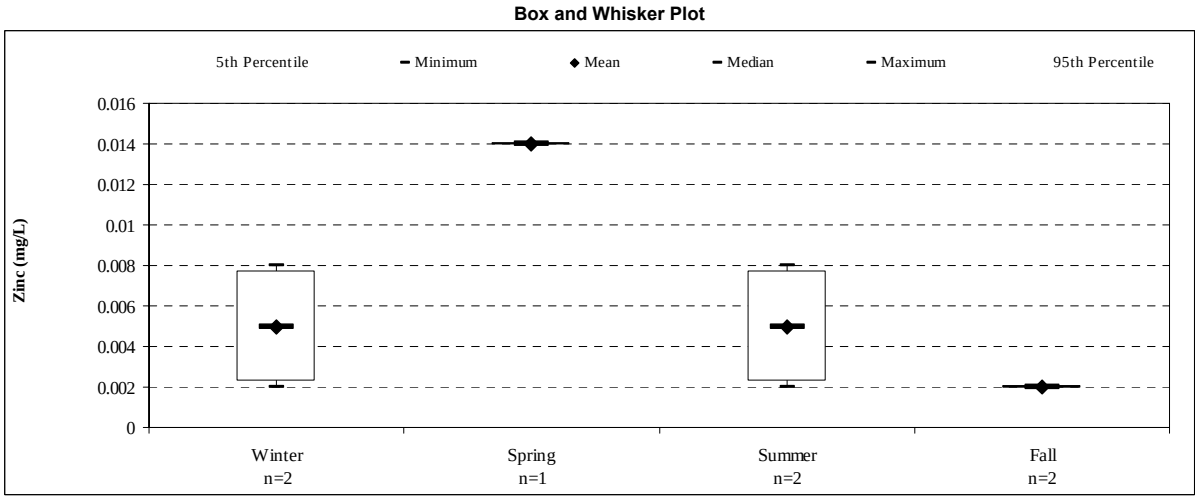


Figure G-1-8-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Unnamed Creek 3



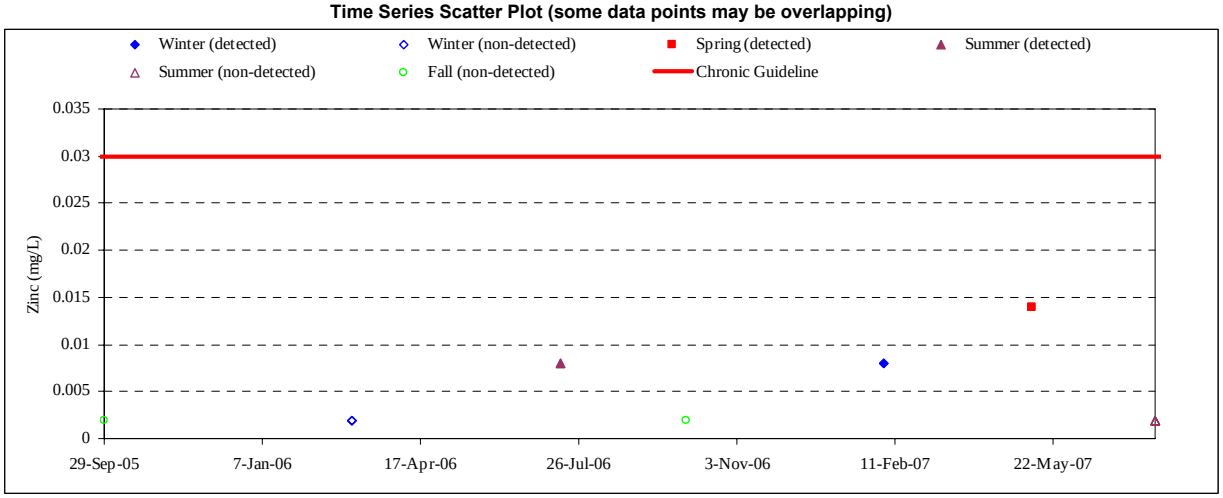
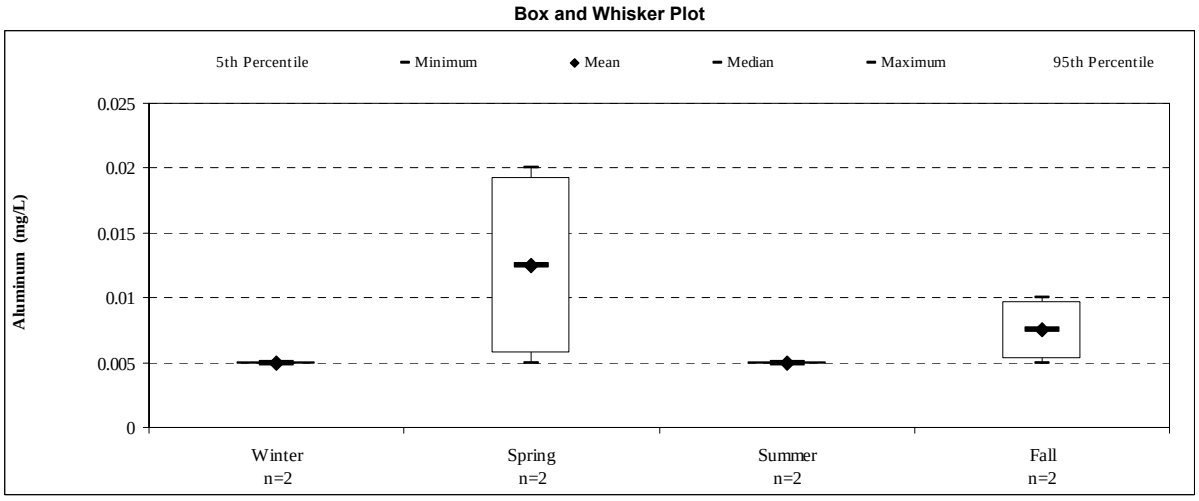


Figure G-1-8-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Unnamed Creek 3



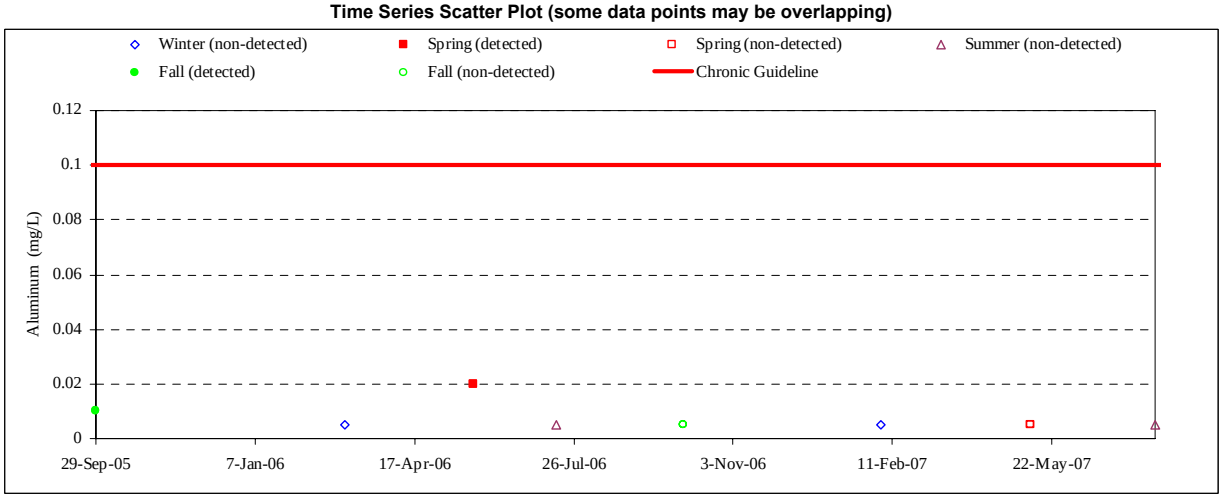
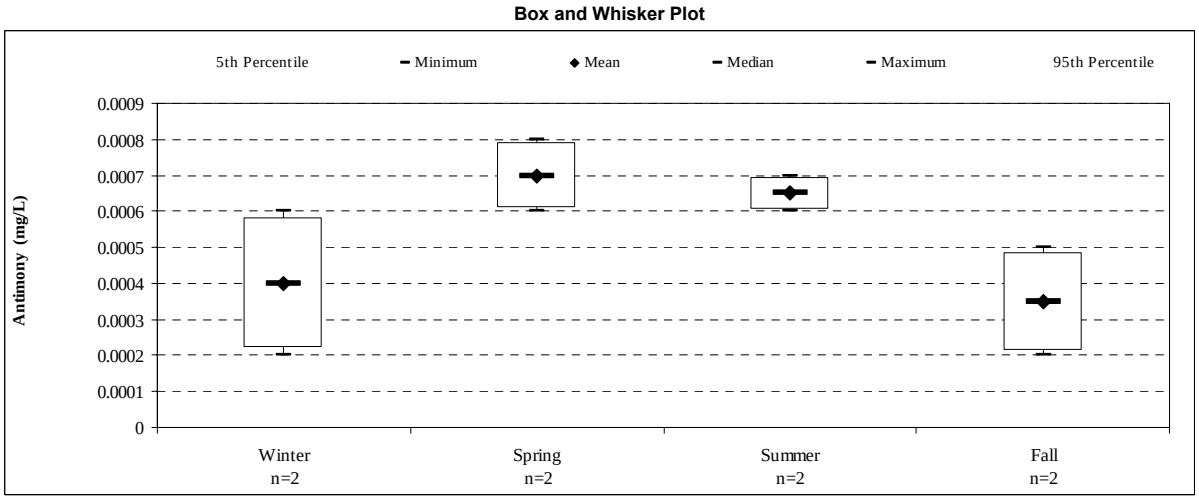


Figure G-1-8-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Unnamed Creek 3



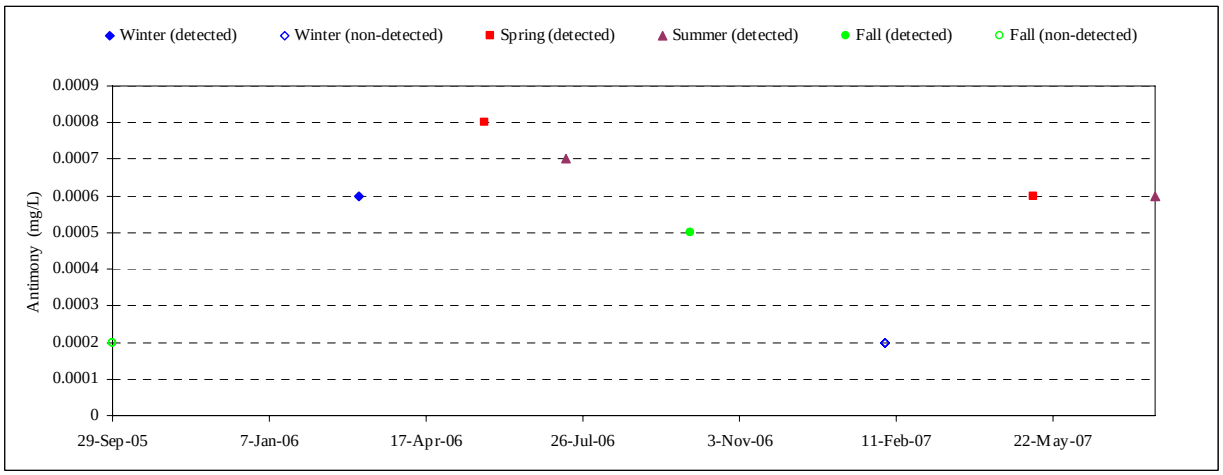
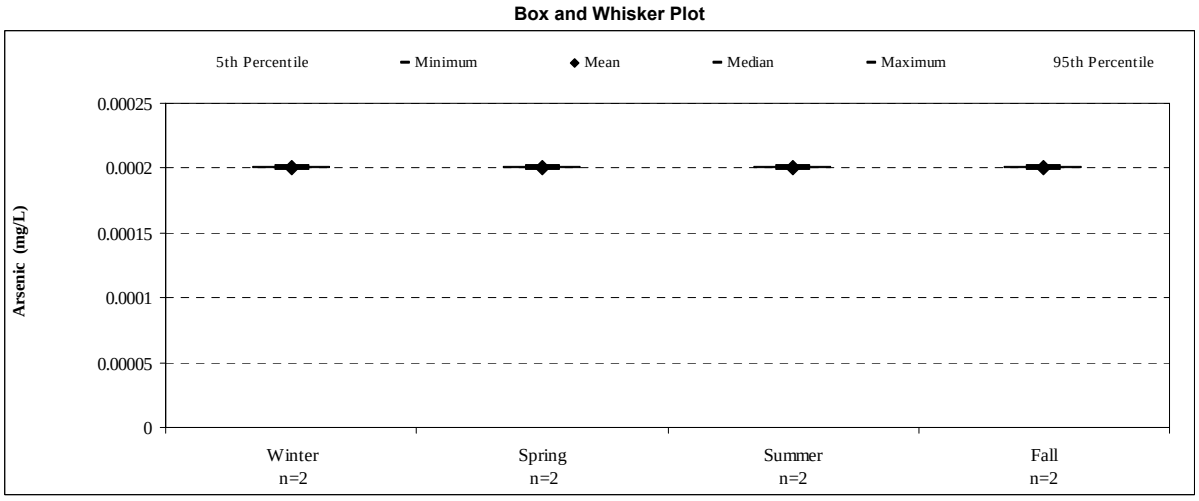


Figure G-1-8-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Unnamed Creek 3



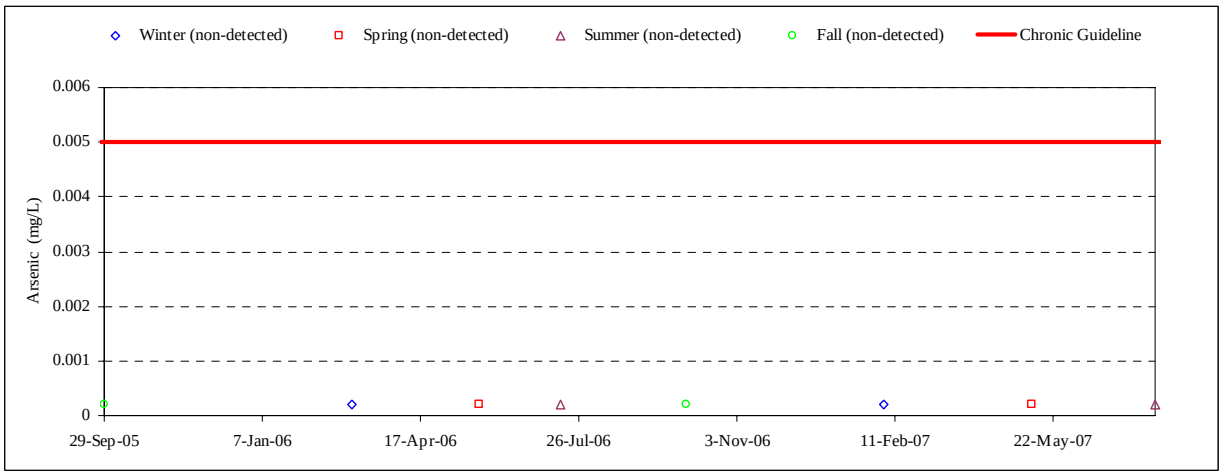
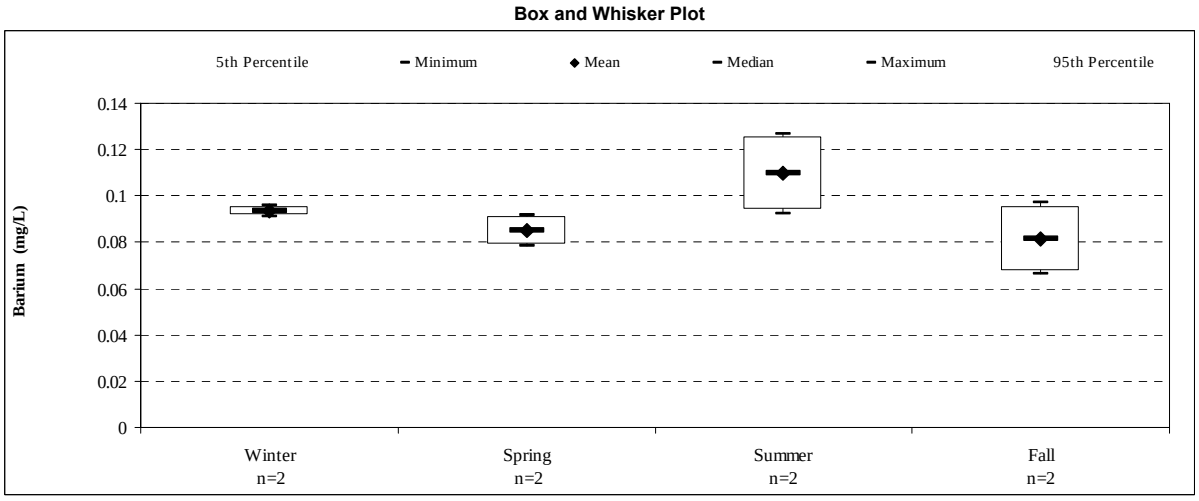


Figure G-1-8-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Unnamed Creek 3



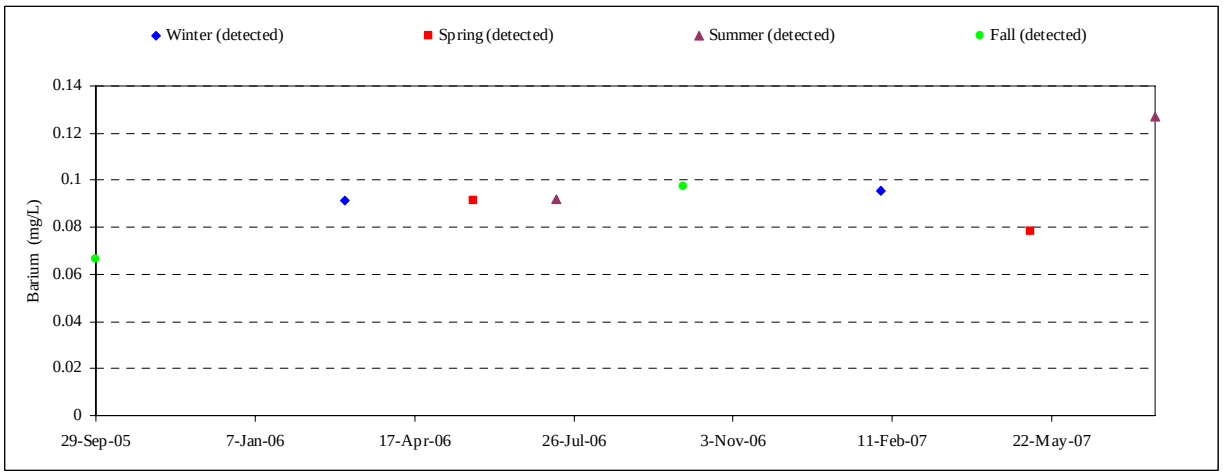
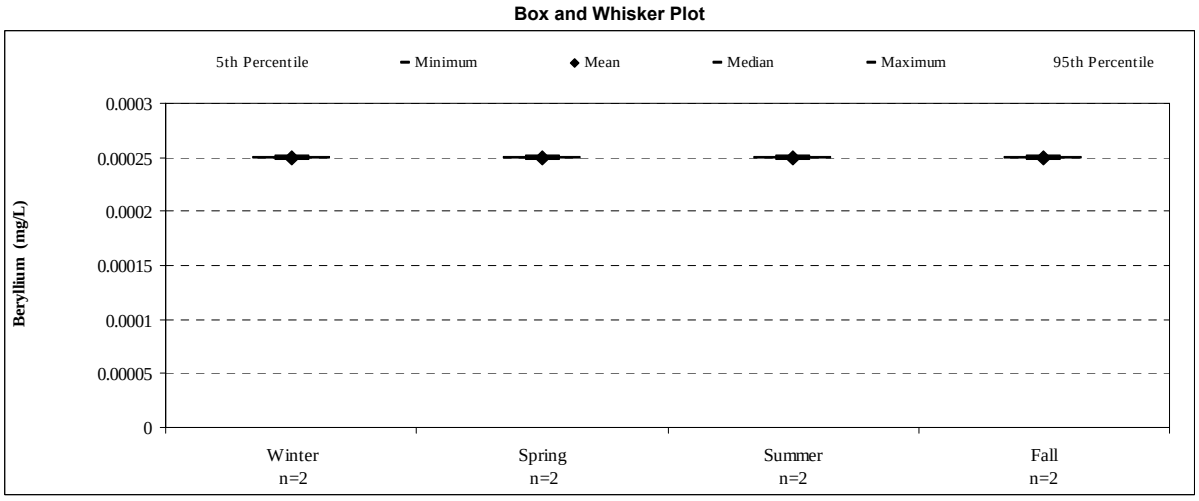


Figure G-1-8-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Unnamed Creek 3



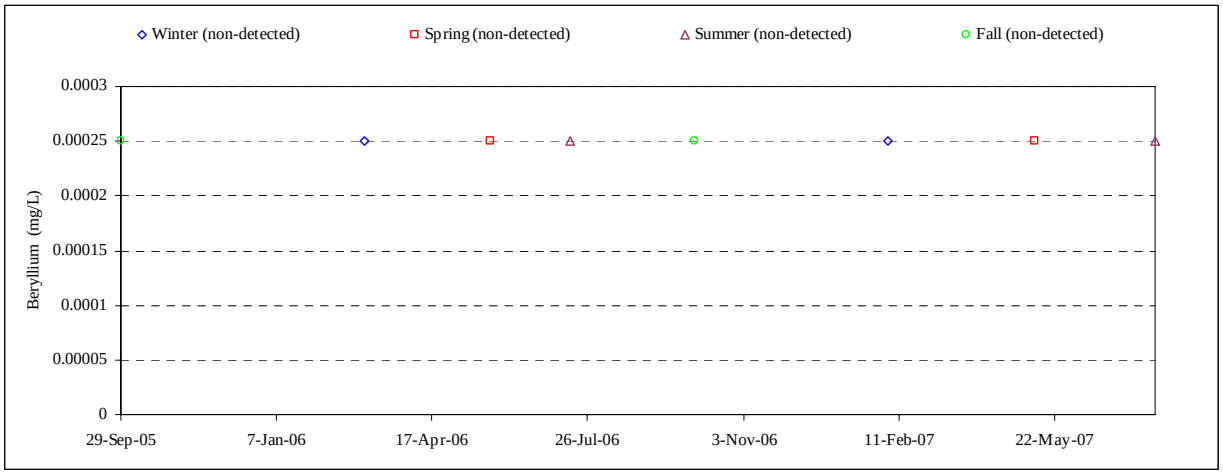
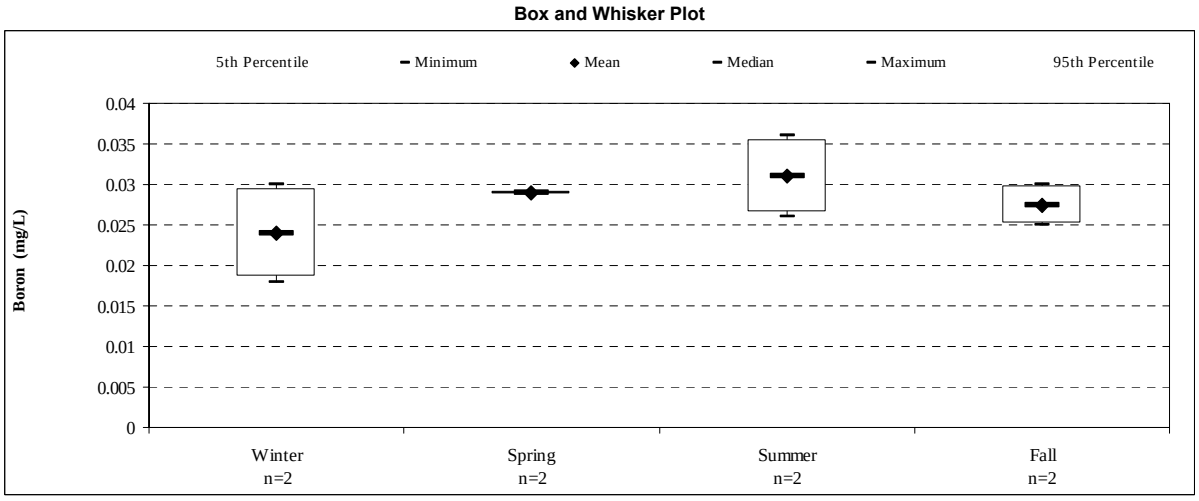


Figure G-1-8-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Unnamed Creek 3



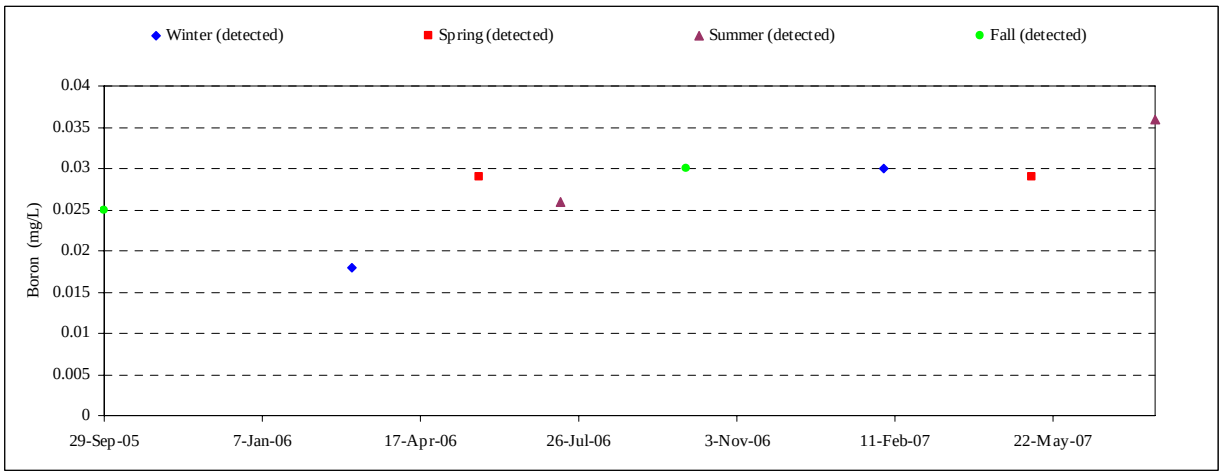
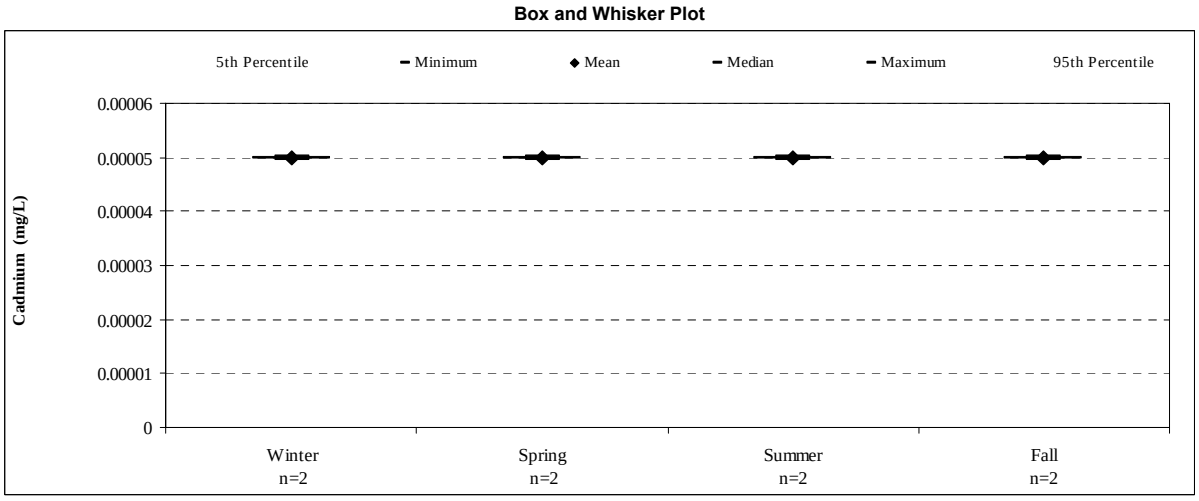


Figure G-1-8-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Unnamed Creek 3



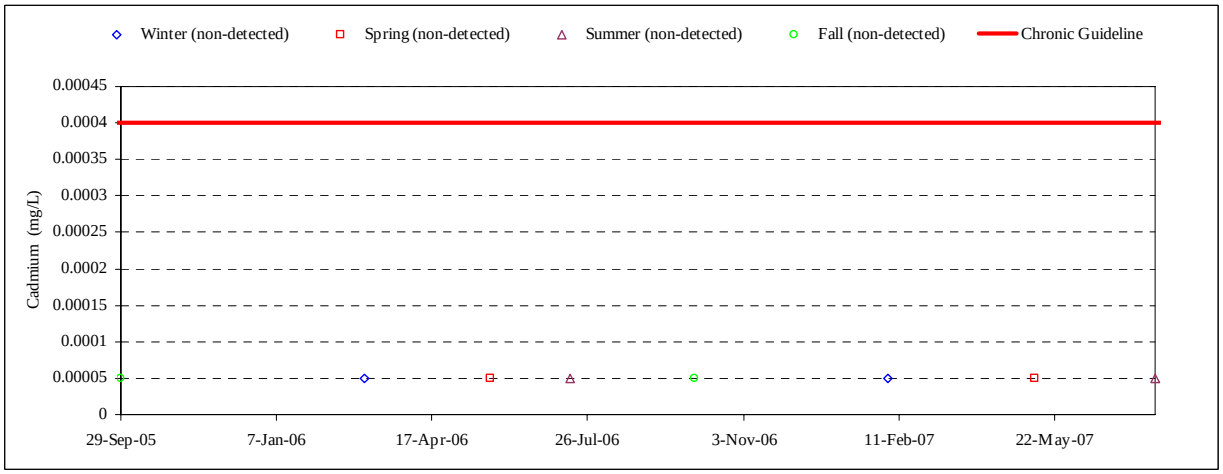
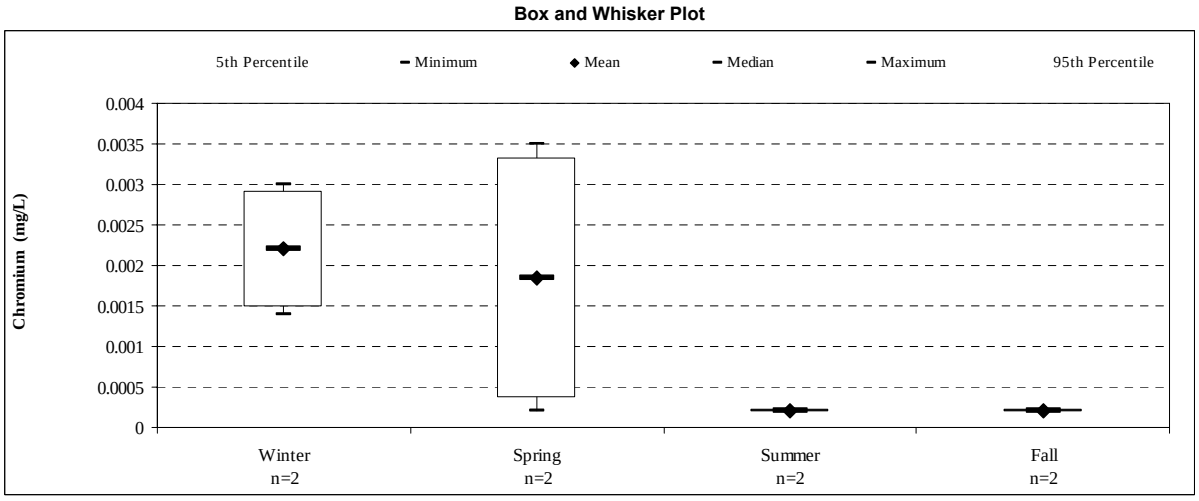


Figure G-1-8-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Unnamed Creek 3



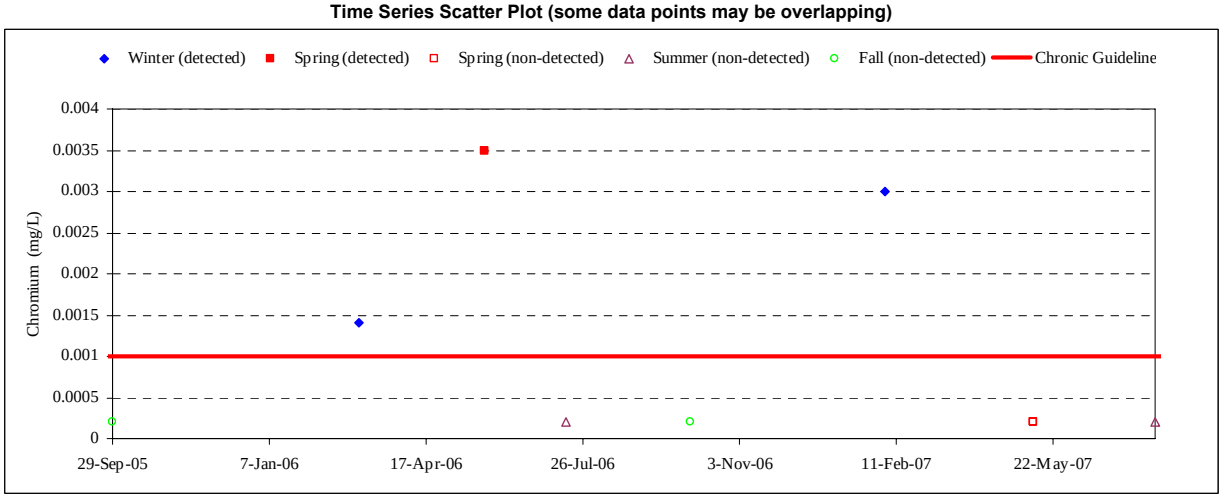
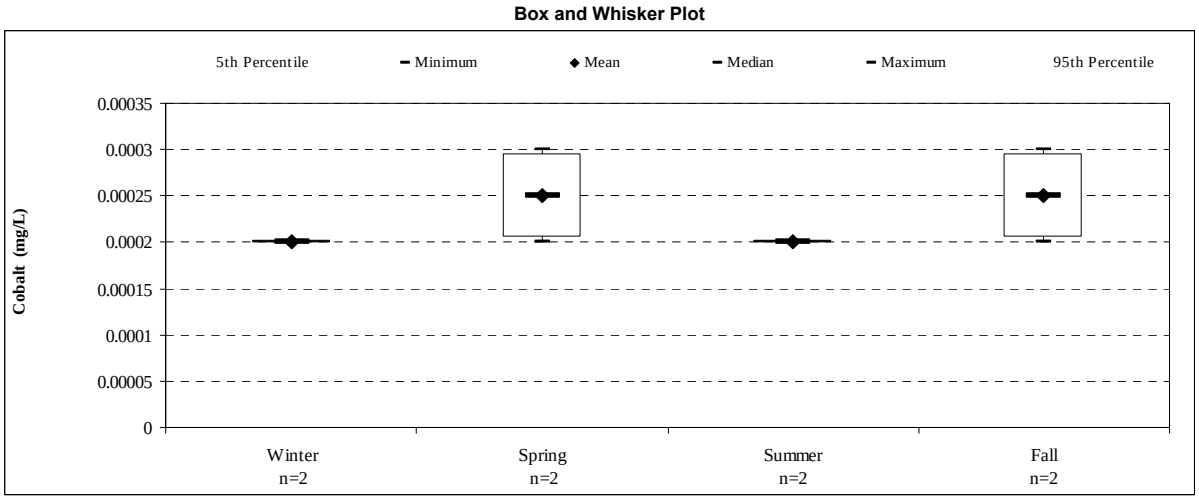


Figure G-1-8-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Unnamed Creek 3



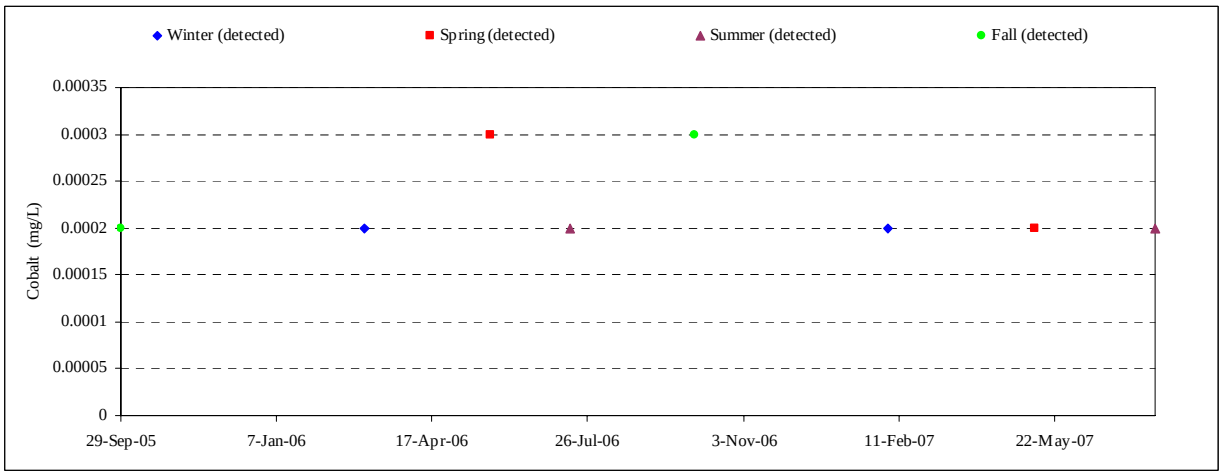
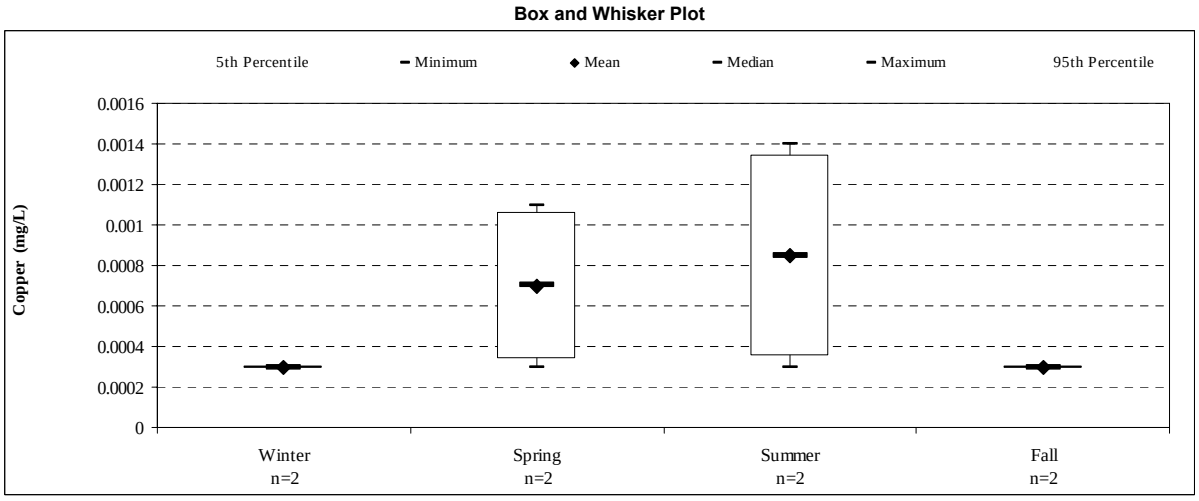


Figure G-1-8-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Unnamed Creek 3



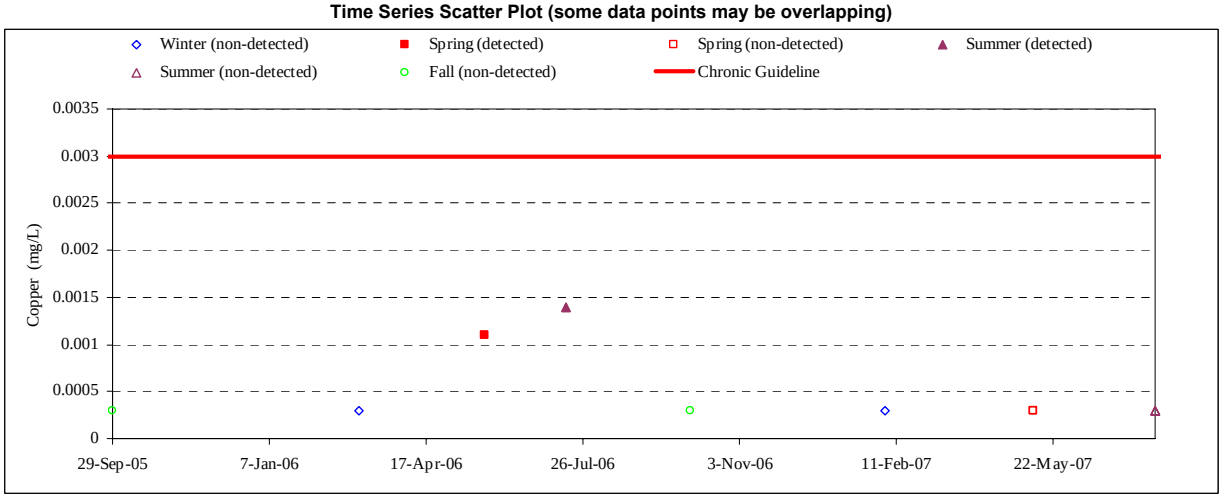
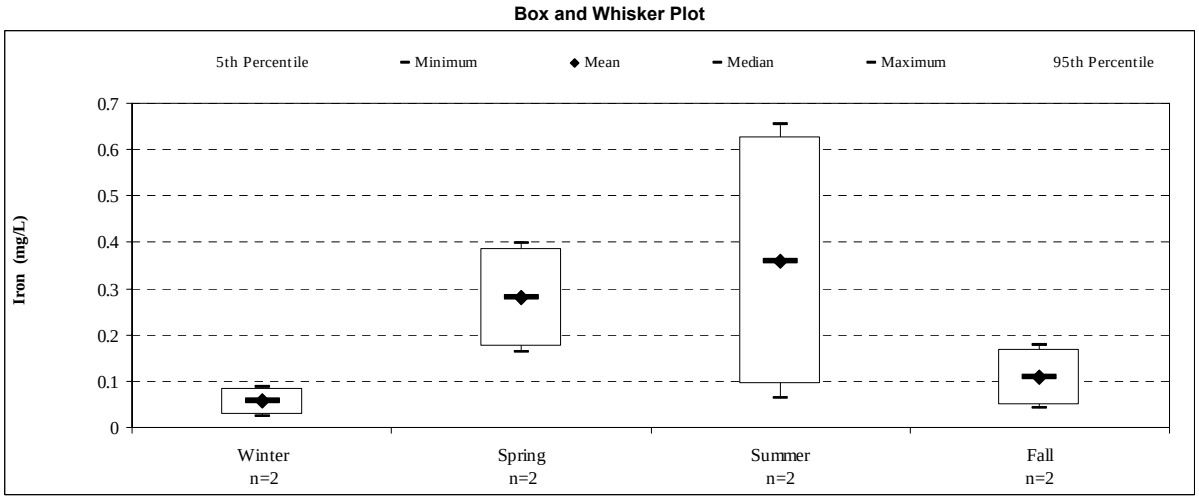


Figure G-1-8-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Unnamed Creek 3



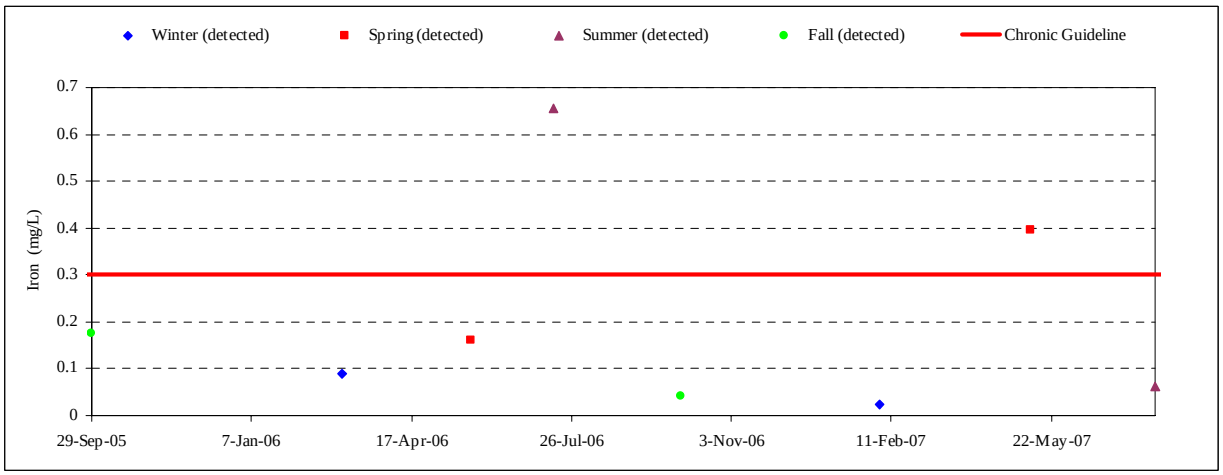
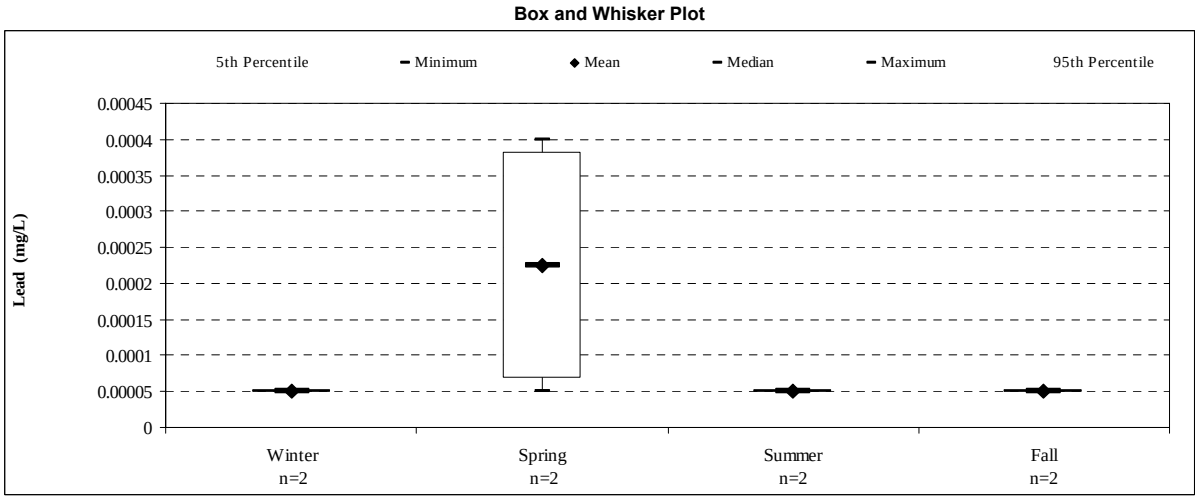


Figure G-1-8-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Unnamed Creek 3



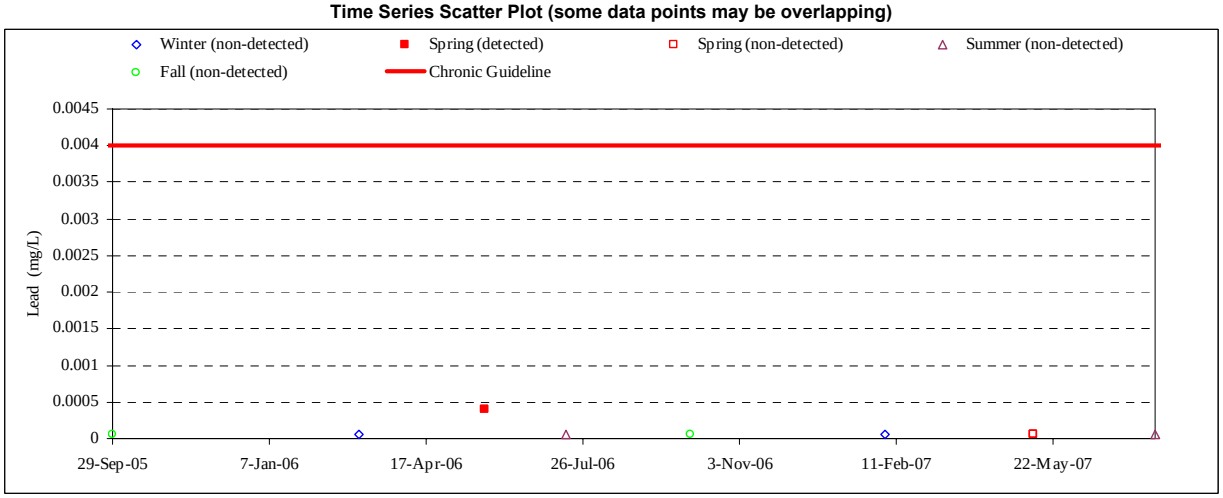
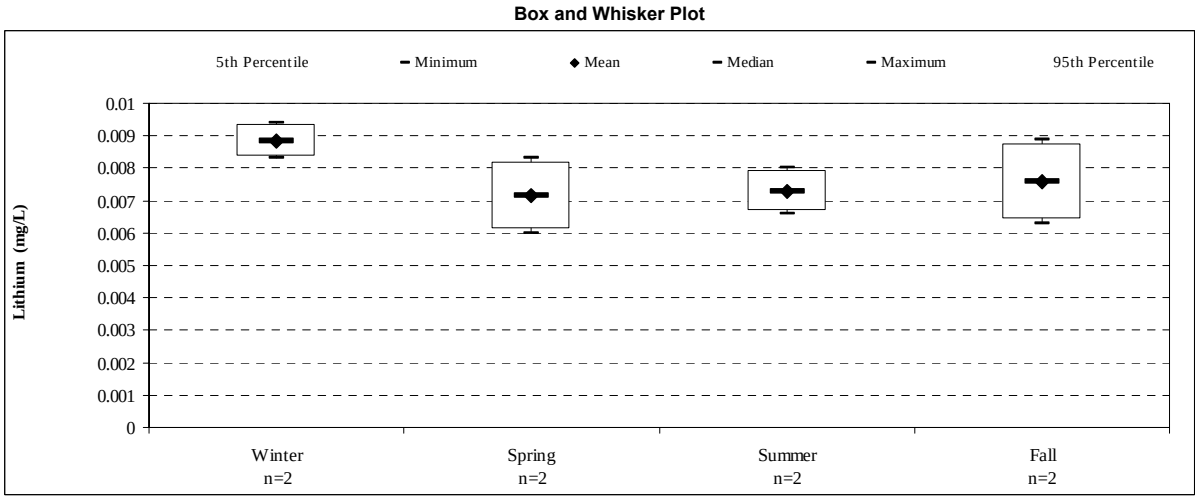


Figure G-1-8-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Unnamed Creek 3



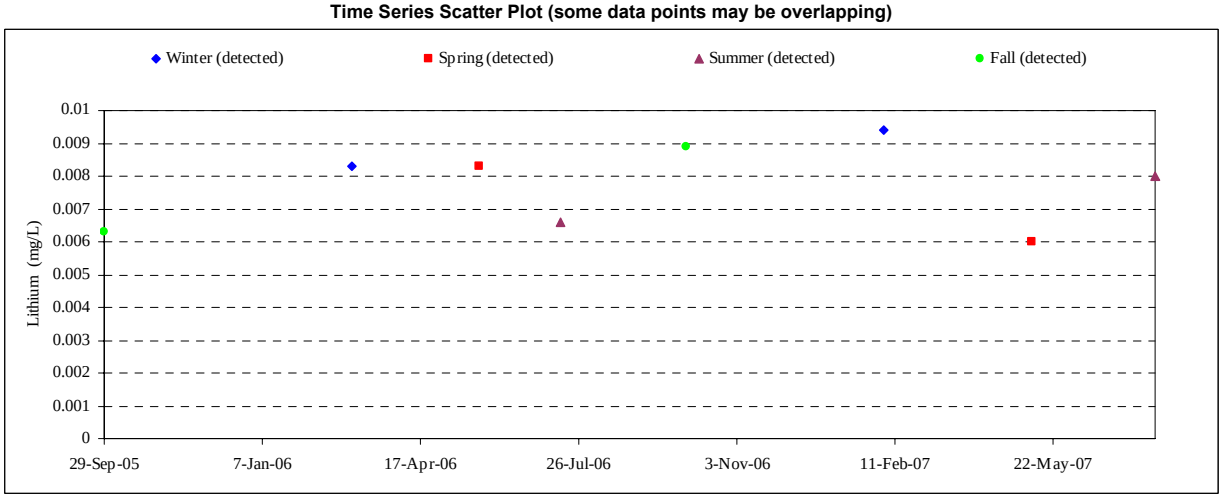
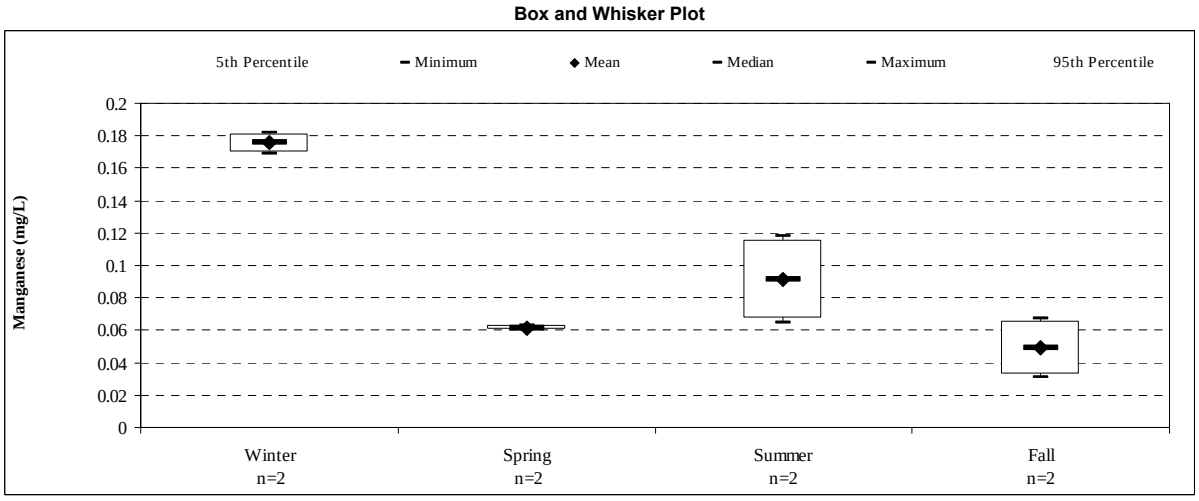


Figure G-1-8-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Unnamed Creek 3



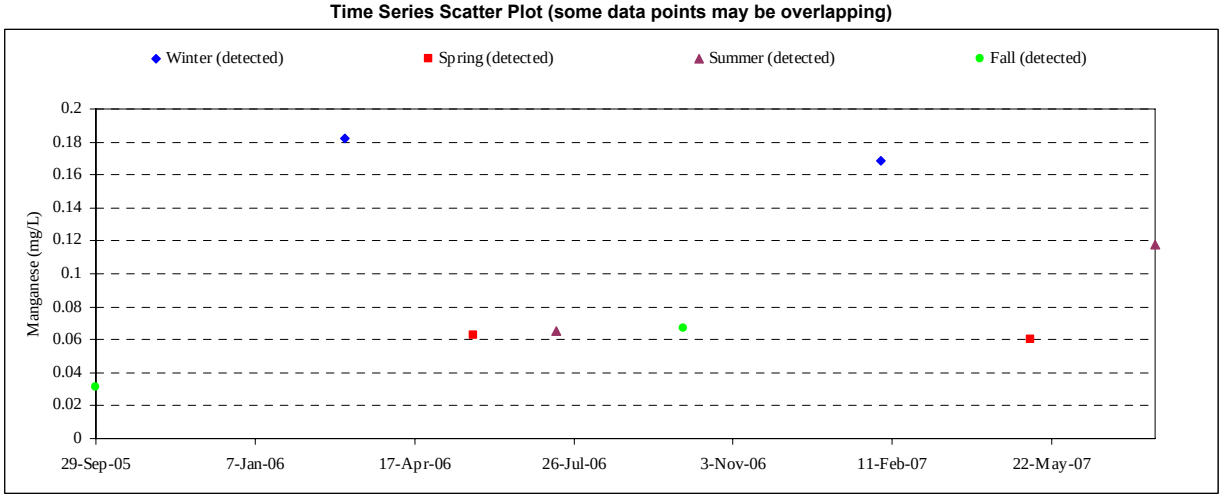
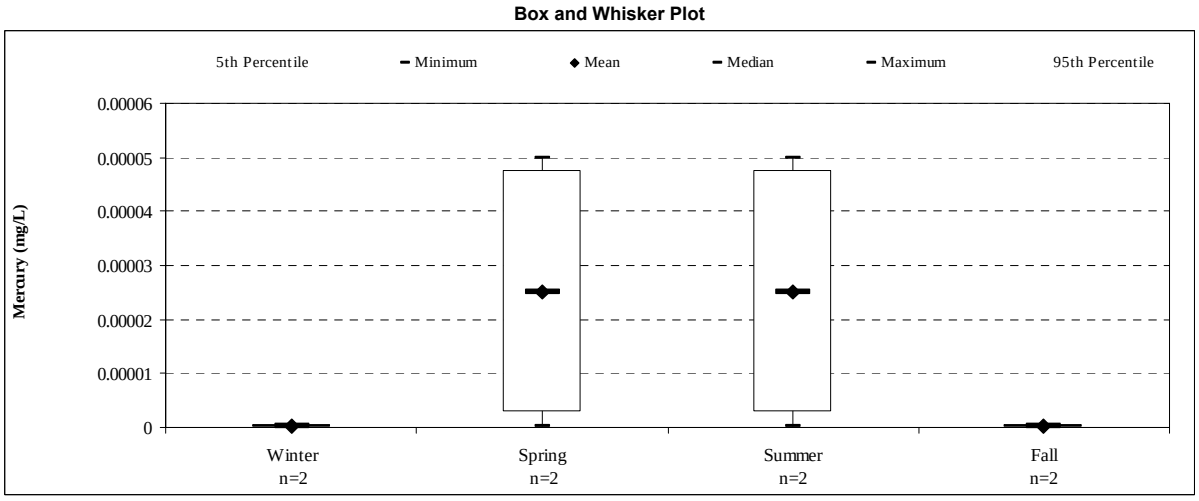


Figure G-1-8-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Unnamed Creek 3



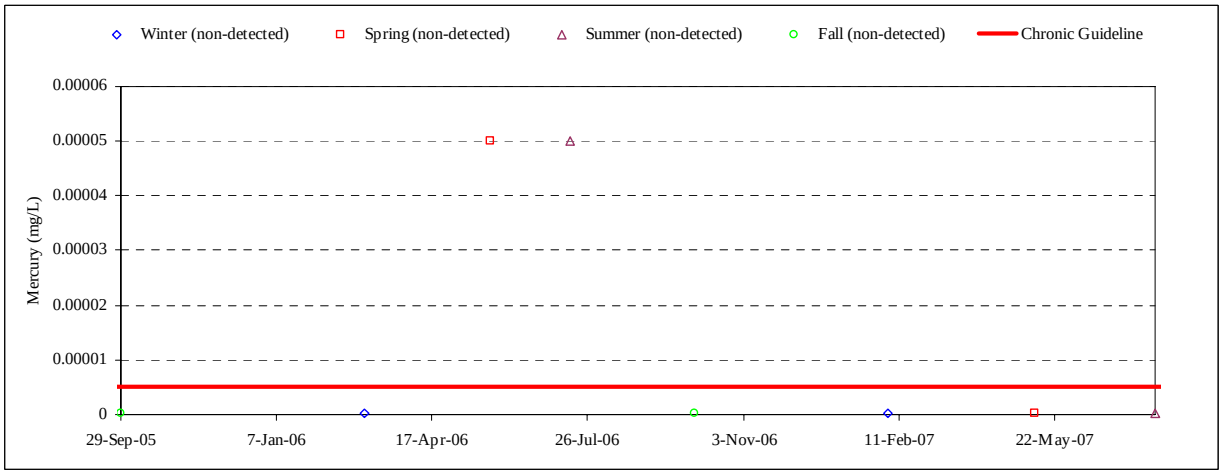
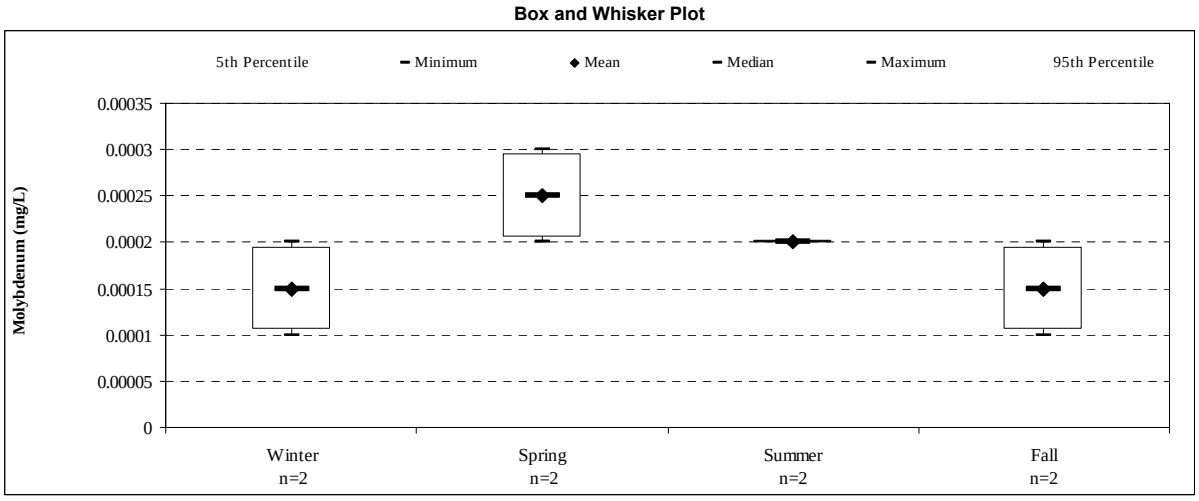


Figure G-1-8-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Unnamed Creek 3



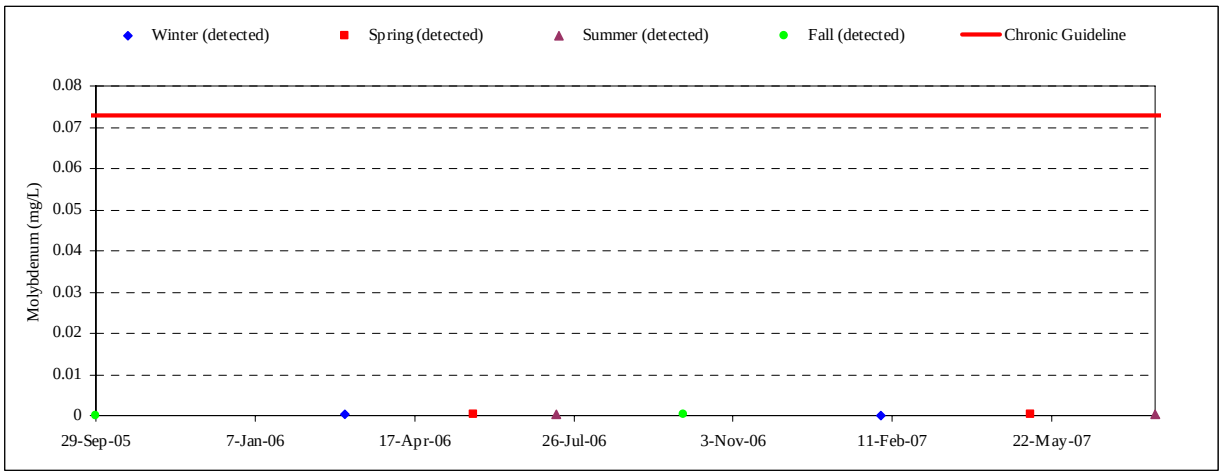
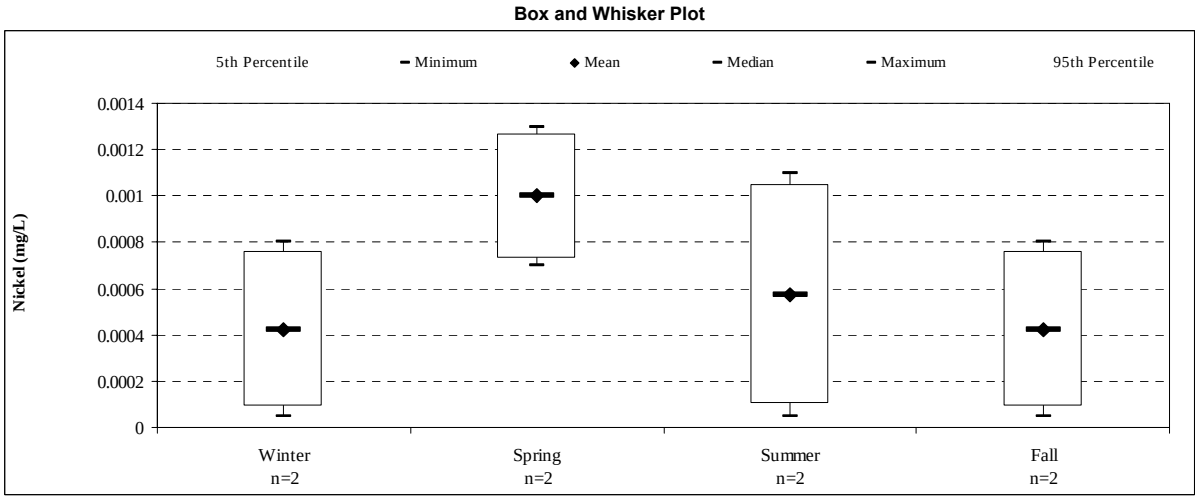


Figure G-1-8-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Unnamed Creek 3



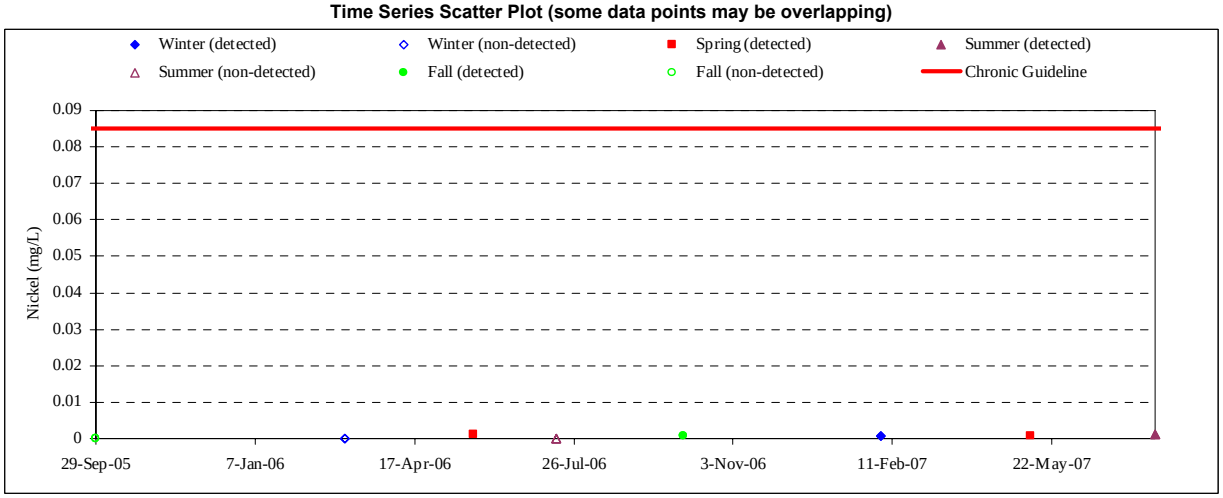
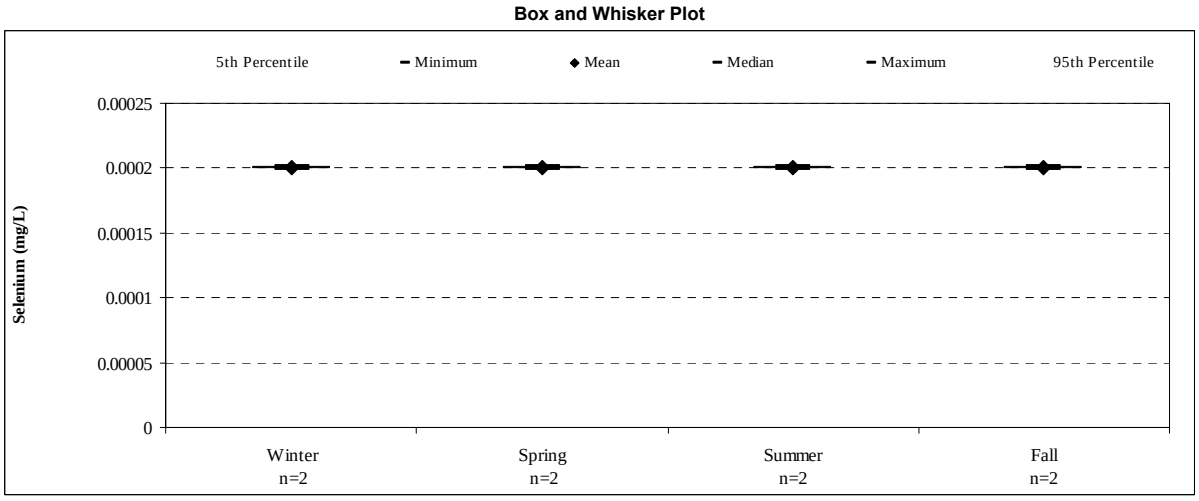


Figure G-1-8-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Unnamed Creek 3



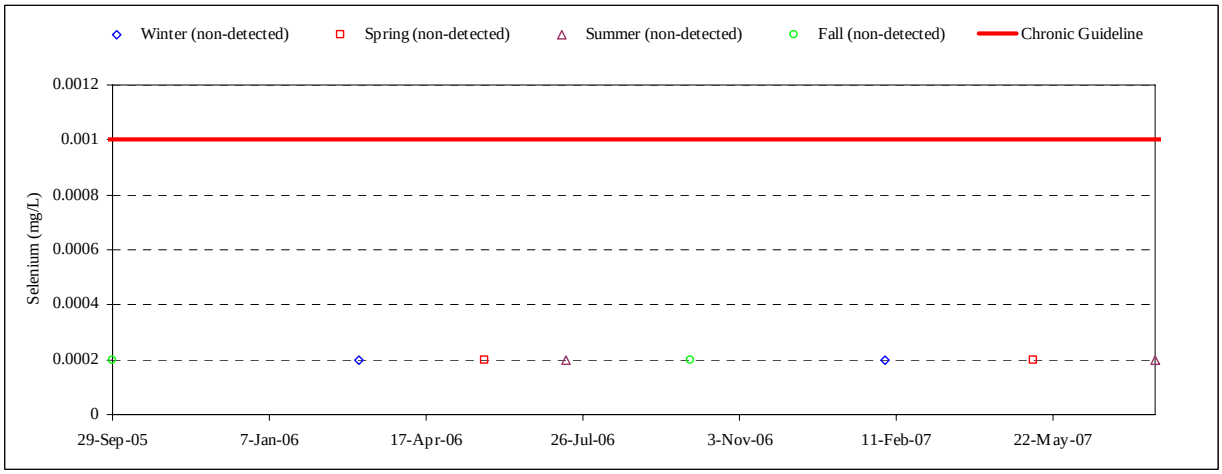
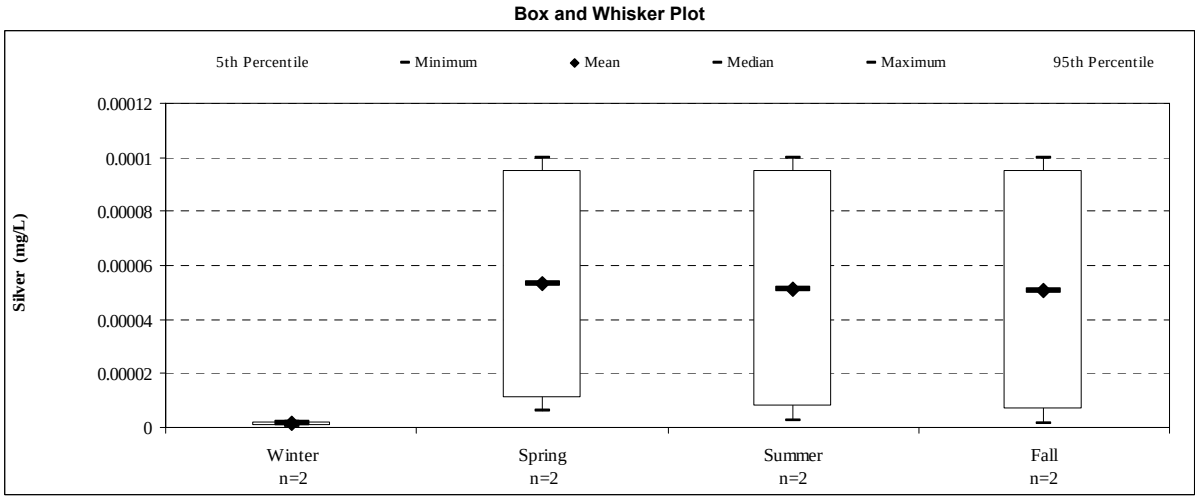


Figure G-1-8-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Unnamed Creek 3



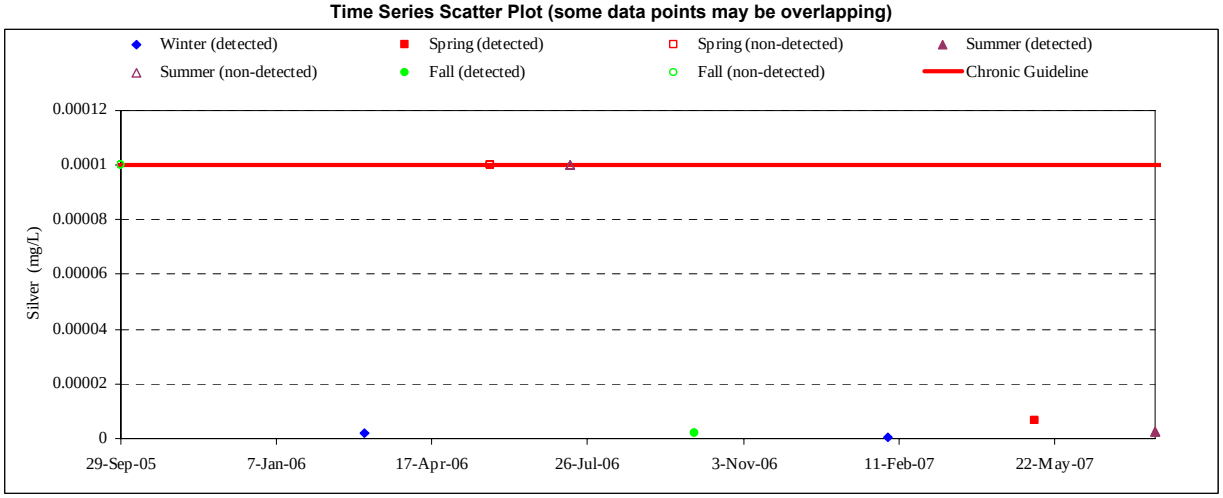
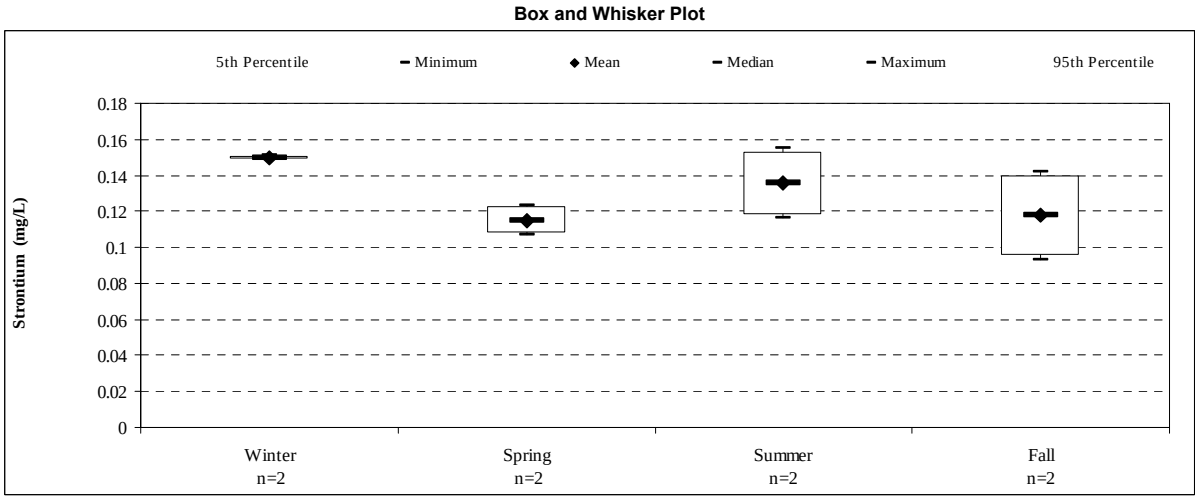


Figure G-1-8-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Unnamed Creek 3



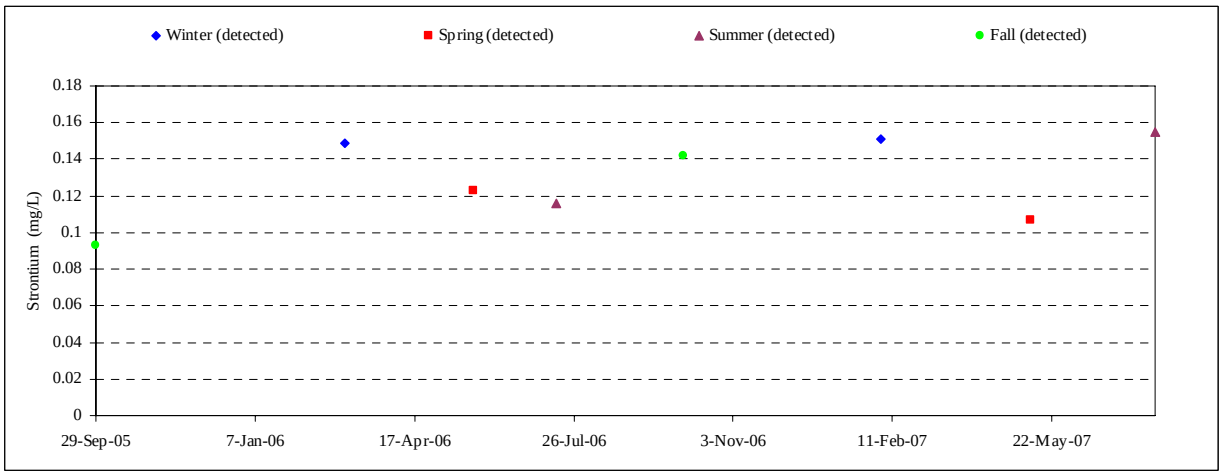


Figure G-1-8-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Unnamed Creek 3

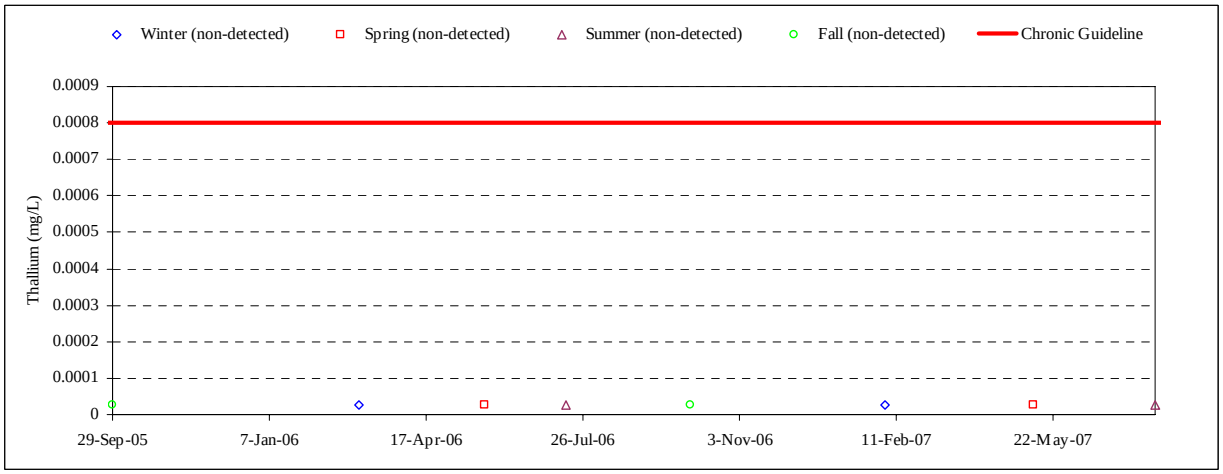
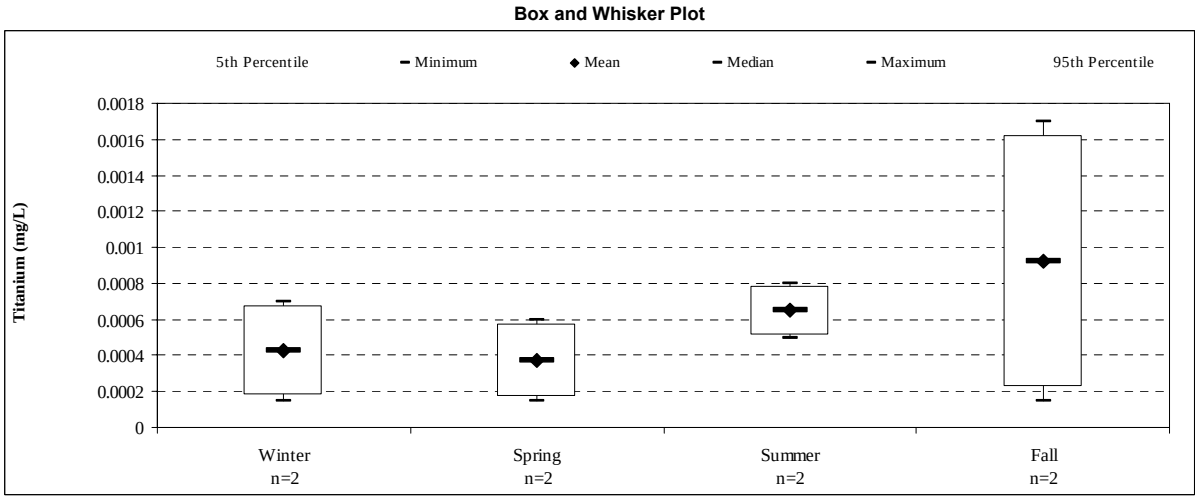


Figure G-1-8-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Unnamed Creek 3



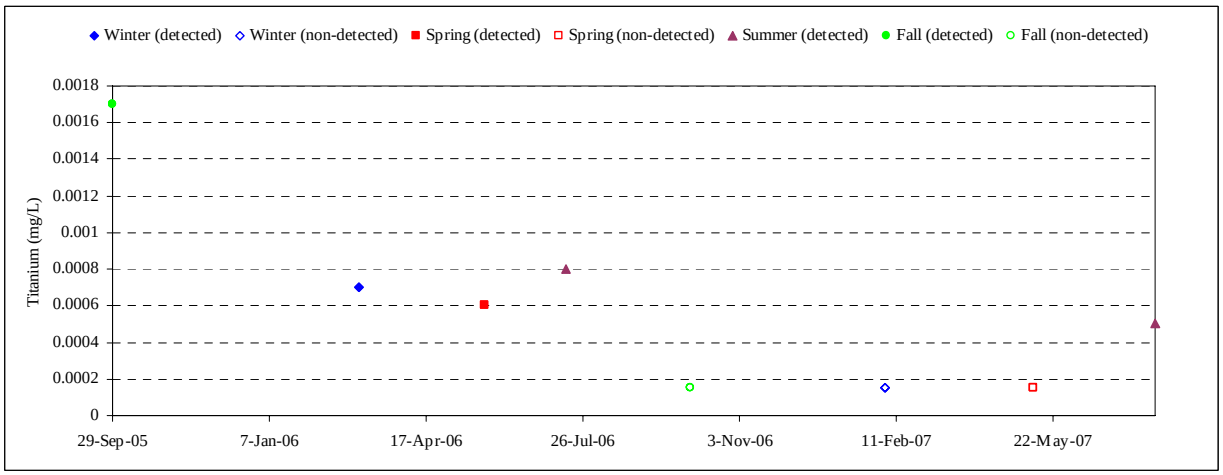
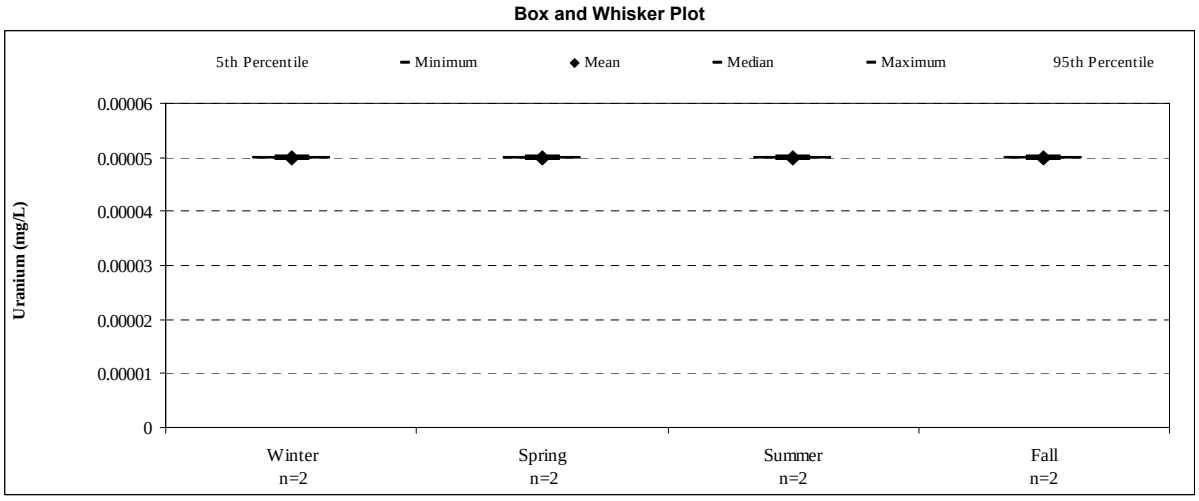


Figure G-1-8-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Unnamed Creek 3



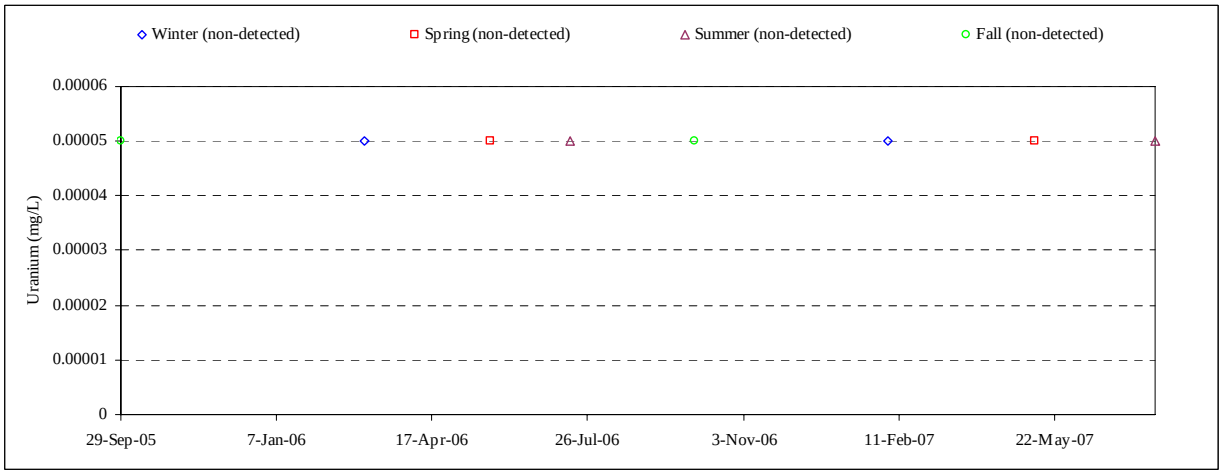
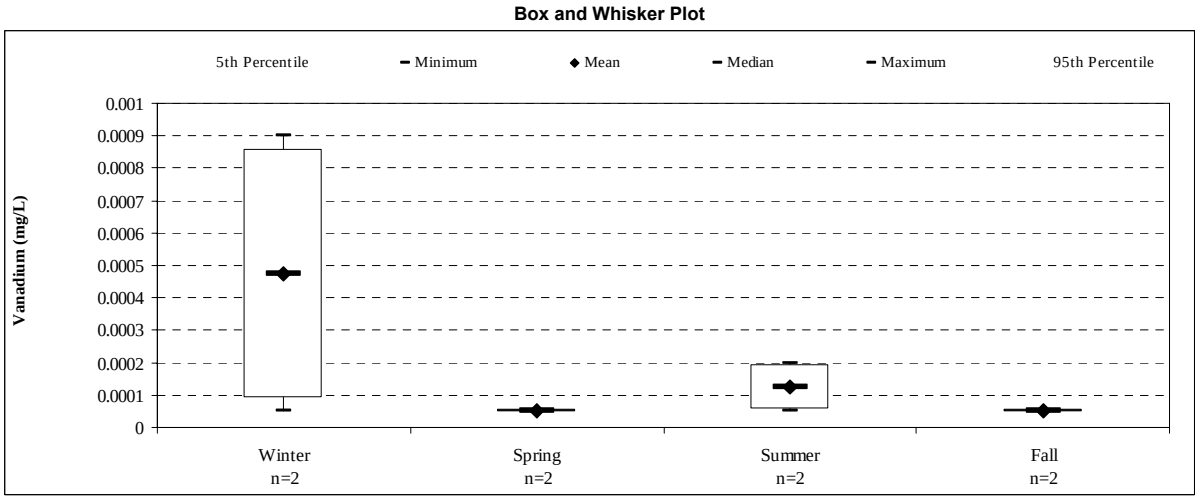


Figure G-1-8-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Unnamed Creek 3



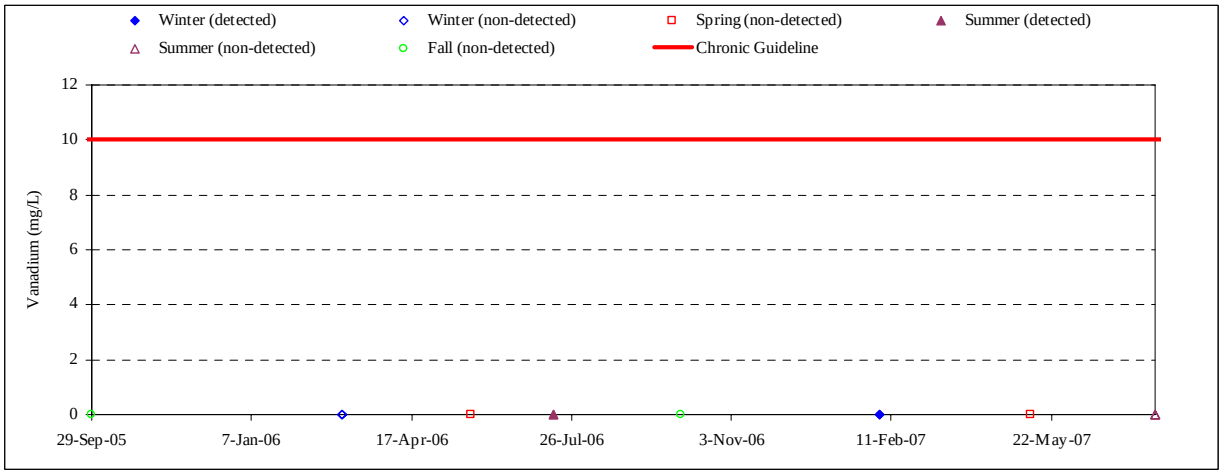
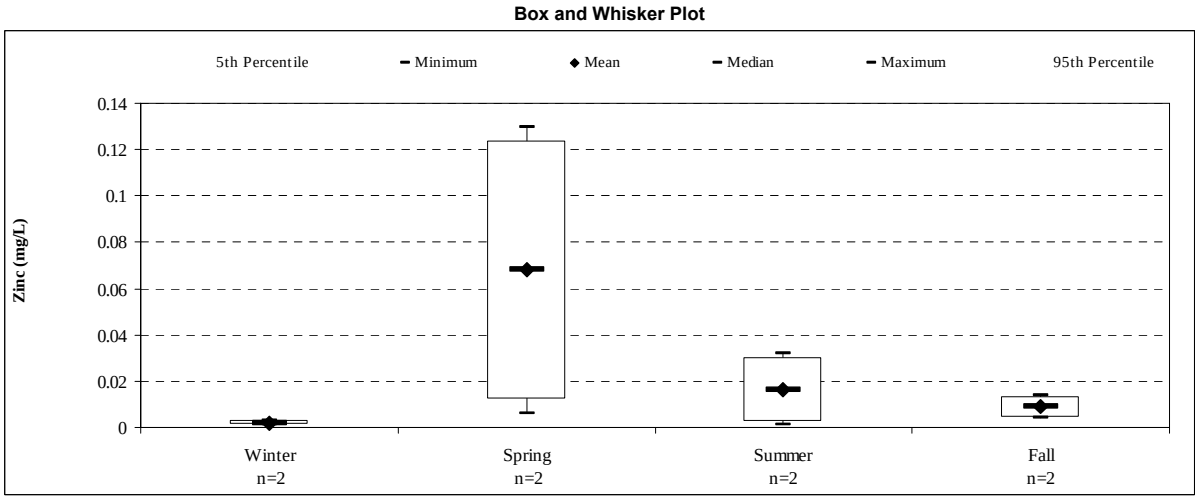


Figure G-1-8-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Unnamed Creek 3



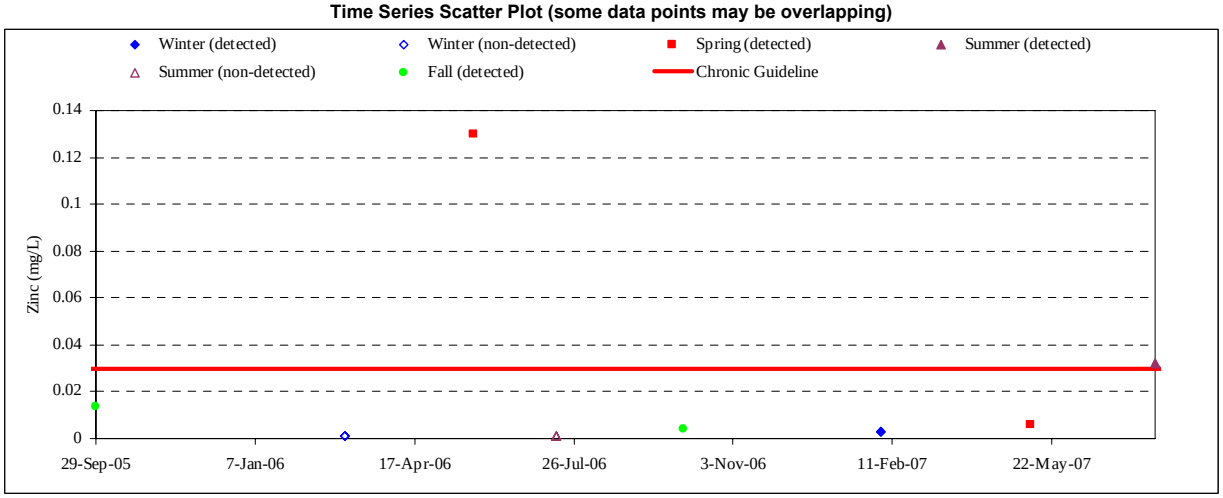
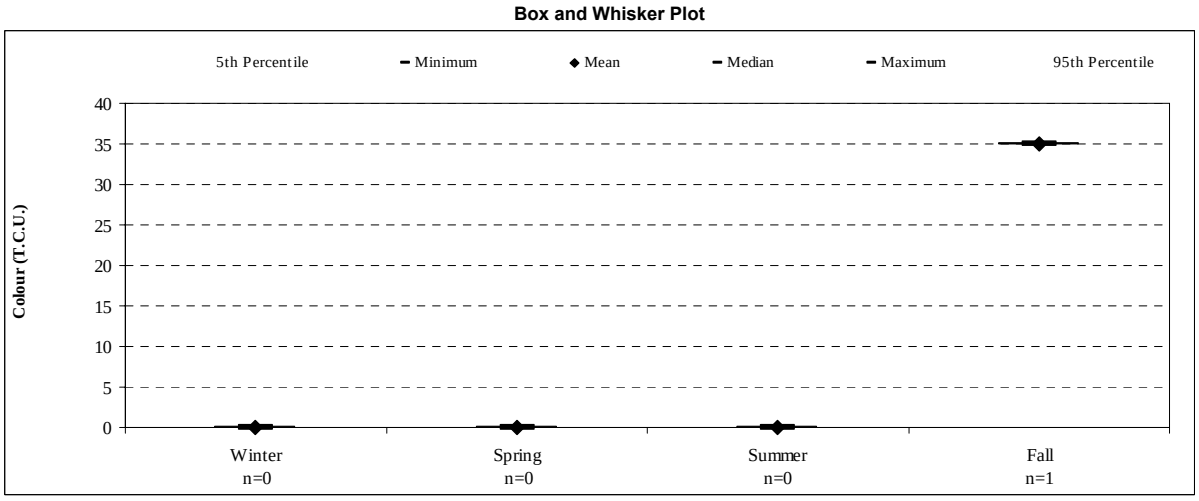


Figure G-1-9-5 Box Whisker and Time Series Scatter Plots of Observed Colour in McClelland Lake Fen



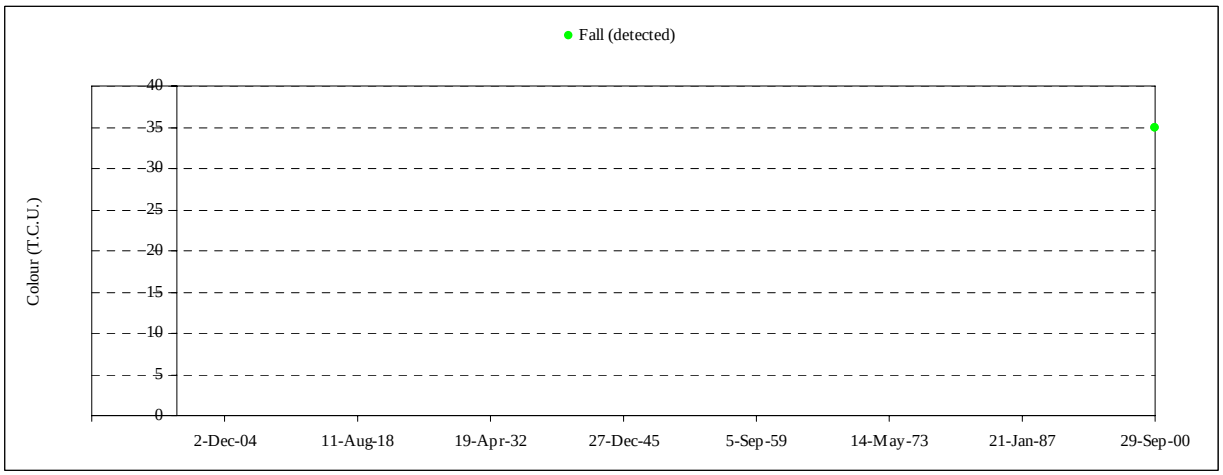


Figure G-1-9-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in McClelland Lake Fen

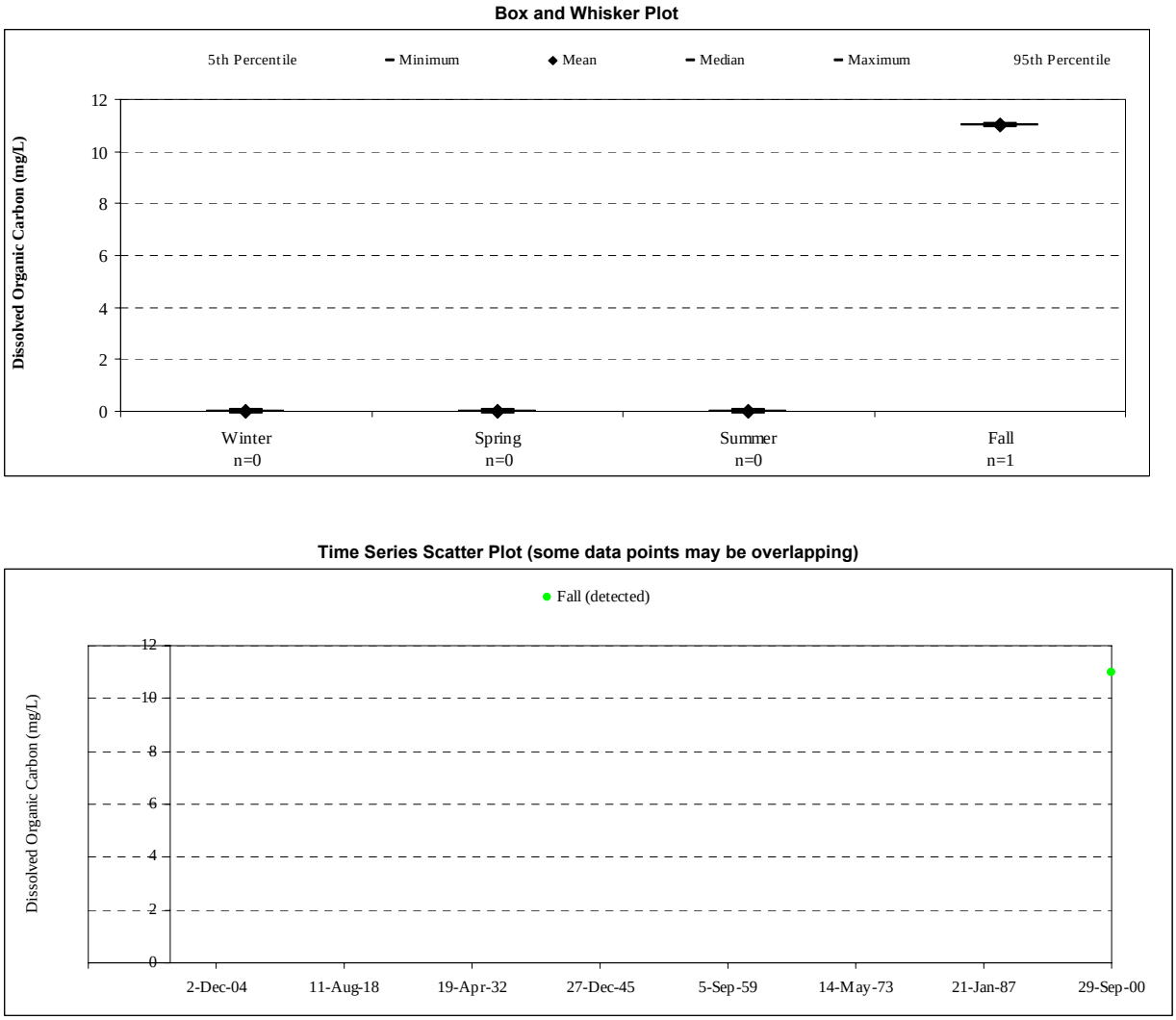
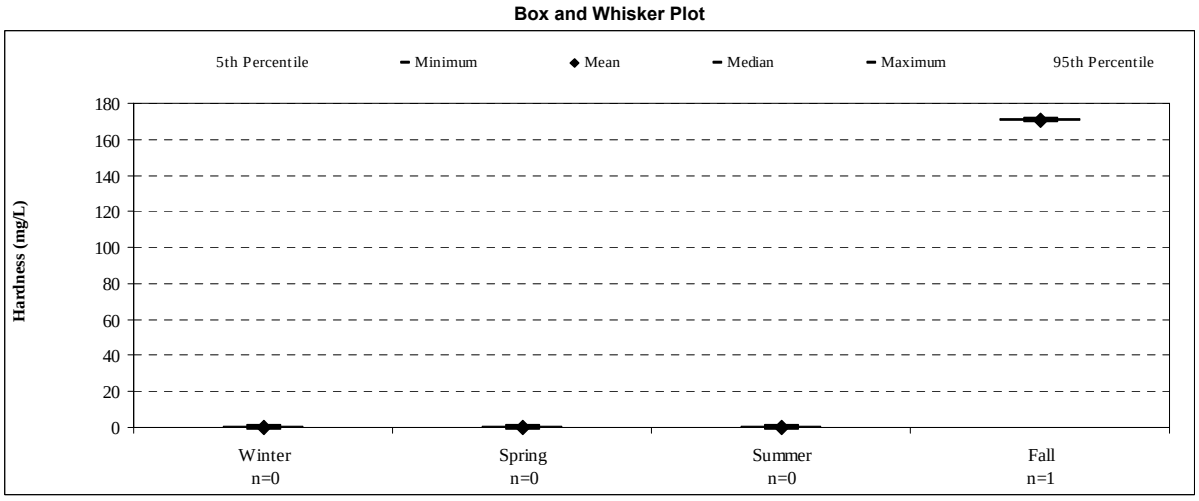


Figure G-1-9-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in McClelland Lake Fen



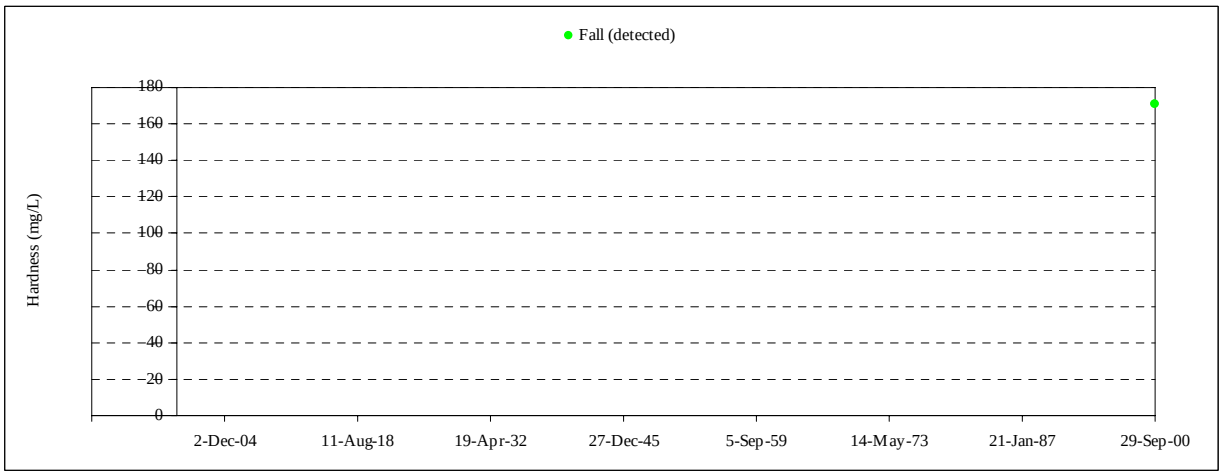
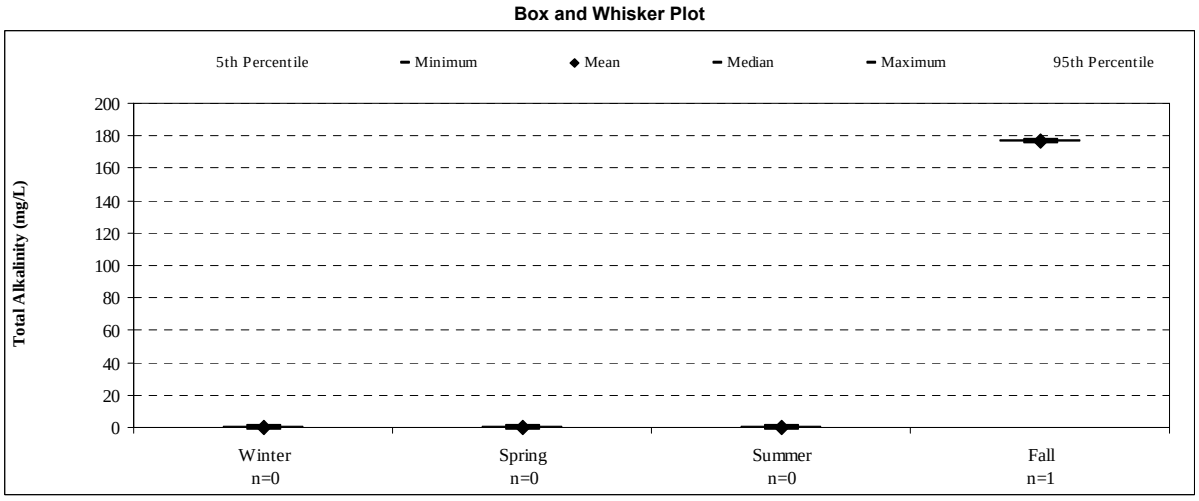


Figure G-1-9-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in McClelland Lake Fen



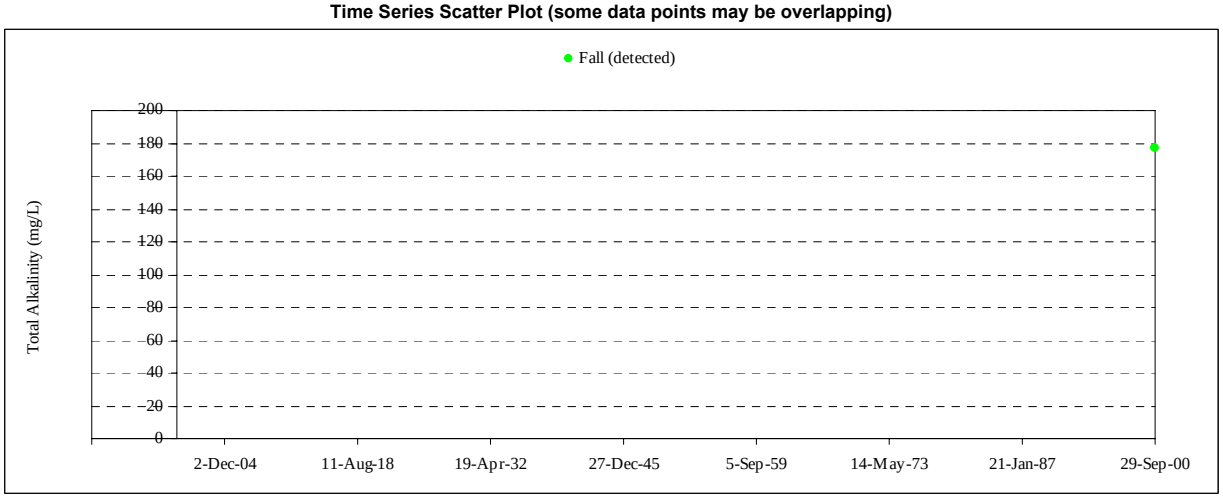
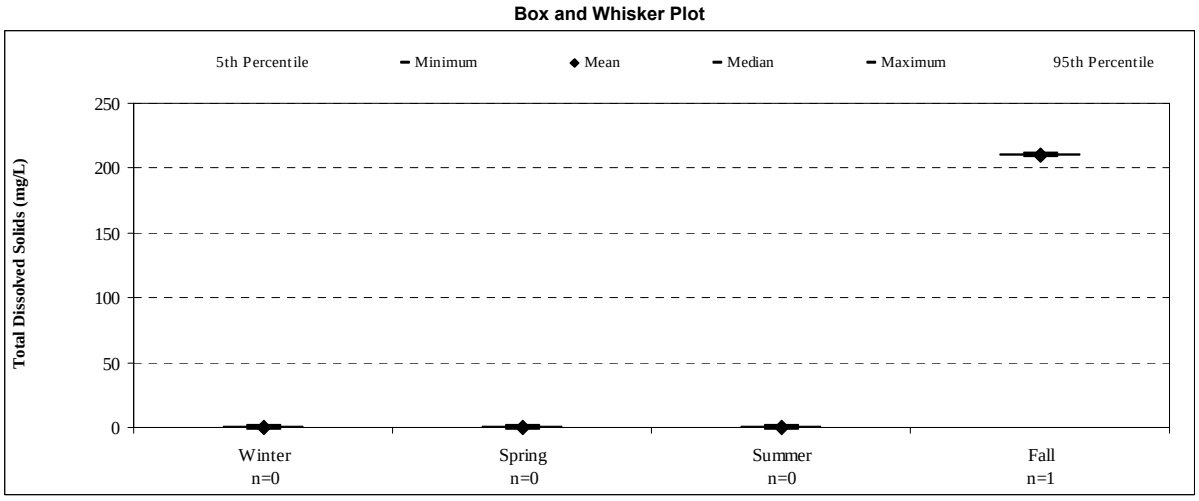


Figure G-1-9-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in McClelland Lake Fen



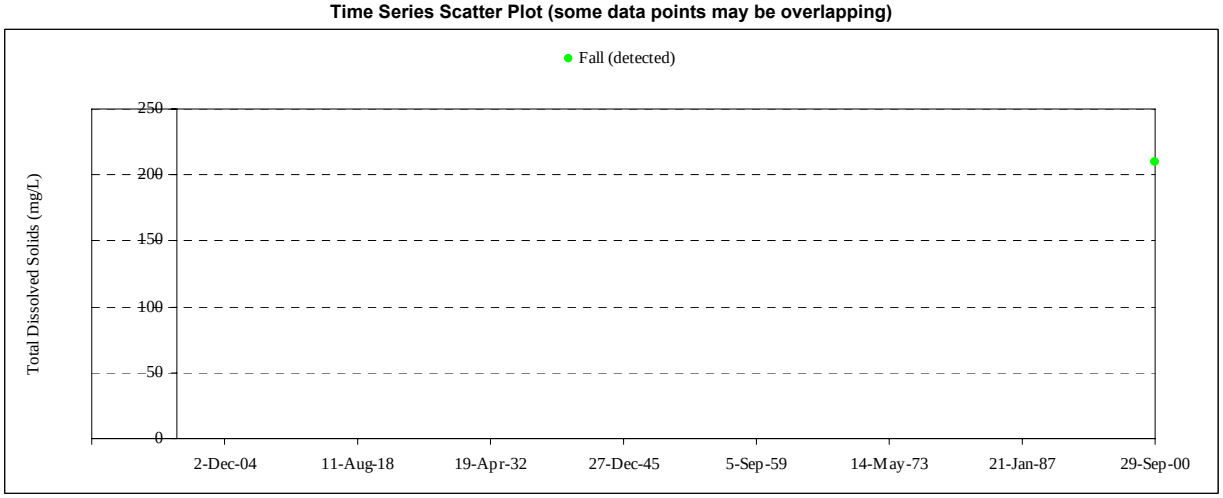
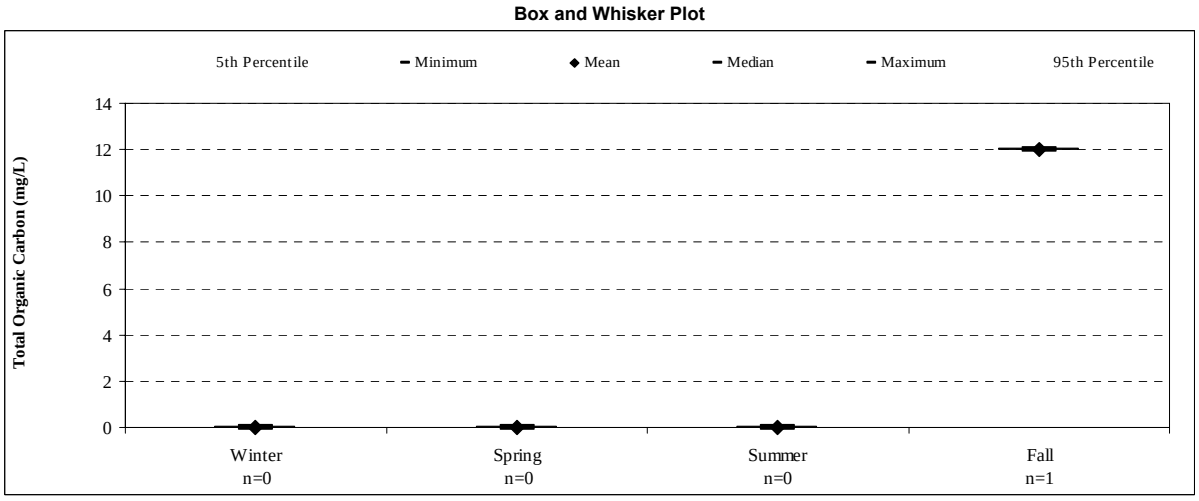


Figure G-1-9-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in McClelland Lake Fen



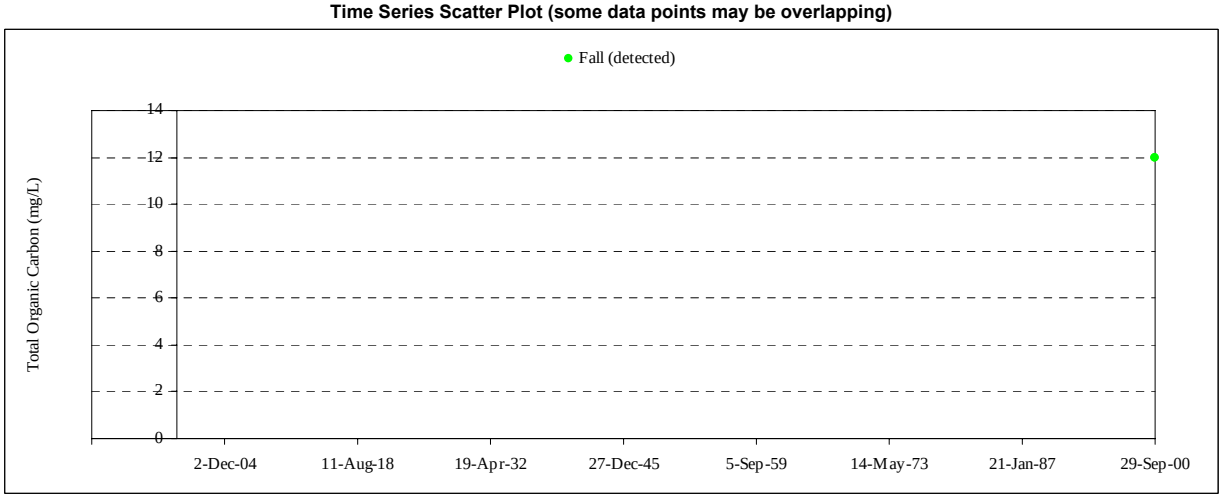
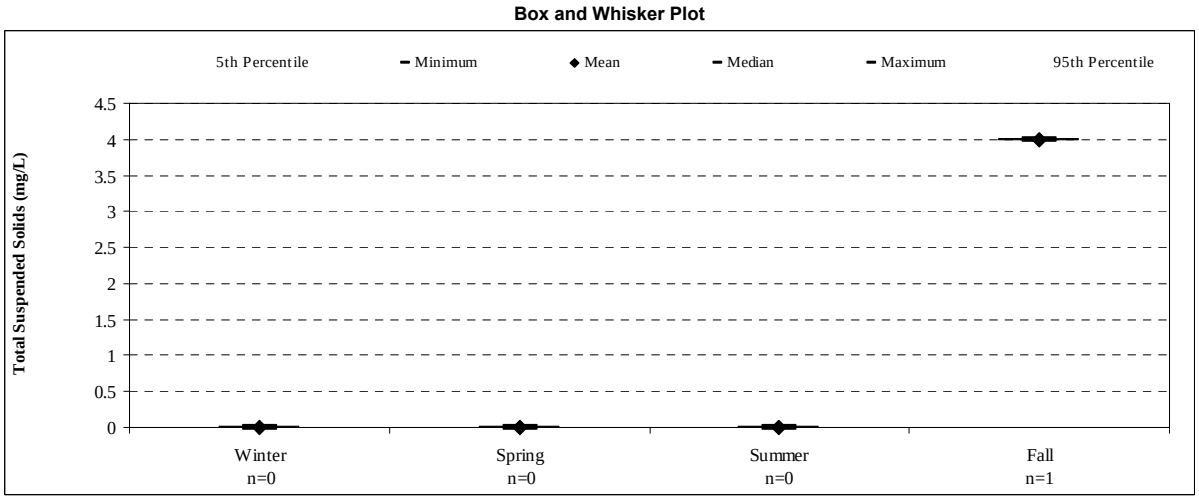


Figure G-1-9-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in McClelland Lake Fen



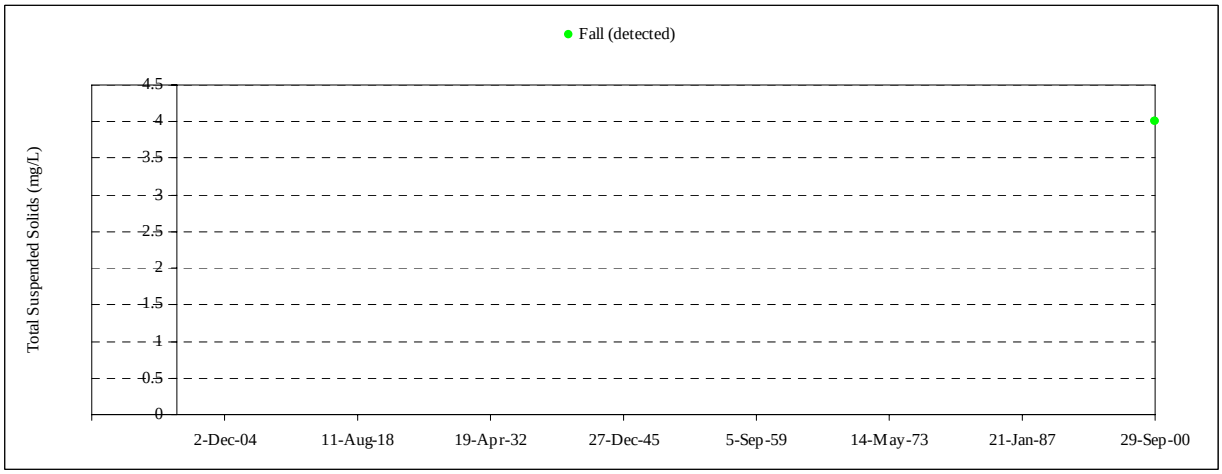
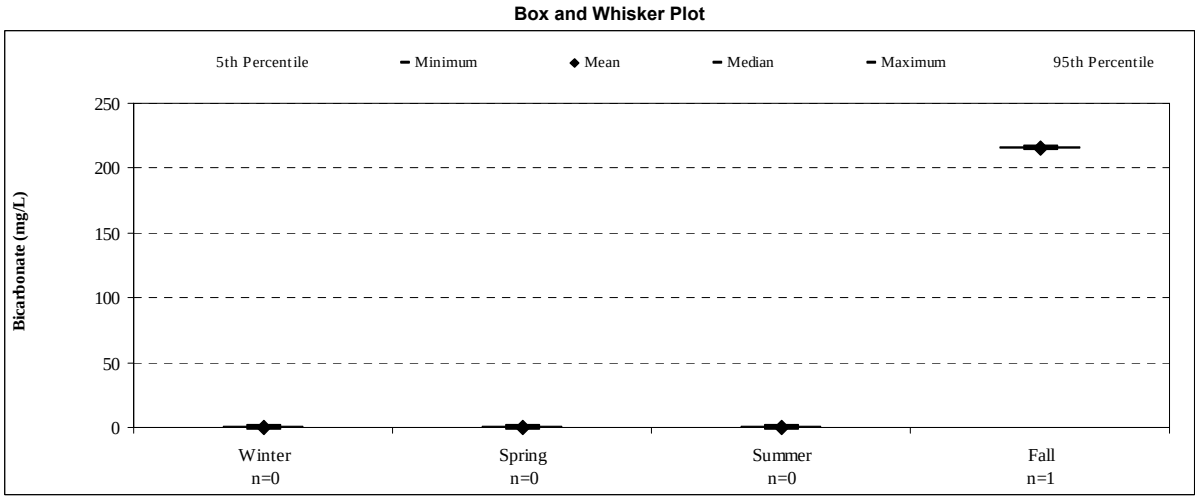


Figure G-1-9-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in McClelland Lake Fen



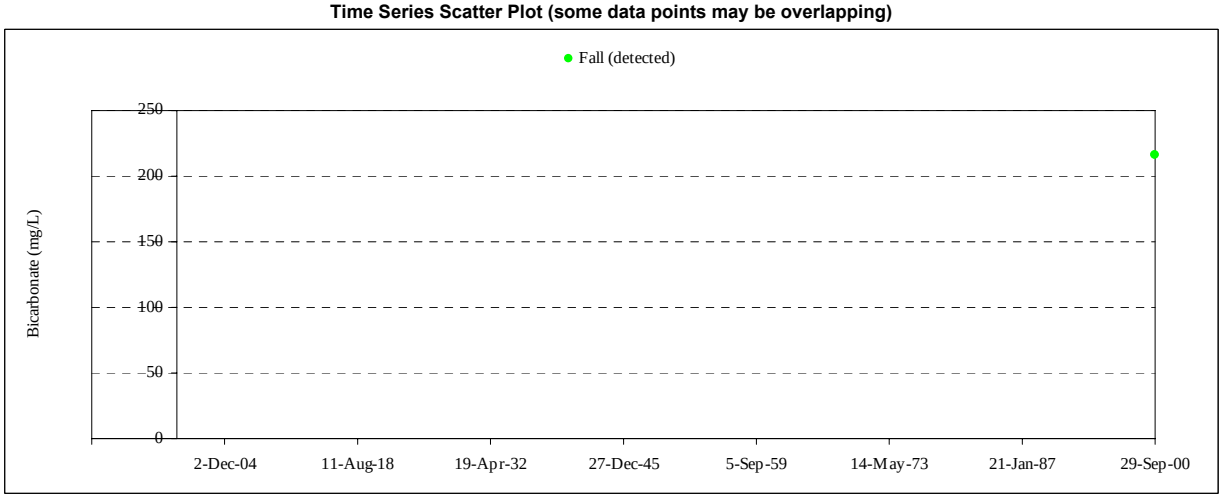
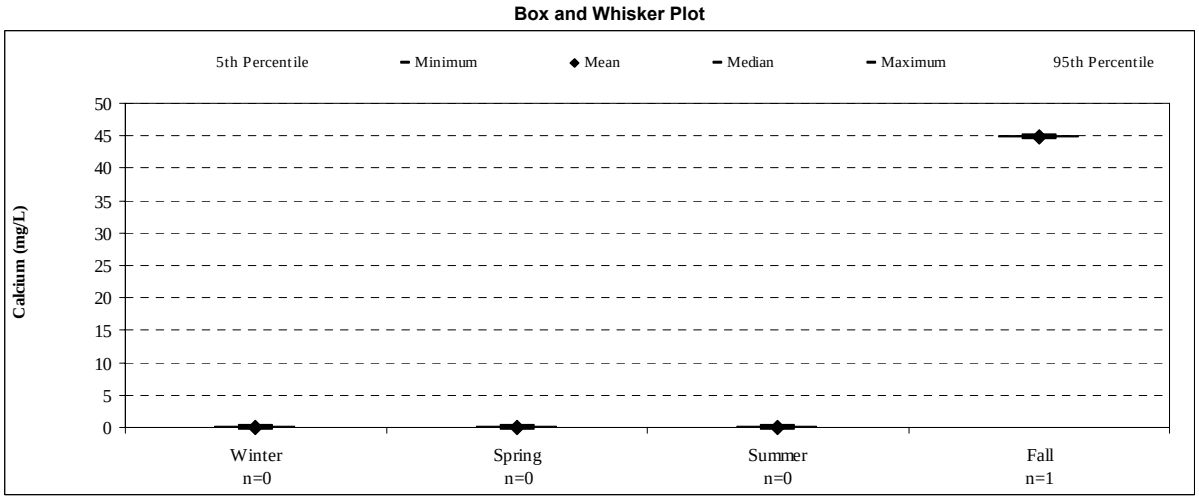


Figure G-1-9-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in McClelland Lake Fen



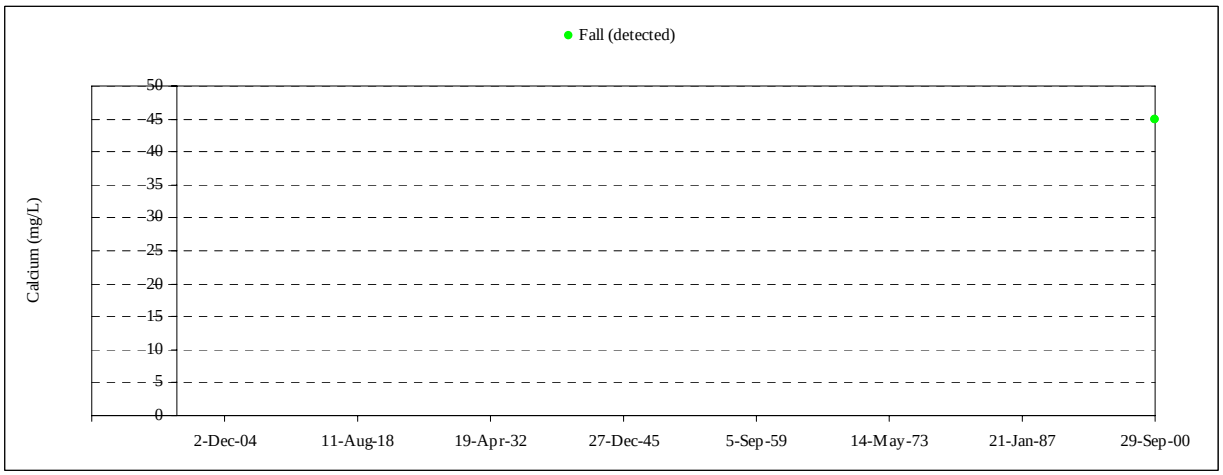
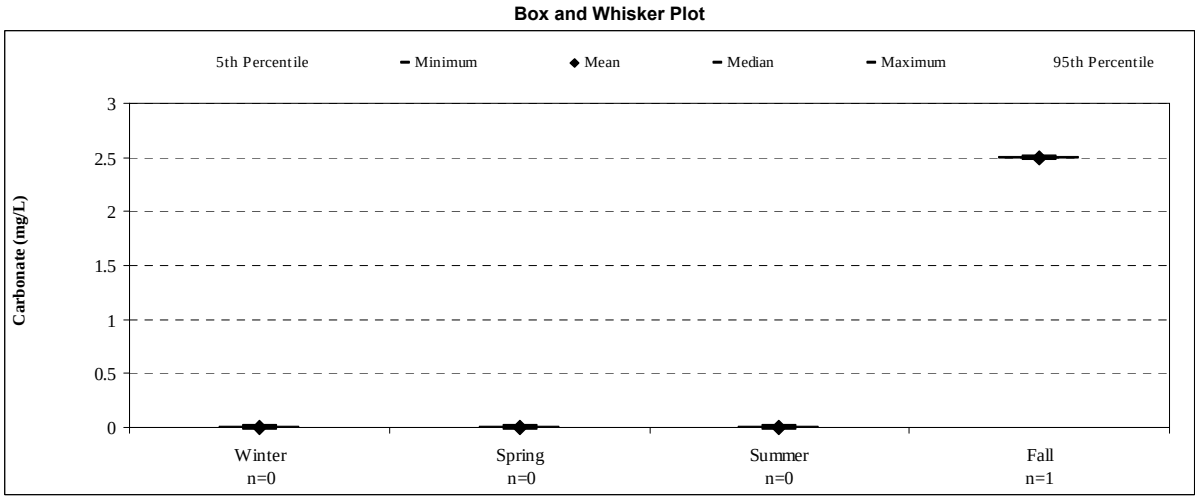


Figure G-1-9-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in McClelland Lake Fen



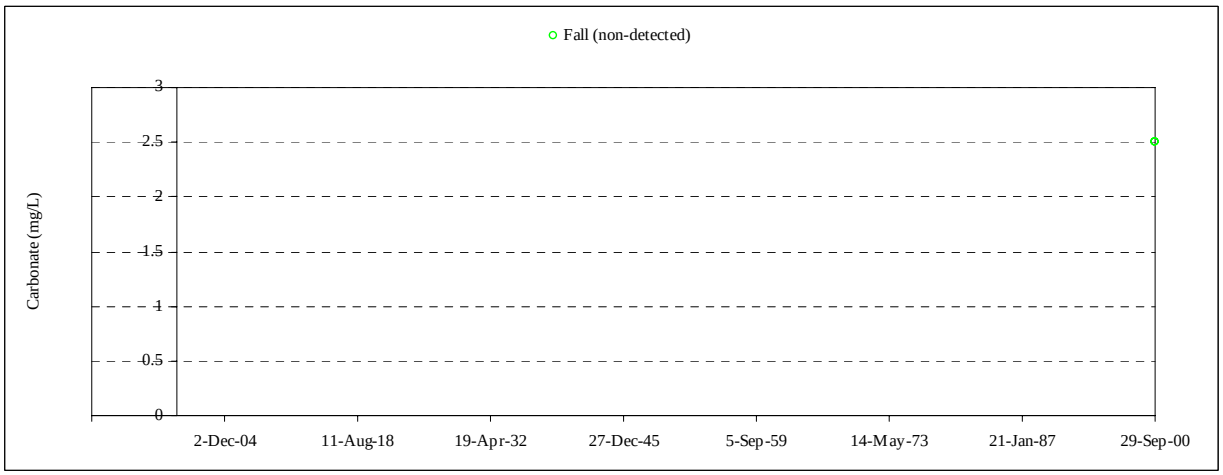
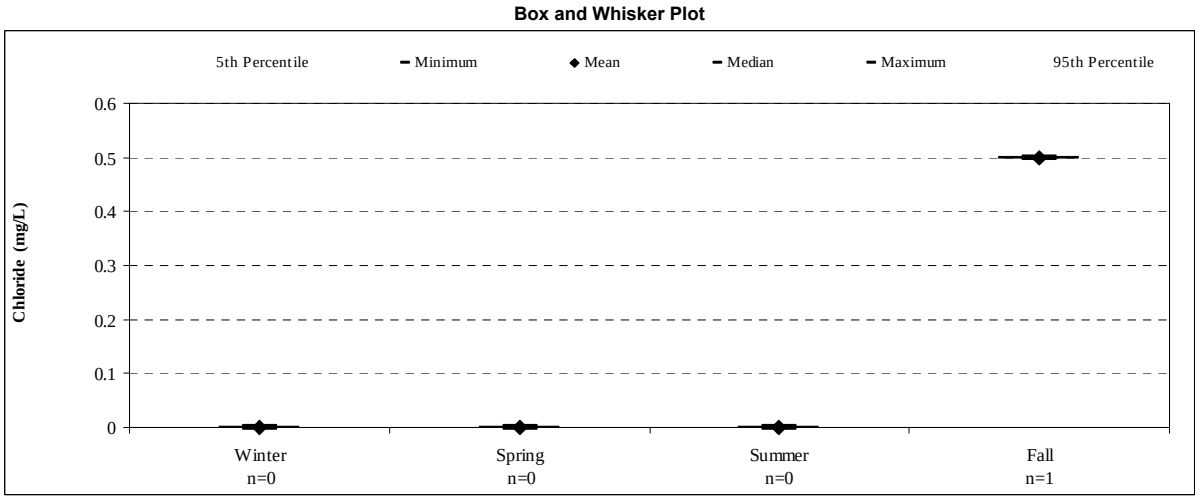


Figure G-1-9-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in McClelland Lake Fen



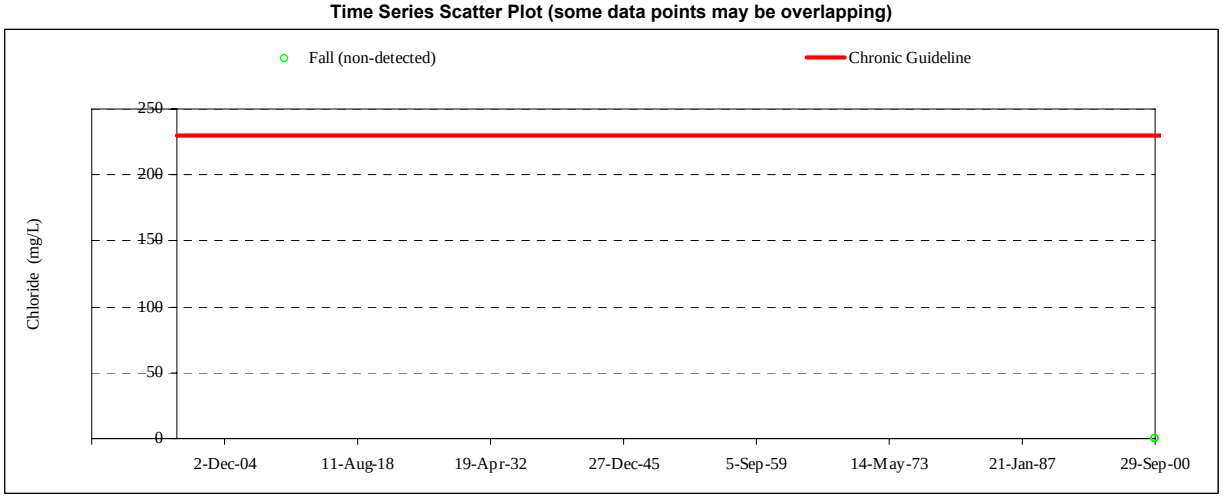
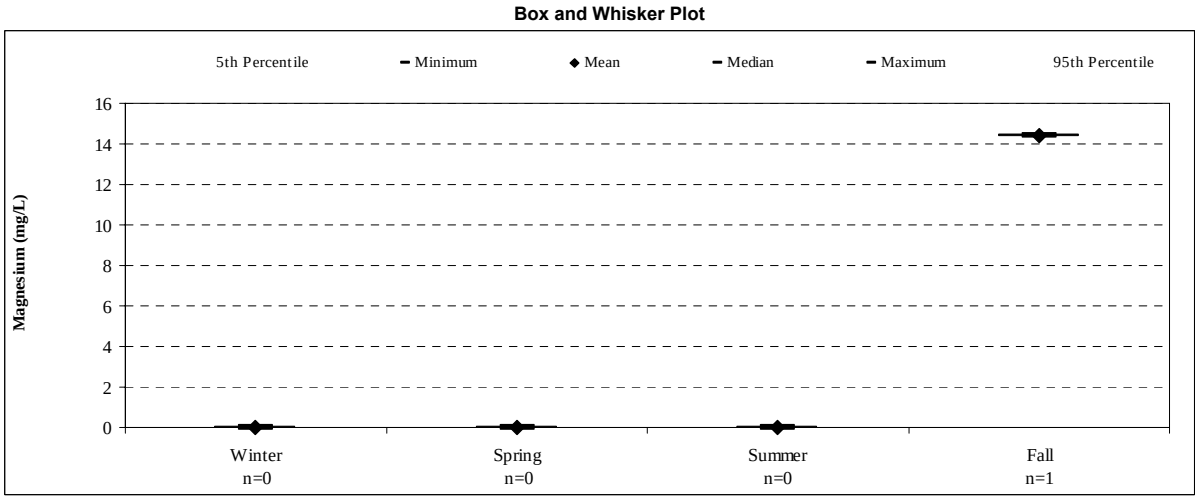


Figure G-1-9-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in McClelland Lake Fen



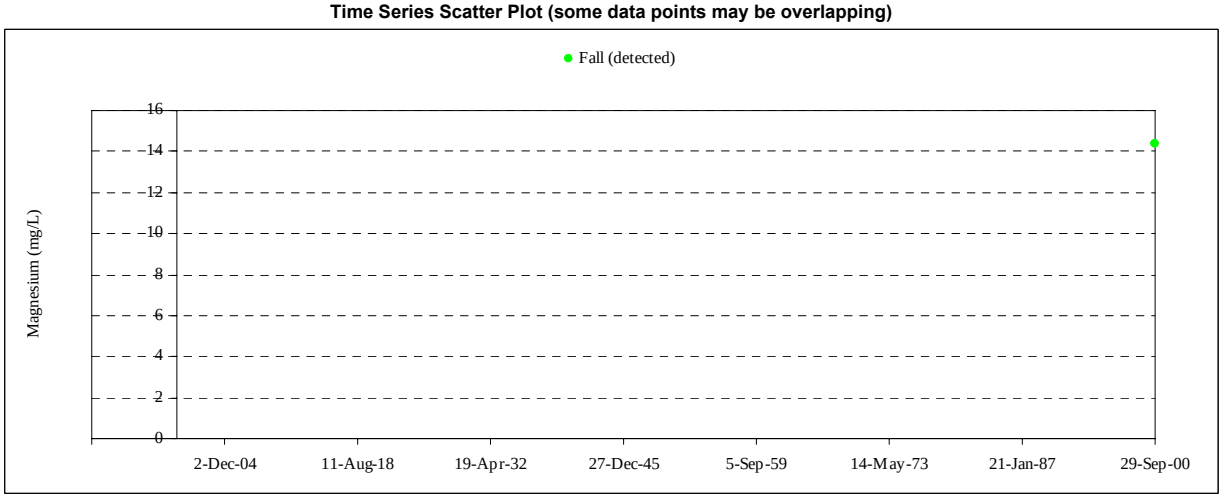
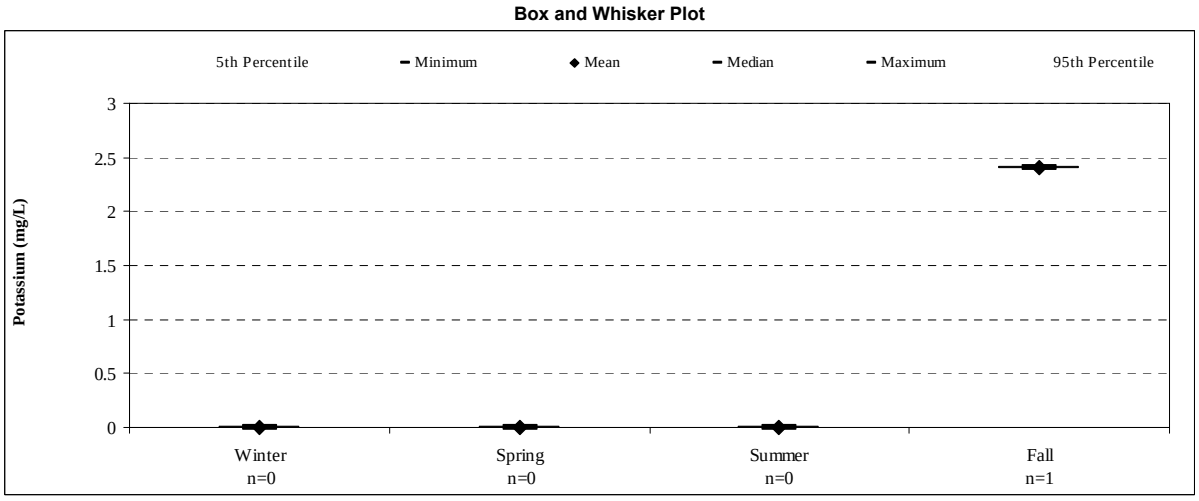


Figure G-1-9-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in McClelland Lake Fen



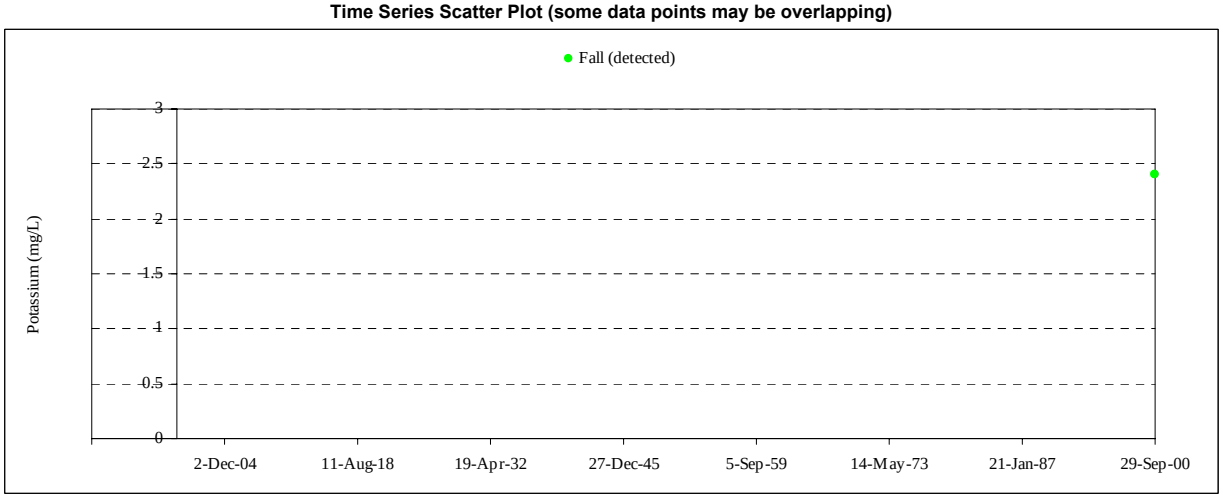
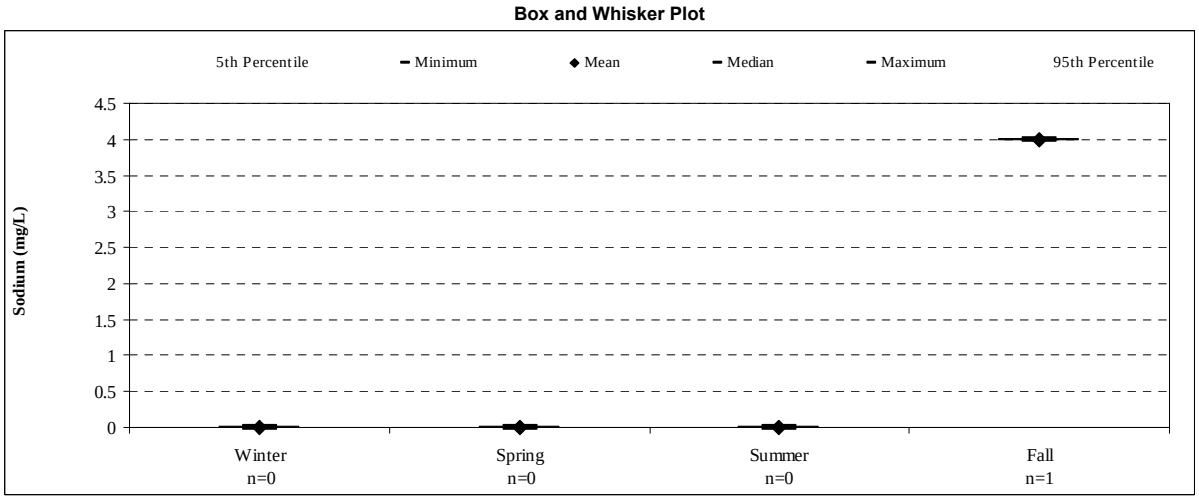


Figure G-1-9-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in McClelland Lake Fen



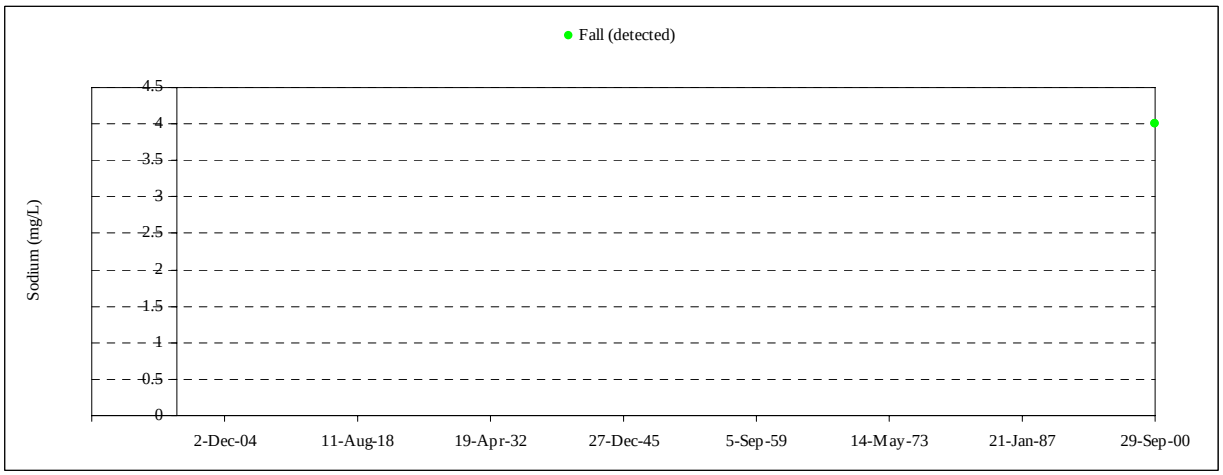
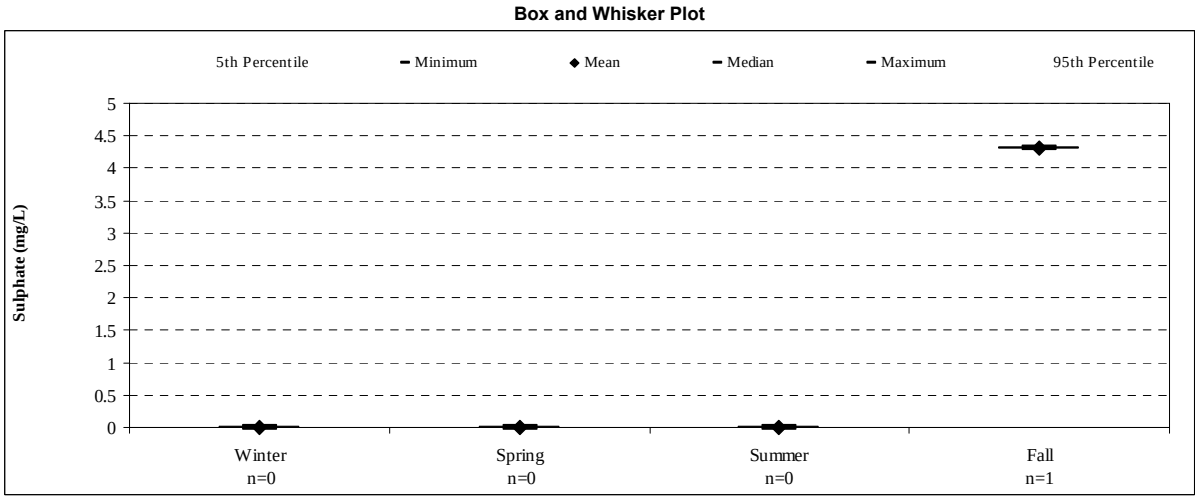


Figure G-1-9-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in McClelland Lake Fen



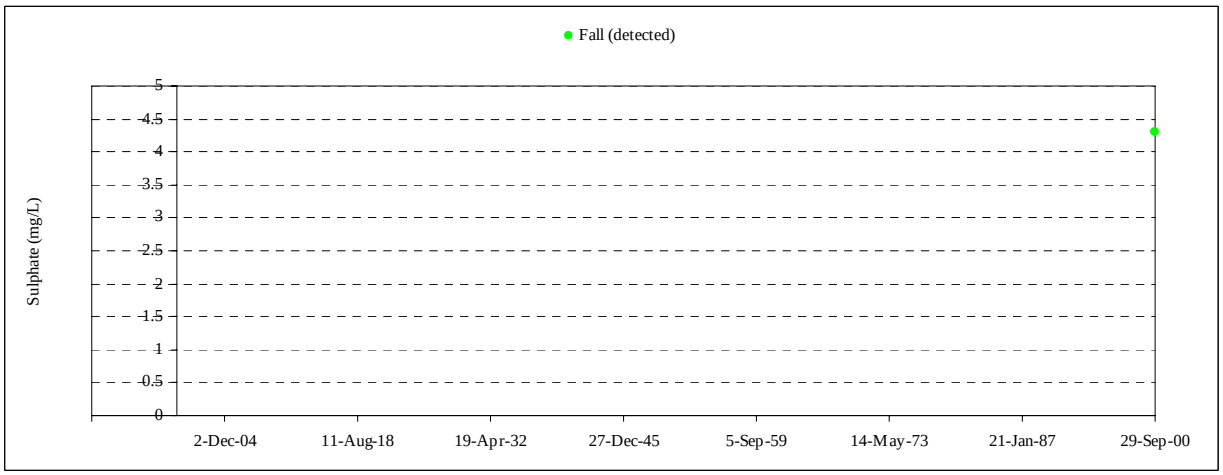
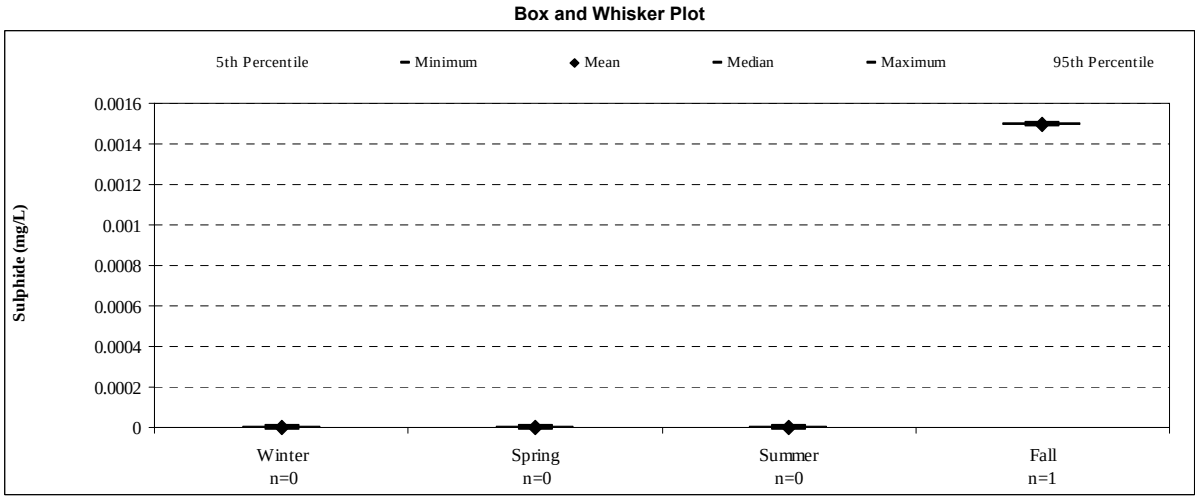


Figure G-1-9-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in McClelland Lake Fen



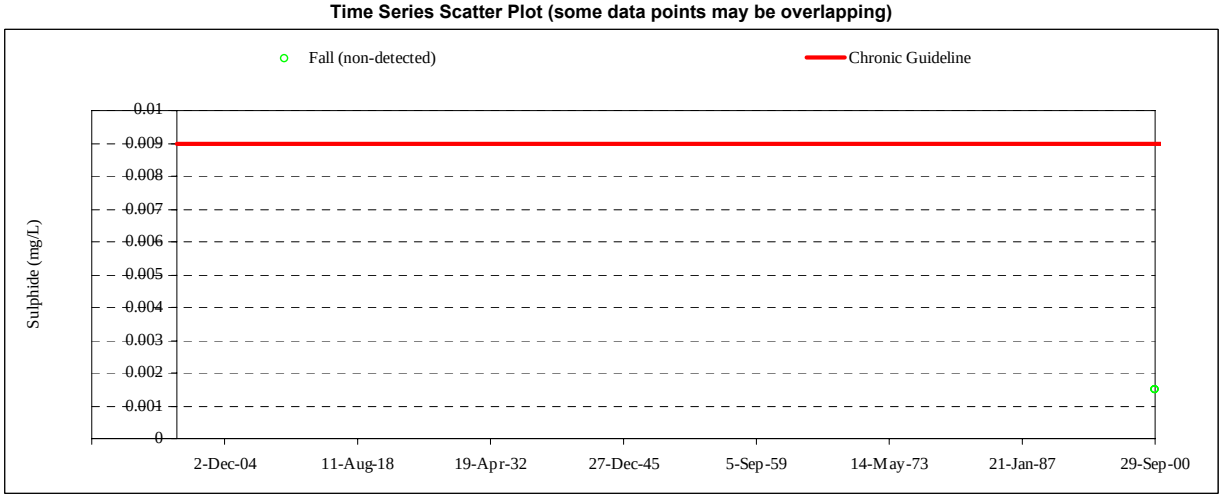
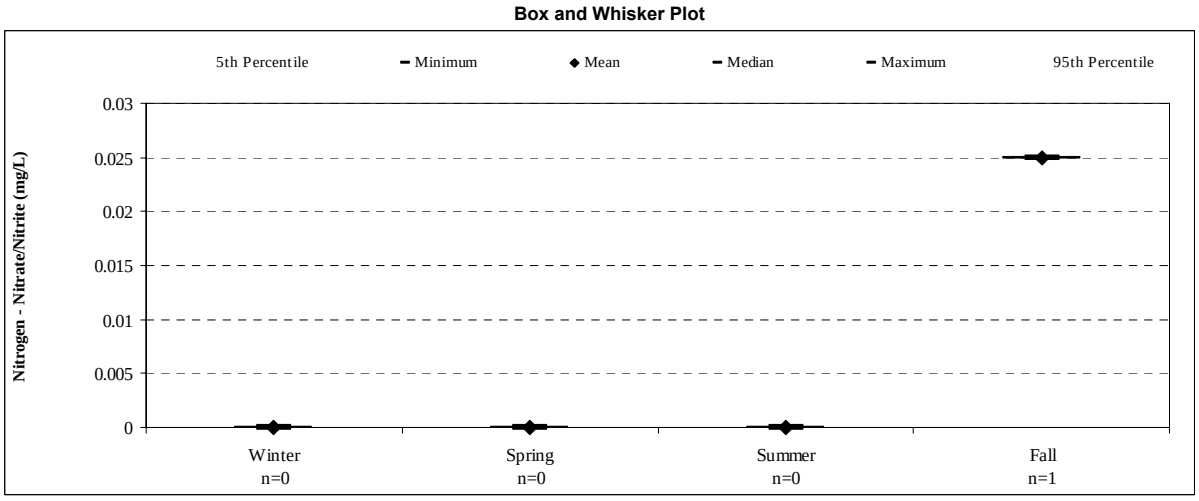


Figure G-1-9-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in McClelland Lake Fen



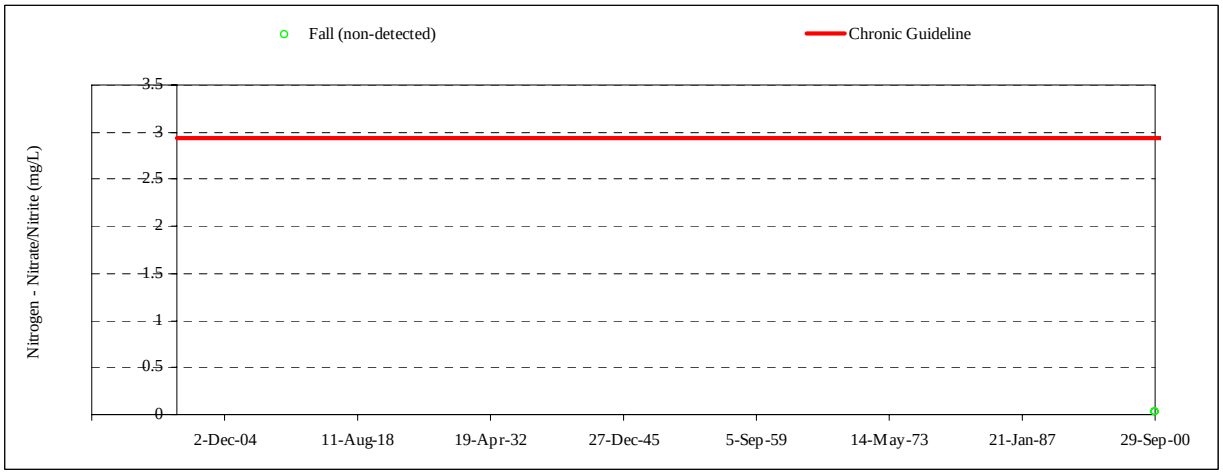
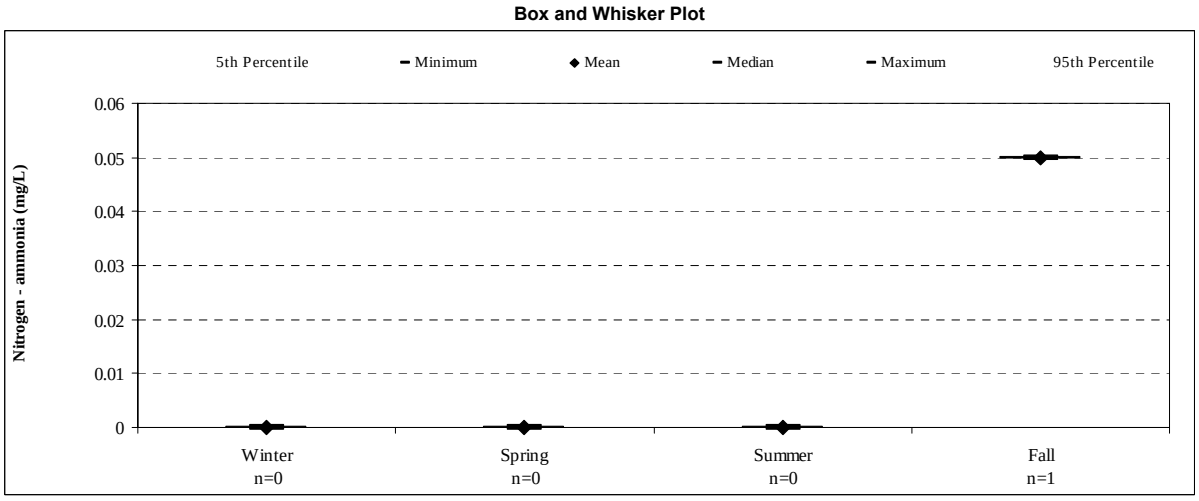


Figure G-1-9-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in McClelland Lake Fen



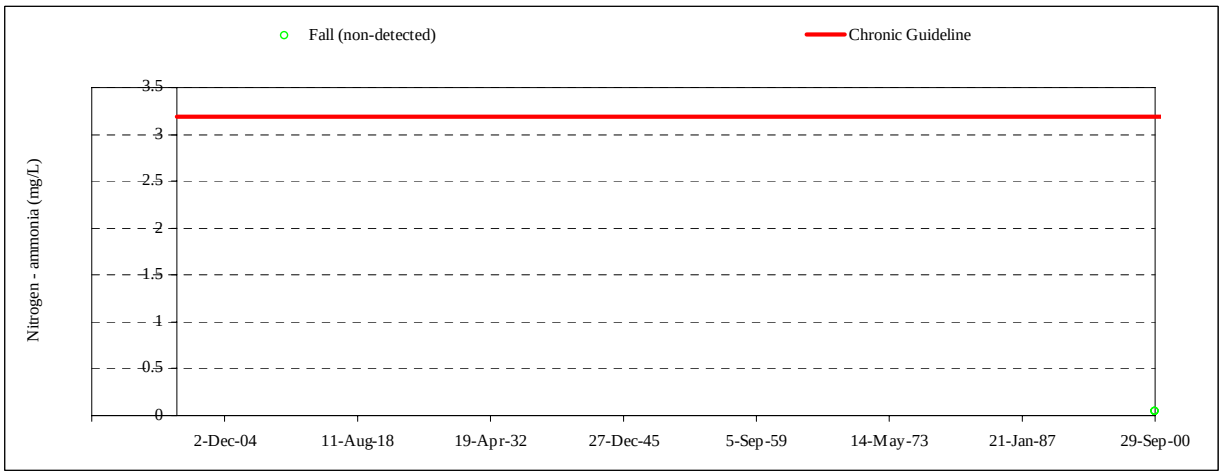
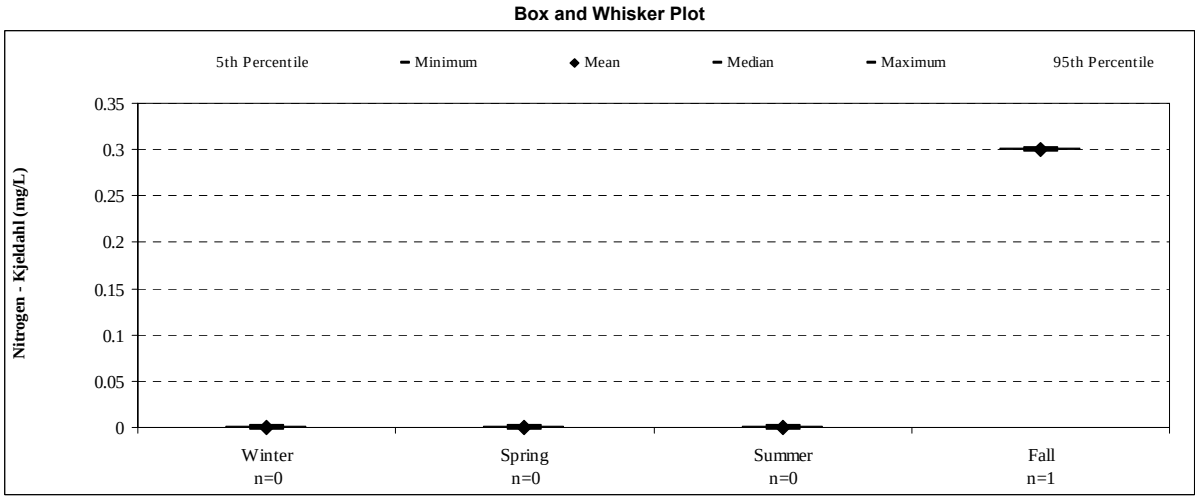


Figure G-1-9-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in McClelland Lake Fen



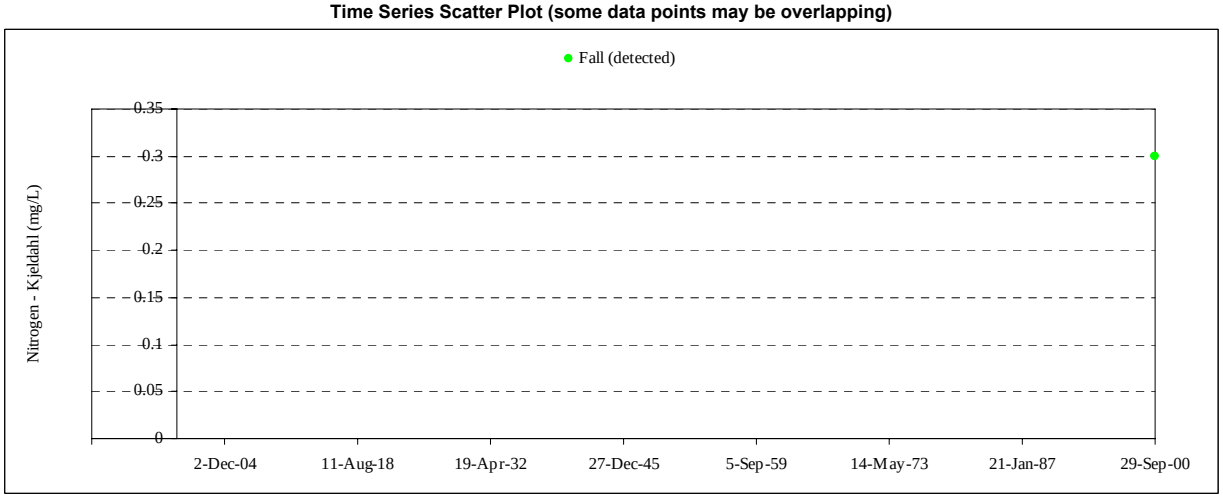
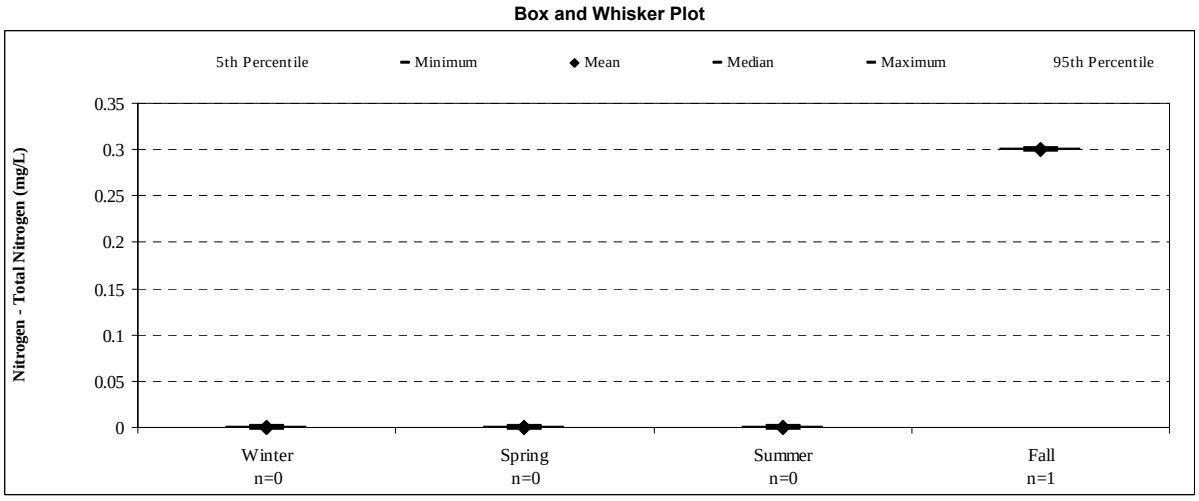


Figure G-1-9-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in McClelland Lake Fen



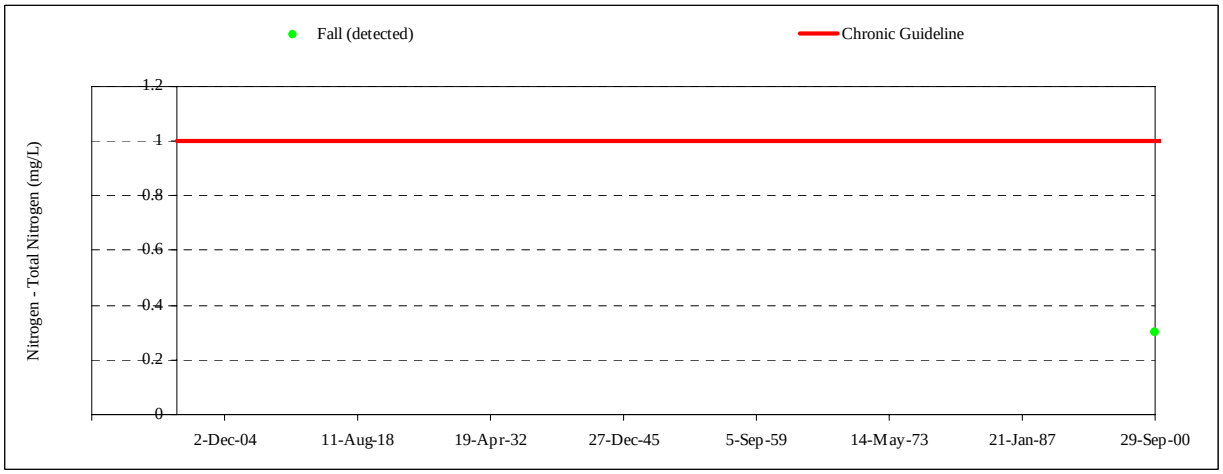
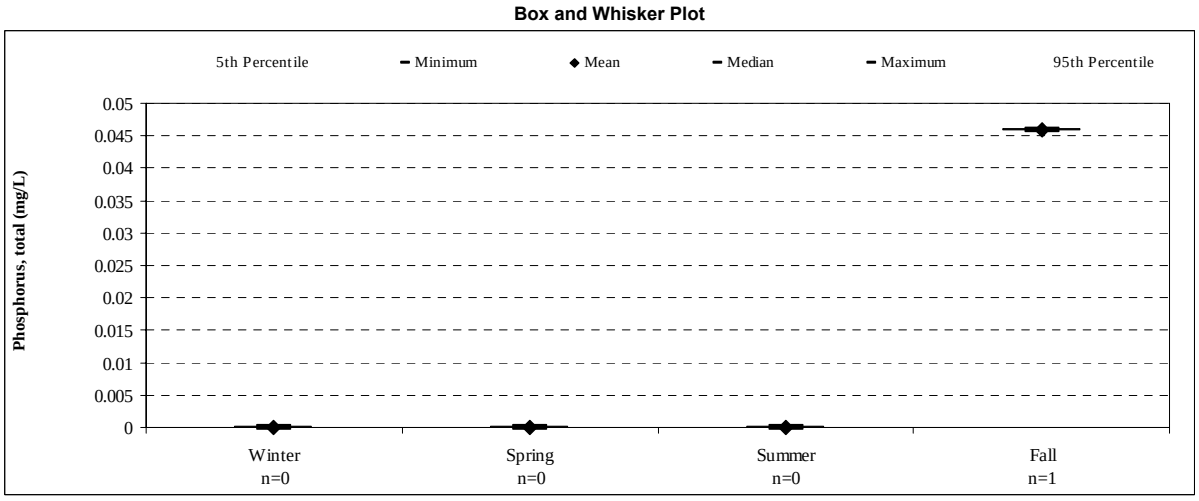


Figure G-1-9-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in McClelland Lake Fen



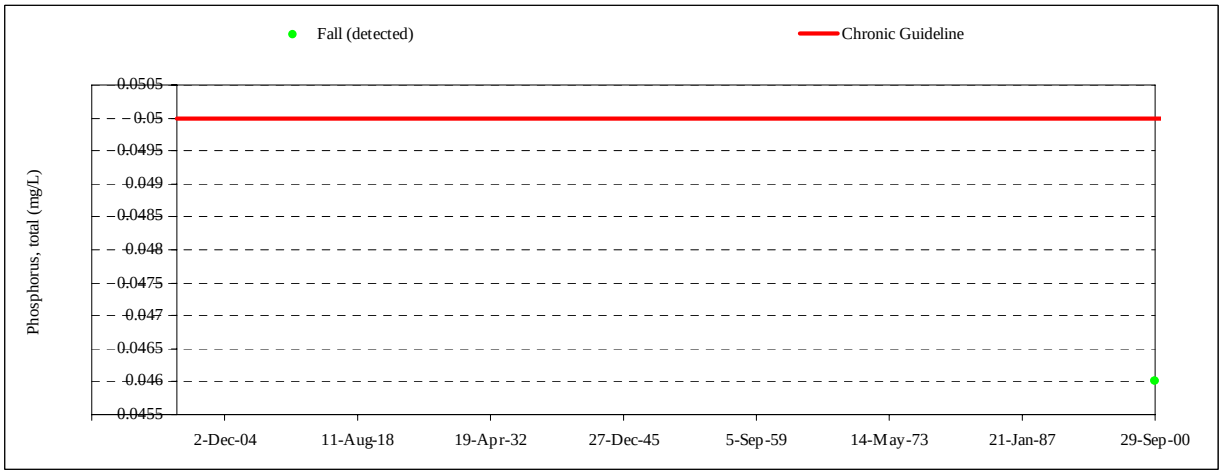
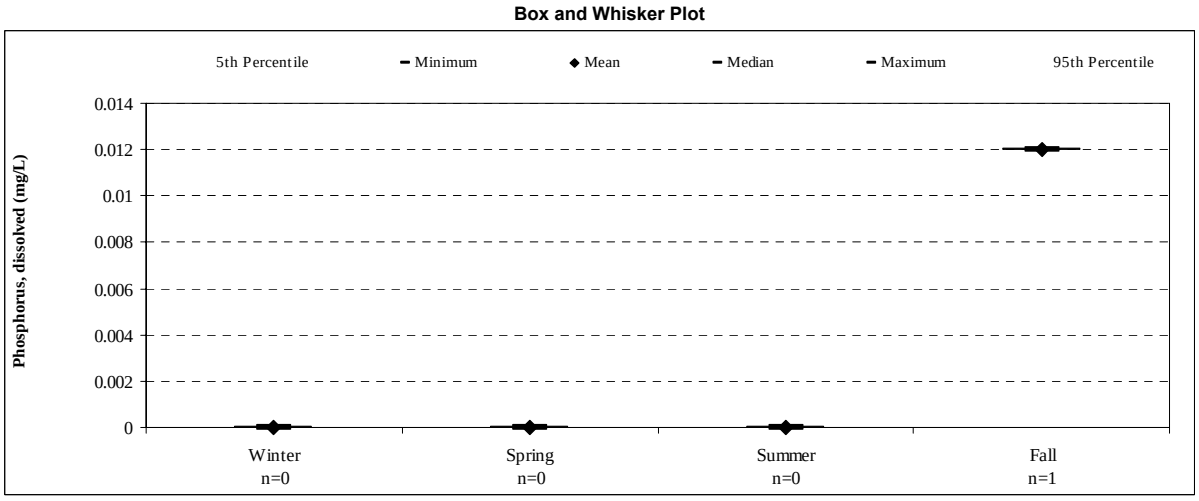


Figure G-1-9-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in McClelland Lake Fen



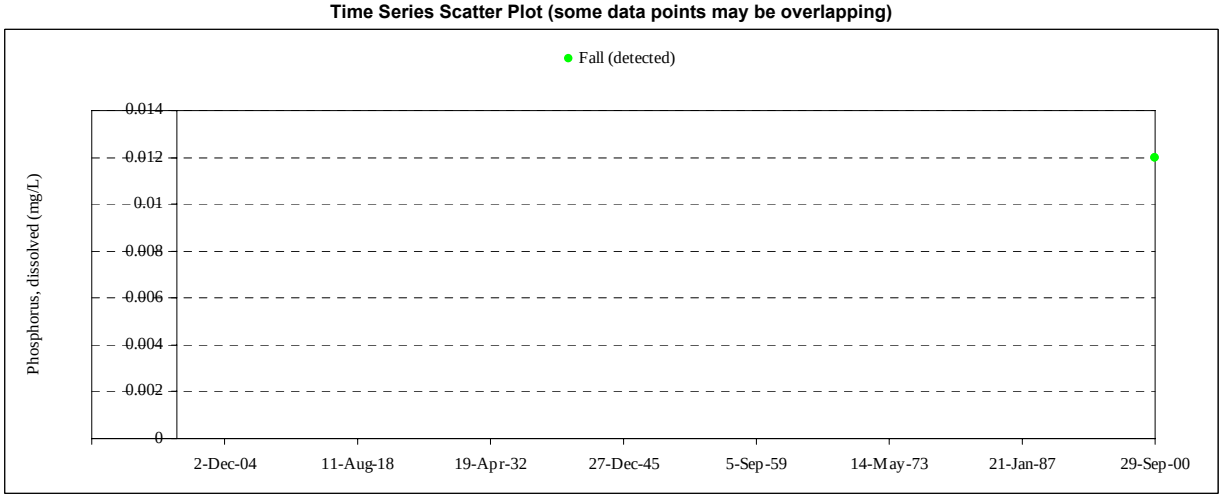
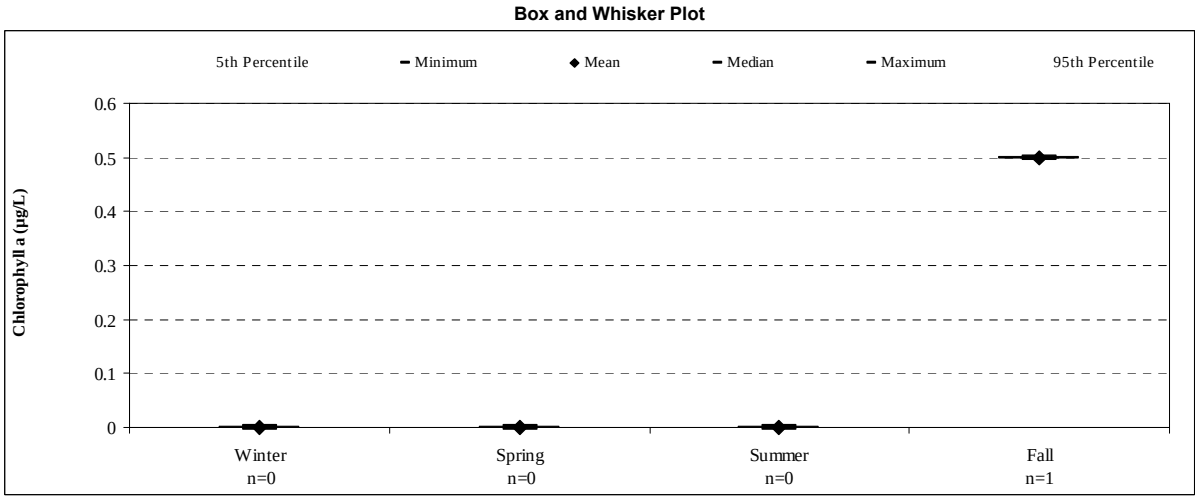


Figure G-1-9-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in McClelland Lake Fen



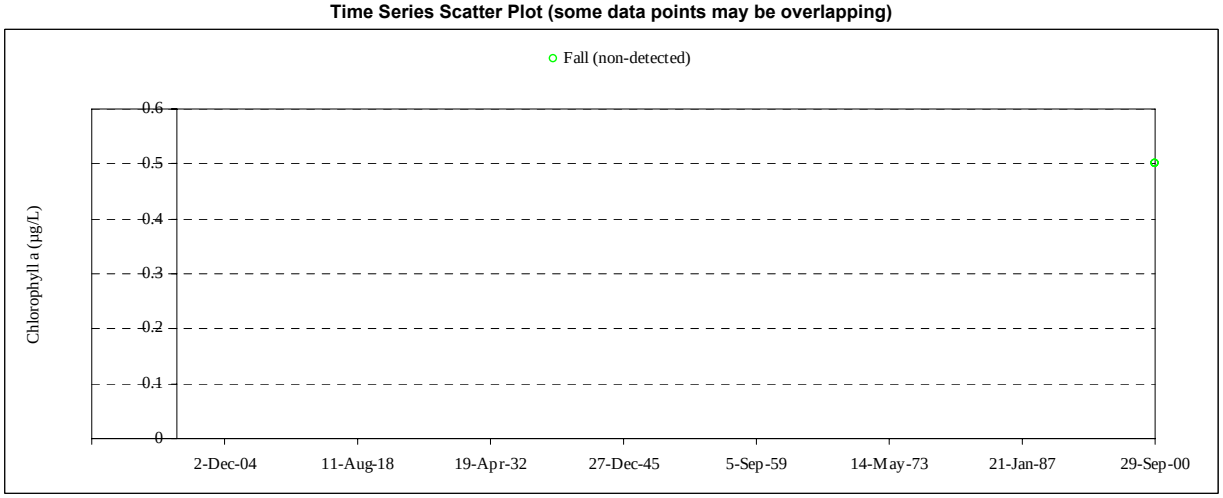


Figure G-1-9-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in McClelland Lake Fen

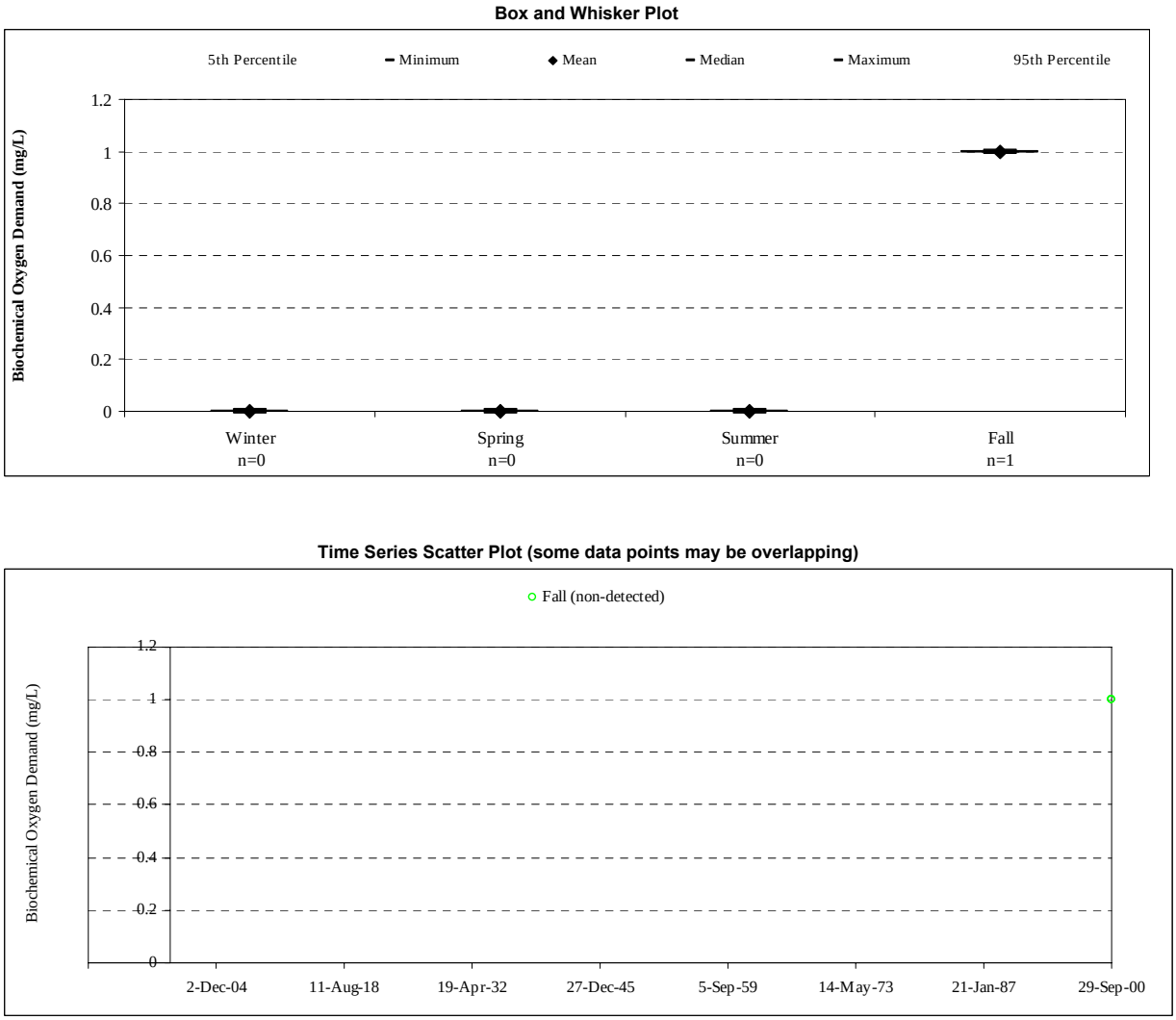
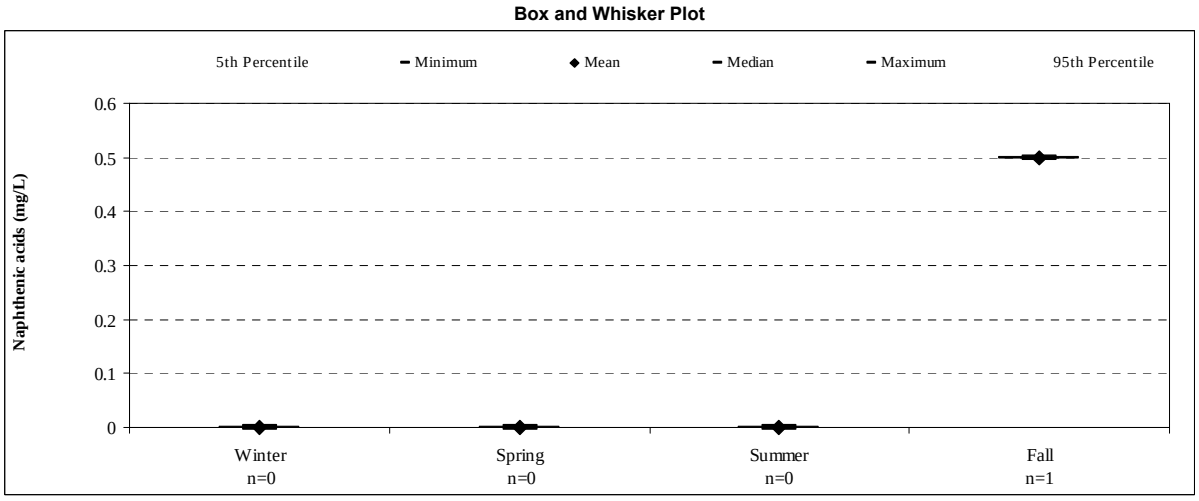


Figure G-1-9-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in McClelland Lake Fen



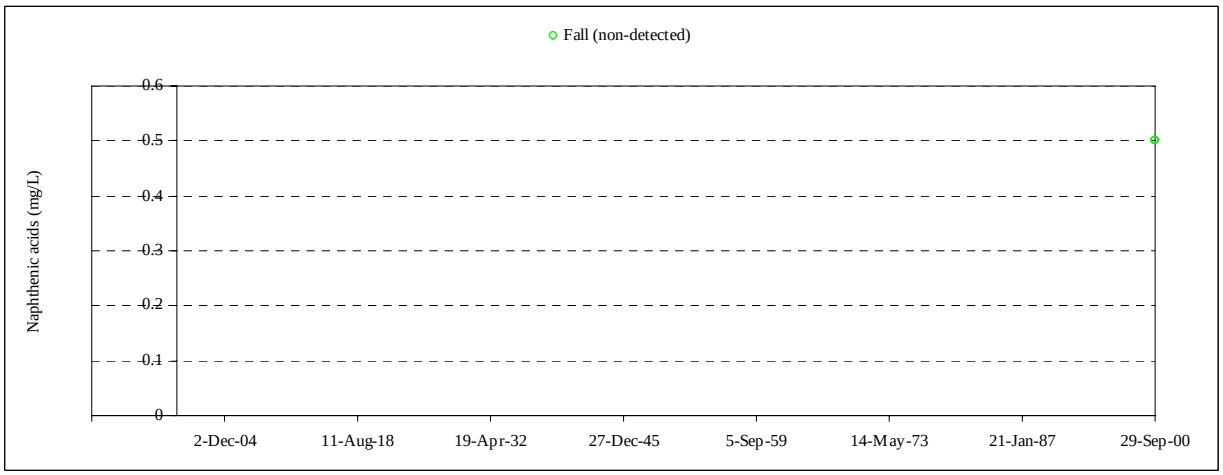
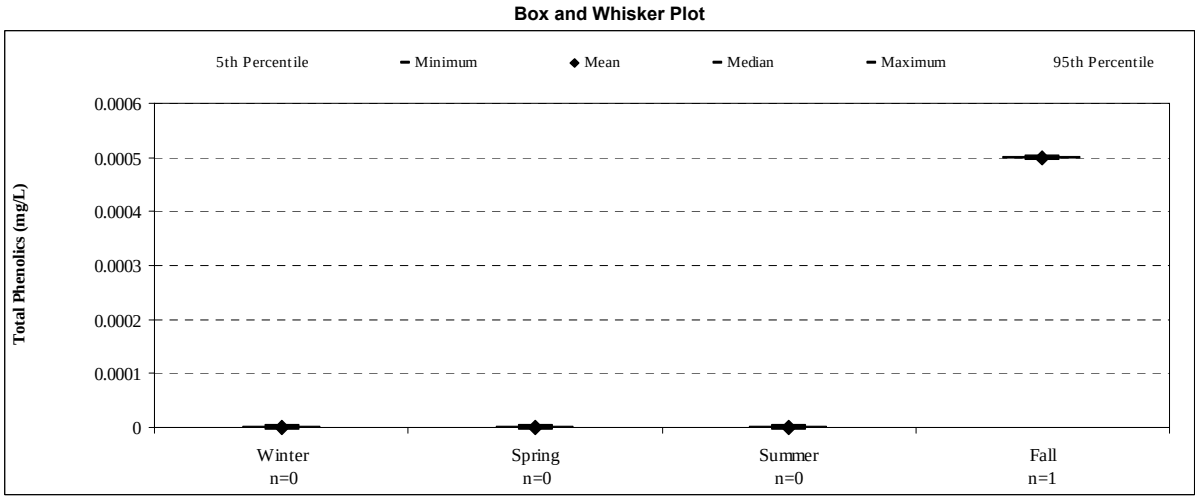


Figure G-1-9-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in McClelland Lake Fen



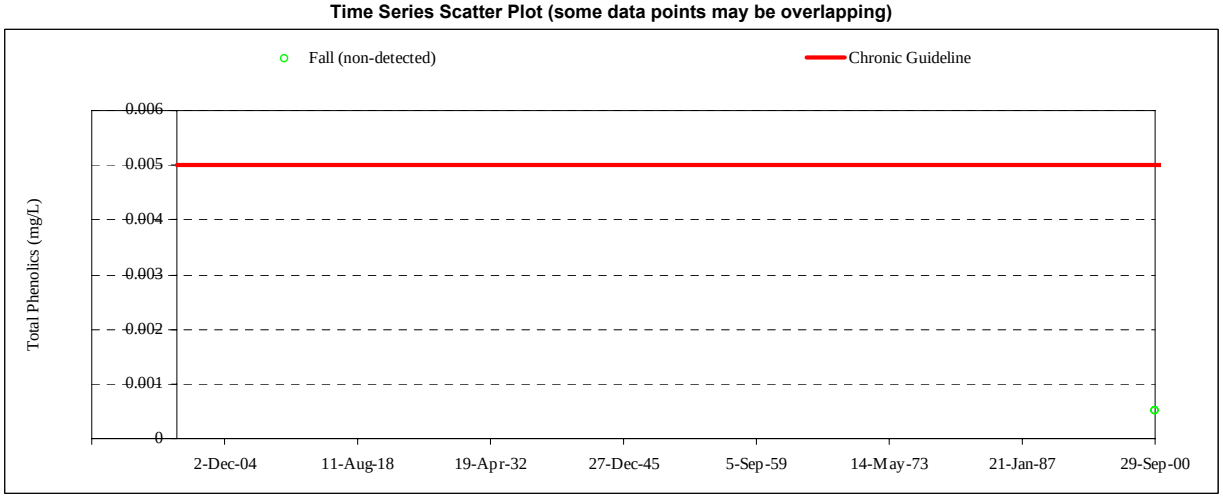
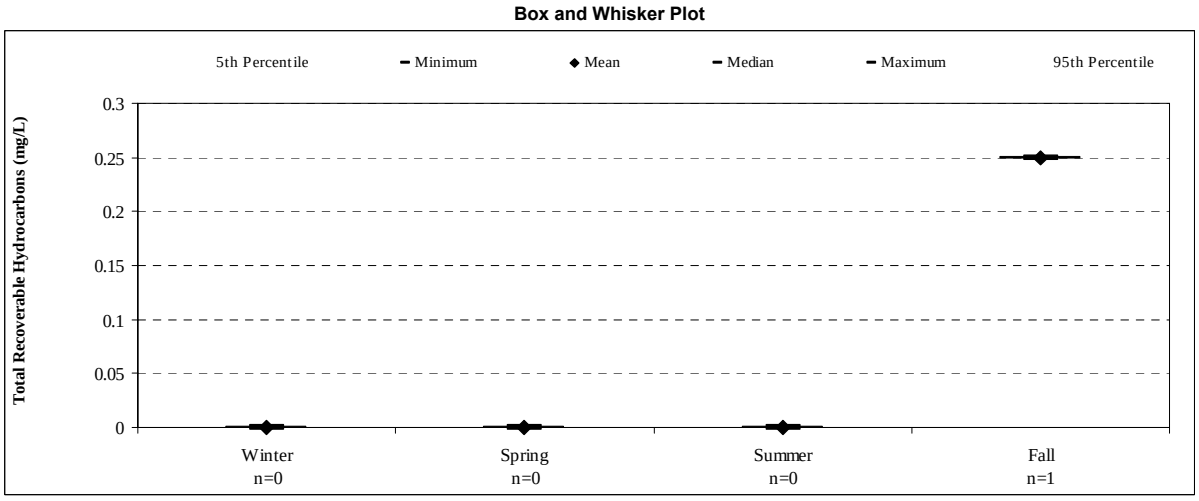


Figure G-1-9-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in McClelland Lake Fen



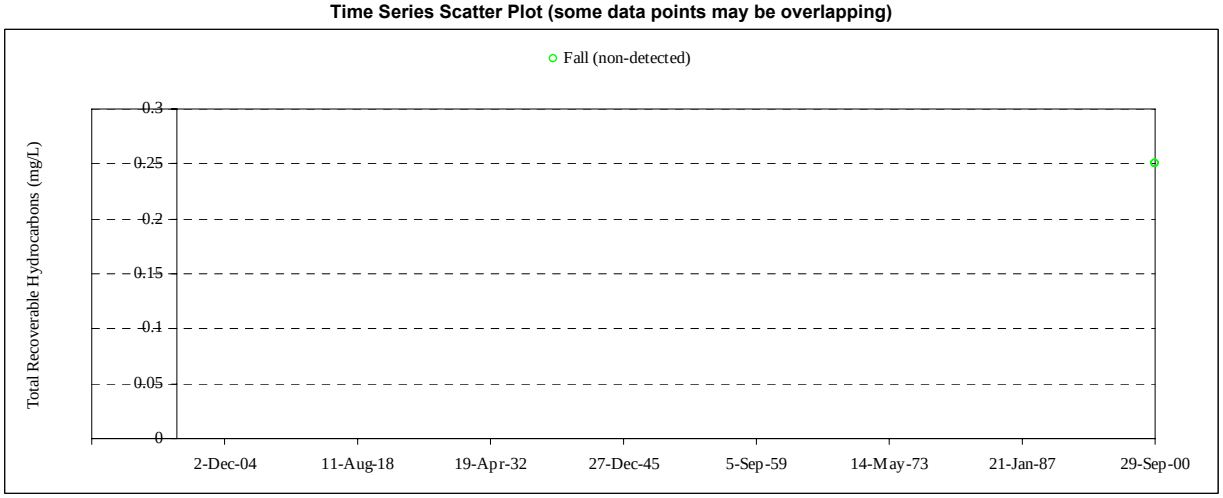
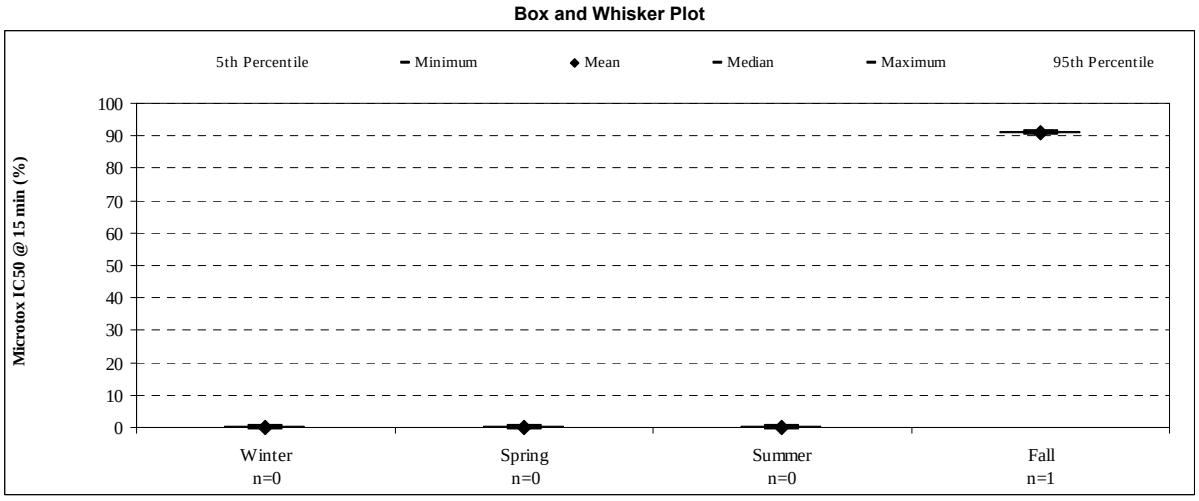


Figure G-1-9-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in McClelland Lake Fen



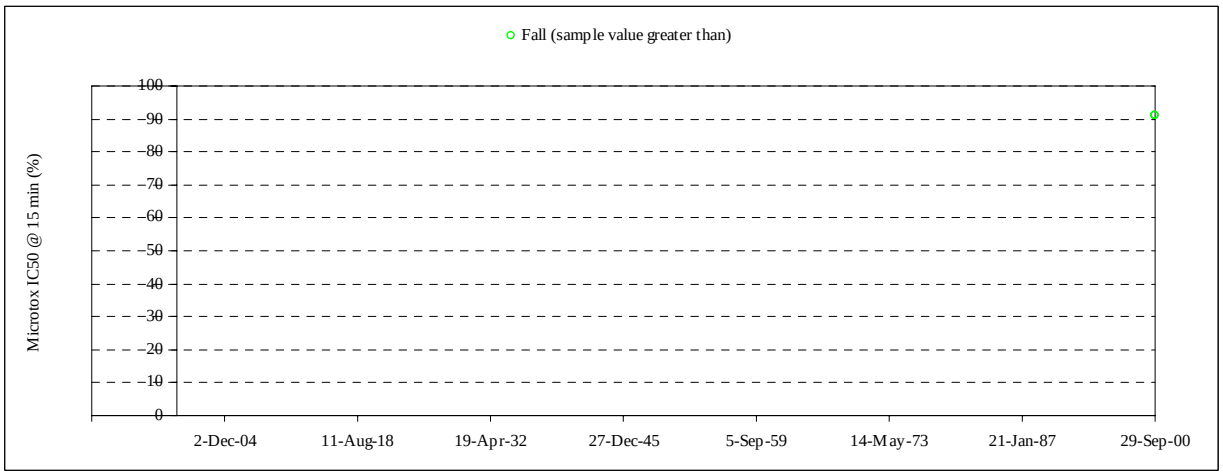
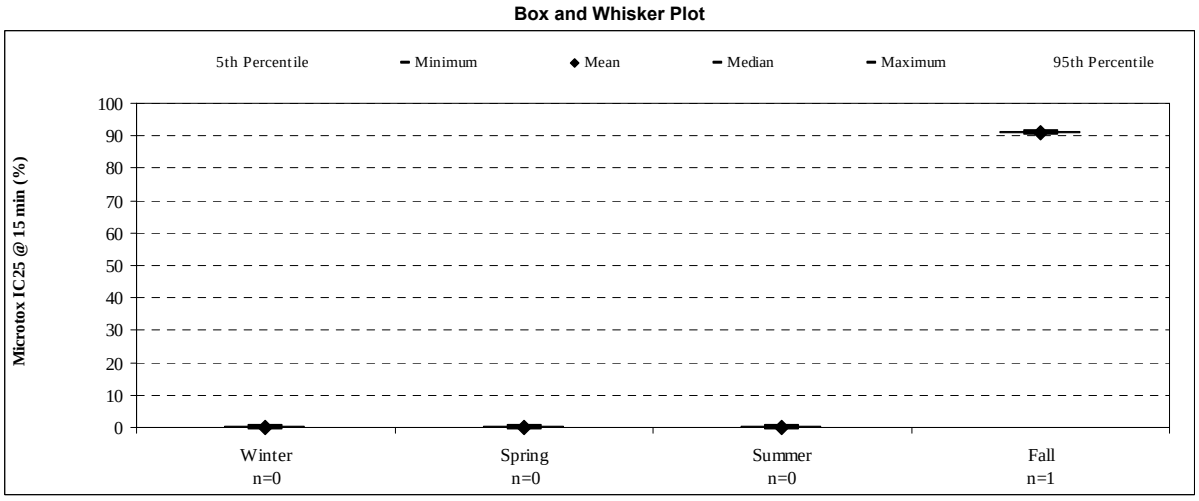


Figure G-1-9-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in McClelland Lake Fen



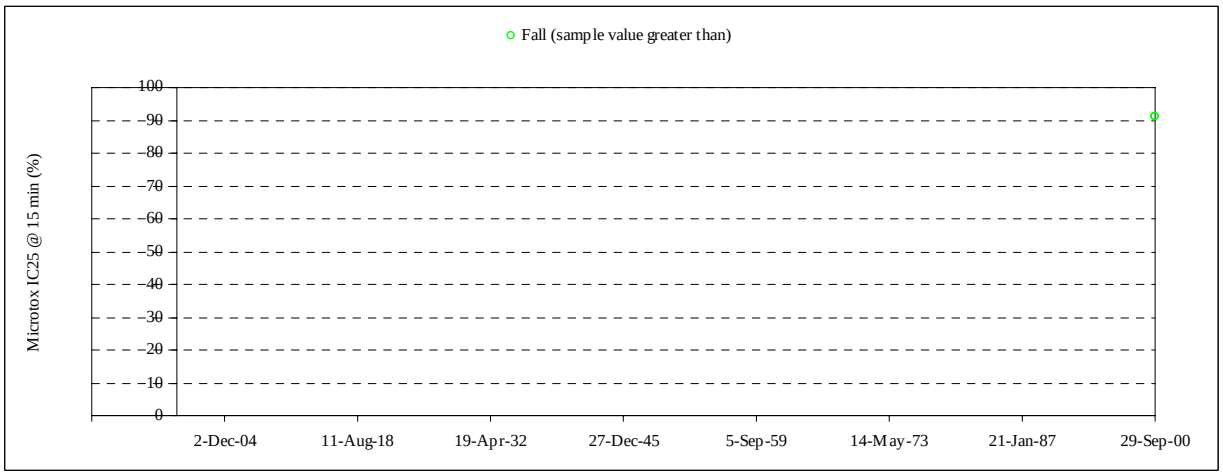
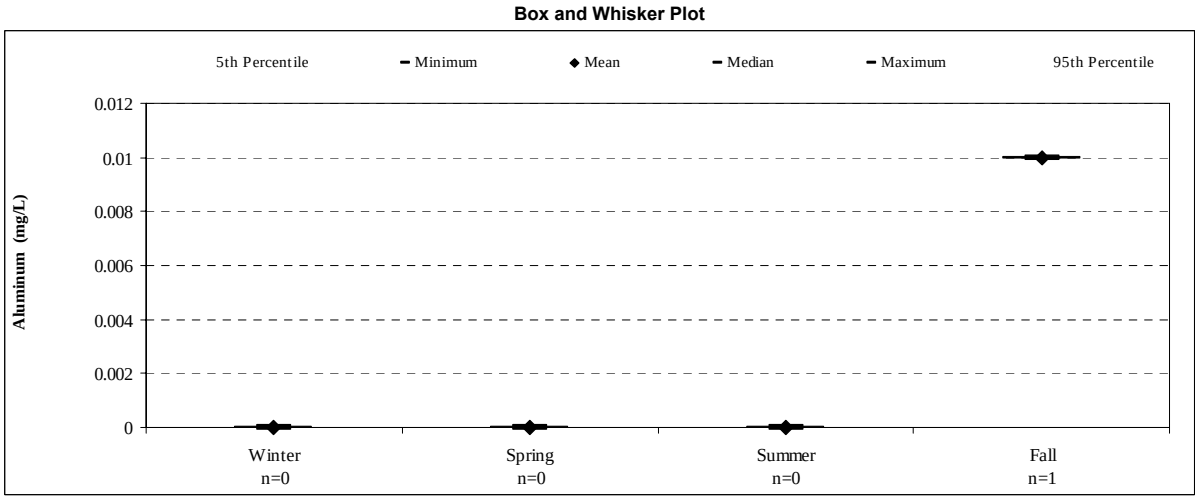


Figure G-1-9-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in McClelland Lake Fen



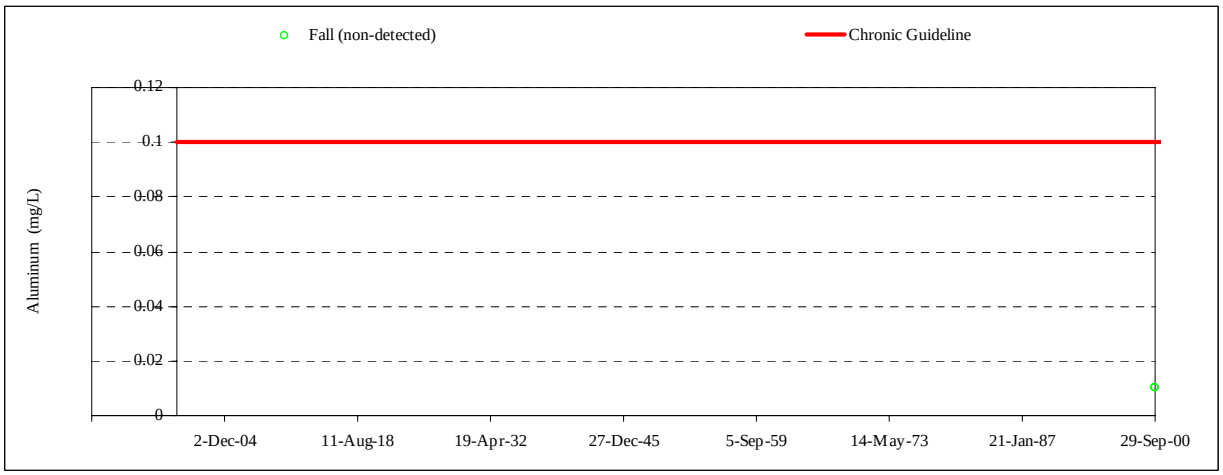


Figure G-1-9-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in McClelland Lake Fen

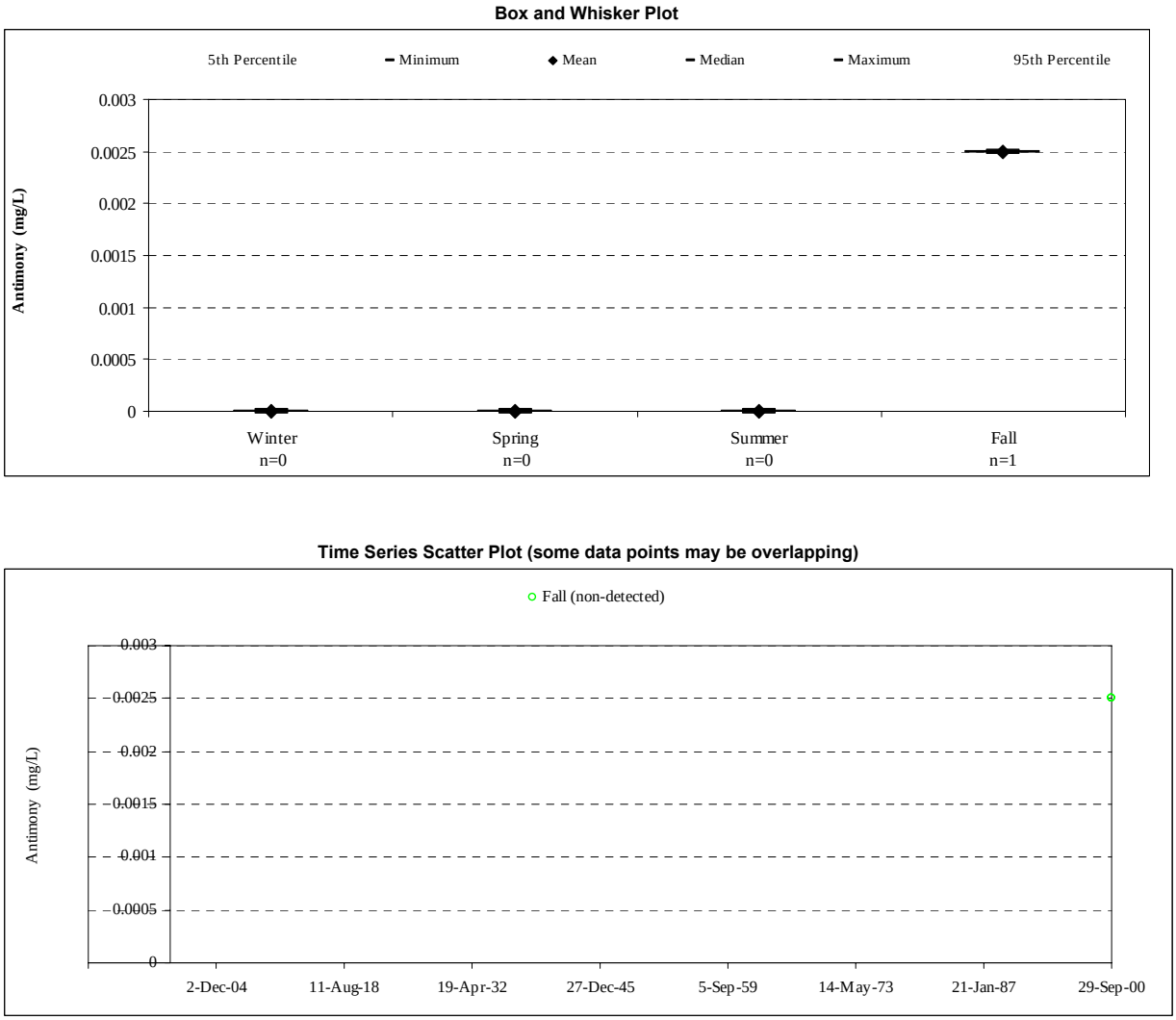
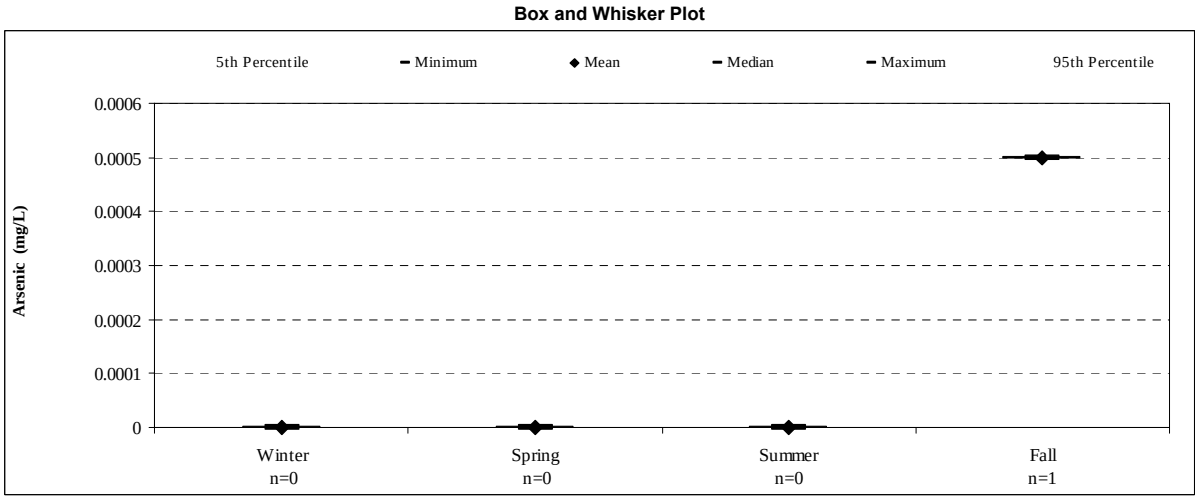


Figure G-1-9-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in McClelland Lake Fen



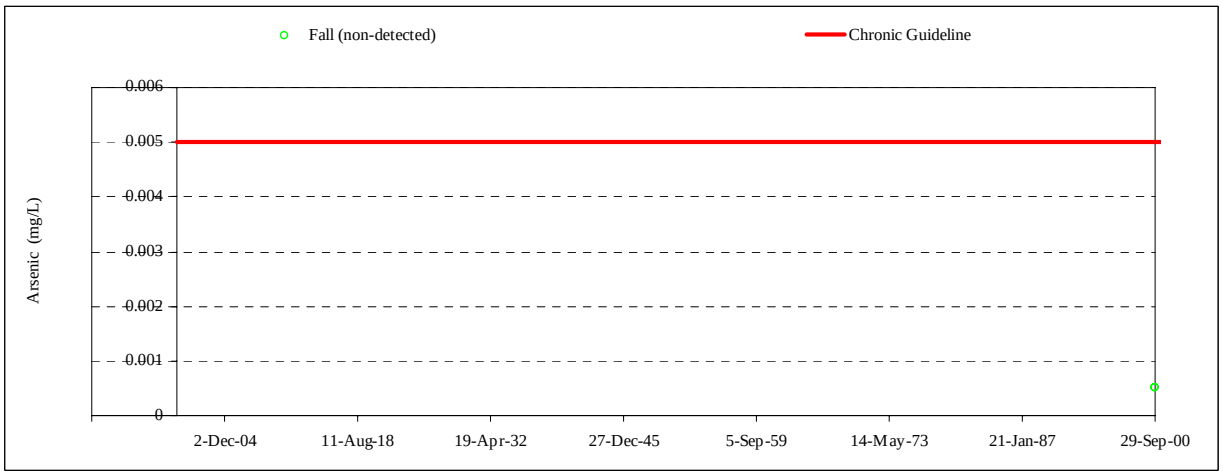
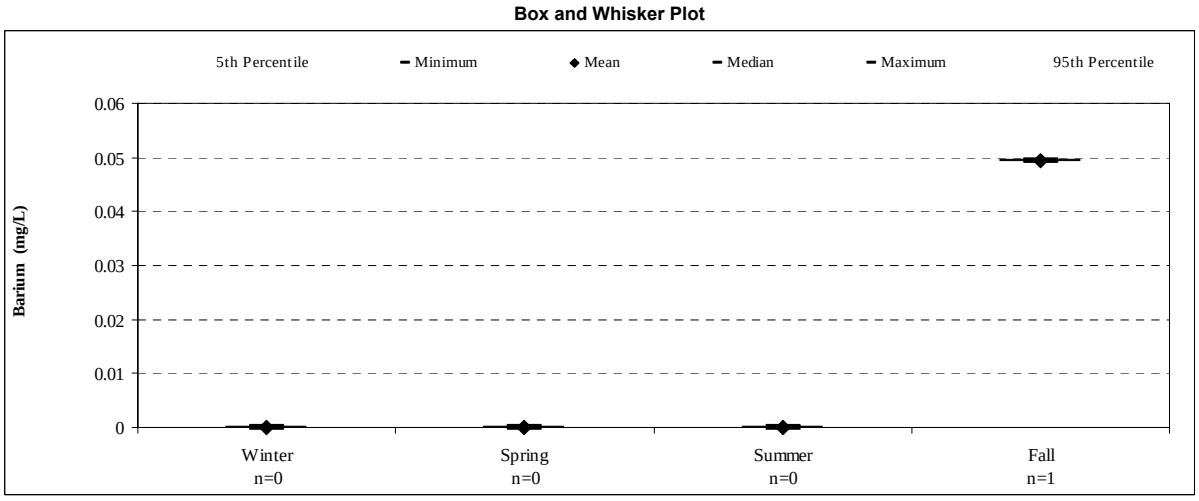


Figure G-1-9-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in McClelland Lake Fen



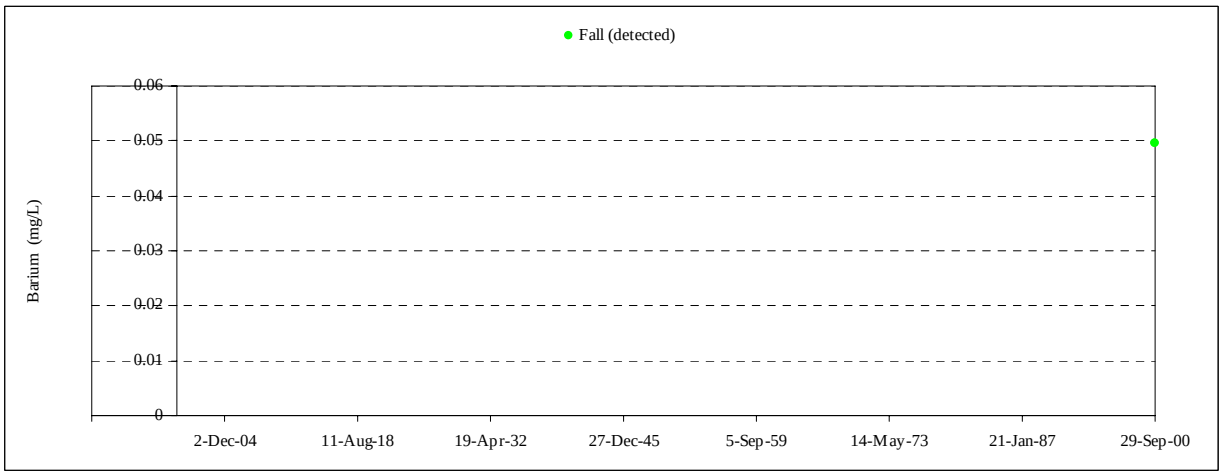
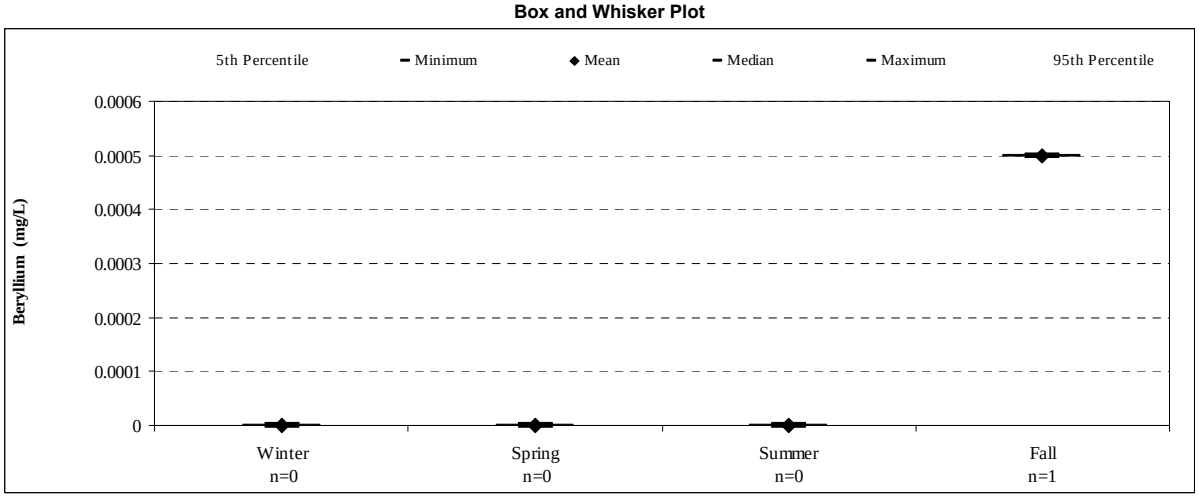


Figure G-1-9-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in McClelland Lake Fen



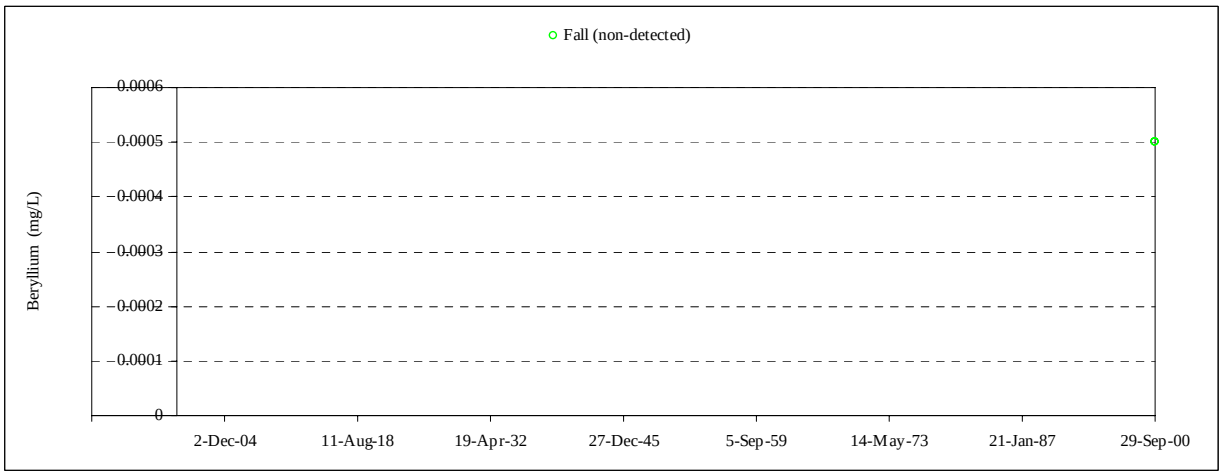
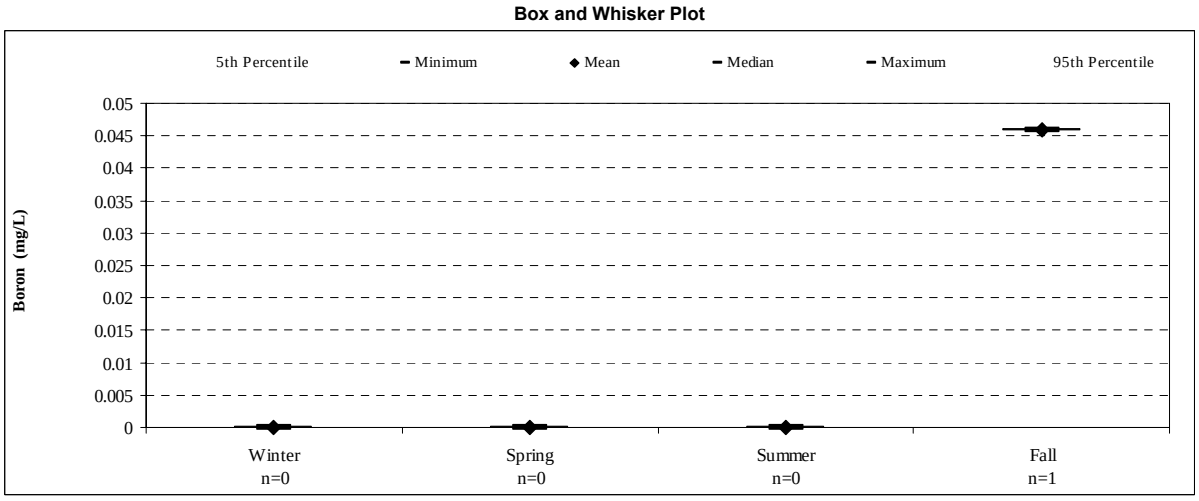


Figure G-1-9-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in McClelland Lake Fen



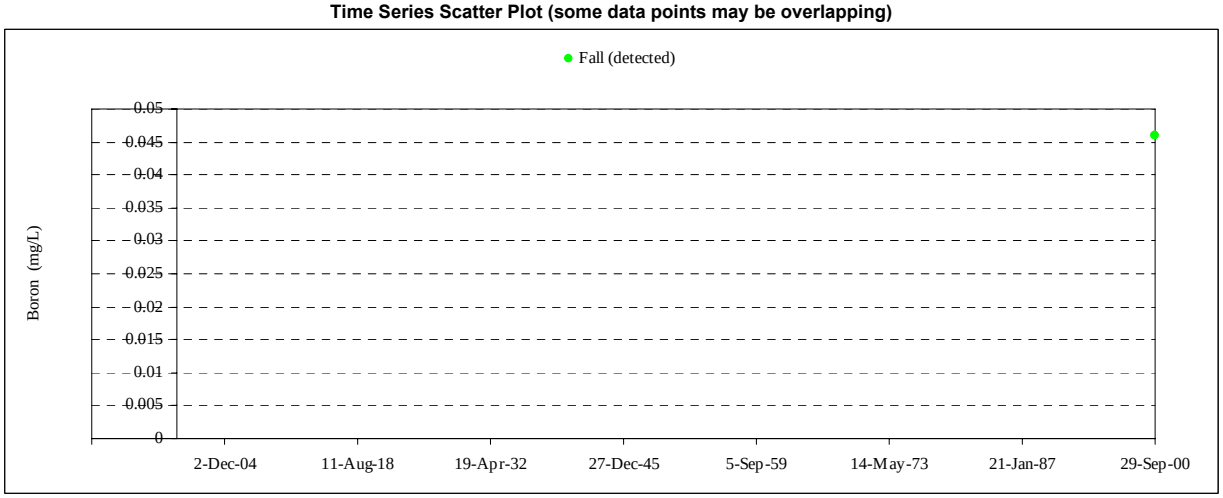
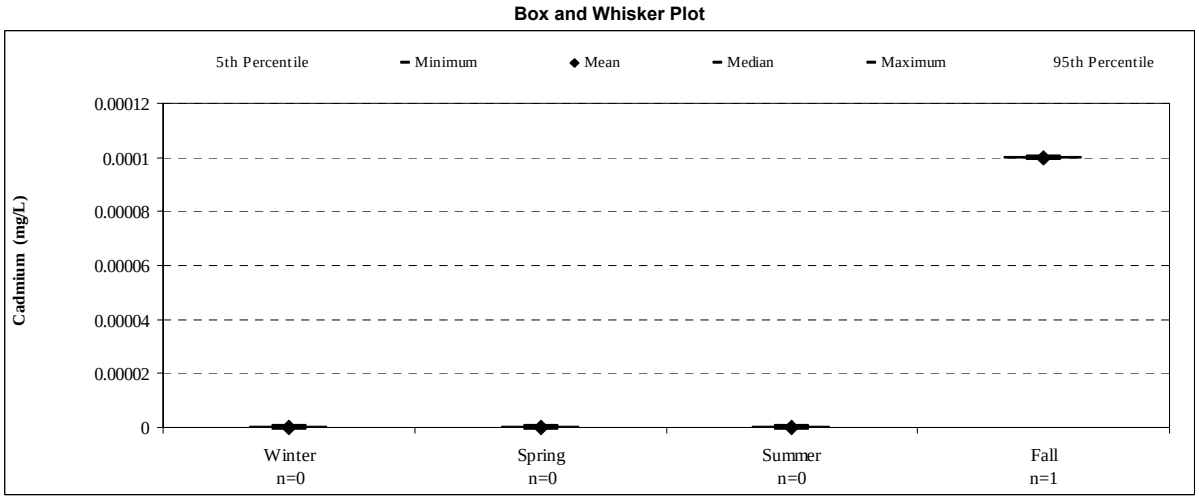


Figure G-1-9-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in McClelland Lake Fen



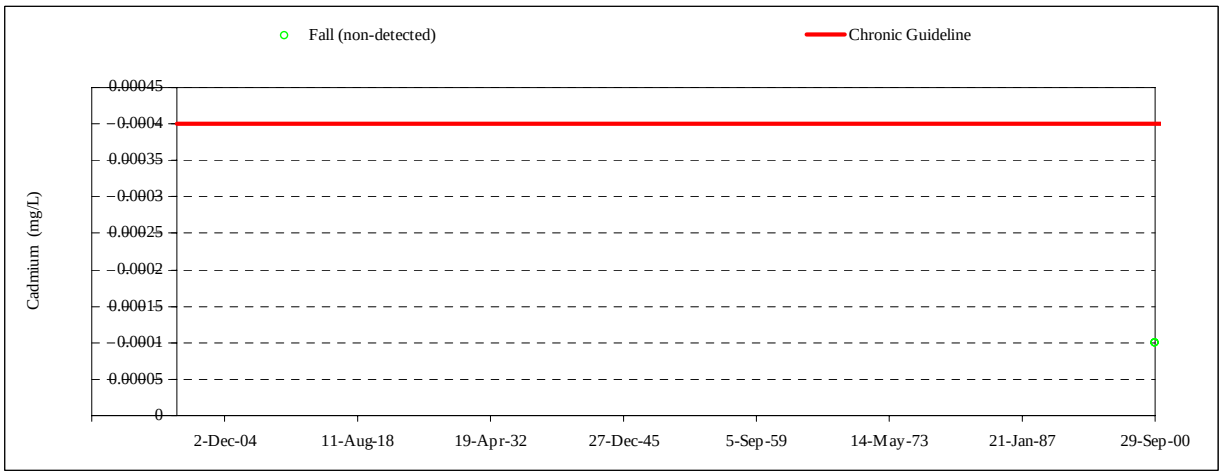
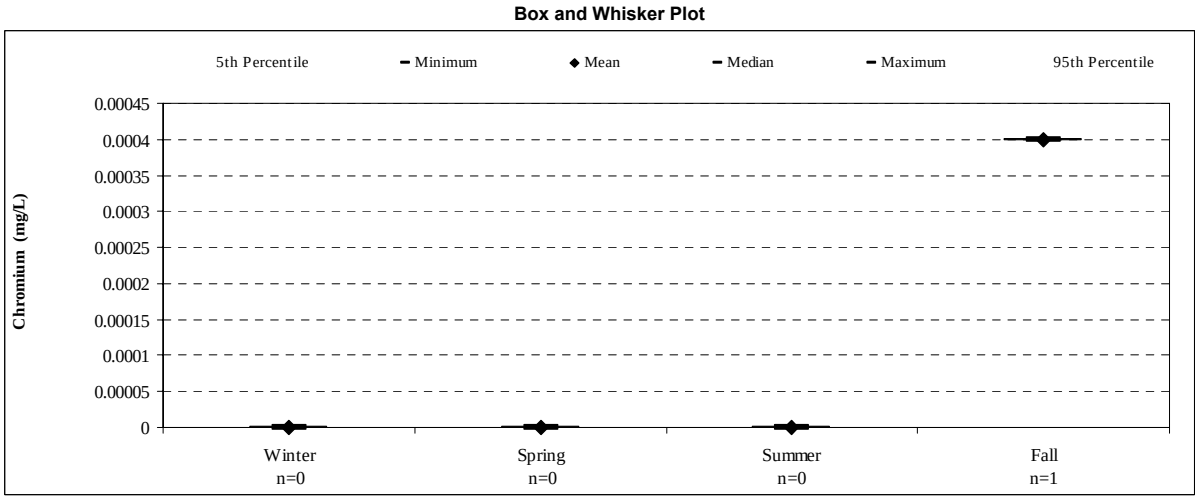


Figure G-1-9-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in McClelland Lake Fen



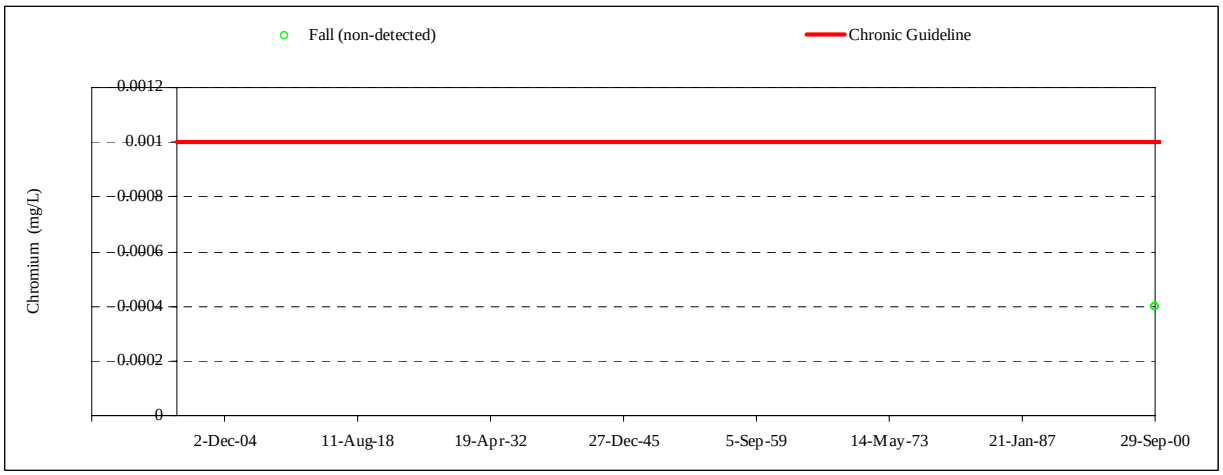
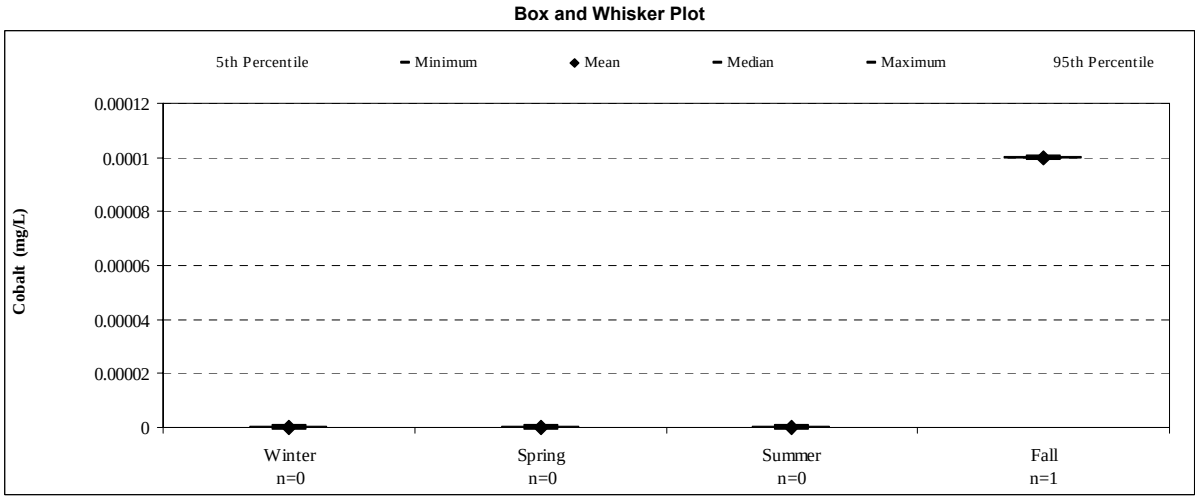


Figure G-1-9-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in McClelland Lake Fen



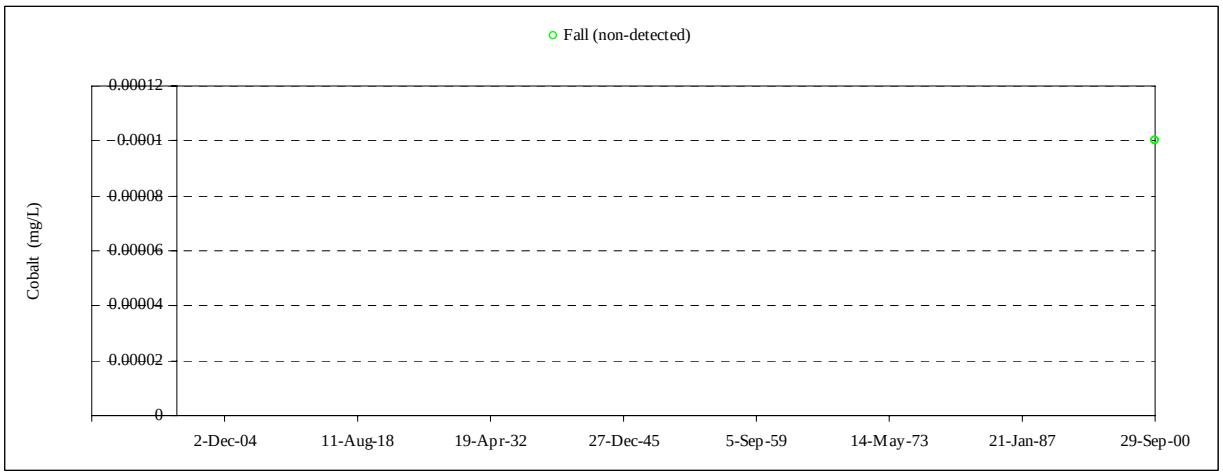
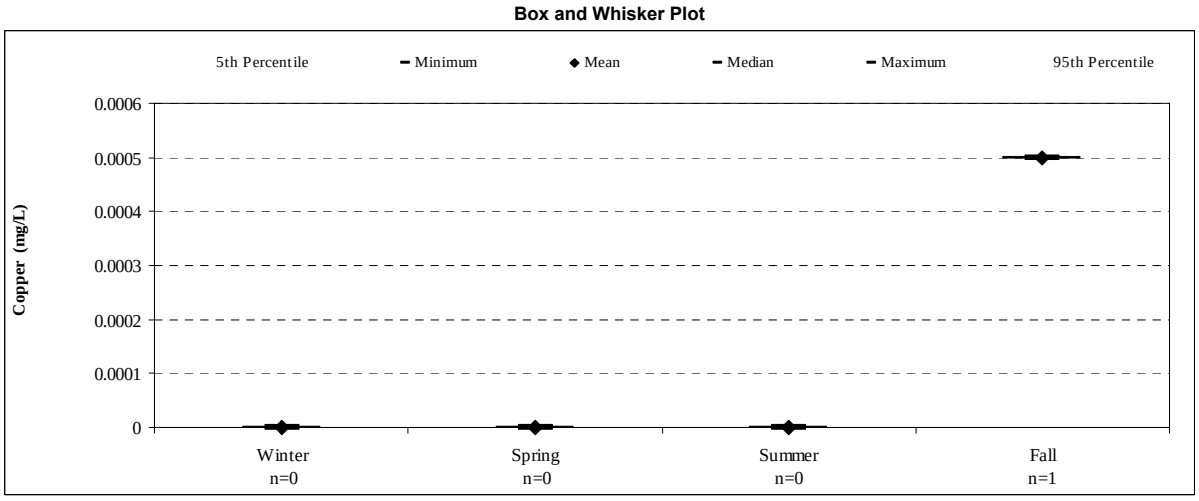


Figure G-1-9-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in McClelland Lake Fen



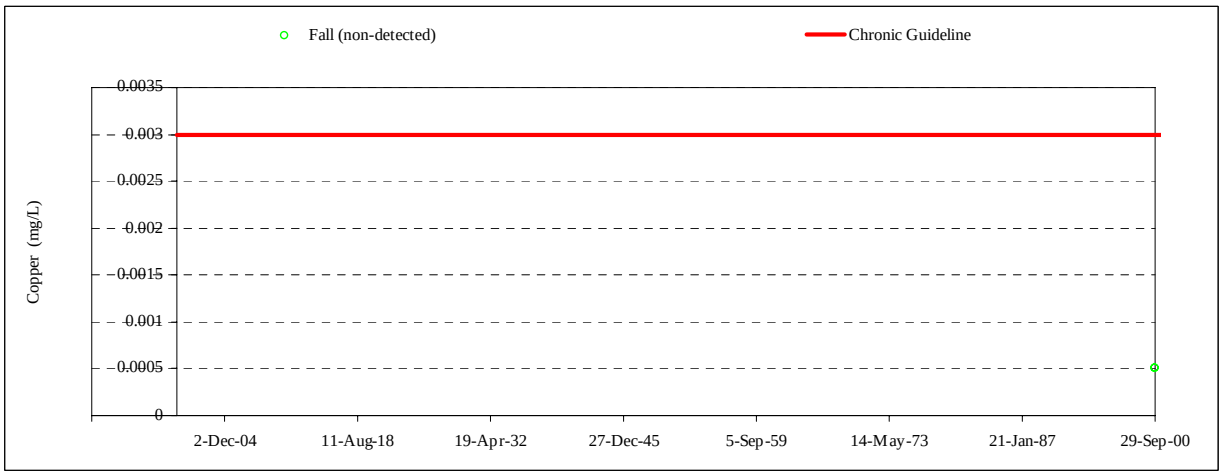
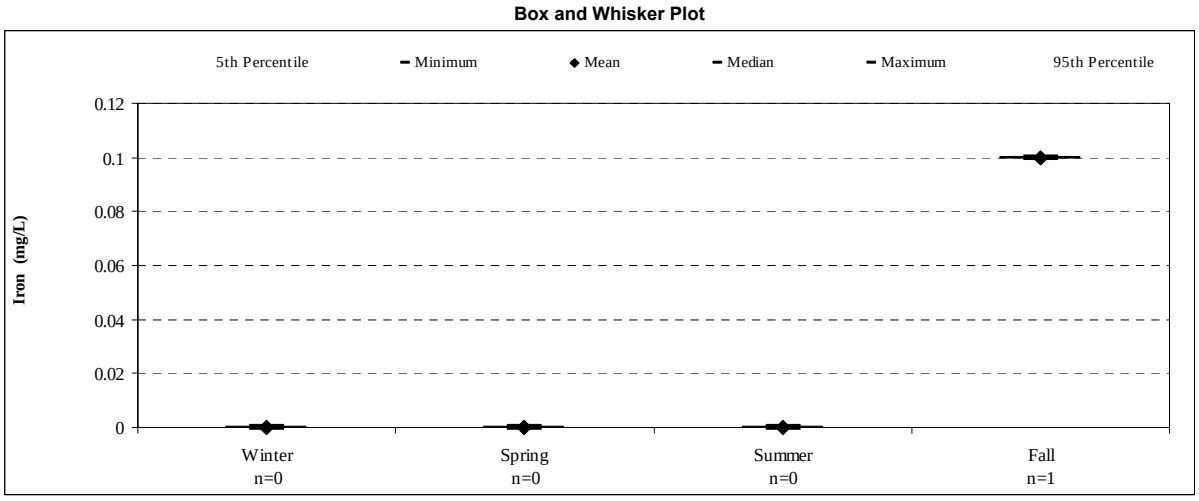


Figure G-1-9-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in McClelland Lake Fen



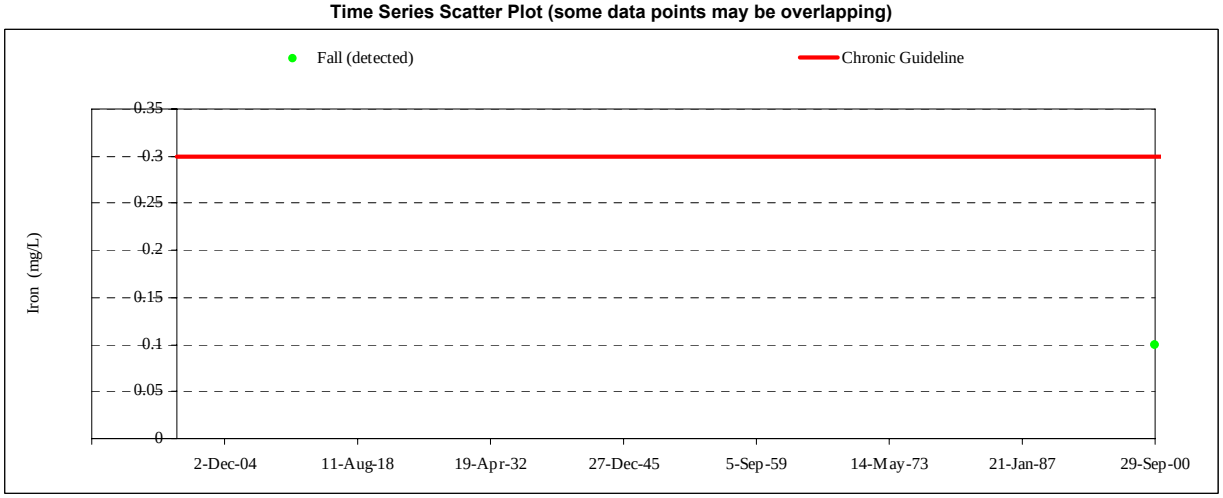
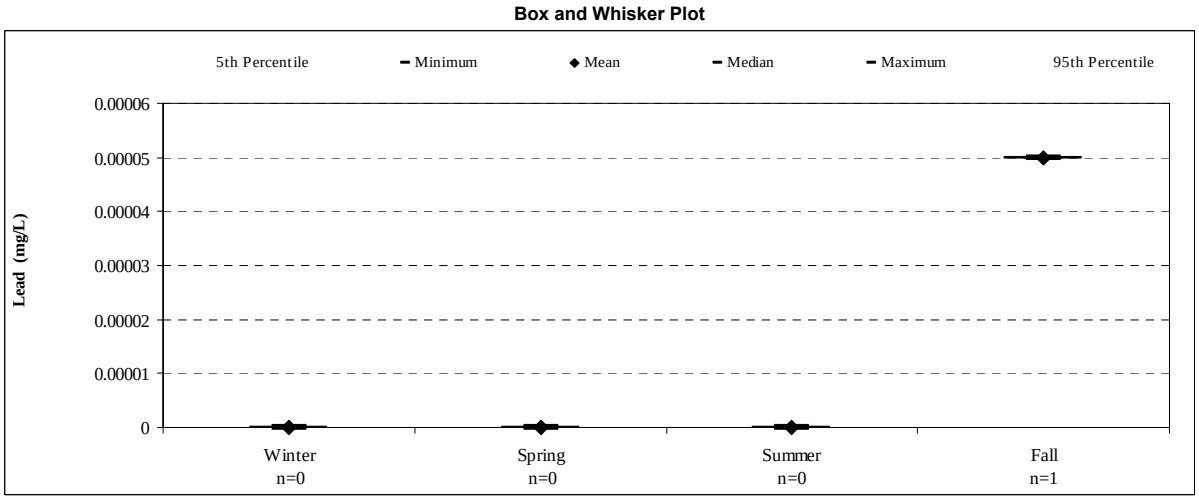


Figure G-1-9-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in McClelland Lake Fen



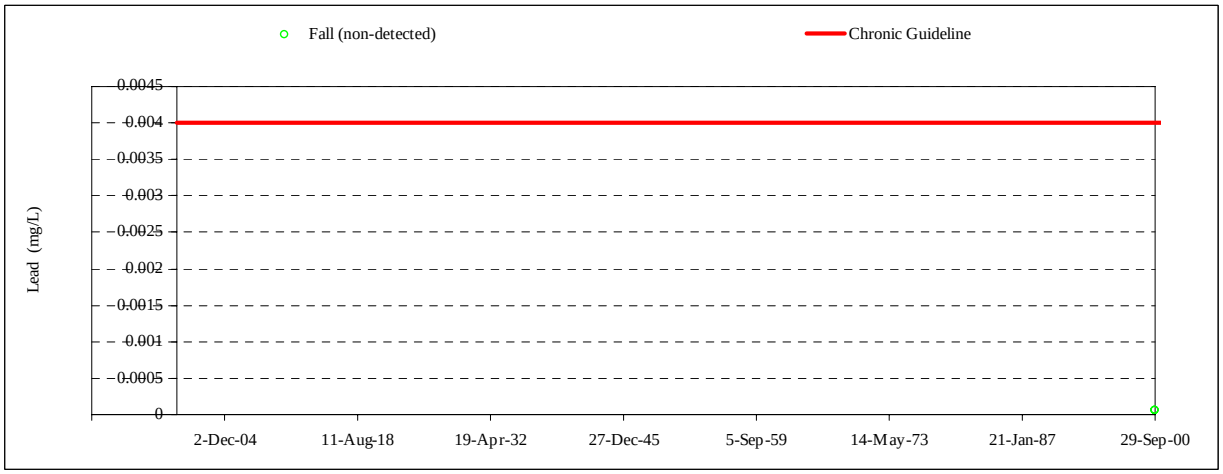
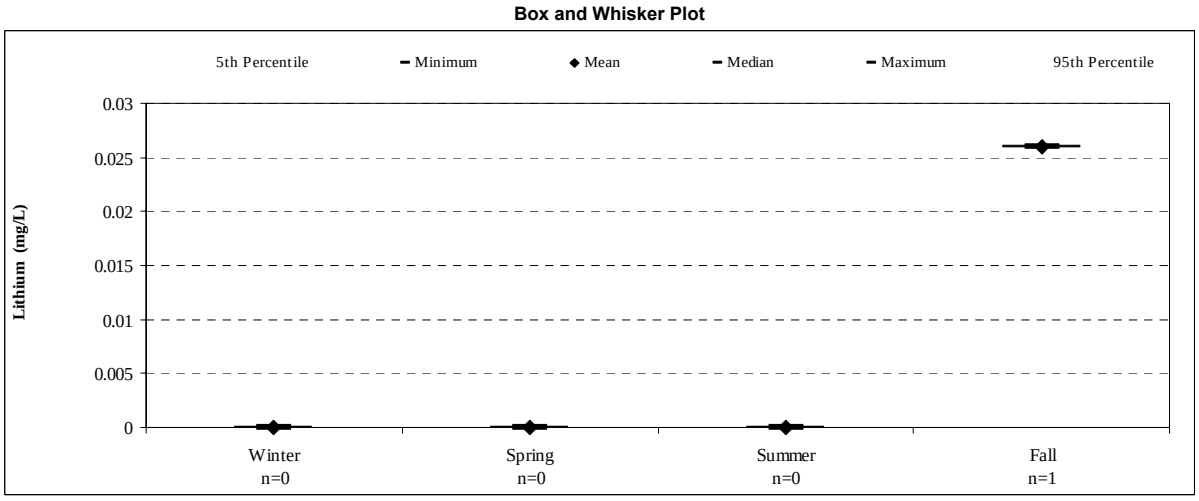


Figure G-1-9-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in McClelland Lake Fen



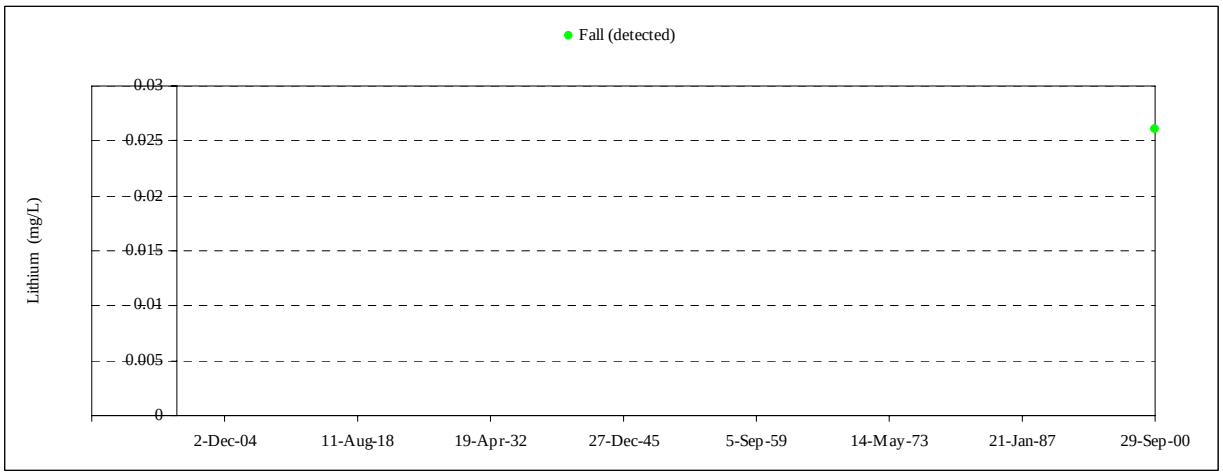
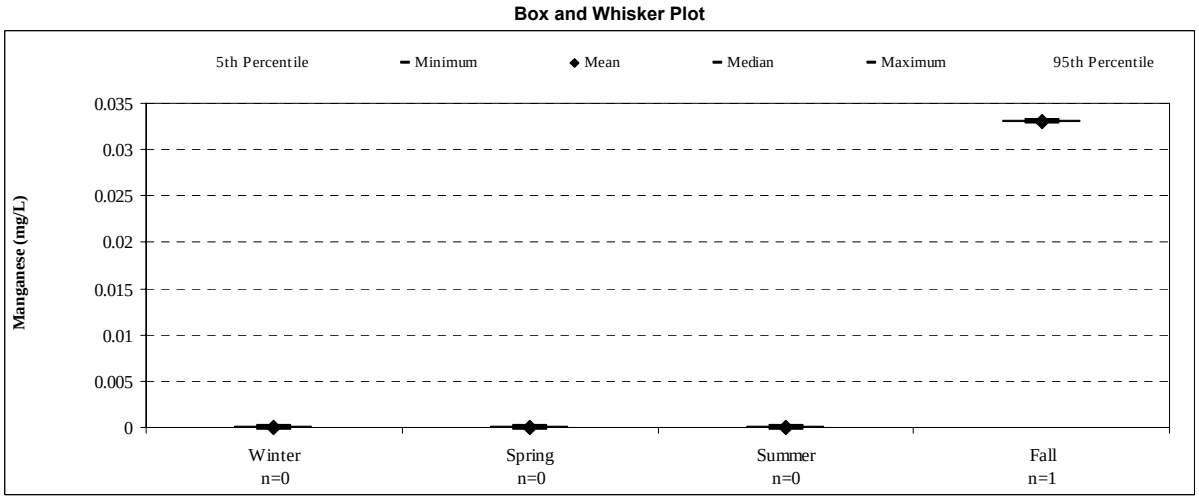


Figure G-1-9-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in McClelland Lake Fen



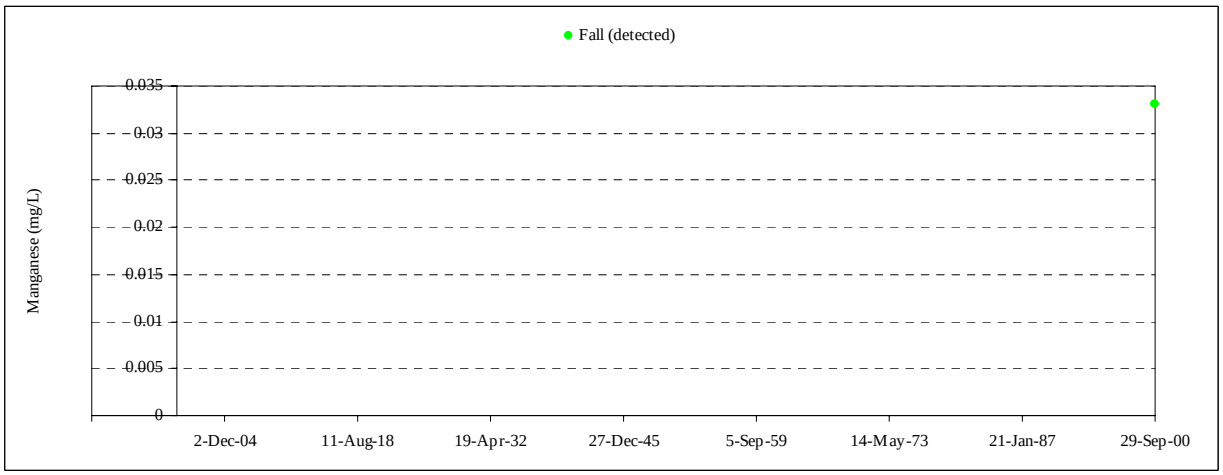
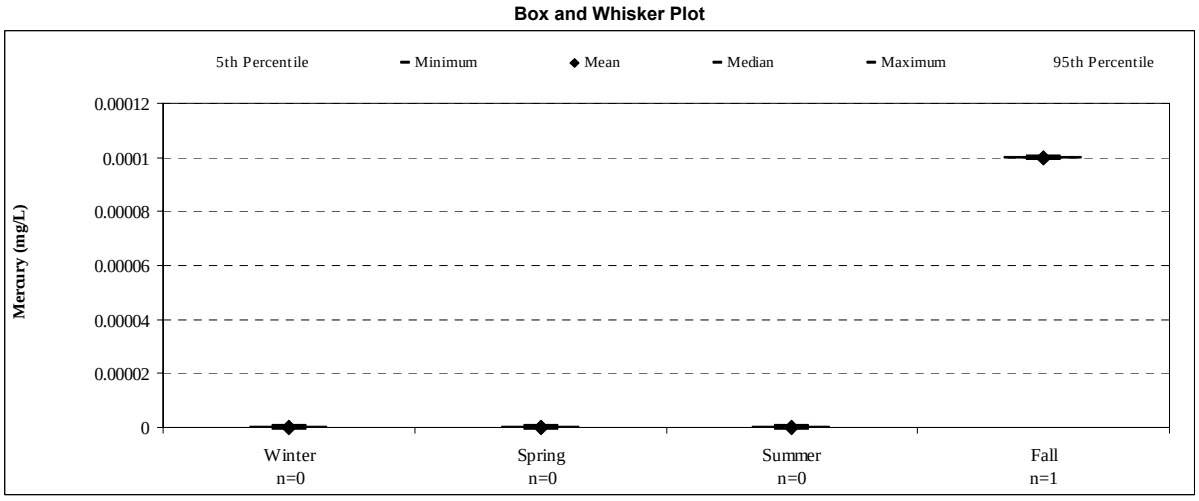


Figure G-1-9-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in McClelland Lake Fen



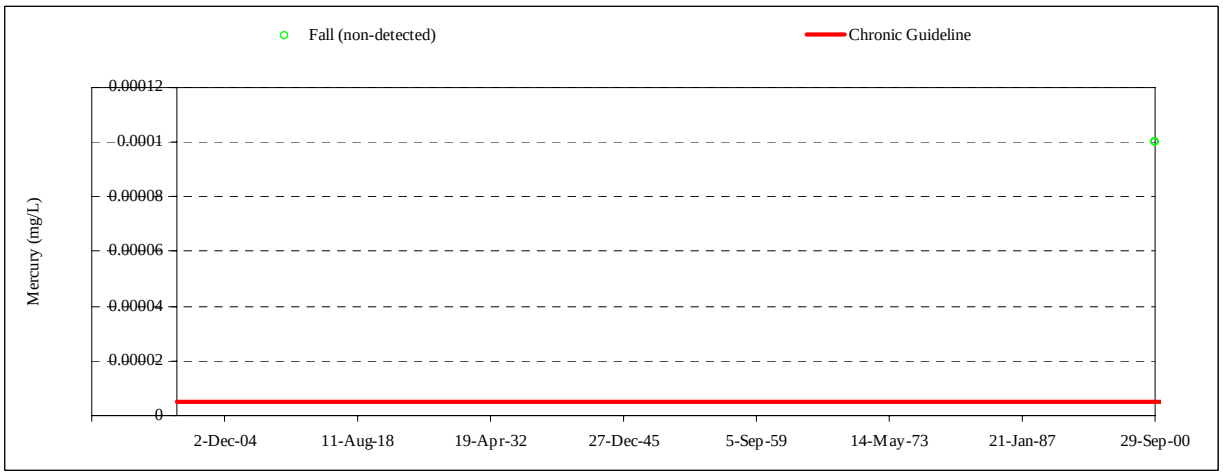
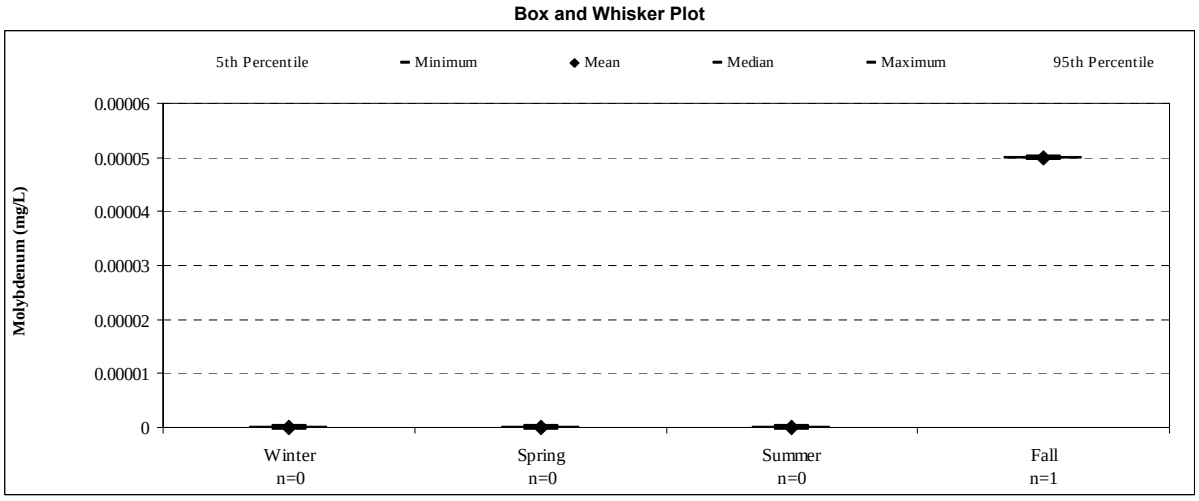


Figure G-1-9-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in McClelland Lake Fen



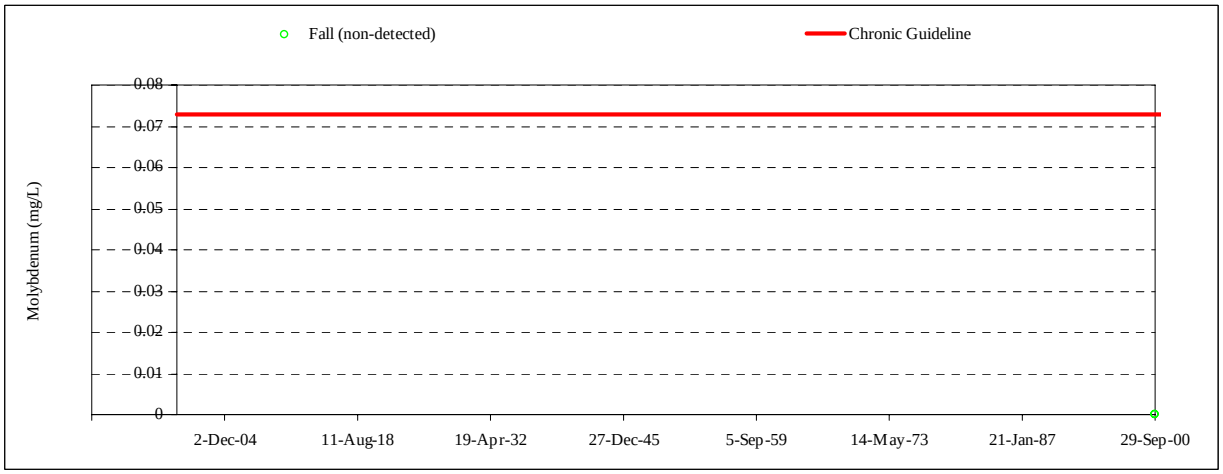
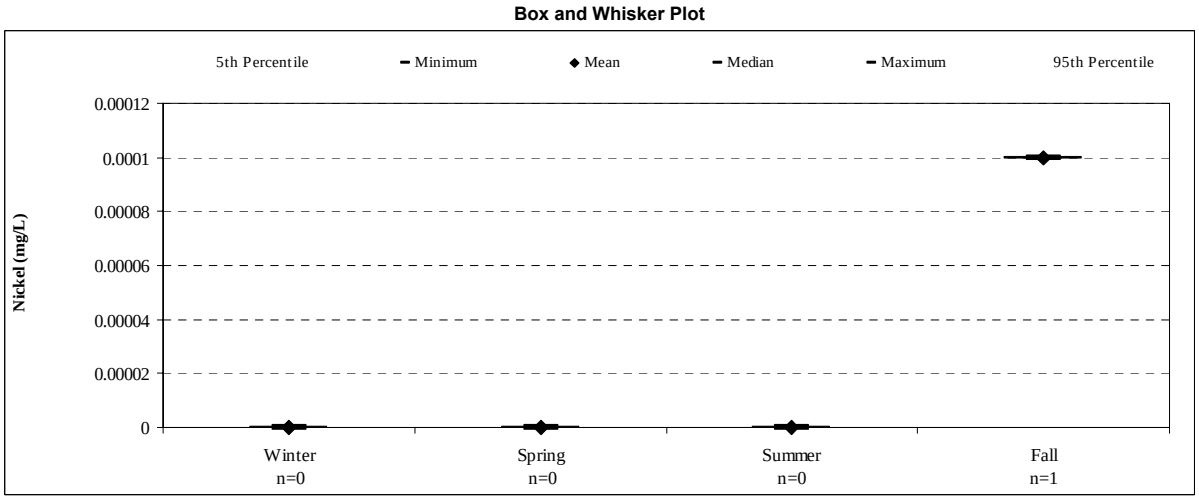


Figure G-1-9-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in McClelland Lake Fen



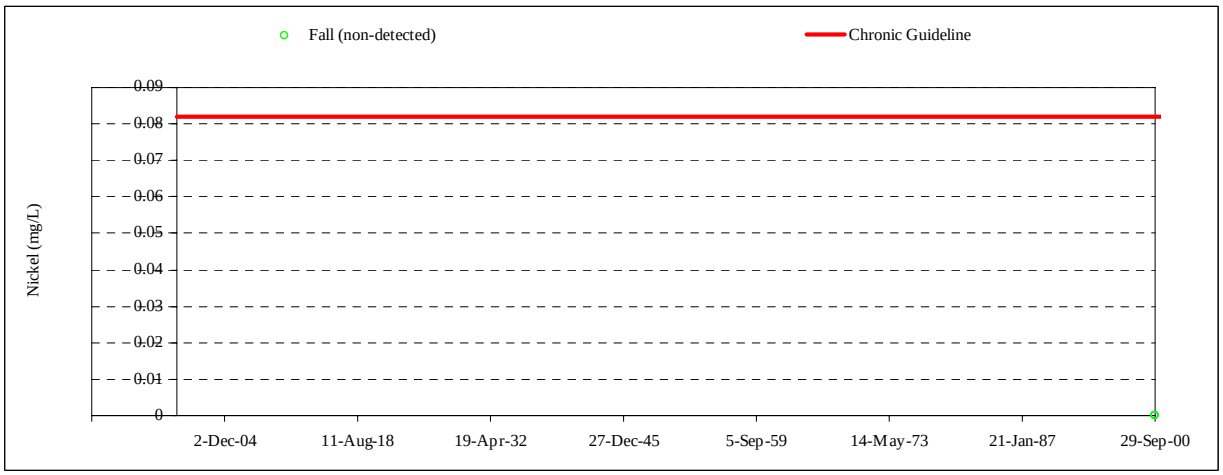
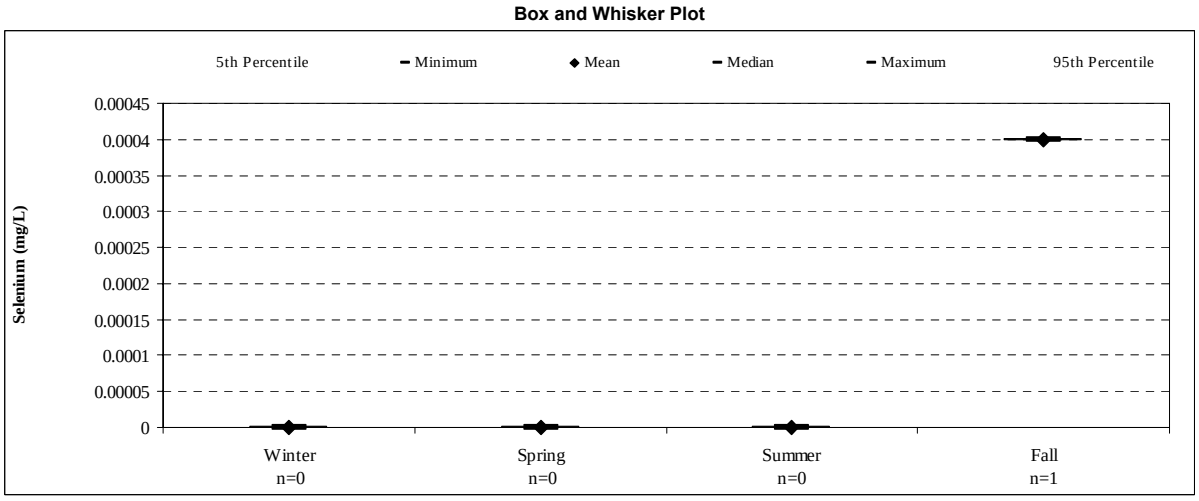


Figure G-1-9-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in McClelland Lake Fen



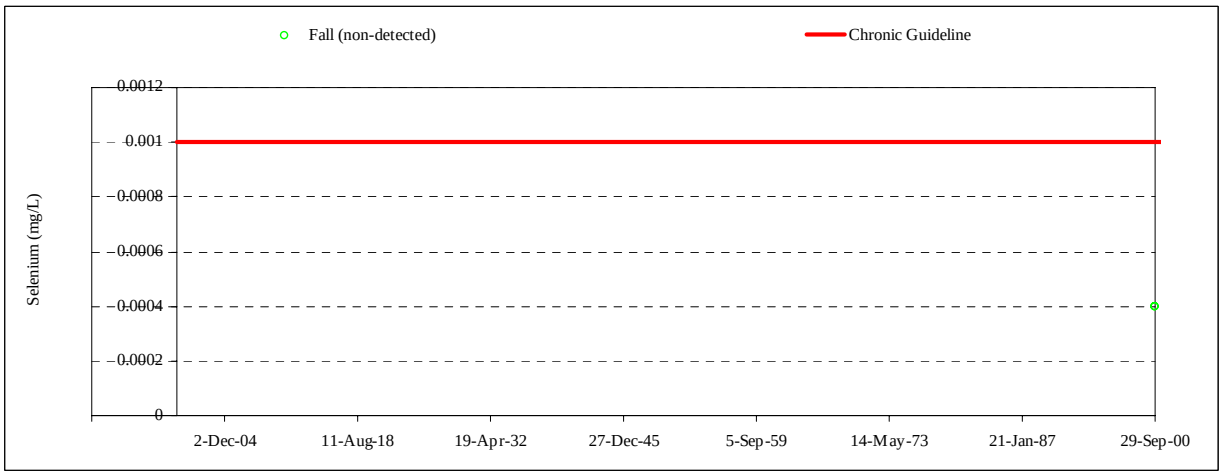
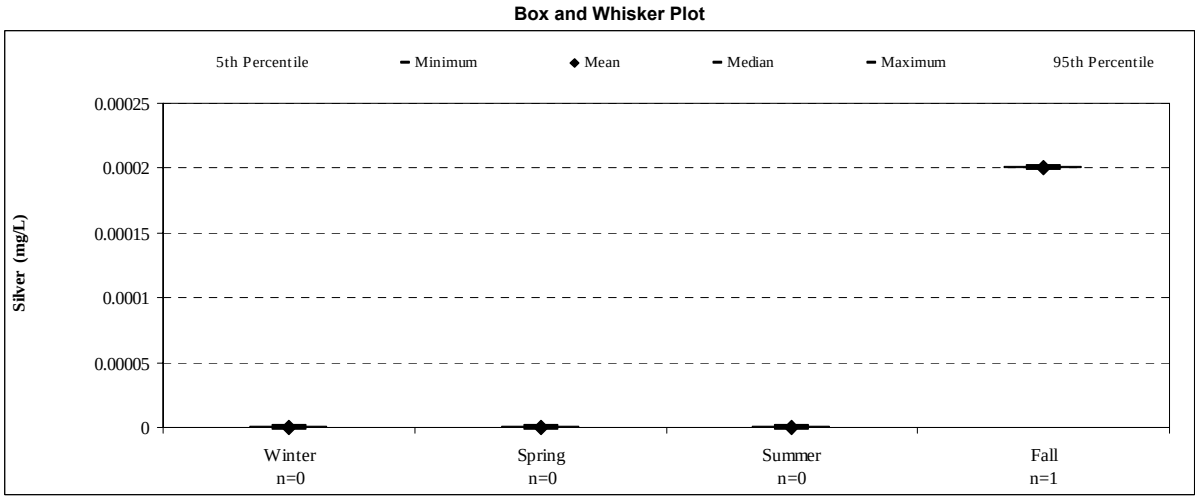


Figure G-1-9-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in McClelland Lake Fen



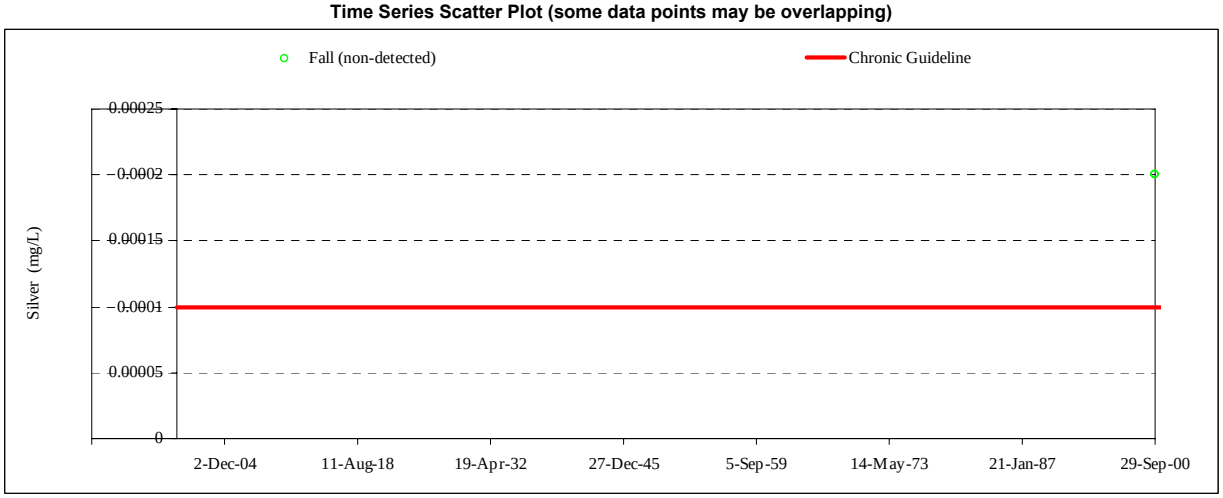
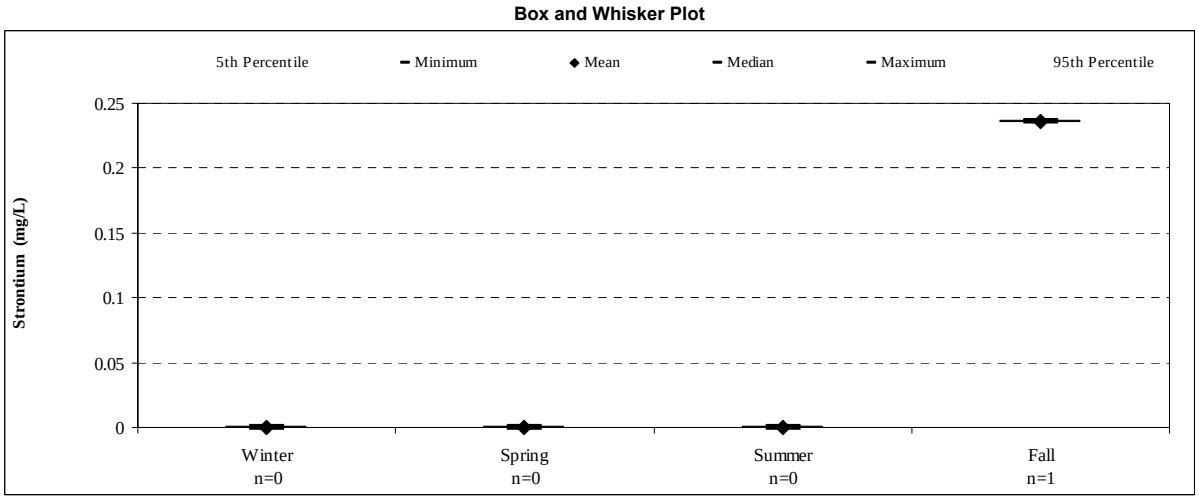


Figure G-1-9-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in McClelland Lake Fen



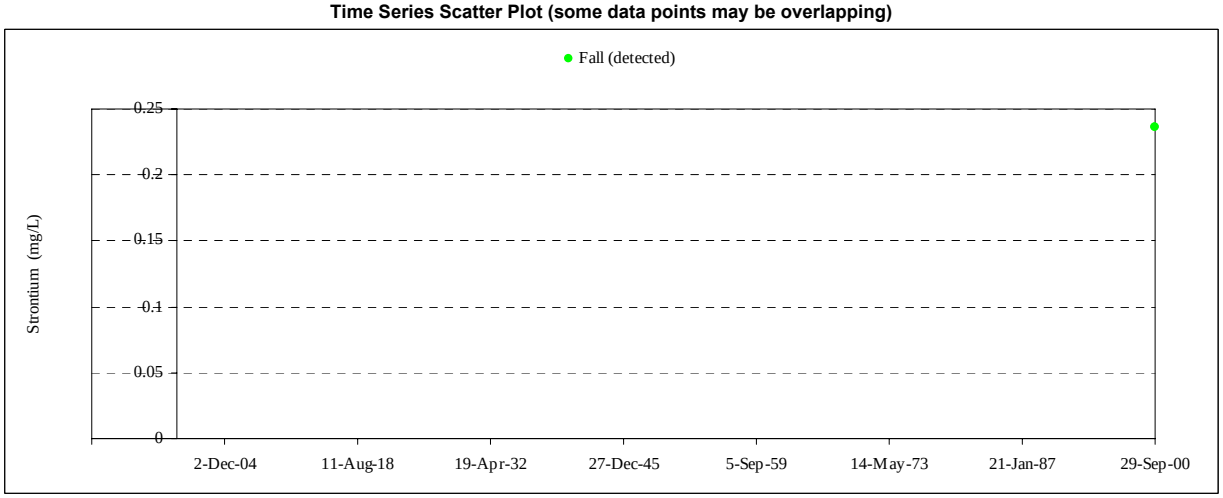
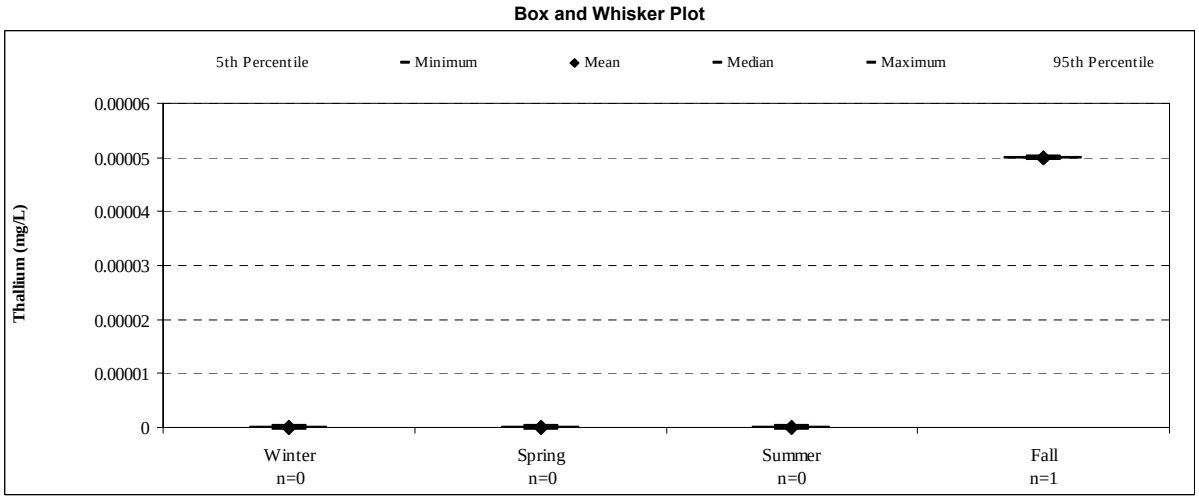


Figure G-1-9-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in McClelland Lake Fen



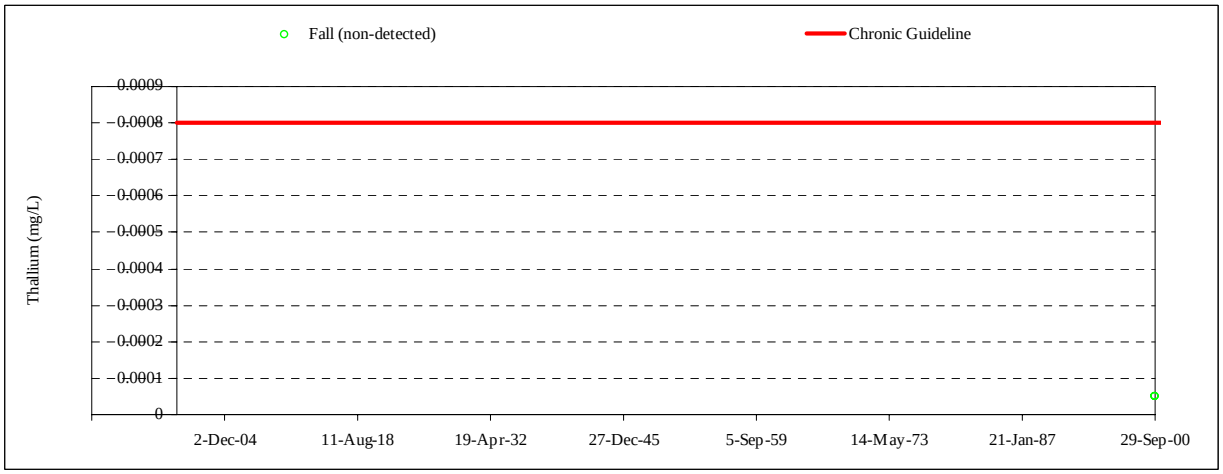
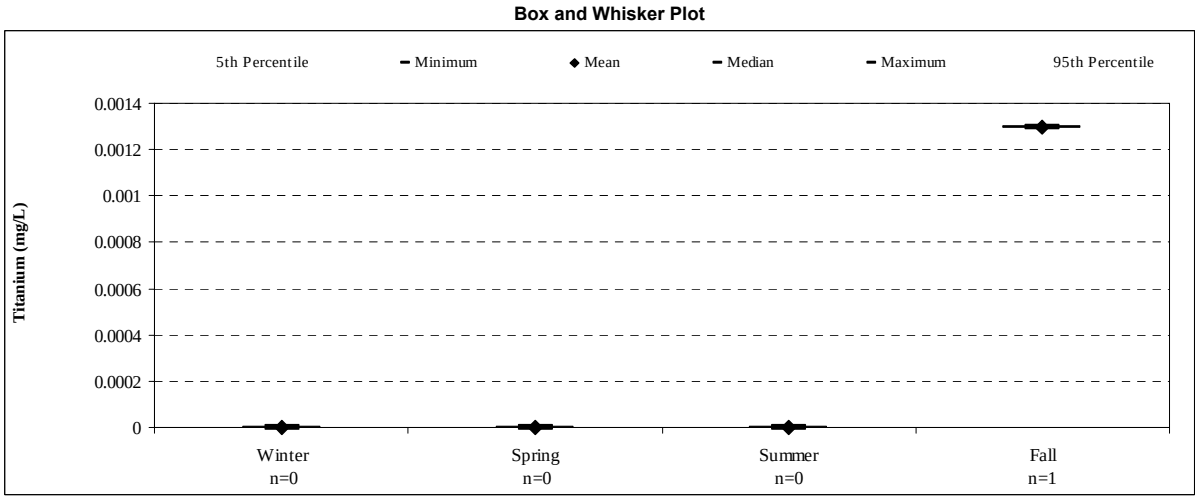


Figure G-1-9-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in McClelland Lake Fen



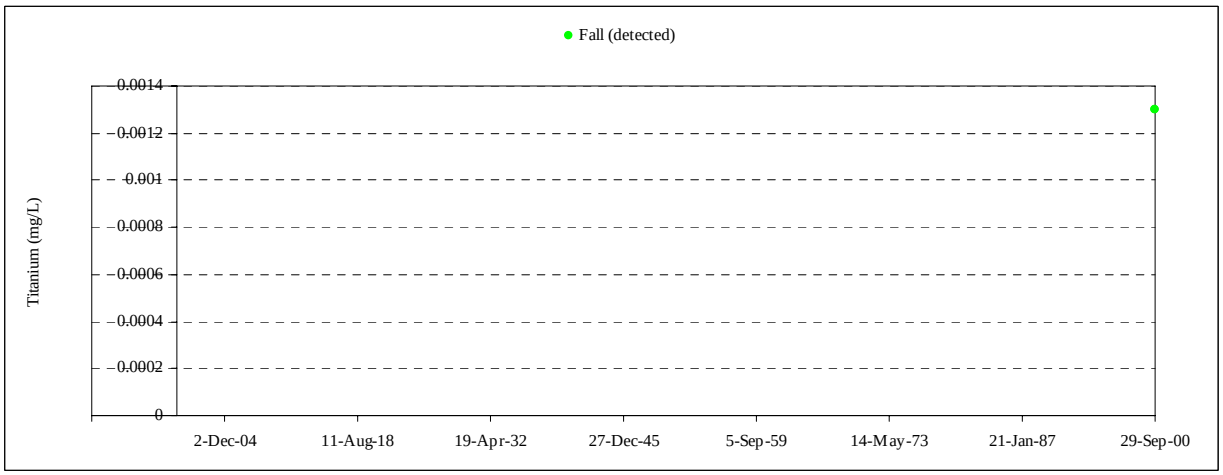
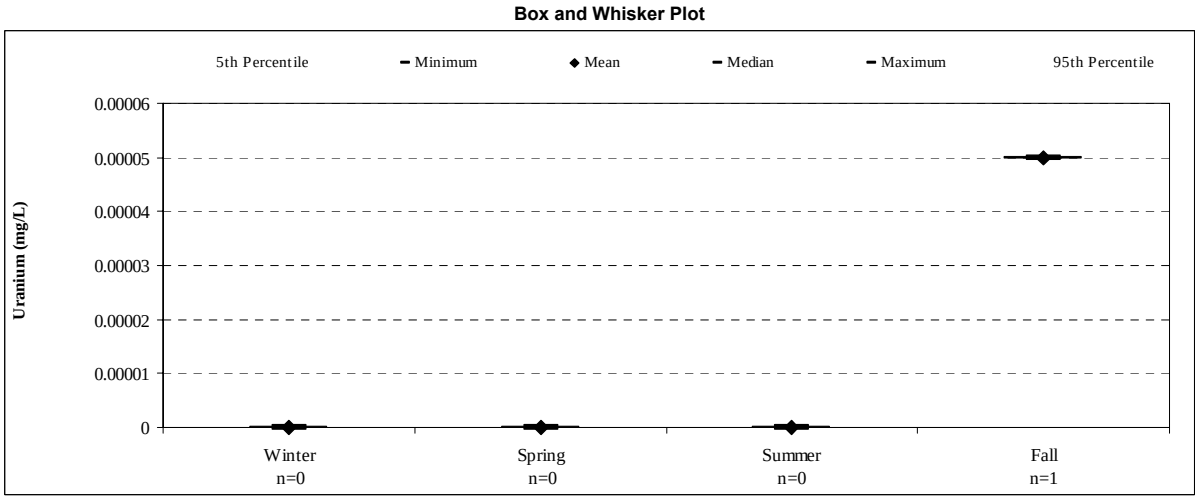


Figure G-1-9-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in McClelland Lake Fen



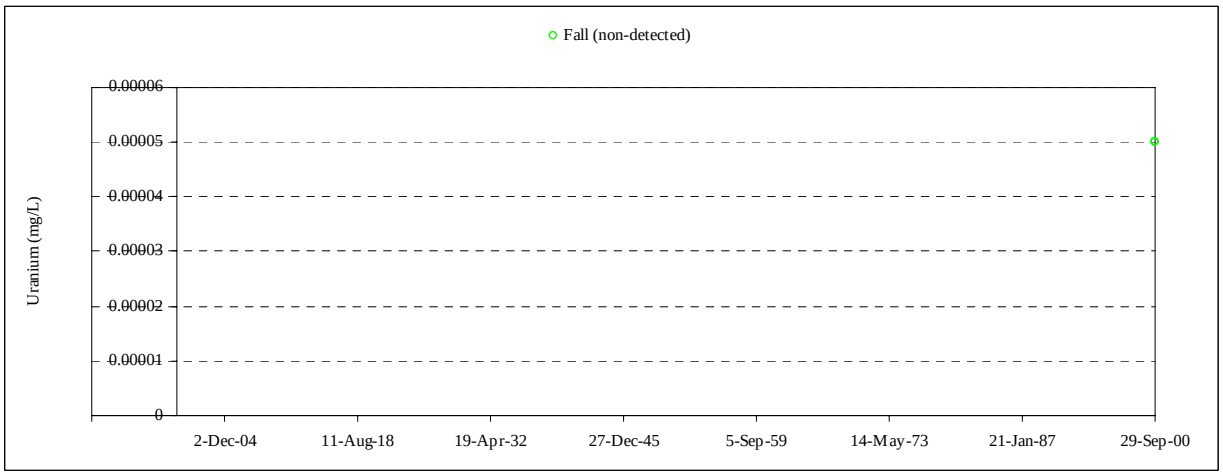
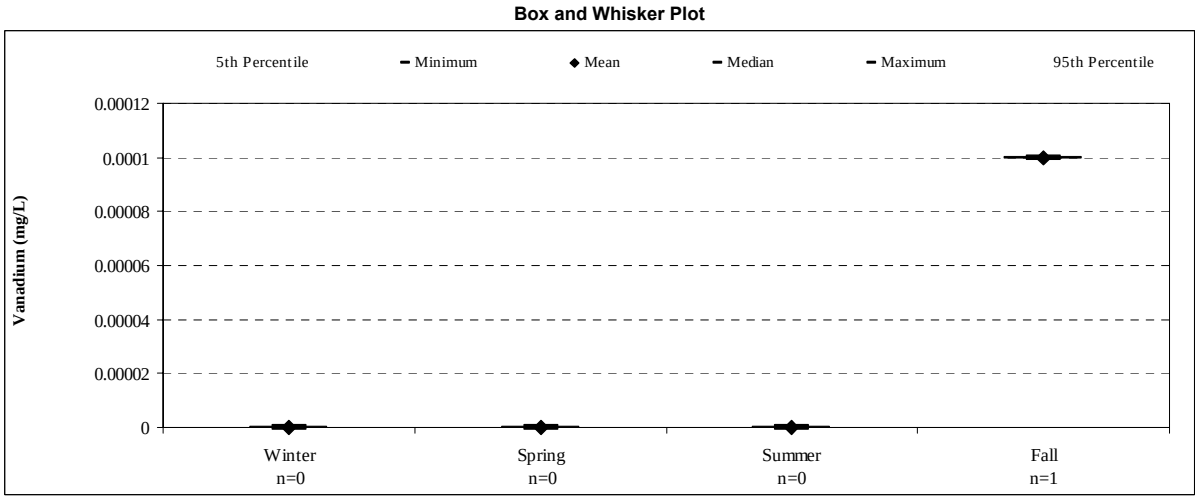


Figure G-1-9-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in McClelland Lake Fen



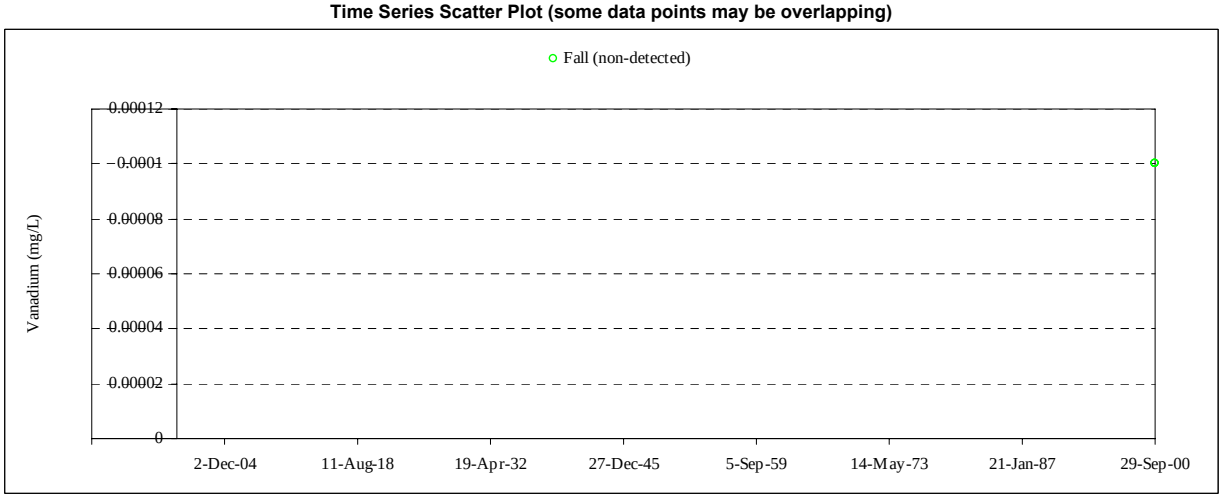
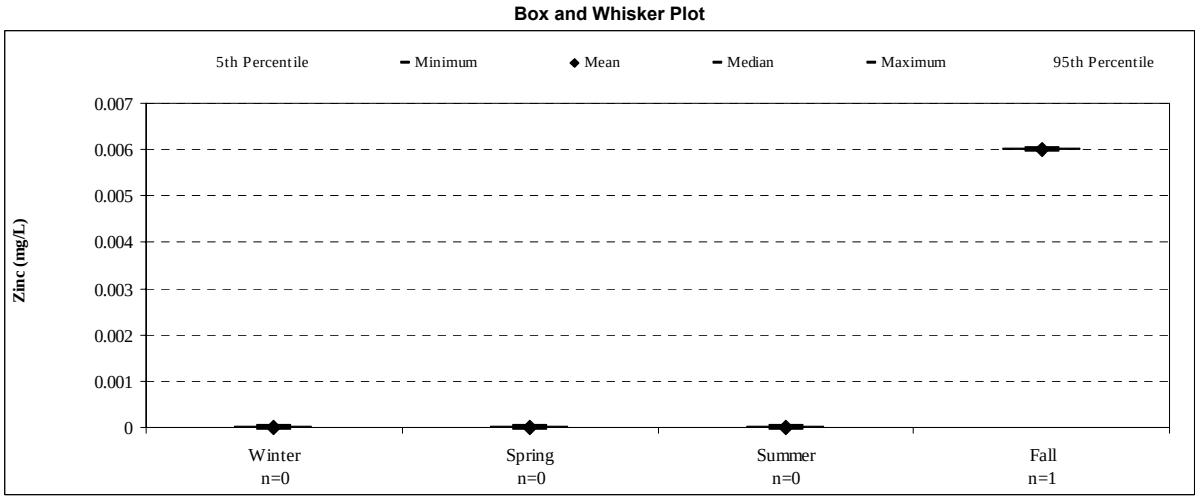


Figure G-1-9-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in McClelland Lake Fen



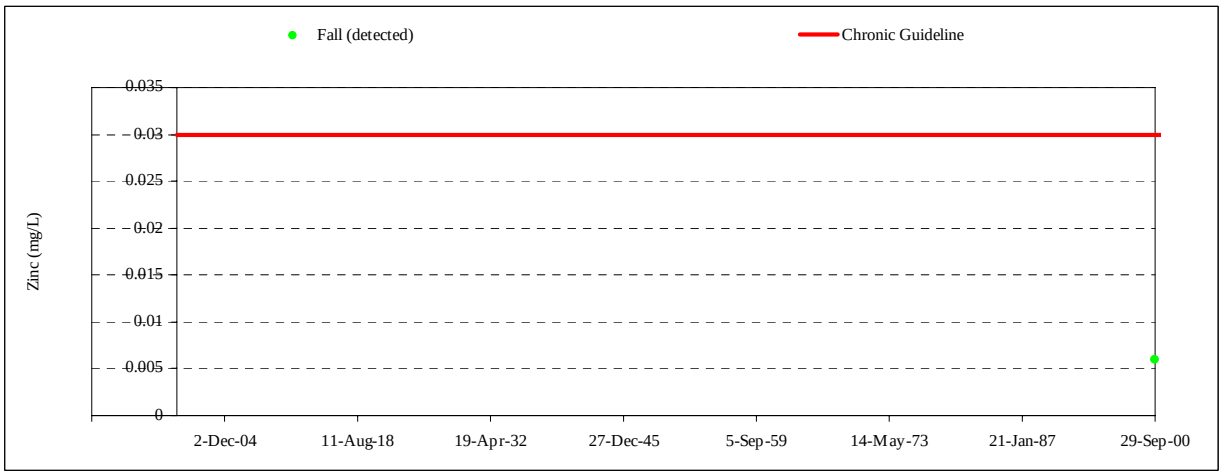
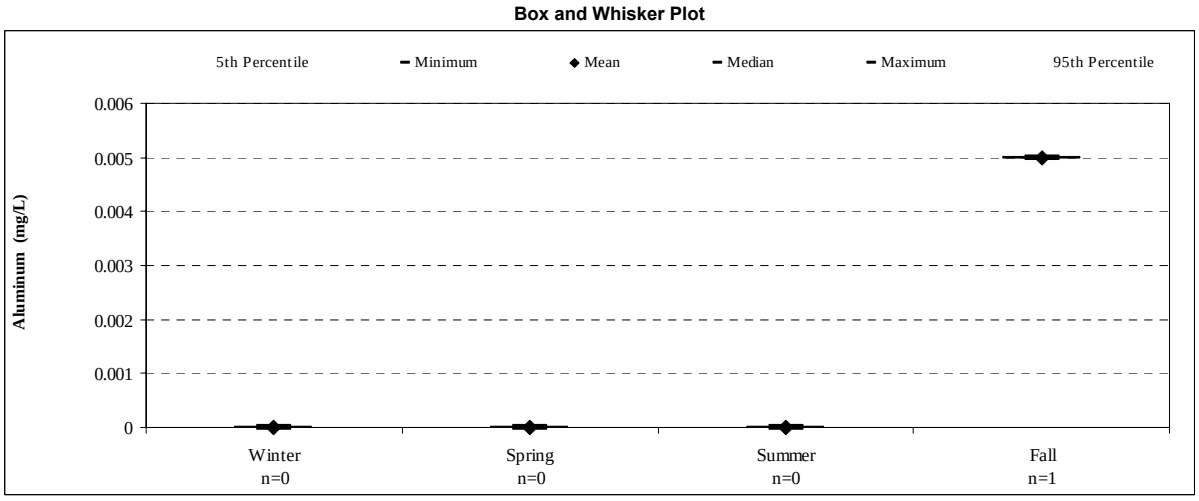


Figure G-1-9-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in McClelland Lake Fen



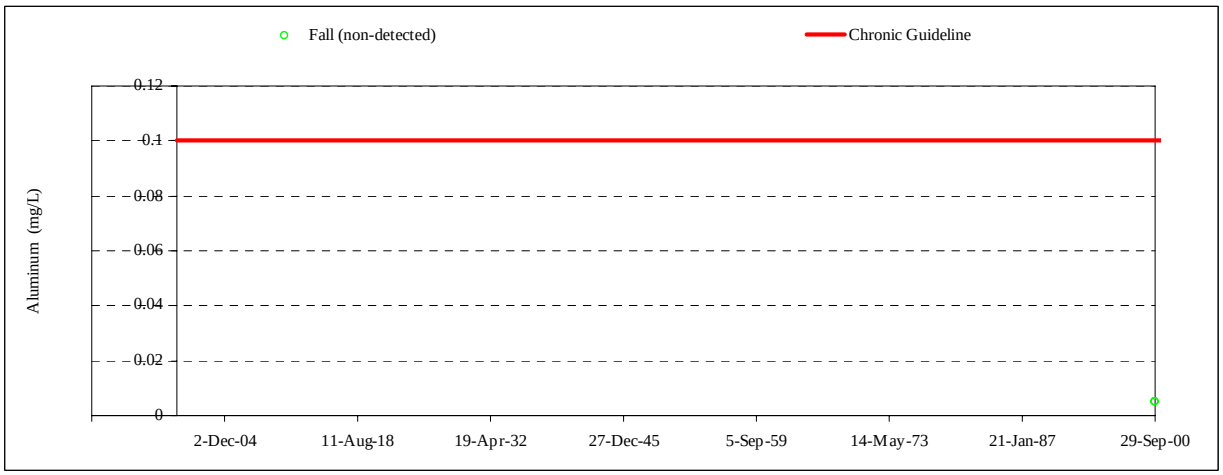
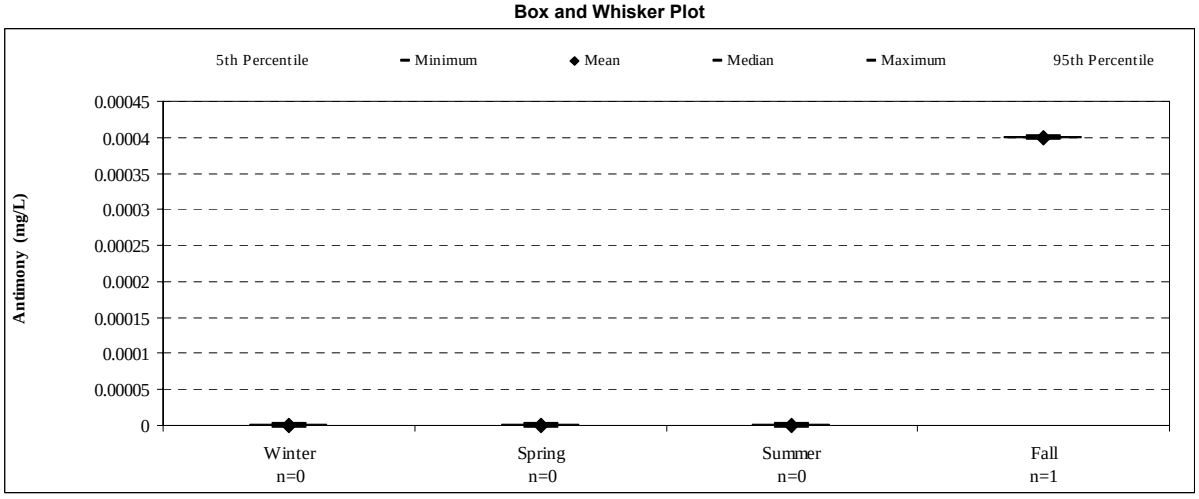


Figure G-1-9-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in McClelland Lake Fen



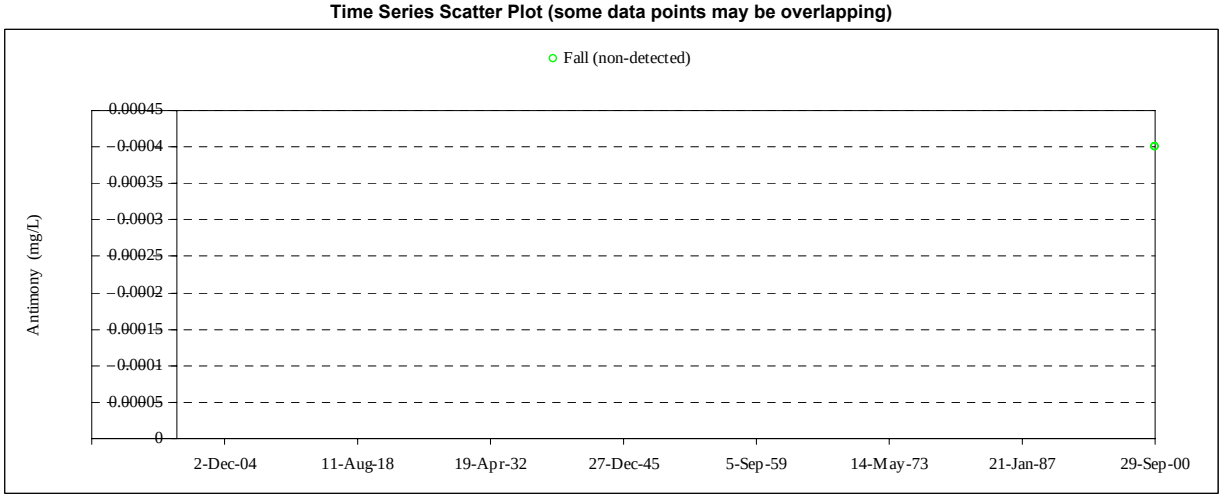
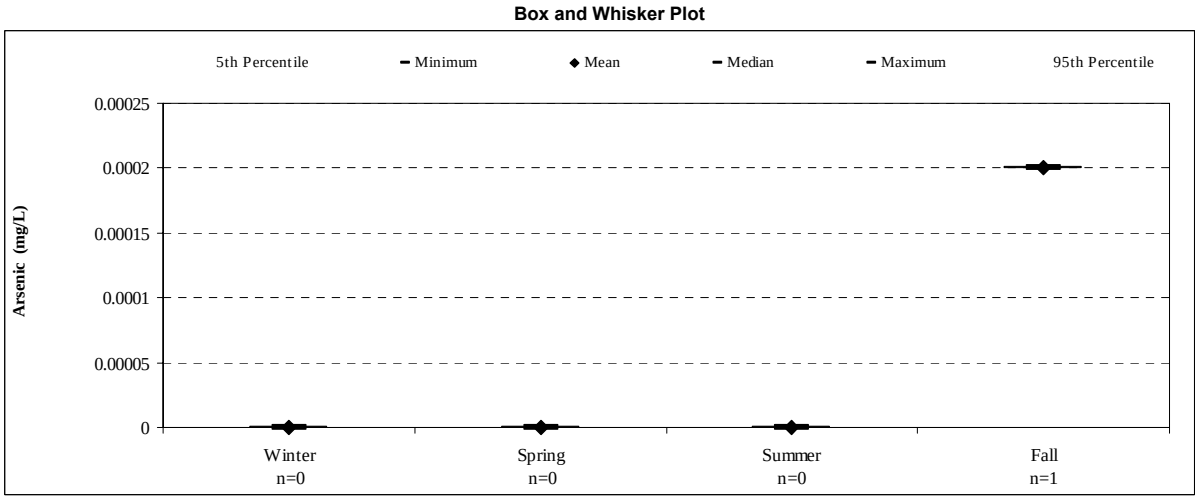


Figure G-1-9-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in McClelland Lake Fen



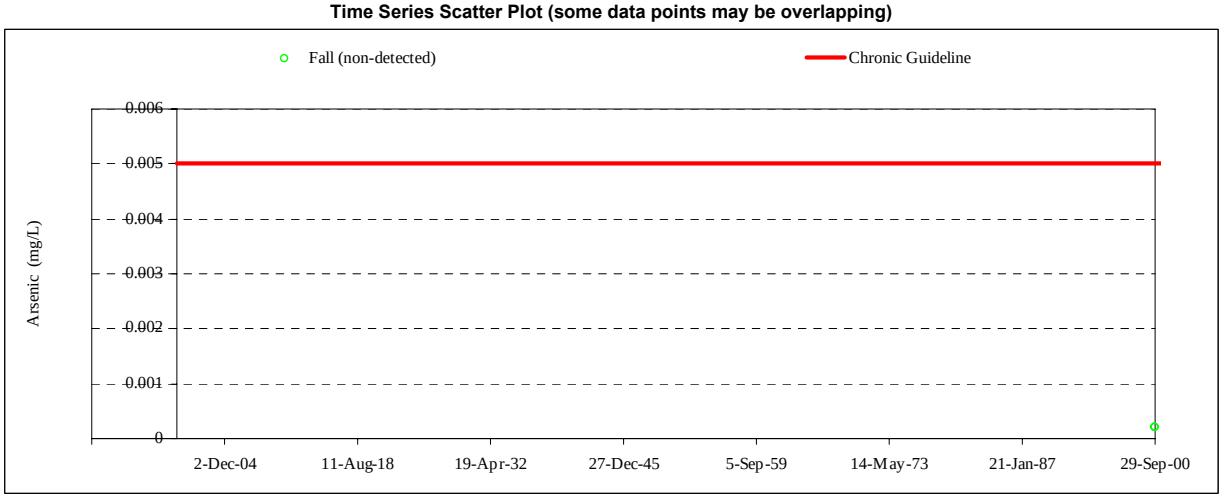
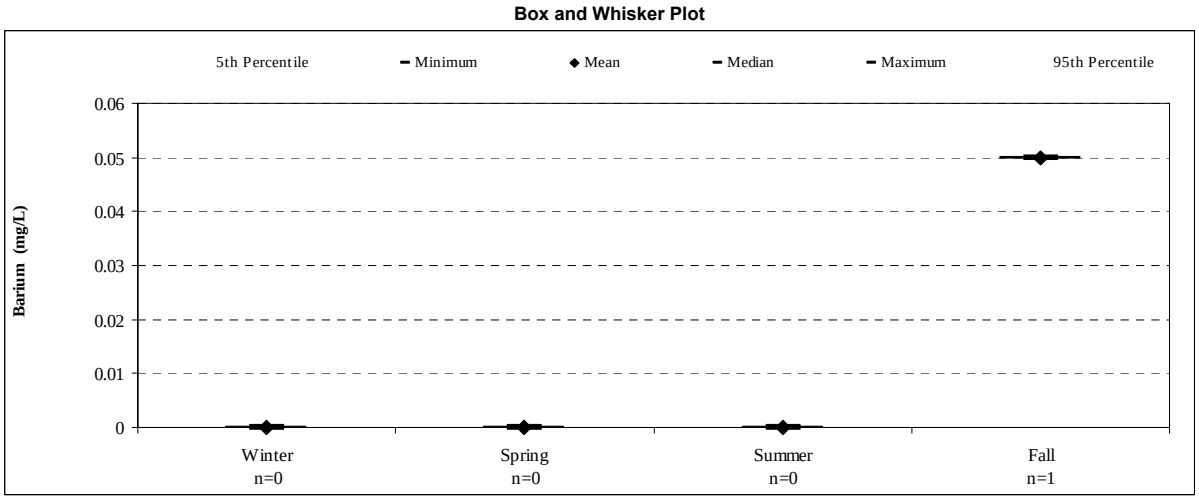


Figure G-1-9-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in McClelland Lake Fen



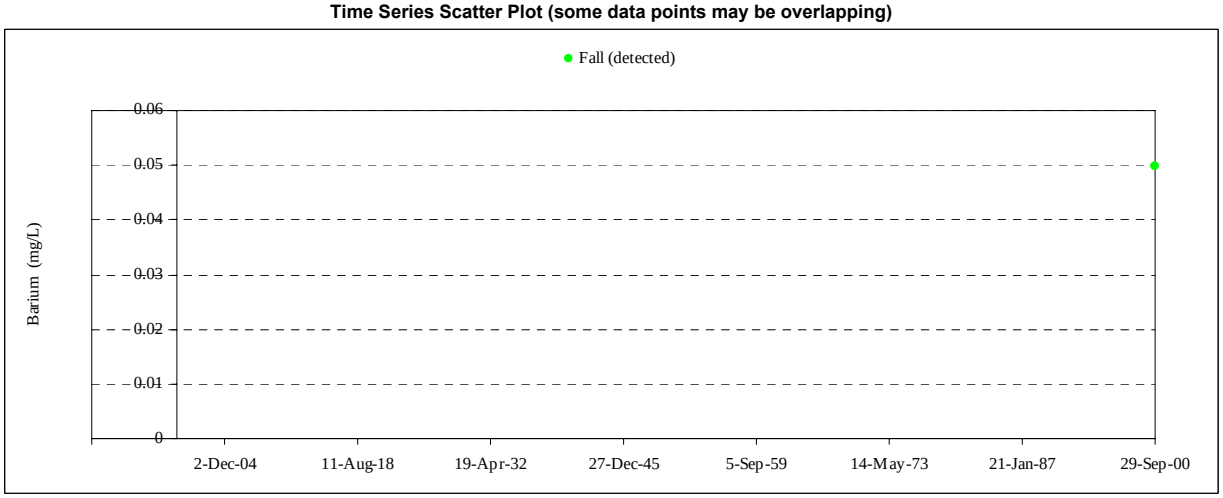
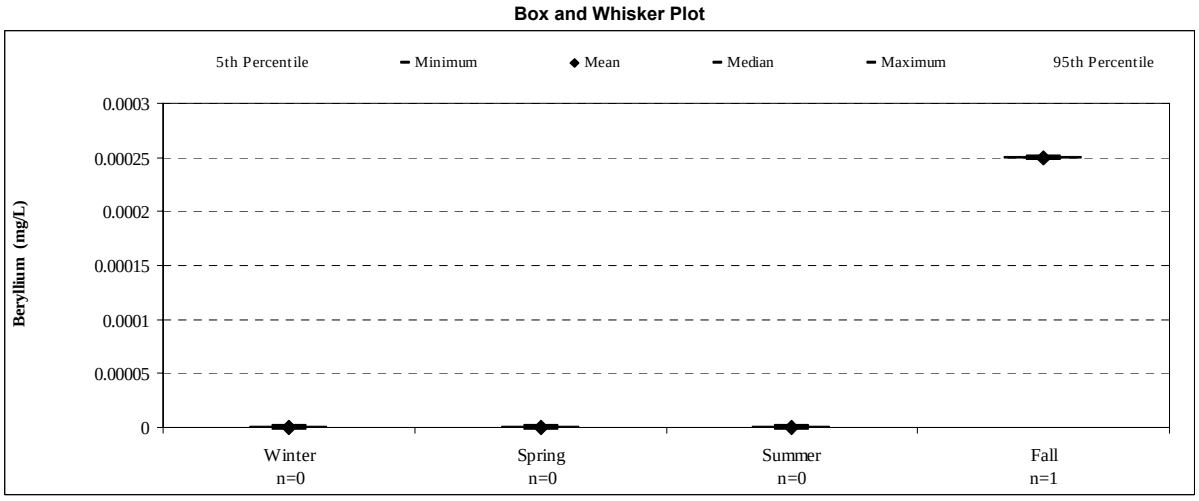


Figure G-1-9-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in McClelland Lake Fen



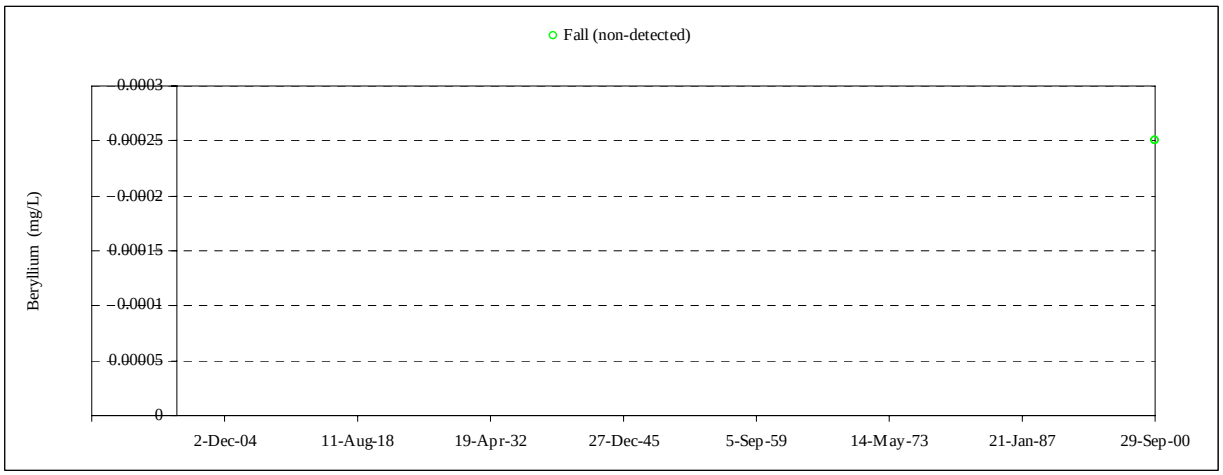
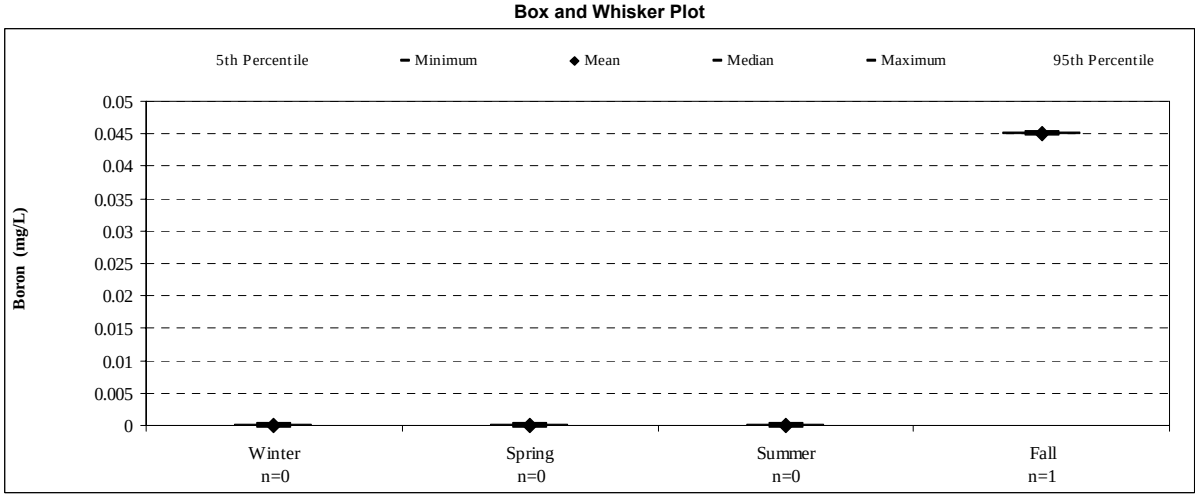


Figure G-1-9-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in McClelland Lake Fen



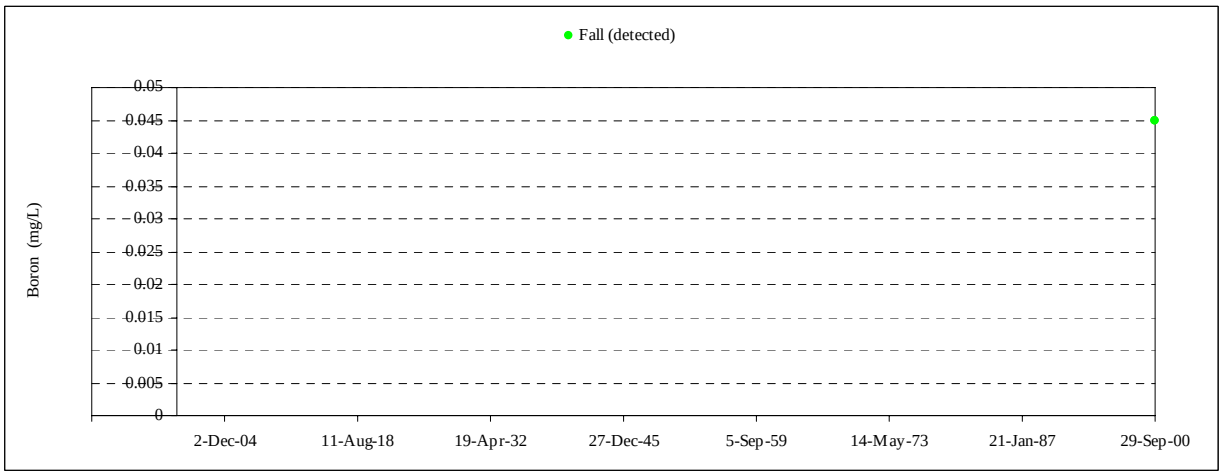
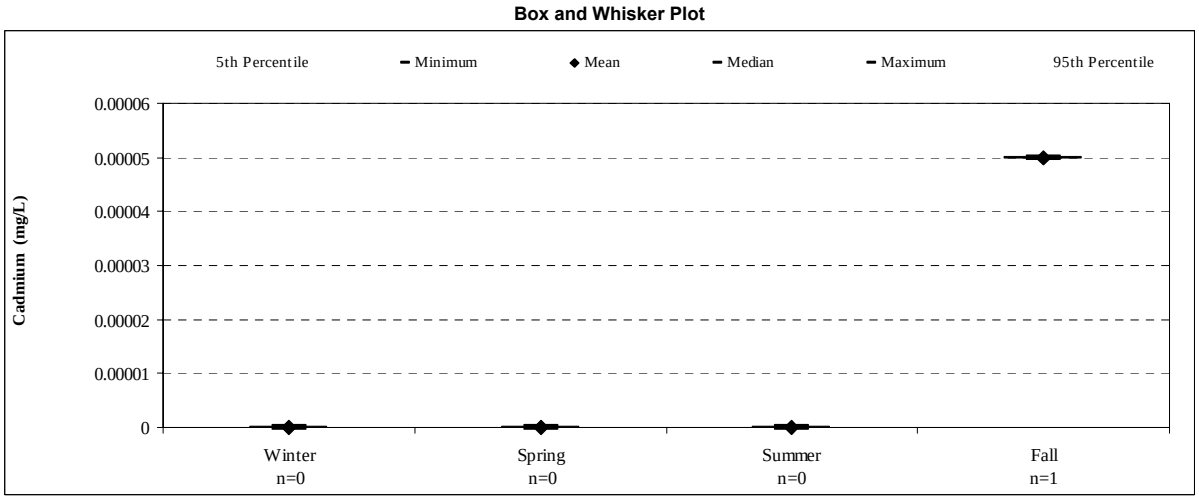


Figure G-1-9-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in McClelland Lake Fen



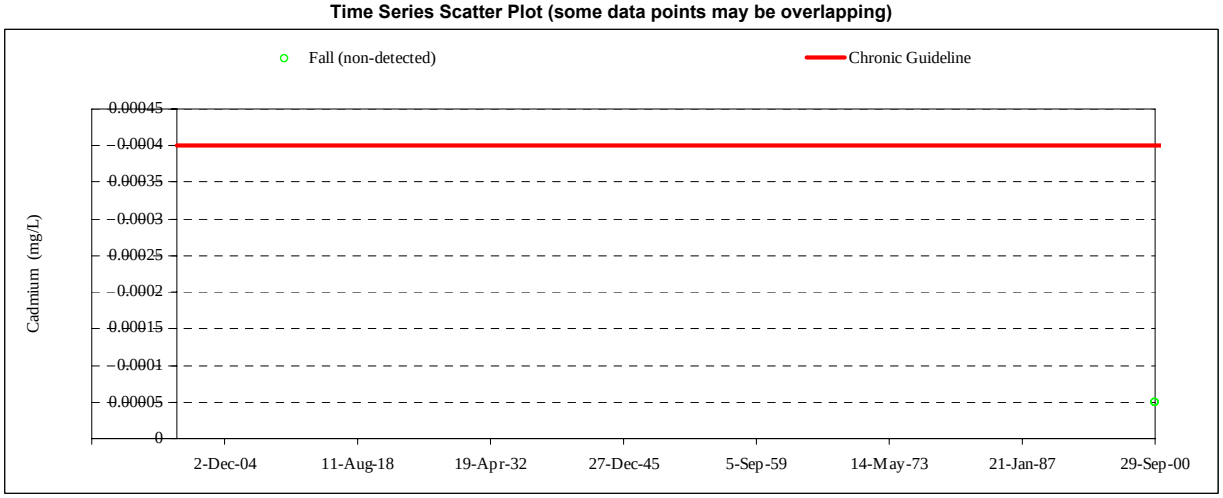
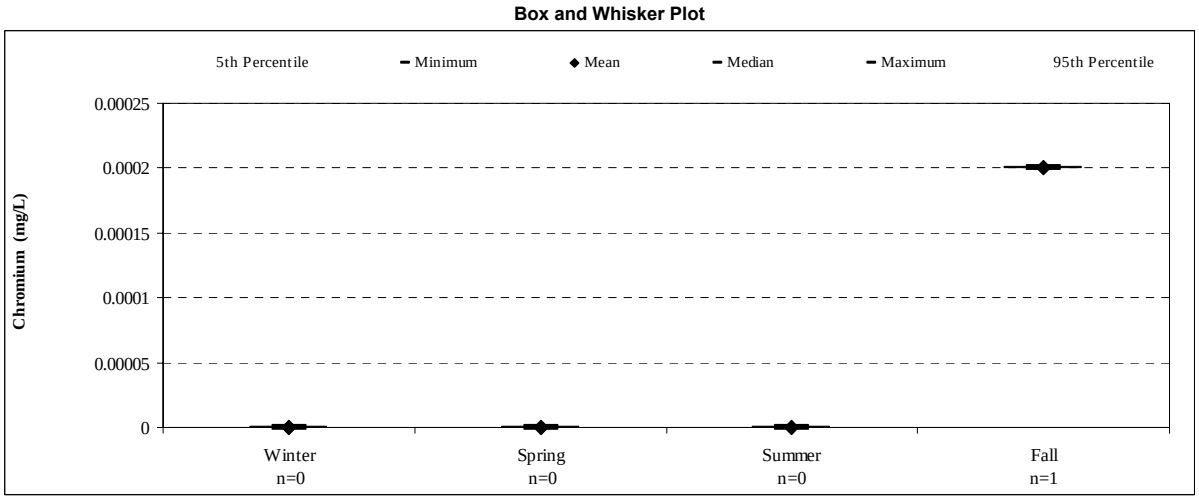


Figure G-1-9-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in McClelland Lake Fen



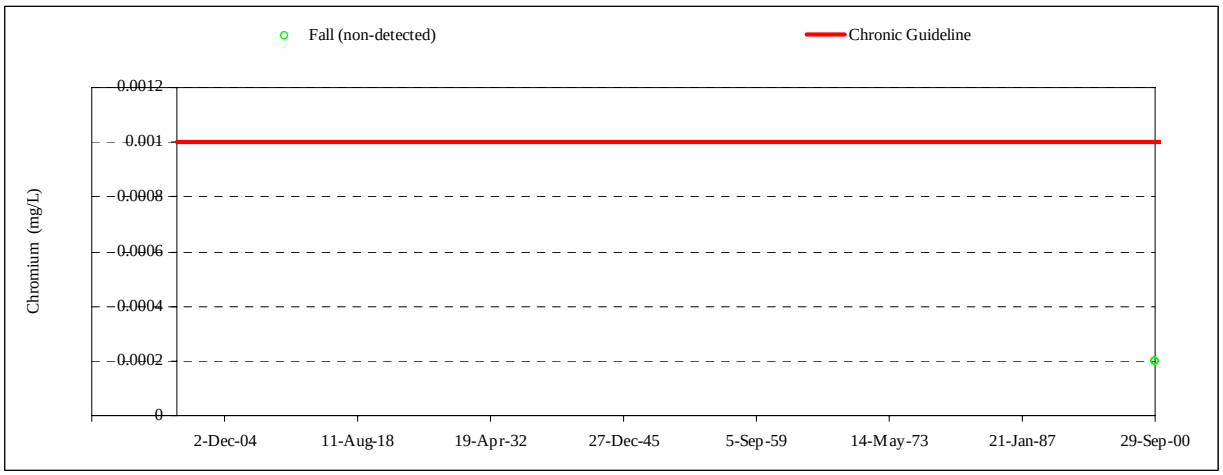
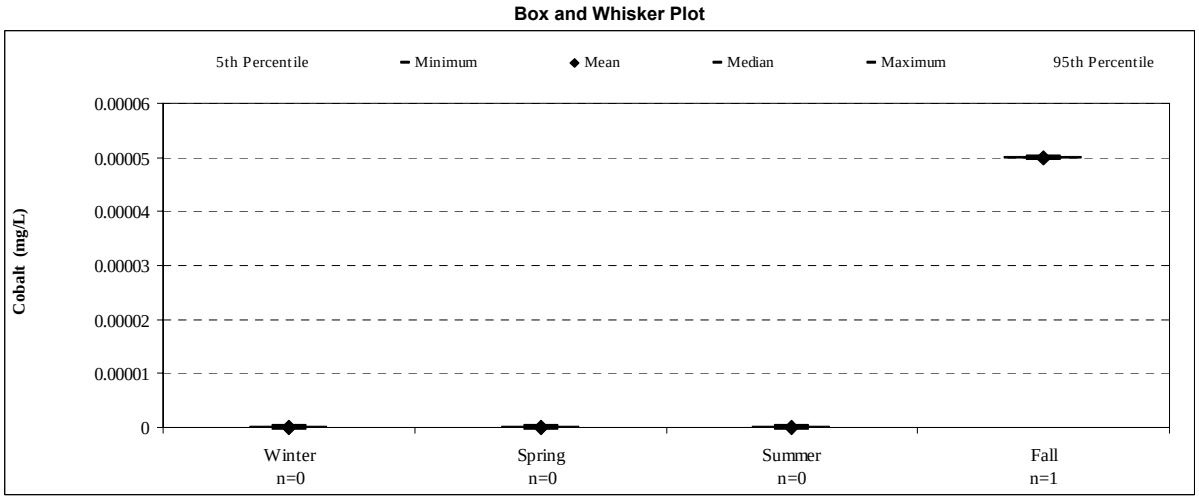


Figure G-1-9-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in McClelland Lake Fen



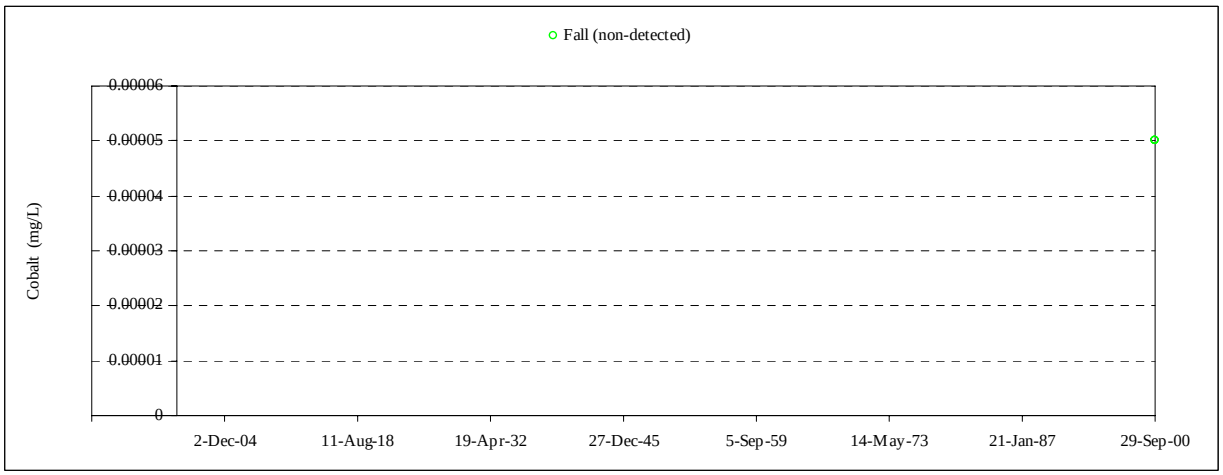
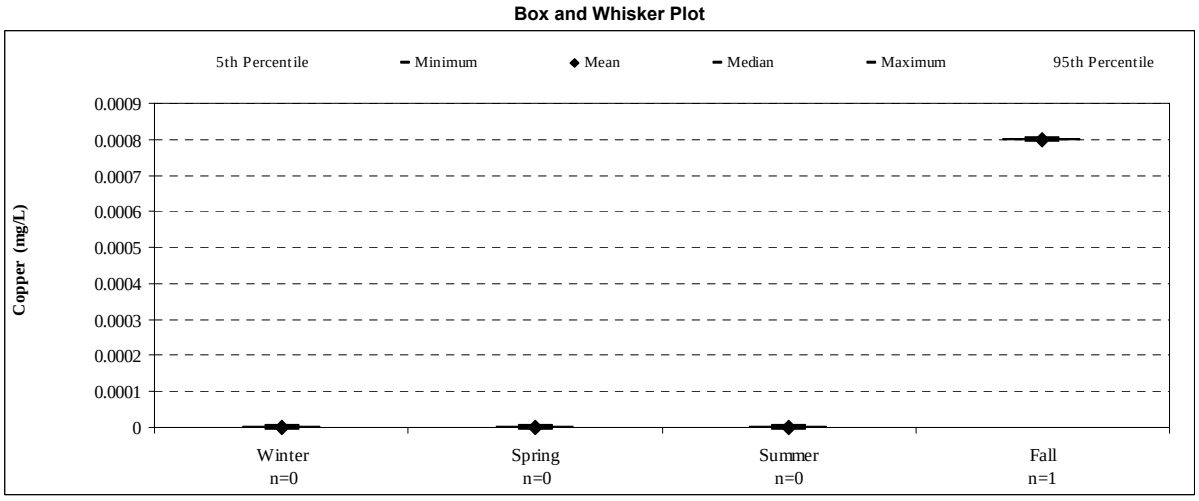


Figure G-1-9-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in McClelland Lake Fen



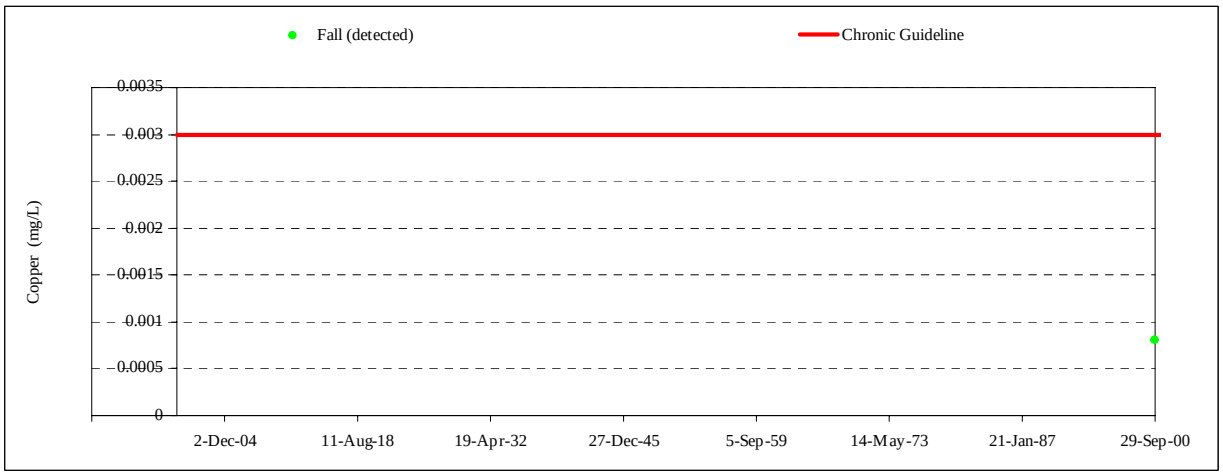
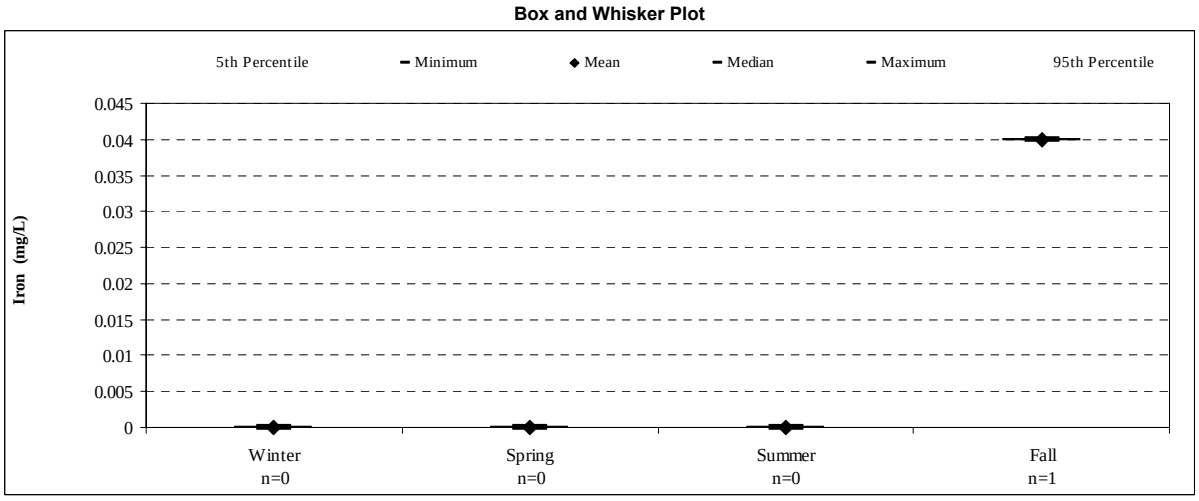


Figure G-1-9-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in McClelland Lake Fen



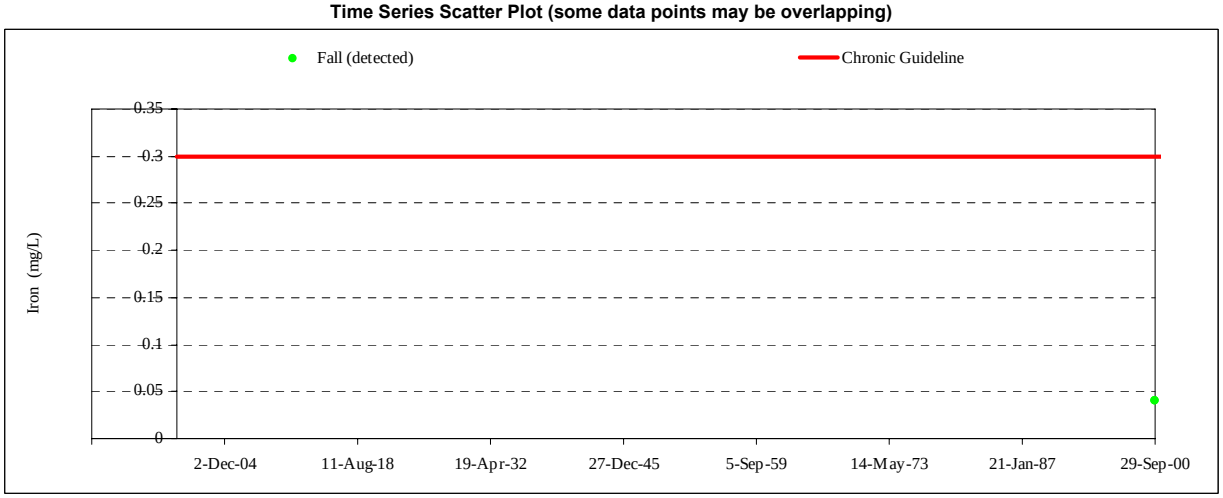
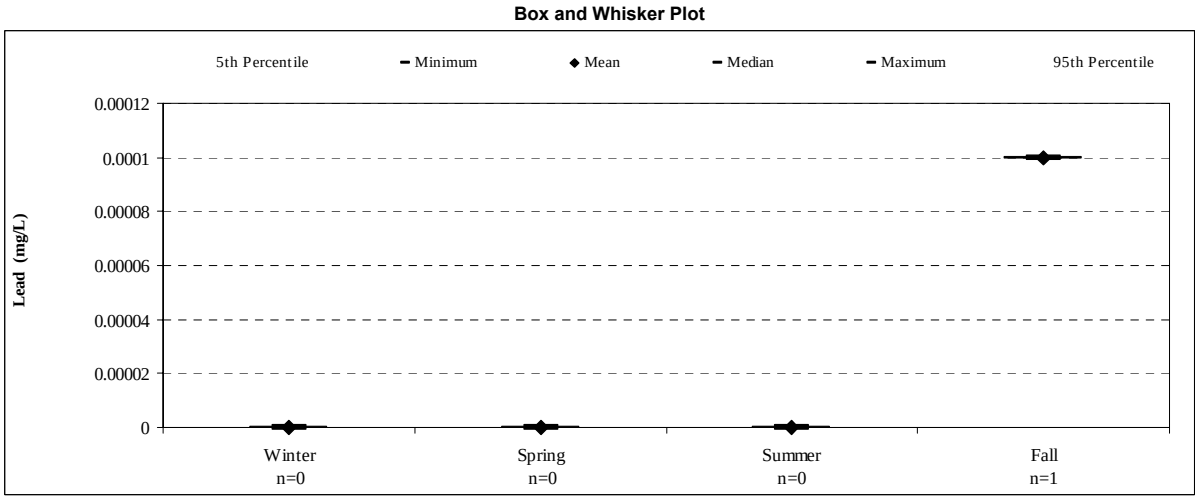


Figure G-1-9-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in McClelland Lake Fen



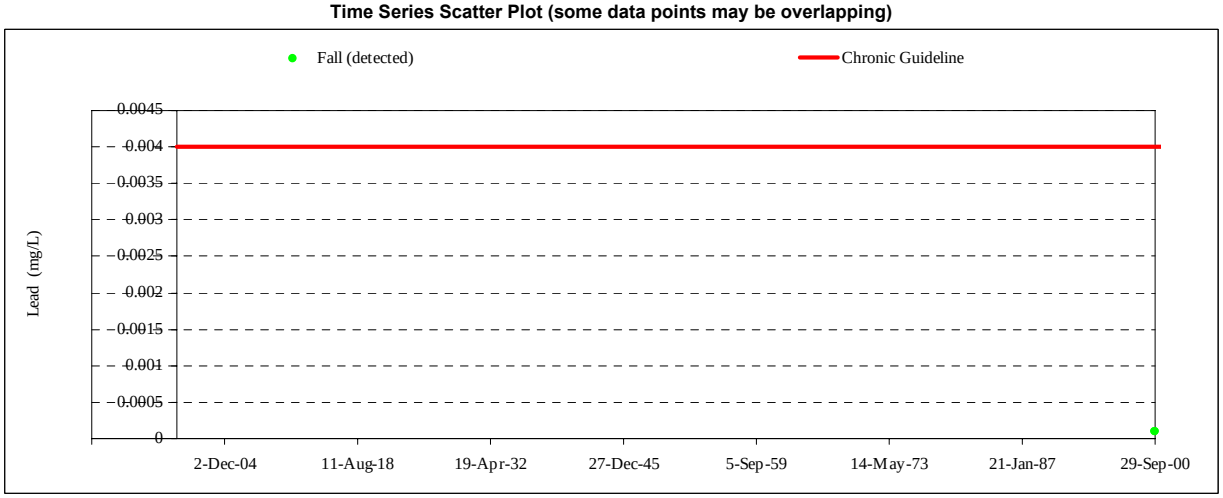
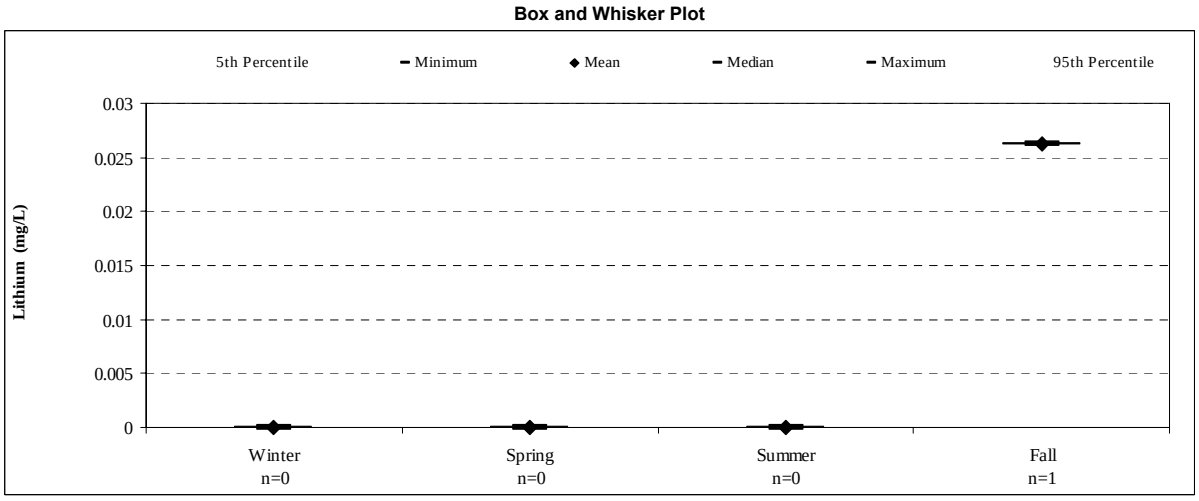


Figure G-1-9-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in McClelland Lake Fen



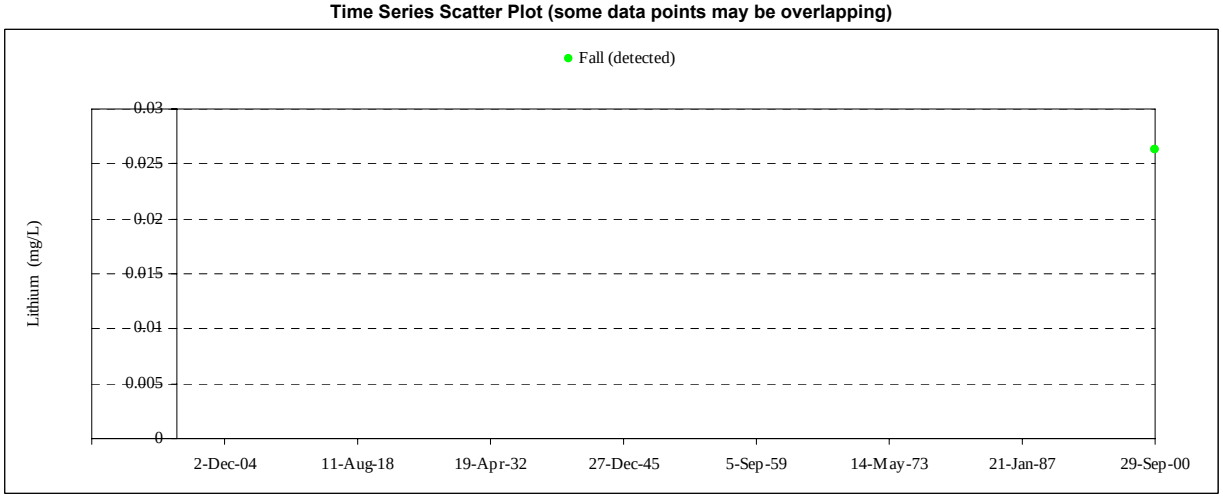
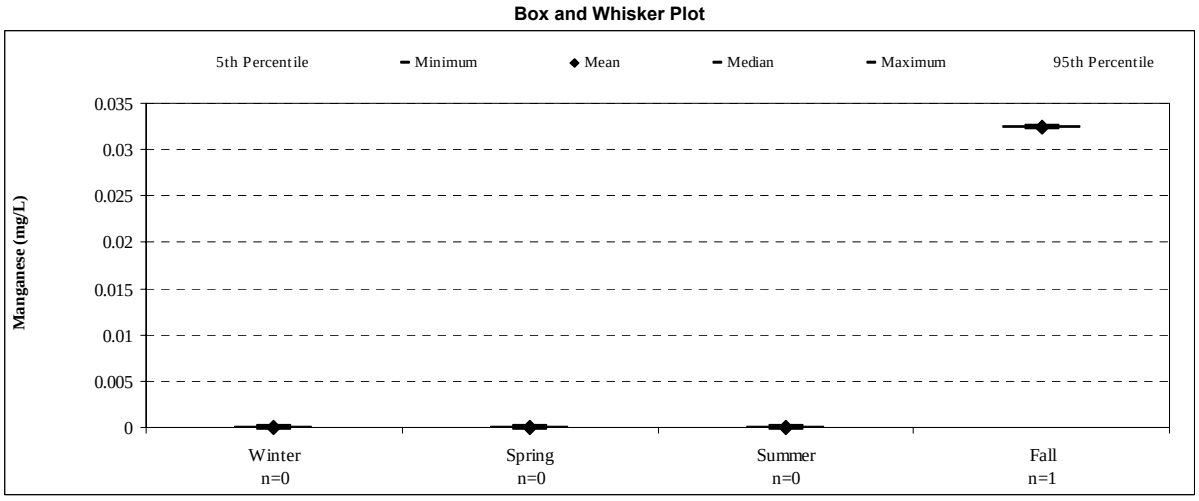


Figure G-1-9-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in McClelland Lake Fen



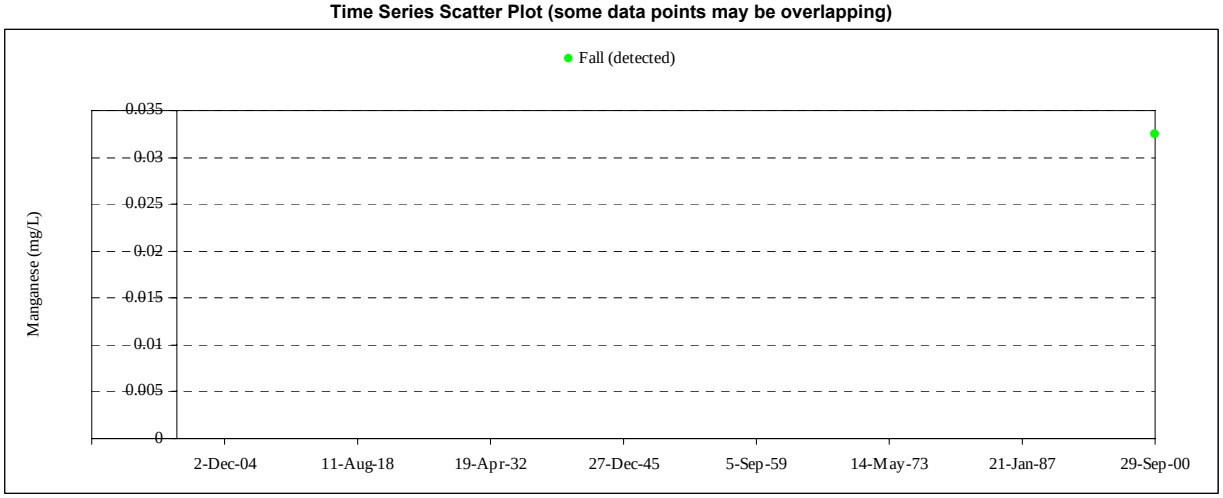
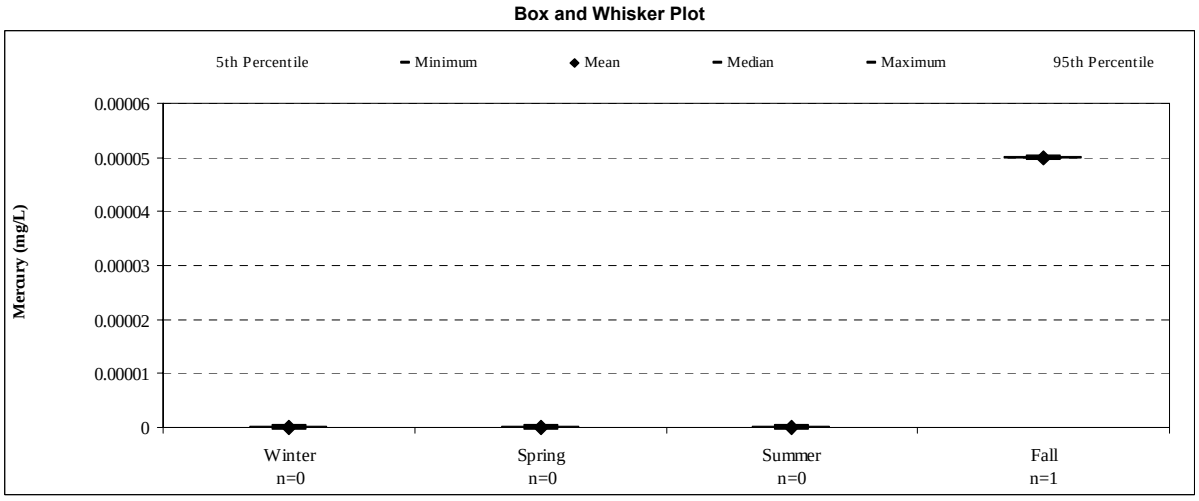


Figure G-1-9-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in McClelland Lake Fen



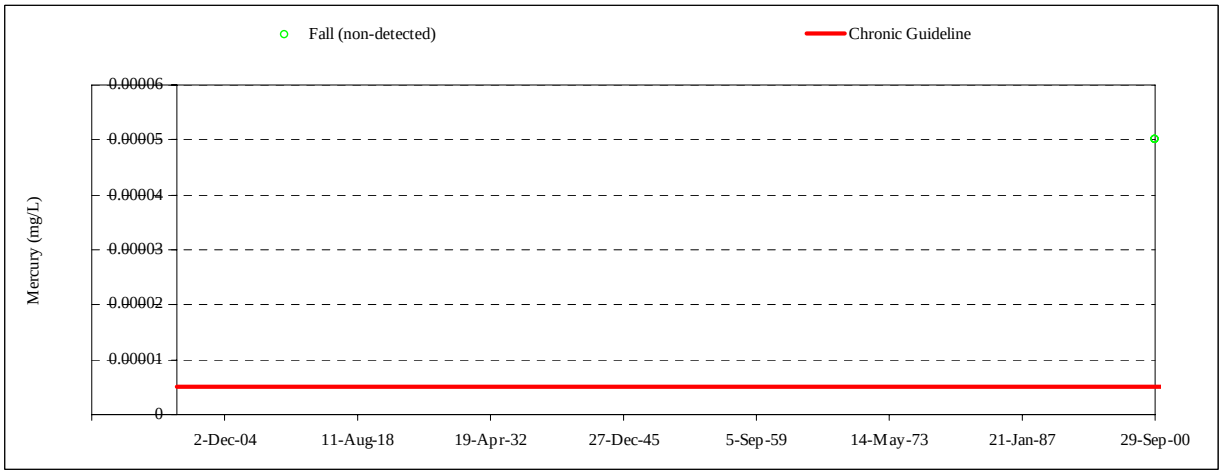
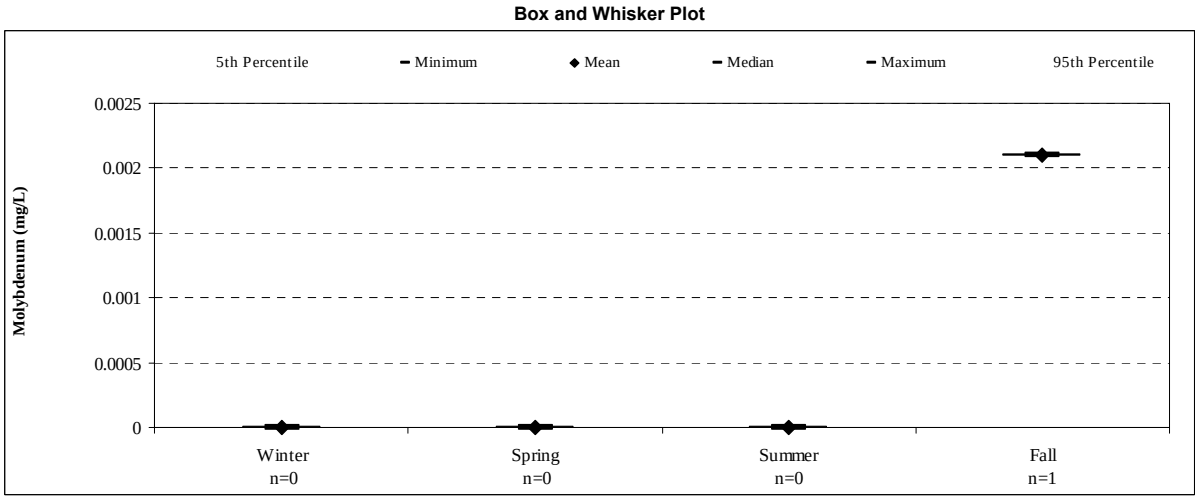


Figure G-1-9-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in McClelland Lake Fen



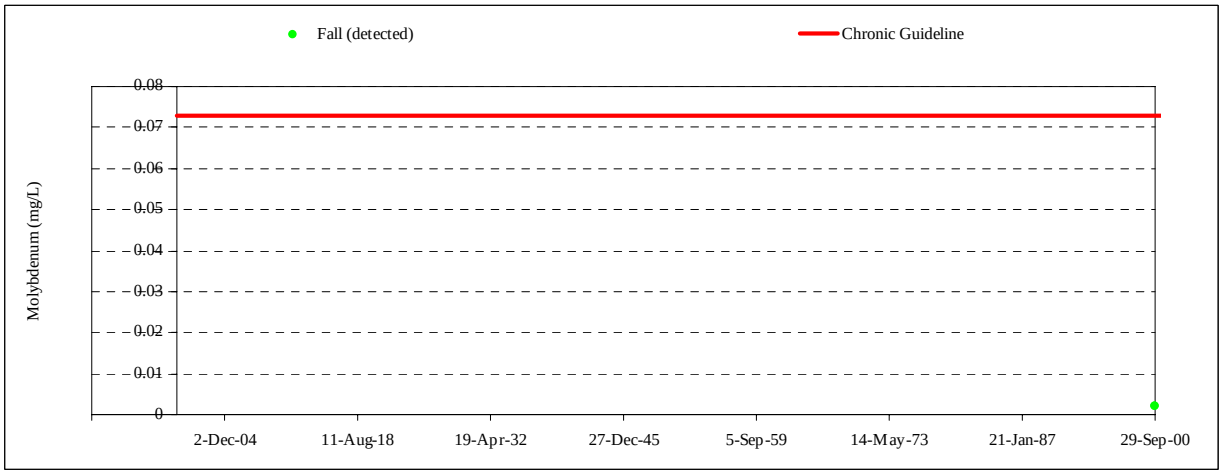
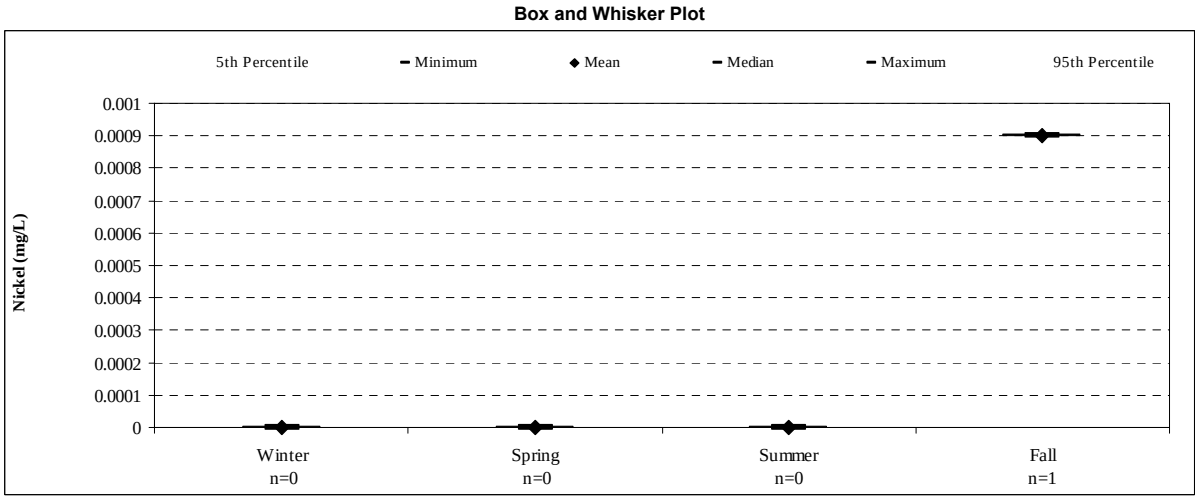


Figure G-1-9-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in McClelland Lake Fen



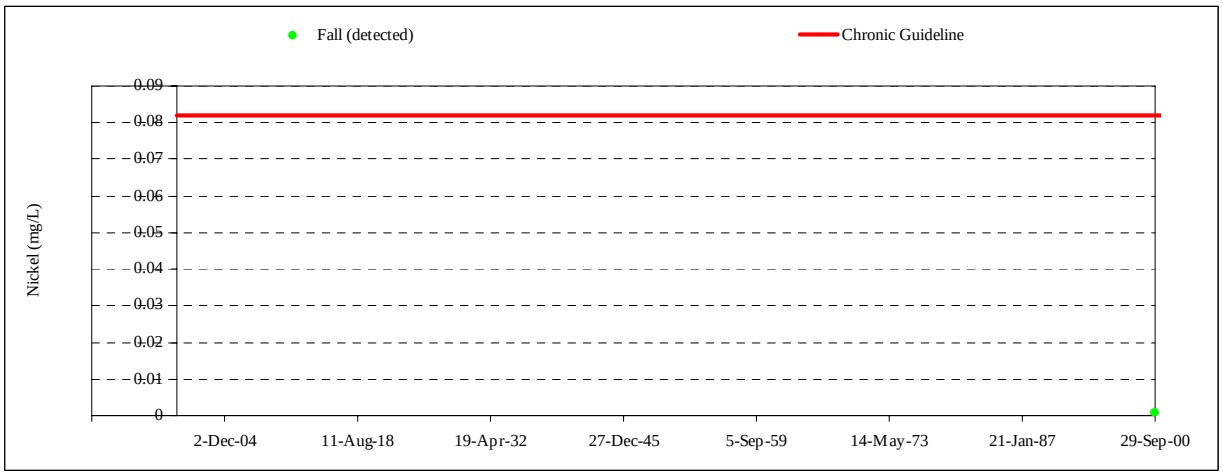
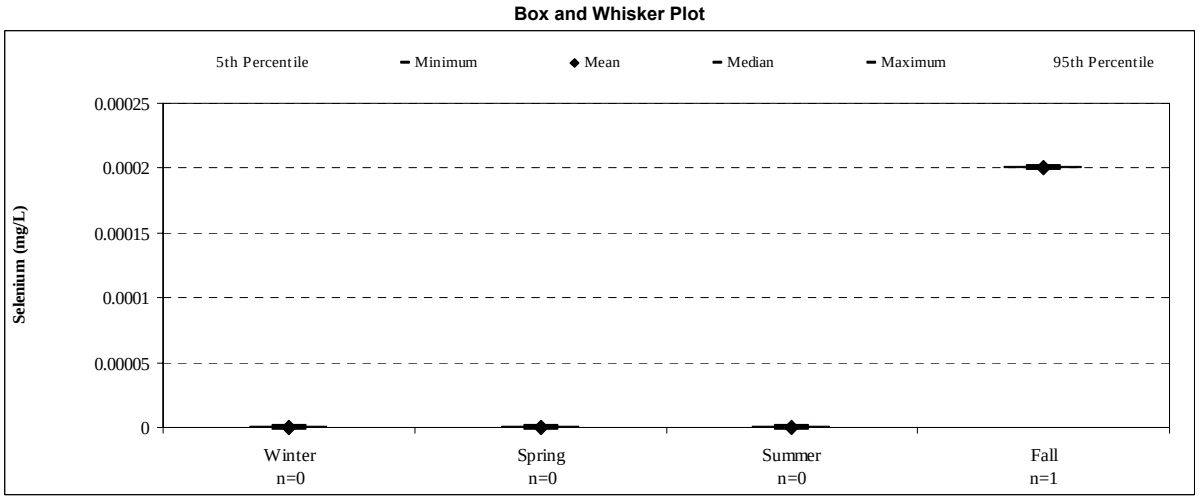


Figure G-1-9-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in McClelland Lake Fen



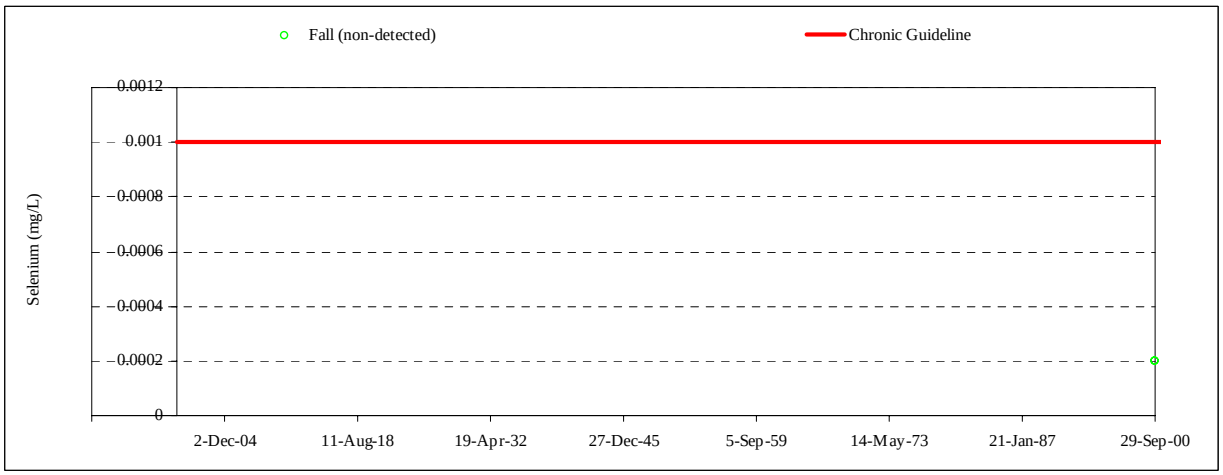
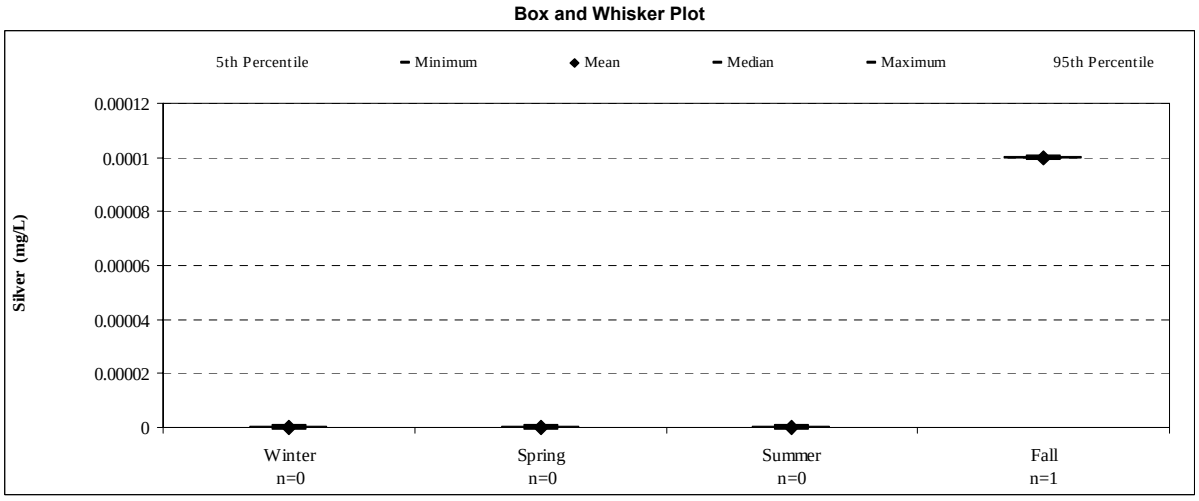


Figure G-1-9-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in McClelland Lake Fen



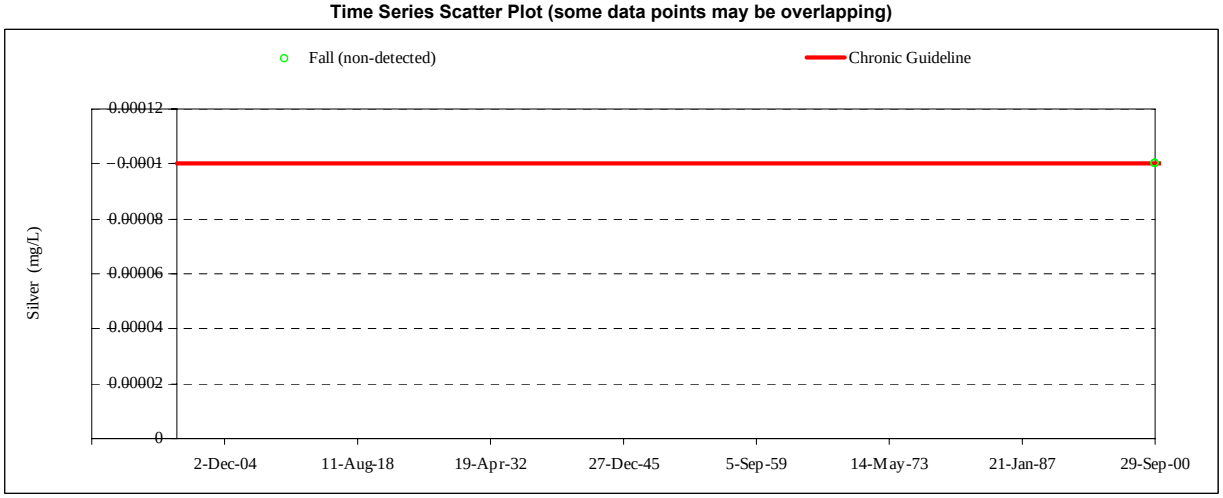
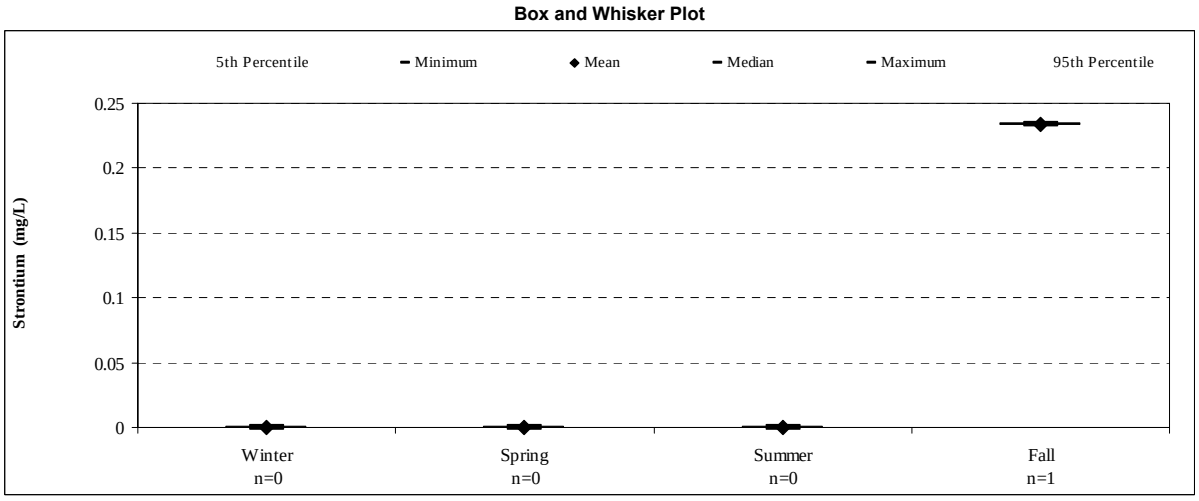


Figure G-1-9-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in McClelland Lake Fen



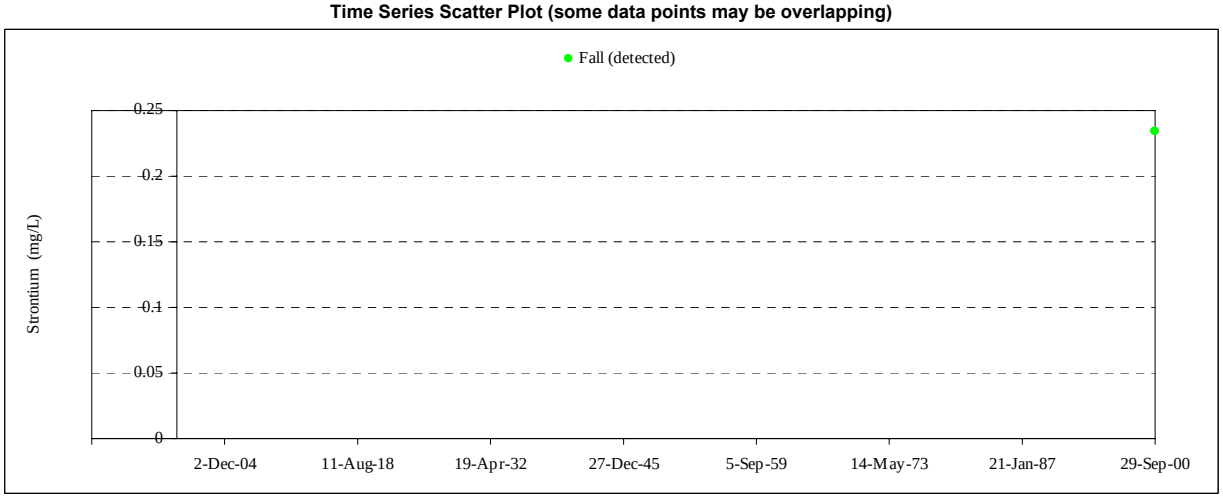
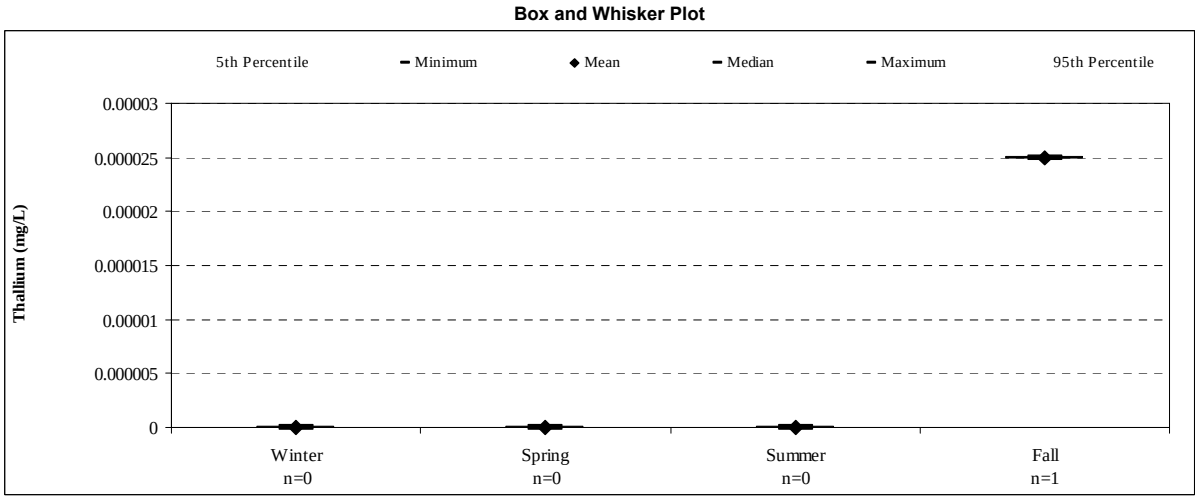


Figure G-1-9-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in McClelland Lake Fen



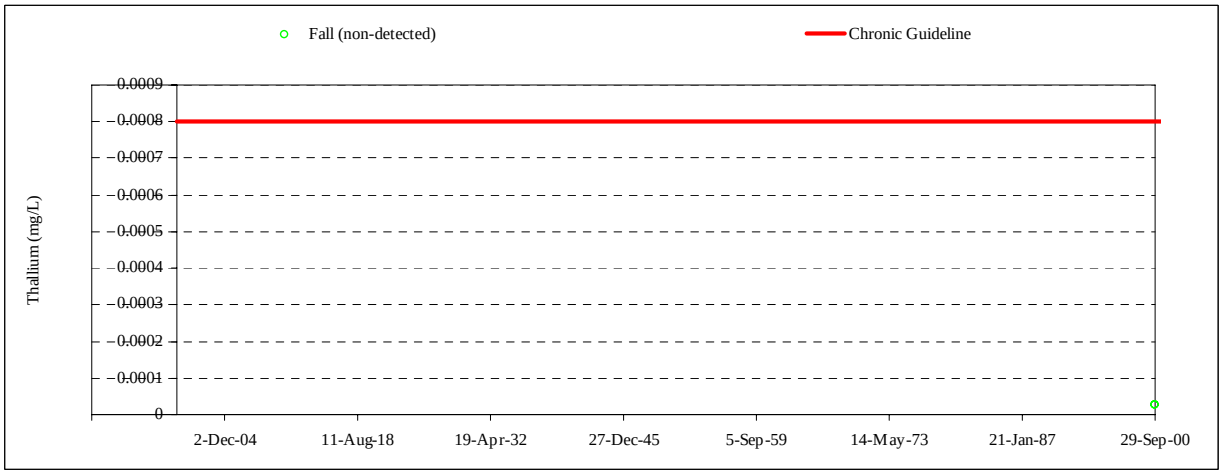
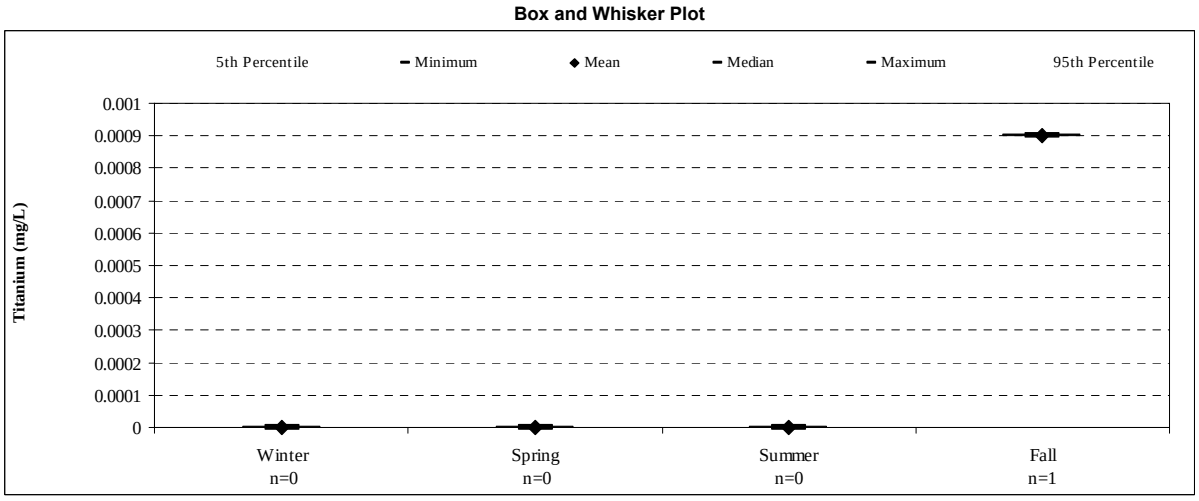


Figure G-1-9-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in McClelland Lake Fen



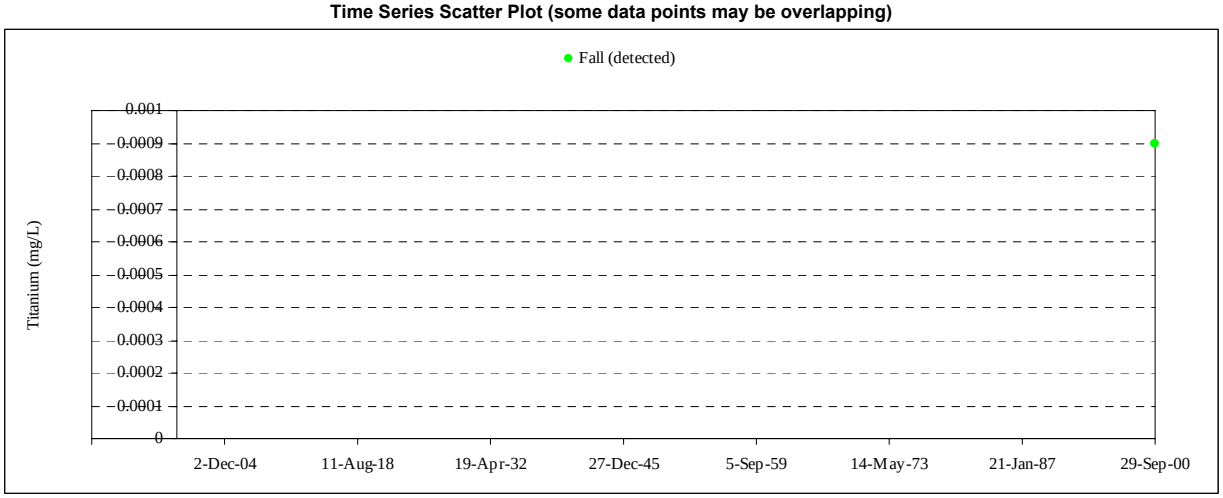
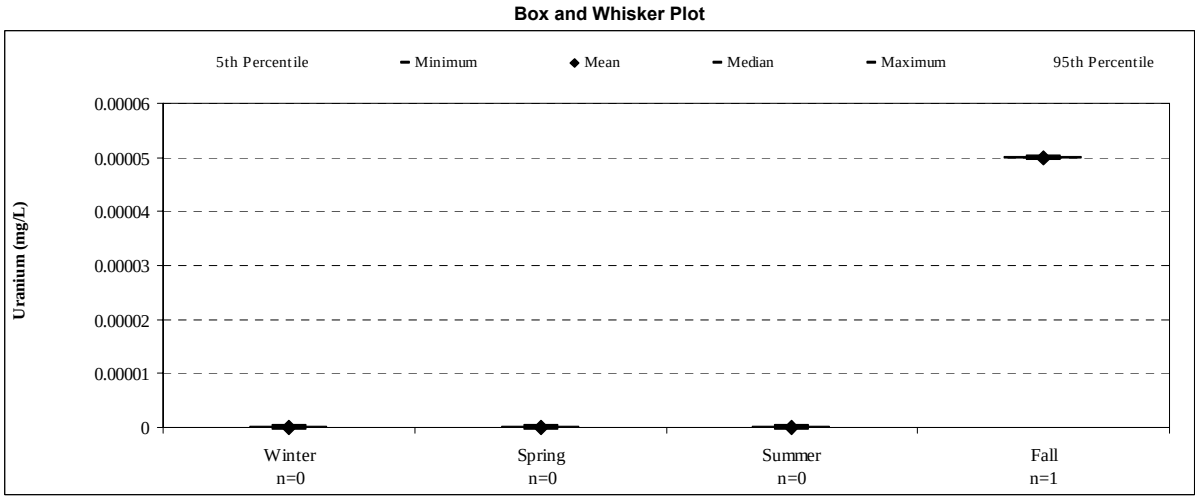


Figure G-1-9-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in McClelland Lake Fen



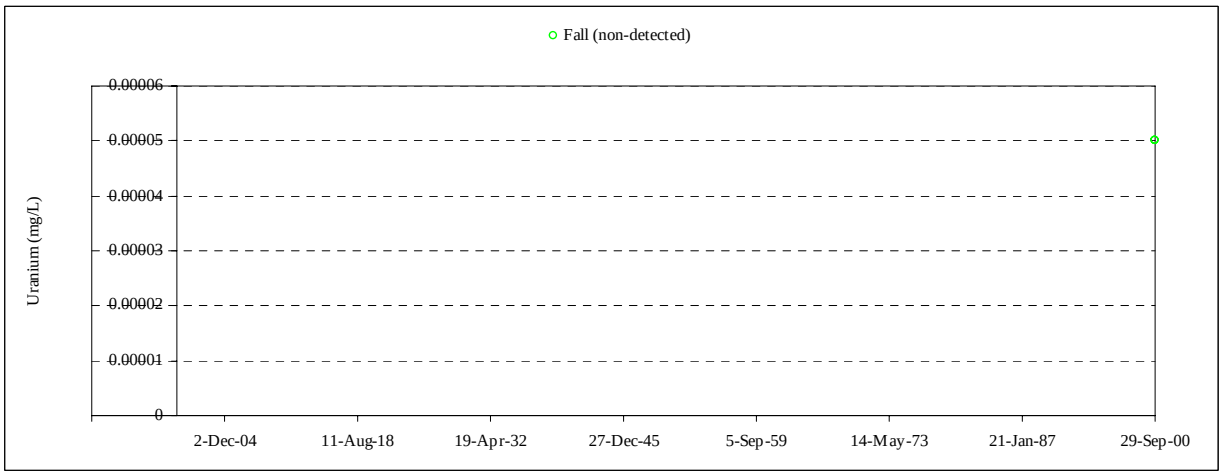
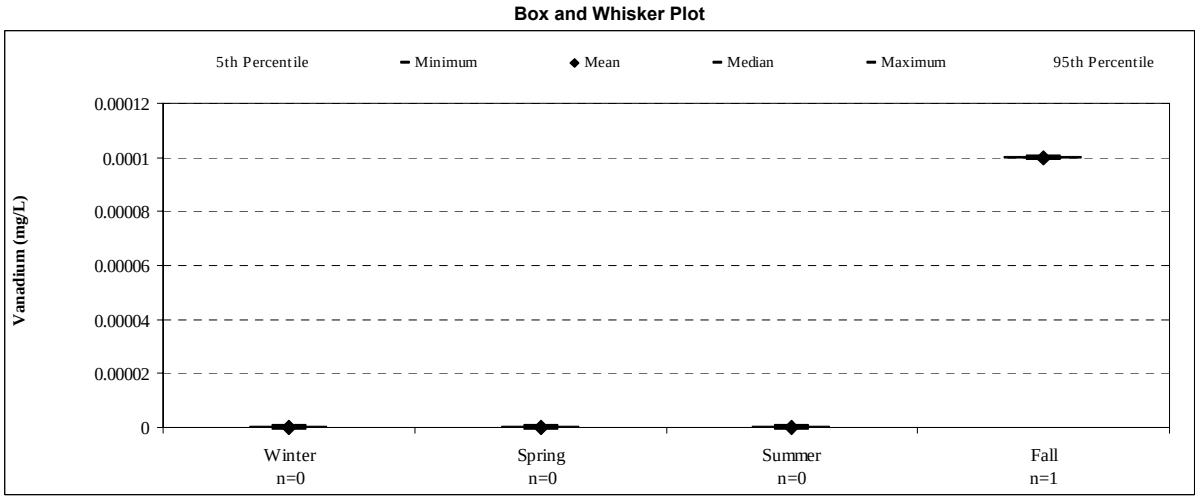


Figure G-1-9-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in McClelland Lake Fen



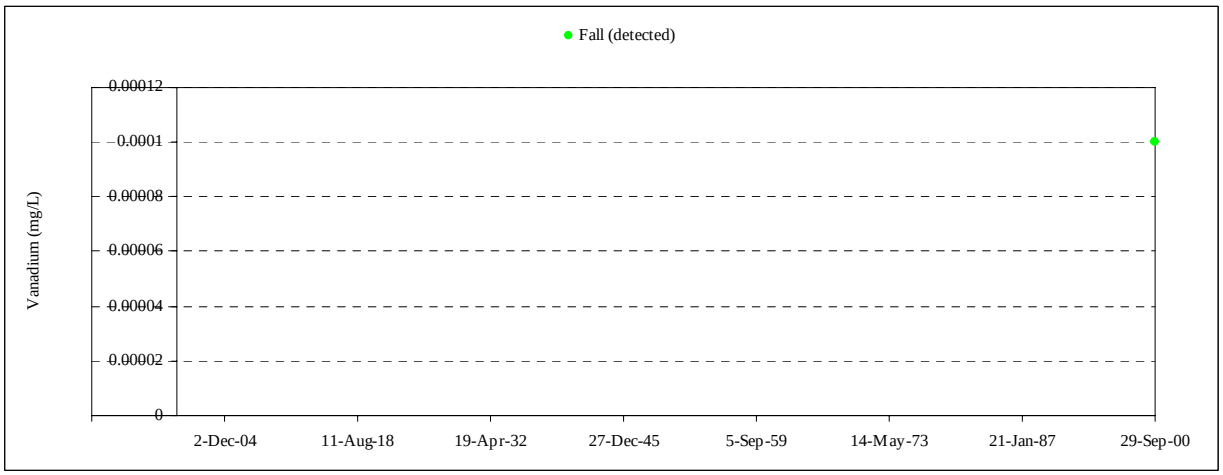
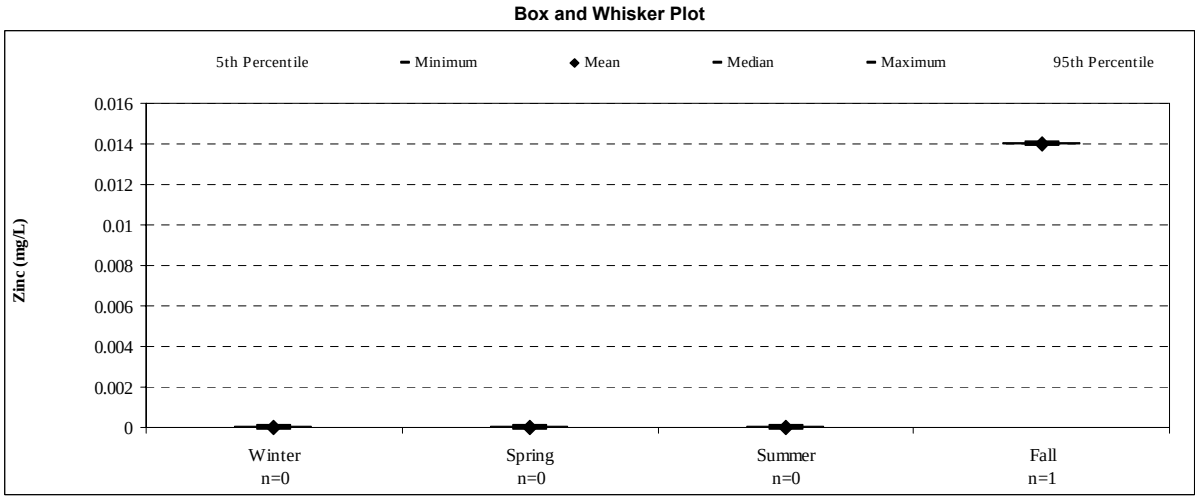


Figure G-1-9-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in McClelland Lake Fen



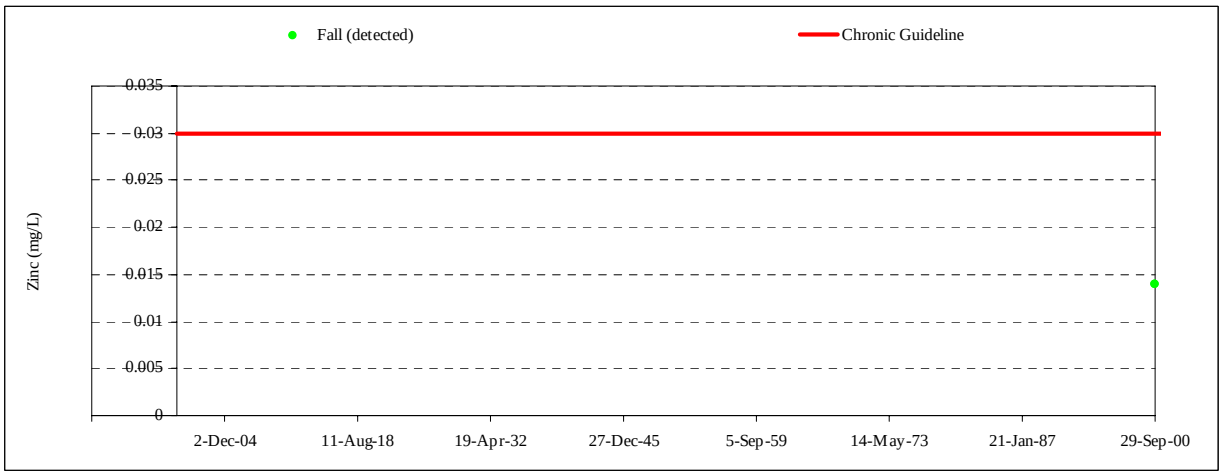


Table G-2. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Jackpine Mine Area

Water Quality Parameters	Muskeg River			Jackpine Creek	Shelly Creek	Stanley Creek	Muskeg Creek	Kearl Lake	Unnamed Lakes
	Upper Segment	Middle Segment	Lower Segment						
	Wapasu Creek and the headwater tributaries of the Muskeg River upstream of Wapasu Creek	Muskeg River upstream of Jackpine Creek	Muskeg River from Jackpine Creek to the mouth	Jackpine Creek and its tributaries	Shelley Creek	Stanley Creek	Muskeg Creek and its tributaries such as Blackfly Creek, Green Stockings Creek, Iyinimin Creek and Khahago Creek	Kearl Lake	Unnamed waterbodies in Muskeg River watershed
pH	G-2-1-1	G-2-2-1	G-2-3-1	G-2-4-1	G-2-5-1	G-2-6-1	G-2-7-1	G-2-8-1	G-2-9-1
Specific Conductance	G-2-1-2	G-2-2-2	G-2-3-2	G-2-4-2	G-2-5-2	G-2-6-2	G-2-7-2	G-2-8-2	G-2-9-2
Temperature	G-2-1-3	G-2-2-3	G-2-3-3	G-2-4-3	G-2-5-3	G-2-6-3	G-2-7-3	G-2-8-3	G-2-9-3
Dissolved Oxygen	G-2-1-4	G-2-2-4	G-2-3-4	G-2-4-4	G-2-5-4	G-2-6-4	G-2-7-4	G-2-8-4	G-2-9-4
Colour	G-2-1-5	G-2-2-5	G-2-3-5	G-2-4-5	G-2-5-5	G-2-6-5	G-2-7-5	G-2-8-5	G-2-9-5
Dissolved Organic Carbon	G-2-1-6	G-2-2-6	G-2-3-6	G-2-4-6	G-2-5-6	G-2-6-6	G-2-7-6	G-2-8-6	G-2-9-6
Hardness	G-2-1-7	G-2-2-7	G-2-3-7	G-2-4-7	G-2-5-7	G-2-6-7	G-2-7-7	G-2-8-7	G-2-9-7
Total Alkalinity	G-2-1-8	G-2-2-8	G-2-3-8	G-2-4-8	G-2-5-8	G-2-6-8	G-2-7-8	G-2-8-8	G-2-9-8
Total Dissolved Solids	G-2-1-9	G-2-2-9	G-2-3-9	G-2-4-9	G-2-5-9	G-2-6-9	G-2-7-9	G-2-8-9	G-2-9-9
Total Organic Carbon	G-2-1-10	G-2-2-10	G-2-3-10	G-2-4-10	G-2-5-10	G-2-6-10	G-2-7-10	G-2-8-10	G-2-9-10
Total Suspended Solids	G-2-1-11	G-2-2-11	G-2-3-11	G-2-4-11	G-2-5-11	G-2-6-11	G-2-7-11	G-2-8-11	G-2-9-11
Bicarbonate	G-2-1-12	G-2-2-12	G-2-3-12	G-2-4-12	G-2-5-12	G-2-6-12	G-2-7-12	G-2-8-12	G-2-9-12
Calcium	G-2-1-13	G-2-2-13	G-2-3-13	G-2-4-13	G-2-5-13	G-2-6-13	G-2-7-13	G-2-8-13	G-2-9-13
Carbonate	G-2-1-14	G-2-2-14	G-2-3-14	G-2-4-14	G-2-5-14	G-2-6-14	G-2-7-14	G-2-8-14	G-2-9-14
Chloride	G-2-1-15	G-2-2-15	G-2-3-15	G-2-4-15	G-2-5-15	G-2-6-15	G-2-7-15	G-2-8-15	G-2-9-15
Magnesium	G-2-1-16	G-2-2-16	G-2-3-16	G-2-4-16	G-2-5-16	G-2-6-16	G-2-7-16	G-2-8-16	G-2-9-16
Potassium	G-2-1-17	G-2-2-17	G-2-3-17	G-2-4-17	G-2-5-17	G-2-6-17	G-2-7-17	G-2-8-17	G-2-9-17
Sodium	G-2-1-18	G-2-2-18	G-2-3-18	G-2-4-18	G-2-5-18	G-2-6-18	G-2-7-18	G-2-8-18	G-2-9-18
Sulphate	G-2-1-19	G-2-2-19	G-2-3-19	G-2-4-19	G-2-5-19	G-2-6-19	G-2-7-19	G-2-8-19	G-2-9-19
Sulphide	G-2-1-20	G-2-2-20	G-2-3-20	G-2-4-20	G-2-5-20	G-2-6-20	G-2-7-20	G-2-8-20	G-2-9-20
Nitrate/Nitrite	G-2-1-21	G-2-2-21	G-2-3-21	G-2-4-21	G-2-5-21	G-2-6-21	G-2-7-21	G-2-8-21	G-2-9-21
Ammonia	G-2-1-22	G-2-2-22	G-2-3-22	G-2-4-22	G-2-5-22	G-2-6-22	G-2-7-22	G-2-8-22	G-2-9-22
Kjeldahl Nitrogen	G-2-1-23	G-2-2-23	G-2-3-23	G-2-4-23	G-2-5-23	G-2-6-23	G-2-7-23	G-2-8-23	G-2-9-23
Total Nitrogen	G-2-1-24	G-2-2-24	G-2-3-24	G-2-4-24	G-2-5-24	G-2-6-24	G-2-7-24	G-2-8-24	G-2-9-24
Total Phosphorus	G-2-1-25	G-2-2-25	G-2-3-25	G-2-4-25	G-2-5-25	G-2-6-25	G-2-7-25	G-2-8-25	G-2-9-25
Dissolved Phosphorus	G-2-1-26	G-2-2-26	G-2-3-26	G-2-4-26	G-2-5-26	G-2-6-26	G-2-7-26	G-2-8-26	G-2-9-26
Chlorophyll *a*	G-2-1-27	G-2-2-27	G-2-3-27	G-2-4-27	G-2-5-27	G-2-6-27	G-2-7-27	G-2-8-27	G-2-9-27
Biochemical Oxygen Demand	G-2-1-28	G-2-2-28	G-2-3-28	G-2-4-28	G-2-5-28	G-2-6-28	G-2-7-28	G-2-8-28	G-2-9-28
Naphthenic acids	G-2-1-29	G-2-2-29	G-2-3-29	G-2-4-29	G-2-5-29	G-2-6-29	G-2-7-29	G-2-8-29	G-2-9-29
Total Phenolics	G-2-1-30	G-2-2-30	G-2-3-30	G-2-4-30	G-2-5-30	G-2-6-30	G-2-7-30	G-2-8-30	G-2-9-30
Total Recoverable Hydrocarbons	G-2-1-31	G-2-2-31	G-2-3-31	G-2-4-31	G-2-5-31	G-2-6-31	G-2-7-31	G-2-8-31	G-2-9-31
Microtox IC50 @ 15 min	G-2-1-32	G-2-2-32	G-2-3-32	G-2-4-32	G-2-5-32	G-2-6-32	G-2-7-32	G-2-8-32	G-2-9-32
Microtox IC25 @ 15 min	G-2-1-33	G-2-2-33	G-2-3-33	G-2-4-33	G-2-5-33	G-2-6-33	G-2-7-33	G-2-8-33	G-2-9-33
Algal Growth Inhibition Test (72 h) - IC25	G-2-1-34	G-2-2-34	G-2-3-34	G-2-4-34	G-2-5-34	G-2-6-34	G-2-7-34	G-2-8-34	G-2-9-34
Algal Growth Inhibition Test (72 h) - IC50	G-2-1-35	G-2-2-35	G-2-3-35	G-2-4-35	G-2-5-35	G-2-6-35	G-2-7-35	G-2-8-35	G-2-9-35
Algal Growth Inhibition Test (72 h) - LOEC	G-2-1-36	G-2-2-36	G-2-3-36	G-2-4-36	G-2-5-36	G-2-6-36	G-2-7-36	G-2-8-36	G-2-9-36
Algal Growth Inhibition Test (72 h) - NOEC	G-2-1-37	G-2-2-37	G-2-3-37	G-2-4-37	G-2-5-37	G-2-6-37	G-2-7-37	G-2-8-37	G-2-9-37
Ceriodaphnia 7 d Mortality Test - LC25	G-2-1-38	G-2-2-38	G-2-3-38	G-2-4-38	G-2-5-38	G-2-6-38	G-2-7-38	G-2-8-38	G-2-9-38
Ceriodaphnia 7 d Mortality Test - LC50	G-2-1-39	G-2-2-39	G-2-3-39	G-2-4-39	G-2-5-39	G-2-6-39	G-2-7-39	G-2-8-39	G-2-9-39
Ceriodaphnia 7 d Mortality Test - LOEC	G-2-1-40	G-2-2-40	G-2-3-40	G-2-4-40	G-2-5-40	G-2-6-40	G-2-7-40	G-2-8-40	G-2-9-40

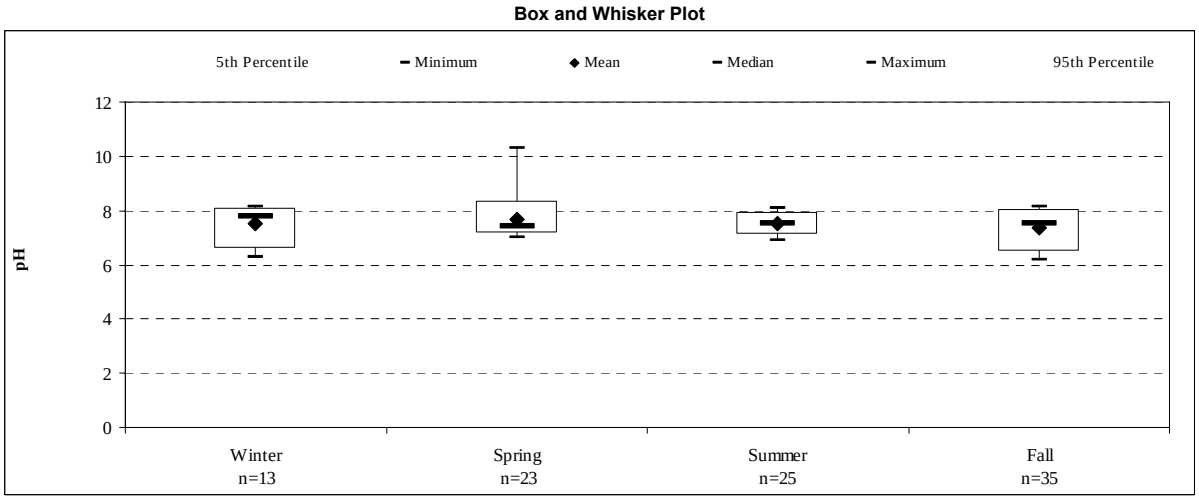
Table G-2. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Jackpine Mine Area

Water Quality Parameters	Muskeg River			Jackpine Creek	Shelly Creek	Stanley Creek	Muskeg Creek	Kearl Lake	Unnamed Lakes
	Upper Segment	Middle Segment	Lower Segment						
Ceriodaphnia 7 d Mortality Test - NOEC	G-2-1-41	G-2-2-41	G-2-3-41	G-2-4-41	G-2-5-41	G-2-6-41	G-2-7-41	G-2-8-41	G-2-9-41
Ceriodaphnia 7 d Reproduction Test - IC25	G-2-1-42	G-2-2-42	G-2-3-42	G-2-4-42	G-2-5-42	G-2-6-42	G-2-7-42	G-2-8-42	G-2-9-42
Ceriodaphnia 7 d Reproduction Test - IC50	G-2-1-43	G-2-2-43	G-2-3-43	G-2-4-43	G-2-5-43	G-2-6-43	G-2-7-43	G-2-8-43	G-2-9-43
Ceriodaphnia 7 d Reproduction Test - LOEC	G-2-1-44	G-2-2-44	G-2-3-44	G-2-4-44	G-2-5-44	G-2-6-44	G-2-7-44	G-2-8-44	G-2-9-44
Ceriodaphnia 7 d Reproduction Test - NOEC	G-2-1-45	G-2-2-45	G-2-3-45	G-2-4-45	G-2-5-45	G-2-6-45	G-2-7-45	G-2-8-45	G-2-9-45
Daphnia 48 h Static Acute Test - LC25	G-2-1-46	G-2-2-46	G-2-3-46	G-2-4-46	G-2-5-46	G-2-6-46	G-2-7-46	G-2-8-46	G-2-9-46
Daphnia 48 h Static Acute Test - LC50	G-2-1-47	G-2-2-47	G-2-3-47	G-2-4-47	G-2-5-47	G-2-6-47	G-2-7-47	G-2-8-47	G-2-9-47
Daphnia 48 h Static Acute Test - LOEC	G-2-1-48	G-2-2-48	G-2-3-48	G-2-4-48	G-2-5-48	G-2-6-48	G-2-7-48	G-2-8-48	G-2-9-48
Daphnia 48 h Static Acute Test - NOEC	G-2-1-49	G-2-2-49	G-2-3-49	G-2-4-49	G-2-5-49	G-2-6-49	G-2-7-49	G-2-8-49	G-2-9-49
Fathead Minnow 7d Growth - IC25	G-2-1-50	G-2-2-50	G-2-3-50	G-2-4-50	G-2-5-50	G-2-6-50	G-2-7-50	G-2-8-50	G-2-9-50
Fathead Minnow 7d Growth - IC50	G-2-1-51	G-2-2-51	G-2-3-51	G-2-4-51	G-2-5-51	G-2-6-51	G-2-7-51	G-2-8-51	G-2-9-51
Fathead Minnow 7d Growth - LOEC	G-2-1-52	G-2-2-52	G-2-3-52	G-2-4-52	G-2-5-52	G-2-6-52	G-2-7-52	G-2-8-52	G-2-9-52
Fathead Minnow 7d Growth - NOEC	G-2-1-53	G-2-2-53	G-2-3-53	G-2-4-53	G-2-5-53	G-2-6-53	G-2-7-53	G-2-8-53	G-2-9-53
Fathead Minnow 7d Mortality Test - LC25	G-2-1-54	G-2-2-54	G-2-3-54	G-2-4-54	G-2-5-54	G-2-6-54	G-2-7-54	G-2-8-54	G-2-9-54
Fathead Minnow 7d Mortality Test - LC50	G-2-1-55	G-2-2-55	G-2-3-55	G-2-4-55	G-2-5-55	G-2-6-55	G-2-7-55	G-2-8-55	G-2-9-55
Fathead Minnow 7d Mortality Test - LOEC	G-2-1-56	G-2-2-56	G-2-3-56	G-2-4-56	G-2-5-56	G-2-6-56	G-2-7-56	G-2-8-56	G-2-9-56
Fathead Minnow 7d Mortality Test - NOEC	G-2-1-57	G-2-2-57	G-2-3-57	G-2-4-57	G-2-5-57	G-2-6-57	G-2-7-57	G-2-8-57	G-2-9-57
Trout 96 h Static Acute Test - LC25	G-2-1-58	G-2-2-58	G-2-3-58	G-2-4-58	G-2-5-58	G-2-6-58	G-2-7-58	G-2-8-58	G-2-9-58
Trout 96 h Static Acute Test - LC50	G-2-1-59	G-2-2-59	G-2-3-59	G-2-4-59	G-2-5-59	G-2-6-59	G-2-7-59	G-2-8-59	G-2-9-59
Trout 96 h Static Acute Test - LOEC	G-2-1-60	G-2-2-60	G-2-3-60	G-2-4-60	G-2-5-60	G-2-6-60	G-2-7-60	G-2-8-60	G-2-9-60
Trout 96 h Static Acute Test - NOEC	G-2-1-61	G-2-2-61	G-2-3-61	G-2-4-61	G-2-5-61	G-2-6-61	G-2-7-61	G-2-8-61	G-2-9-61
Aluminum	G-2-1-62	G-2-2-62	G-2-3-62	G-2-4-62	G-2-5-62	G-2-6-62	G-2-7-62	G-2-8-62	G-2-9-62
Antimony	G-2-1-63	G-2-2-63	G-2-3-63	G-2-4-63	G-2-5-63	G-2-6-63	G-2-7-63	G-2-8-63	G-2-9-63
Arsenic	G-2-1-64	G-2-2-64	G-2-3-64	G-2-4-64	G-2-5-64	G-2-6-64	G-2-7-64	G-2-8-64	G-2-9-64
Barium	G-2-1-65	G-2-2-65	G-2-3-65	G-2-4-65	G-2-5-65	G-2-6-65	G-2-7-65	G-2-8-65	G-2-9-65
Beryllium	G-2-1-66	G-2-2-66	G-2-3-66	G-2-4-66	G-2-5-66	G-2-6-66	G-2-7-66	G-2-8-66	G-2-9-66
Boron	G-2-1-67	G-2-2-67	G-2-3-67	G-2-4-67	G-2-5-67	G-2-6-67	G-2-7-67	G-2-8-67	G-2-9-67
Cadmium	G-2-1-68	G-2-2-68	G-2-3-68	G-2-4-68	G-2-5-68	G-2-6-68	G-2-7-68	G-2-8-68	G-2-9-68
Chromium	G-2-1-69	G-2-2-69	G-2-3-69	G-2-4-69	G-2-5-69	G-2-6-69	G-2-7-69	G-2-8-69	G-2-9-69
Chromium - hexavalent	G-2-1-70	G-2-2-70	G-2-3-70	G-2-4-70	G-2-5-70	G-2-6-70	G-2-7-70	G-2-8-70	G-2-9-70
Cobalt	G-2-1-71	G-2-2-71	G-2-3-71	G-2-4-71	G-2-5-71	G-2-6-71	G-2-7-71	G-2-8-71	G-2-9-71
Copper	G-2-1-72	G-2-2-72	G-2-3-72	G-2-4-72	G-2-5-72	G-2-6-72	G-2-7-72	G-2-8-72	G-2-9-72
Iron	G-2-1-73	G-2-2-73	G-2-3-73	G-2-4-73	G-2-5-73	G-2-6-73	G-2-7-73	G-2-8-73	G-2-9-73
Lead	G-2-1-74	G-2-2-74	G-2-3-74	G-2-4-74	G-2-5-74	G-2-6-74	G-2-7-74	G-2-8-74	G-2-9-74
Lithium	G-2-1-75	G-2-2-75	G-2-3-75	G-2-4-75	G-2-5-75	G-2-6-75	G-2-7-75	G-2-8-75	G-2-9-75

Table G-2. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Jackpine Mine Area

Water Quality Parameters	Muskeg River			Jackpine Creek	Shelly Creek	Stanley Creek	Muskeg Creek	Kearl Lake	Unnamed Lakes
	Upper Segment	Middle Segment	Lower Segment						
Manganese	G-2-1-76	G-2-2-76	G-2-3-76	G-2-4-76	G-2-5-76	G-2-6-76	G-2-7-76	G-2-8-76	G-2-9-76
Mercury	G-2-1-77	G-2-2-77	G-2-3-77	G-2-4-77	G-2-5-77	G-2-6-77	G-2-7-77	G-2-8-77	G-2-9-77
Methyl Mercury	G-2-1-78	G-2-2-78	G-2-3-78	G-2-4-78	G-2-5-78	G-2-6-78	G-2-7-78	G-2-8-78	G-2-9-78
Molybdenum	G-2-1-79	G-2-2-79	G-2-3-79	G-2-4-79	G-2-5-79	G-2-6-79	G-2-7-79	G-2-8-79	G-2-9-79
Nickel	G-2-1-80	G-2-2-80	G-2-3-80	G-2-4-80	G-2-5-80	G-2-6-80	G-2-7-80	G-2-8-80	G-2-9-80
Selenium	G-2-1-81	G-2-2-81	G-2-3-81	G-2-4-81	G-2-5-81	G-2-6-81	G-2-7-81	G-2-8-81	G-2-9-81
Silicon	G-2-1-82	G-2-2-82	G-2-3-82	G-2-4-82	G-2-5-82	G-2-6-82	G-2-7-82	G-2-8-82	G-2-9-82
Silver	G-2-1-83	G-2-2-83	G-2-3-83	G-2-4-83	G-2-5-83	G-2-6-83	G-2-7-83	G-2-8-83	G-2-9-83
Strontium	G-2-1-84	G-2-2-84	G-2-3-84	G-2-4-84	G-2-5-84	G-2-6-84	G-2-7-84	G-2-8-84	G-2-9-84
Sulphur	G-2-1-85	G-2-2-85	G-2-3-85	G-2-4-85	G-2-5-85	G-2-6-85	G-2-7-85	G-2-8-85	G-2-9-85
Thallium	G-2-1-86	G-2-2-86	G-2-3-86	G-2-4-86	G-2-5-86	G-2-6-86	G-2-7-86	G-2-8-86	G-2-9-86
Titanium	G-2-1-87	G-2-2-87	G-2-3-87	G-2-4-87	G-2-5-87	G-2-6-87	G-2-7-87	G-2-8-87	G-2-9-87
Uranium	G-2-1-88	G-2-2-88	G-2-3-88	G-2-4-88	G-2-5-88	G-2-6-88	G-2-7-88	G-2-8-88	G-2-9-88
Vanadium	G-2-1-89	G-2-2-89	G-2-3-89	G-2-4-89	G-2-5-89	G-2-6-89	G-2-7-89	G-2-8-89	G-2-9-89
Zinc	G-2-1-90	G-2-2-90	G-2-3-90	G-2-4-90	G-2-5-90	G-2-6-90	G-2-7-90	G-2-8-90	G-2-9-90
Aluminum	G-2-1-91	G-2-2-91	G-2-3-91	G-2-4-91	G-2-5-91	G-2-6-91	G-2-7-91	G-2-8-91	G-2-9-91
Antimony	G-2-1-92	G-2-2-92	G-2-3-92	G-2-4-92	G-2-5-92	G-2-6-92	G-2-7-92	G-2-8-92	G-2-9-92
Arsenic	G-2-1-93	G-2-2-93	G-2-3-93	G-2-4-93	G-2-5-93	G-2-6-93	G-2-7-93	G-2-8-93	G-2-9-93
Barium	G-2-1-94	G-2-2-94	G-2-3-94	G-2-4-94	G-2-5-94	G-2-6-94	G-2-7-94	G-2-8-94	G-2-9-94
Beryllium	G-2-1-95	G-2-2-95	G-2-3-95	G-2-4-95	G-2-5-95	G-2-6-95	G-2-7-95	G-2-8-95	G-2-9-95
Boron	G-2-1-96	G-2-2-96	G-2-3-96	G-2-4-96	G-2-5-96	G-2-6-96	G-2-7-96	G-2-8-96	G-2-9-96
Cadmium	G-2-1-97	G-2-2-97	G-2-3-97	G-2-4-97	G-2-5-97	G-2-6-97	G-2-7-97	G-2-8-97	G-2-9-97
Chromium	G-2-1-98	G-2-2-98	G-2-3-98	G-2-4-98	G-2-5-98	G-2-6-98	G-2-7-98	G-2-8-98	G-2-9-98
Chromium - hexavalent	G-2-1-99	G-2-2-99	G-2-3-99	G-2-4-99	G-2-5-99	G-2-6-99	G-2-7-99	G-2-8-99	G-2-9-99
Cobalt	G-2-1-100	G-2-2-100	G-2-3-100	G-2-4-100	G-2-5-100	G-2-6-100	G-2-7-100	G-2-8-100	G-2-9-100
Copper	G-2-1-101	G-2-2-101	G-2-3-101	G-2-4-101	G-2-5-101	G-2-6-101	G-2-7-101	G-2-8-101	G-2-9-101
Iron	G-2-1-102	G-2-2-102	G-2-3-102	G-2-4-102	G-2-5-102	G-2-6-102	G-2-7-102	G-2-8-102	G-2-9-102
Lead	G-2-1-103	G-2-2-103	G-2-3-103	G-2-4-103	G-2-5-103	G-2-6-103	G-2-7-103	G-2-8-103	G-2-9-103
Lithium	G-2-1-104	G-2-2-104	G-2-3-104	G-2-4-104	G-2-5-104	G-2-6-104	G-2-7-104	G-2-8-104	G-2-9-104
Manganese	G-2-1-105	G-2-2-105	G-2-3-105	G-2-4-105	G-2-5-105	G-2-6-105	G-2-7-105	G-2-8-105	G-2-9-105
Mercury	G-2-1-106	G-2-2-106	G-2-3-106	G-2-4-106	G-2-5-106	G-2-6-106	G-2-7-106	G-2-8-106	G-2-9-106
Molybdenum	G-2-1-107	G-2-2-107	G-2-3-107	G-2-4-107	G-2-5-107	G-2-6-107	G-2-7-107	G-2-8-107	G-2-9-107
Nickel	G-2-1-108	G-2-2-108	G-2-3-108	G-2-4-108	G-2-5-108	G-2-6-108	G-2-7-108	G-2-8-108	G-2-9-108
Selenium	G-2-1-109	G-2-2-109	G-2-3-109	G-2-4-109	G-2-5-109	G-2-6-109	G-2-7-109	G-2-8-109	G-2-9-109
Silicon	G-2-1-110	G-2-2-110	G-2-3-110	G-2-4-110	G-2-5-110	G-2-6-110	G-2-7-110	G-2-8-110	G-2-9-110
Silver	G-2-1-111	G-2-2-111	G-2-3-111	G-2-4-111	G-2-5-111	G-2-6-111	G-2-7-111	G-2-8-111	G-2-9-111
Strontium	G-2-1-112	G-2-2-112	G-2-3-112	G-2-4-112	G-2-5-112	G-2-6-112	G-2-7-112	G-2-8-112	G-2-9-112
Sulphur	G-2-1-113	G-2-2-113	G-2-3-113	G-2-4-113	G-2-5-113	G-2-6-113	G-2-7-113	G-2-8-113	G-2-9-113
Thallium	G-2-1-114	G-2-2-114	G-2-3-114	G-2-4-114	G-2-5-114	G-2-6-114	G-2-7-114	G-2-8-114	G-2-9-114
Titanium	G-2-1-115	G-2-2-115	G-2-3-115	G-2-4-115	G-2-5-115	G-2-6-115	G-2-7-115	G-2-8-115	G-2-9-115
Uranium	G-2-1-116	G-2-2-116	G-2-3-116	G-2-4-116	G-2-5-116	G-2-6-116	G-2-7-116	G-2-8-116	G-2-9-116
Vanadium	G-2-1-117	G-2-2-117	G-2-3-117	G-2-4-117	G-2-5-117	G-2-6-117	G-2-7-117	G-2-8-117	G-2-9-117
Zinc	G-2-1-118	G-2-2-118	G-2-3-118	G-2-4-118	G-2-5-118	G-2-6-118	G-2-7-118	G-2-8-118	G-2-9-118

Figure G-2-1-1 Box Whisker and Time Series Scatter Plots of Observed pH in Upper Segment of Muskeg River



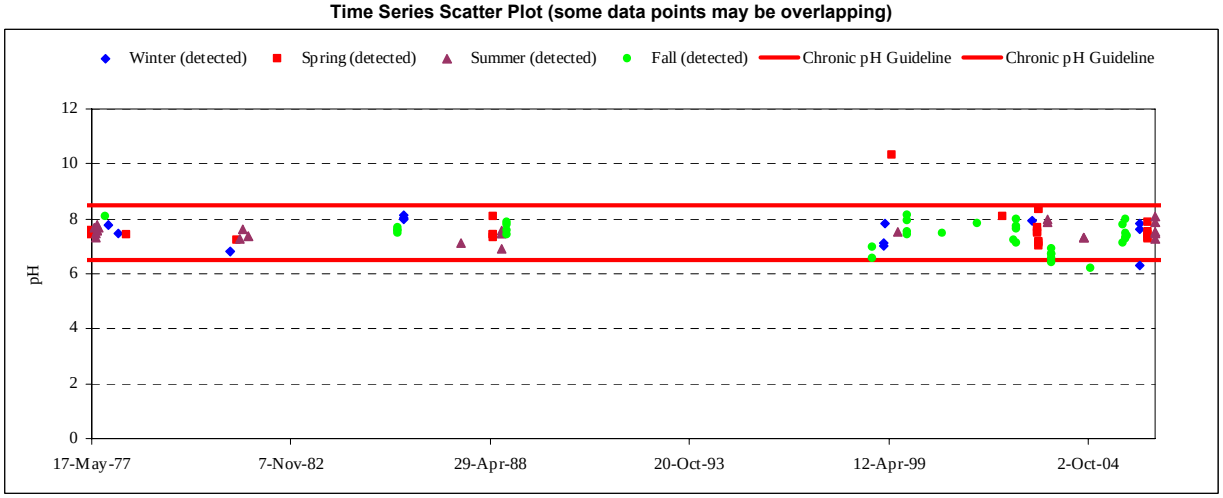
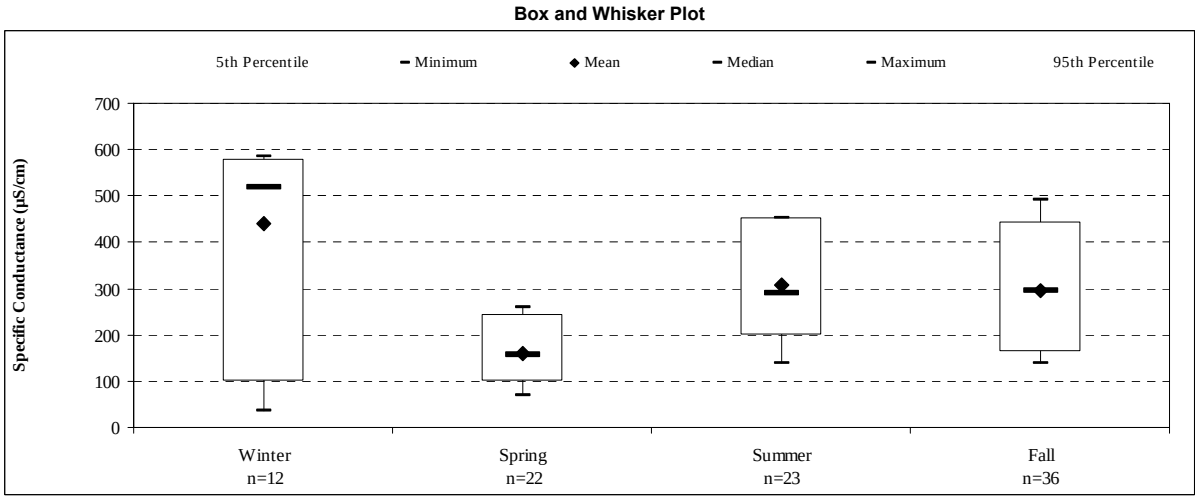


Figure G-2-1-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Upper Segment of Muskeg River



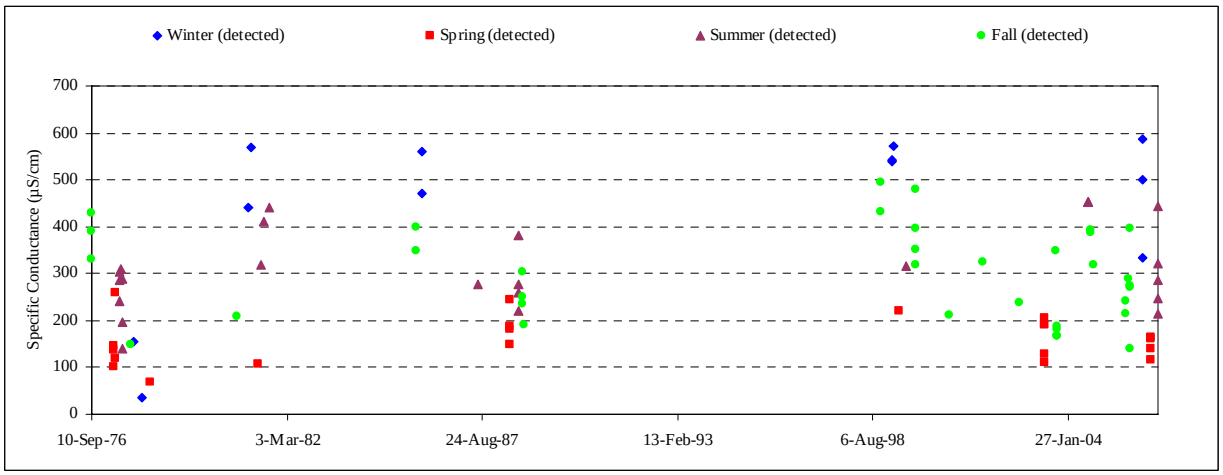
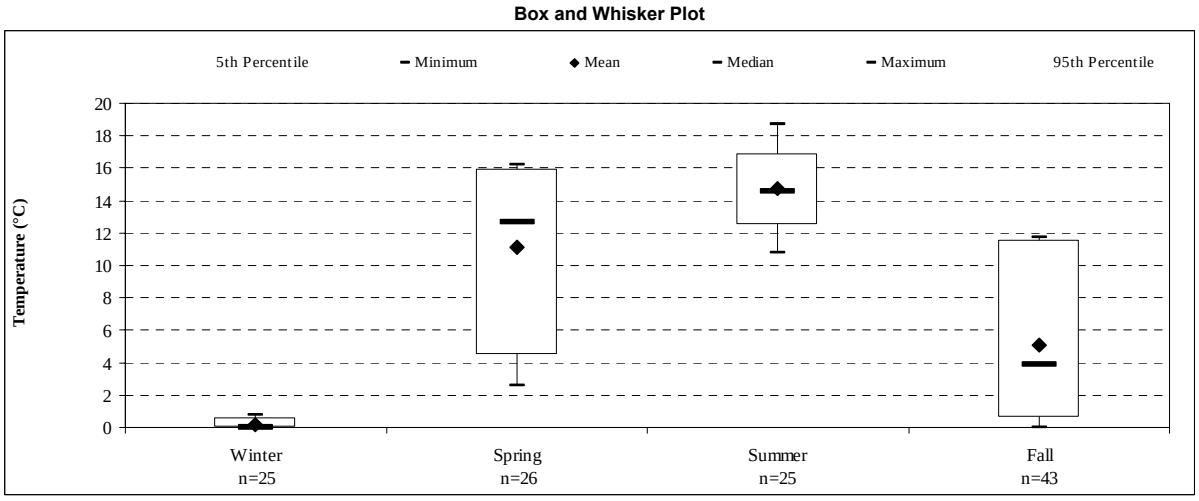


Figure G-2-1-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Upper Segment of Muskeg River



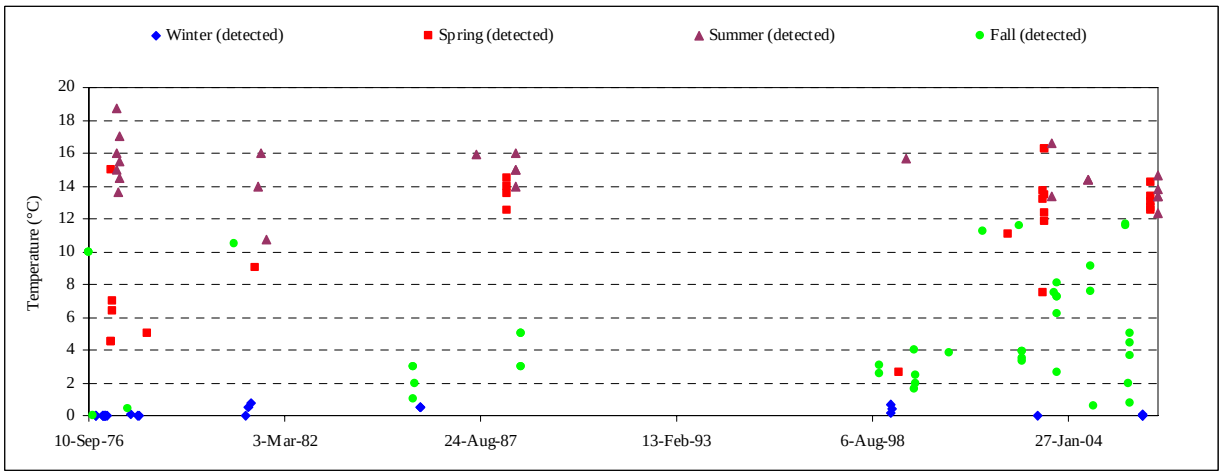
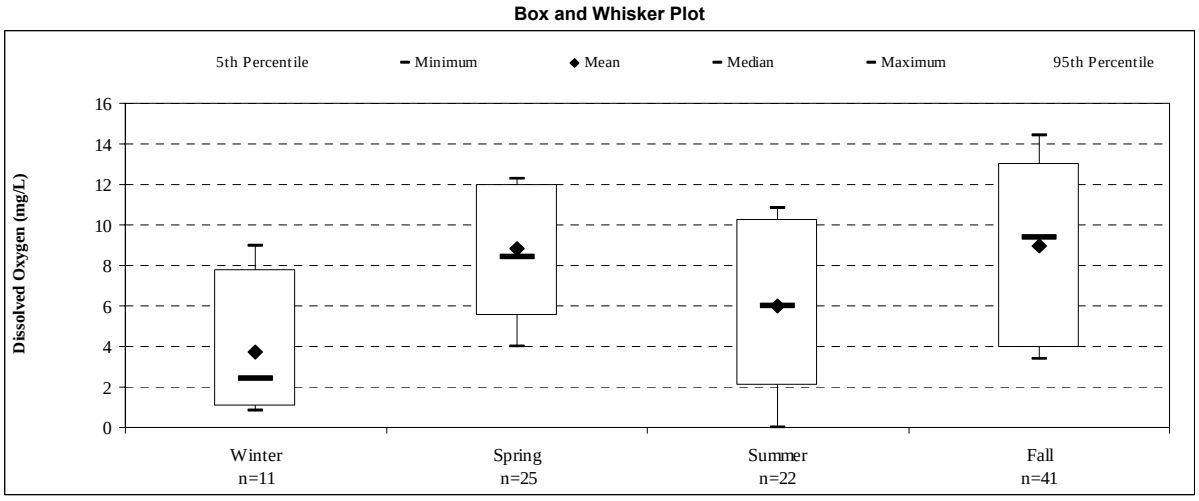


Figure G-2-1-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Upper Segment of Muskeg River



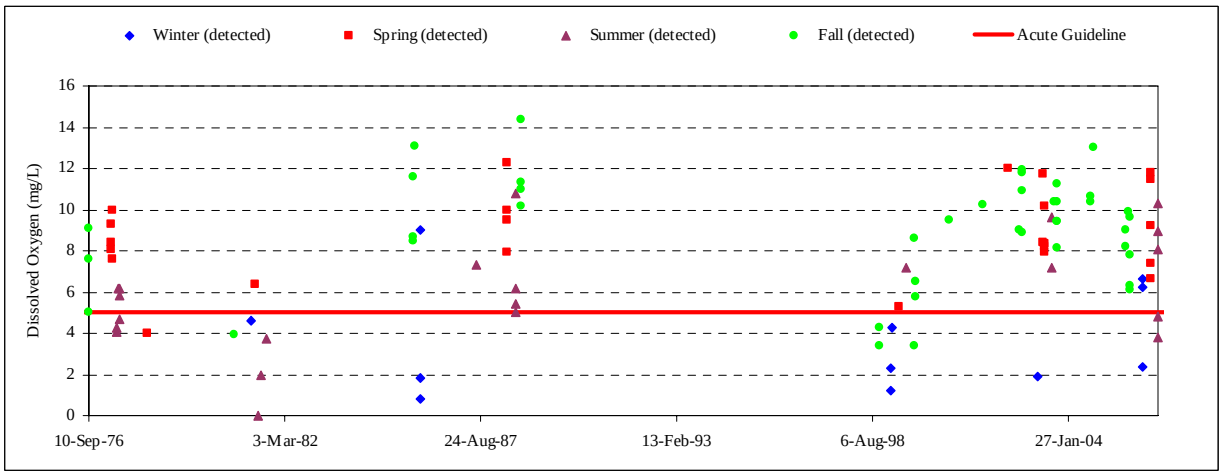
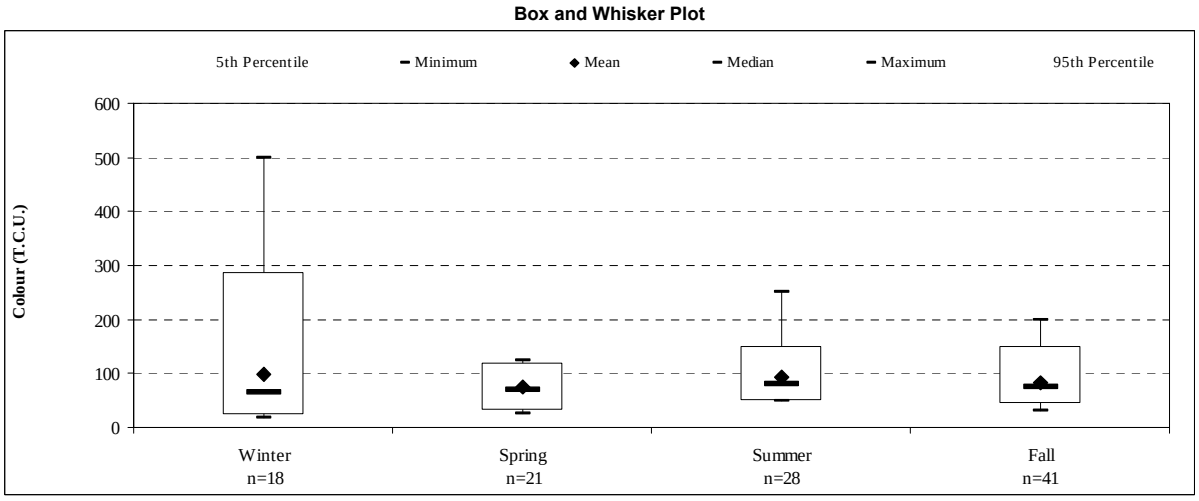


Figure G-2-1-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Upper Segment of Muskeg River



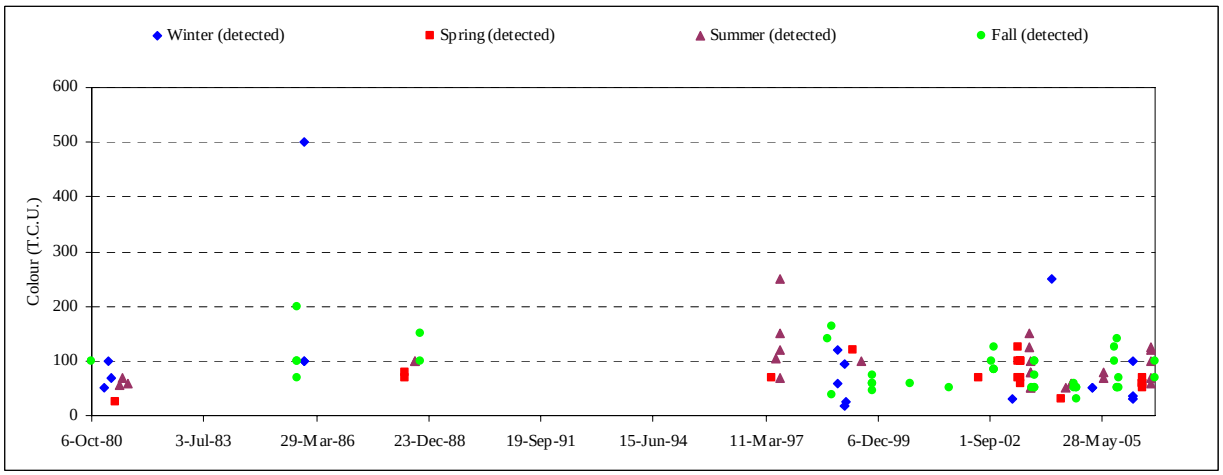
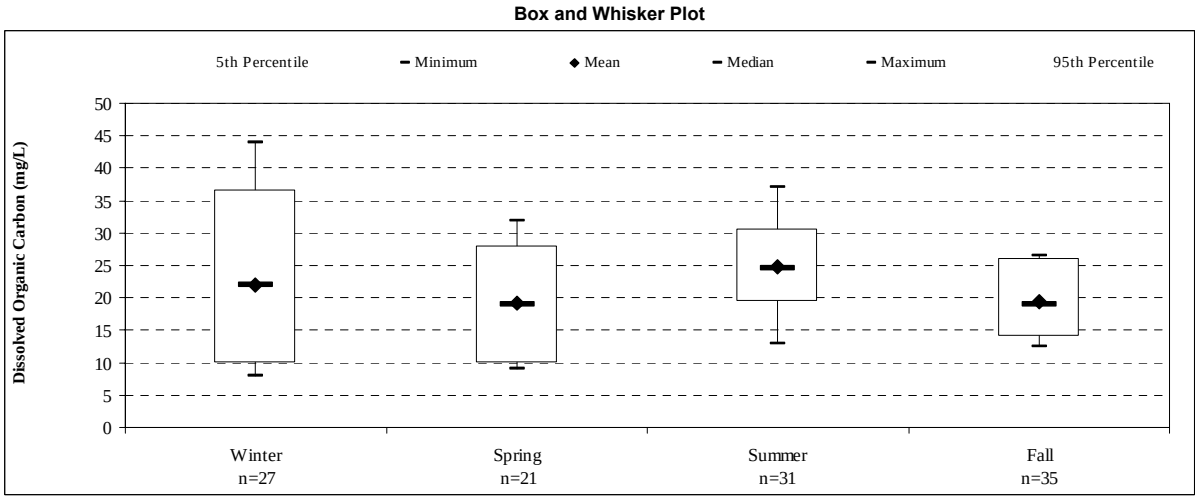


Figure G-2-1-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Upper Segment of Muskeg River



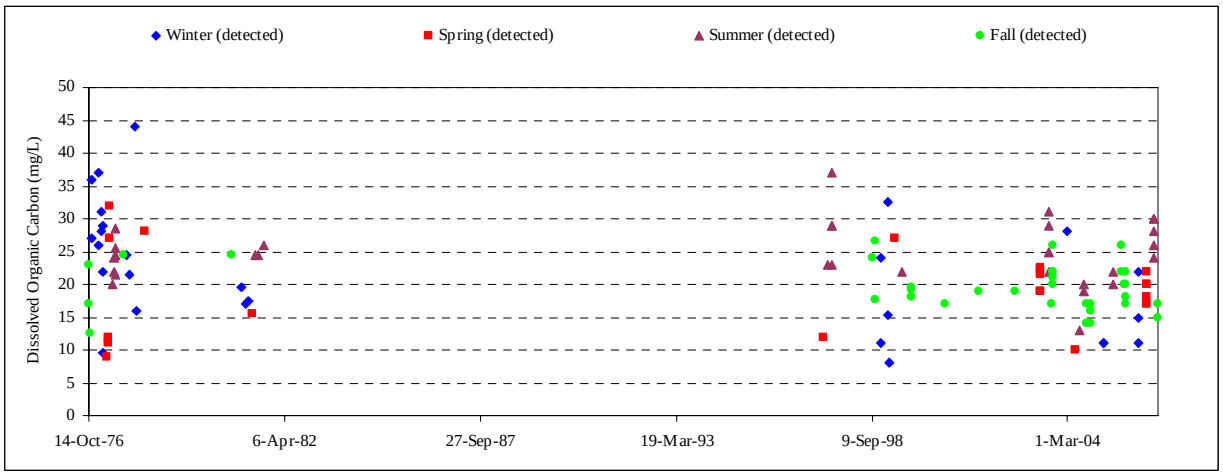
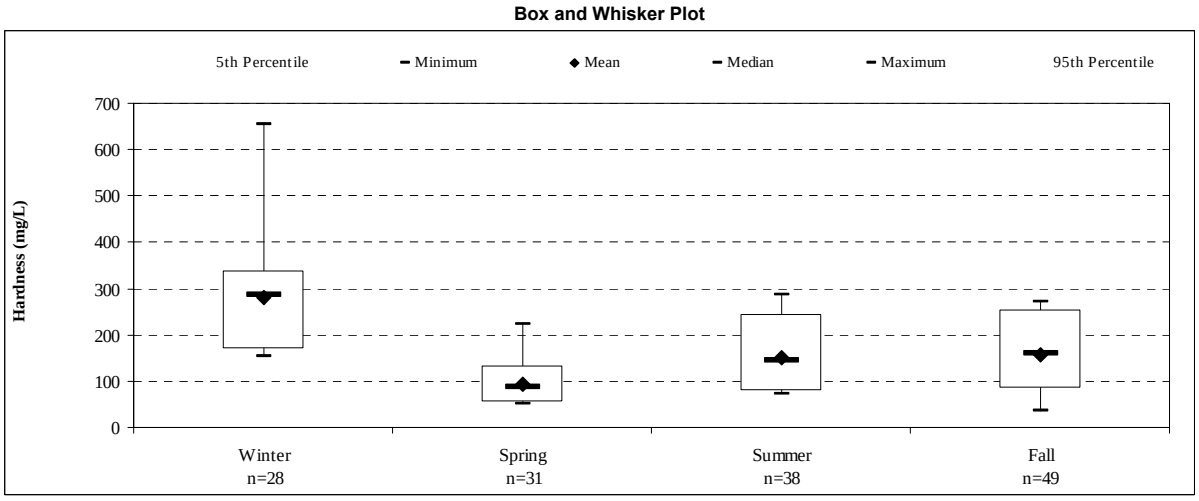


Figure G-2-1-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Upper Segment of Muskeg River



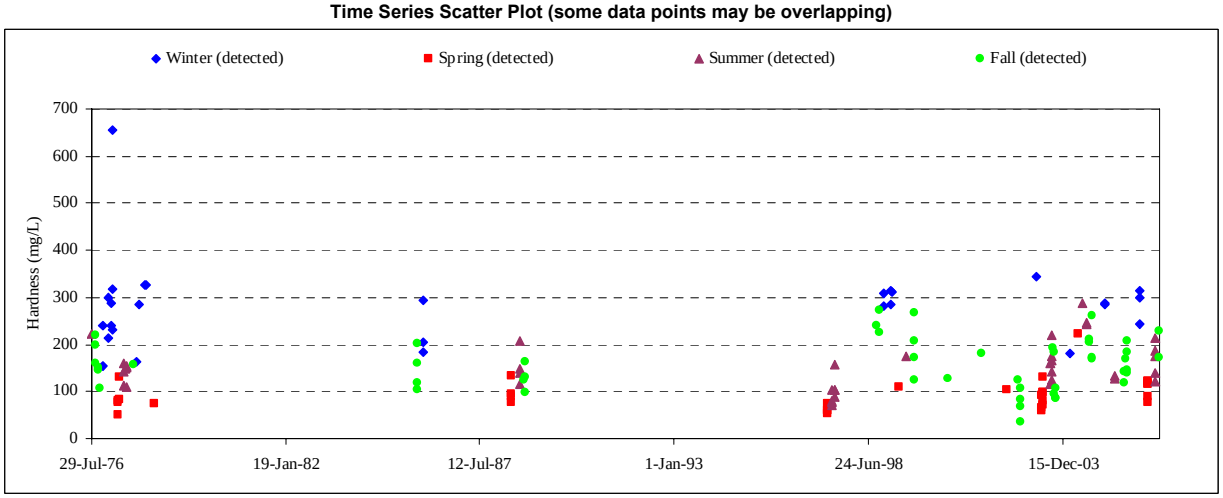
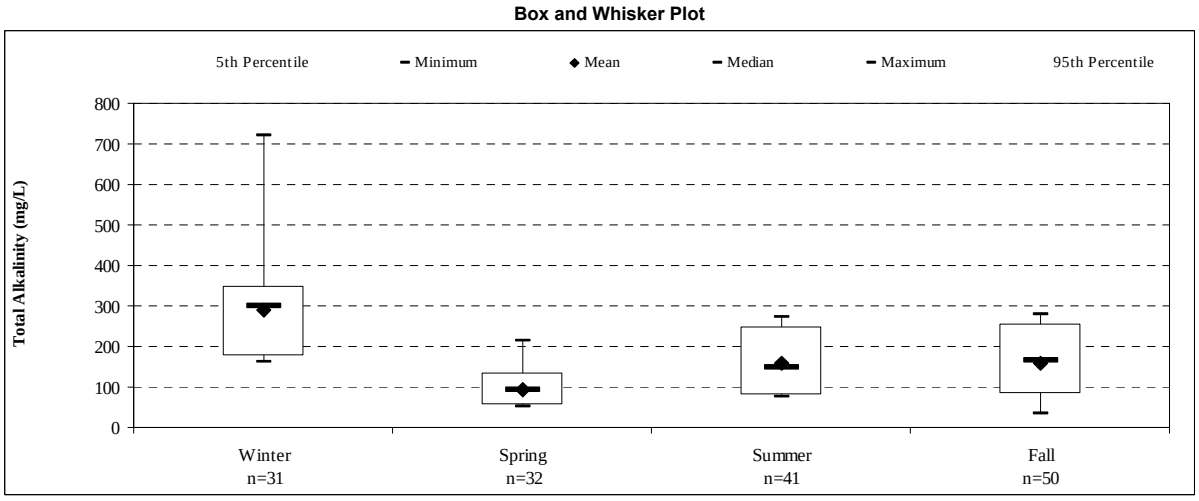


Figure G-2-1-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Upper Segment of Muskeg River



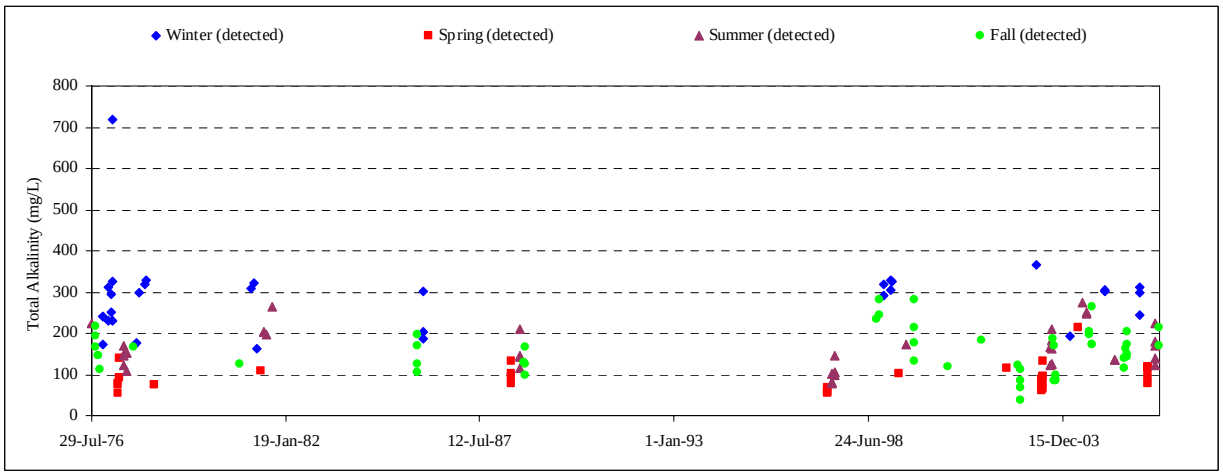
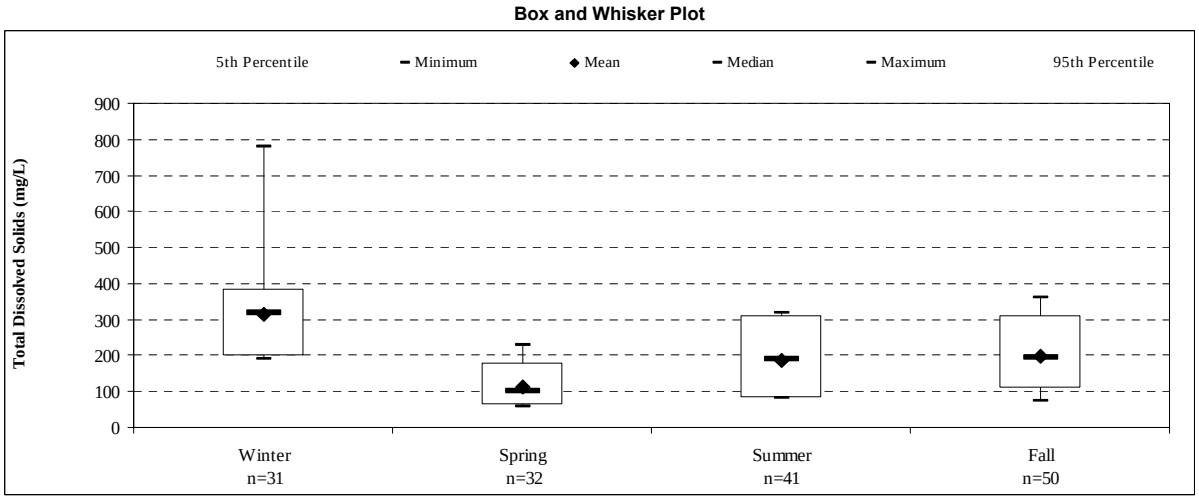


Figure G-2-1-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Upper Segment of Muskeg River



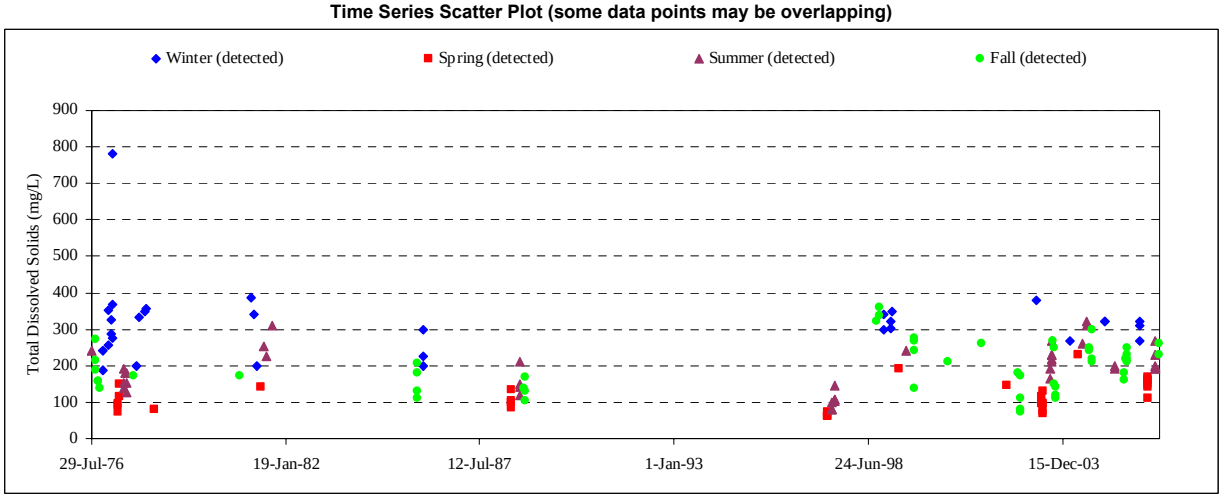
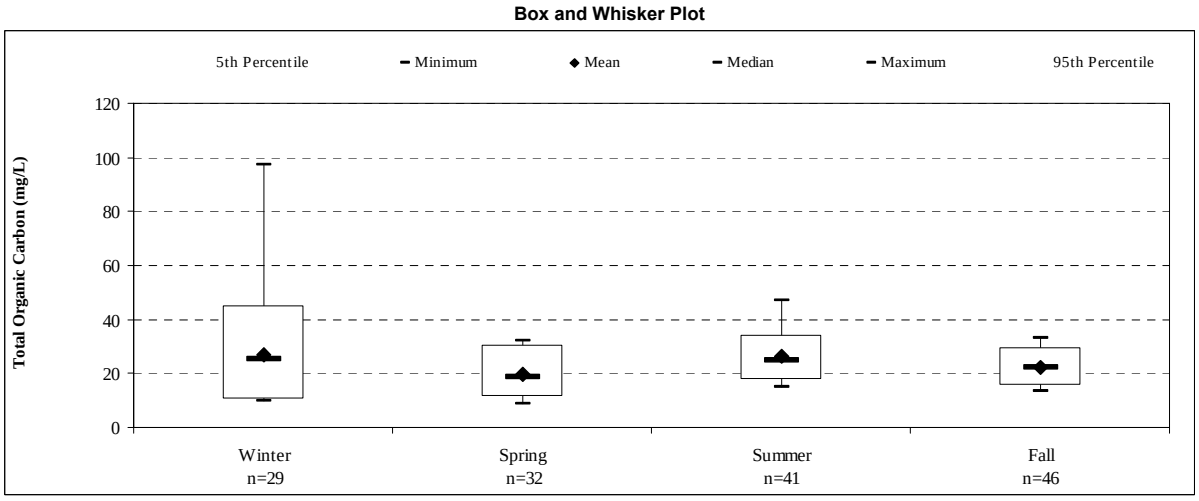


Figure G-2-1-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Upper Segment of Muskeg River



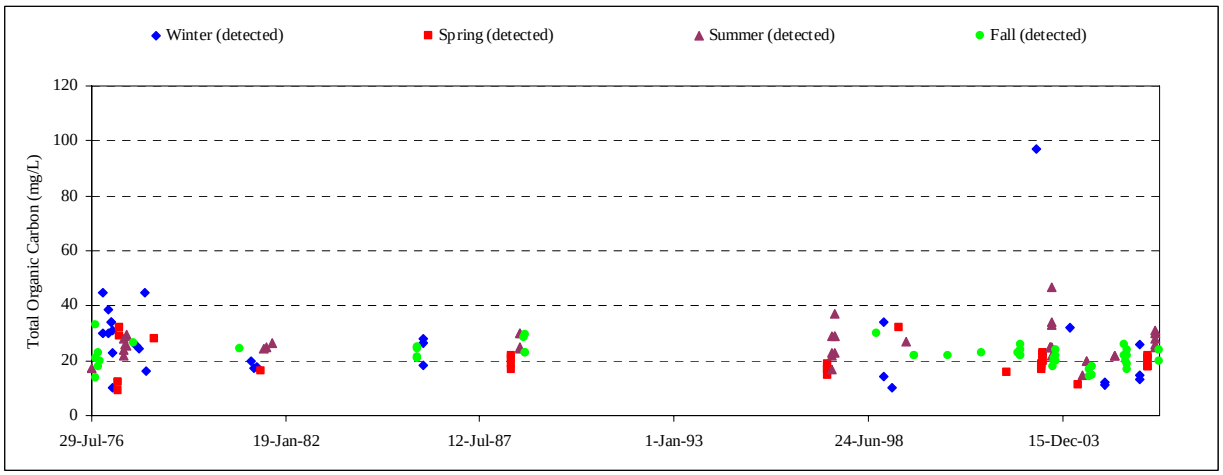
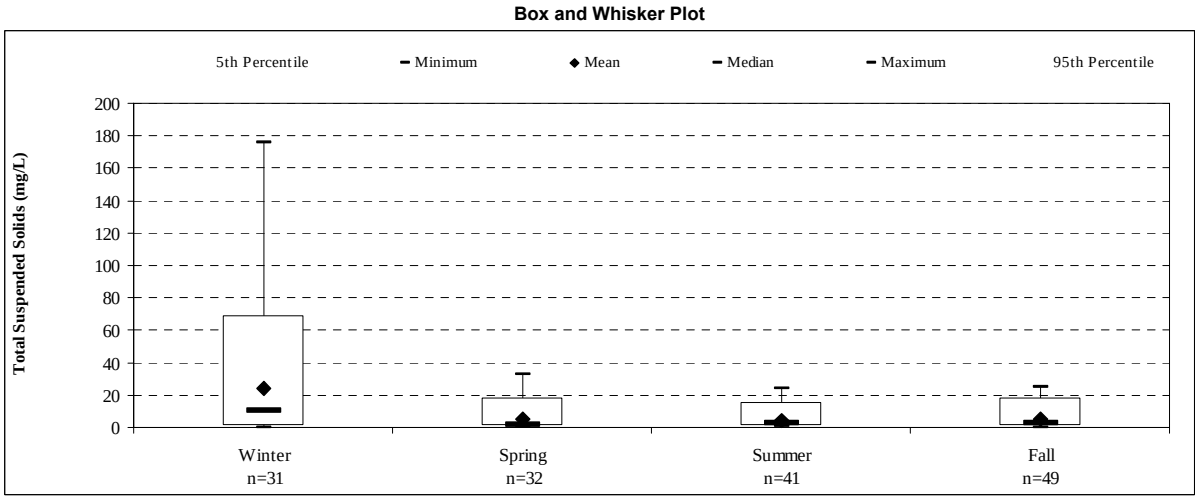


Figure G-2-1-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Upper Segment of Muskeg River



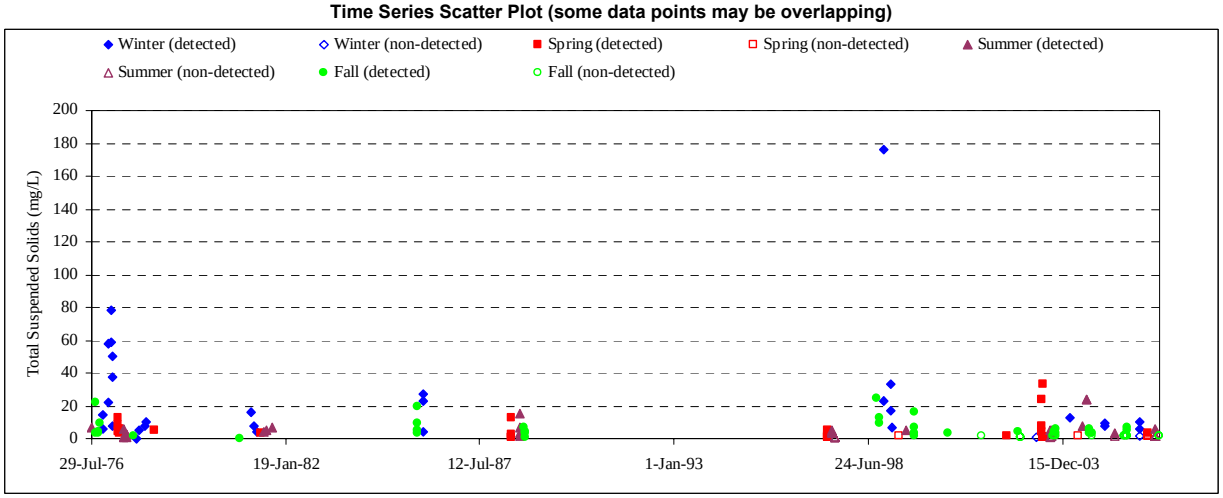
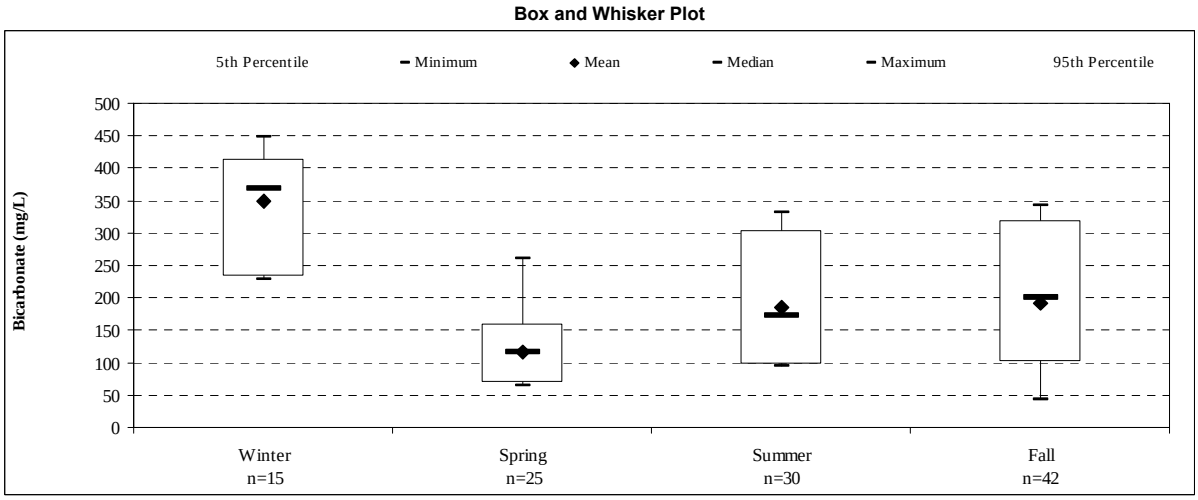


Figure G-2-1-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Upper Segment of Muskeg River



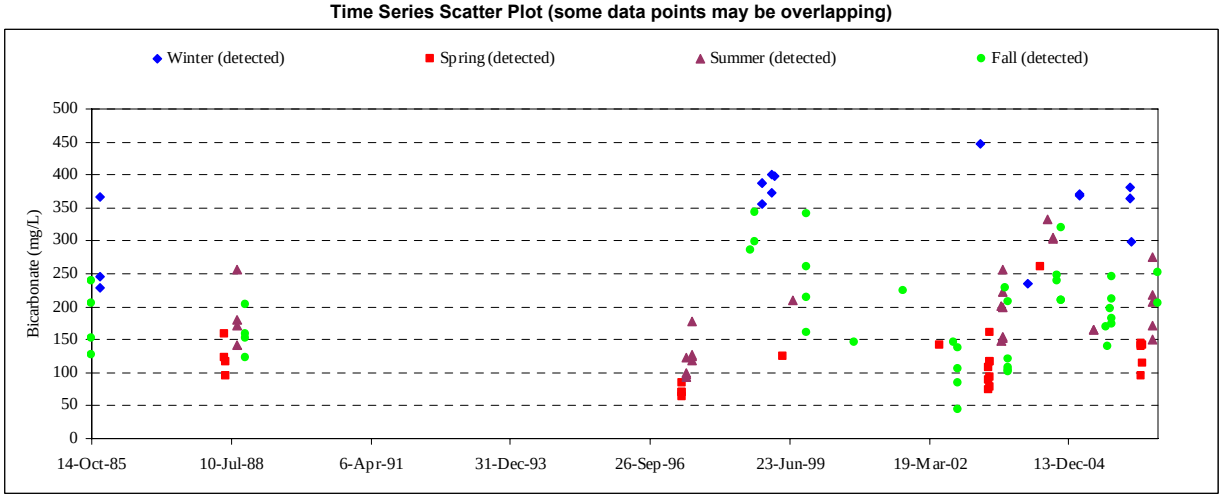
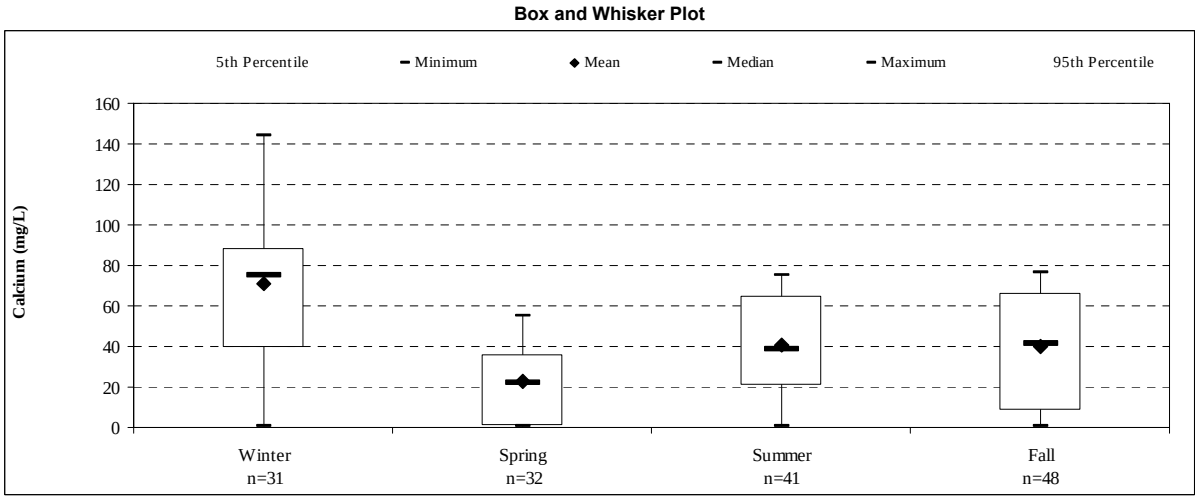


Figure G-2-1-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Upper Segment of Muskeg River



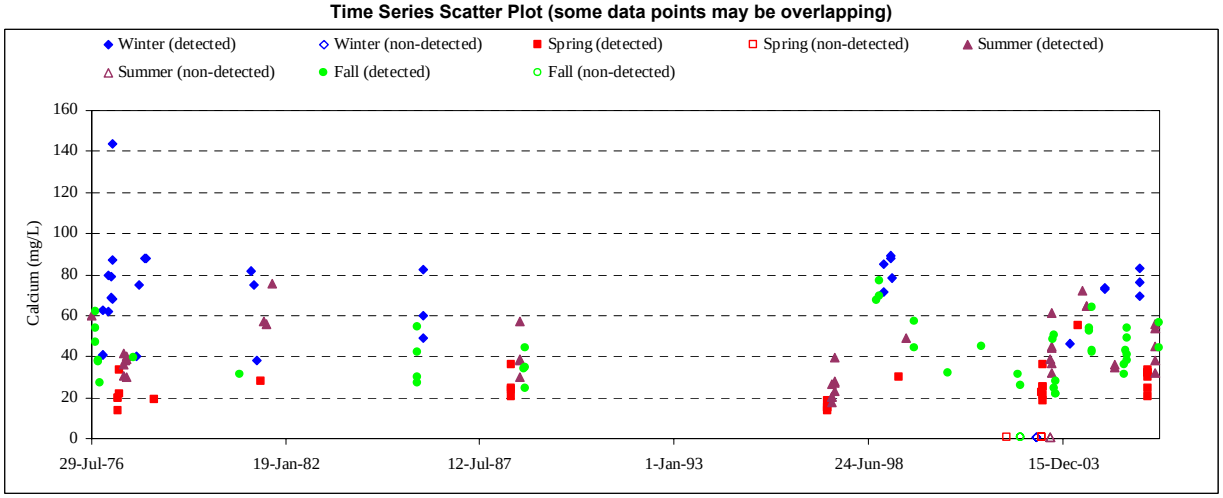
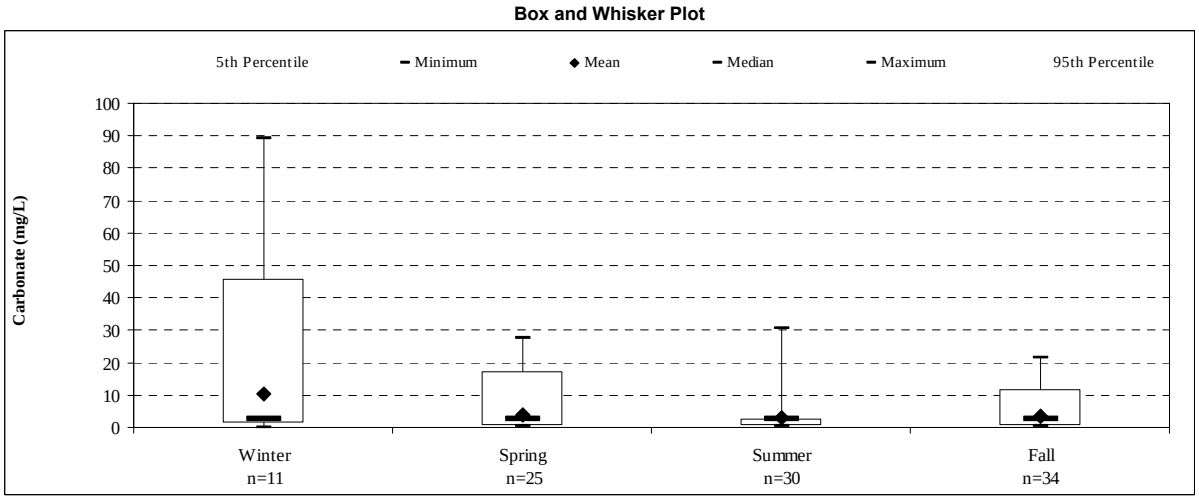


Figure G-2-1-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Upper Segment of Muskeg River



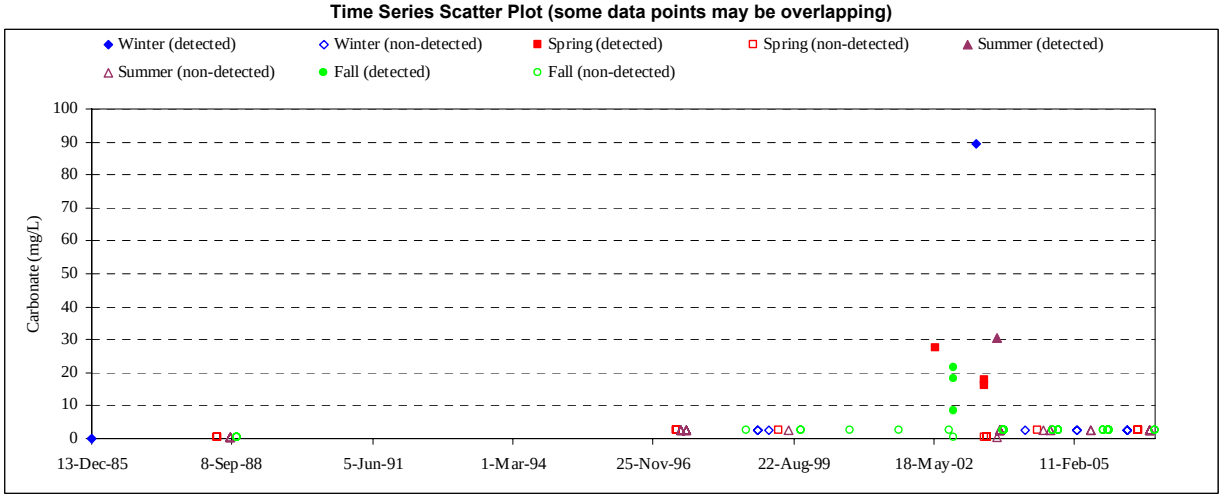


Figure G-2-1-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Upper Segment of Muskeg River

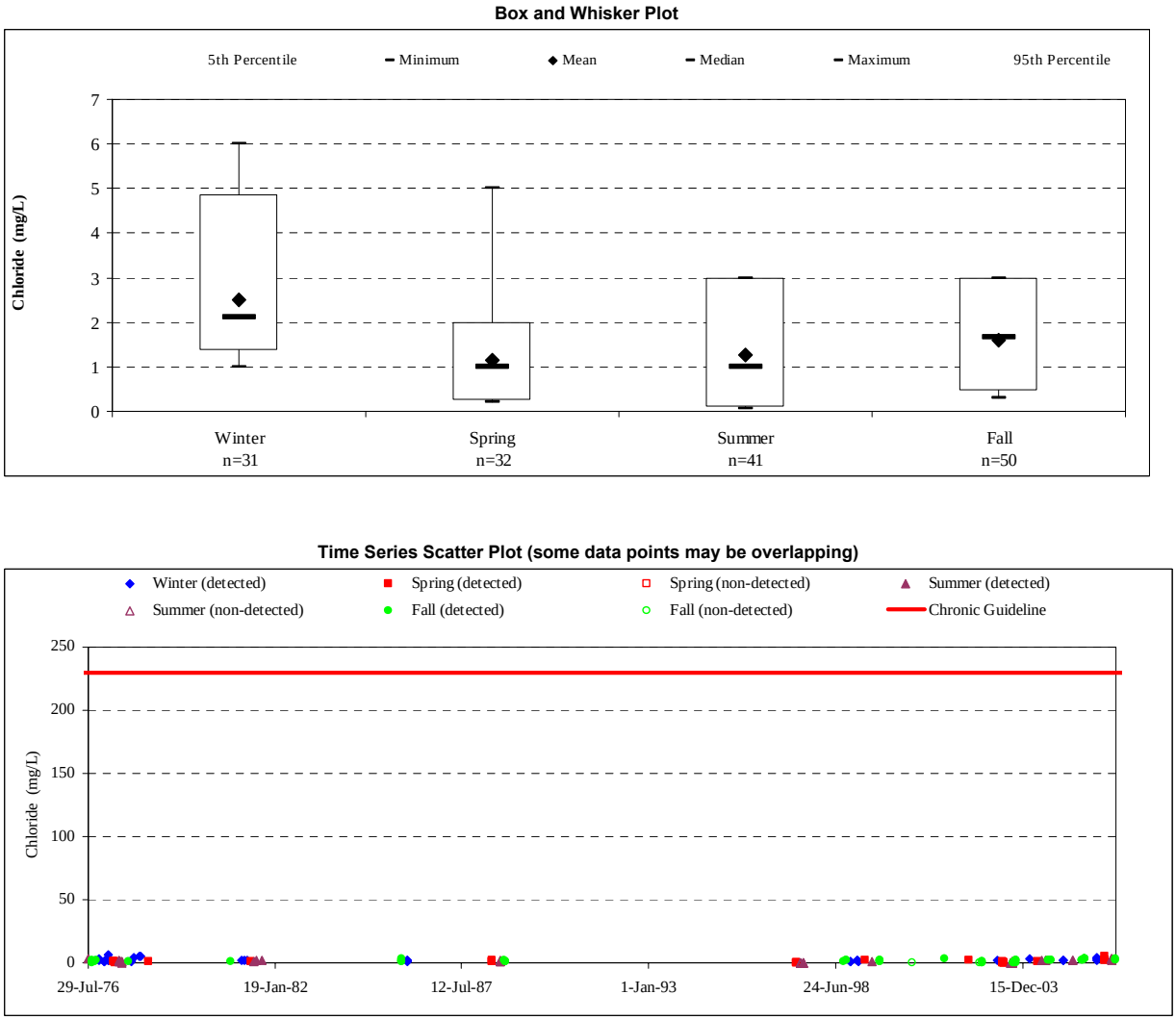
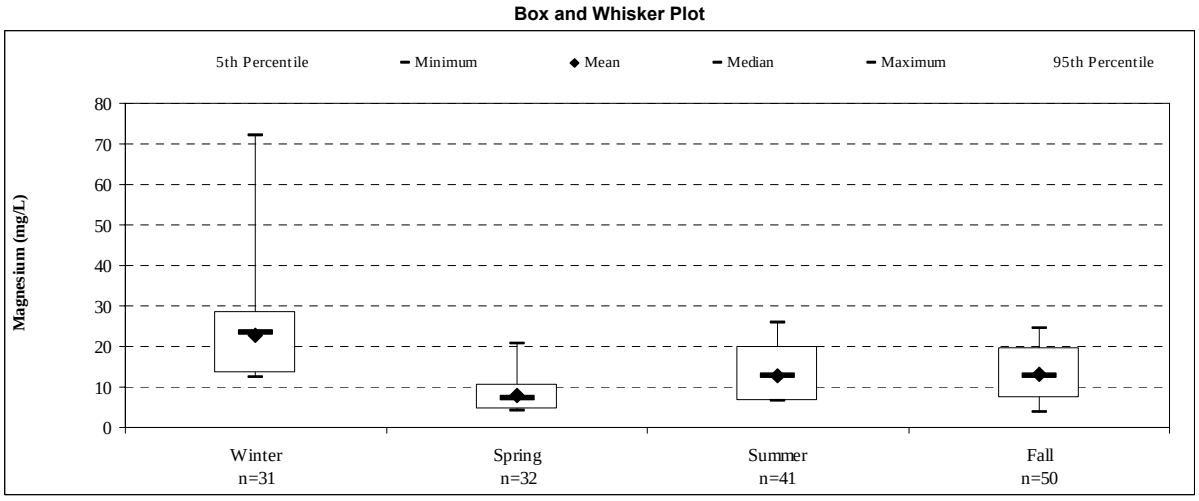


Figure G-2-1-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Upper Segment of Muskeg River



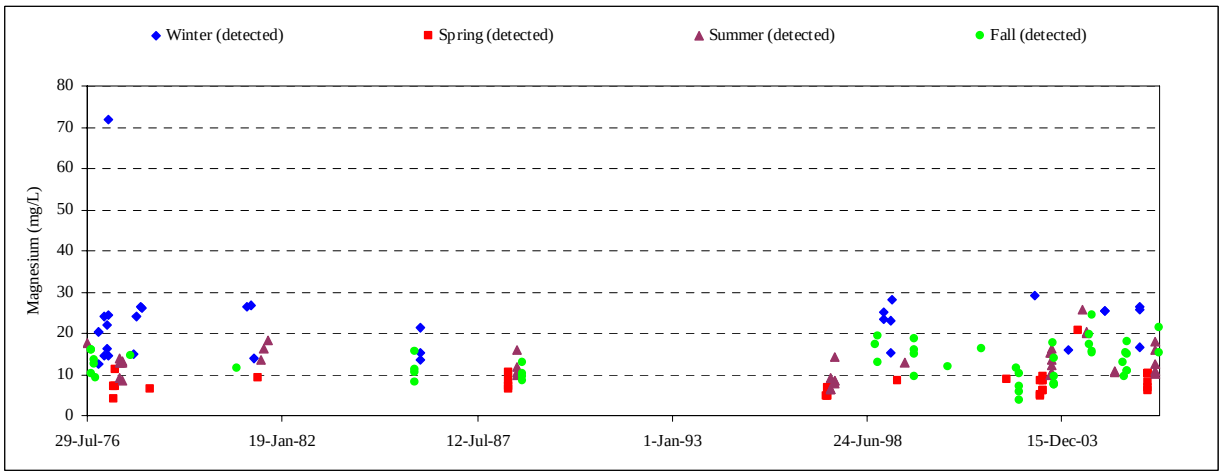
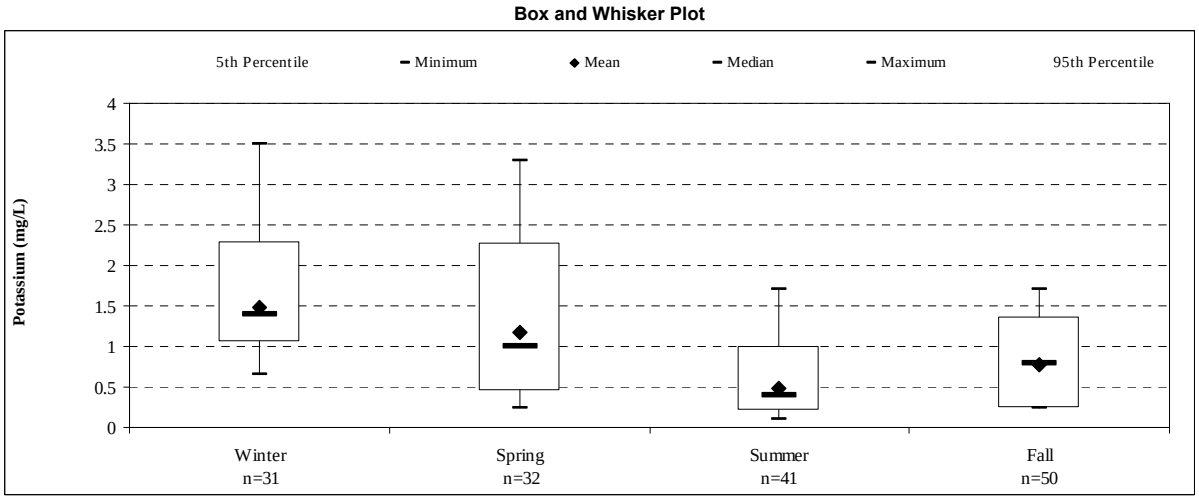


Figure G-2-1-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Upper Segment of Muskeg River



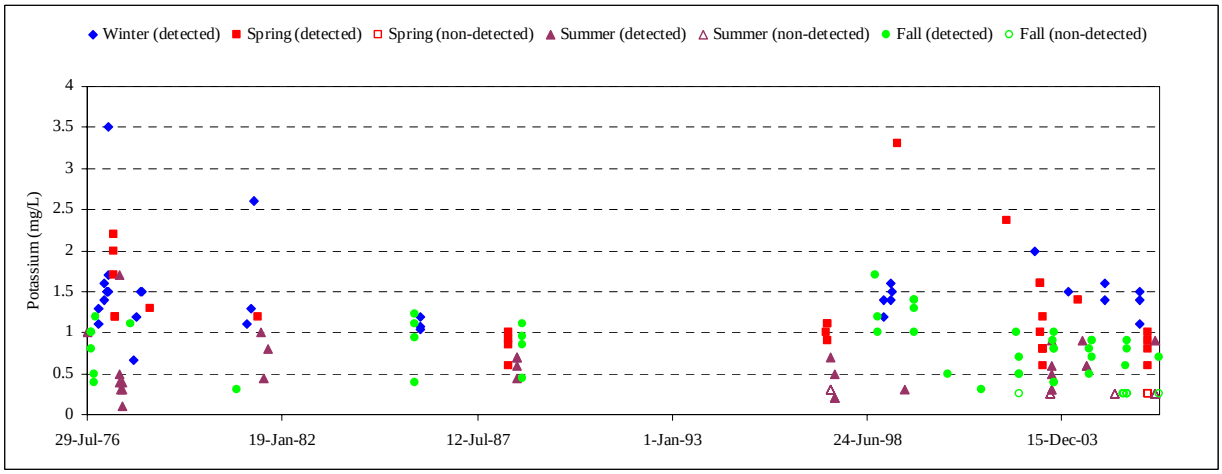
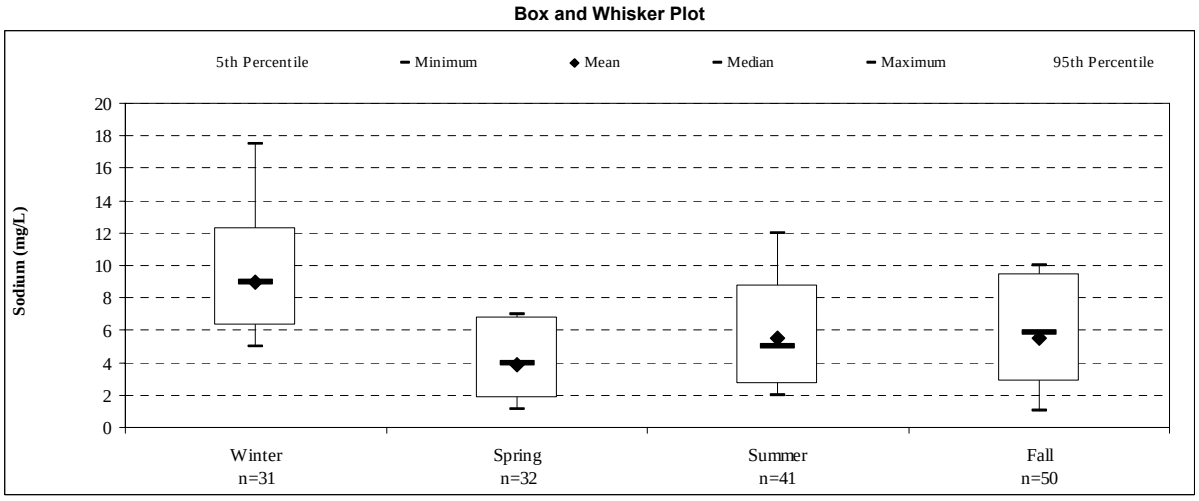


Figure G-2-1-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Upper Segment of Muskeg River



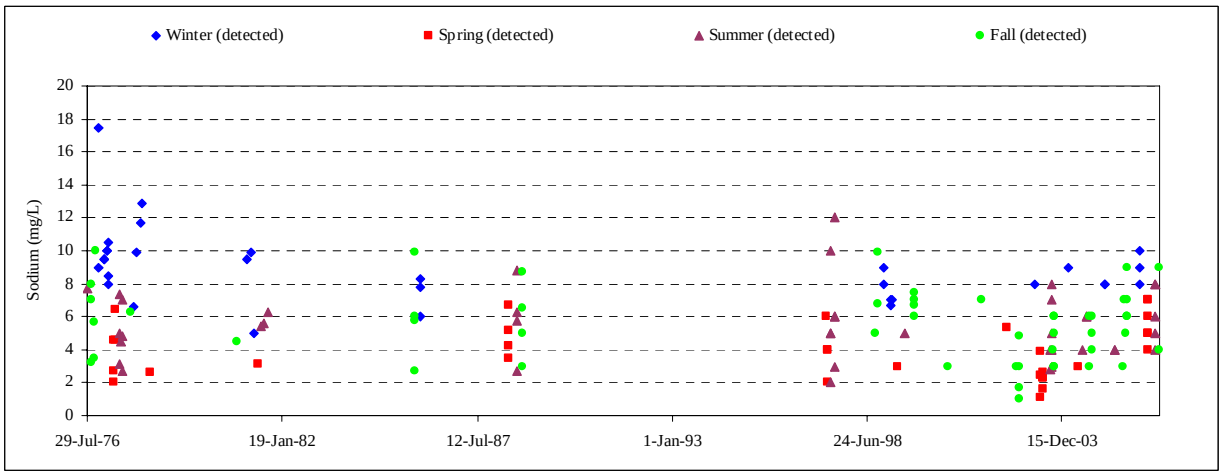
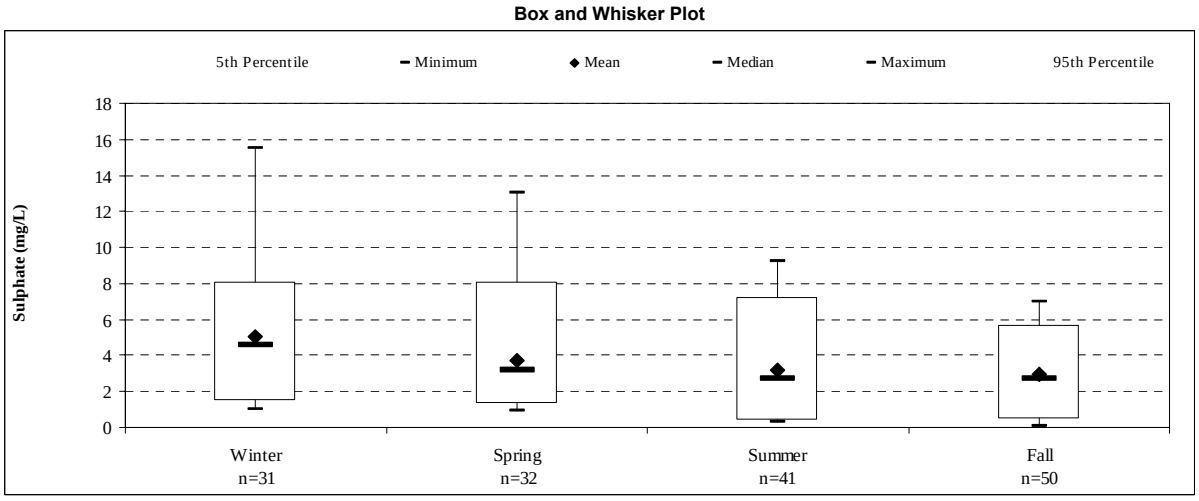


Figure G-2-1-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Upper Segment of Muskeg River



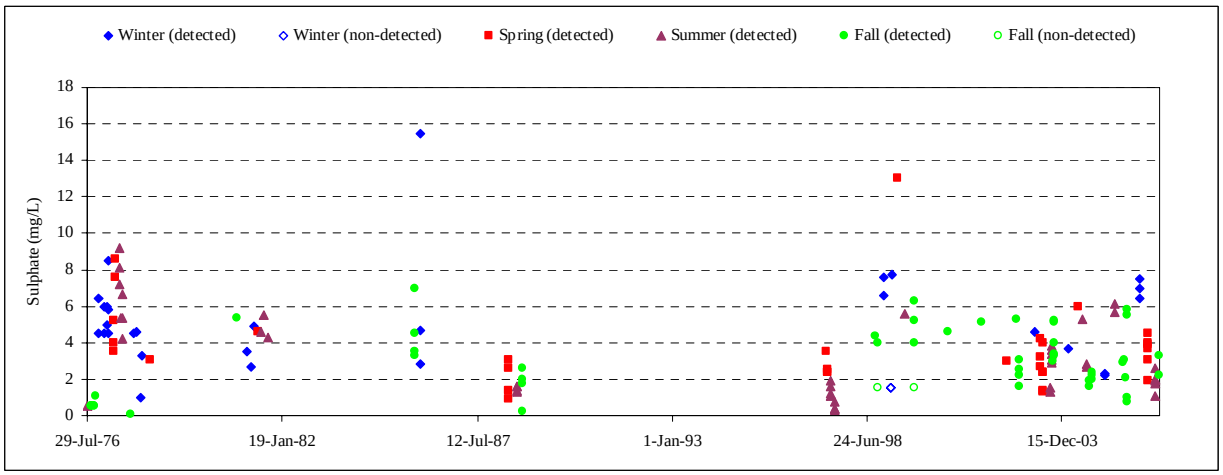


Figure G-2-1-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Upper Segment of Muskeg River

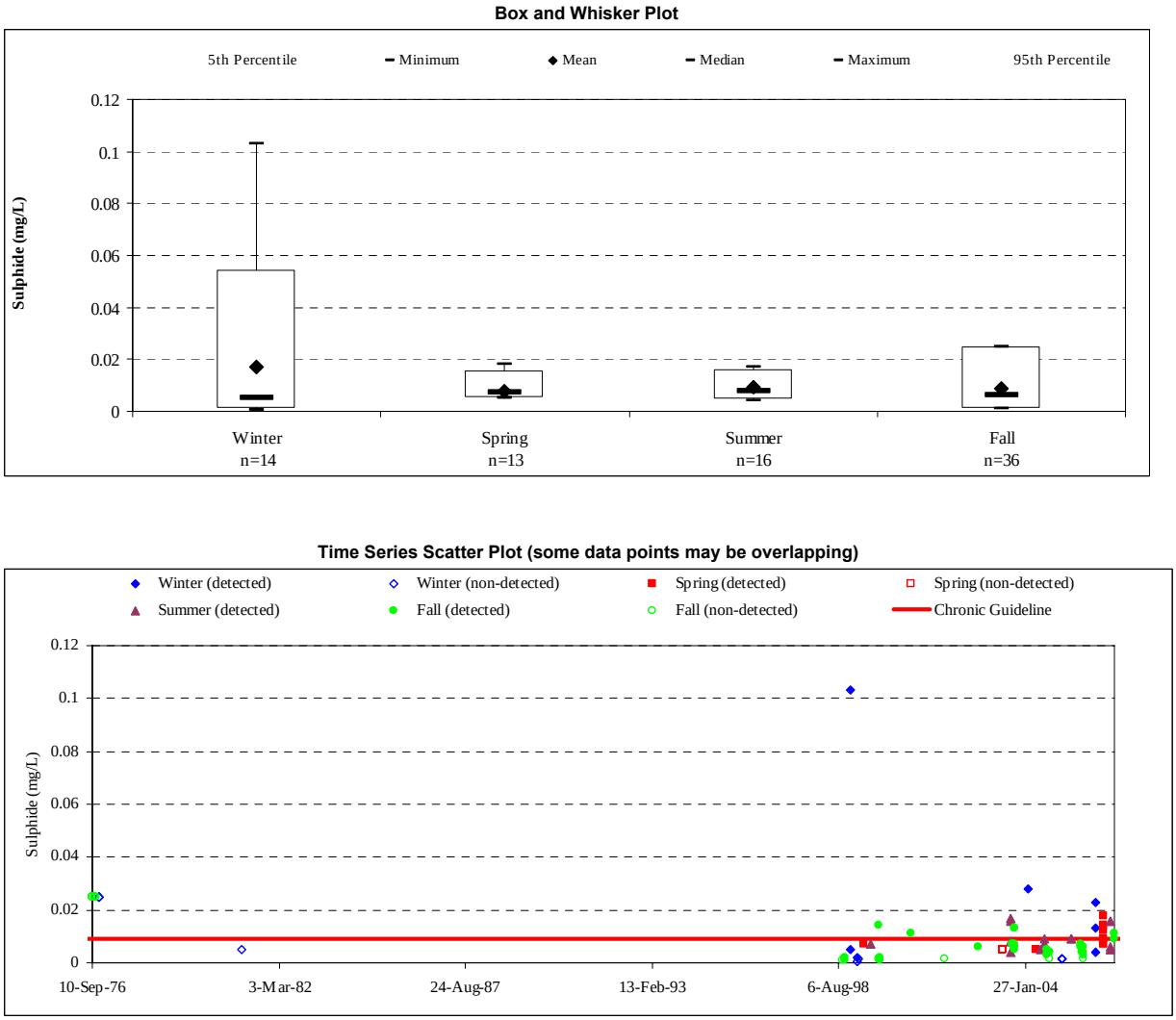
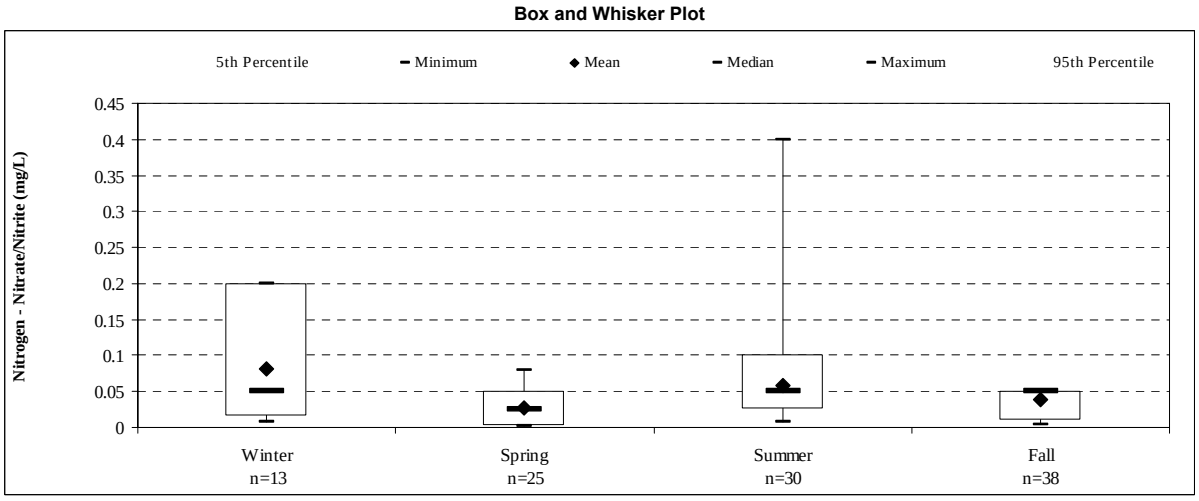


Figure G-2-1-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Upper Segment of Muskeg River



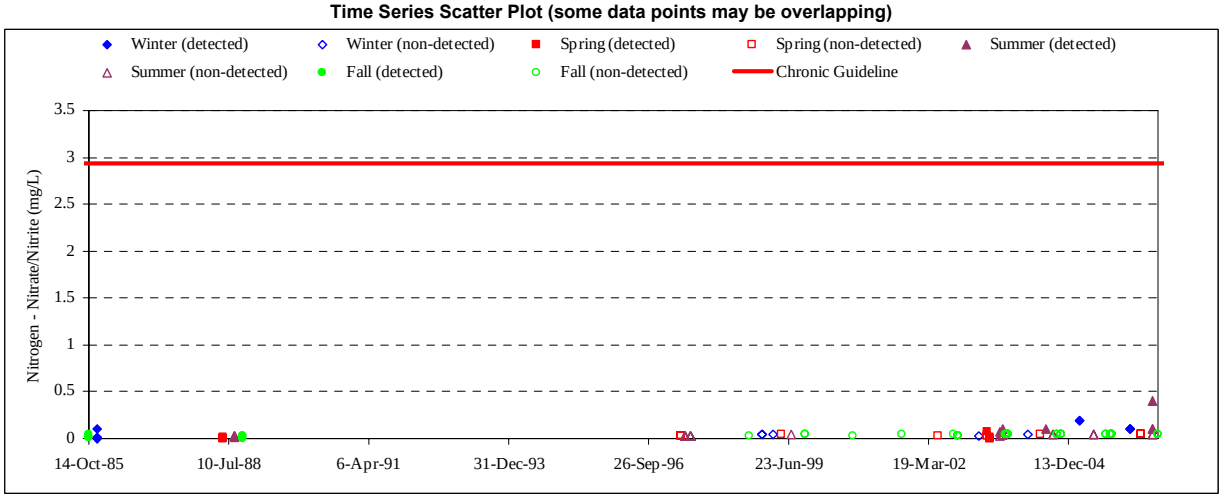
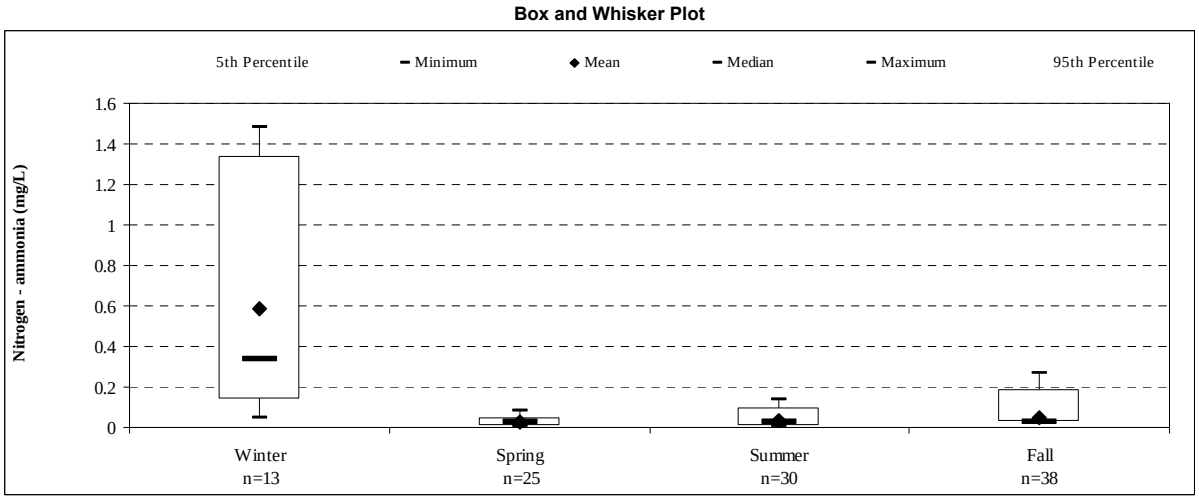


Figure G-2-1-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Upper Segment of Muskeg River



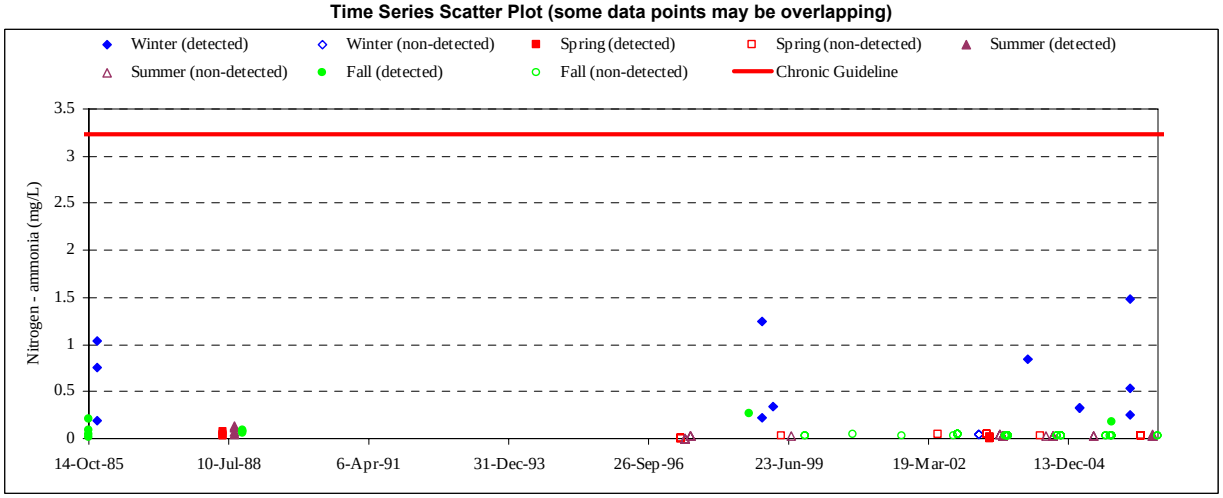
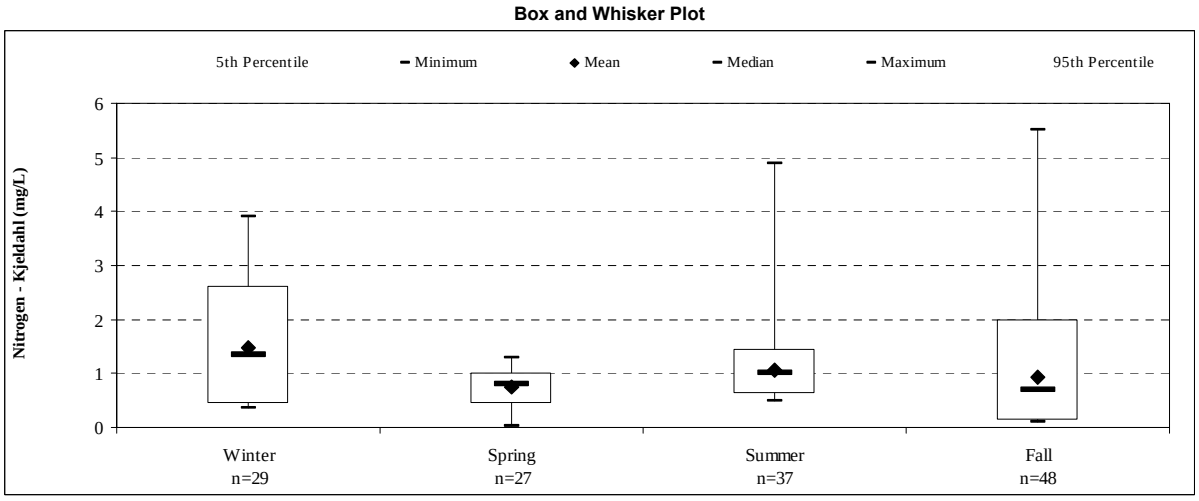


Figure G-2-1-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Upper Segment of Muskeg River



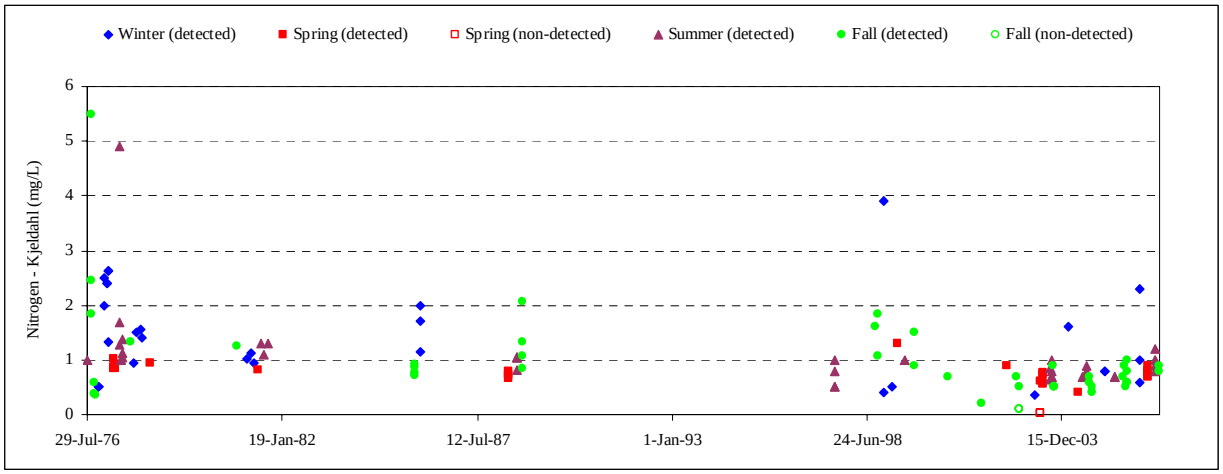


Figure G-2-1-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Upper Segment of Muskeg River

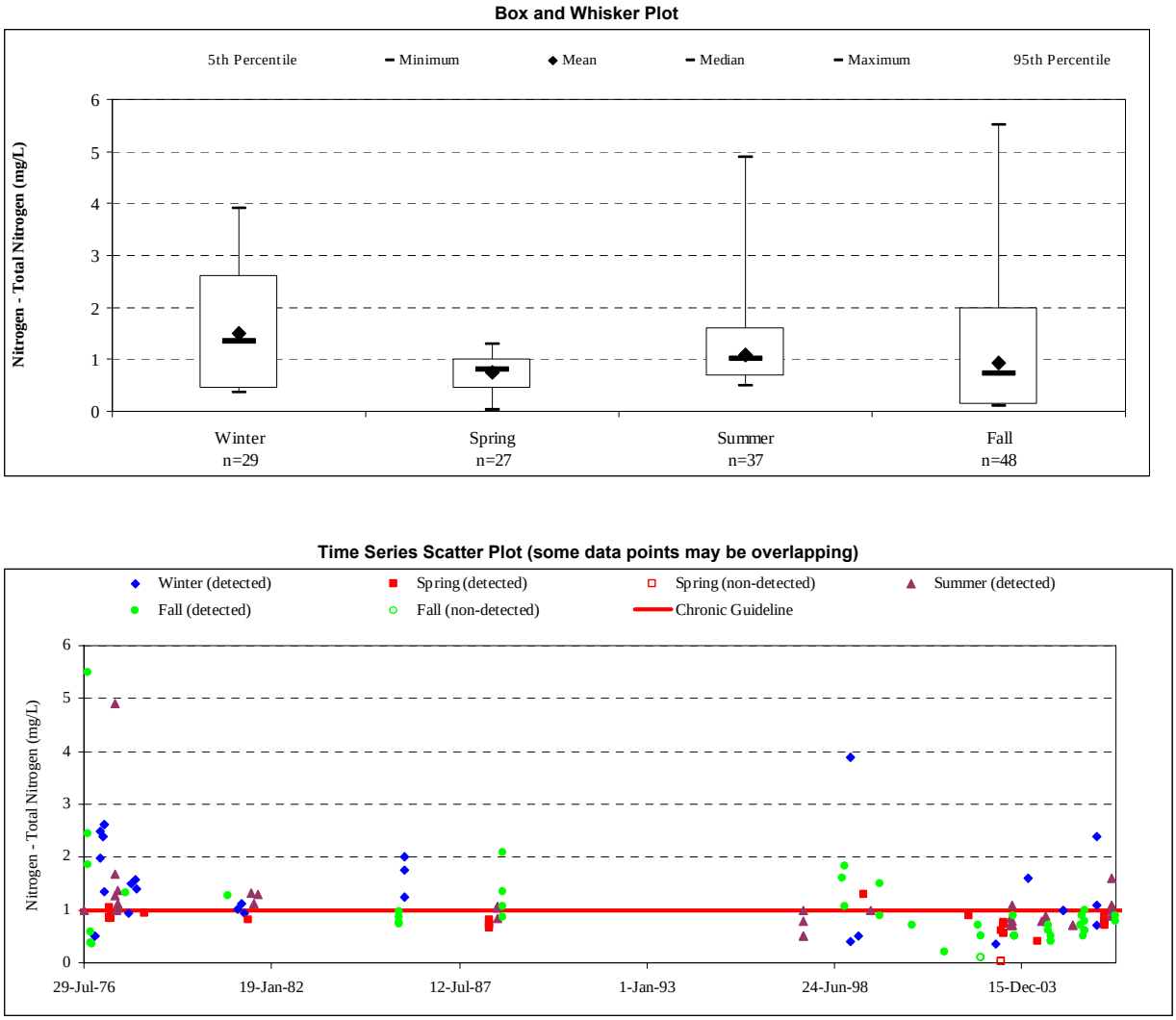


Figure G-2-1-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Upper Segment of Muskeg River

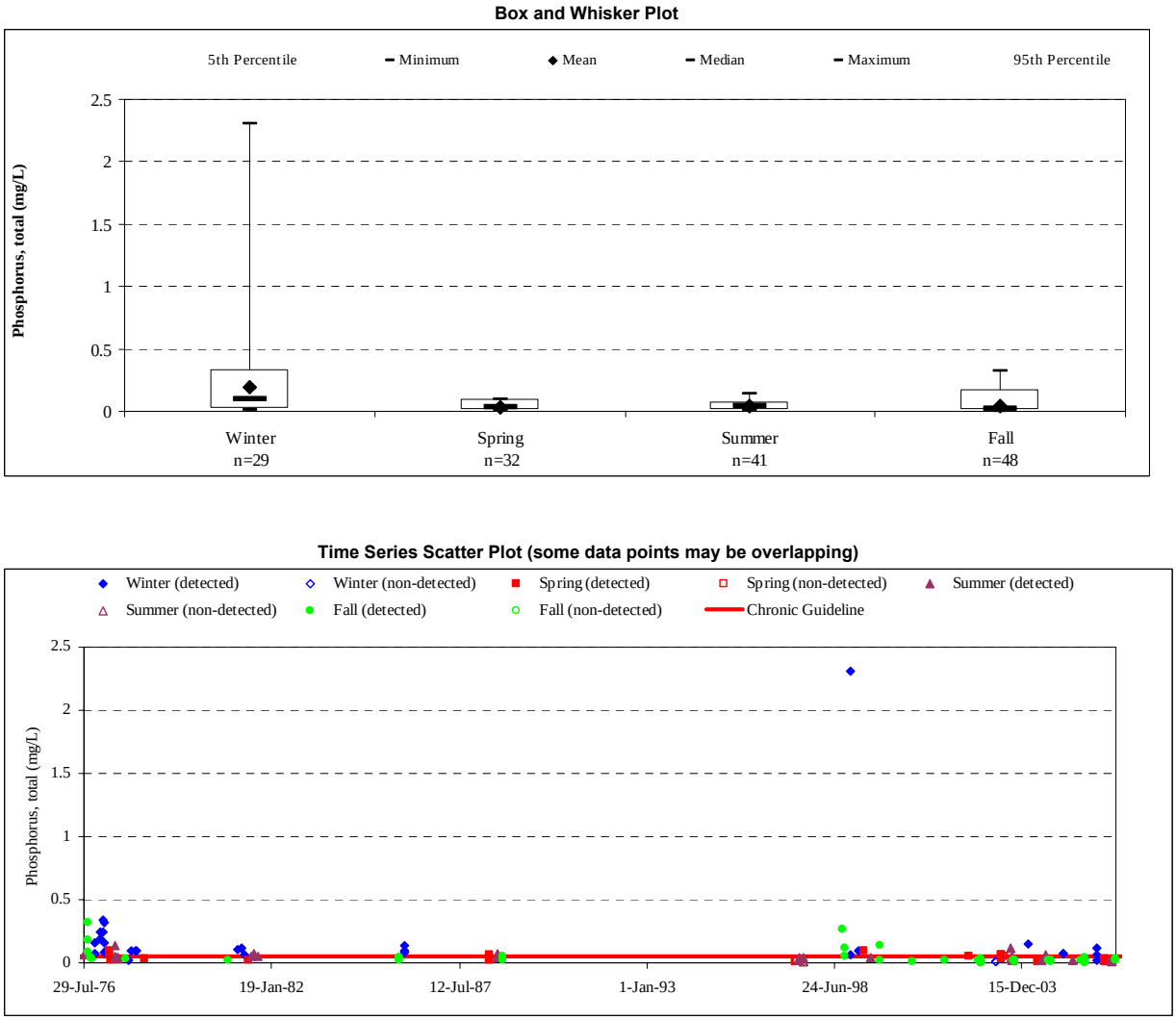
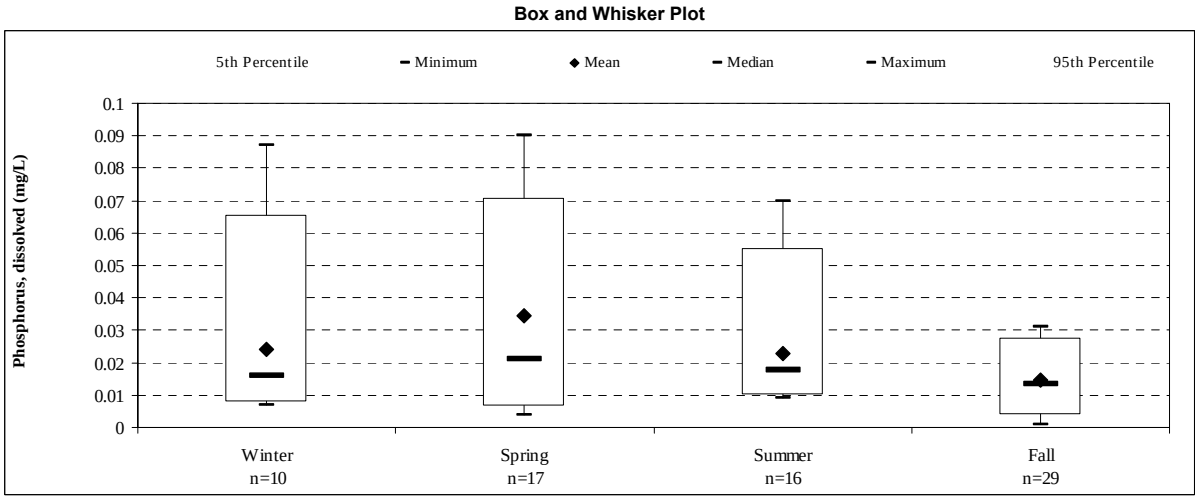


Figure G-2-1-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Upper Segment of Muskeg River



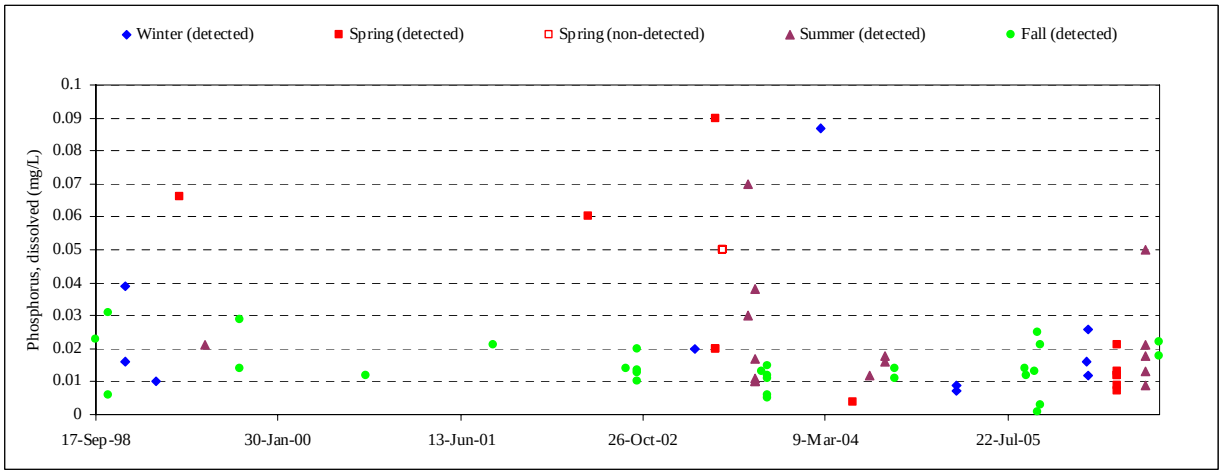
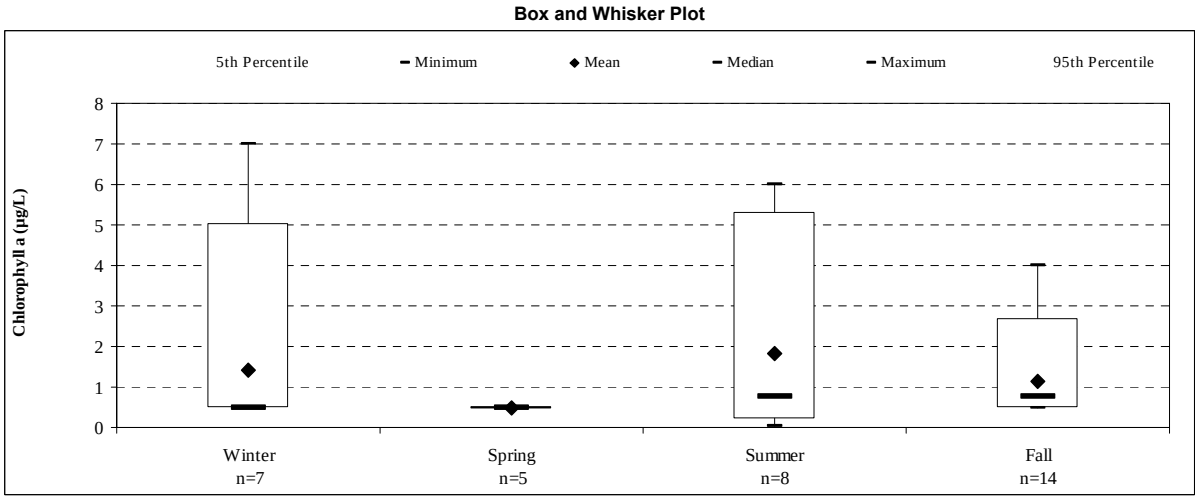


Figure G-2-1-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Upper Segment of Muskeg River



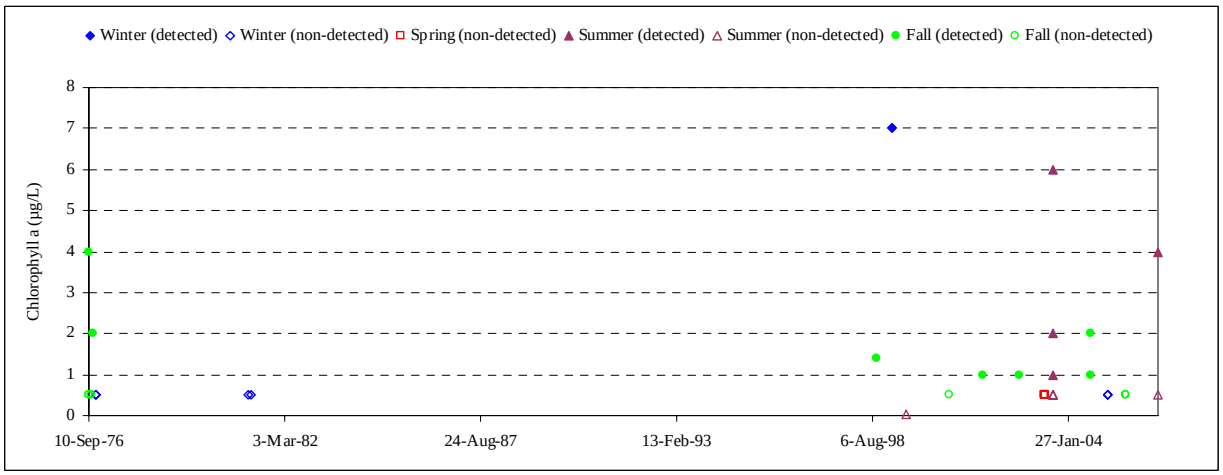


Figure G-2-1-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Upper Segment of Muskeg River

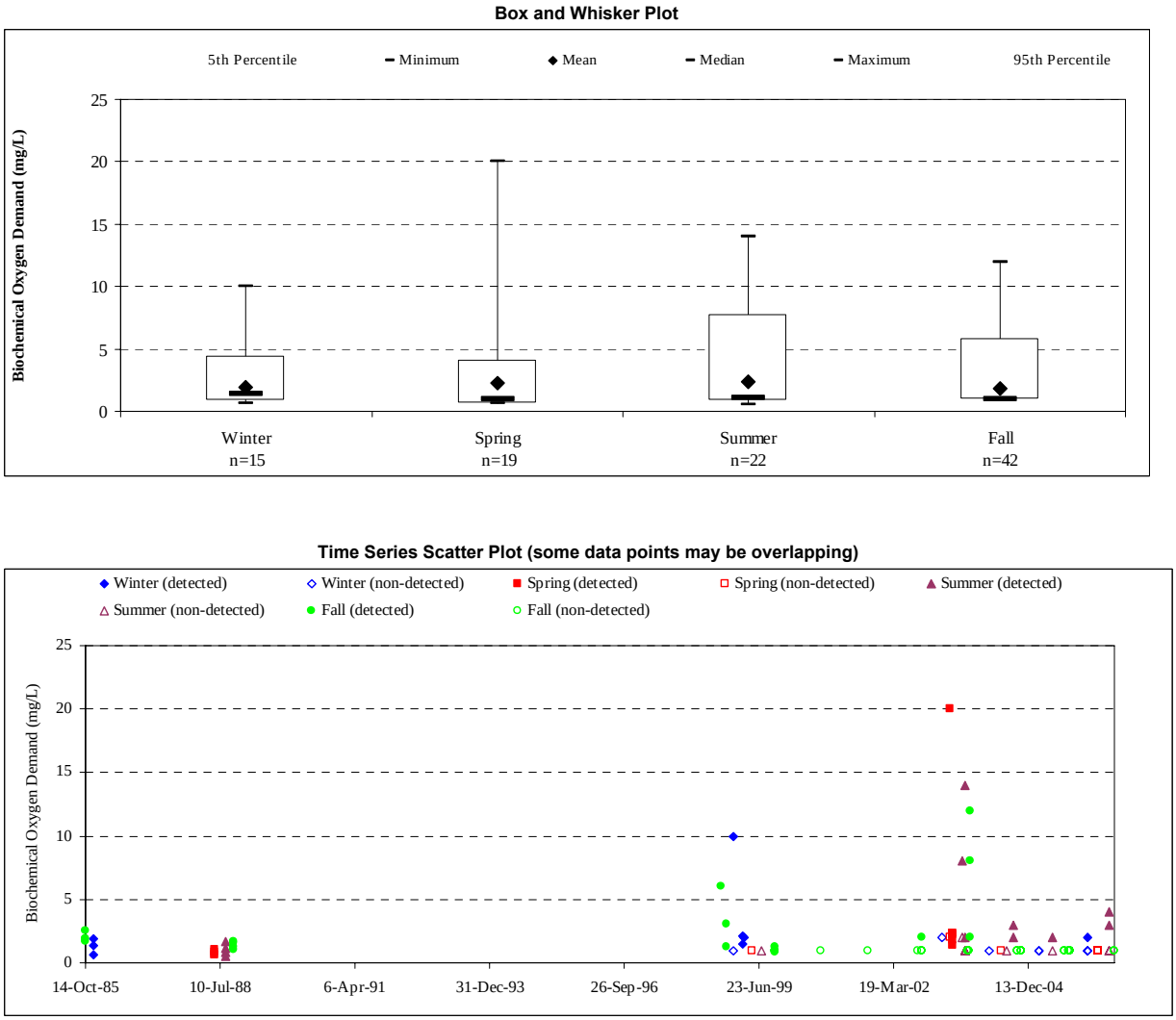


Figure G-2-1-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Upper Segment of Muskeg River

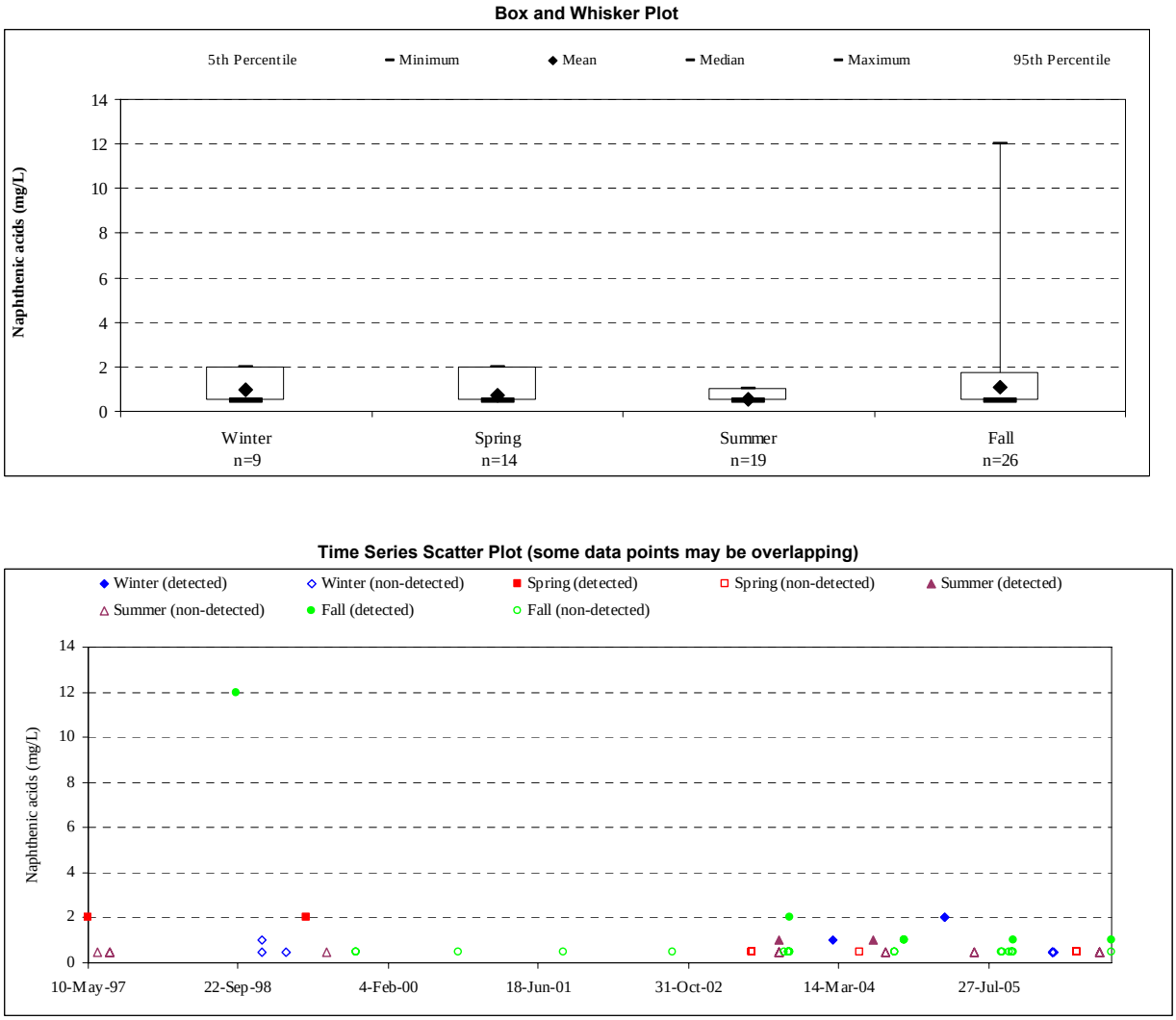


Figure G-2-1-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Upper Segment of Muskeg River

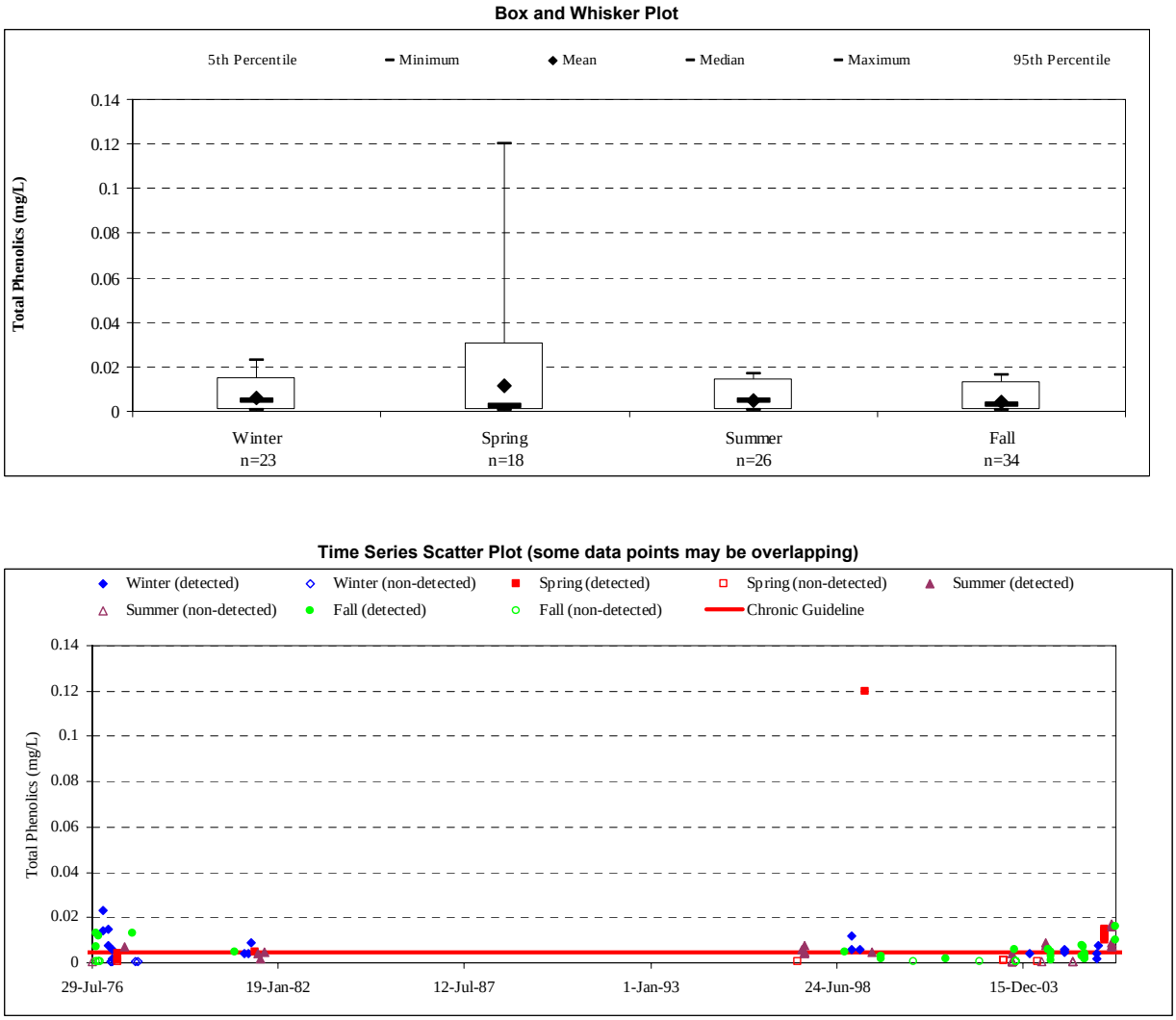


Figure G-2-1-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Upper Segment of Muskeg River

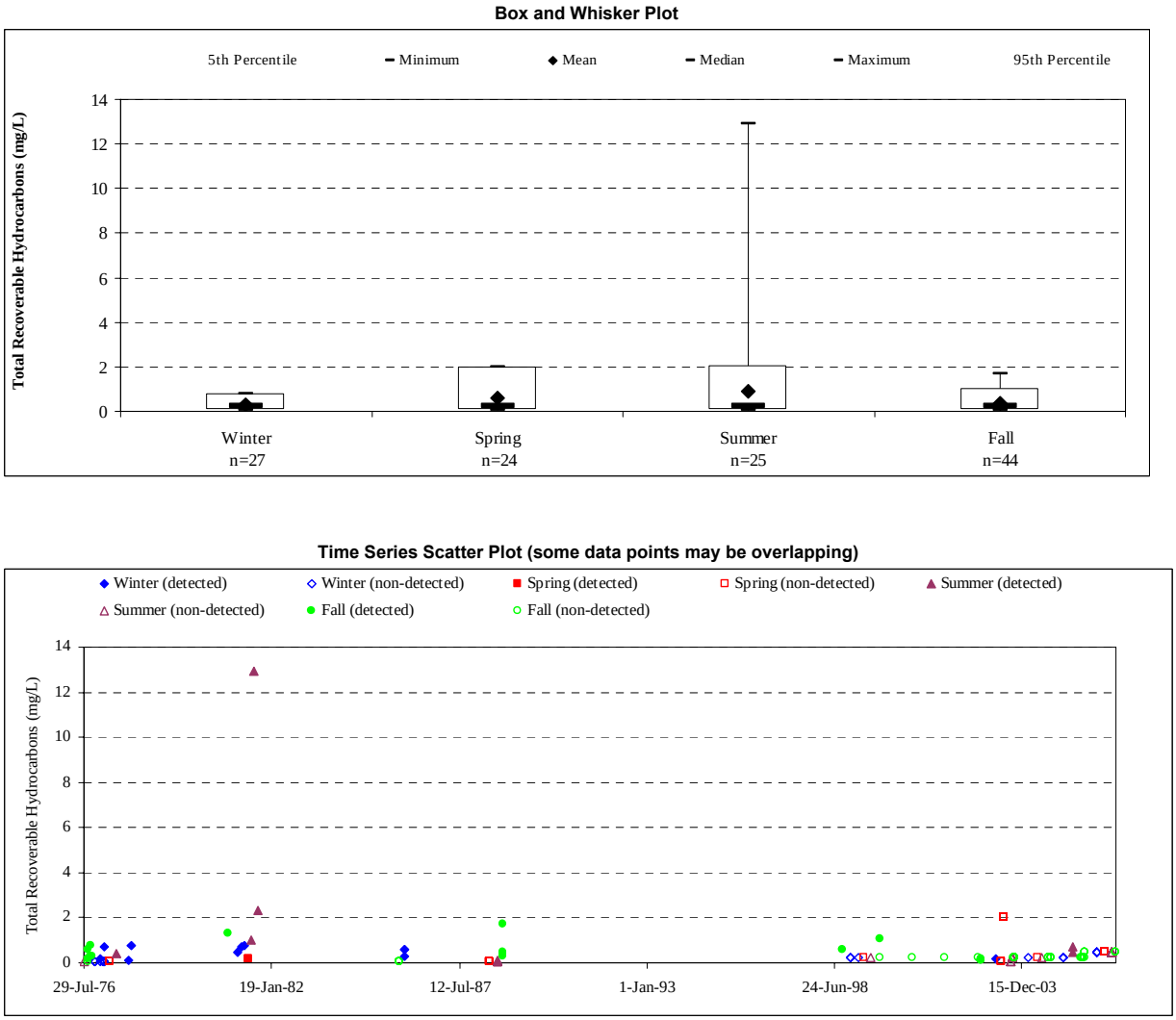
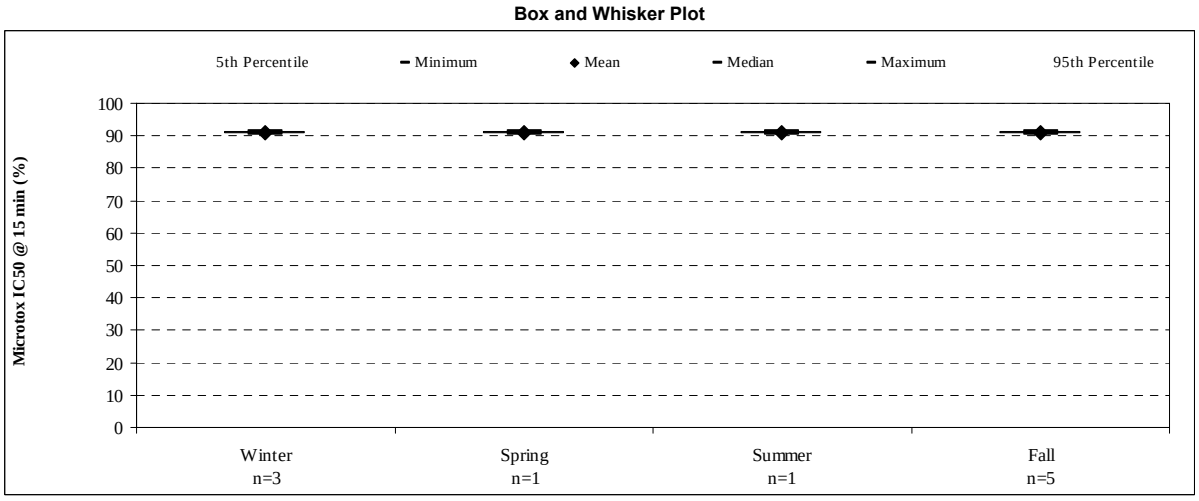


Figure G-2-1-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Upper Segment of Muskeg River



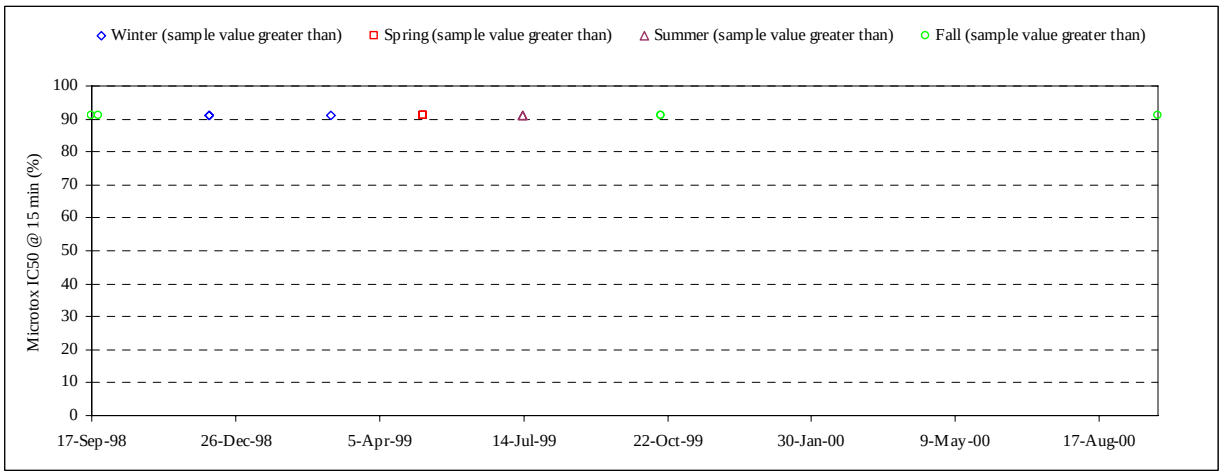


Figure G-2-1-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Upper Segment of Muskeg River

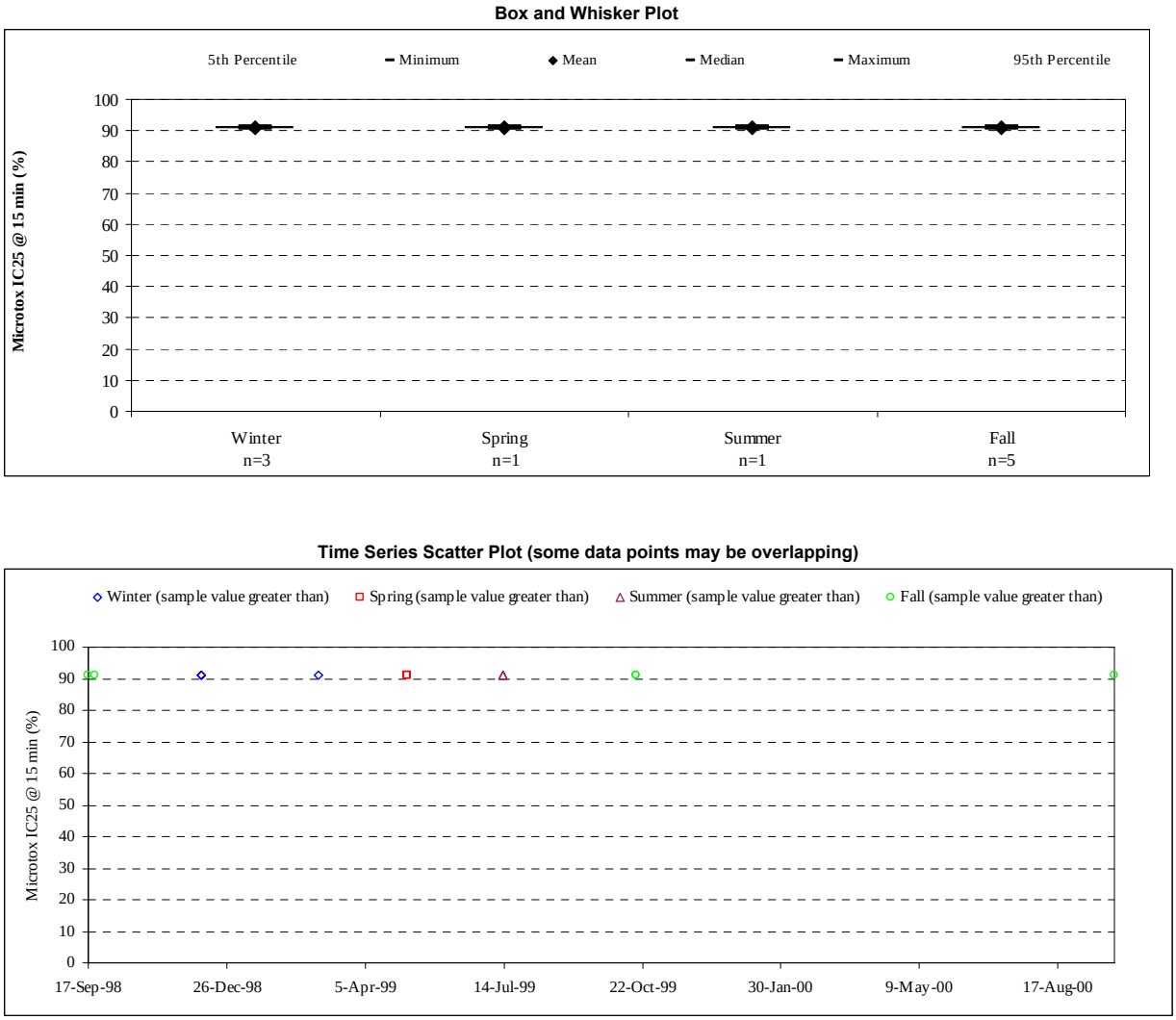
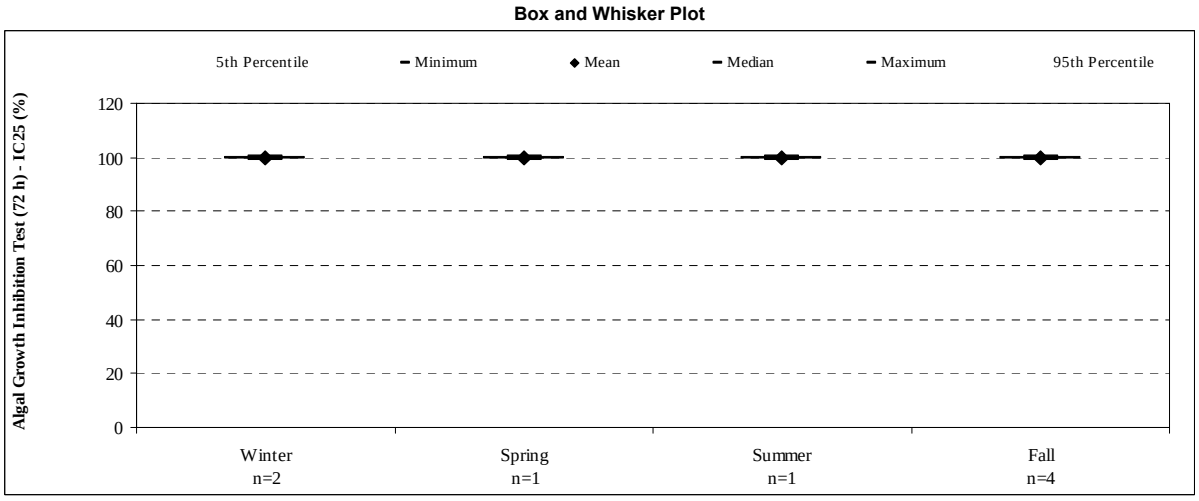


Figure G-2-1-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Upper Segment of Muskeg River



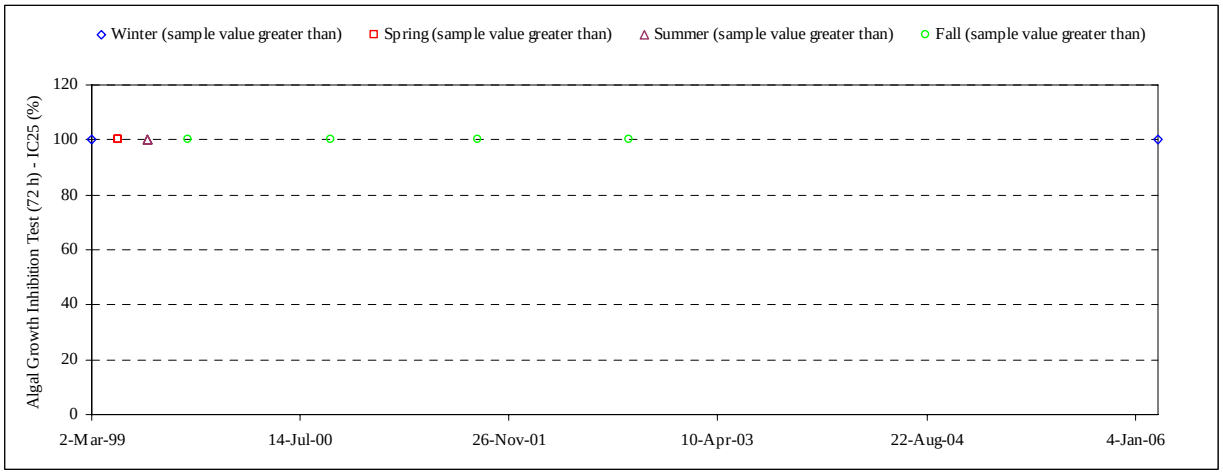
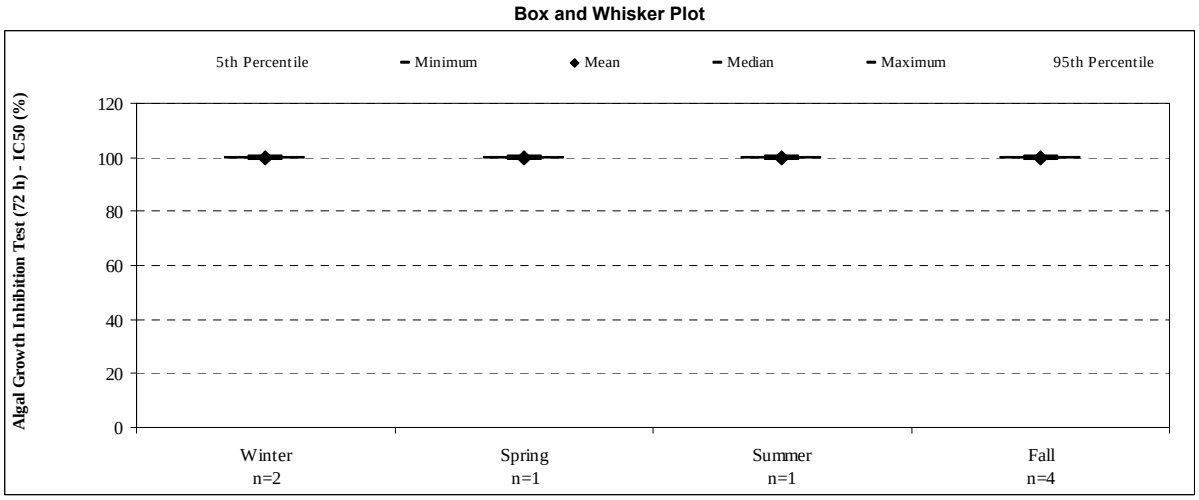


Figure G-2-1-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Upper Segment of Muskeg River



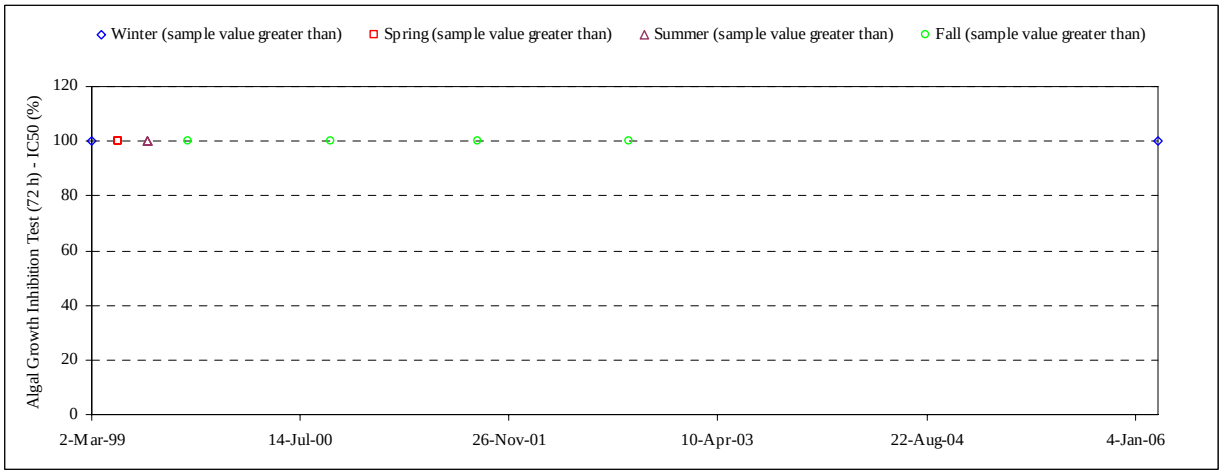
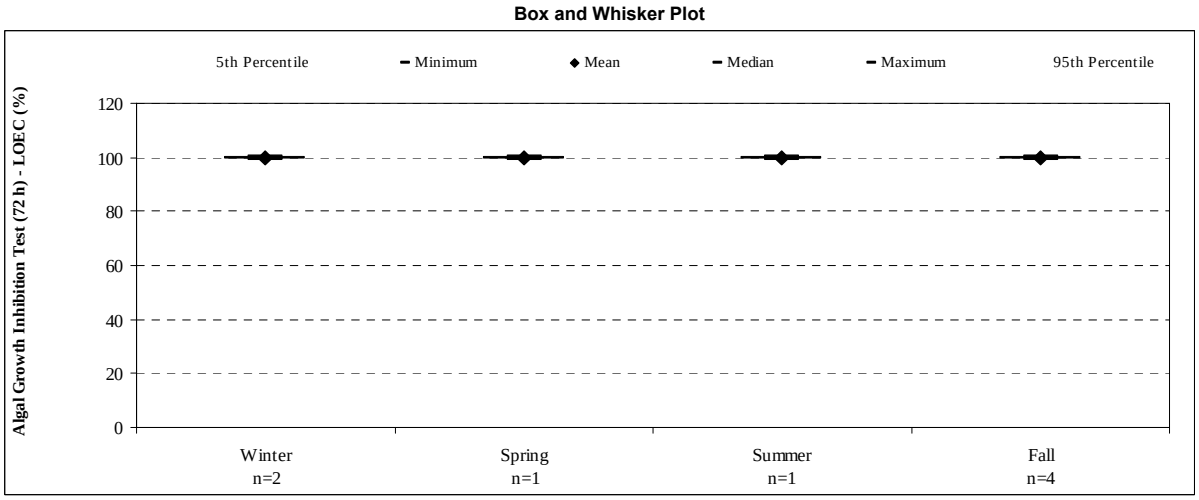


Figure G-2-1-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Upper Segment of Muskeg River



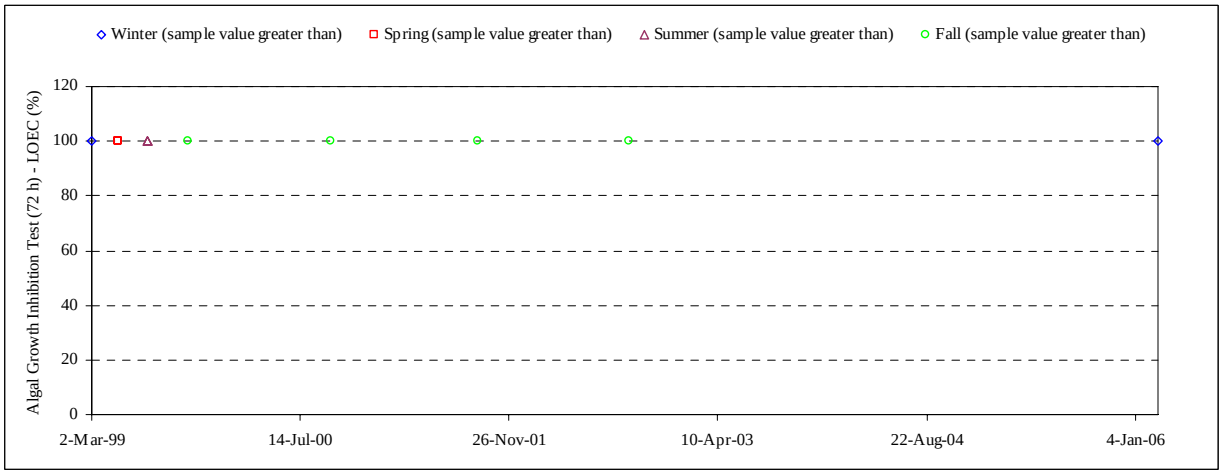
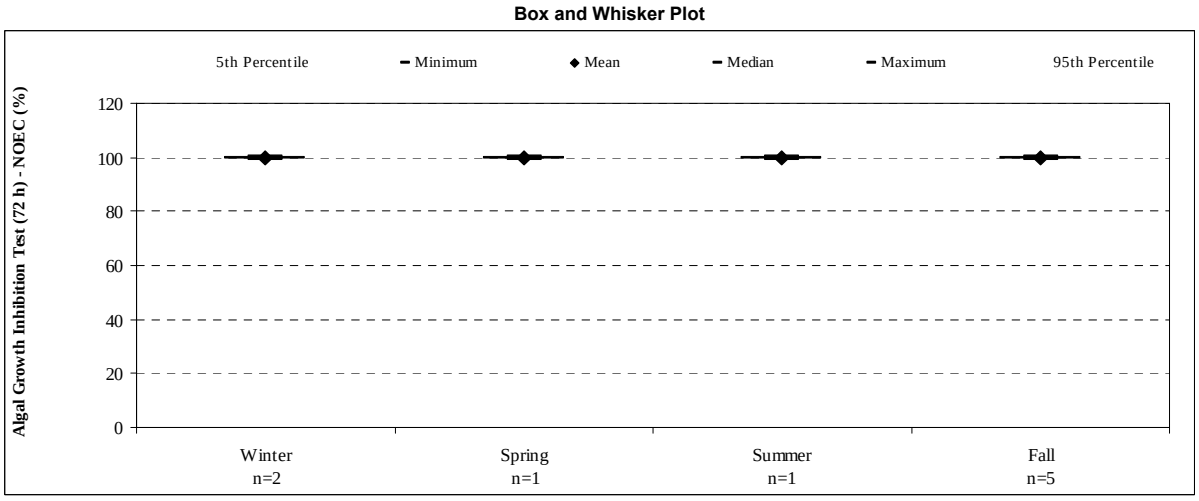


Figure G-2-1-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Upper Segment of Muskeg River



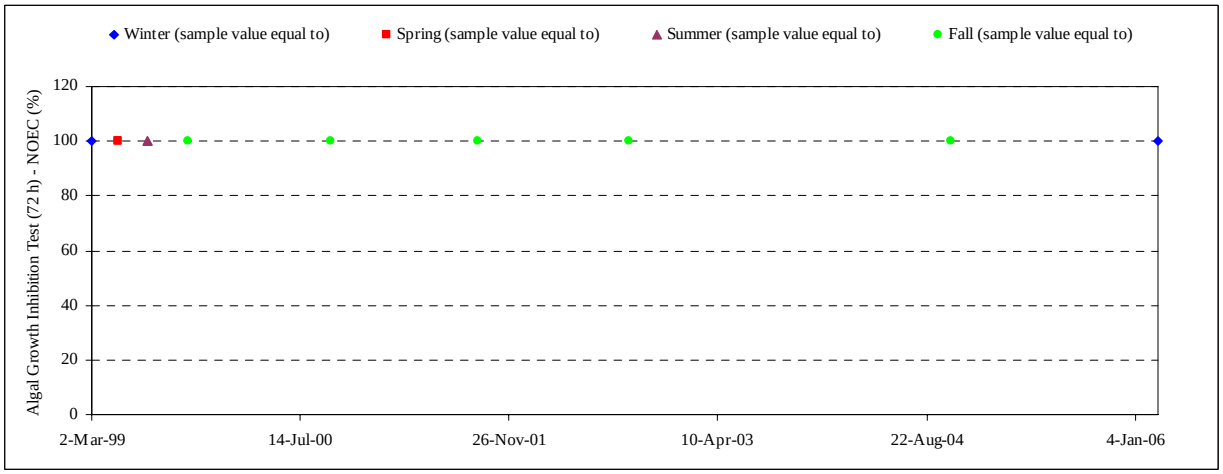
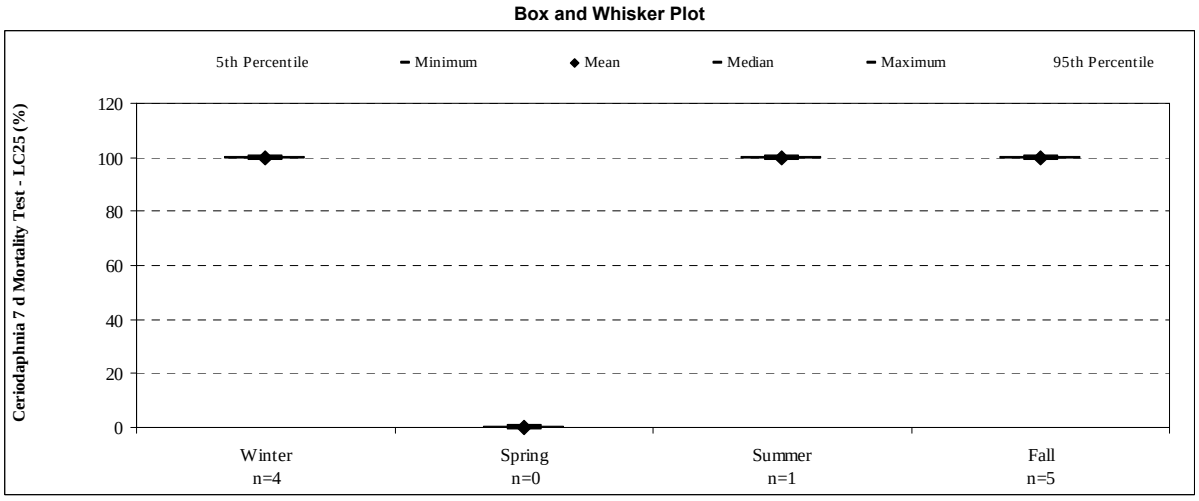


Figure G-2-1-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Upper Segment of Muskeg River



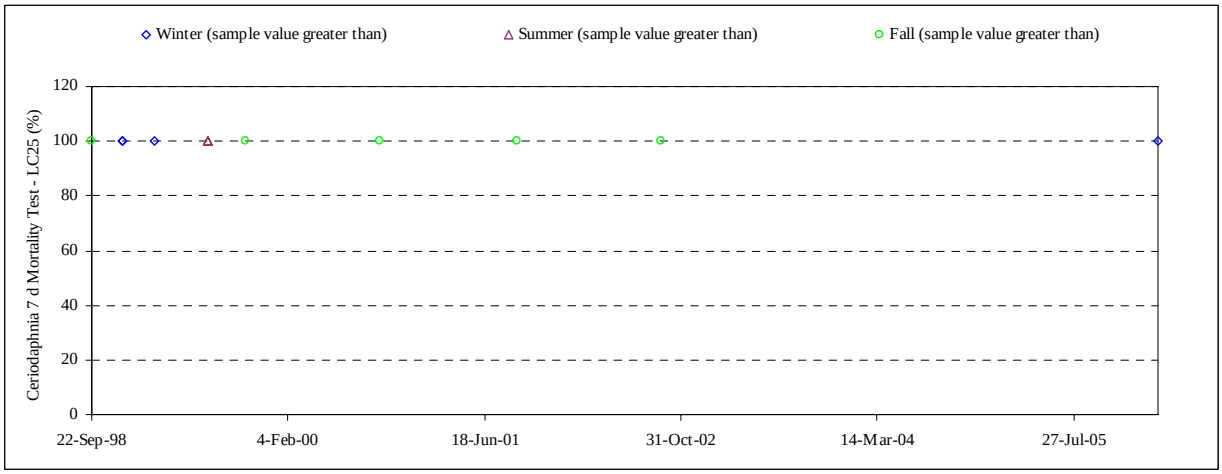
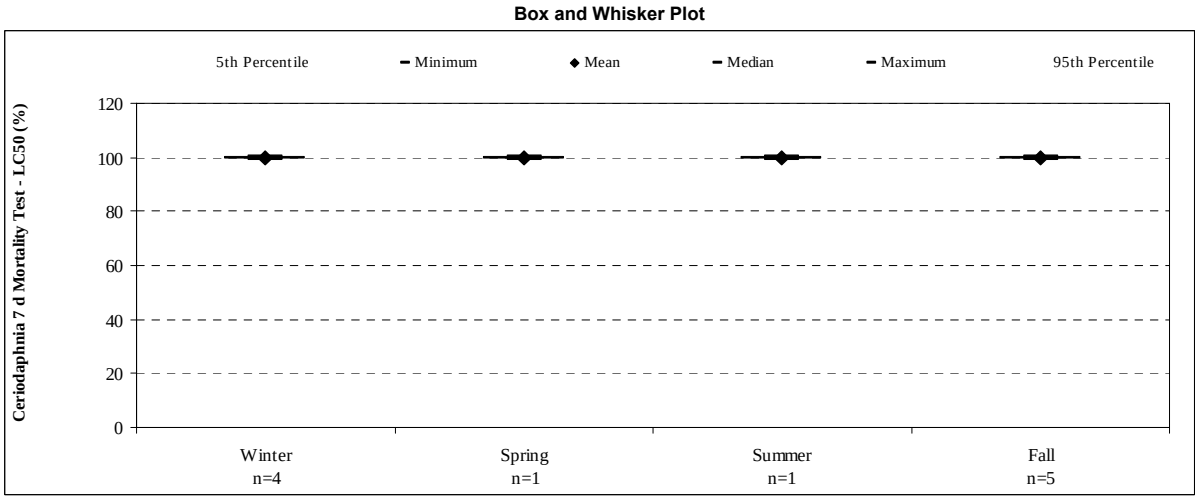


Figure G-2-1-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Upper Segment of Muskeg River



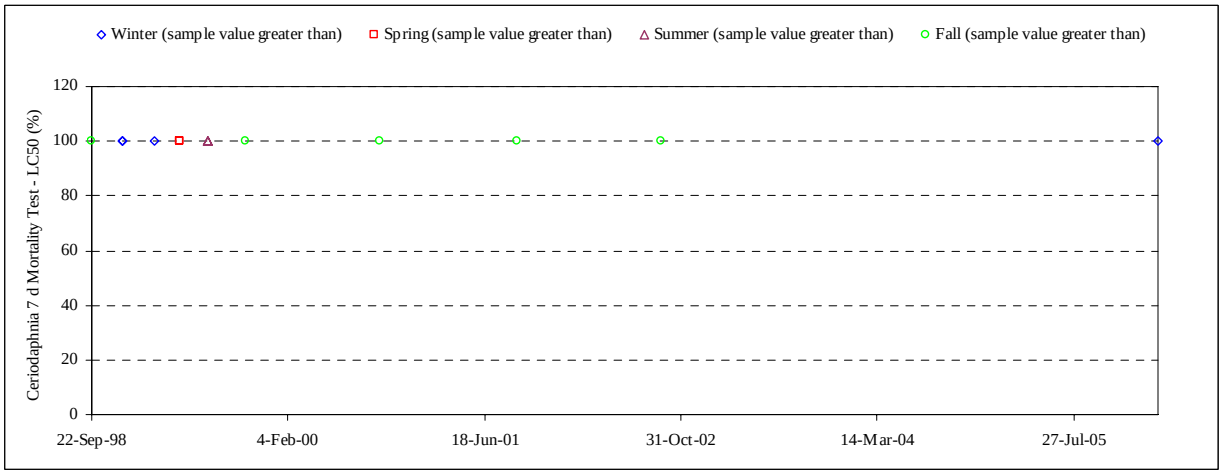
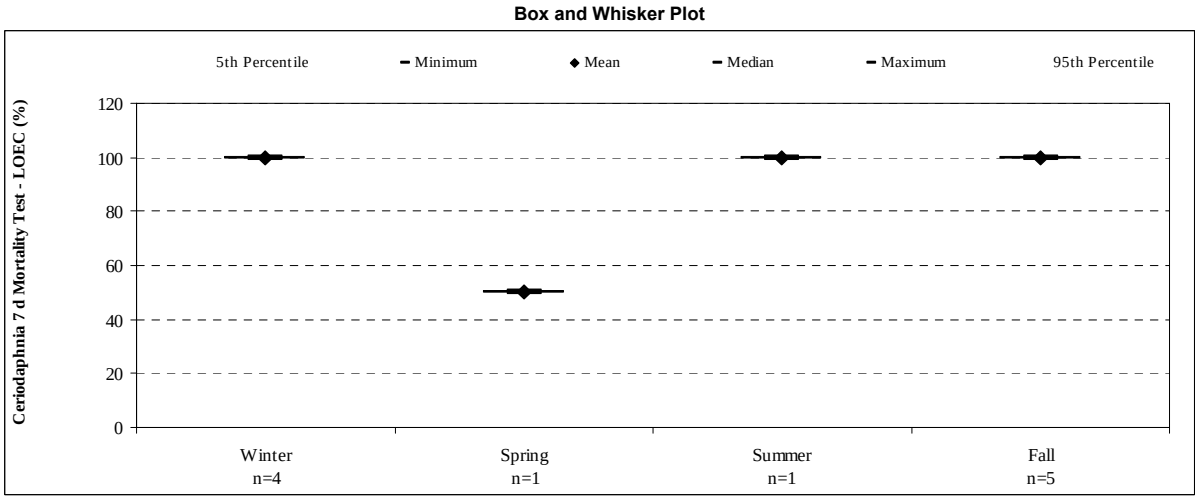


Figure G-2-1-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Upper Segment of Muskeg River



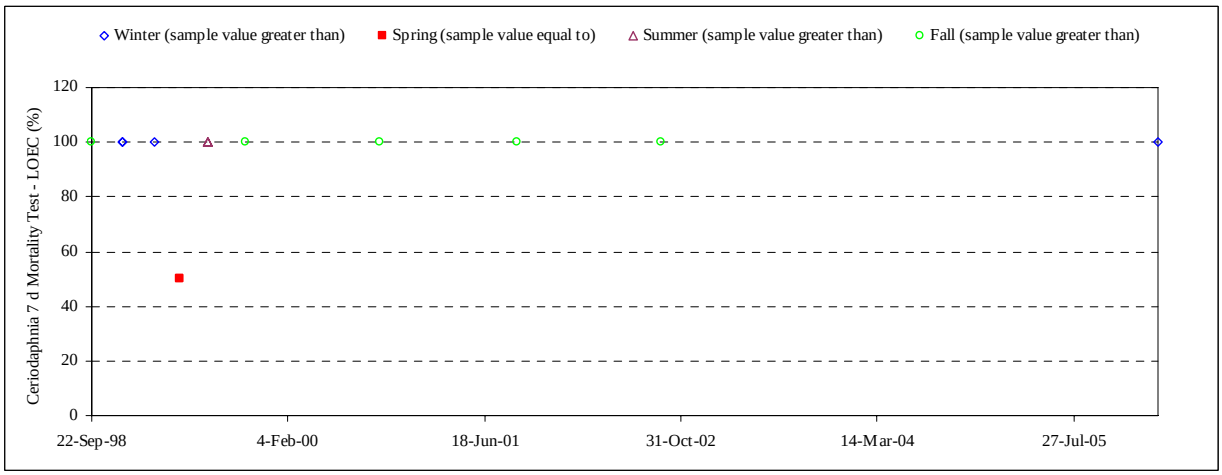
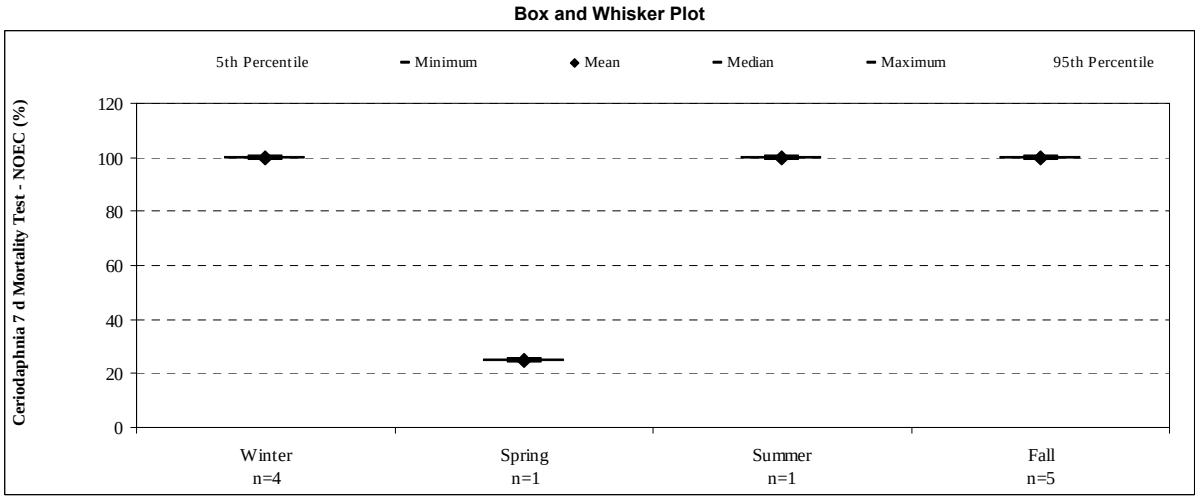


Figure G-2-1-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Upper Segment of Muskeg River



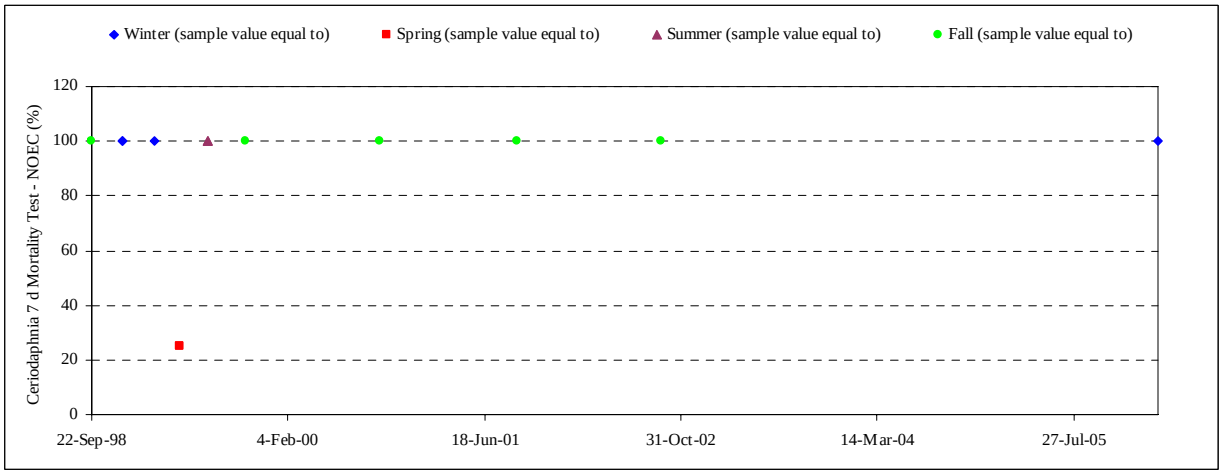
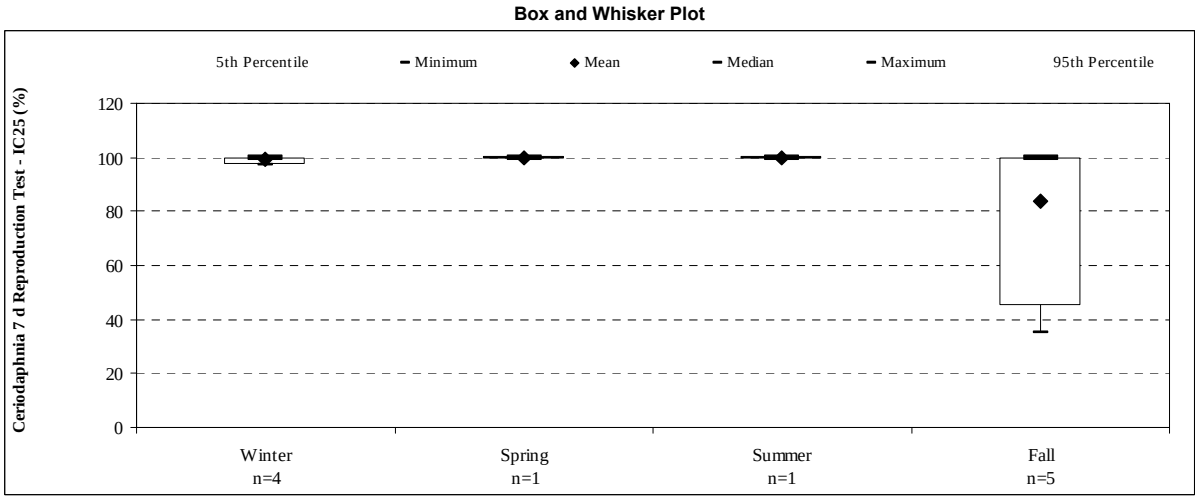


Figure G-2-1-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Upper Segment of Muskeg River



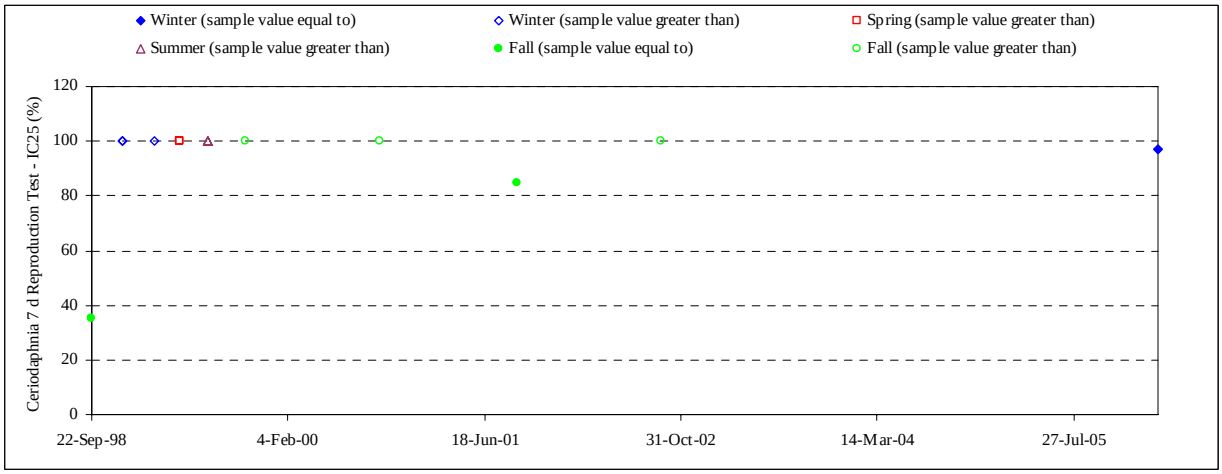
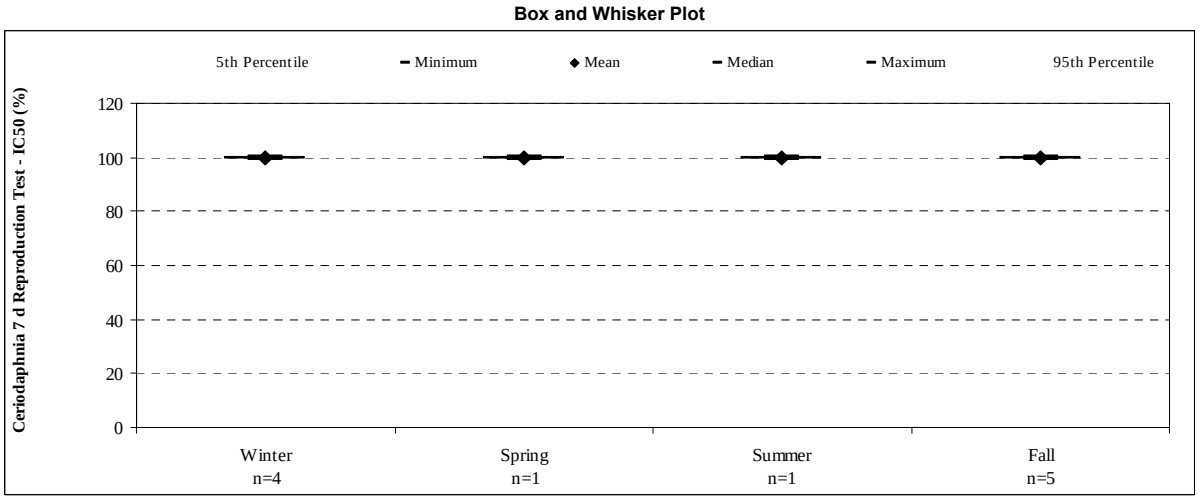
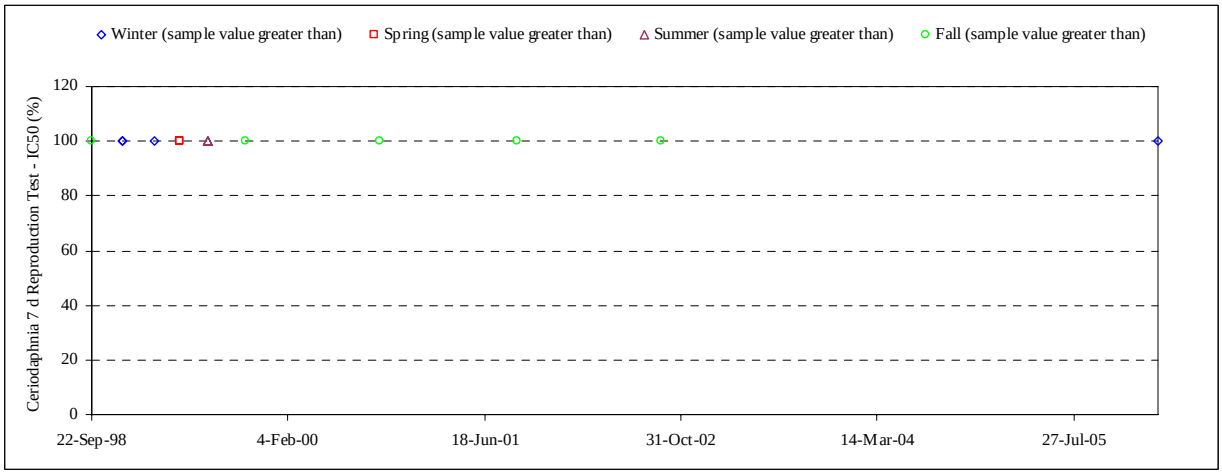


Figure G-2-1-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Upper Segment of Muskeg River





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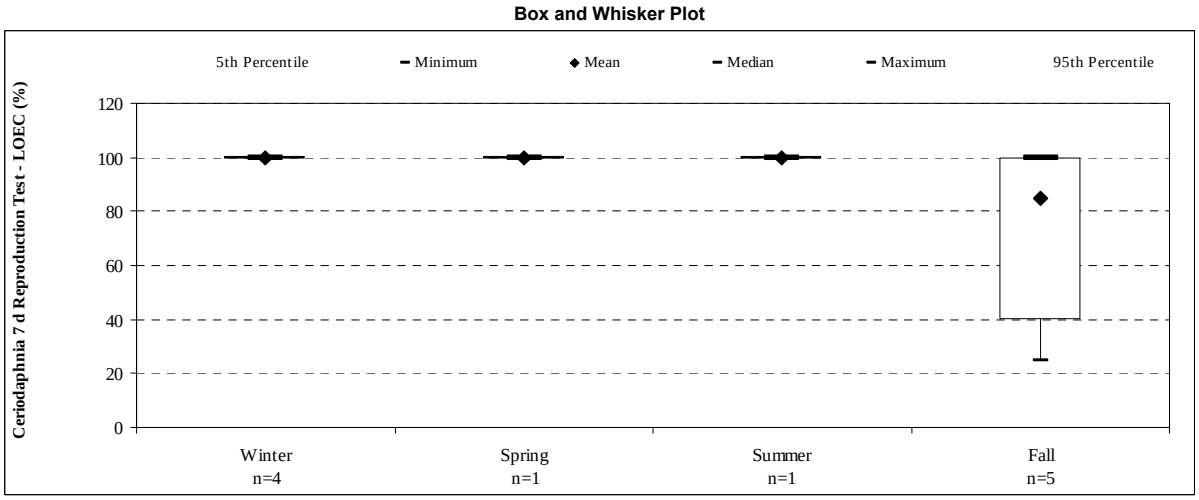


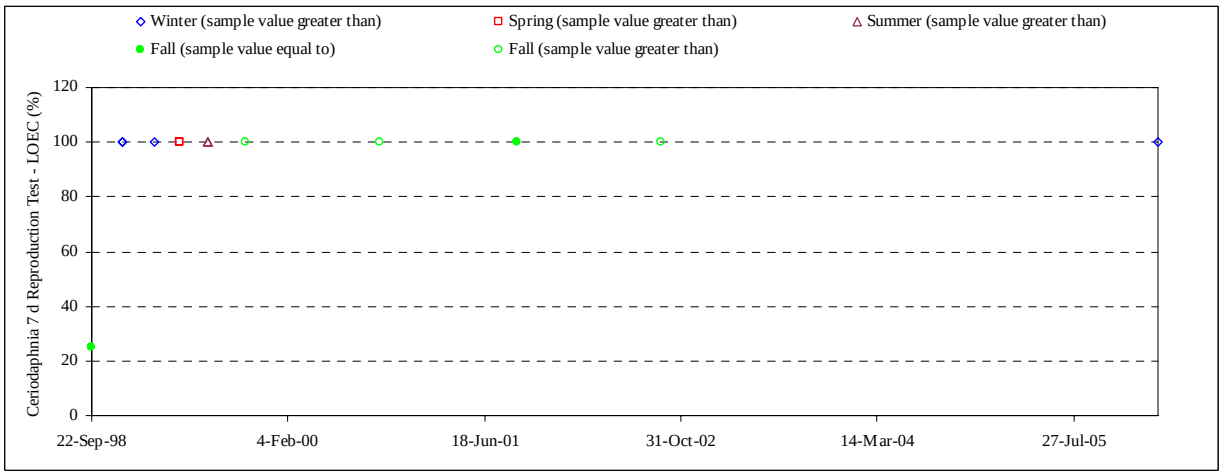
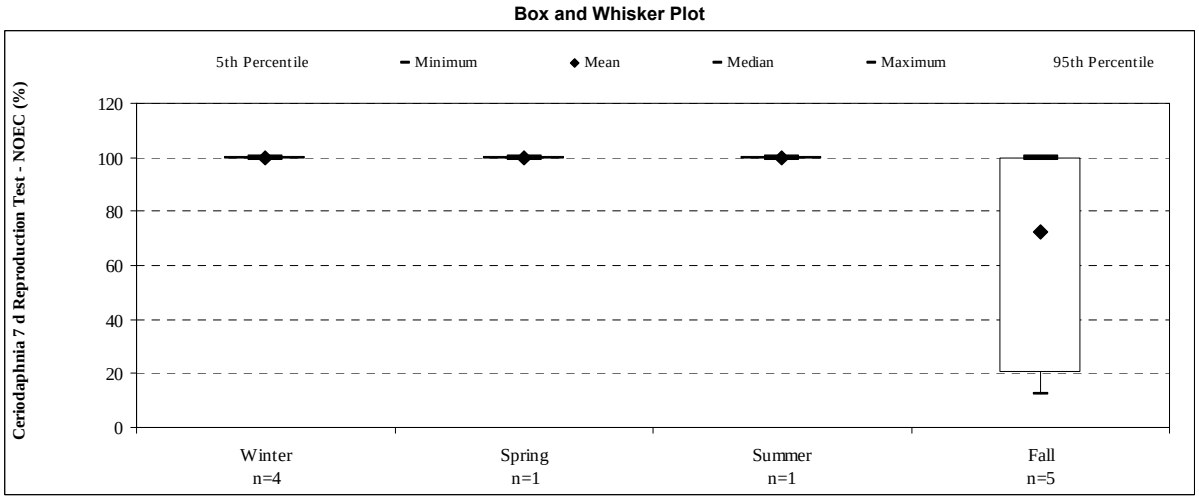


Figure G-2-1-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Upper Segment of Muskeg River



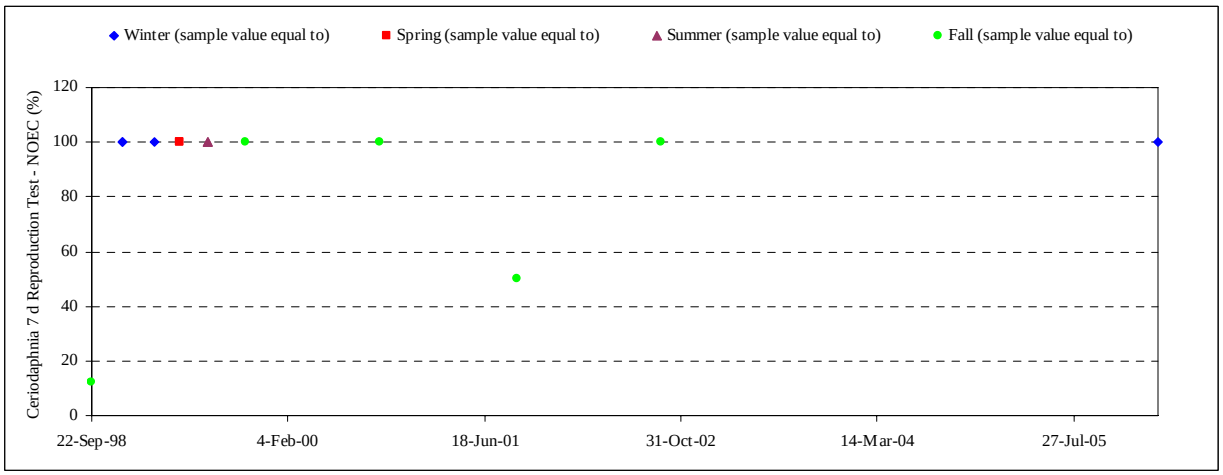
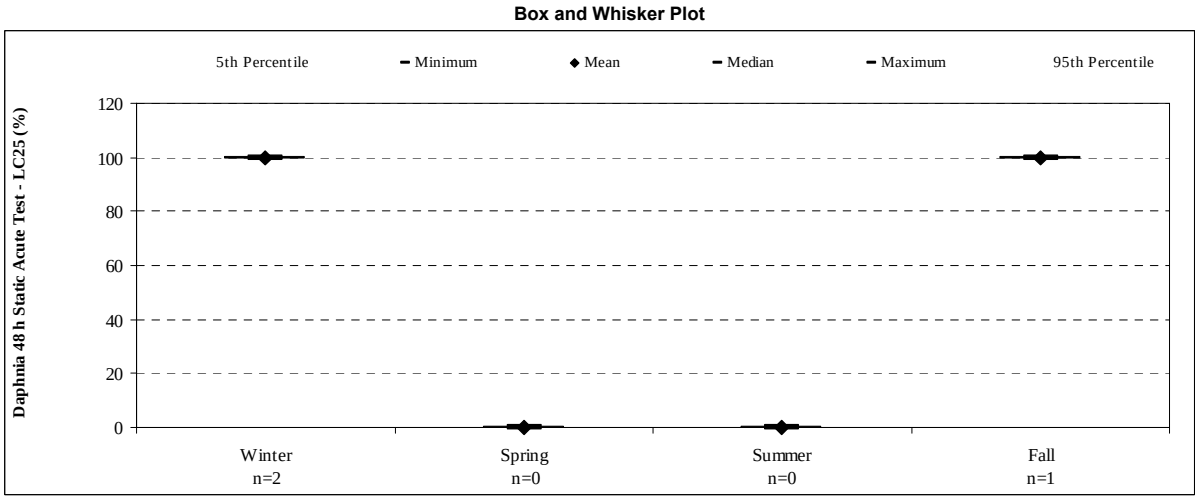


Figure G-2-1-46 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - LC25 in Upper Segment of Muskeg River



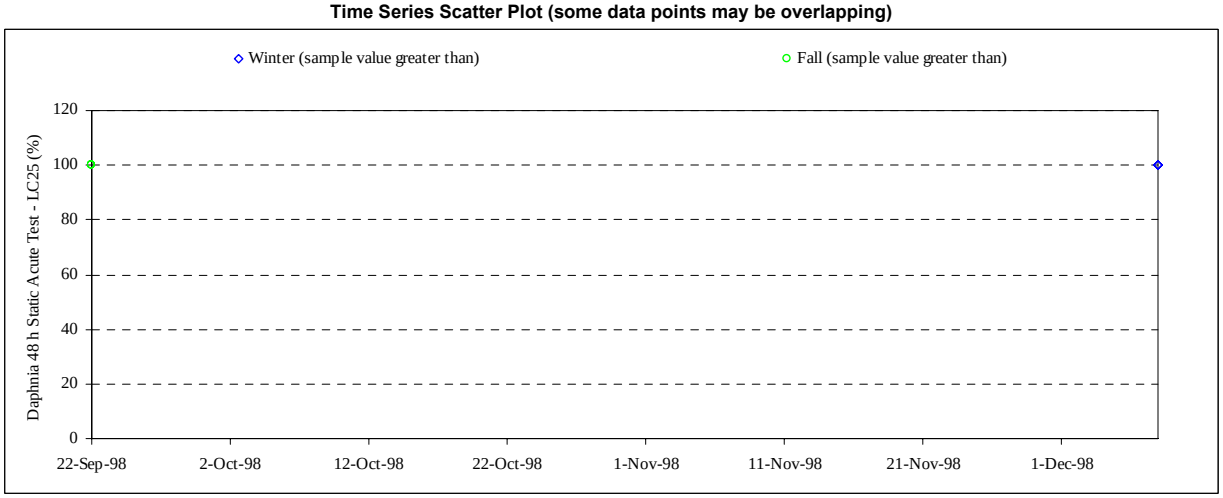
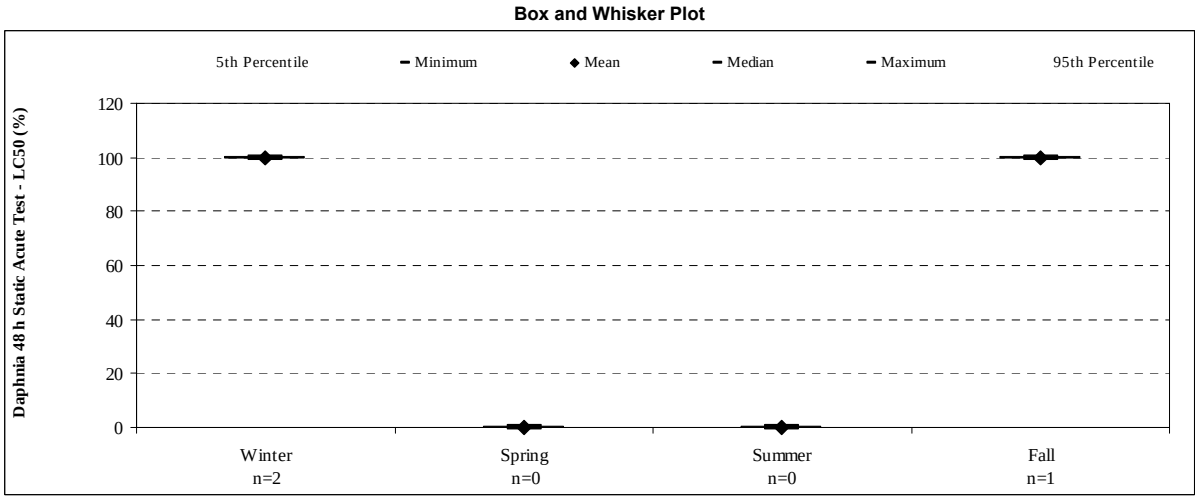


Figure G-2-1-47 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - LC50 in Upper Segment of Muskeg River



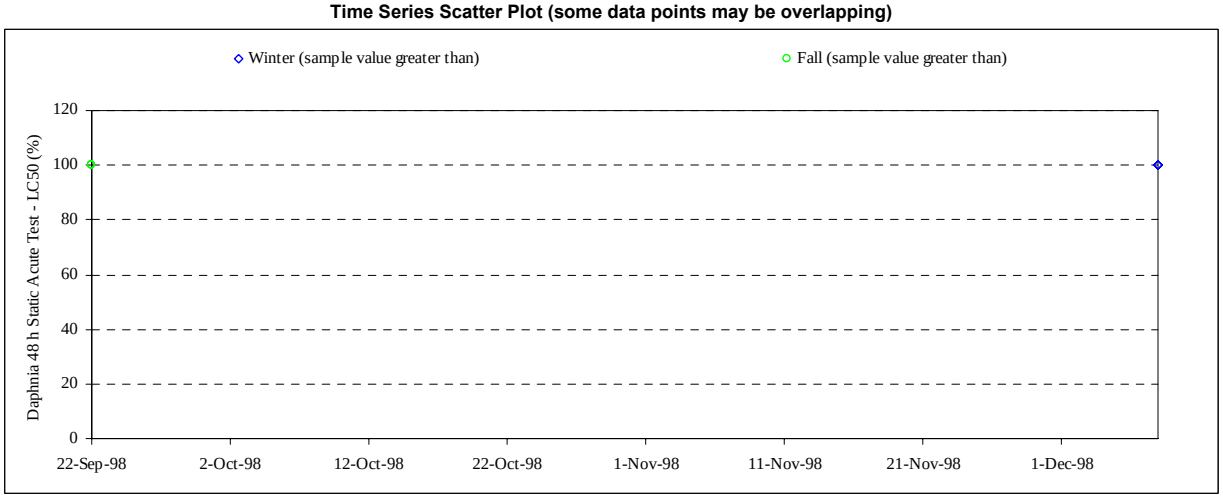
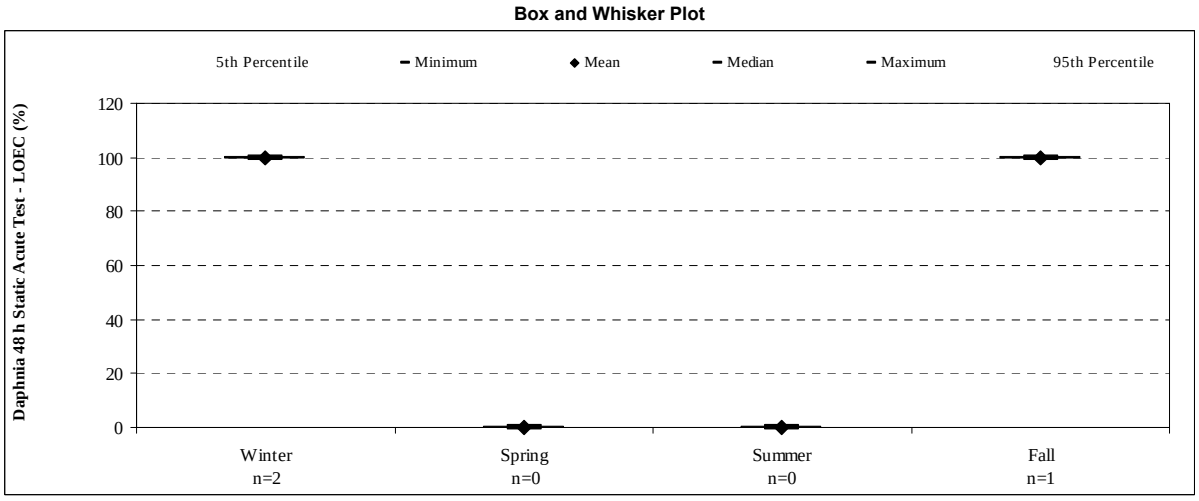


Figure G-2-1-48 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - LOEC in Upper Segment of Muskeg River



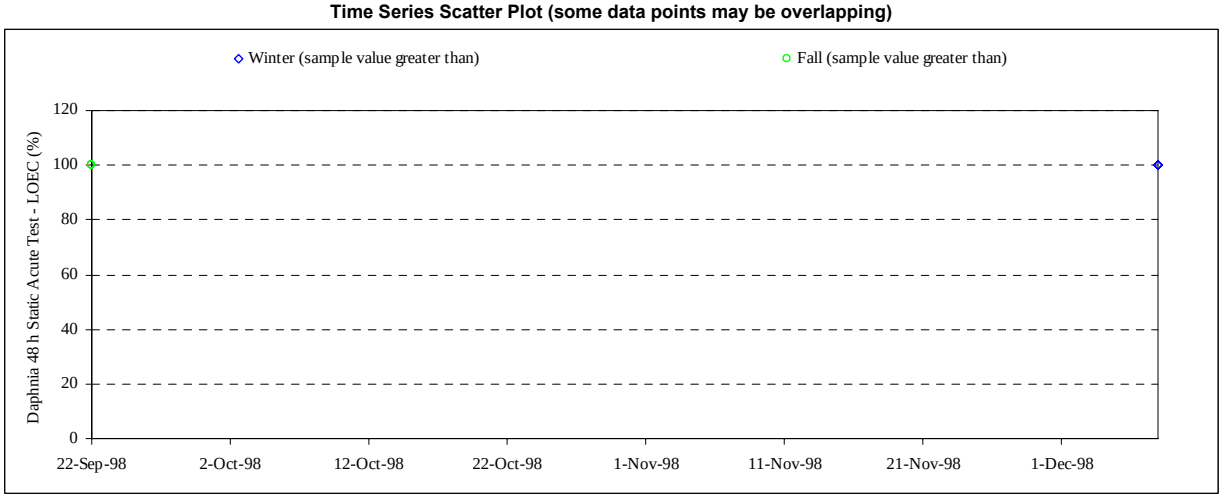
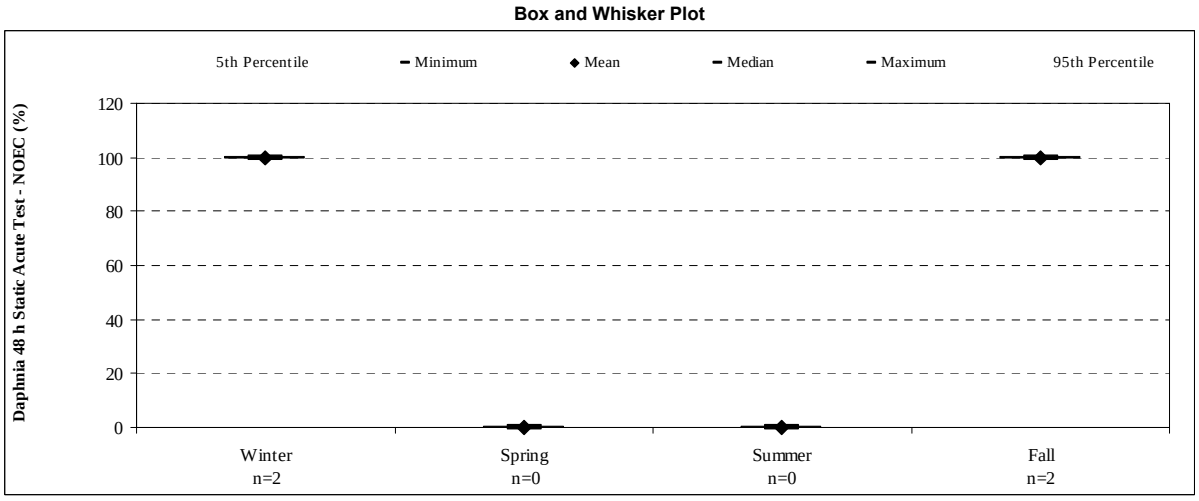


Figure G-2-1-49 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - NOEC in Upper Segment of Muskeg River



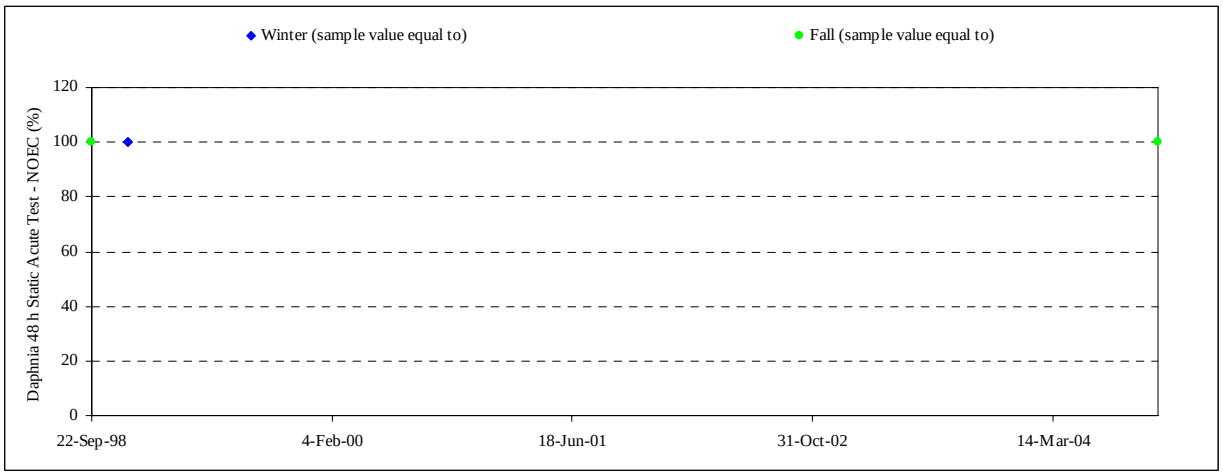


Figure G-2-1-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Upper Segment of Muskeg River

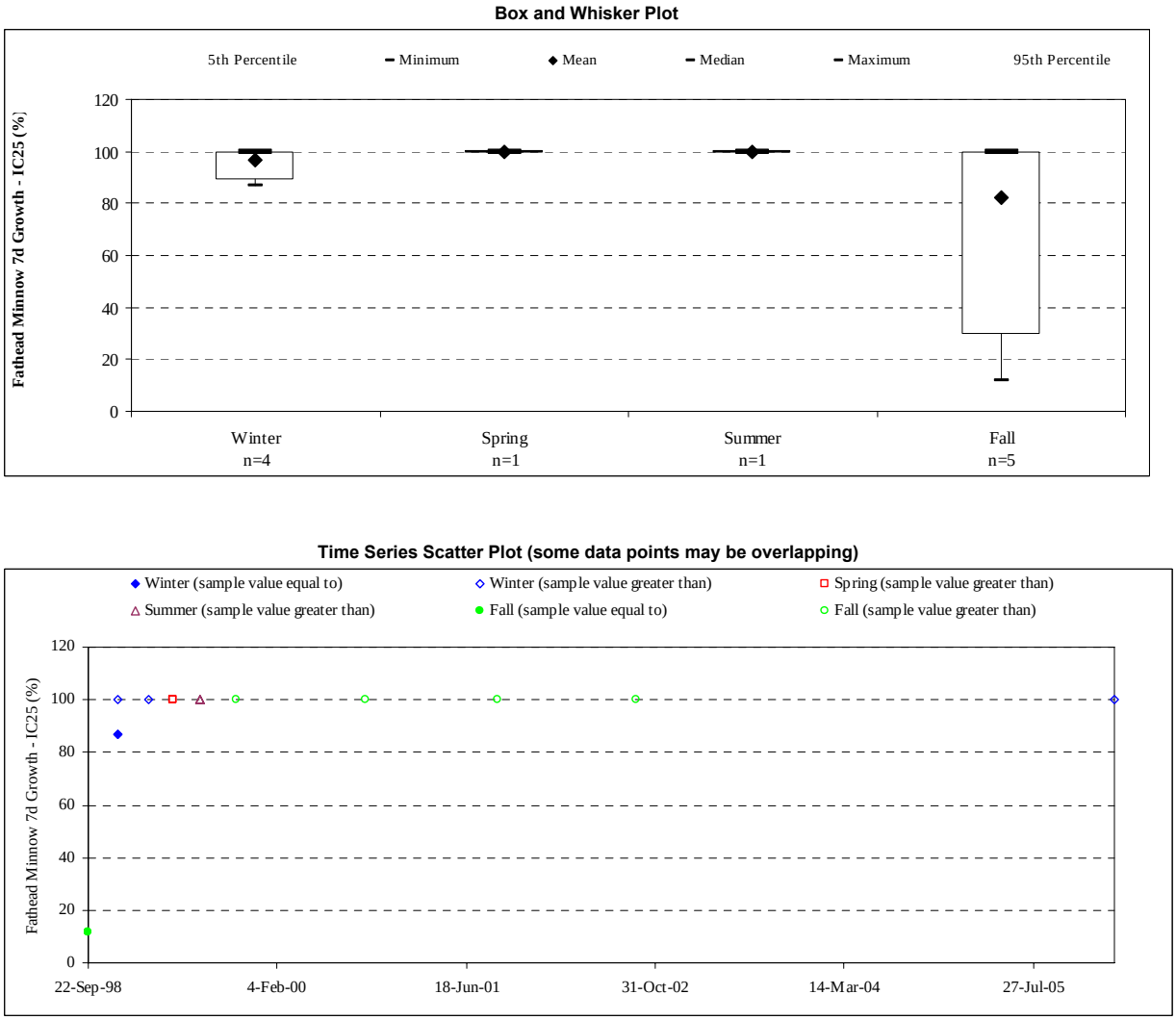
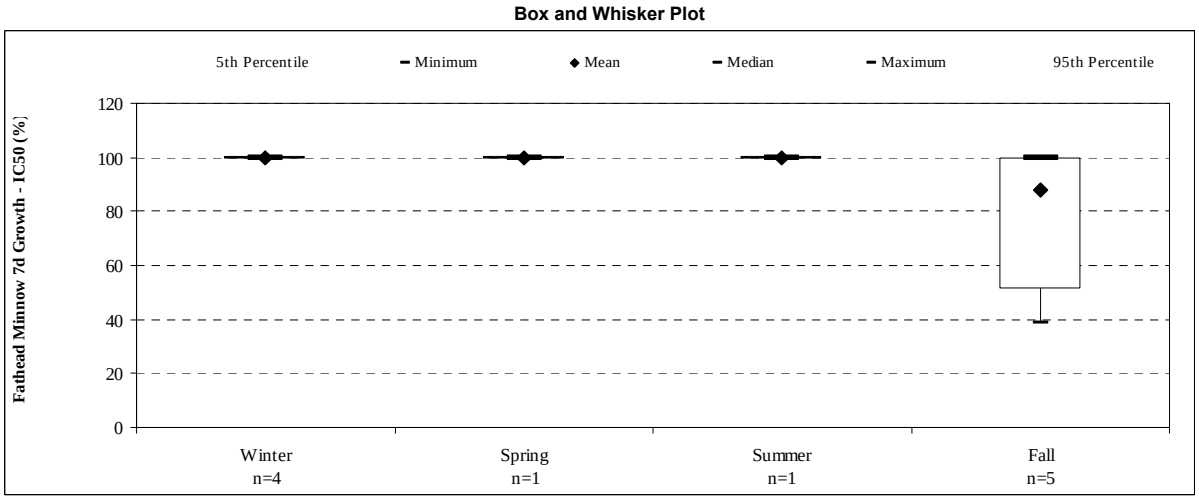


Figure G-2-1-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Upper Segment of Muskeg River



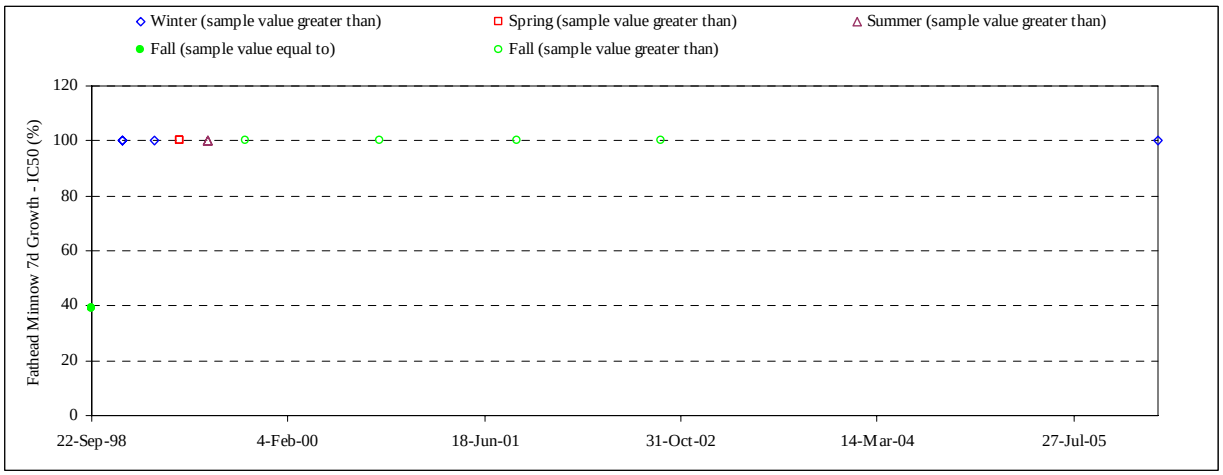


Figure G-2-1-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Upper Segment of Muskeg River

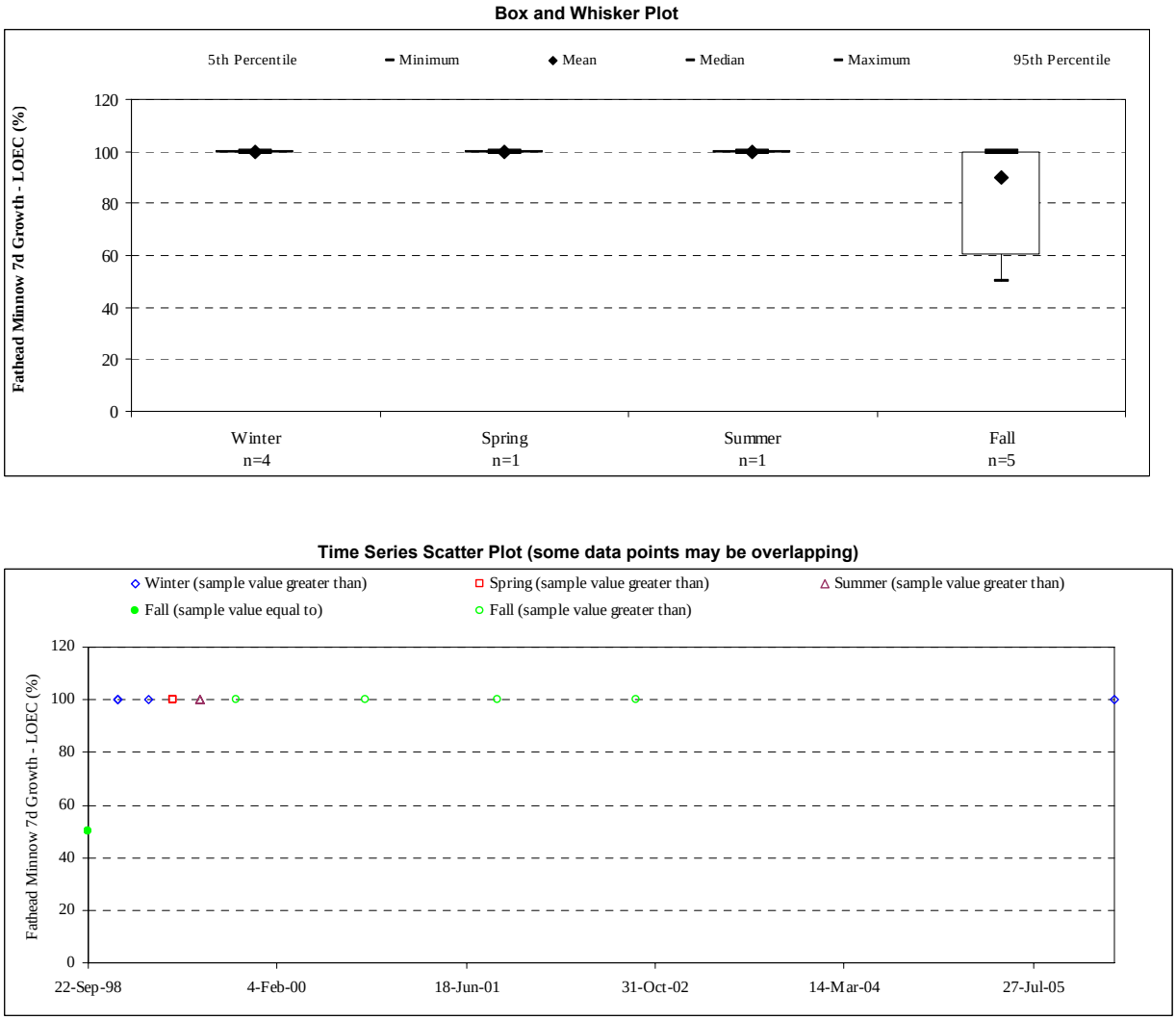
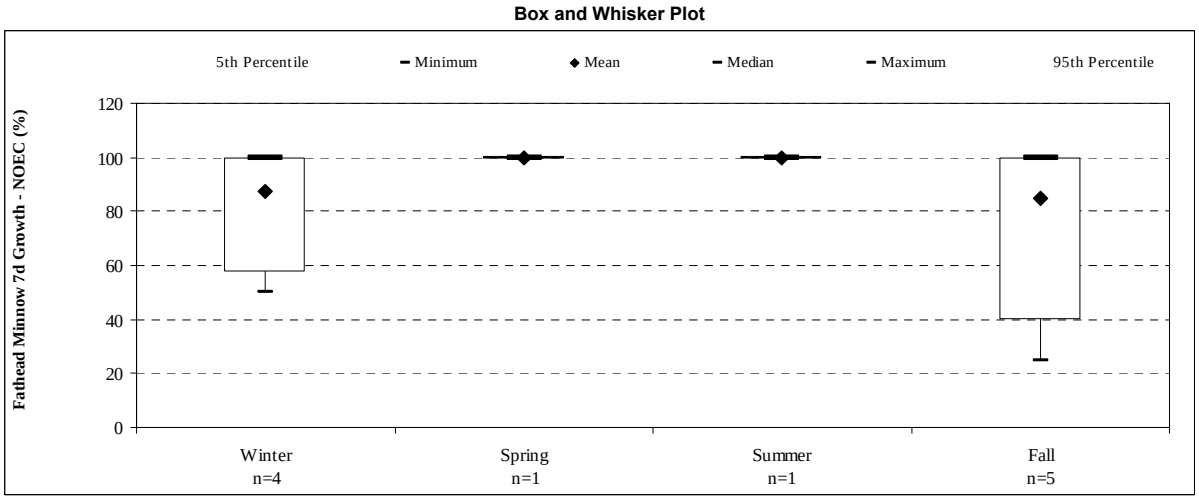


Figure G-2-1-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Upper Segment of Muskeg River



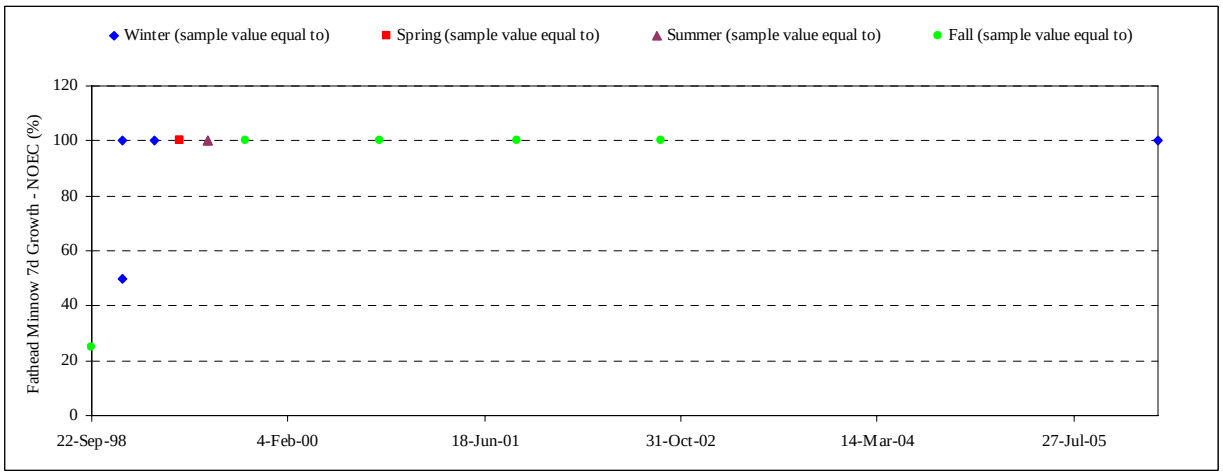


Figure G-2-1-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Upper Segment of Muskeg River

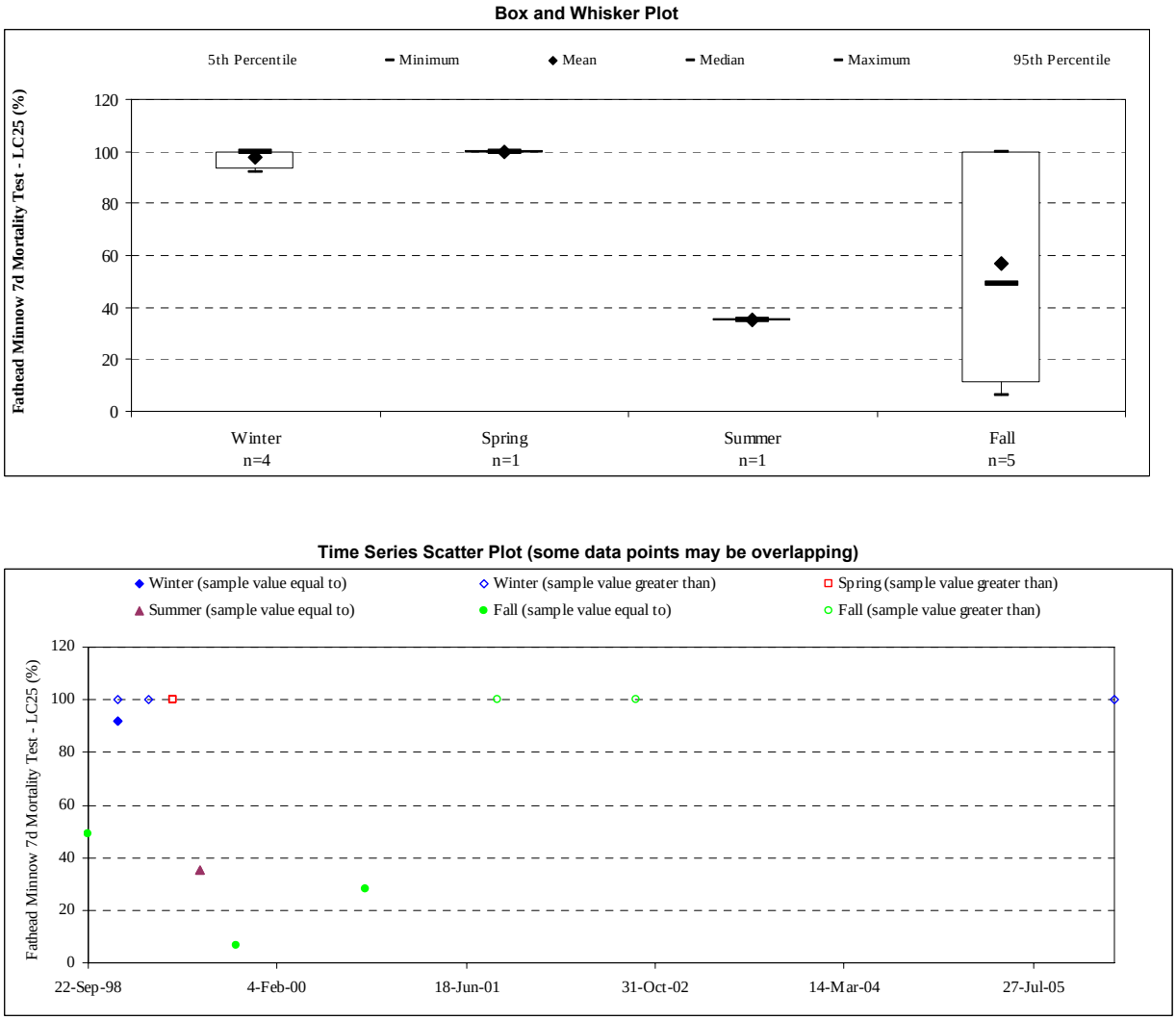
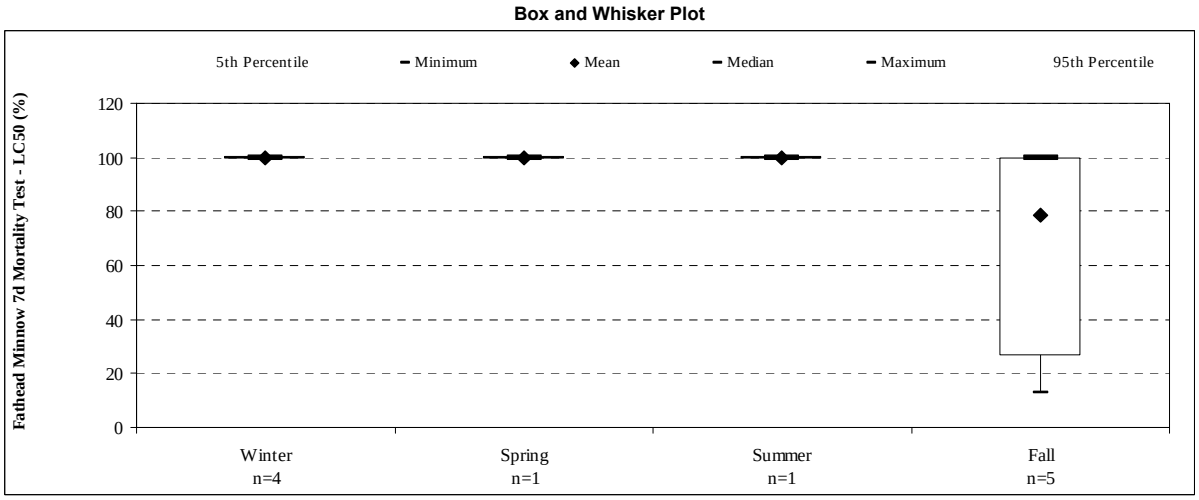


Figure G-2-1-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Upper Segment of Muskeg River



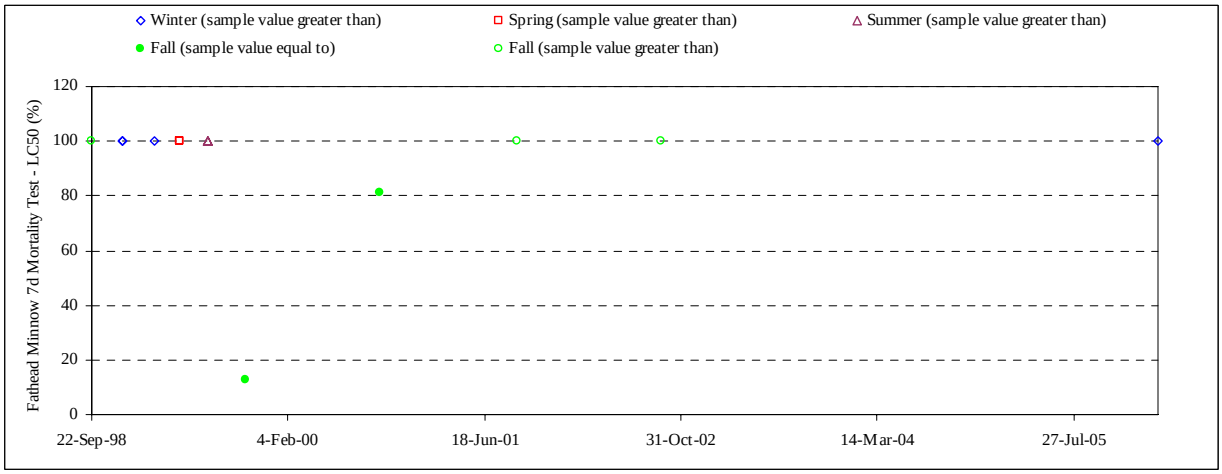


Figure G-2-1-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Upper Segment of Muskeg River

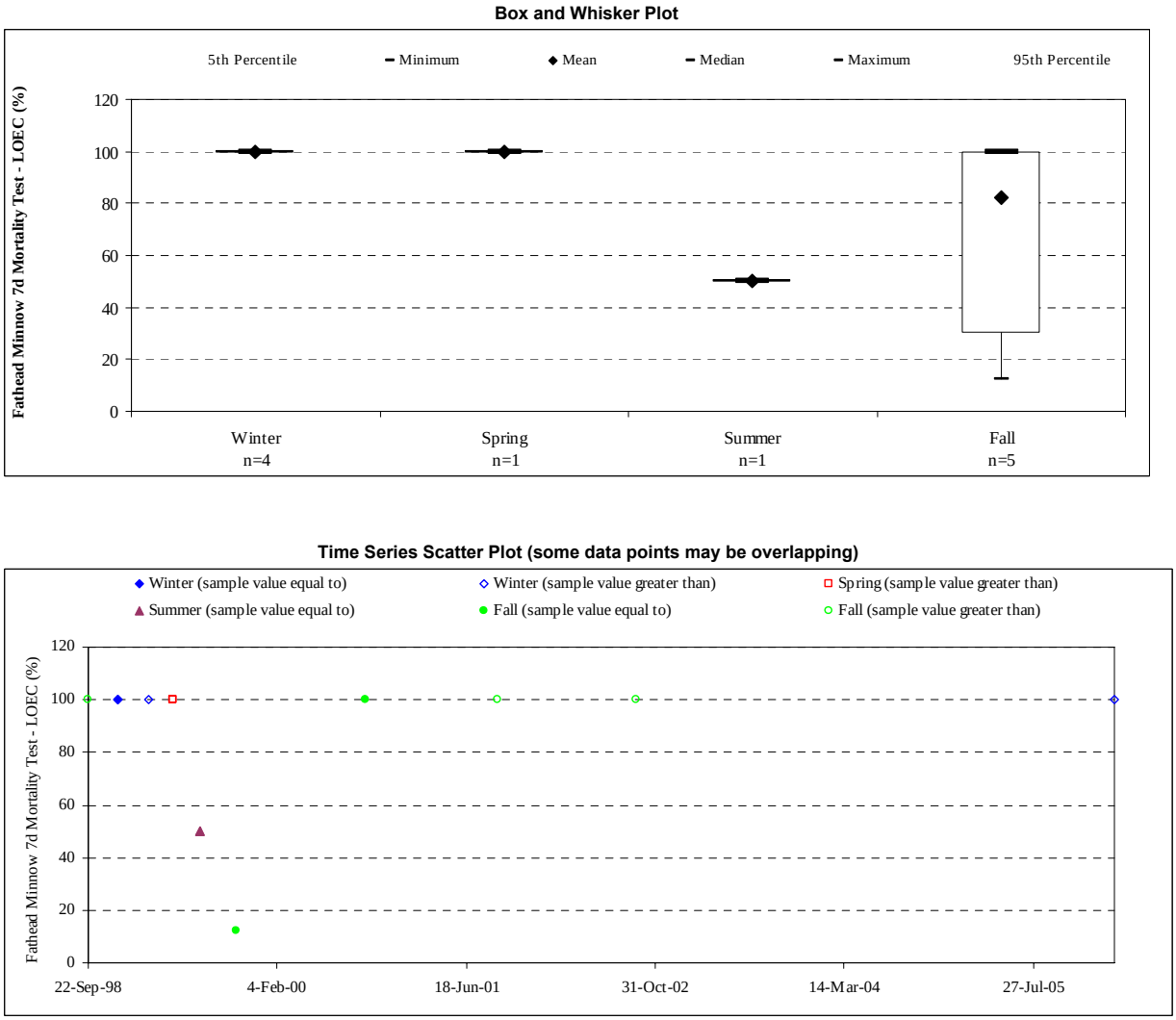
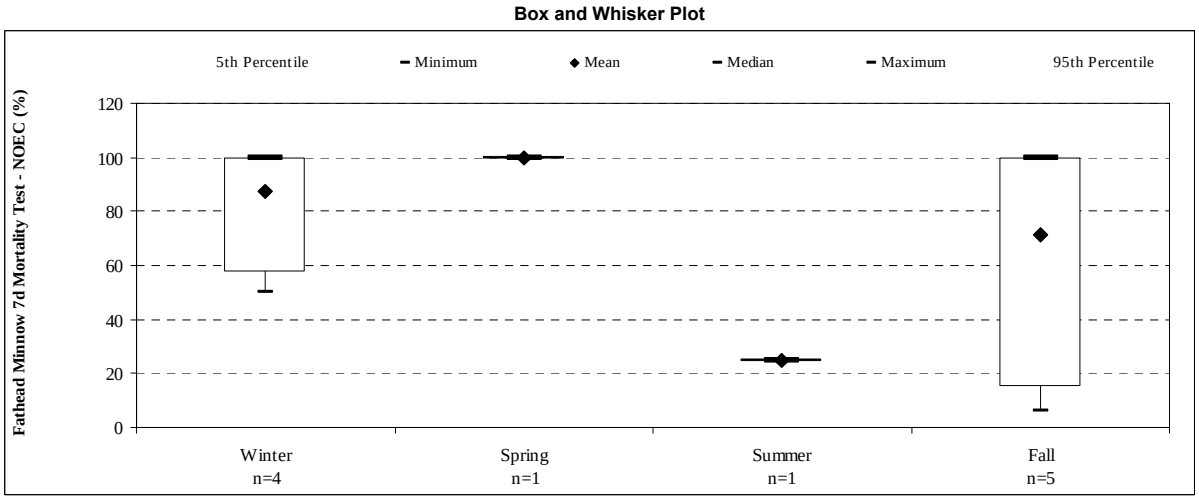


Figure G-2-1-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Upper Segment of Muskeg River



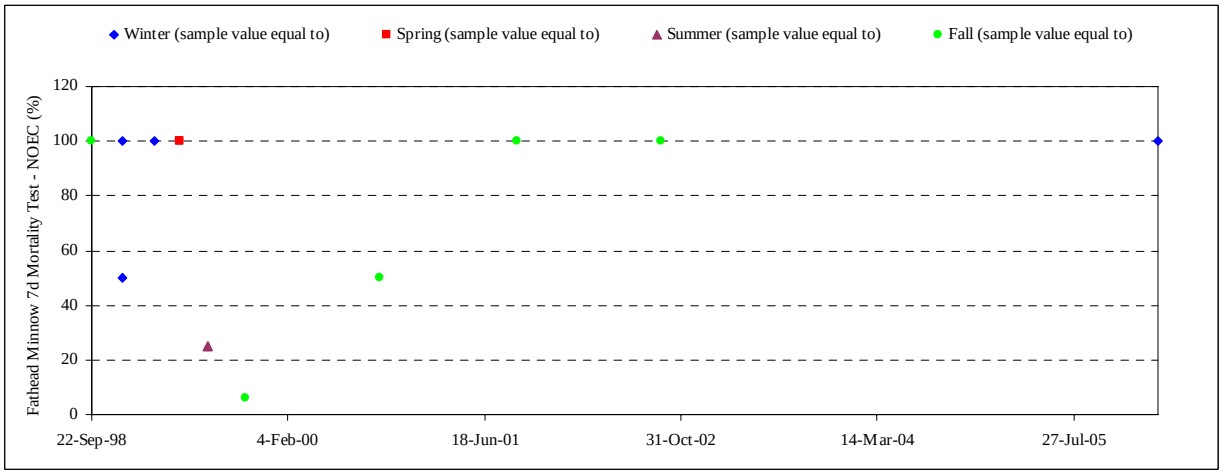
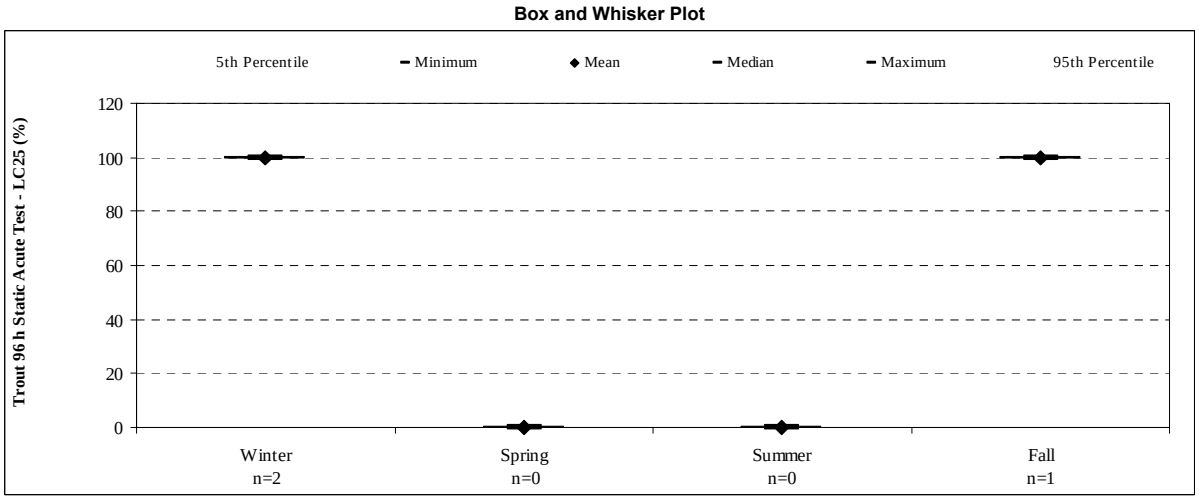


Figure G-2-1-58 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LC25 in Upper Segment of Muskeg River



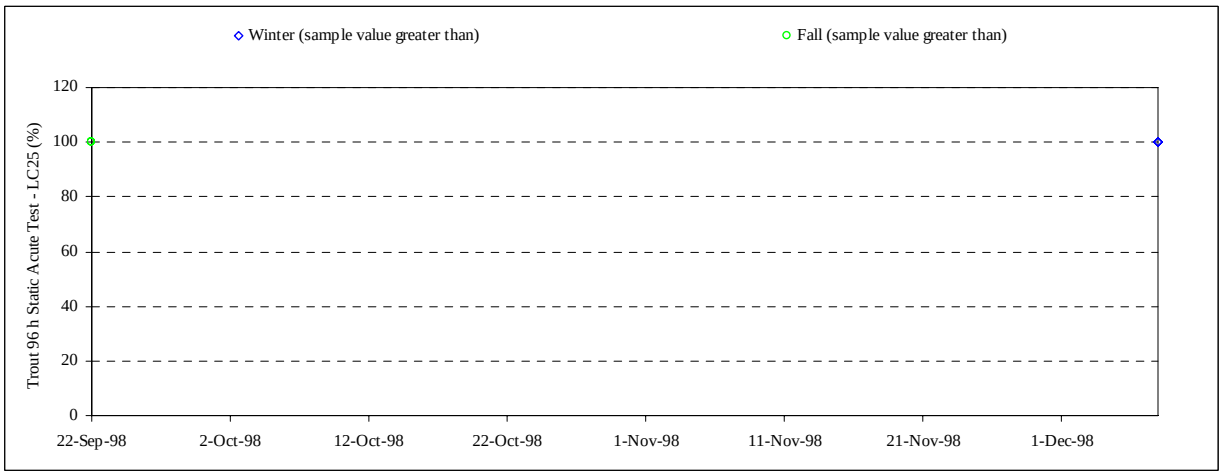
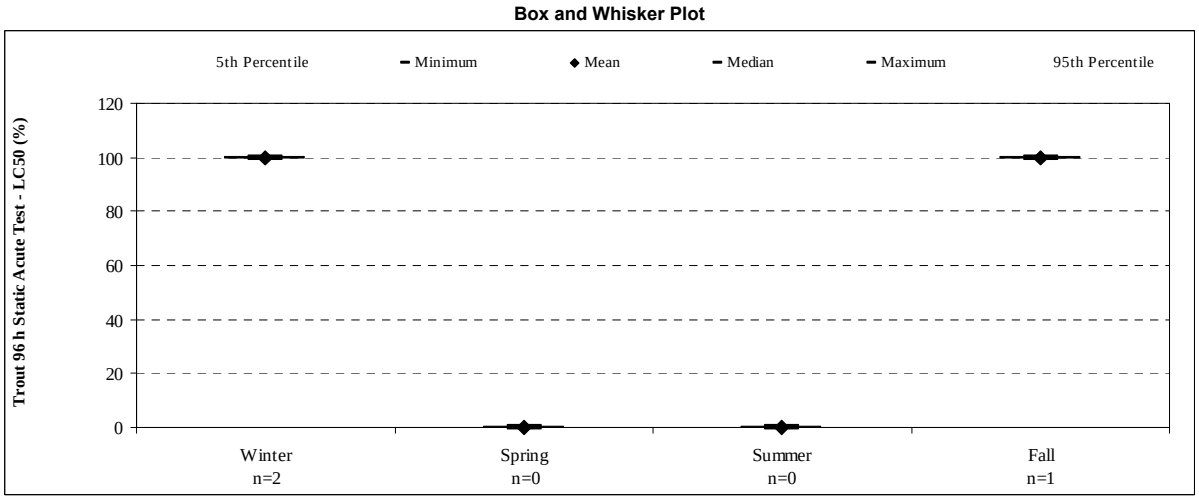


Figure G-2-1-59 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LC50 in Upper Segment of Muskeg River



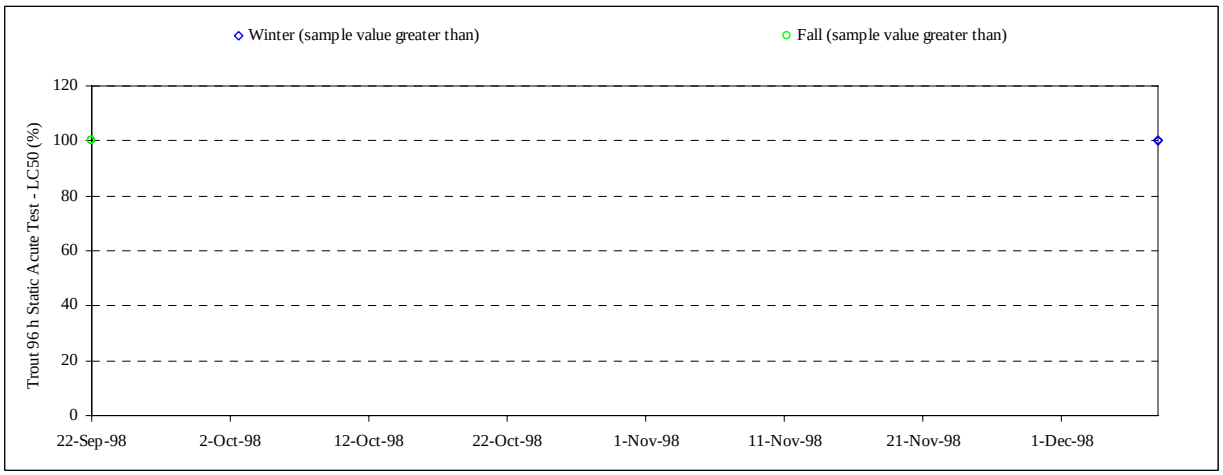
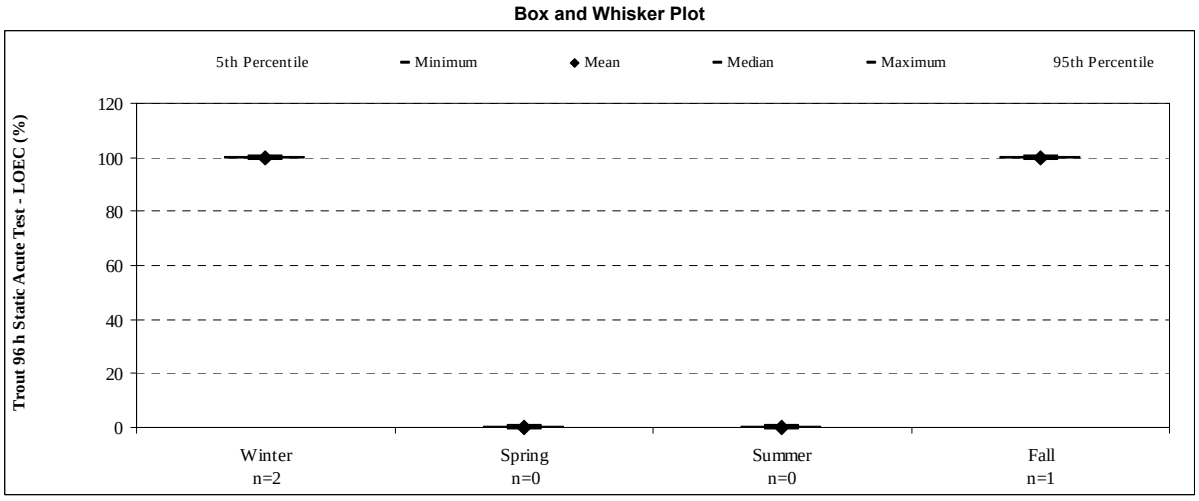


Figure G-2-1-60 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LOEC in Upper Segment of Muskeg River



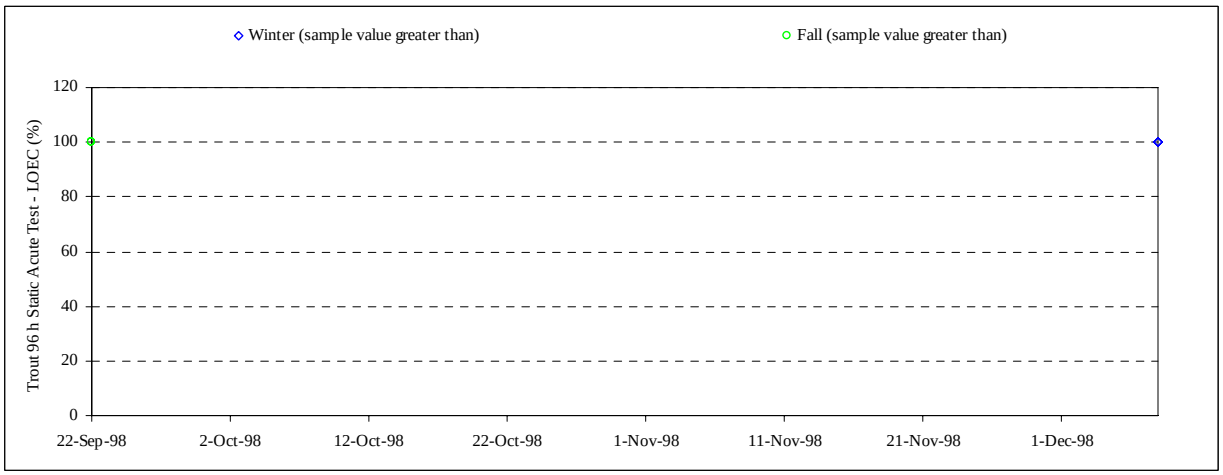
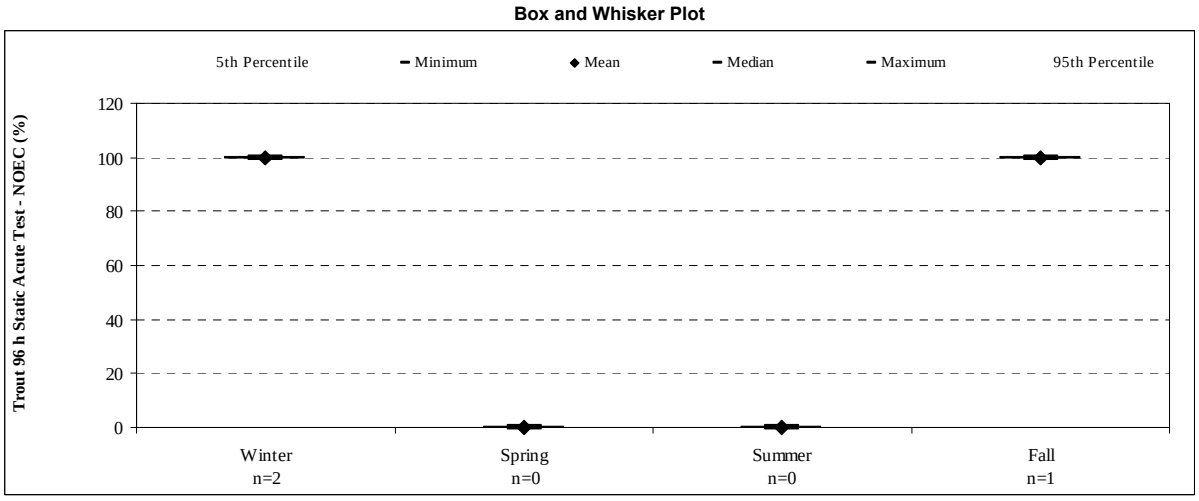


Figure G-2-1-61 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - NOEC in Upper Segment of Muskeg River



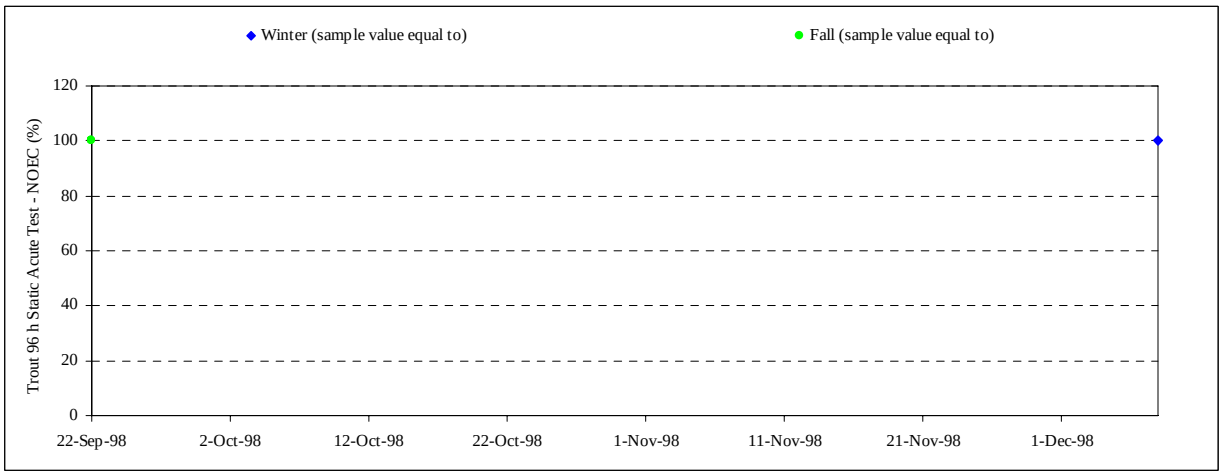
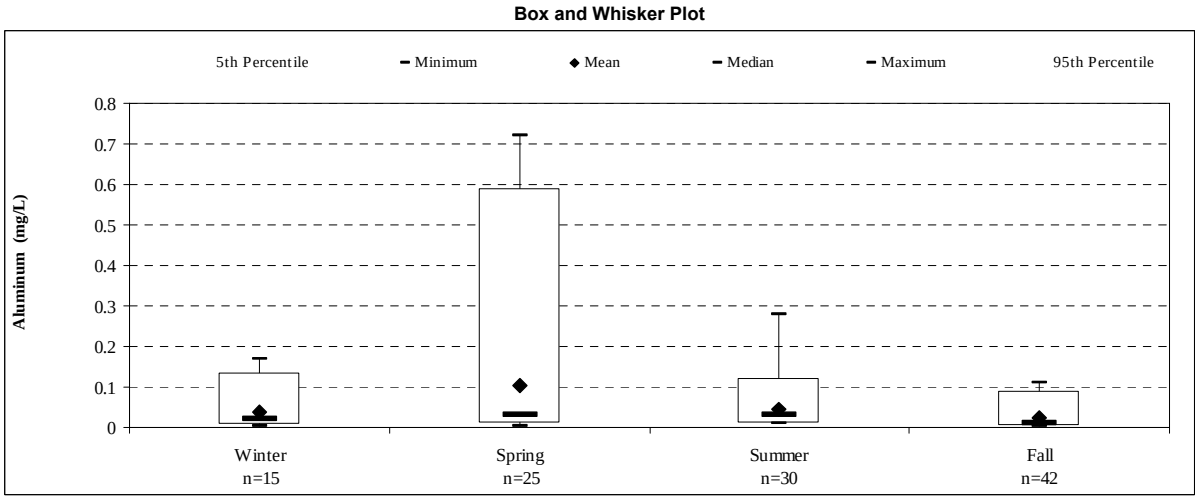


Figure G-2-1-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Upper Segment of Muskeg River



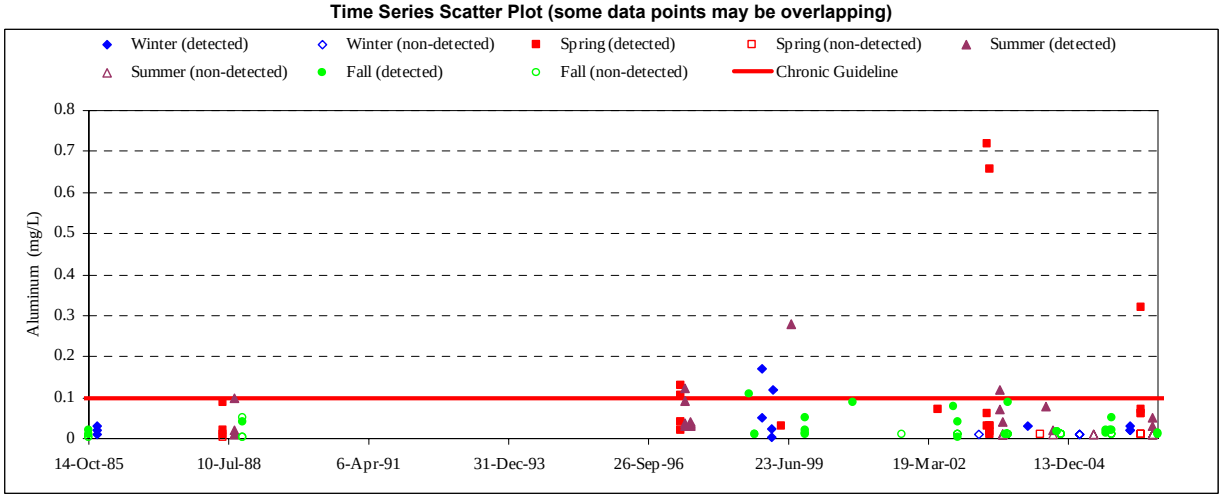


Figure G-2-1-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Upper Segment of Muskeg River

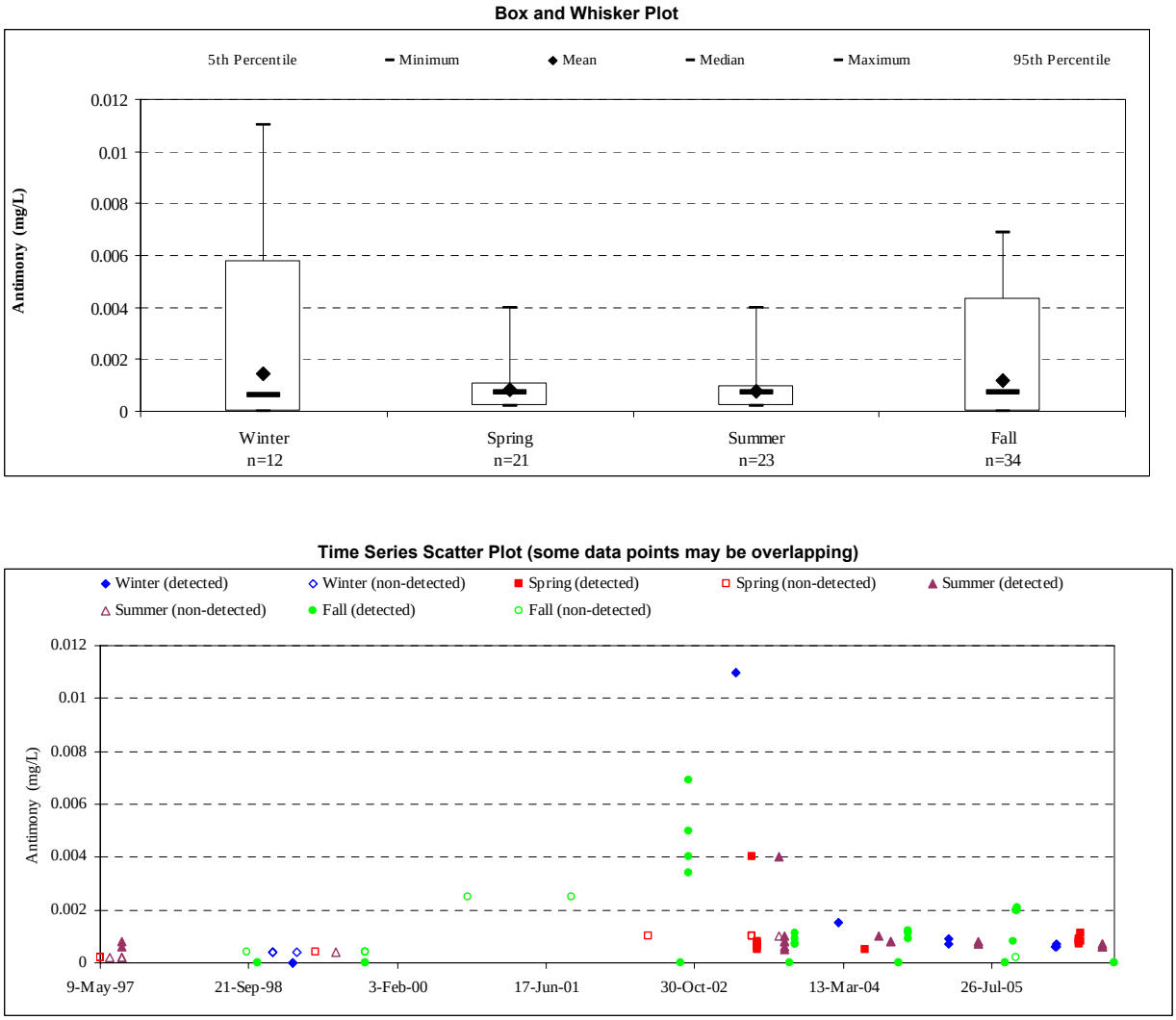
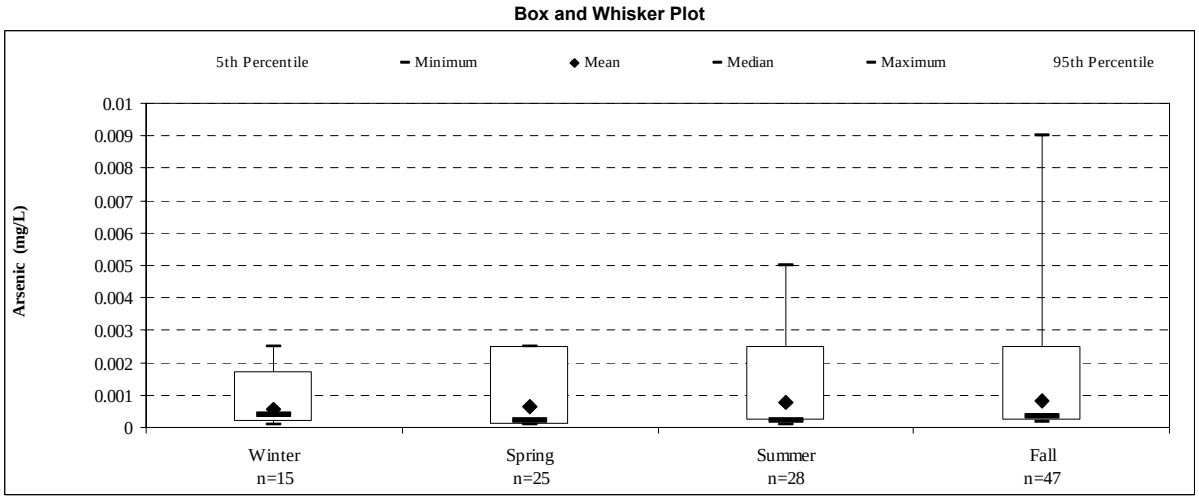


Figure G-2-1-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Upper Segment of Muskeg River



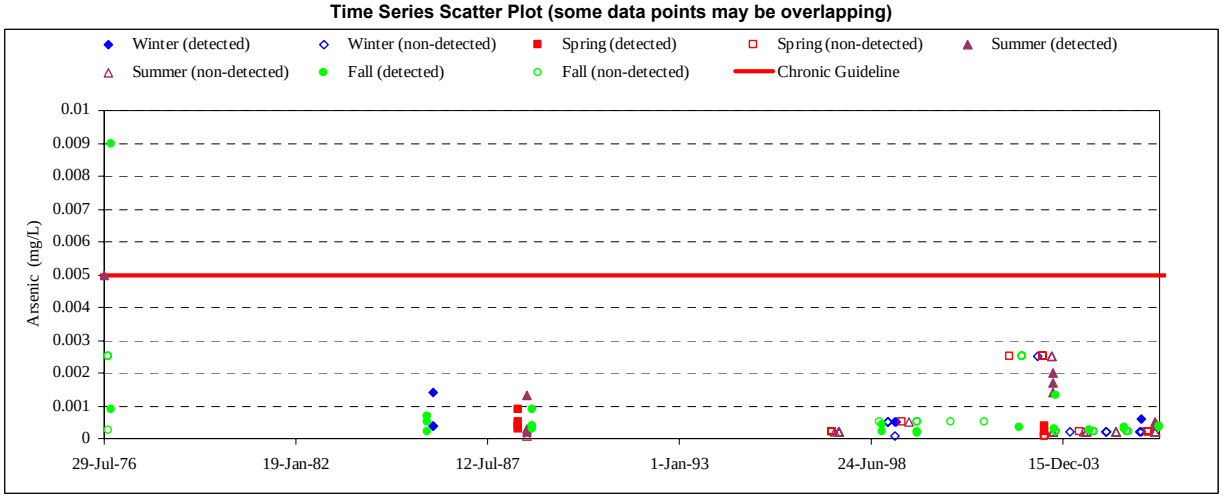
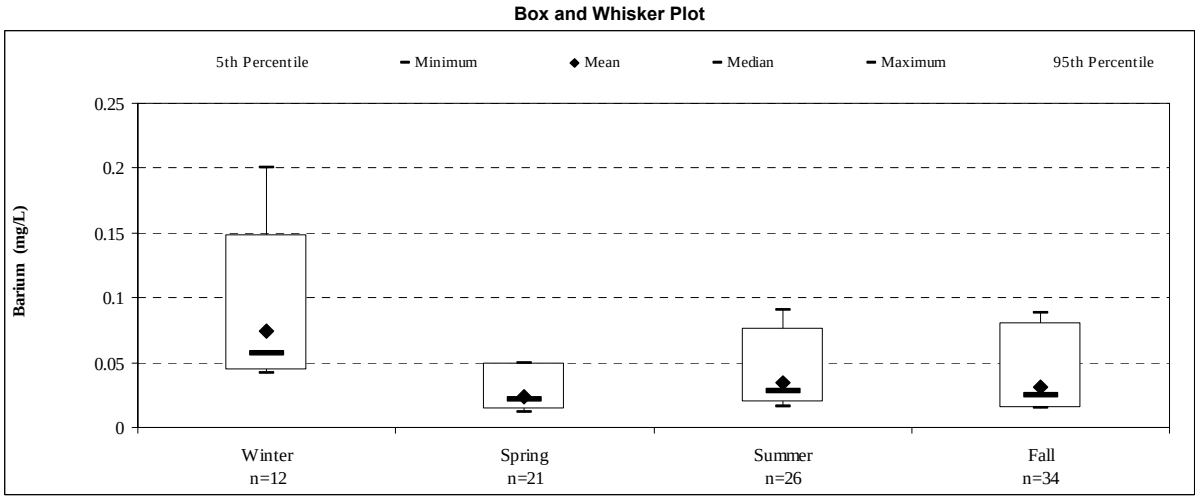


Figure G-2-1-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Upper Segment of Muskeg River



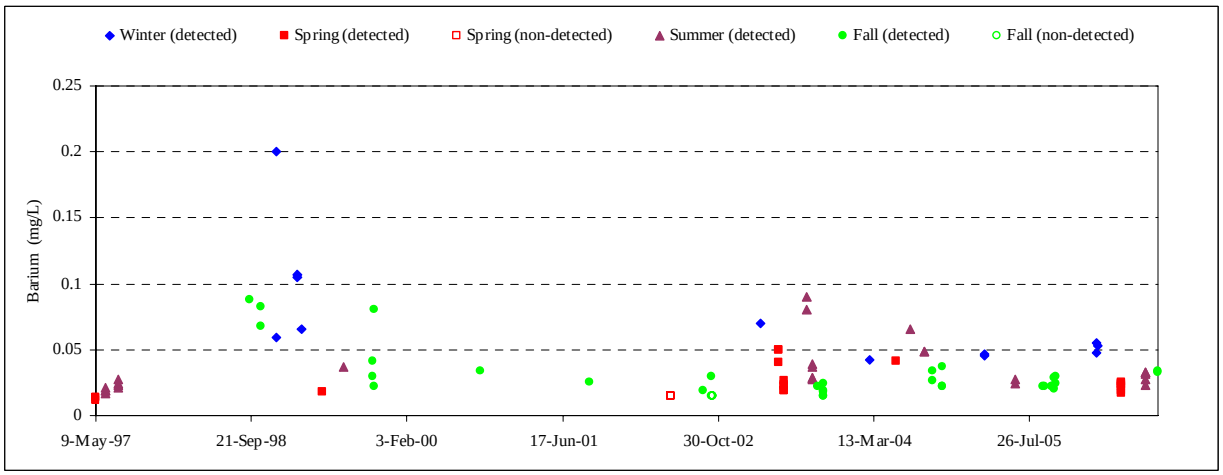


Figure G-2-1-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Upper Segment of Muskeg River

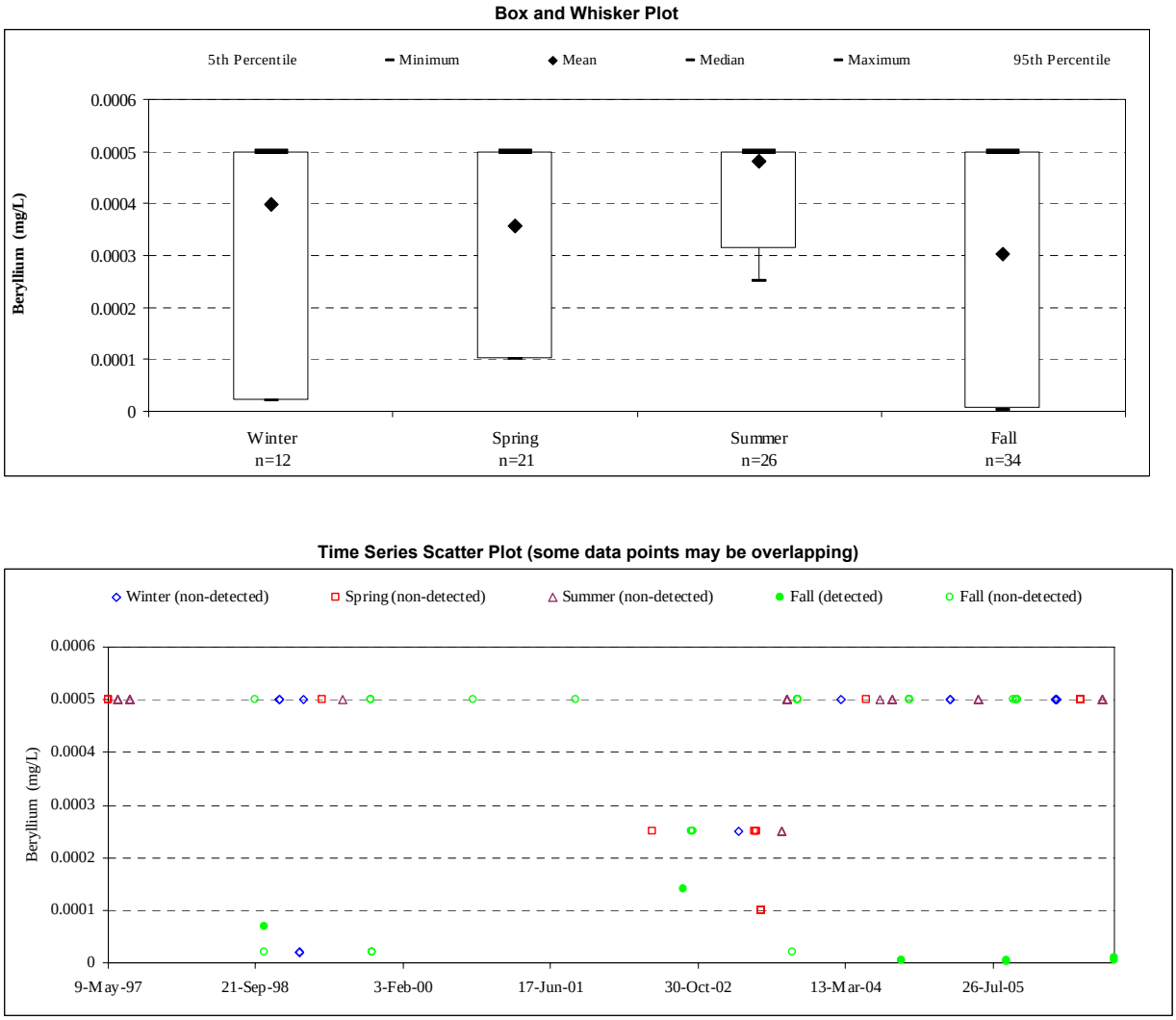
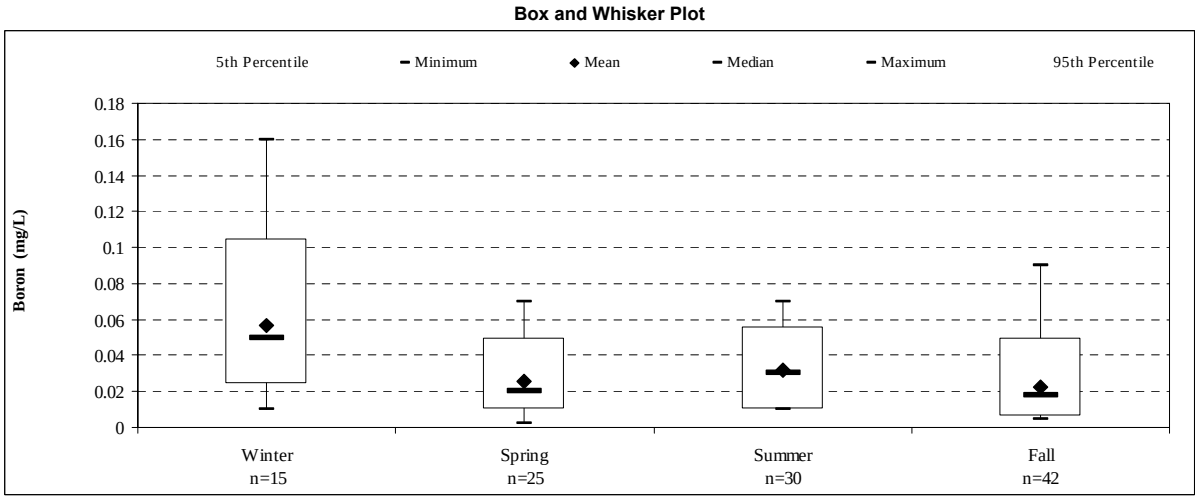


Figure G-2-1-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Upper Segment of Muskeg River



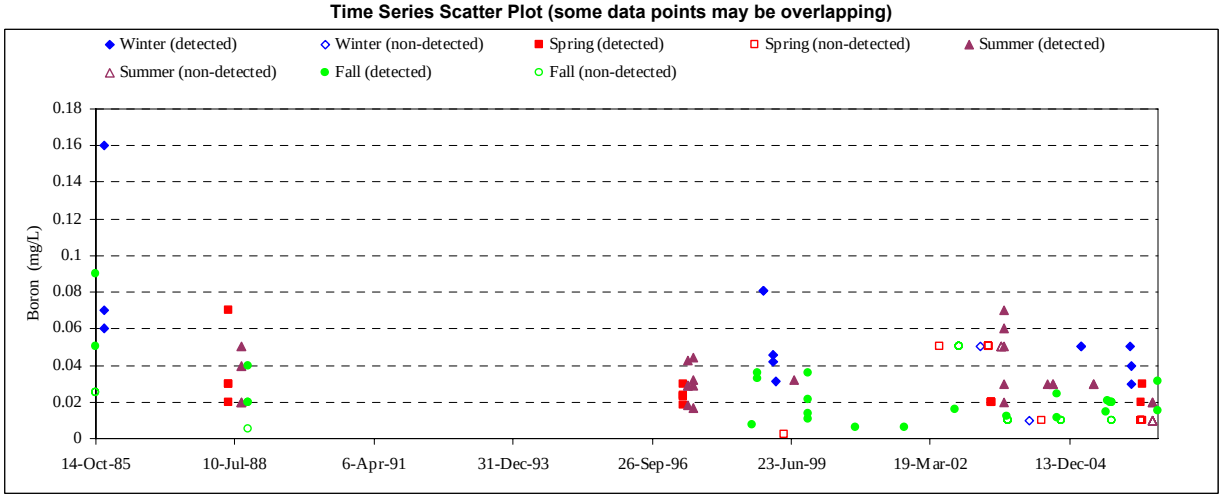


Figure G-2-1-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Upper Segment of Muskeg River

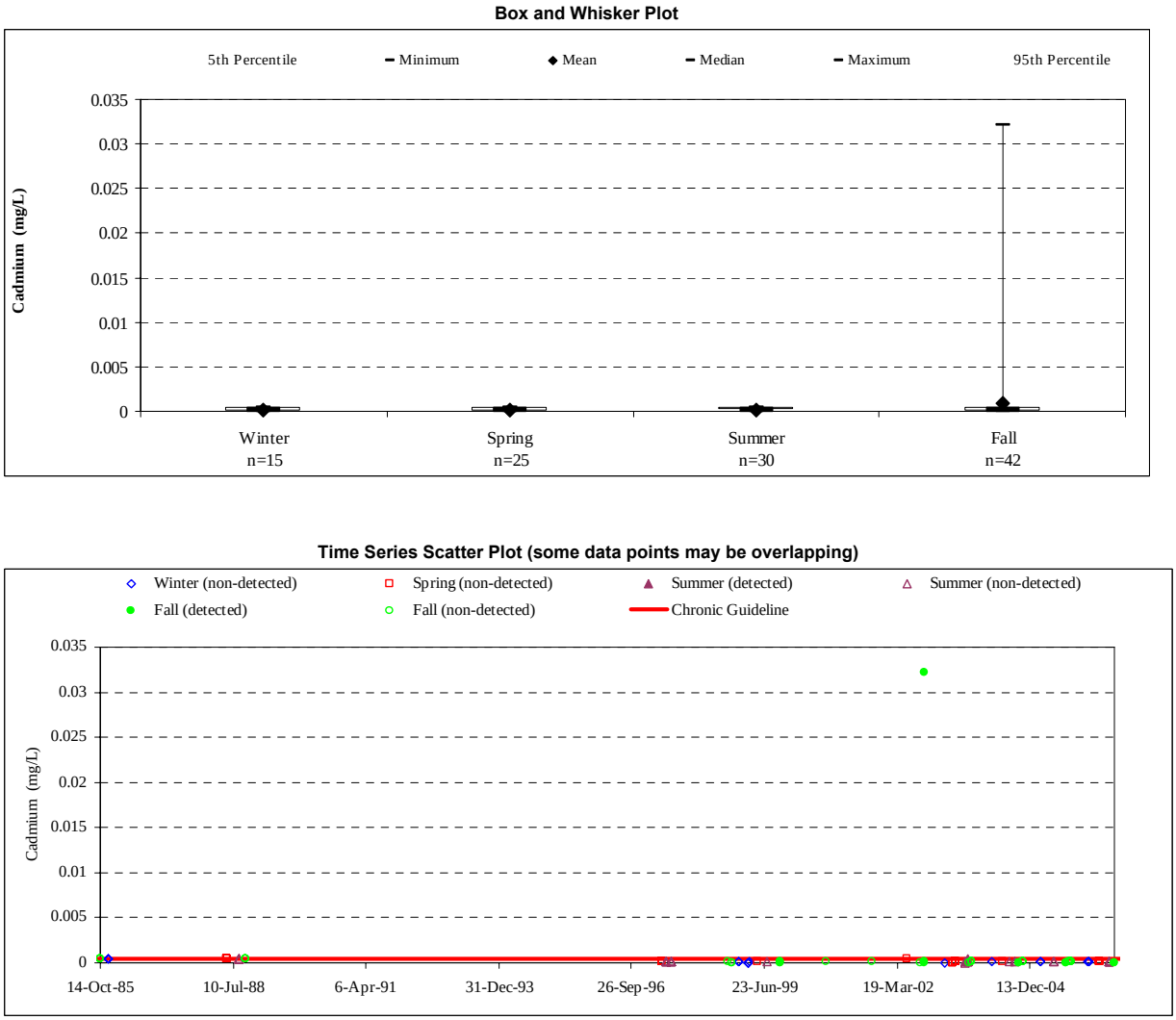


Figure G-2-1-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Upper Segment of Muskeg River

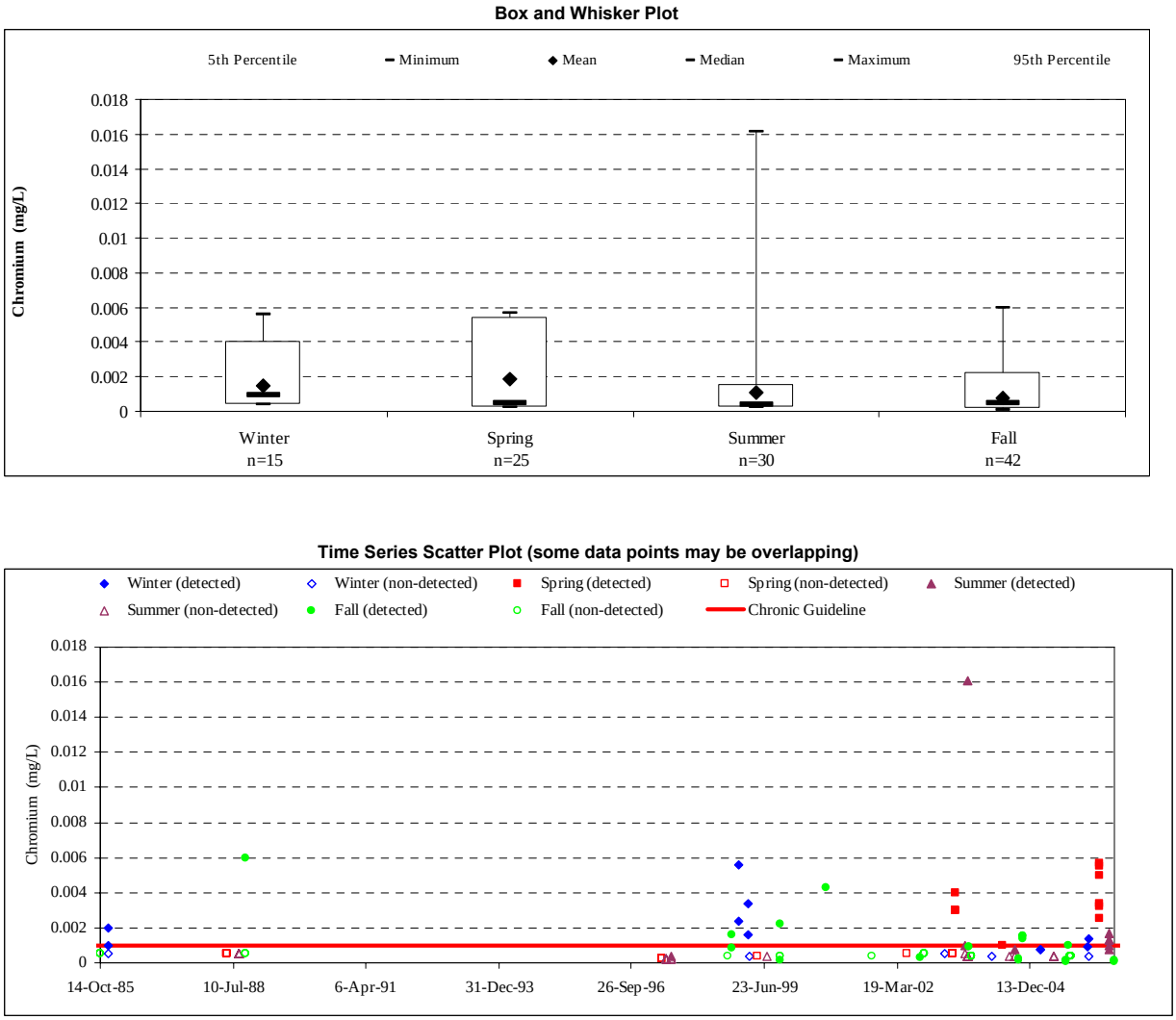
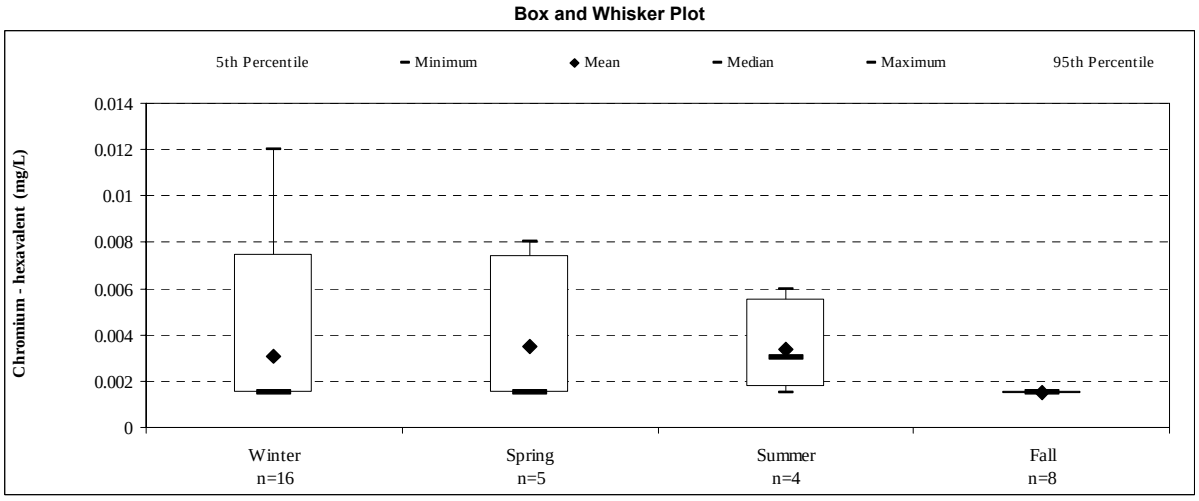


Figure G-2-1-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Upper Segment of Muskeg River



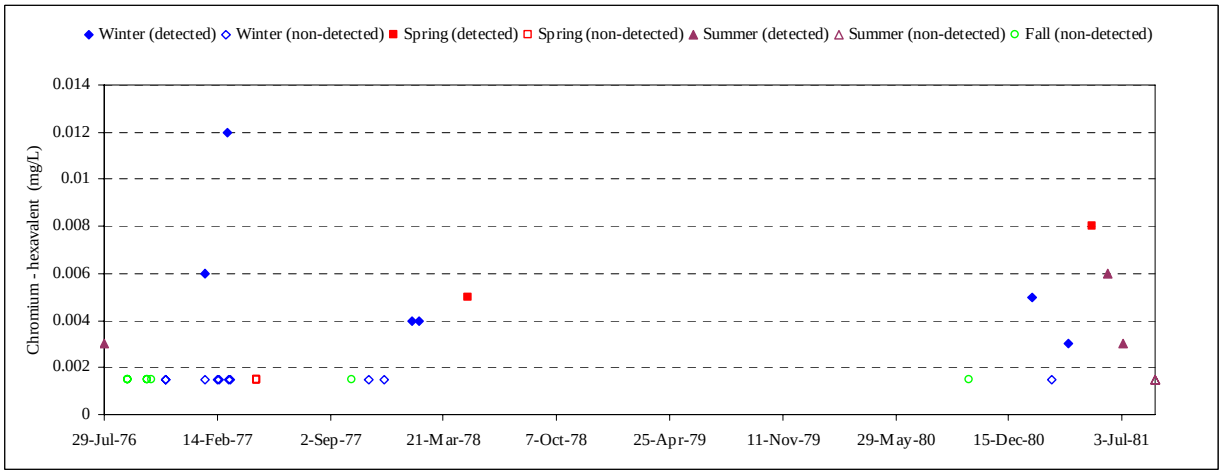


Figure G-2-1-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Upper Segment of Muskeg River

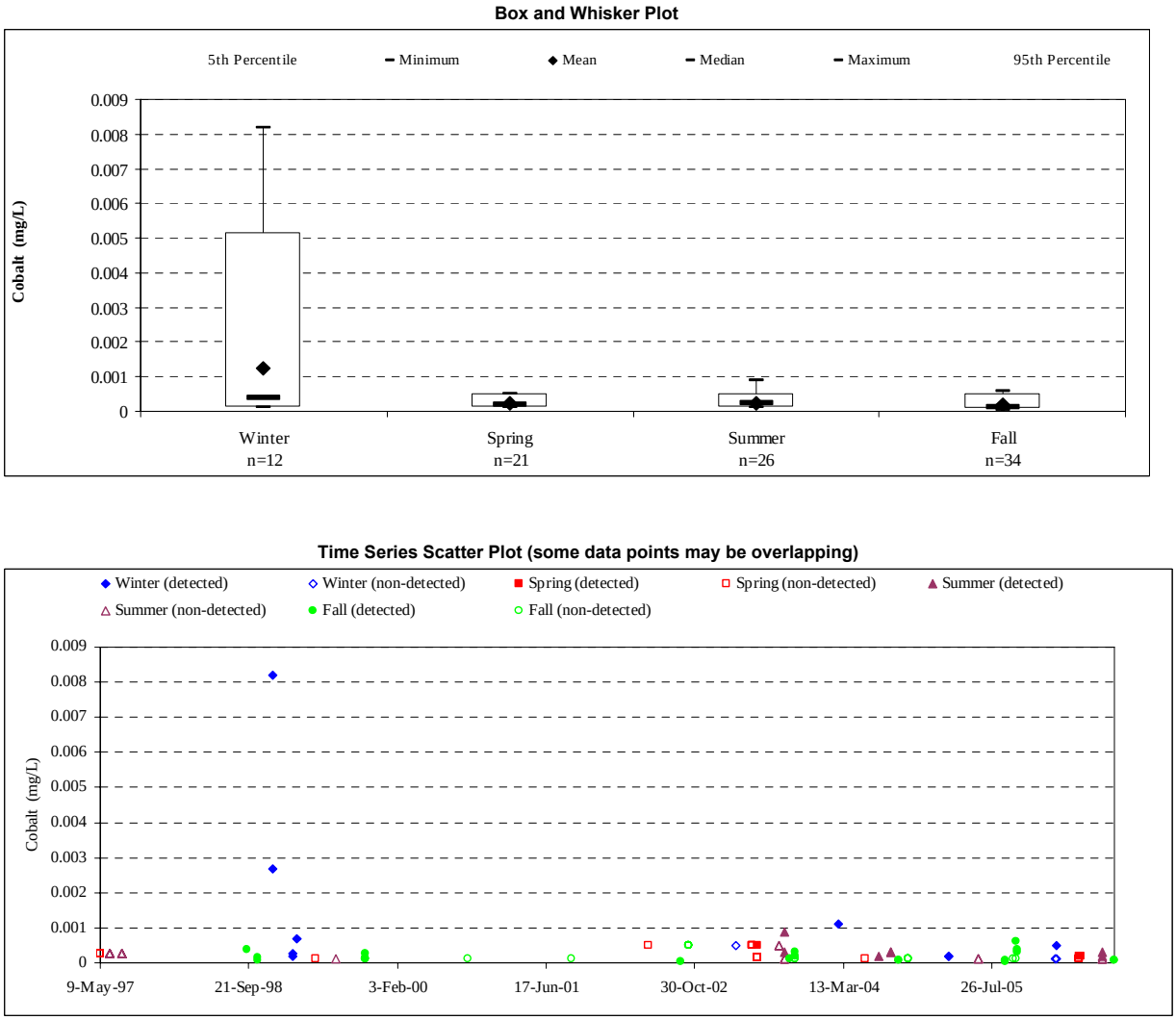


Figure G-2-1-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Upper Segment of Muskeg River

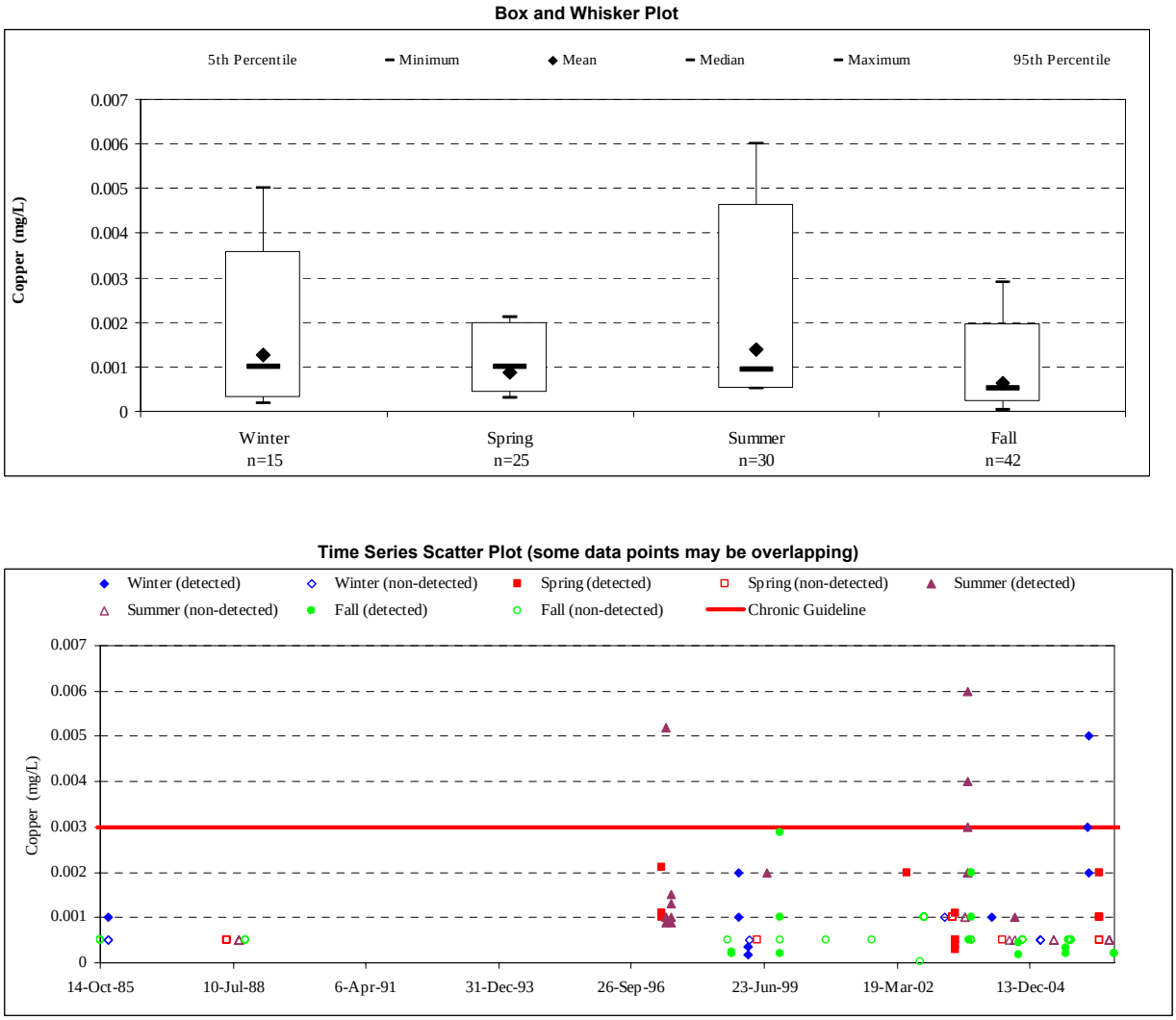
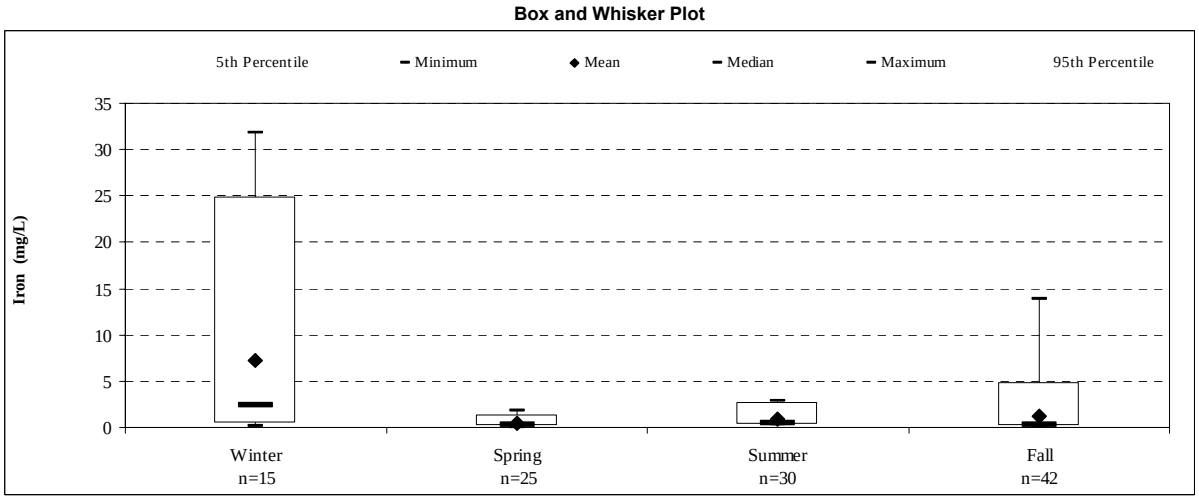


Figure G-2-1-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Upper Segment of Muskeg River



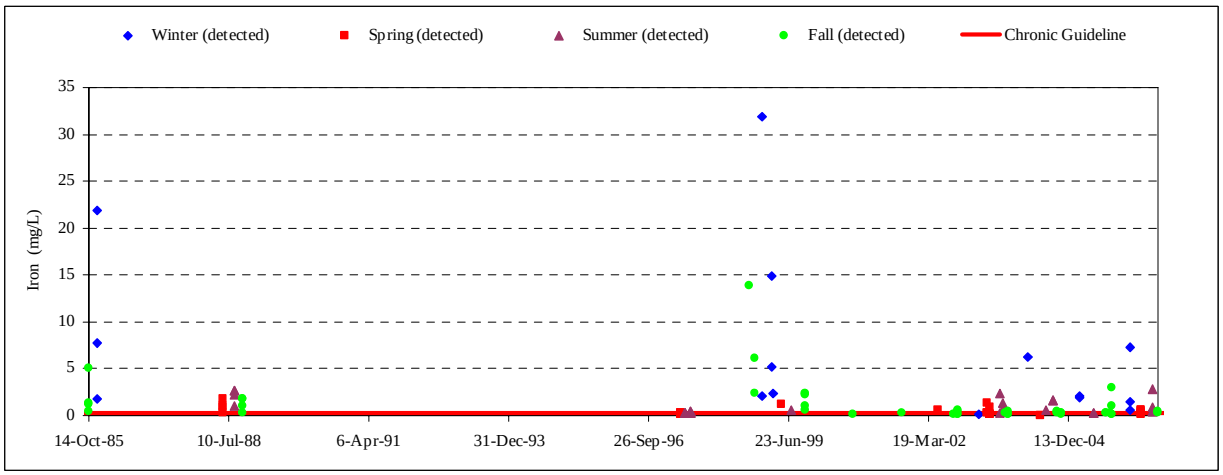
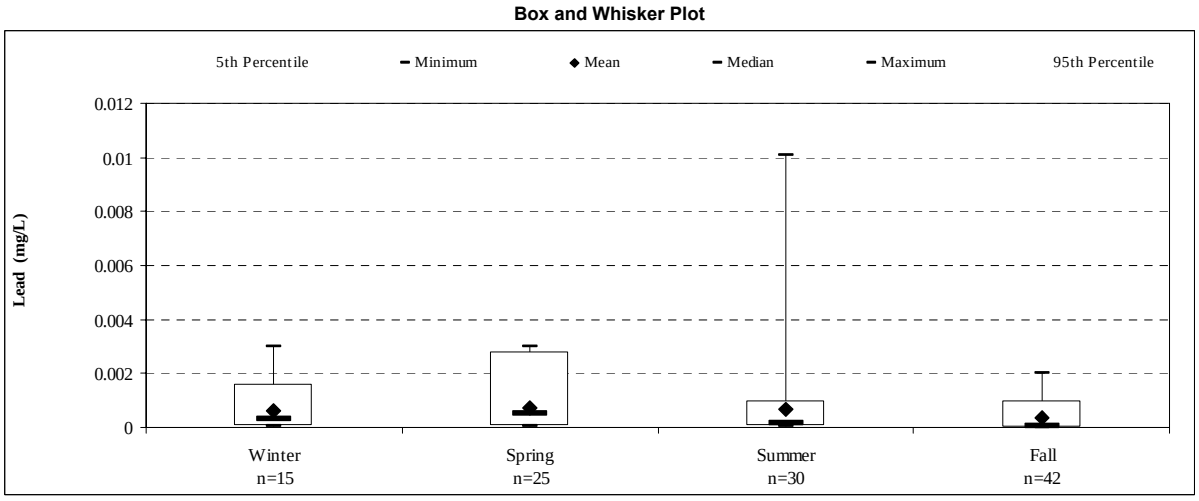


Figure G-2-1-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Upper Segment of Muskeg River



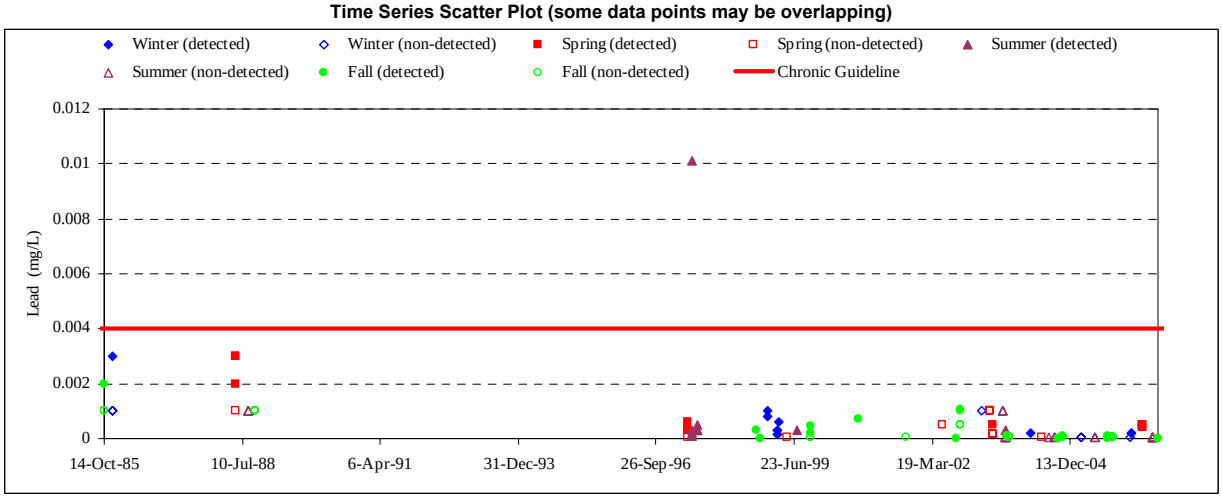
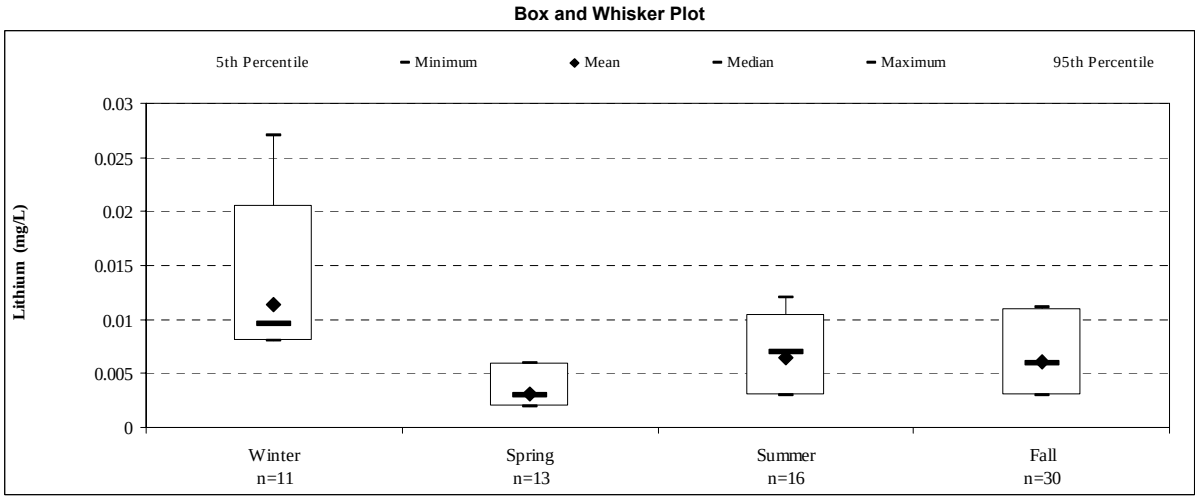


Figure G-2-1-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Upper Segment of Muskeg River



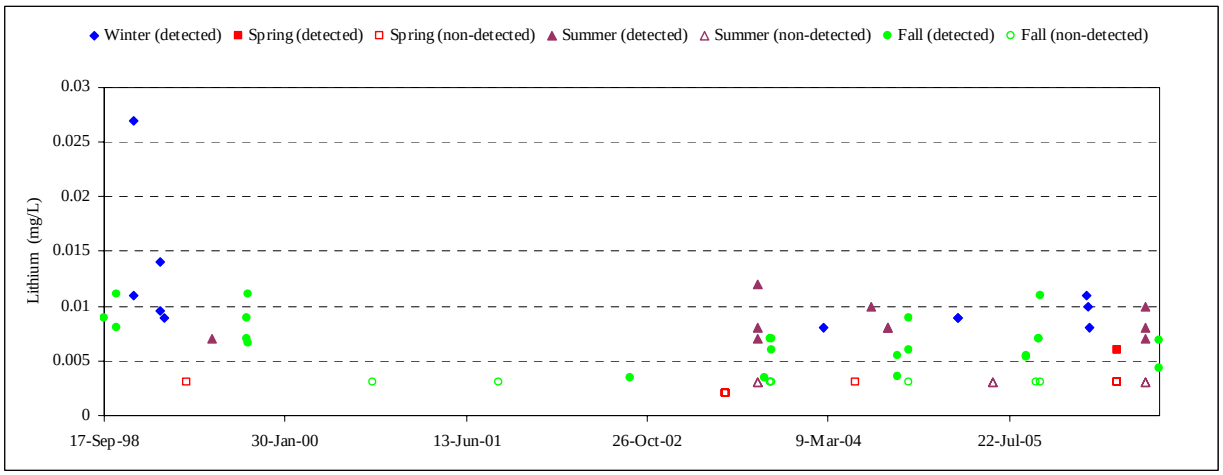
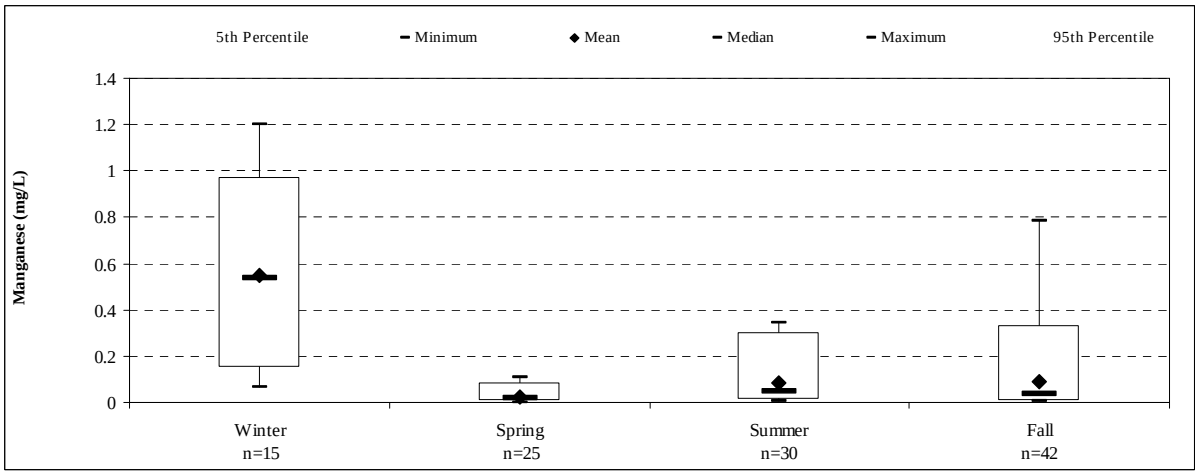


Figure G-2-1-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Upper Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

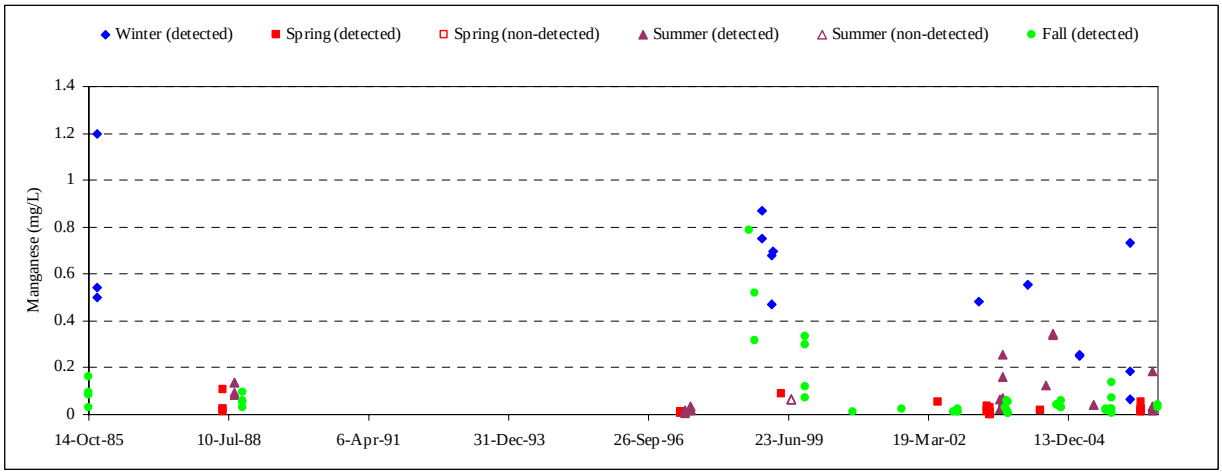
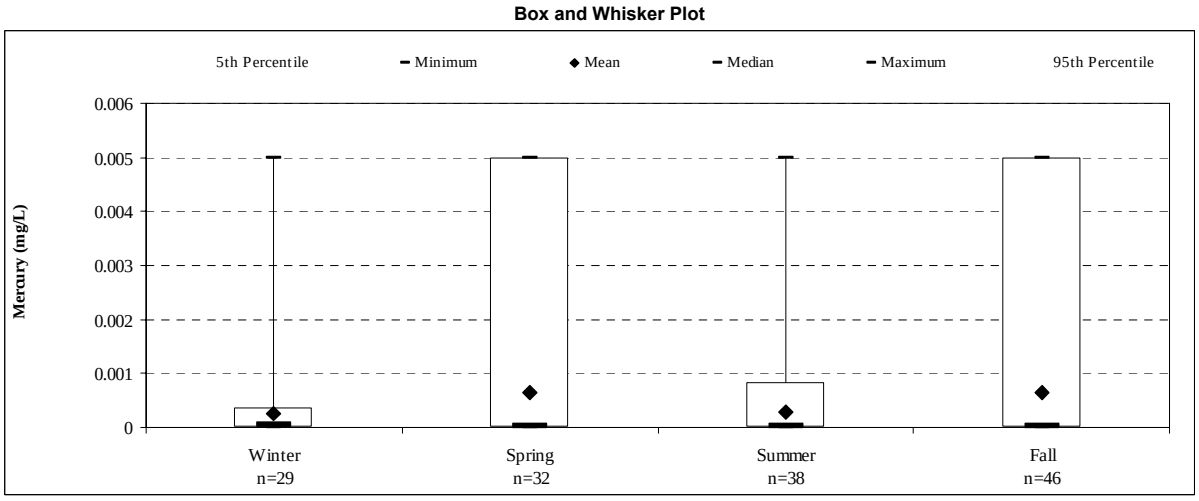


Figure G-2-1-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Upper Segment of Muskeg River



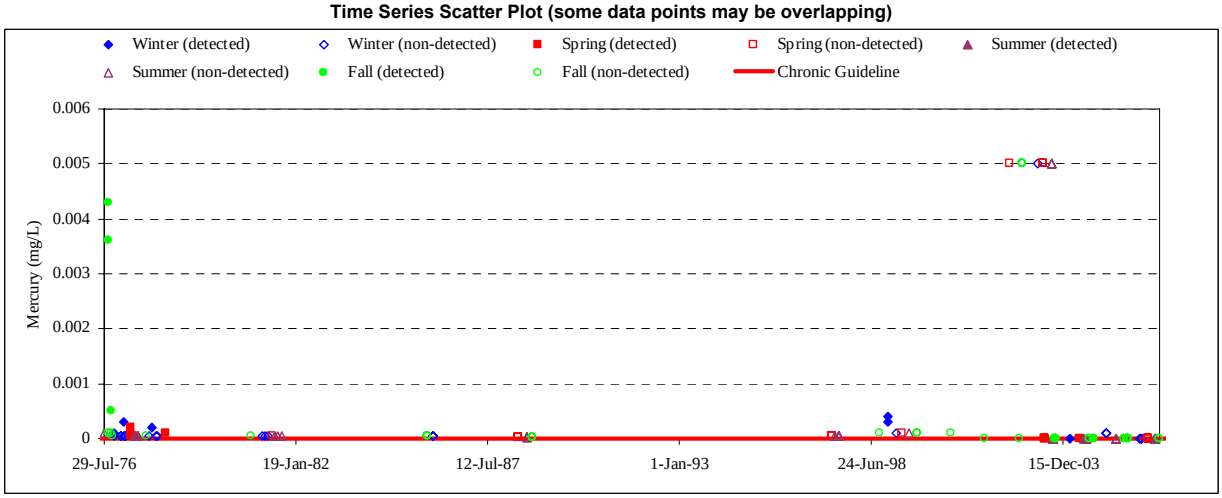
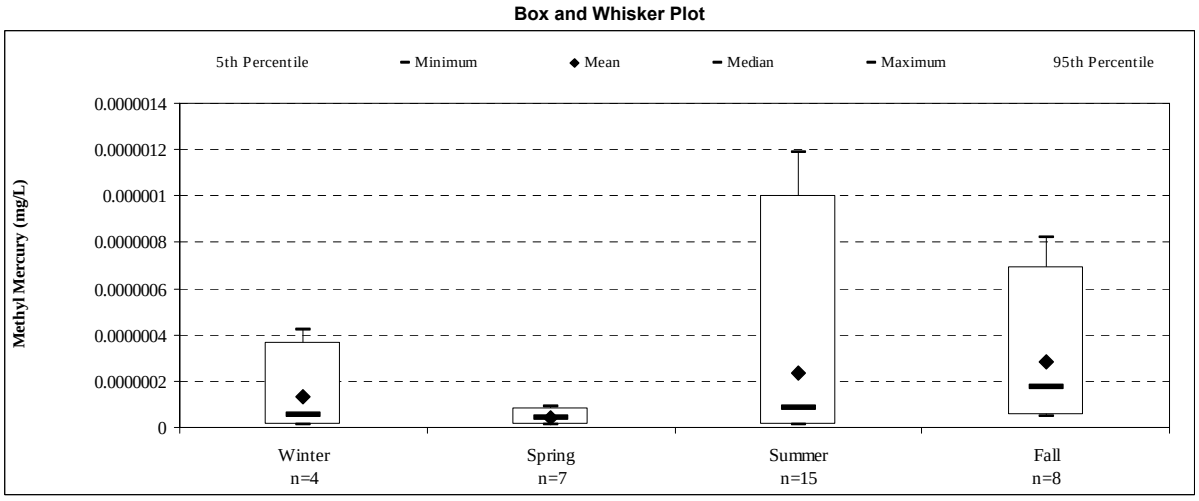


Figure G-2-1-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Upper Segment of Muskeg River



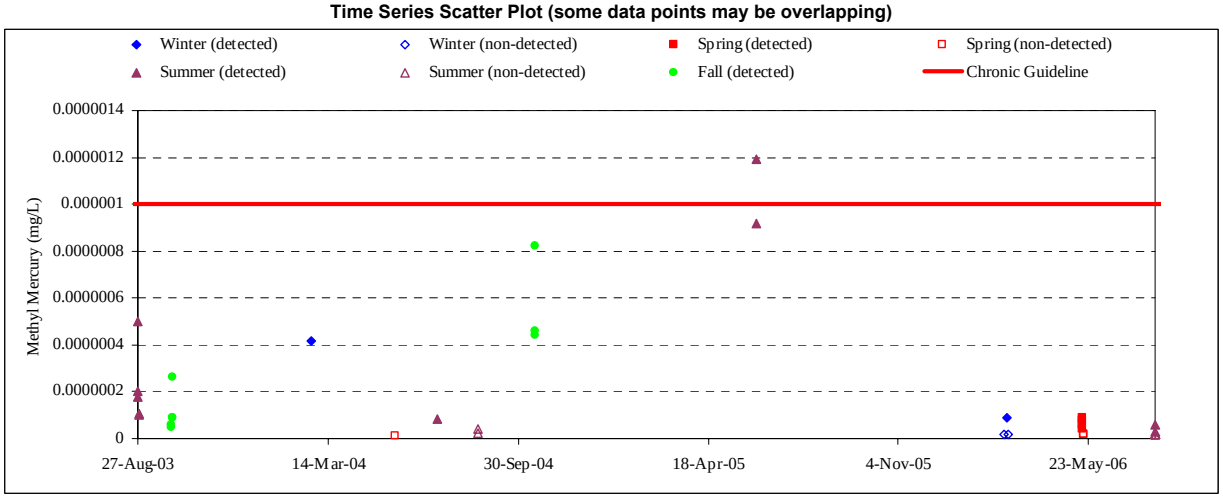


Figure G-2-1-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Upper Segment of Muskeg River

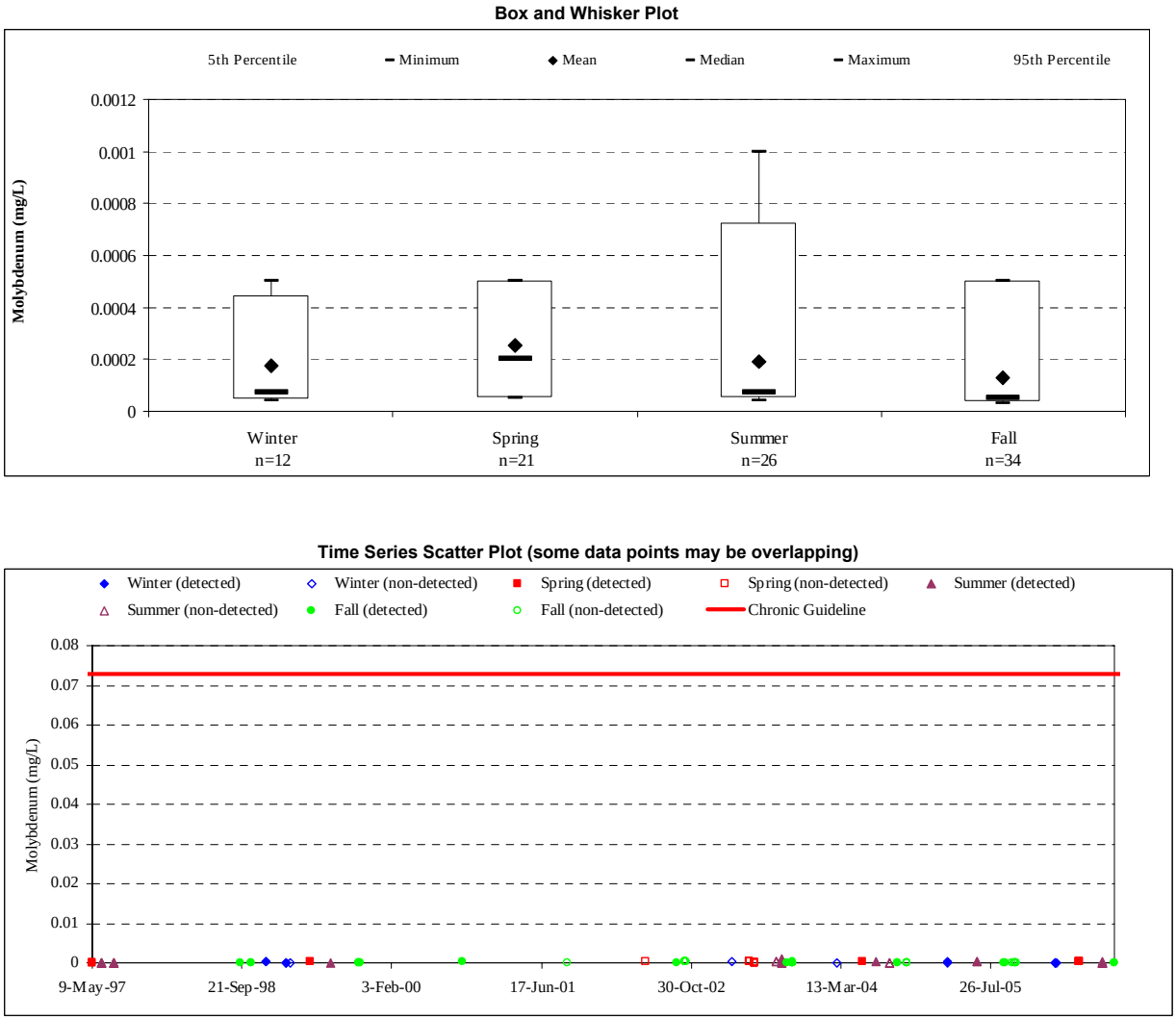
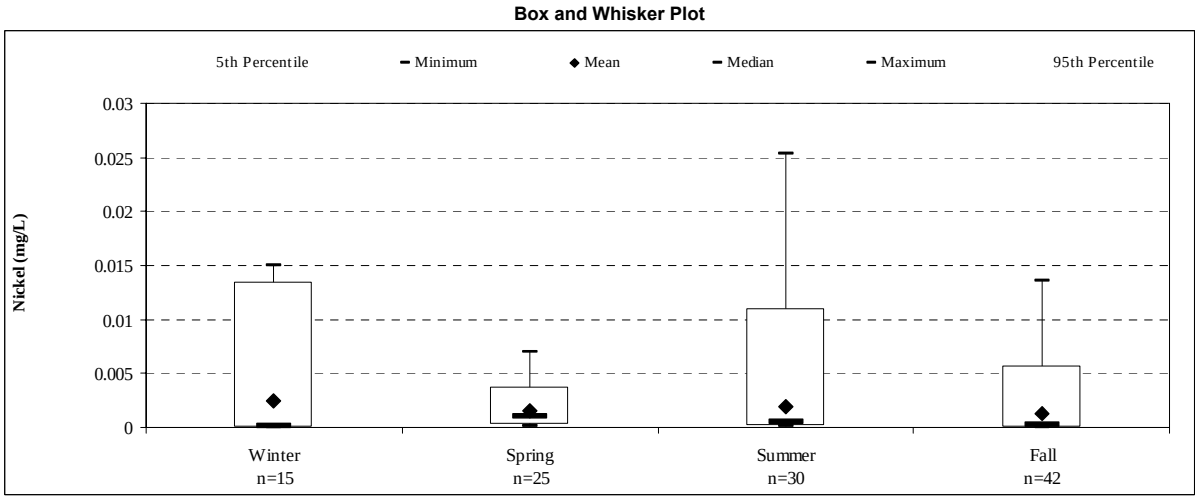


Figure G-2-1-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Upper Segment of Muskeg River



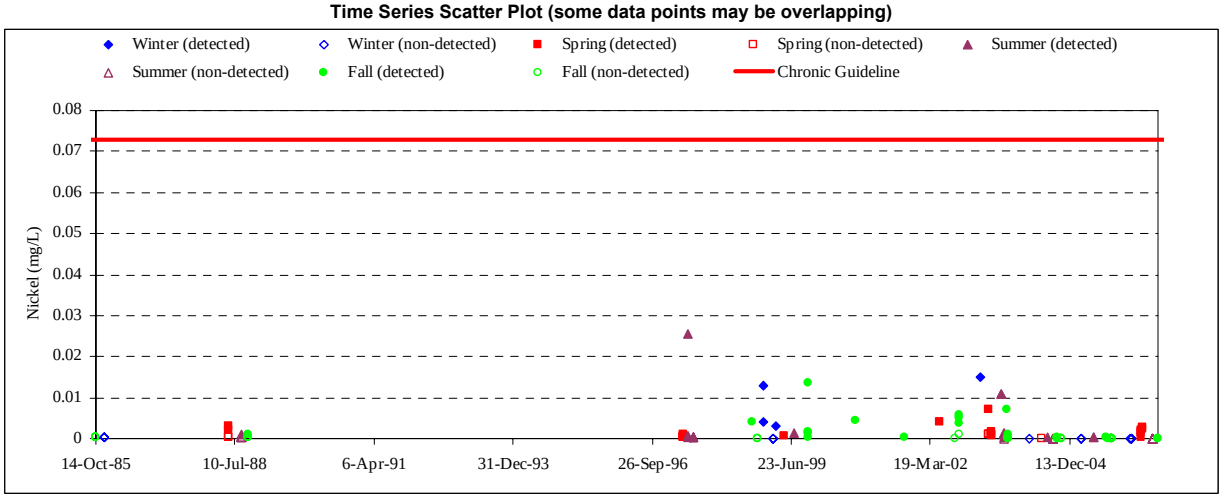
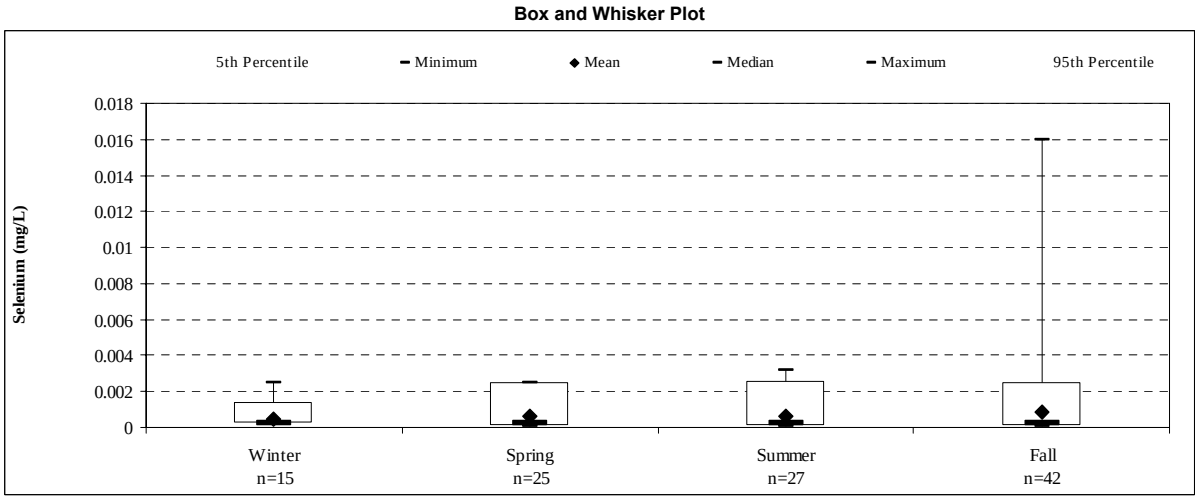


Figure G-2-1-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Upper Segment of Muskeg River



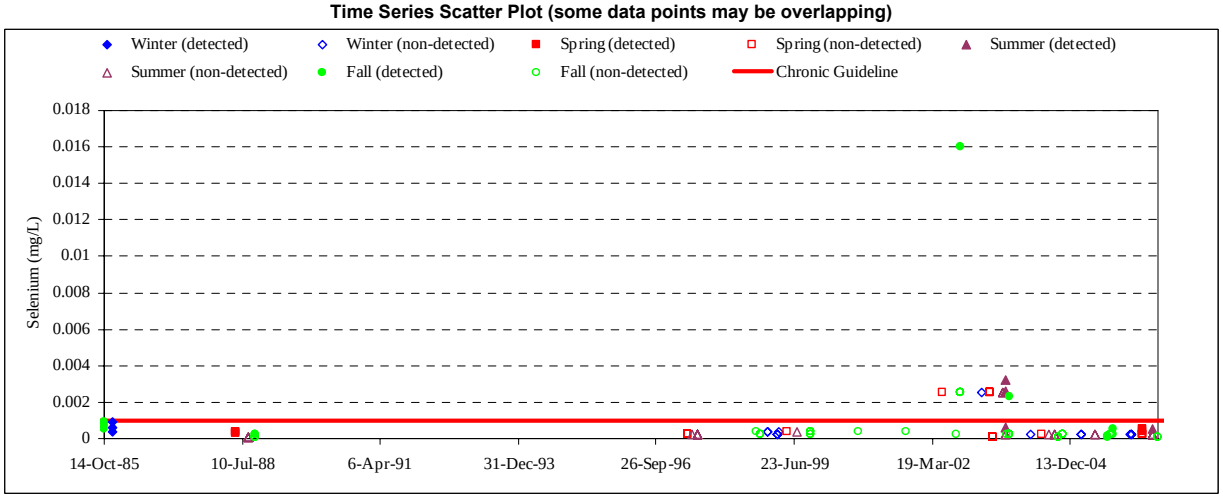


Figure G-2-1-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Upper Segment of Muskeg River

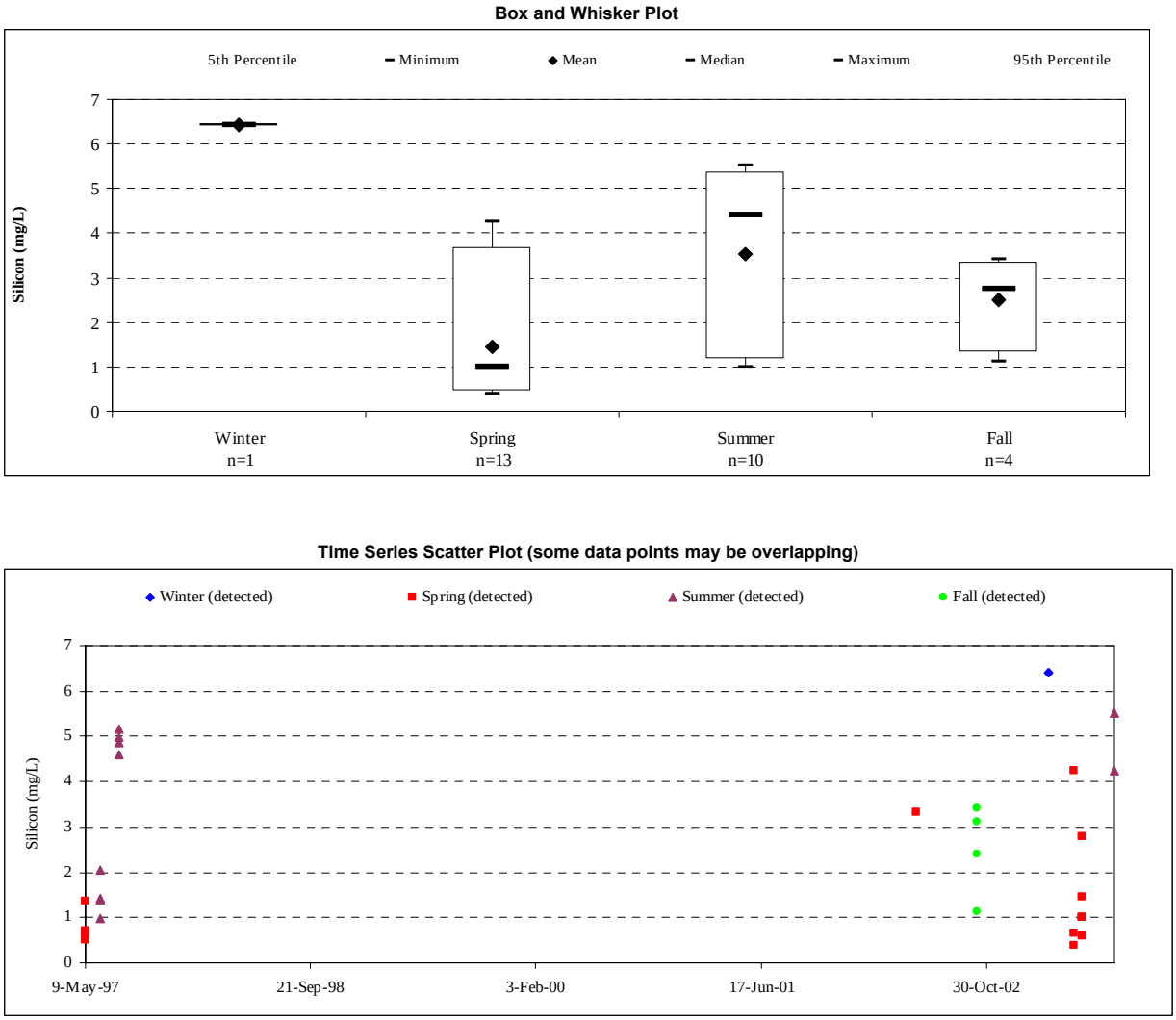


Figure G-2-1-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Upper Segment of Muskeg River

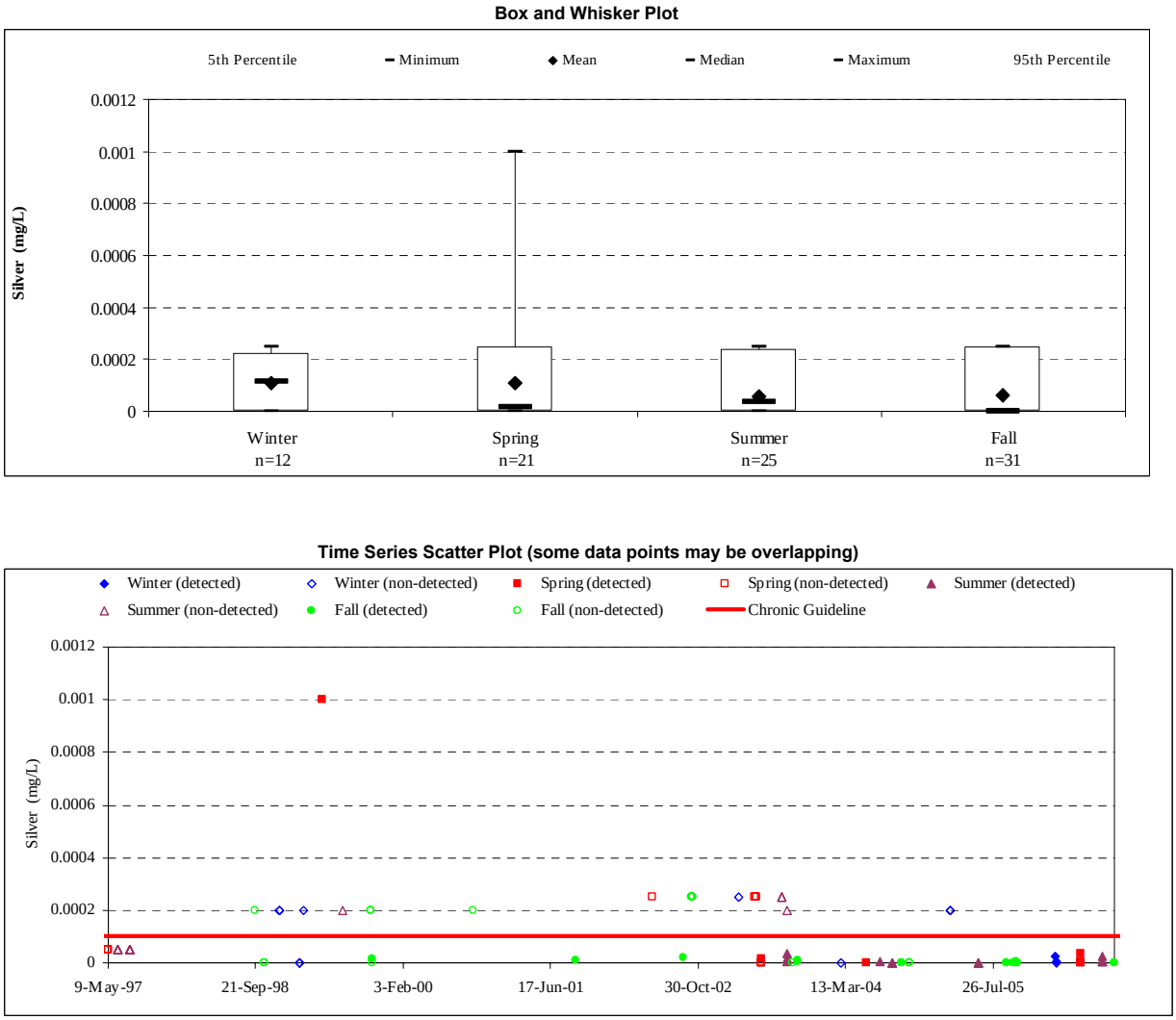


Figure G-2-1-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Upper Segment of Muskeg River

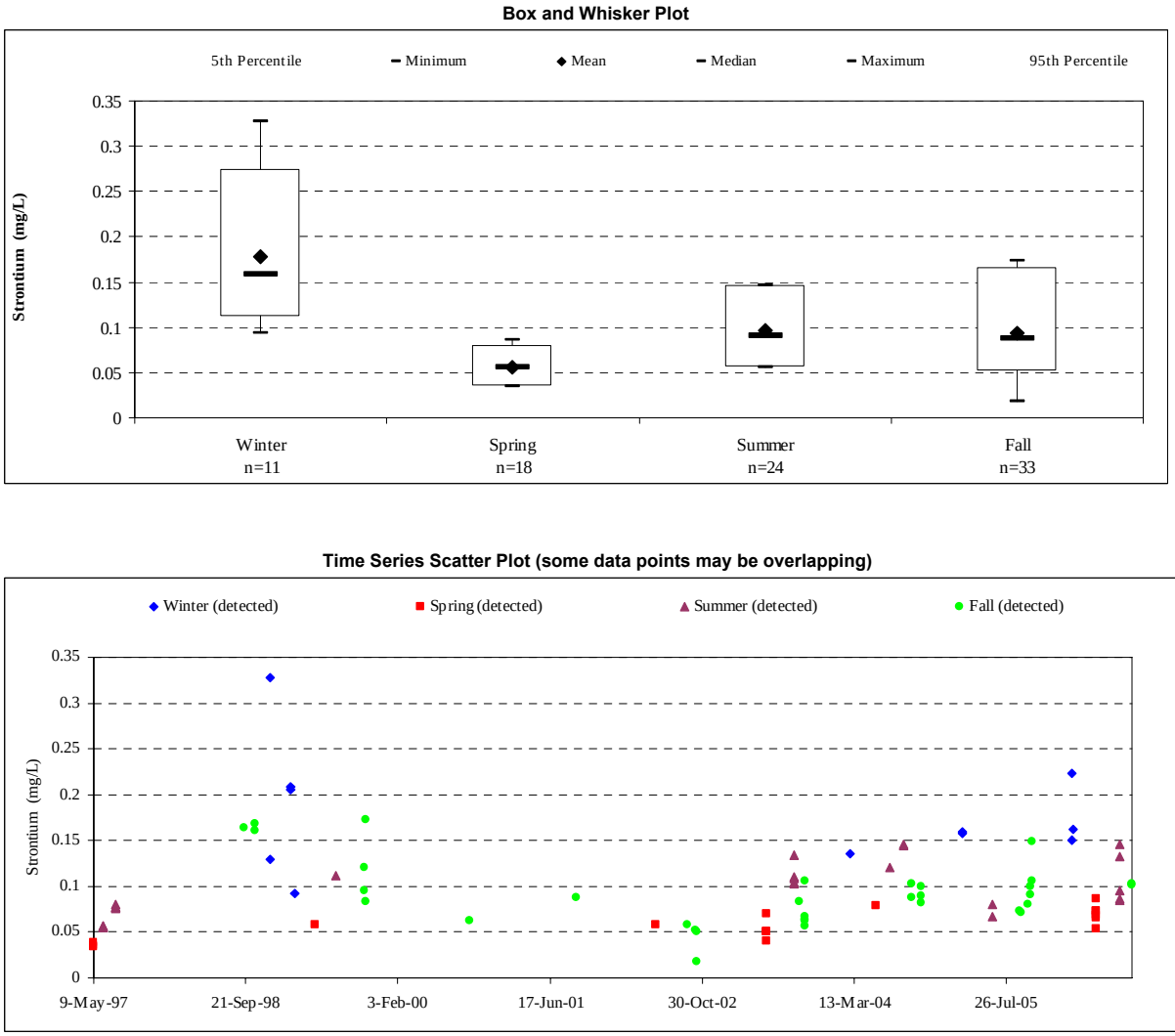


Figure G-2-1-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Upper Segment of Muskeg River

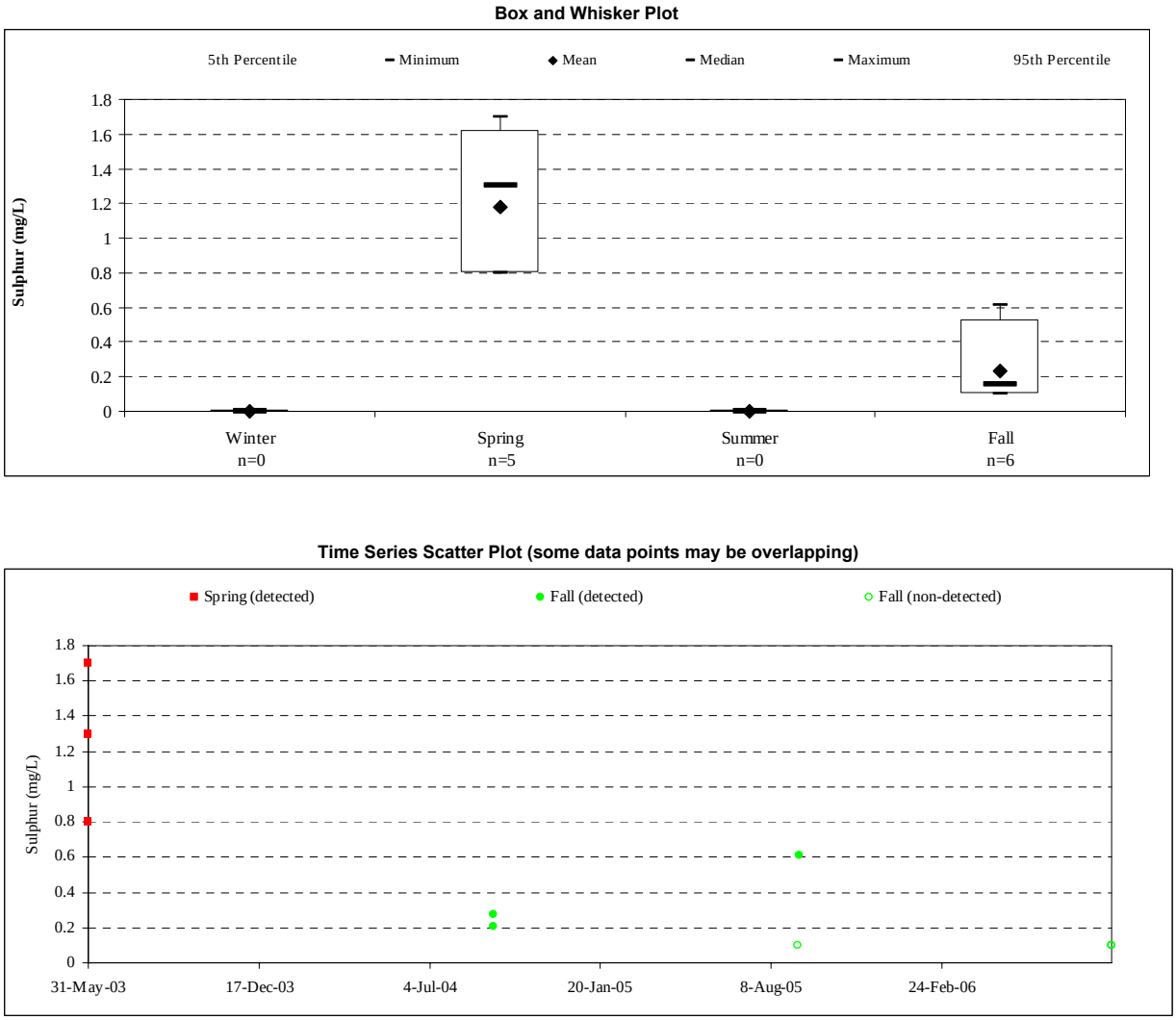
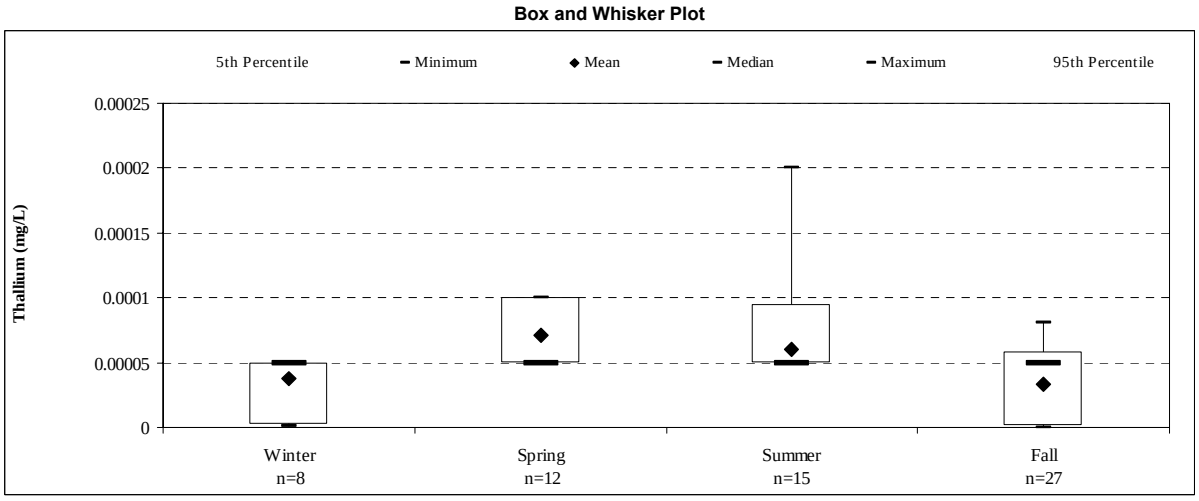


Figure G-2-1-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Upper Segment of Muskeg River



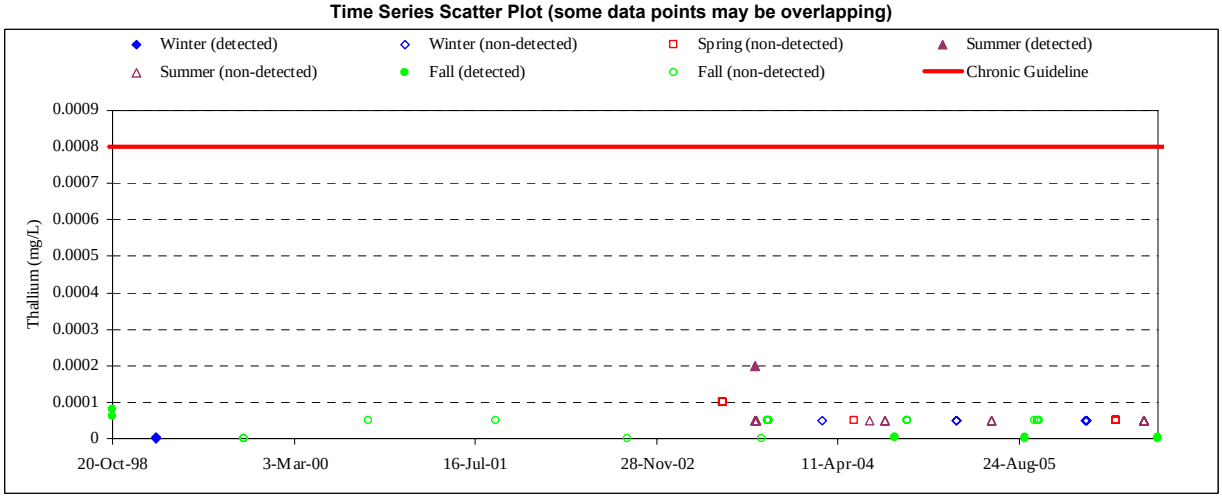


Figure G-2-1-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Upper Segment of Muskeg River

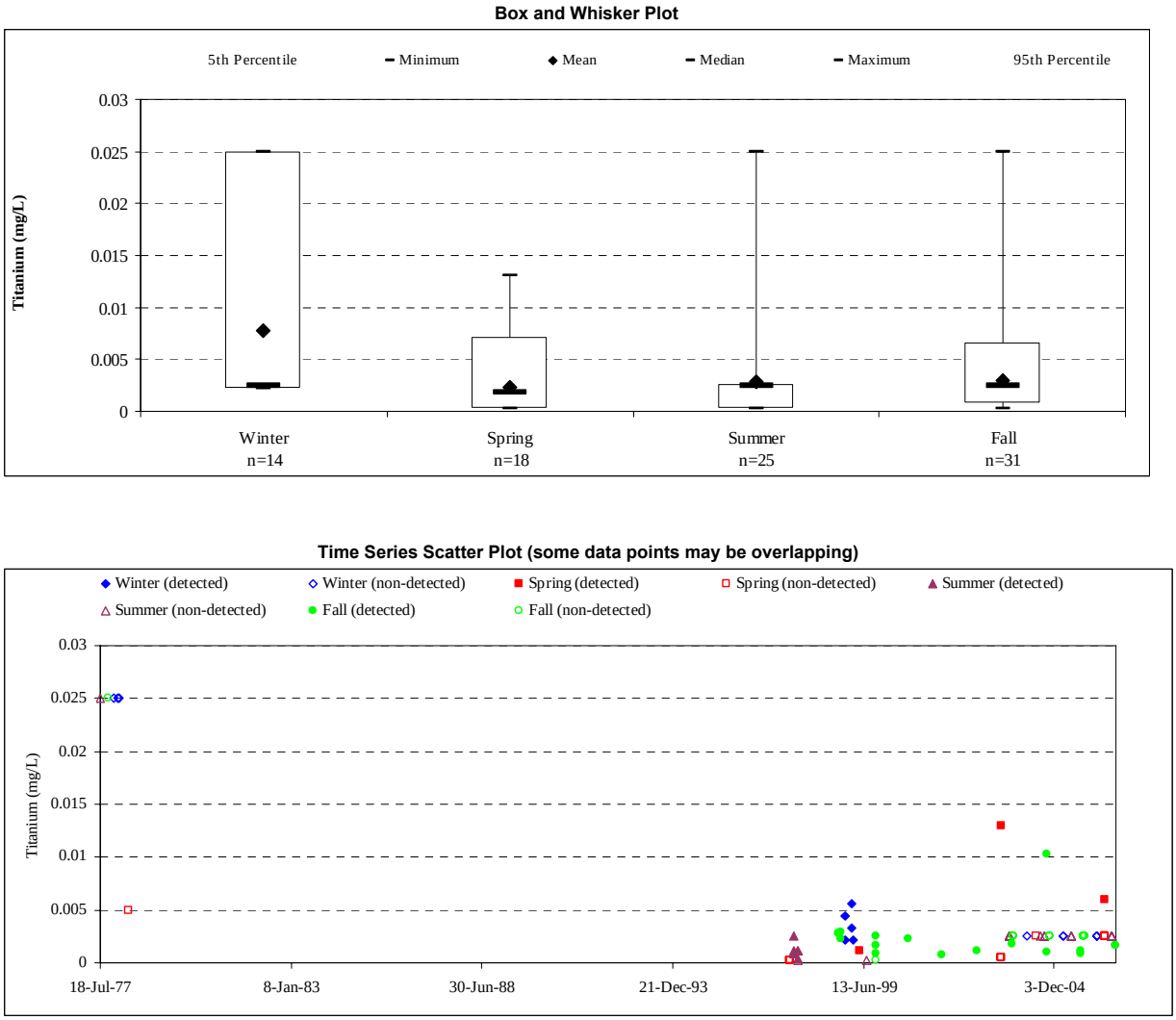
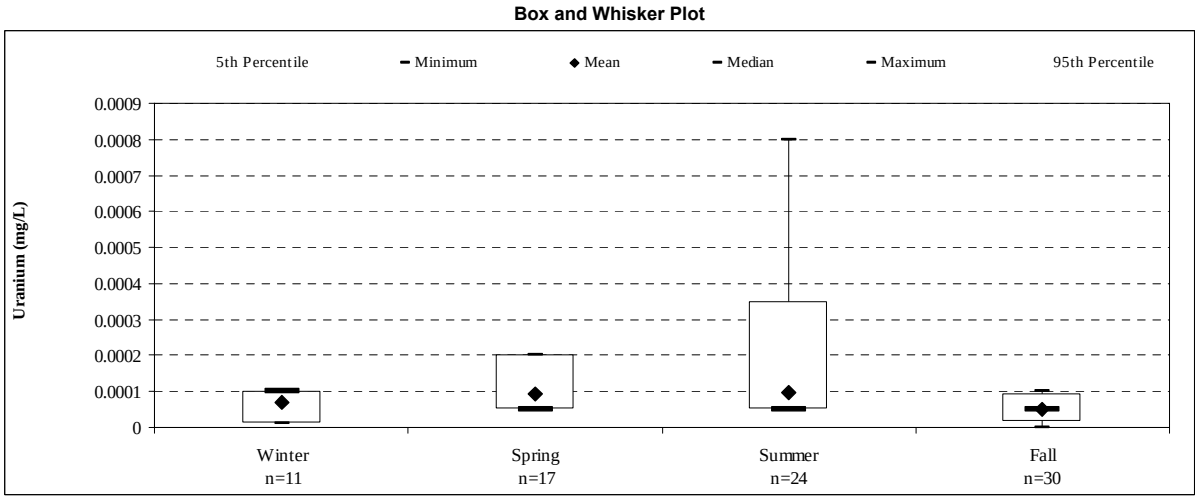


Figure G-2-1-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Upper Segment of Muskeg River



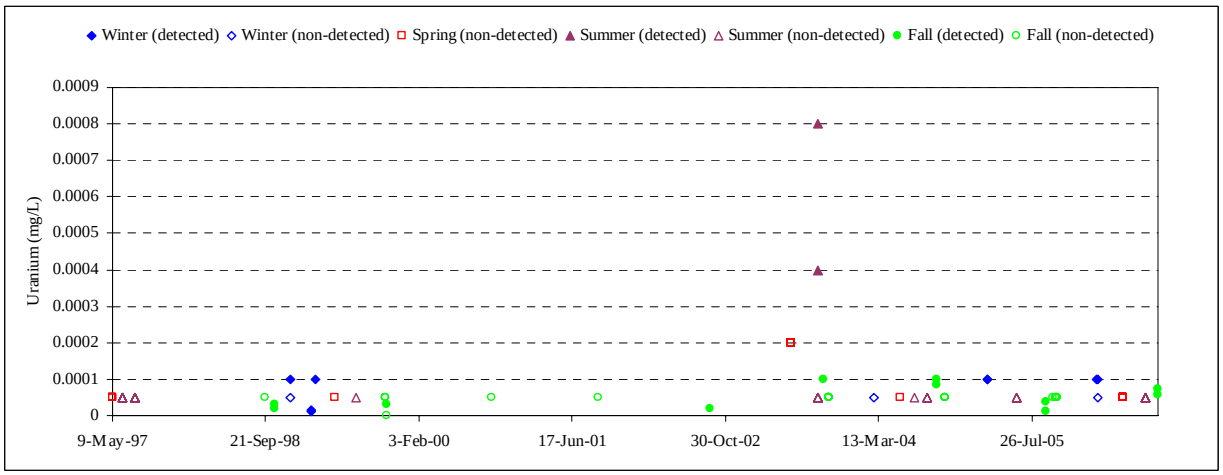


Figure G-2-1-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Upper Segment of Muskeg River

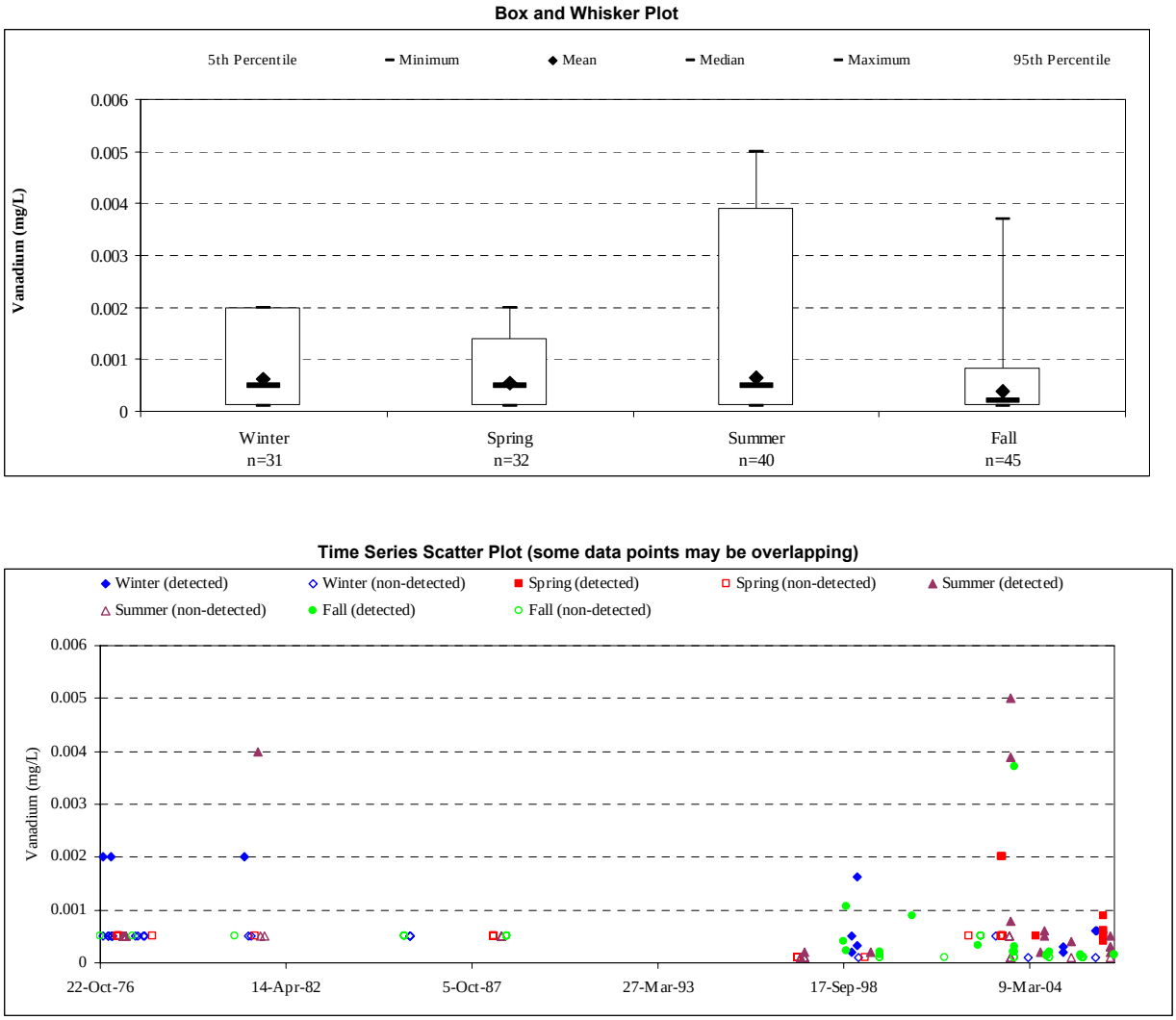


Figure G-2-1-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Upper Segment of Muskeg River

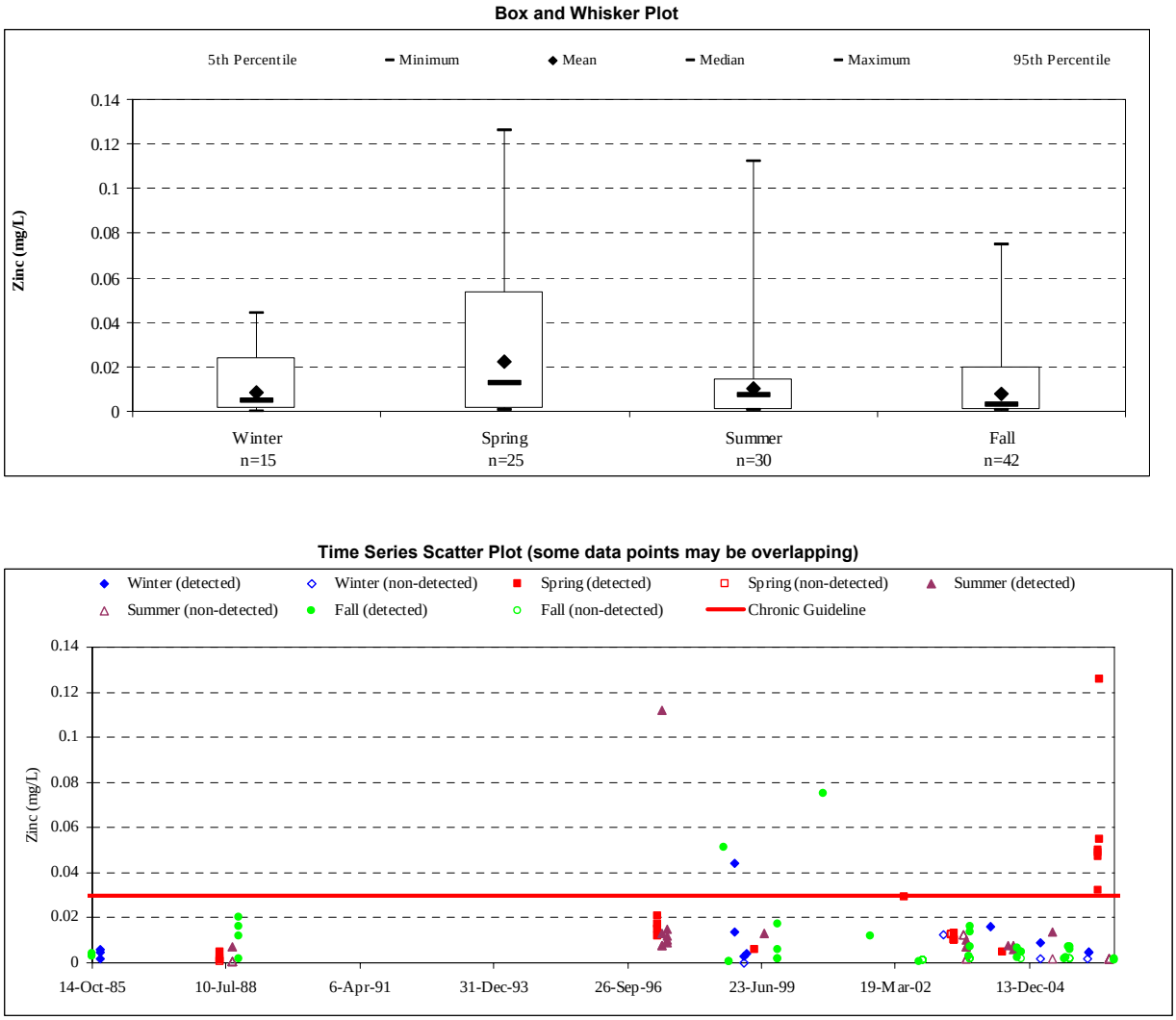
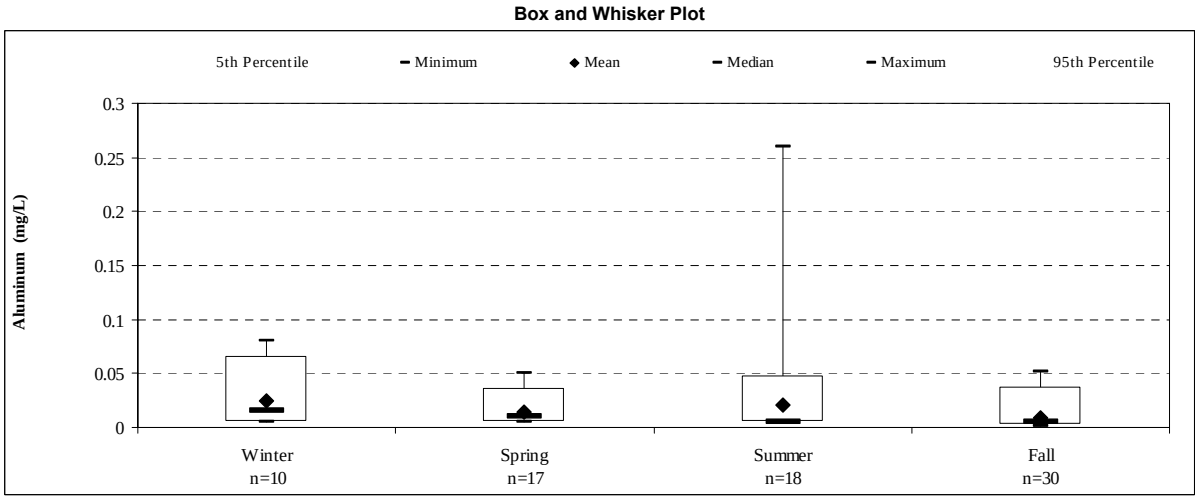


Figure G-2-1-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Upper Segment of Muskeg River



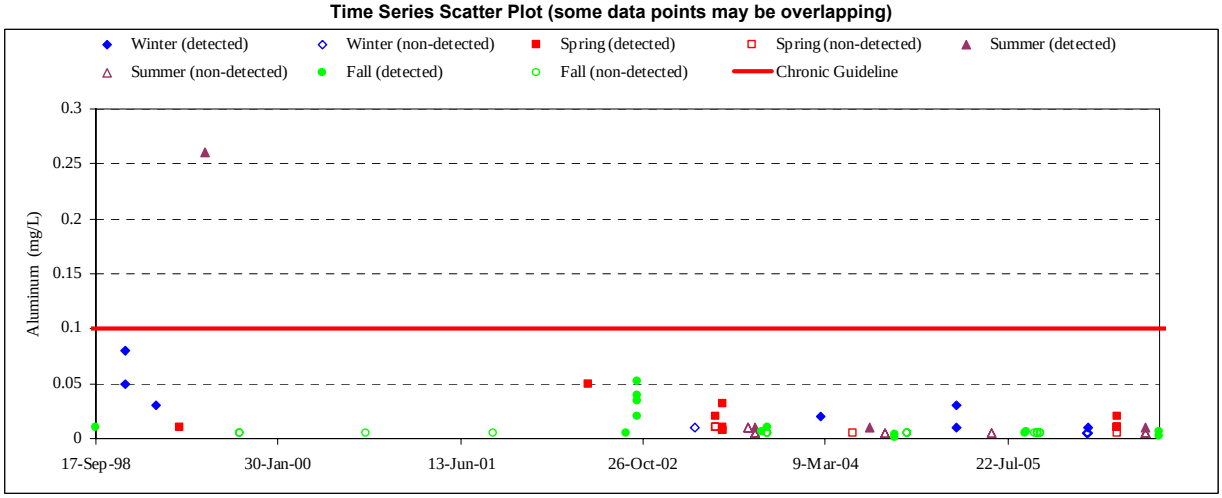


Figure G-2-1-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Upper Segment of Muskeg River

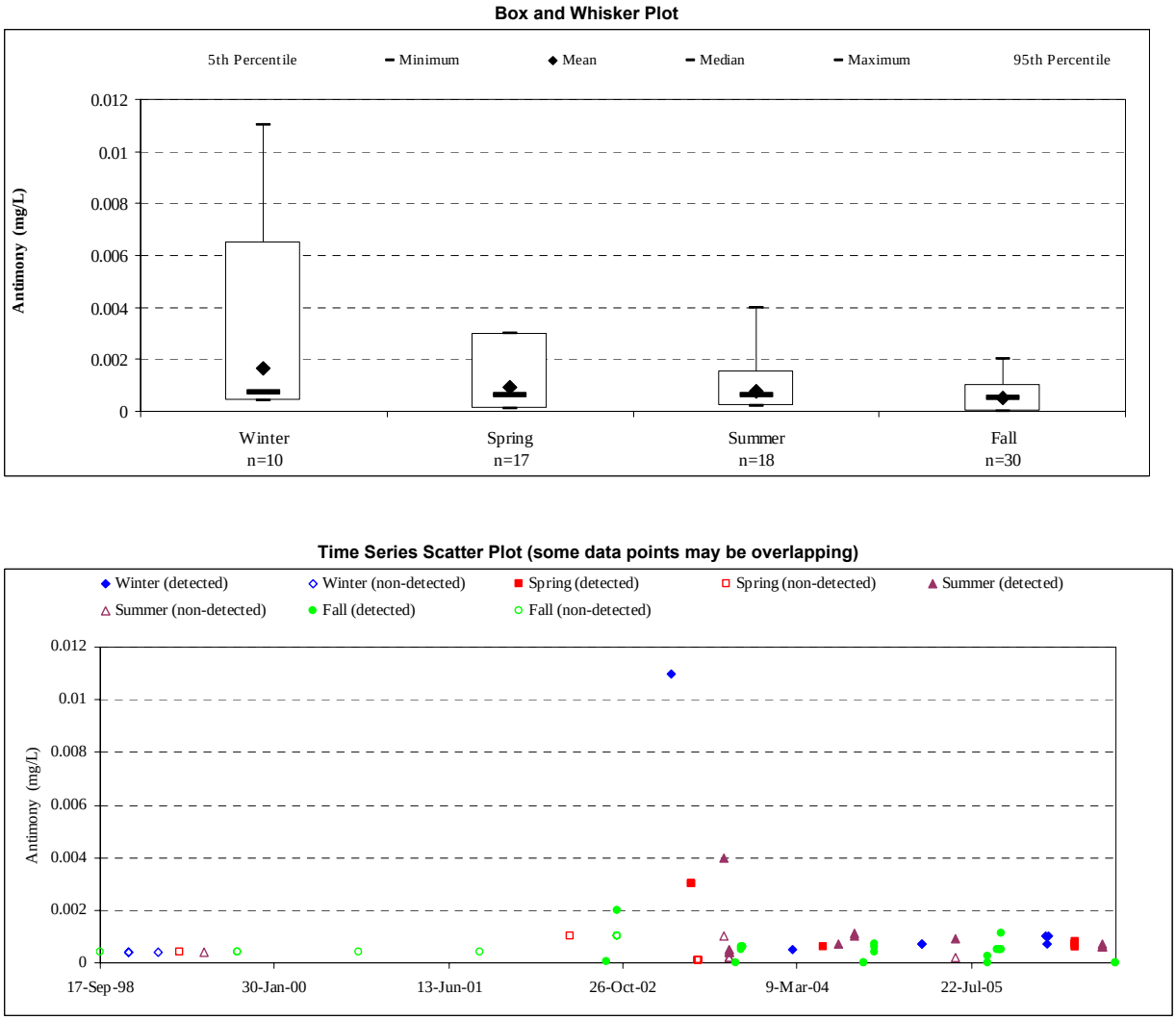
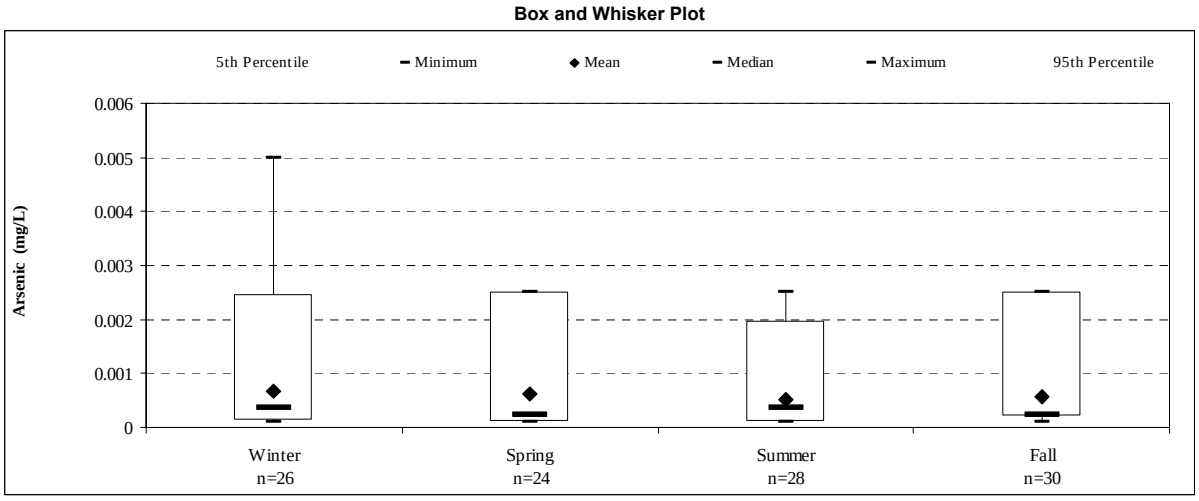


Figure G-2-1-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Upper Segment of Muskeg River



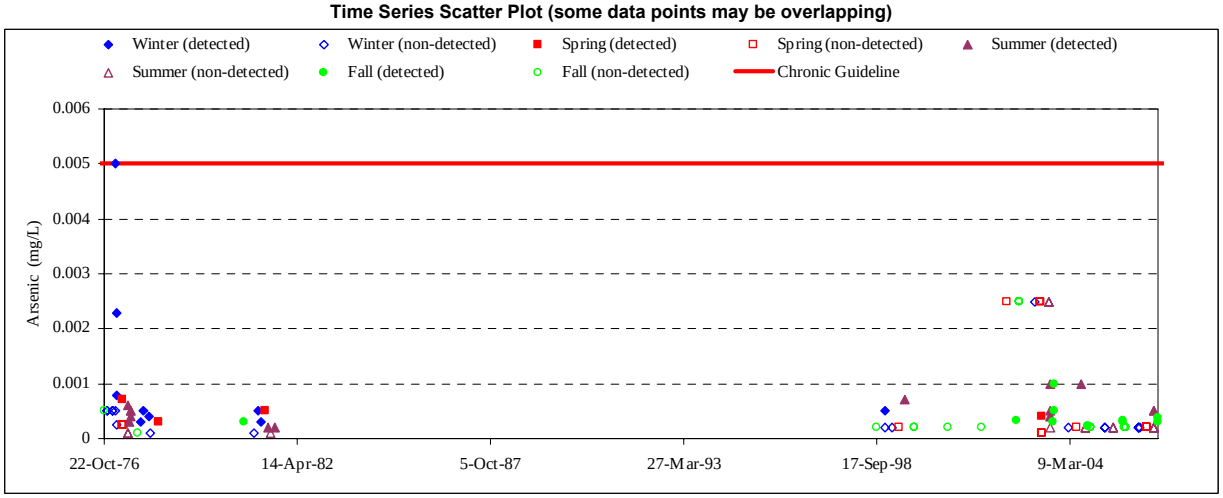
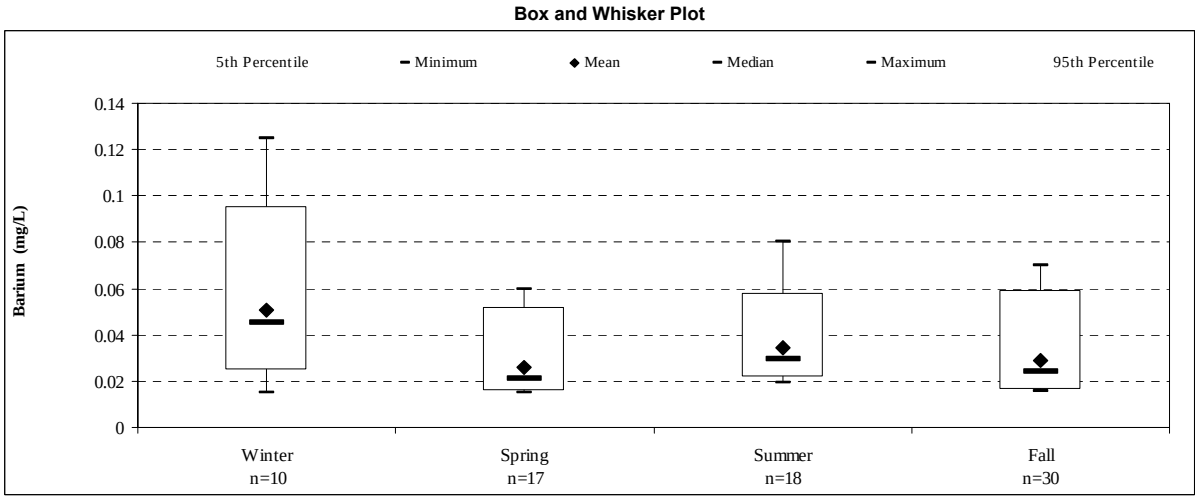


Figure G-2-1-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Upper Segment of Muskeg River



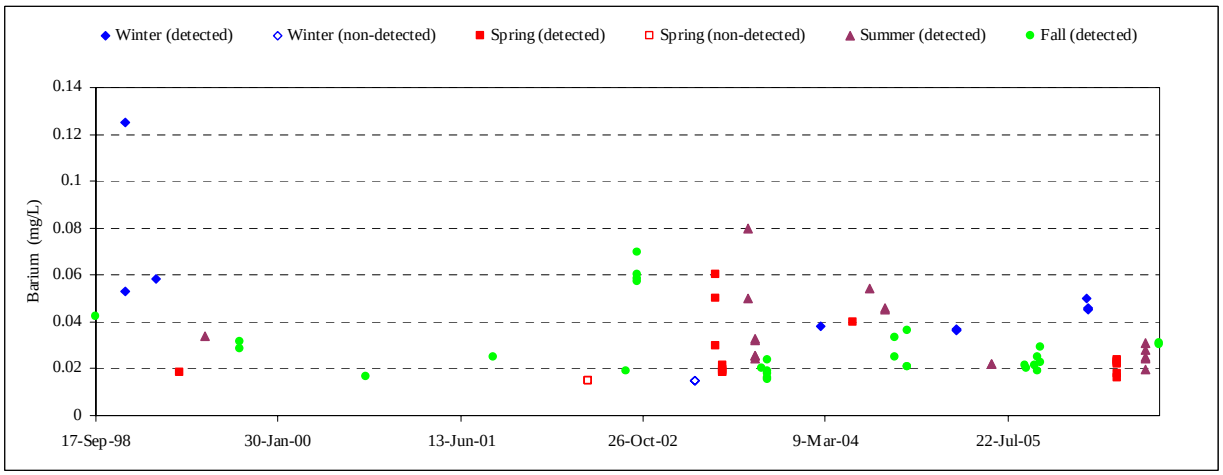
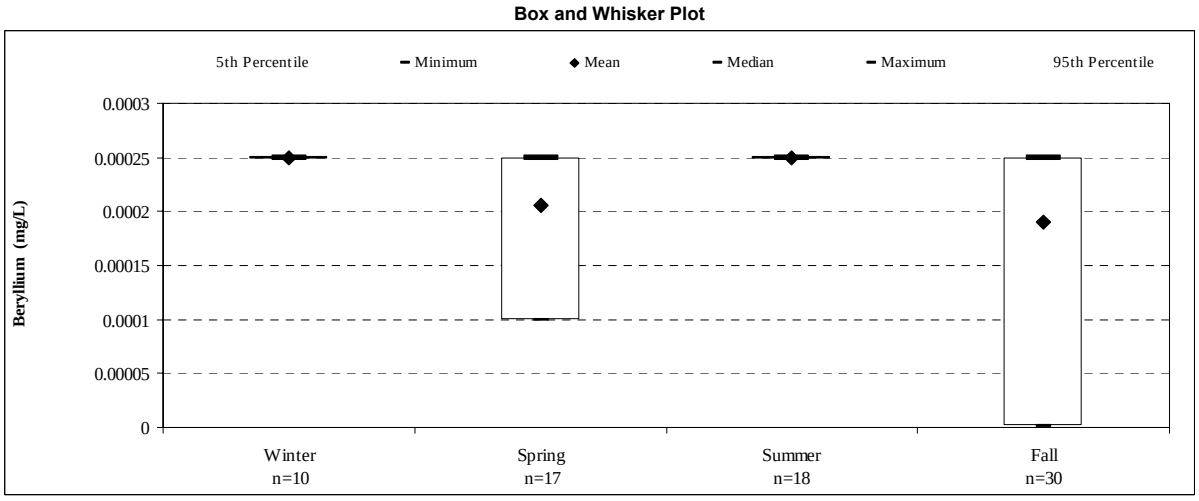


Figure G-2-1-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Upper Segment of Muskeg River



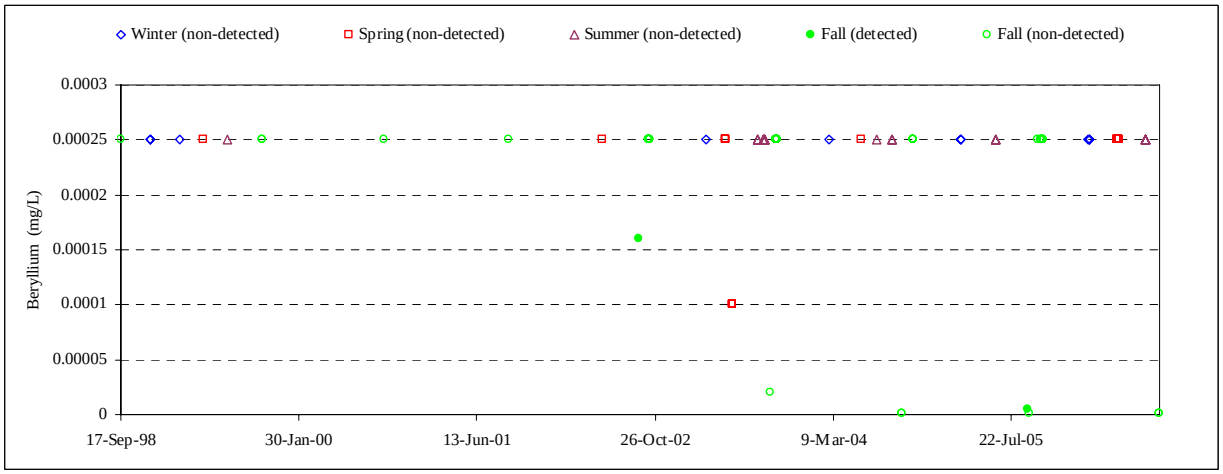
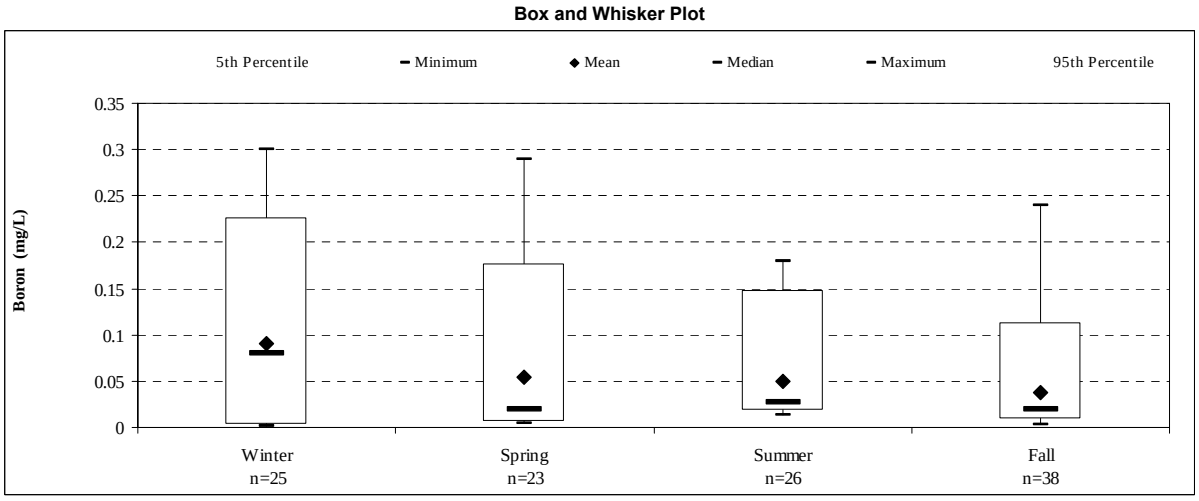


Figure G-2-1-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Upper Segment of Muskeg River



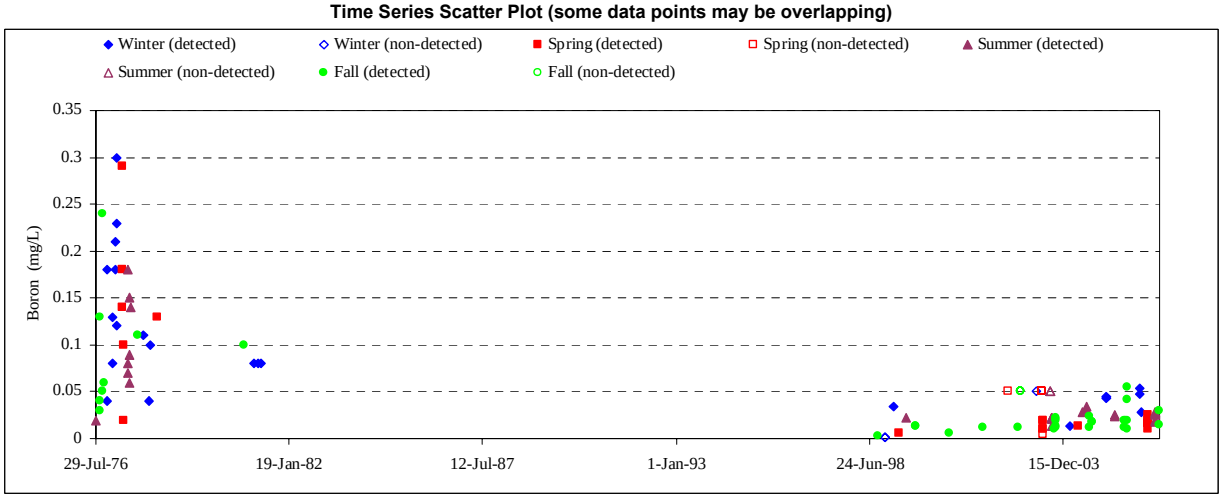
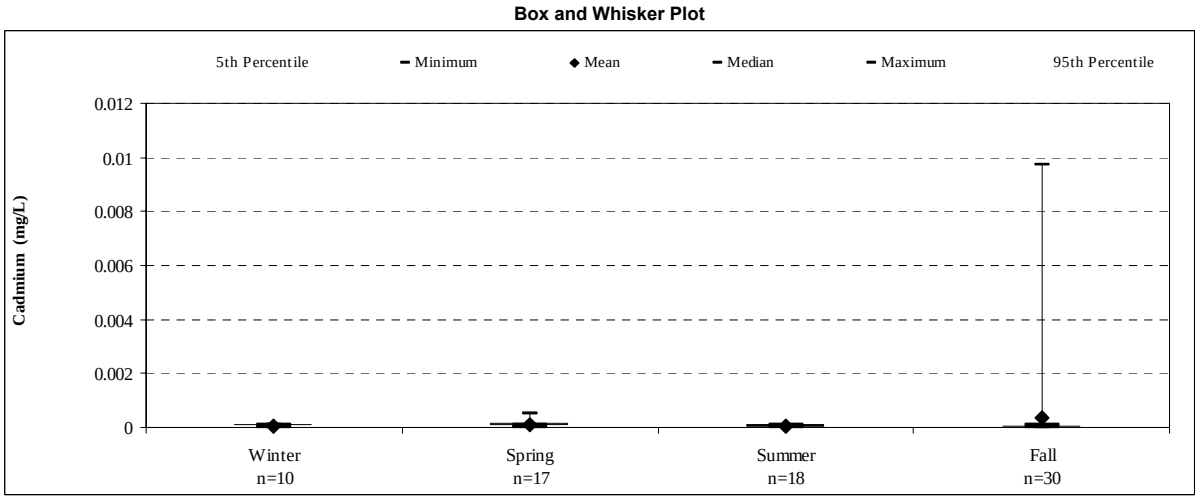


Figure G-2-1-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Upper Segment of Muskeg River



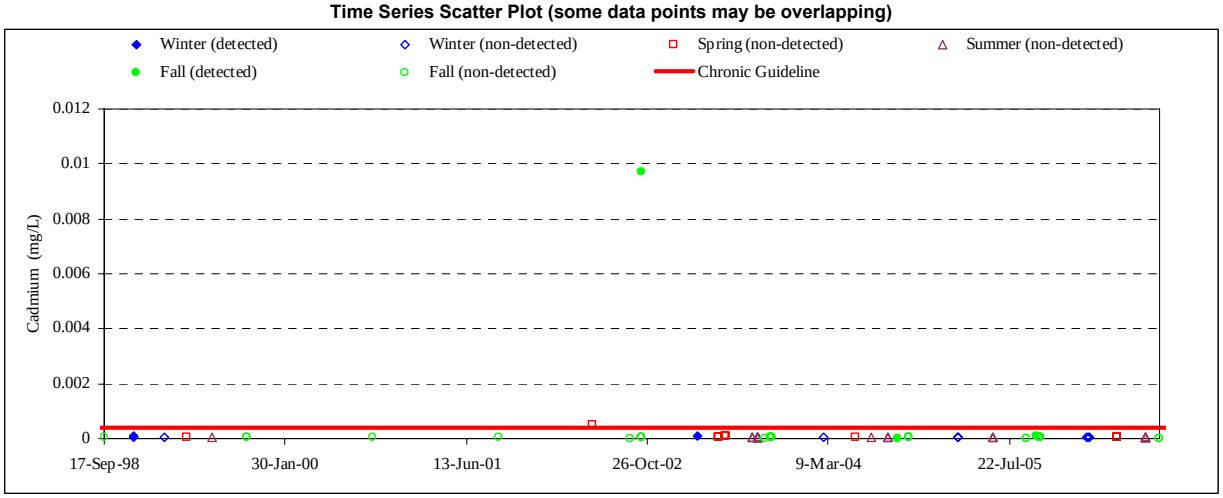
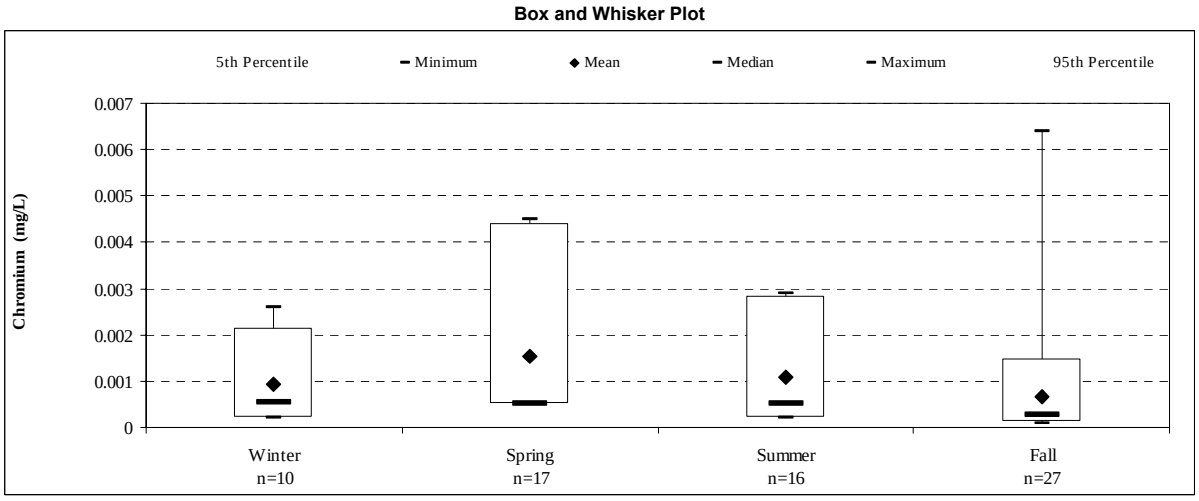


Figure G-2-1-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Upper Segment of Muskeg River



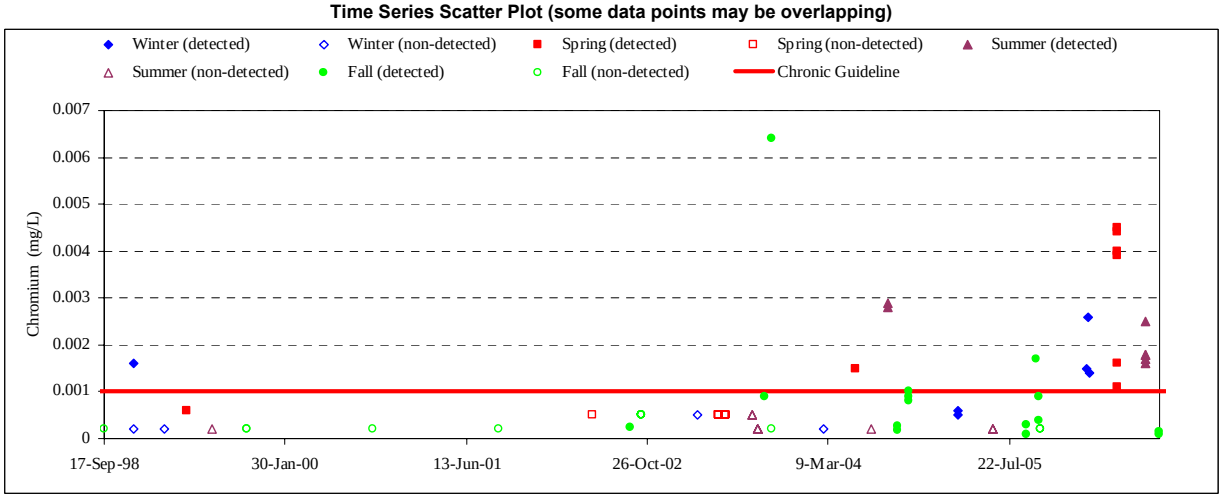
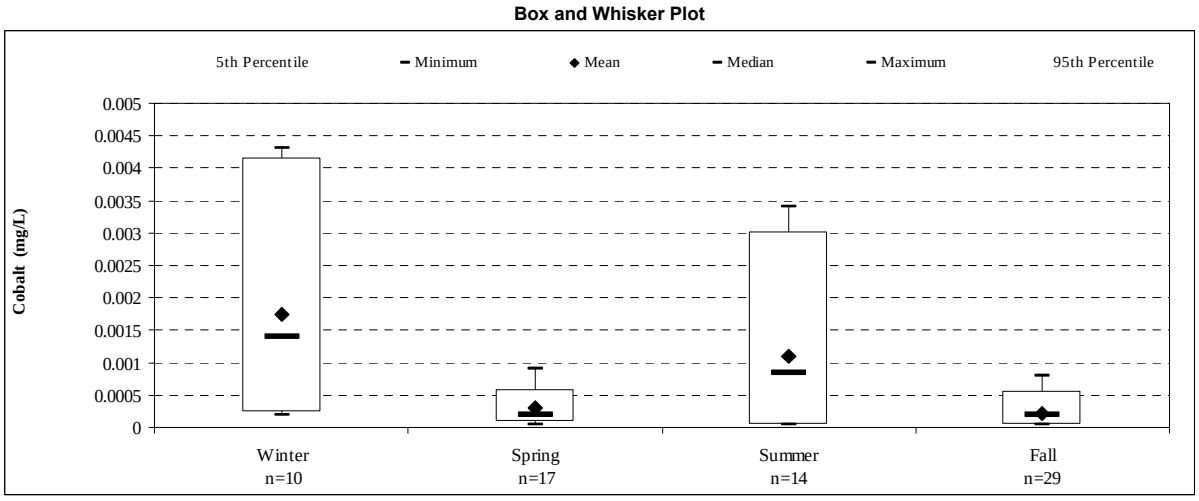


Figure G-2-1-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Upper Segment of Muskeg River



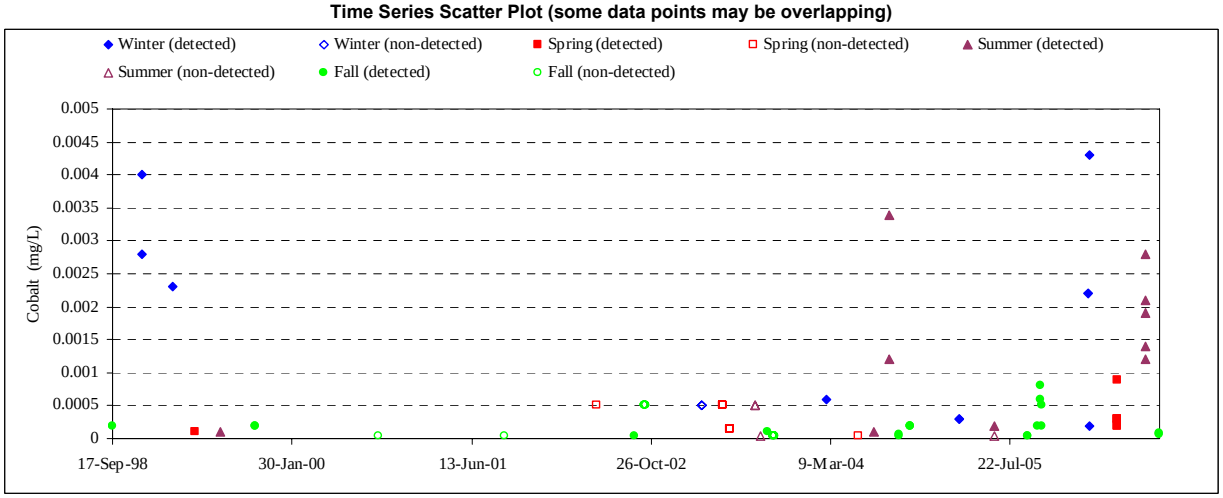
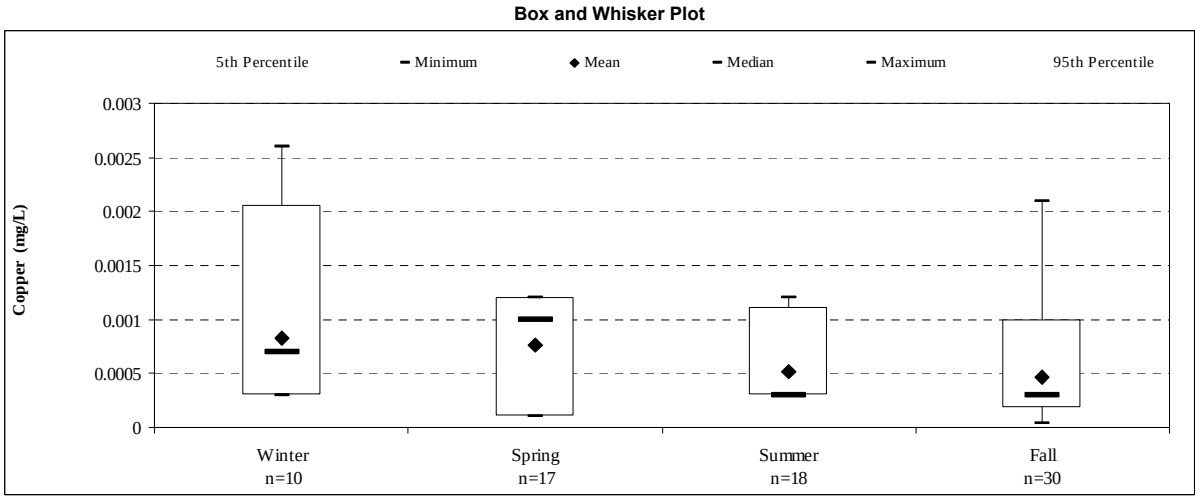


Figure G-2-1-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Upper Segment of Muskeg River



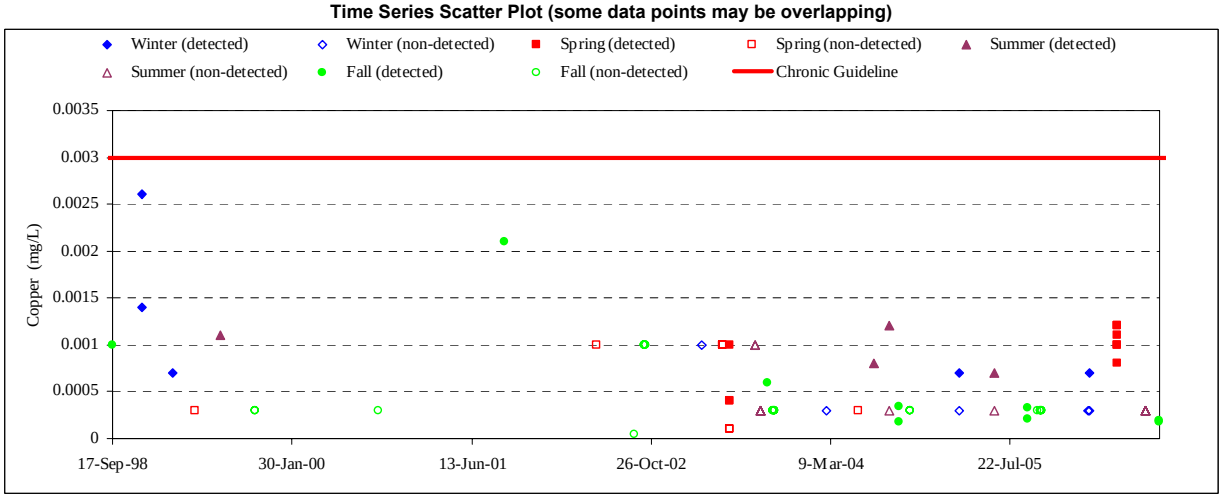
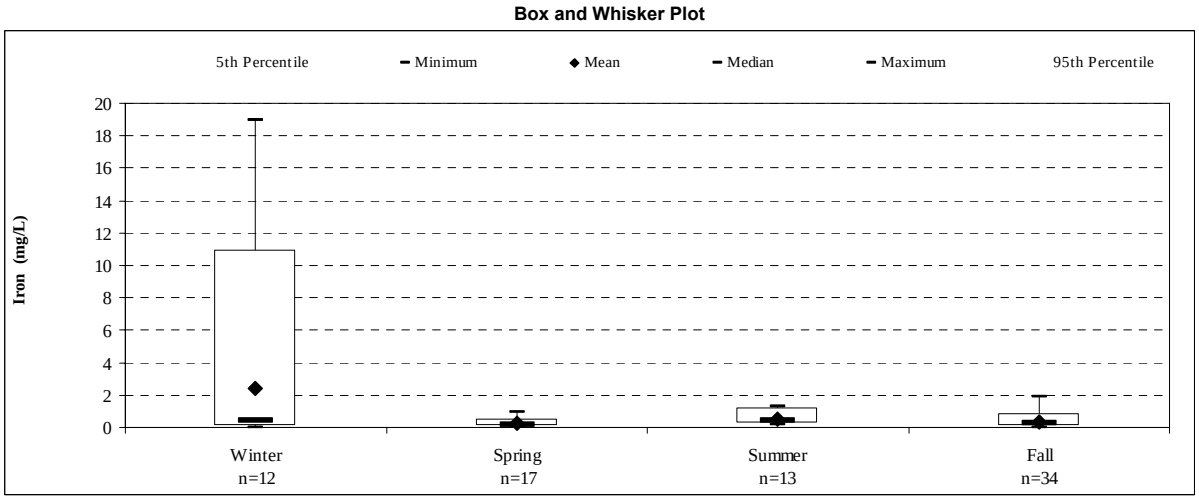


Figure G-2-1-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Upper Segment of Muskeg River



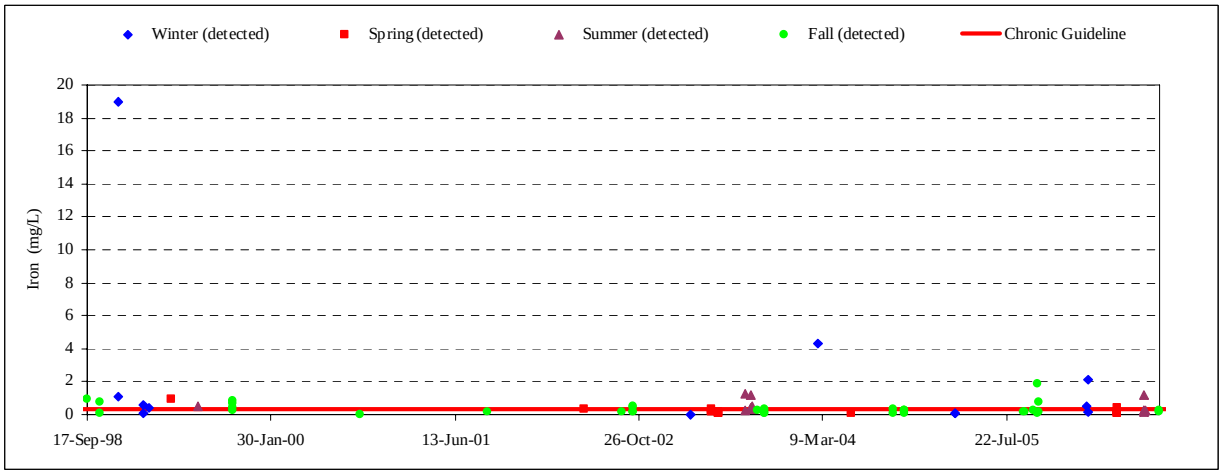
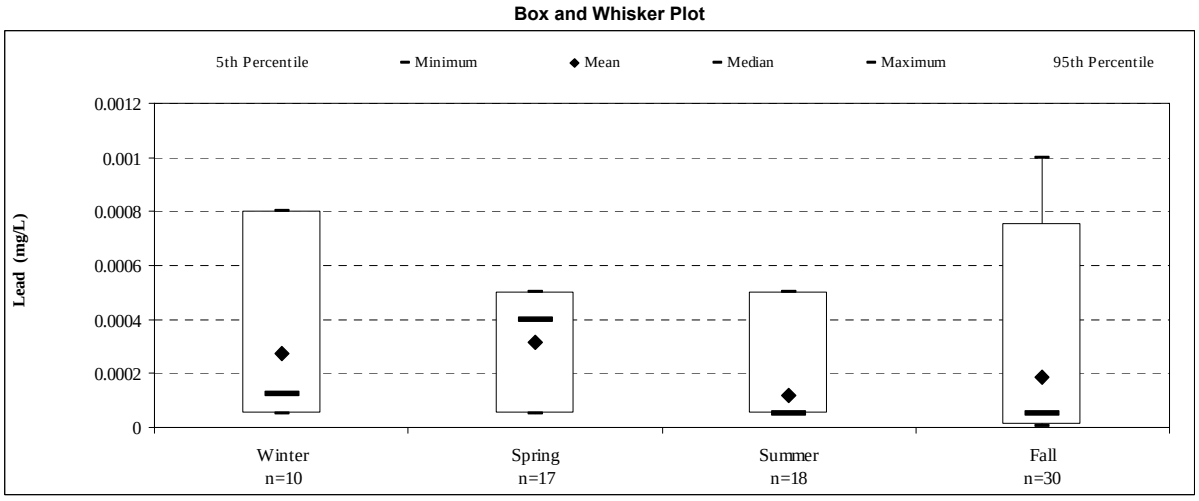


Figure G-2-1-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Upper Segment of Muskeg River



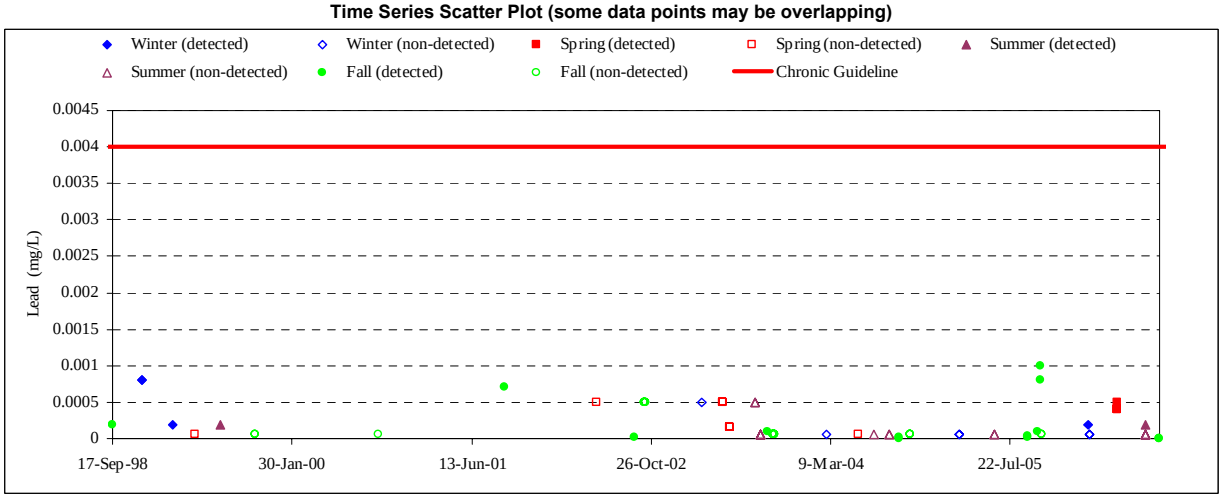
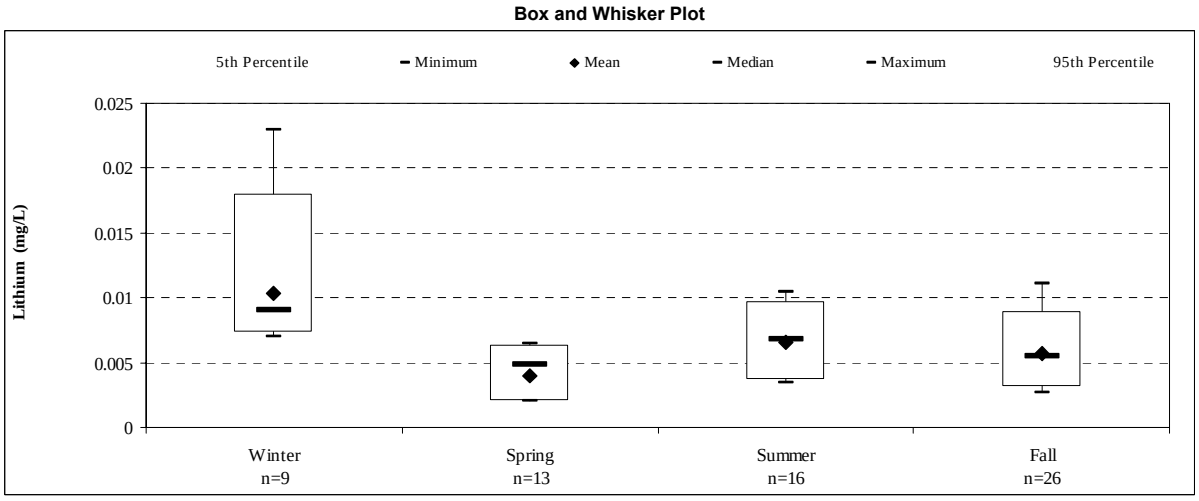


Figure G-2-1-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Upper Segment of Muskeg River



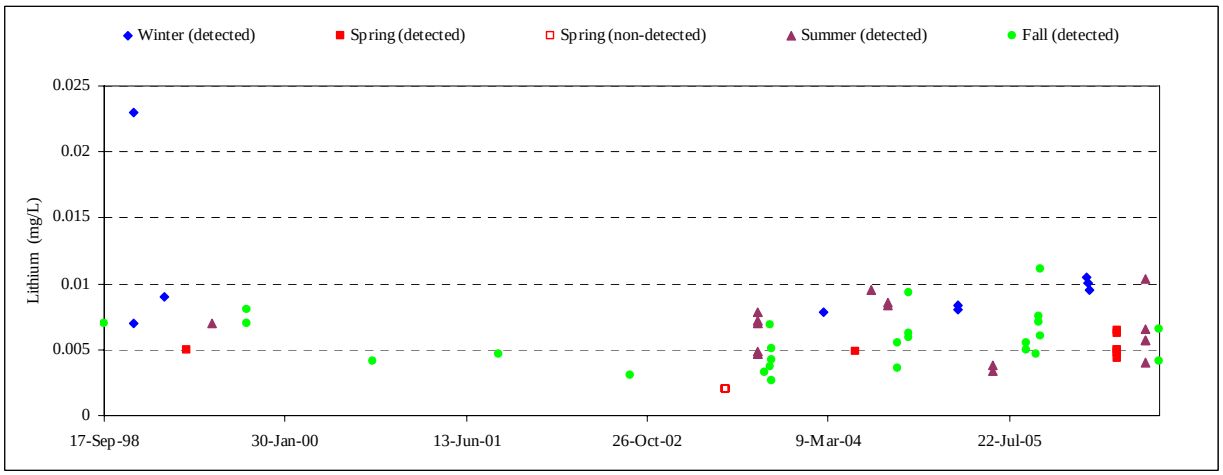
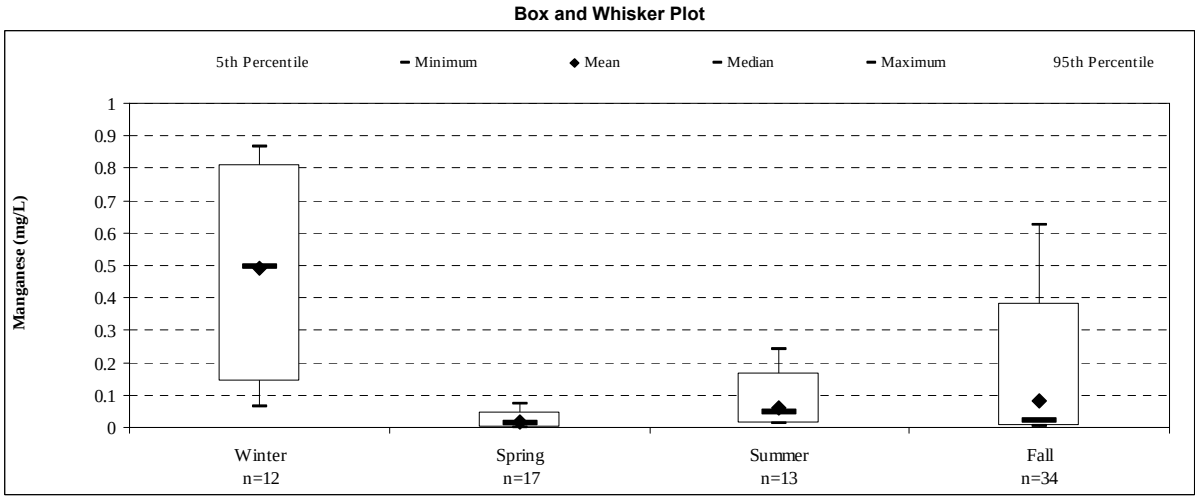


Figure G-2-1-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Upper Segment of Muskeg River



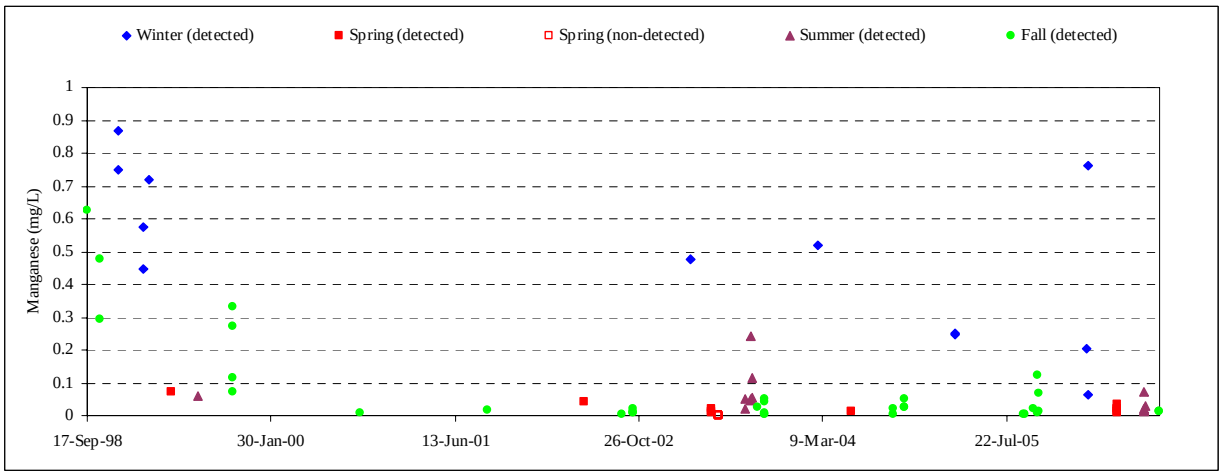
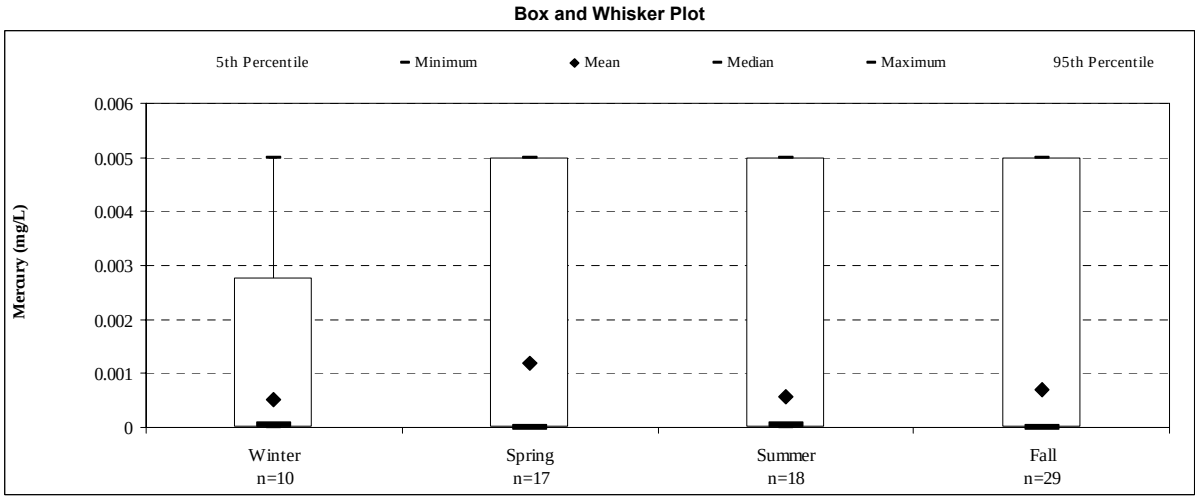


Figure G-2-1-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Upper Segment of Muskeg River



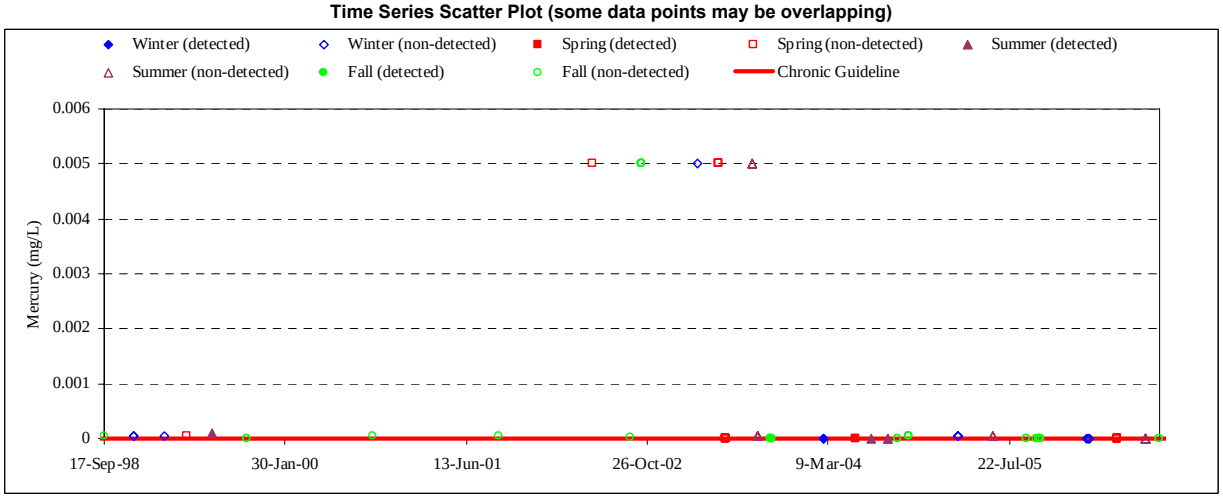


Figure G-2-1-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Upper Segment of Muskeg River

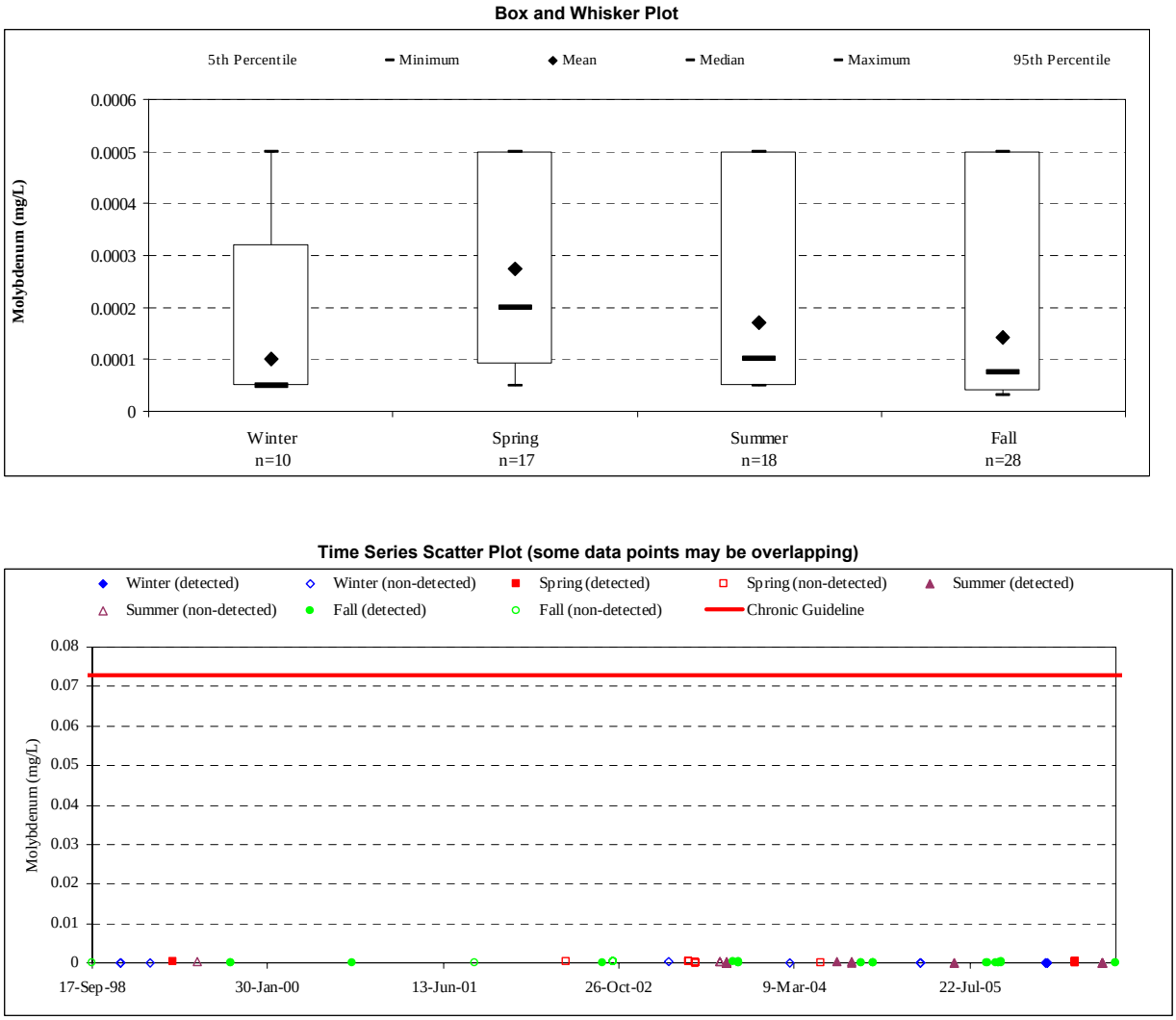


Figure G-2-1-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Upper Segment of Muskeg River

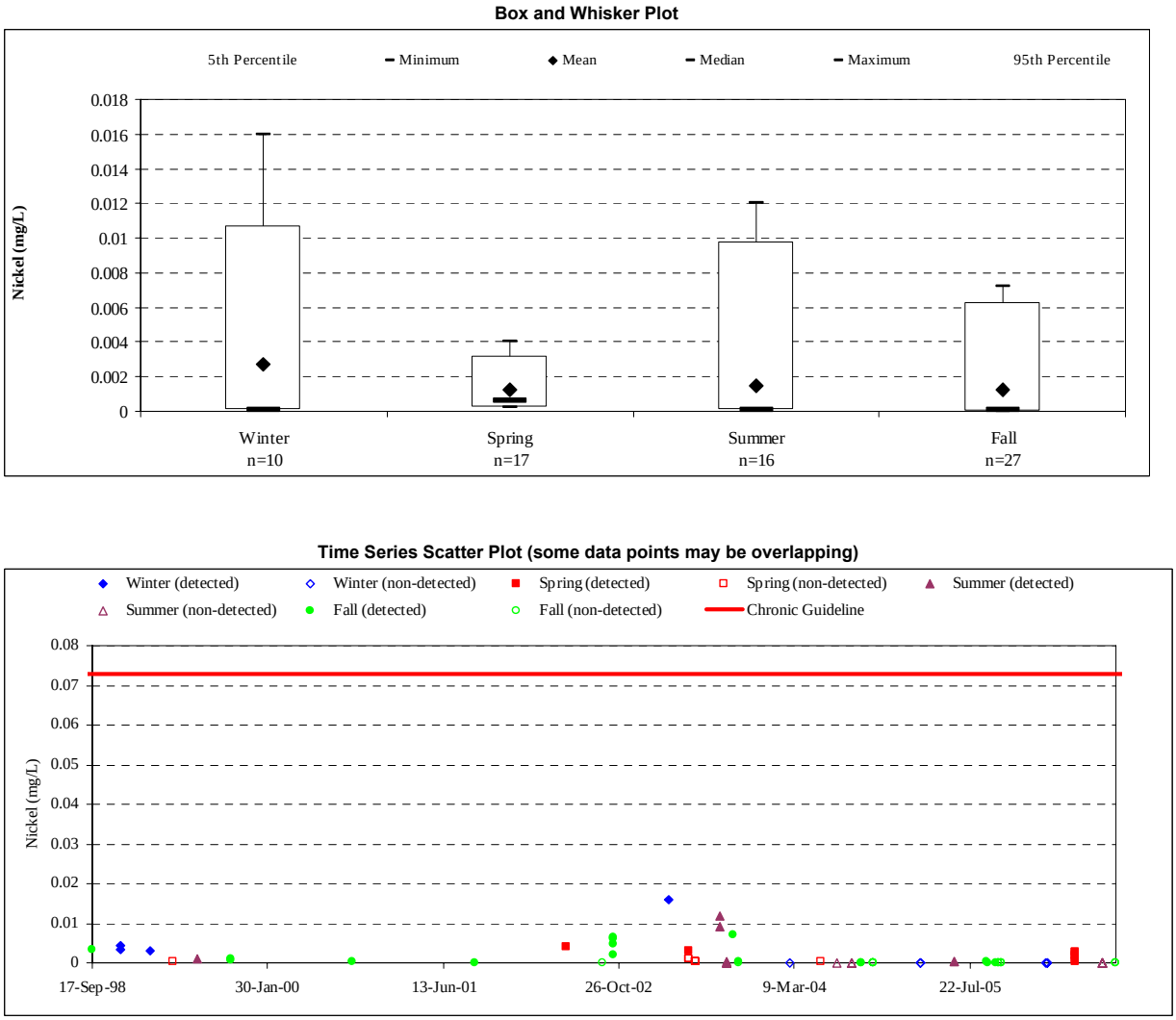
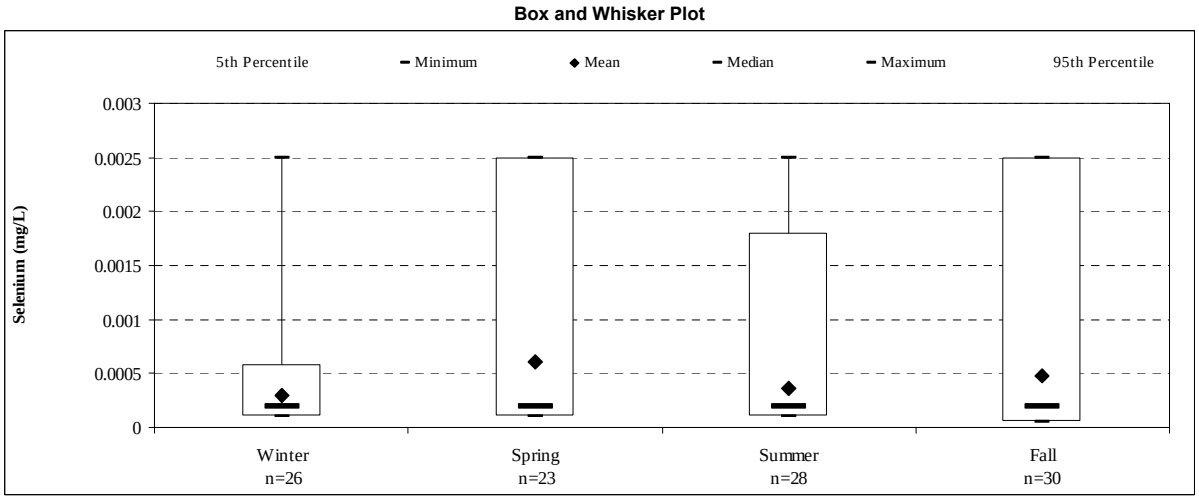


Figure G-2-1-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Upper Segment of Muskeg River



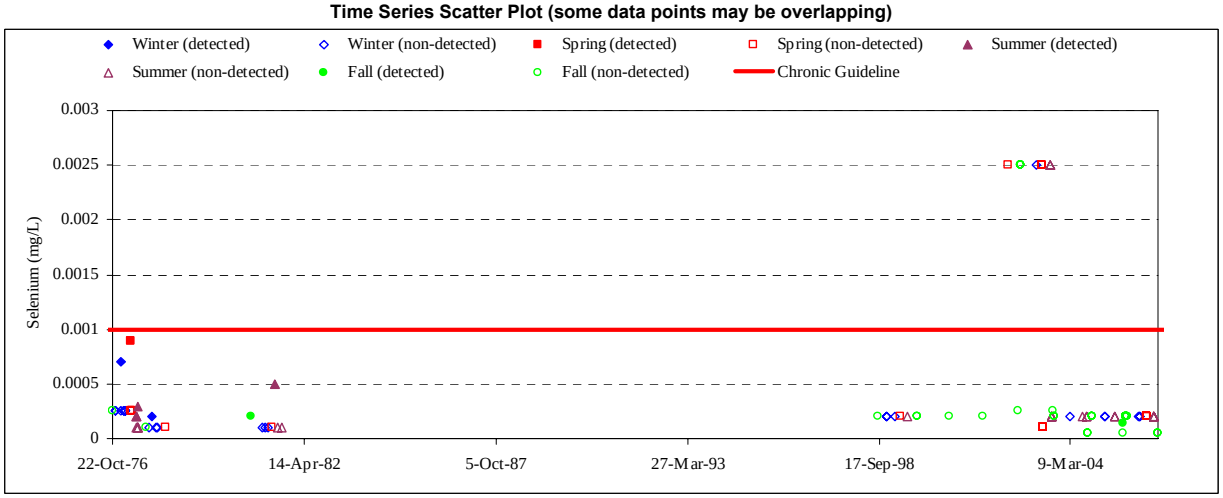
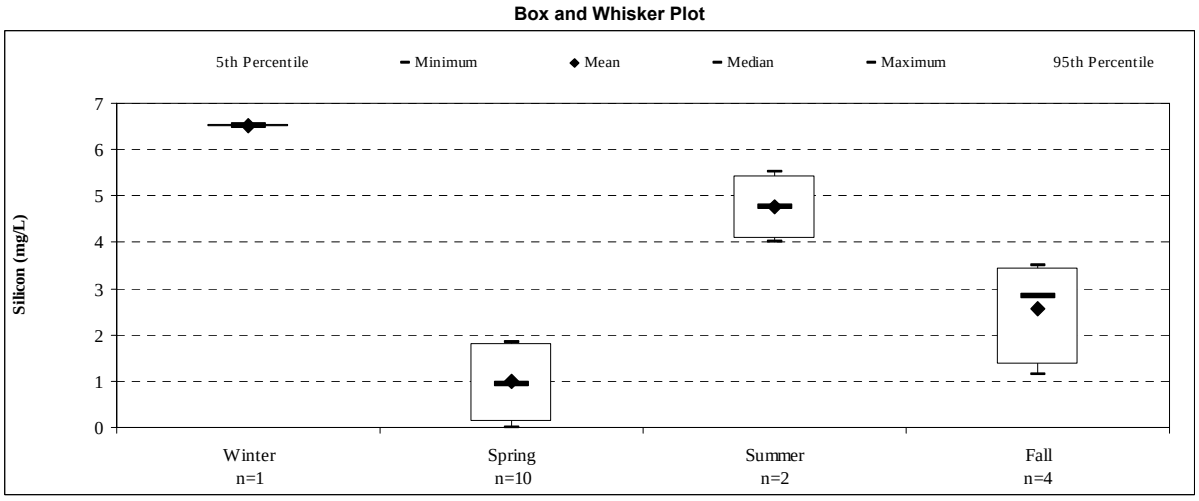


Figure G-2-1-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Upper Segment of Muskeg River



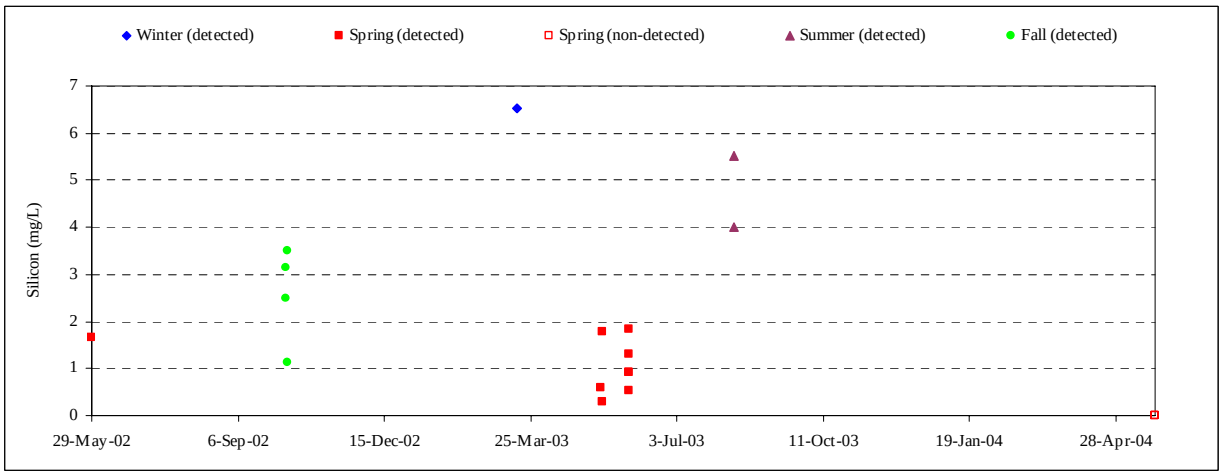
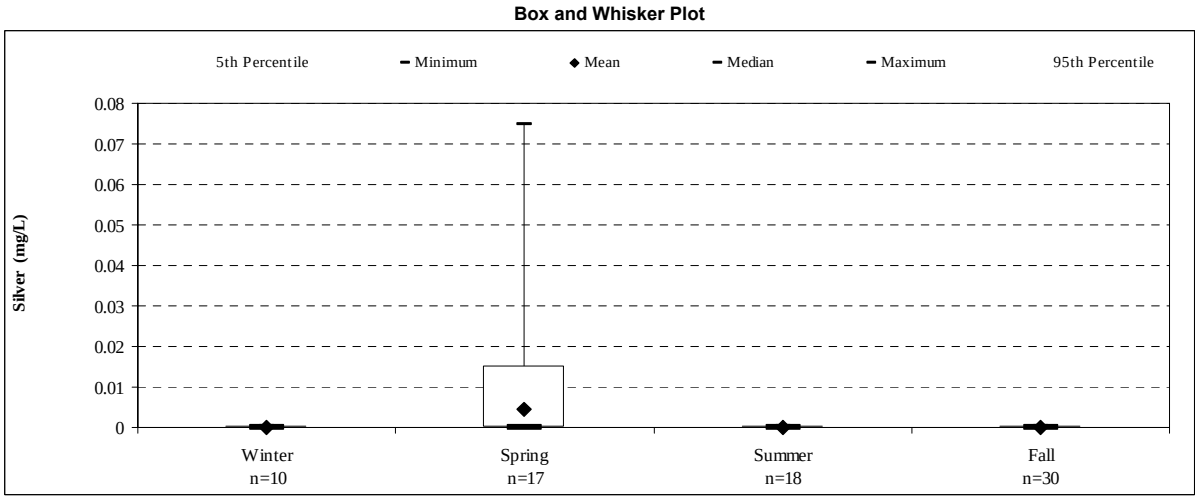


Figure G-2-1-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Upper Segment of Muskeg River



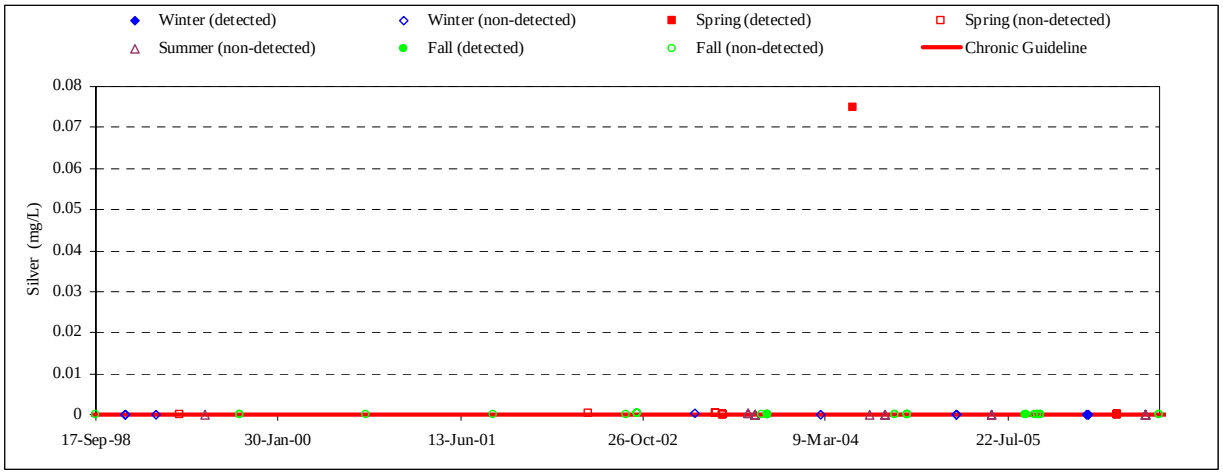
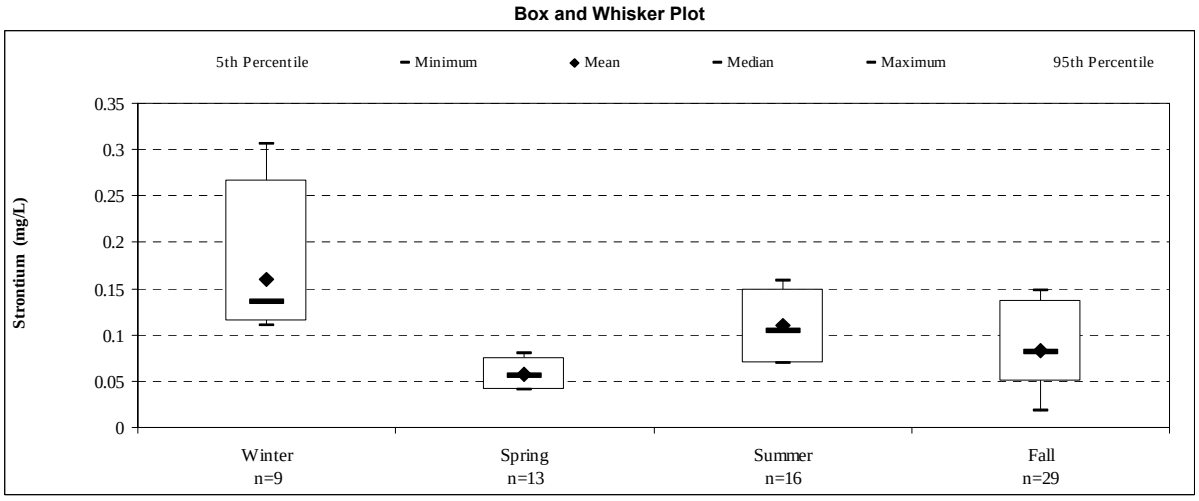


Figure G-2-1-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Upper Segment of Muskeg River



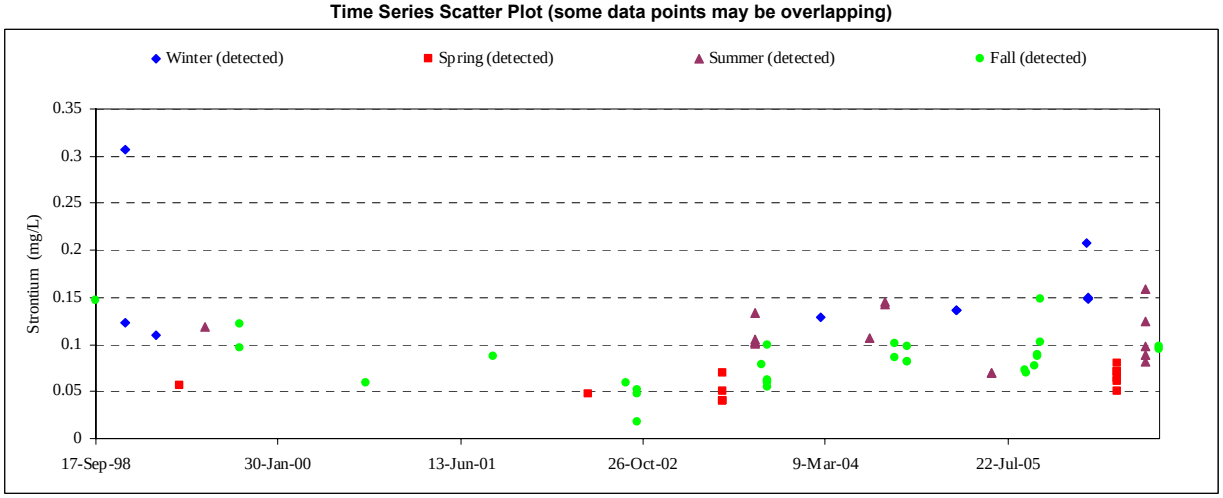
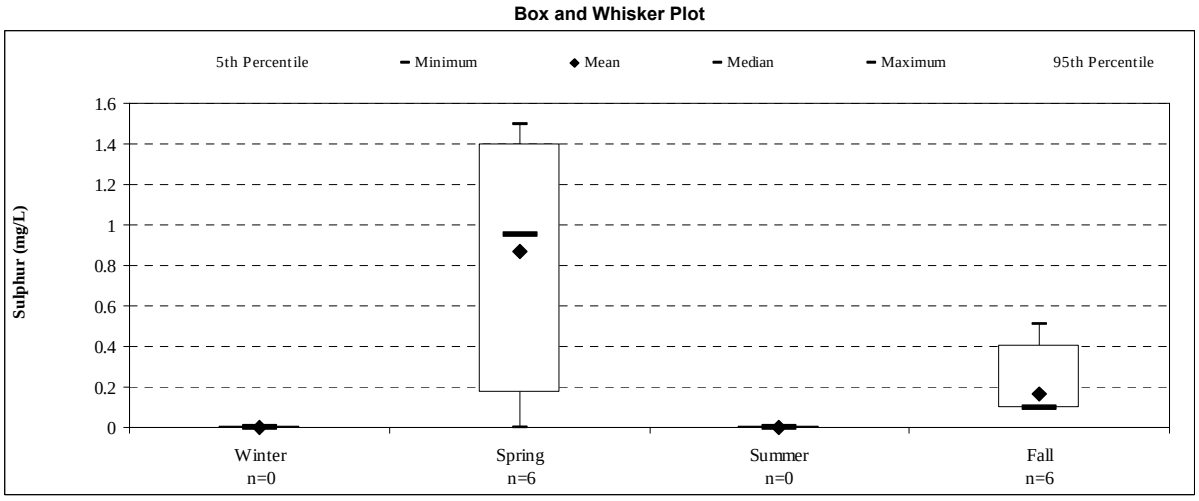


Figure G-2-1-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Upper Segment of Muskeg River



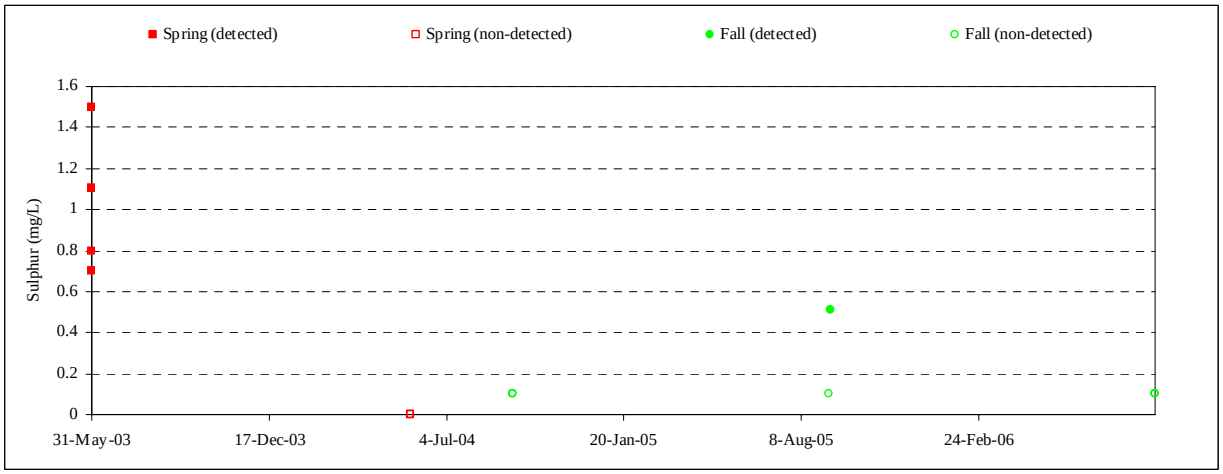
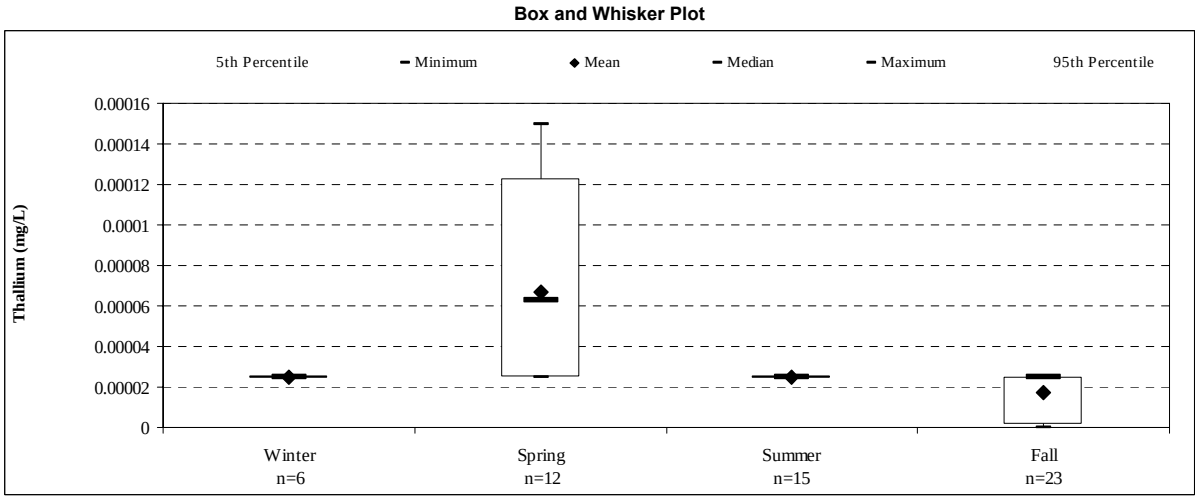


Figure G-2-1-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Upper Segment of Muskeg River



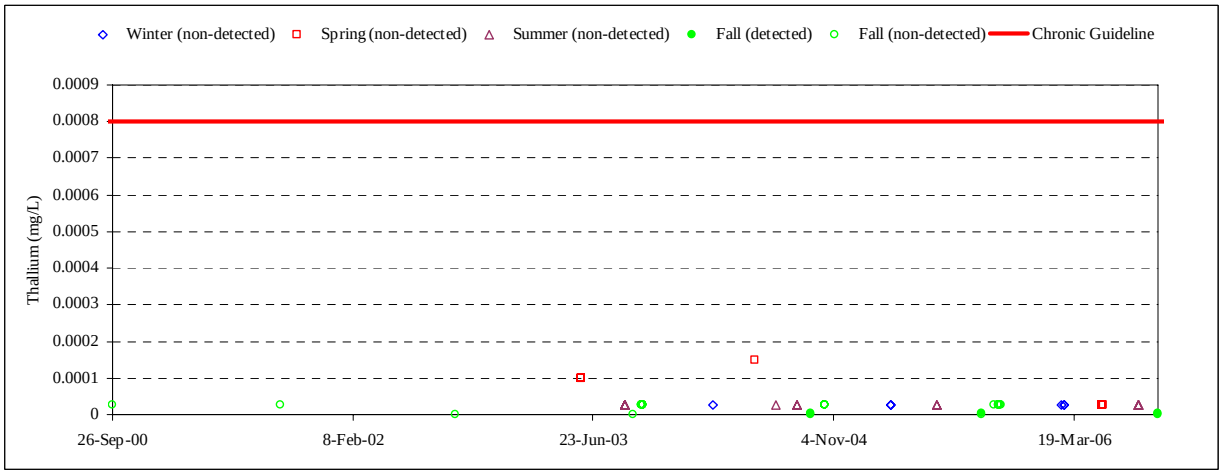
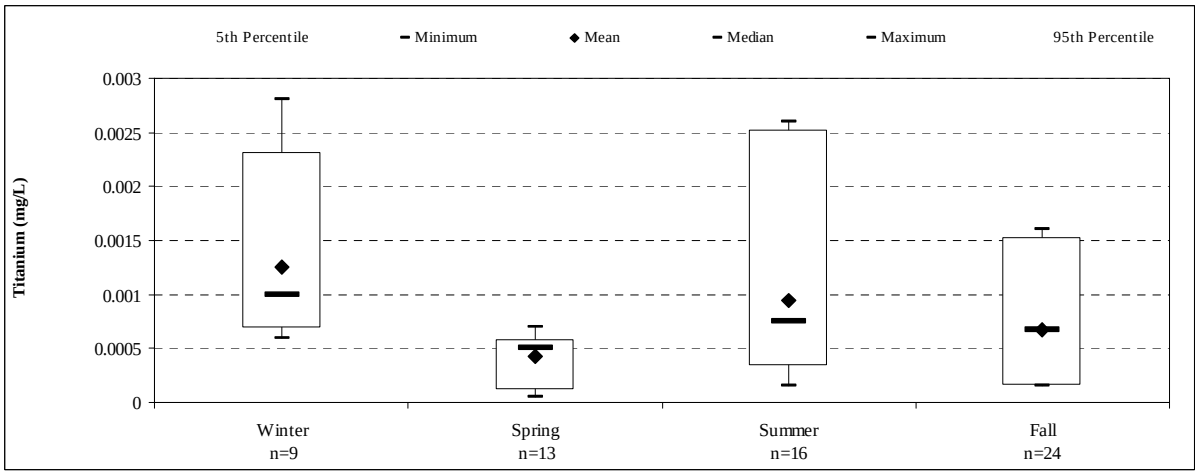


Figure G-2-1-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Upper Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

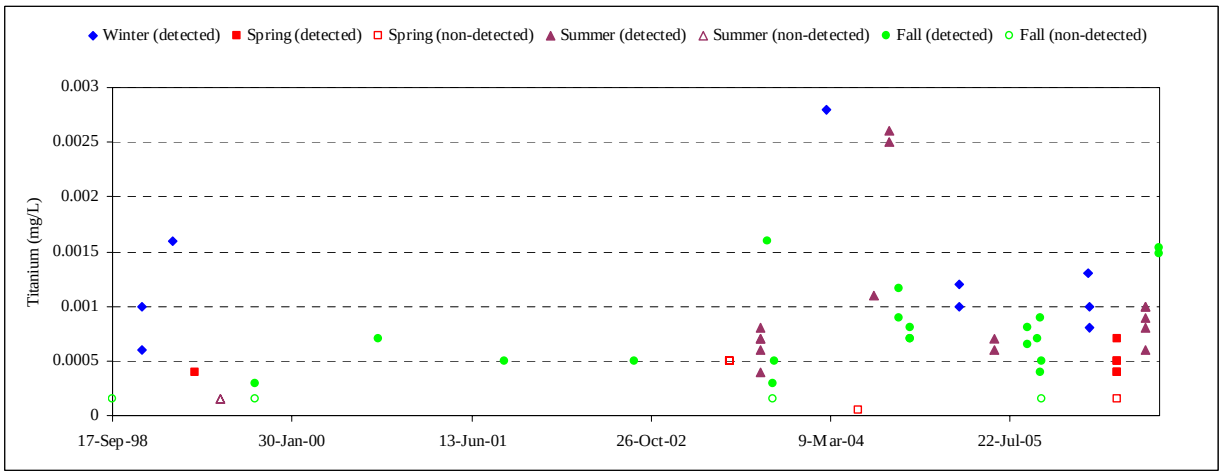
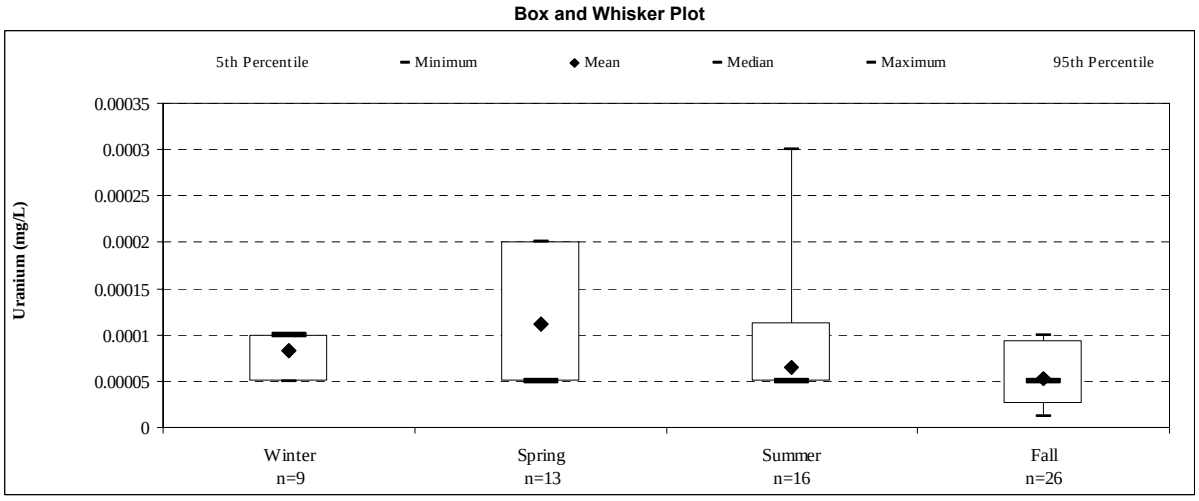


Figure G-2-1-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Upper Segment of Muskeg River



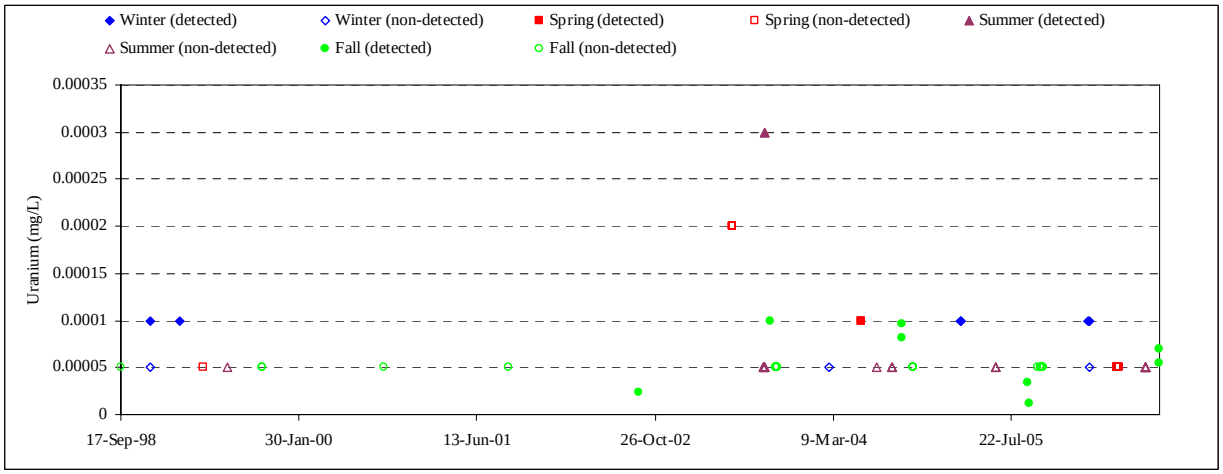
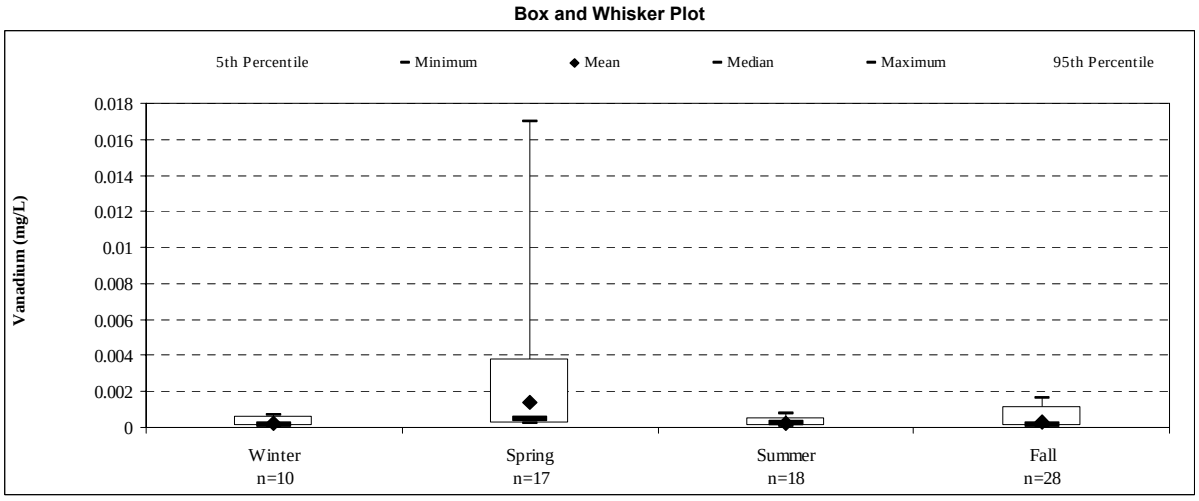


Figure G-2-1-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Upper Segment of Muskeg River



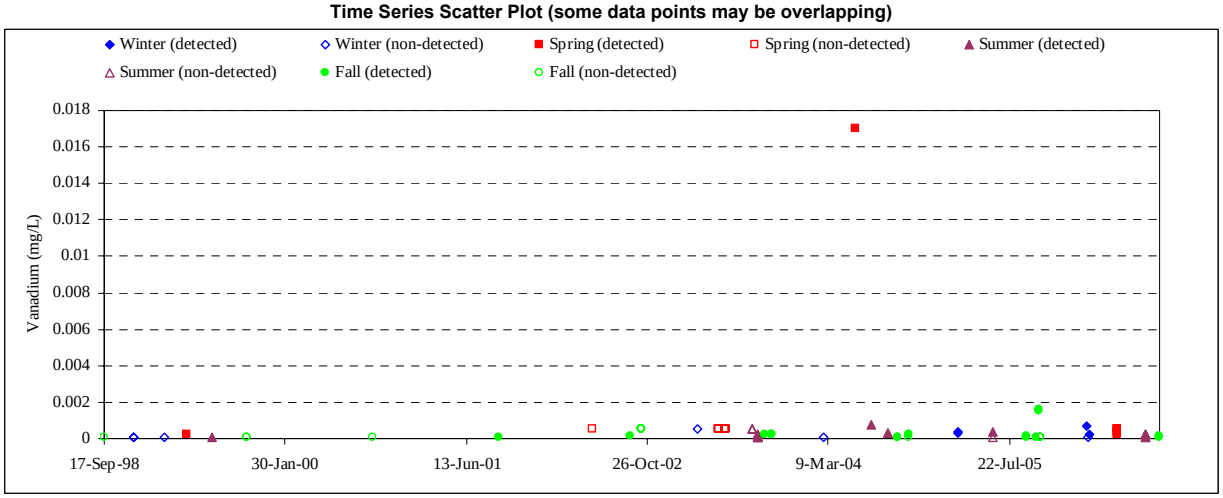
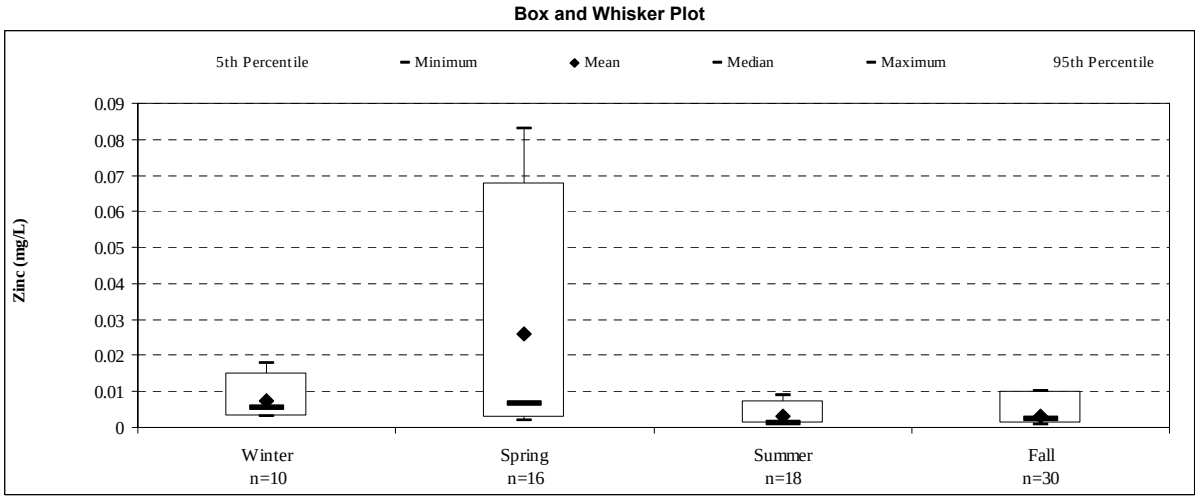


Figure G-2-1-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Upper Segment of Muskeg River



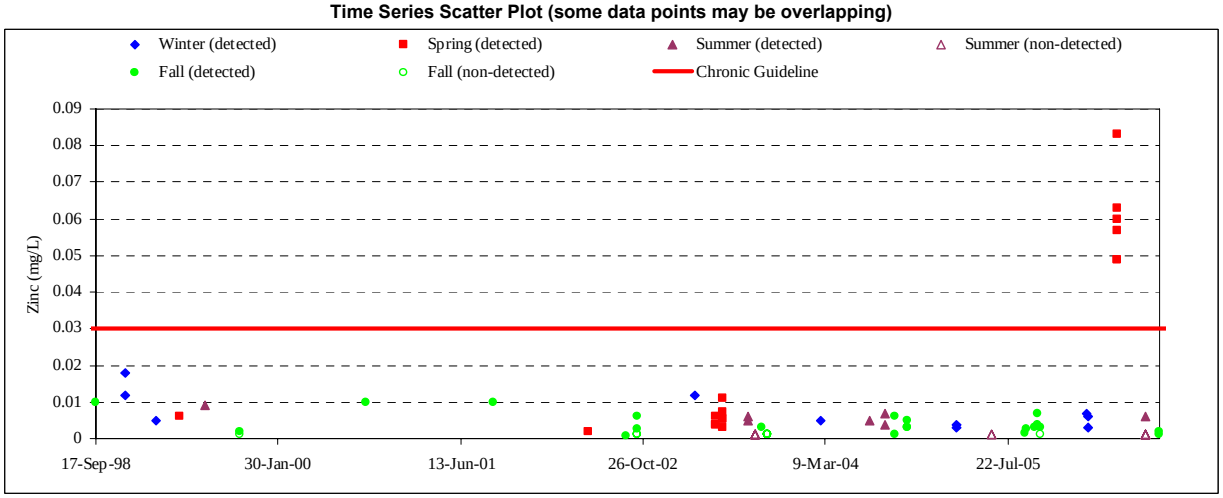
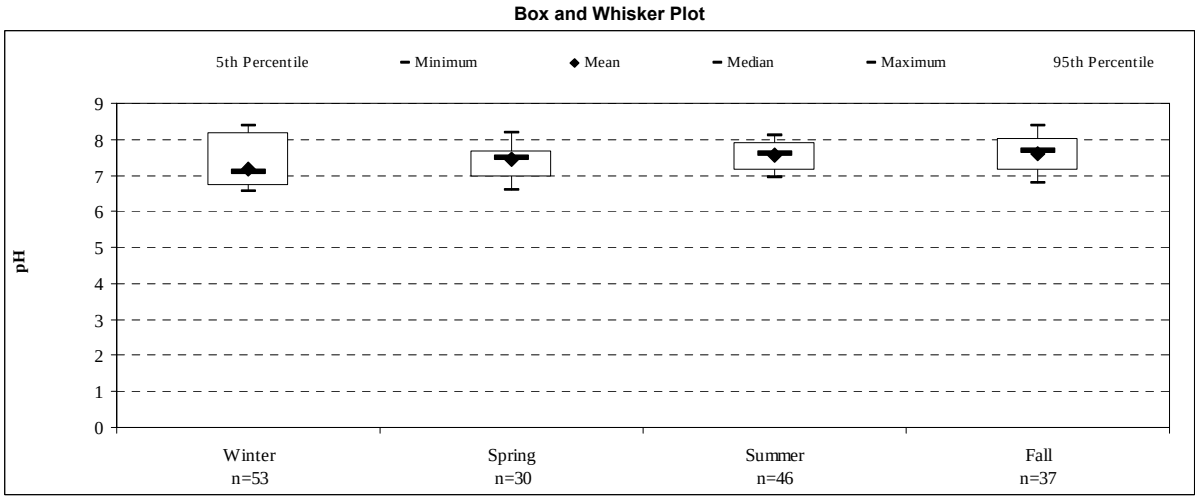


Figure G-2-2-1 Box Whisker and Time Series Scatter Plots of Observed pH in Middle Segment of Muskeg River



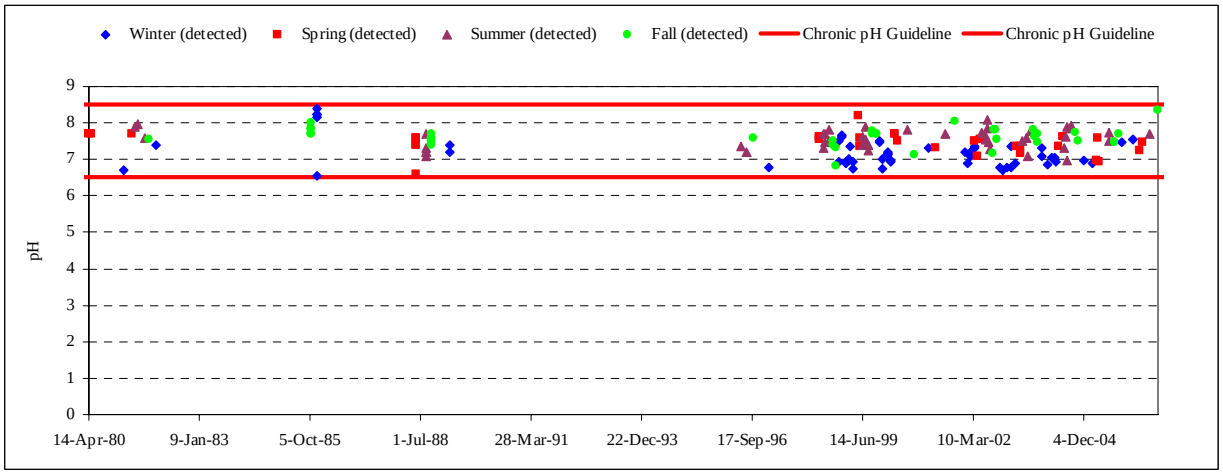
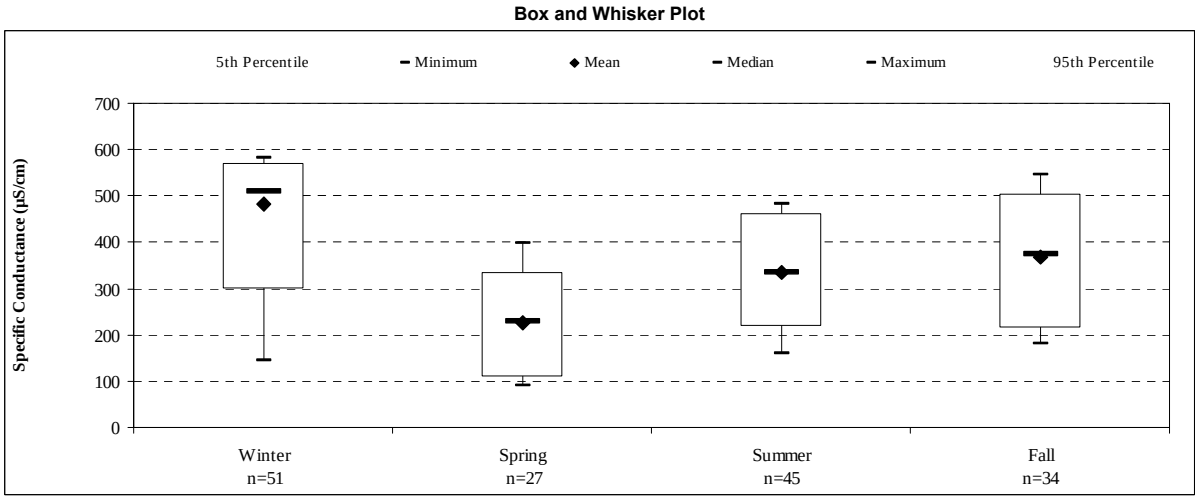


Figure G-2-2-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Middle Segment of Muskeg River



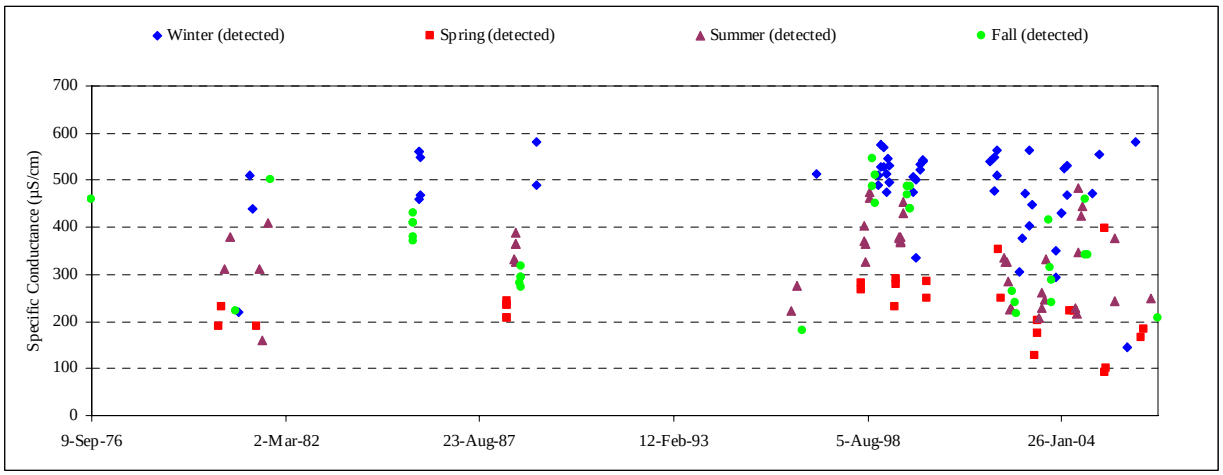


Figure G-2-2-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Middle Segment of Muskeg River

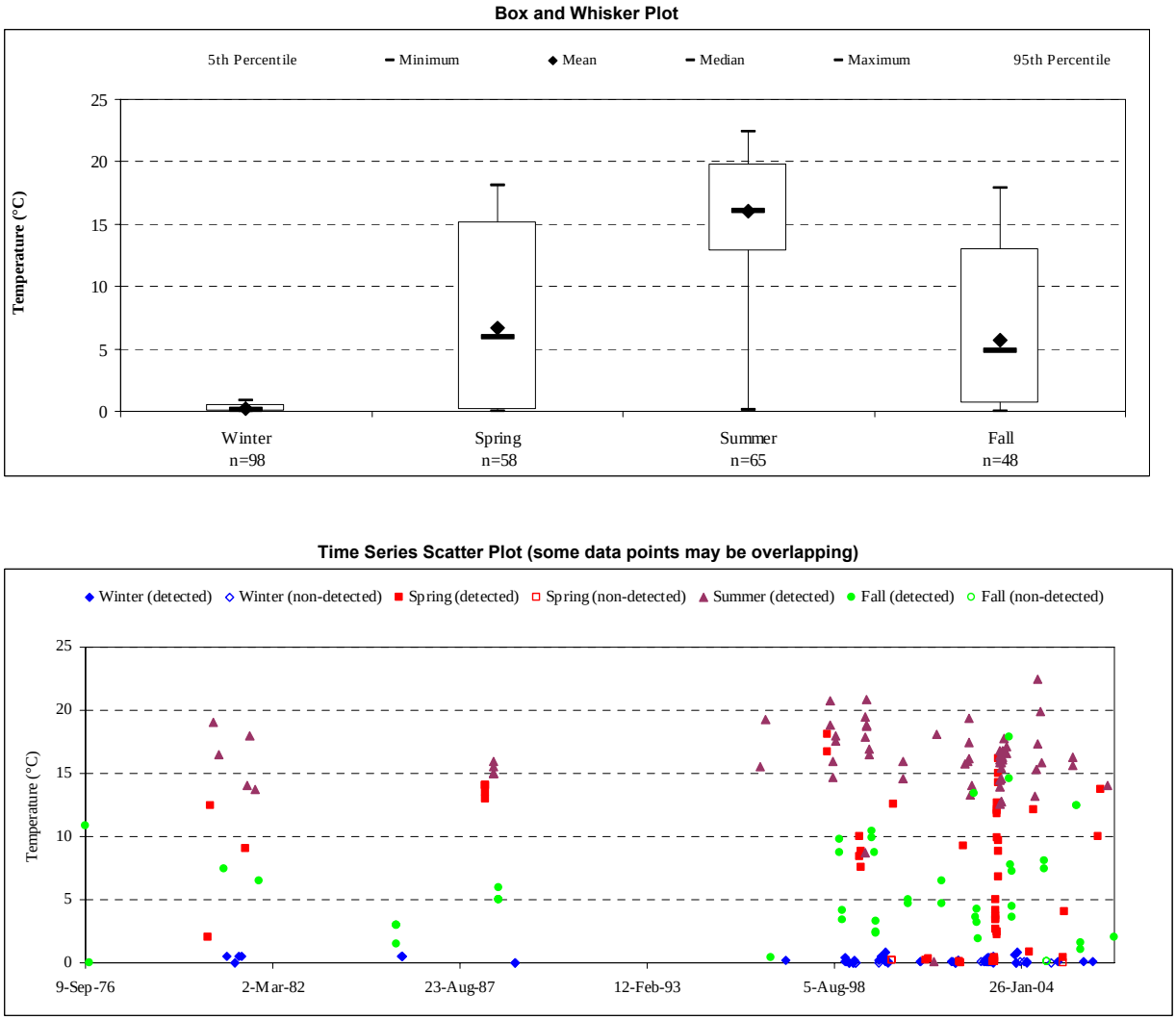
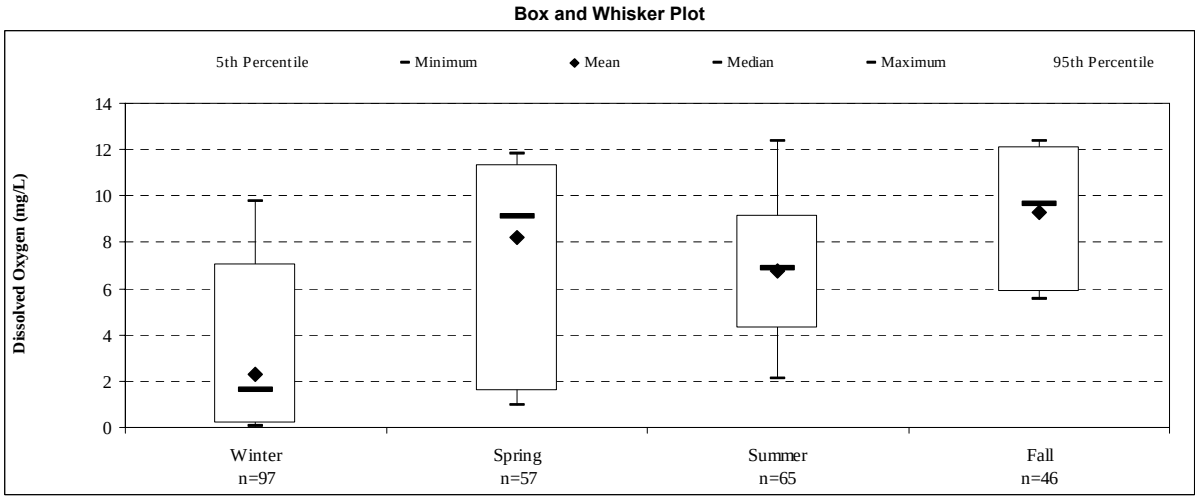


Figure G-2-2-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Middle Segment of Muskeg River



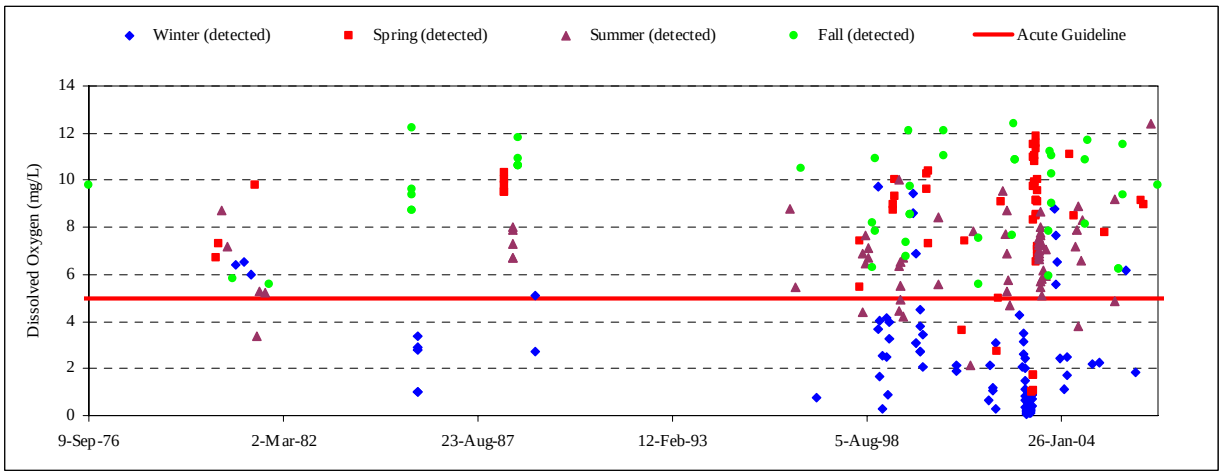


Figure G-2-2-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Middle Segment of Muskeg River

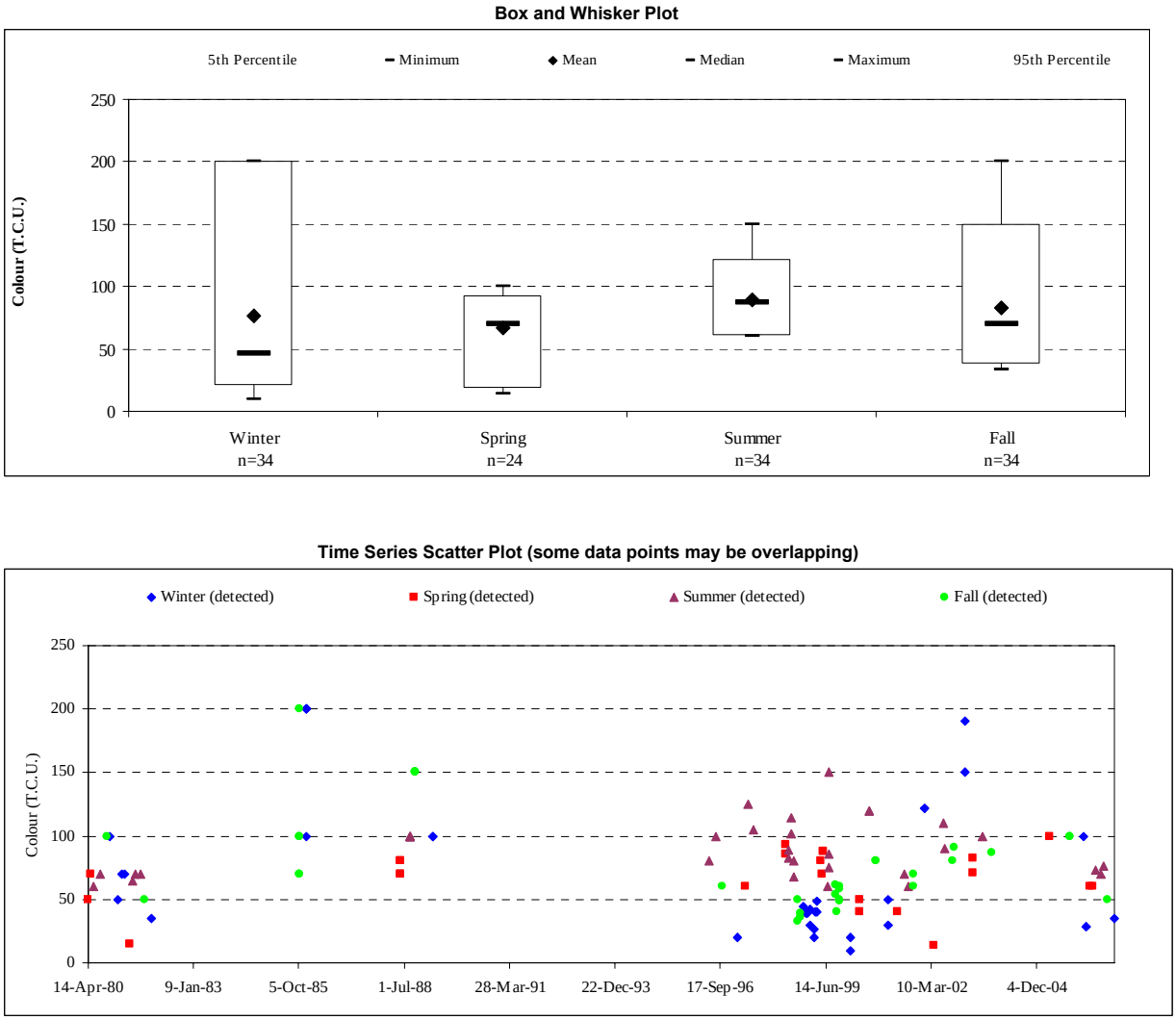
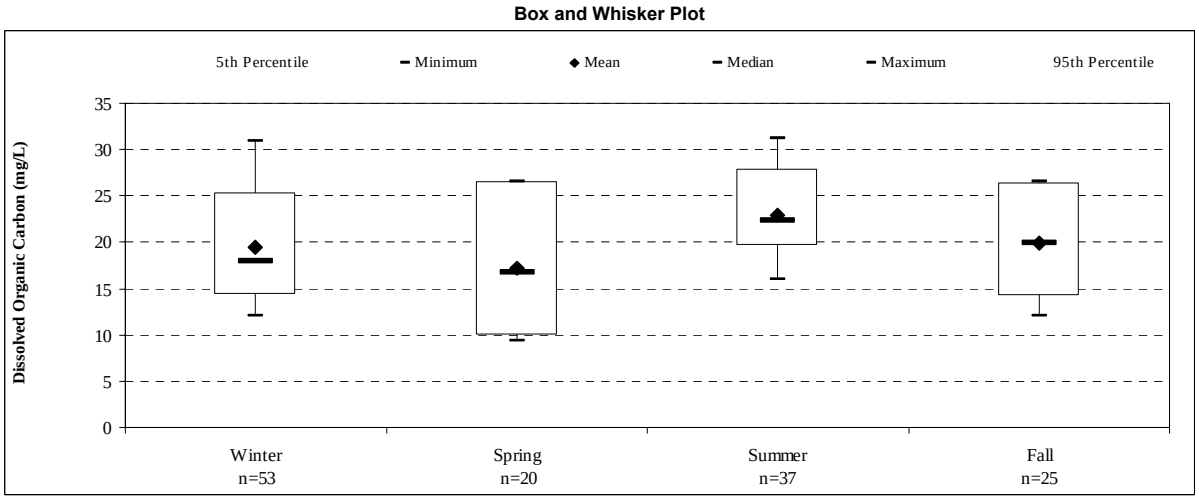


Figure G-2-2-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Middle Segment of Muskeg River



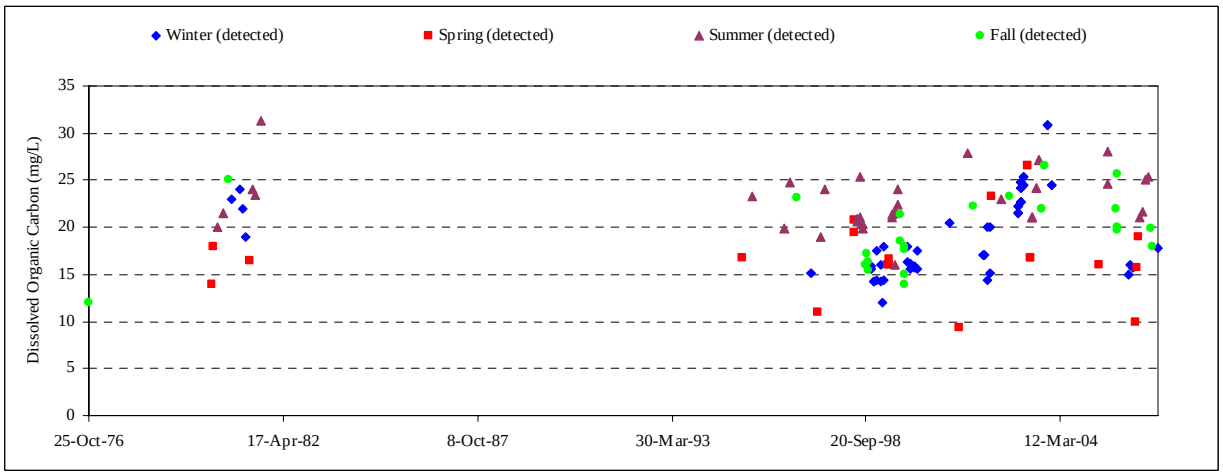
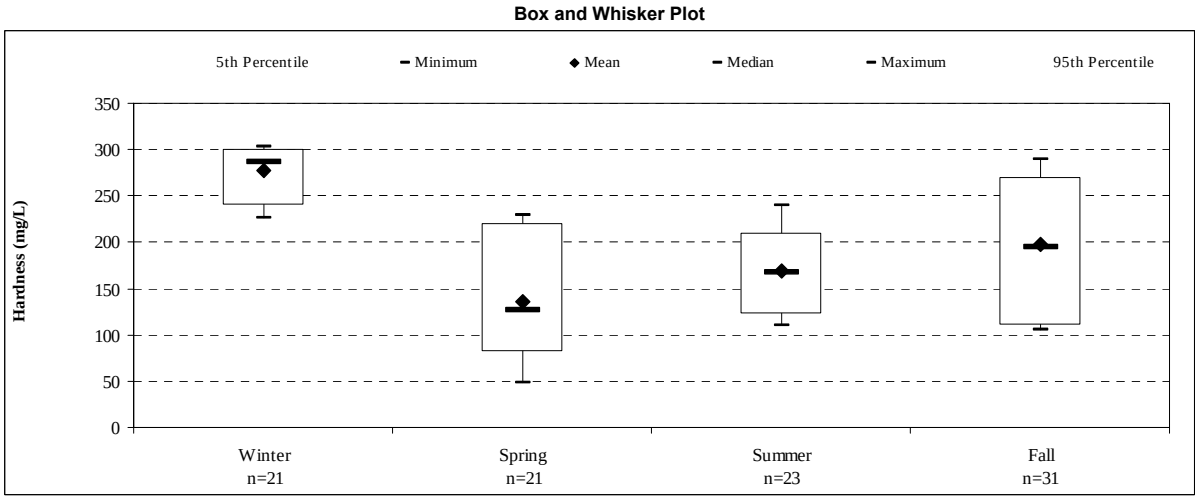


Figure G-2-2-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Middle Segment of Muskeg River



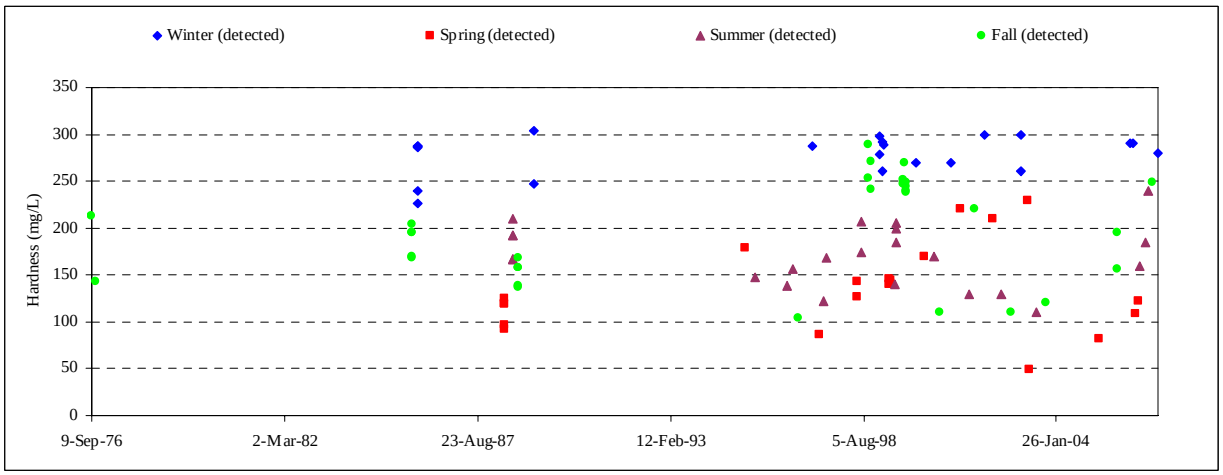
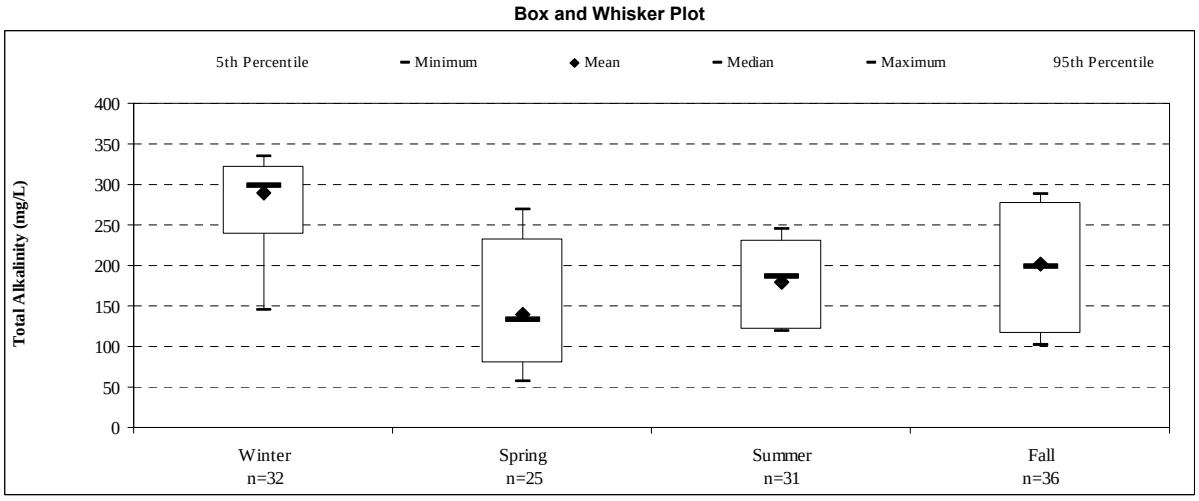


Figure G-2-2-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Middle Segment of Muskeg River



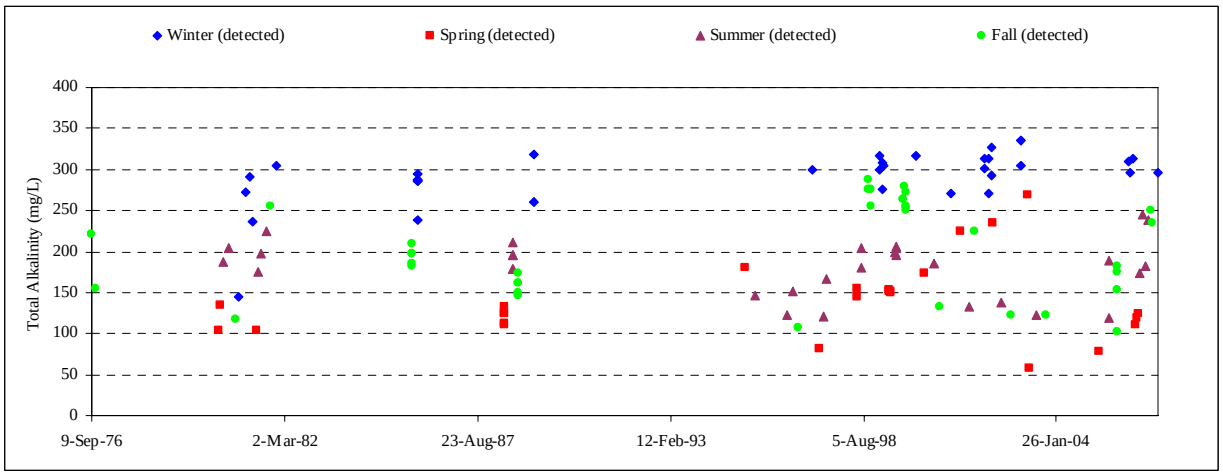
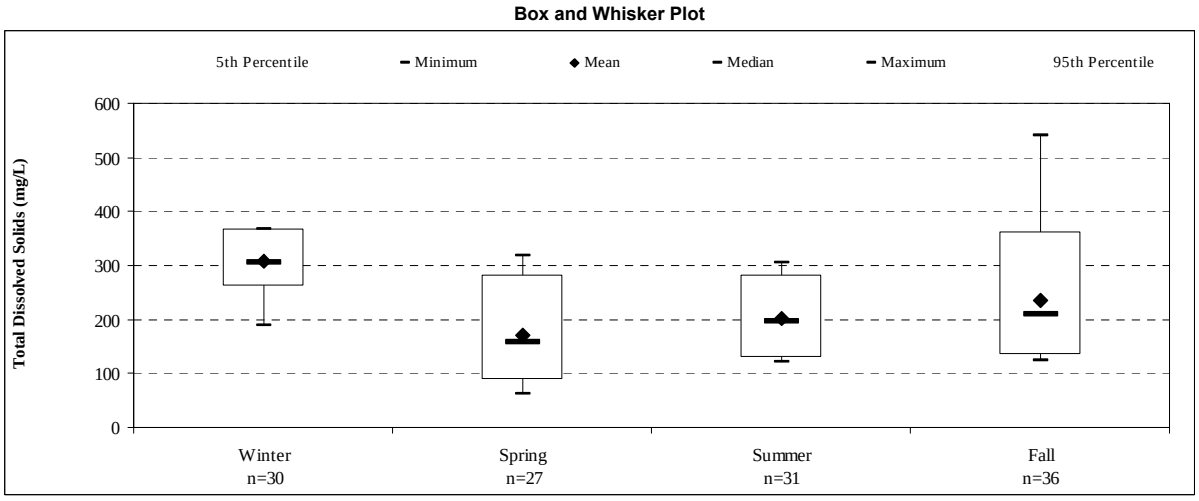


Figure G-2-2-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Middle Segment of Muskeg River



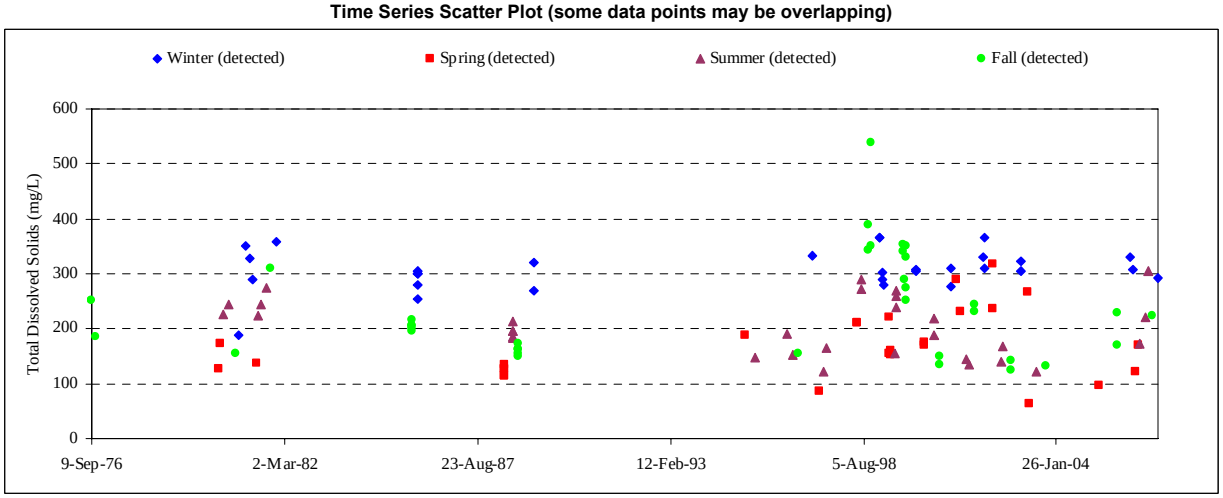
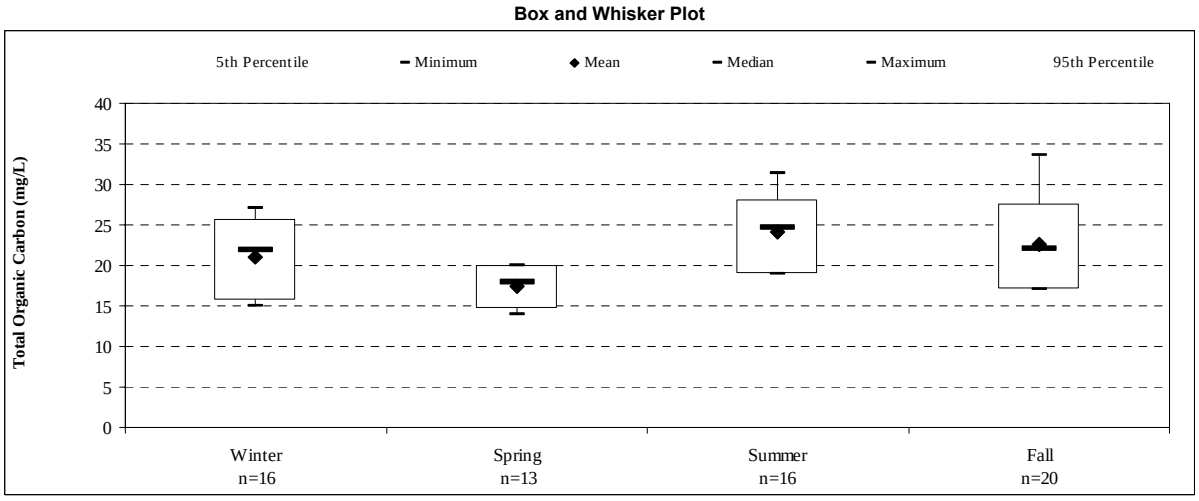


Figure G-2-2-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Middle Segment of Muskeg River



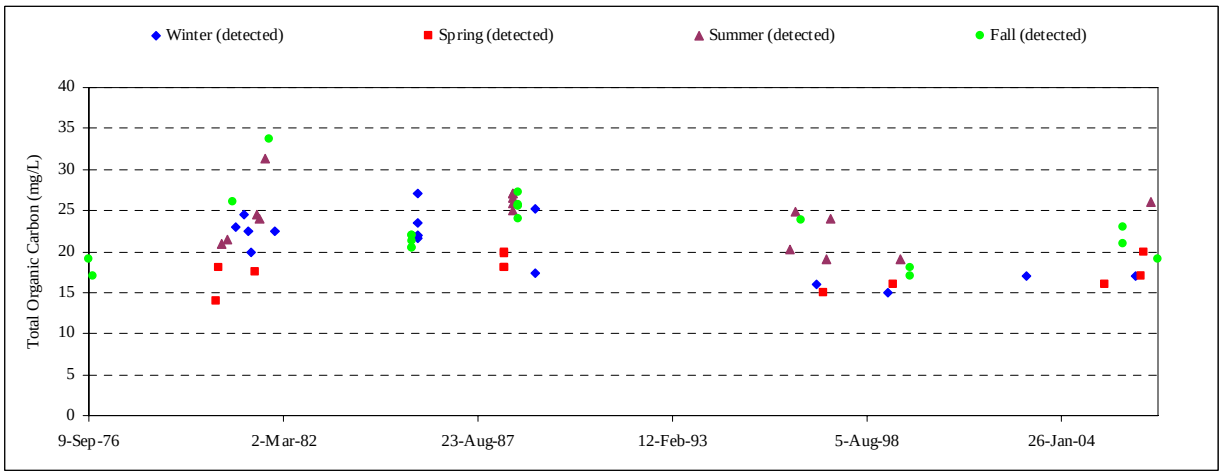


Figure G-2-2-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Middle Segment of Muskeg River

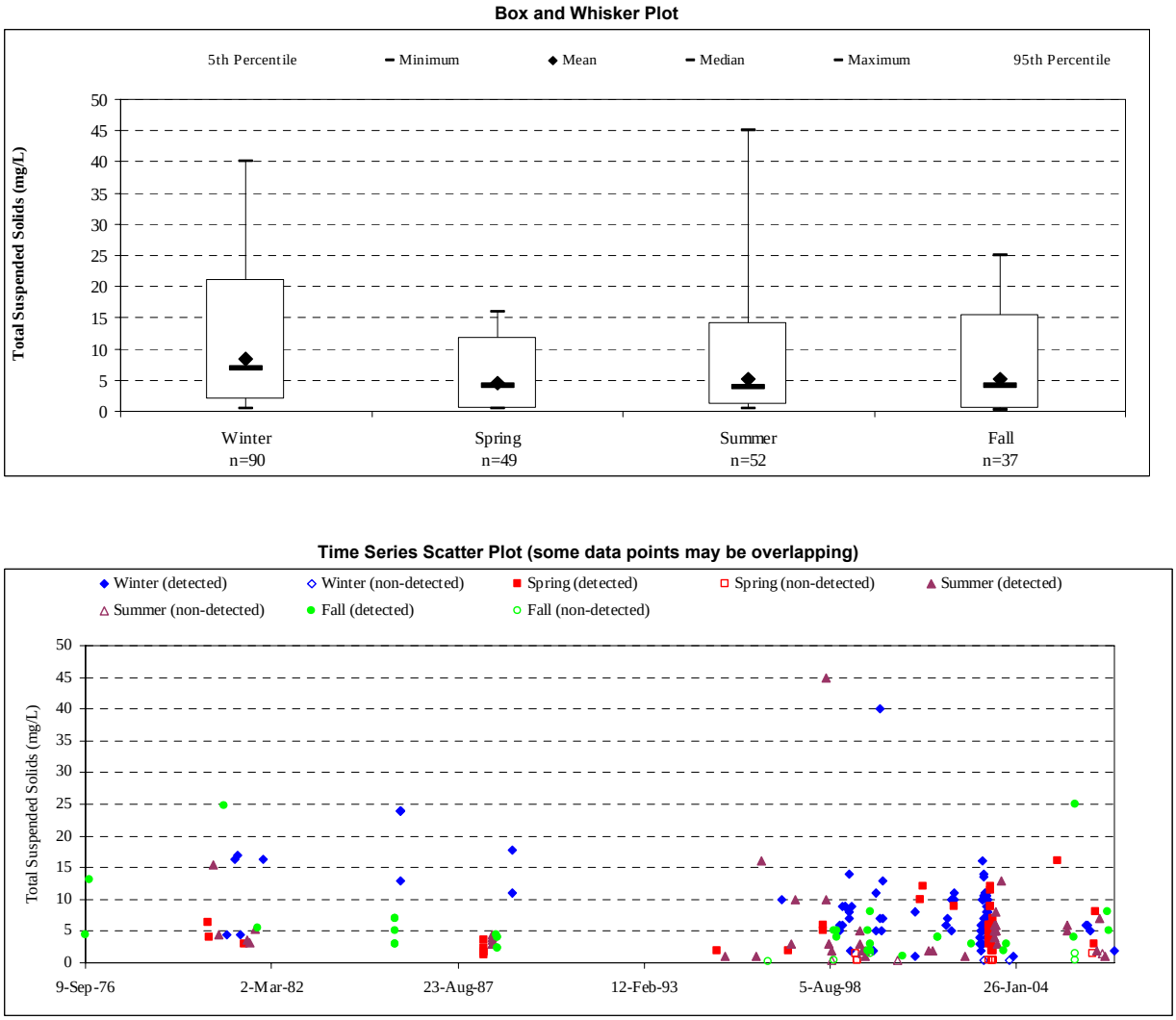
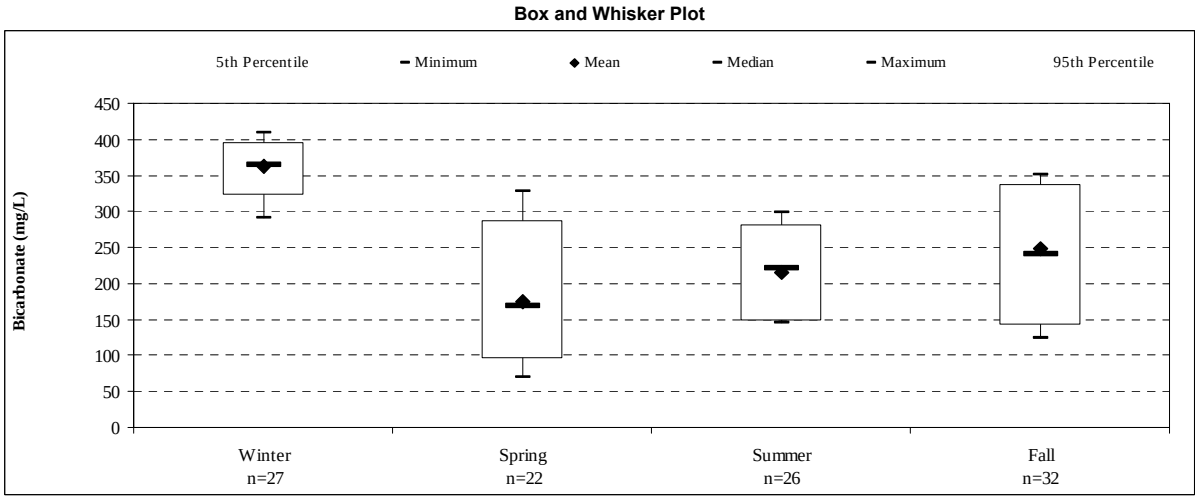


Figure G-2-2-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Middle Segment of Muskeg River



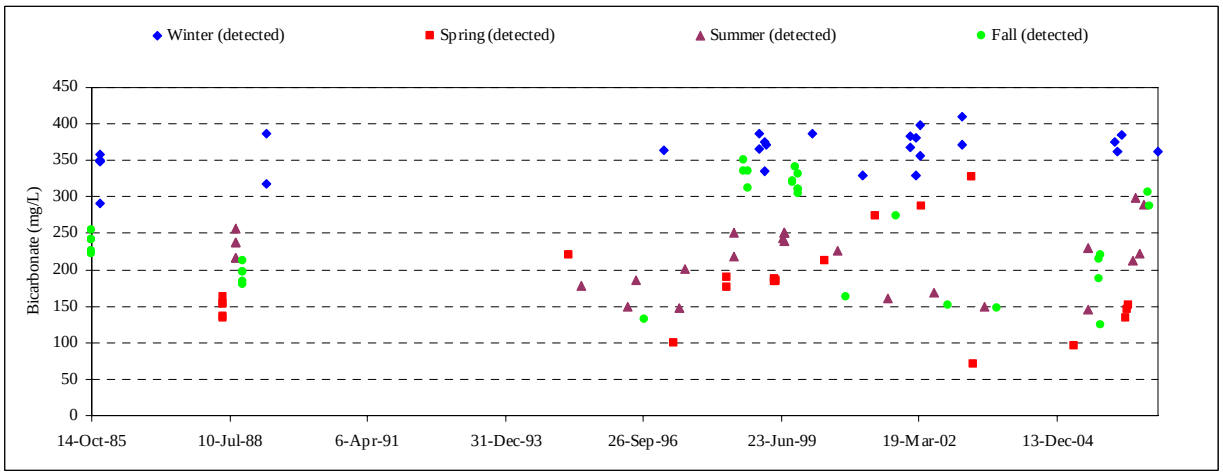
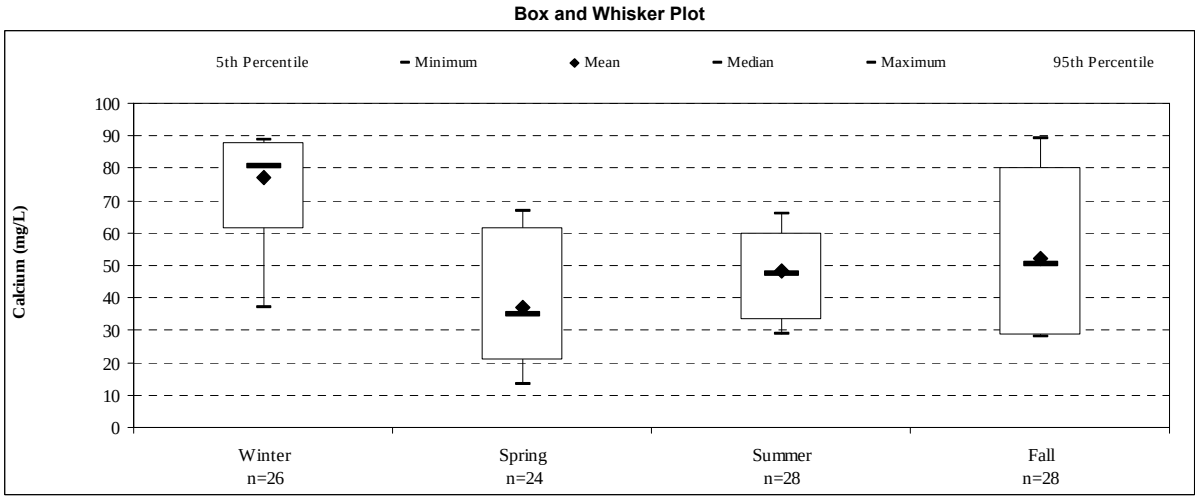


Figure G-2-2-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Middle Segment of Muskeg River



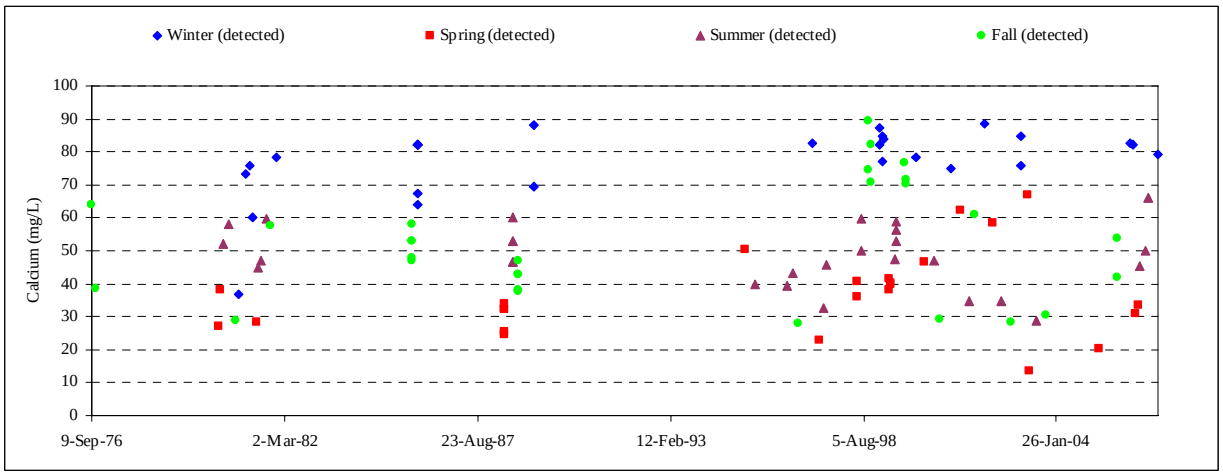
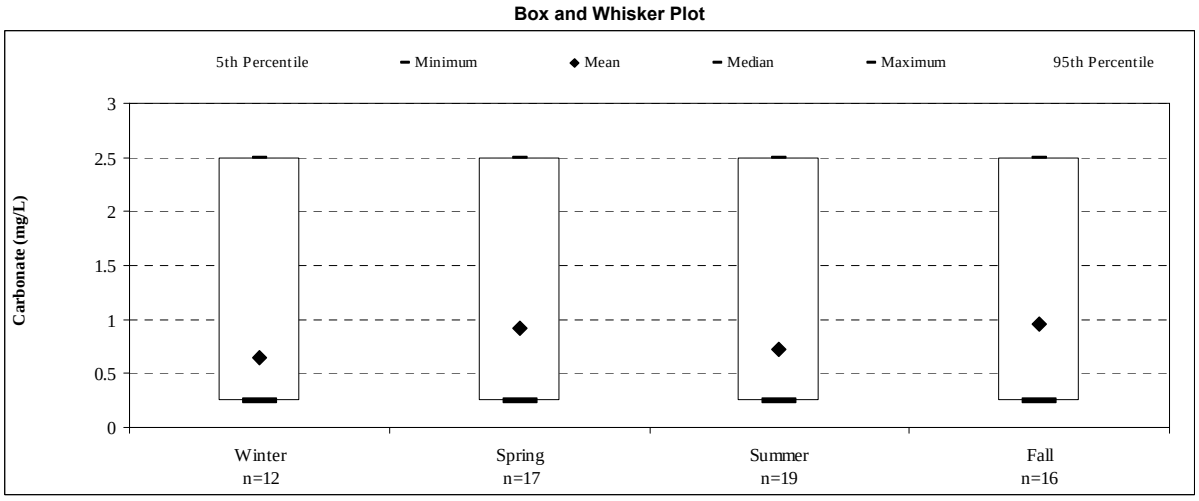


Figure G-2-2-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Middle Segment of Muskeg River



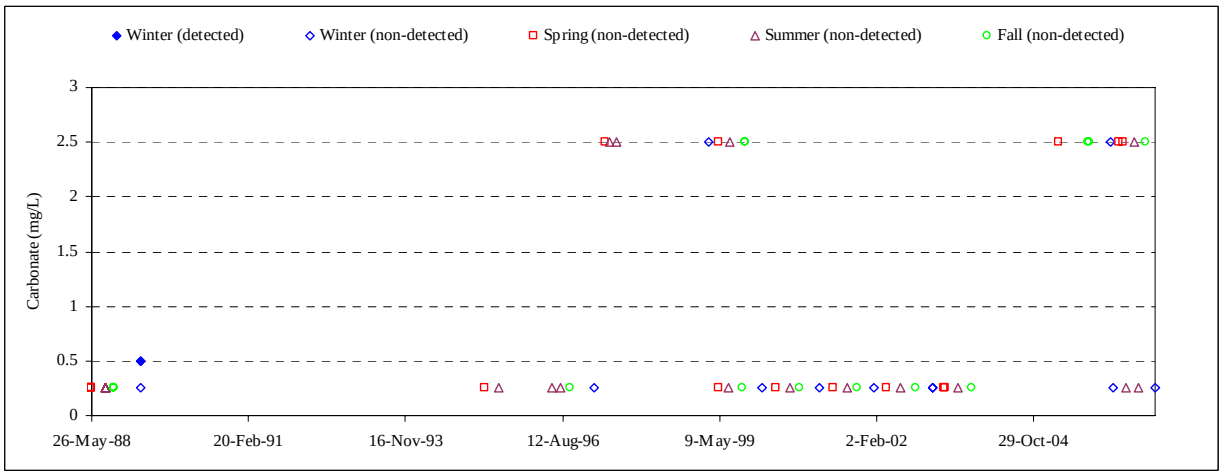


Figure G-2-2-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Middle Segment of Muskeg River

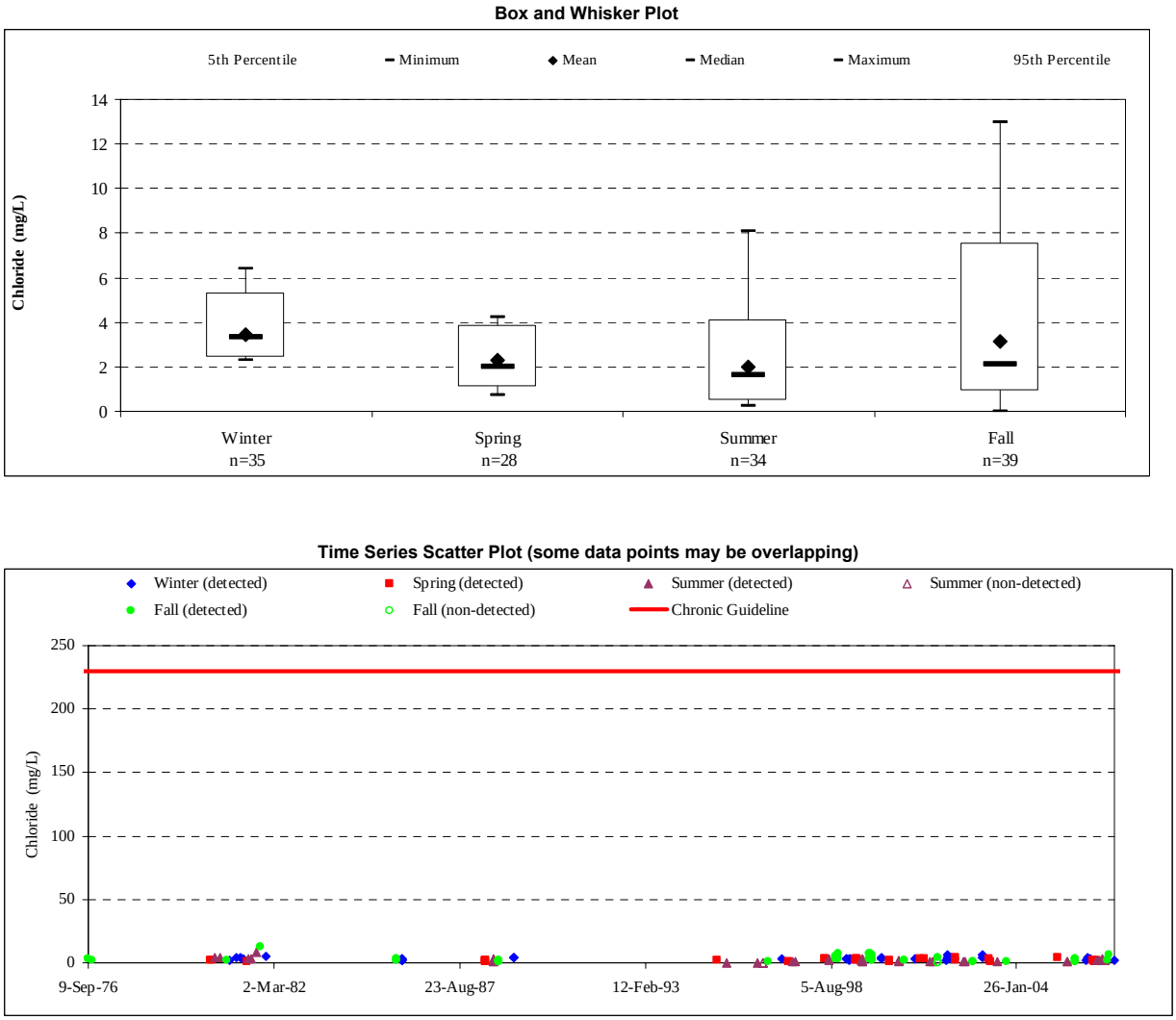
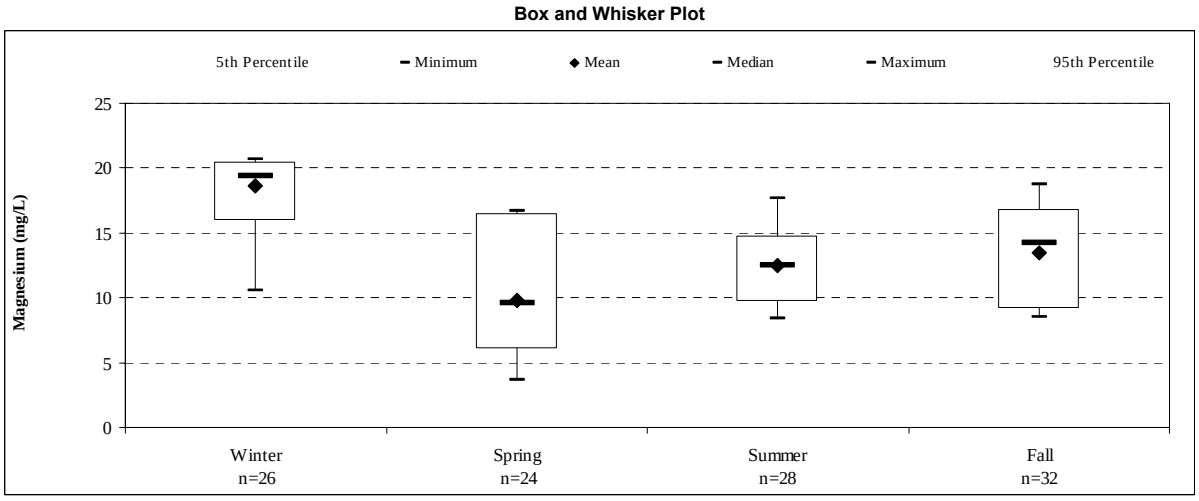


Figure G-2-2-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Middle Segment of Muskeg River



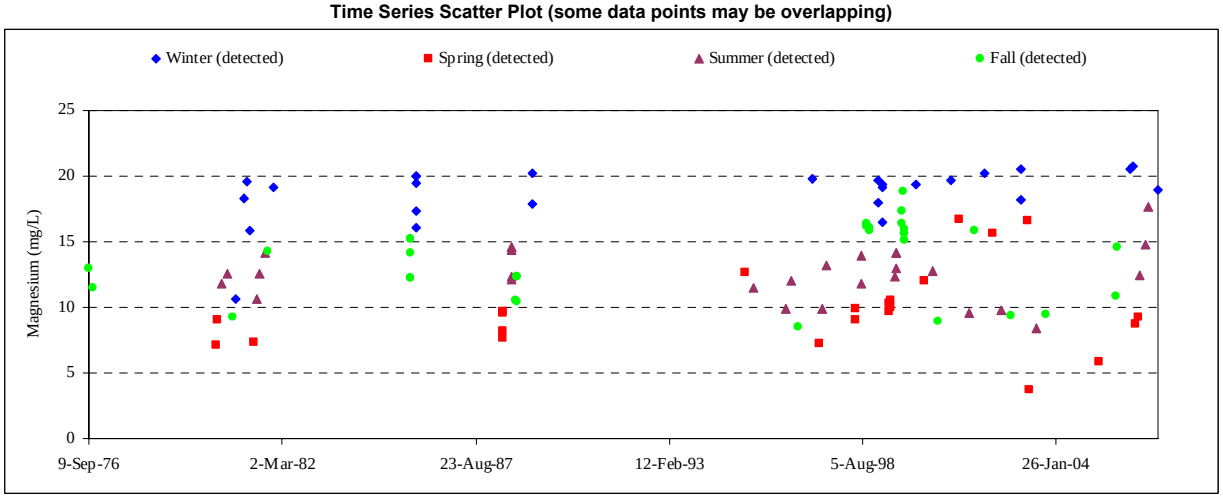


Figure G-2-2-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Middle Segment of Muskeg River

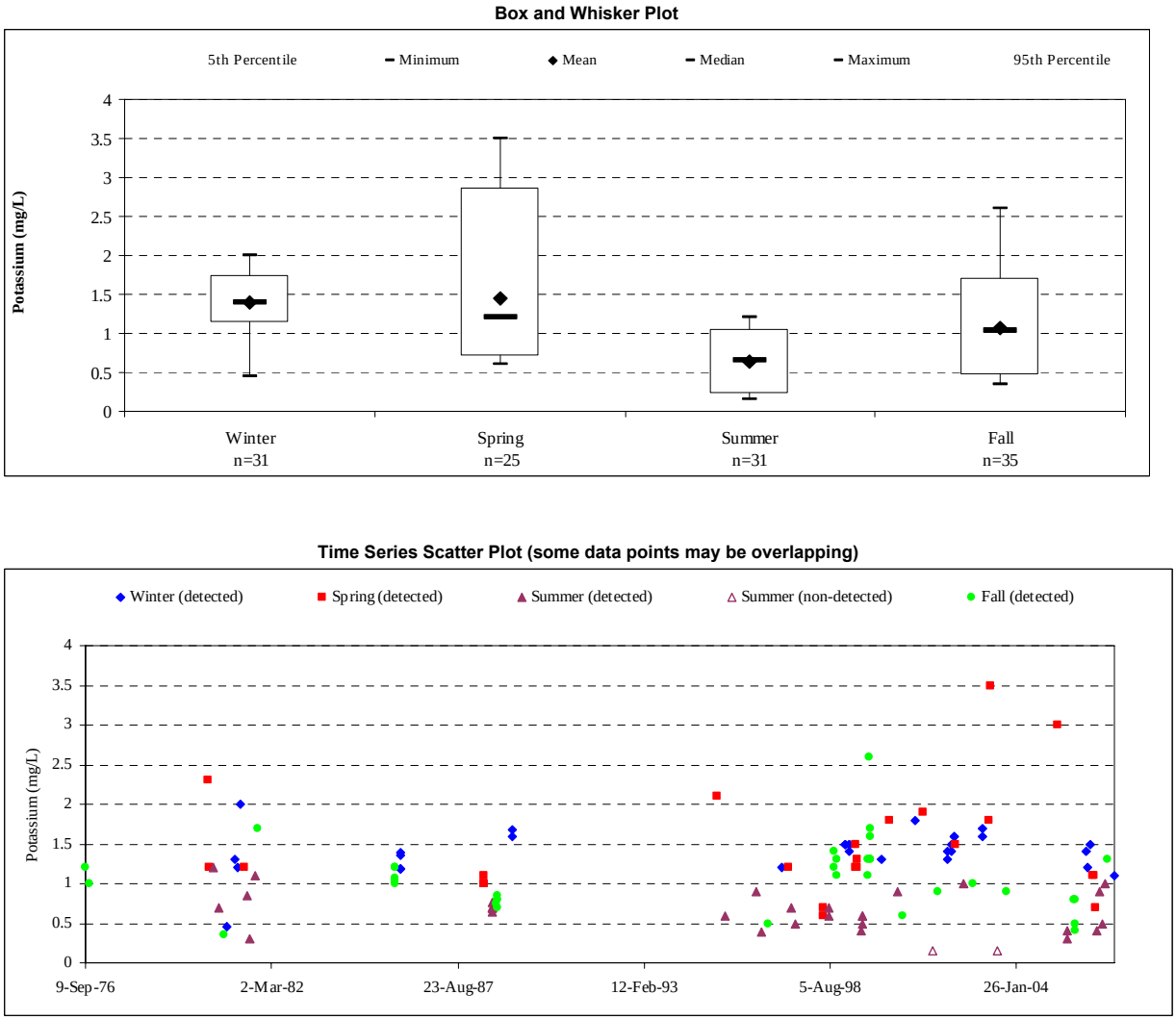
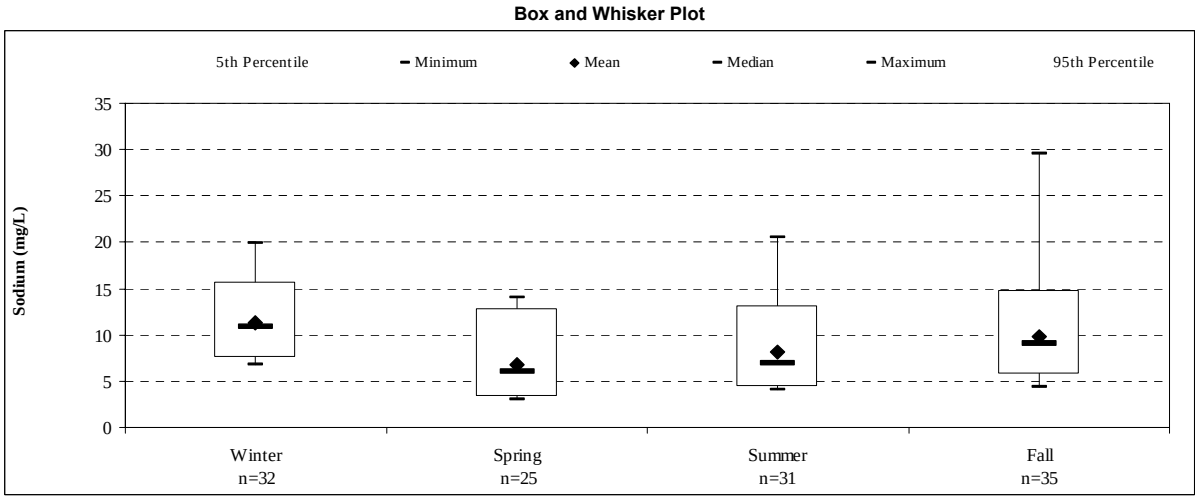


Figure G-2-2-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Middle Segment of Muskeg River



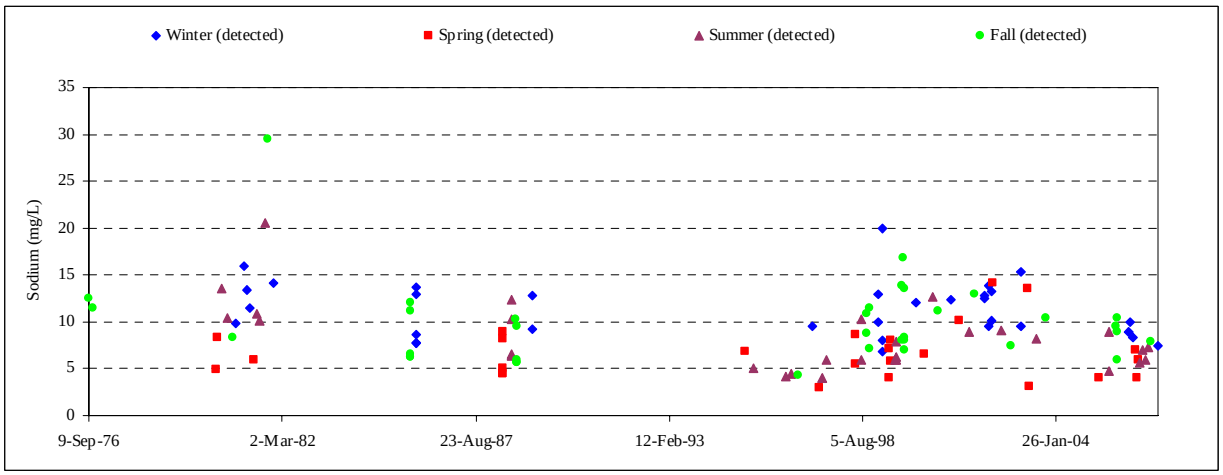
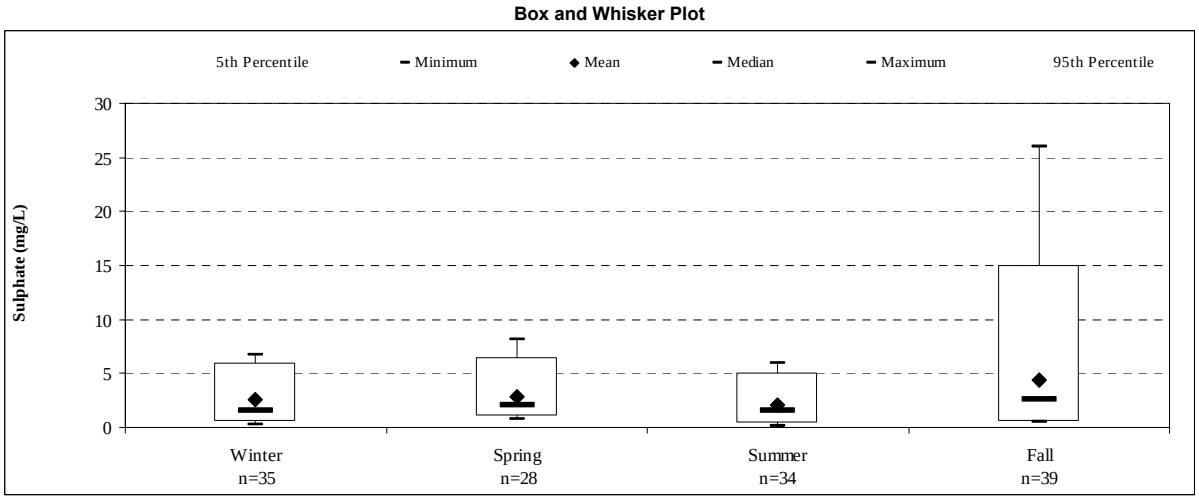


Figure G-2-2-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Middle Segment of Muskeg River



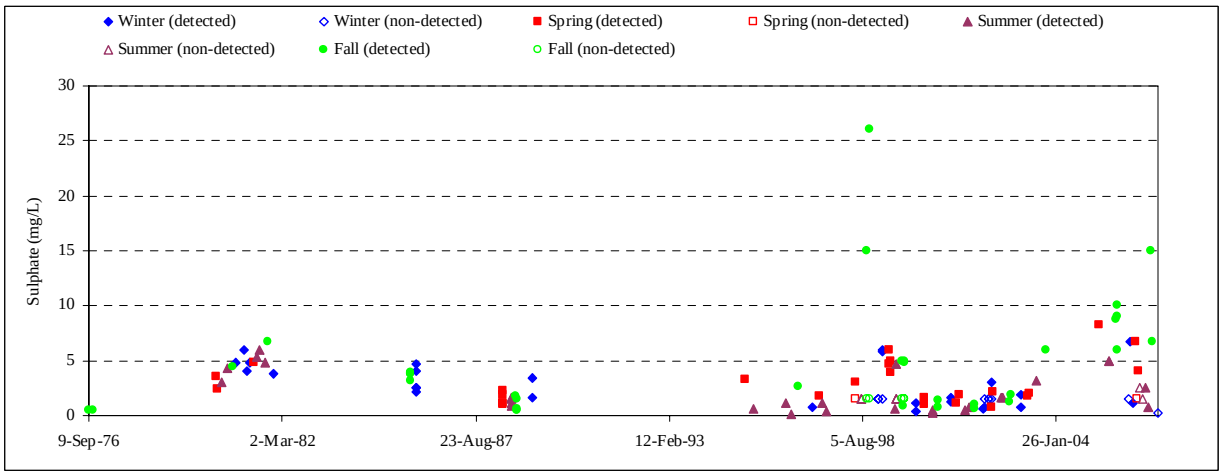
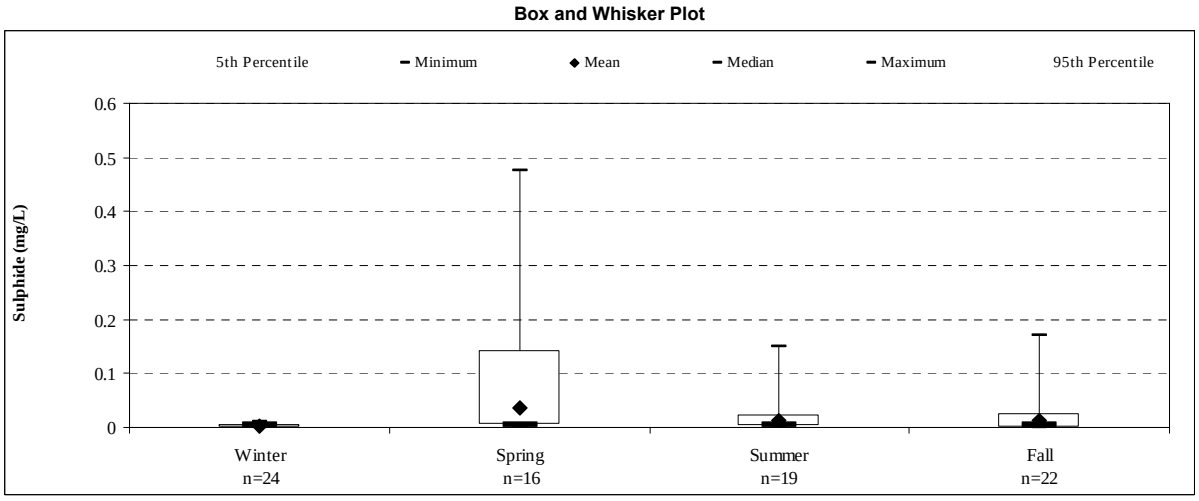


Figure G-2-2-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Middle Segment of Muskeg River



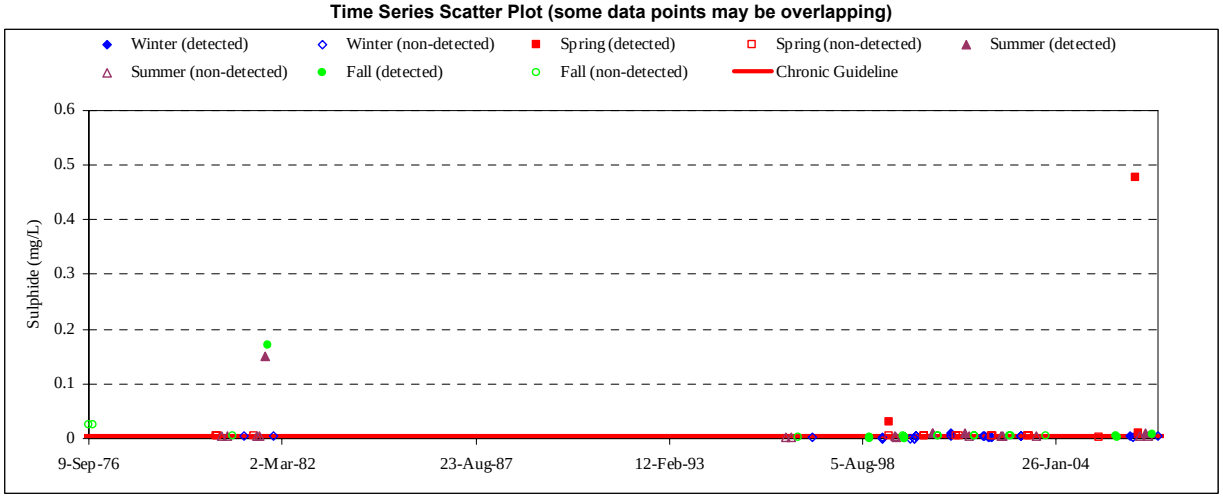
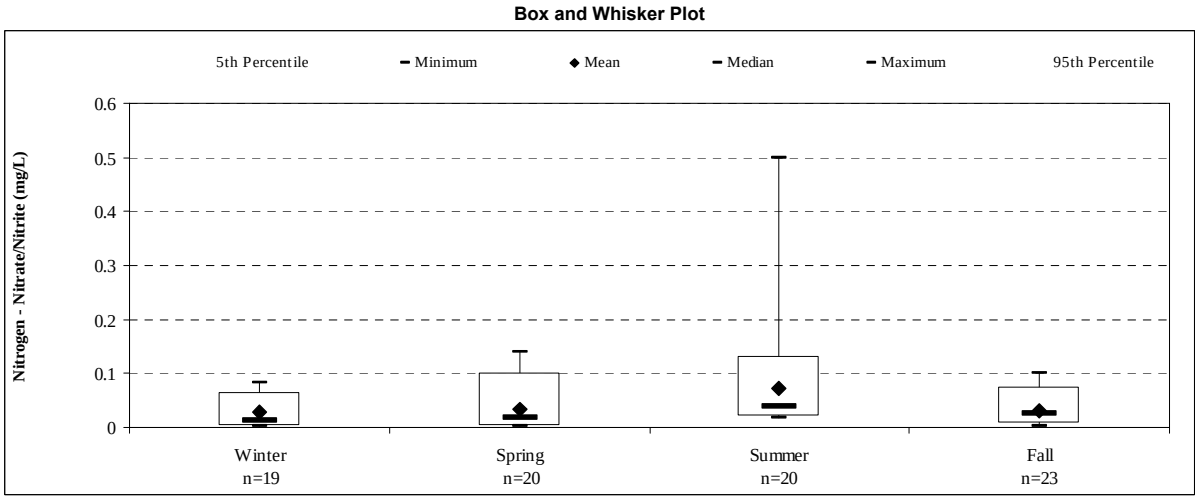


Figure G-2-2-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Middle Segment of Muskeg River



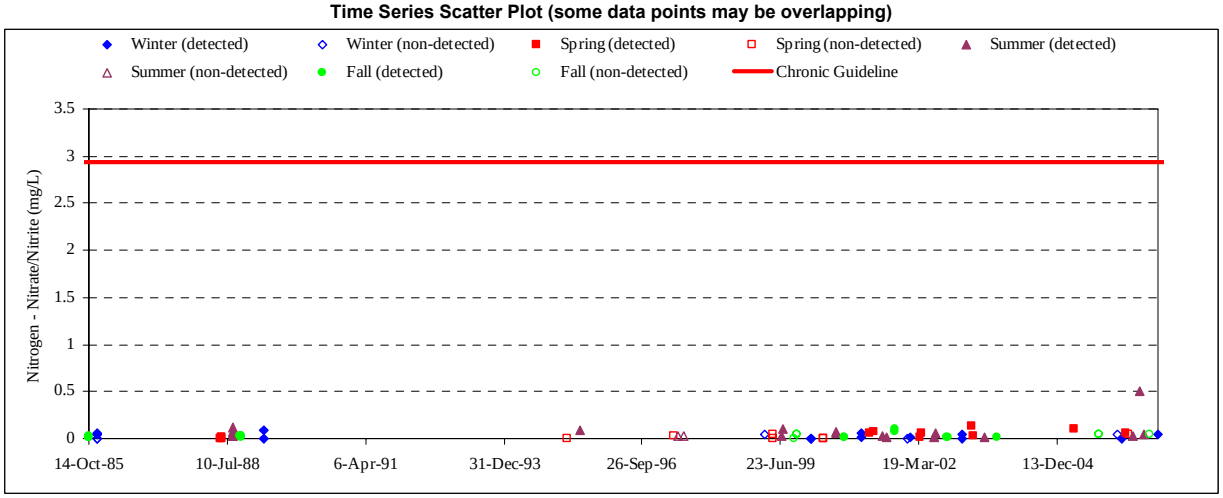
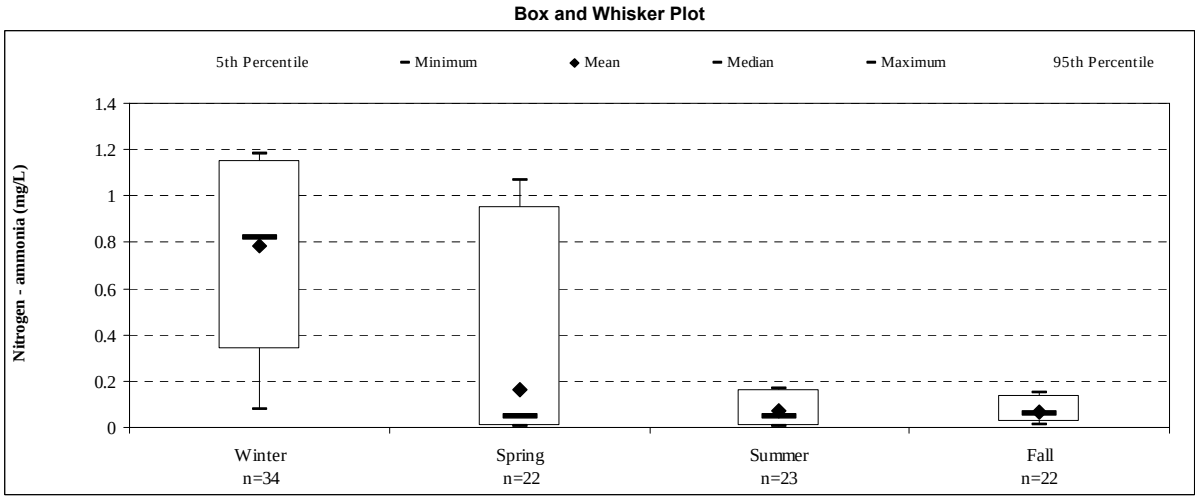


Figure G-2-2-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Middle Segment of Muskeg River



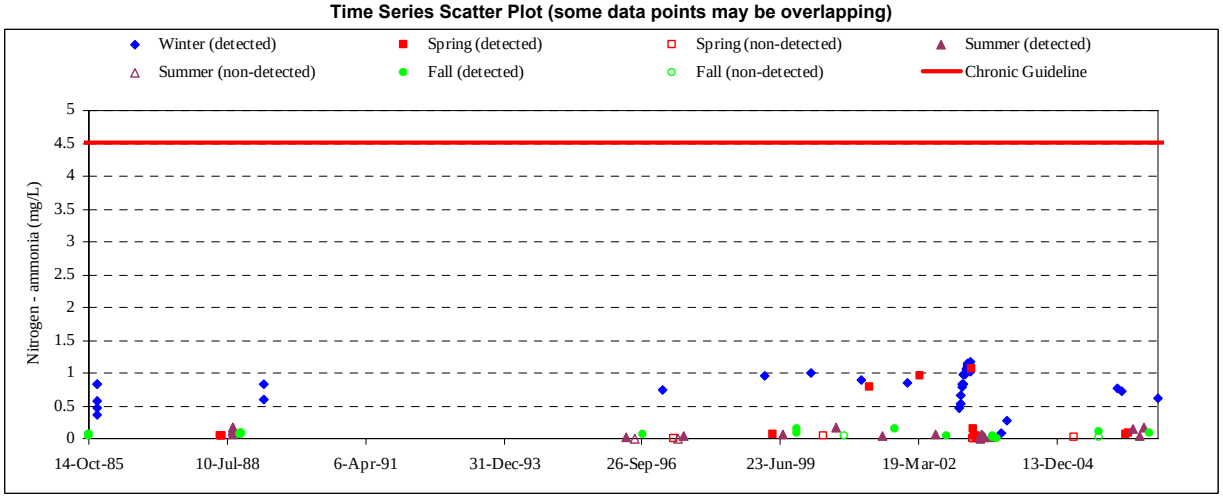
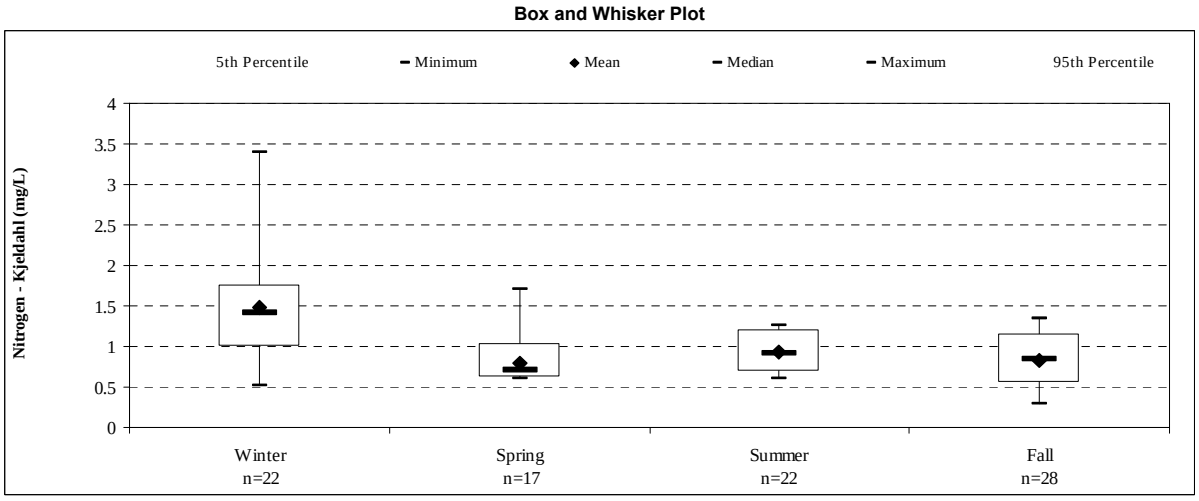


Figure G-2-2-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Middle Segment of Muskeg River



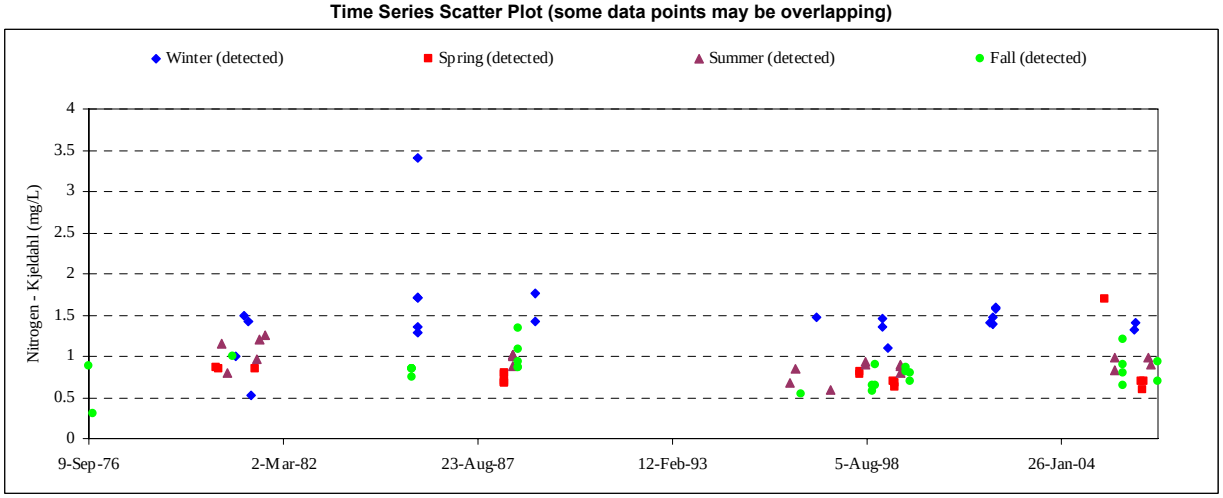
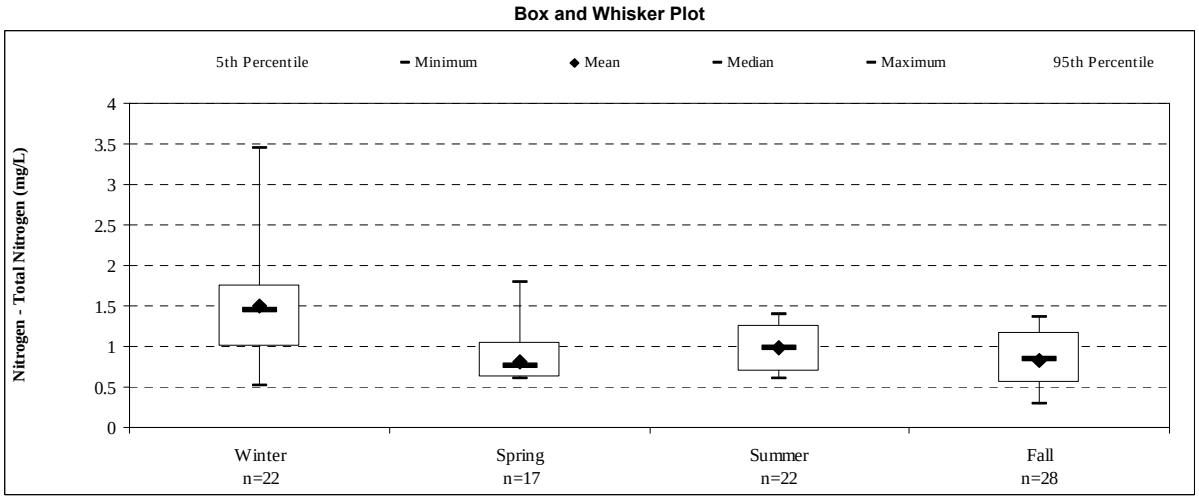


Figure G-2-2-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Middle Segment of Muskeg River



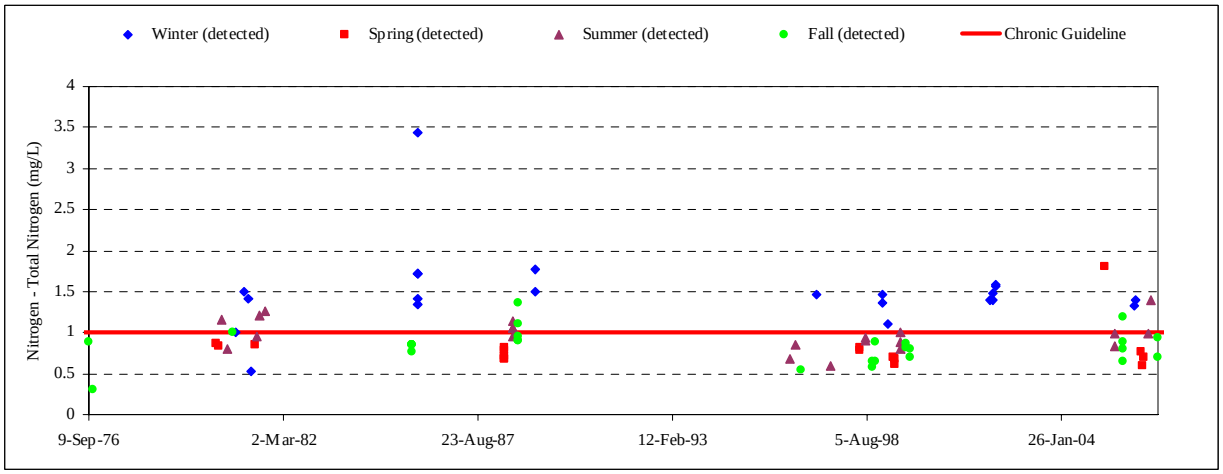
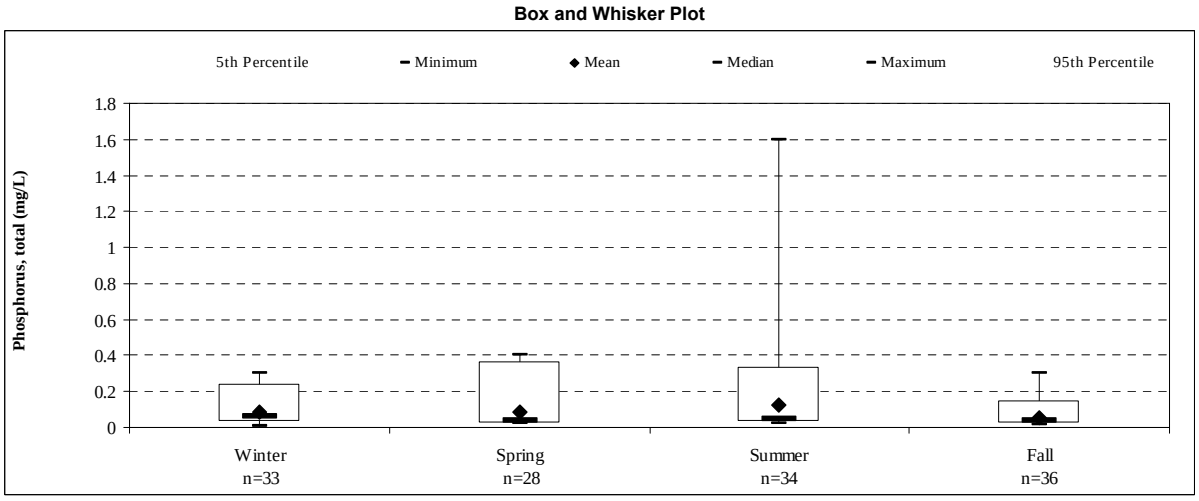


Figure G-2-2-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Middle Segment of Muskeg River



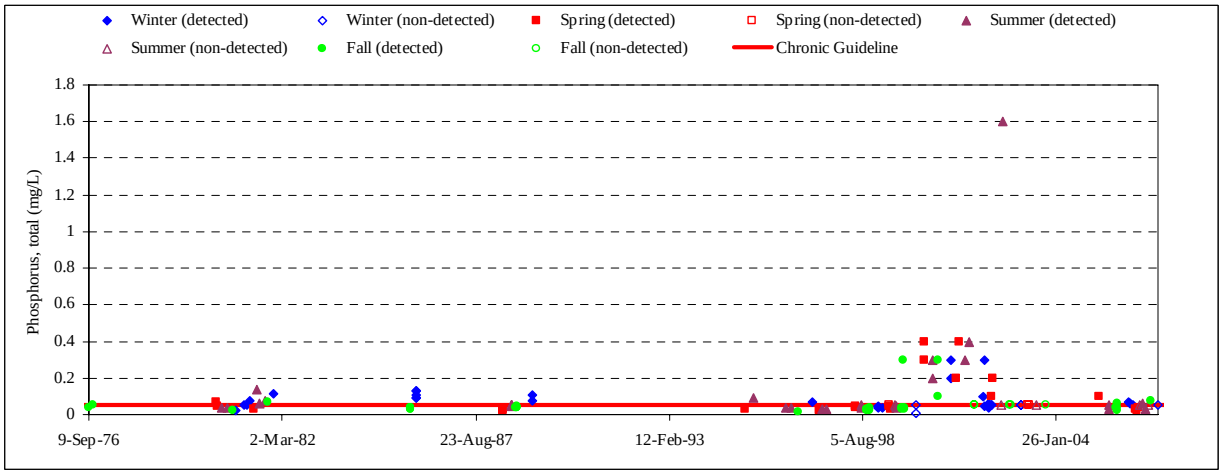
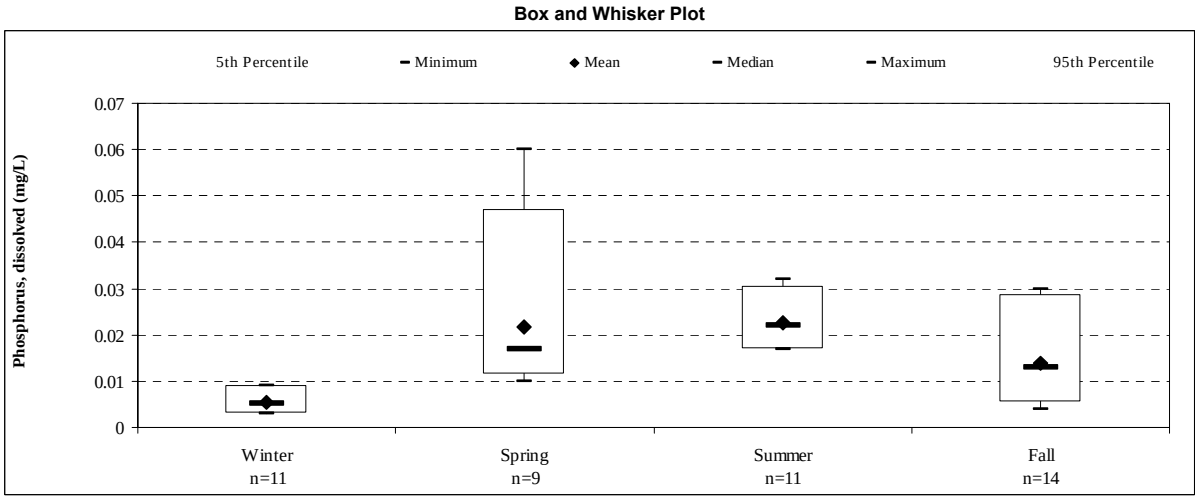


Figure G-2-2-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Middle Segment of Muskeg River



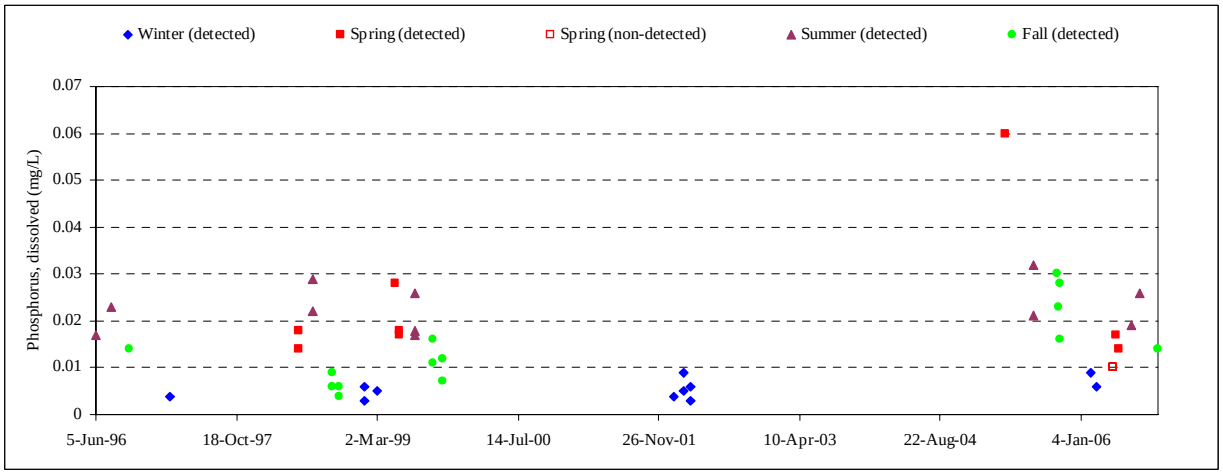
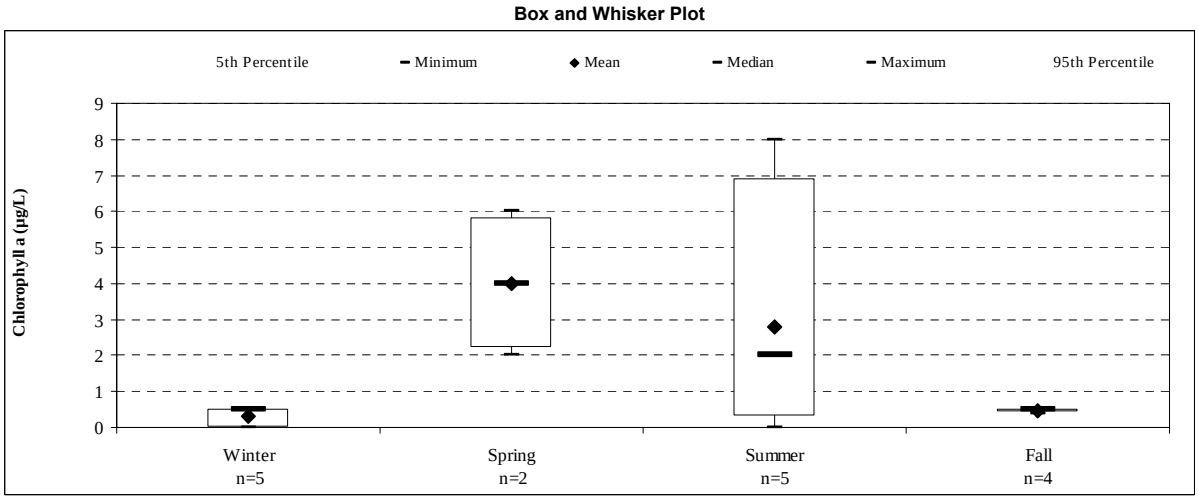


Figure G-2-2-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Middle Segment of Muskeg River



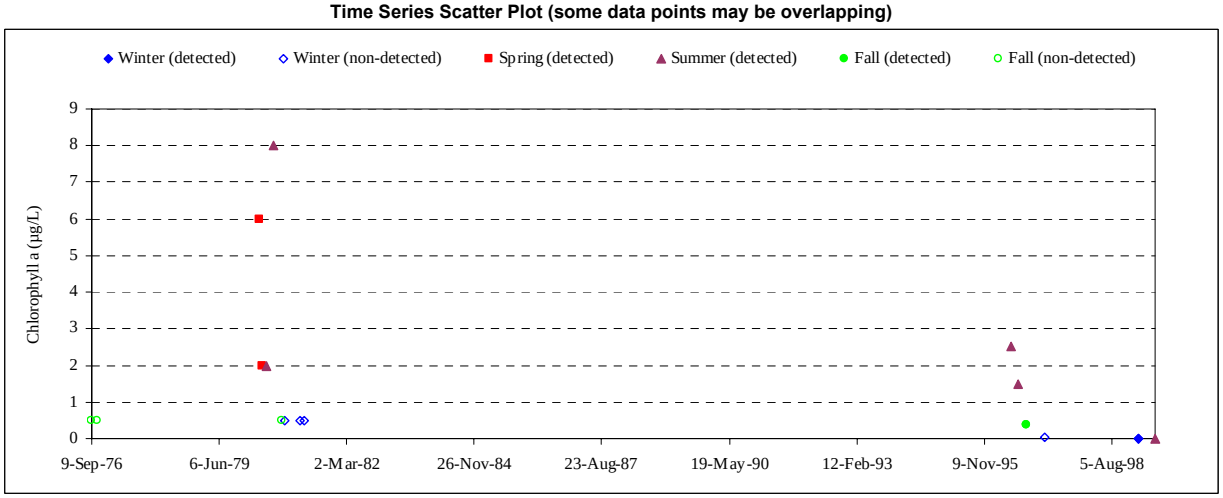
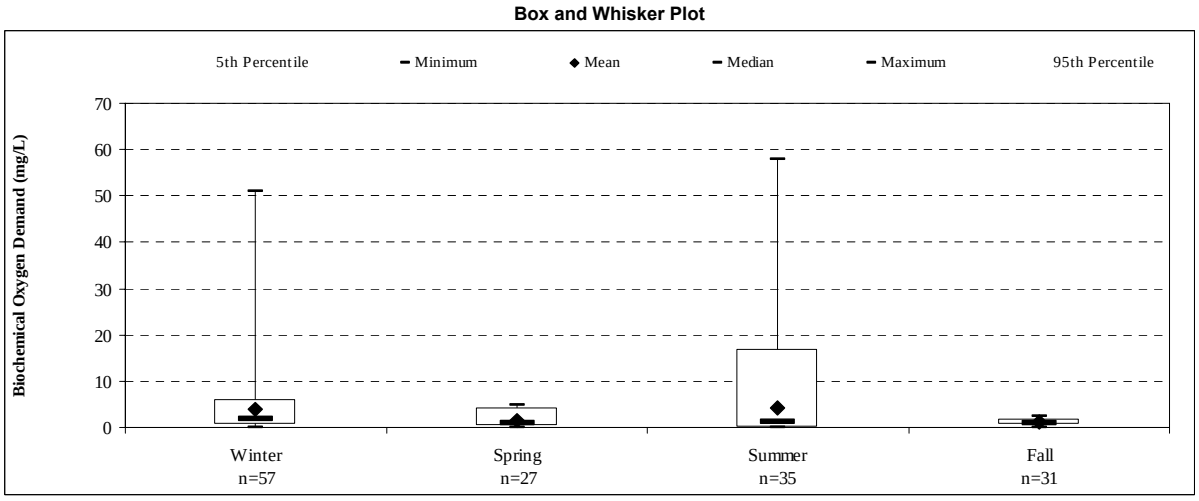


Figure G-2-2-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Middle Segment of Muskeg River



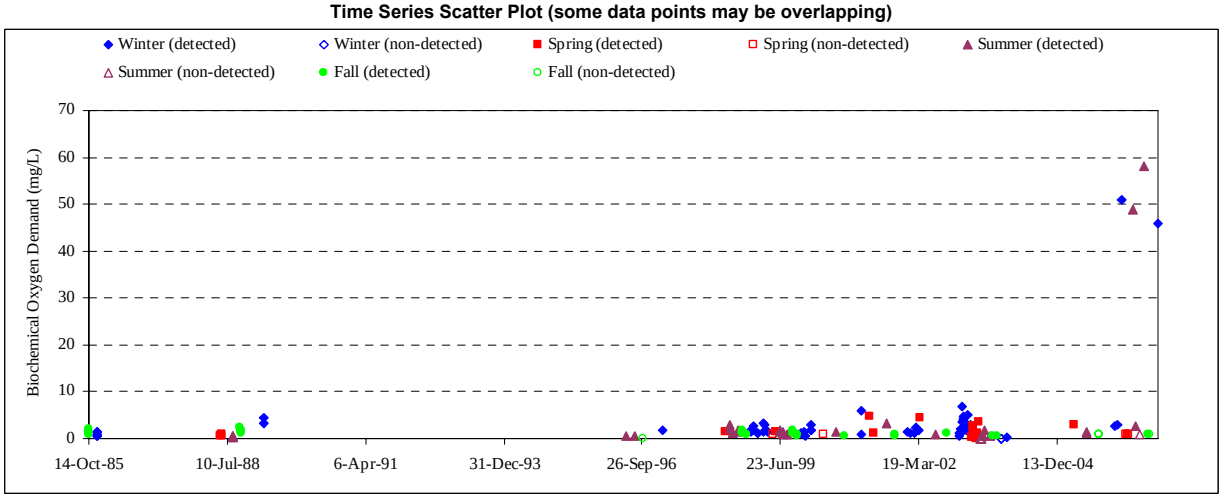
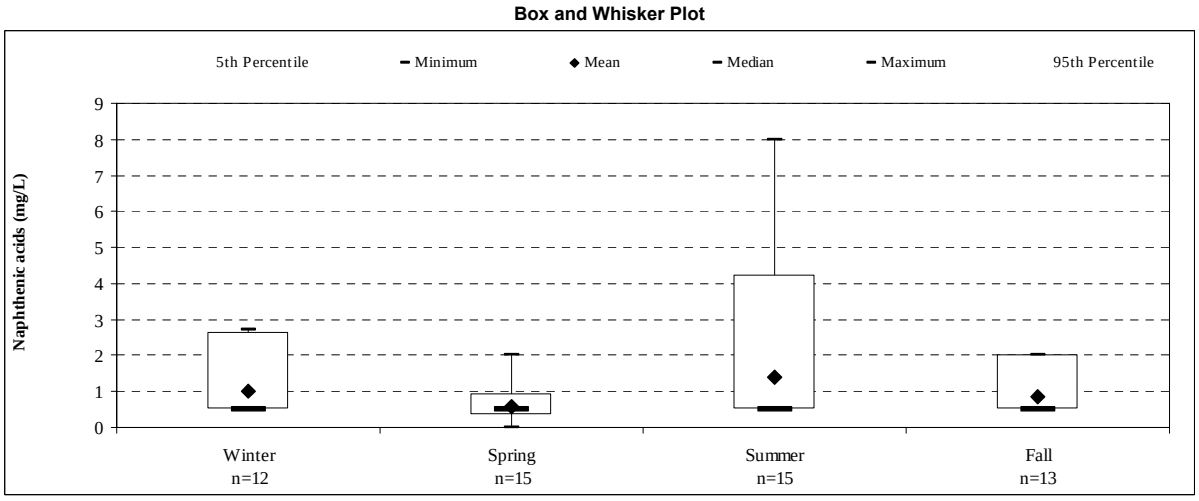


Figure G-2-2-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Middle Segment of Muskeg River



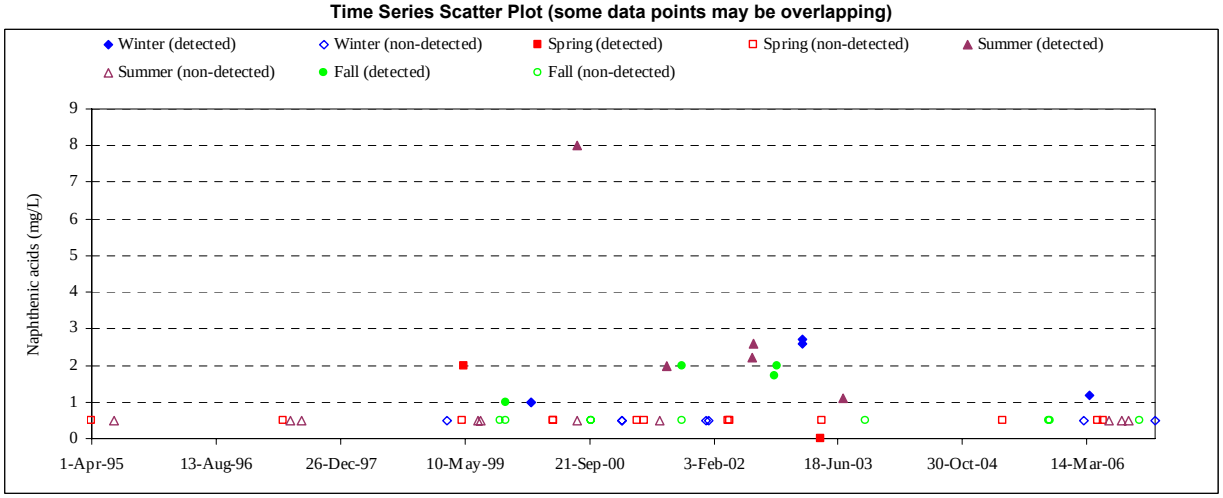
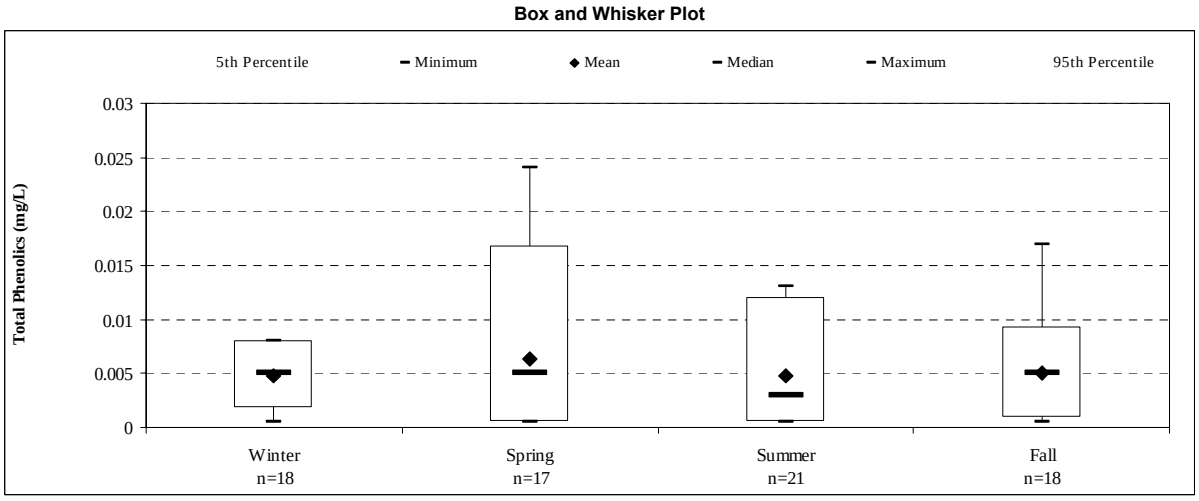


Figure G-2-2-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Middle Segment of Muskeg River



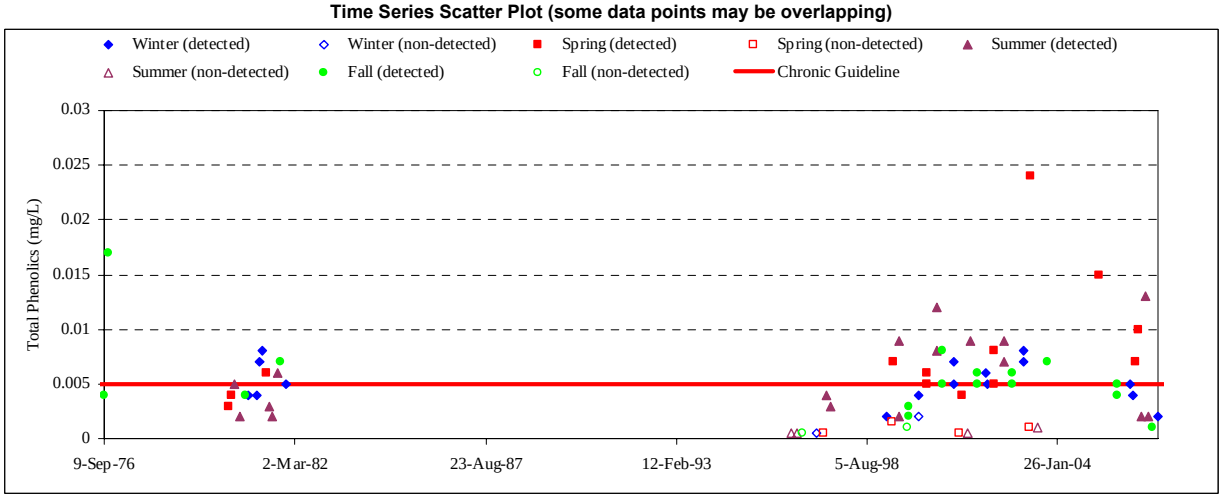
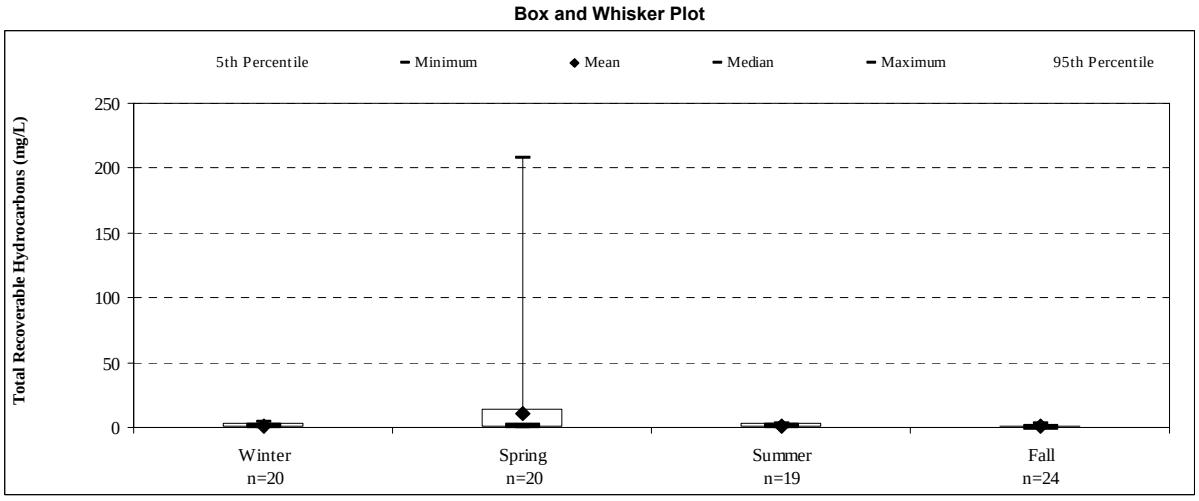


Figure G-2-2-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Middle Segment of Muskeg River



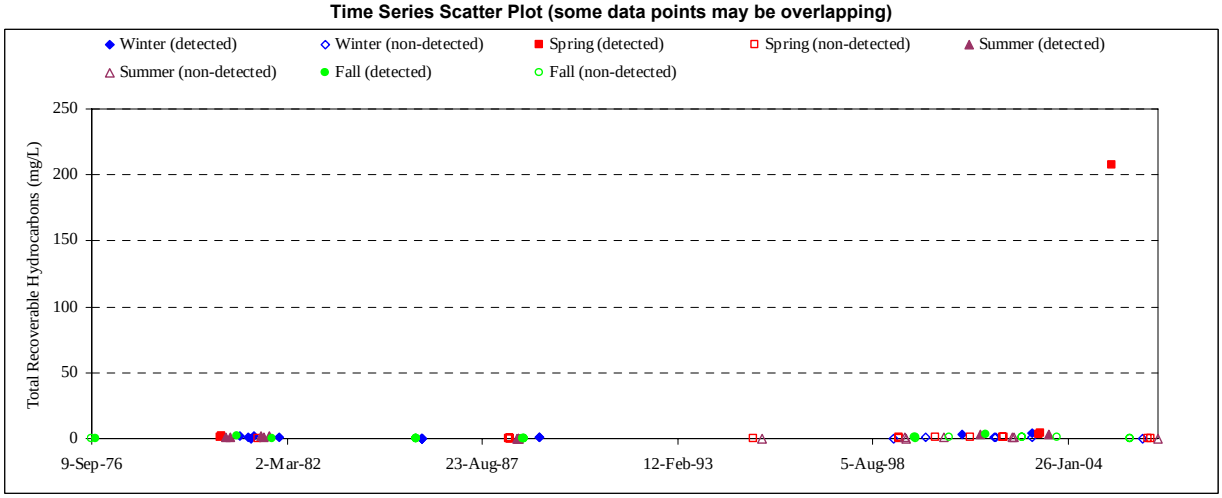


Figure G-2-2-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Middle Segment of Muskeg River

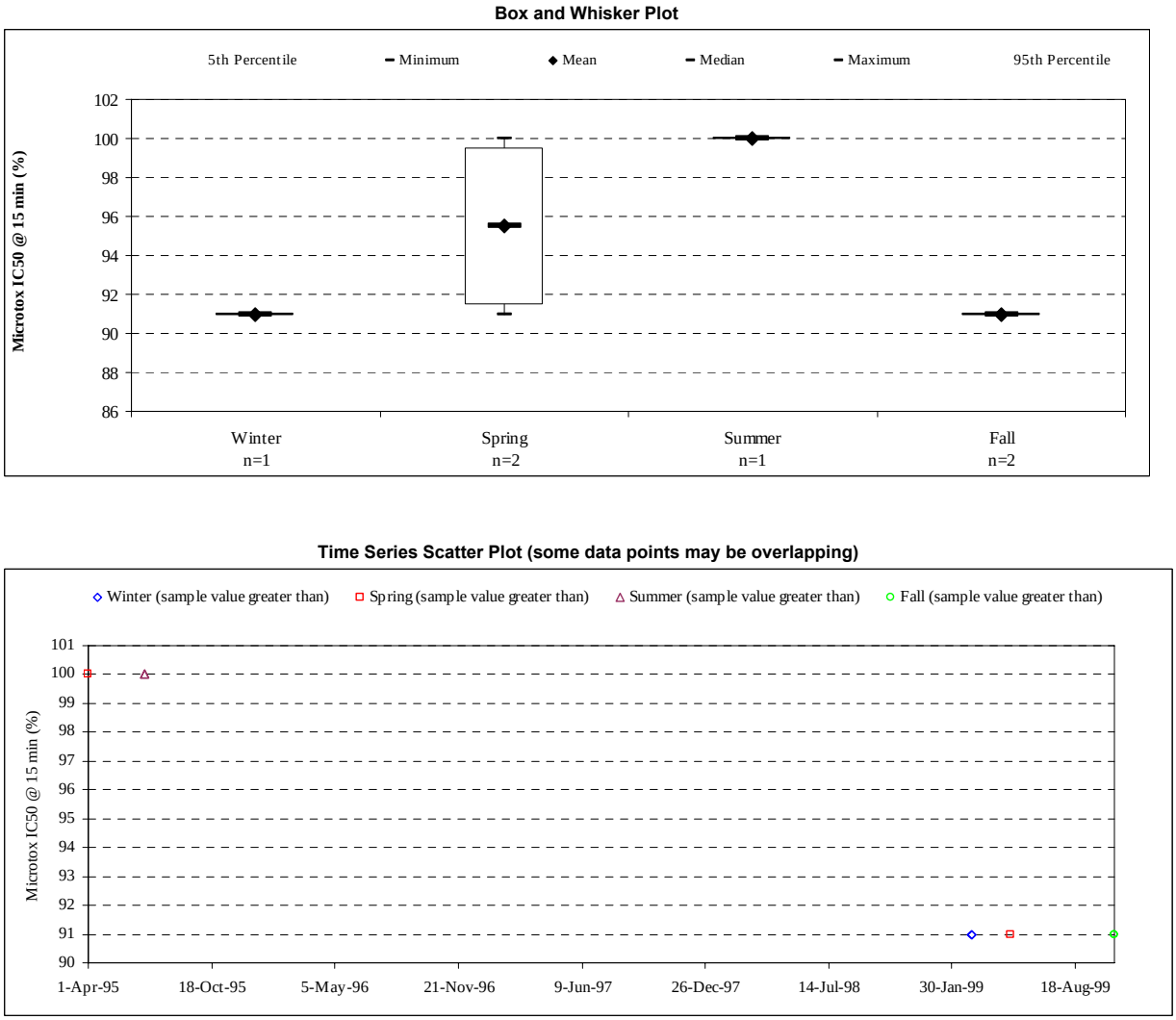
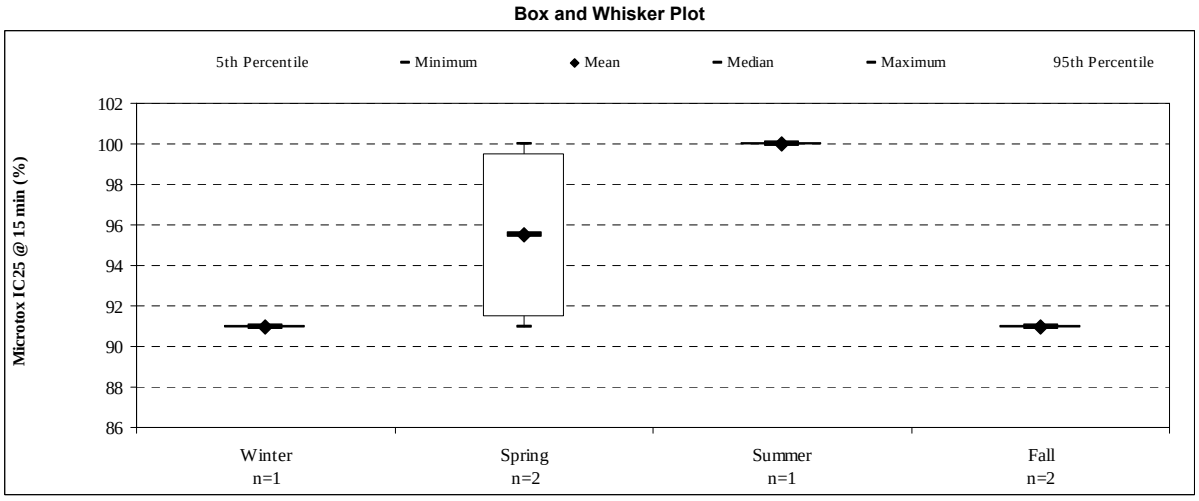


Figure G-2-2-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Middle Segment of Muskeg River



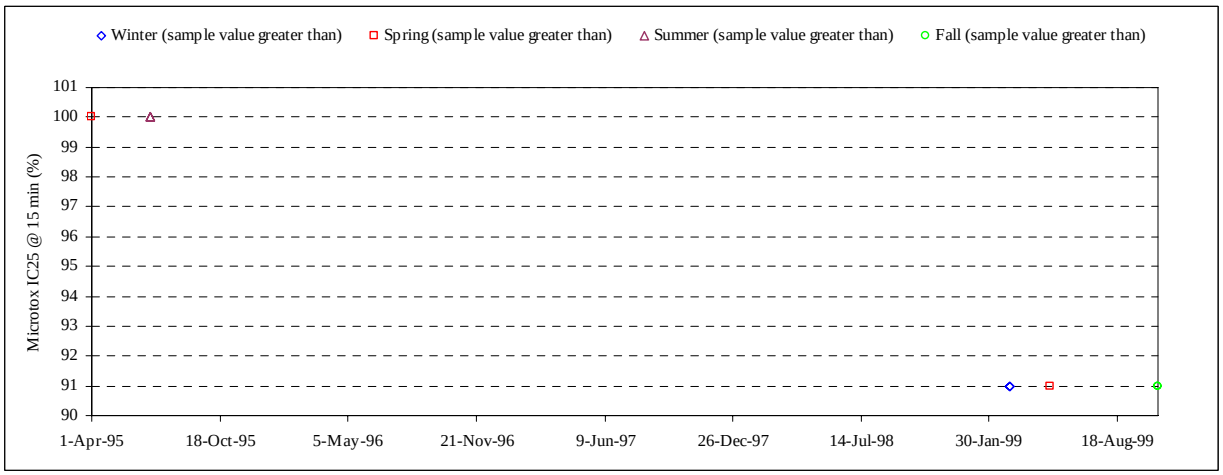
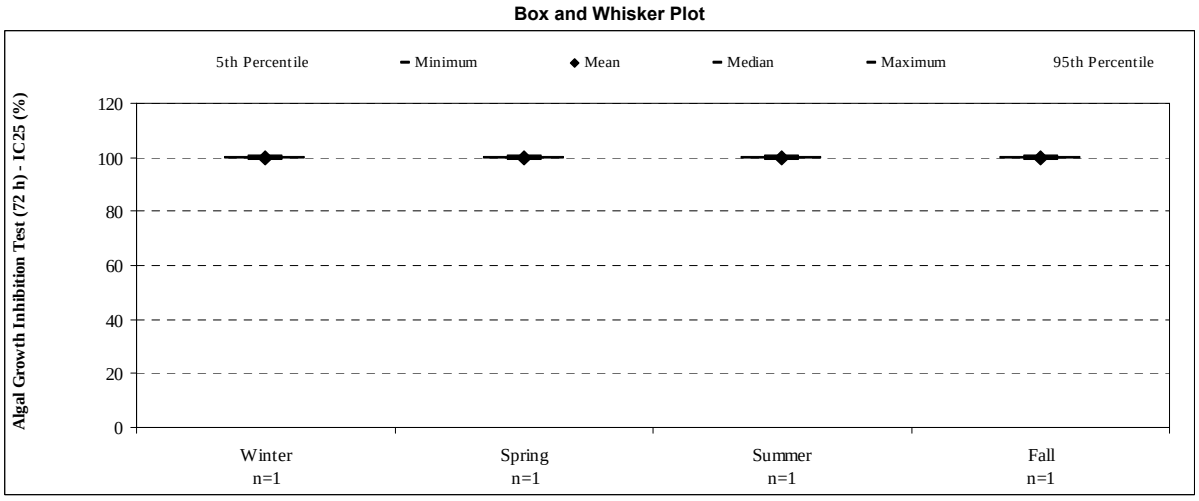


Figure G-2-2-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Middle Segment of Muskeg River



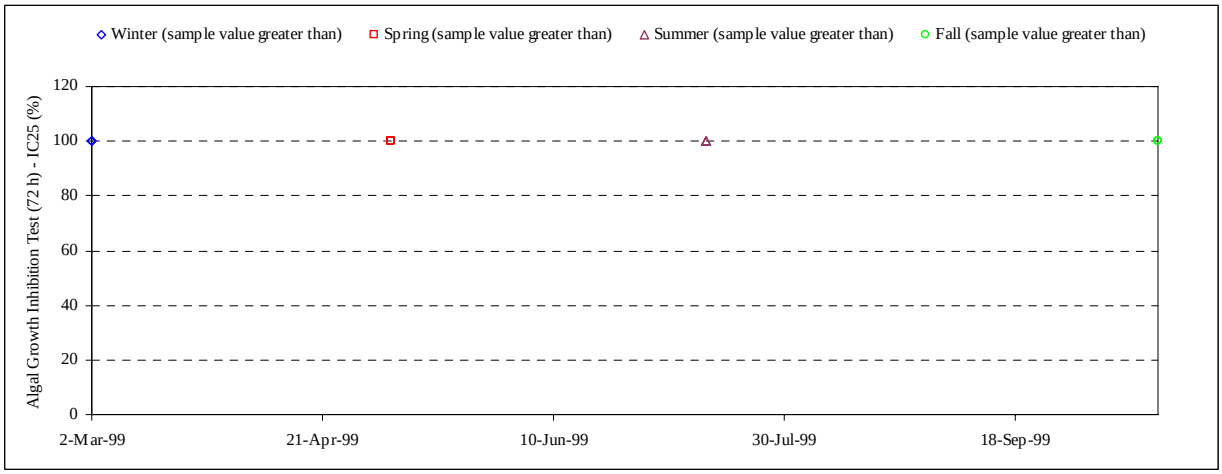
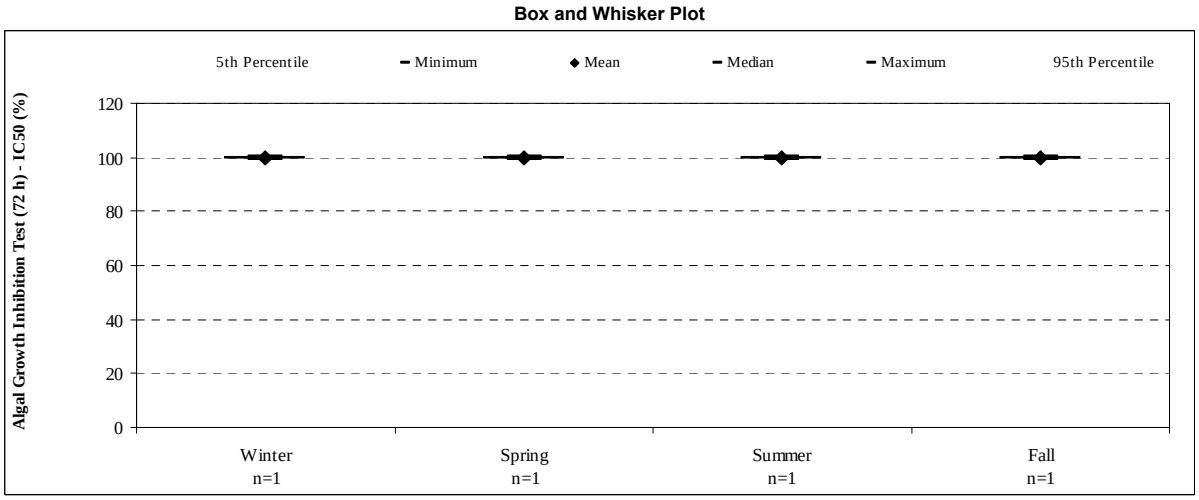


Figure G-2-2-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Middle Segment of Muskeg River



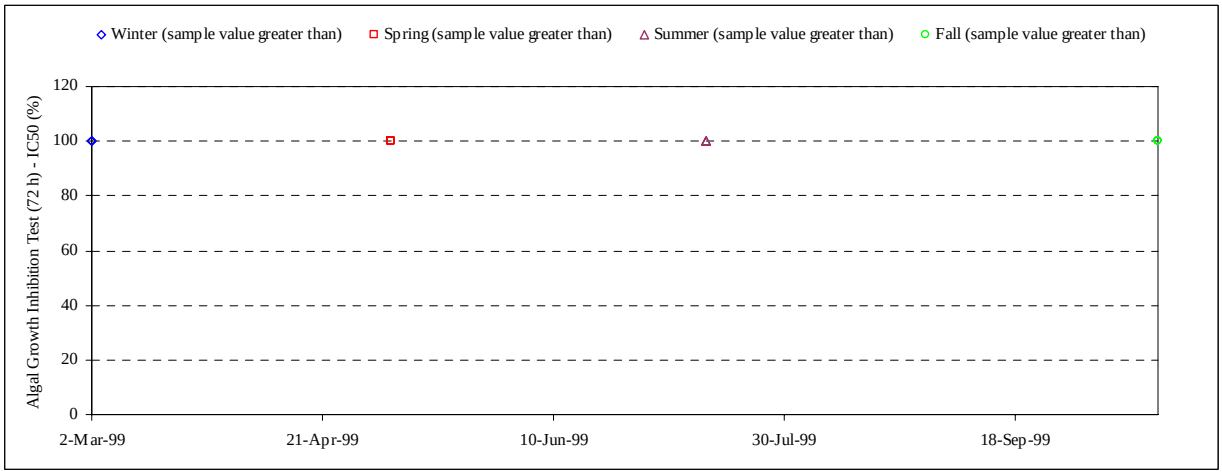
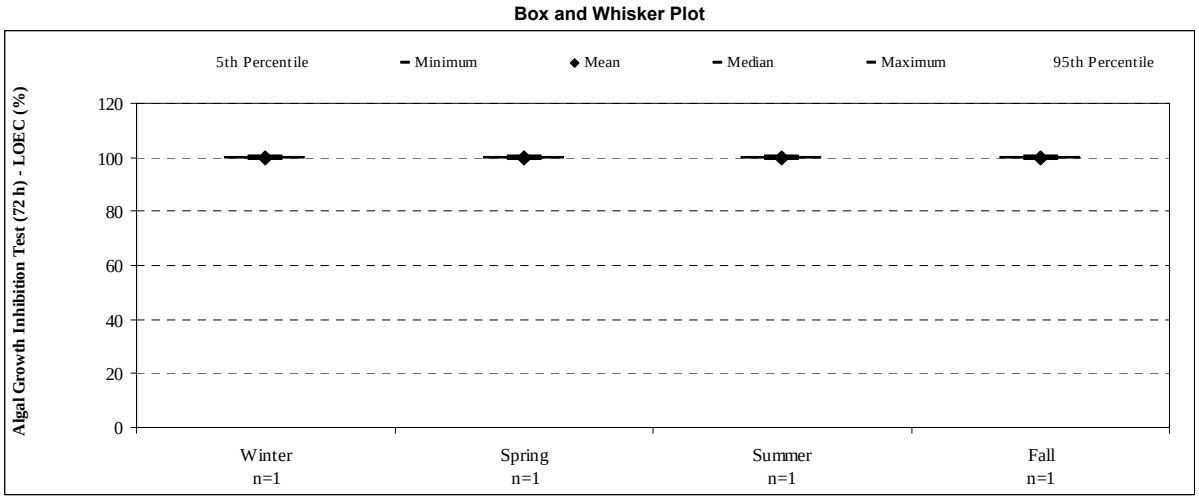


Figure G-2-2-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Middle Segment of Muskeg River



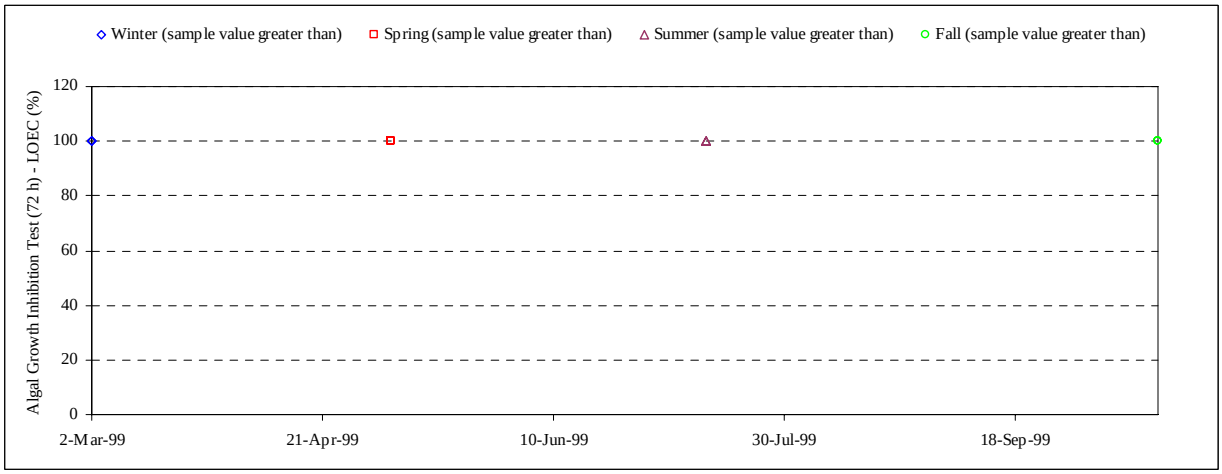
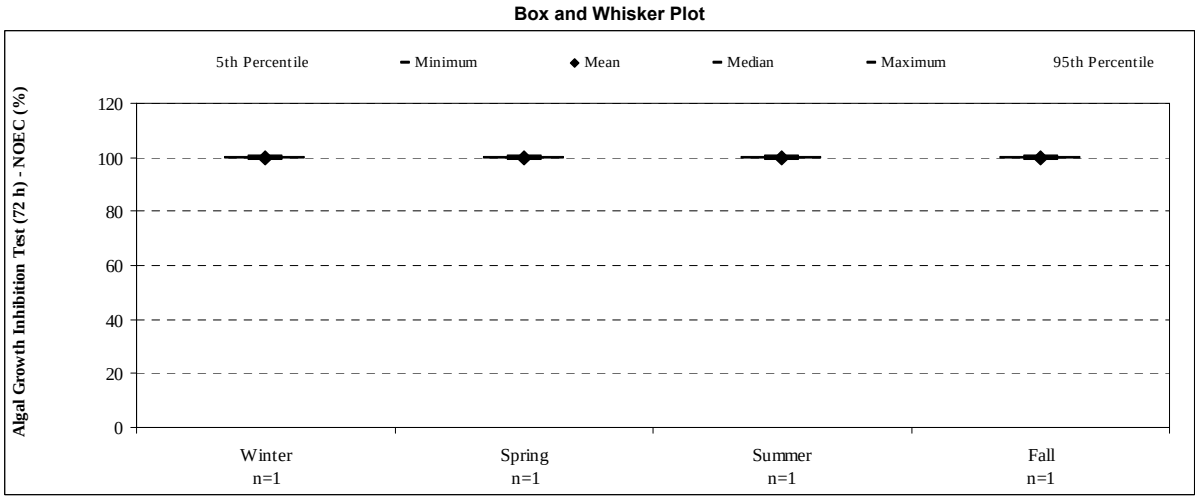


Figure G-2-2-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Middle Segment of Muskeg River



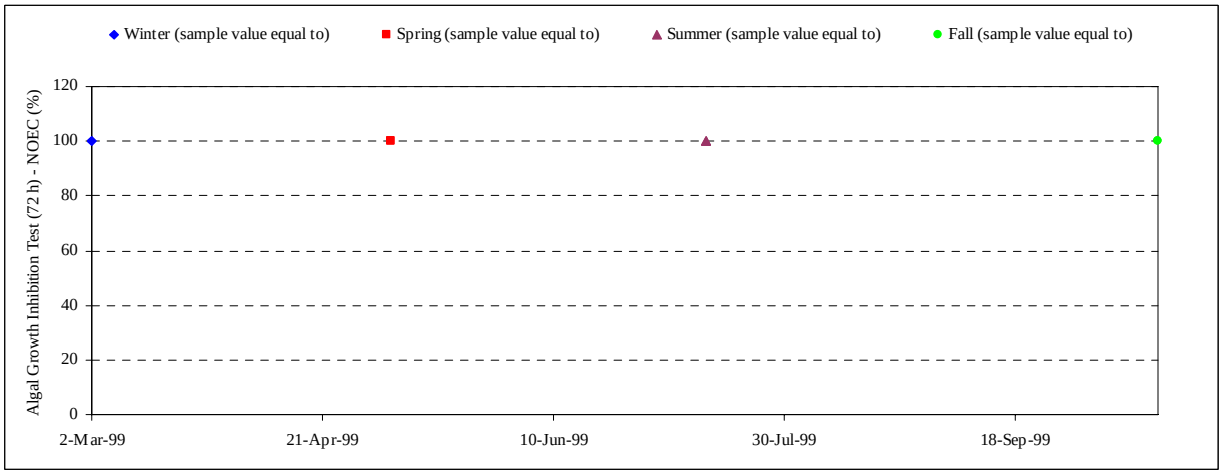
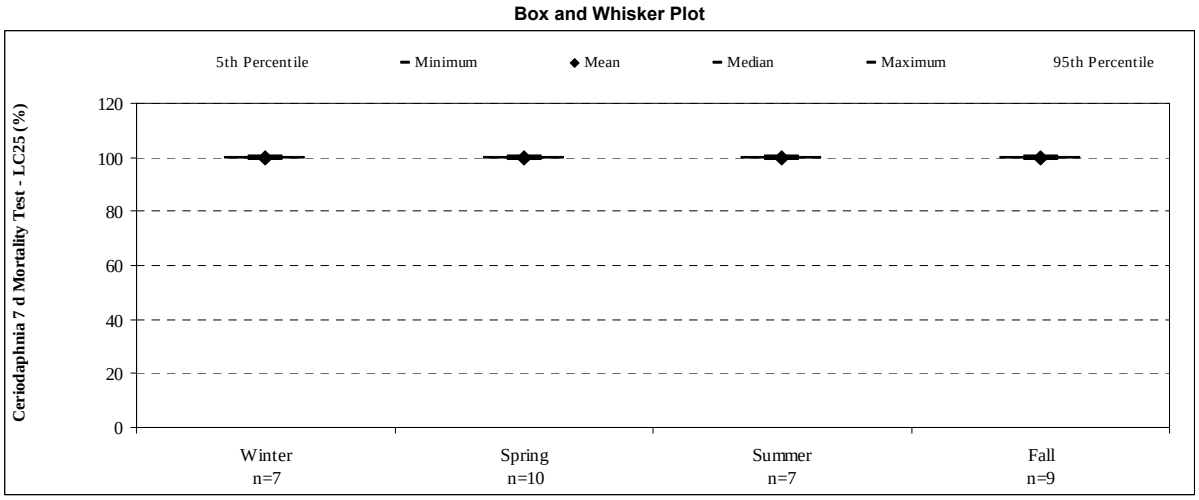


Figure G-2-2-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Middle Segment of Muskeg River



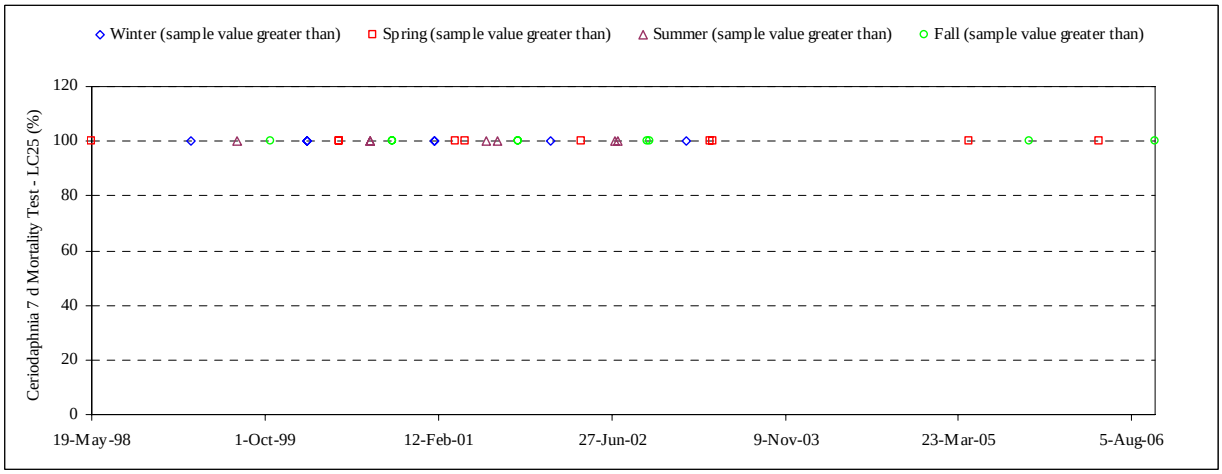


Figure G-2-2-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Middle Segment of Muskeg River

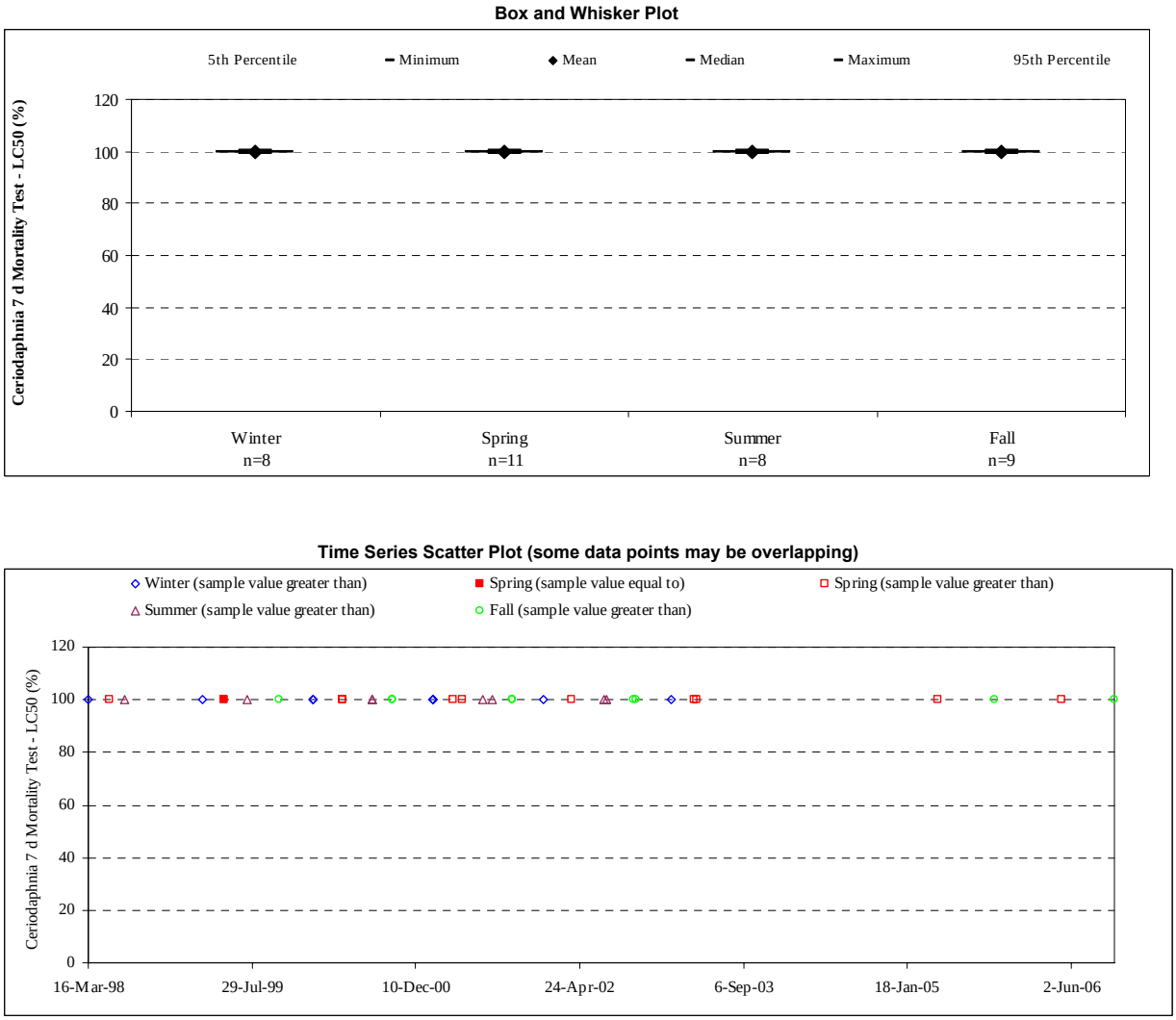
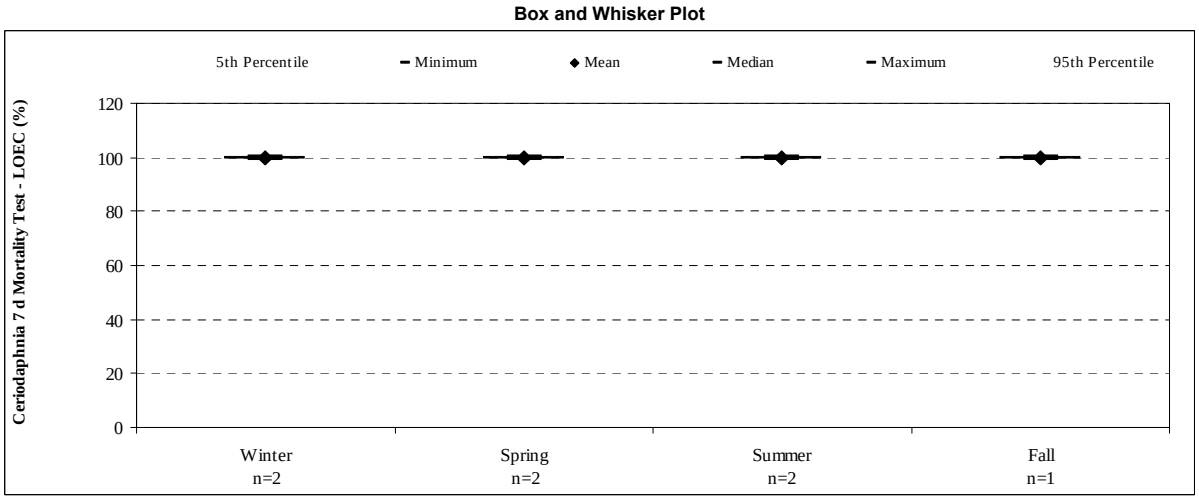


Figure G-2-2-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Middle Segment of Muskeg River



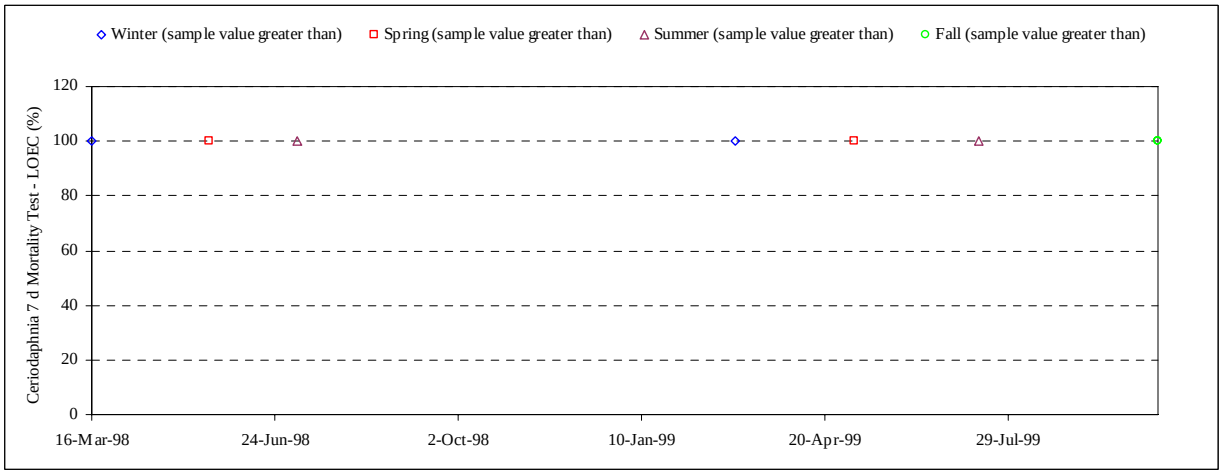
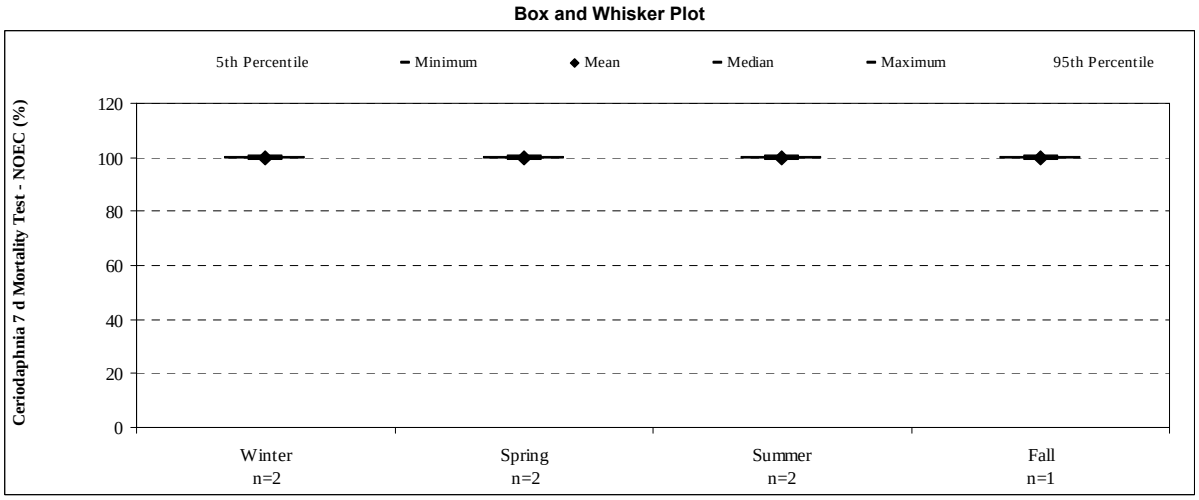


Figure G-2-2-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Middle Segment of Muskeg River



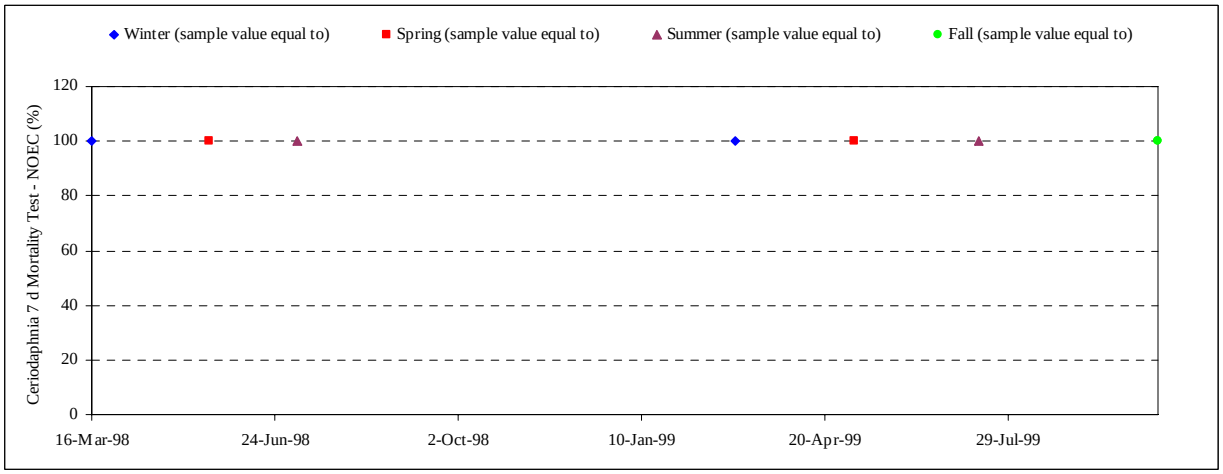
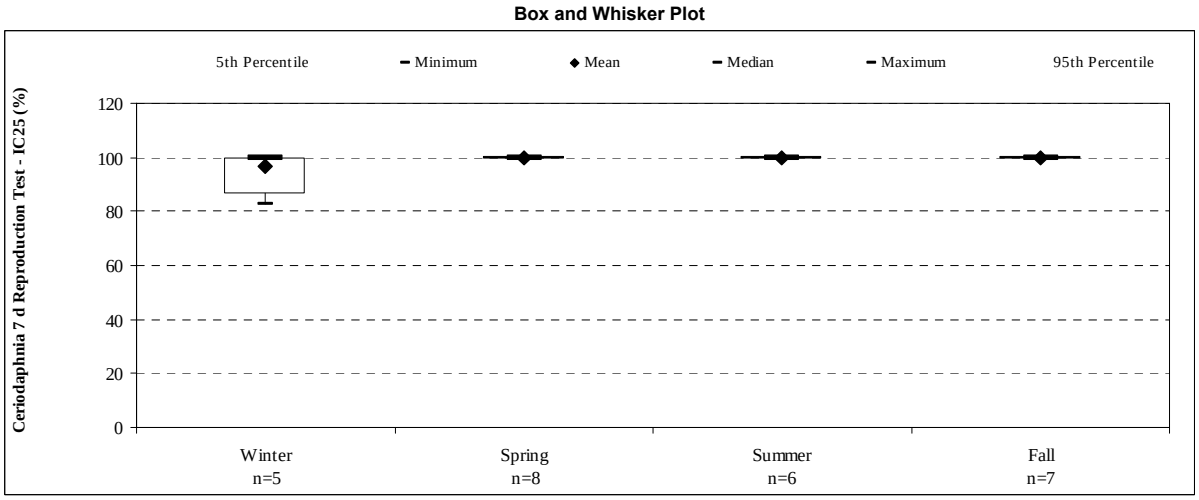


Figure G-2-2-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Middle Segment of Muskeg River



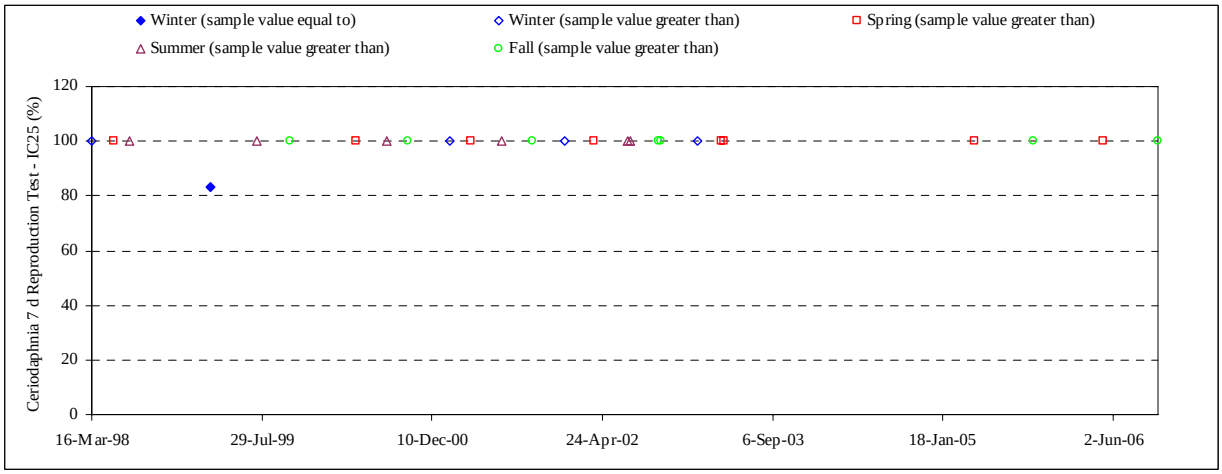
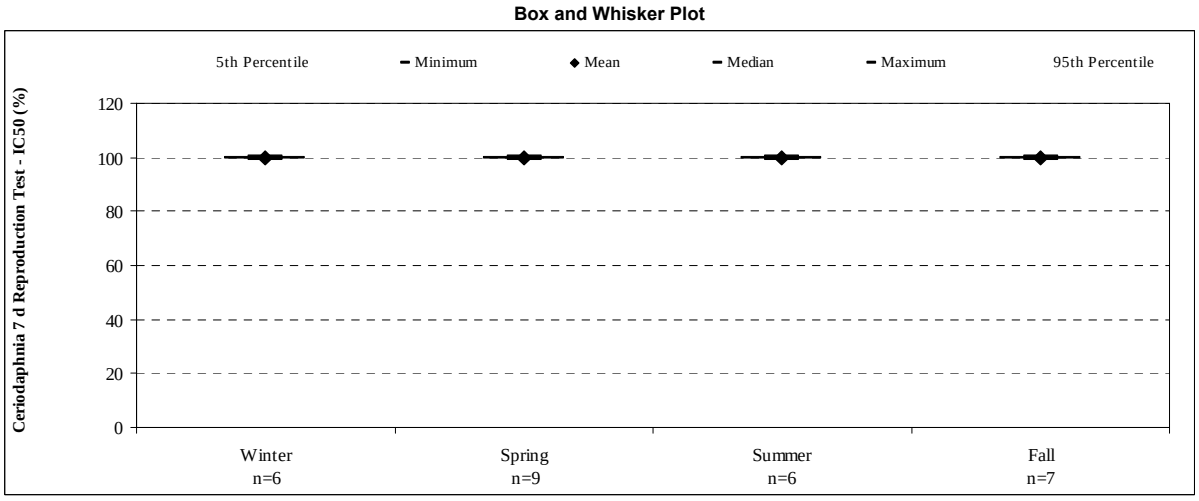


Figure G-2-2-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Middle Segment of Muskeg River



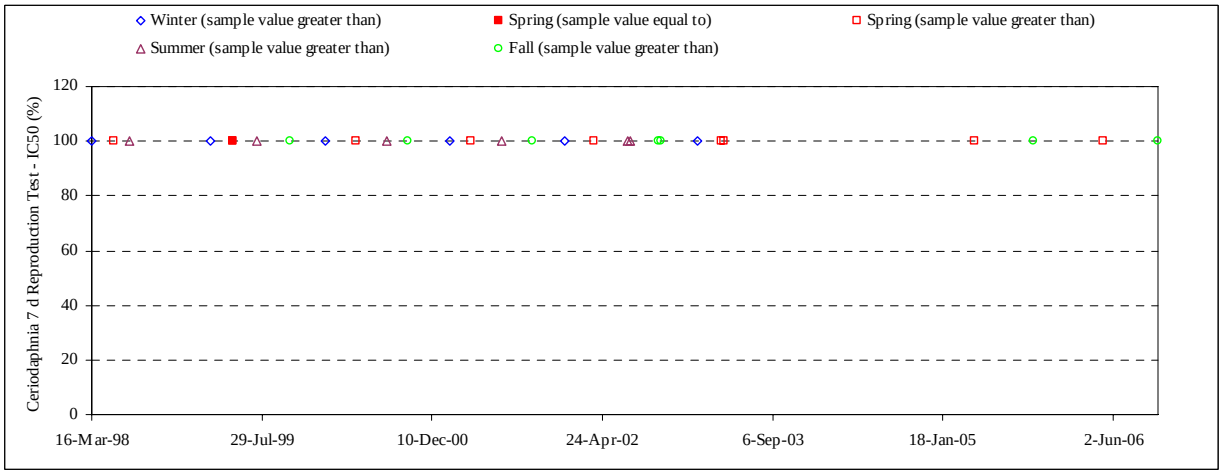
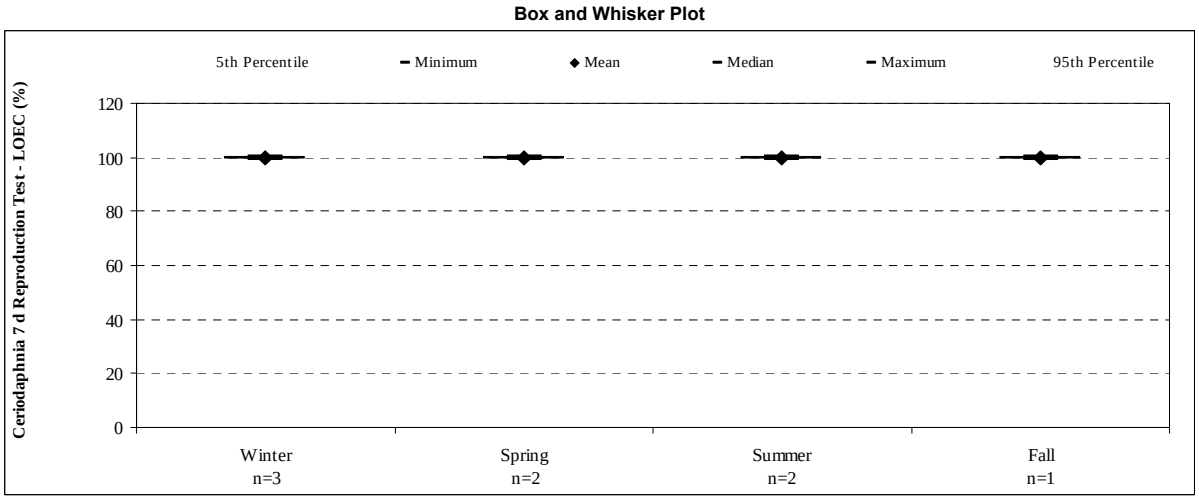


Figure G-2-2-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Middle Segment of Muskeg River



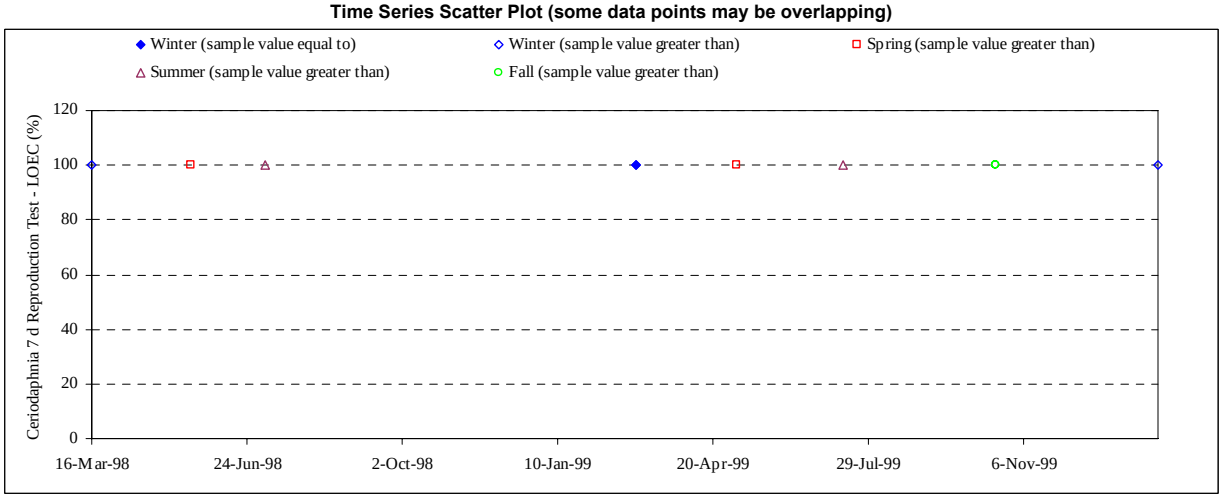
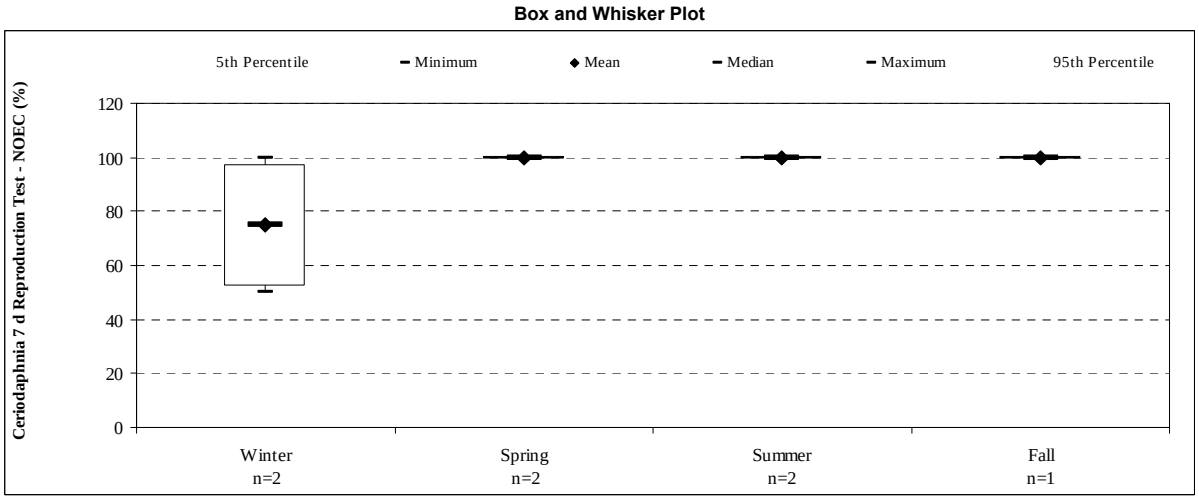


Figure G-2-2-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Middle Segment of Muskeg River



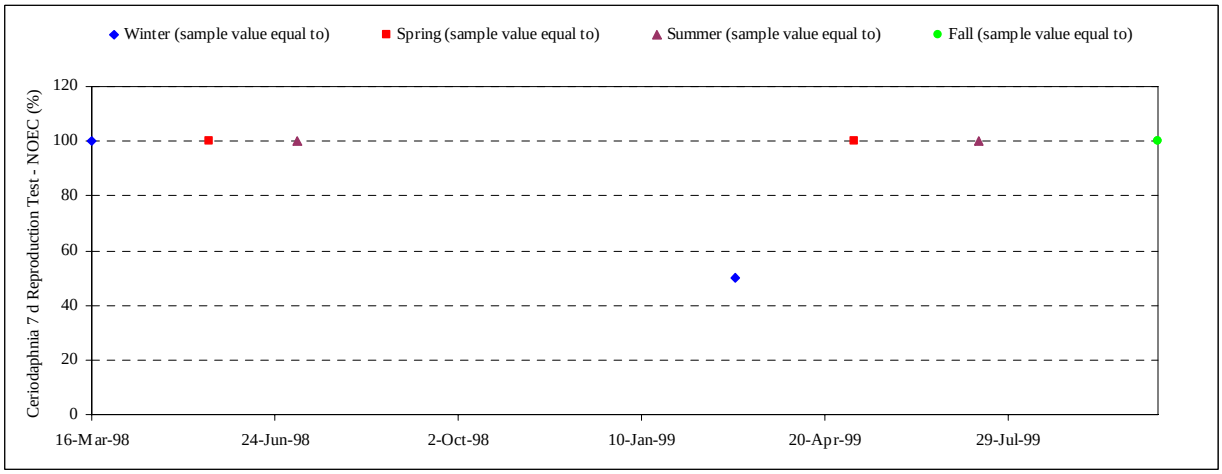
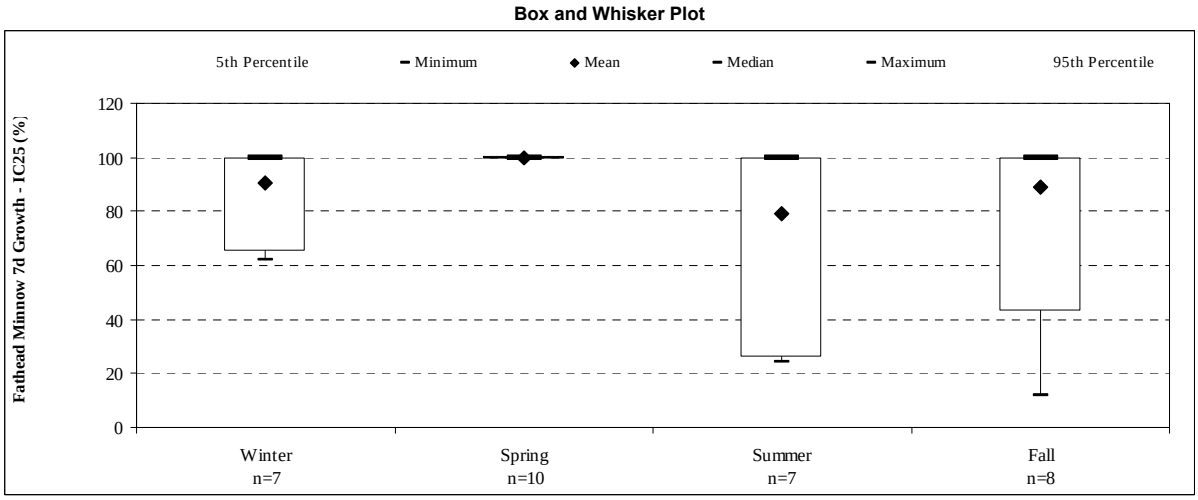


Figure G-2-2-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Middle Segment of Muskeg River



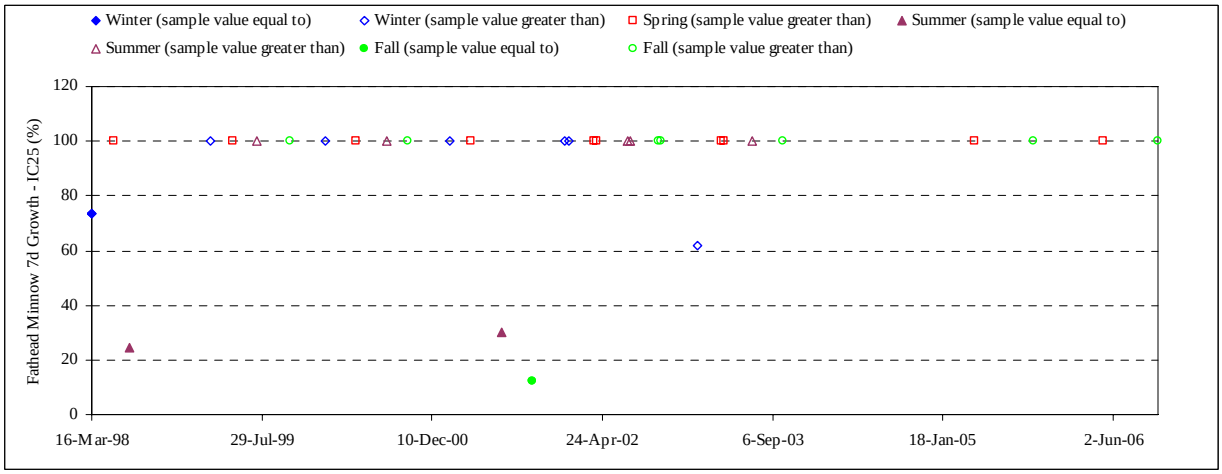


Figure G-2-2-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Middle Segment of Muskeg River

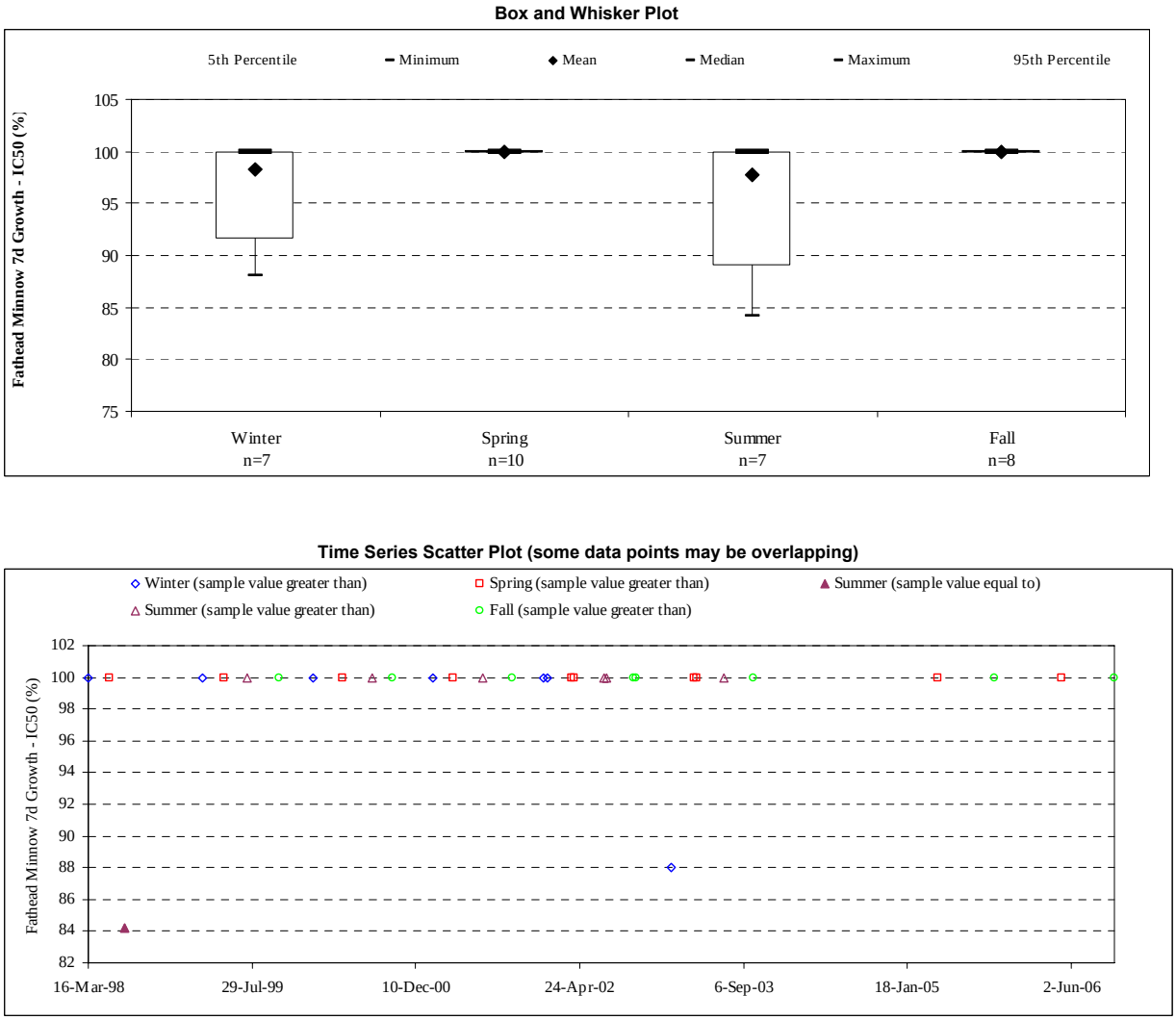
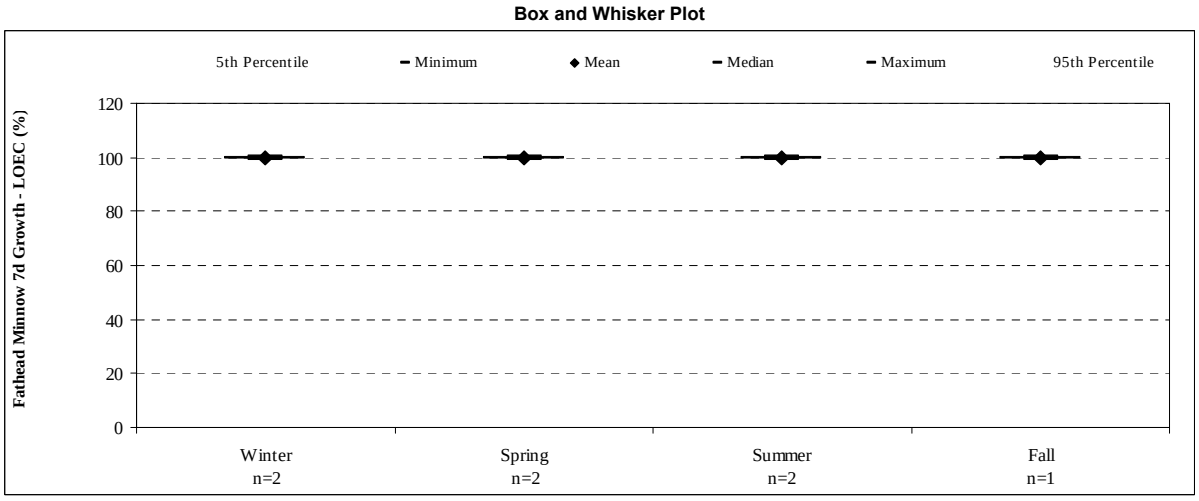


Figure G-2-2-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Middle Segment of Muskeg River



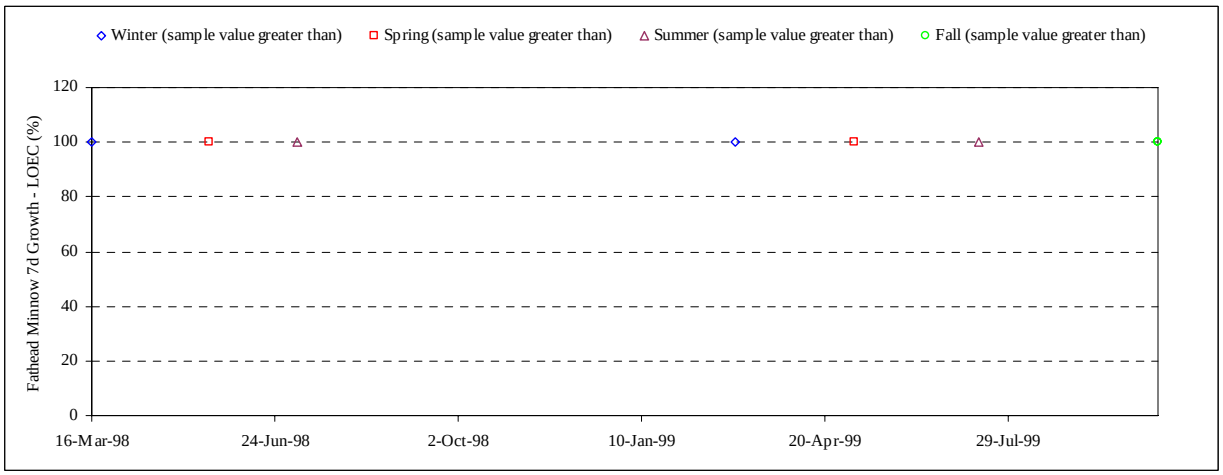
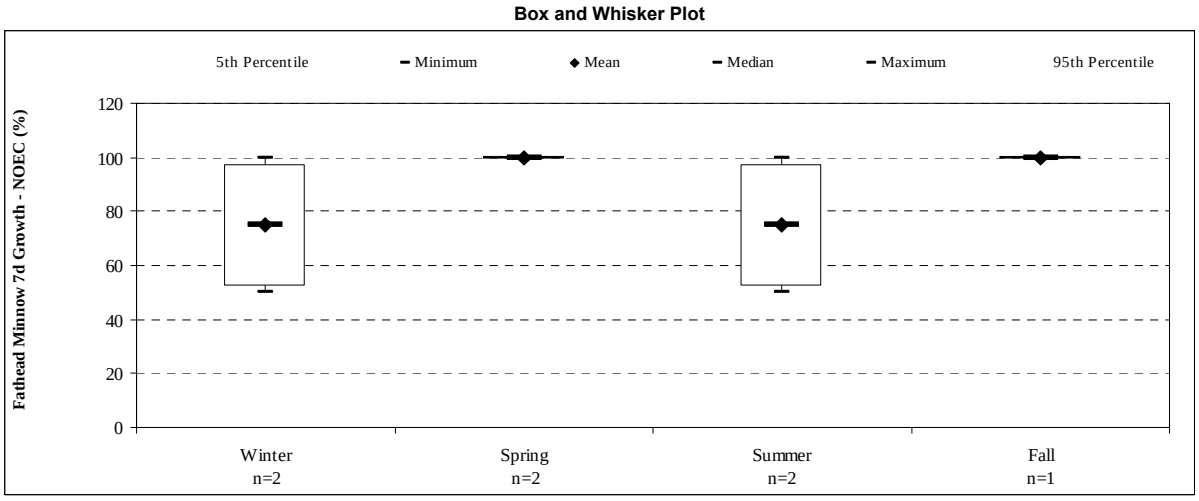


Figure G-2-2-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Middle Segment of Muskeg River



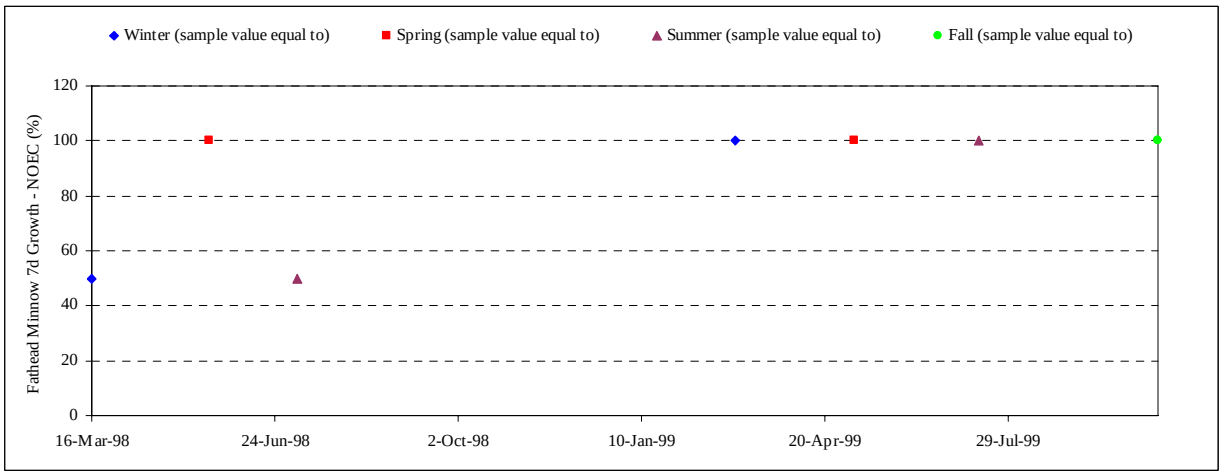
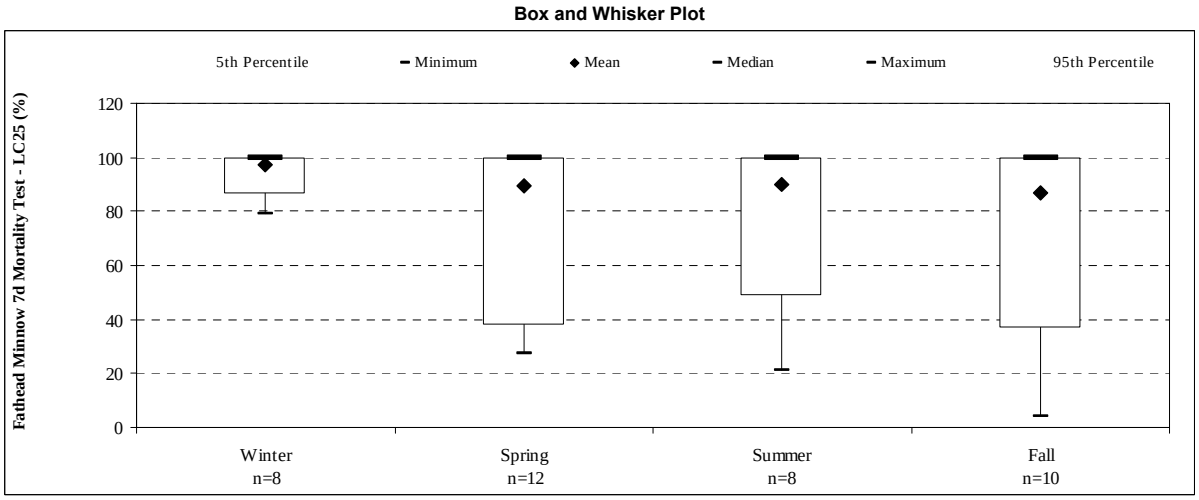


Figure G-2-2-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Middle Segment of Muskeg River



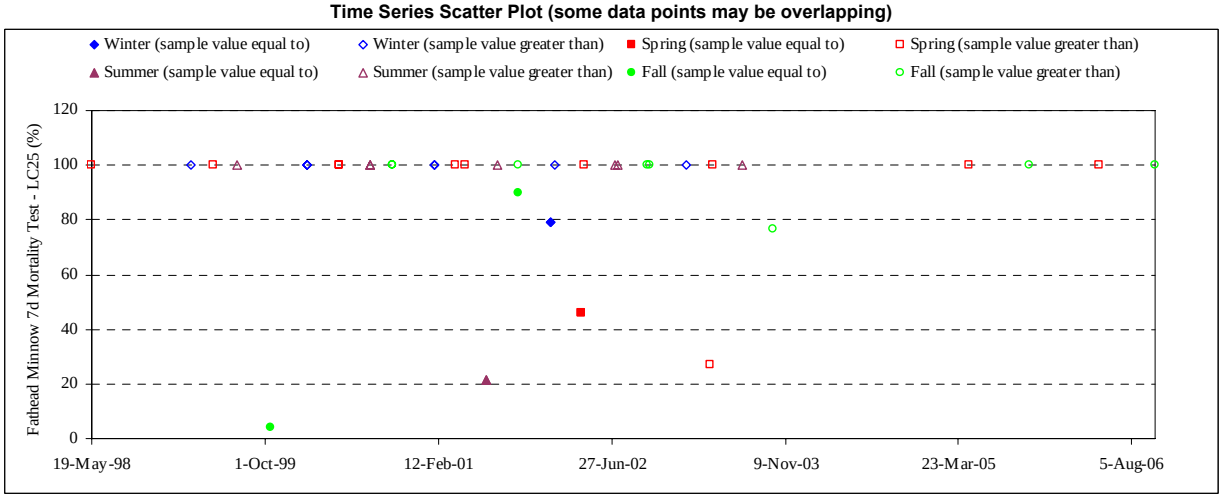
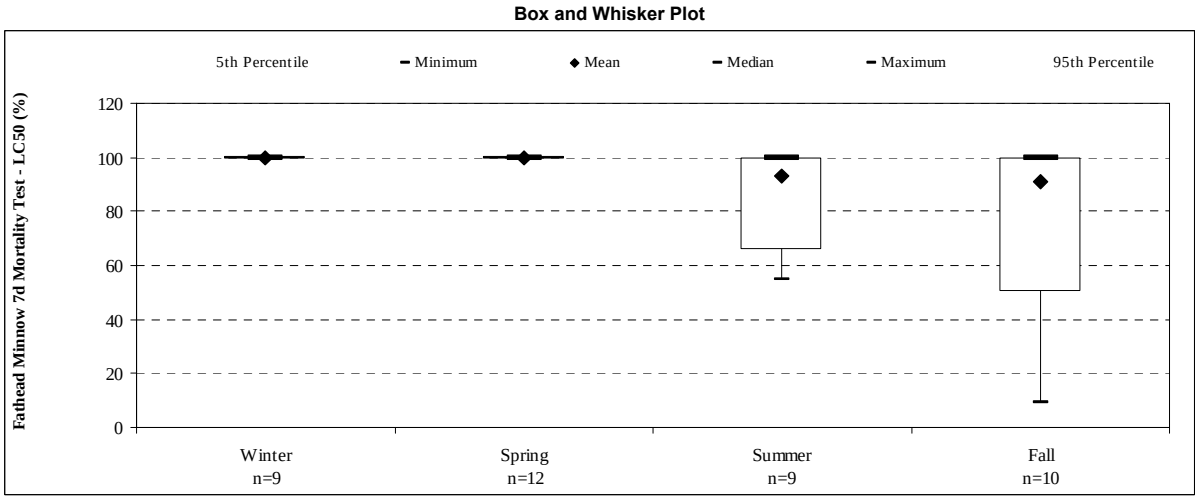


Figure G-2-2-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Middle Segment of Muskeg River



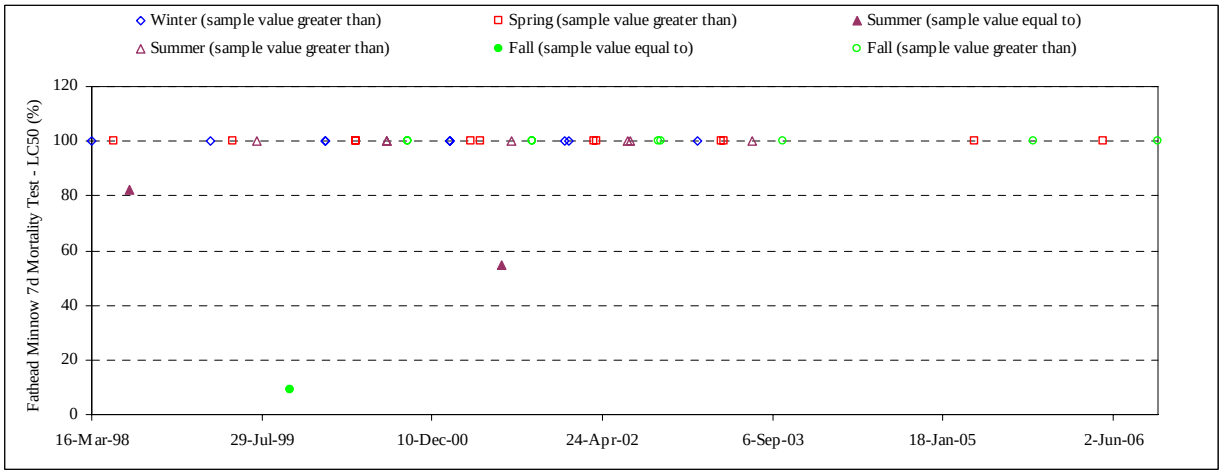
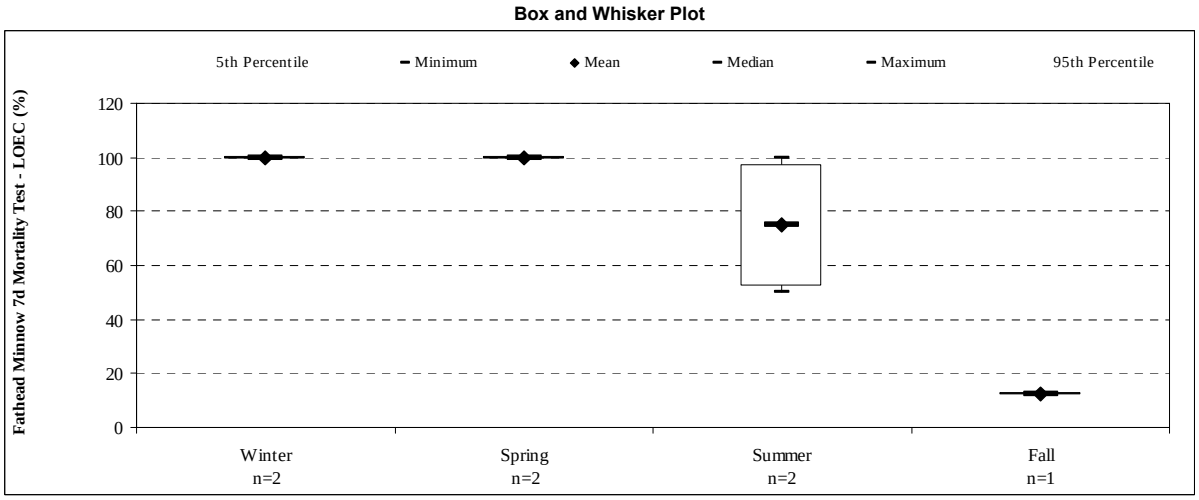


Figure G-2-2-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Middle Segment of Muskeg River



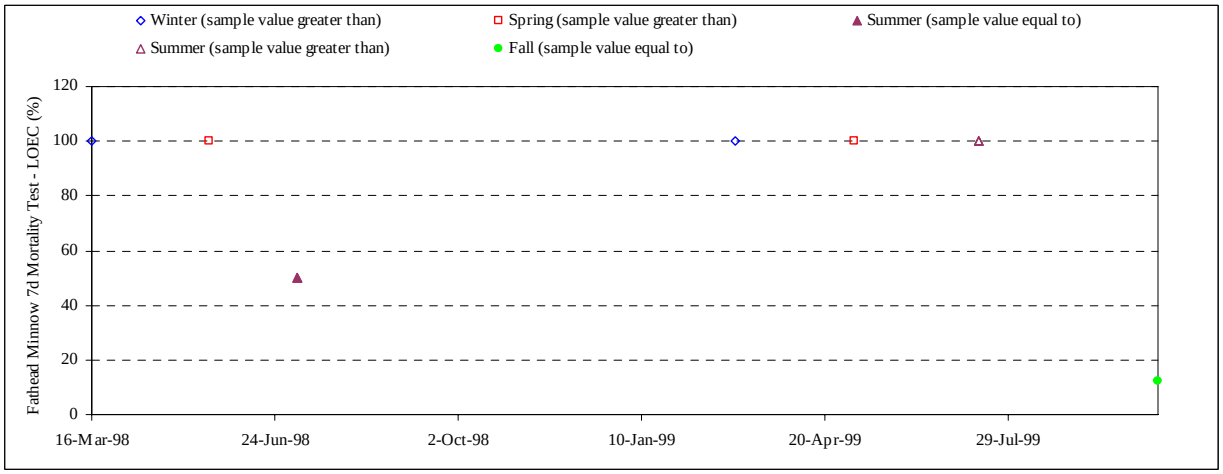
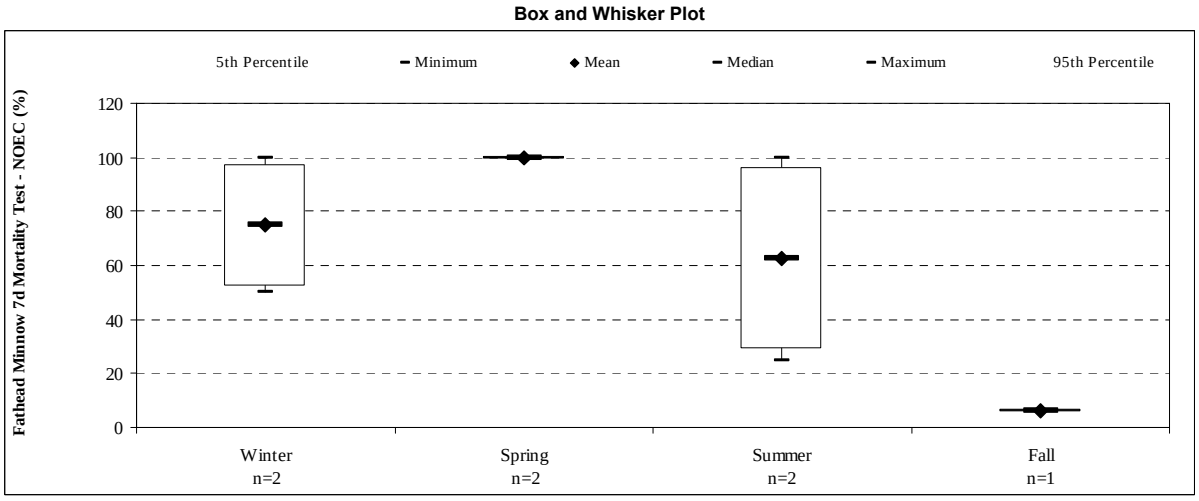


Figure G-2-2-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Middle Segment of Muskeg River



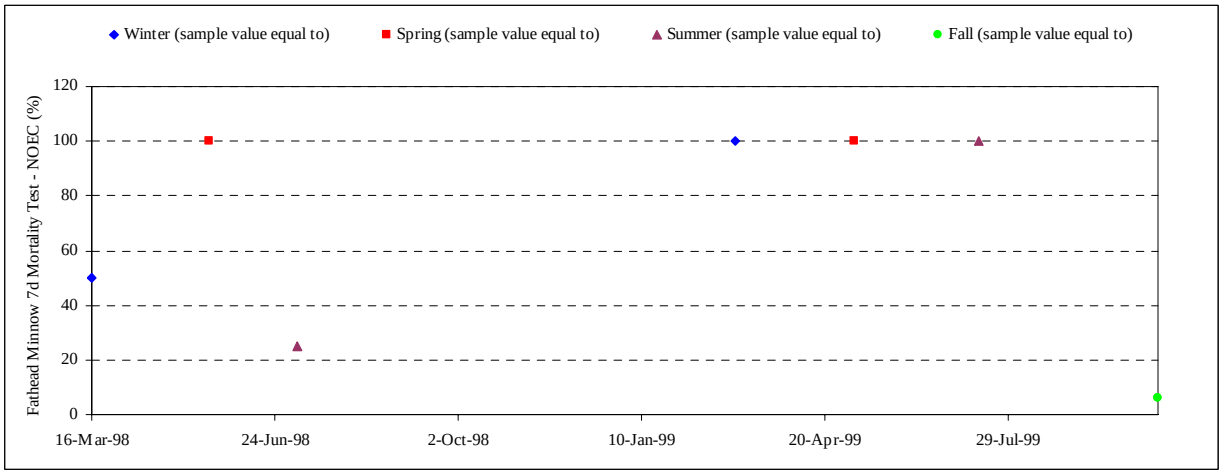
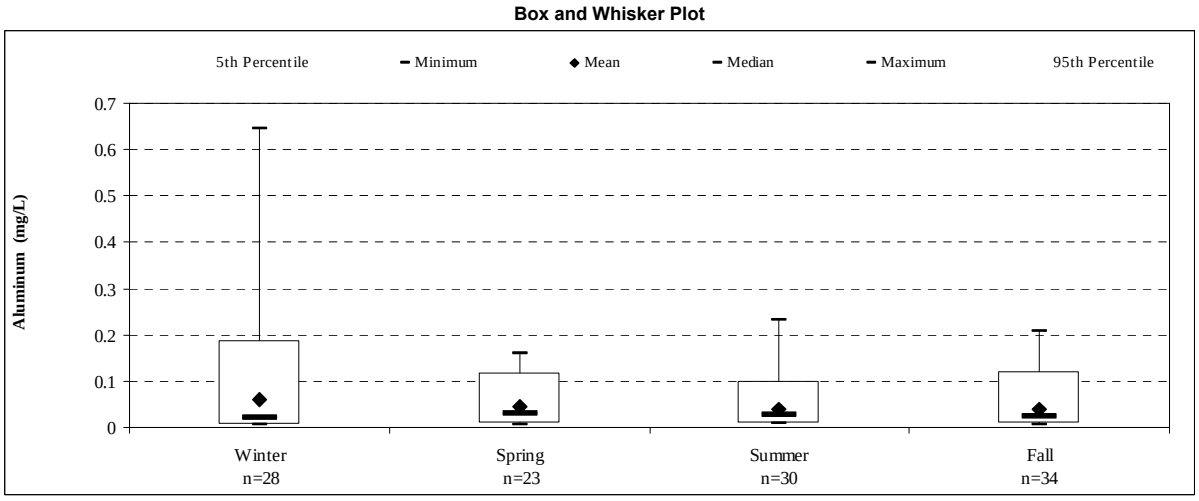


Figure G-2-2-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Middle Segment of Muskeg River



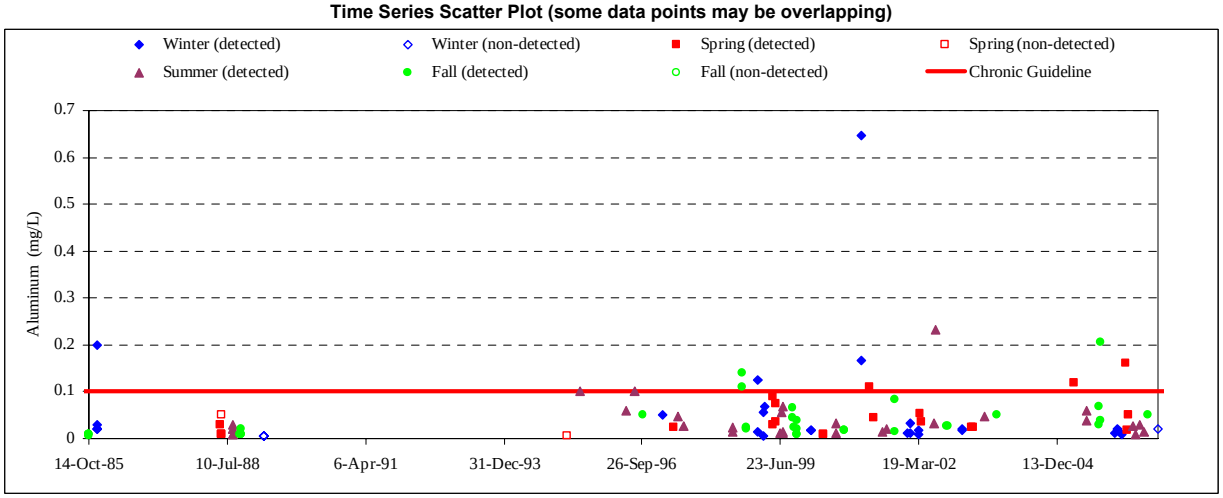


Figure G-2-2-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Middle Segment of Muskeg River

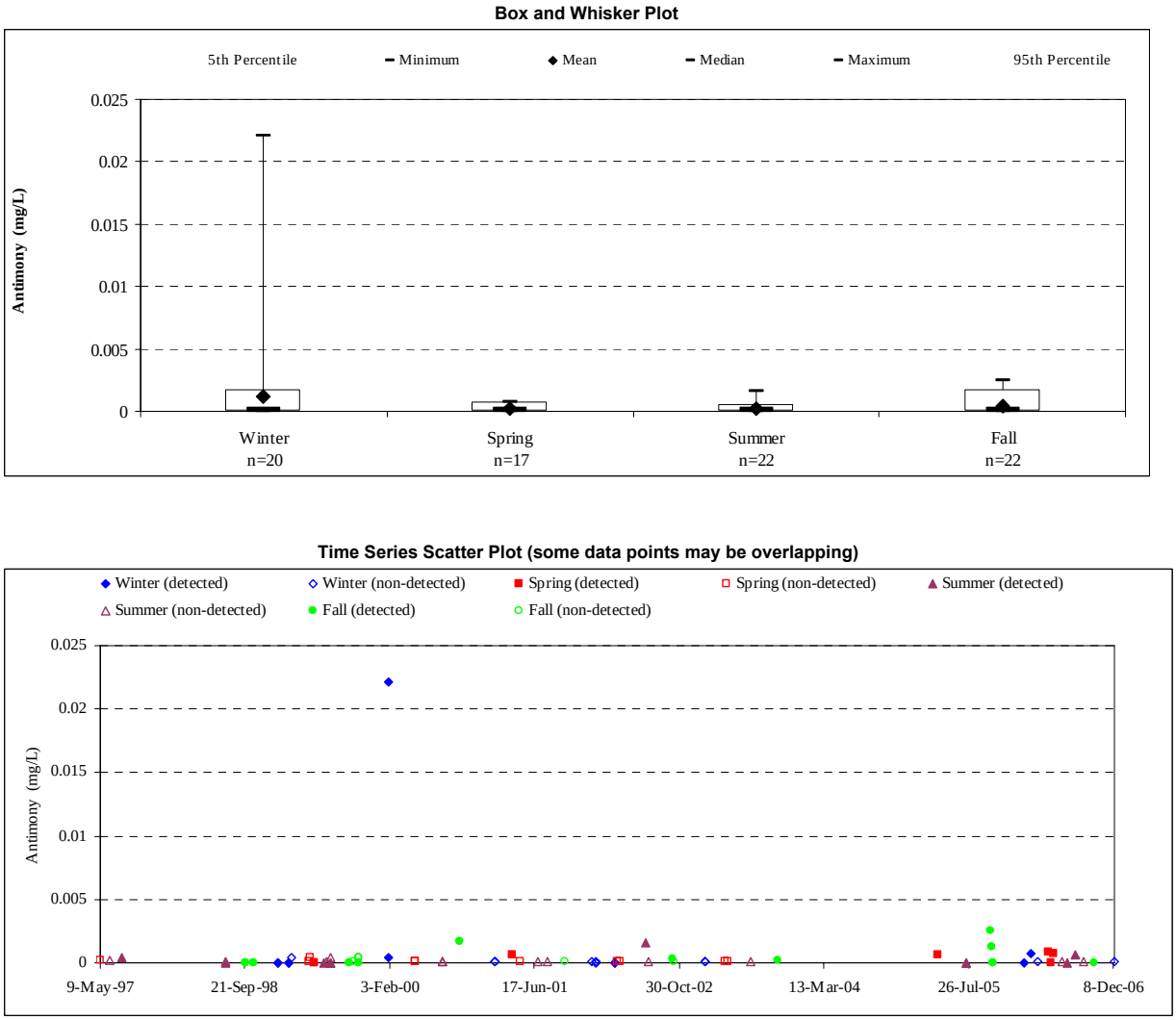
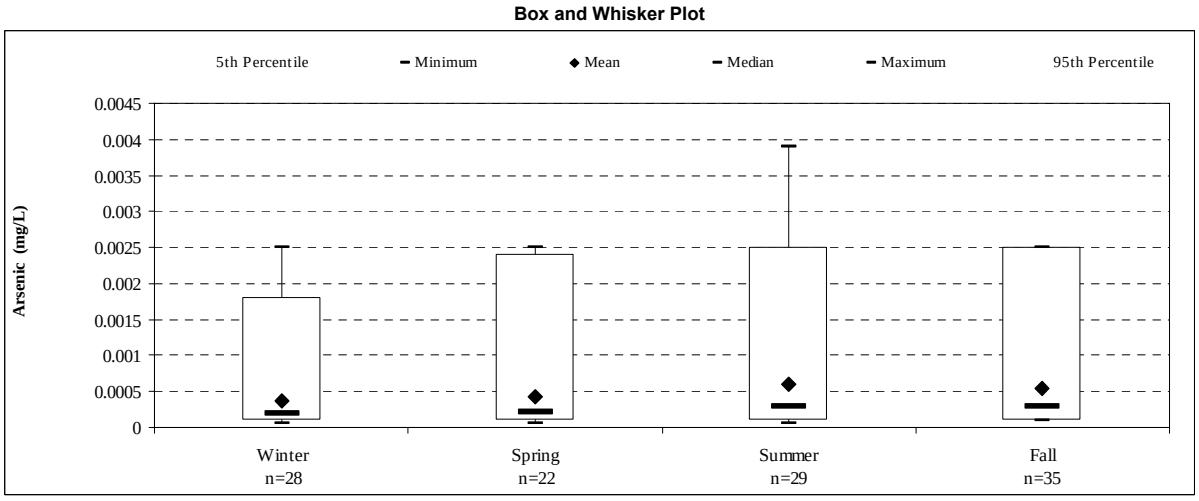


Figure G-2-2-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Middle Segment of Muskeg River



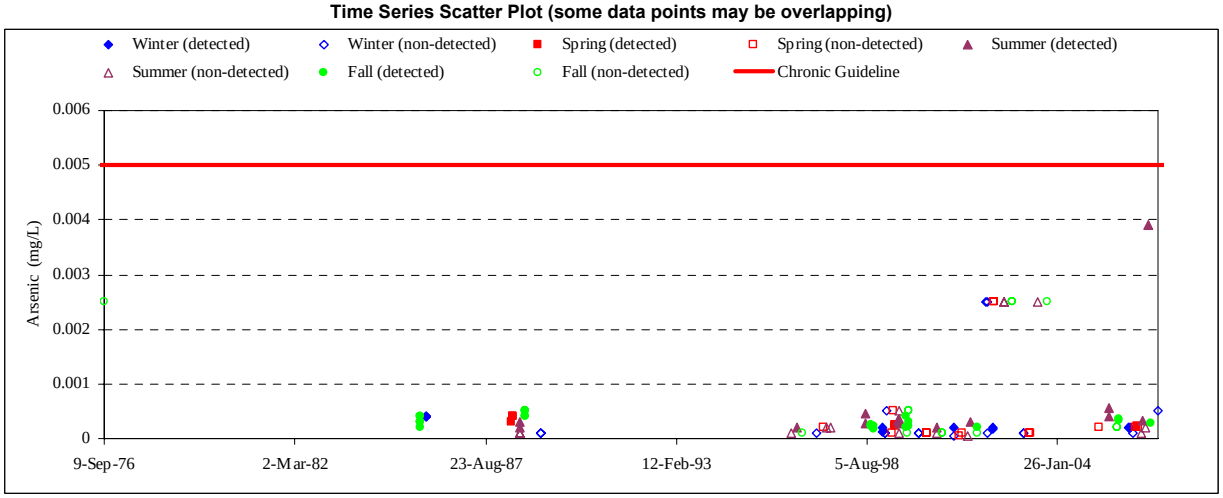
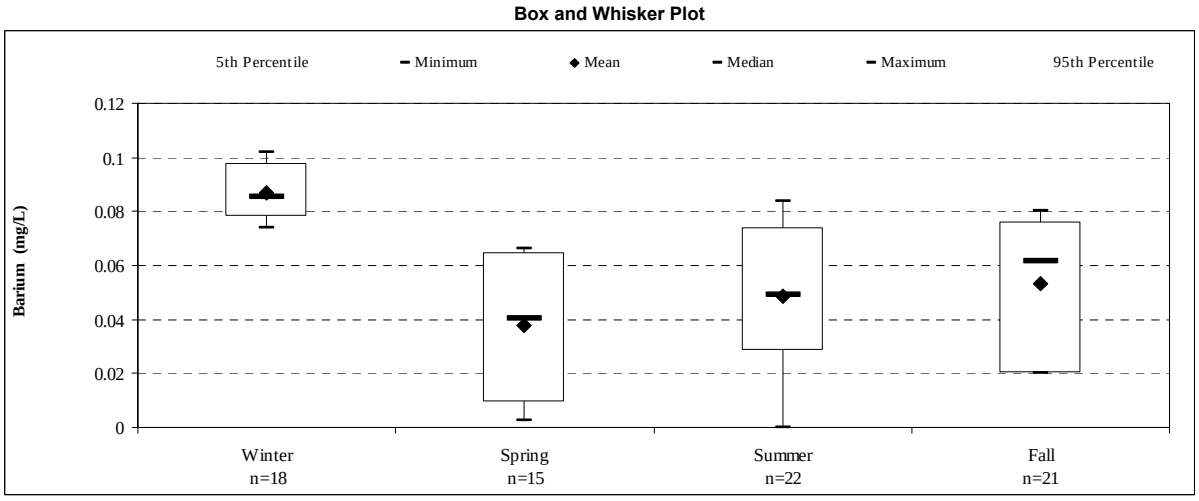


Figure G-2-2-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Middle Segment of Muskeg River



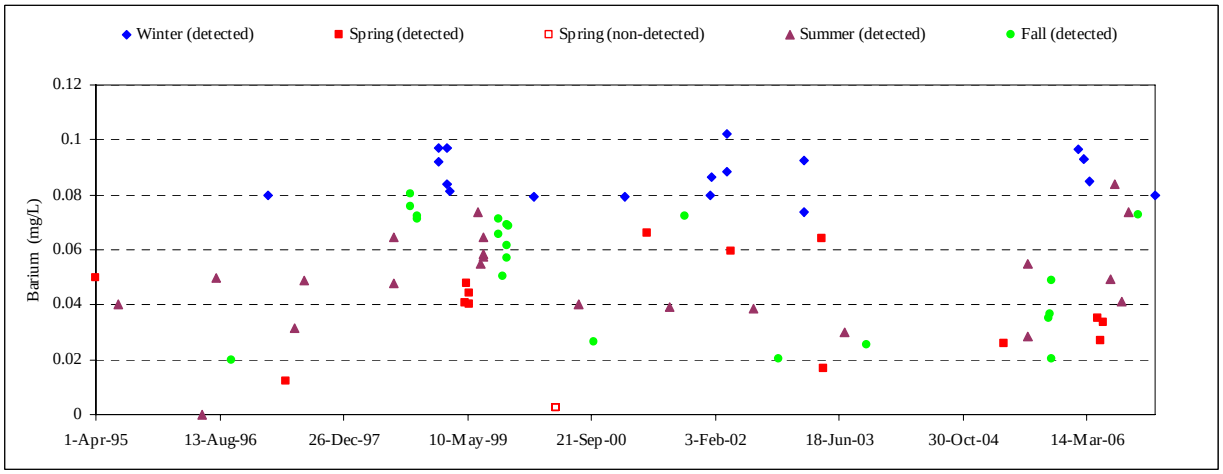
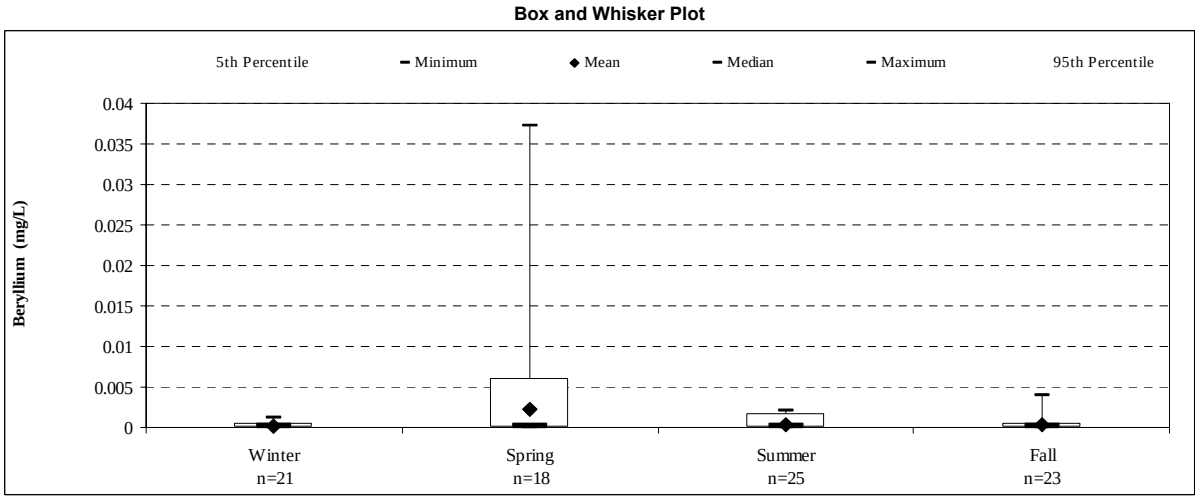


Figure G-2-2-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Middle Segment of Muskeg River



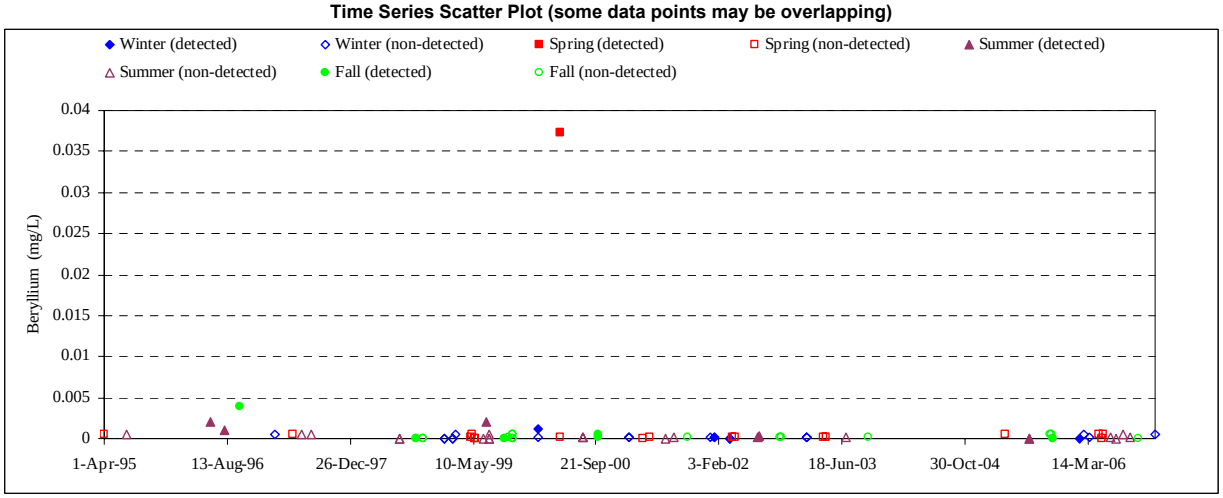
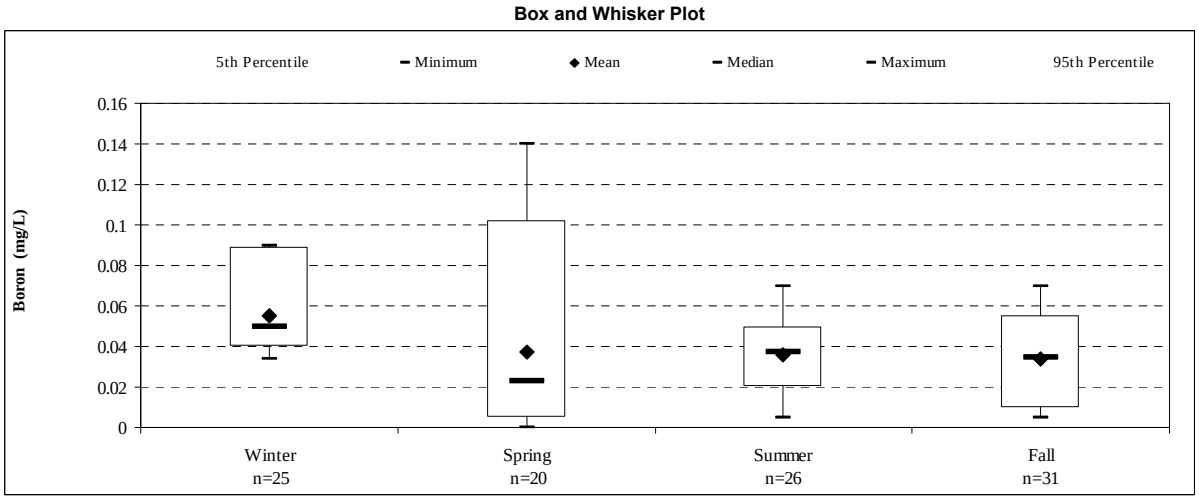


Figure G-2-2-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Middle Segment of Muskeg River



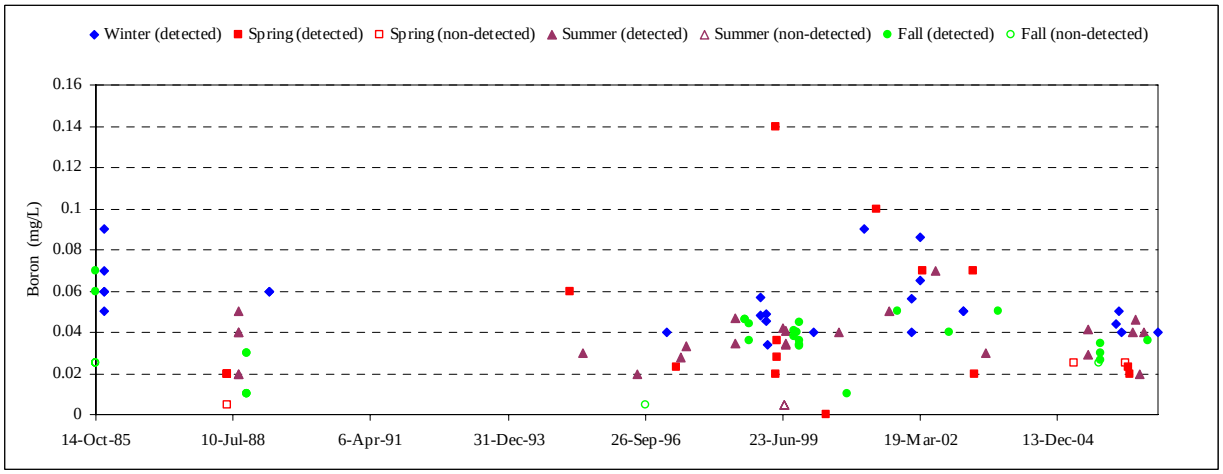
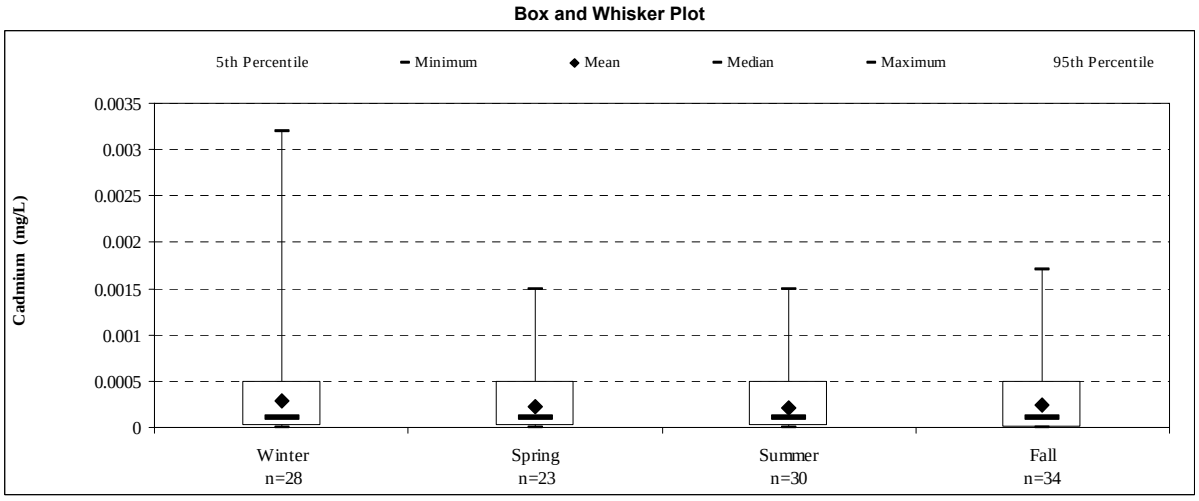


Figure G-2-2-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Middle Segment of Muskeg River



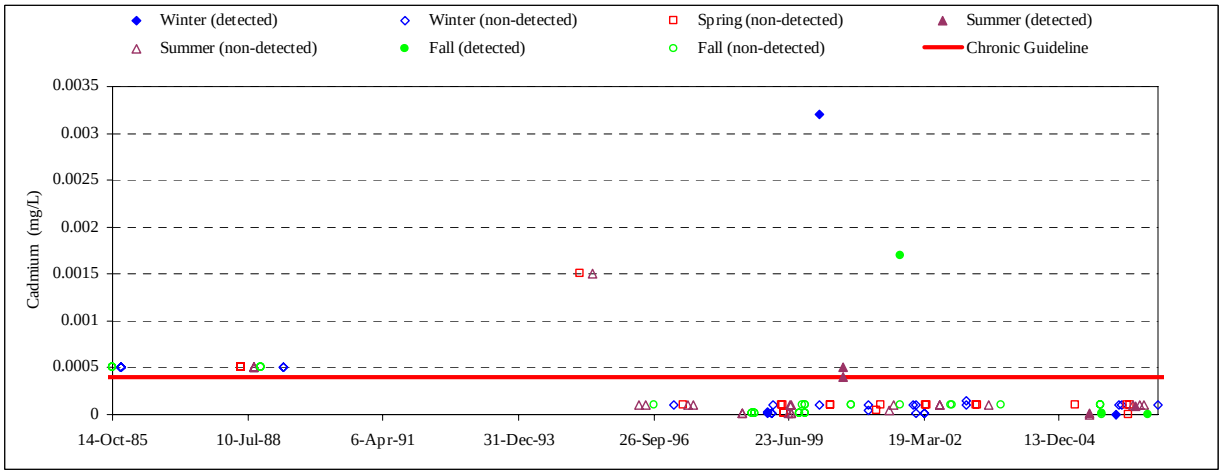


Figure G-2-2-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Middle Segment of Muskeg River

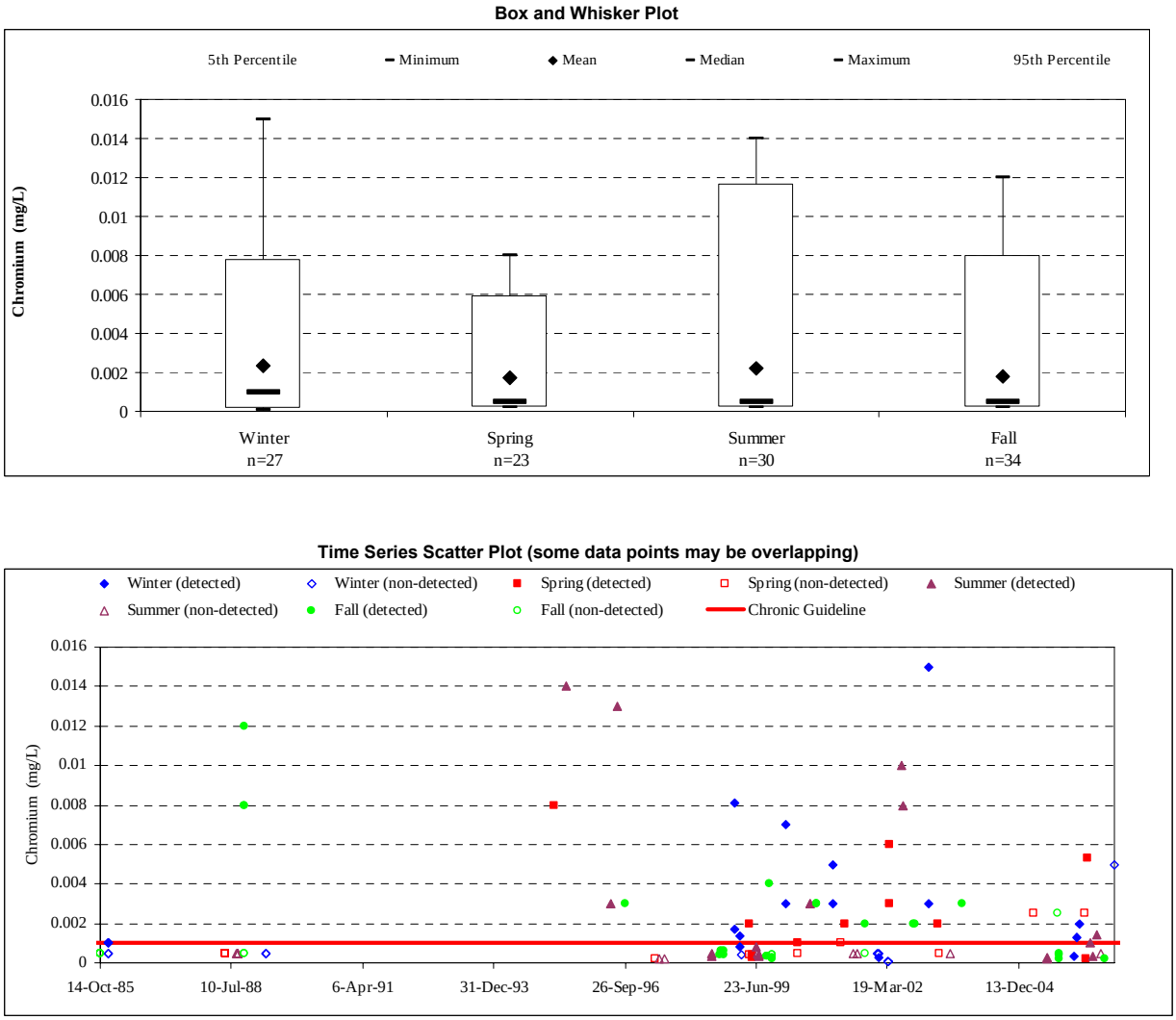
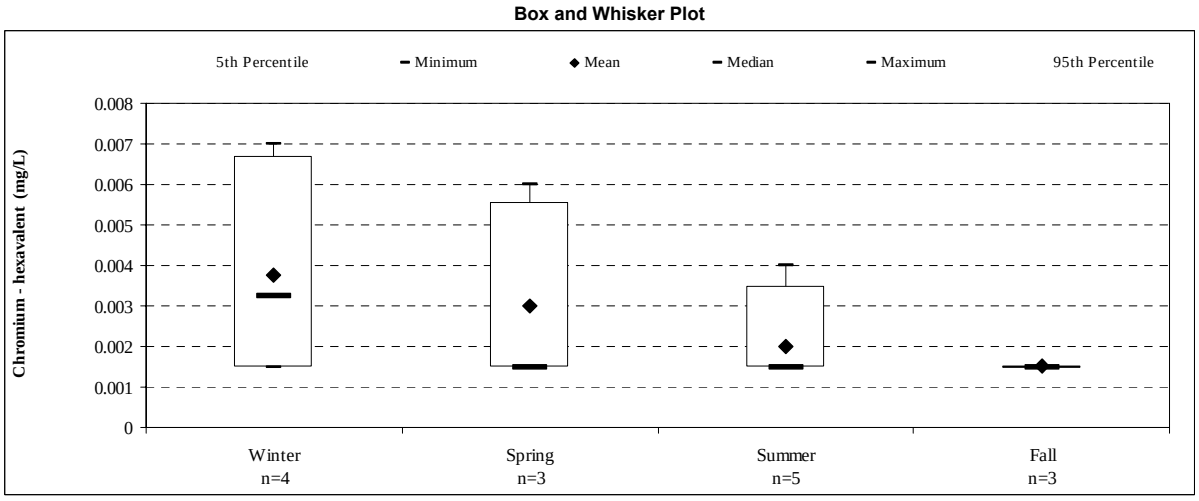


Figure G-2-2-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Middle Segment of Muskeg River



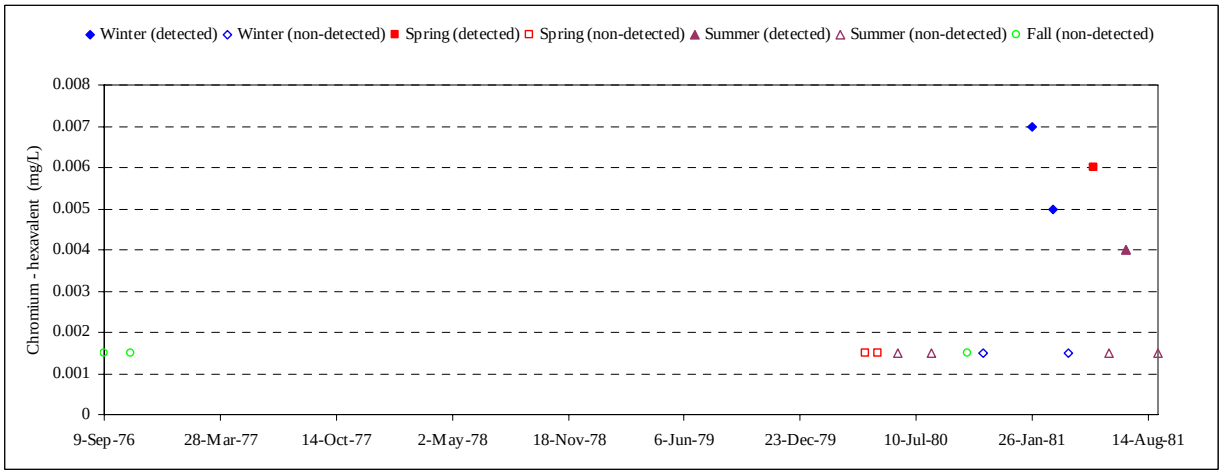
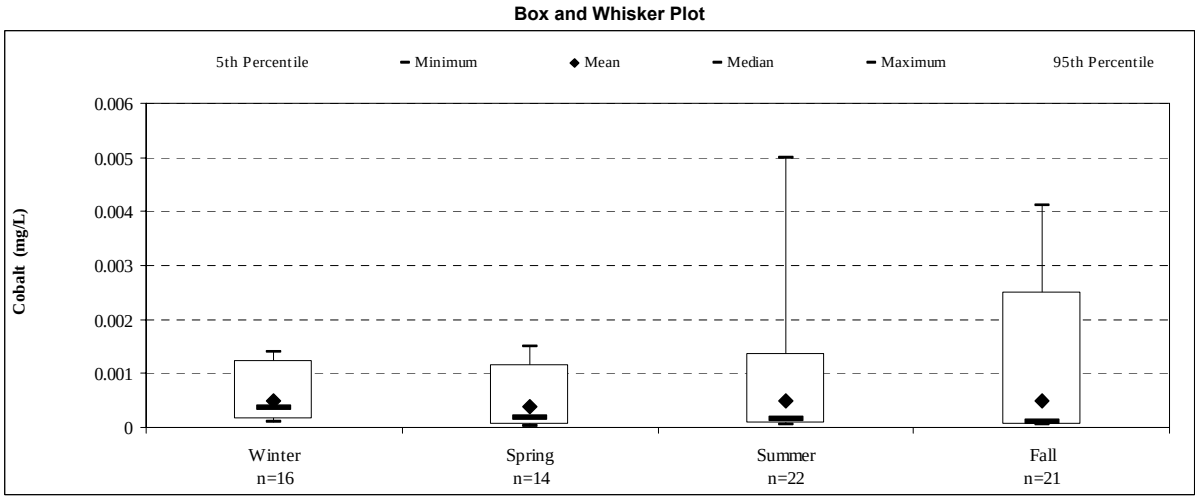


Figure G-2-2-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Middle Segment of Muskeg River



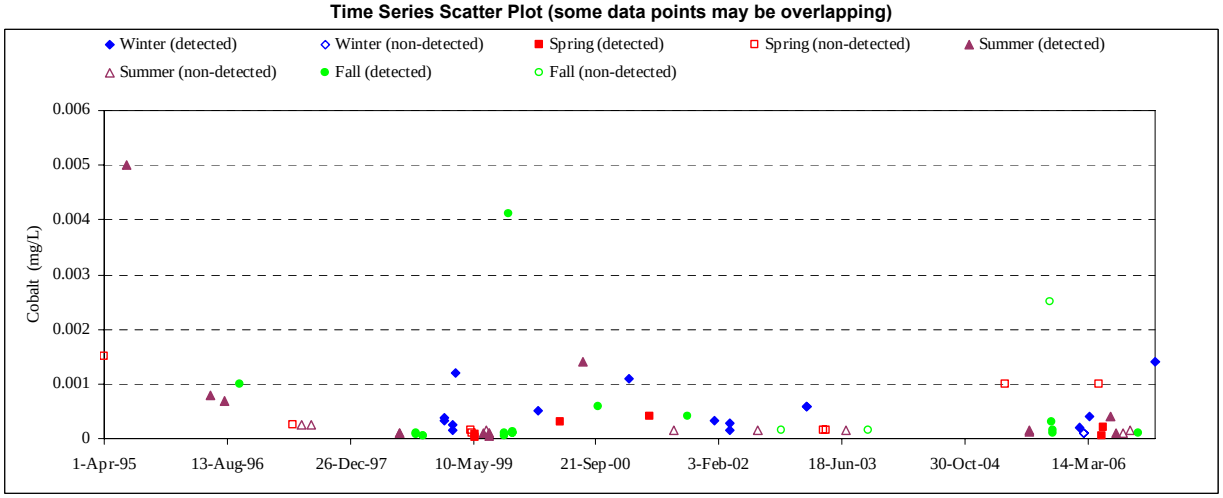


Figure G-2-2-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Middle Segment of Muskeg River

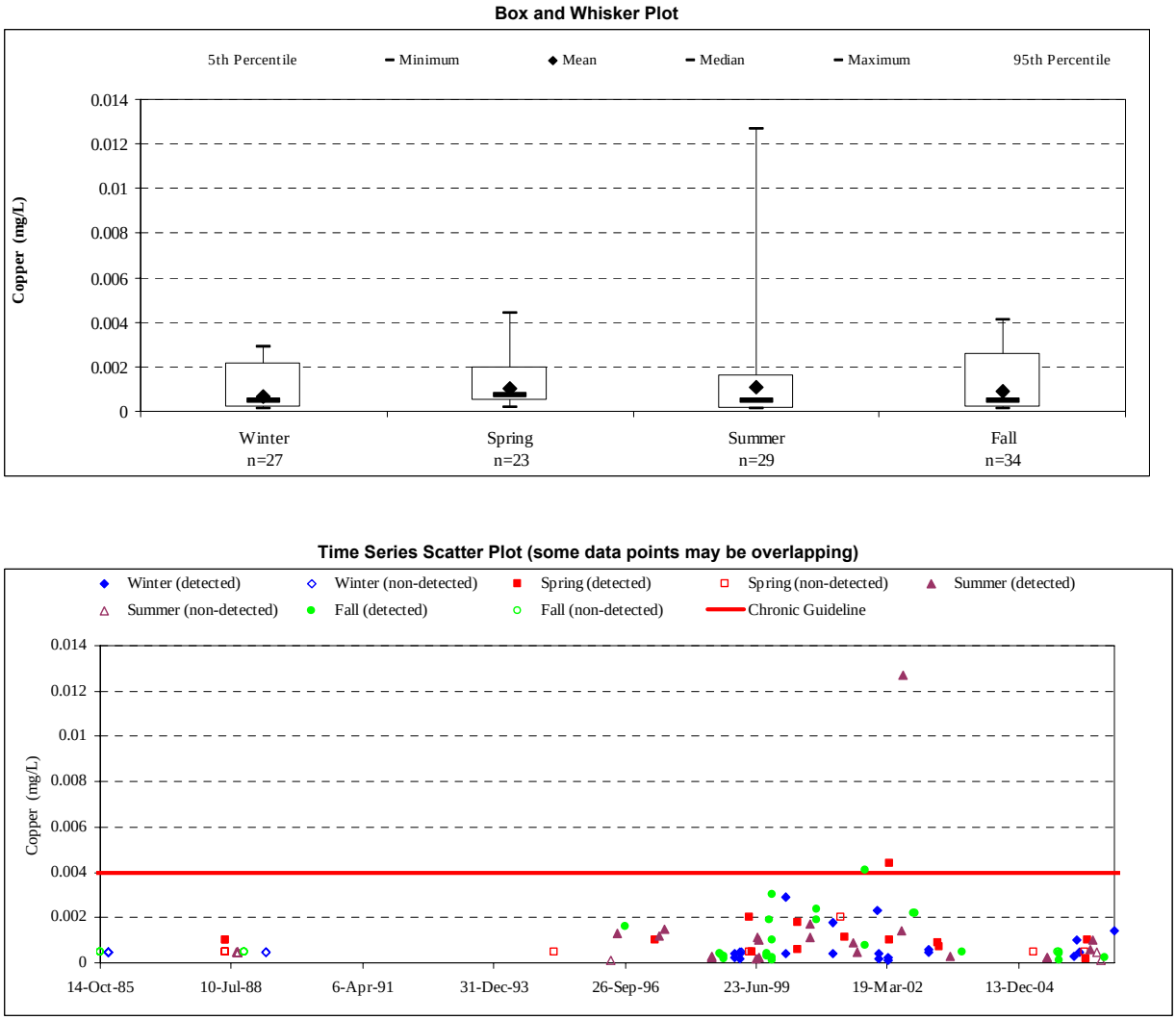
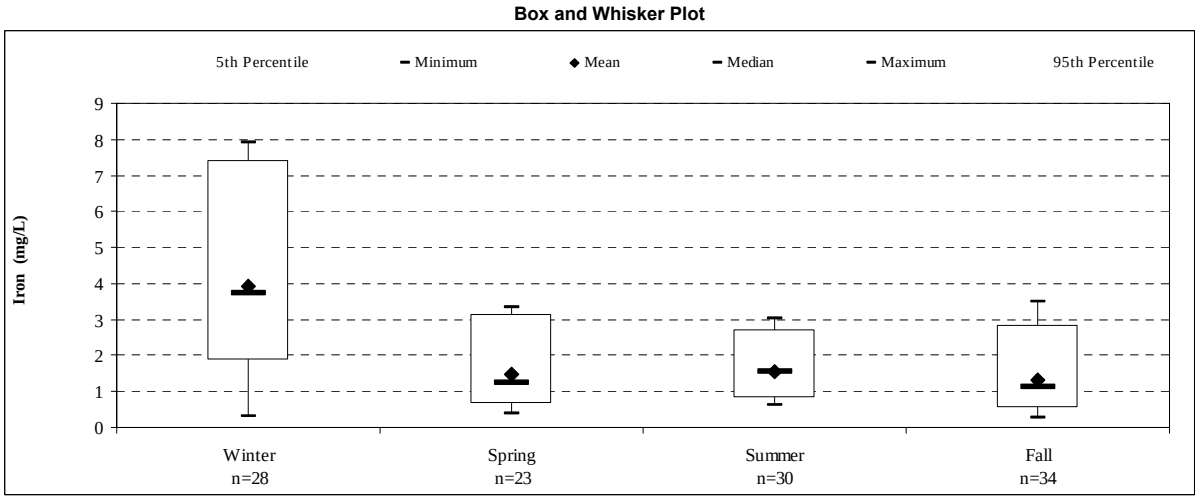


Figure G-2-2-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Middle Segment of Muskeg River



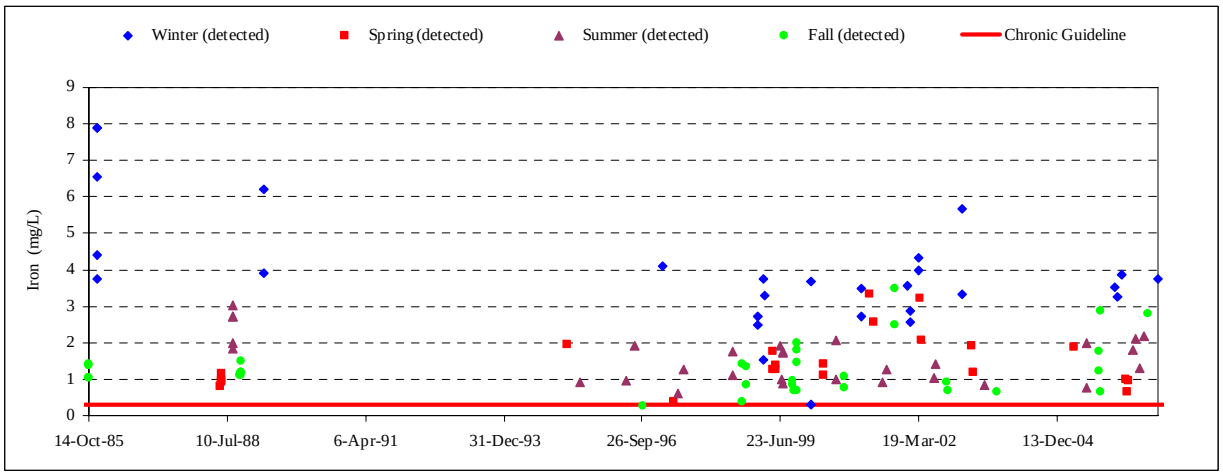
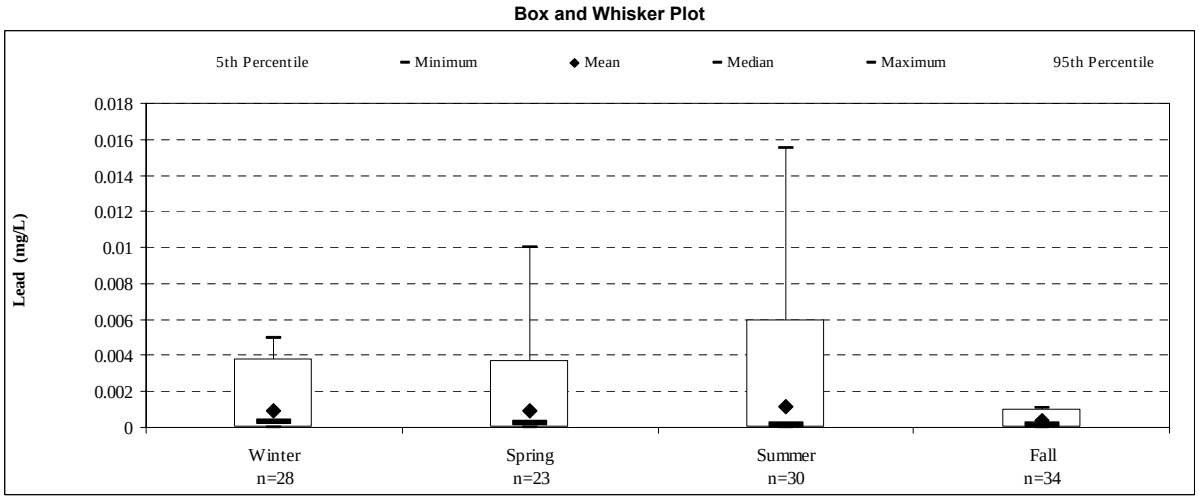


Figure G-2-2-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Middle Segment of Muskeg River



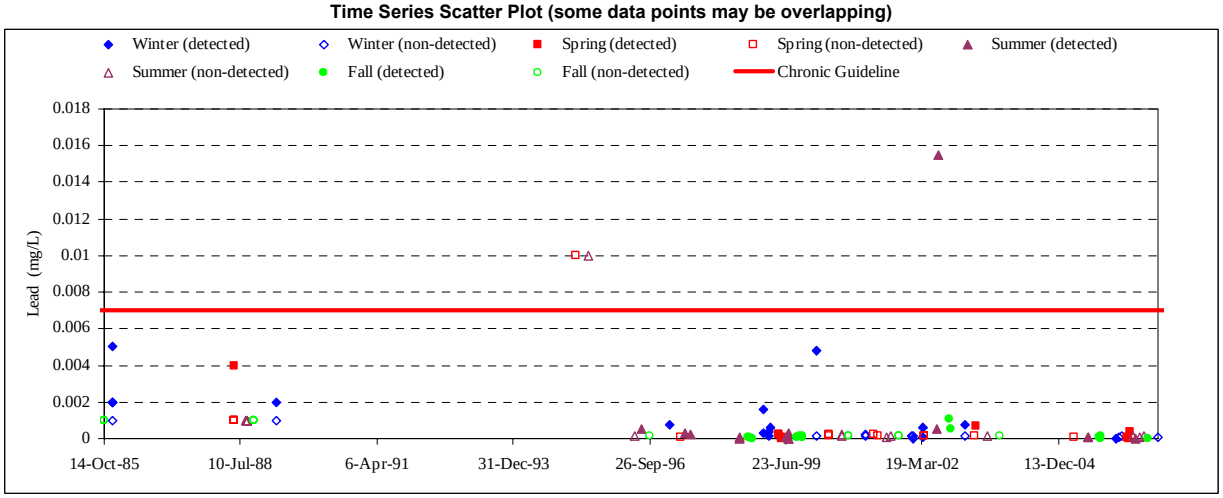
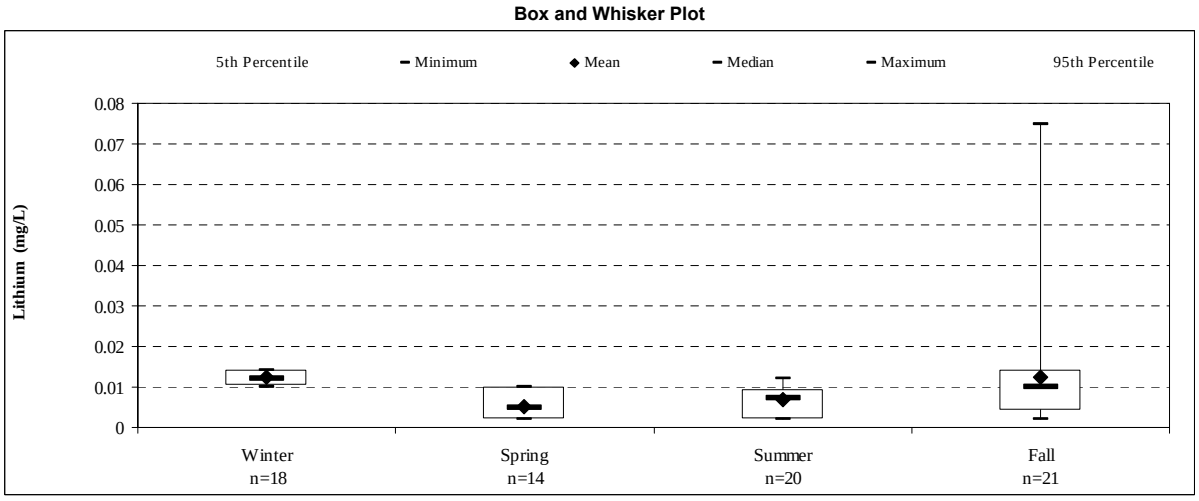


Figure G-2-2-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Middle Segment of Muskeg River



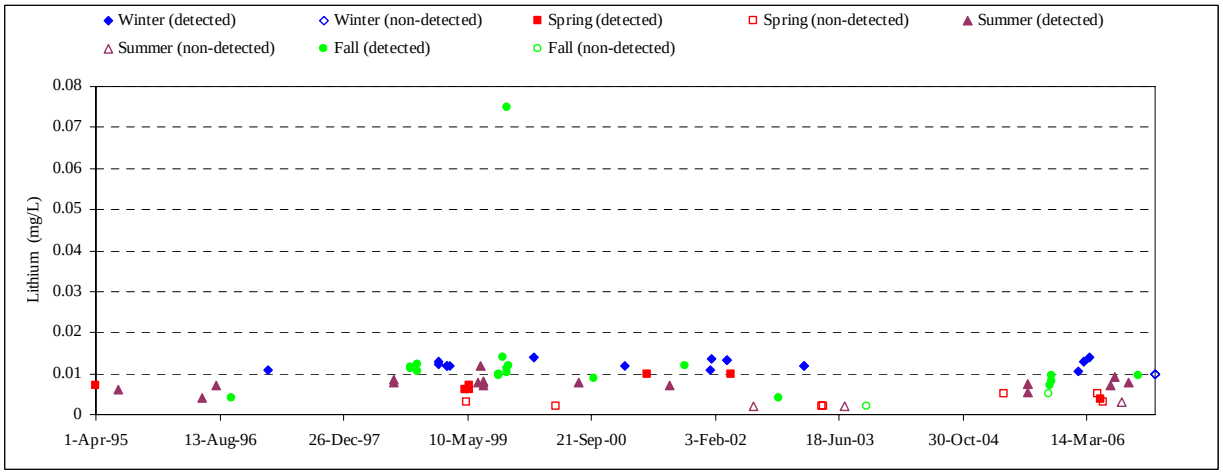


Figure G-2-2-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Middle Segment of Muskeg River

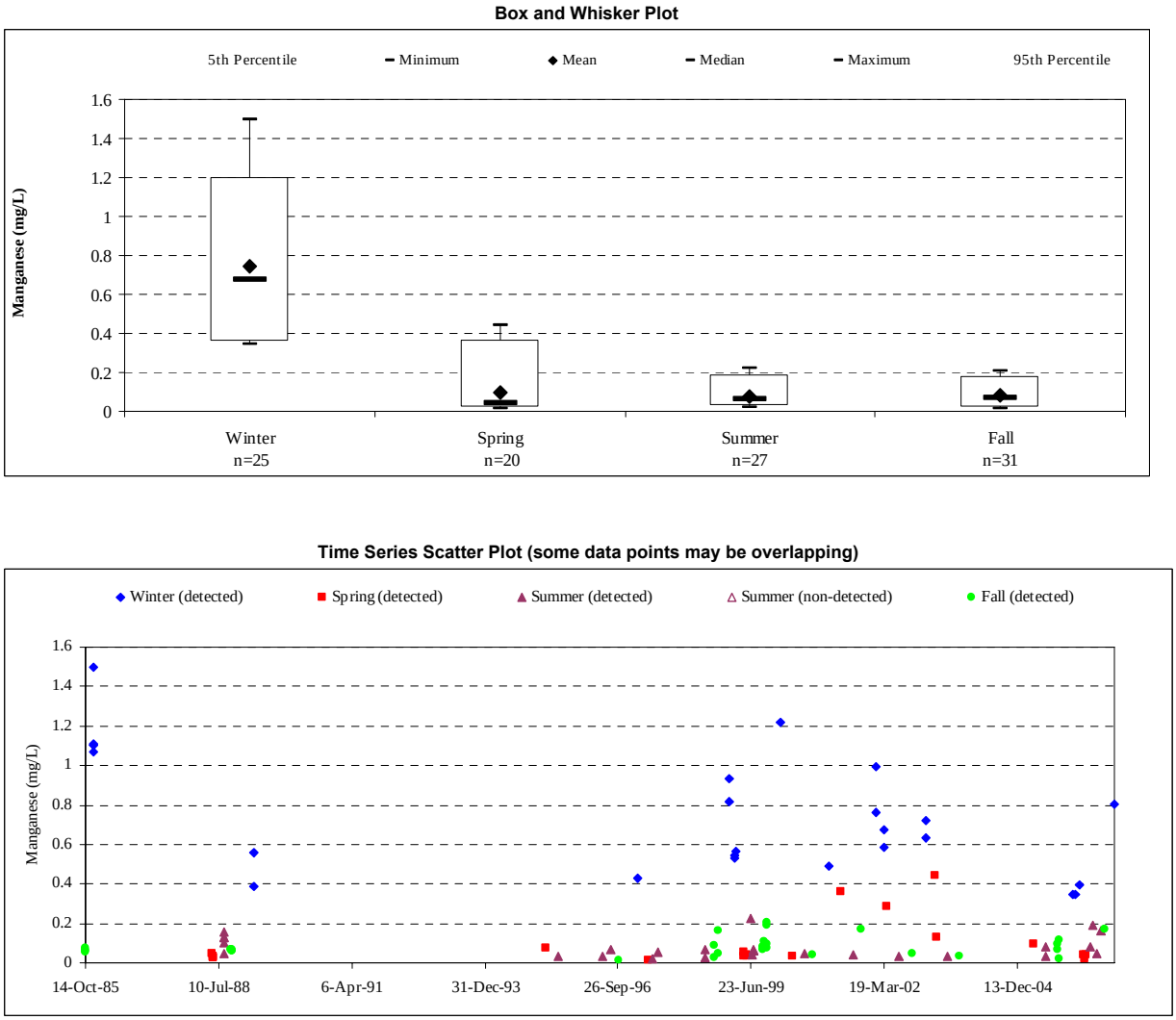
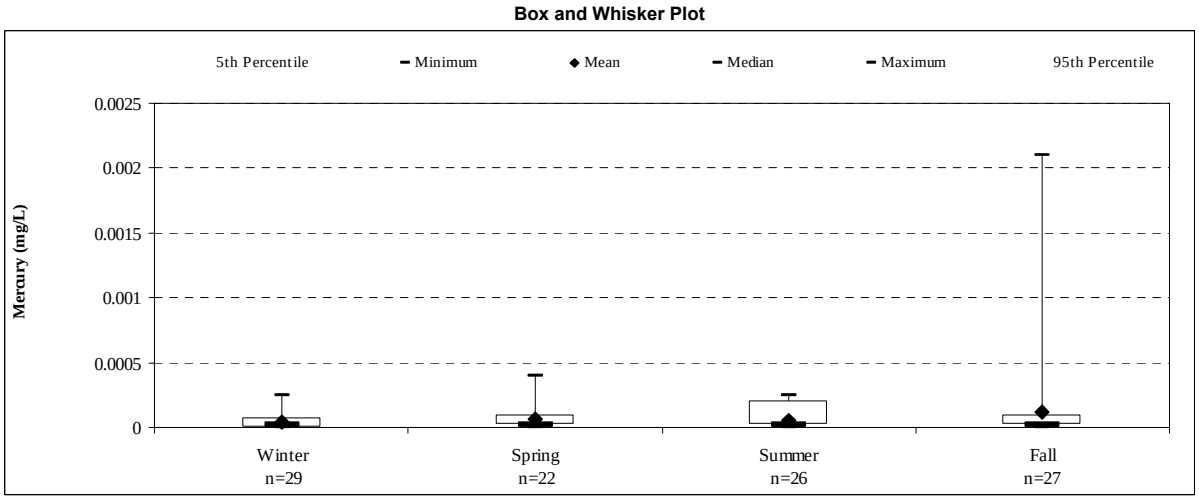


Figure G-2-2-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Middle Segment of Muskeg River



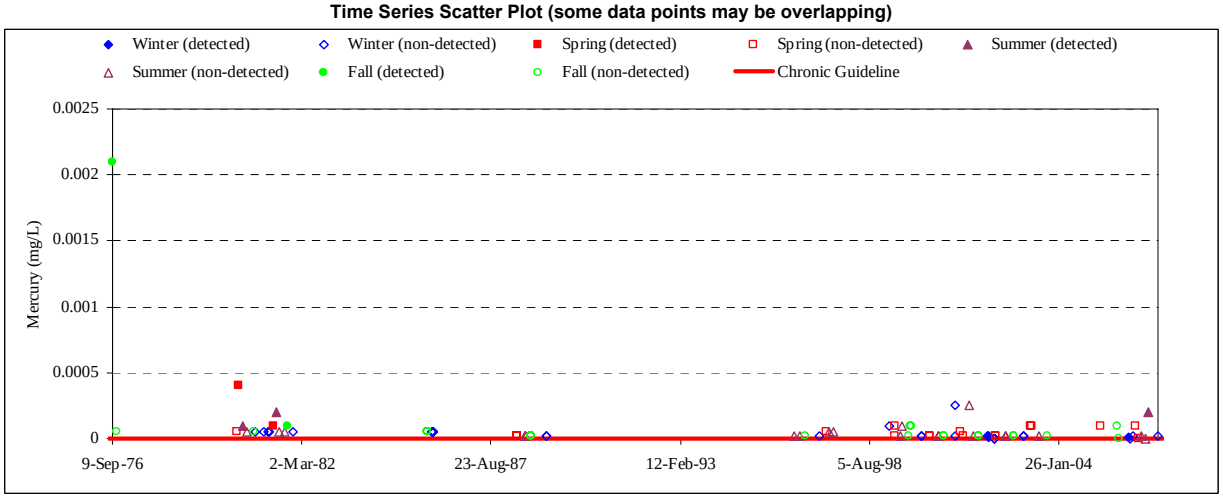
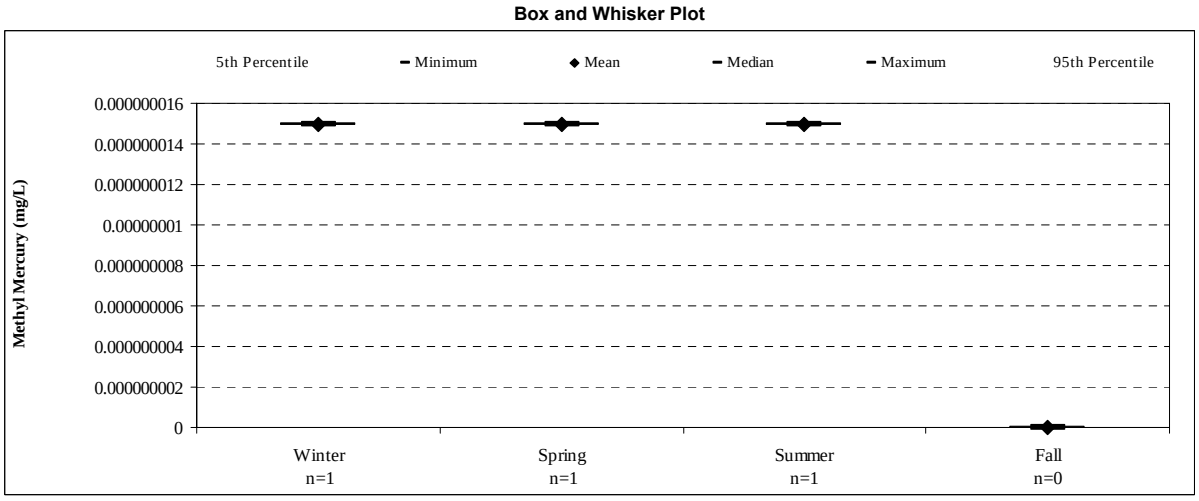


Figure G-2-2-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Middle Segment of Muskeg River



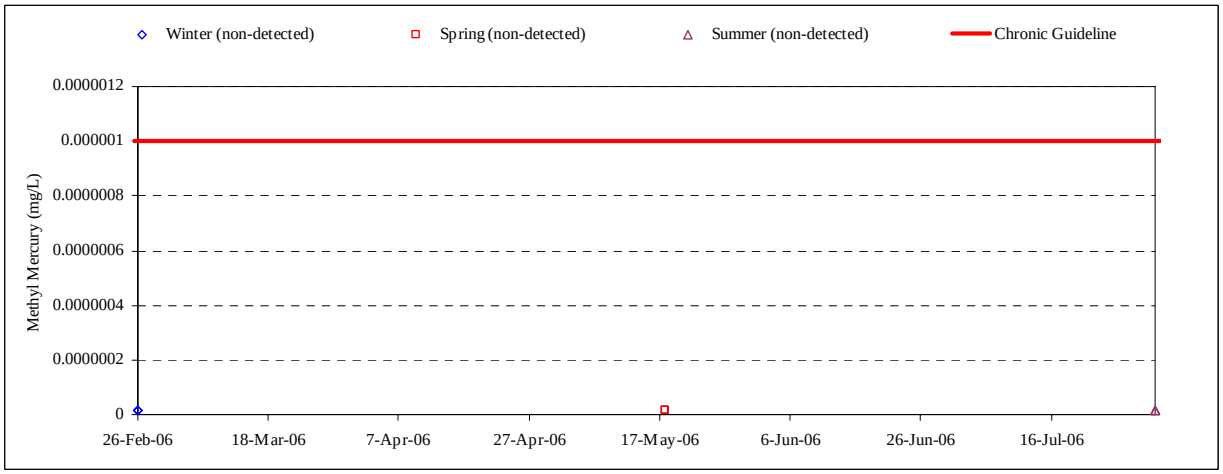
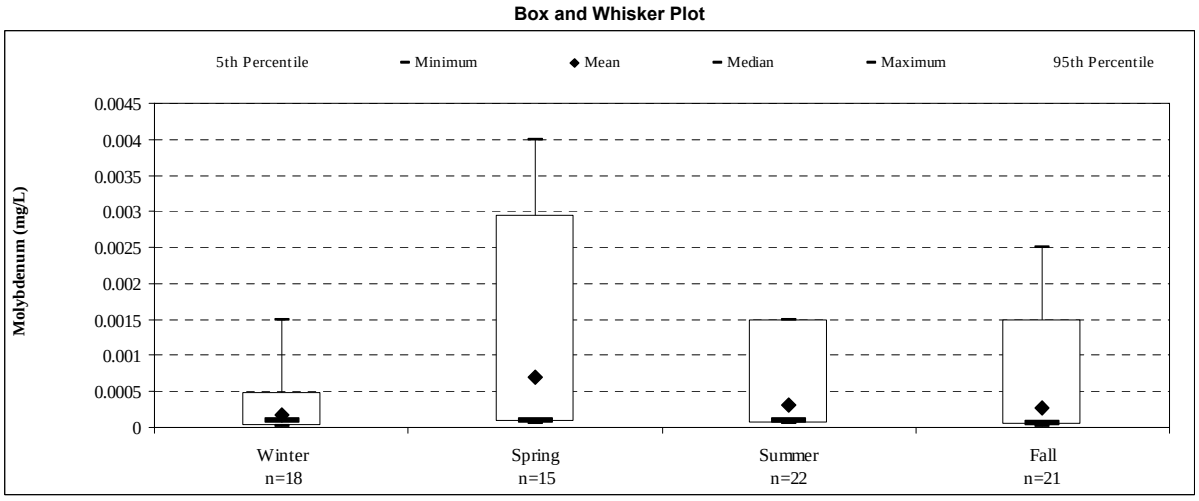


Figure G-2-2-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Middle Segment of Muskeg River



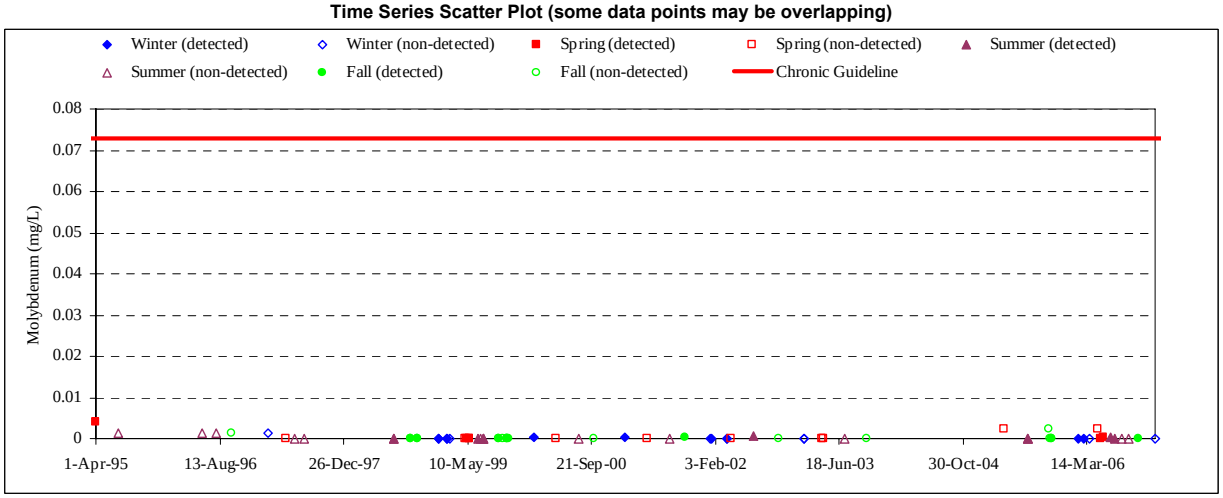


Figure G-2-2-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Middle Segment of Muskeg River

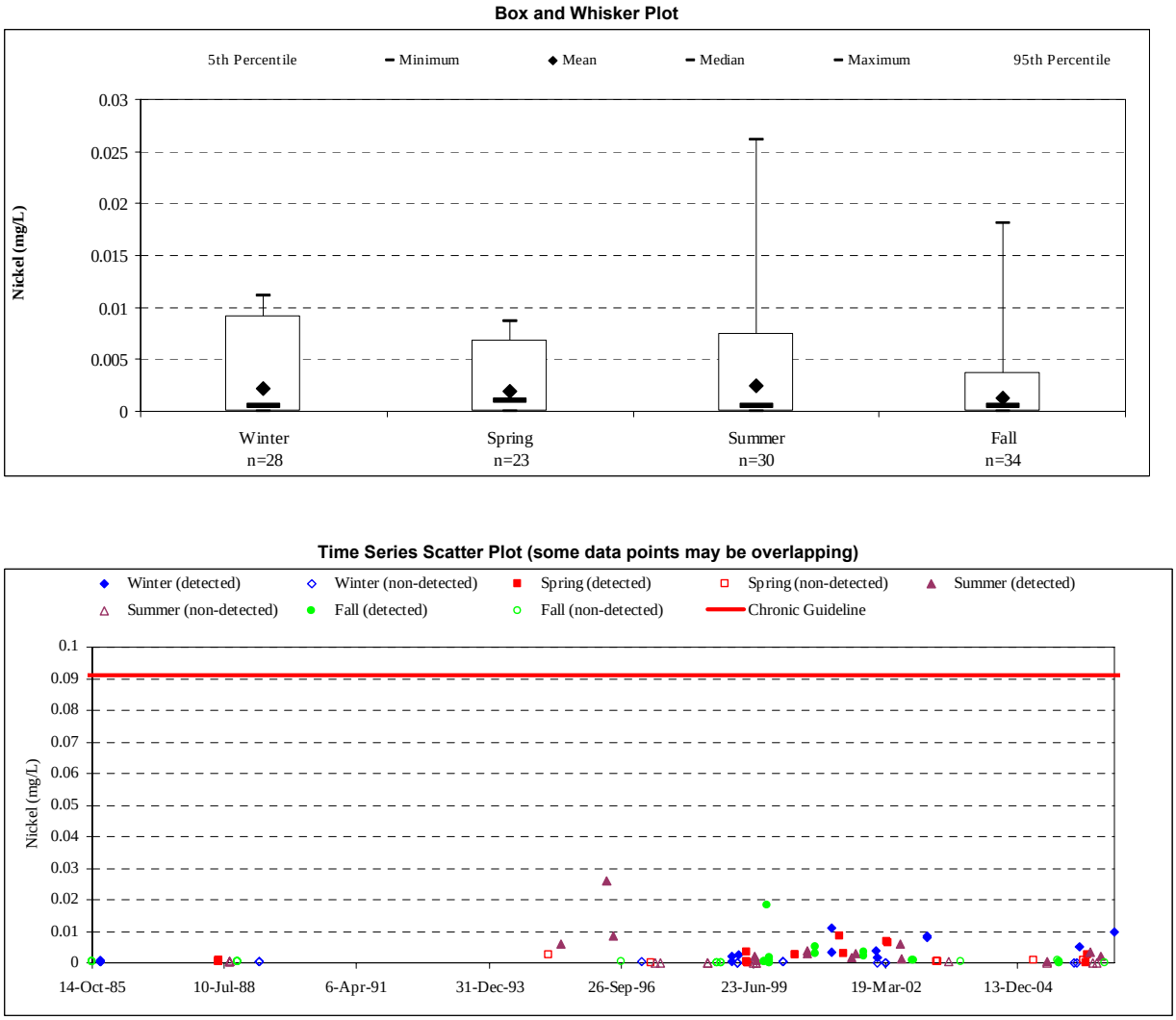
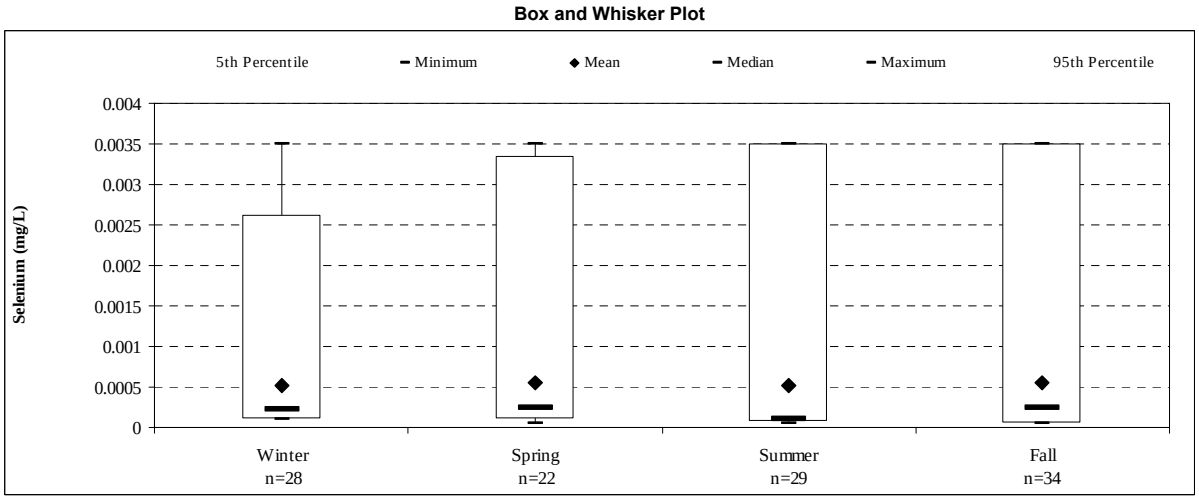


Figure G-2-2-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Middle Segment of Muskeg River



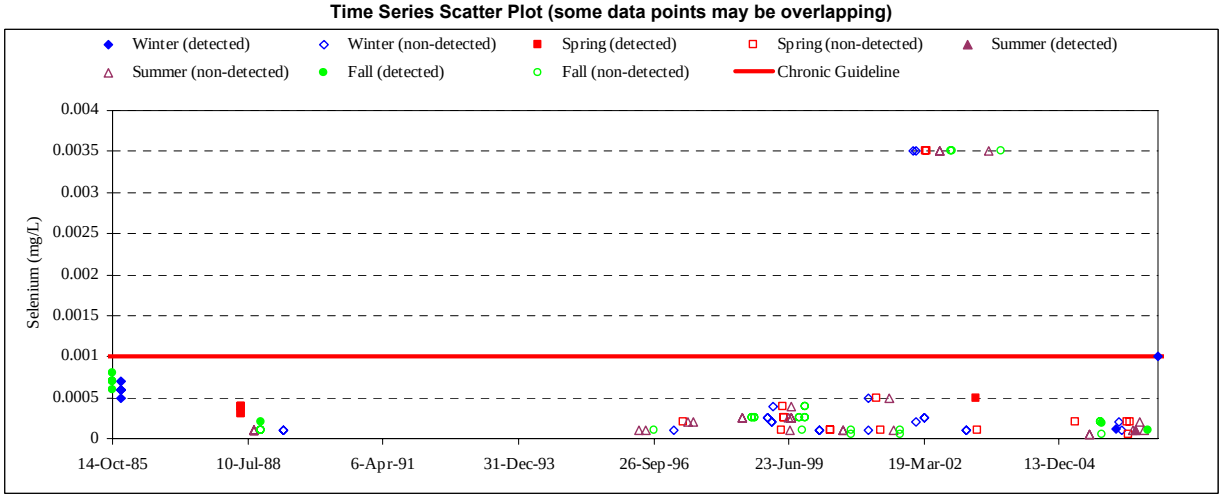
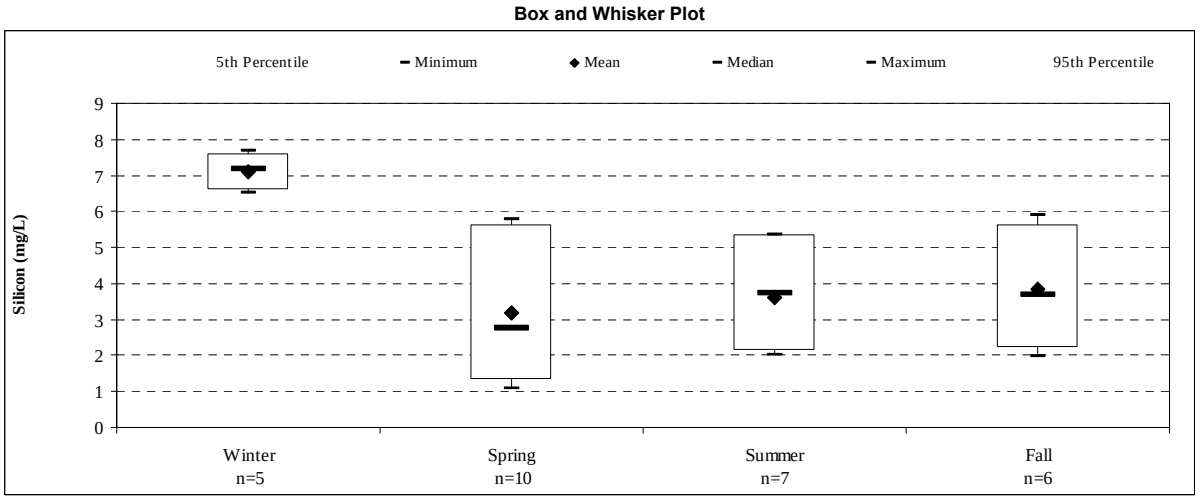


Figure G-2-2-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Middle Segment of Muskeg River



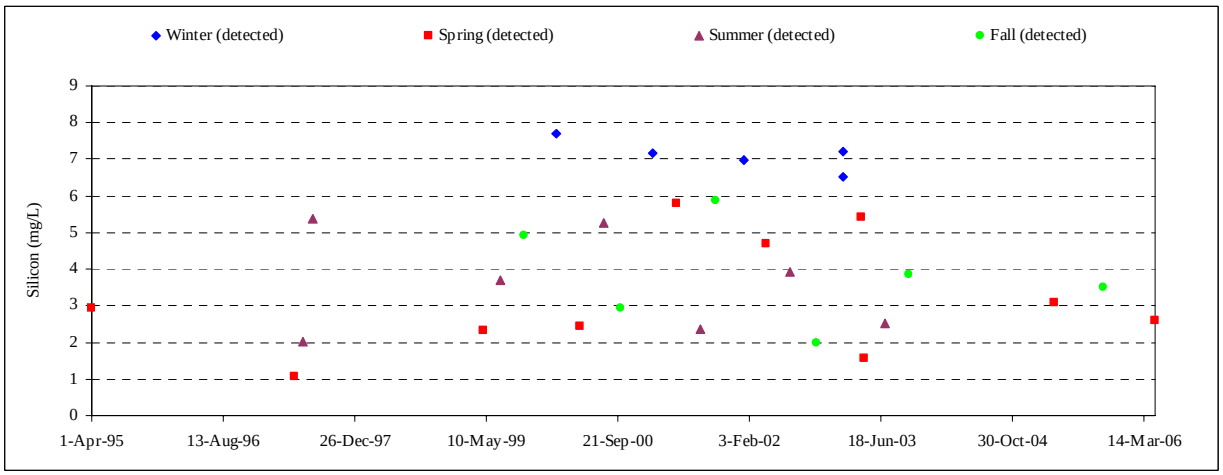
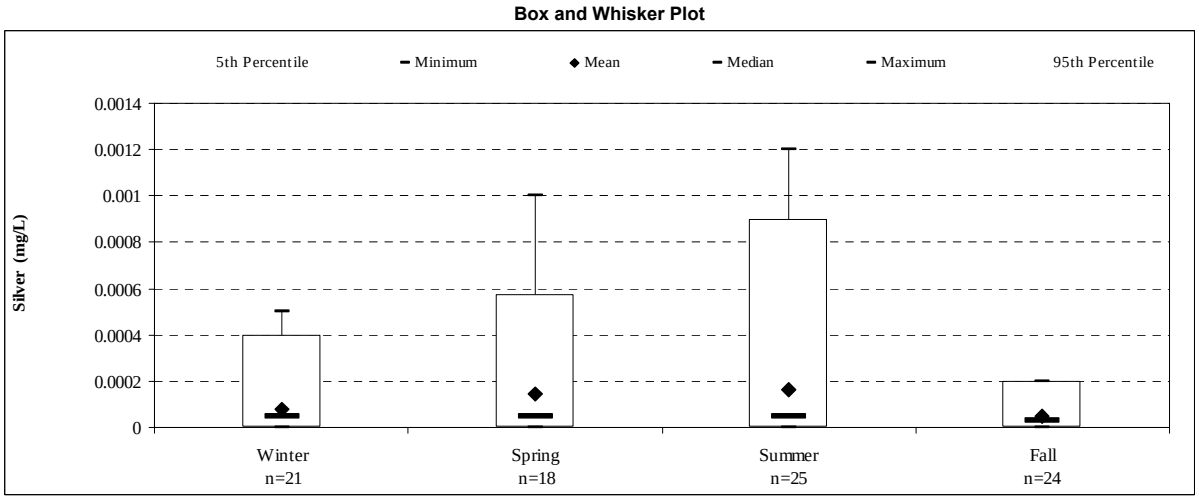


Figure G-2-2-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Middle Segment of Muskeg River



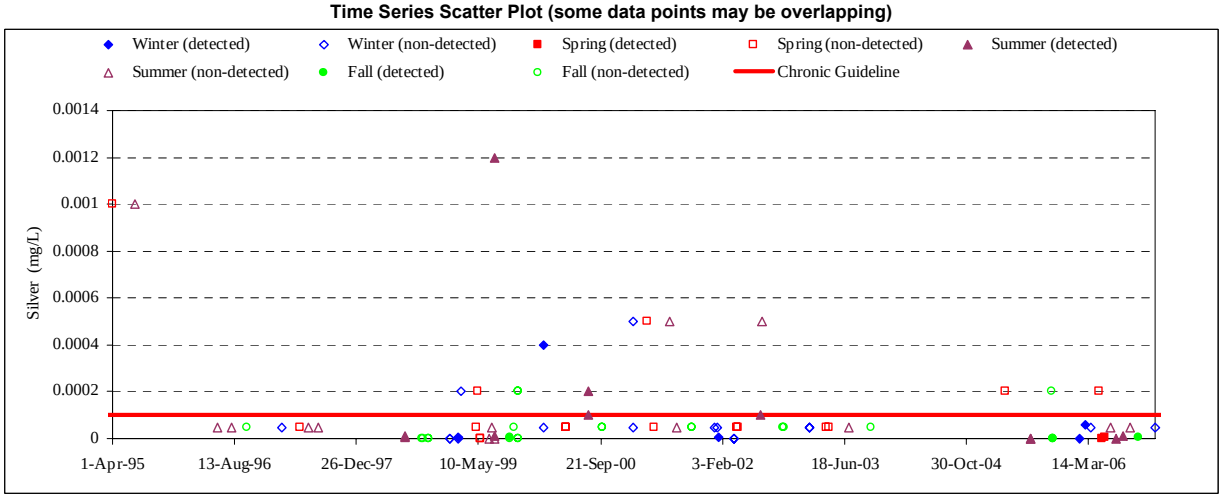
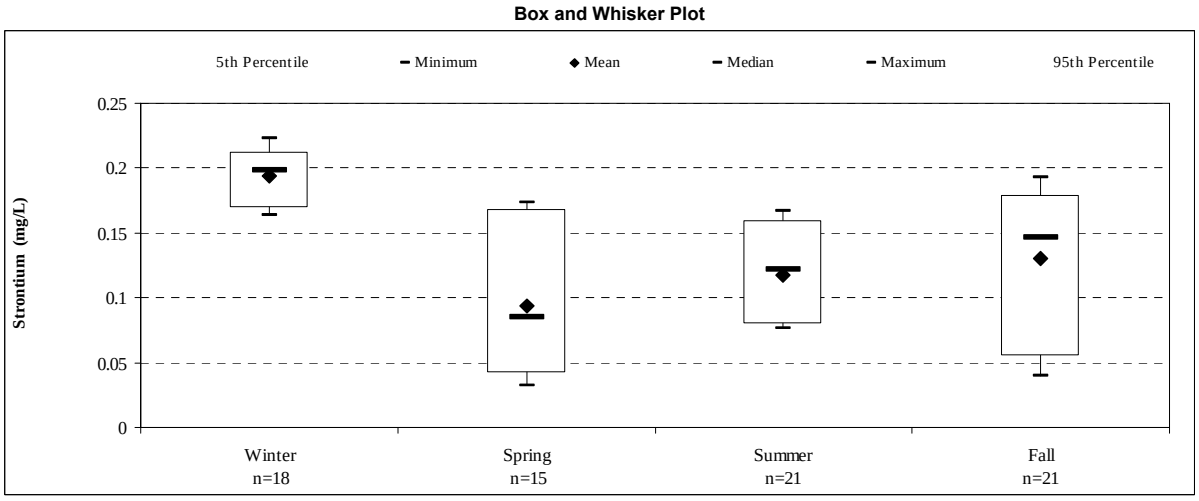


Figure G-2-2-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Middle Segment of Muskeg River



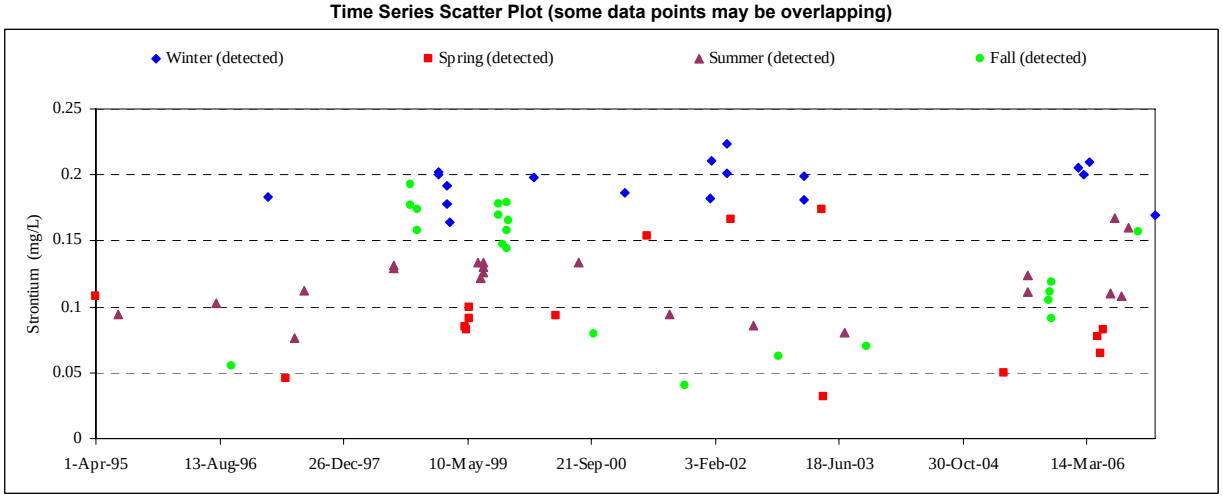
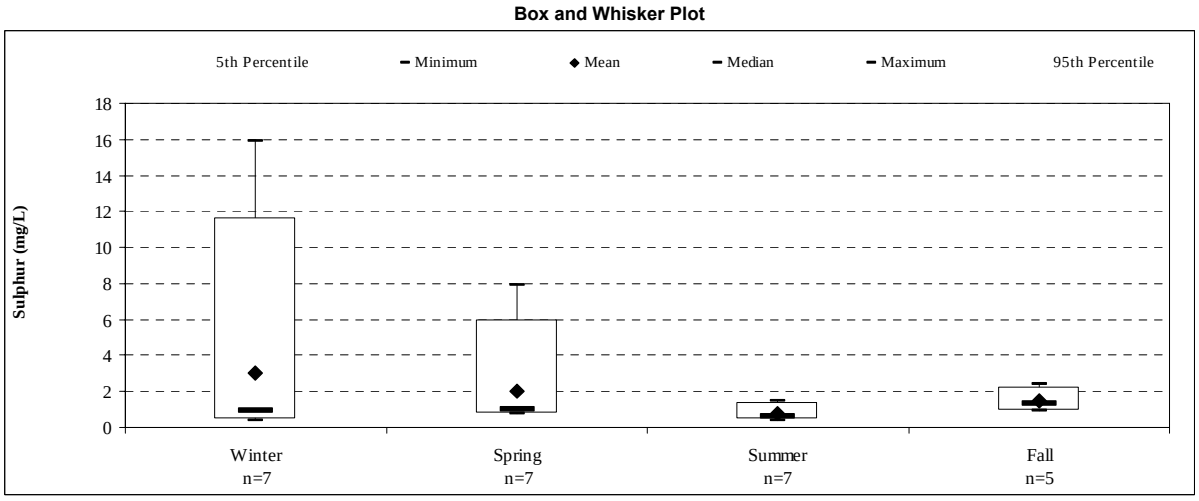


Figure G-2-2-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Middle Segment of Muskeg River



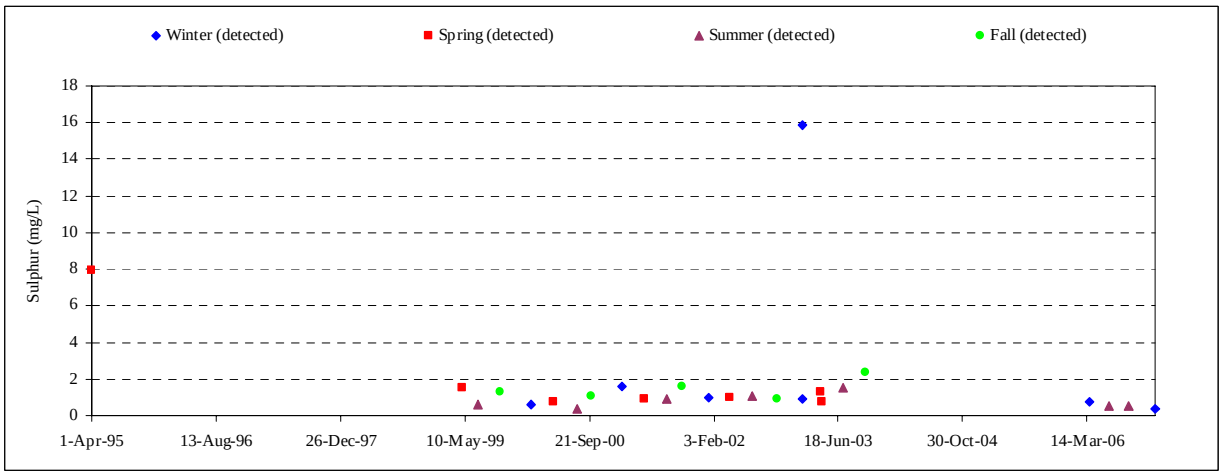


Figure G-2-2-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Middle Segment of Muskeg River

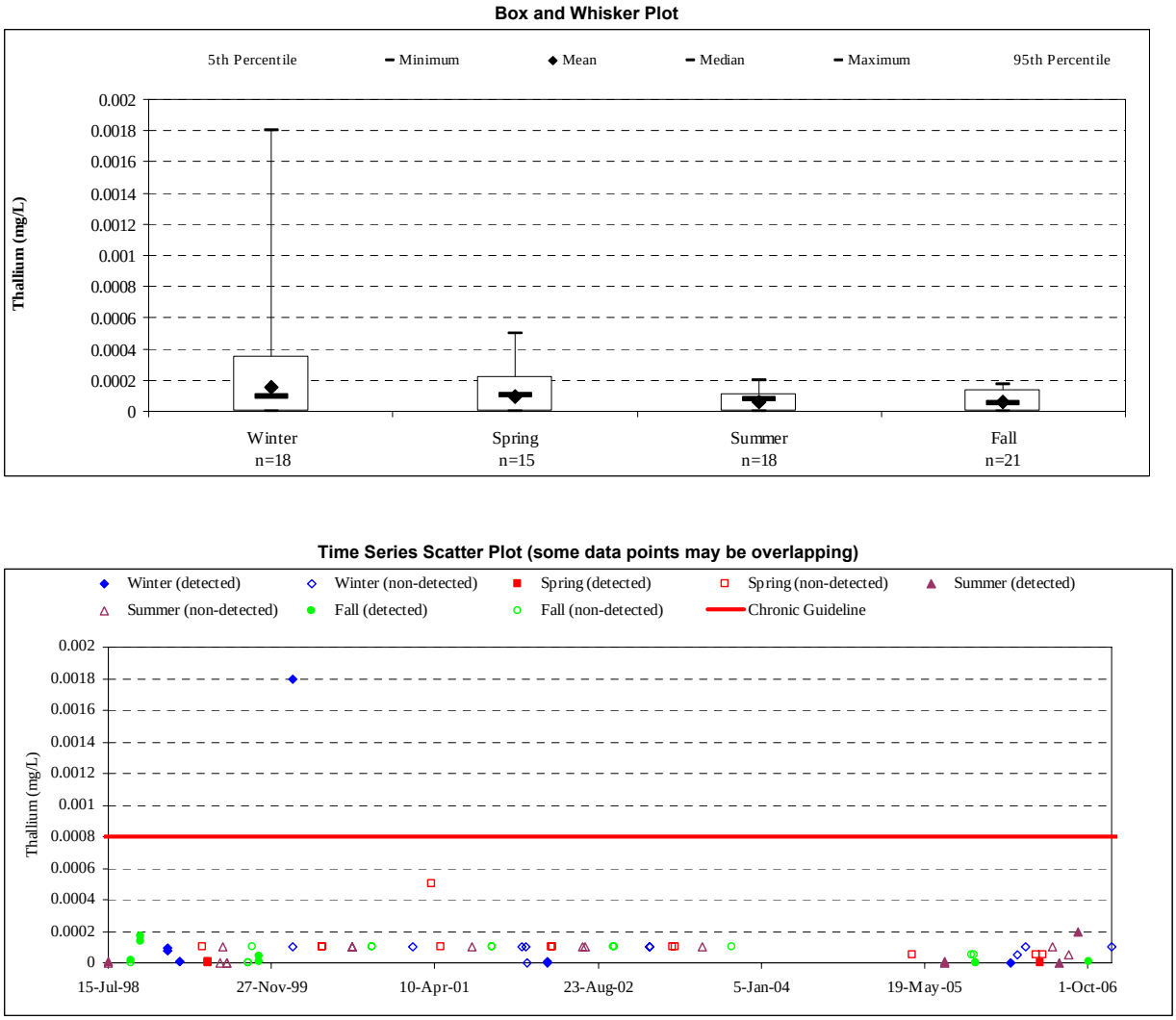
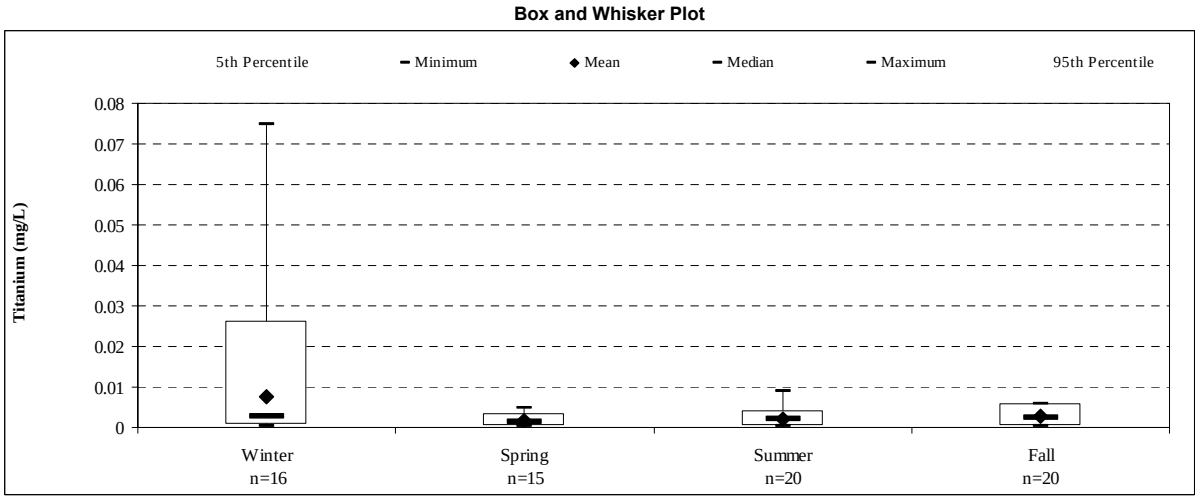


Figure G-2-2-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Middle Segment of Muskeg River



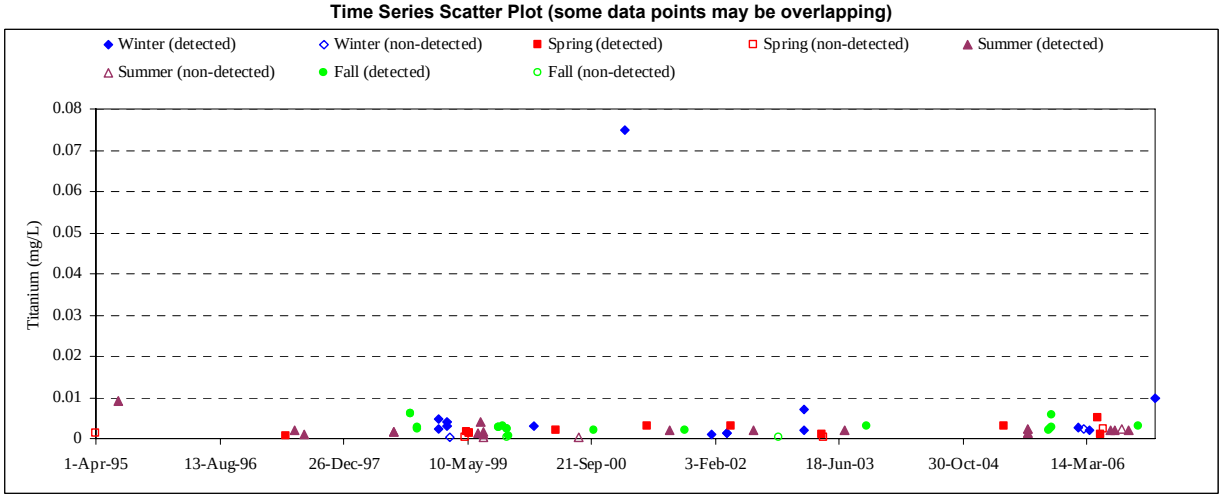
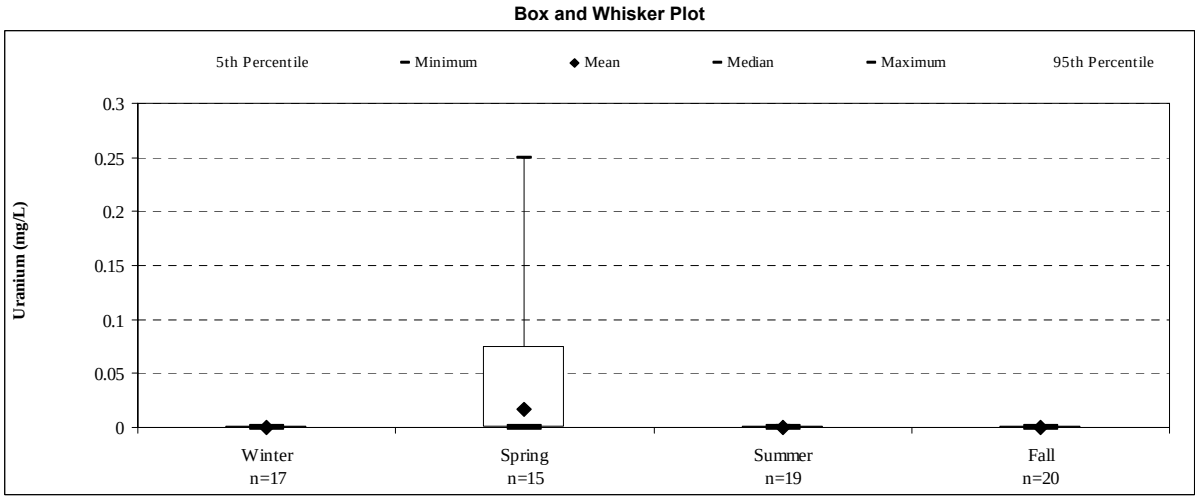


Figure G-2-2-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Middle Segment of Muskeg River



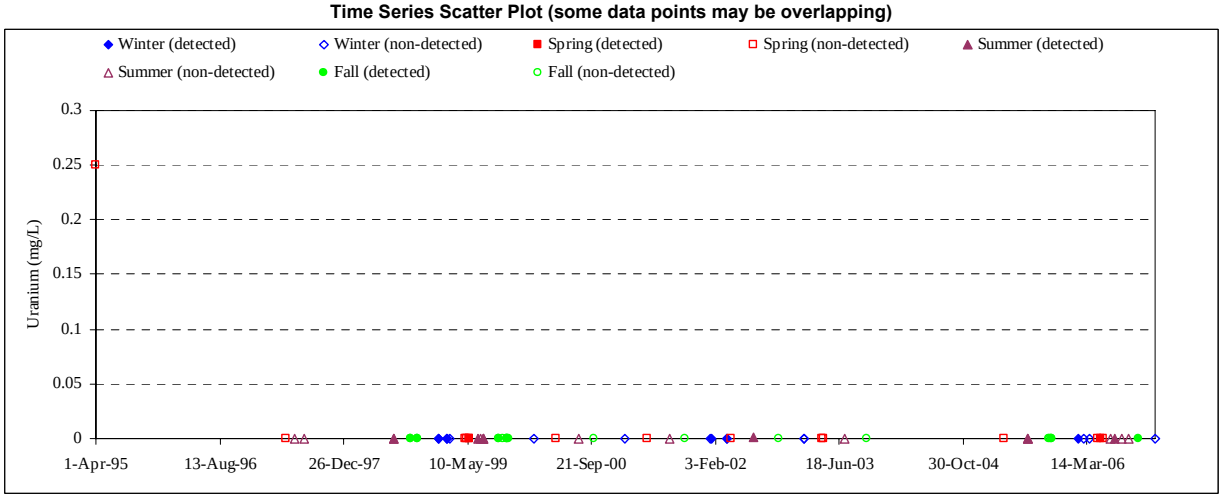
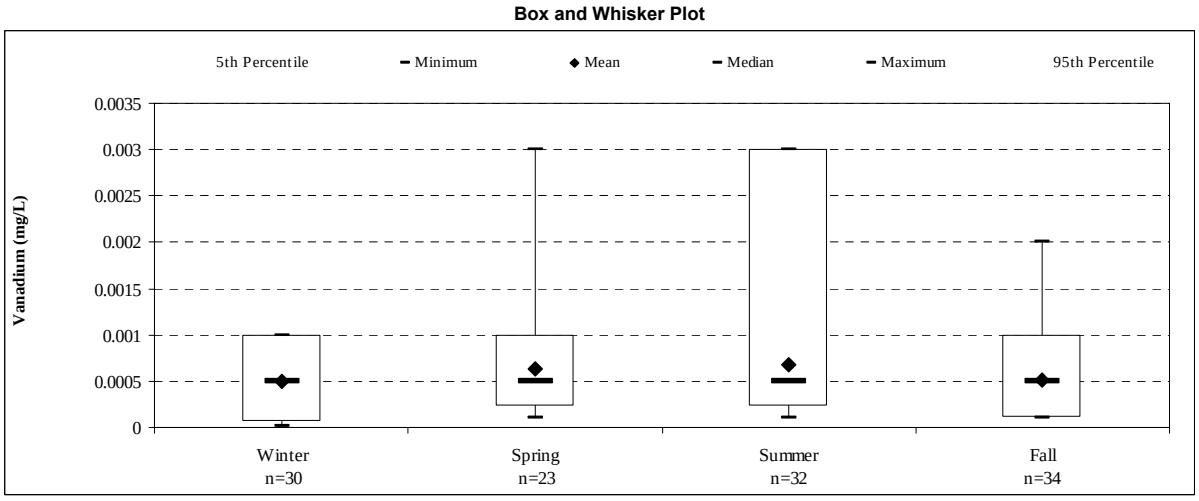


Figure G-2-2-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Middle Segment of Muskeg River



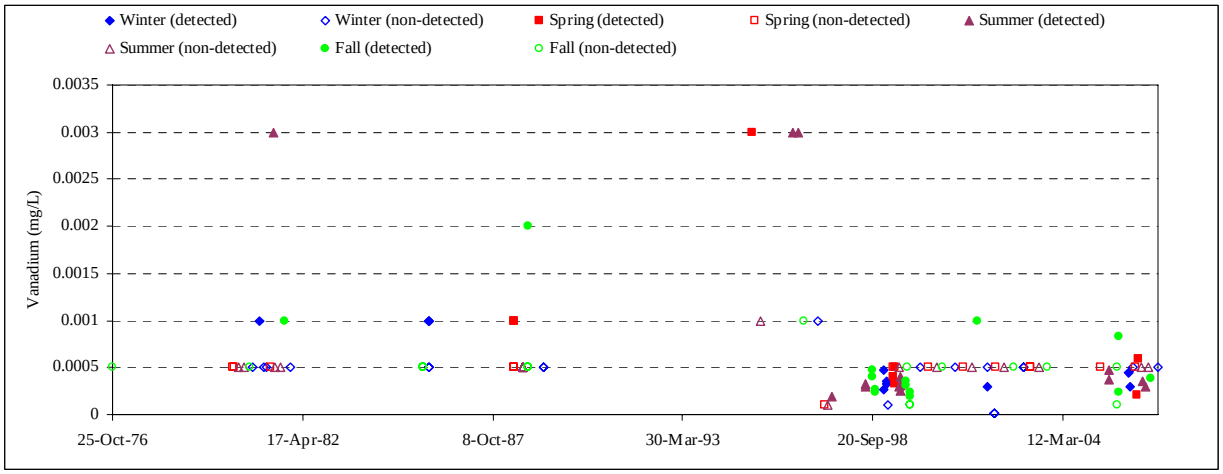
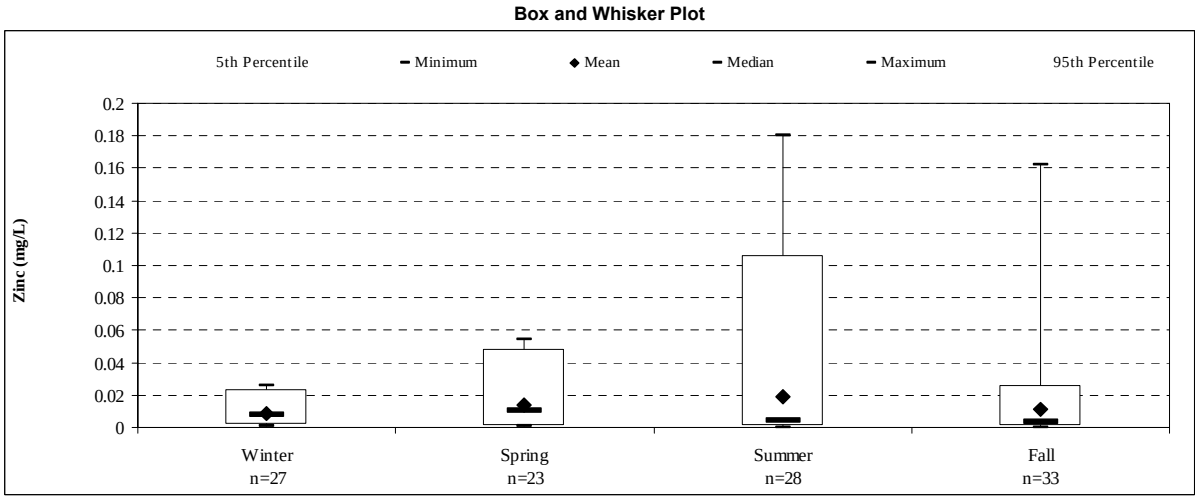


Figure G-2-2-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Middle Segment of Muskeg River



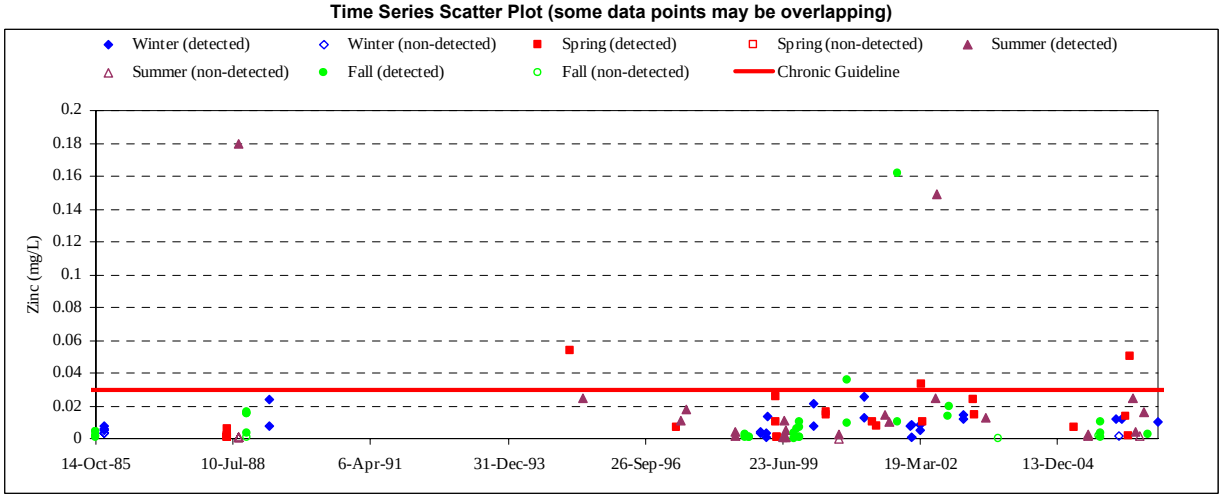
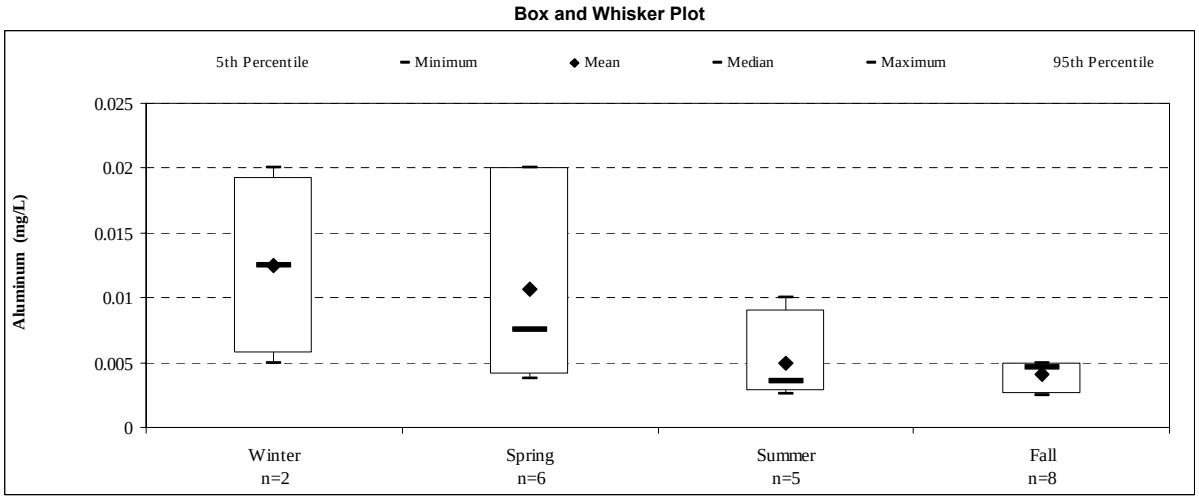


Figure G-2-2-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Middle Segment of Muskeg River



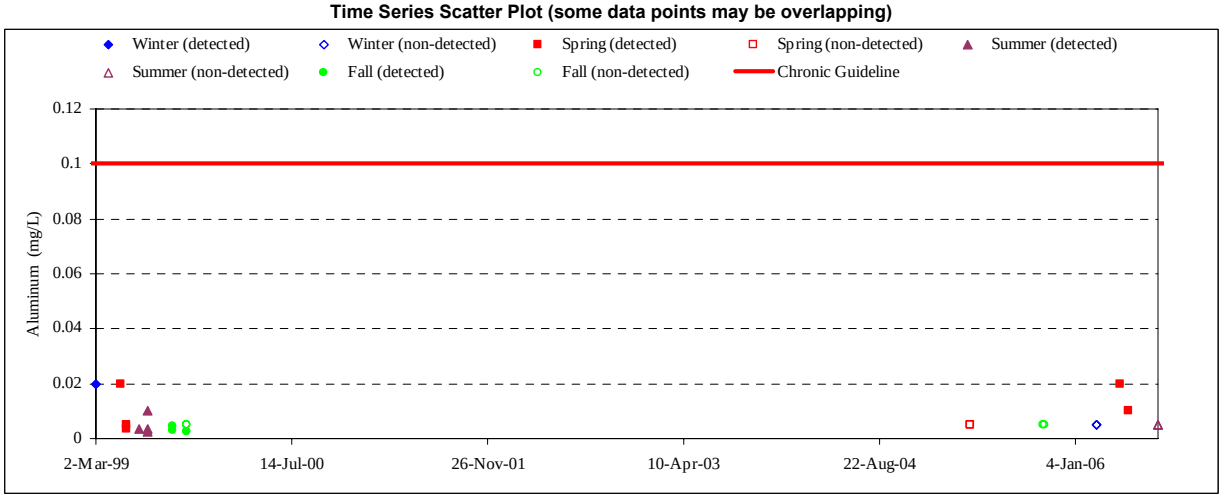
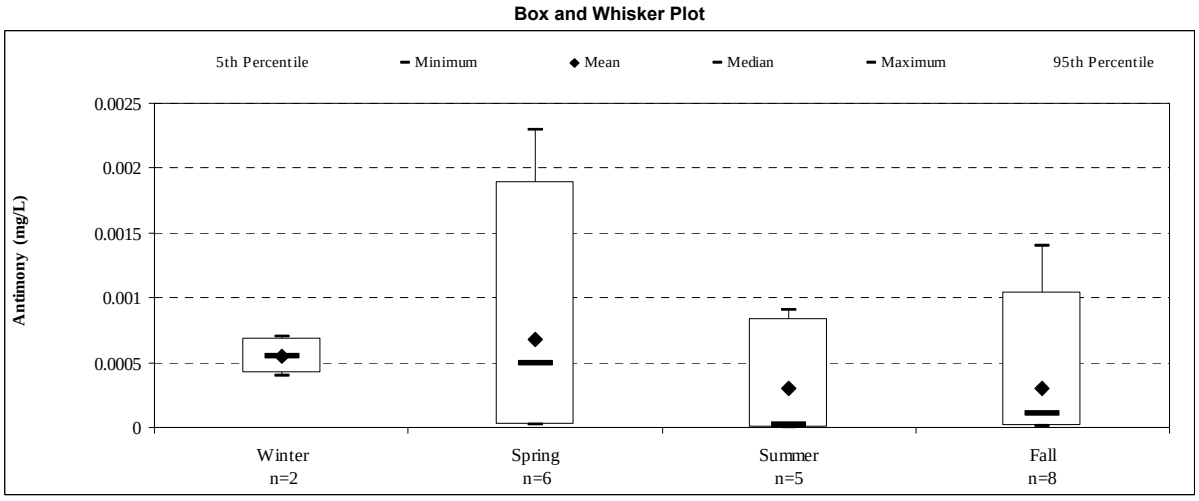


Figure G-2-2-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Middle Segment of Muskeg River



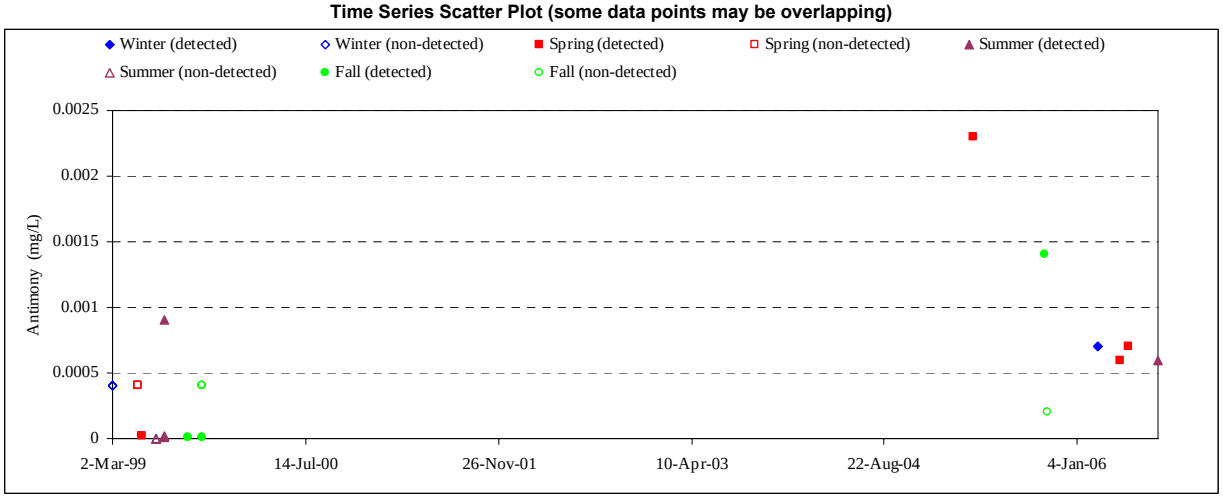
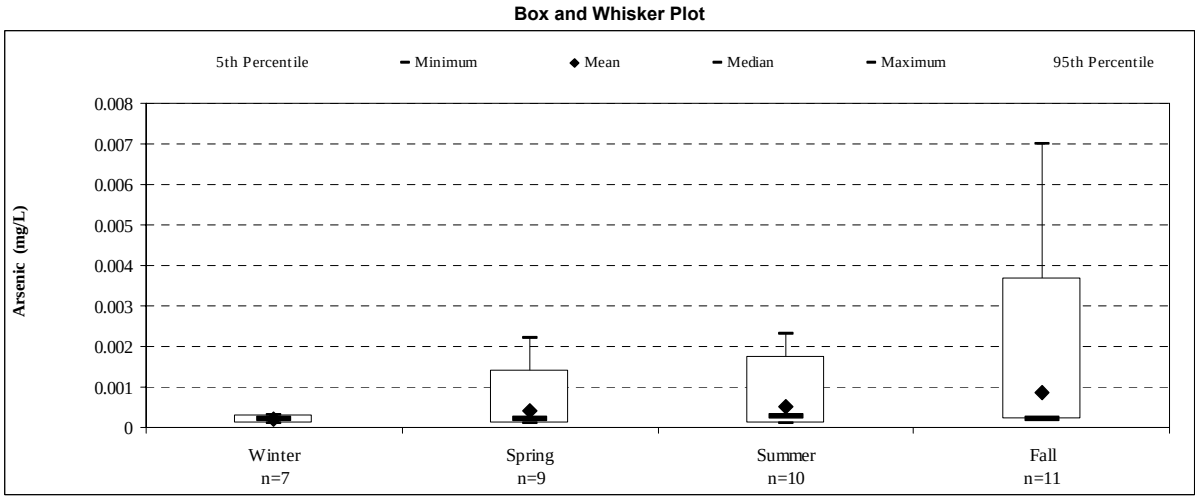


Figure G-2-2-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Middle Segment of Muskeg River



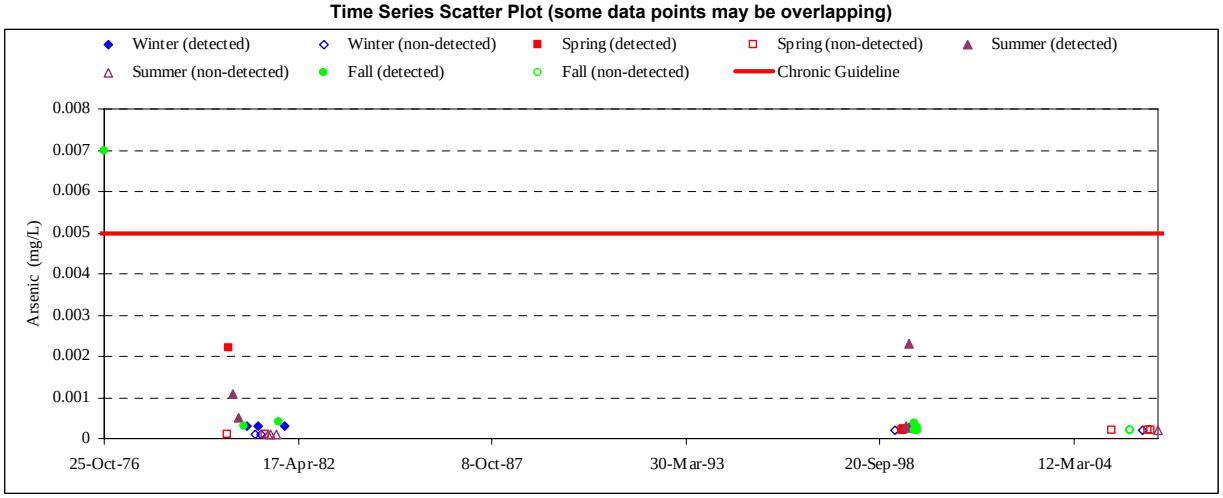
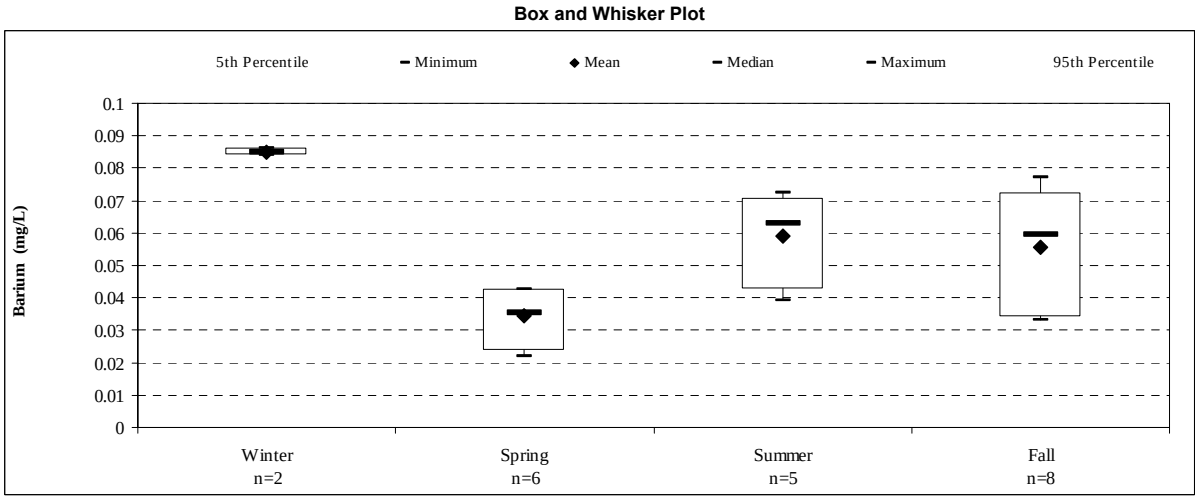


Figure G-2-2-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Middle Segment of Muskeg River



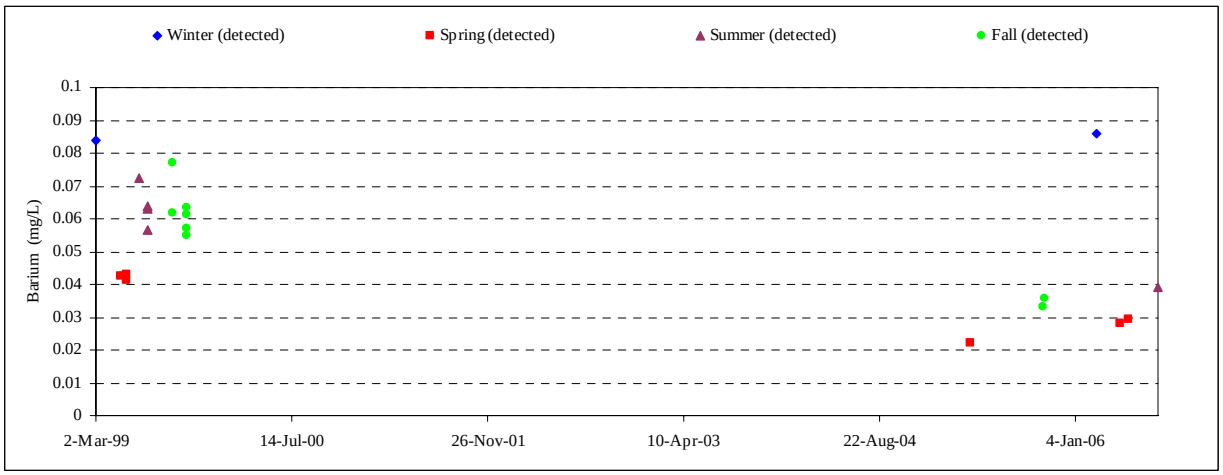
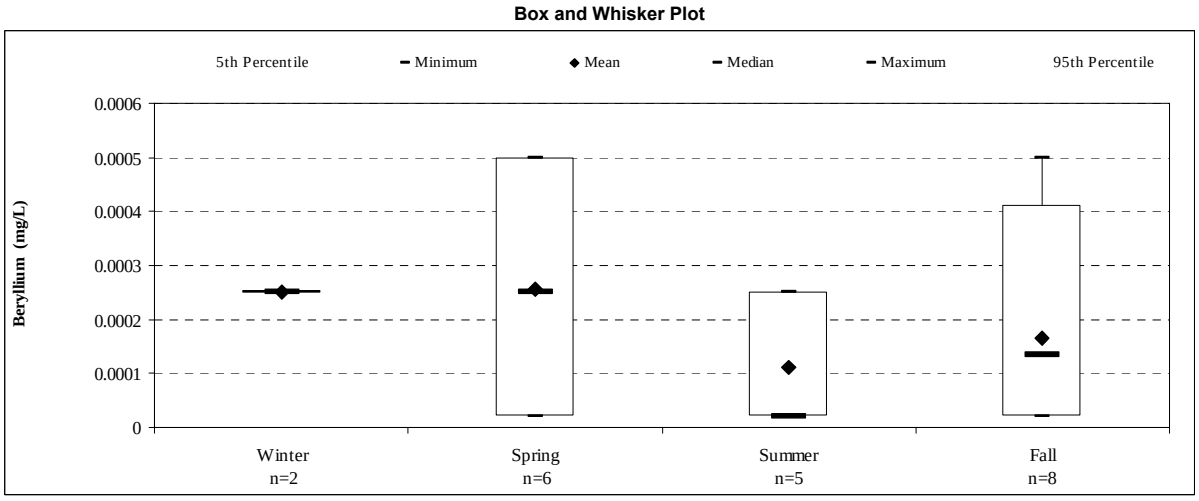


Figure G-2-2-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Middle Segment of Muskeg River



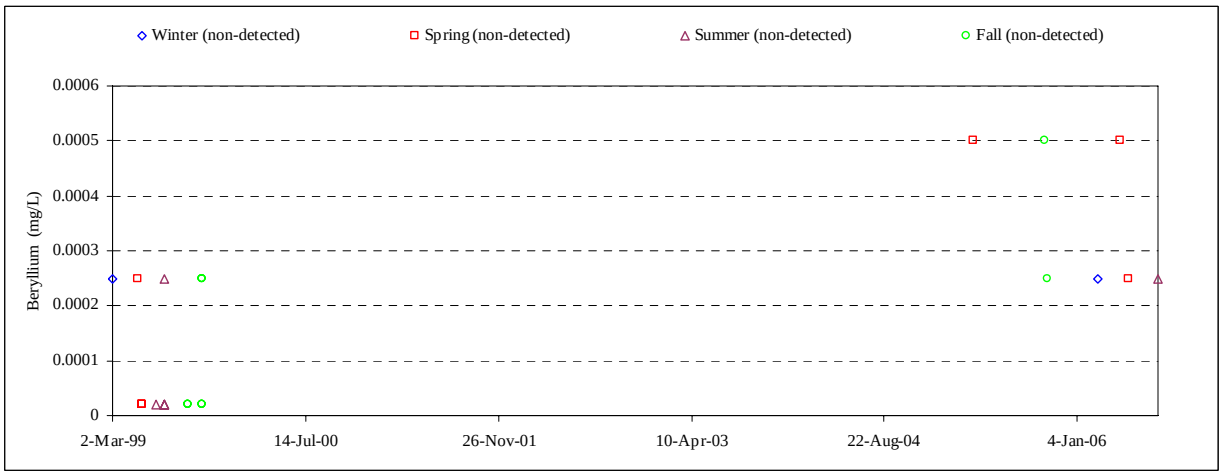
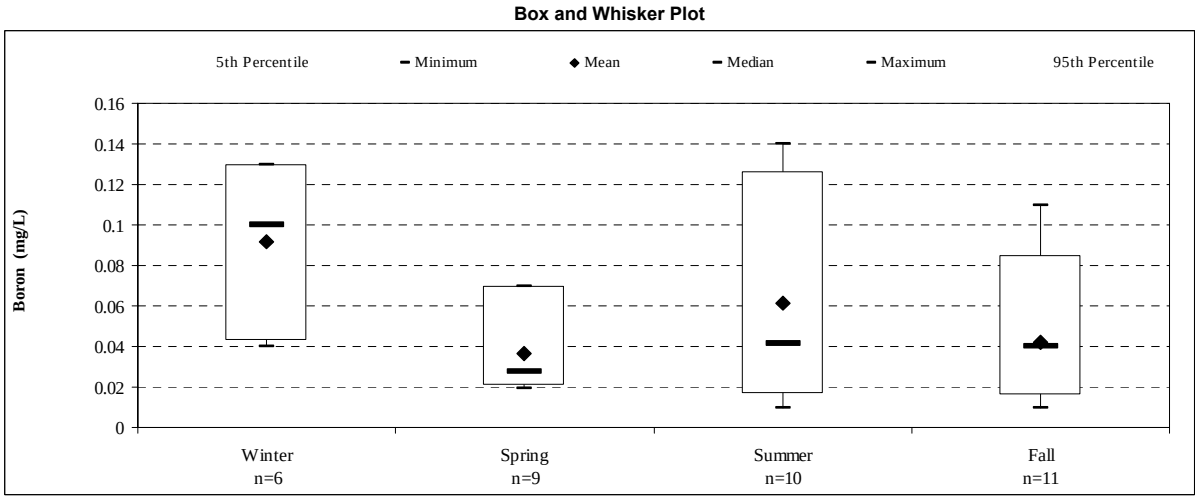


Figure G-2-2-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Middle Segment of Muskeg River



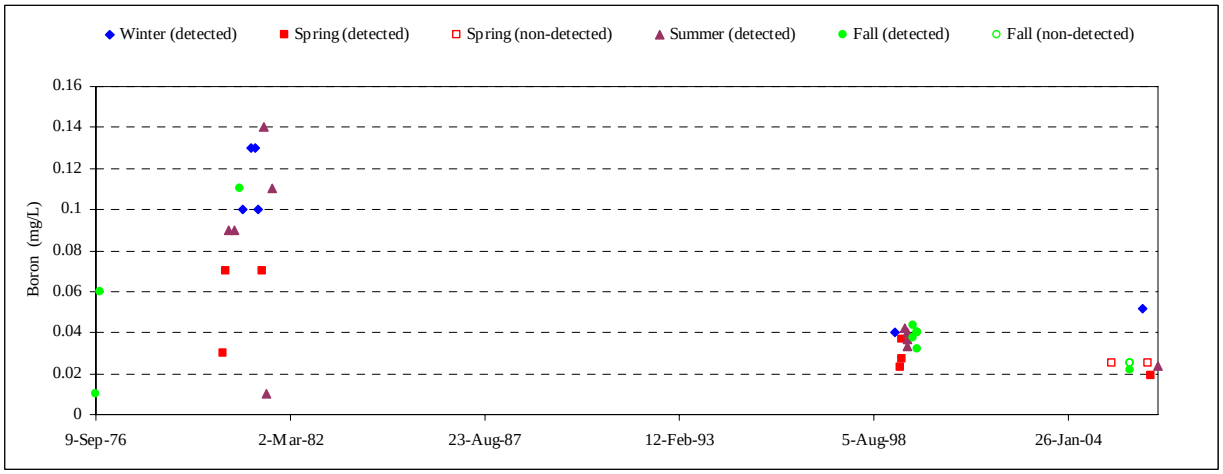
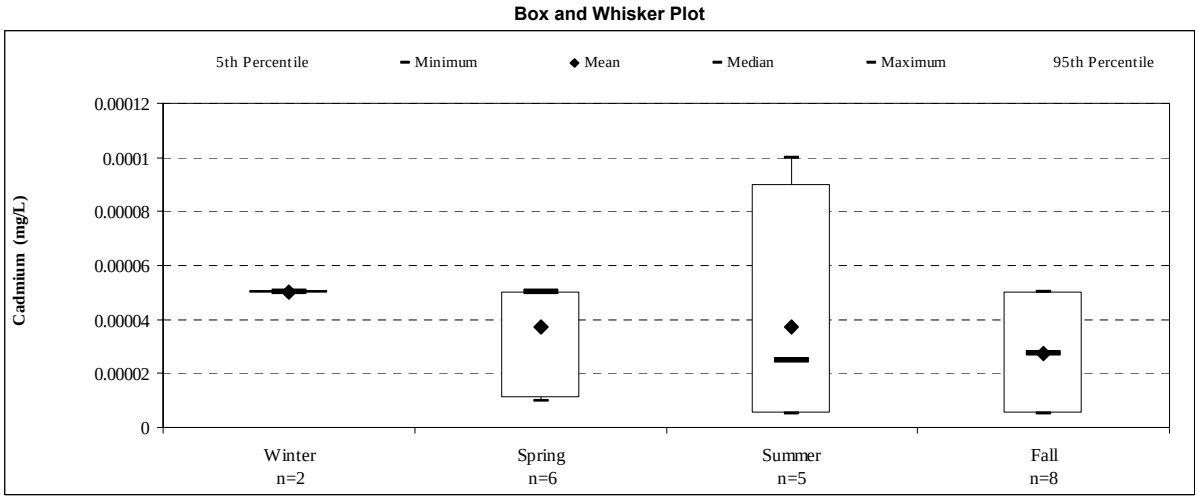


Figure G-2-2-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Middle Segment of Muskeg River



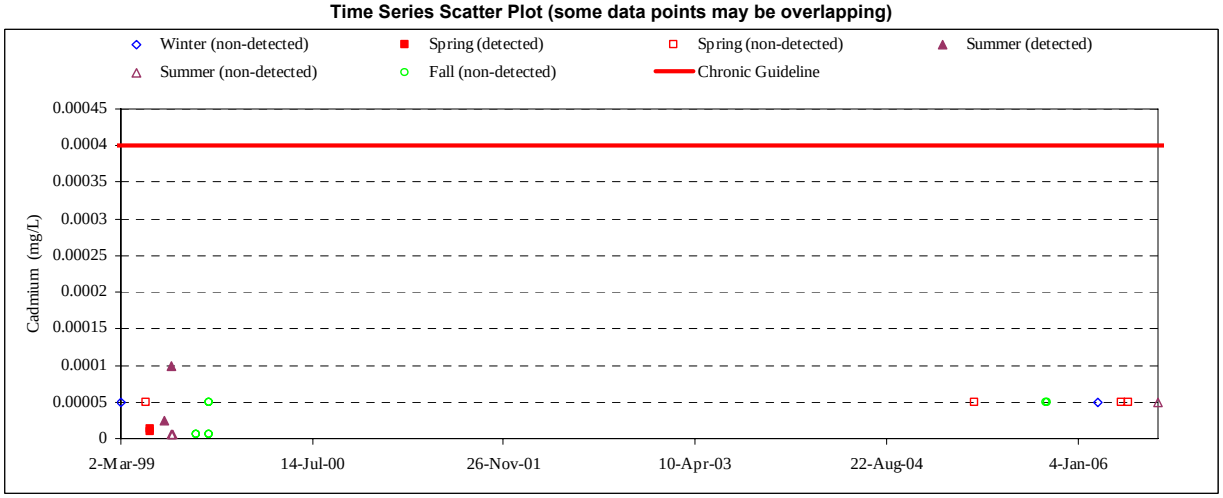
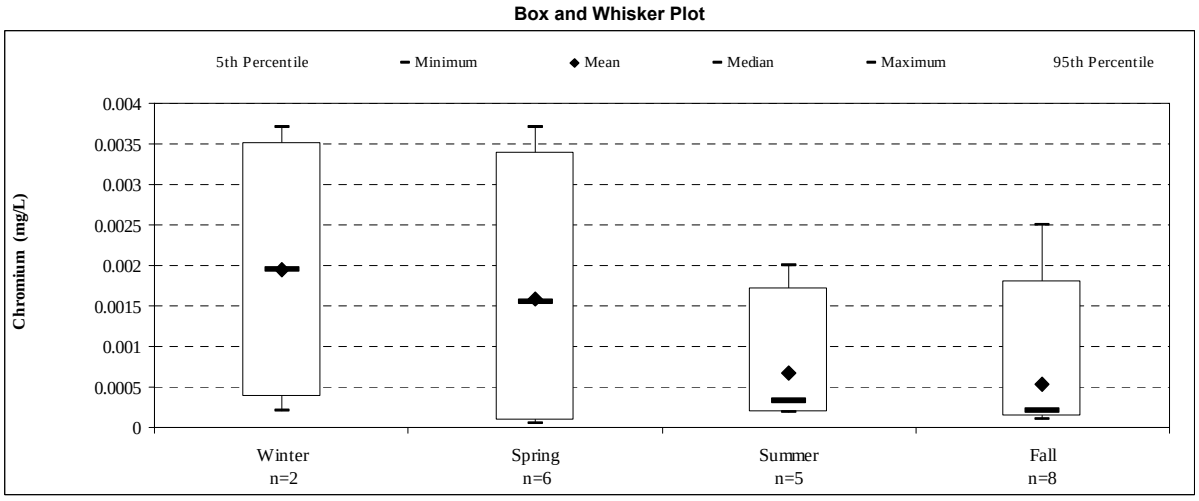


Figure G-2-2-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Middle Segment of Muskeg River



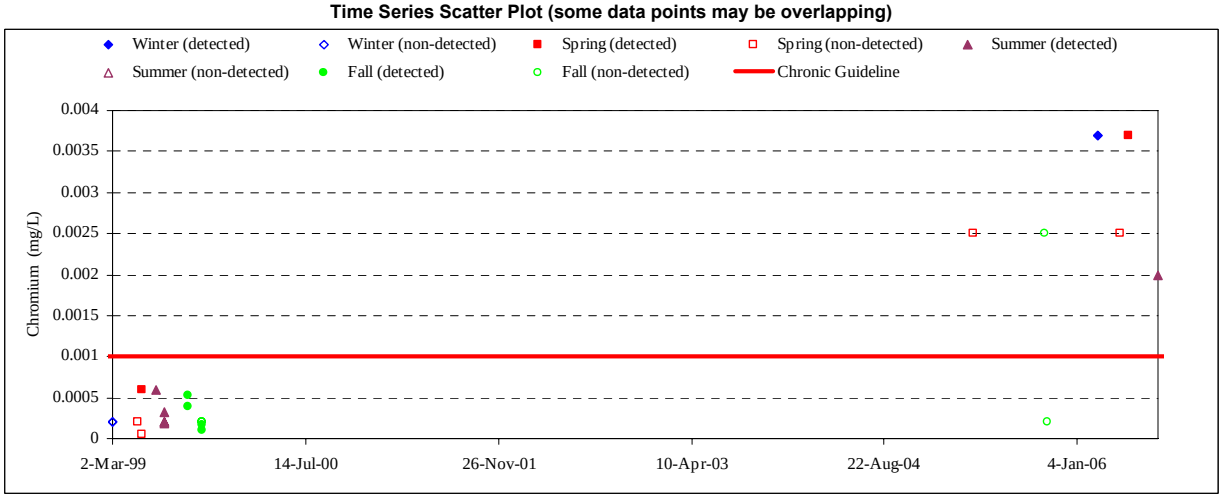
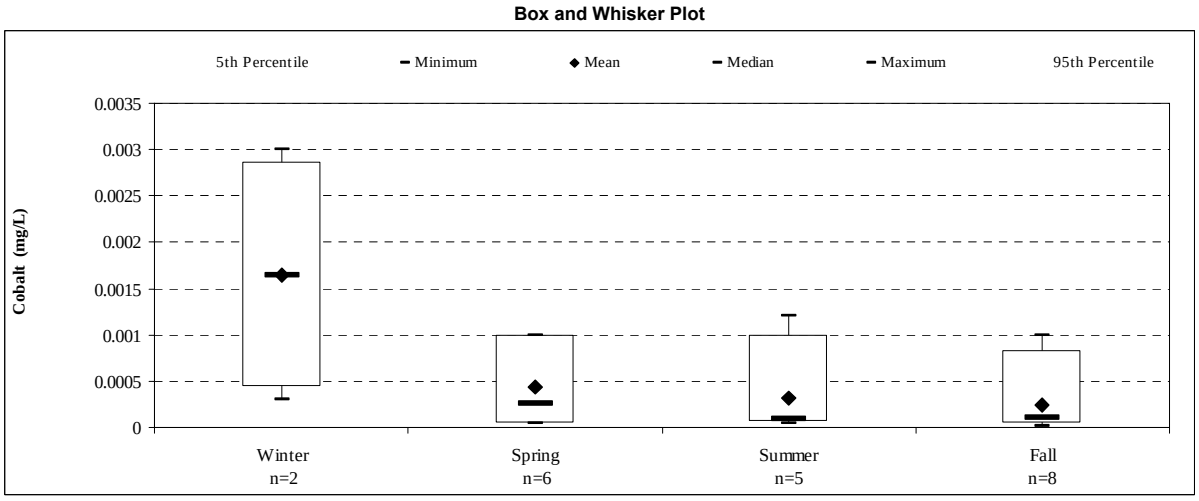


Figure G-2-2-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Middle Segment of Muskeg River



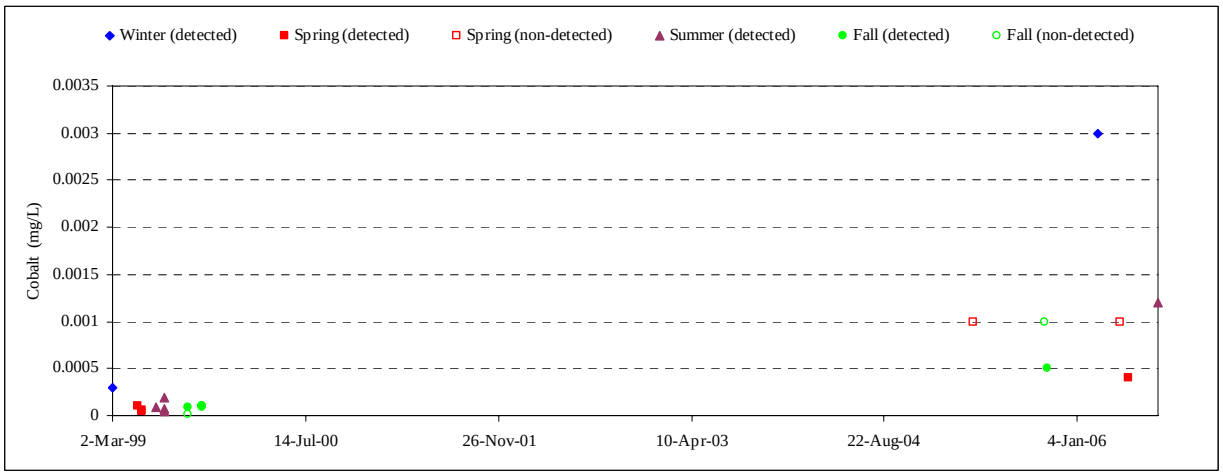
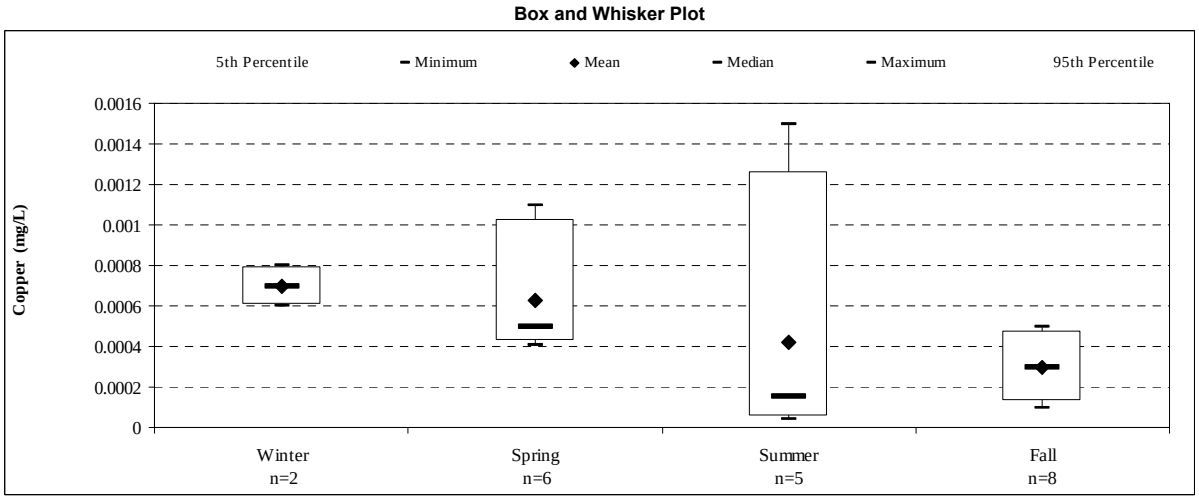


Figure G-2-2-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Middle Segment of Muskeg River



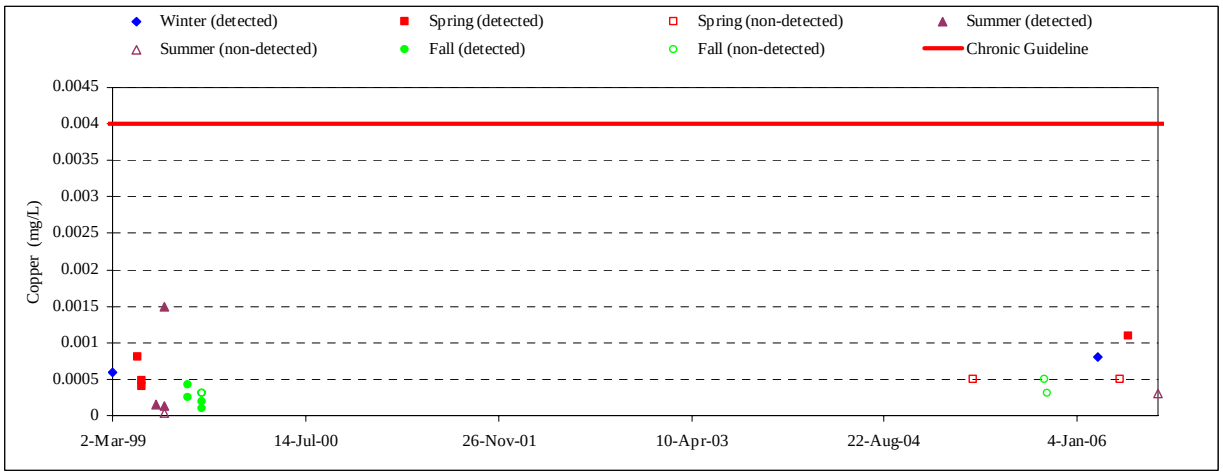
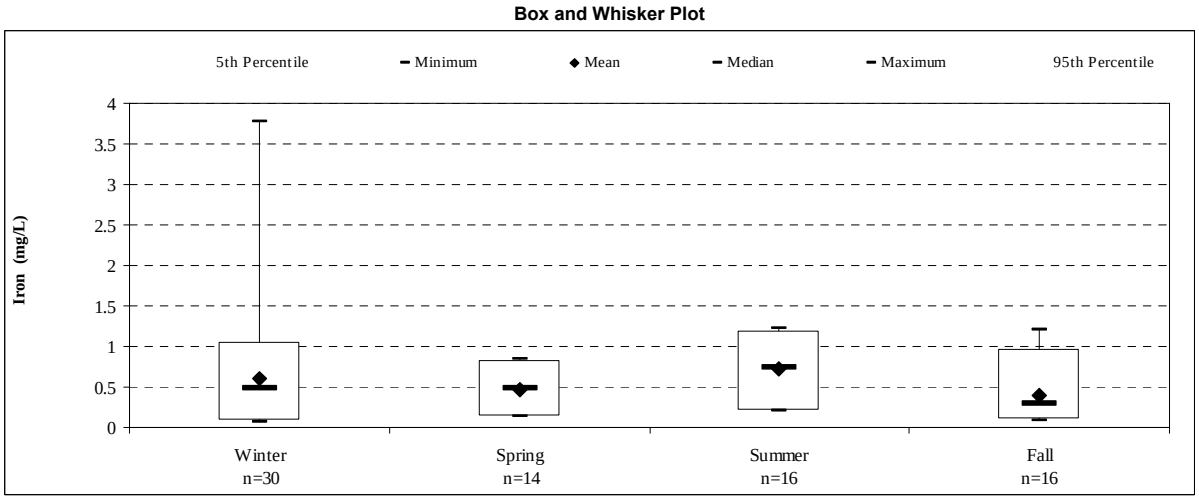


Figure G-2-2-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Middle Segment of Muskeg River



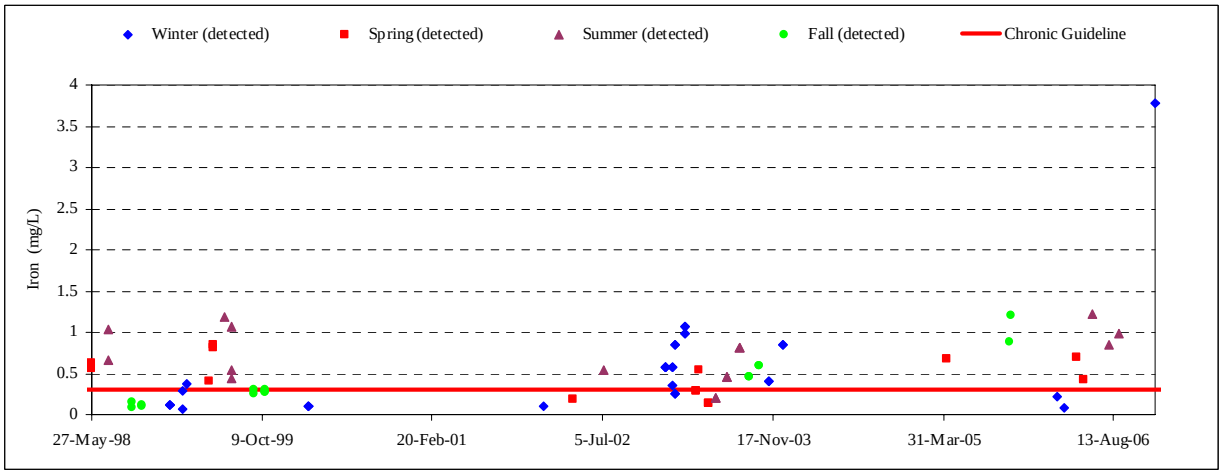
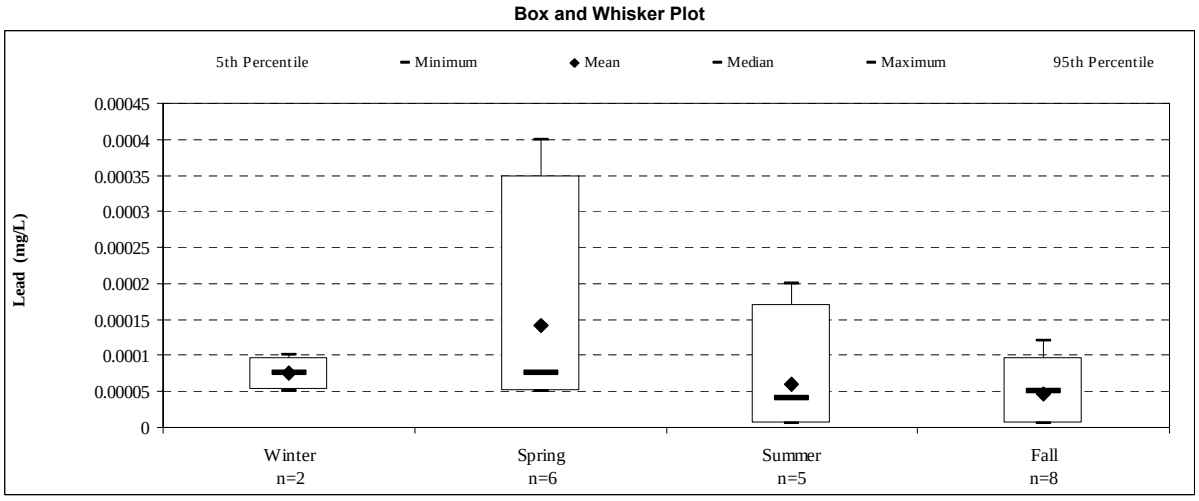


Figure G-2-2-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Middle Segment of Muskeg River



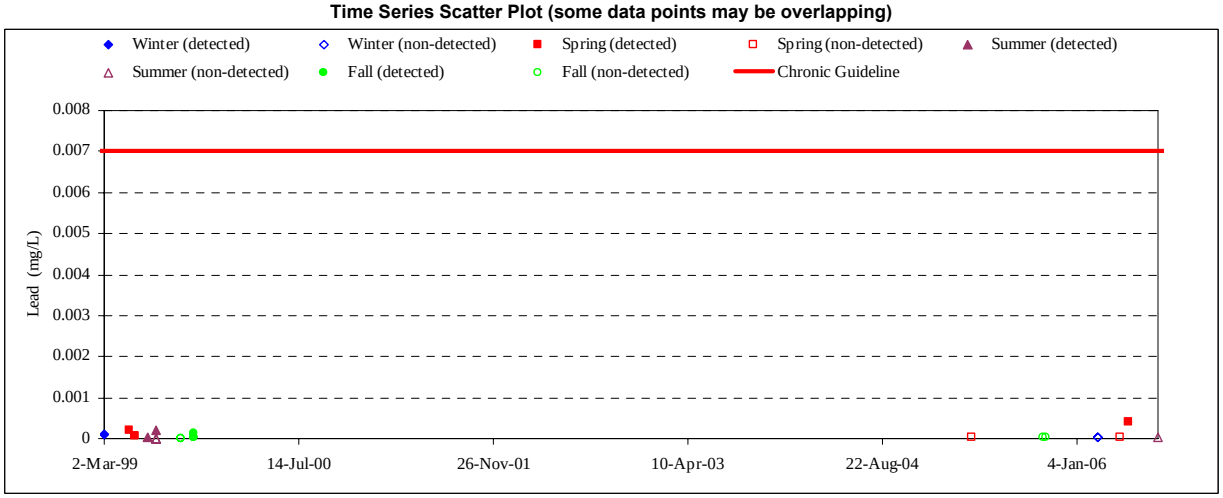
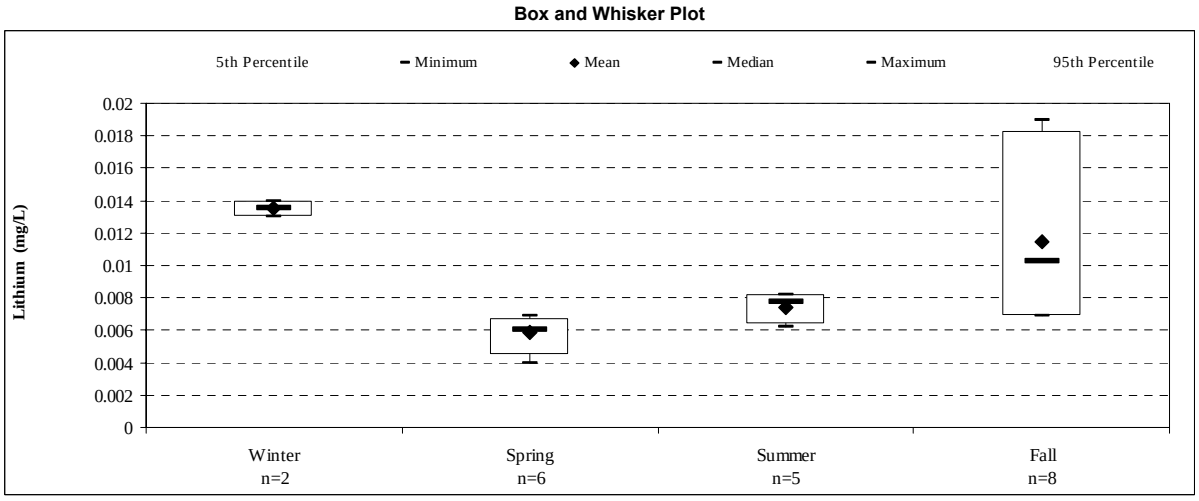


Figure G-2-2-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Middle Segment of Muskeg River



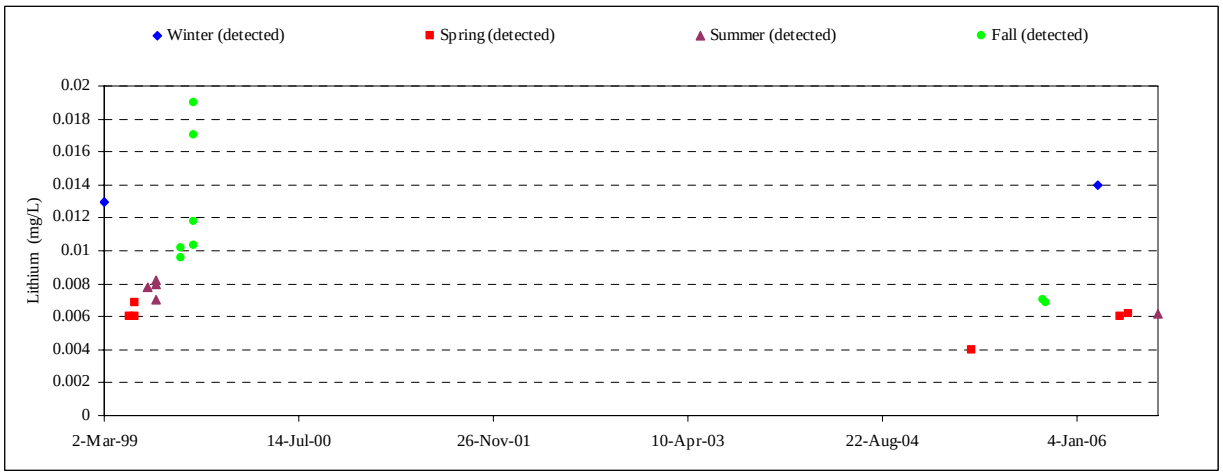
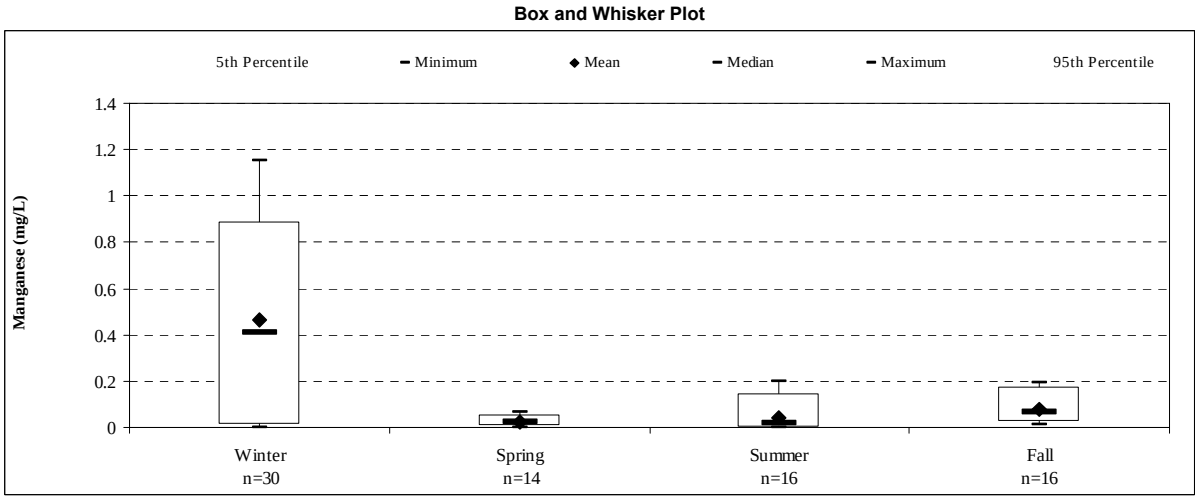


Figure G-2-2-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Middle Segment of Muskeg River



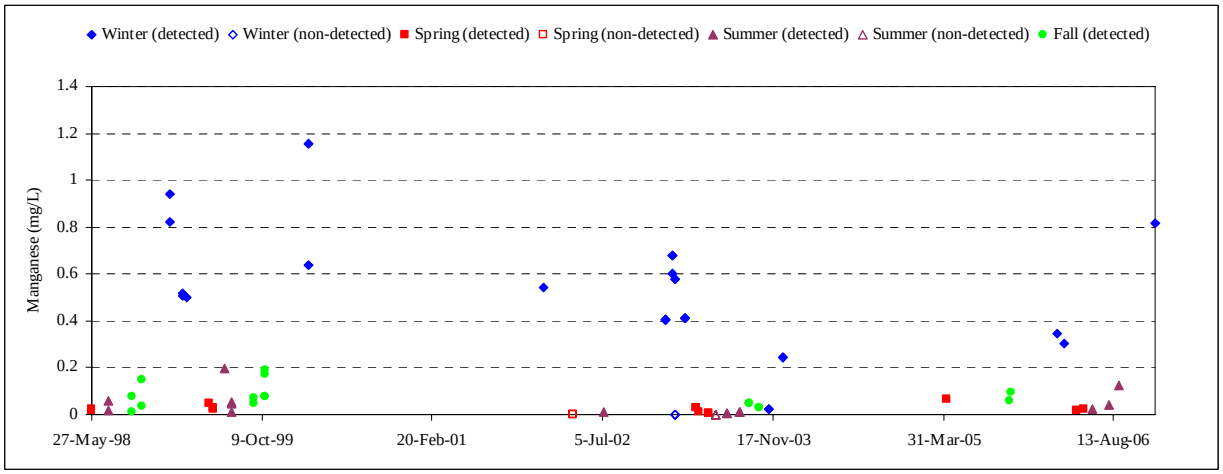
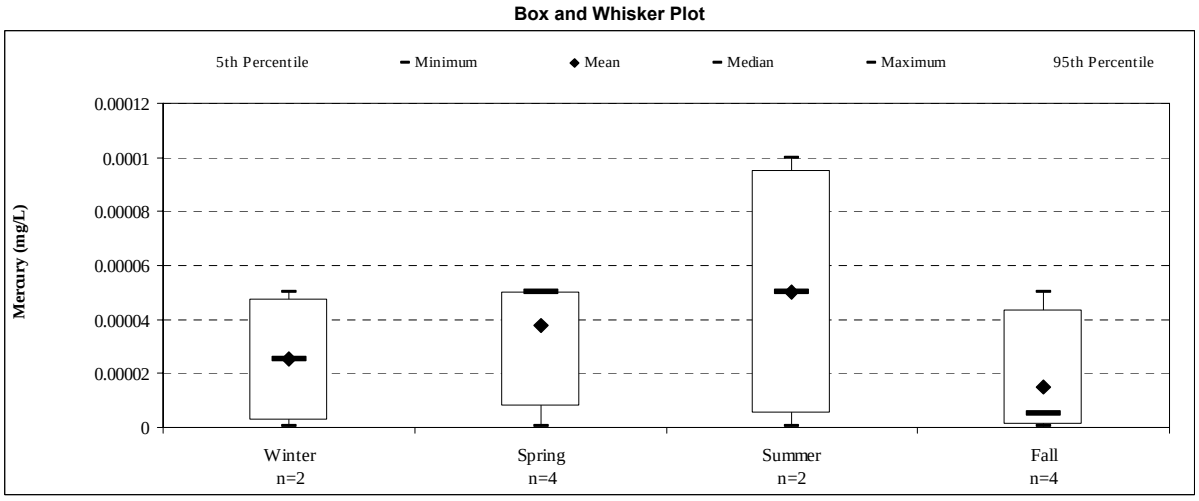


Figure G-2-2-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Middle Segment of Muskeg River



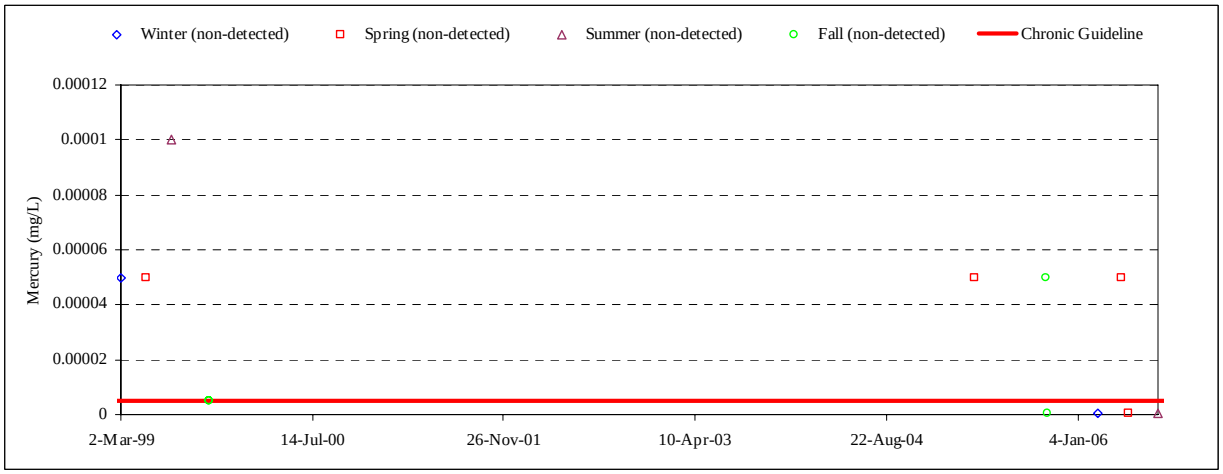
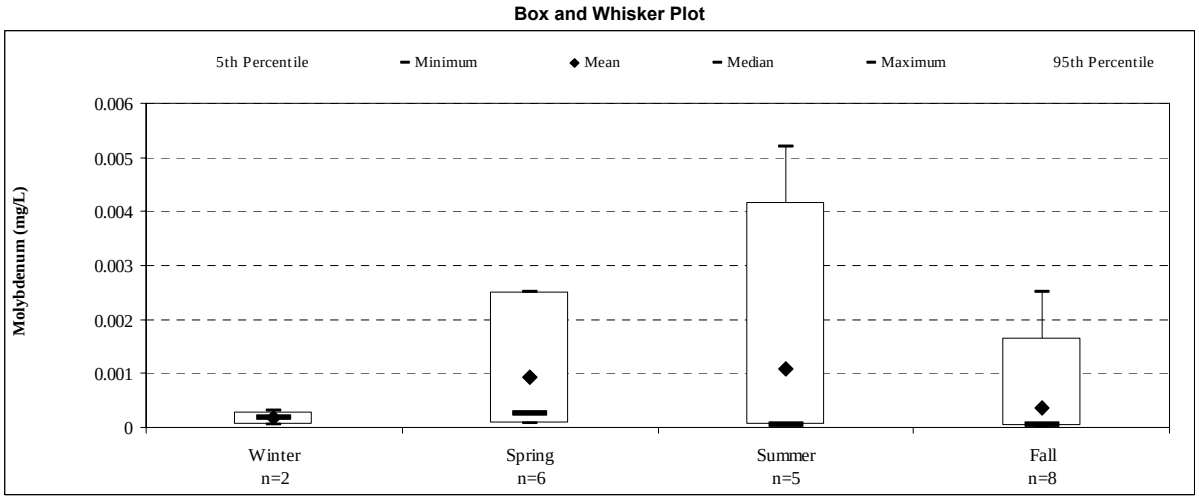


Figure G-2-2-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Middle Segment of Muskeg River



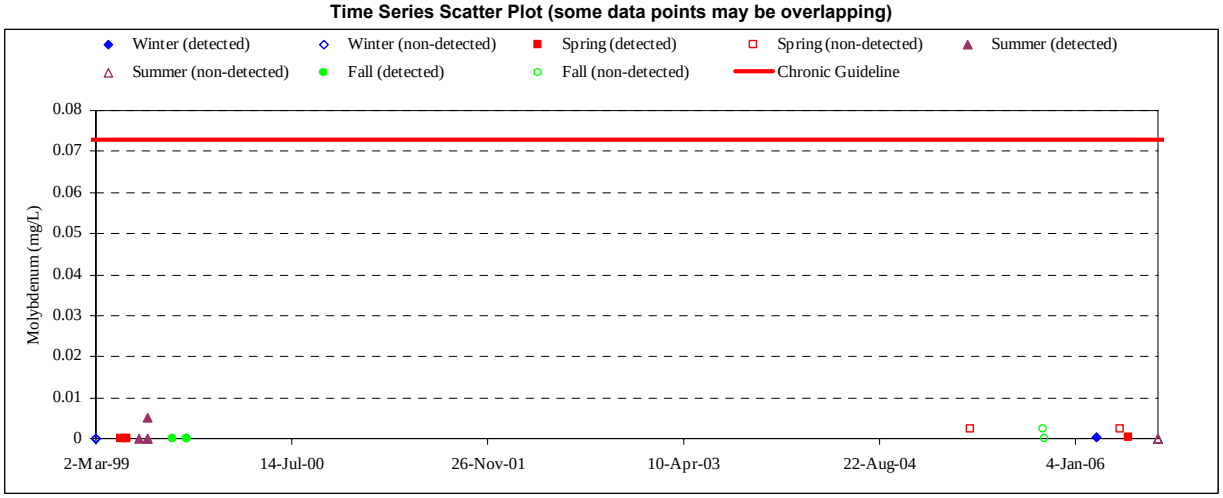
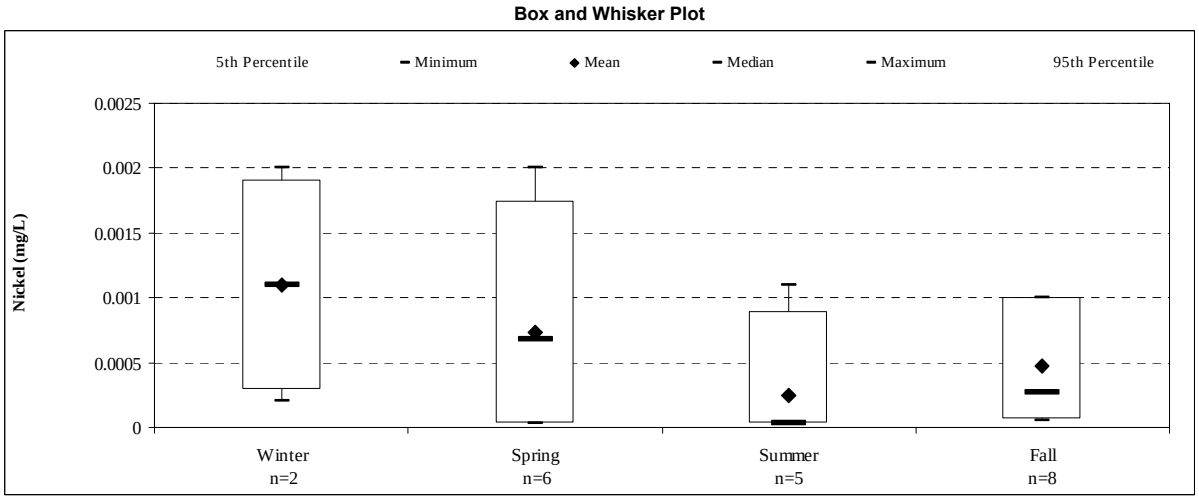


Figure G-2-2-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Middle Segment of Muskeg River



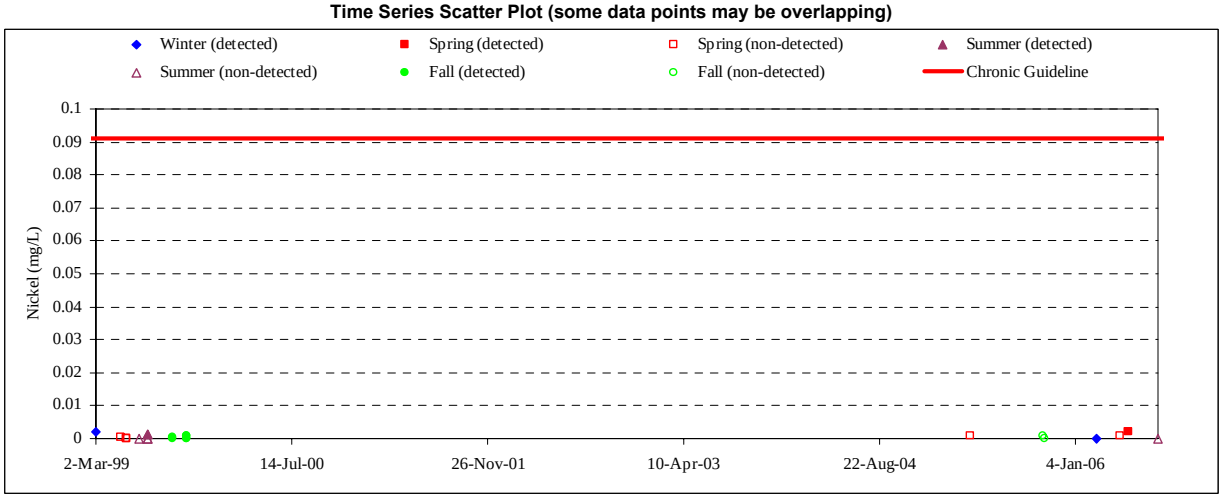
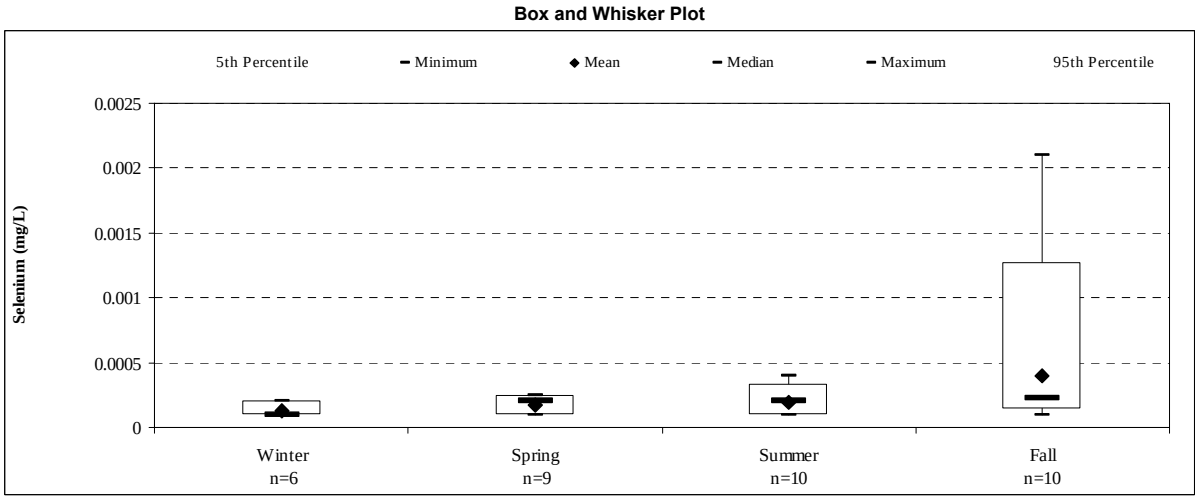


Figure G-2-2-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Middle Segment of Muskeg River



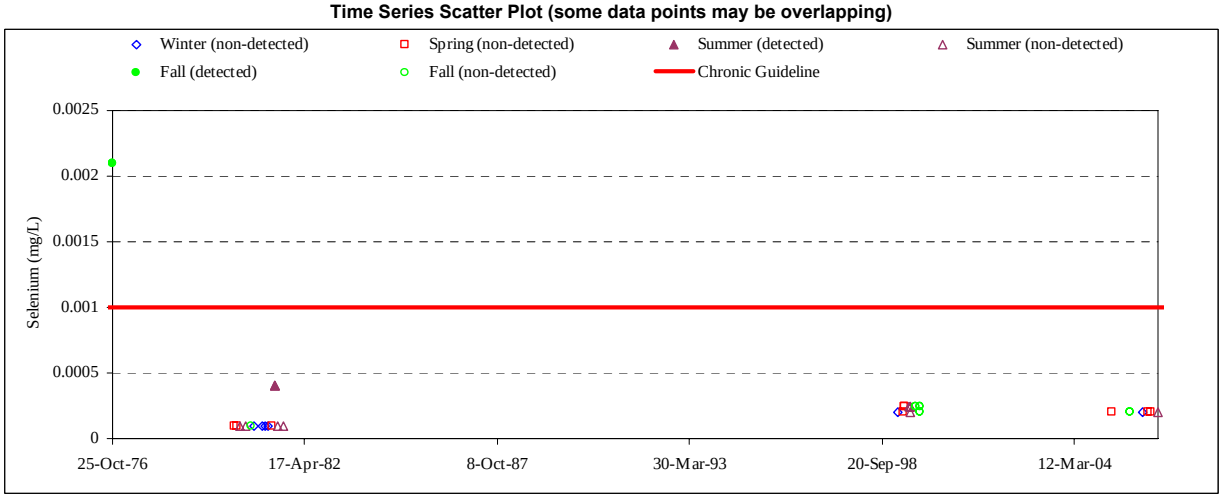
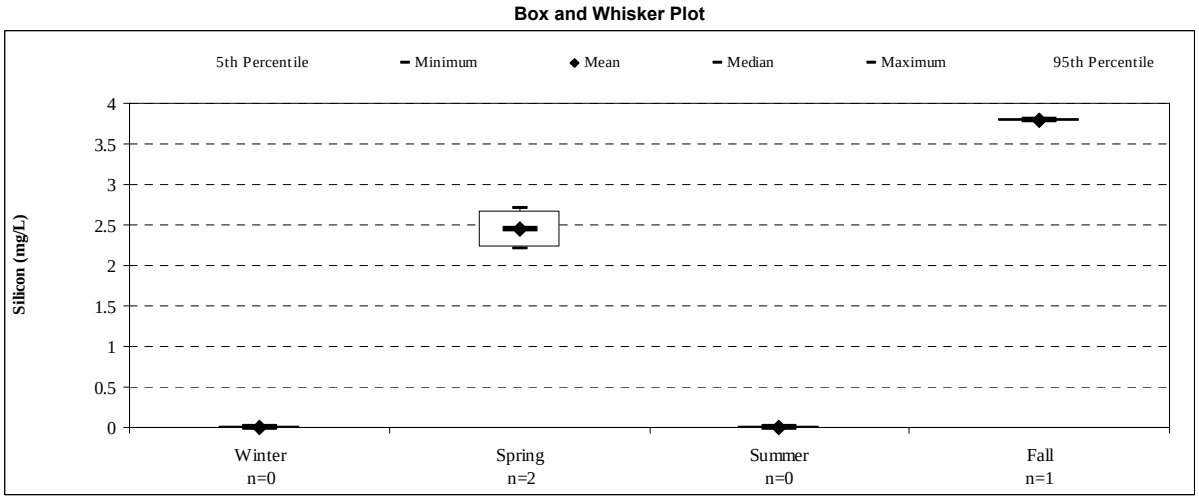


Figure G-2-2-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Middle Segment of Muskeg River



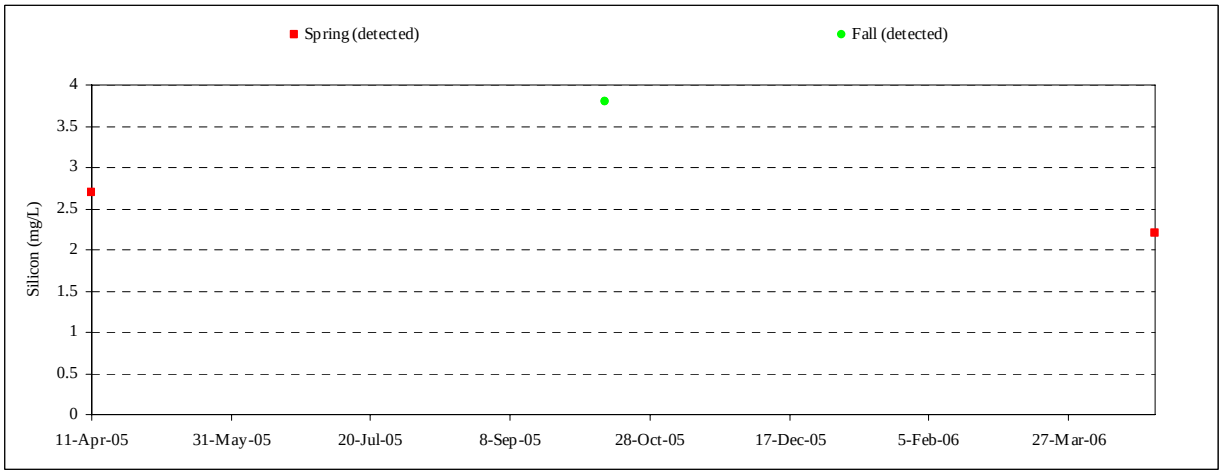
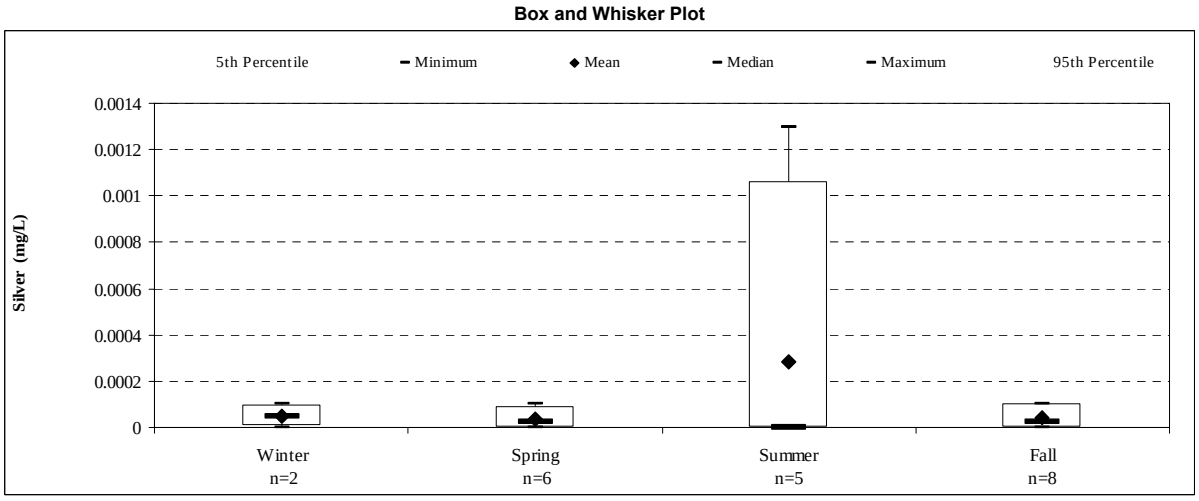


Figure G-2-2-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Middle Segment of Muskeg River



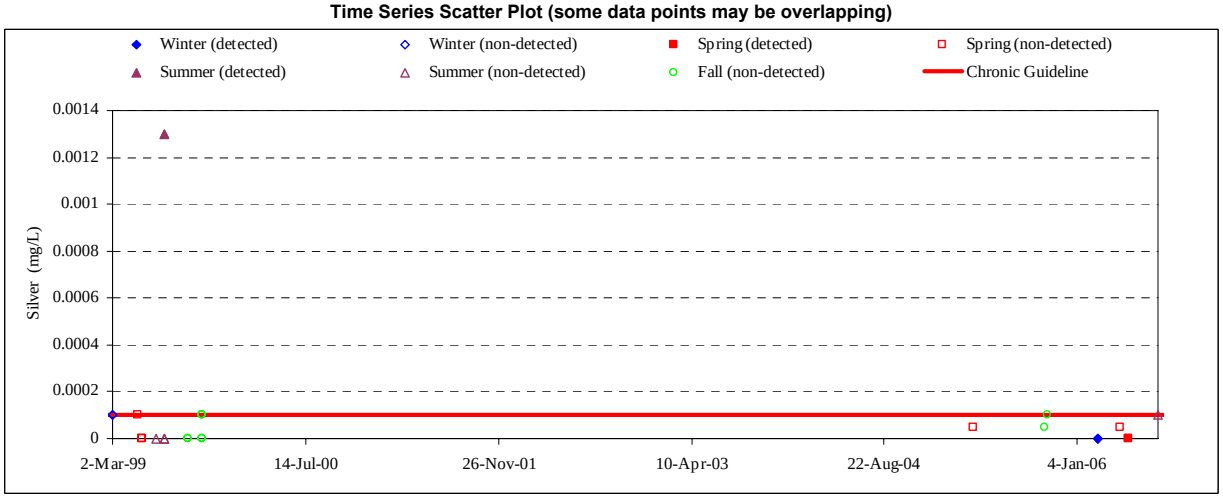
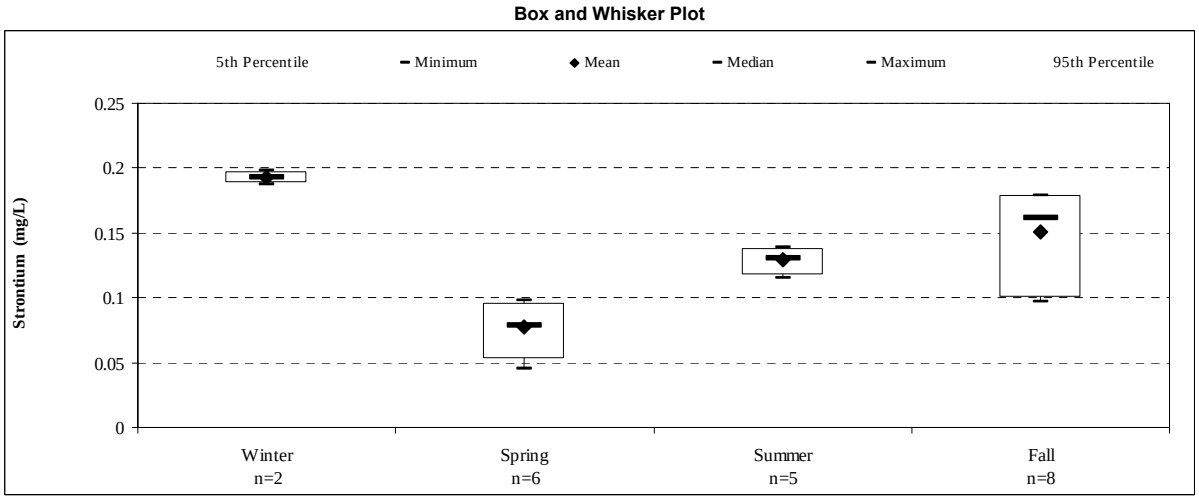


Figure G-2-2-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Middle Segment of Muskeg River



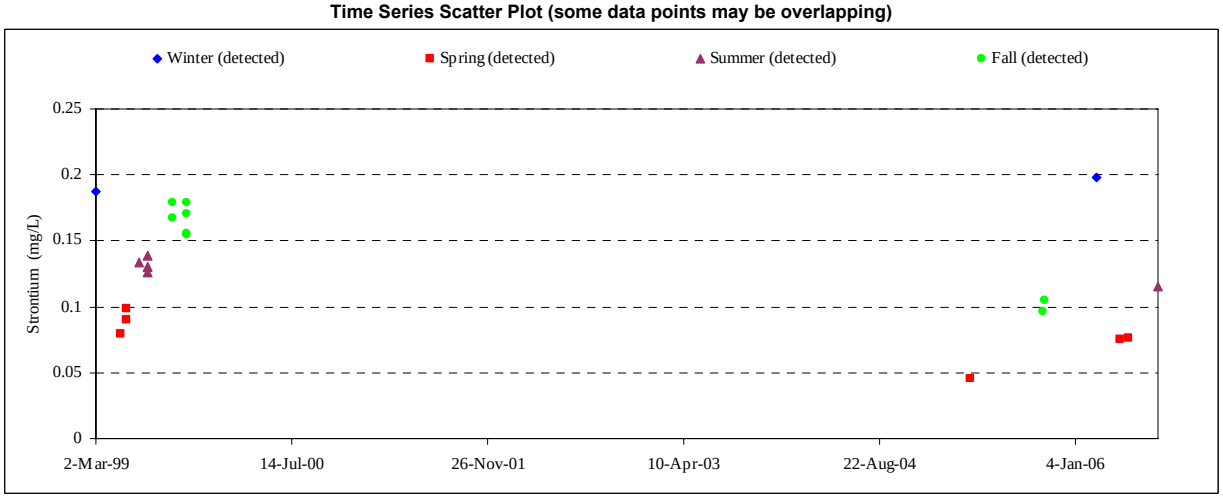
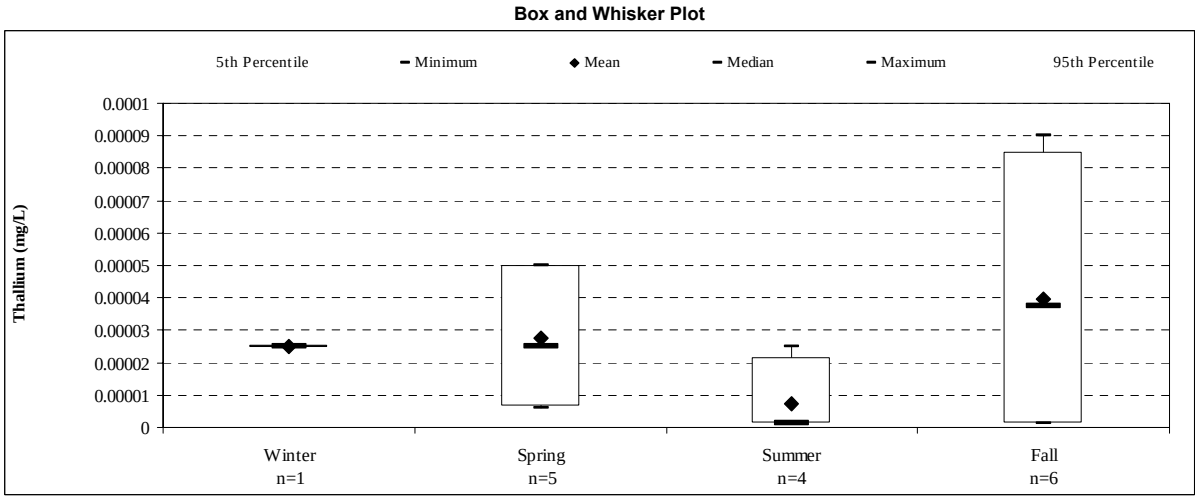


Figure G-2-2-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Middle Segment of Muskeg River



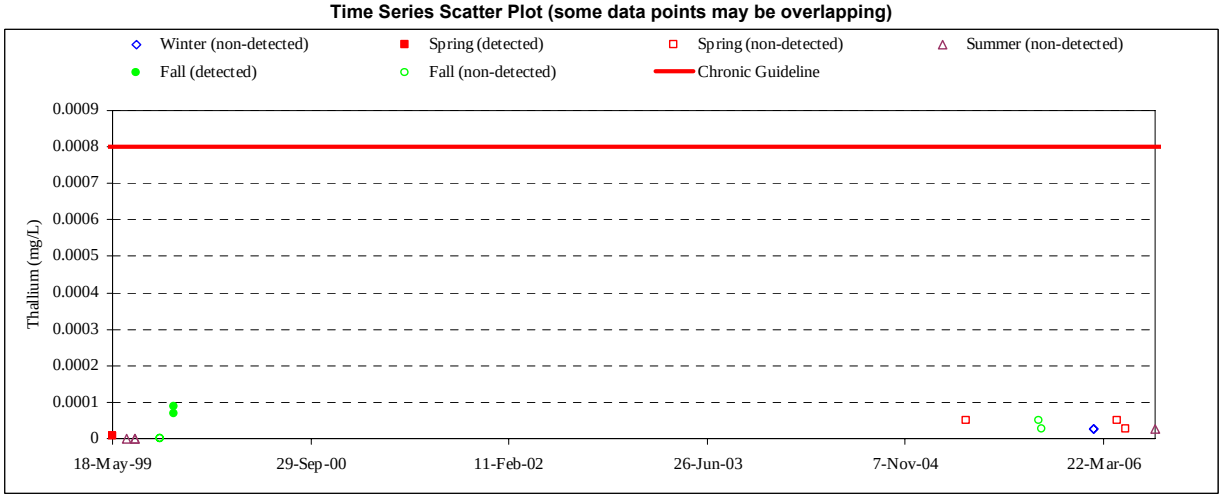
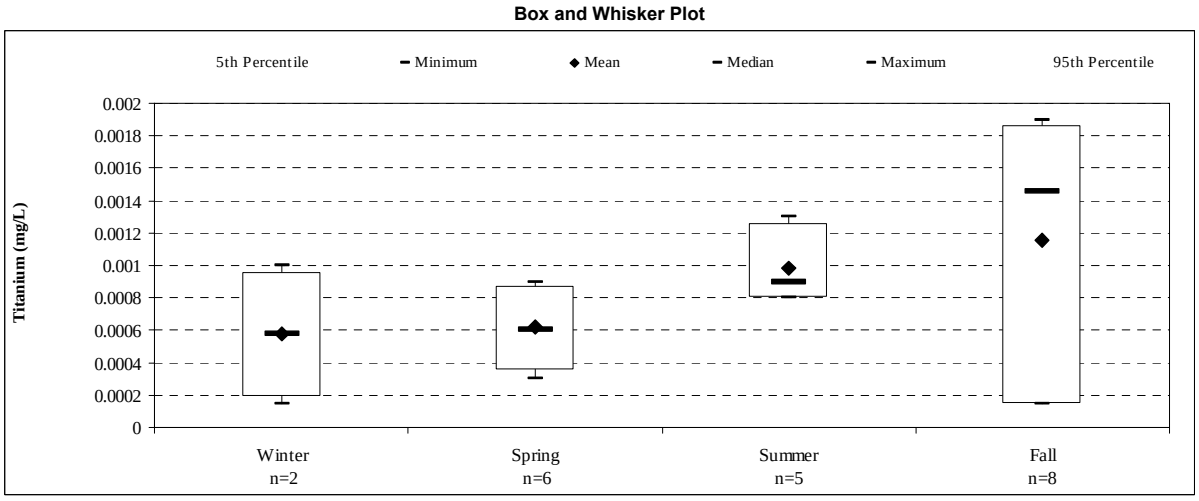


Figure G-2-2-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Middle Segment of Muskeg River



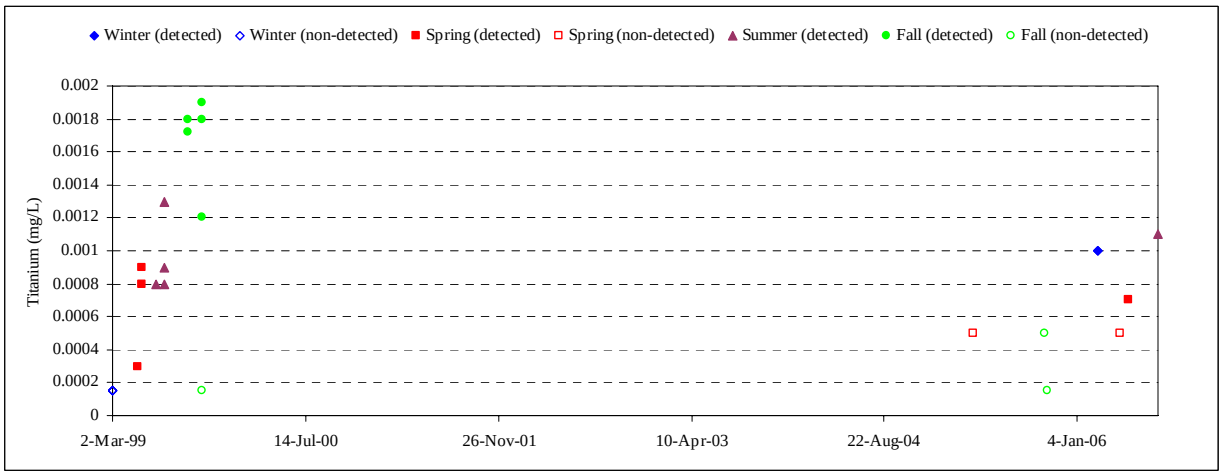
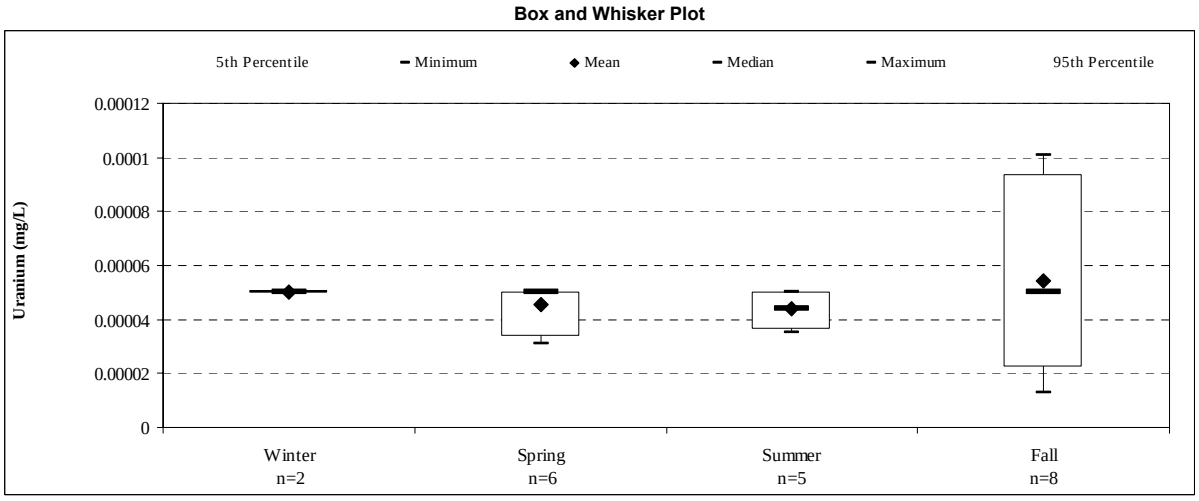


Figure G-2-2-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Middle Segment of Muskeg River



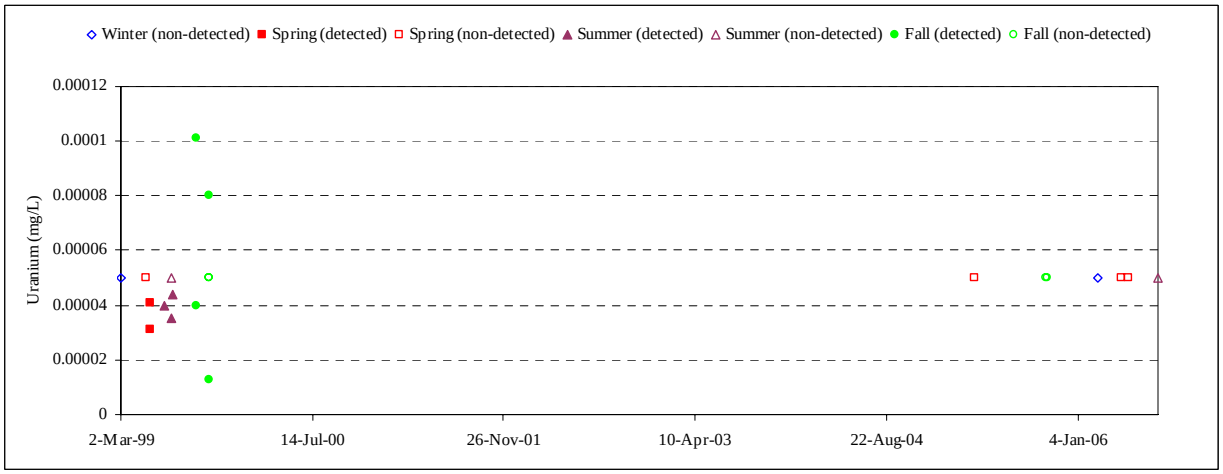
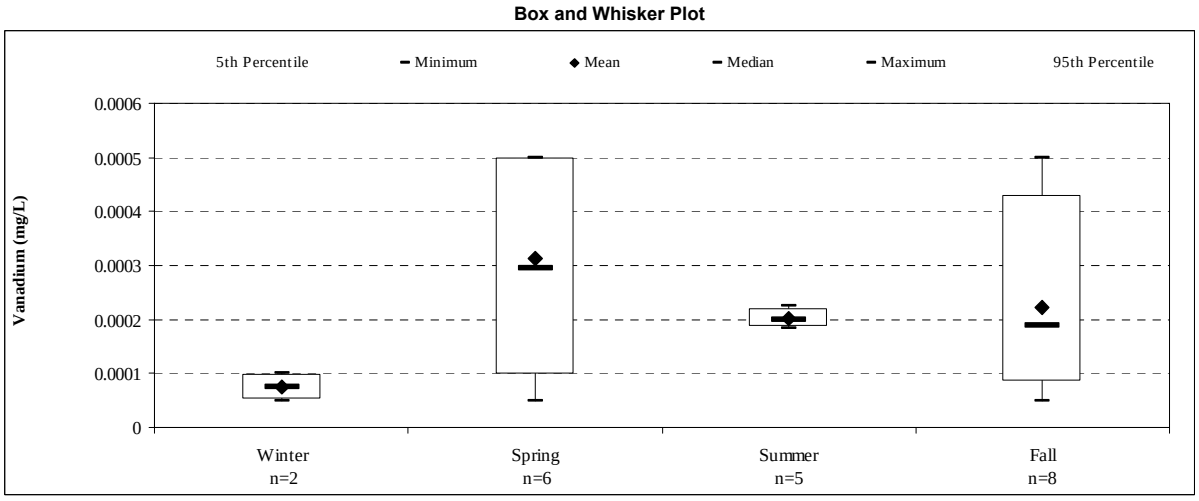


Figure G-2-2-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Middle Segment of Muskeg River



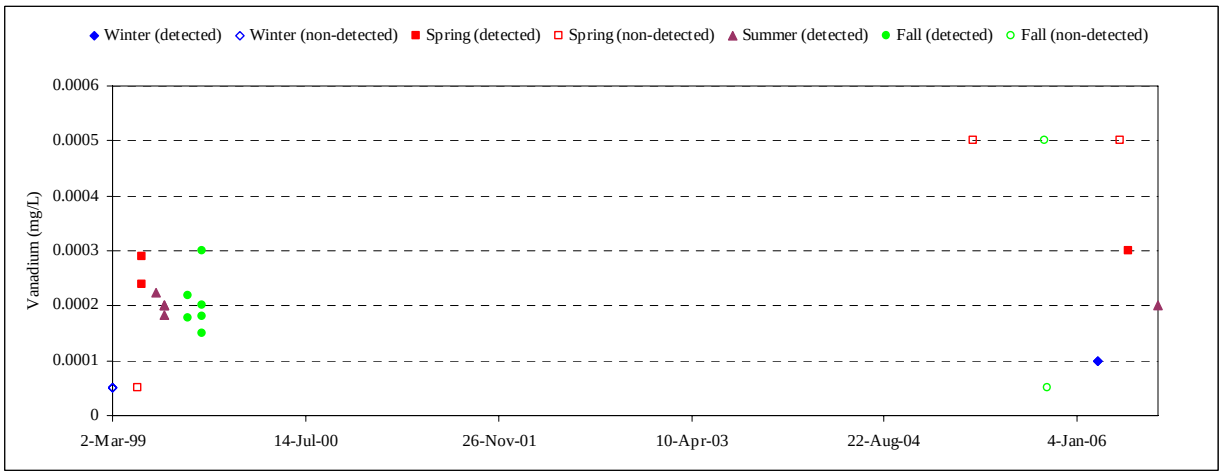
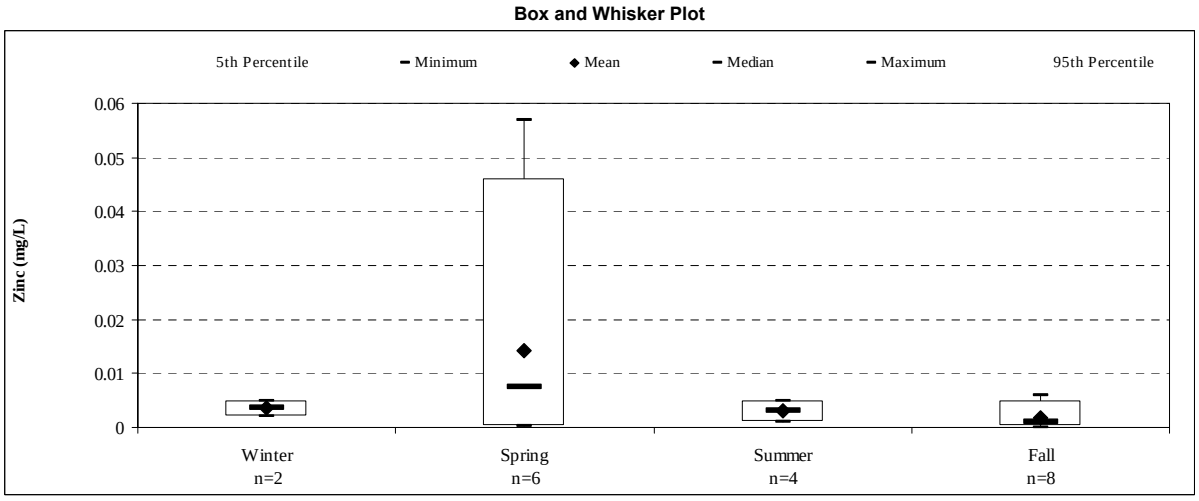


Figure G-2-2-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Middle Segment of Muskeg River



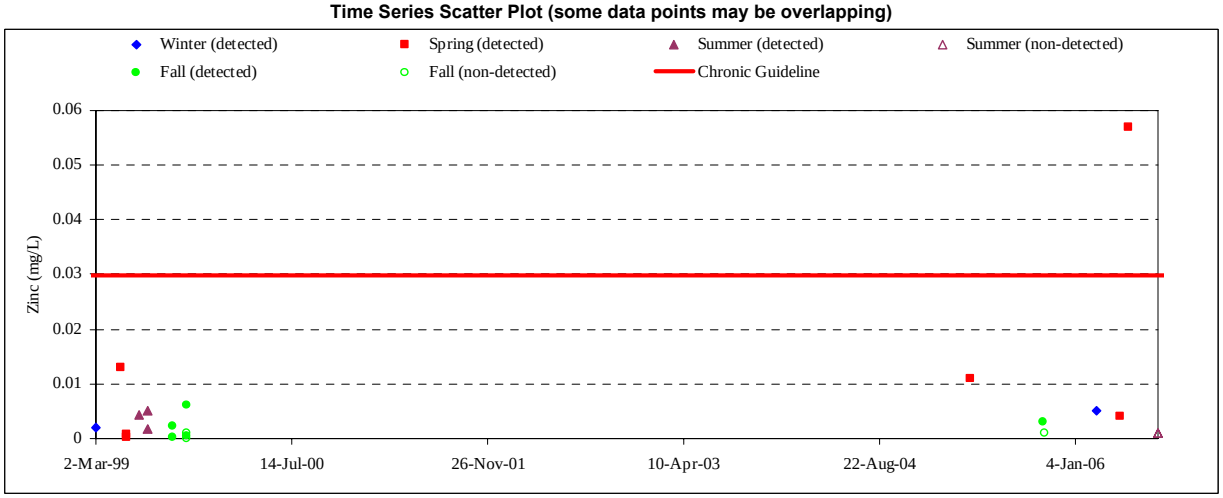
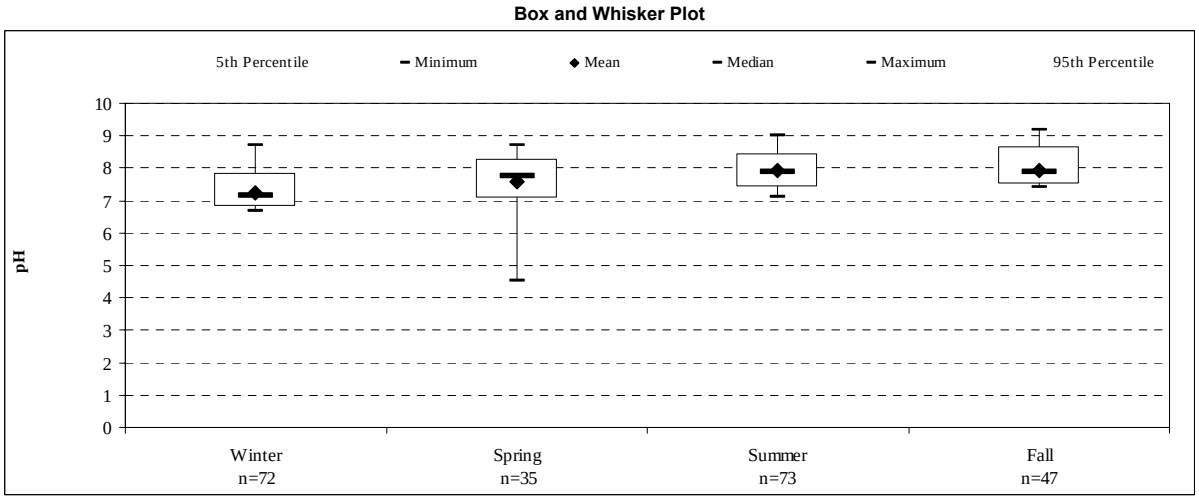


Figure G-2-3-1 Box Whisker and Time Series Scatter Plots of Observed pH in Lower Segment of Muskeg River



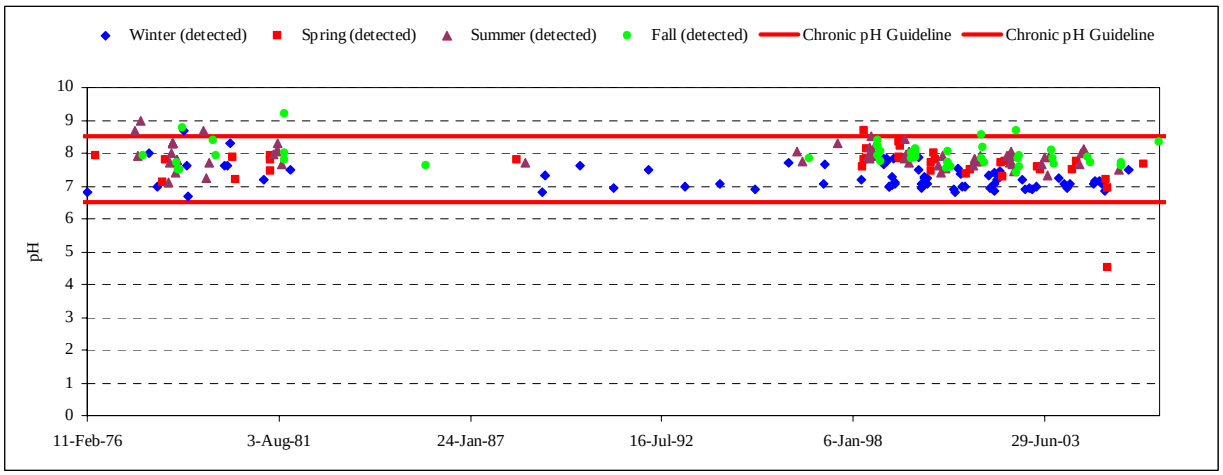
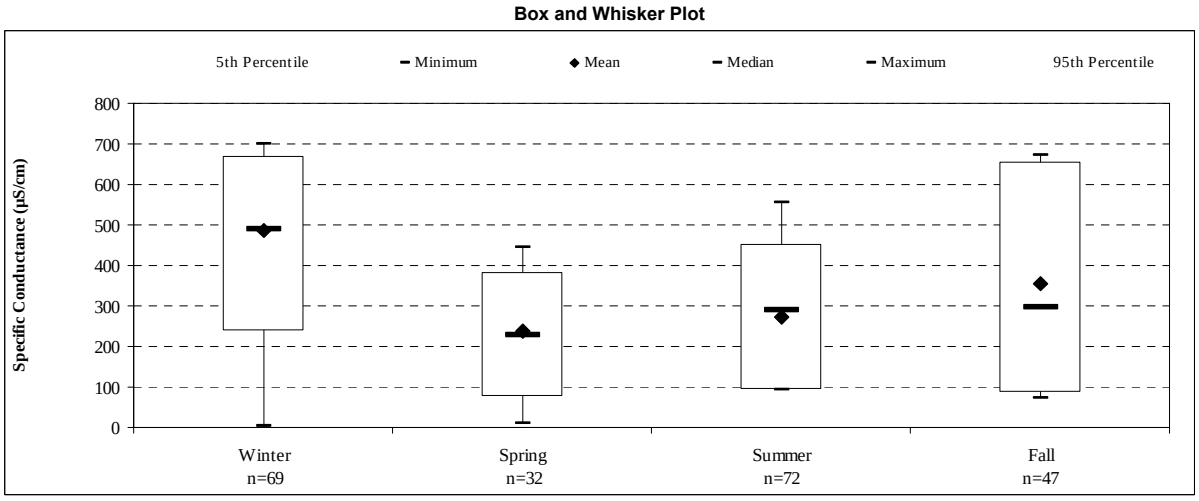


Figure G-2-3-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Lower Segment of Muskeg River



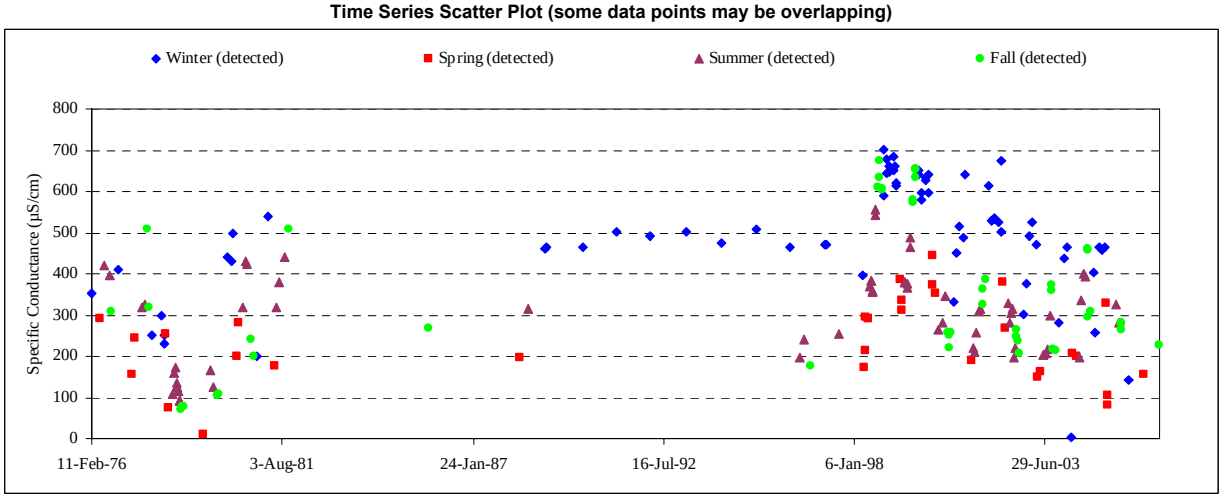
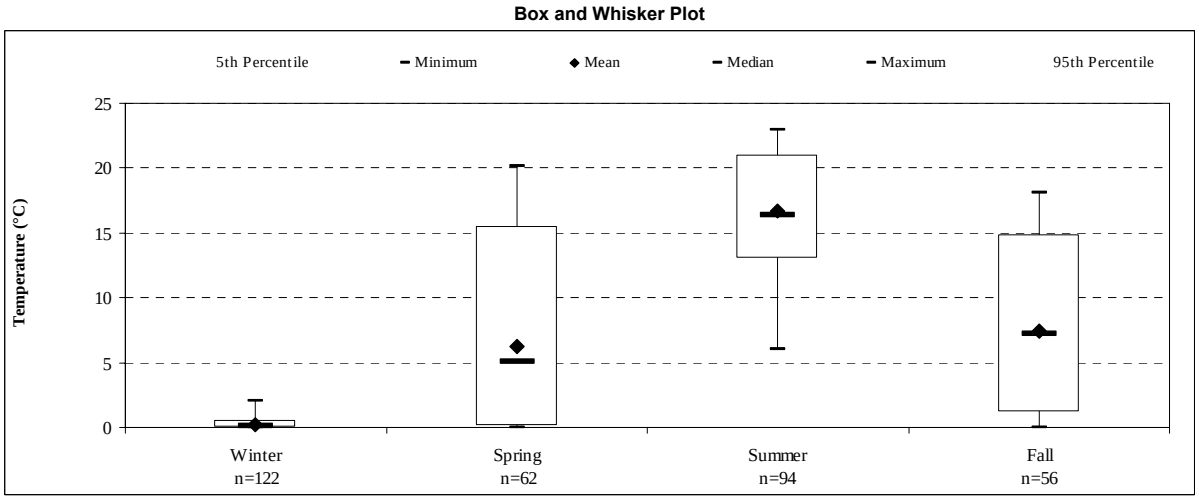


Figure G-2-3-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Lower Segment of Muskeg River



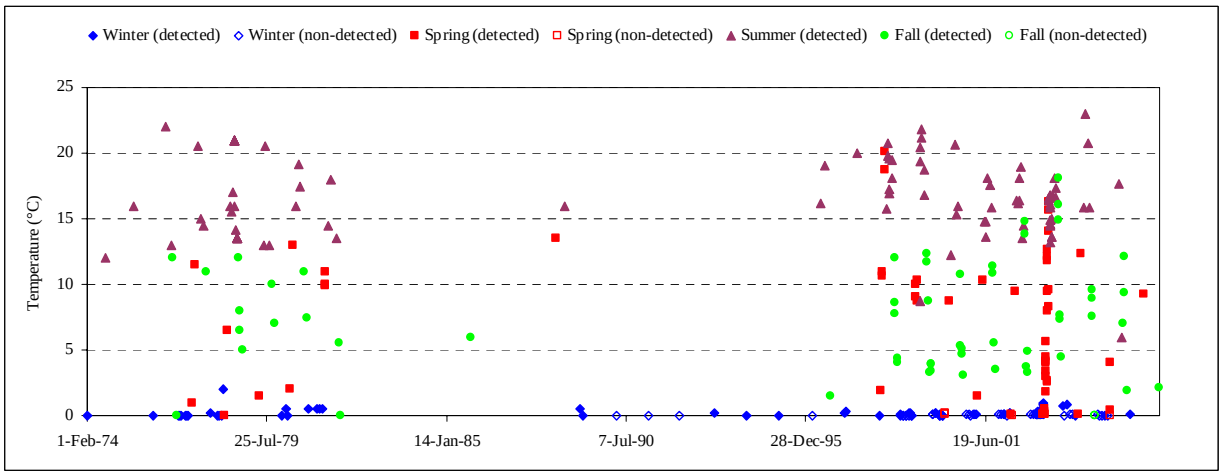
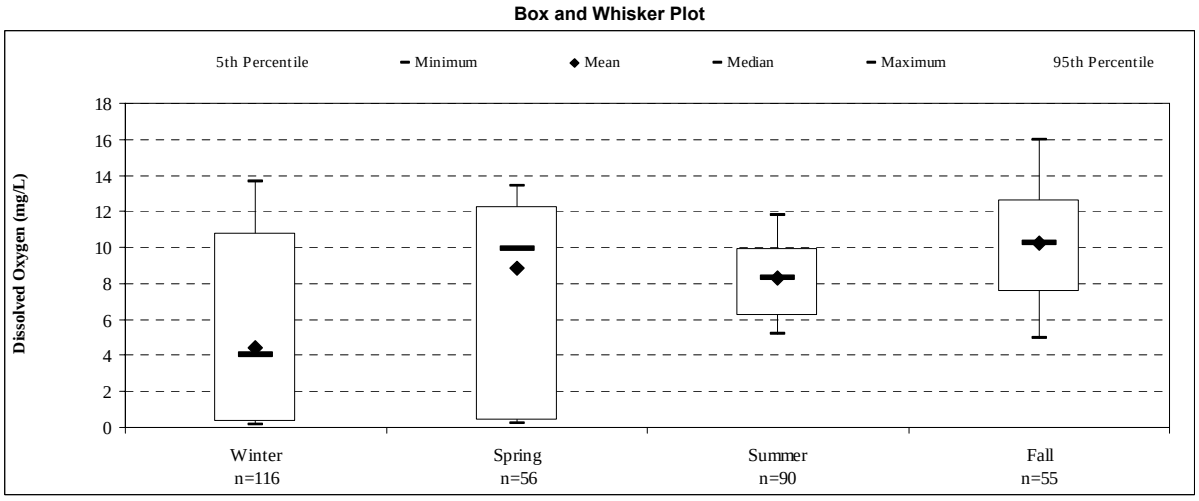


Figure G-2-3-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Lower Segment of Muskeg River



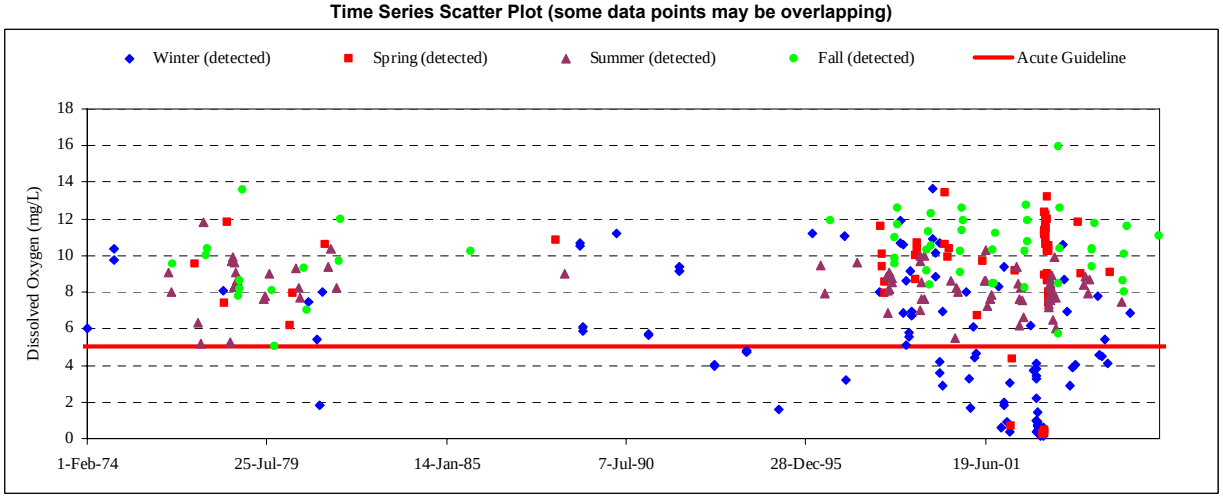
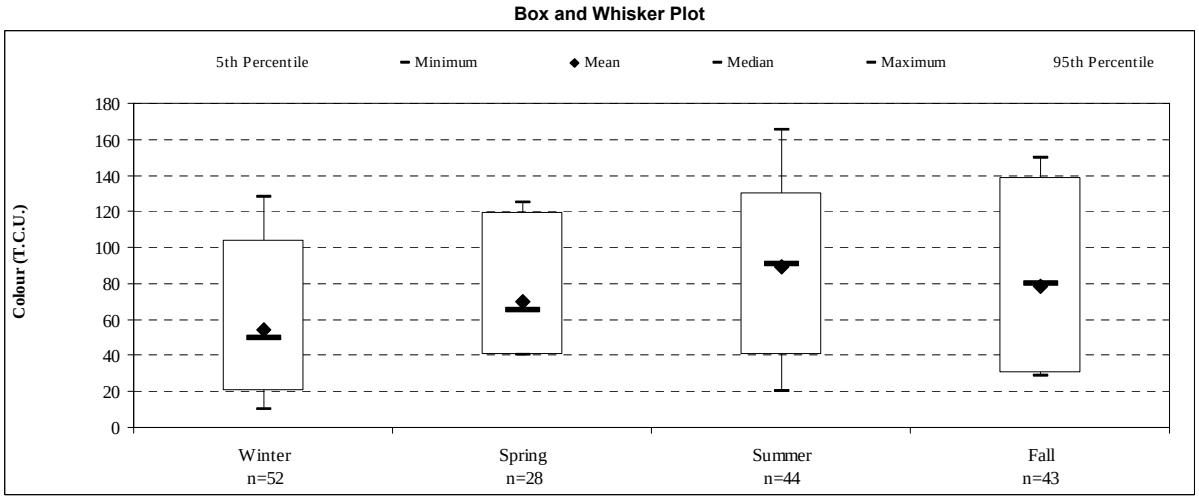


Figure G-2-3-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Lower Segment of Muskeg River



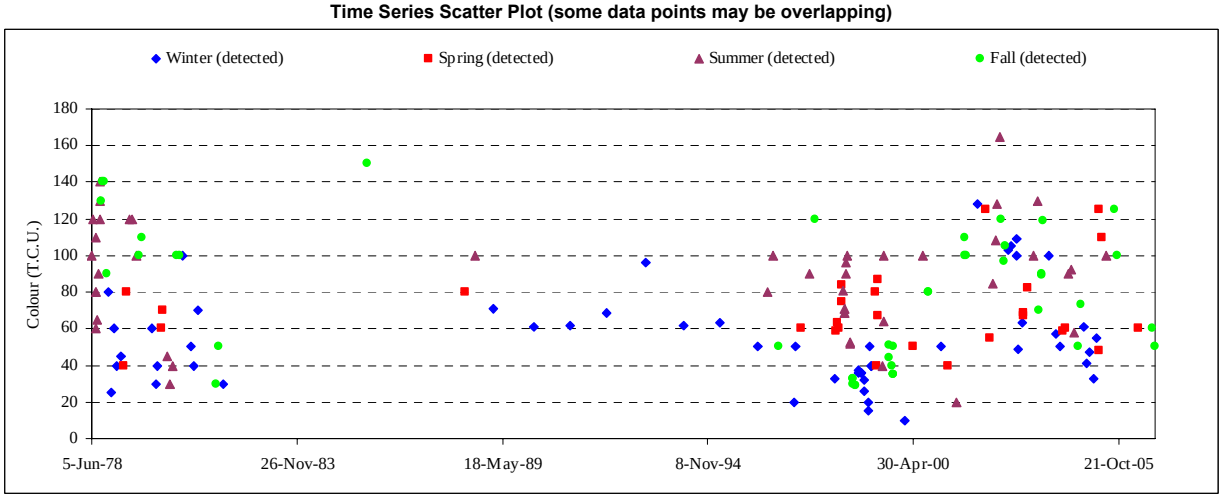
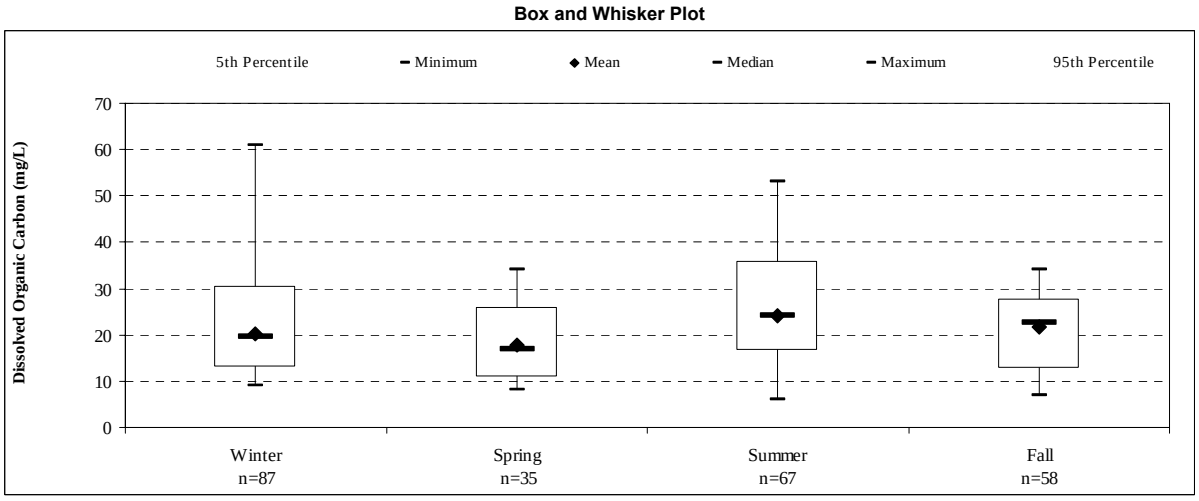


Figure G-2-3-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Lower Segment of Muskeg River



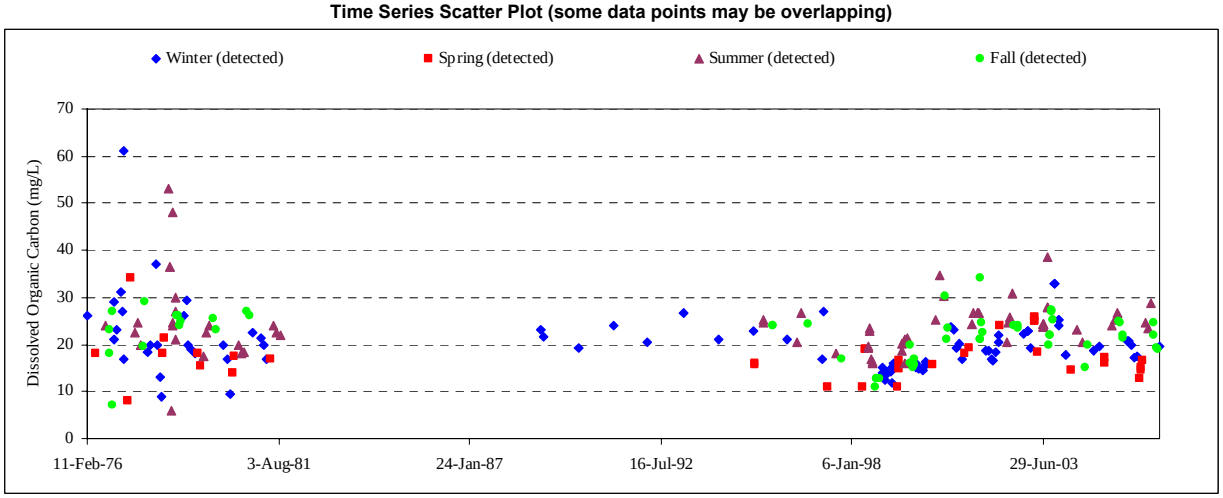
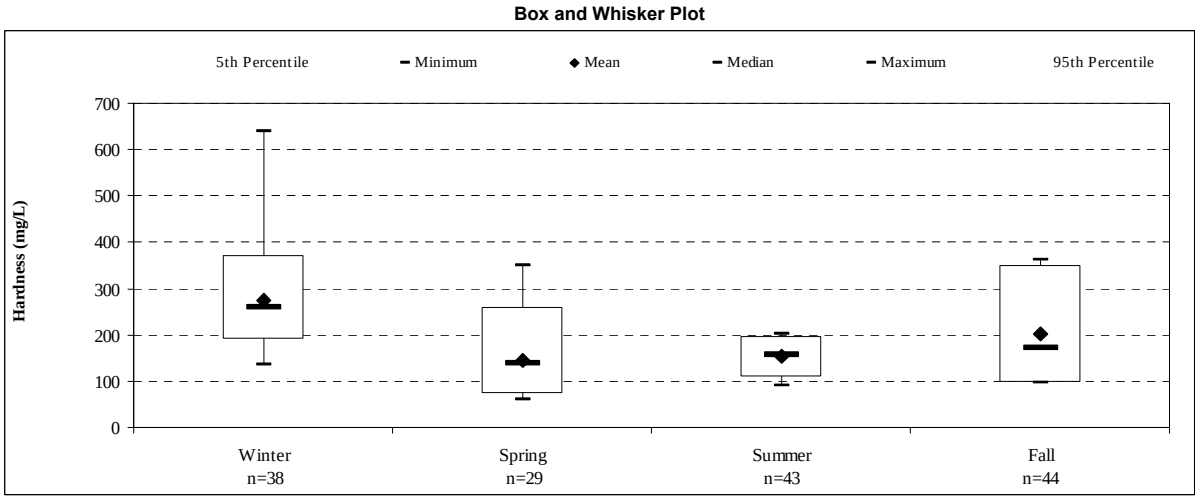


Figure G-2-3-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Lower Segment of Muskeg River



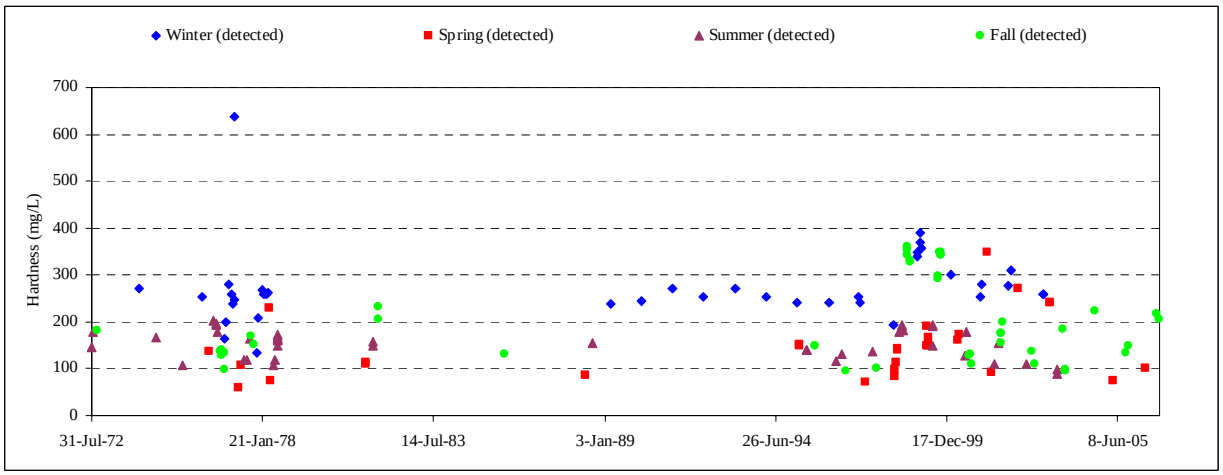
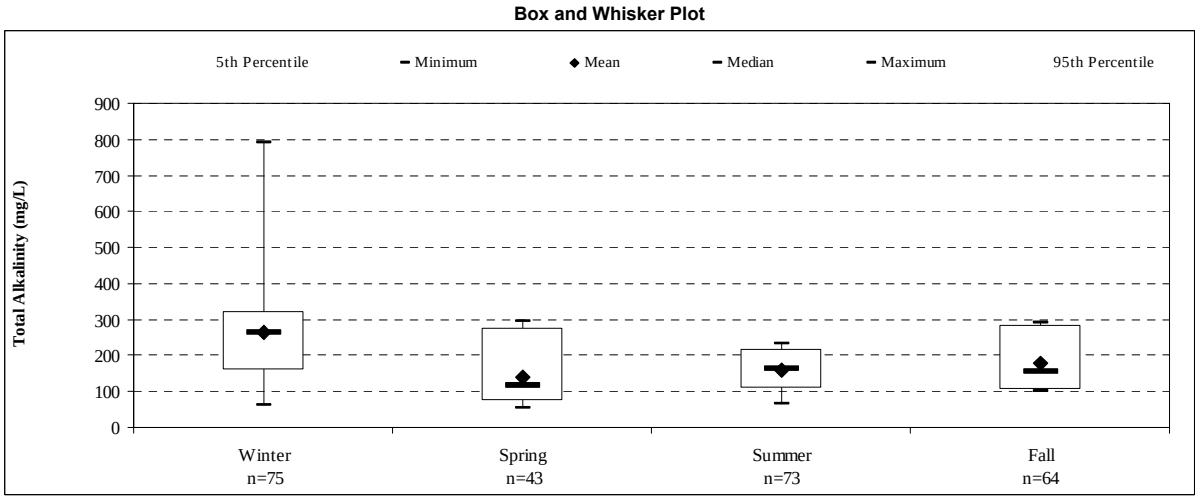


Figure G-2-3-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Lower Segment of Muskeg River



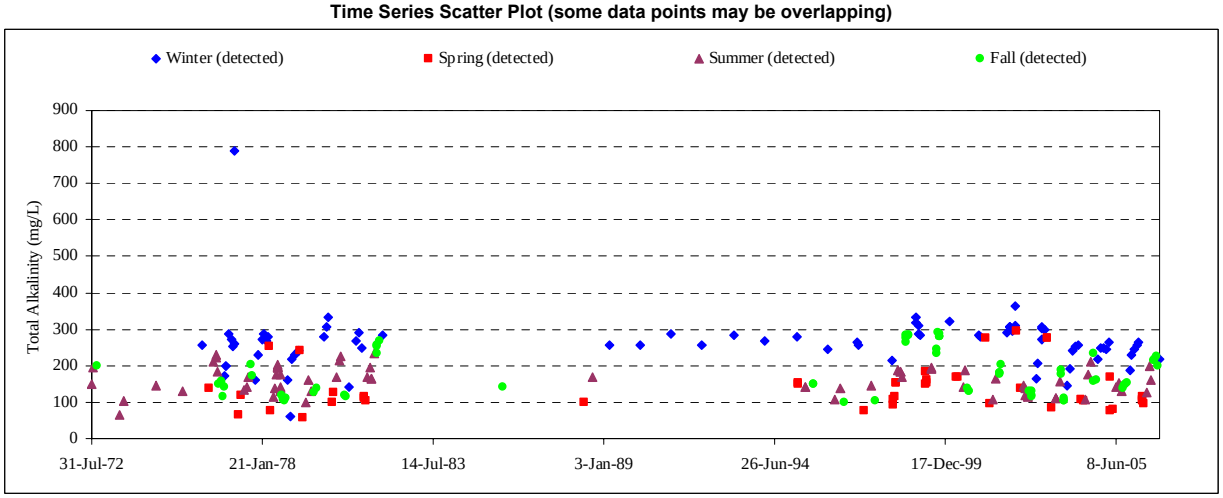
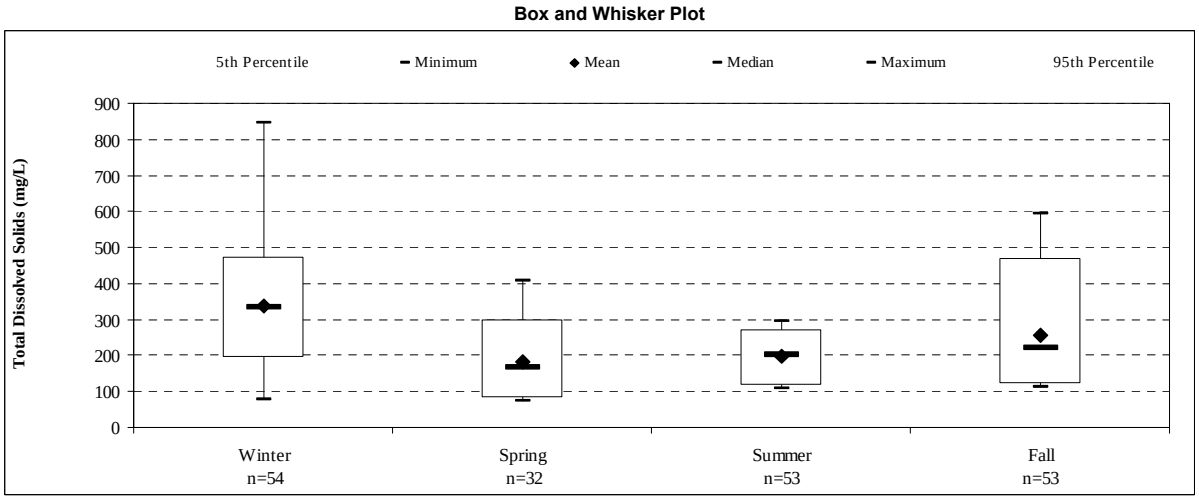


Figure G-2-3-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Lower Segment of Muskeg River



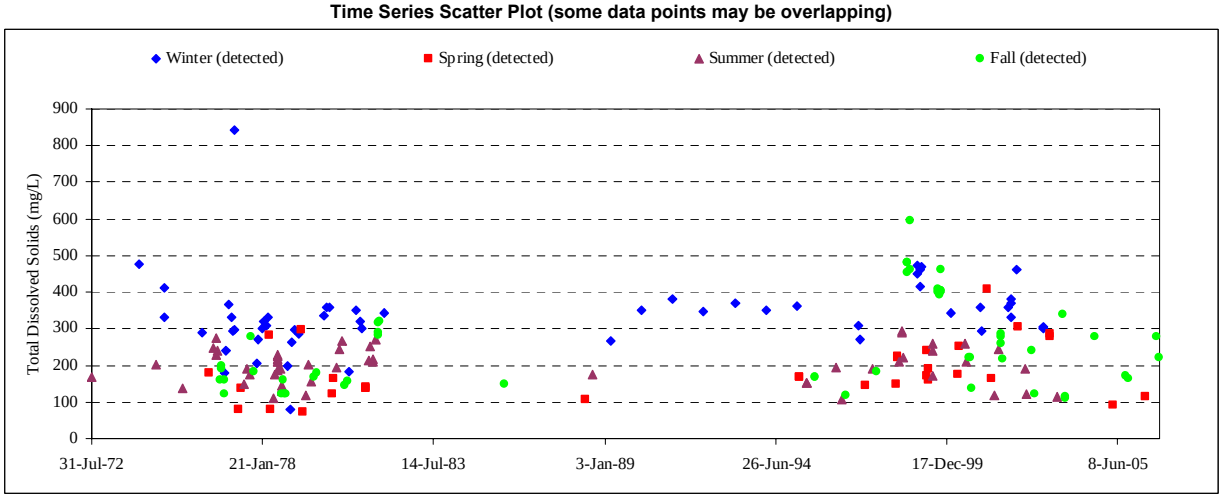
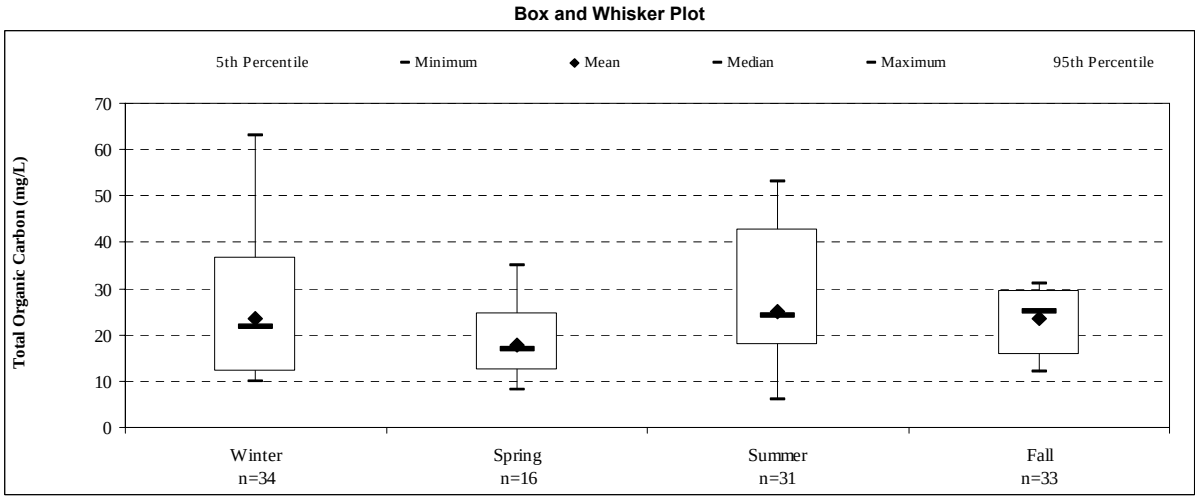


Figure G-2-3-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Lower Segment of Muskeg River



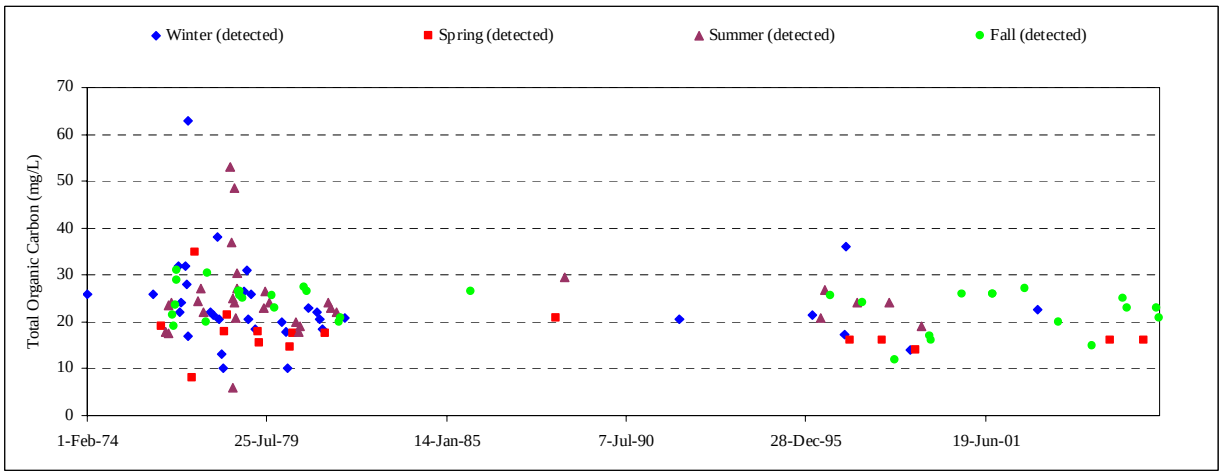
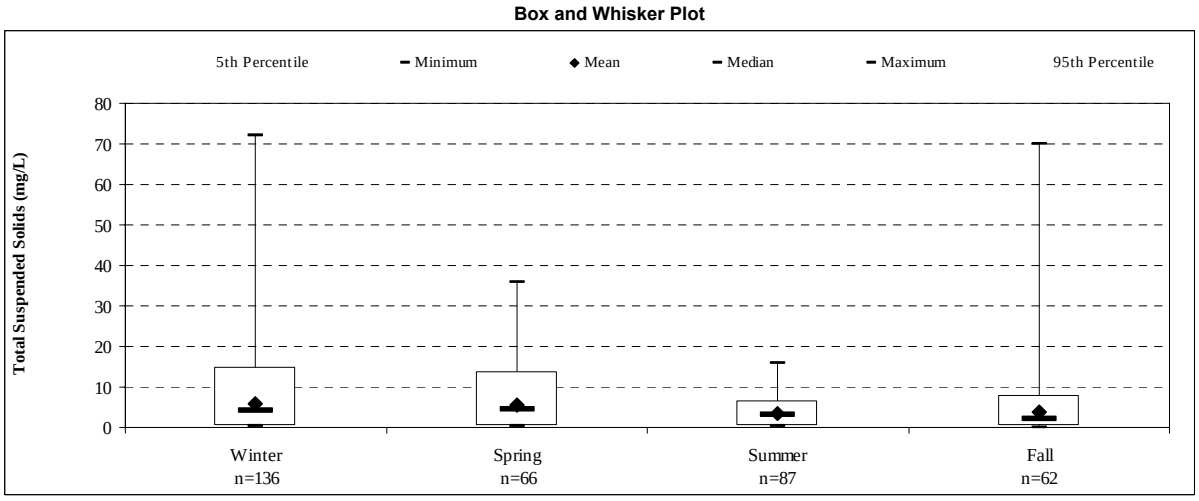


Figure G-2-3-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Lower Segment of Muskeg River



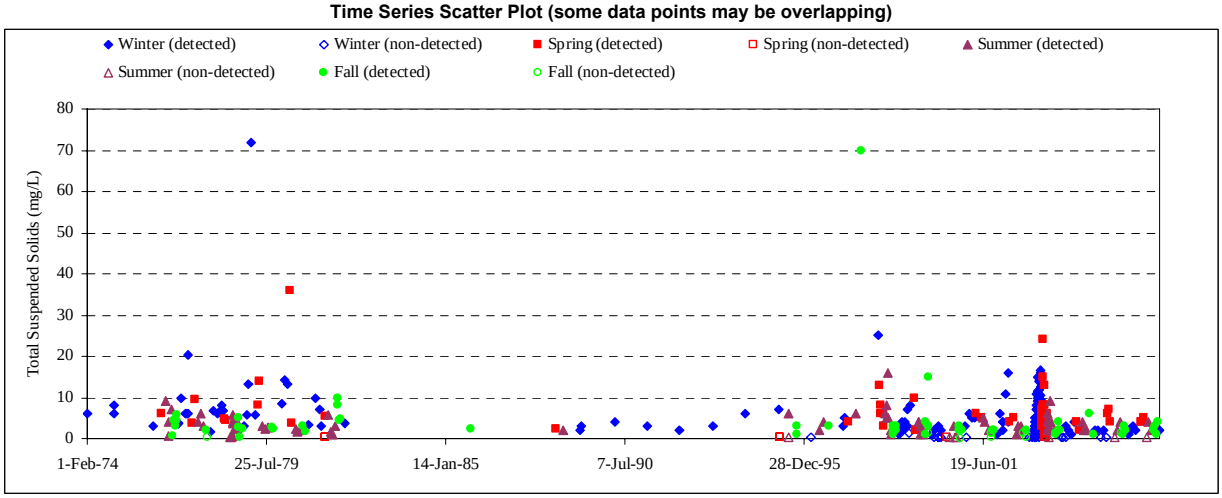
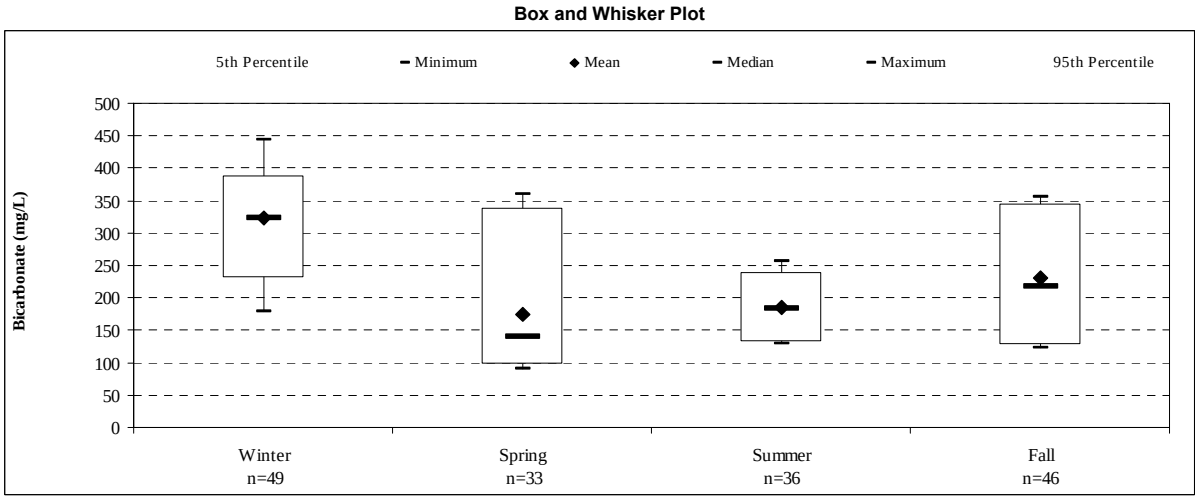


Figure G-2-3-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Lower Segment of Muskeg River



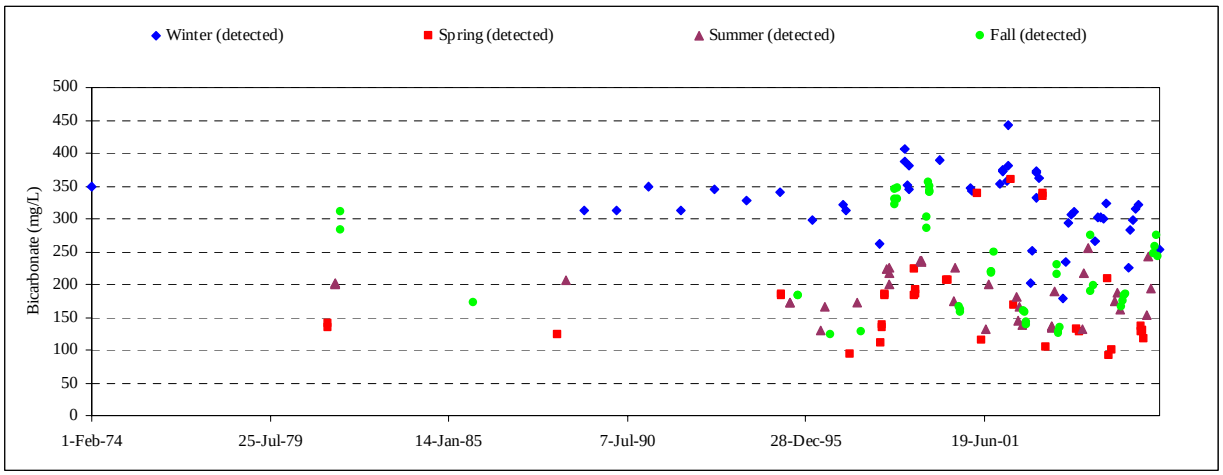
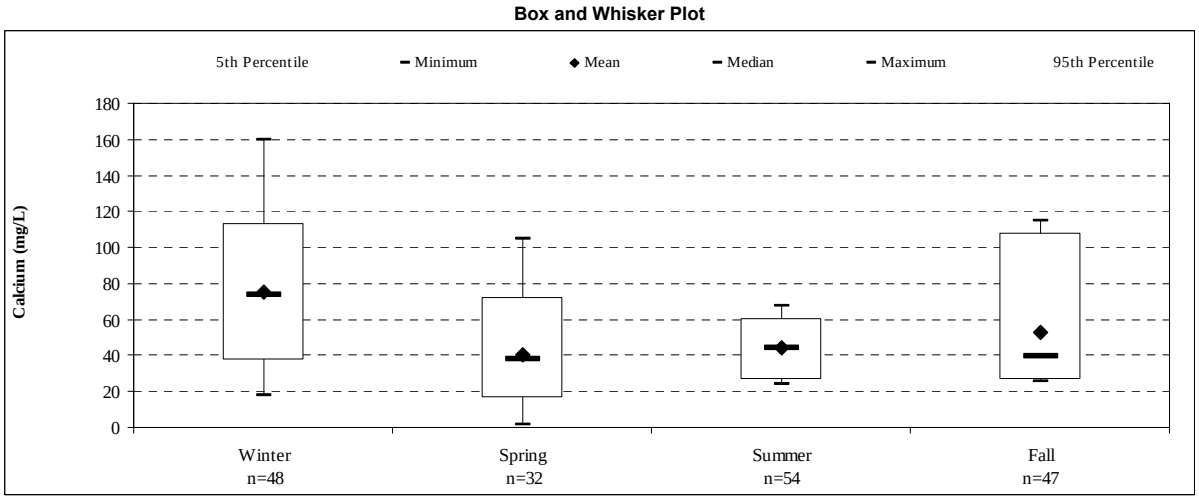


Figure G-2-3-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Lower Segment of Muskeg River



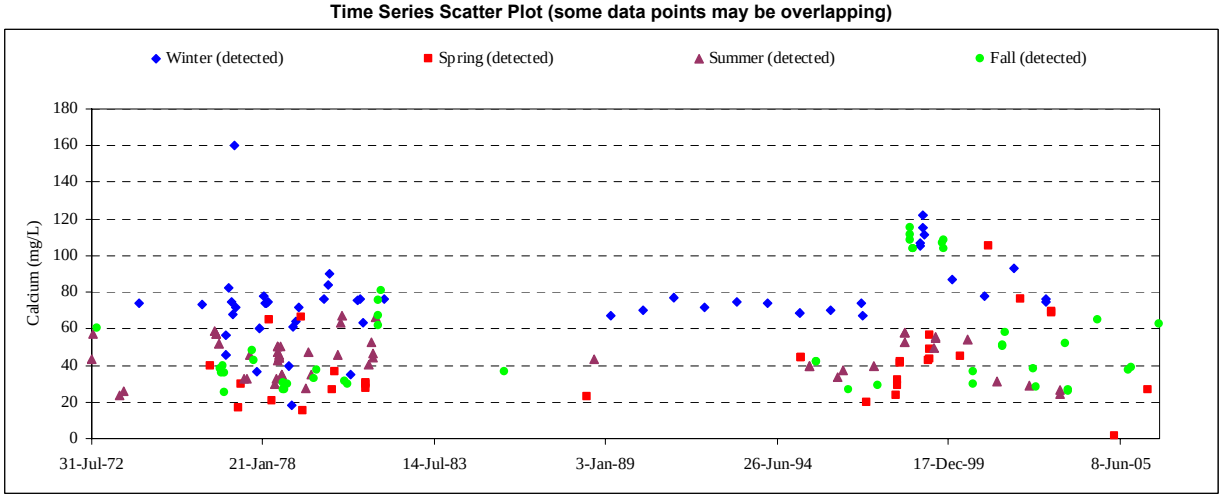
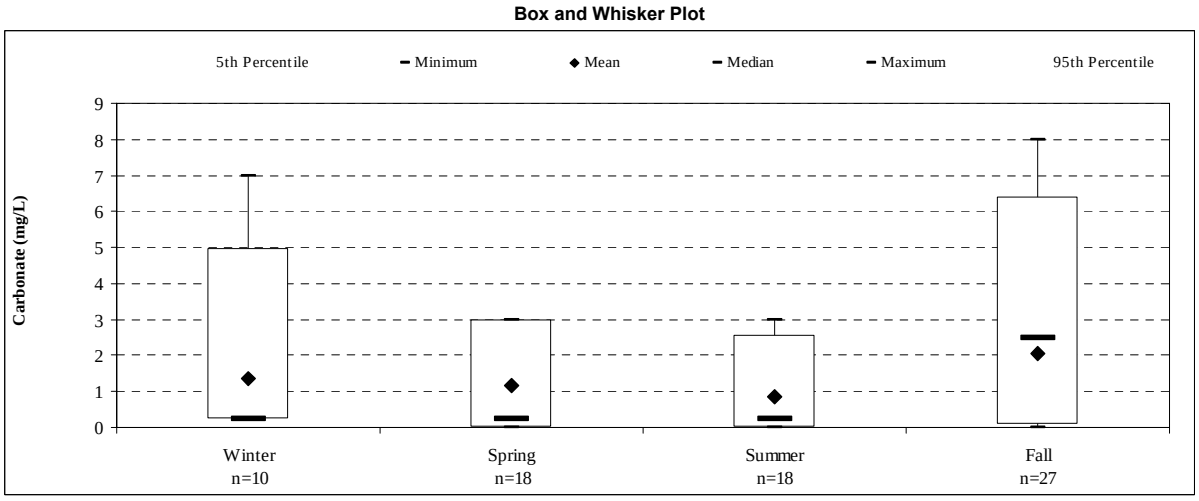


Figure G-2-3-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Lower Segment of Muskeg River



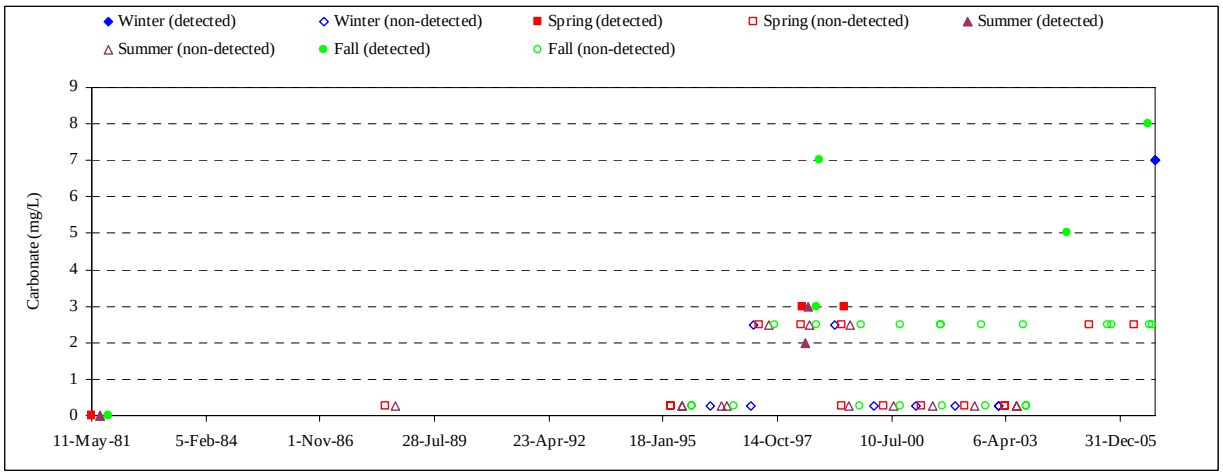
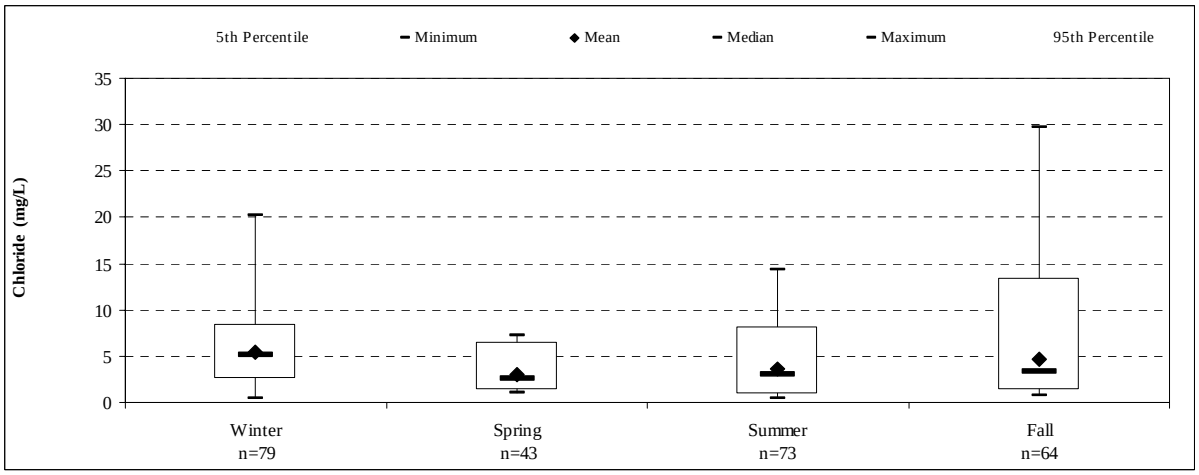


Figure G-2-3-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Lower Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

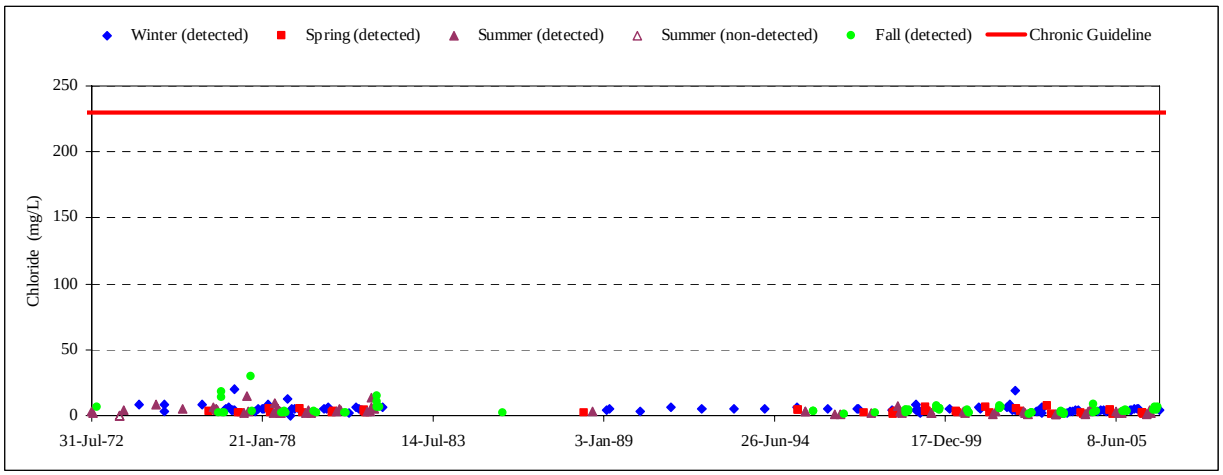
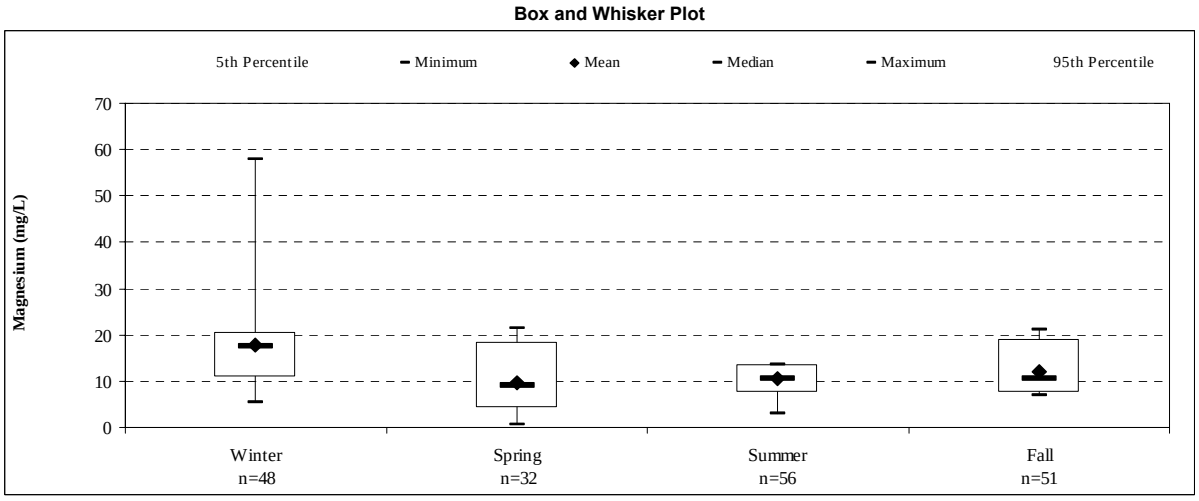


Figure G-2-3-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Lower Segment of Muskeg River



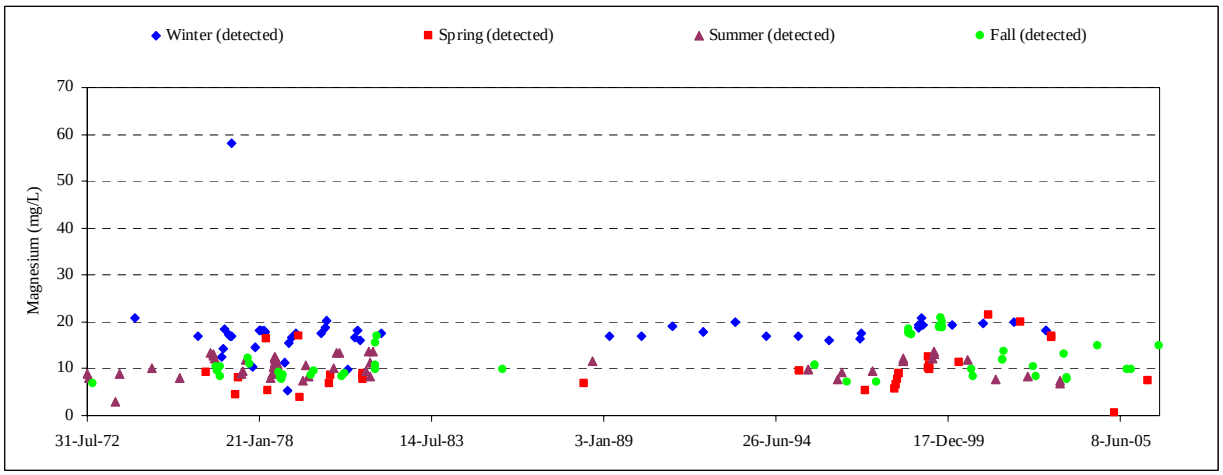
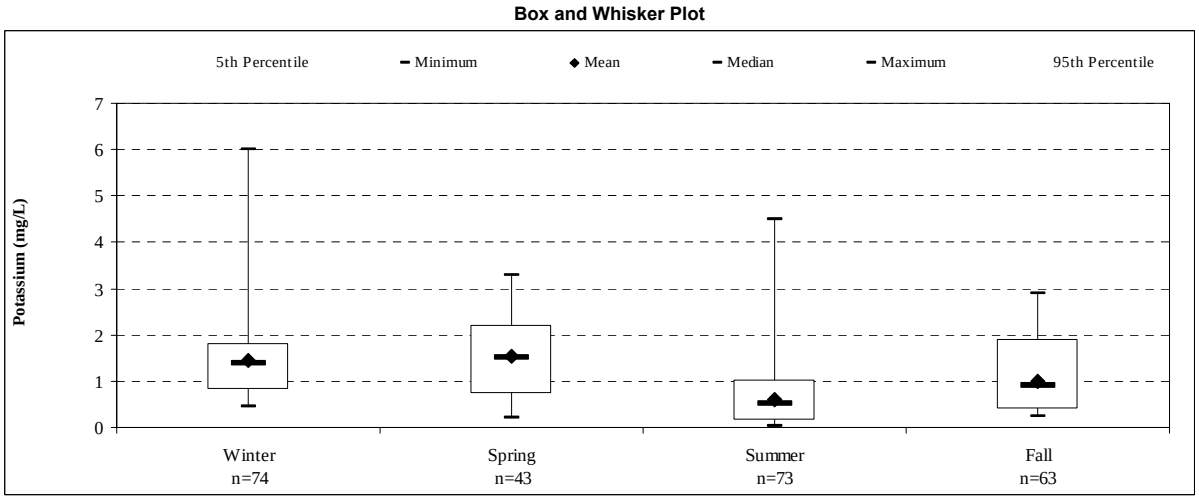


Figure G-2-3-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Lower Segment of Muskeg River



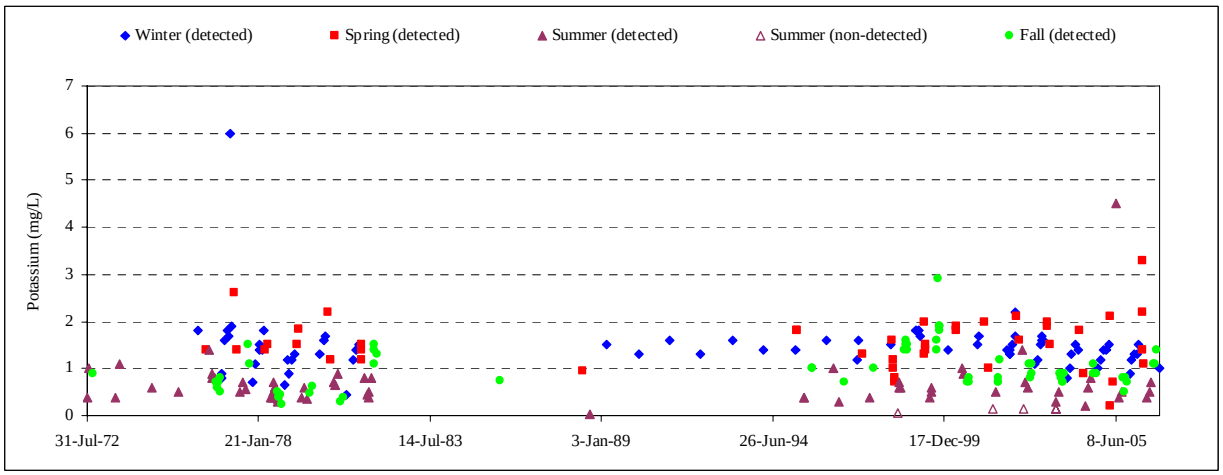
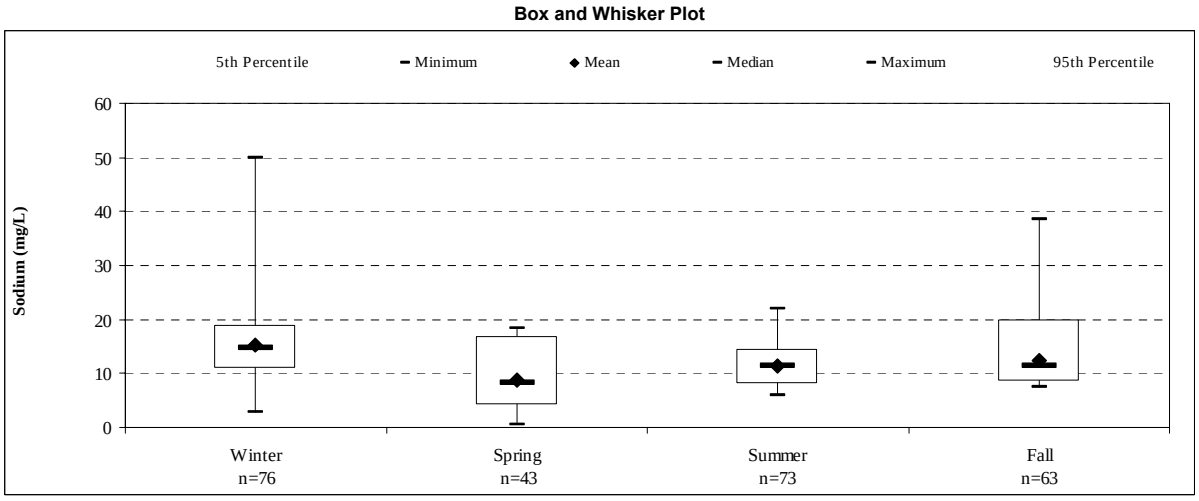


Figure G-2-3-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Lower Segment of Muskeg River



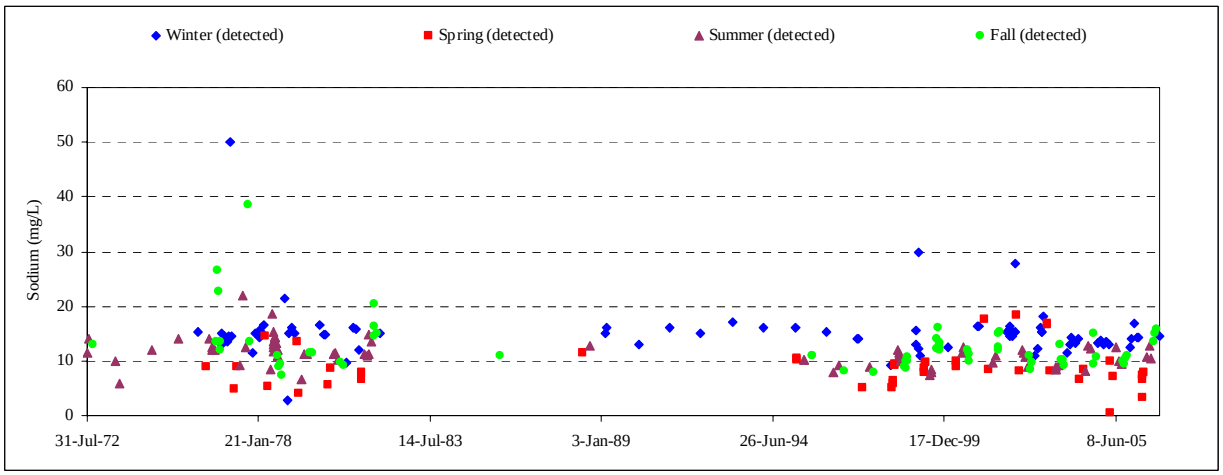
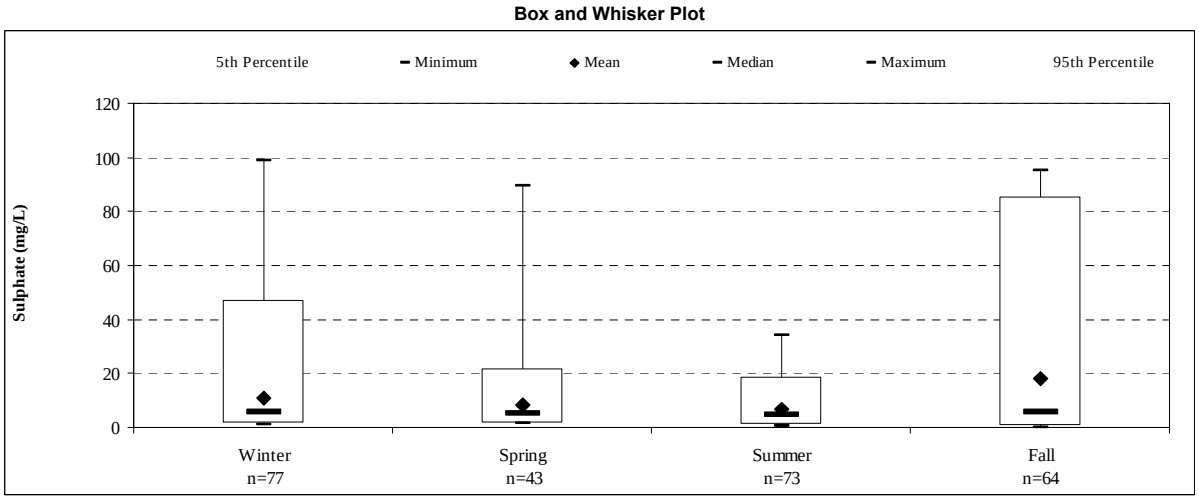


Figure G-2-3-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Lower Segment of Muskeg River



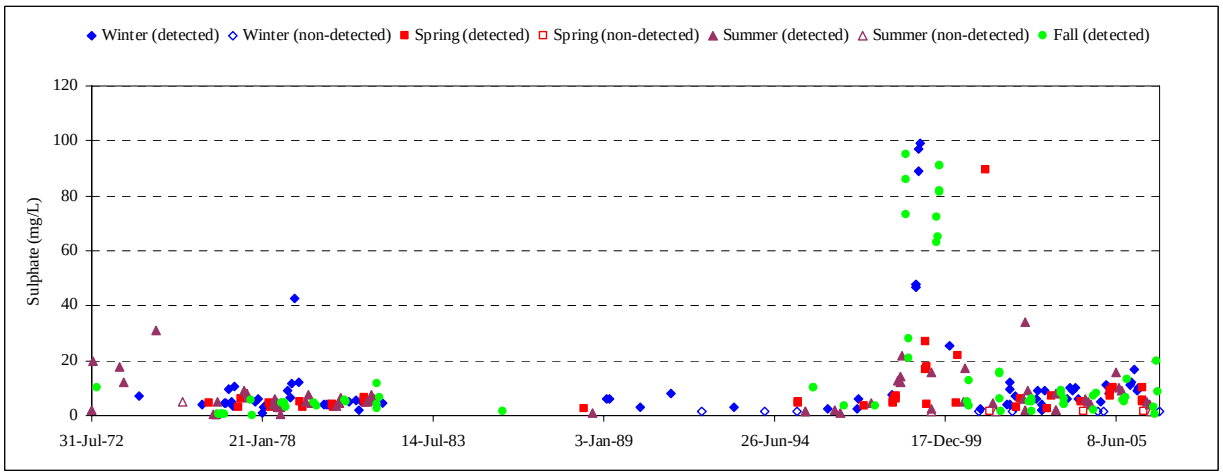
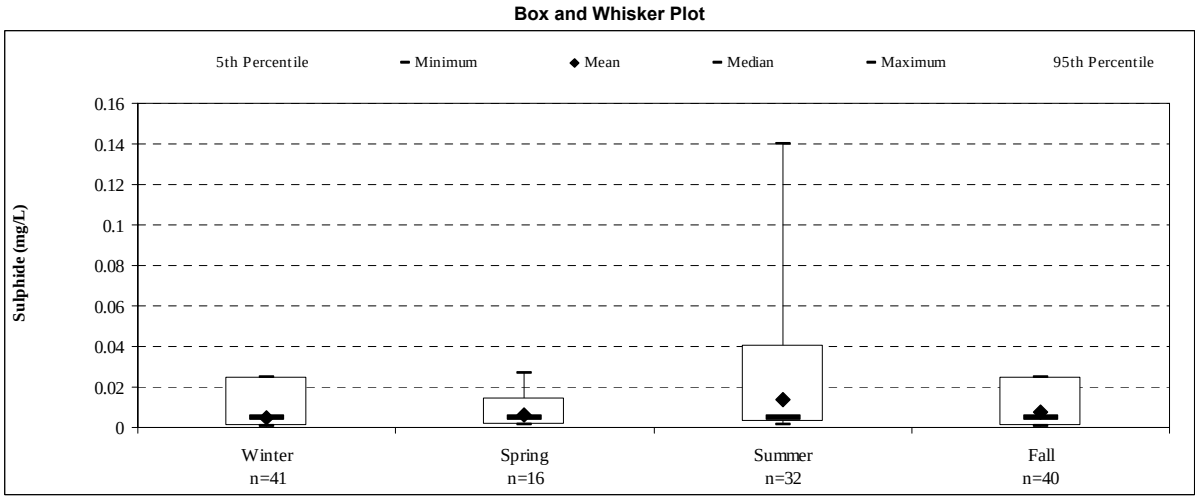


Figure G-2-3-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Lower Segment of Muskeg River



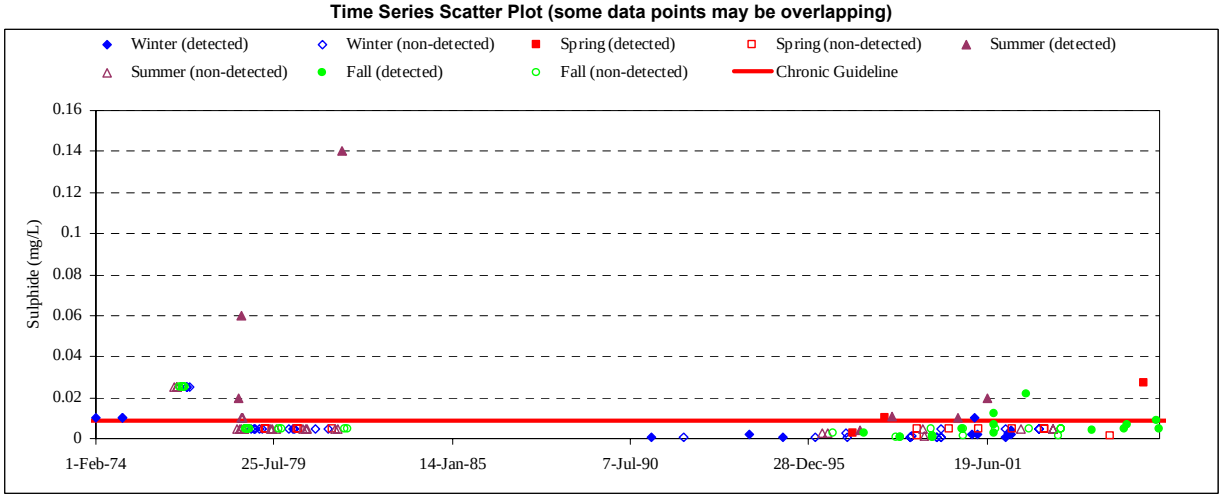
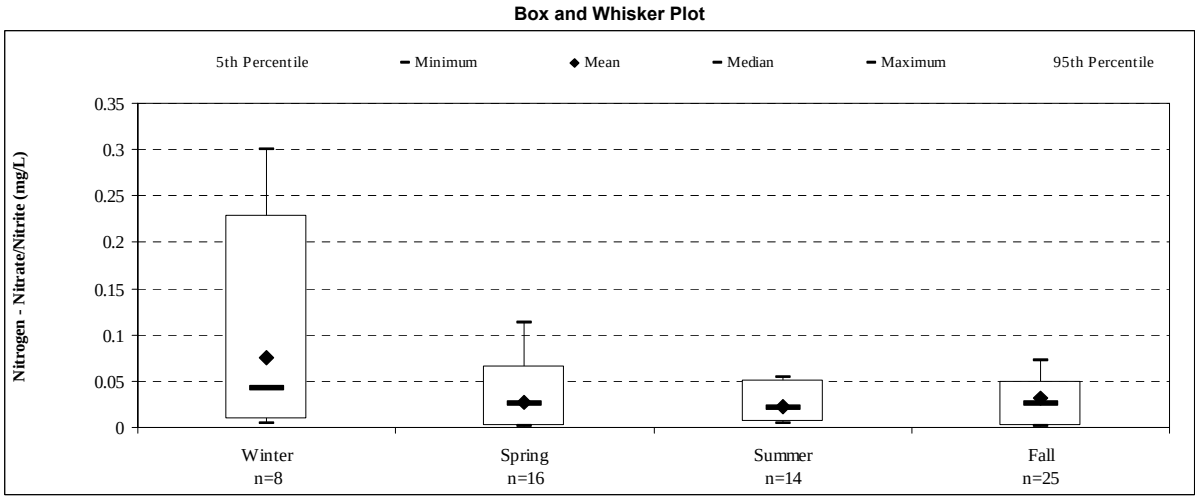


Figure G-2-3-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Lower Segment of Muskeg River



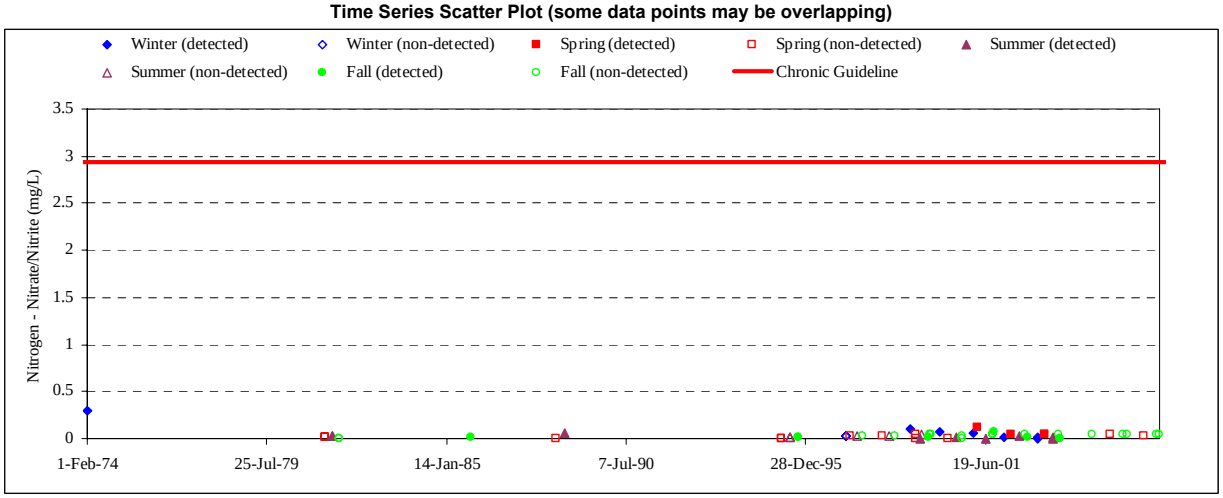
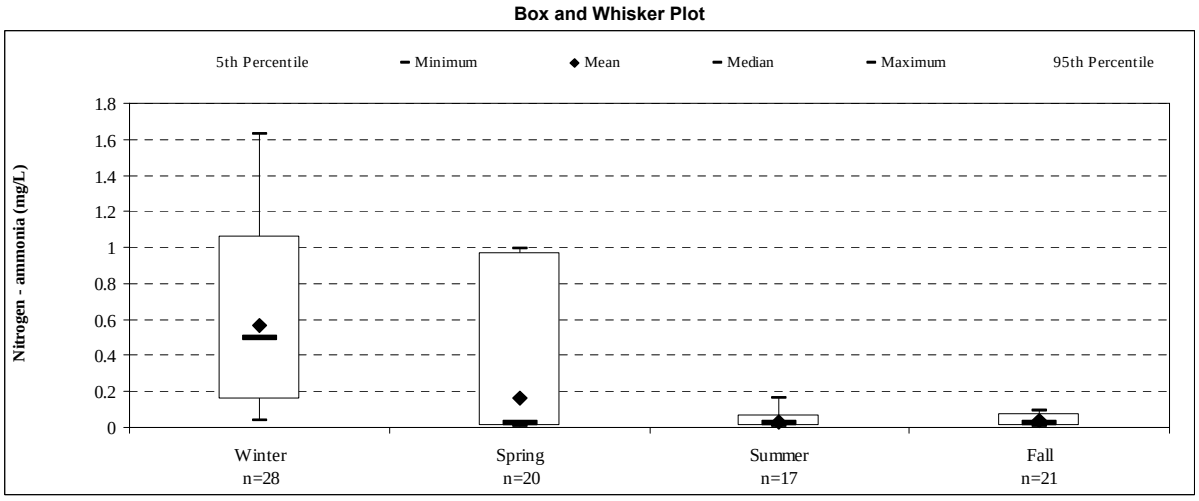


Figure G-2-3-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Lower Segment of Muskeg River



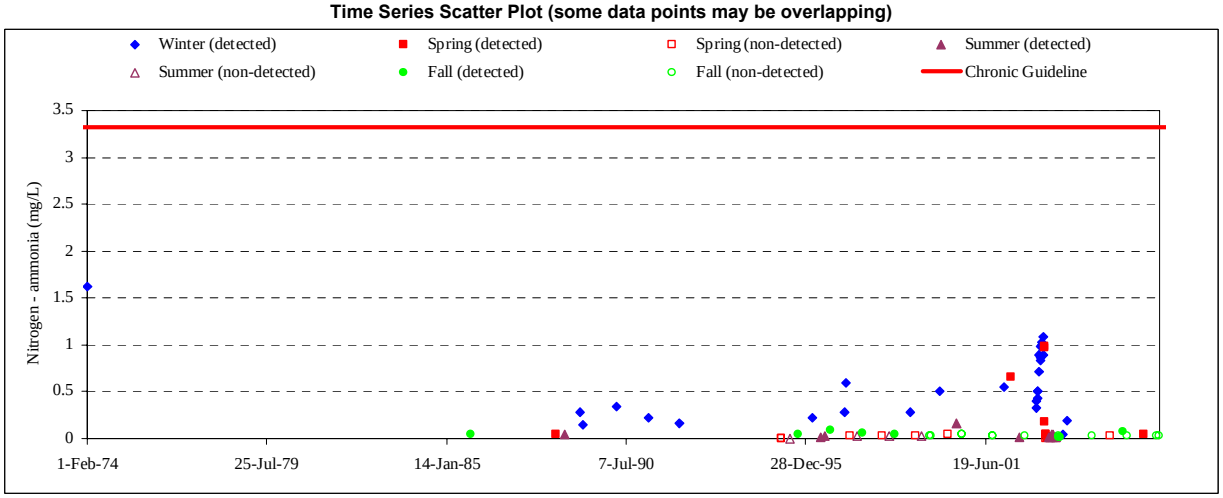
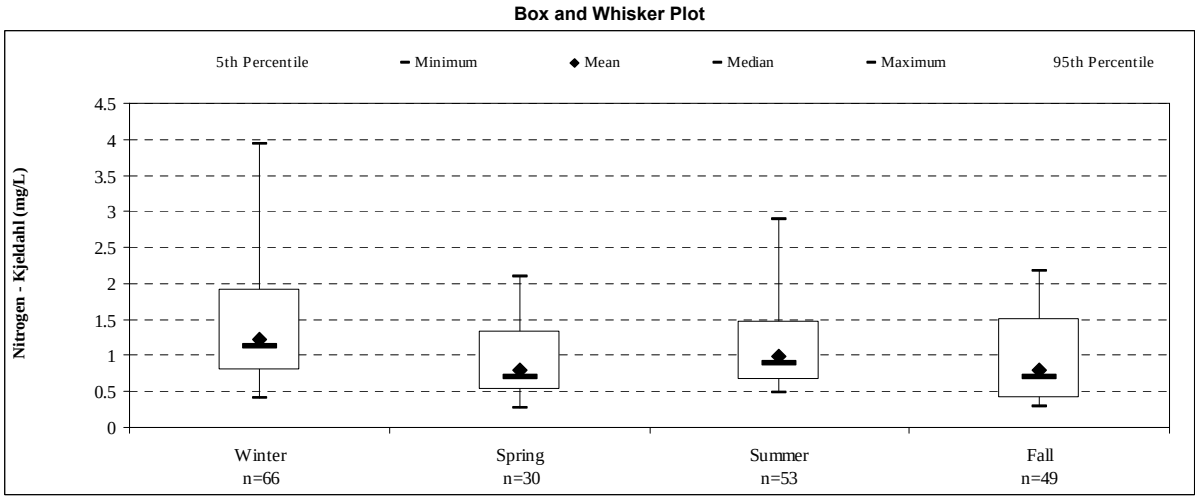


Figure G-2-3-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Lower Segment of Muskeg River



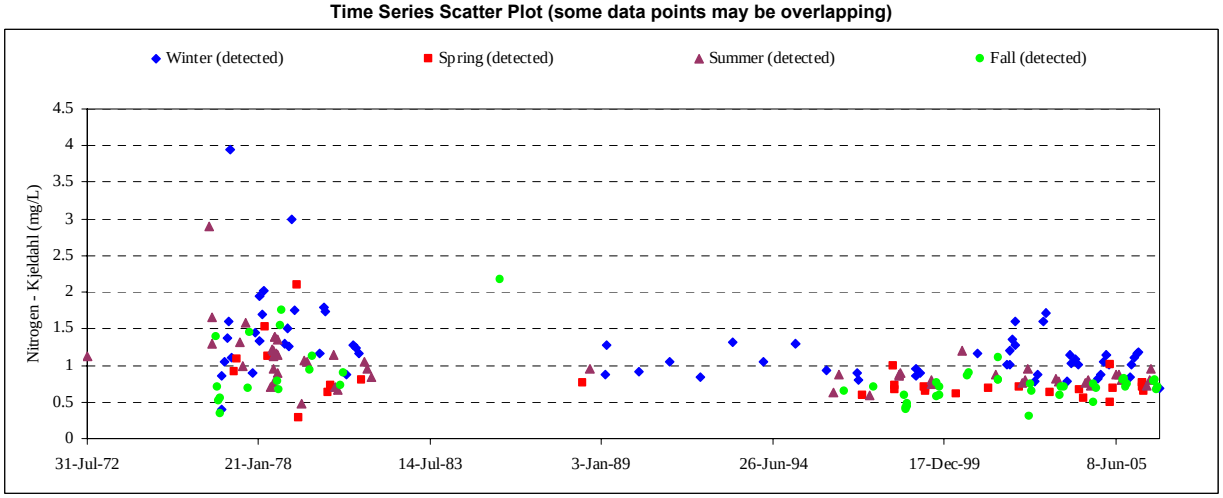
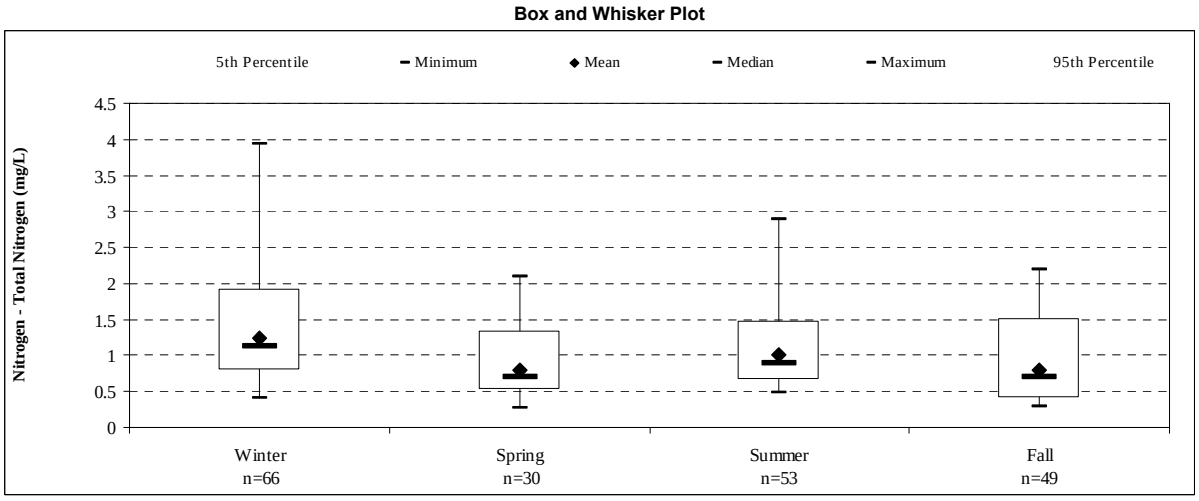


Figure G-2-3-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Lower Segment of Muskeg River



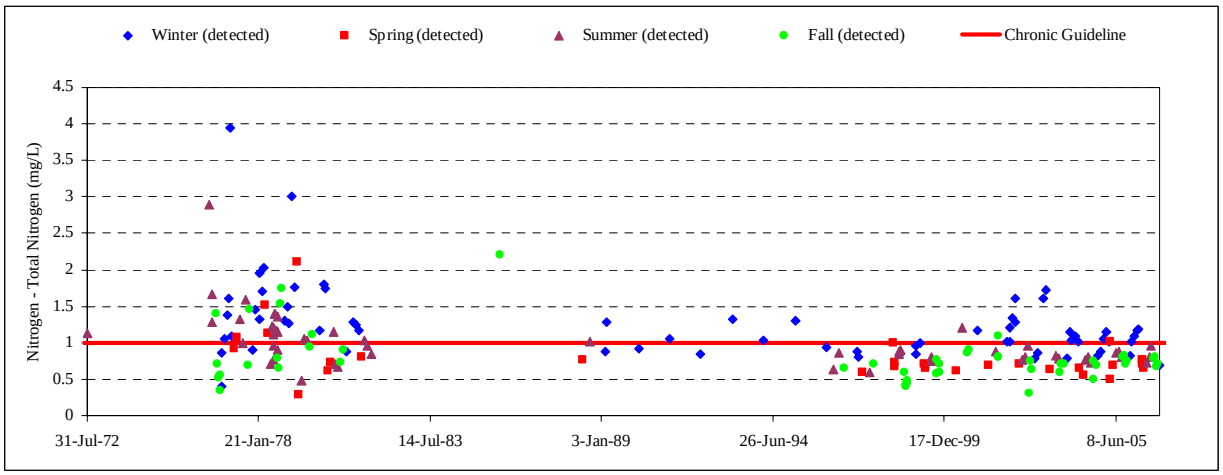
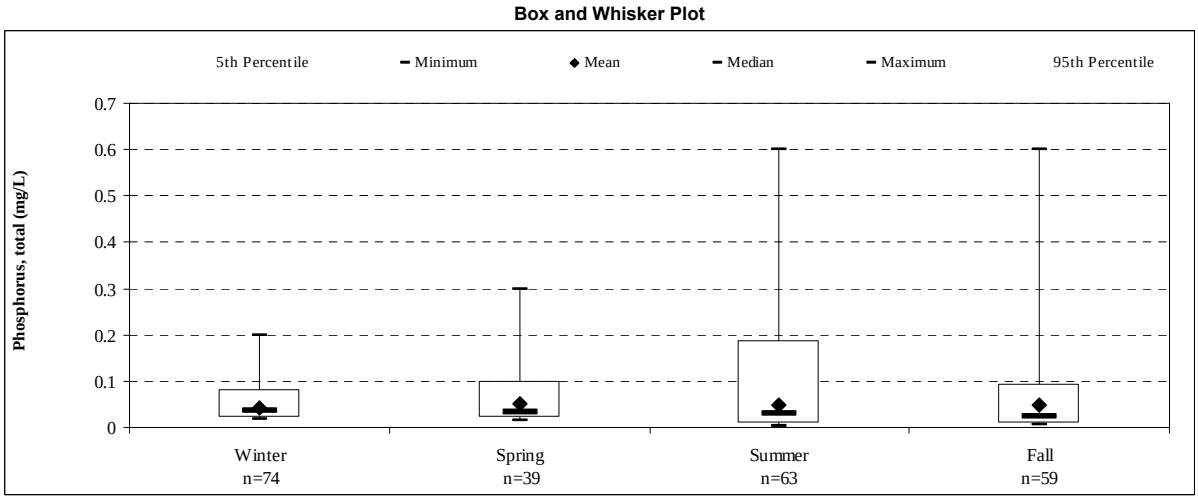


Figure G-2-3-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Lower Segment of Muskeg River



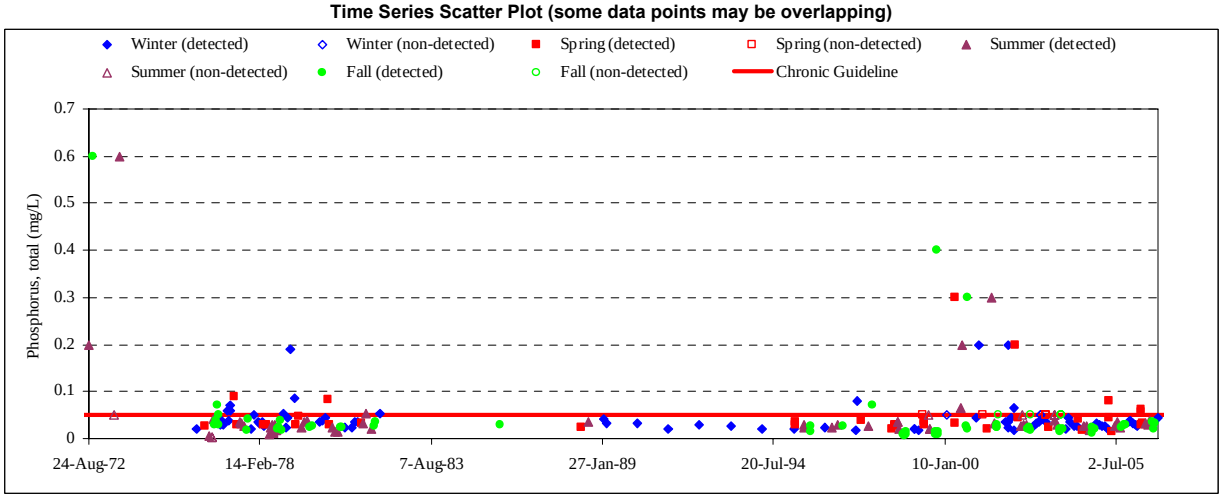


Figure G-2-3-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Lower Segment of Muskeg River

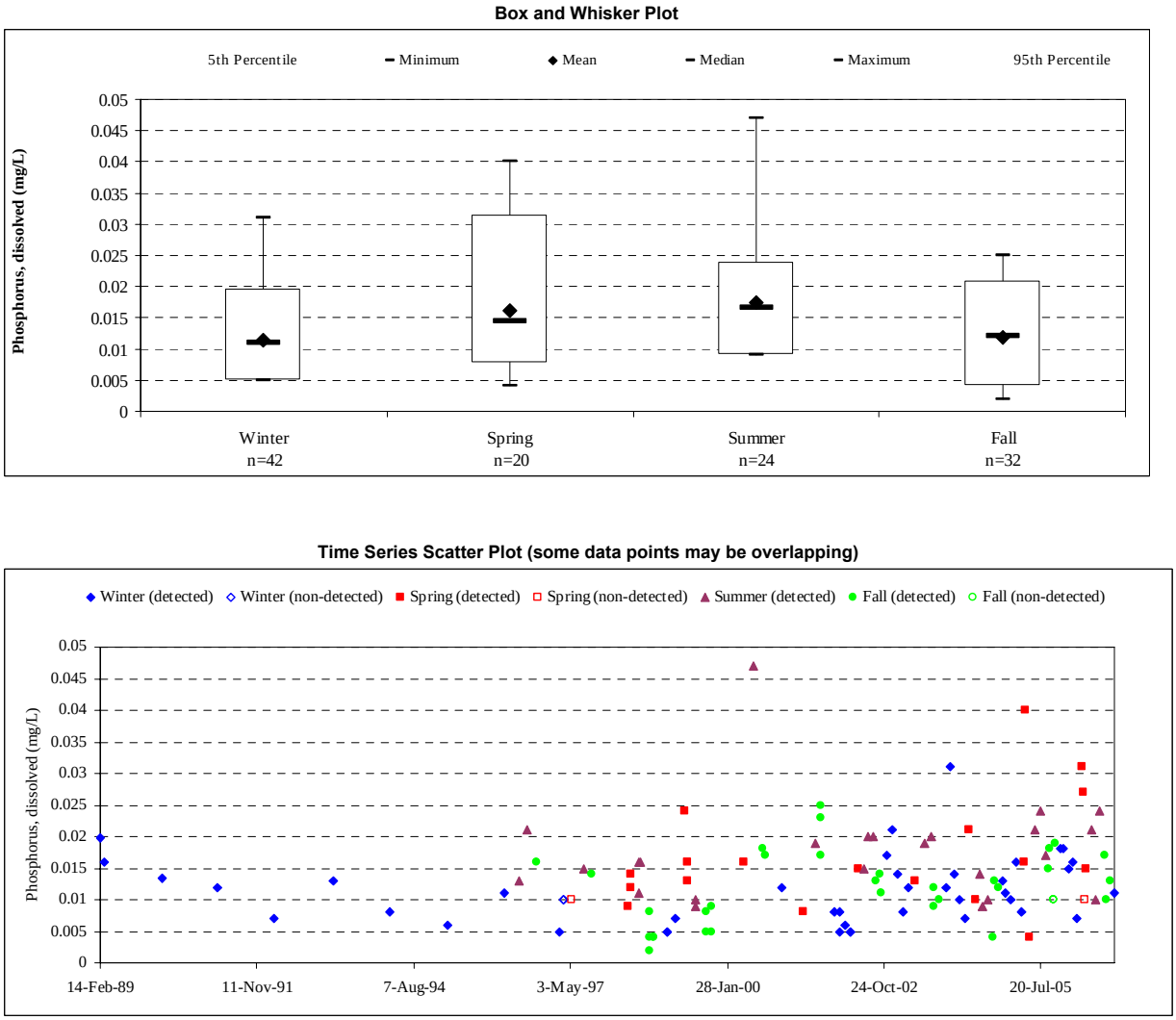
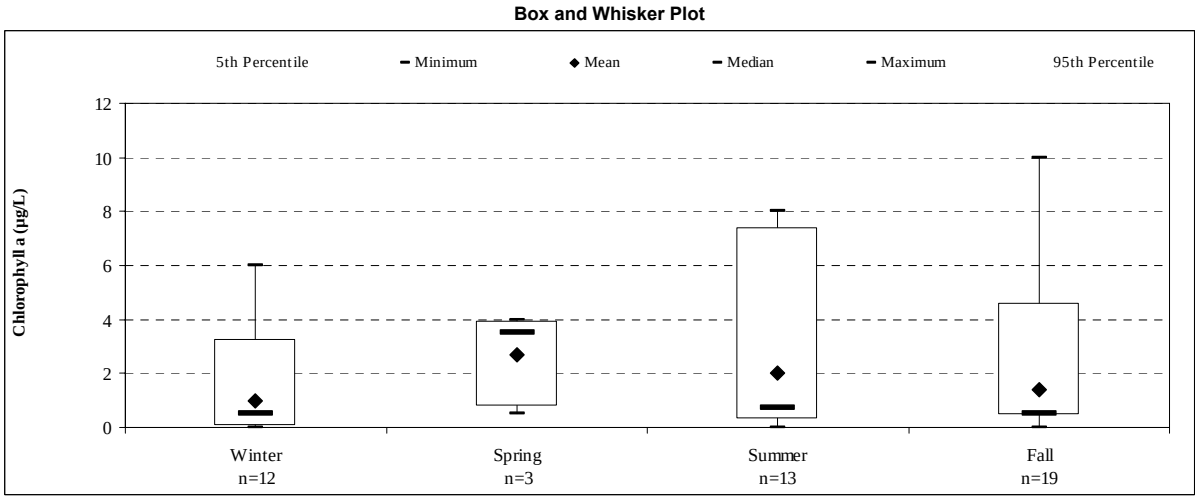


Figure G-2-3-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Lower Segment of Muskeg River



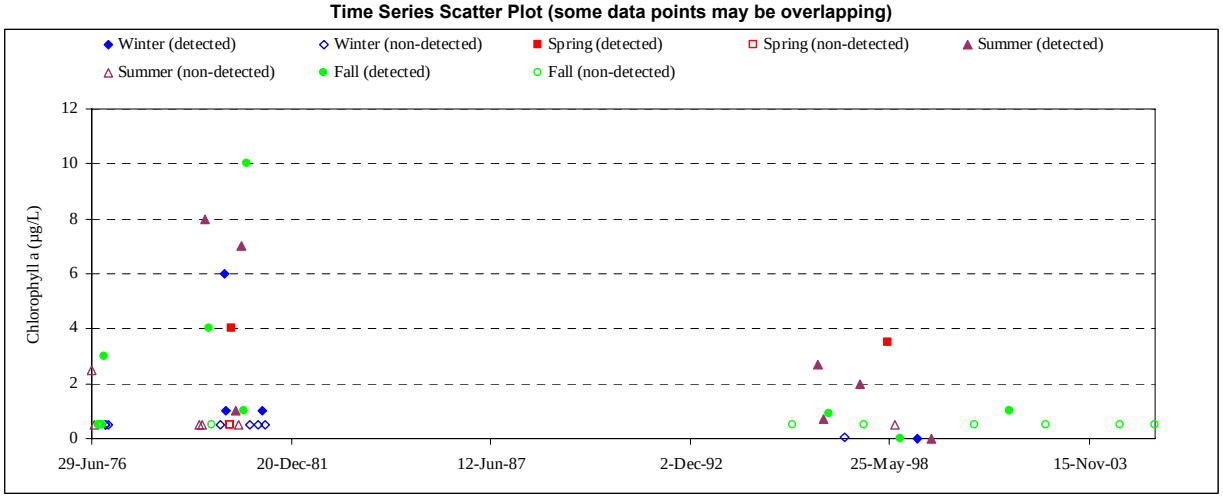
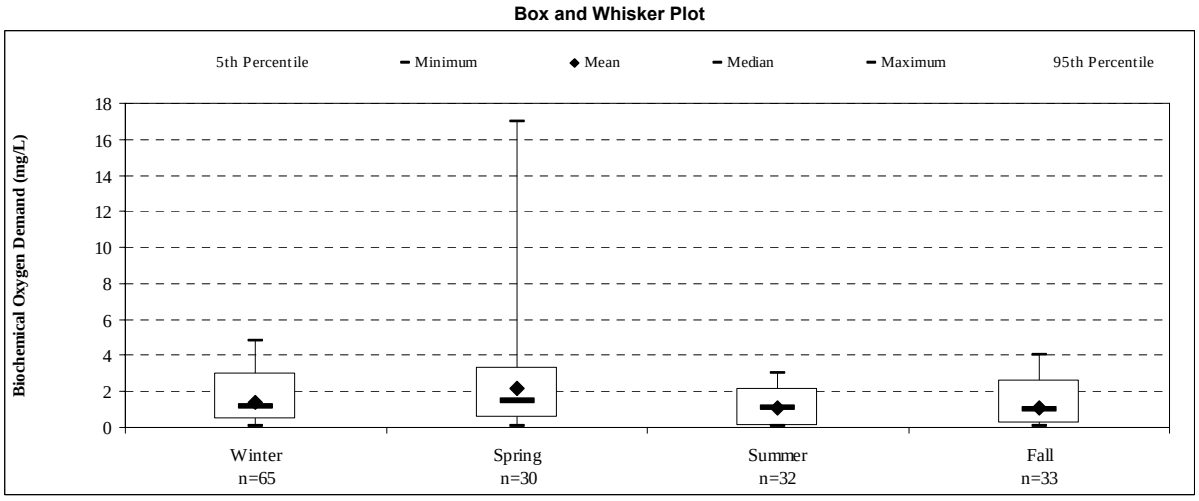


Figure G-2-3-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Lower Segment of Muskeg River



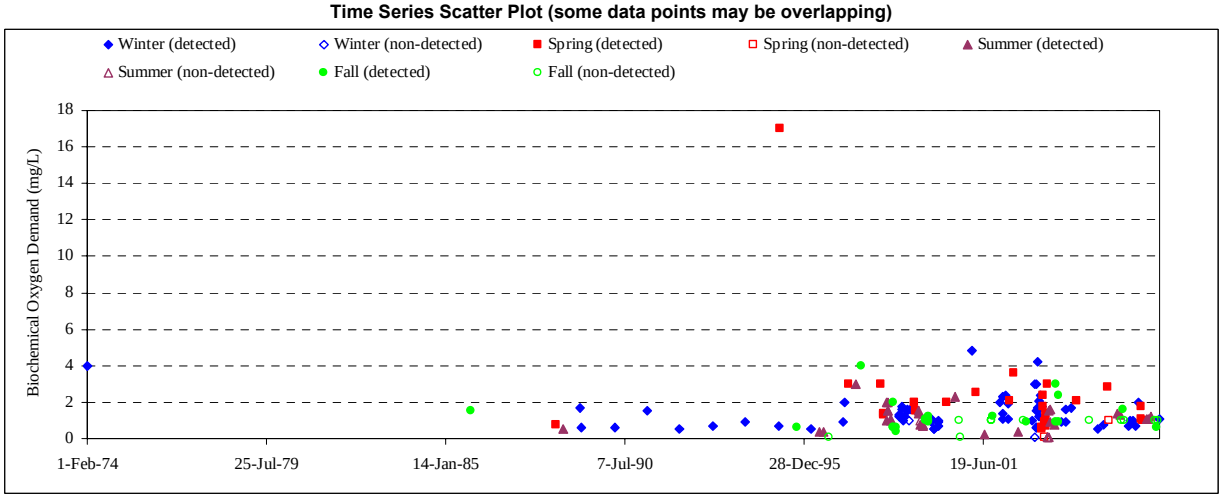
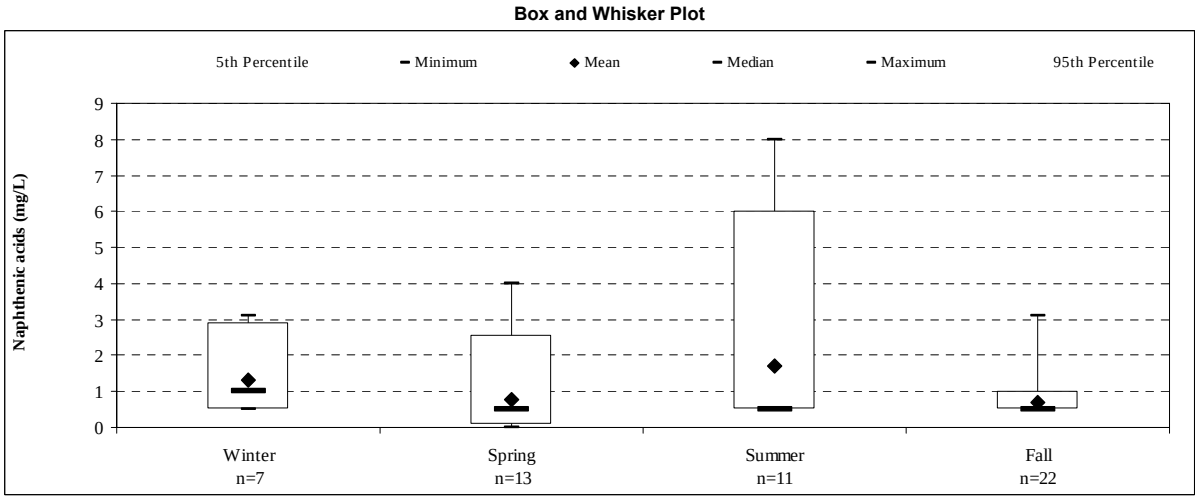


Figure G-2-3-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Lower Segment of Muskeg River



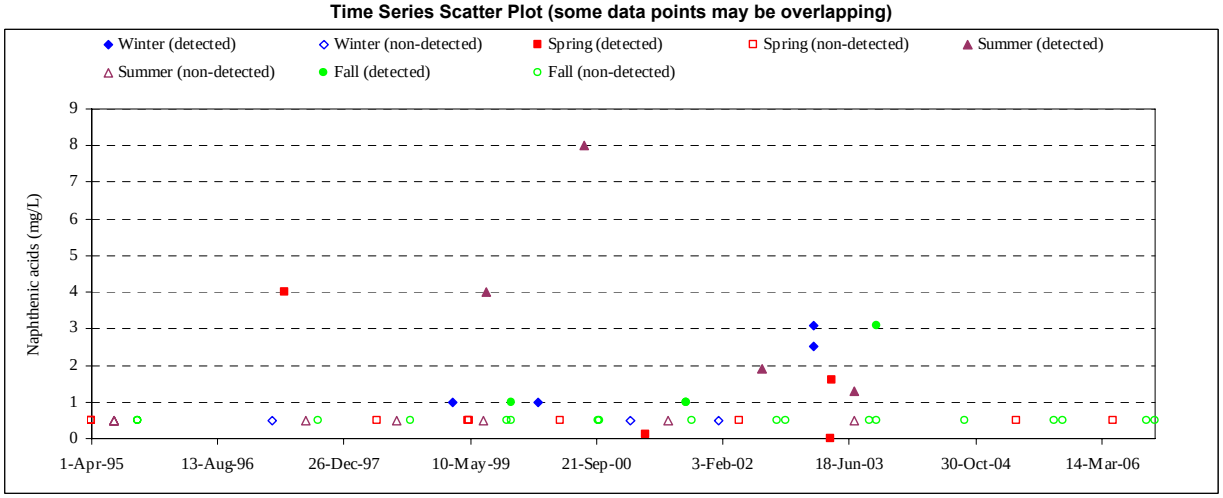
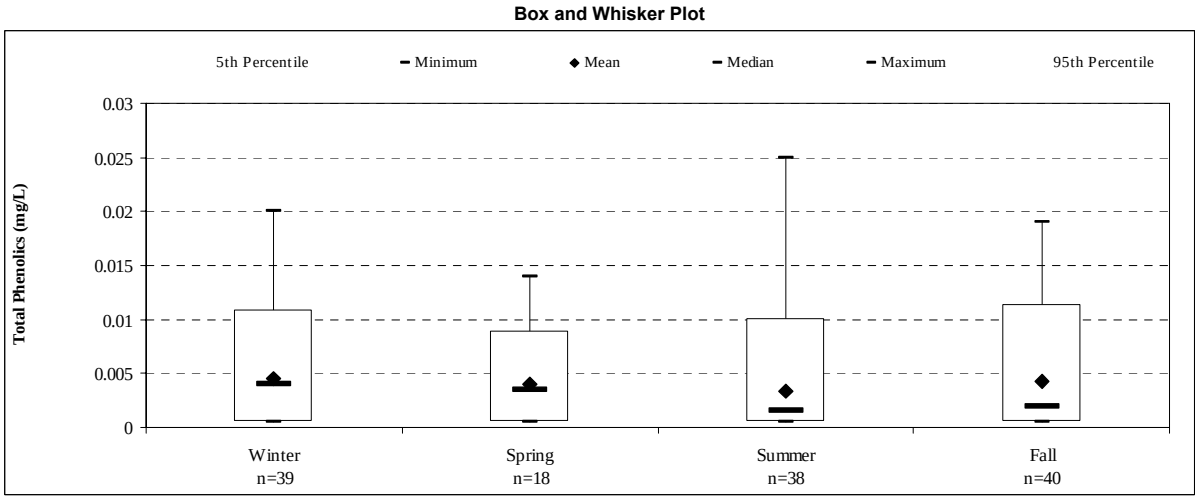


Figure G-2-3-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Lower Segment of Muskeg River



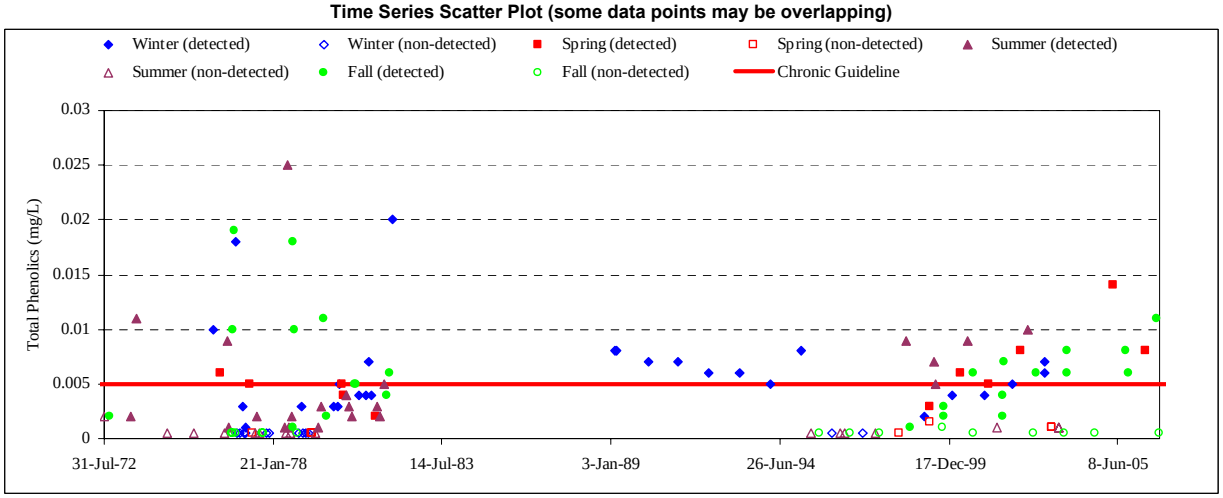
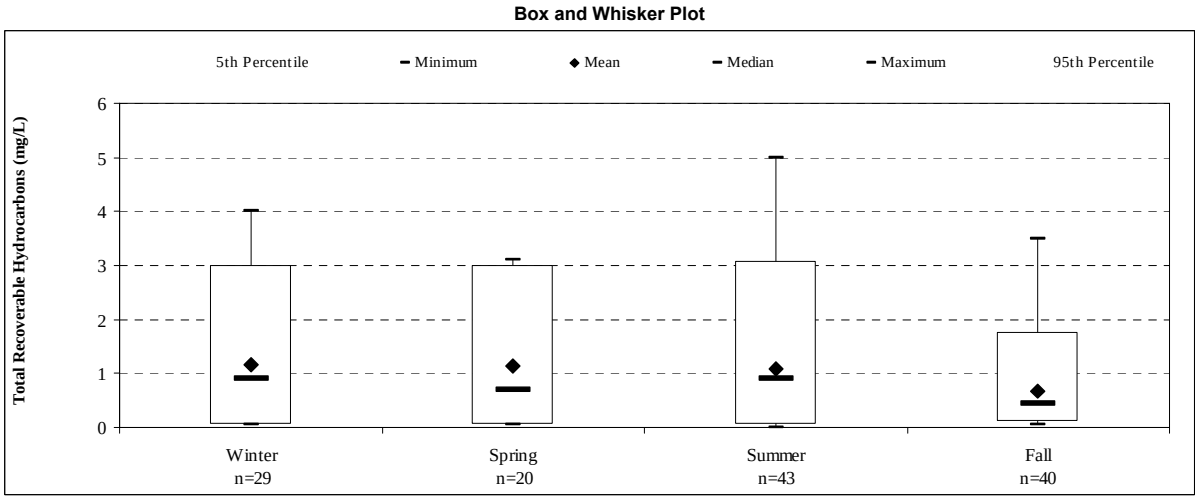


Figure G-2-3-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Lower Segment of Muskeg River



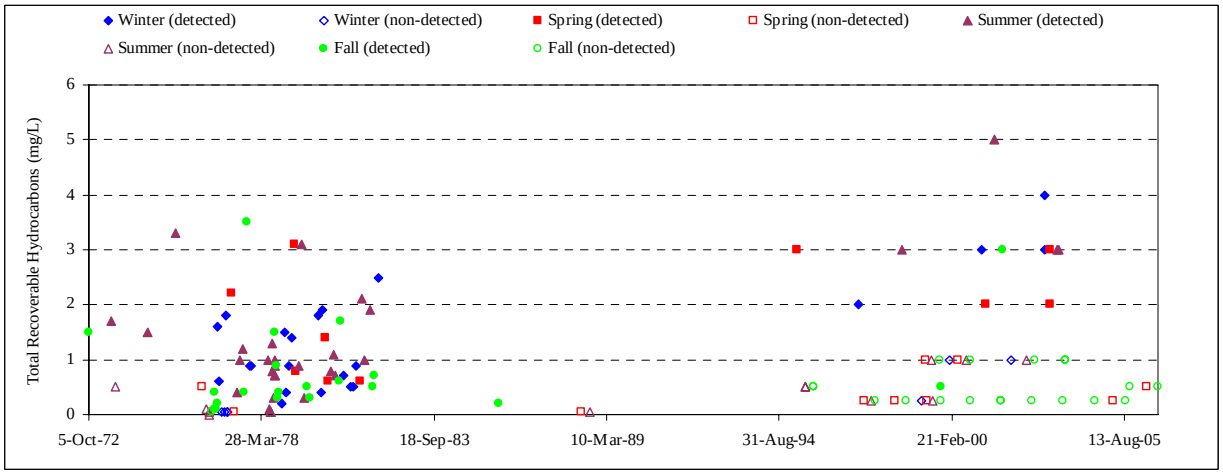
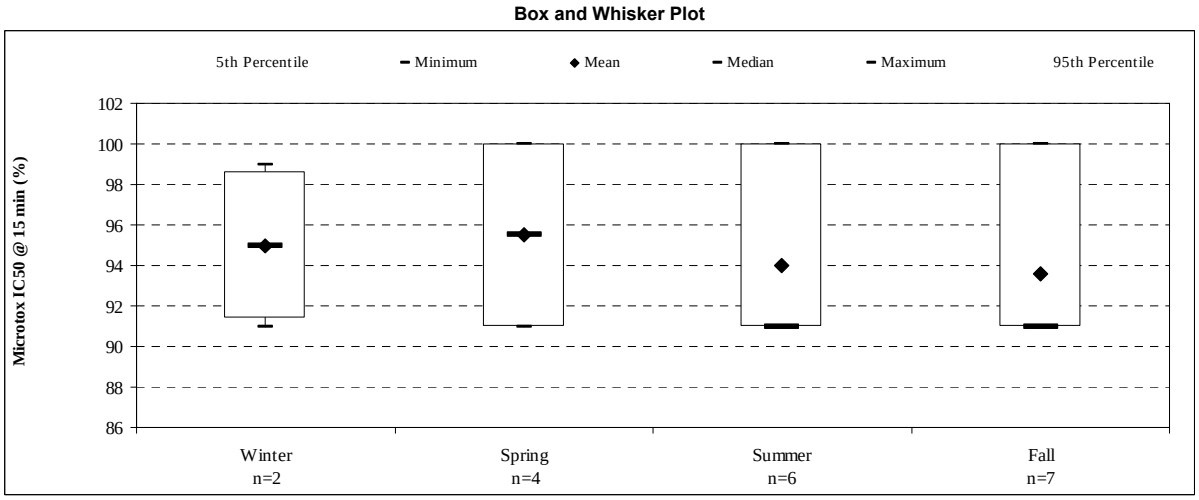


Figure G-2-3-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Lower Segment of Muskeg River



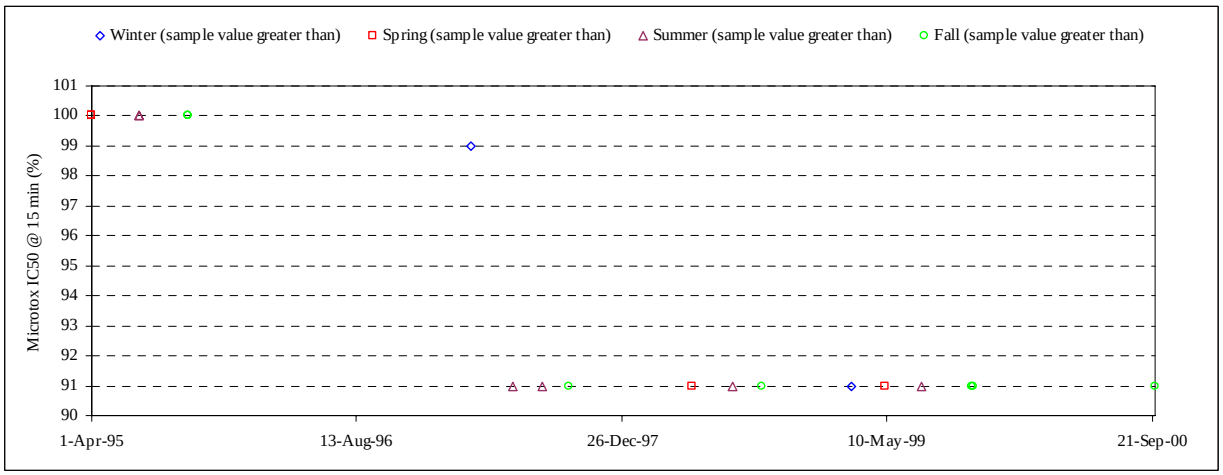
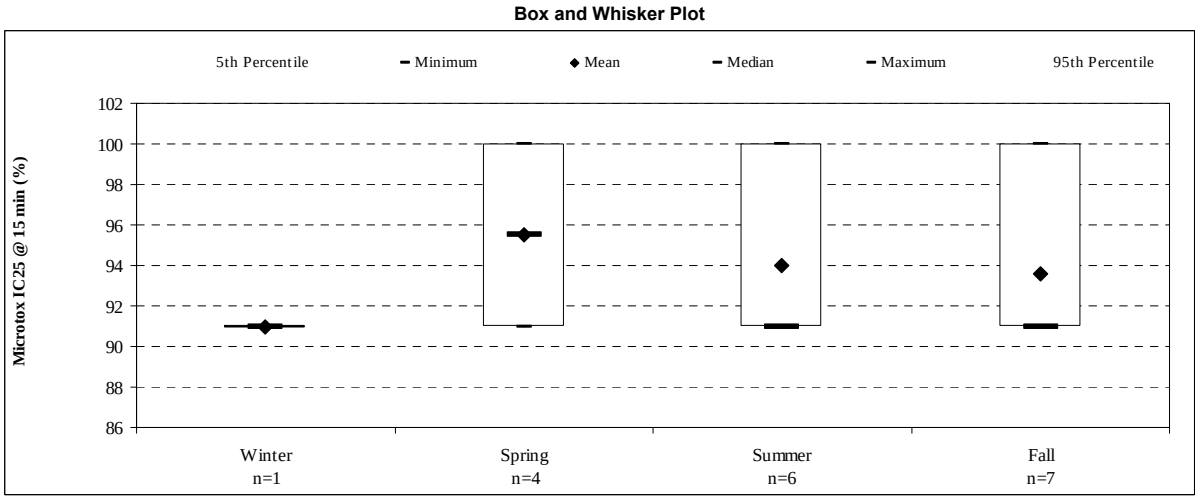


Figure G-2-3-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Lower Segment of Muskeg River



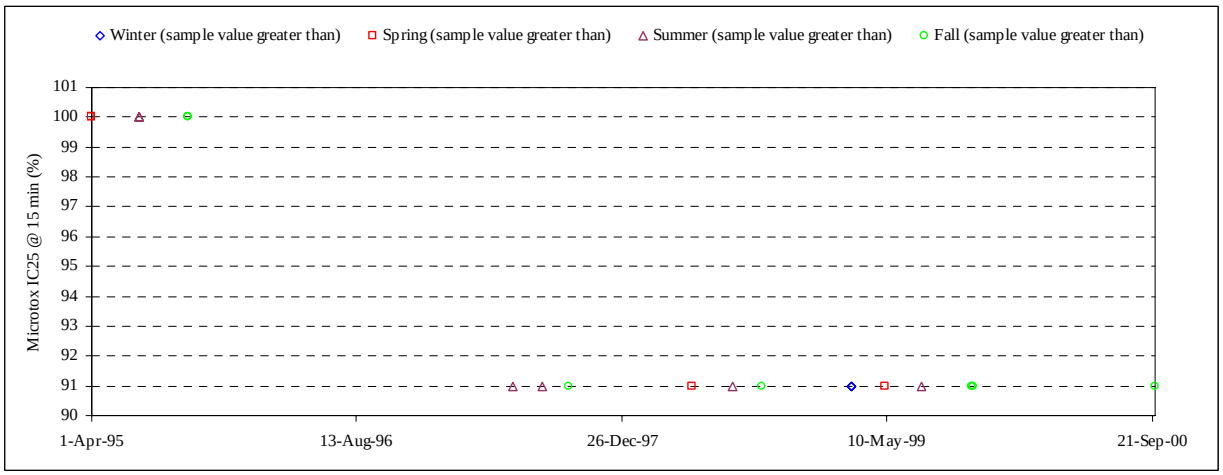
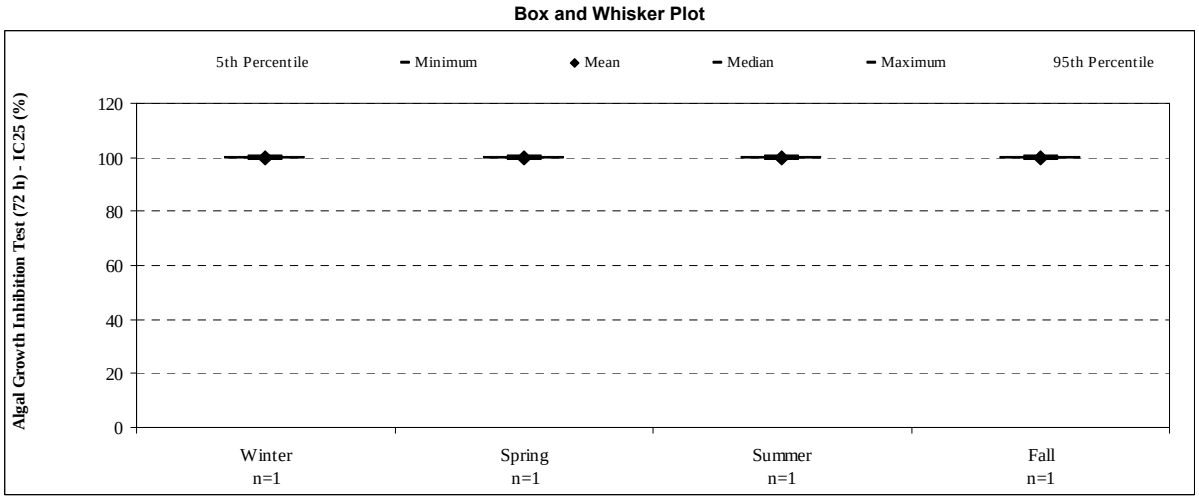


Figure G-2-3-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Lower Segment of Muskeg River



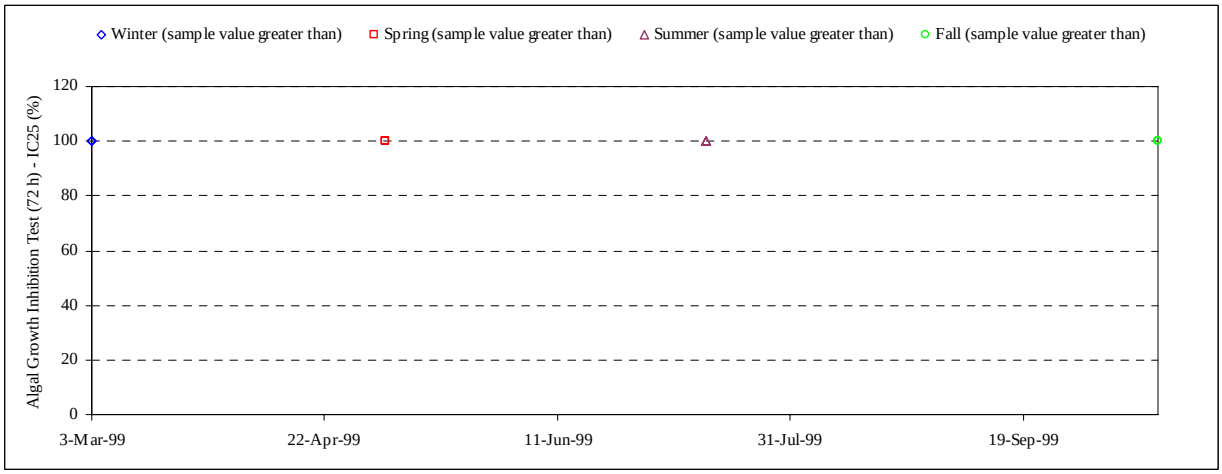
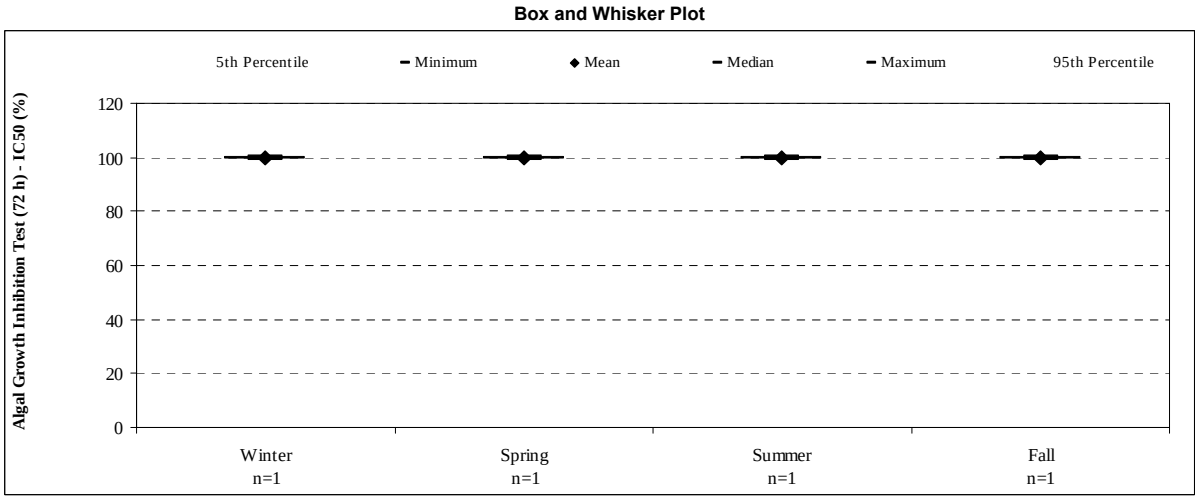


Figure G-2-3-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Lower Segment of Muskeg River



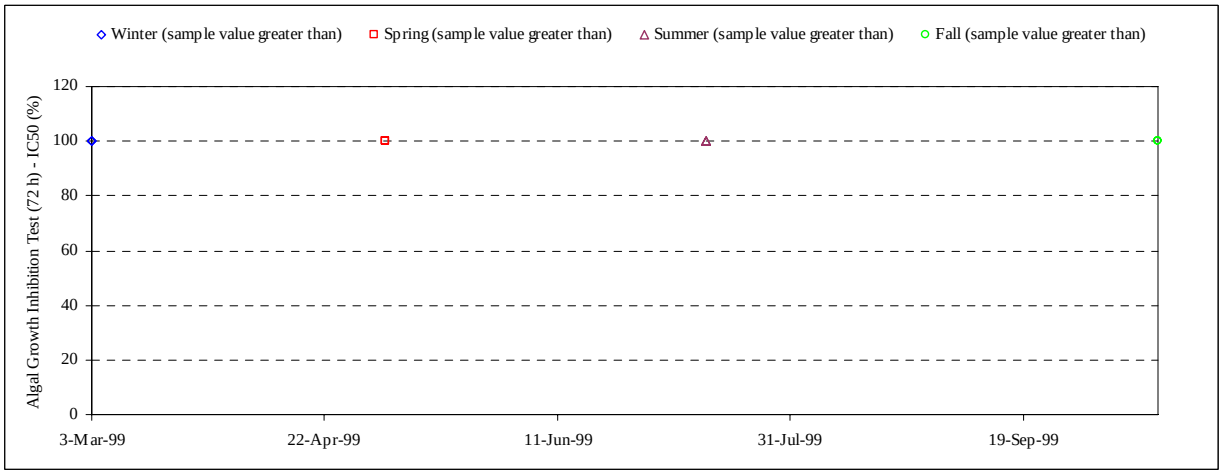
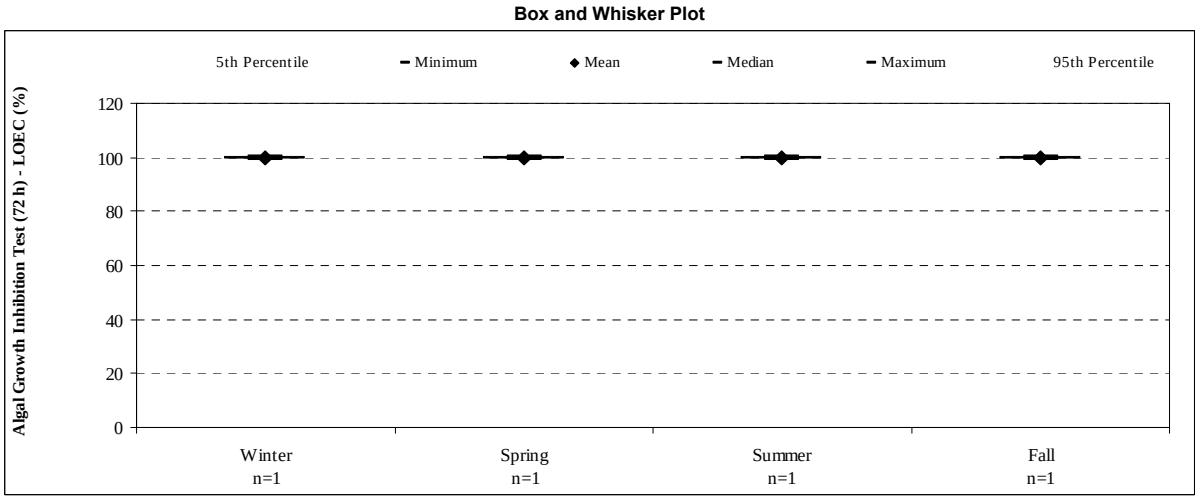


Figure G-2-3-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Lower Segment of Muskeg River



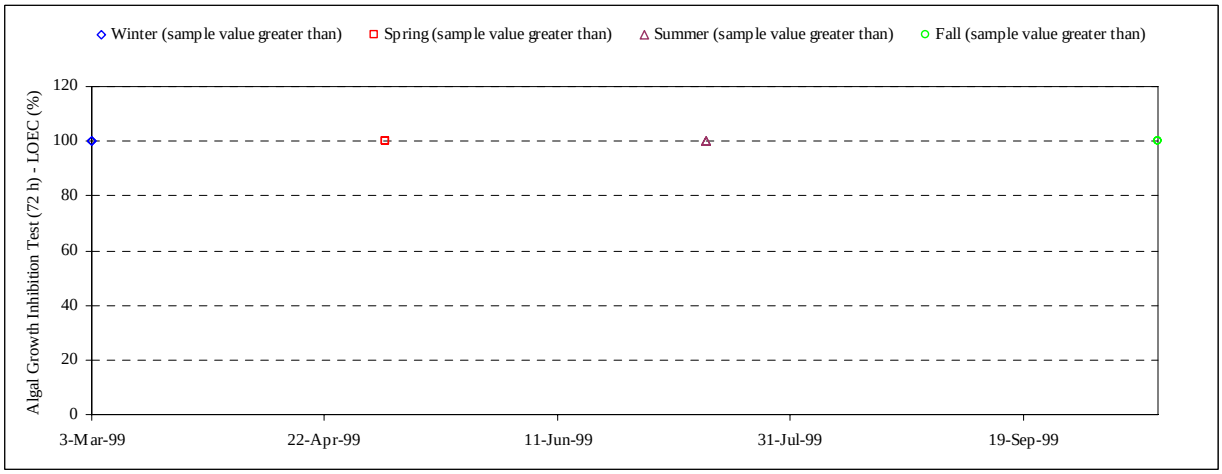
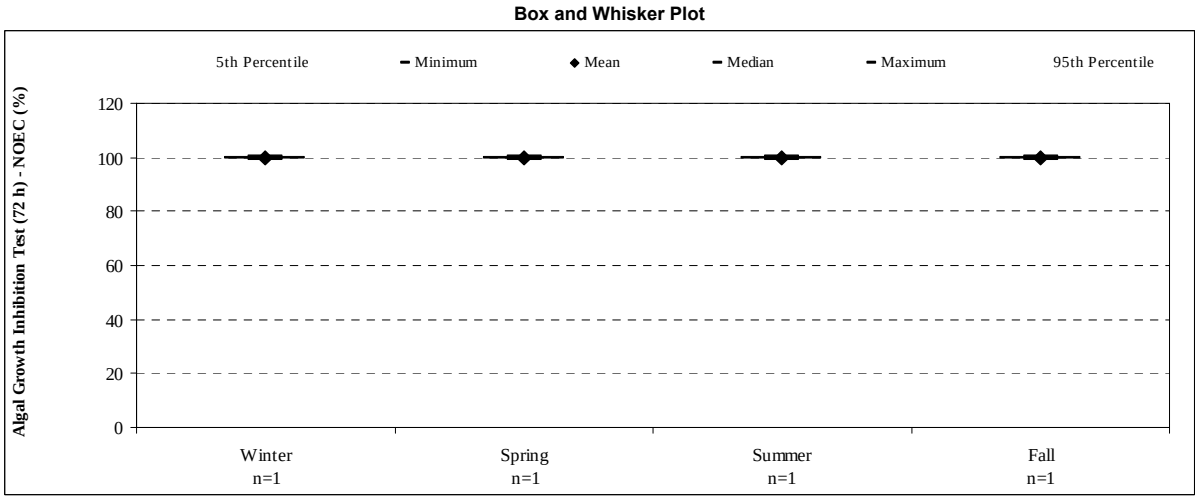


Figure G-2-3-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Lower Segment of Muskeg River



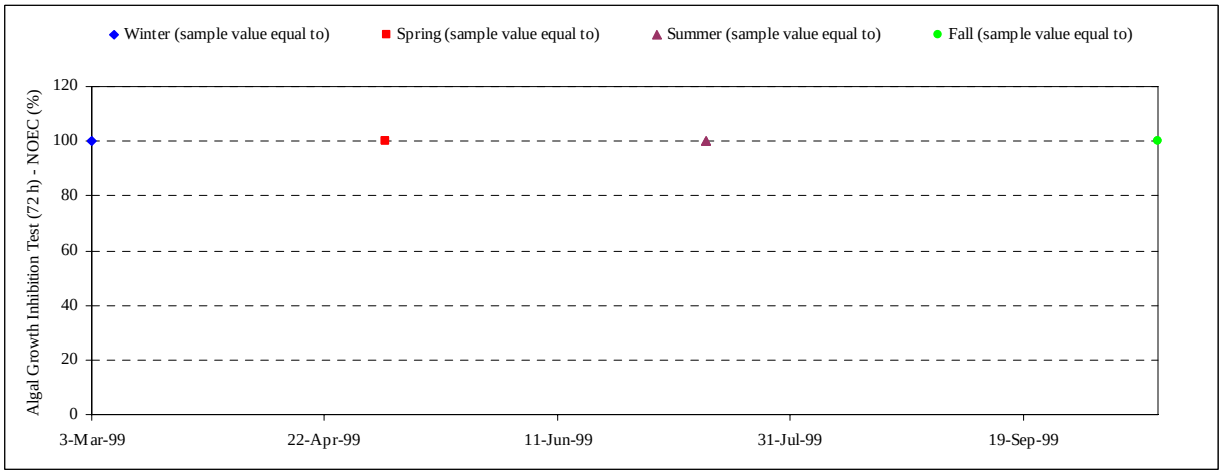
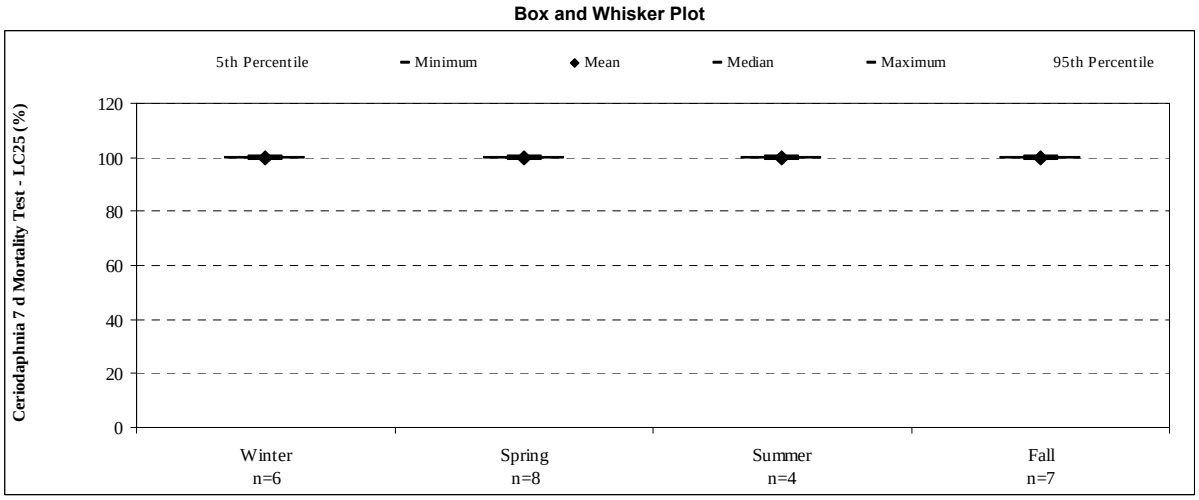


Figure G-2-3-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Lower Segment of Muskeg River



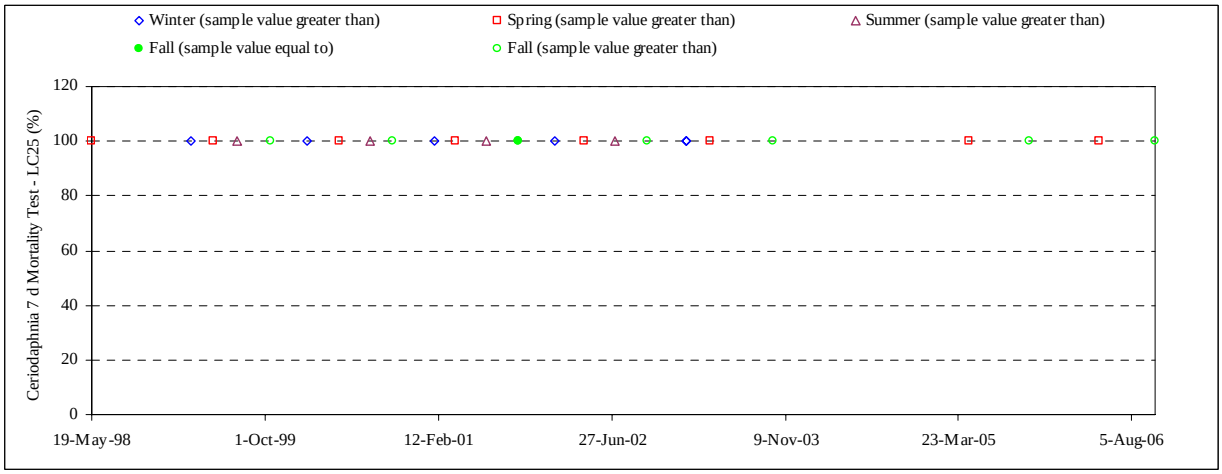
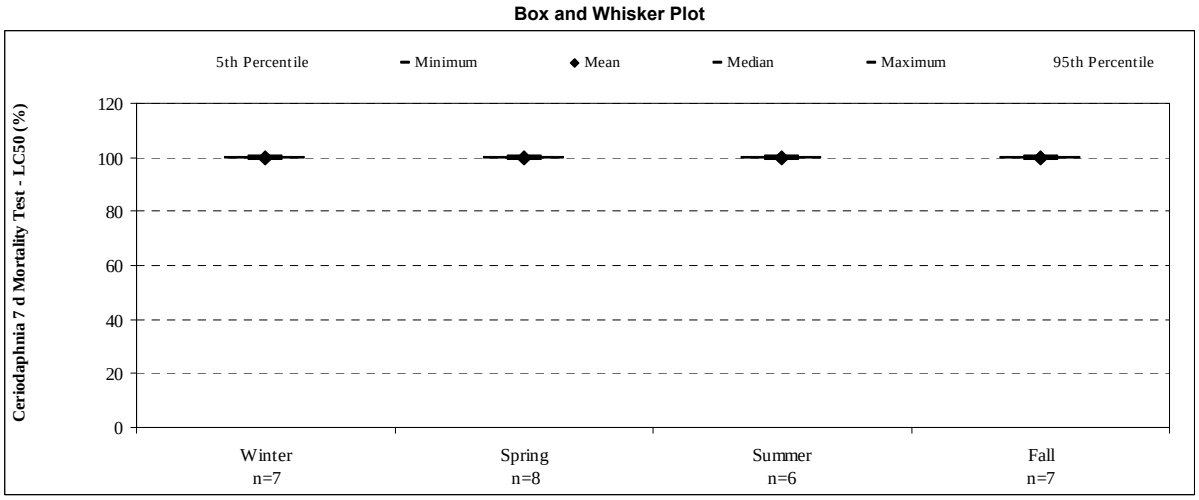


Figure G-2-3-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Lower Segment of Muskeg River



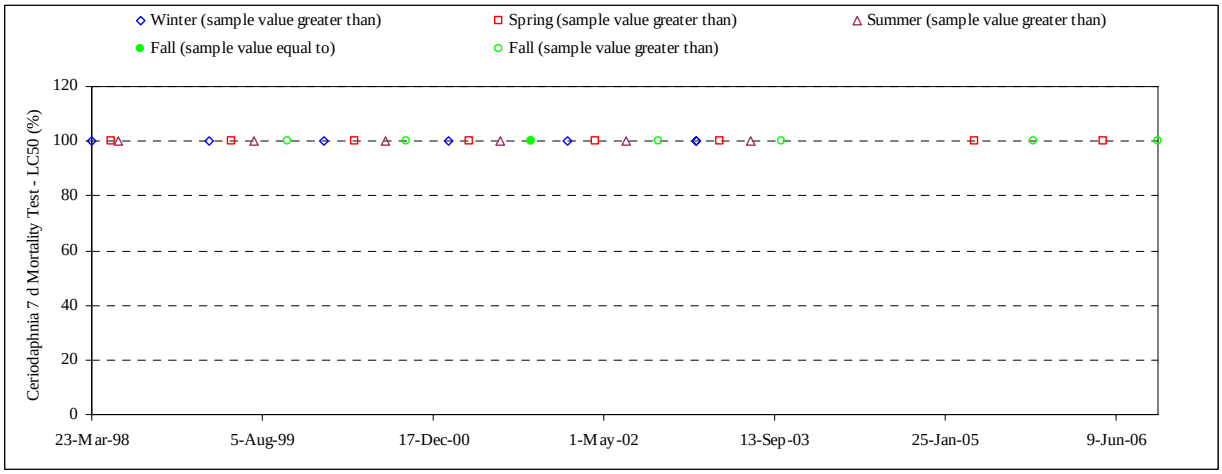
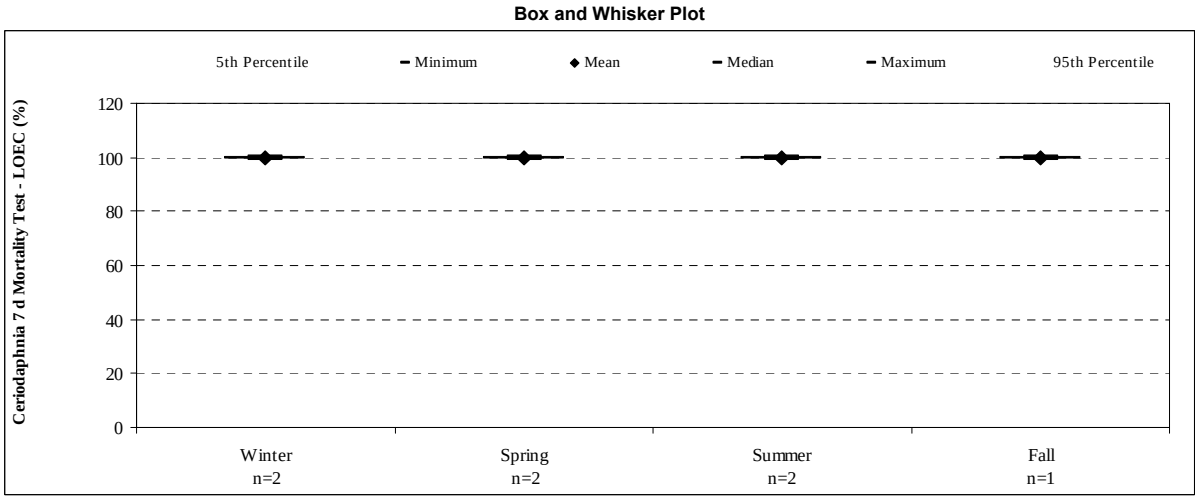


Figure G-2-3-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Lower Segment of Muskeg River



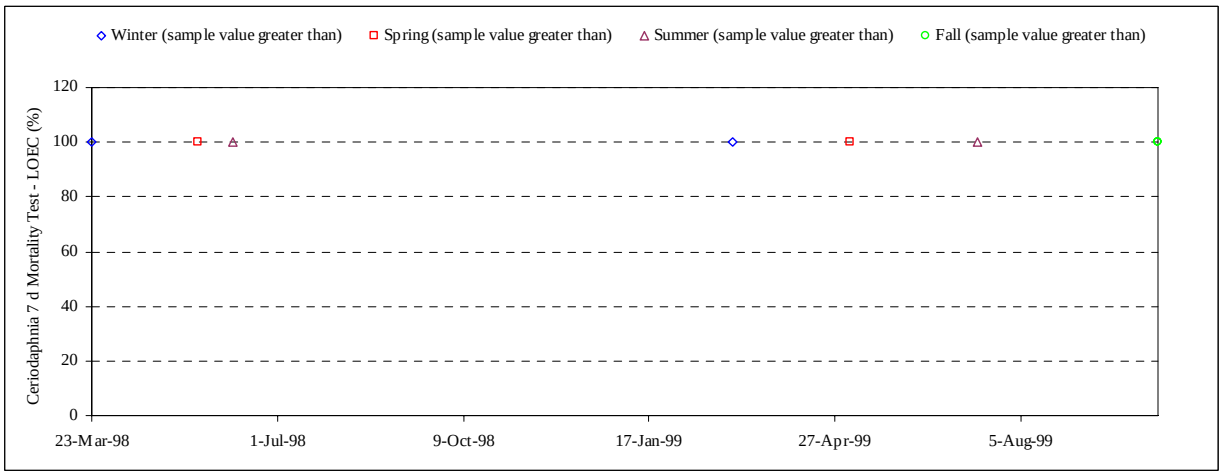
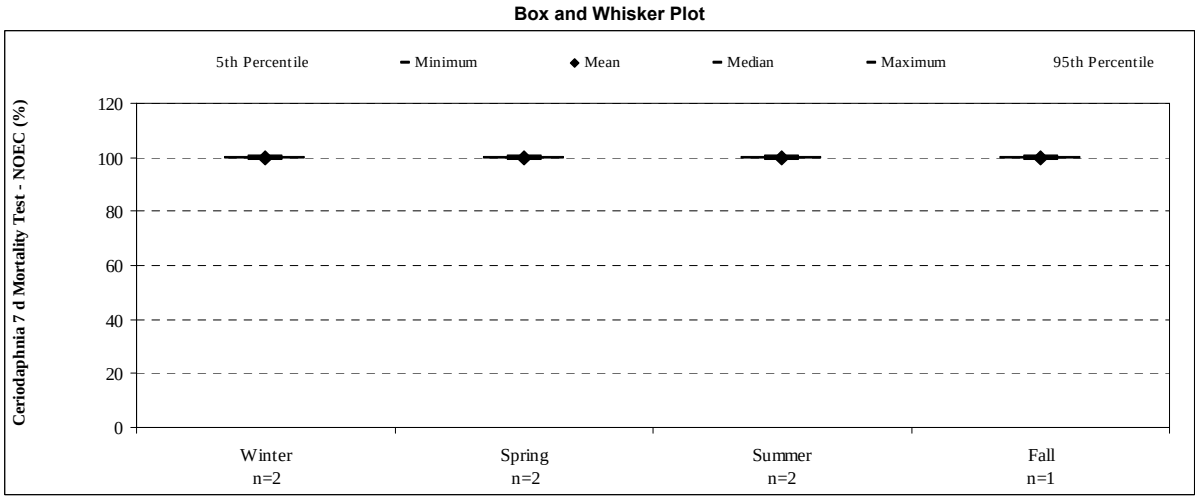


Figure G-2-3-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Lower Segment of Muskeg River



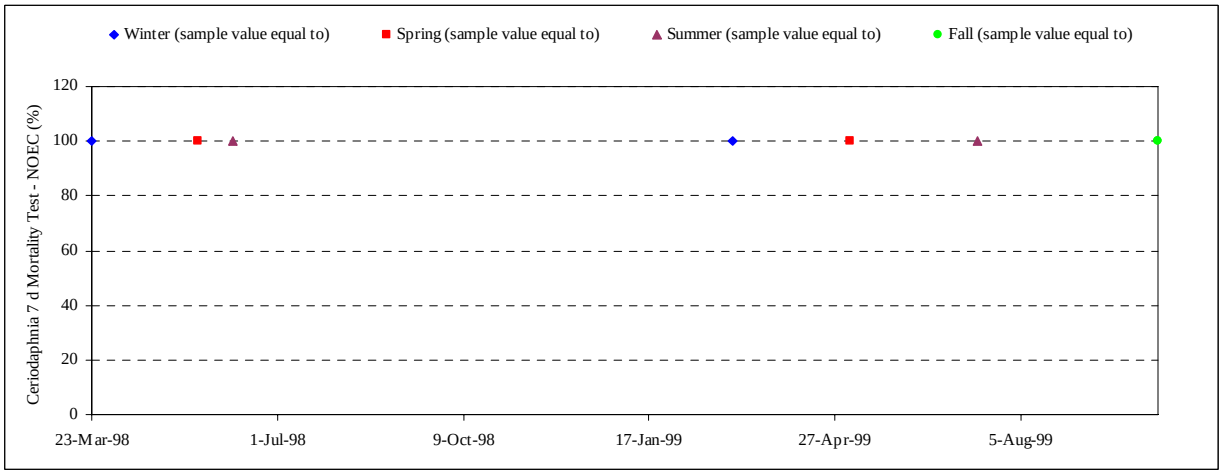
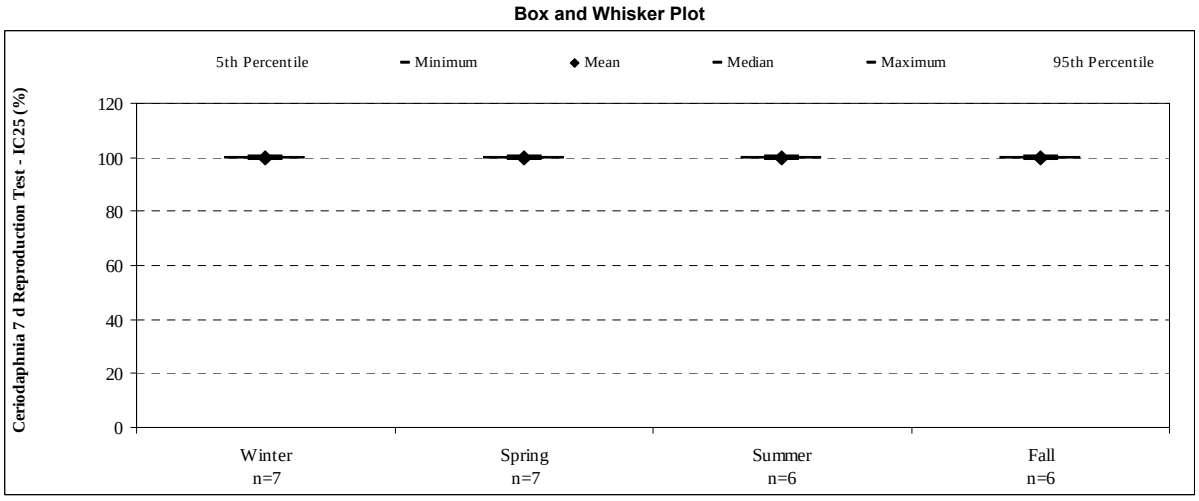


Figure G-2-3-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Lower Segment of Muskeg River



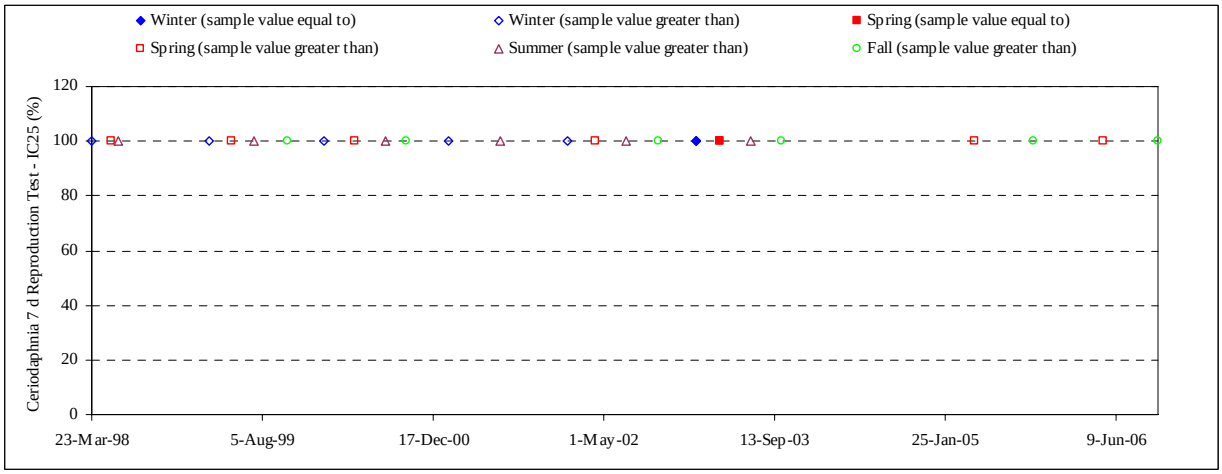
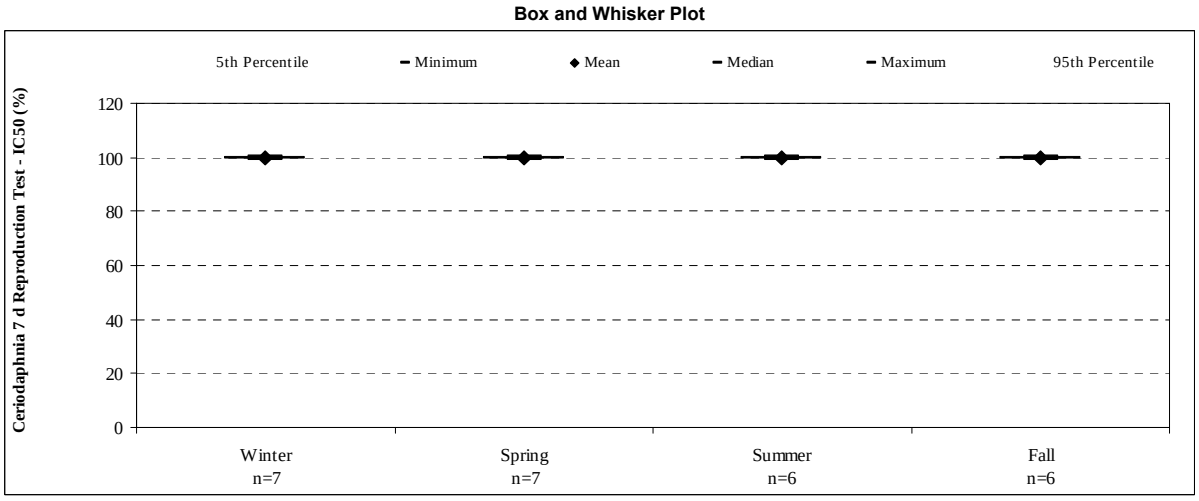


Figure G-2-3-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Lower Segment of Muskeg River



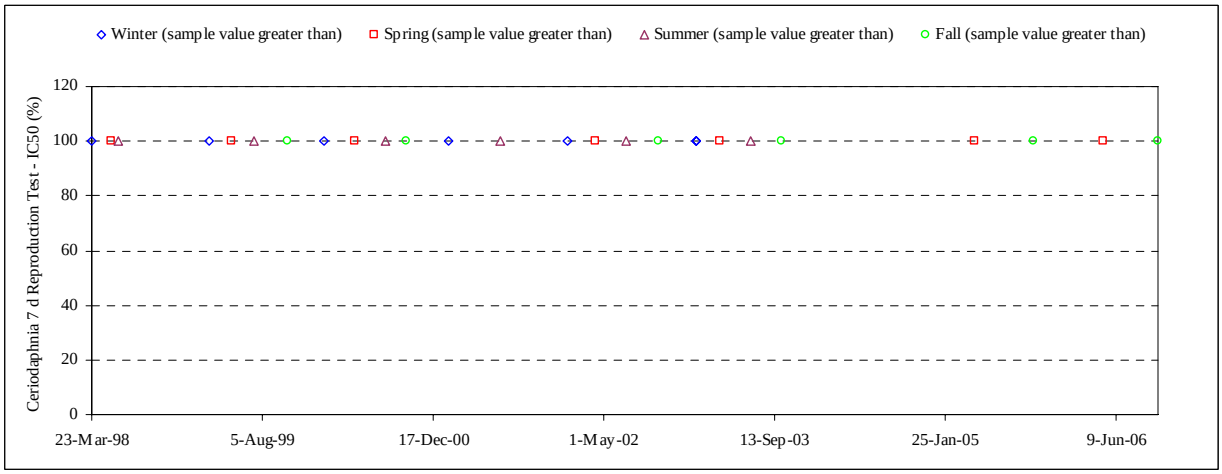
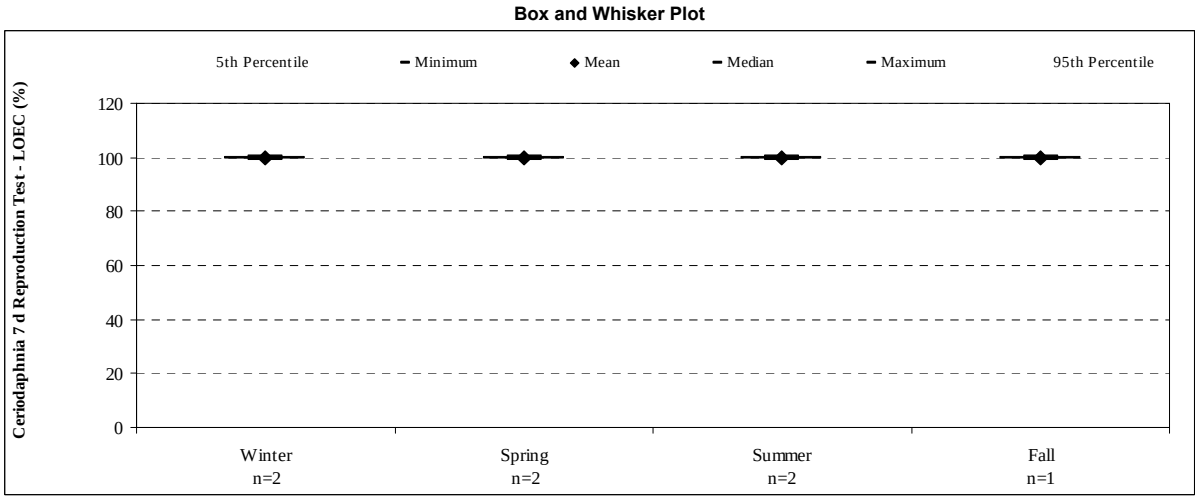


Figure G-2-3-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Lower Segment of Muskeg River



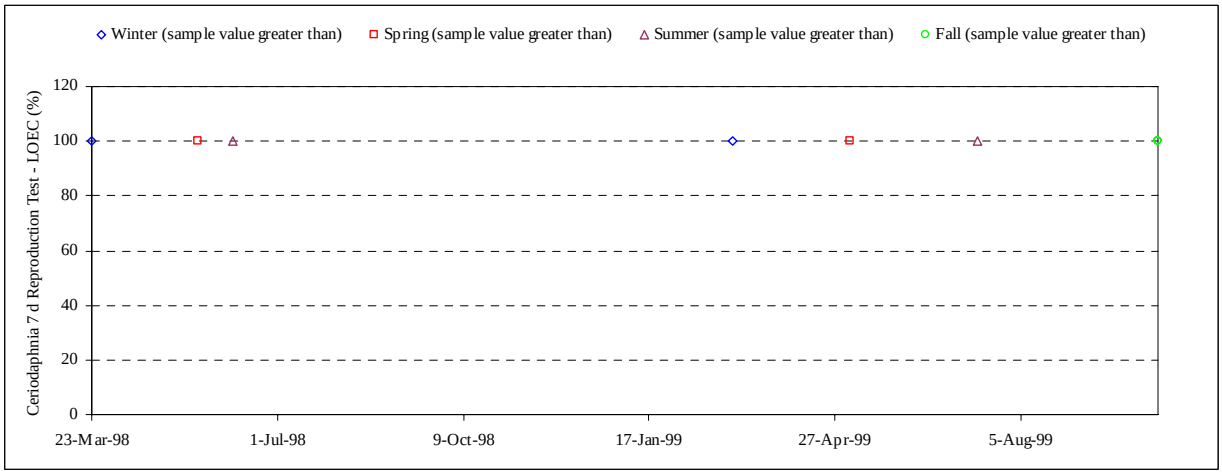
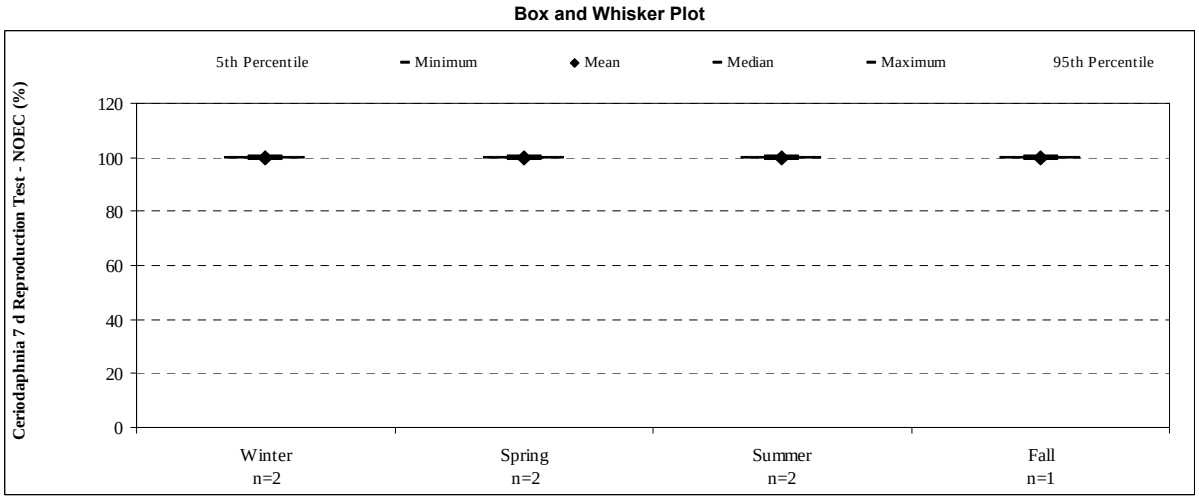


Figure G-2-3-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Lower Segment of Muskeg River



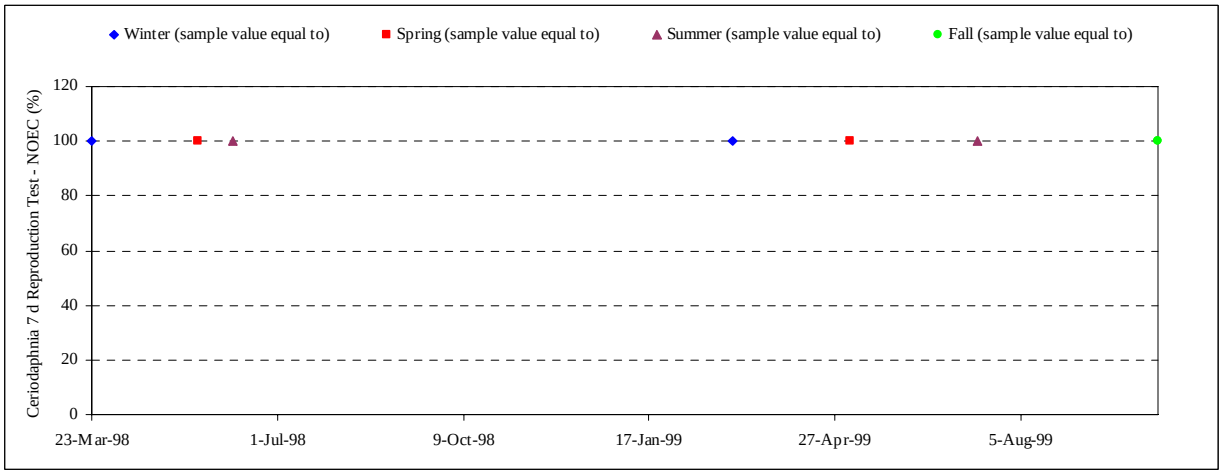


Figure G-2-3-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Lower Segment of Muskeg River

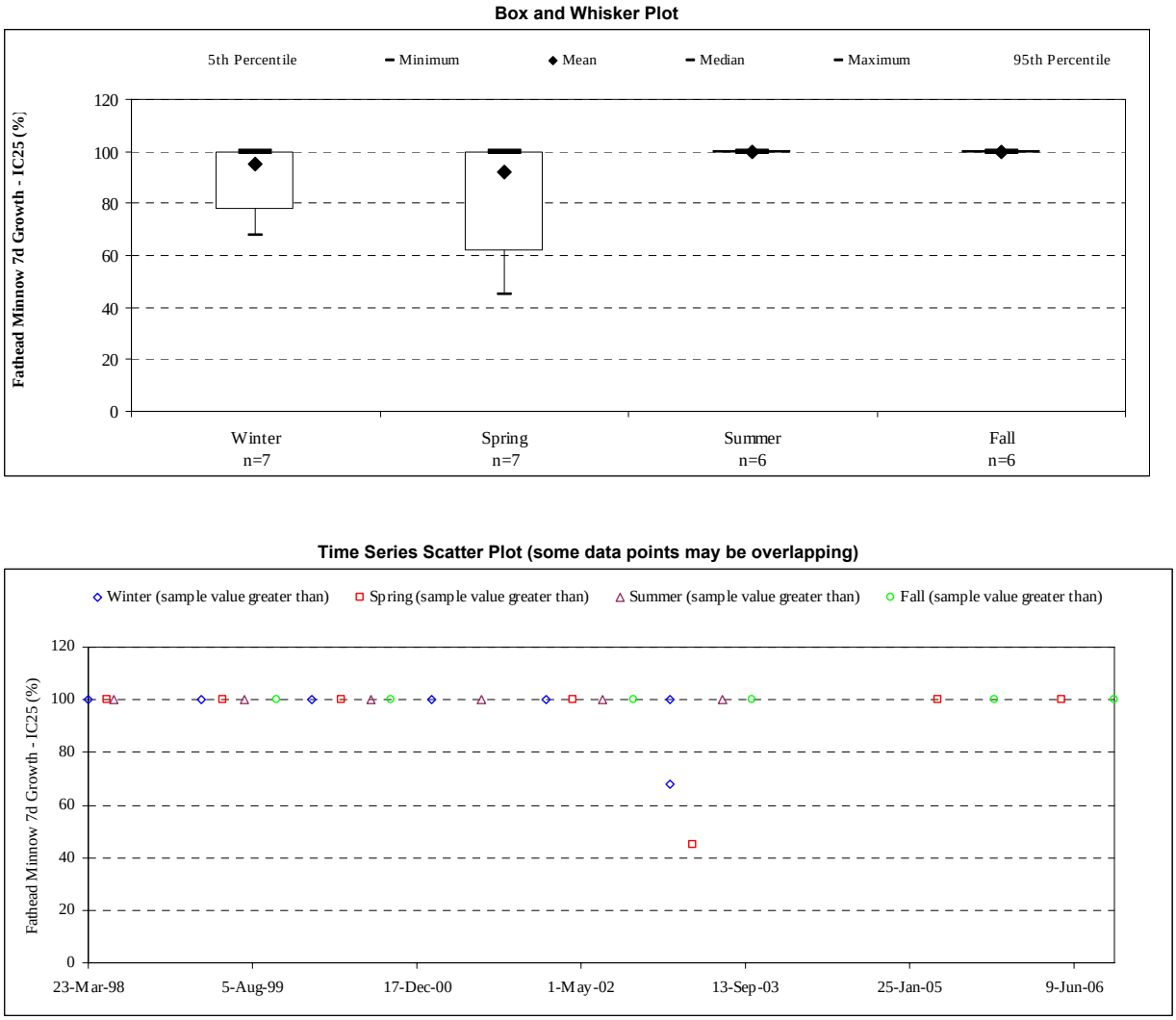


Figure G-2-3-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Lower Segment of Muskeg River

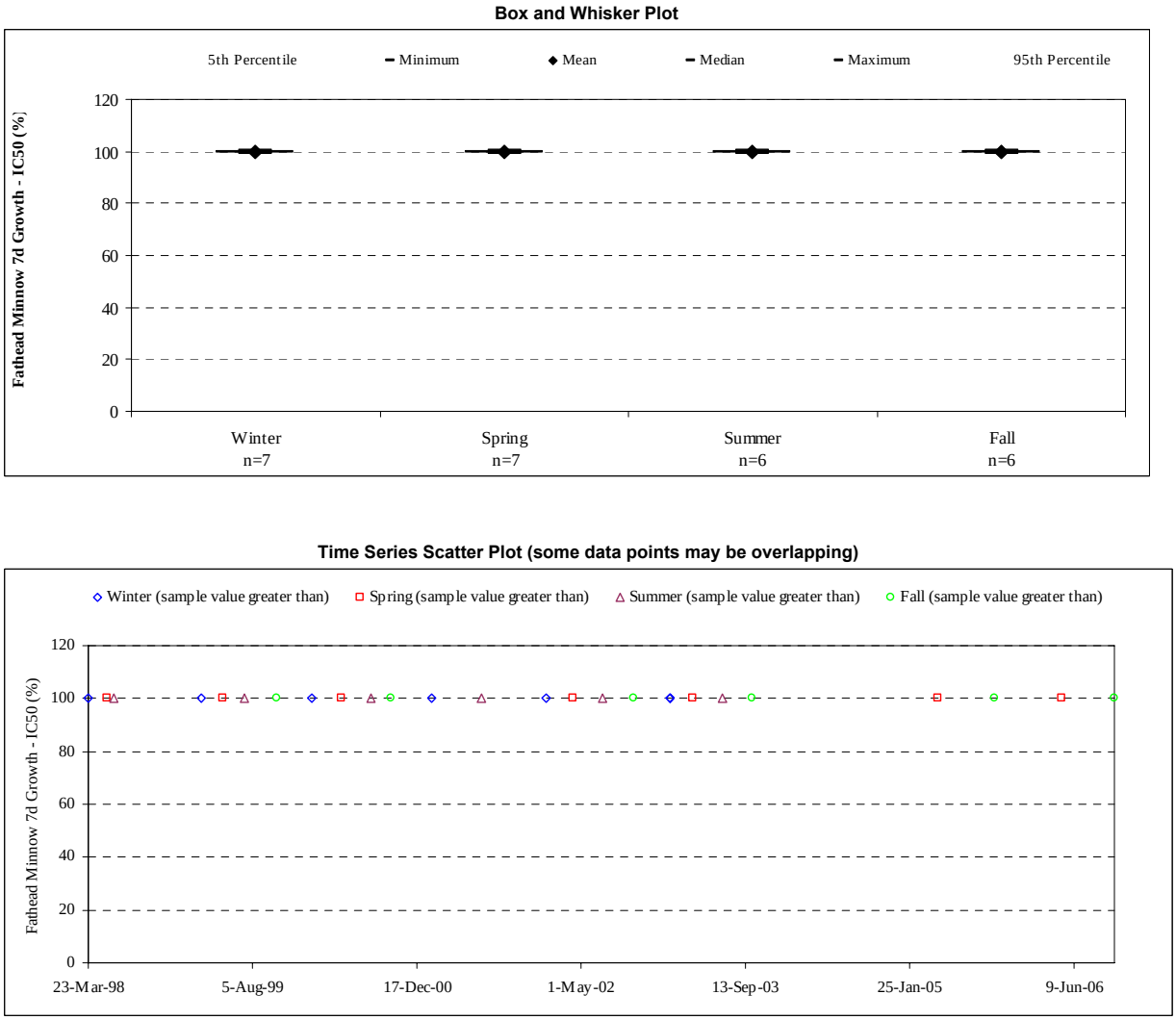
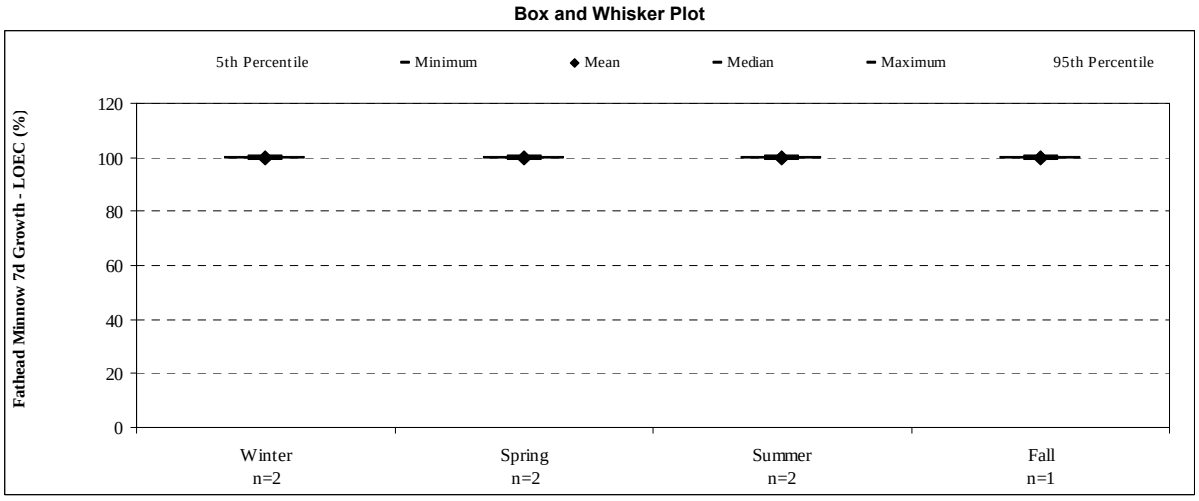


Figure G-2-3-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Lower Segment of Muskeg River



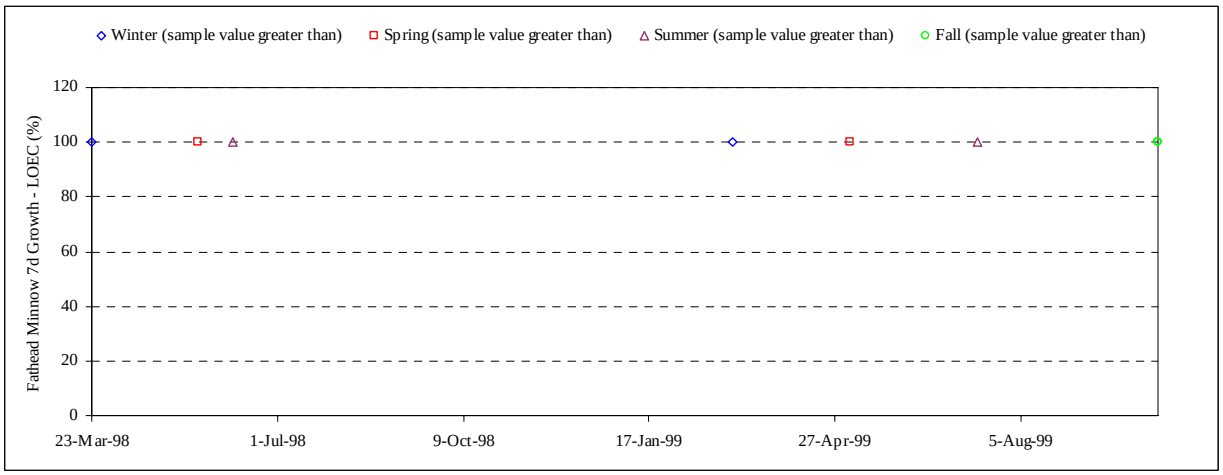
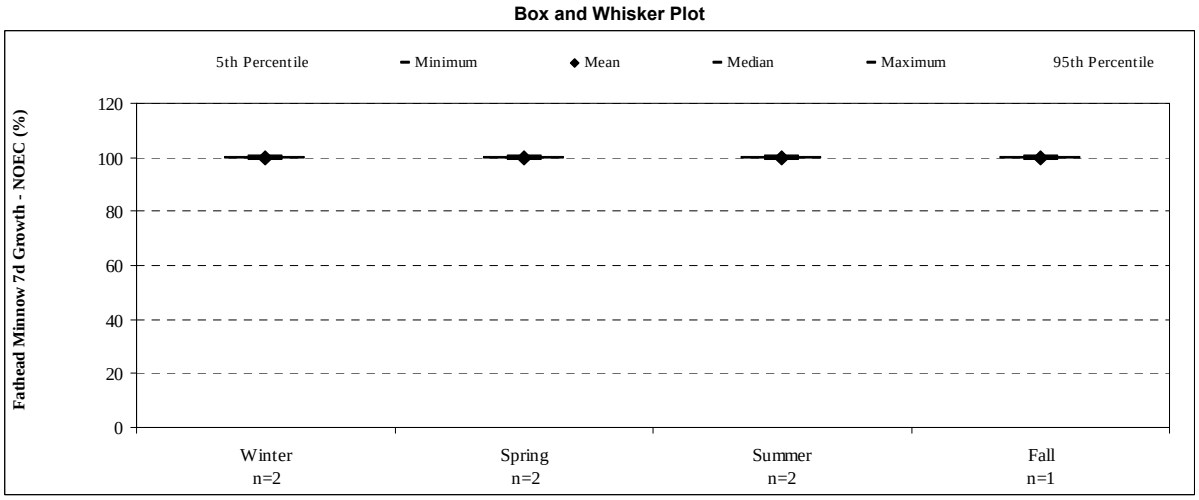


Figure G-2-3-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Lower Segment of Muskeg River



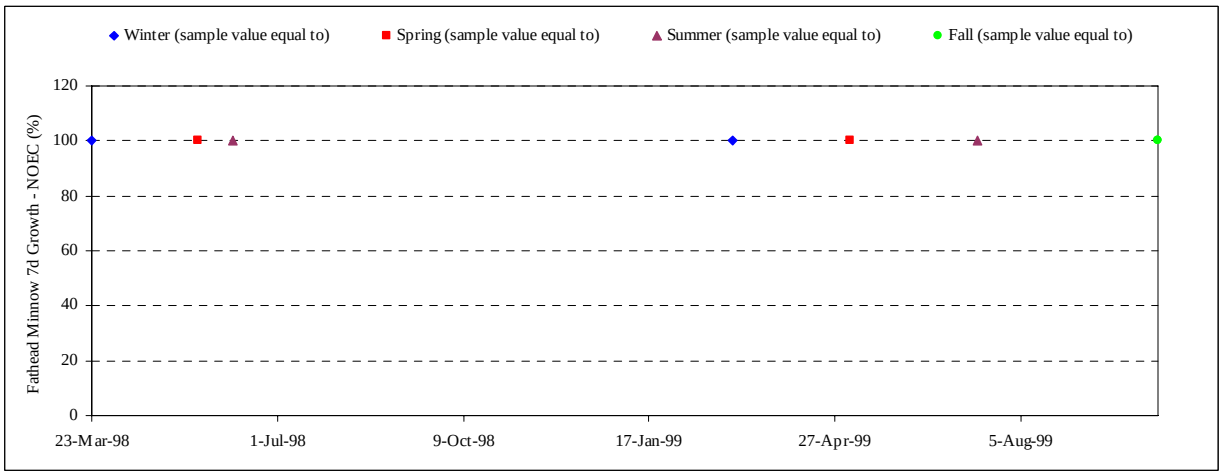
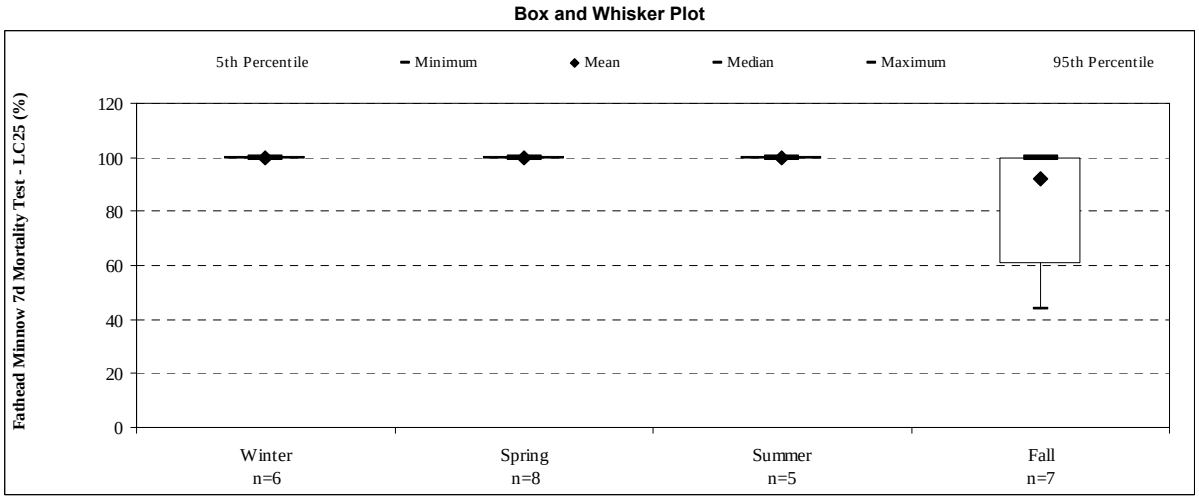


Figure G-2-3-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Lower Segment of Muskeg River



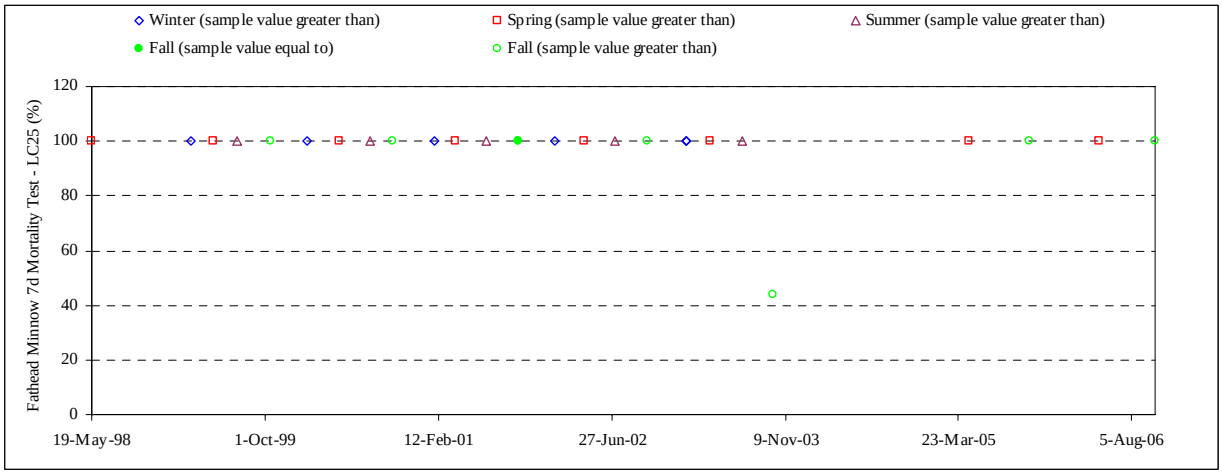
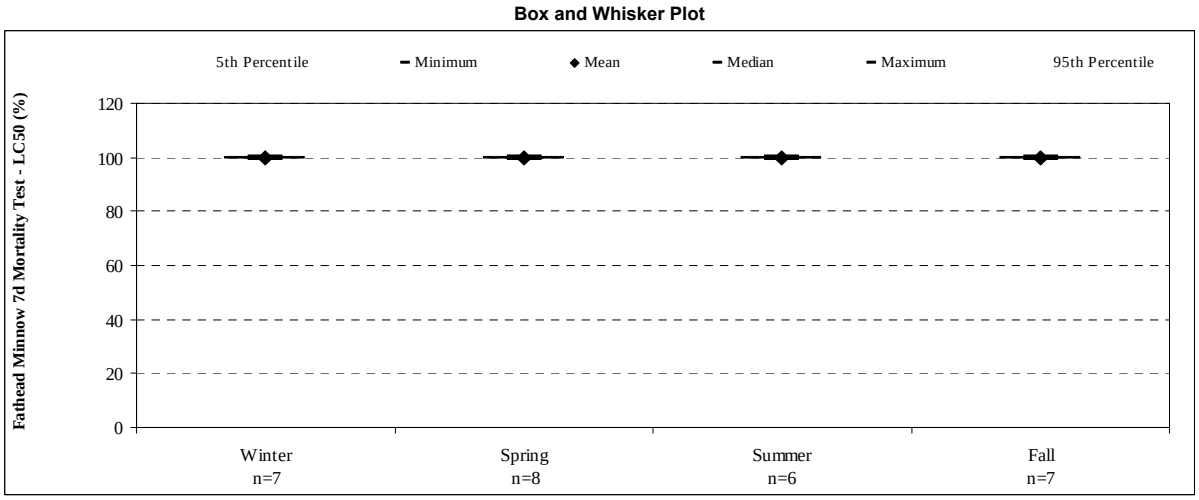


Figure G-2-3-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Lower Segment of Muskeg River



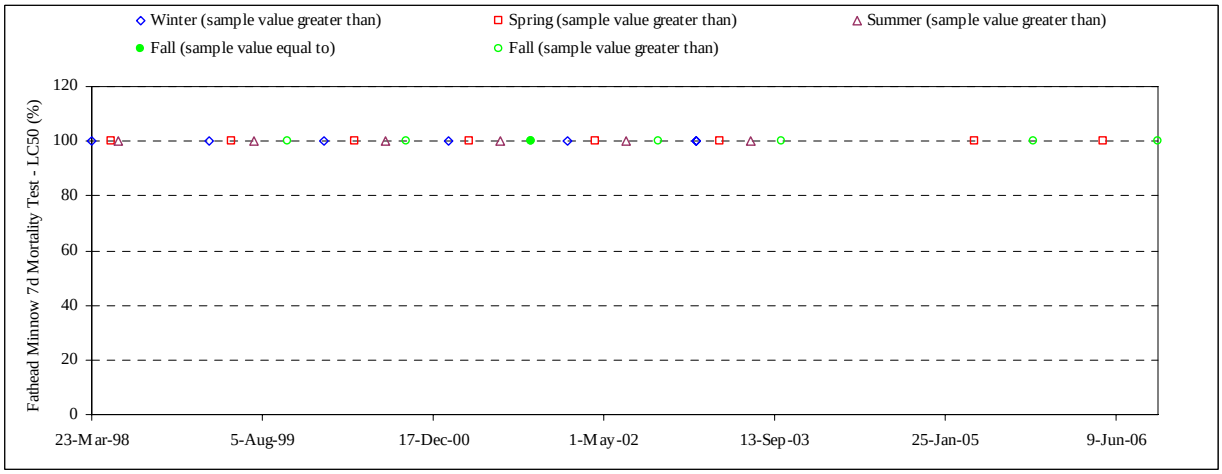
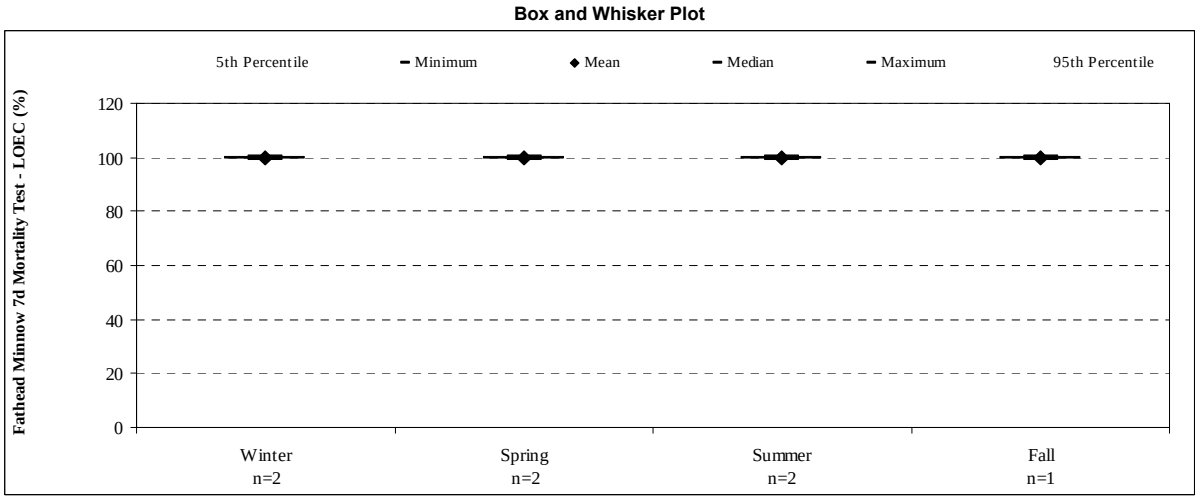


Figure G-2-3-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Lower Segment of Muskeg River



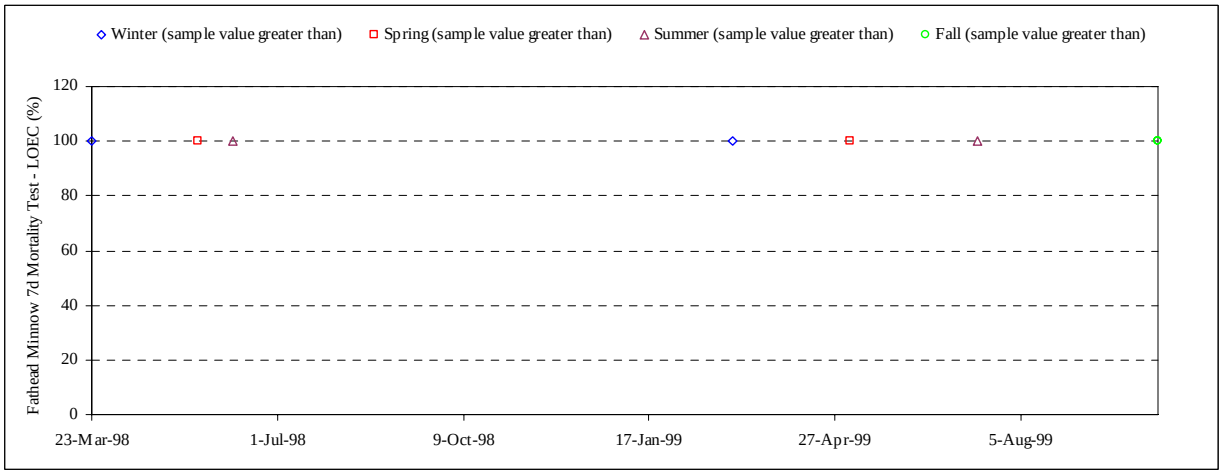
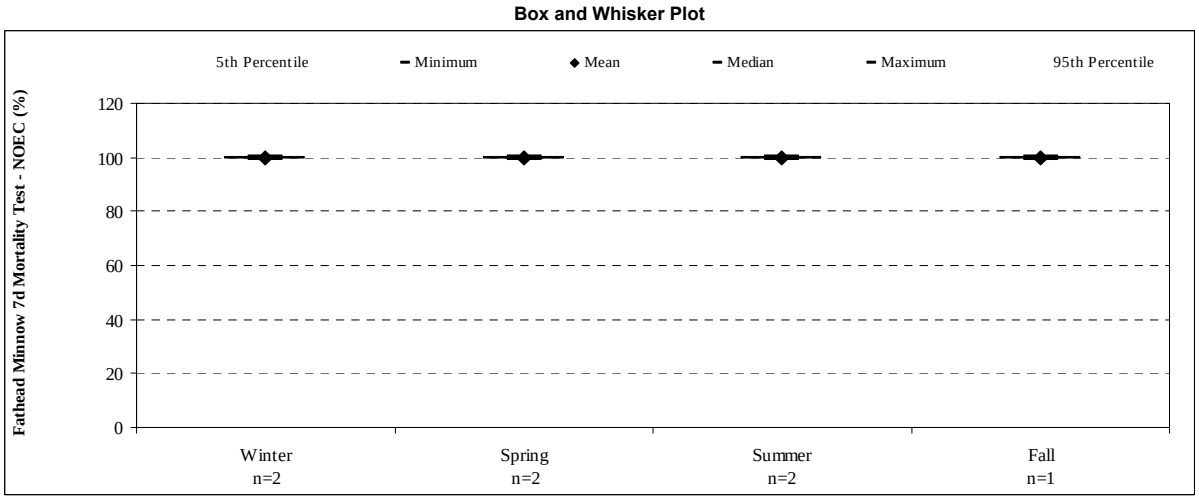


Figure G-2-3-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Lower Segment of Muskeg River



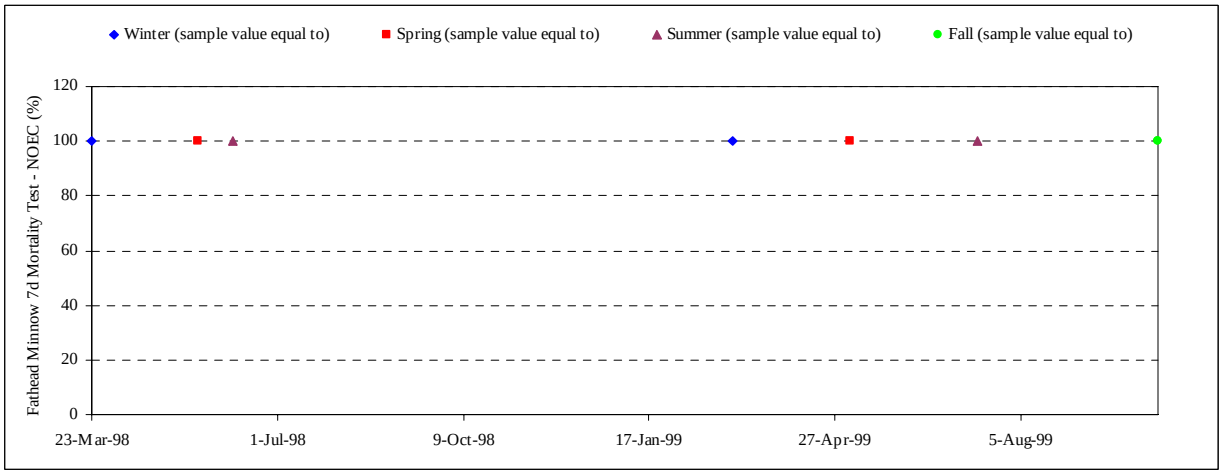
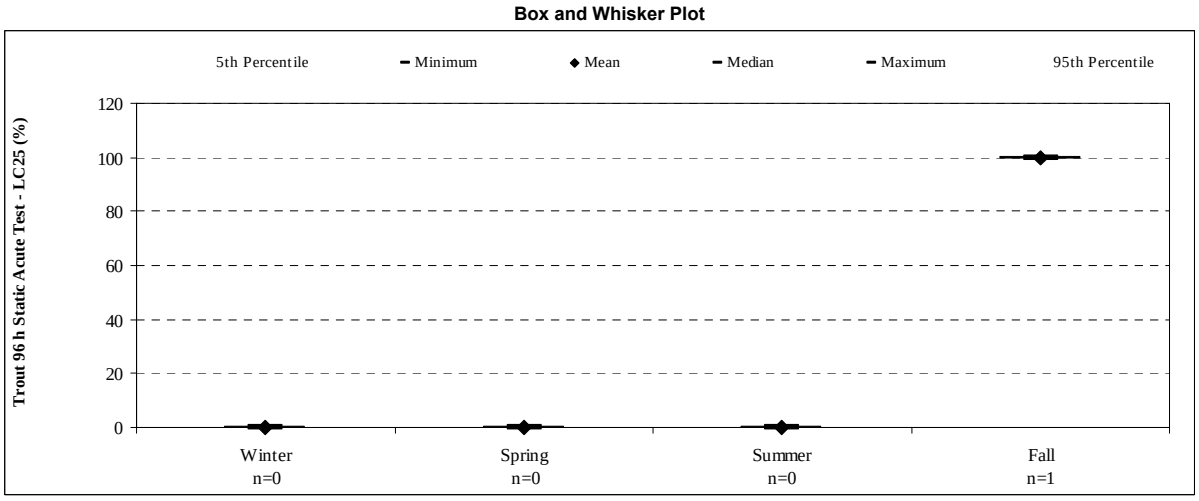


Figure G-2-3-58 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LC25 in Lower Segment of Muskeg River



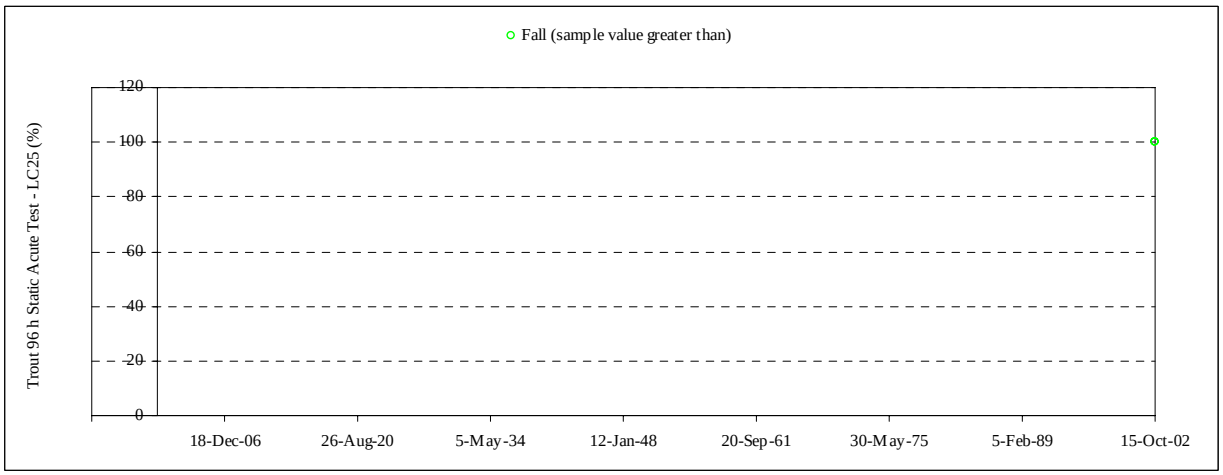
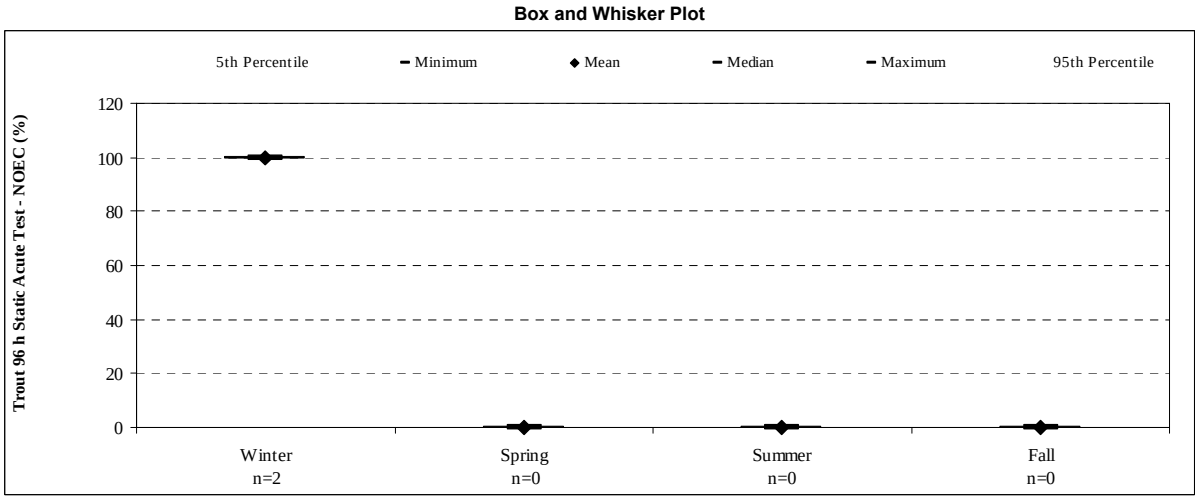


Figure G-2-3-61 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - NOEC in Lower Segment of Muskeg River



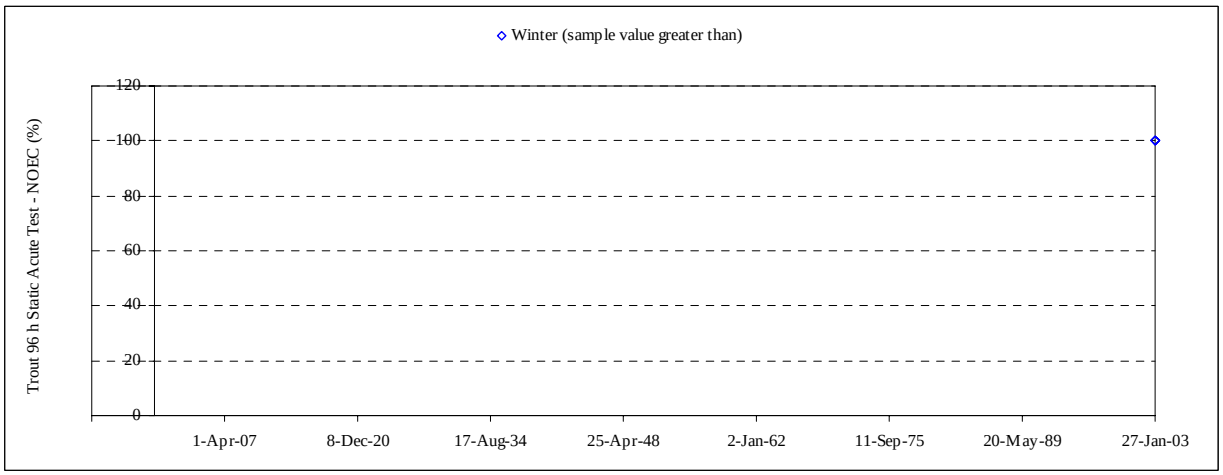
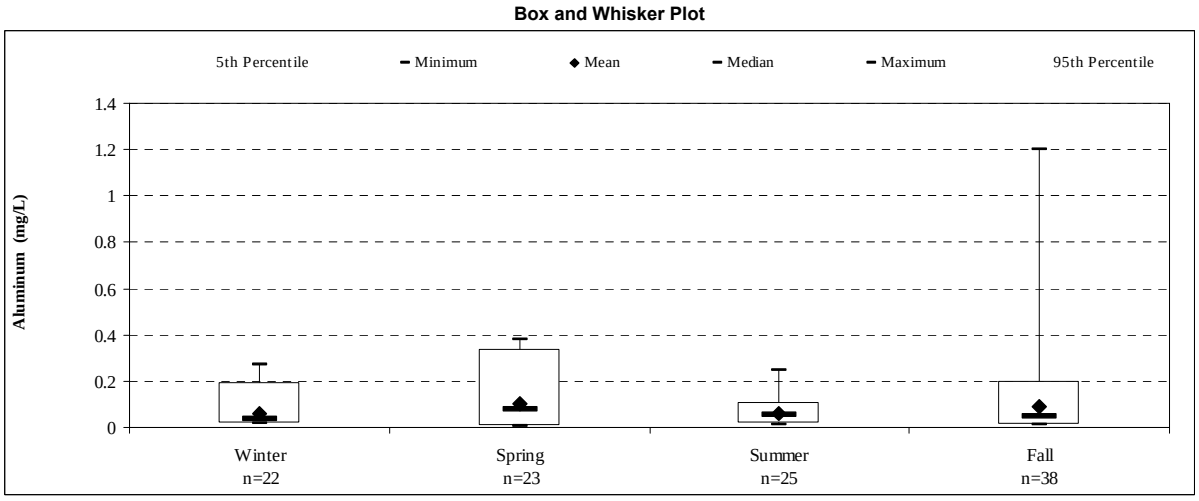


Figure G-2-3-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Lower Segment of Muskeg River



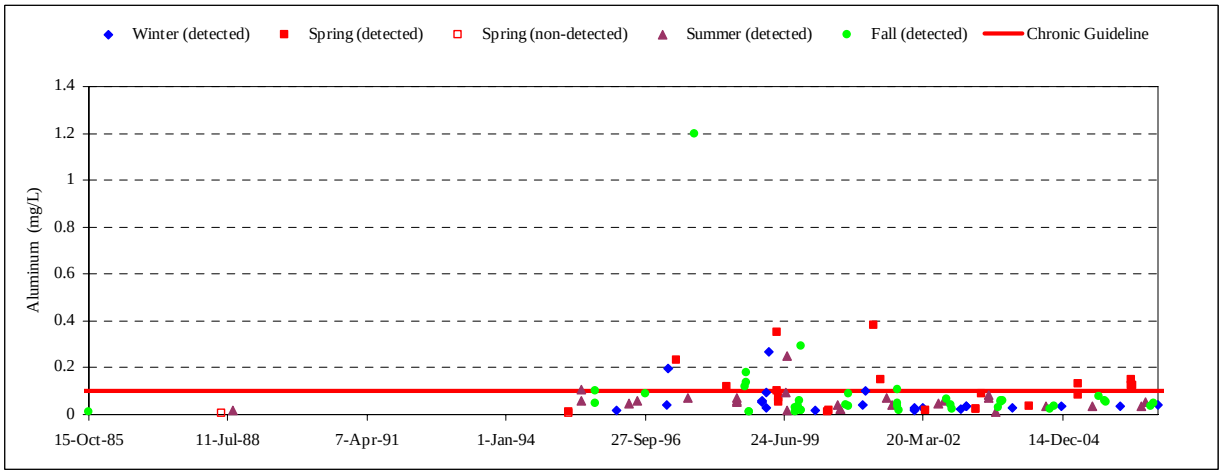
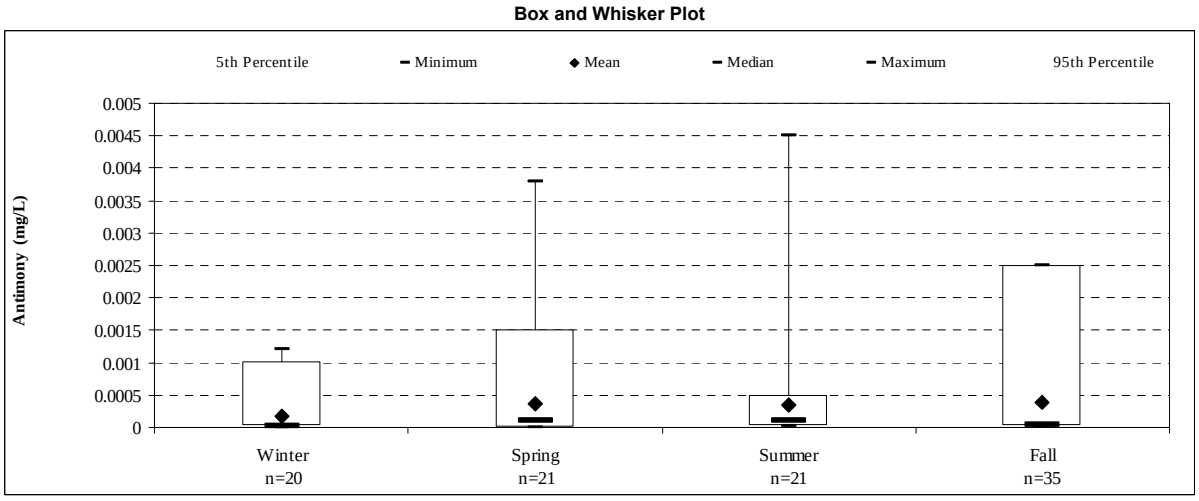


Figure G-2-3-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Lower Segment of Muskeg River



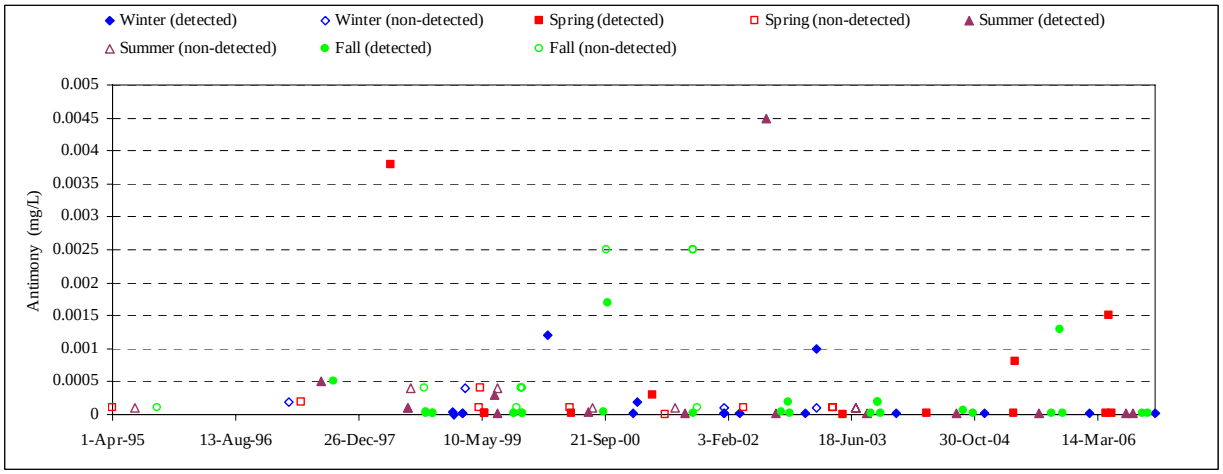
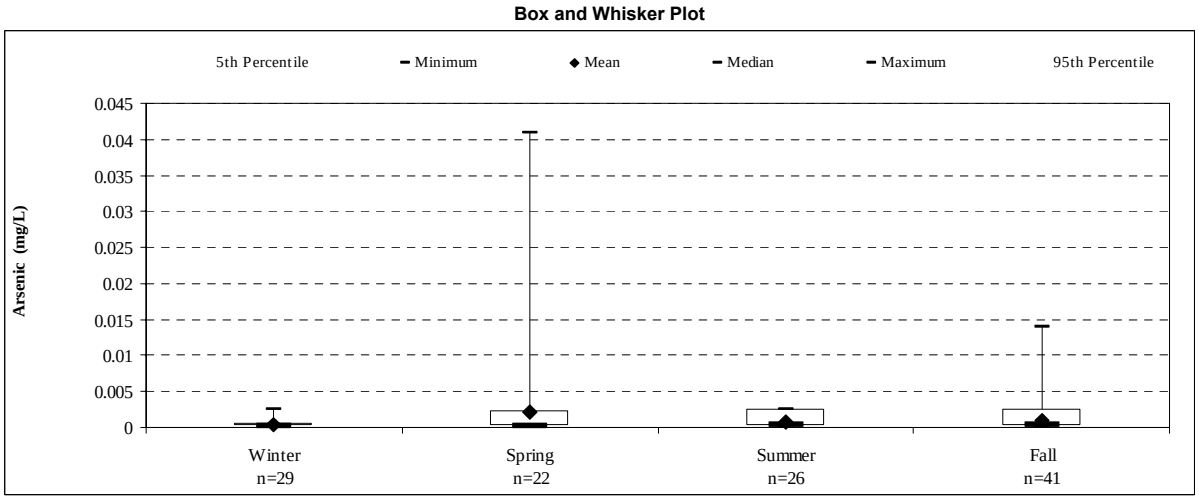


Figure G-2-3-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Lower Segment of Muskeg River



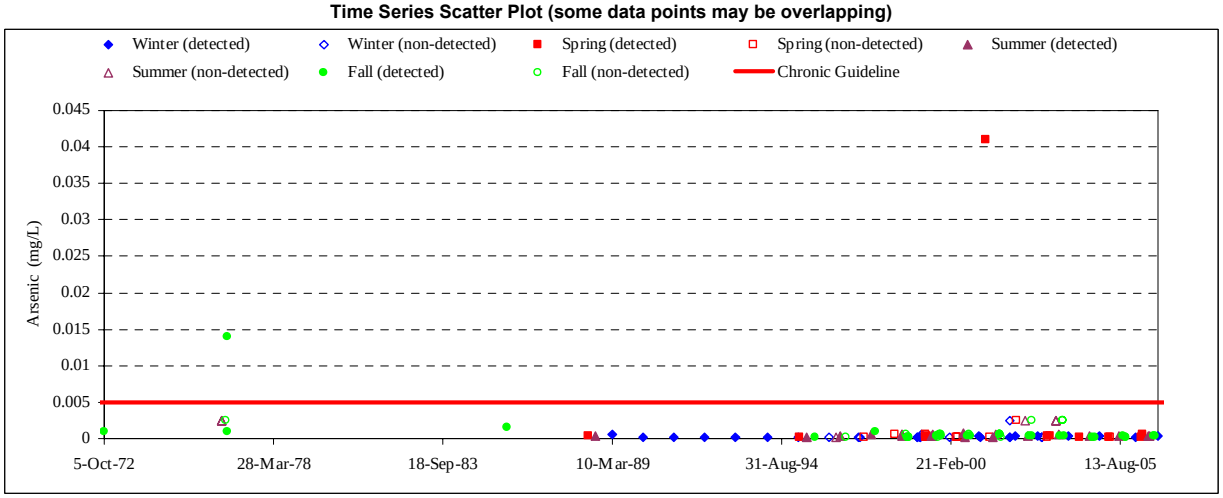
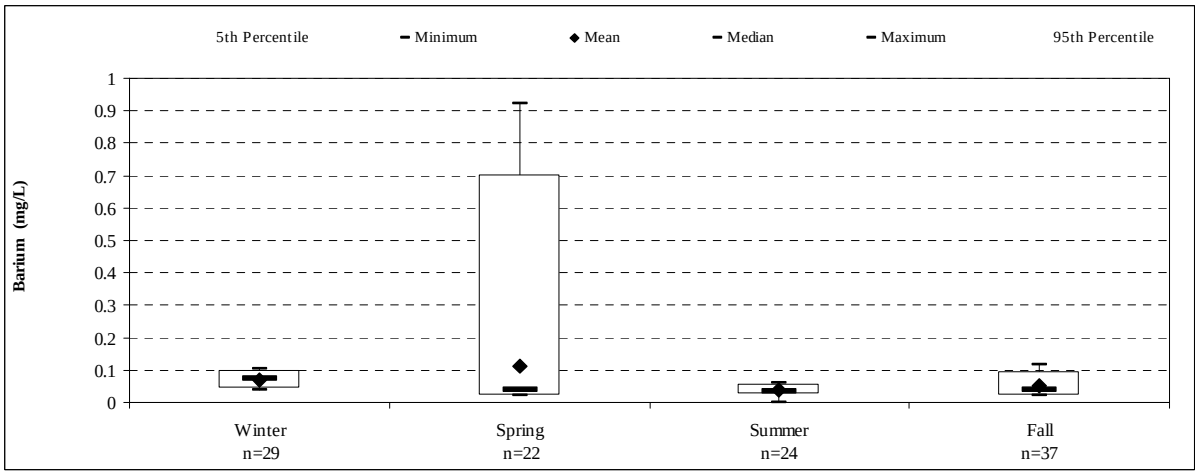


Figure G-2-3-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Lower Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

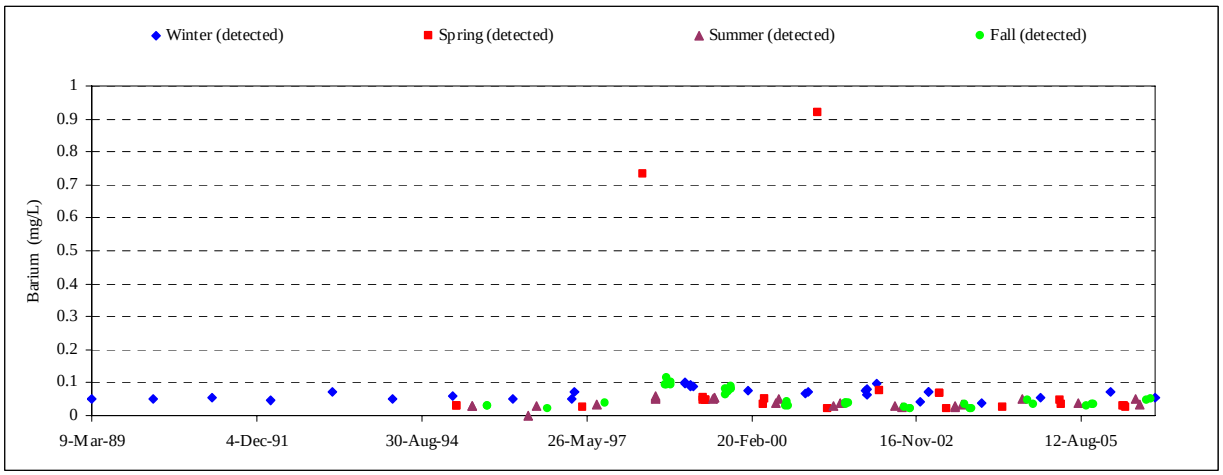
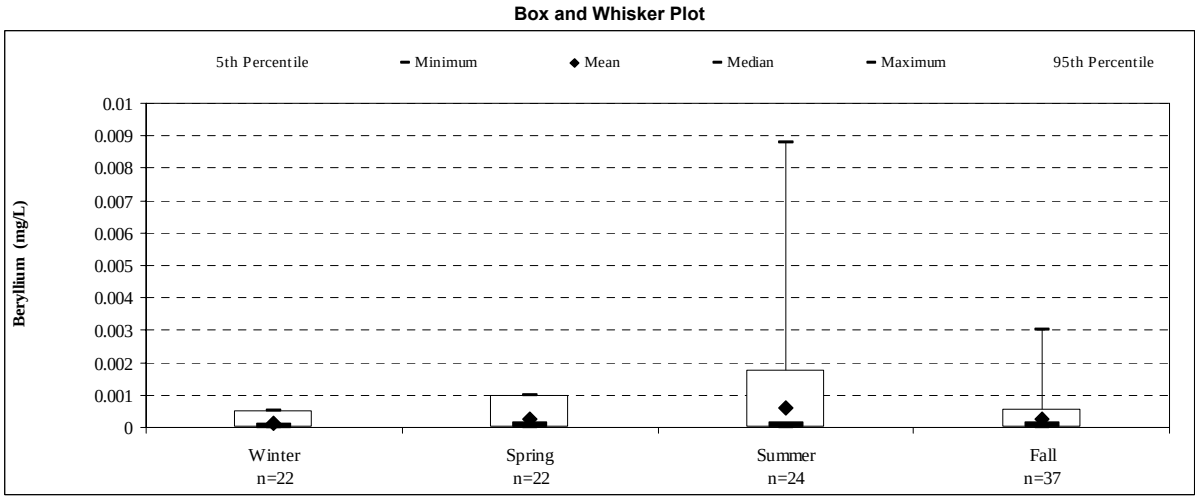


Figure G-2-3-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Lower Segment of Muskeg River



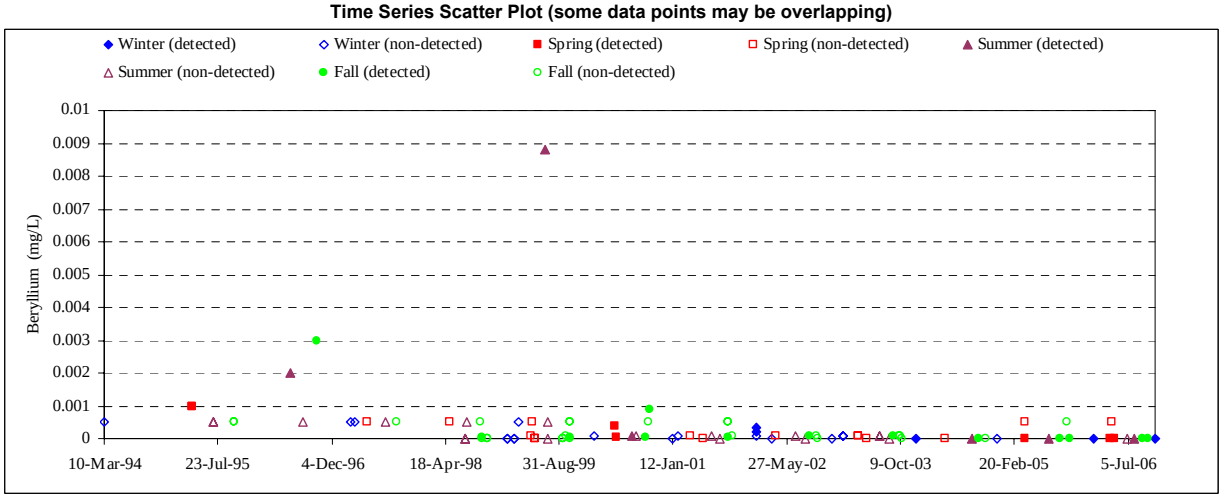
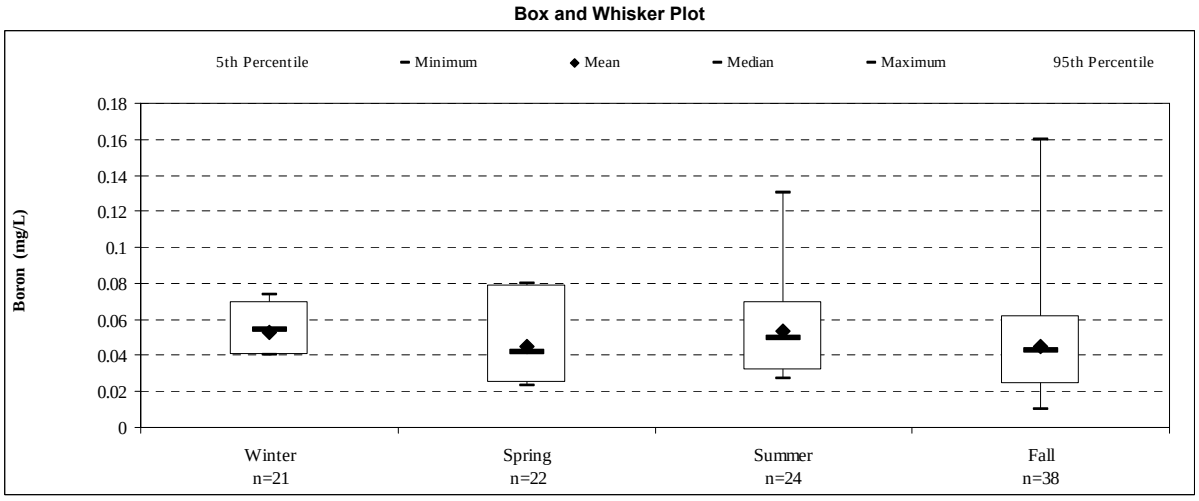


Figure G-2-3-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Lower Segment of Muskeg River



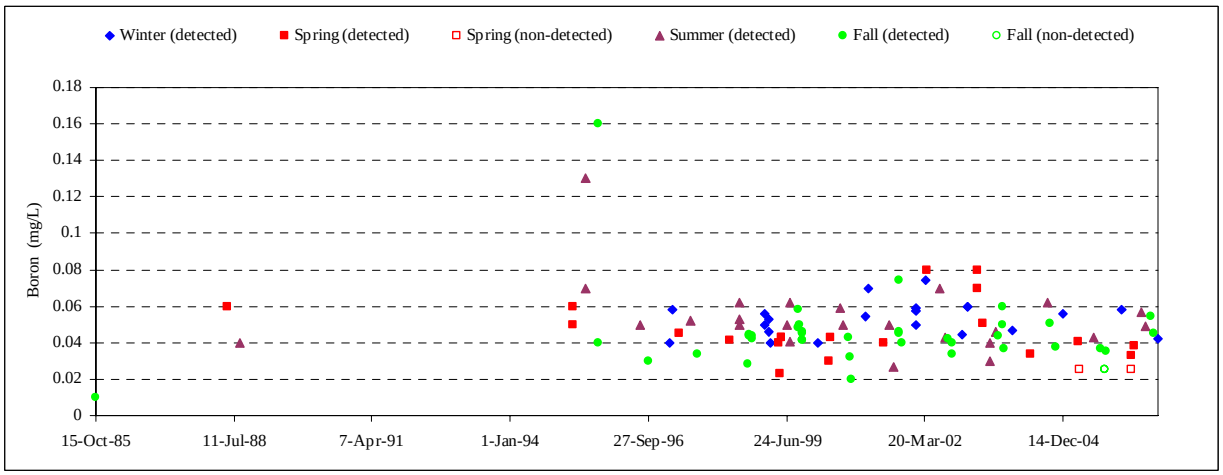
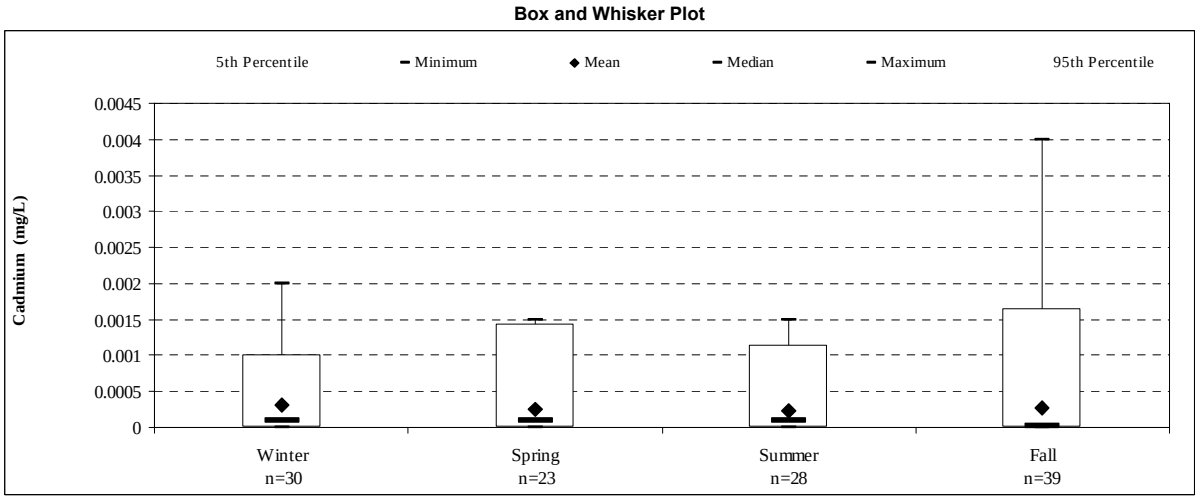


Figure G-2-3-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Lower Segment of Muskeg River



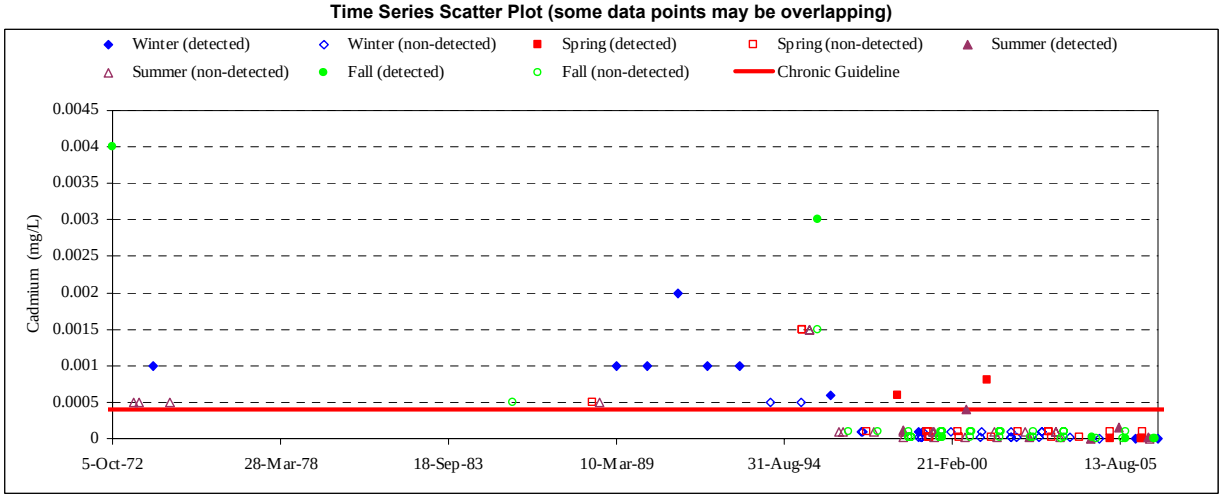
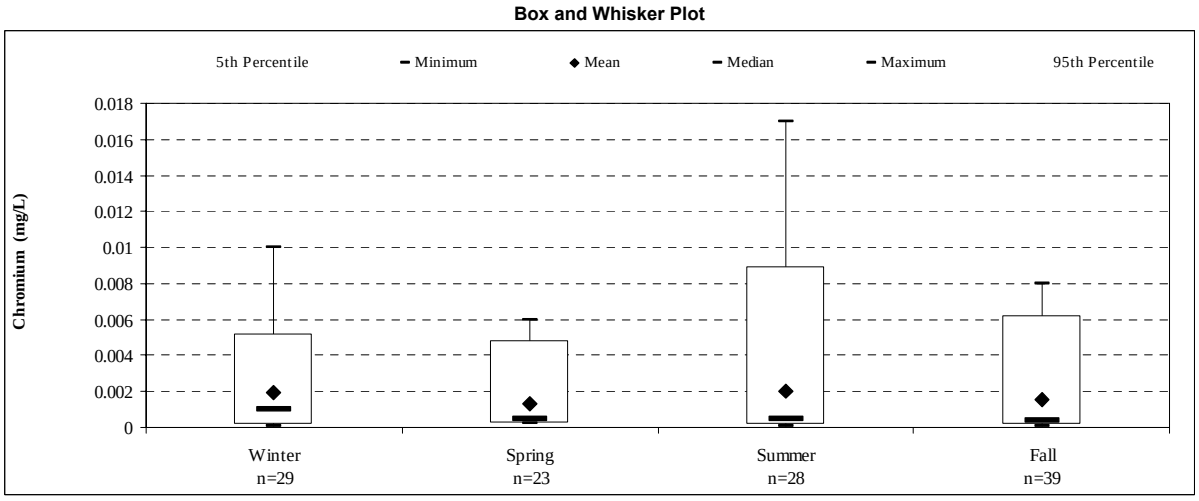


Figure G-2-3-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Lower Segment of Muskeg River



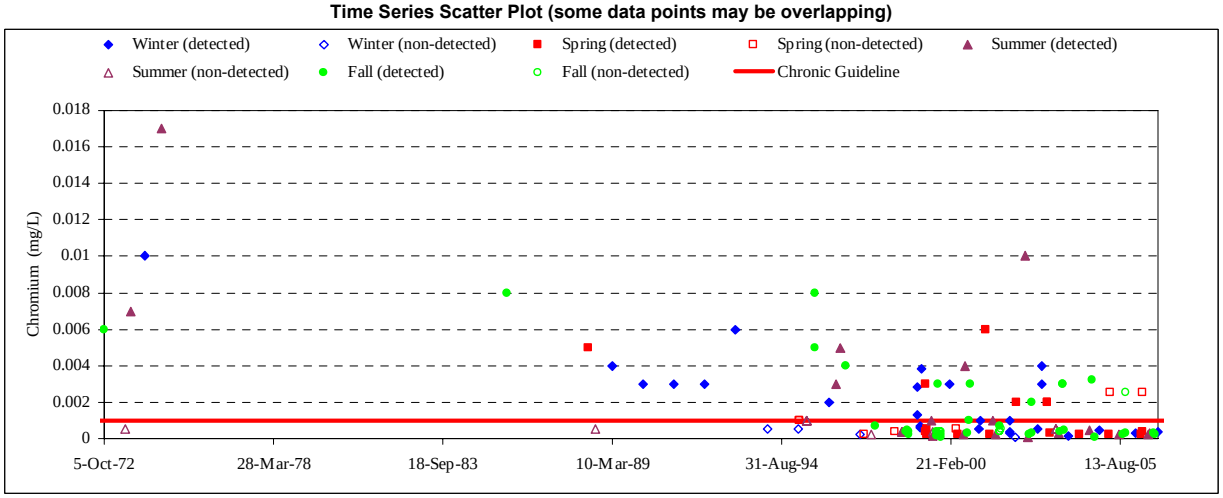
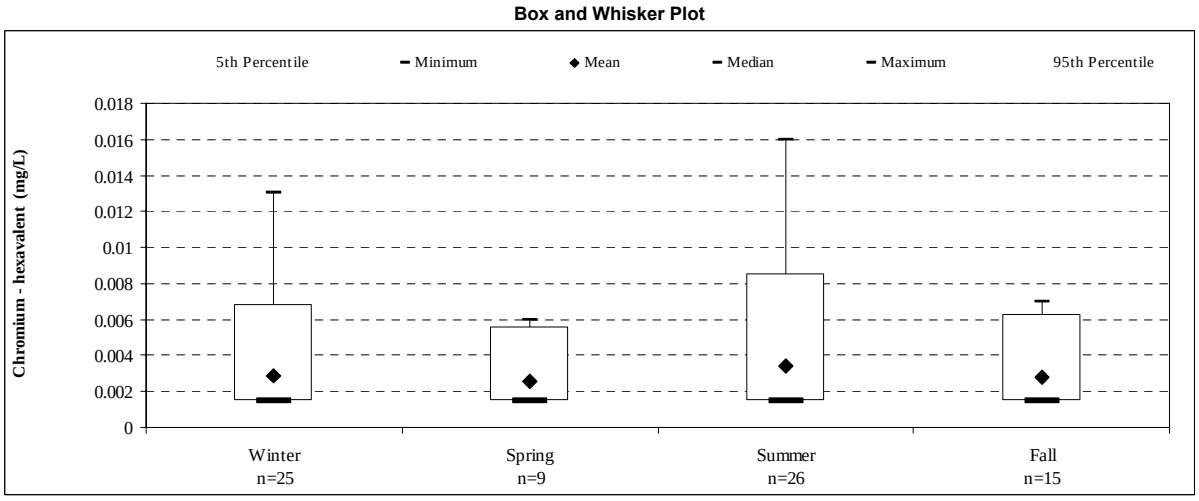


Figure G-2-3-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Lower Segment of Muskeg River



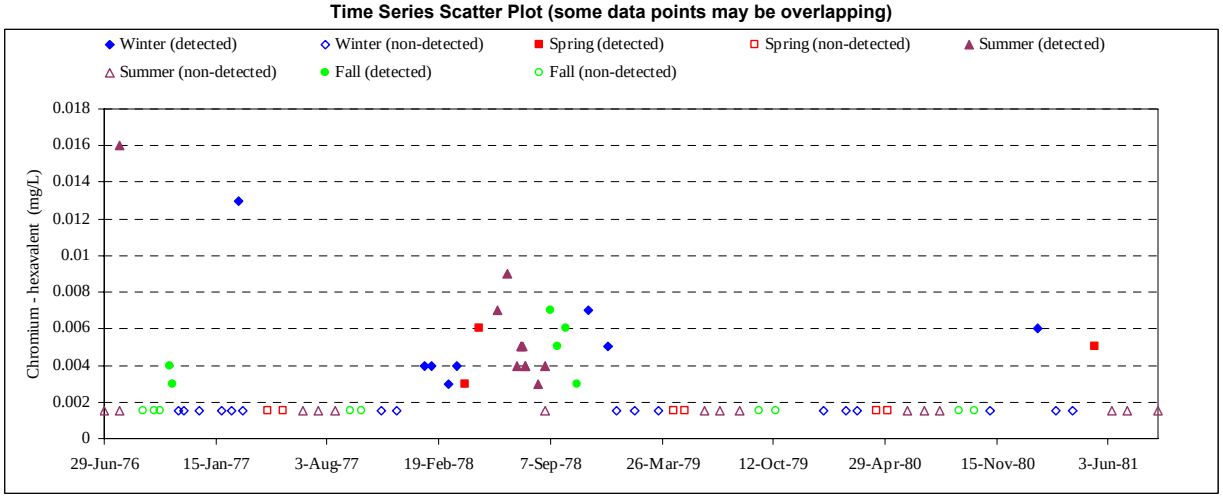
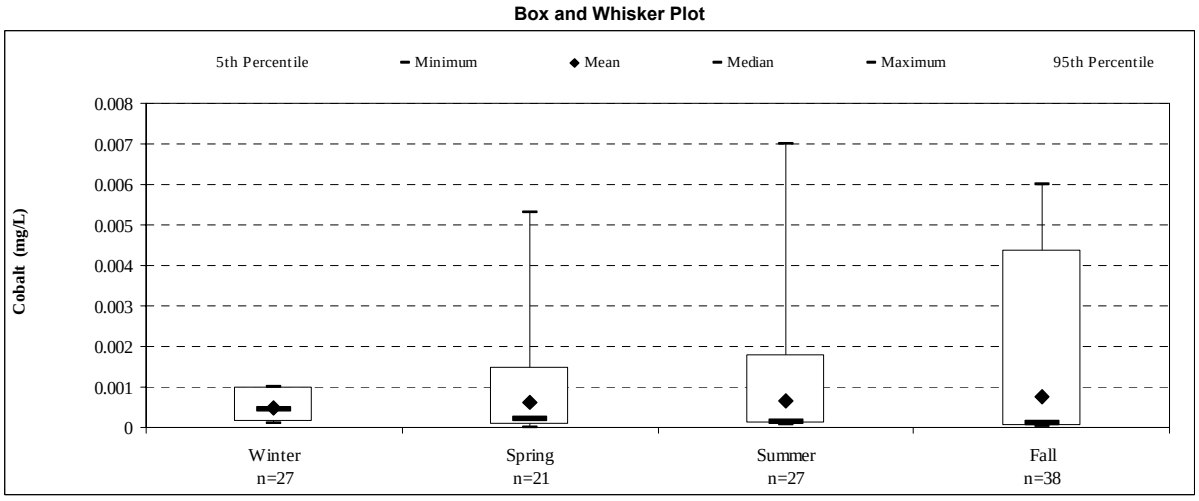


Figure G-2-3-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Lower Segment of Muskeg River



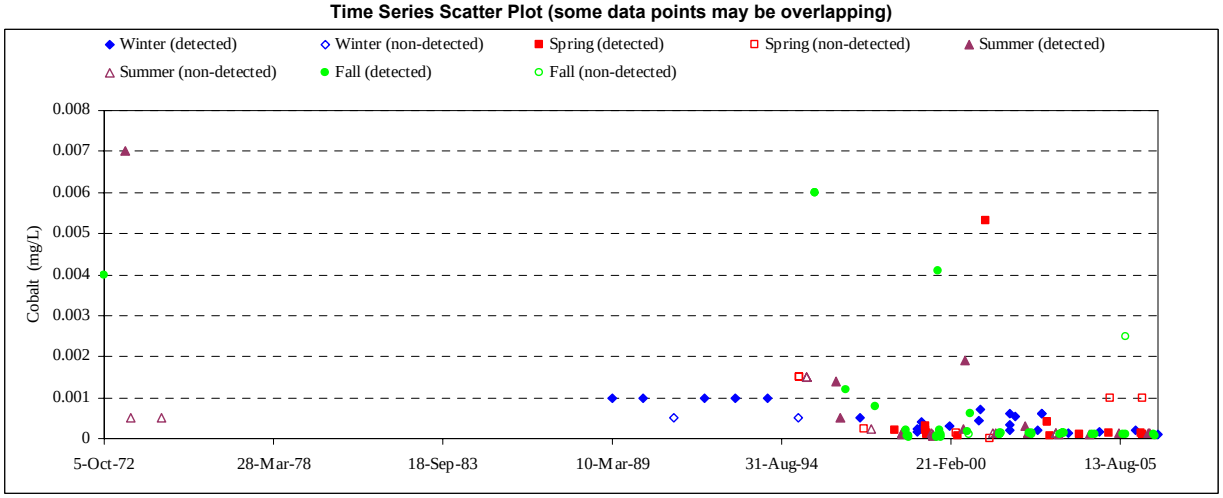
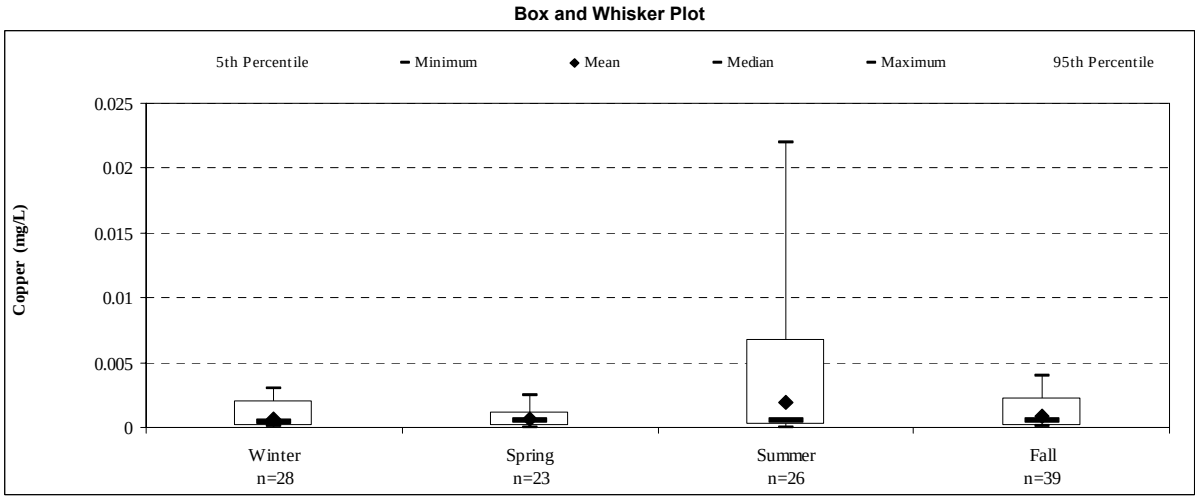


Figure G-2-3-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Lower Segment of Muskeg River



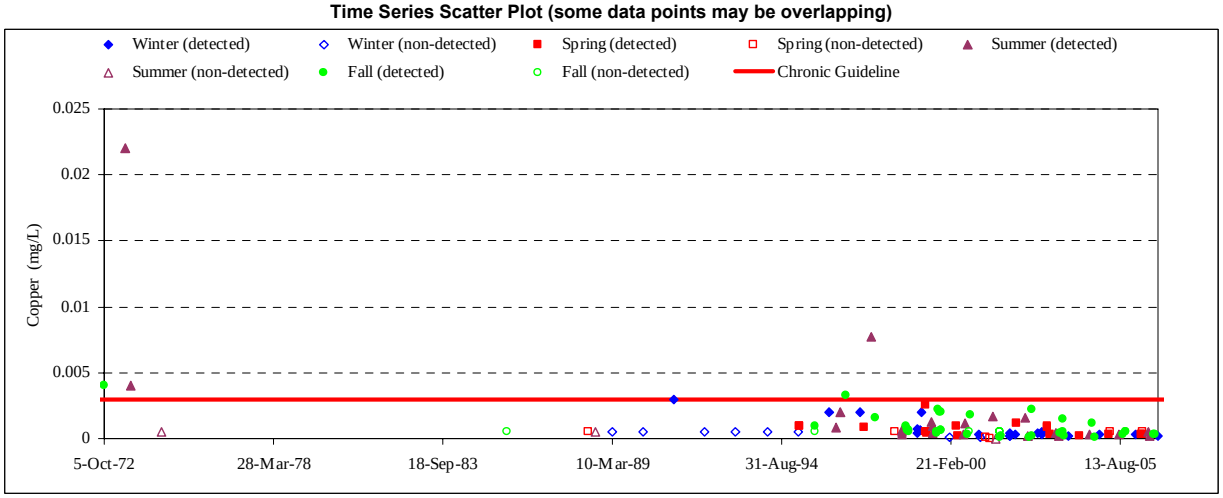
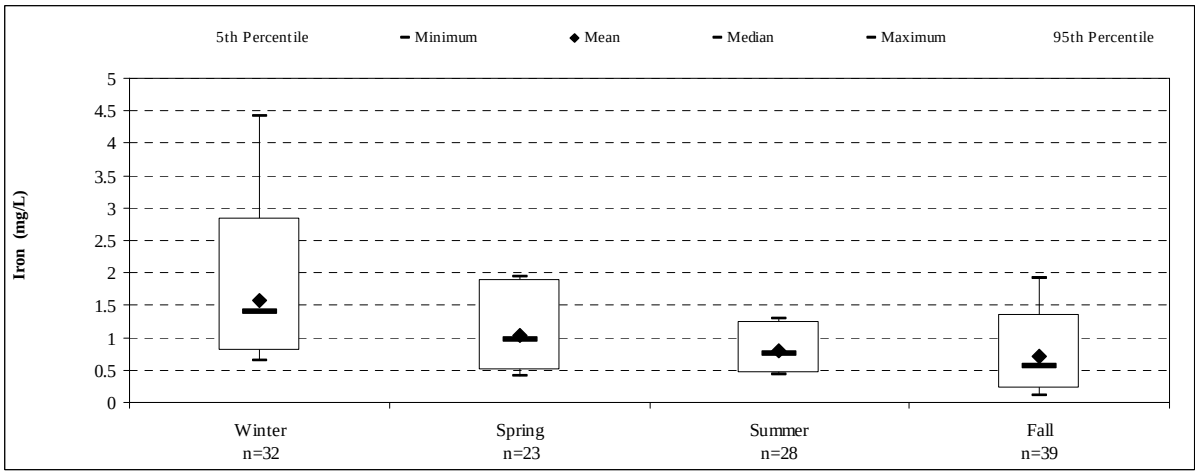


Figure G-2-3-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Lower Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

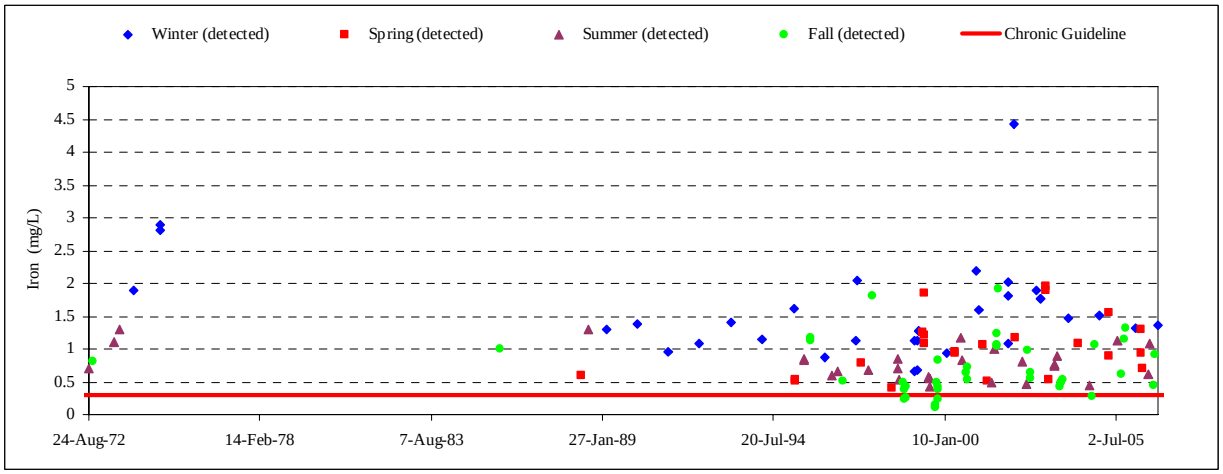
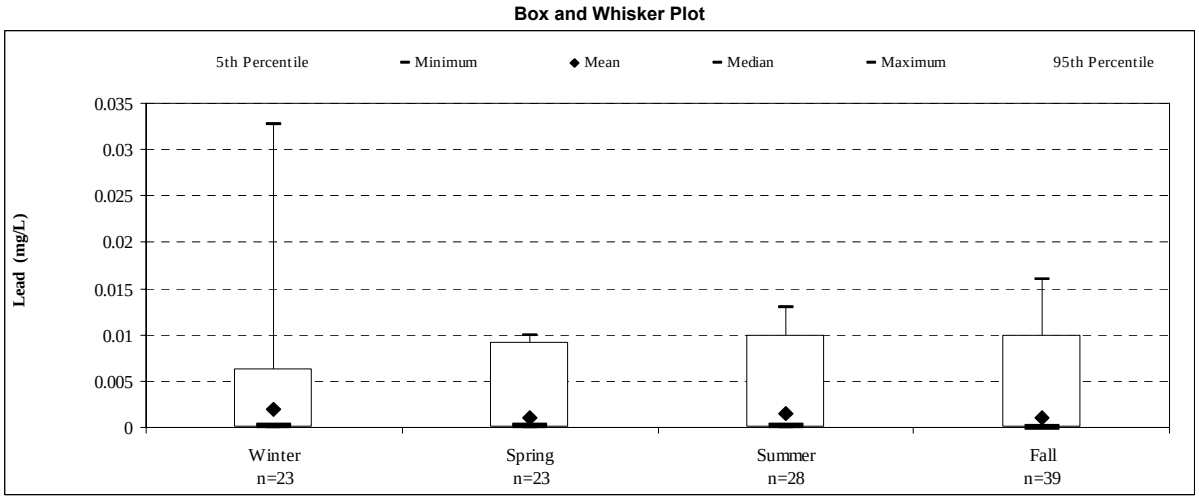


Figure G-2-3-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Lower Segment of Muskeg River



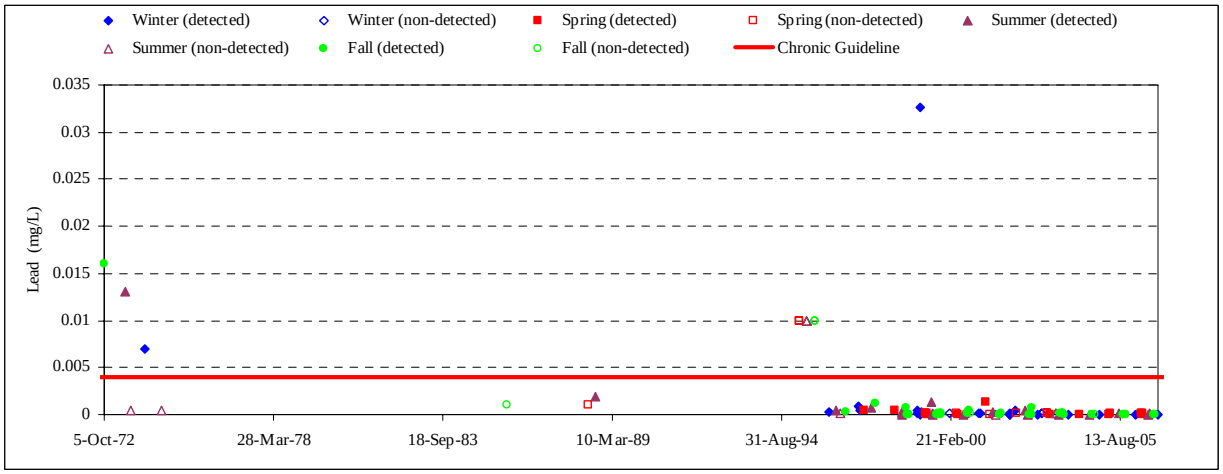
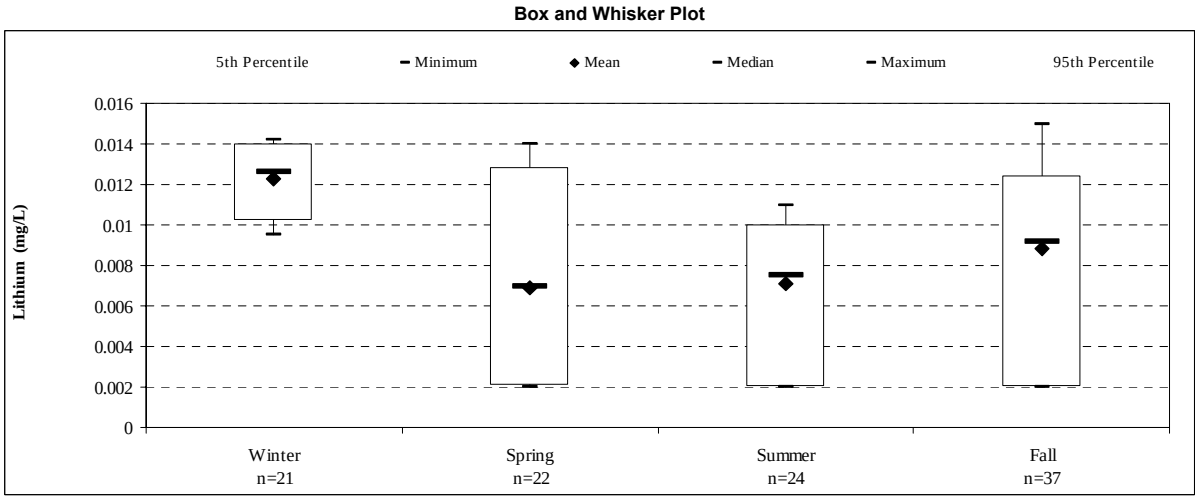


Figure G-2-3-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Lower Segment of Muskeg River



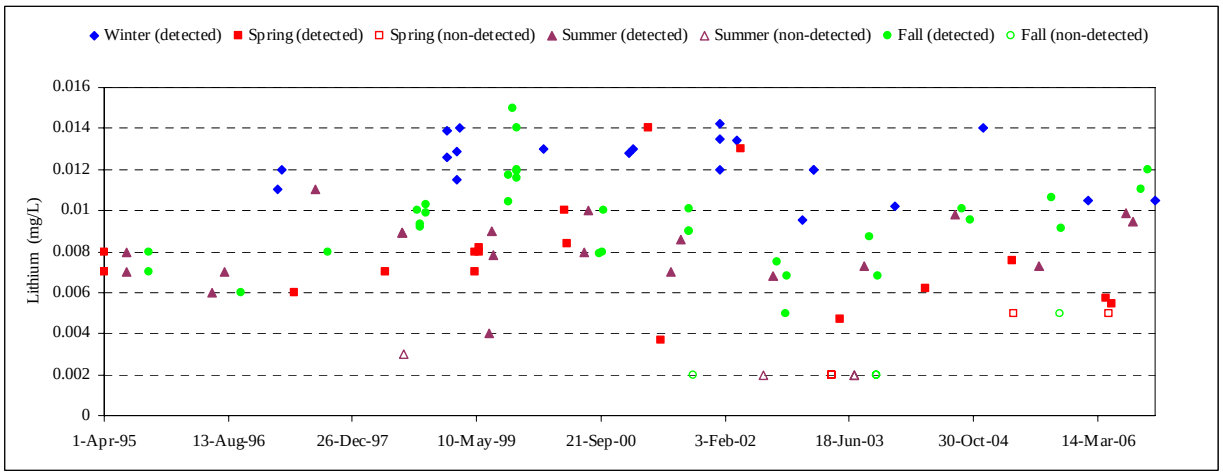
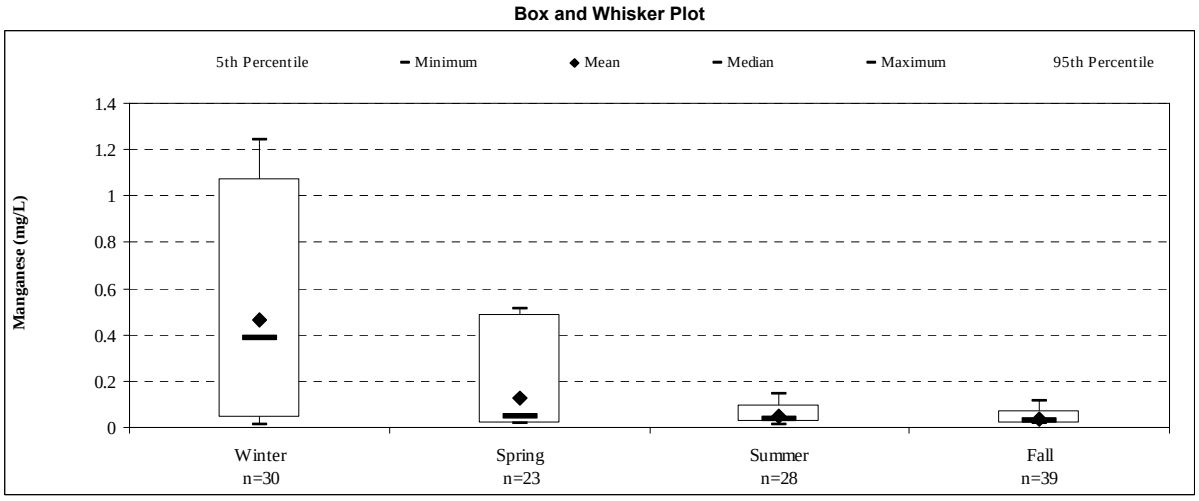


Figure G-2-3-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Lower Segment of Muskeg River



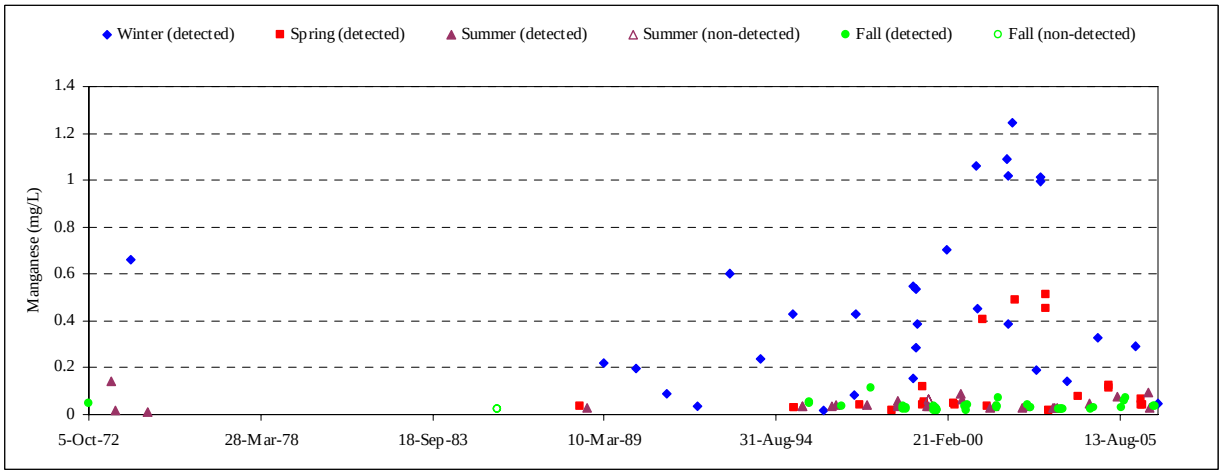
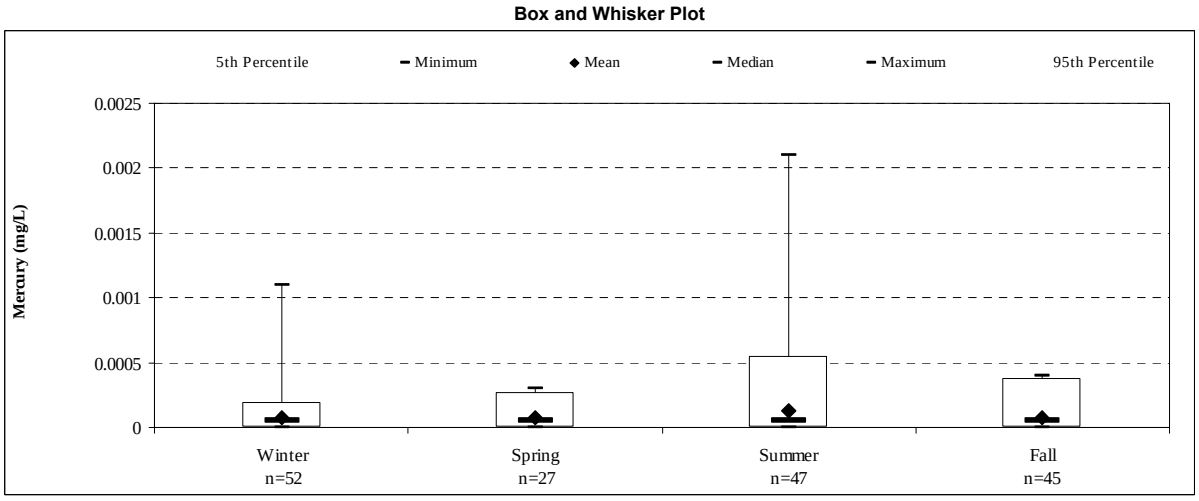


Figure G-2-3-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Lower Segment of Muskeg River



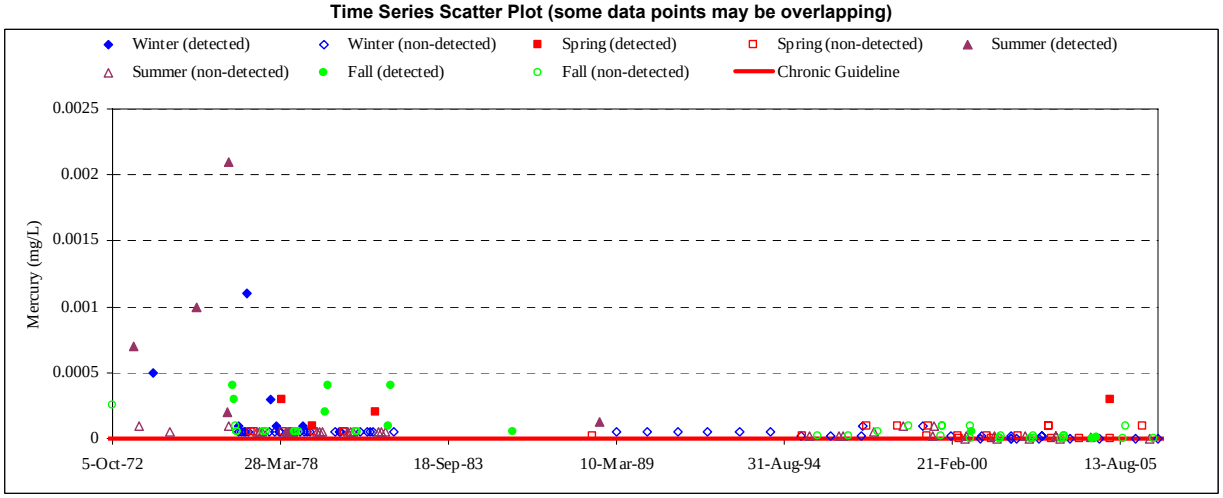
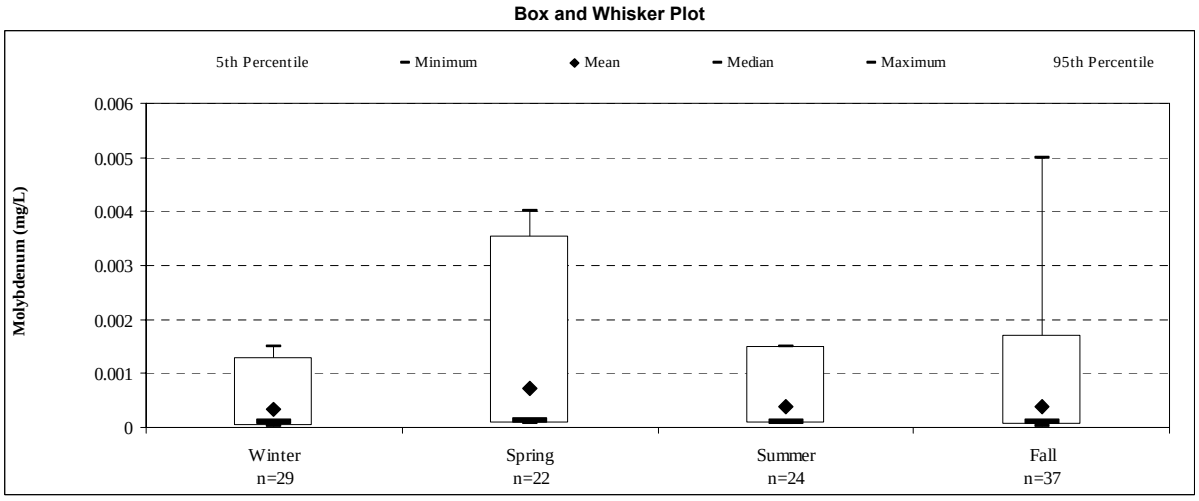


Figure G-2-3-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Lower Segment of Muskeg River



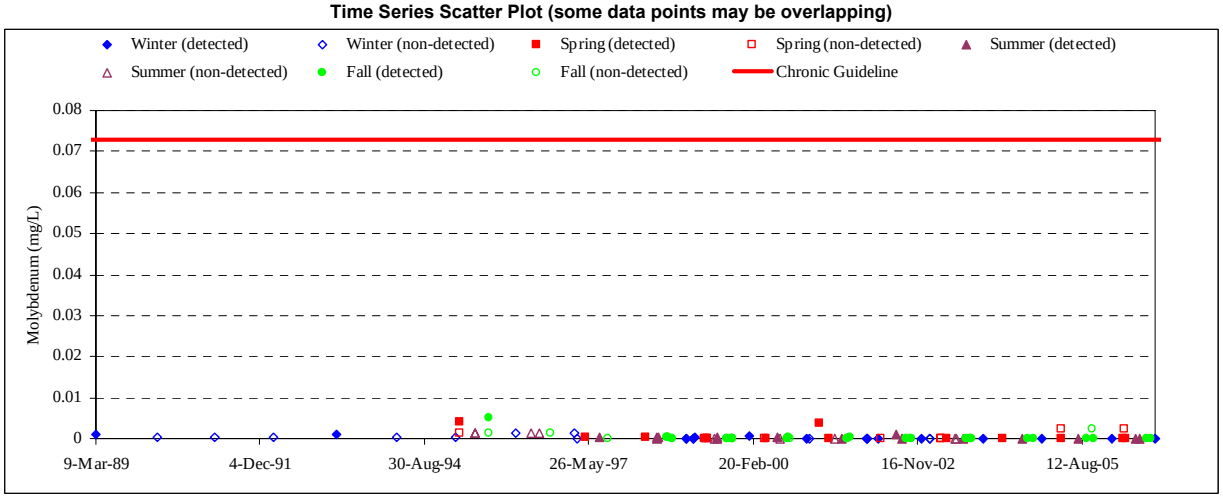


Figure G-2-3-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Lower Segment of Muskeg Rive

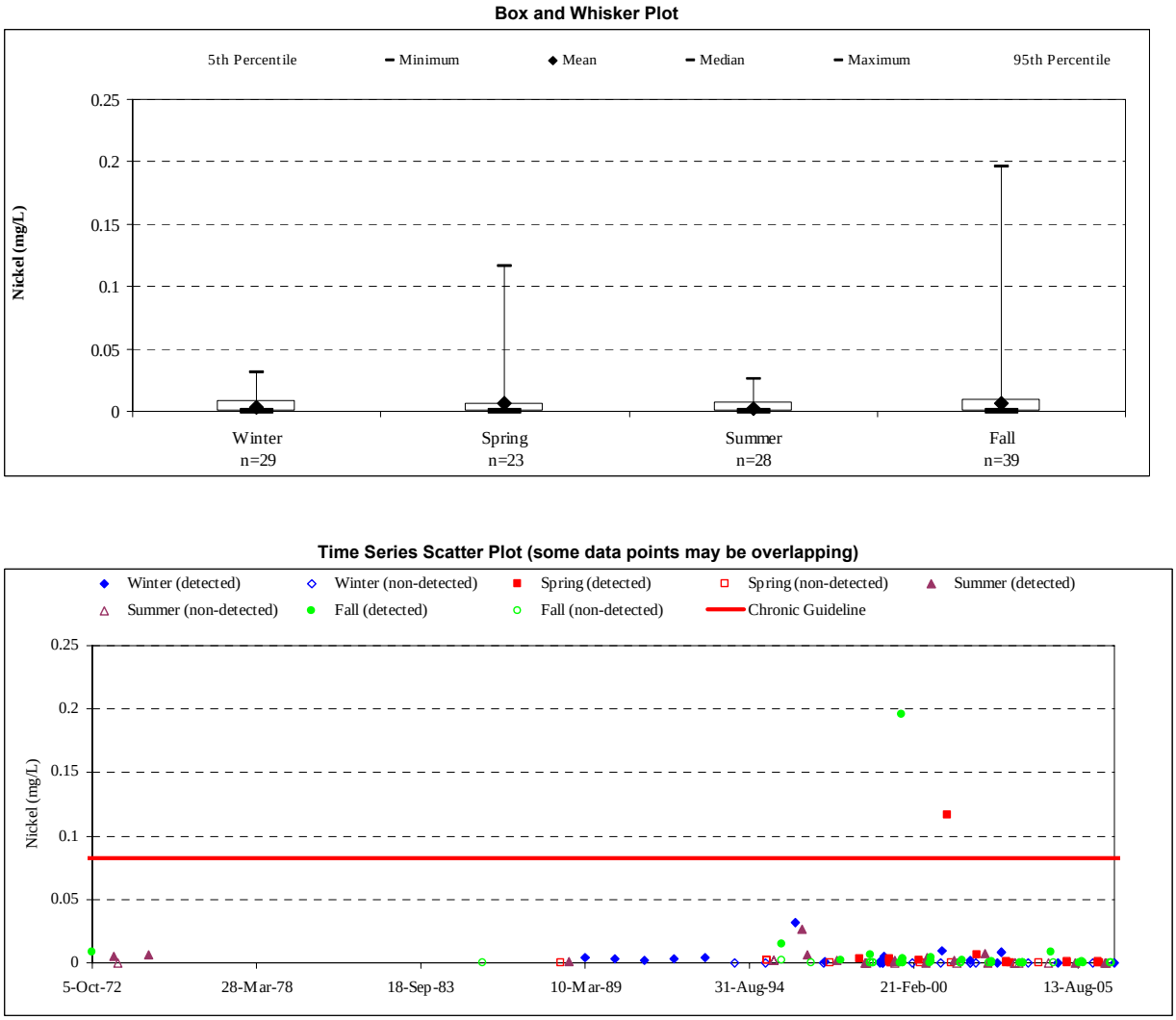
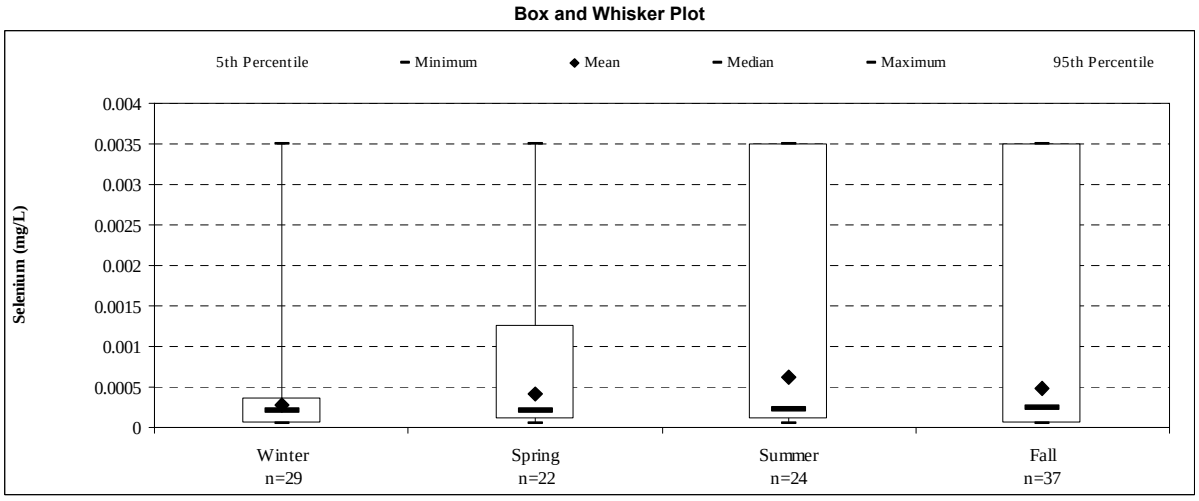


Figure G-2-3-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Lower Segment of Muskeg River



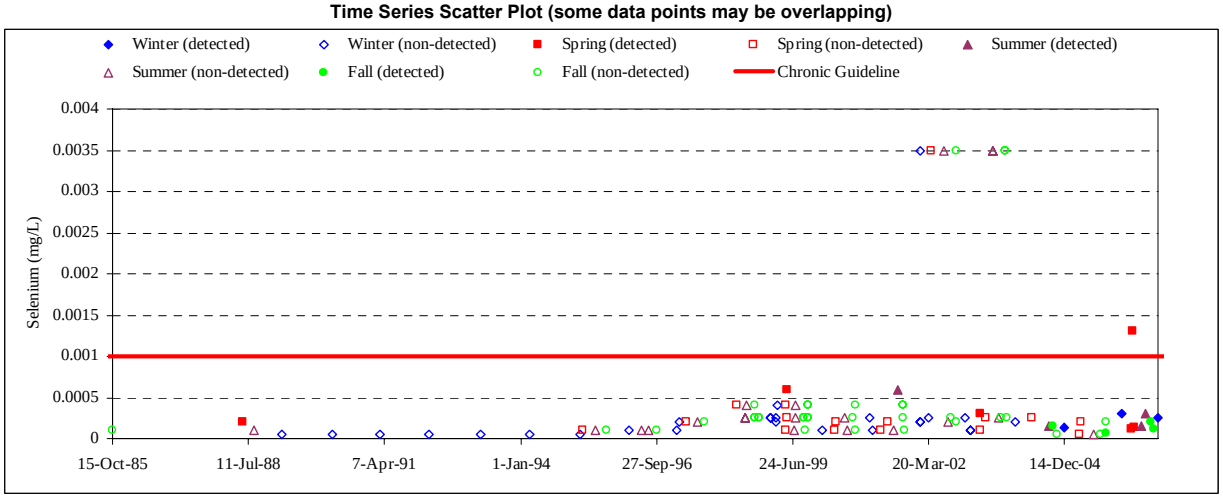
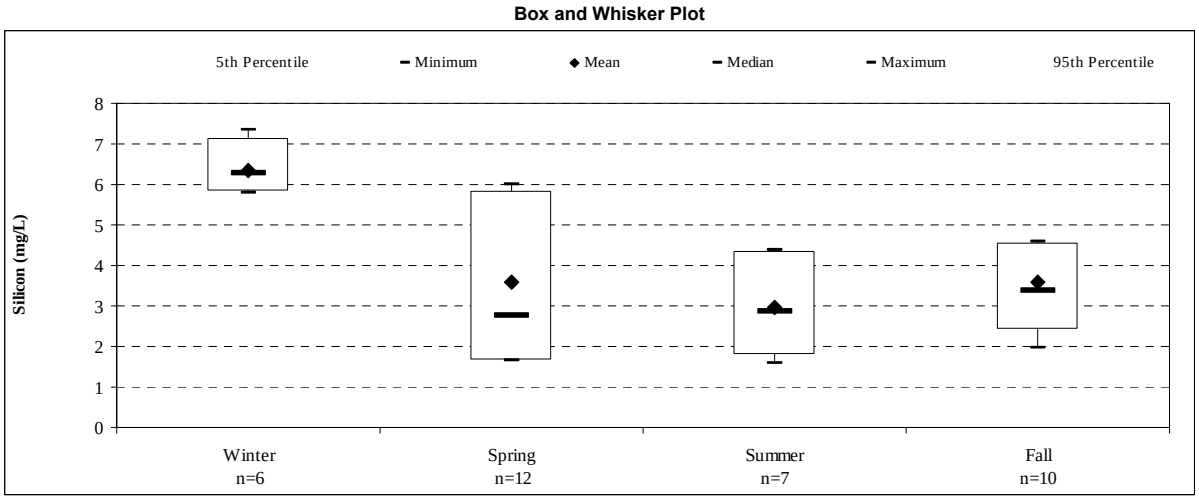


Figure G-2-3-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Lower Segment of Muskeg River



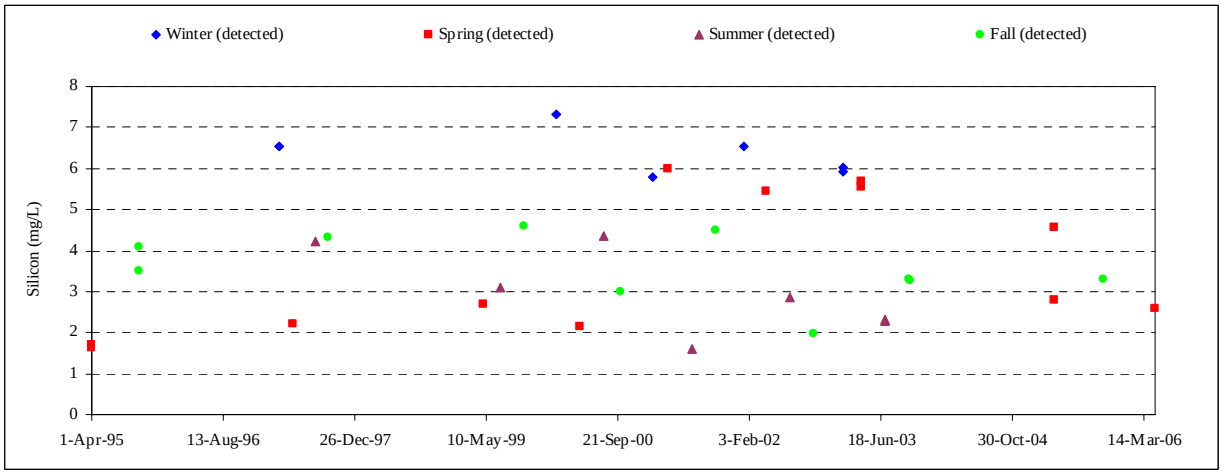
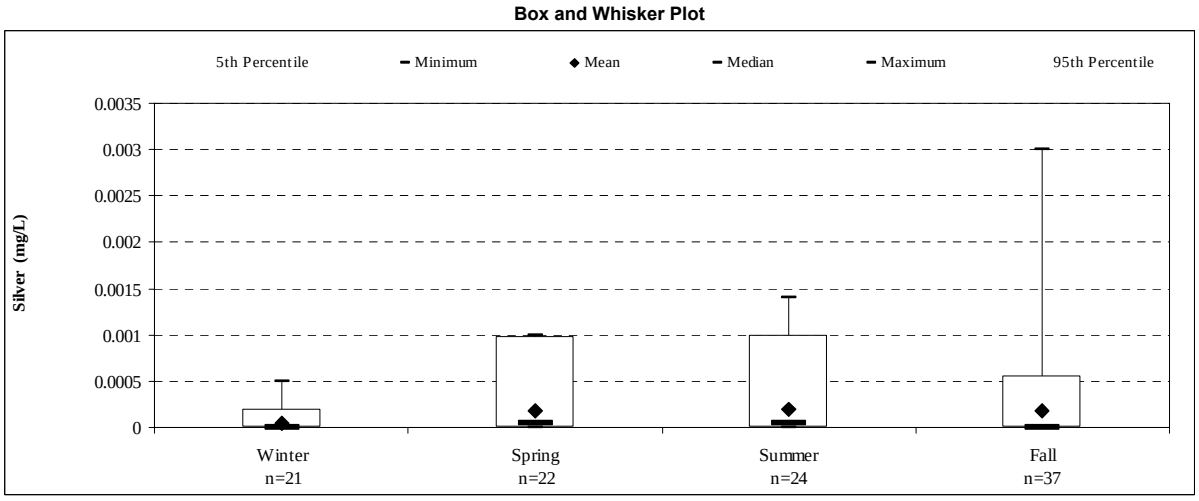


Figure G-2-3-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Lower Segment of Muskeg Rive



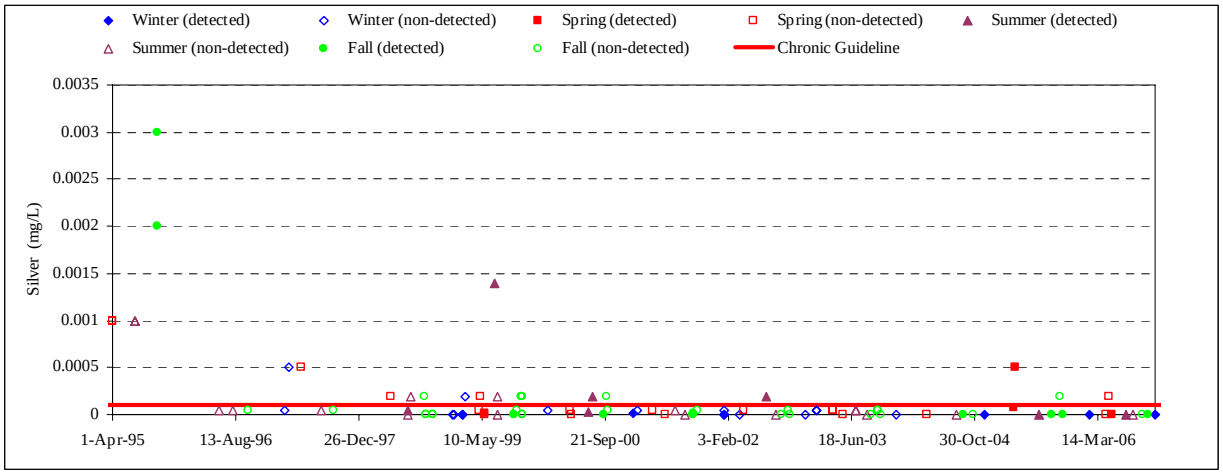
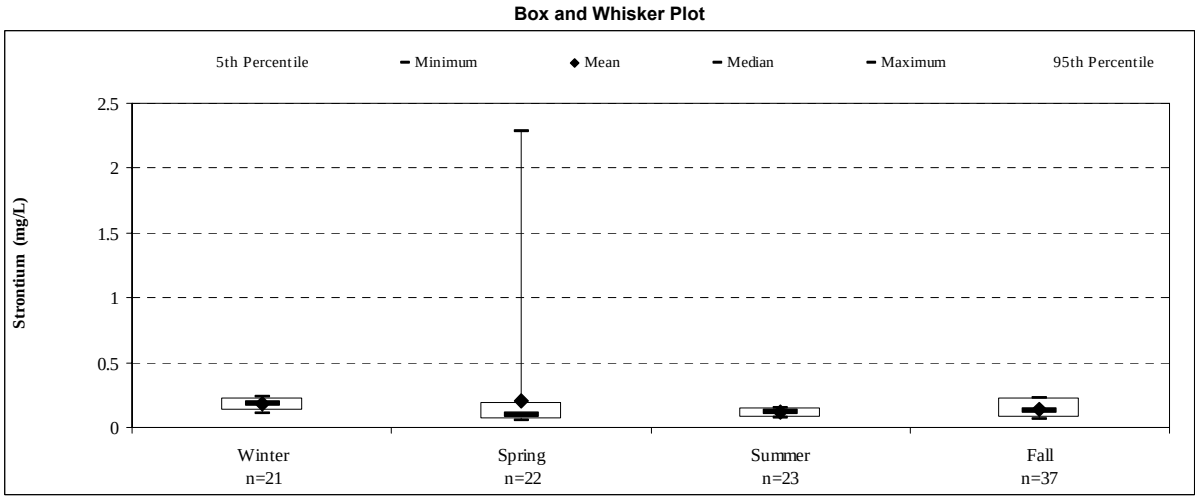


Figure G-2-3-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Lower Segment of Muskeg River



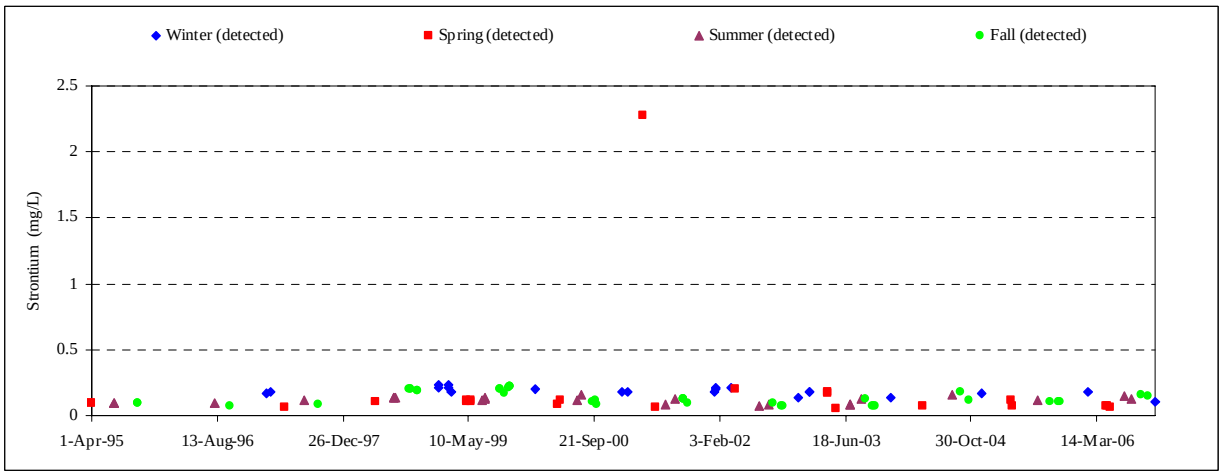
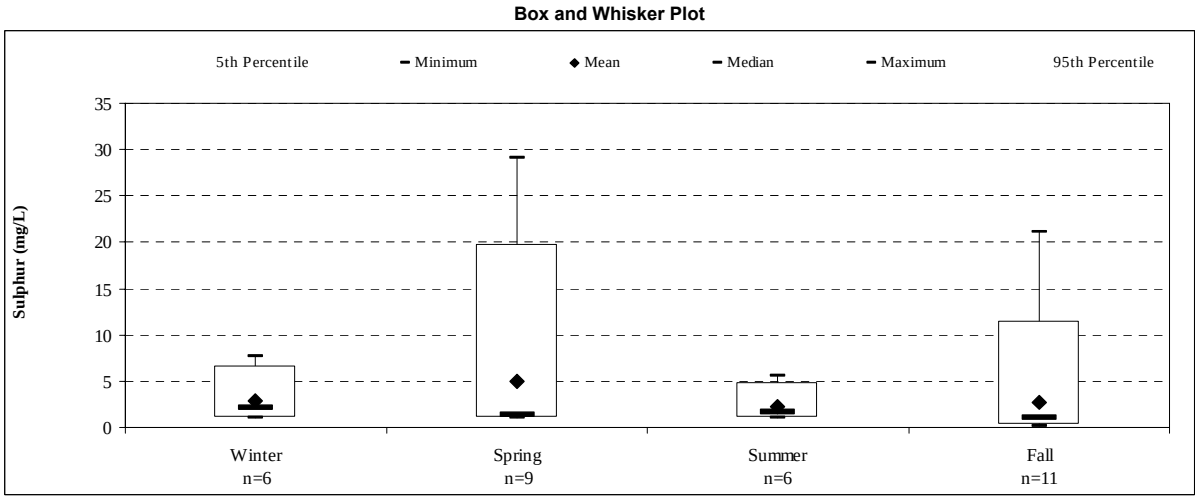


Figure G-2-3-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Lower Segment of Muskeg River



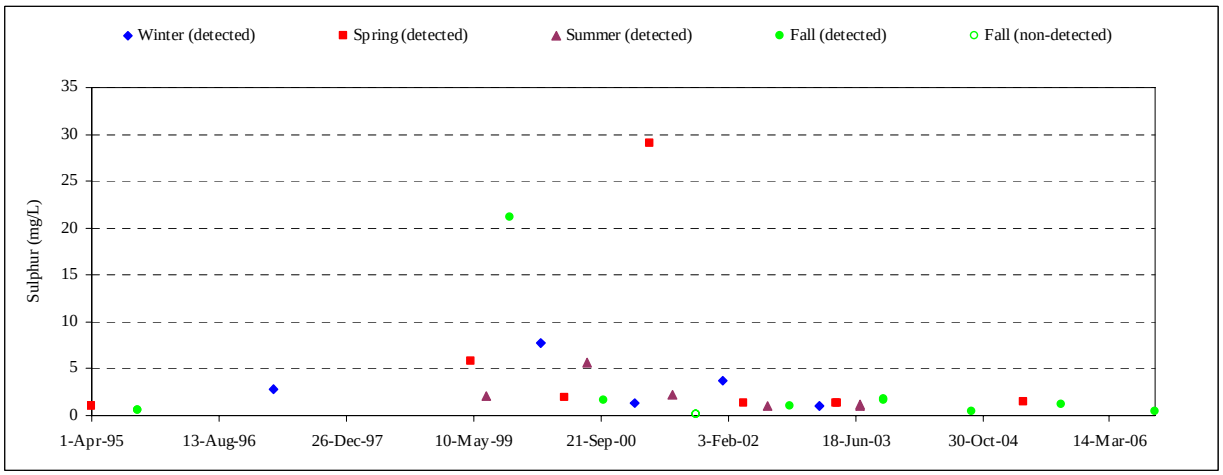
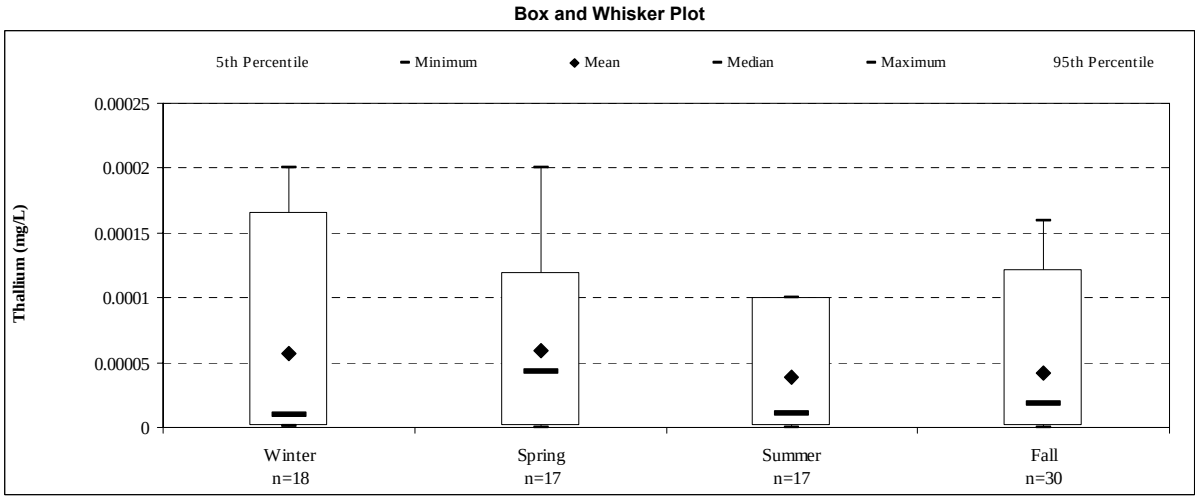


Figure G-2-3-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Lower Segment of Muskeg River



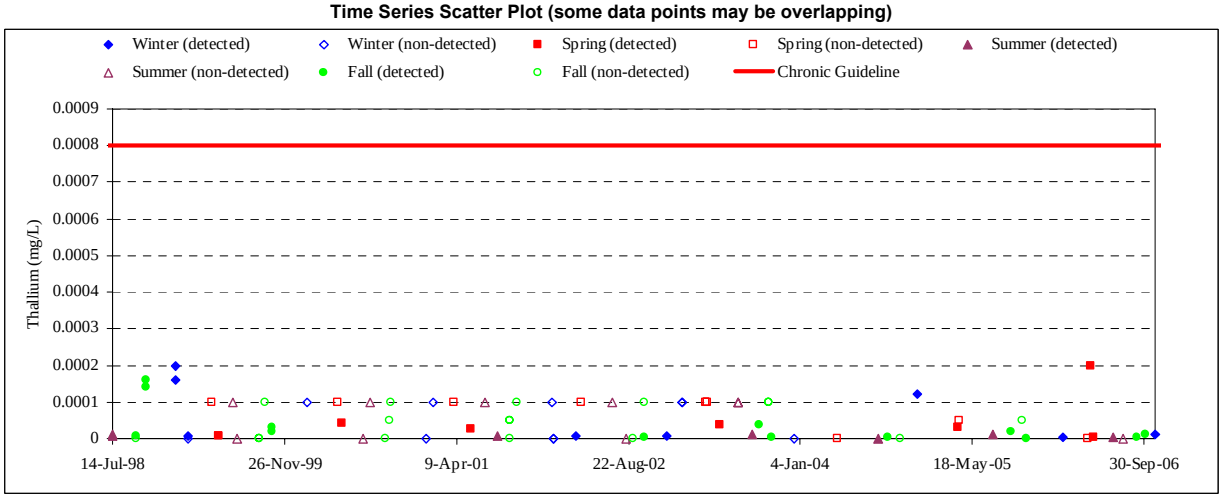
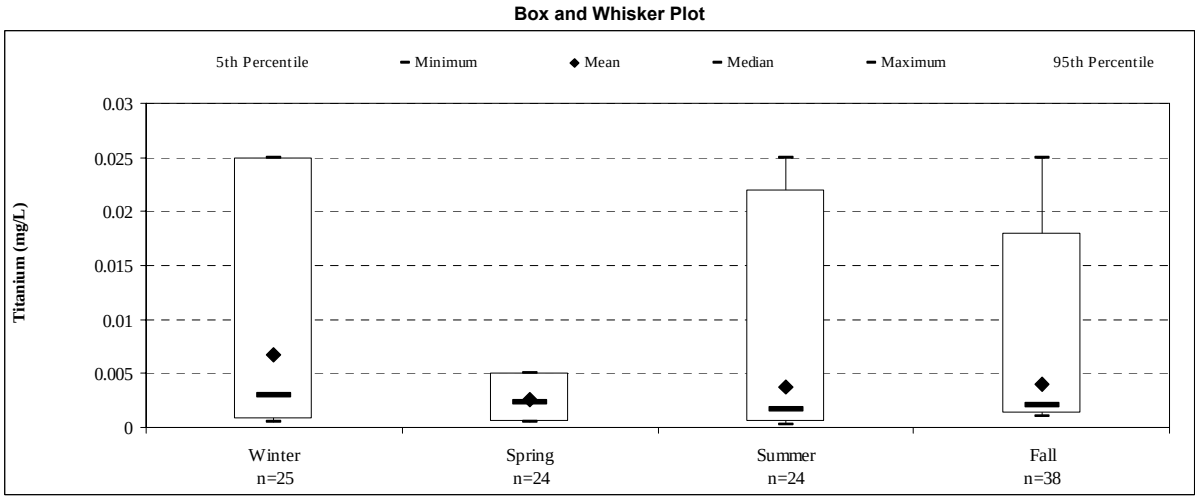


Figure G-2-3-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Lower Segment of Muskeg River



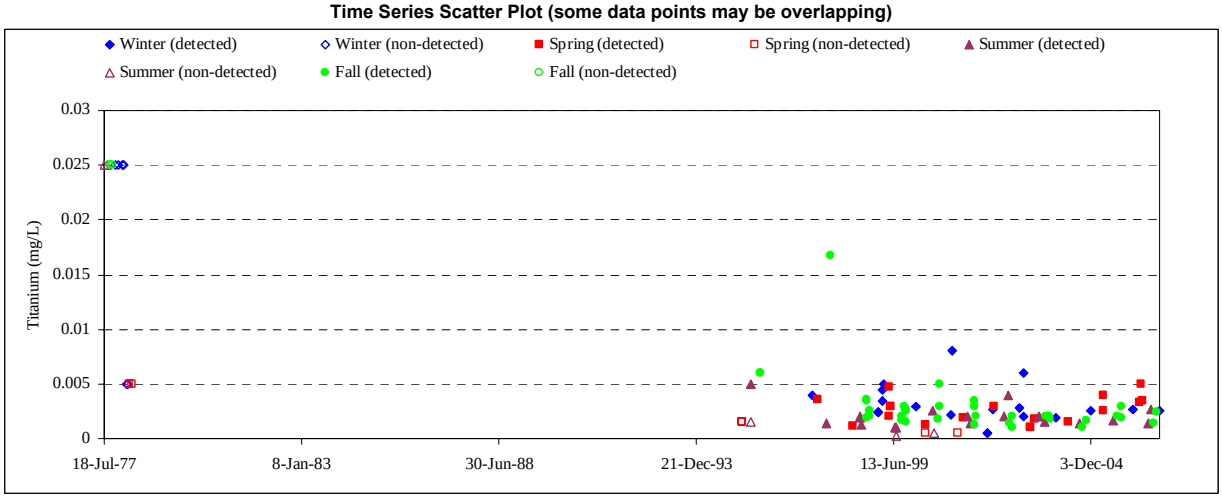
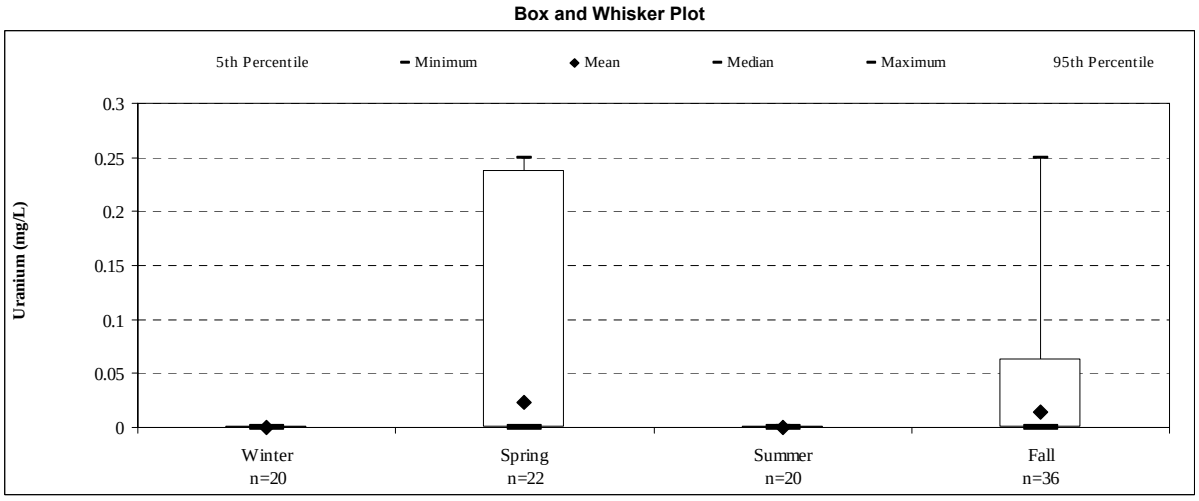


Figure G-2-3-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Lower Segment of Muskeg River



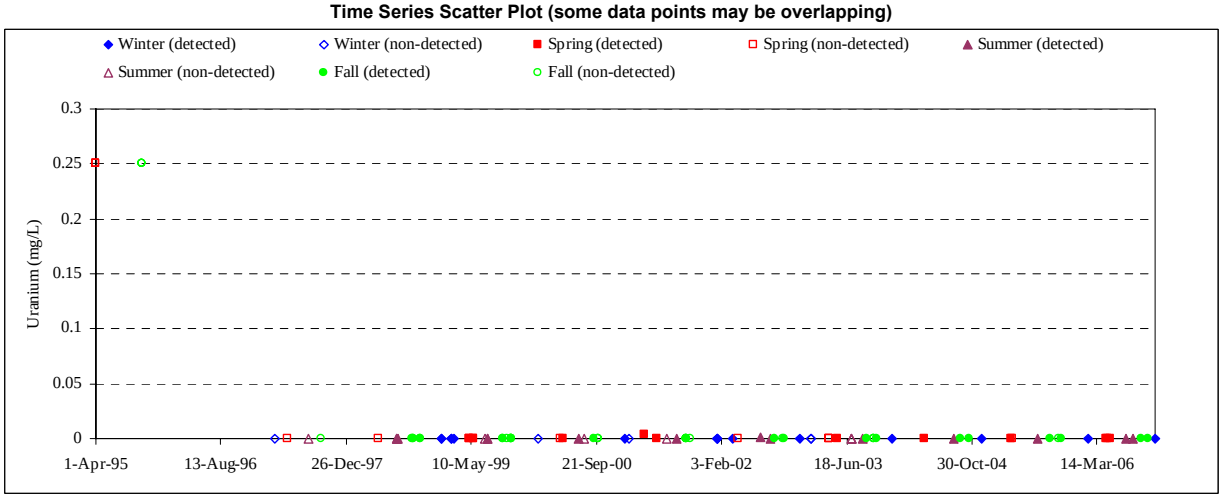


Figure G-2-3-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Lower Segment of Muskeg River

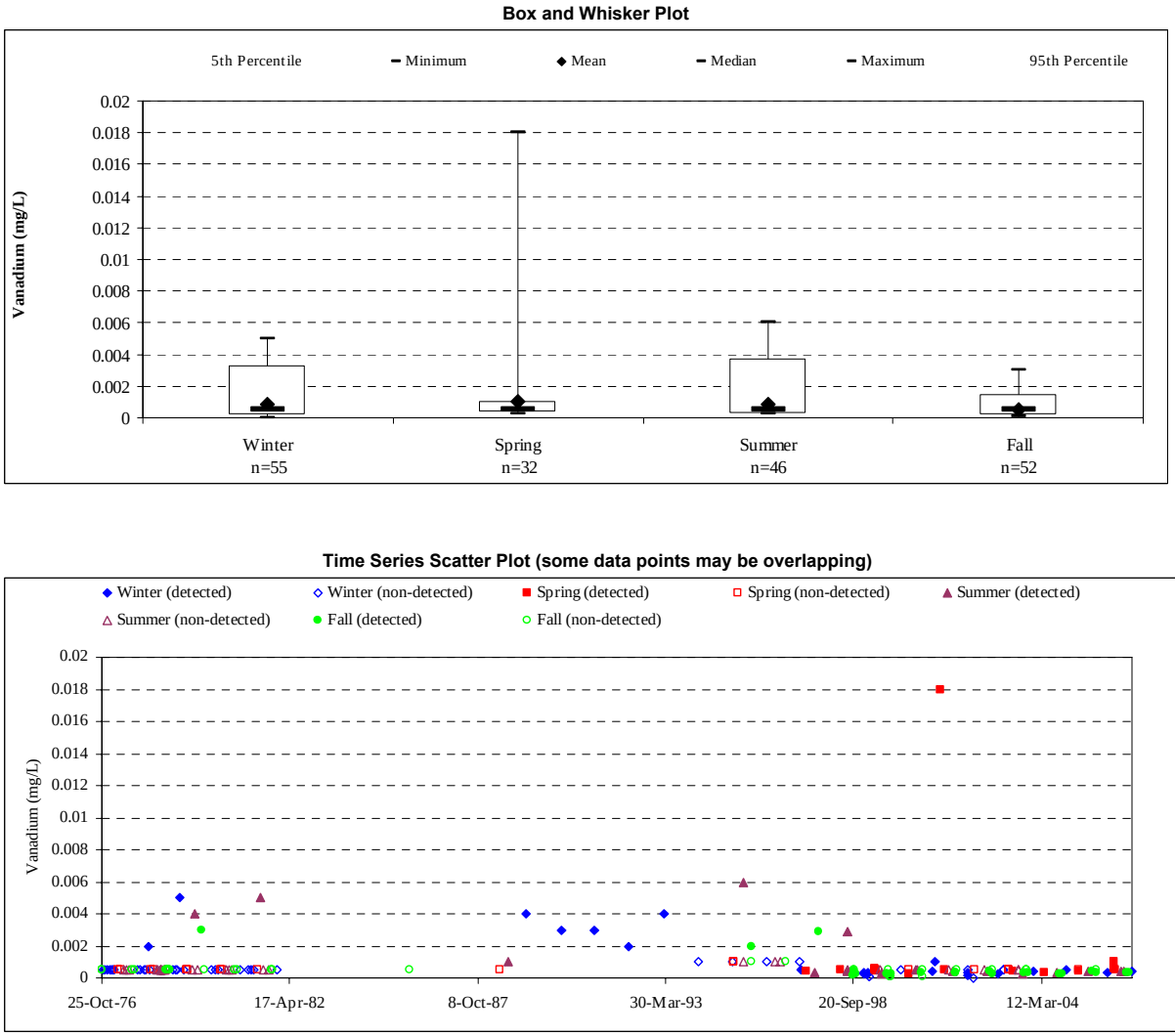
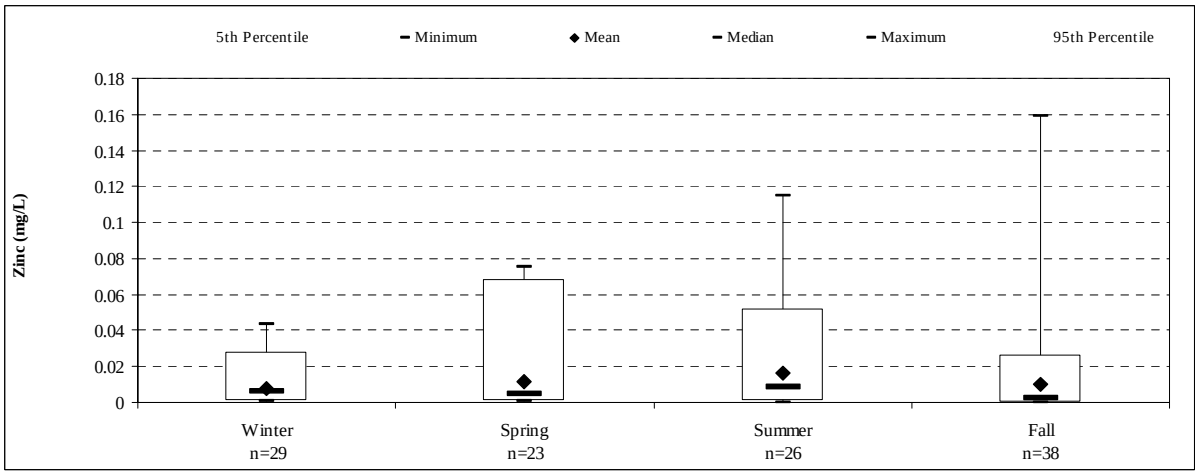


Figure G-2-3-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Lower Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

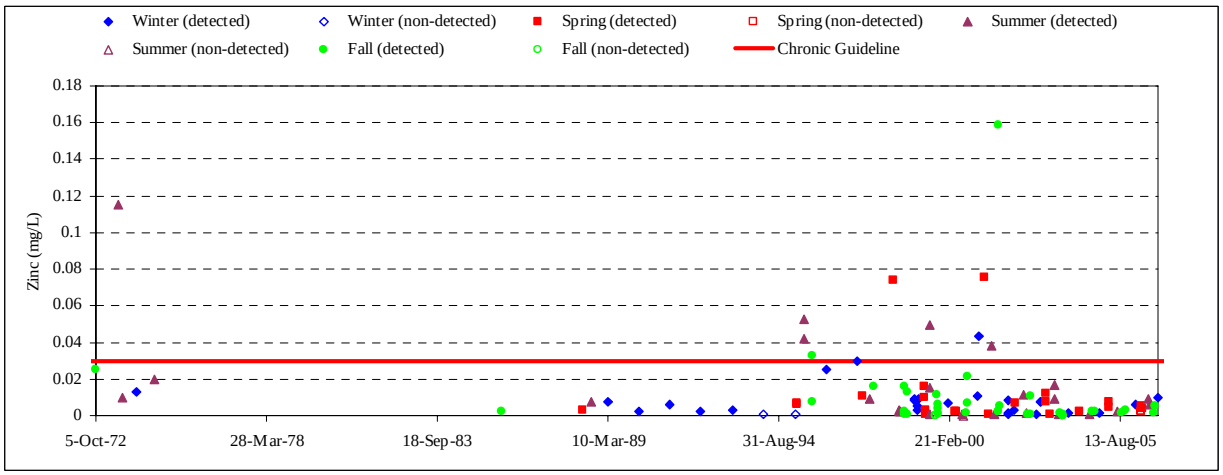


Figure G-2-3-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Lower Segment of Muskeg River

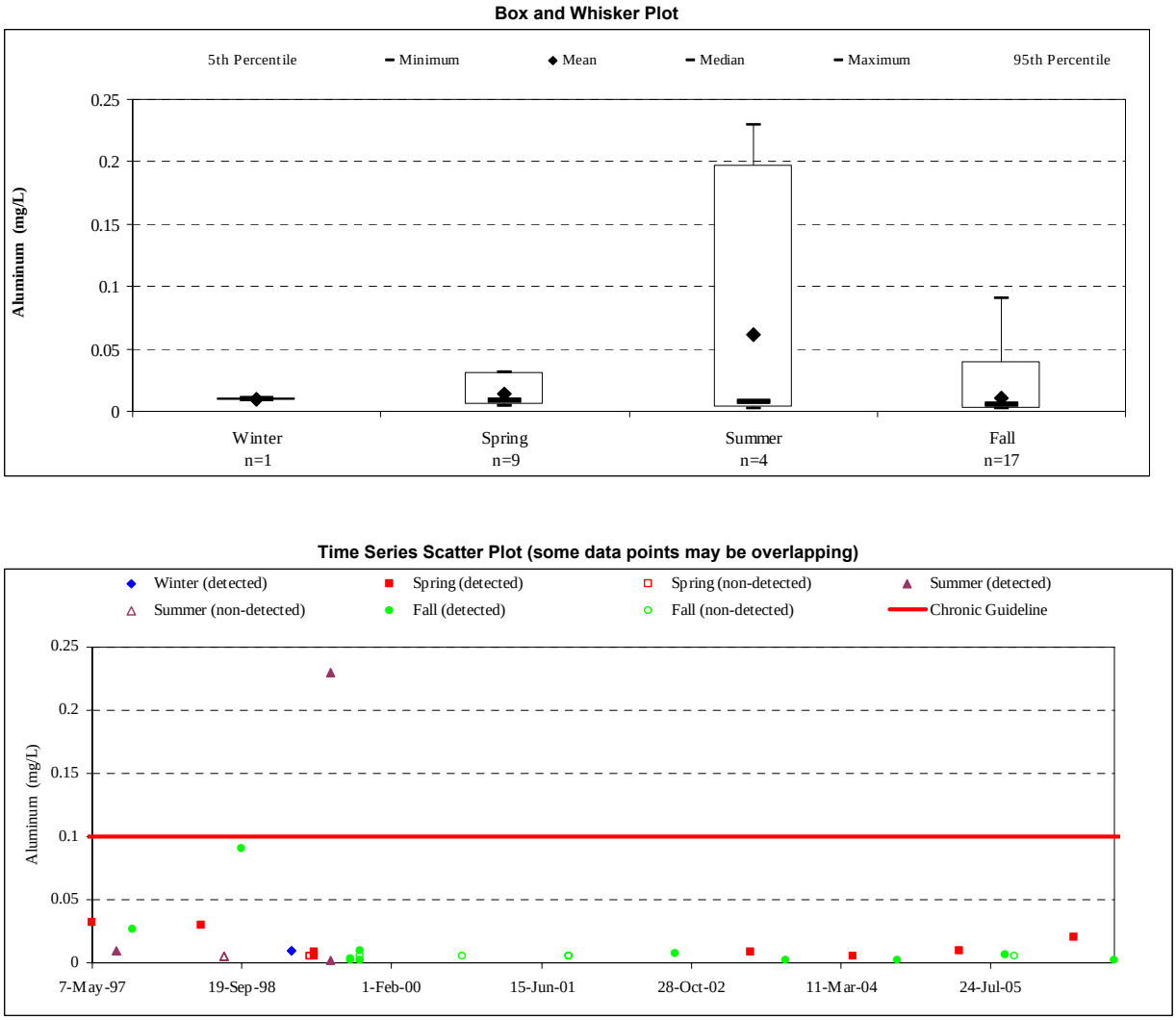
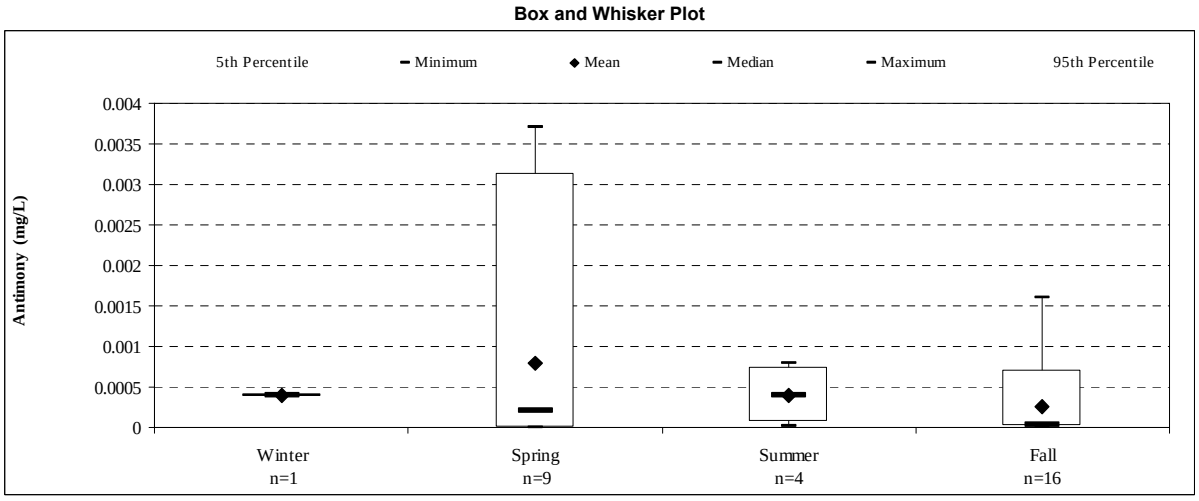


Figure G-2-3-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Lower Segment of Muskeg River



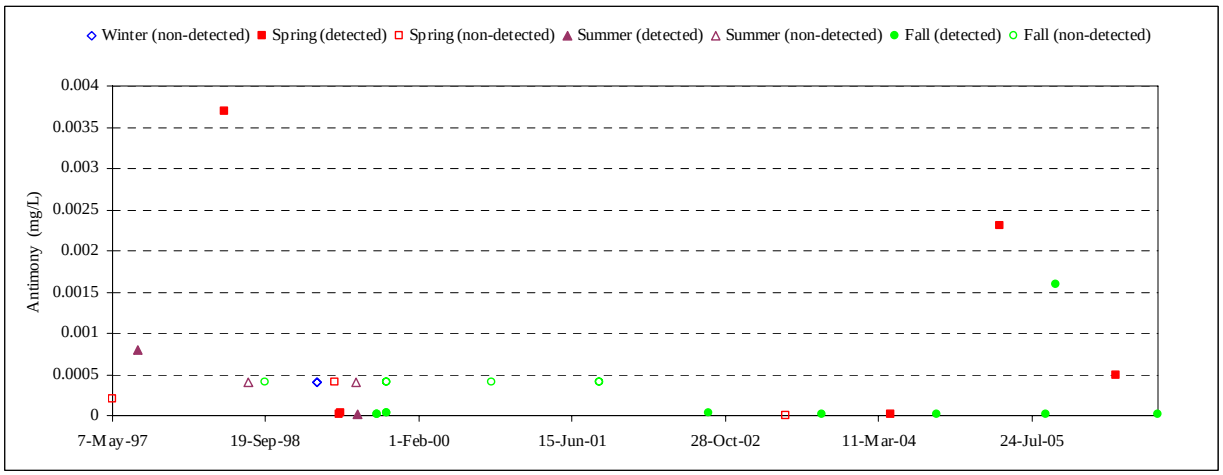
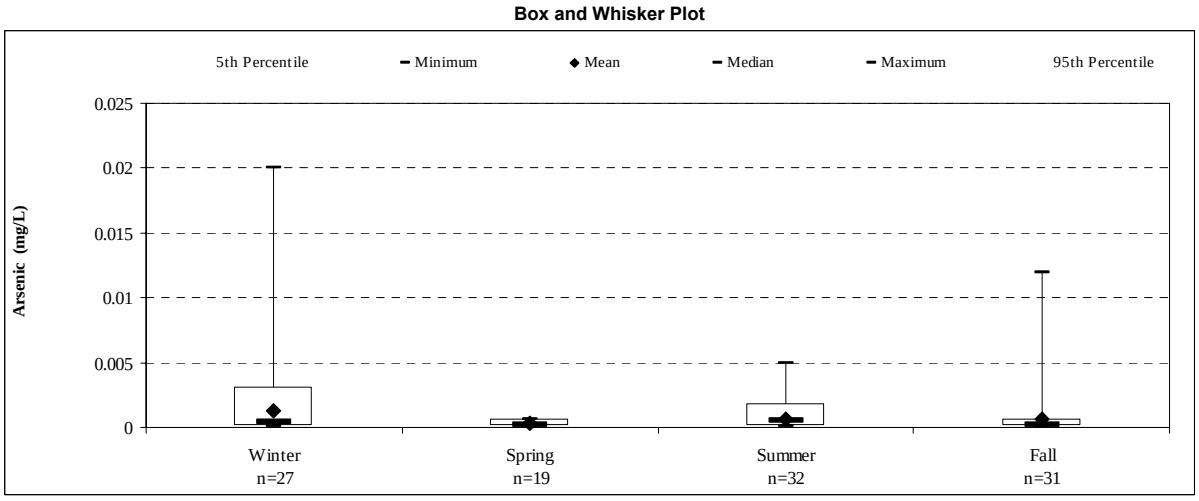


Figure G-2-3-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Lower Segment of Muskeg River



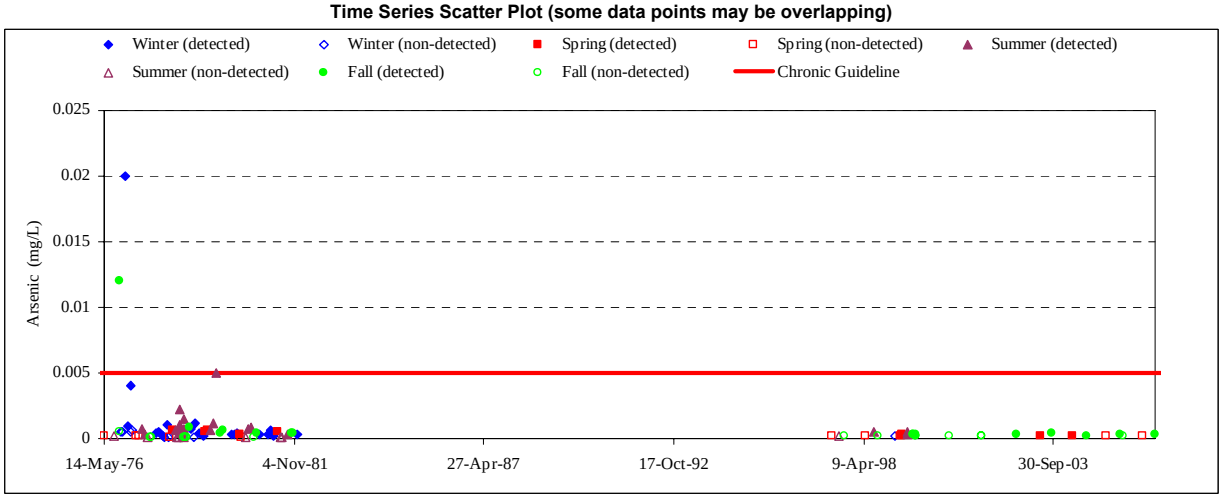
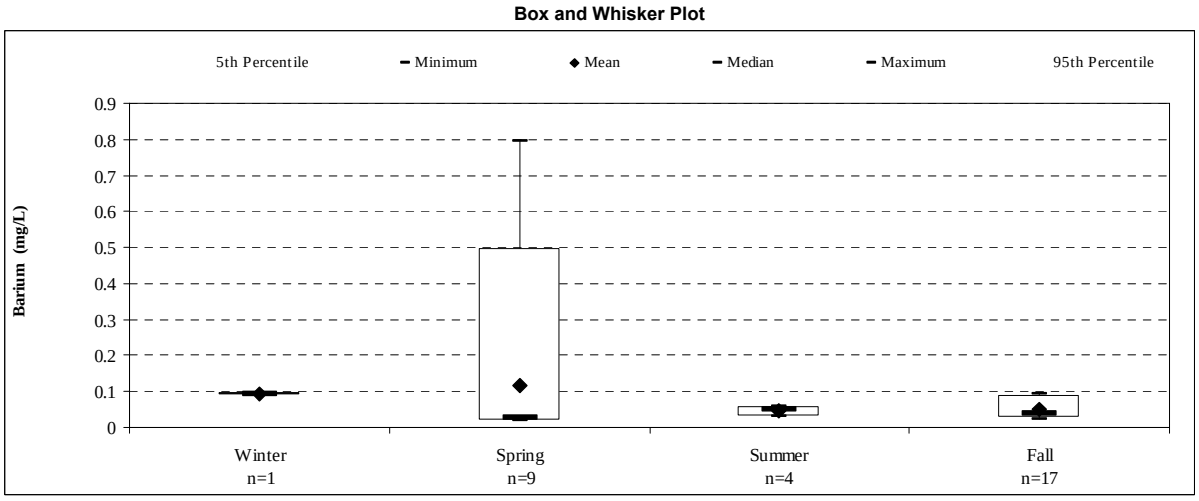


Figure G-2-3-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Lower Segment of Muskeg River



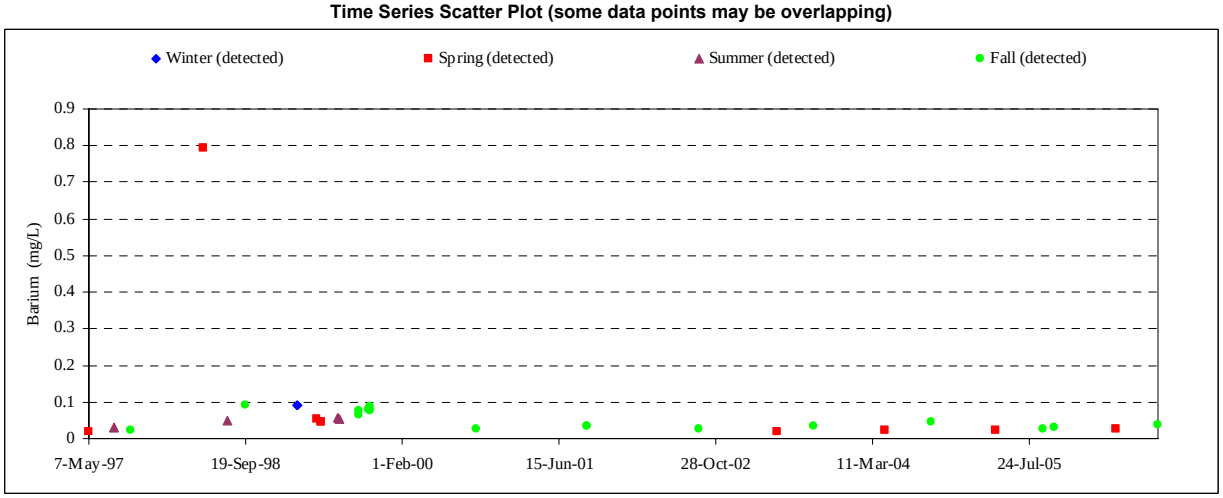
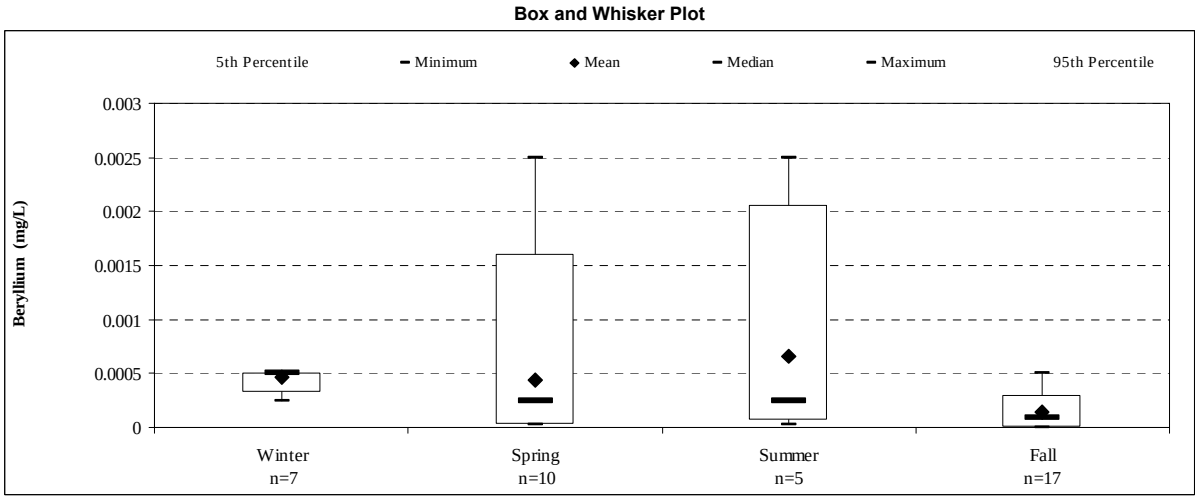


Figure G-2-3-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Lower Segment of Muskeg River



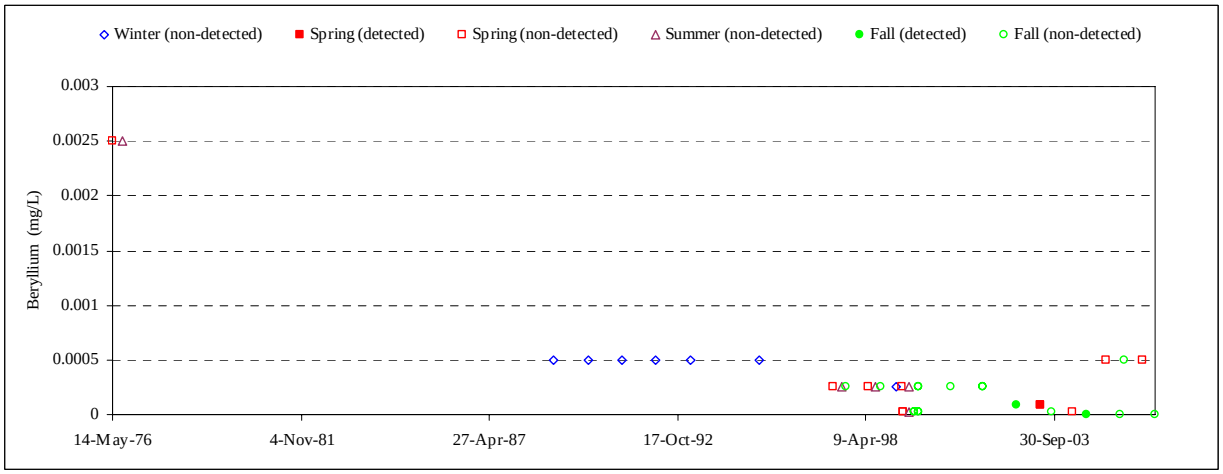
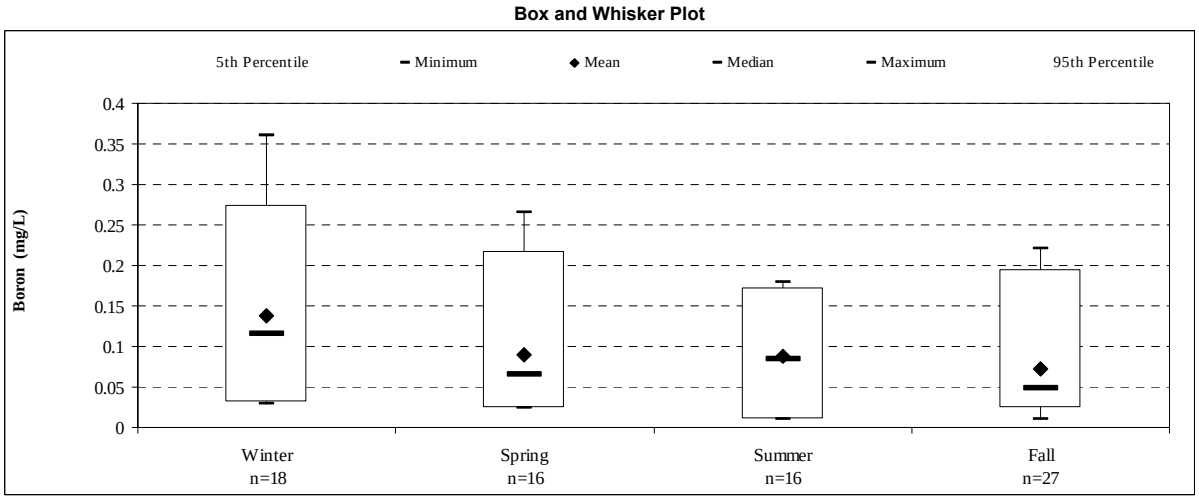


Figure G-2-3-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Lower Segment of Muskeg River



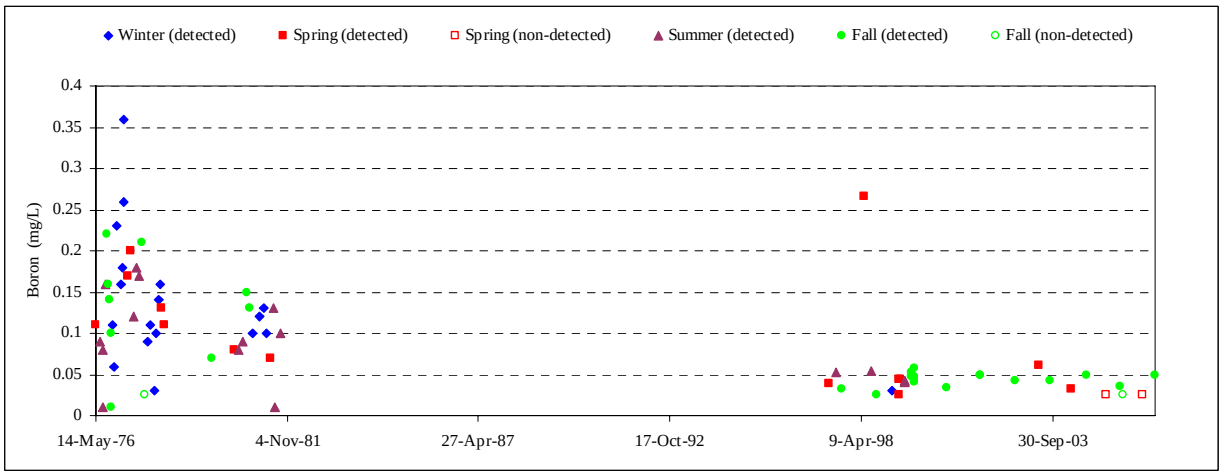
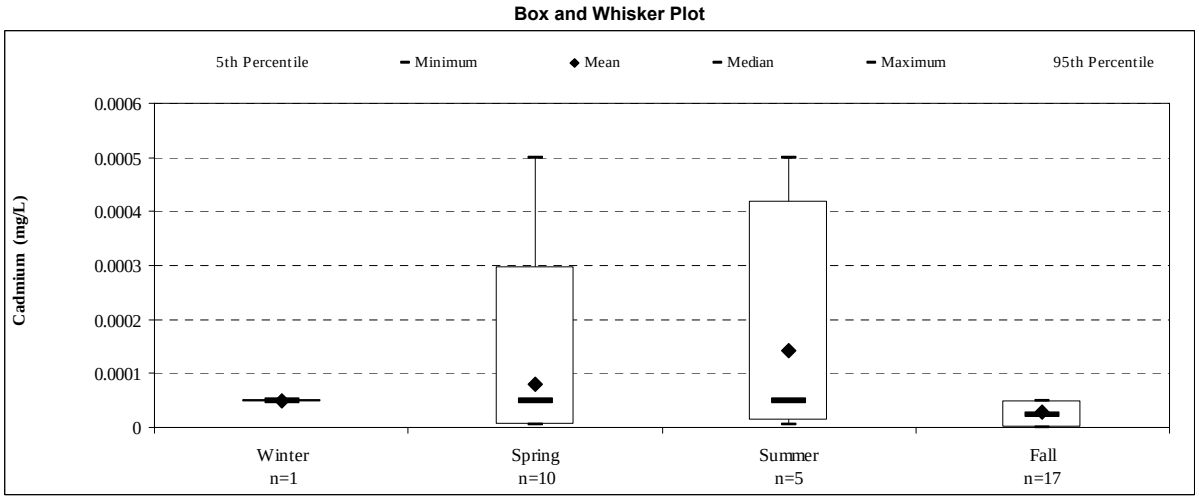


Figure G-2-3-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Lower Segment of Muskeg River



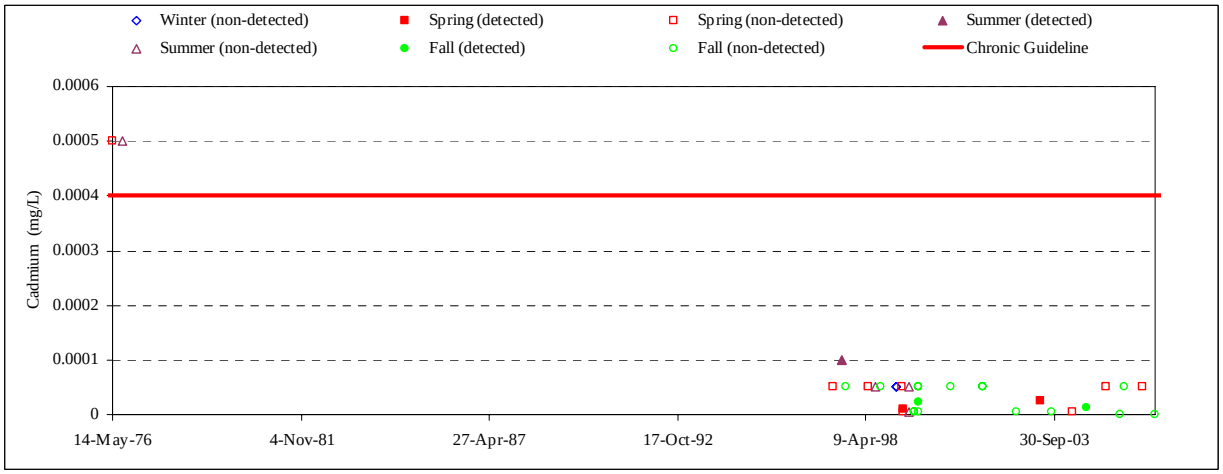
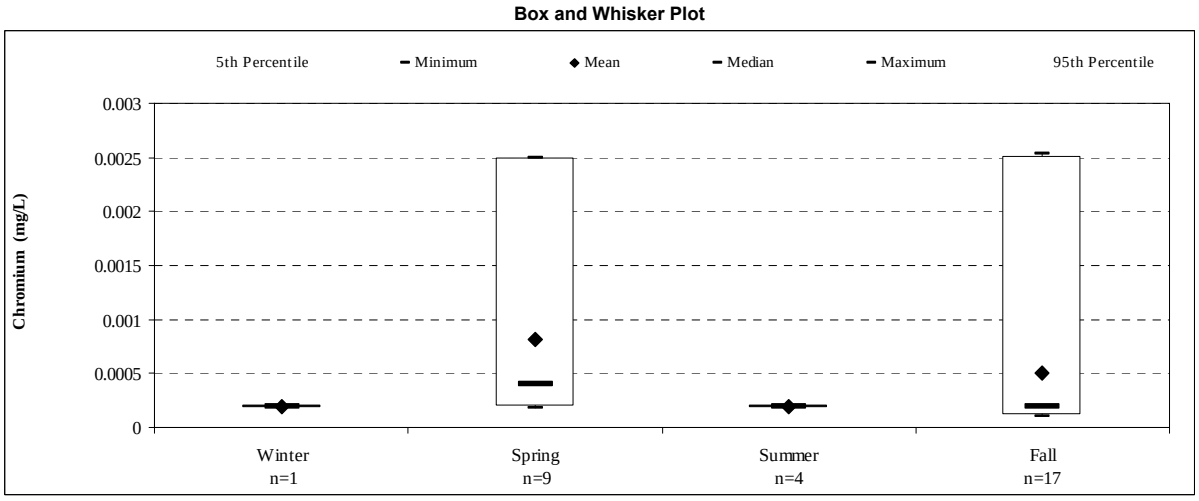


Figure G-2-3-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Lower Segment of Muskeg River



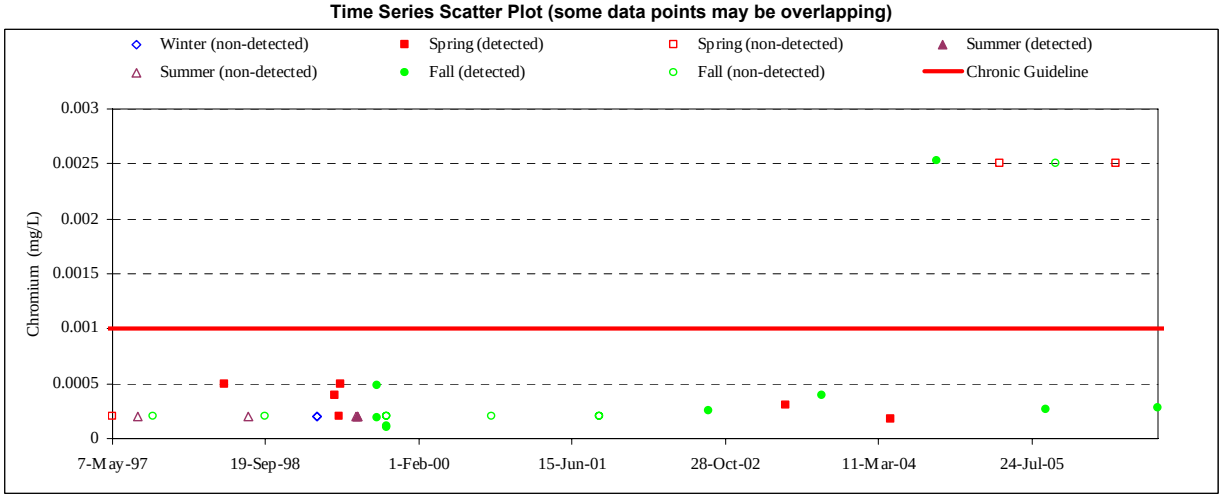
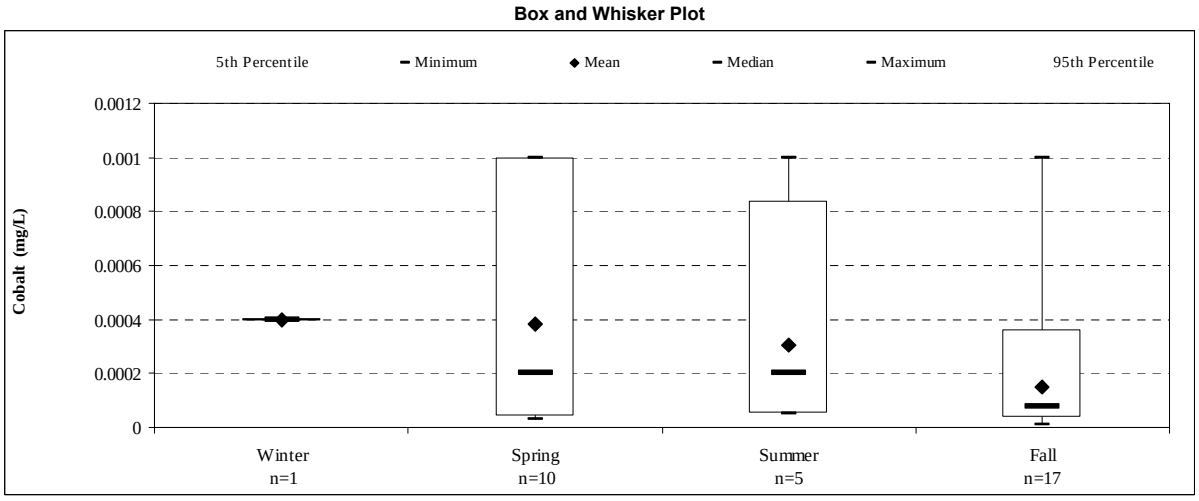


Figure G-2-3-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Lower Segment of Muskeg River



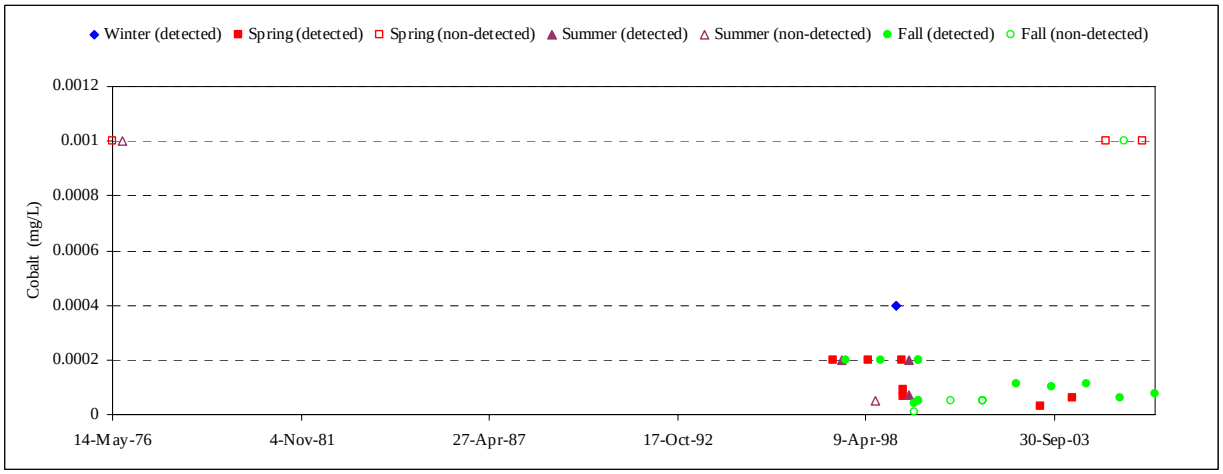
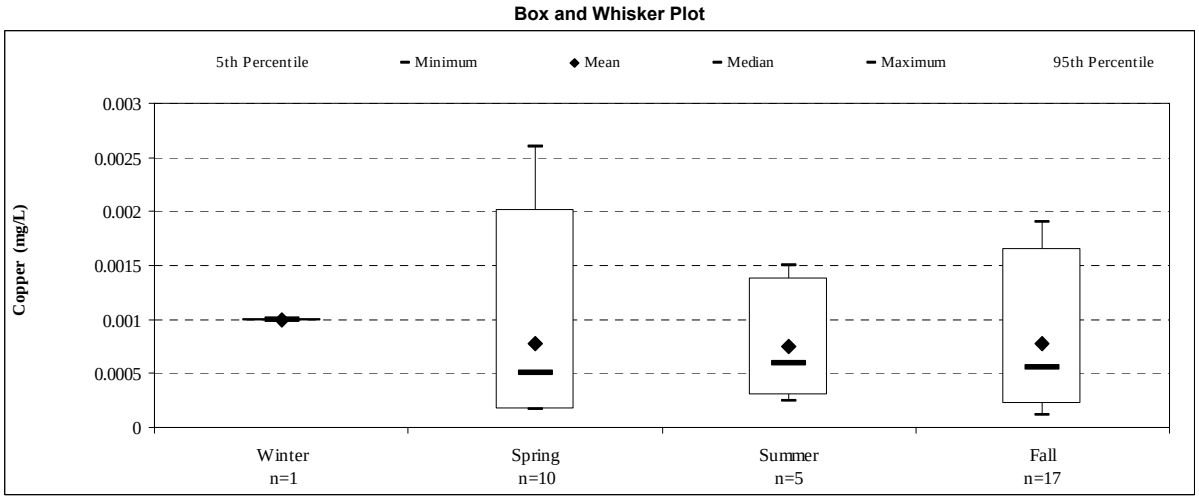


Figure G-2-3-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Lower Segment of Muskeg River



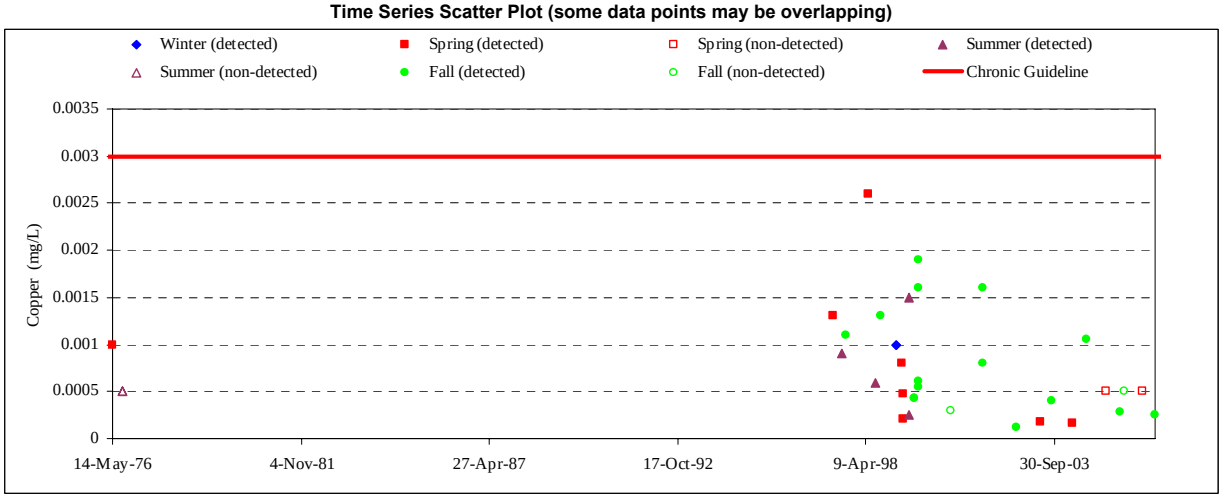
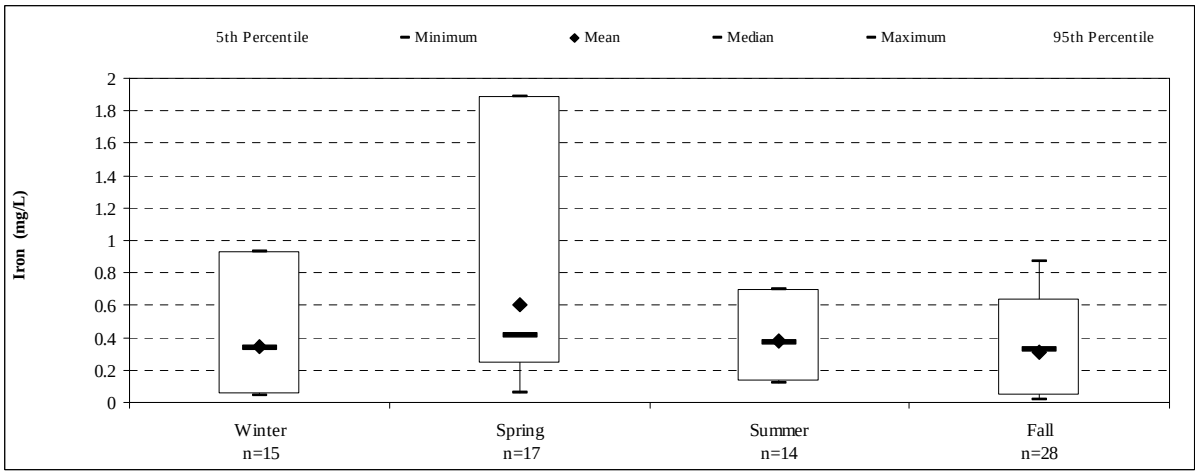


Figure G-2-3-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Lower Segment of Muskeg River

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

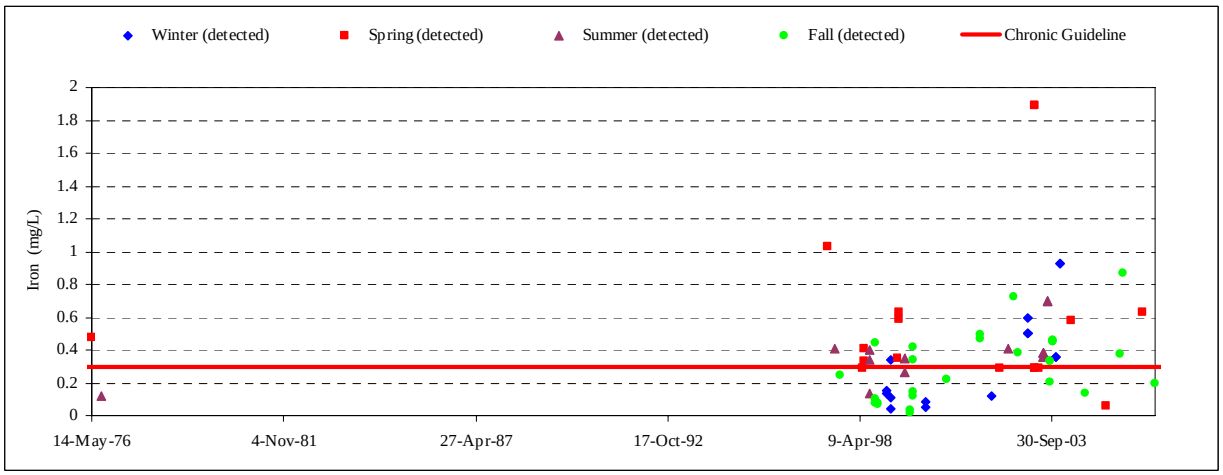
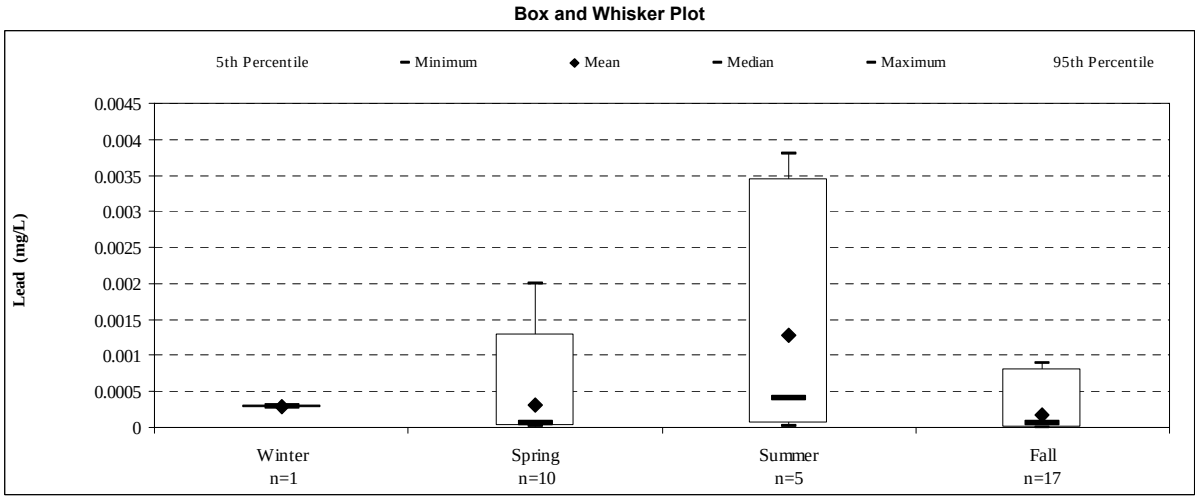


Figure G-2-3-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Lower Segment of Muskeg River



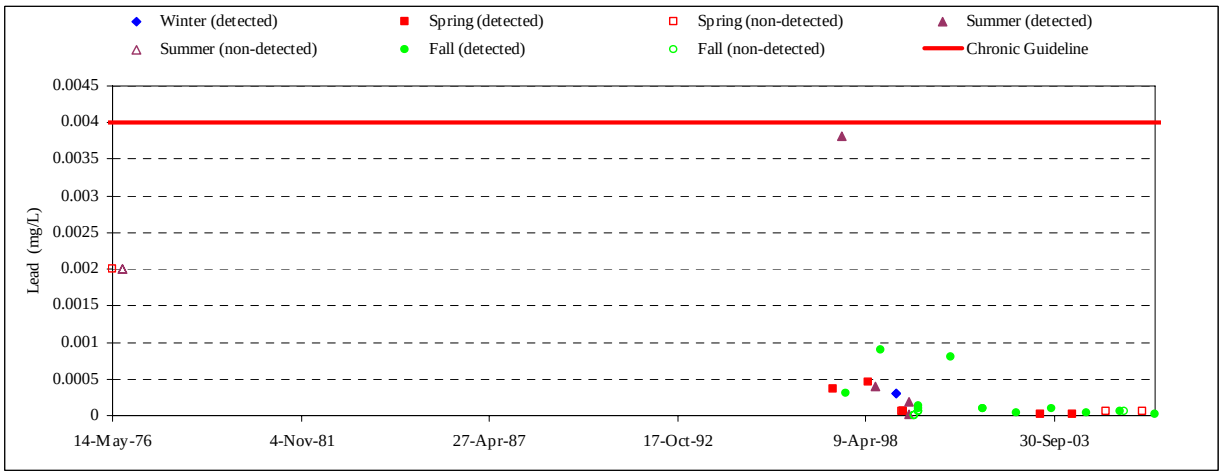
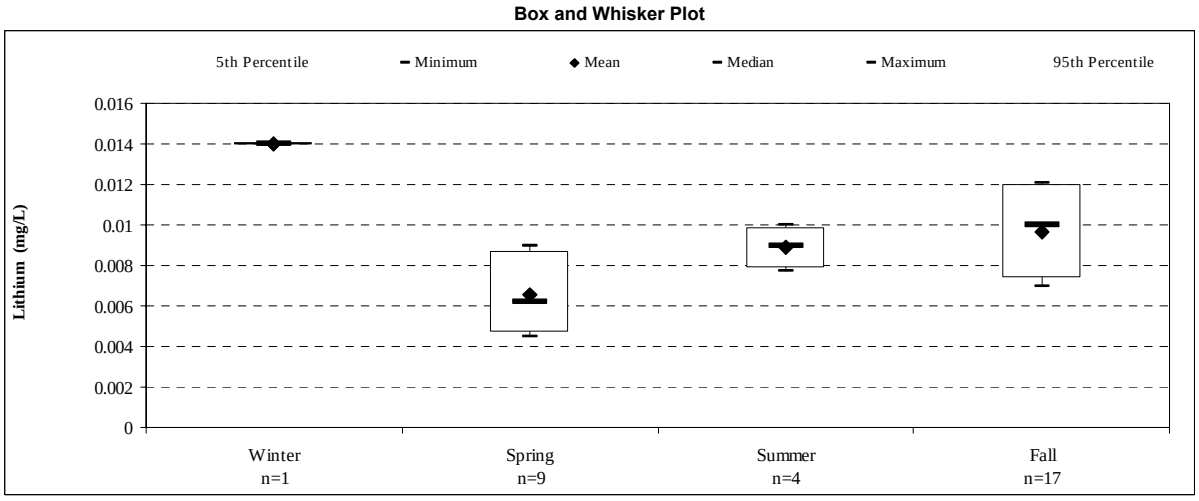


Figure G-2-3-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Lower Segment of Muskeg River



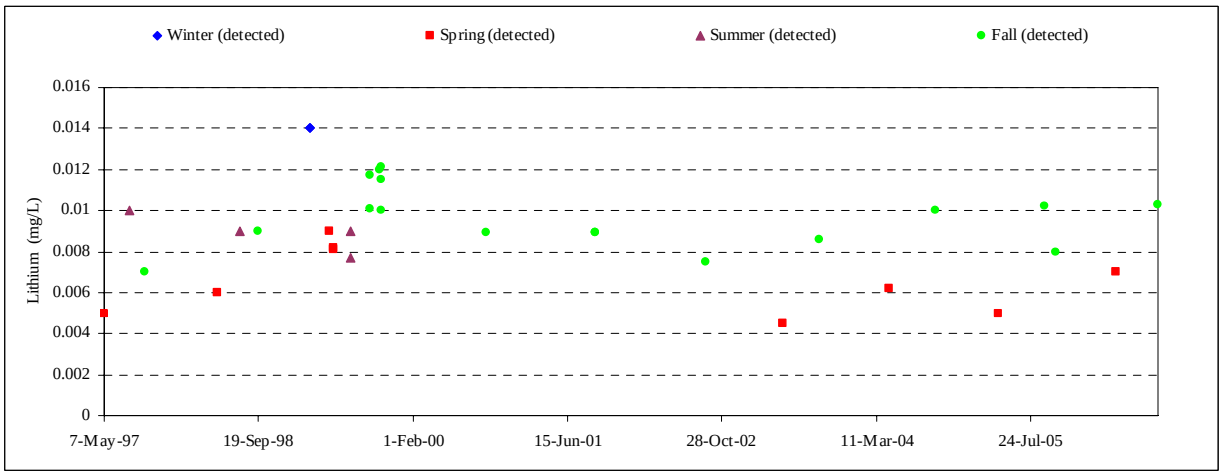
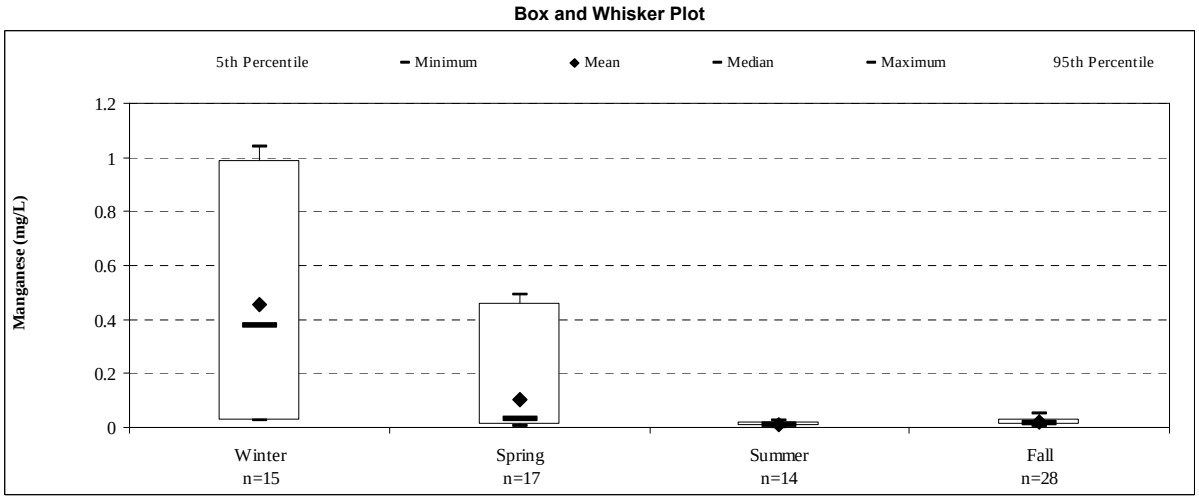


Figure G-2-3-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Lower Segment of Muskeg River



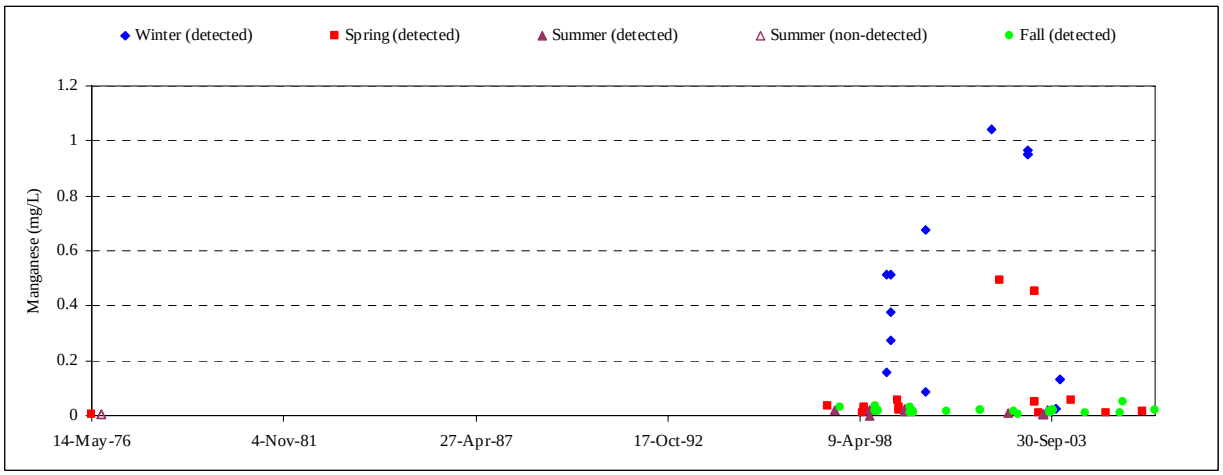
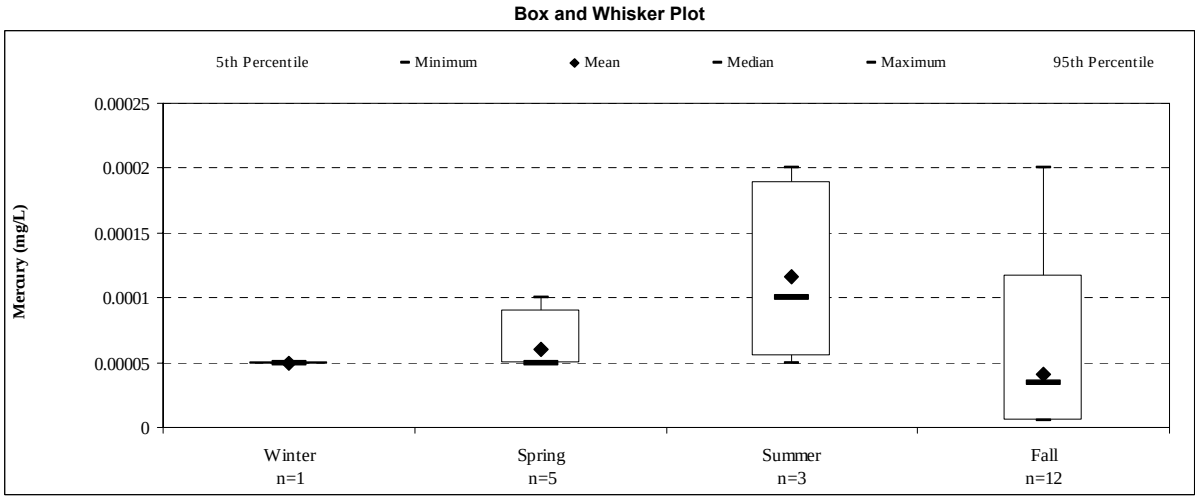


Figure G-2-3-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Lower Segment of Muskeg River



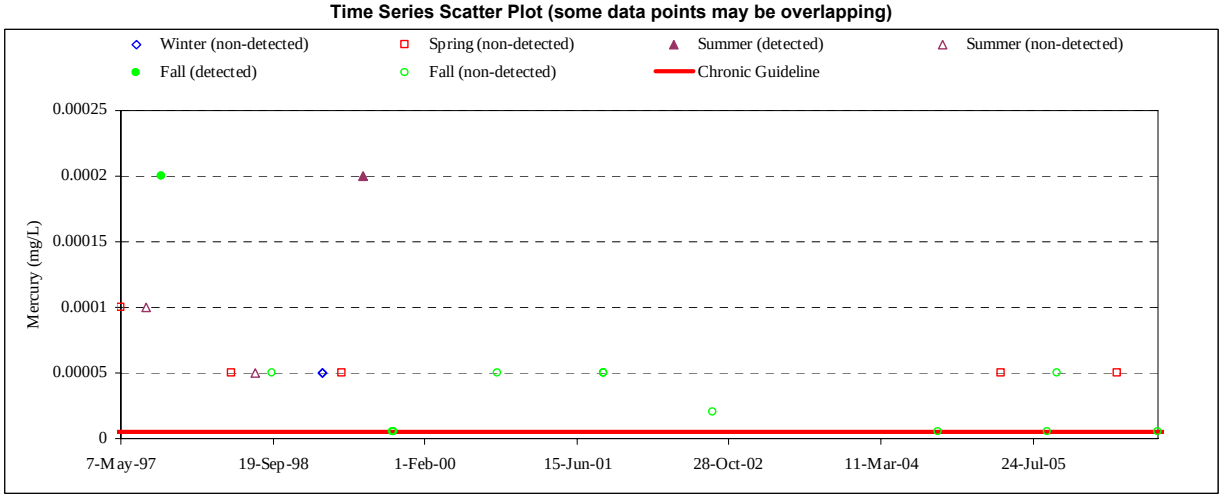
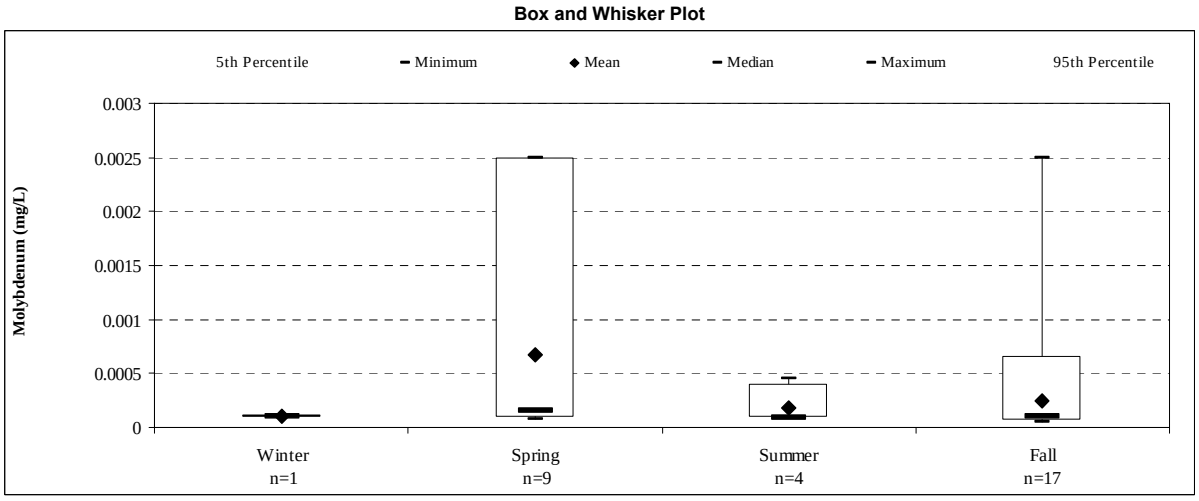


Figure G-2-3-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Lower Segment of Muskeg River



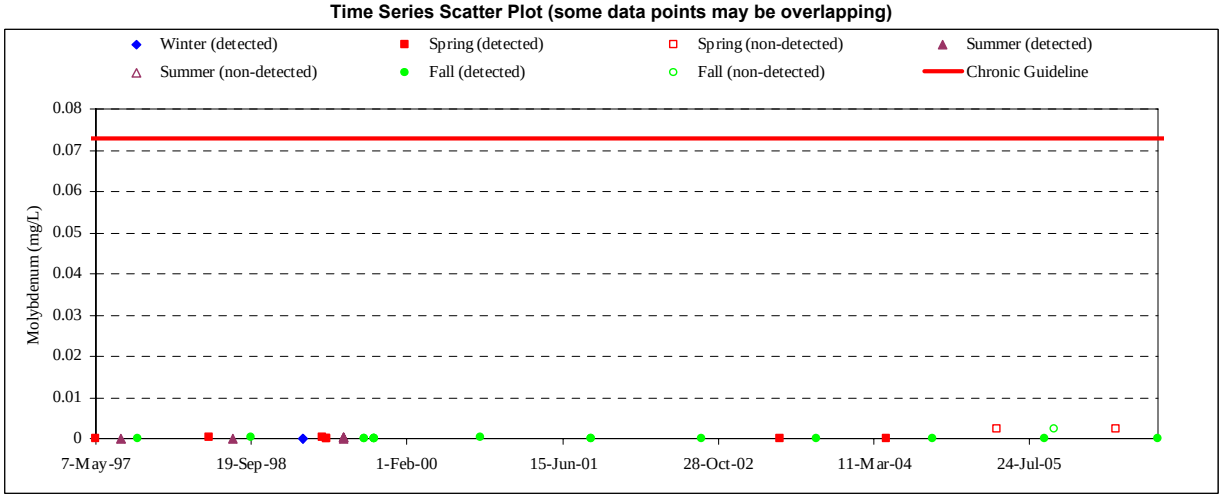
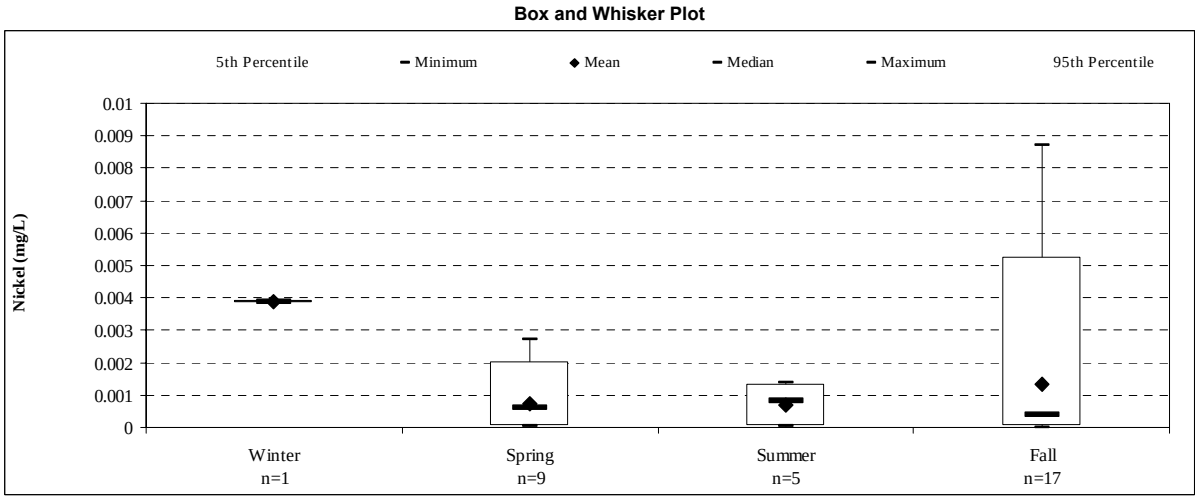


Figure G-2-3-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Lower Segment of Muskeg River



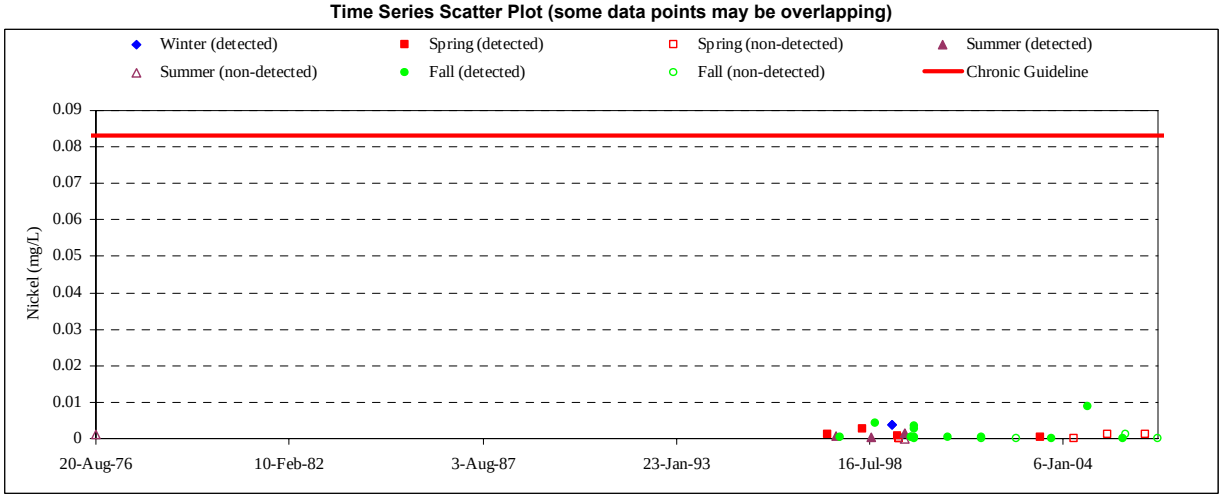
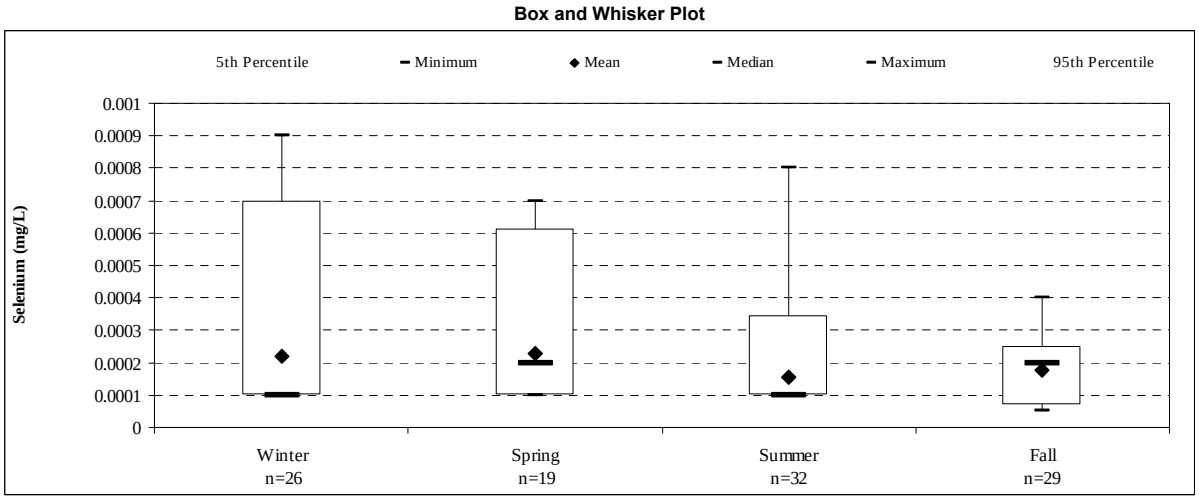


Figure G-2-3-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Lower Segment of Muskeg River



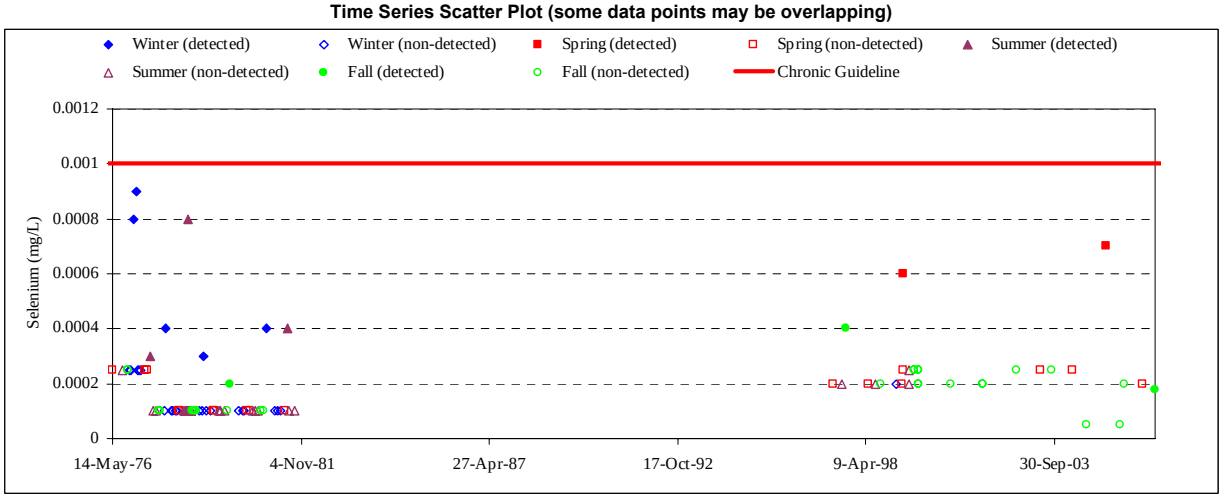
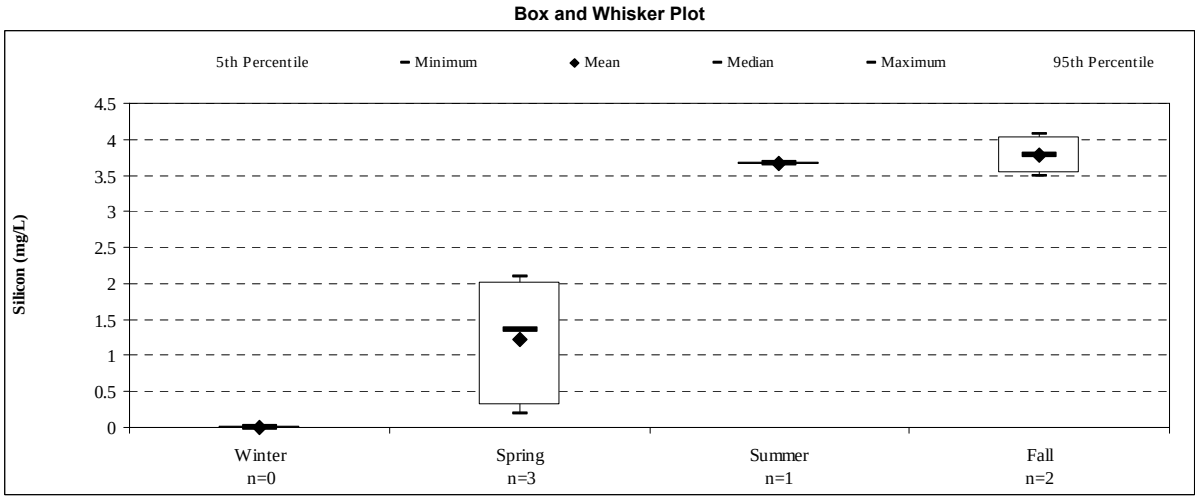


Figure G-2-3-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Lower Segment of Muskeg River



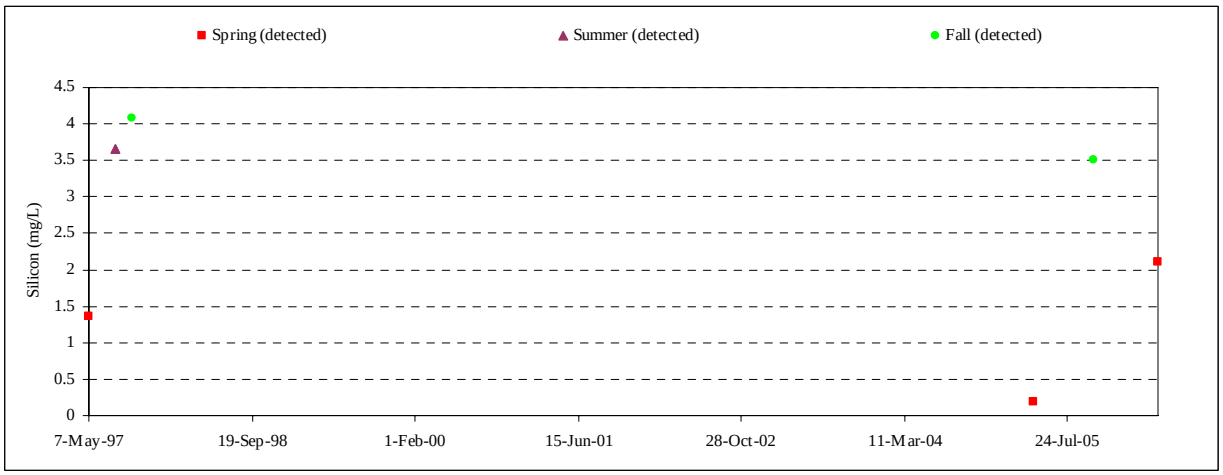
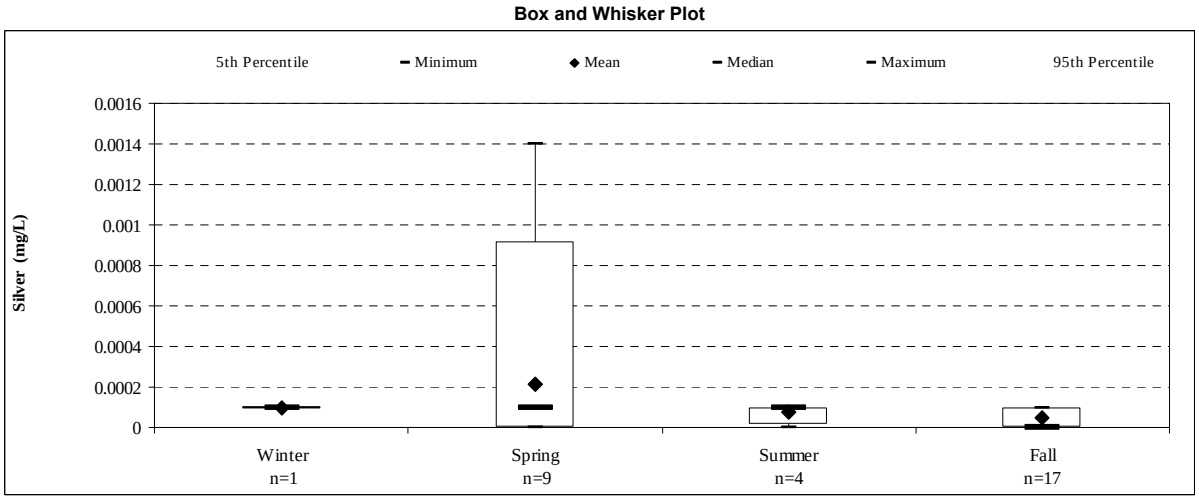


Figure G-2-3-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Lower Segment of Muskeg River



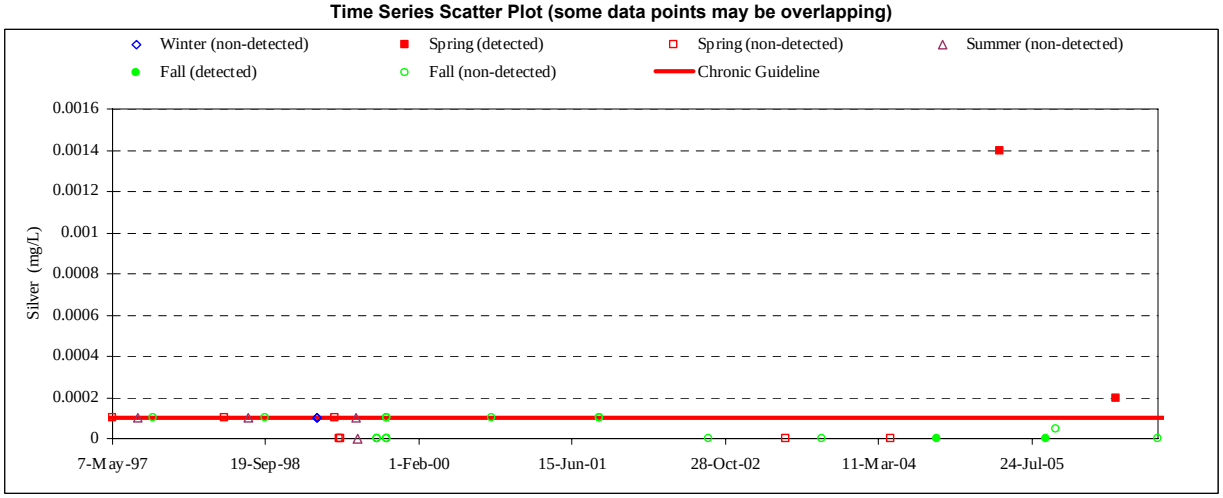
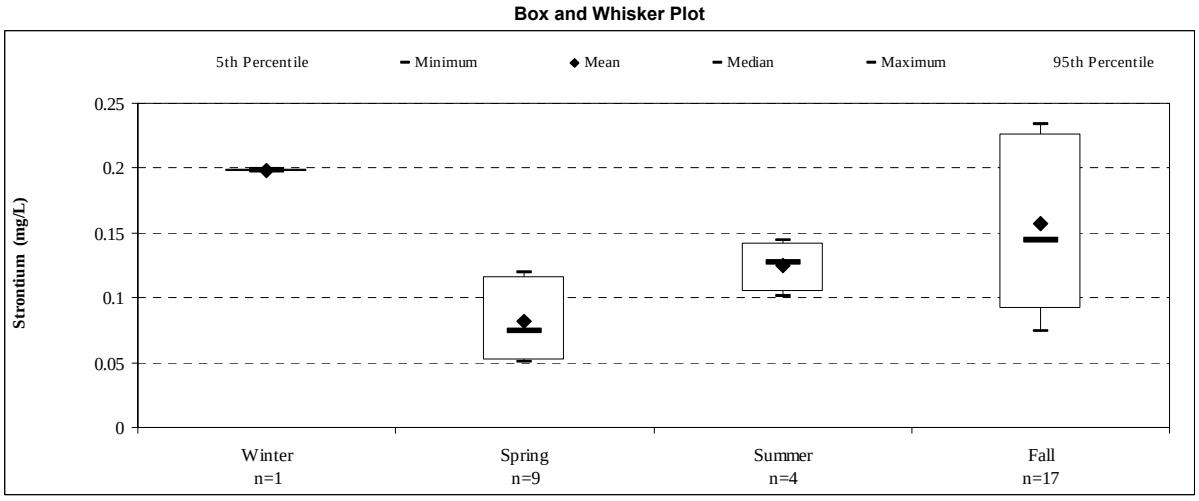


Figure G-2-3-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Lower Segment of Muskeg River



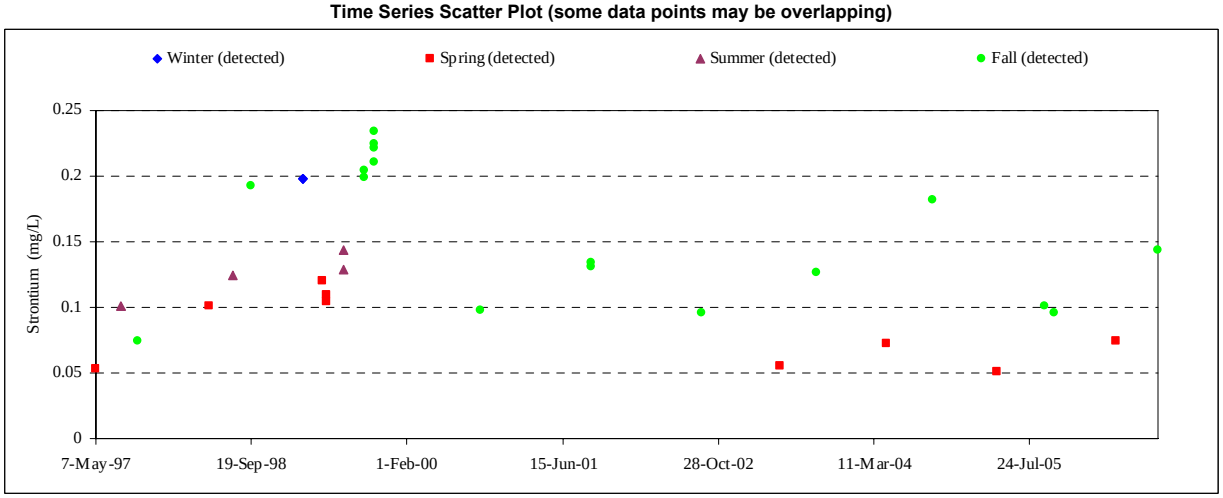
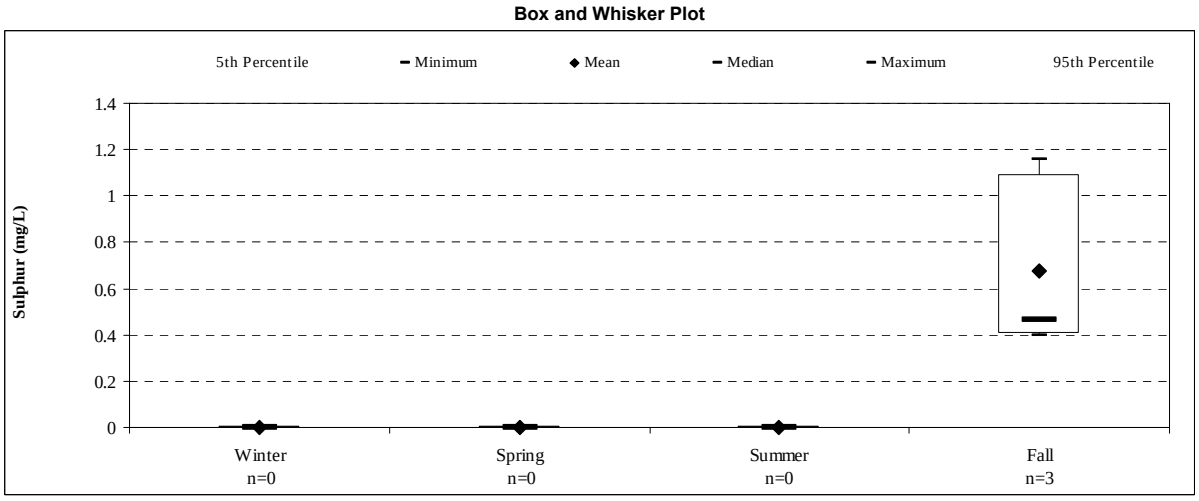


Figure G-2-3-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Lower Segment of Muskeg River



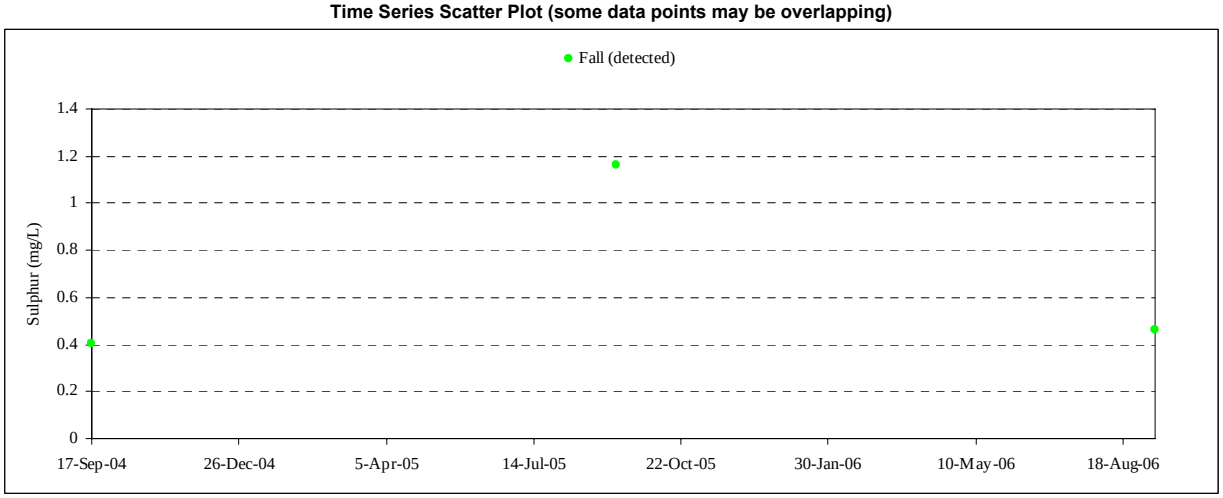
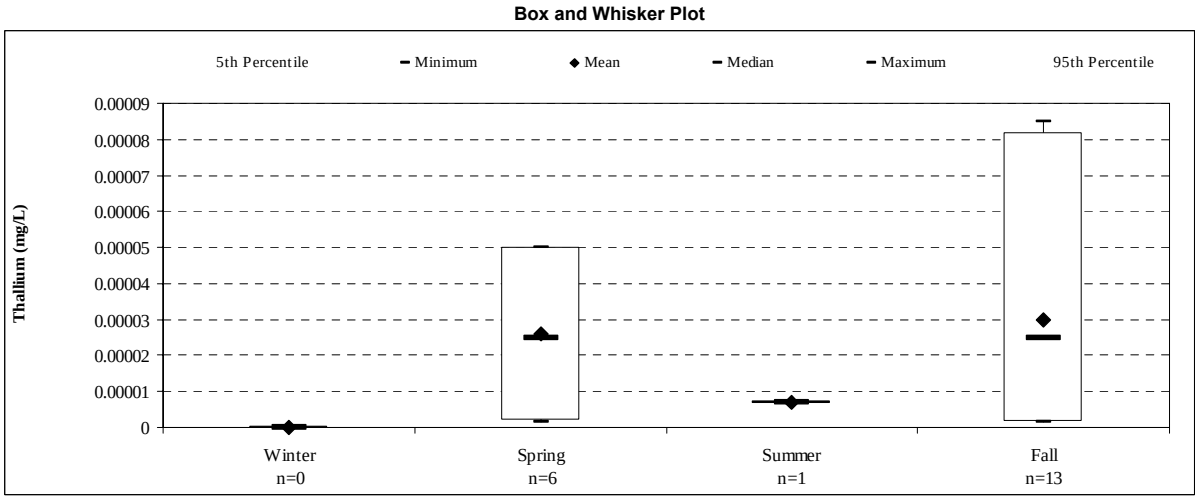


Figure G-2-3-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Lower Segment of Muskeg River



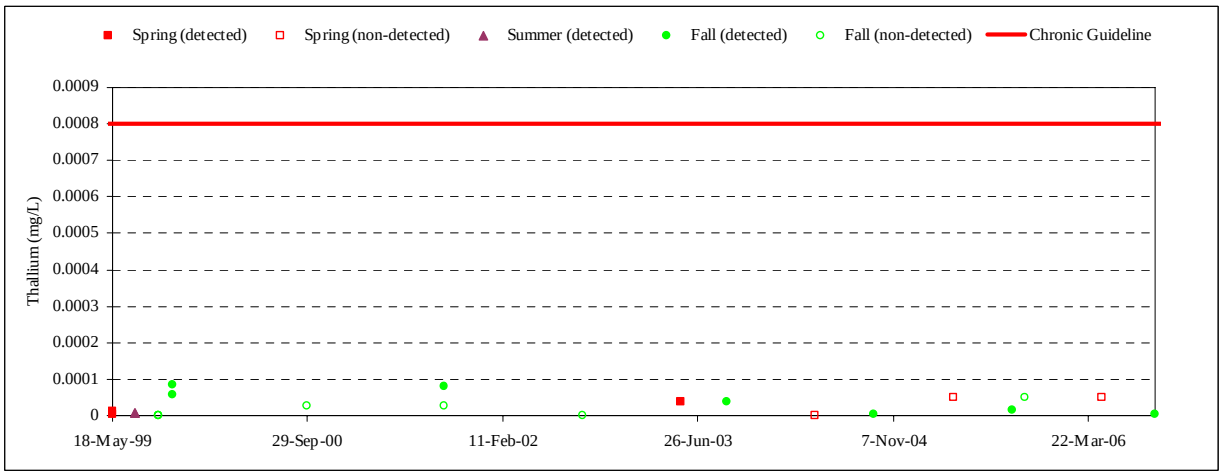
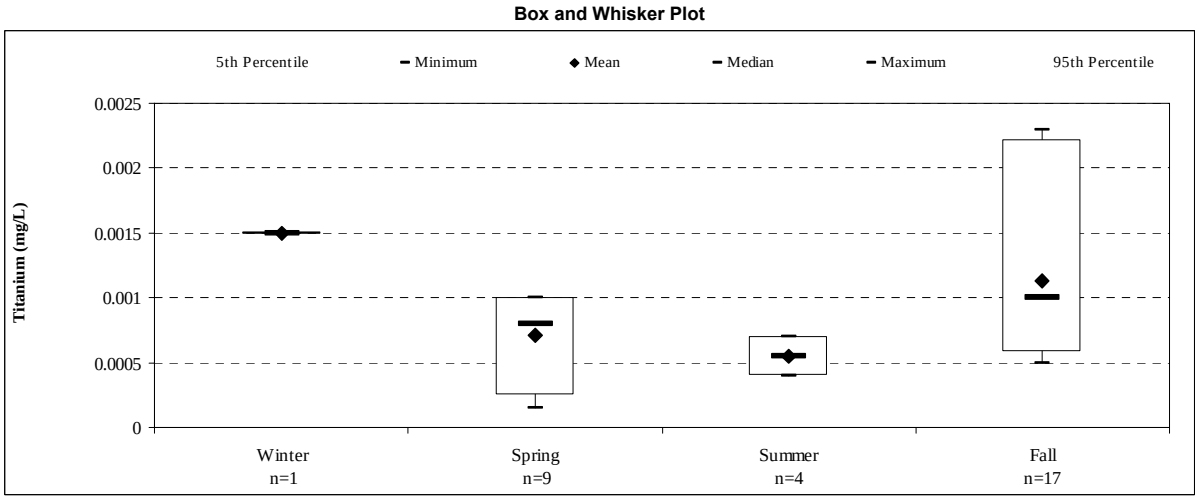


Figure G-2-3-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Lower Segment of Muskeg River



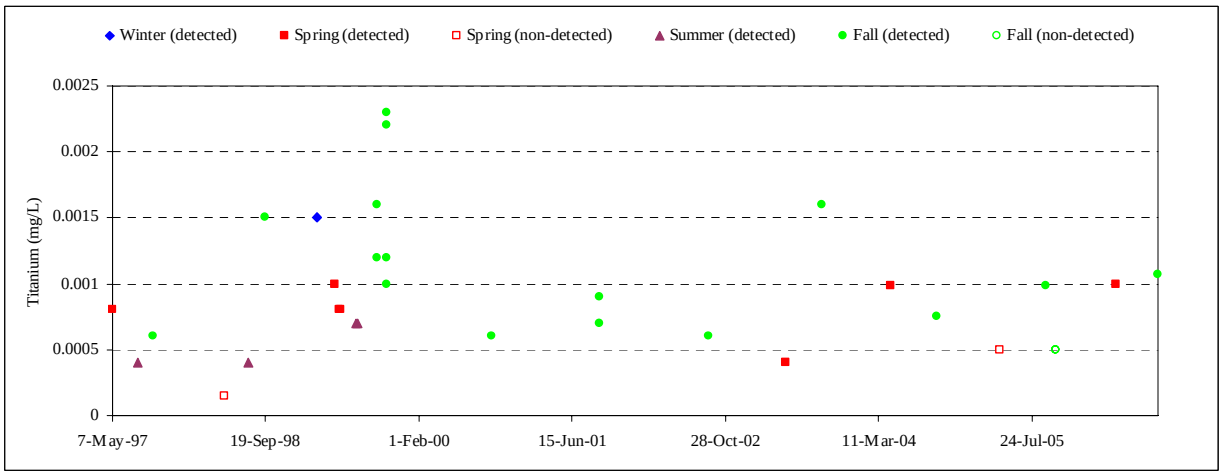
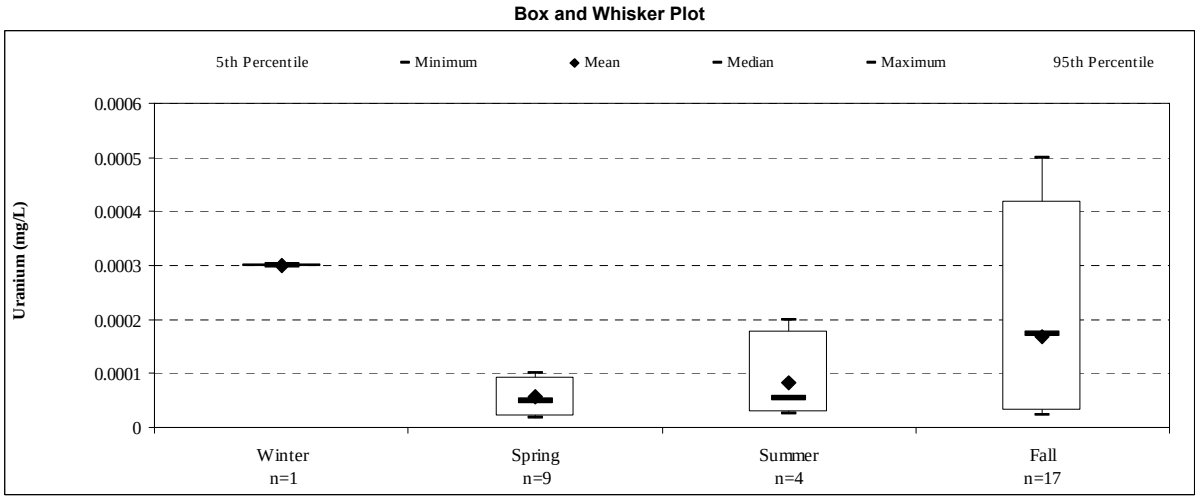


Figure G-2-3-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Lower Segment of Muskeg River



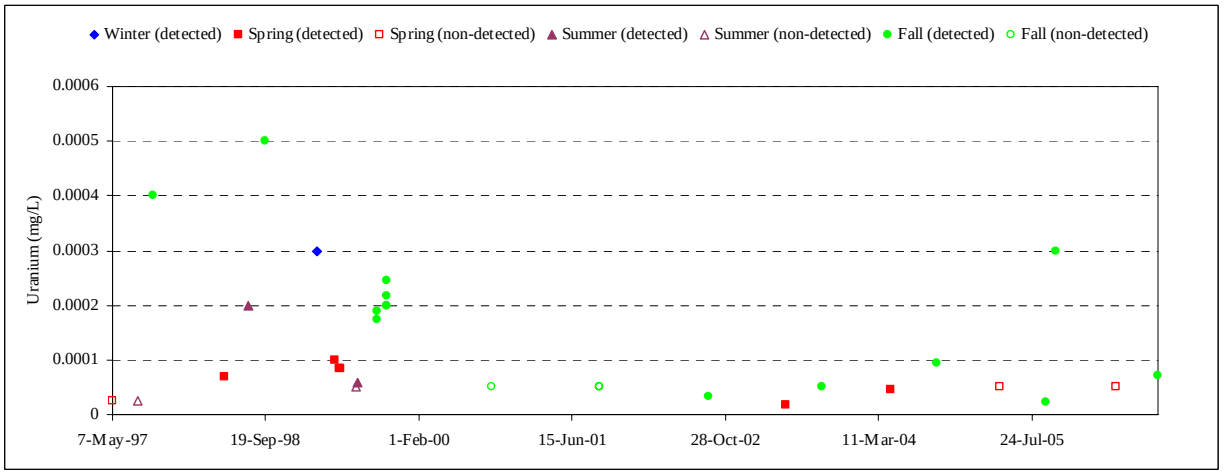
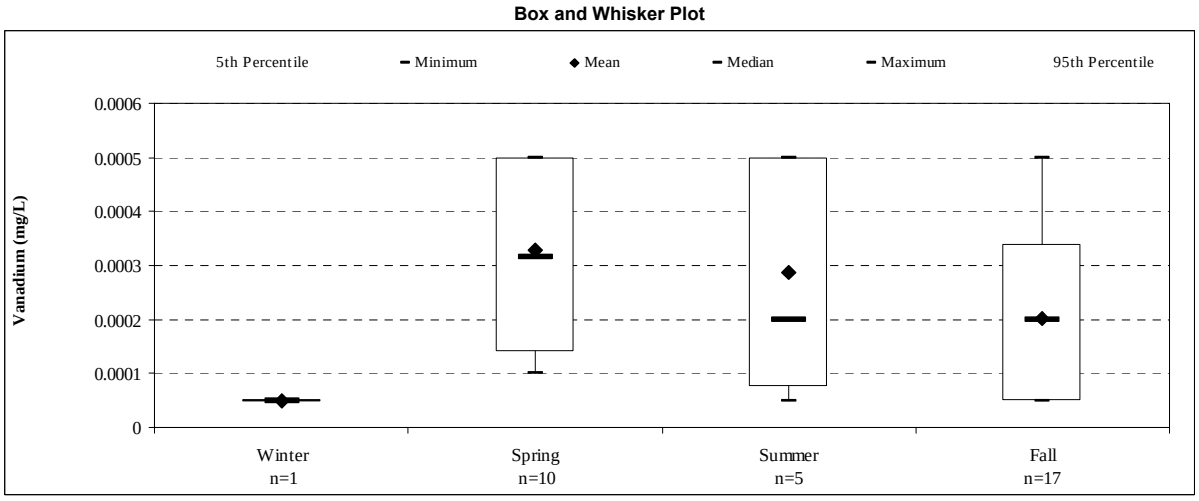


Figure G-2-3-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Lower Segment of Muskeg River



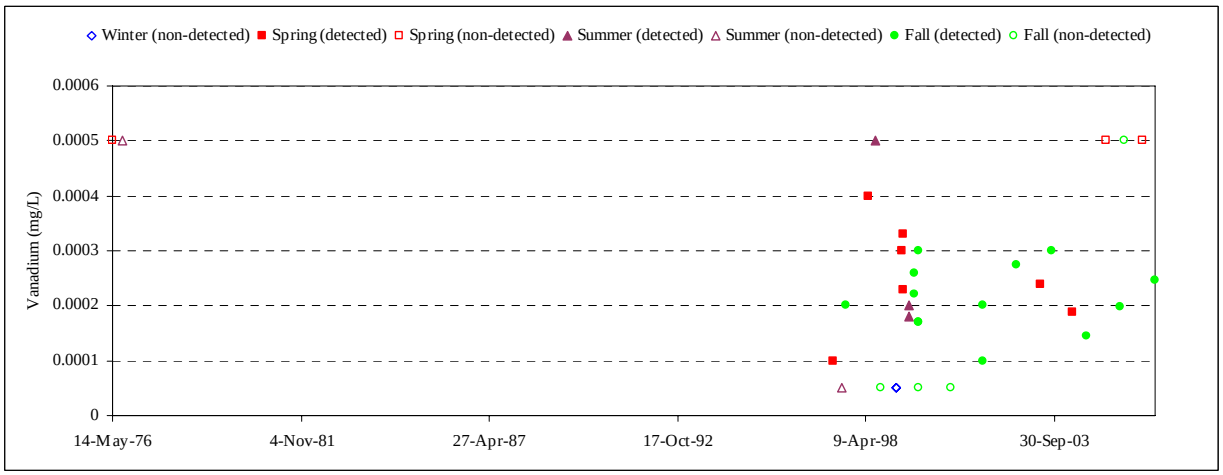
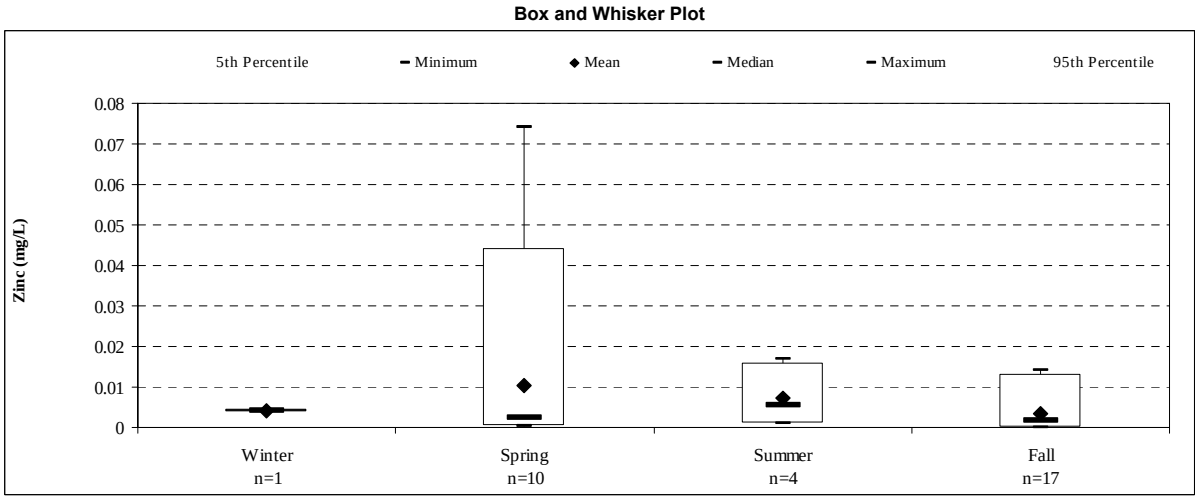


Figure G-2-3-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Lower Segment of Muskeg River



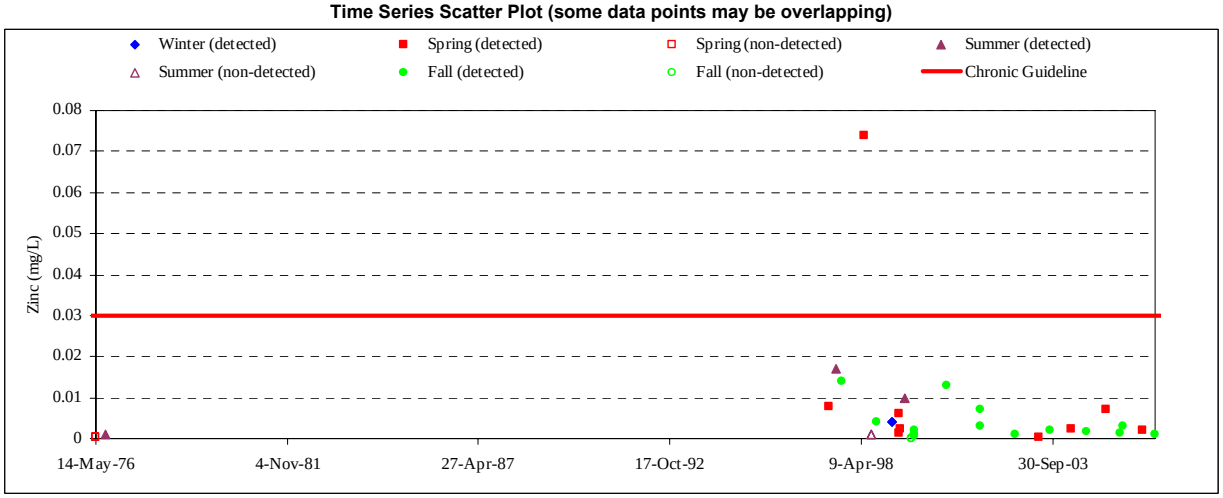
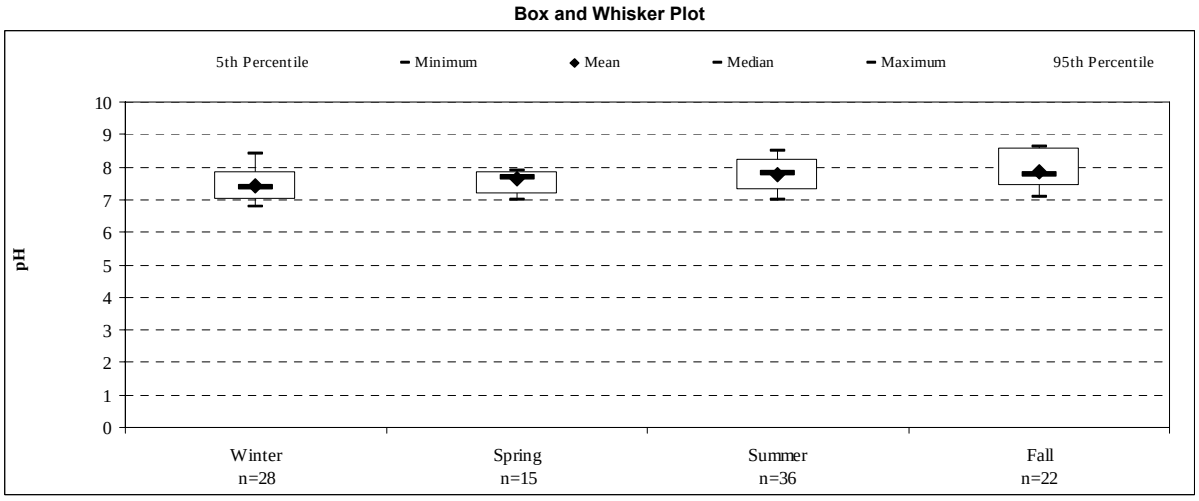


Figure G-2-4-1 Box Whisker and Time Series Scatter Plots of Observed pH in Jackpine Creek



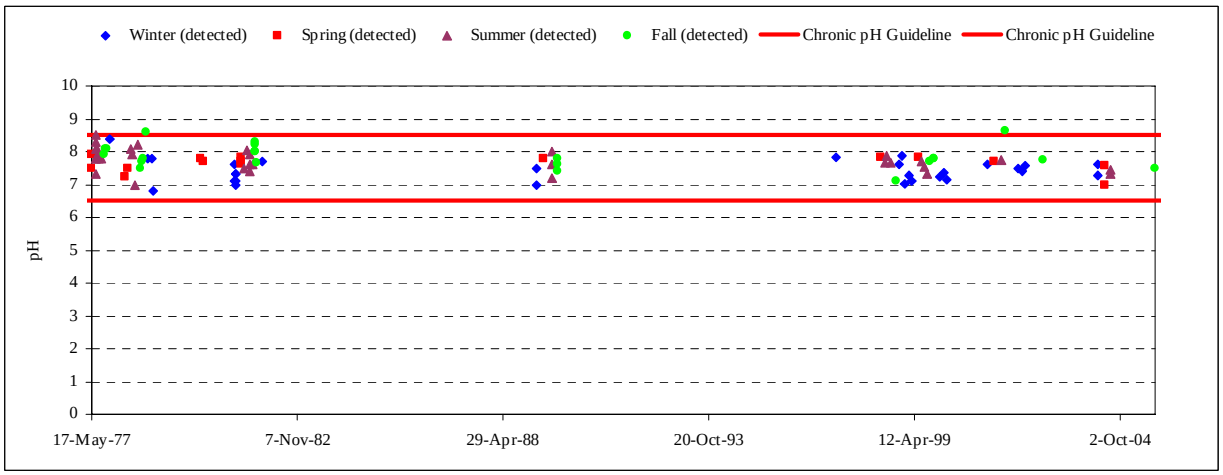
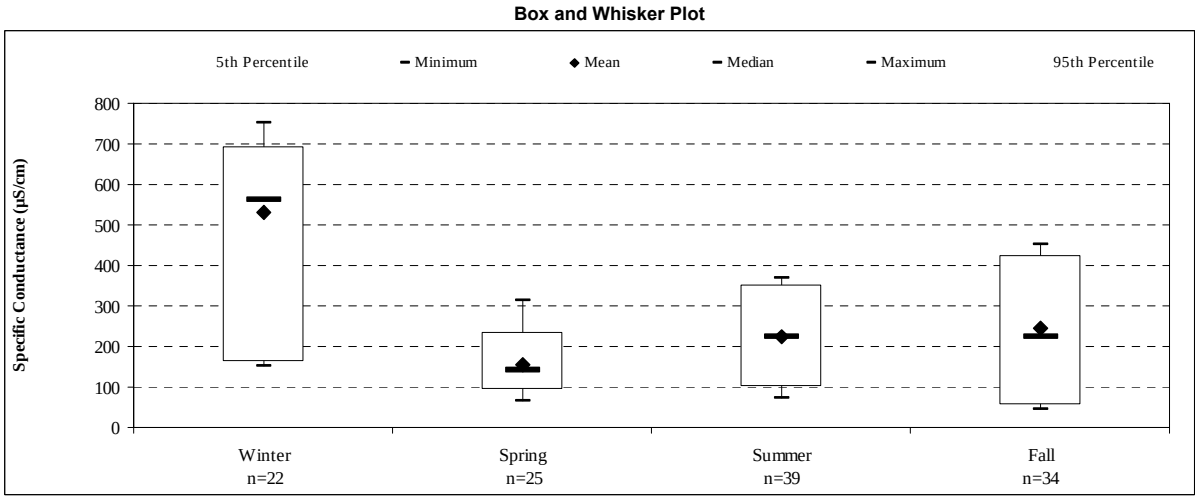


Figure G-2-4-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Jackpine Creek



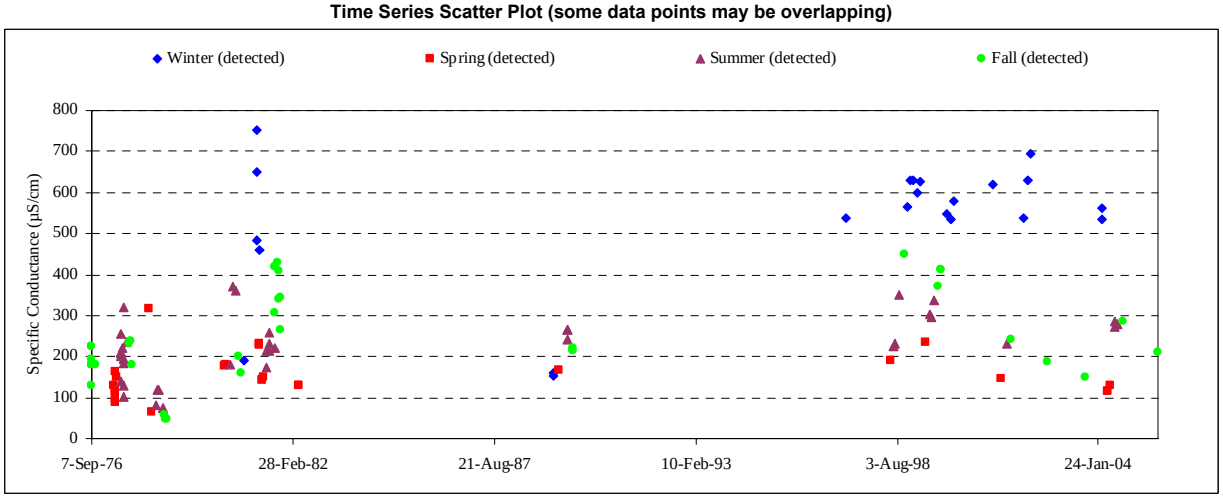
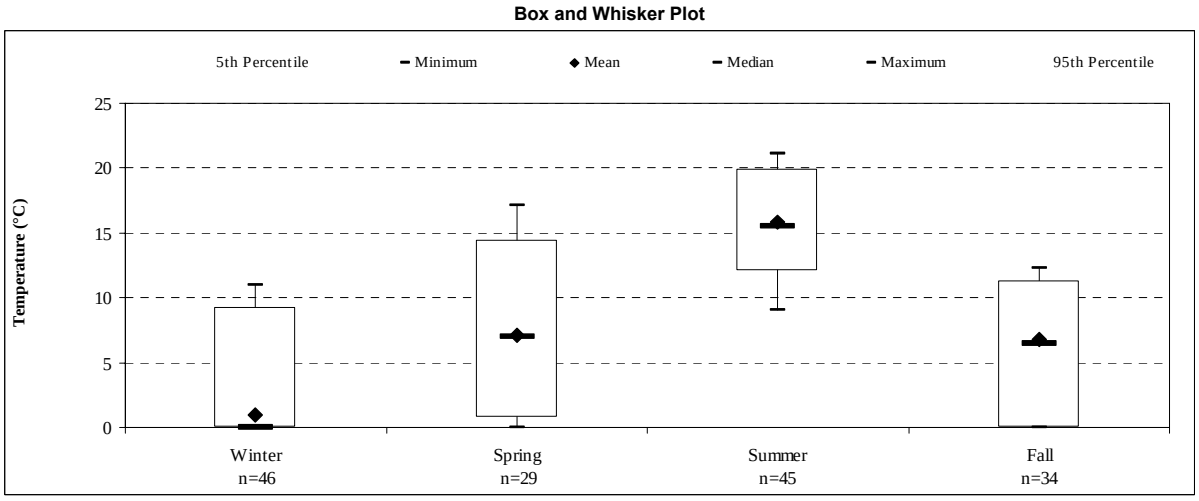


Figure G-2-4-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Jackpine Creek



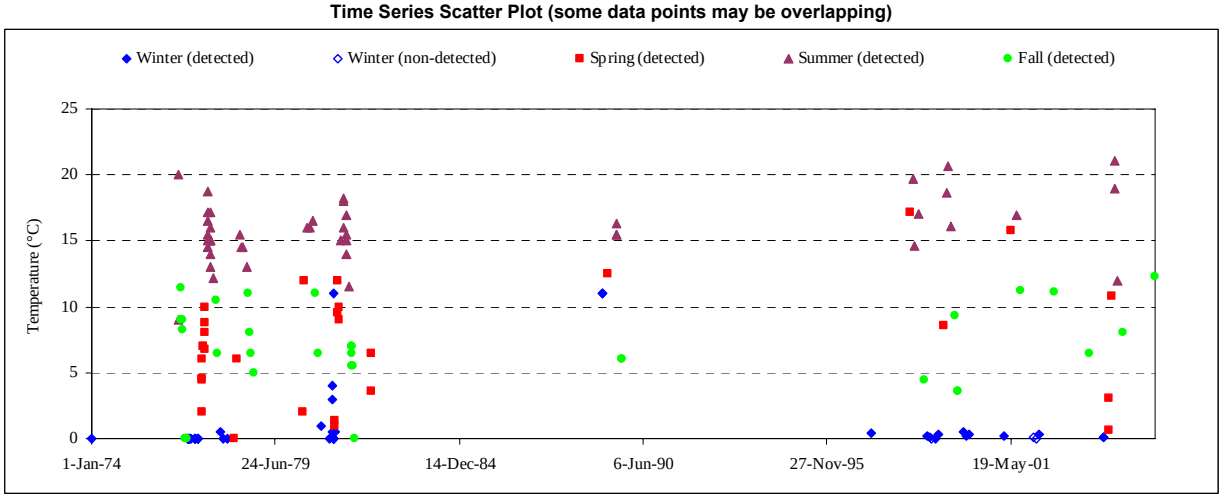
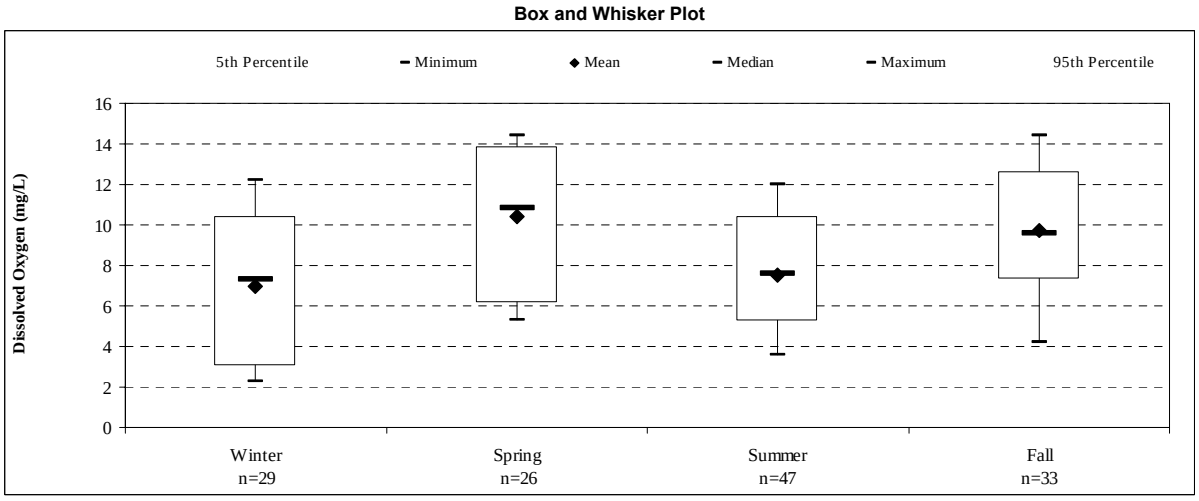


Figure G-2-4-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Jackpine Creek



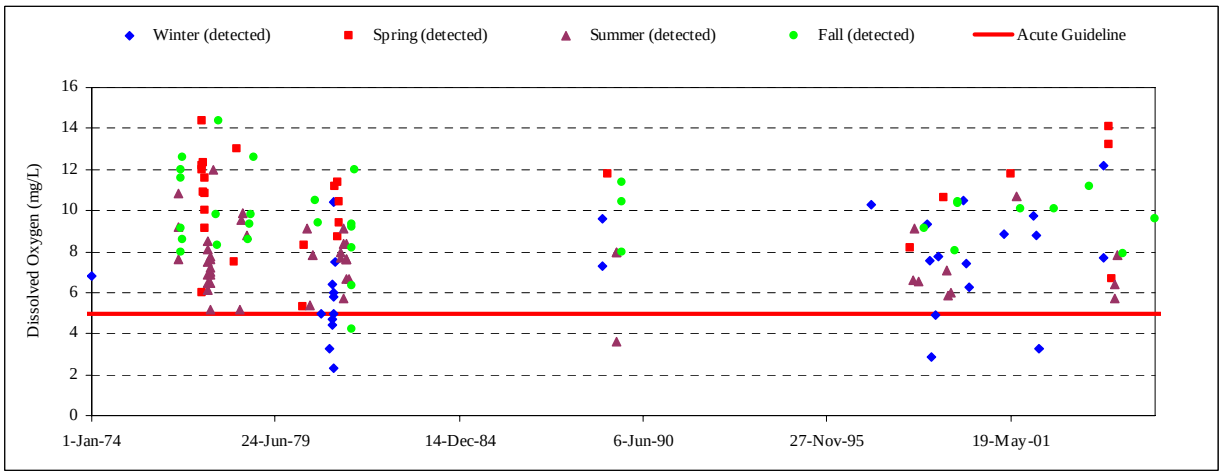


Figure G-2-4-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Jackpine Creek

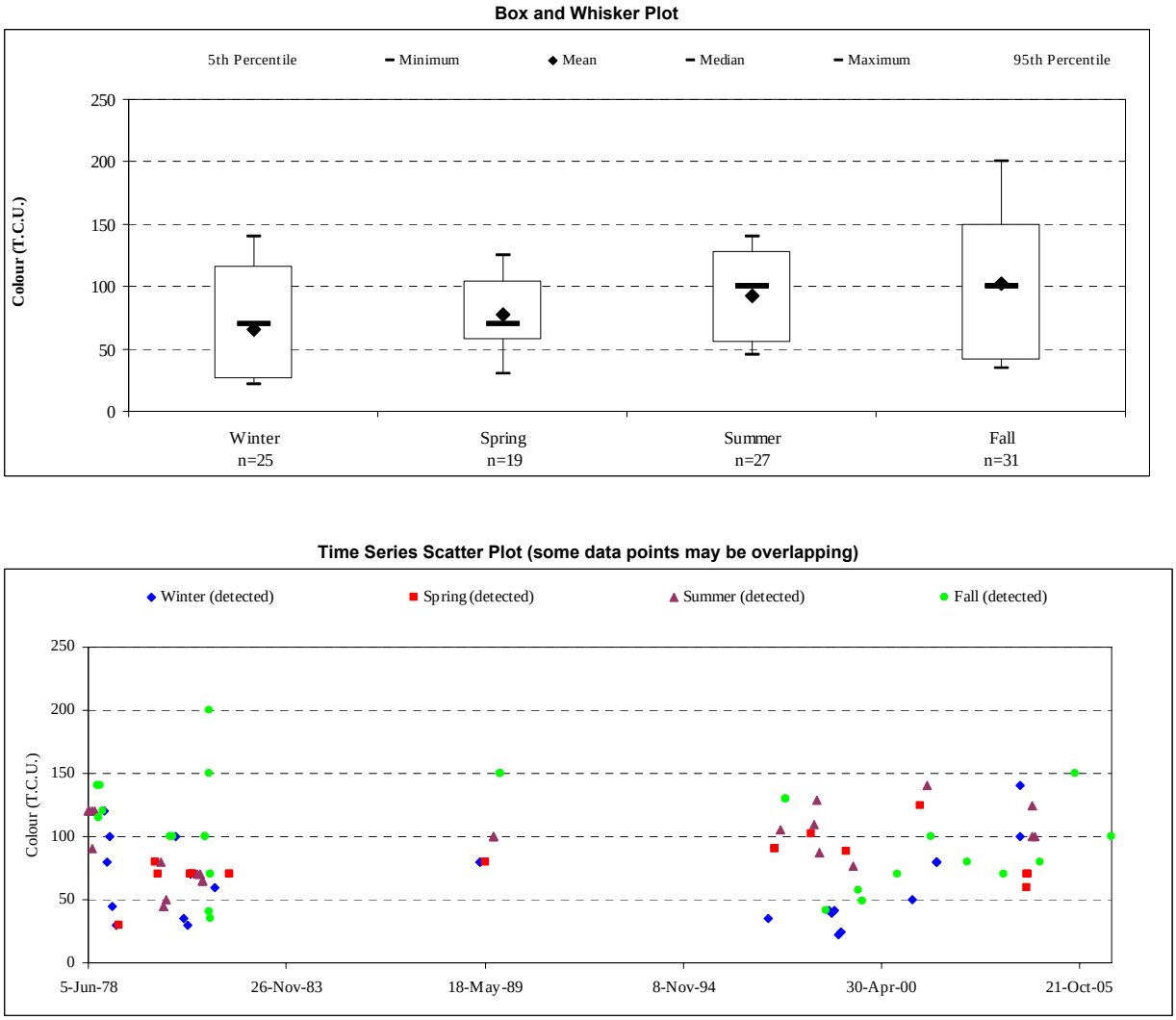
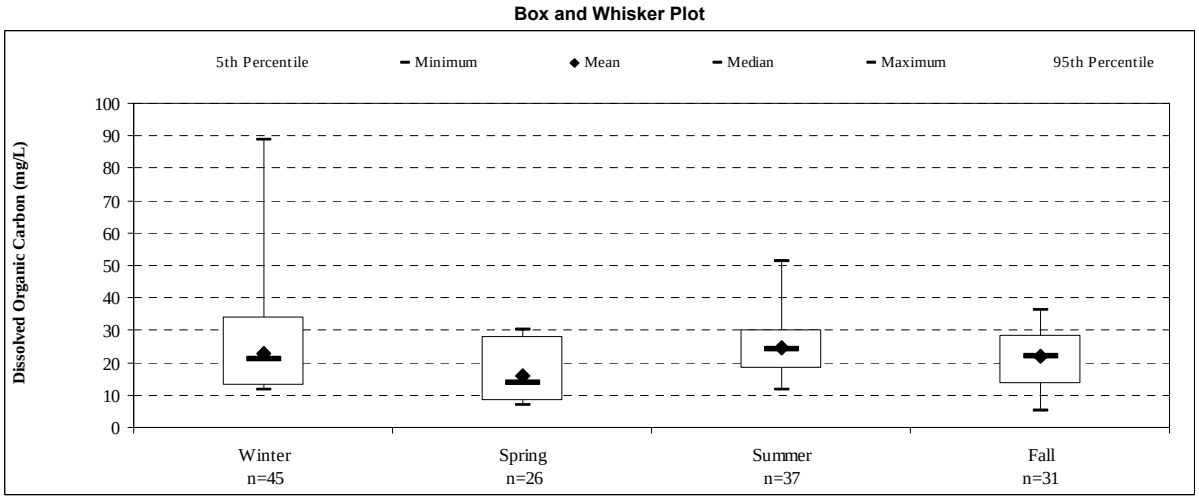


Figure G-2-4-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Jackpine Creek



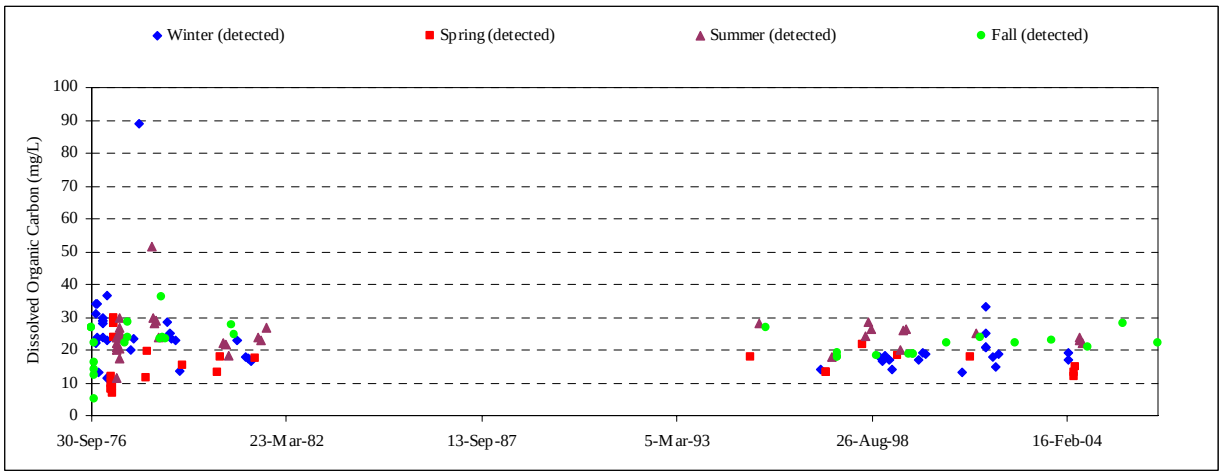
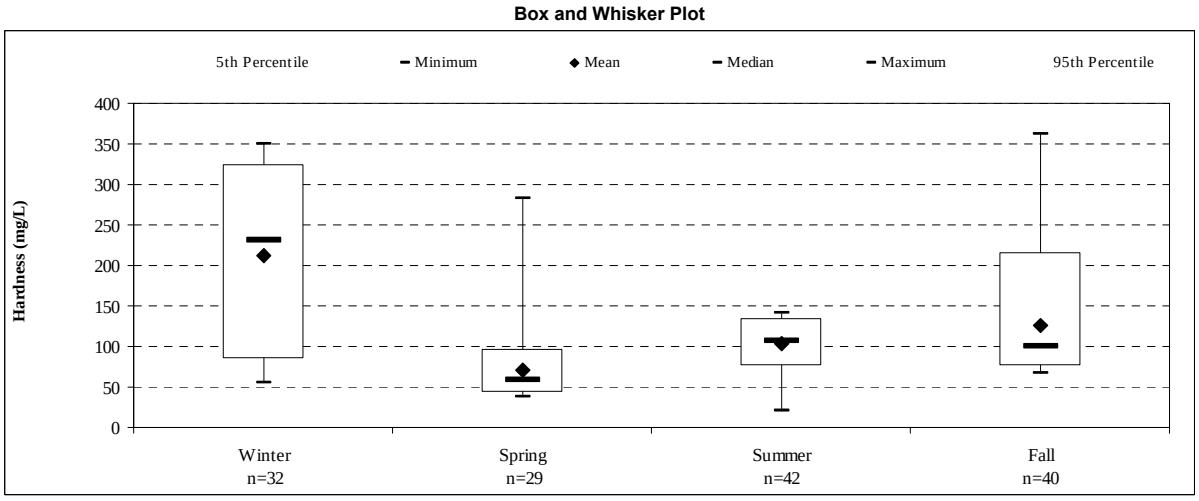


Figure G-2-4-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Jackpine Creek



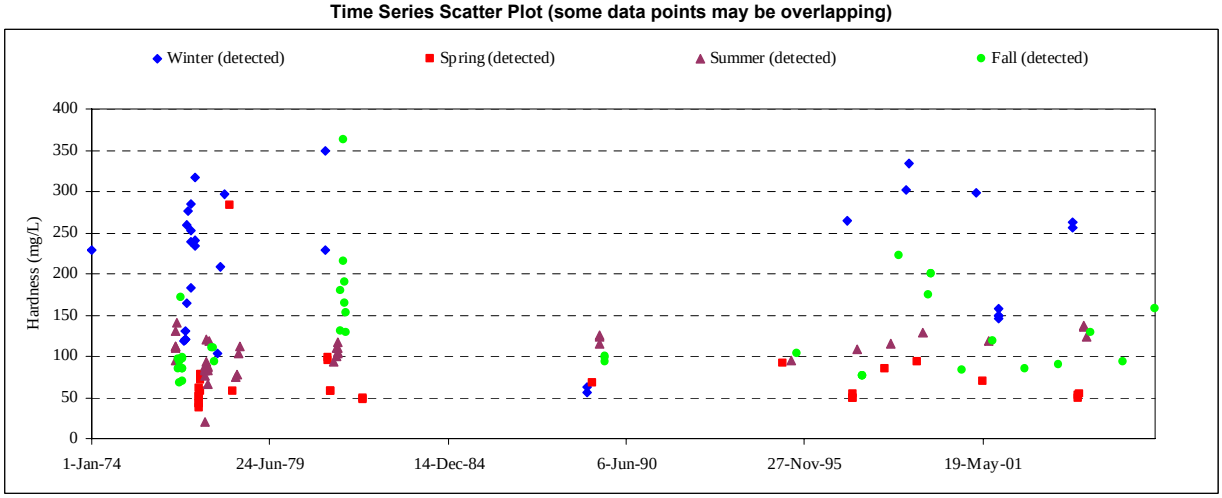


Figure G-2-4-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Jackpine Creek

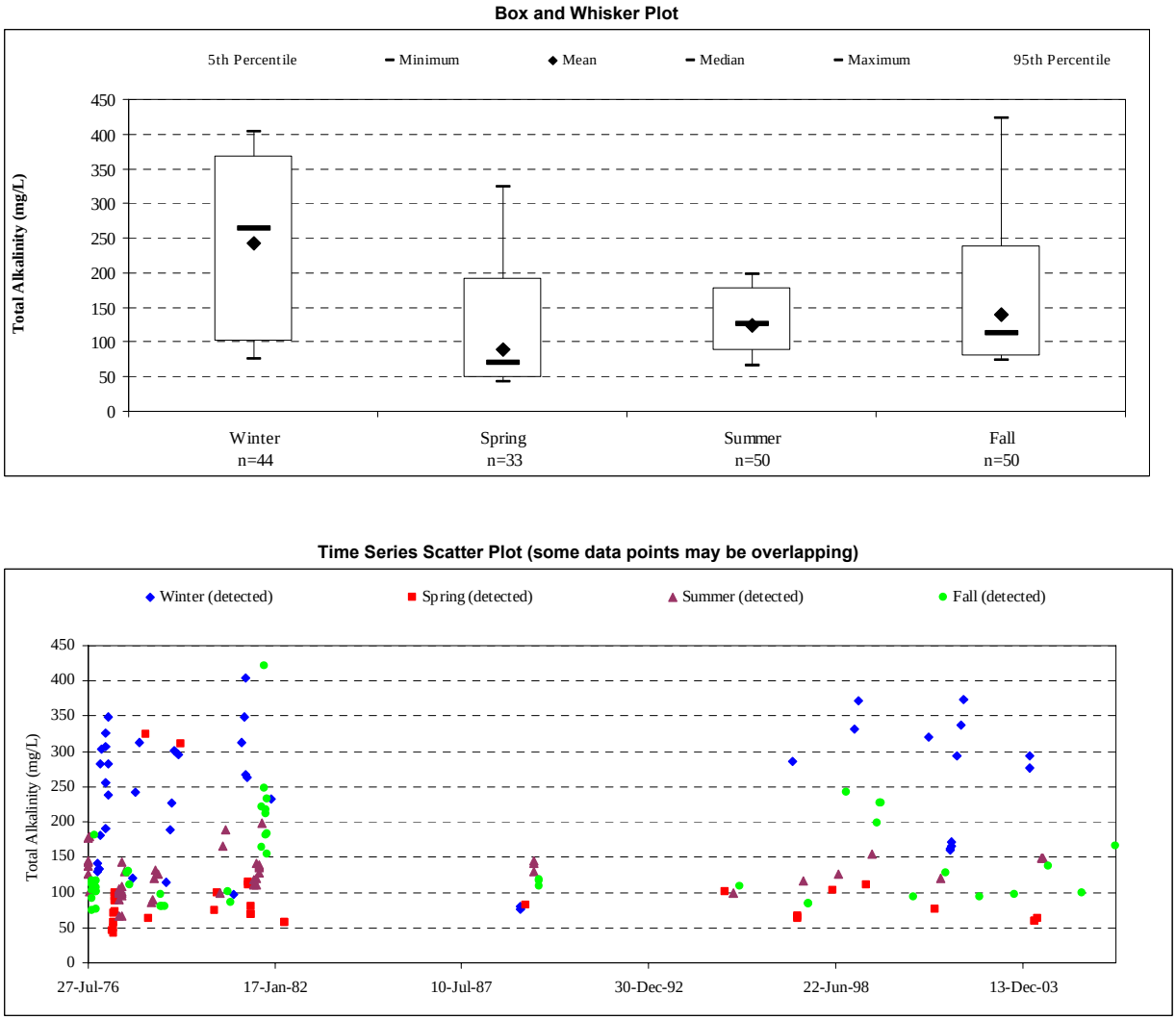
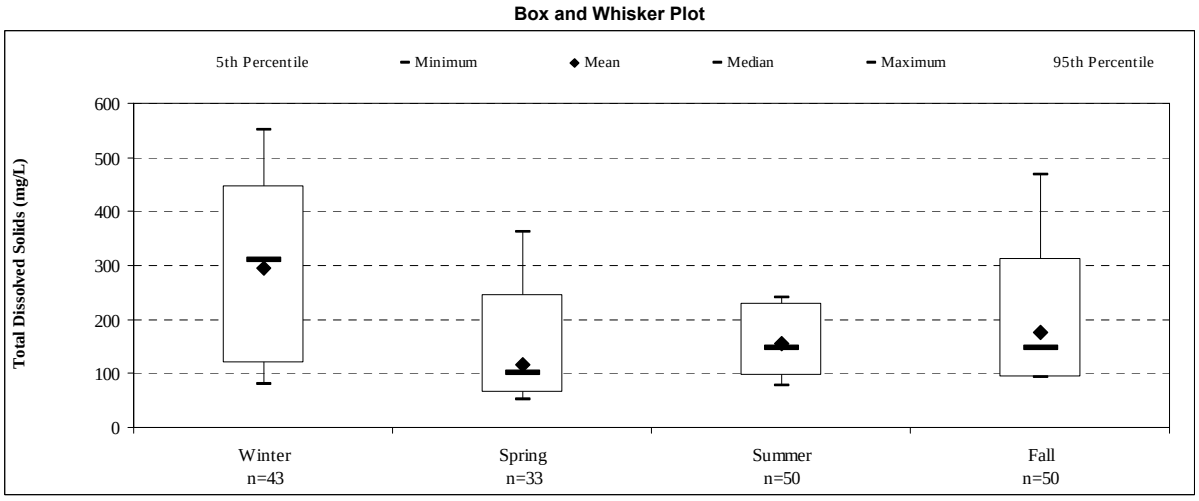


Figure G-2-4-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Jackpine Creek



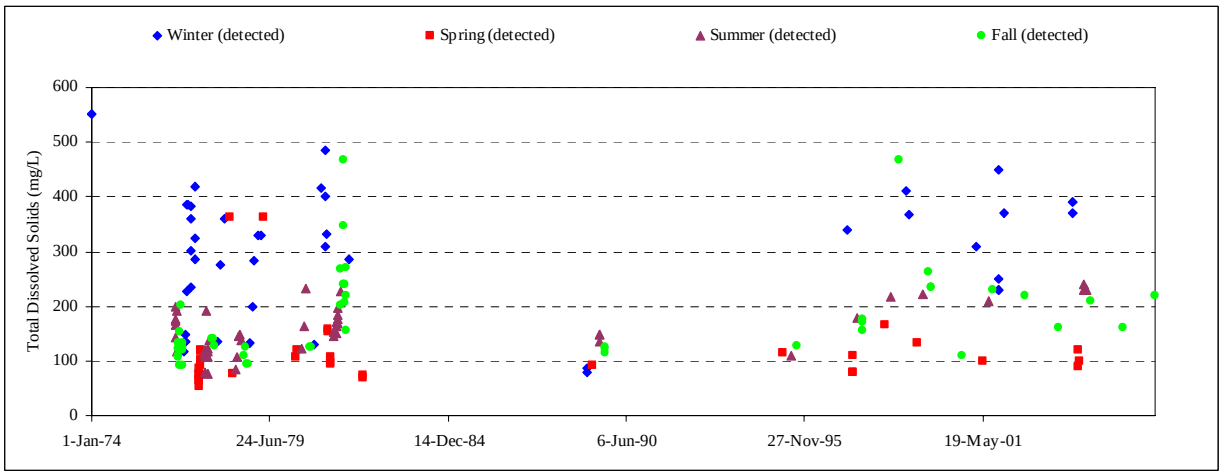
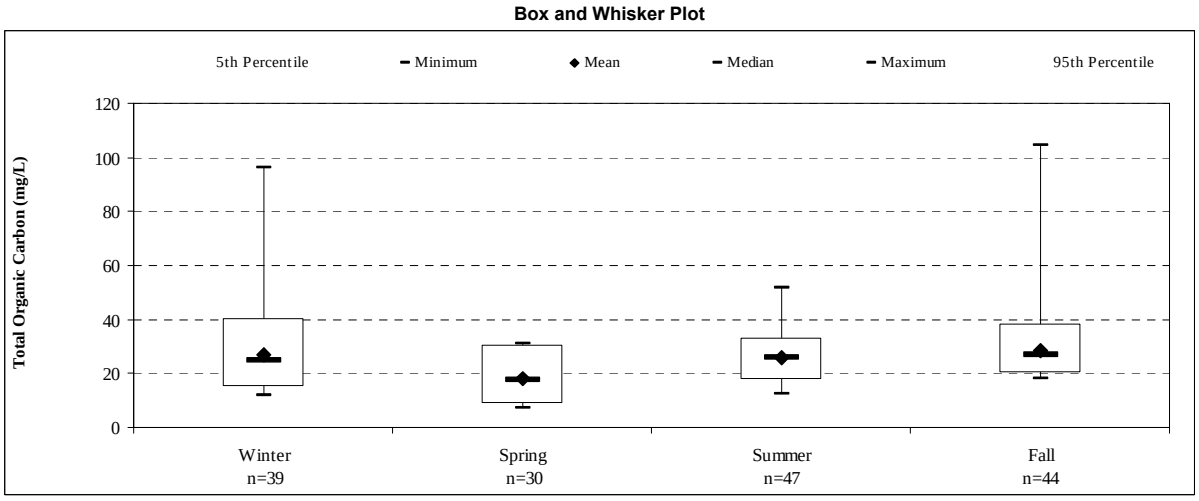


Figure G-2-4-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Jackpine Creek



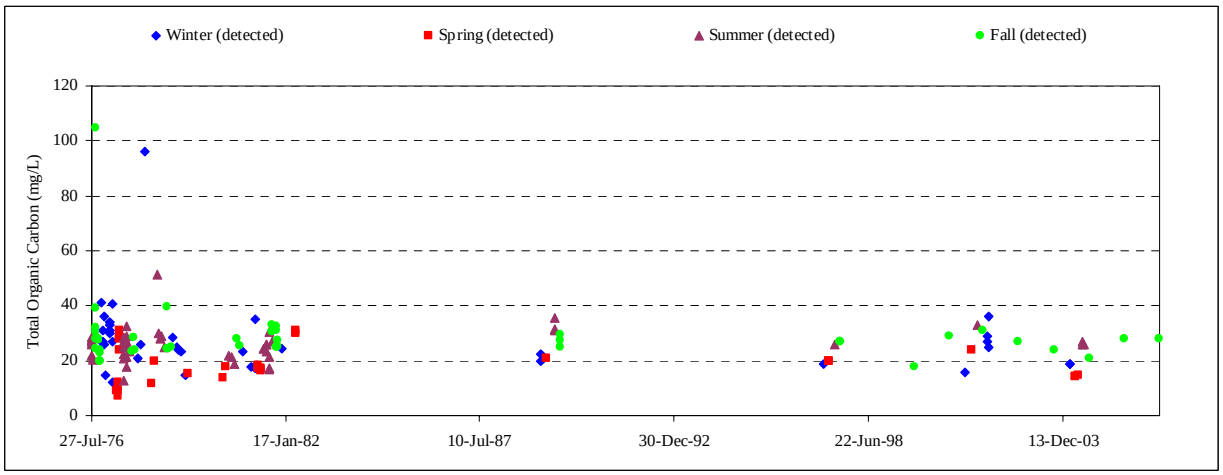
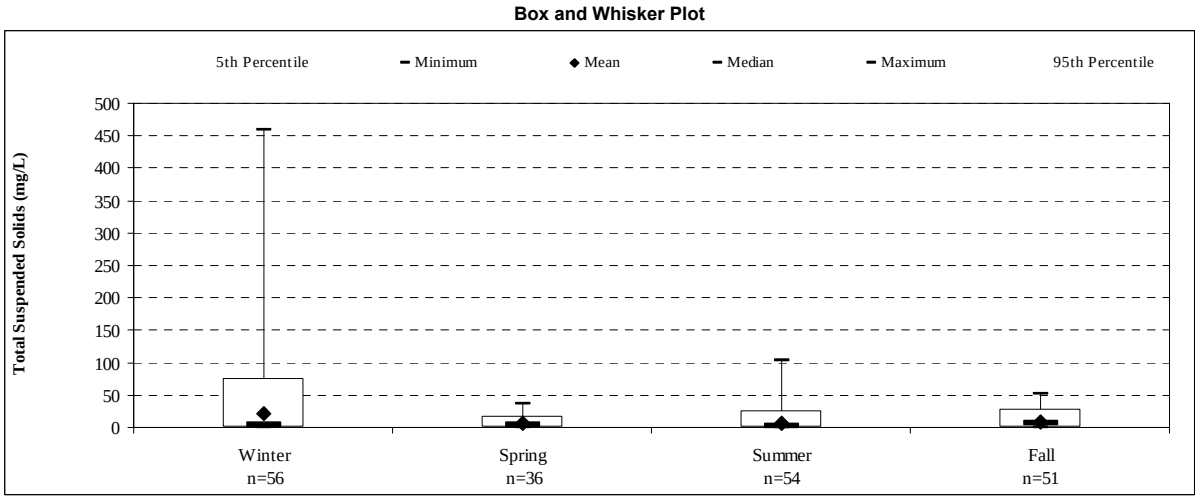


Figure G-2-4-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Jackpine Creek



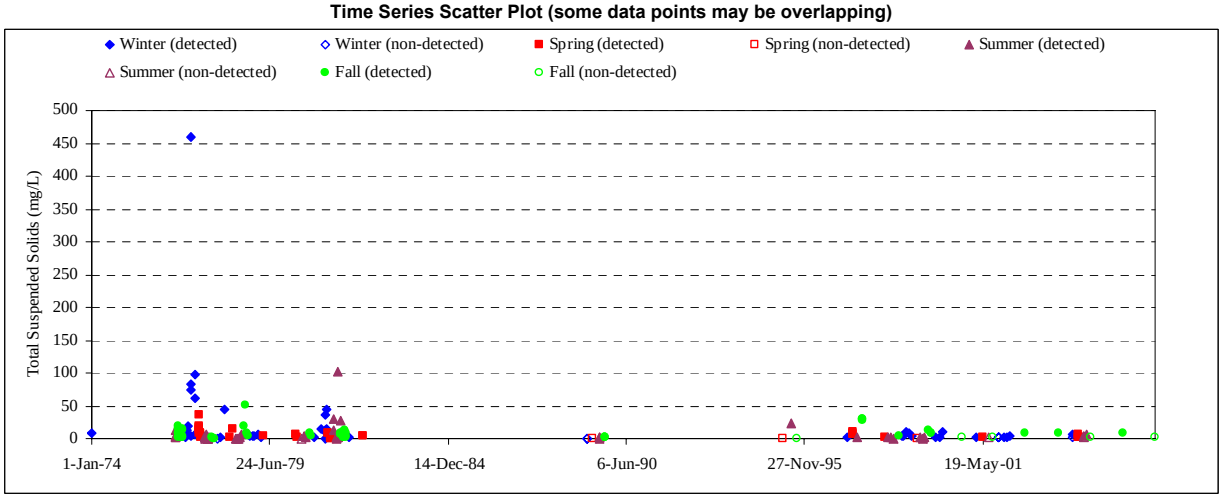
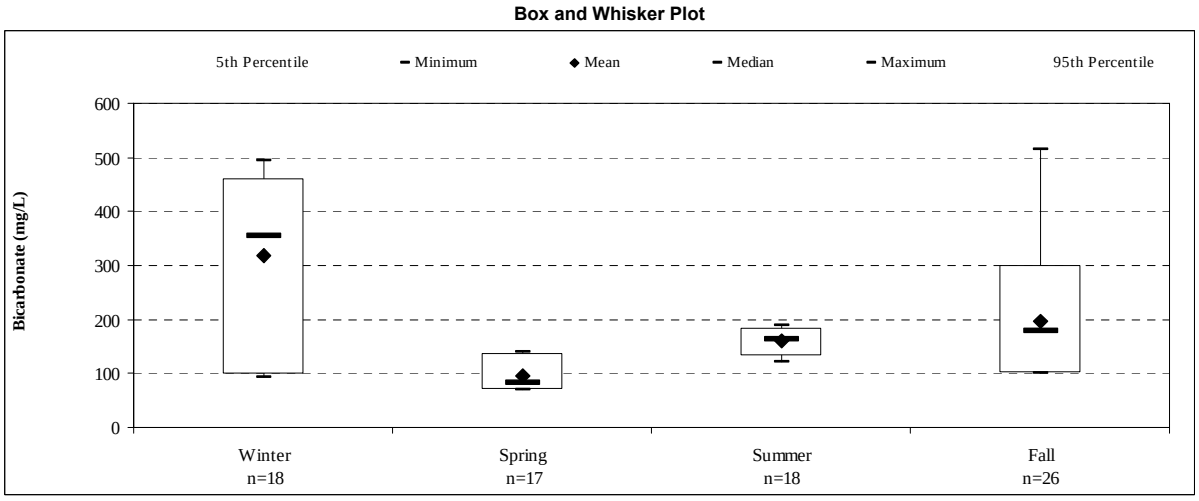


Figure G-2-4-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Jackpine Creek



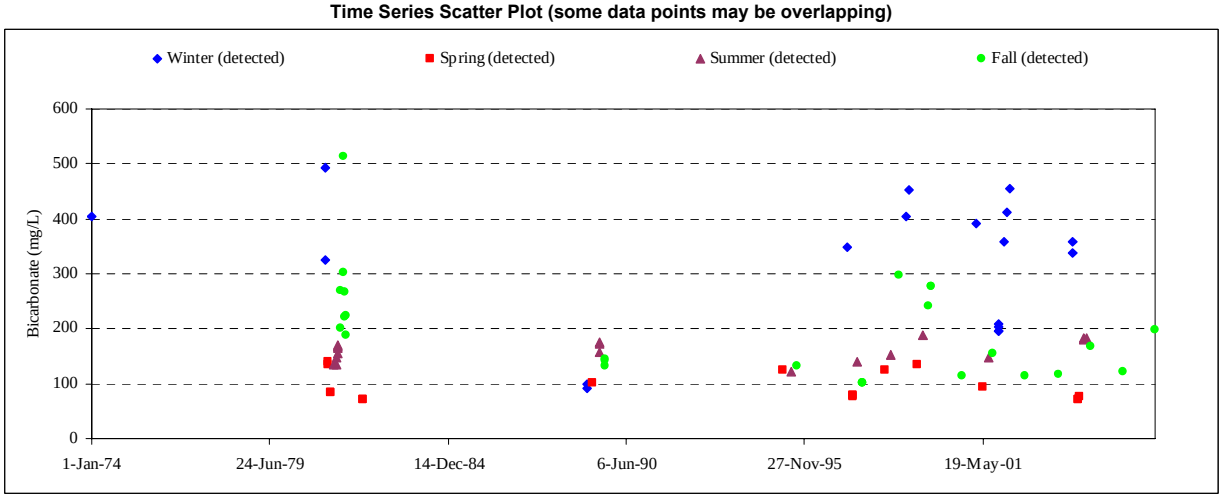
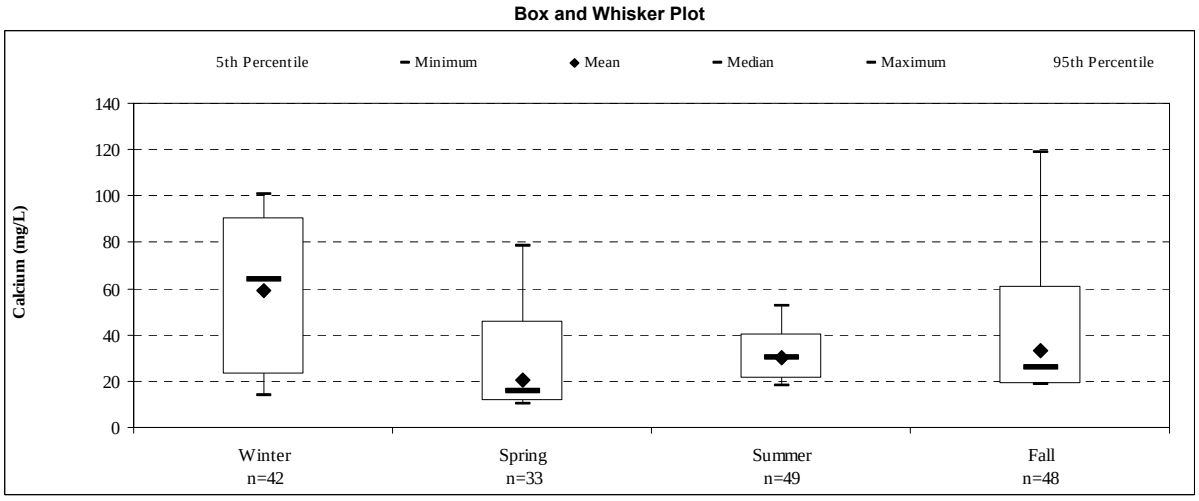


Figure G-2-4-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Jackpine Creek



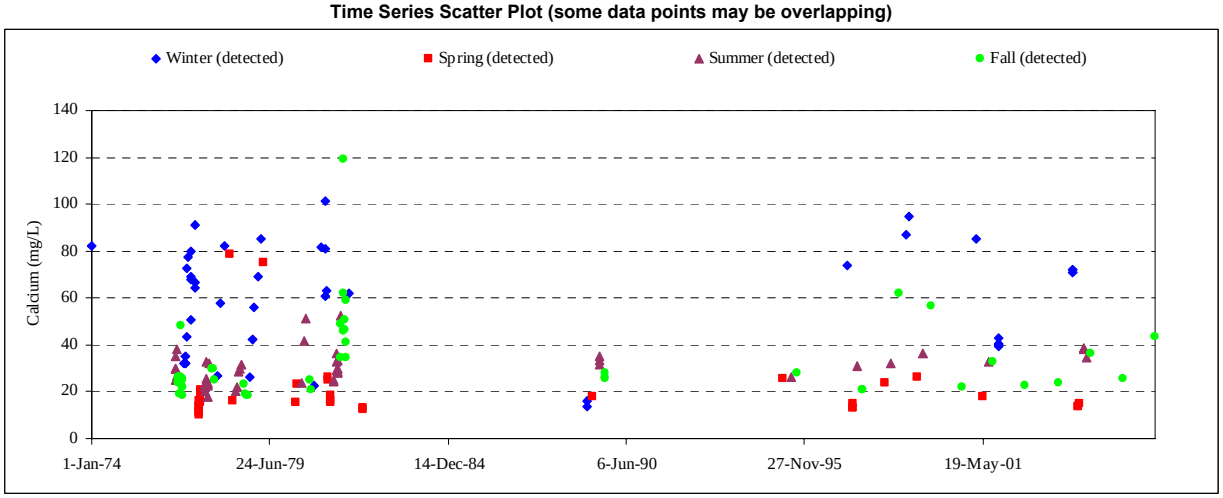
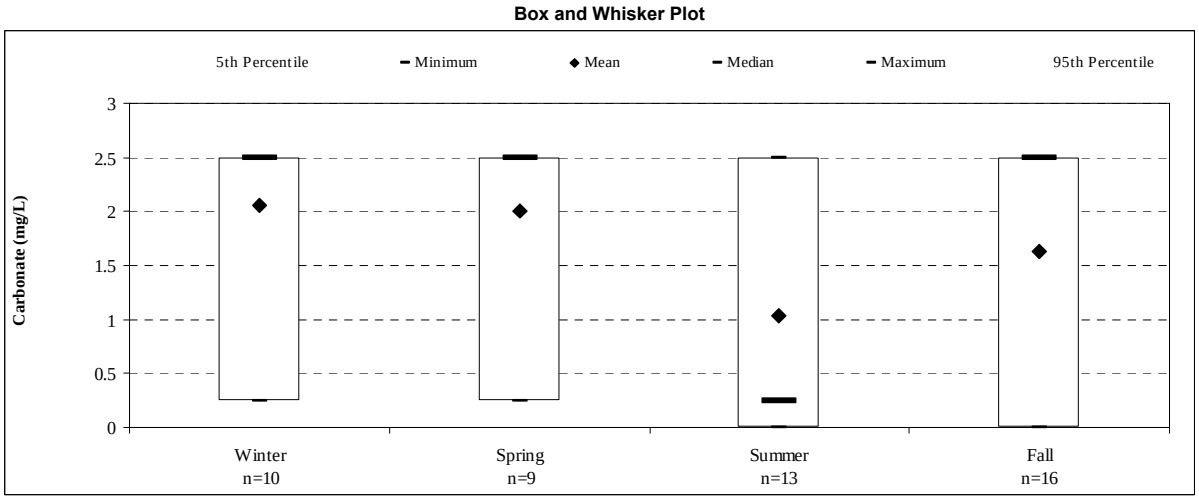


Figure G-2-4-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Jackpine Creek



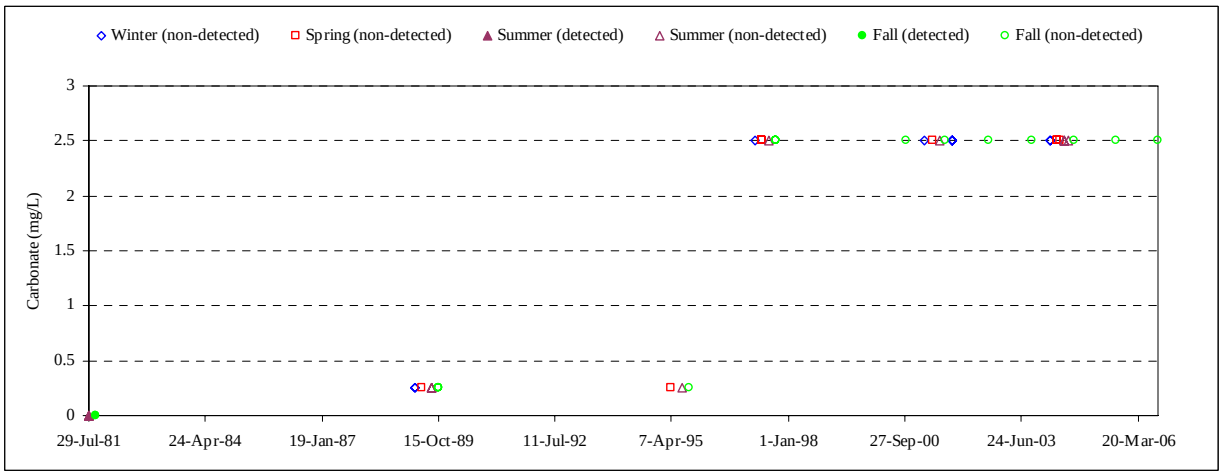
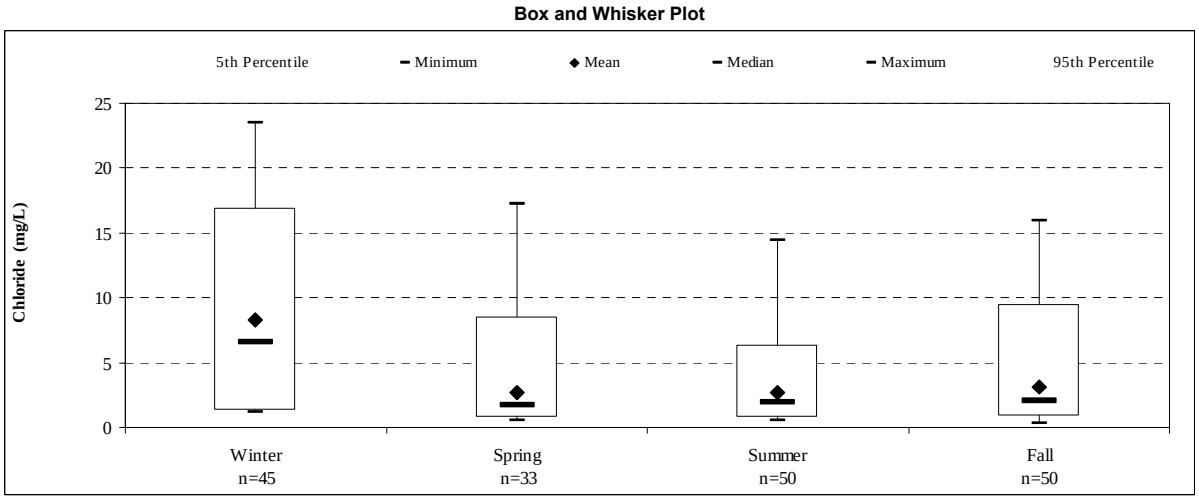


Figure G-2-4-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Jackpine Creek



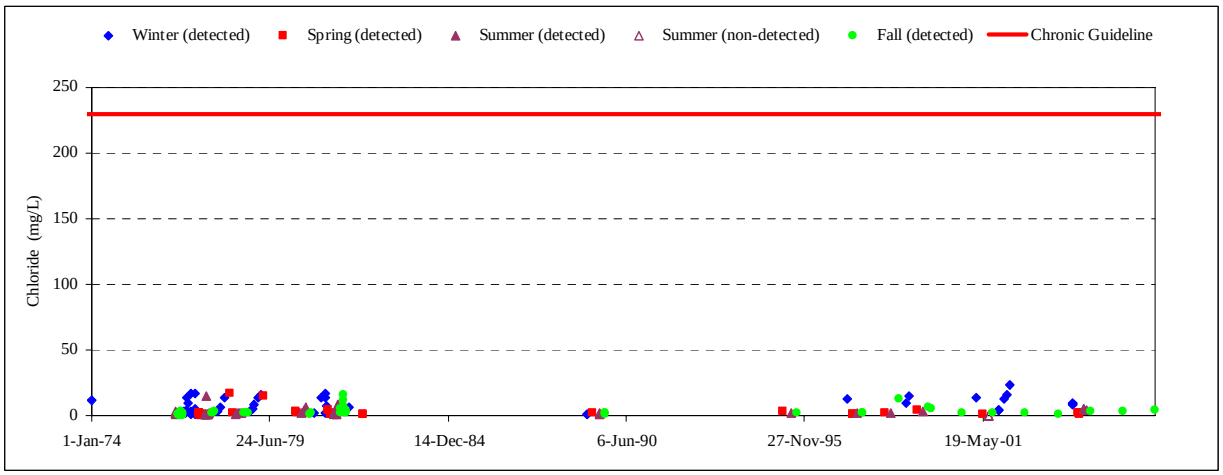
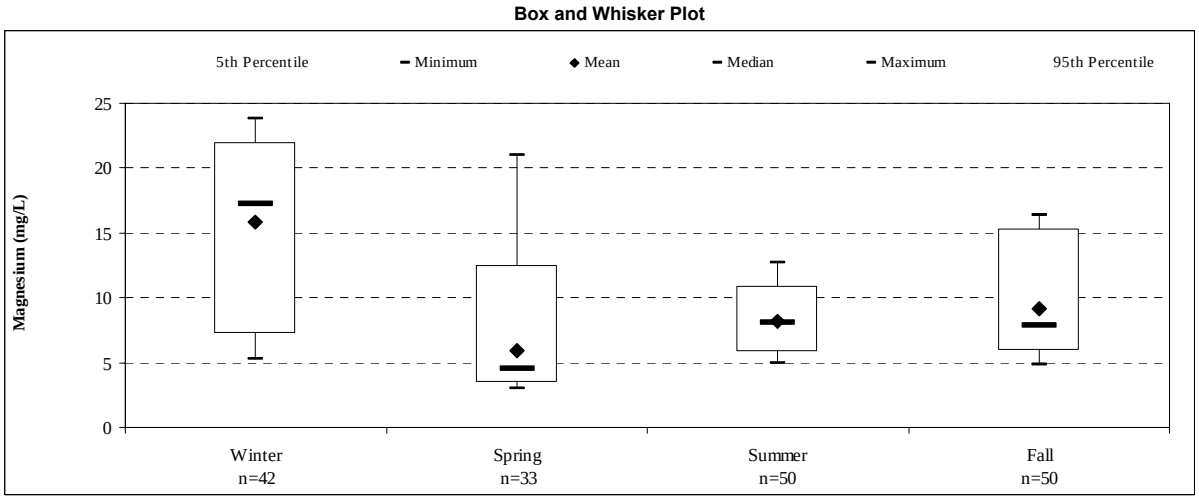


Figure G-2-4-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Jackpine Creek



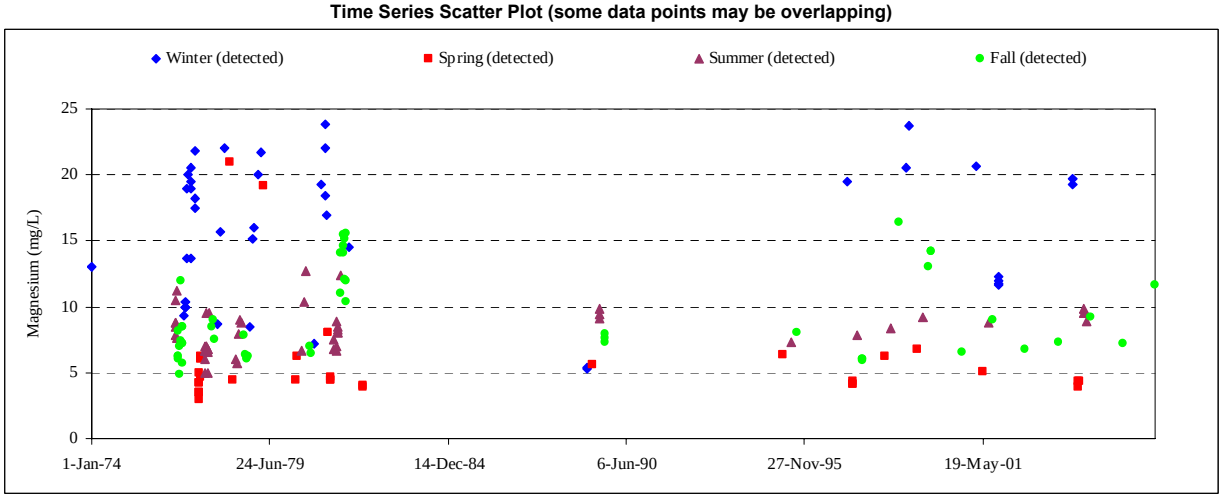
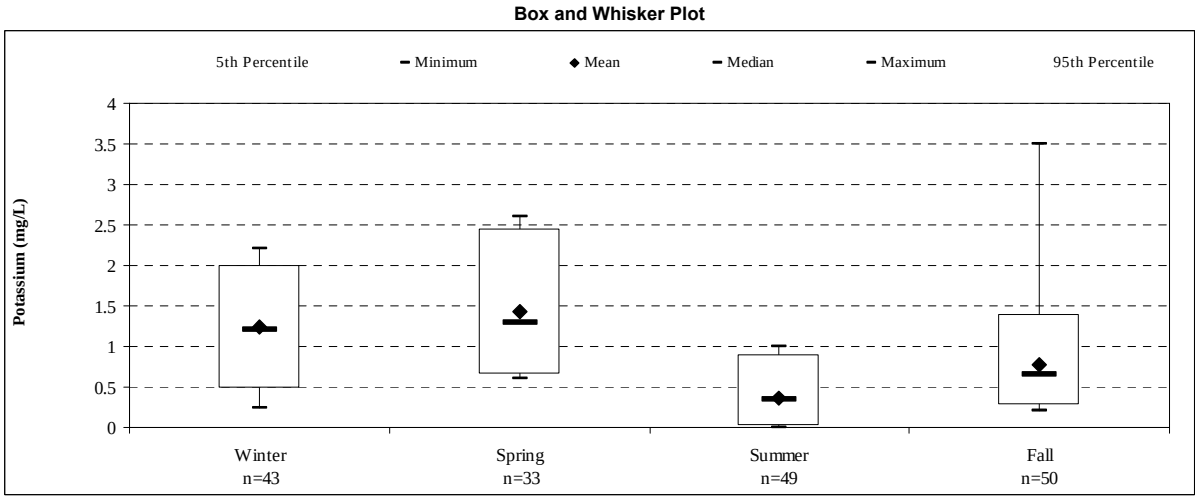


Figure G-2-4-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Jackpine Creek



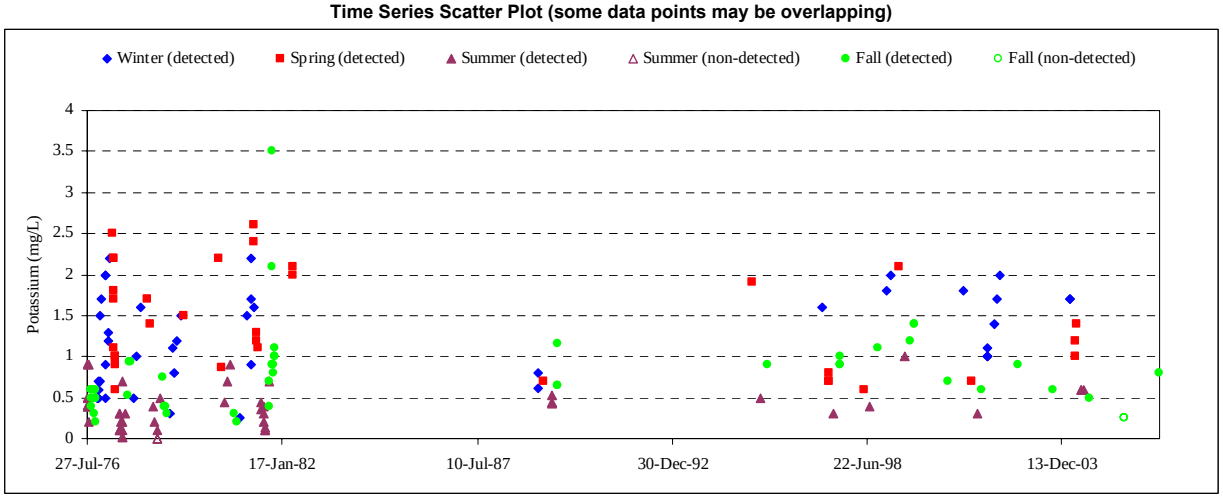
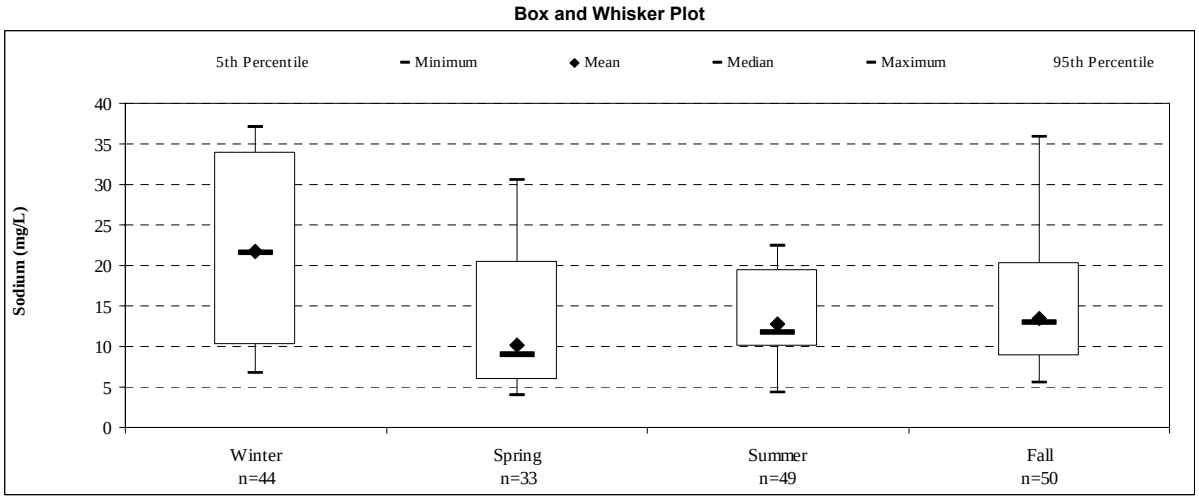


Figure G-2-4-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Jackpine Creek



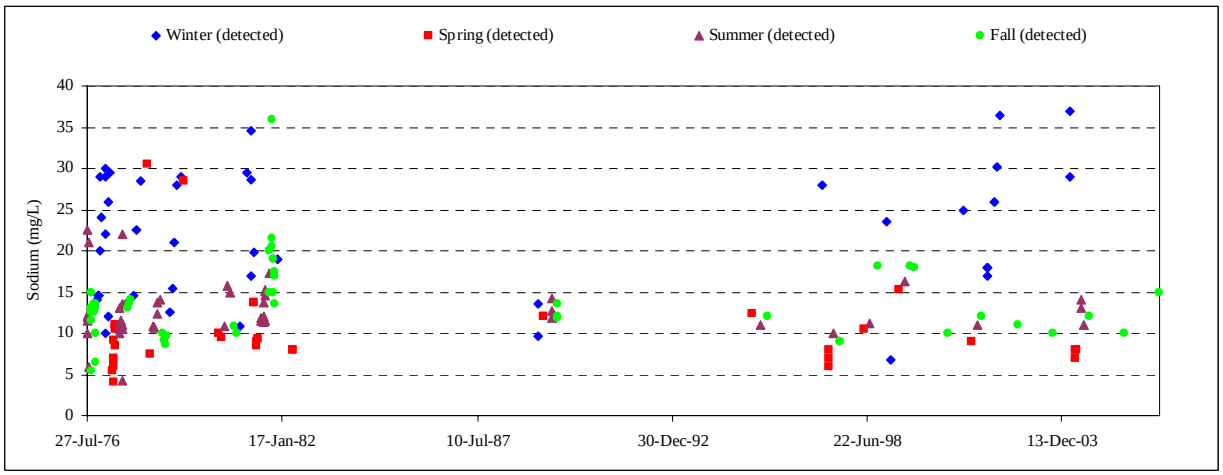
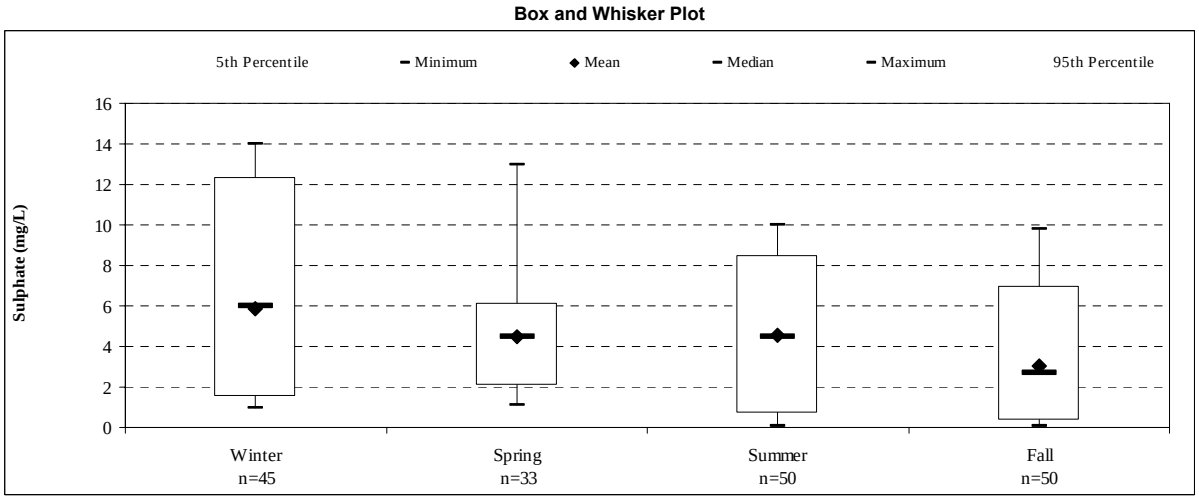


Figure G-2-4-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Jackpine Creek



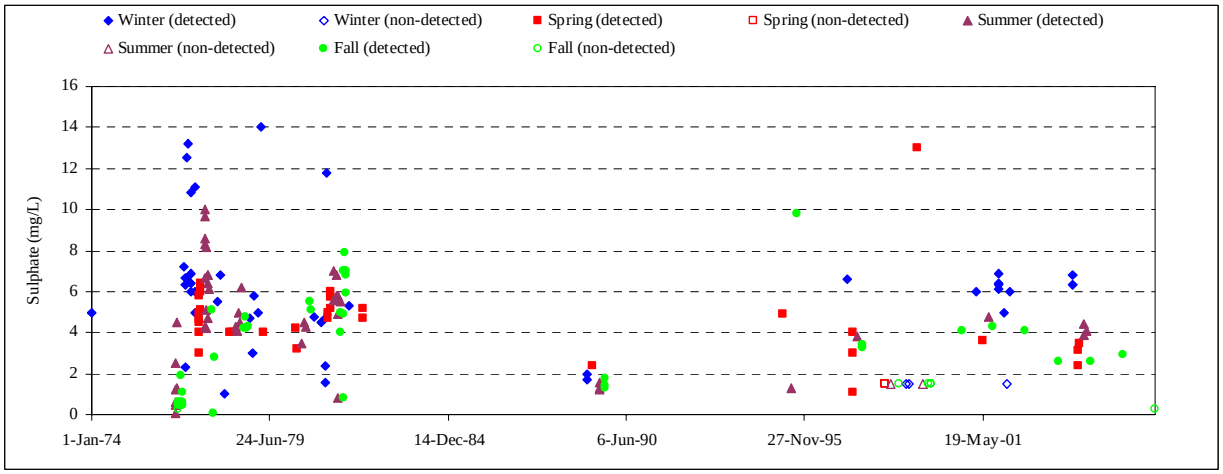
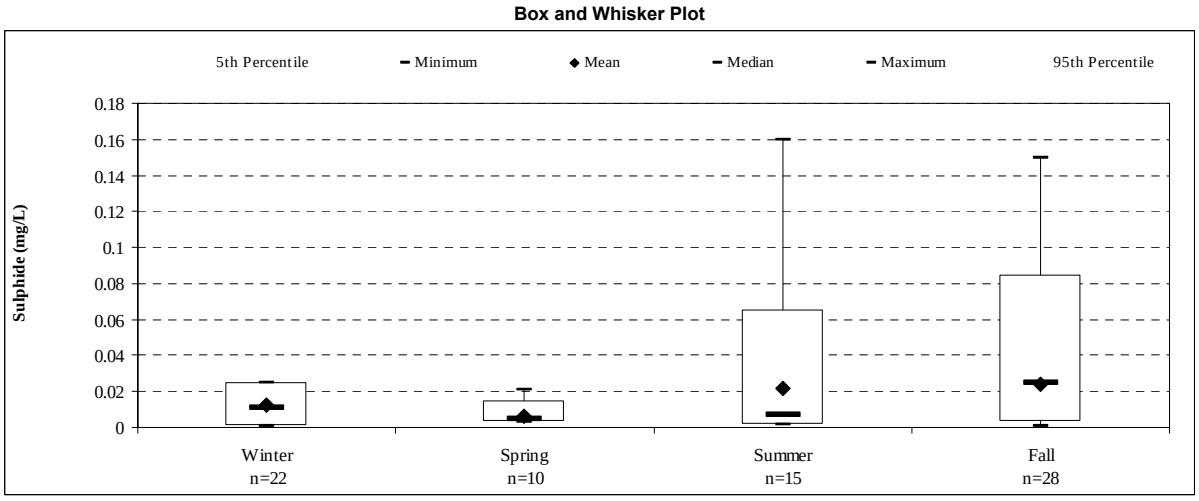


Figure G-2-4-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Jackpine Creek



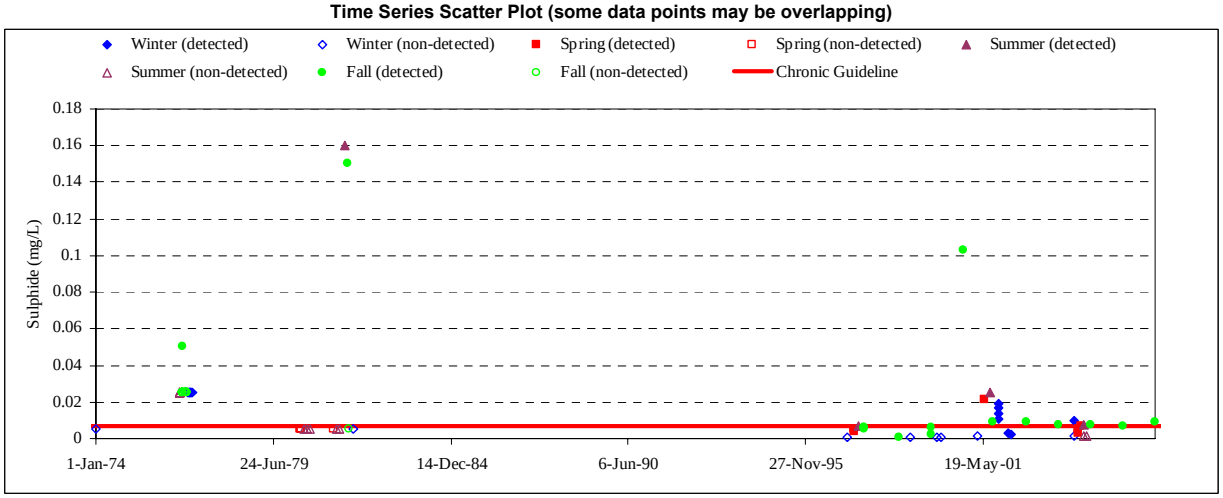
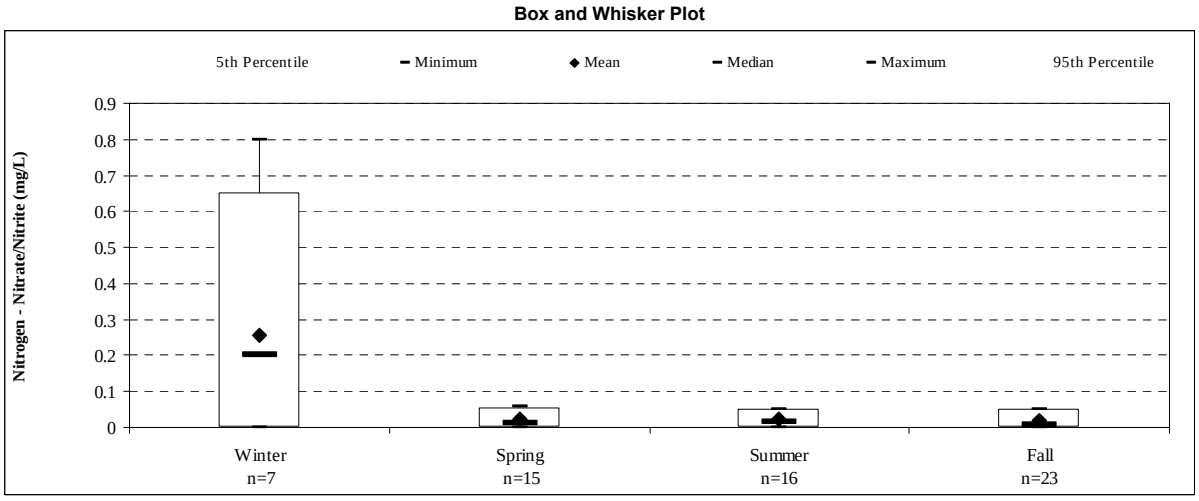


Figure G-2-4-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Jackpine Creek



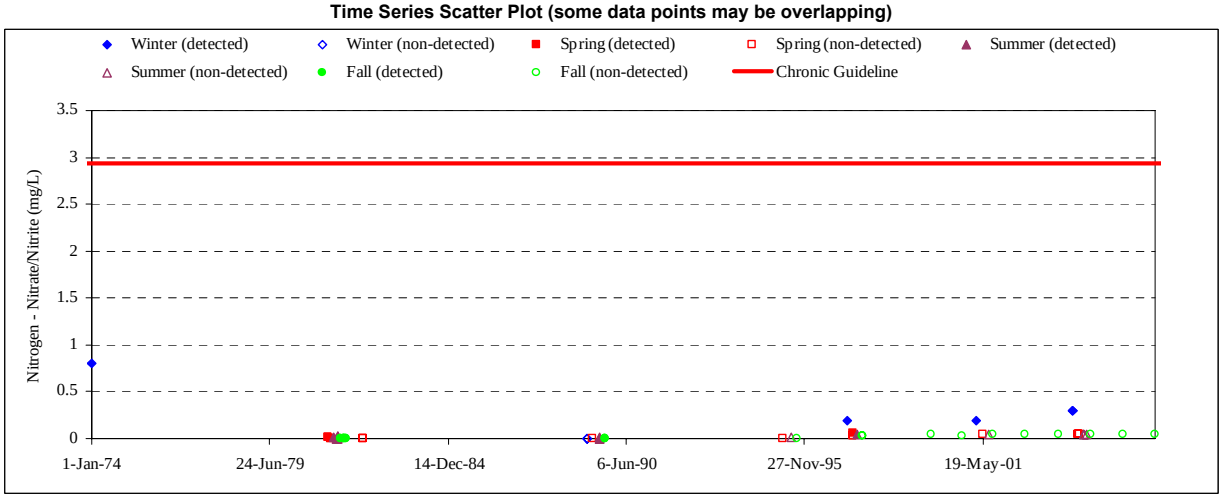
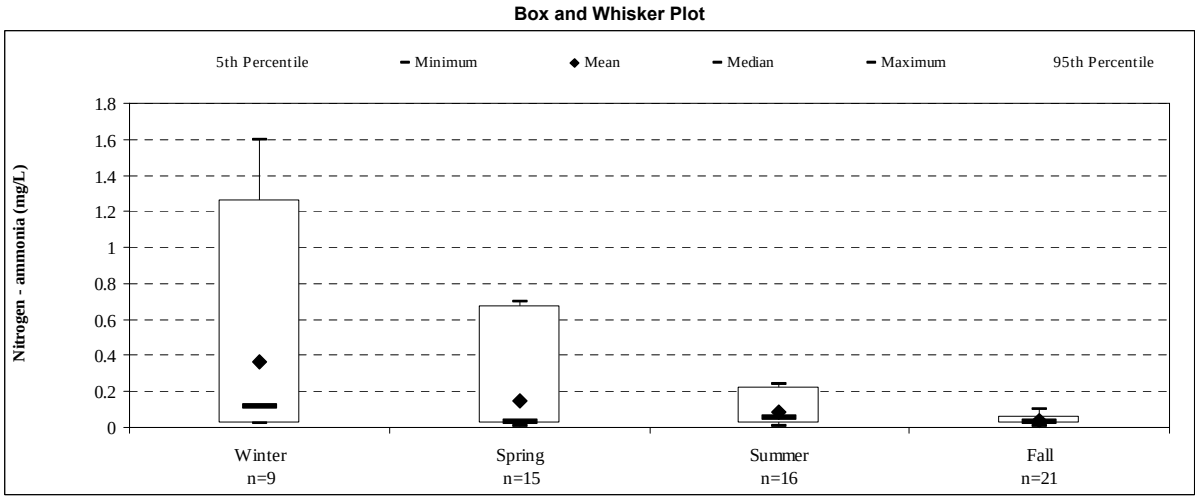


Figure G-2-4-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Jackpine Creek



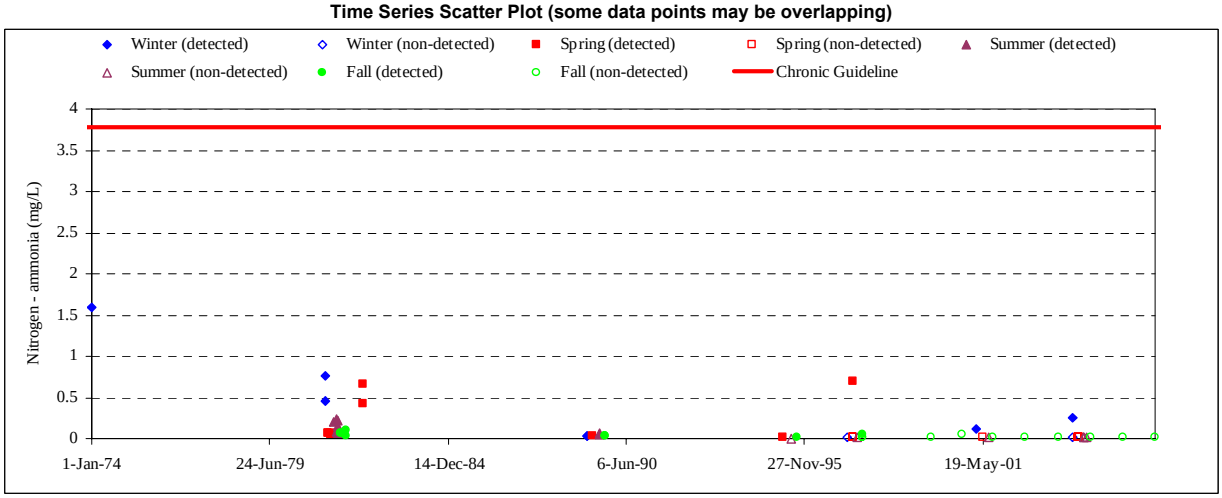


Figure G-2-4-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Jackpine Creek

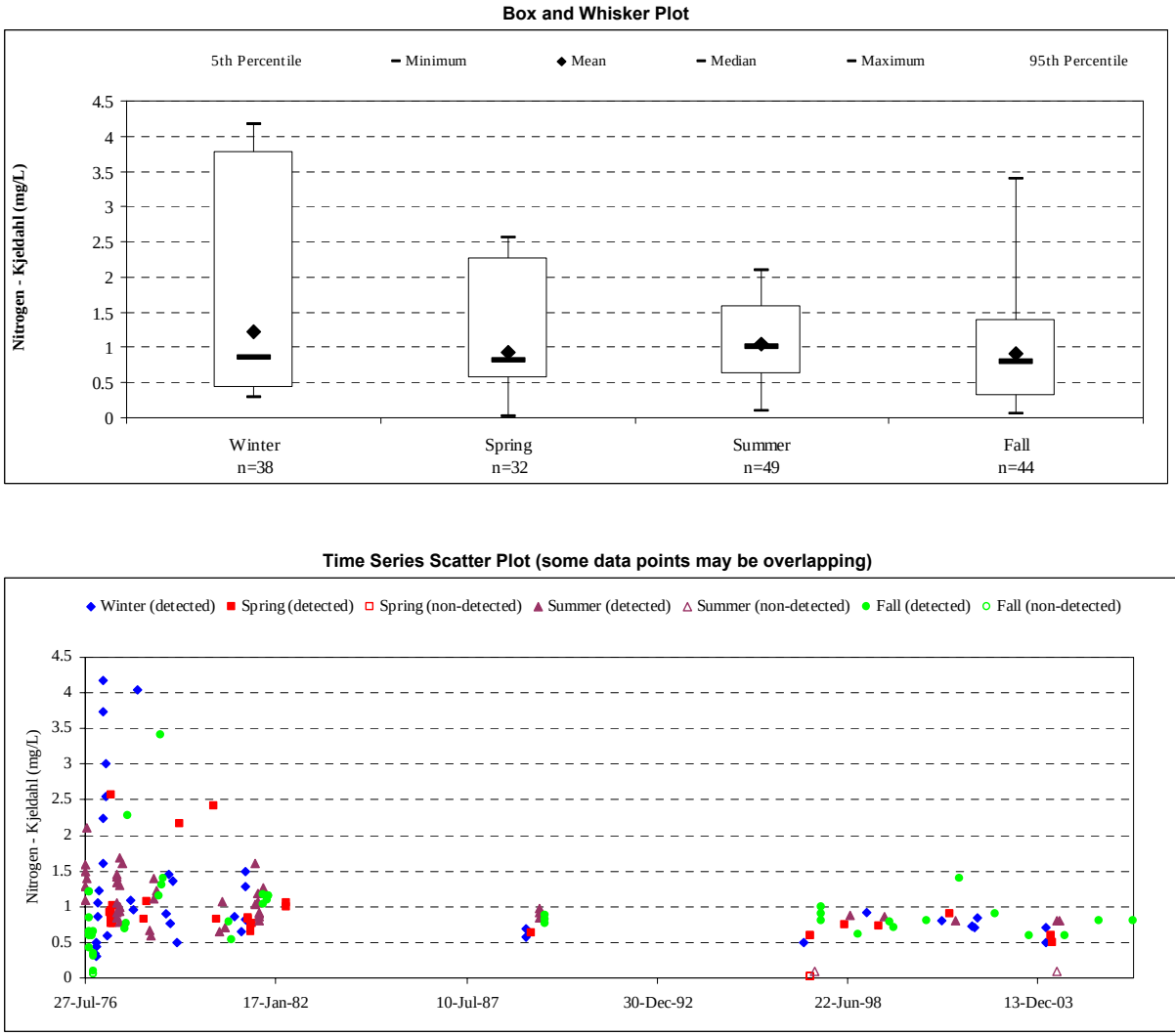
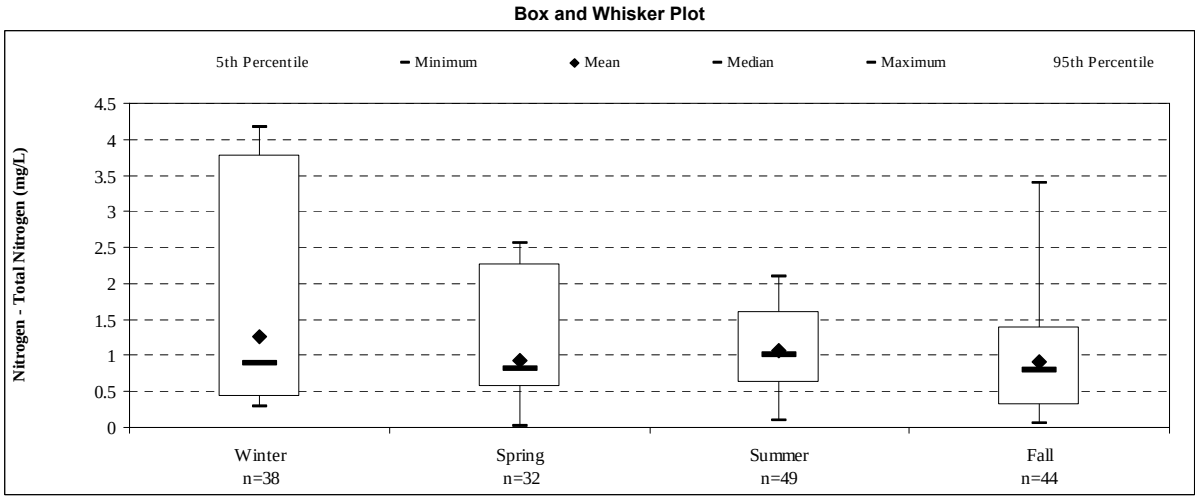


Figure G-2-4-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Jackpine Creek



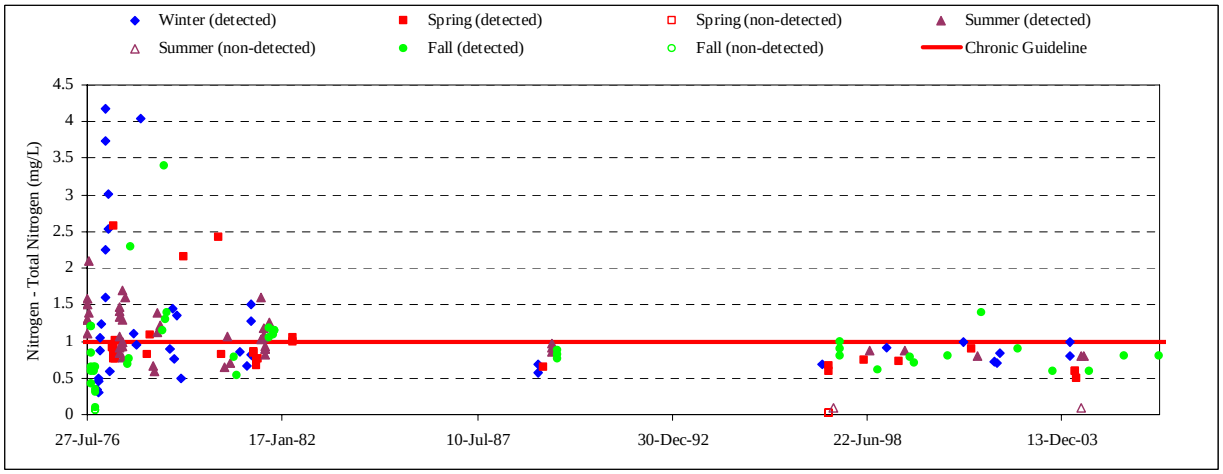
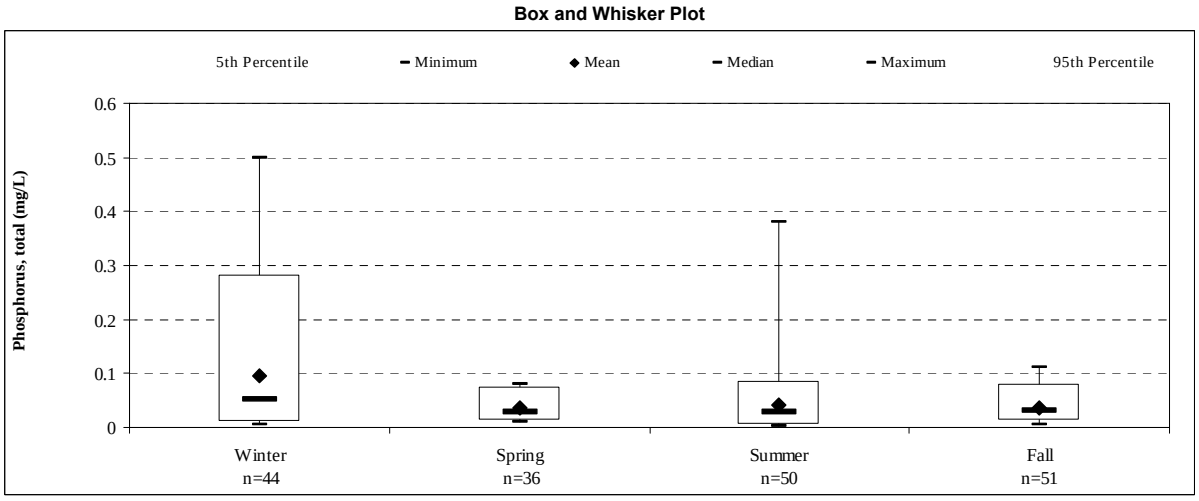


Figure G-2-4-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Jackpine Creek



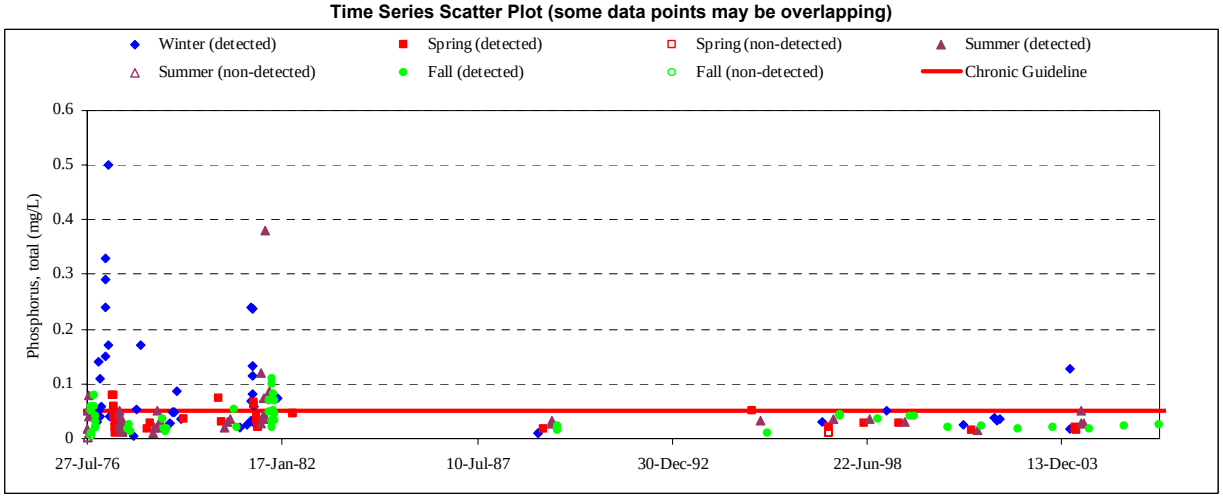
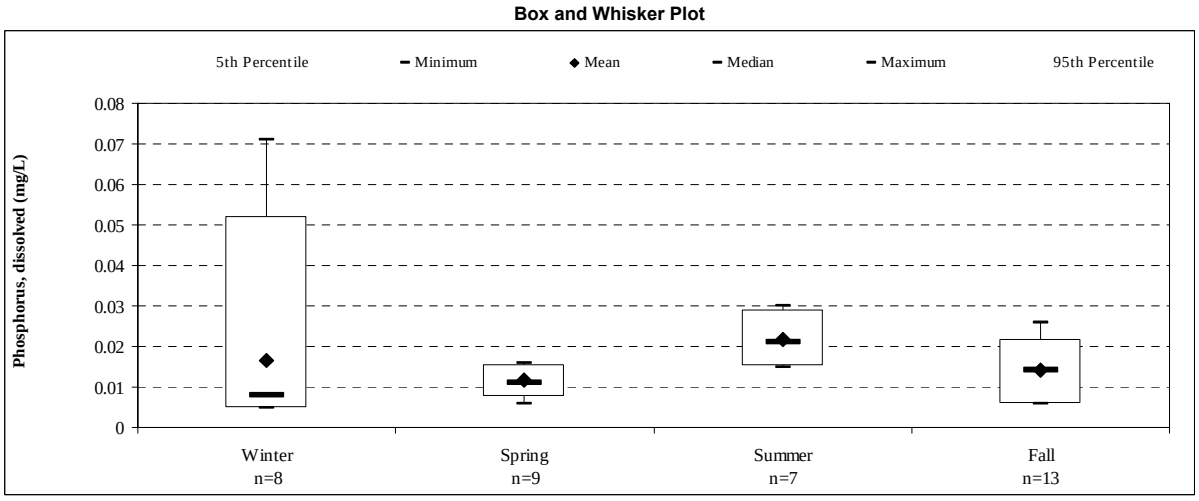


Figure G-2-4-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Jackpine Creek



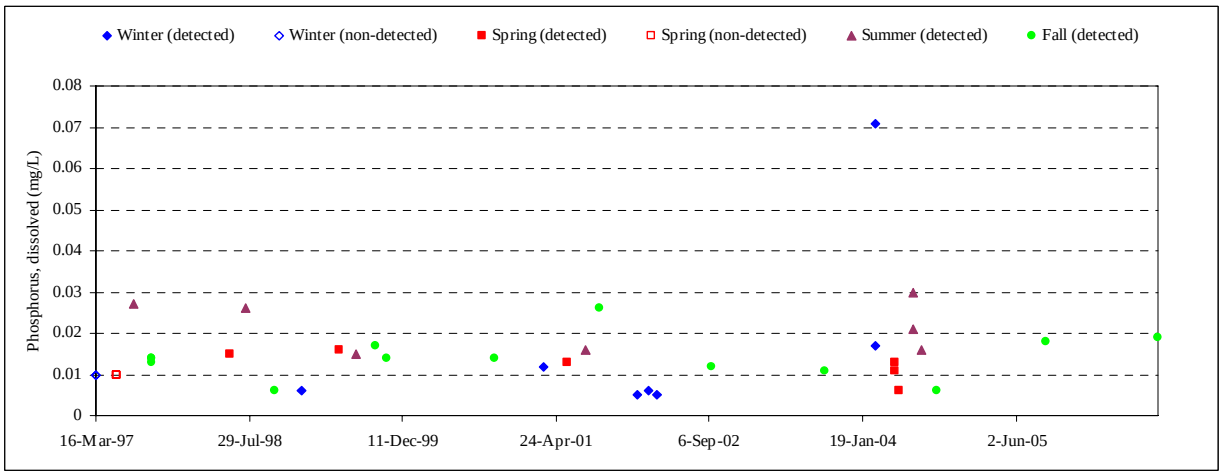
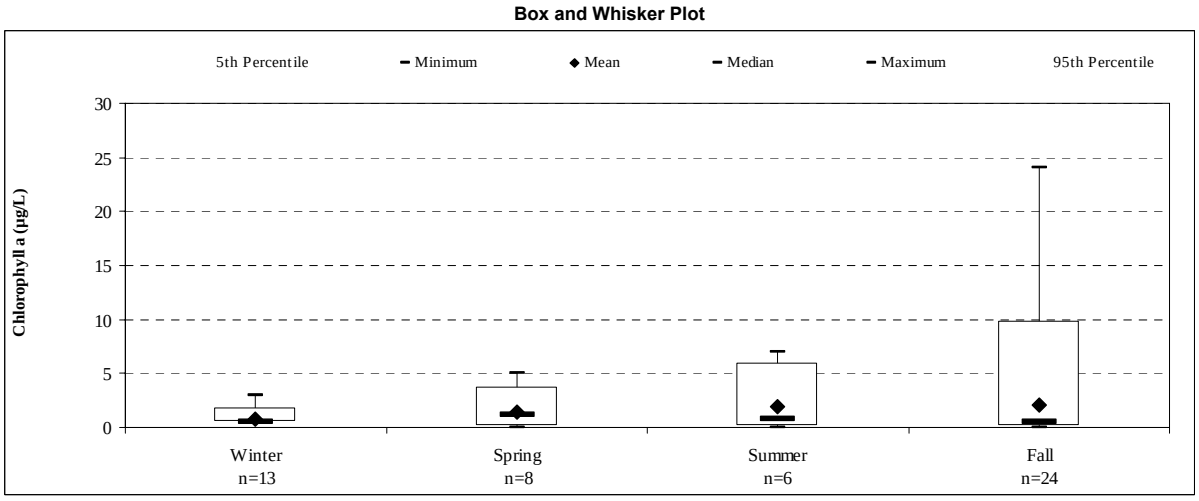


Figure G-2-4-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Jackpine Creek



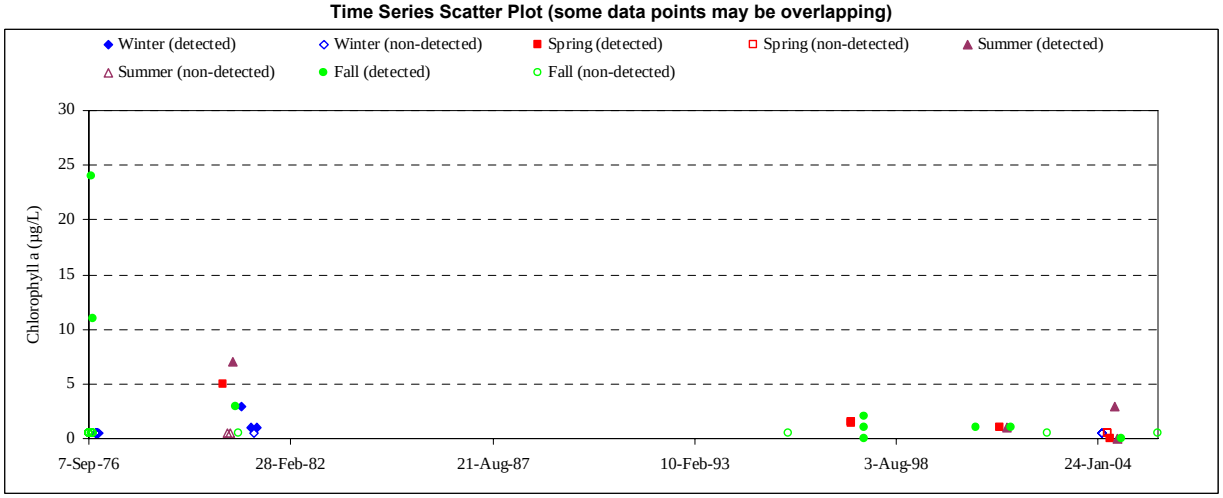


Figure G-2-4-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Jackpine Creek

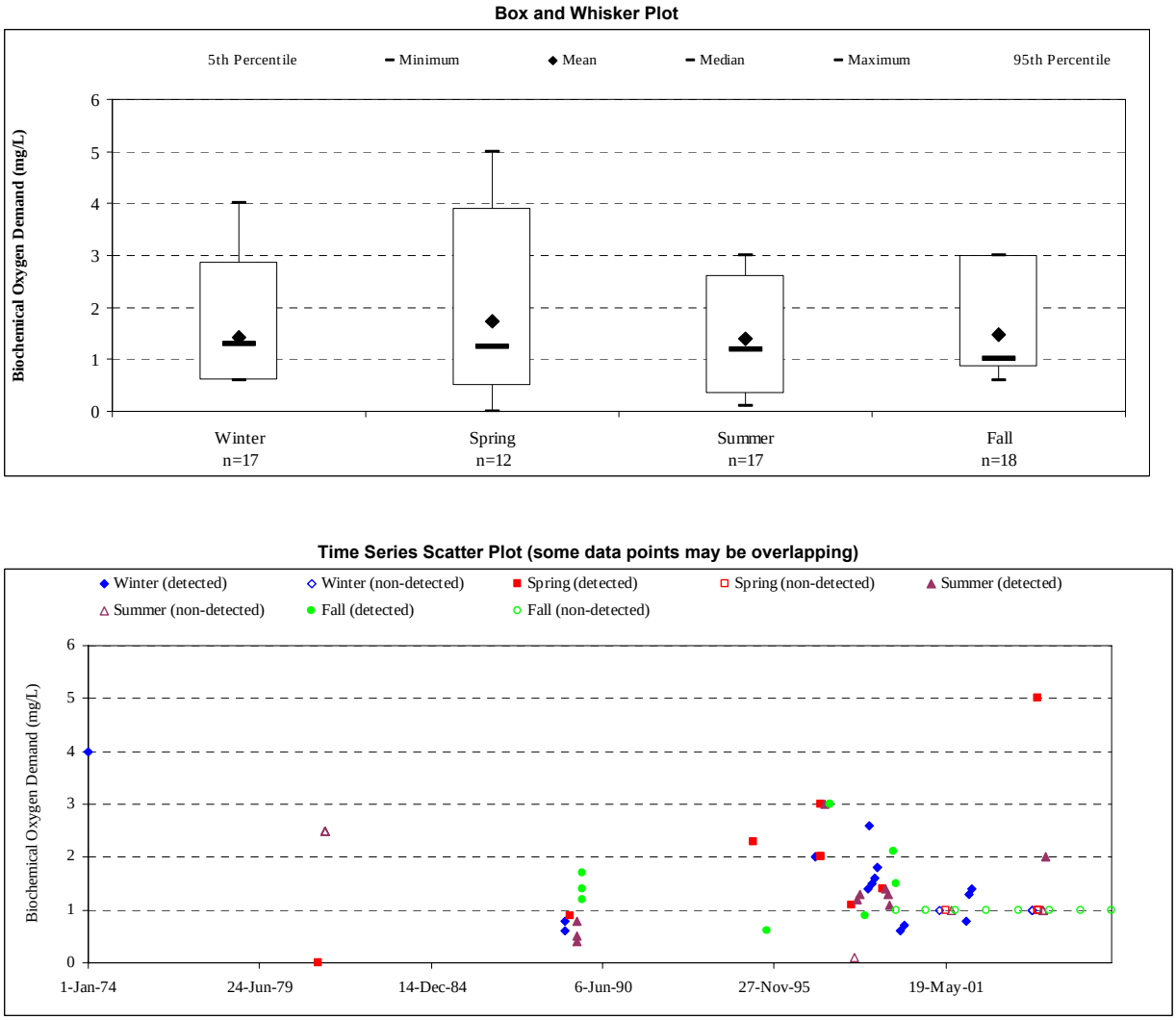
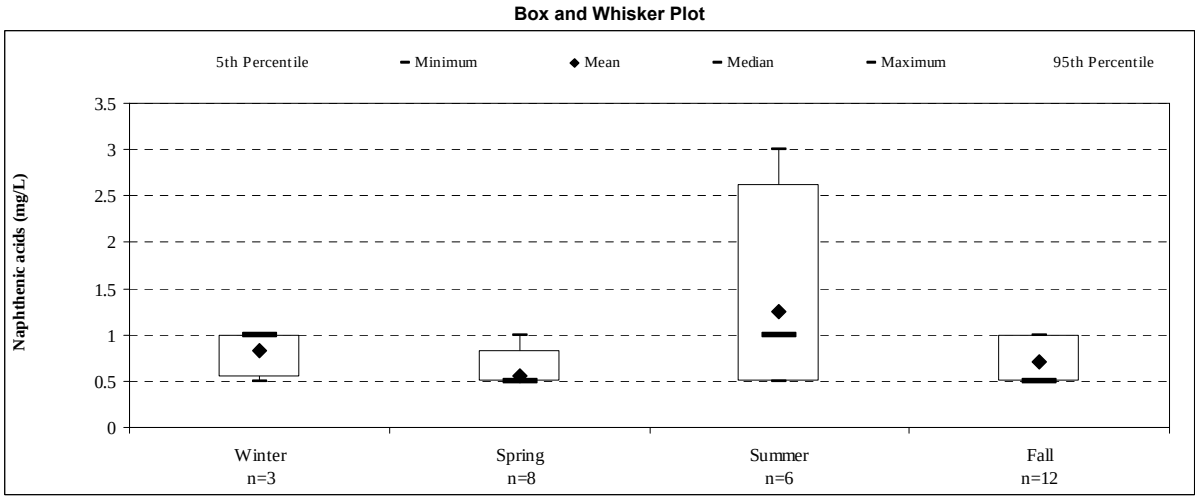


Figure G-2-4-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Jackpine Creek



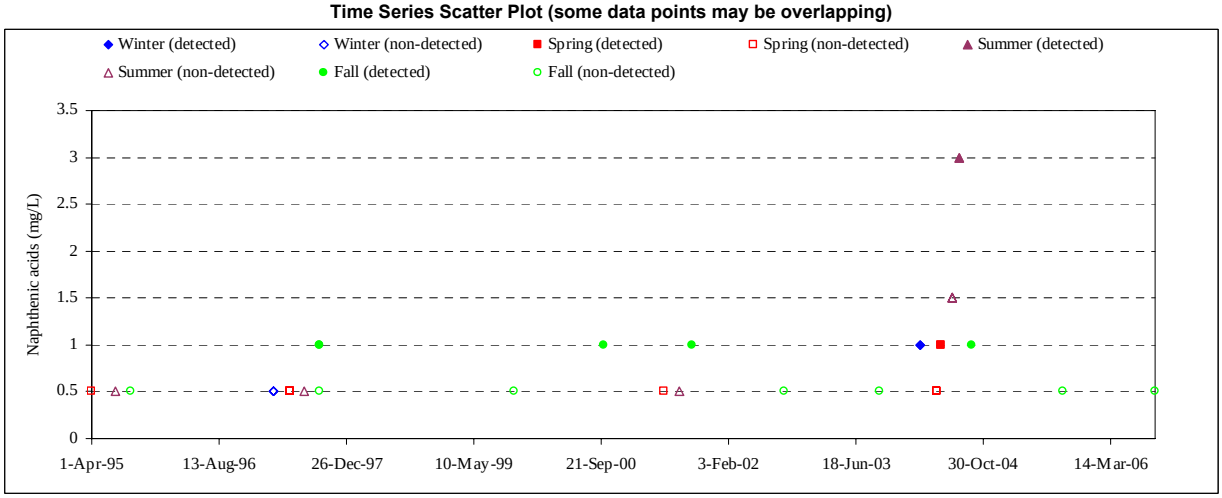


Figure G-2-4-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Jackpine Creek

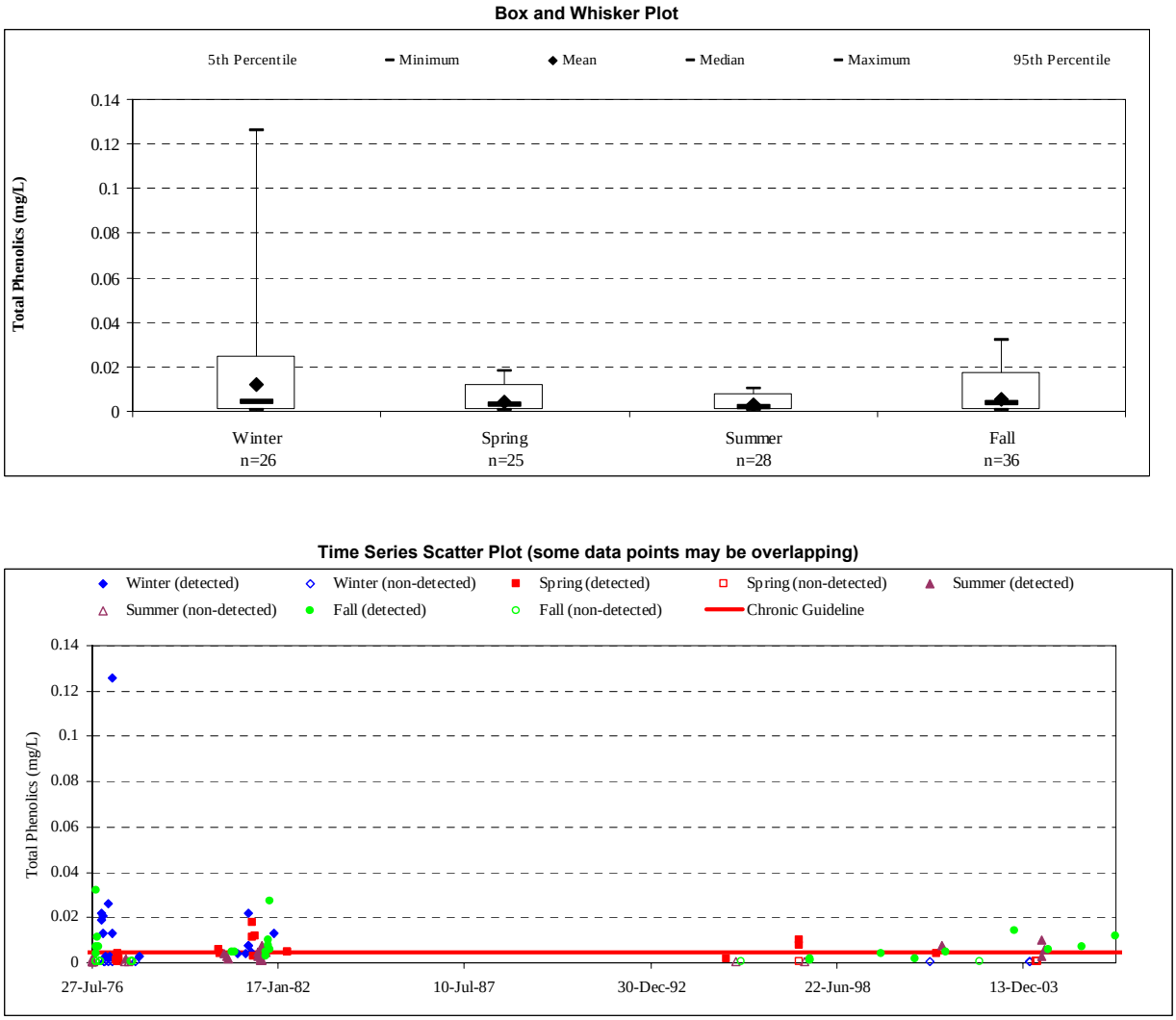


Figure G-2-4-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Jackpine Creek

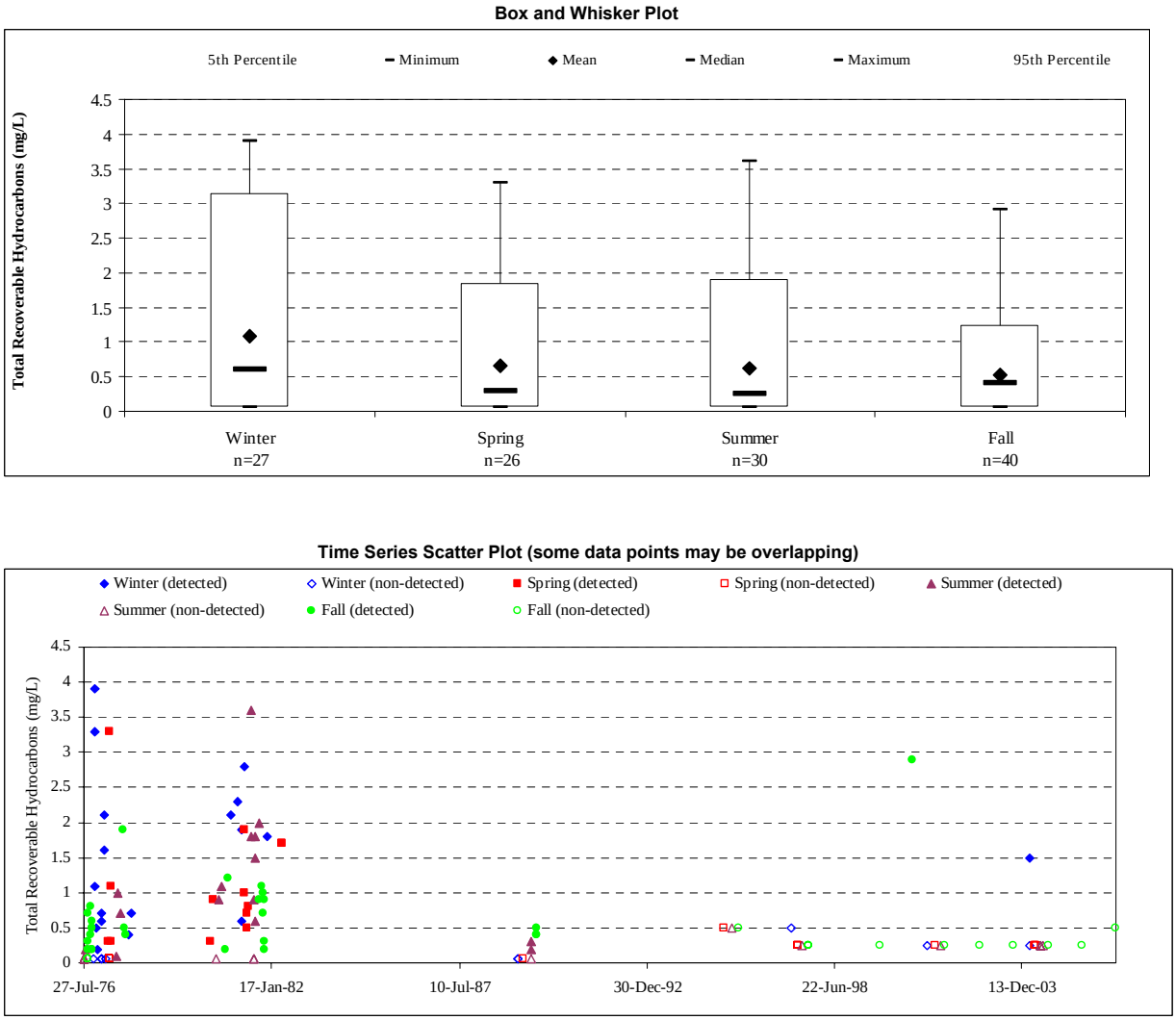


Figure G-2-4-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Jackpine Creek

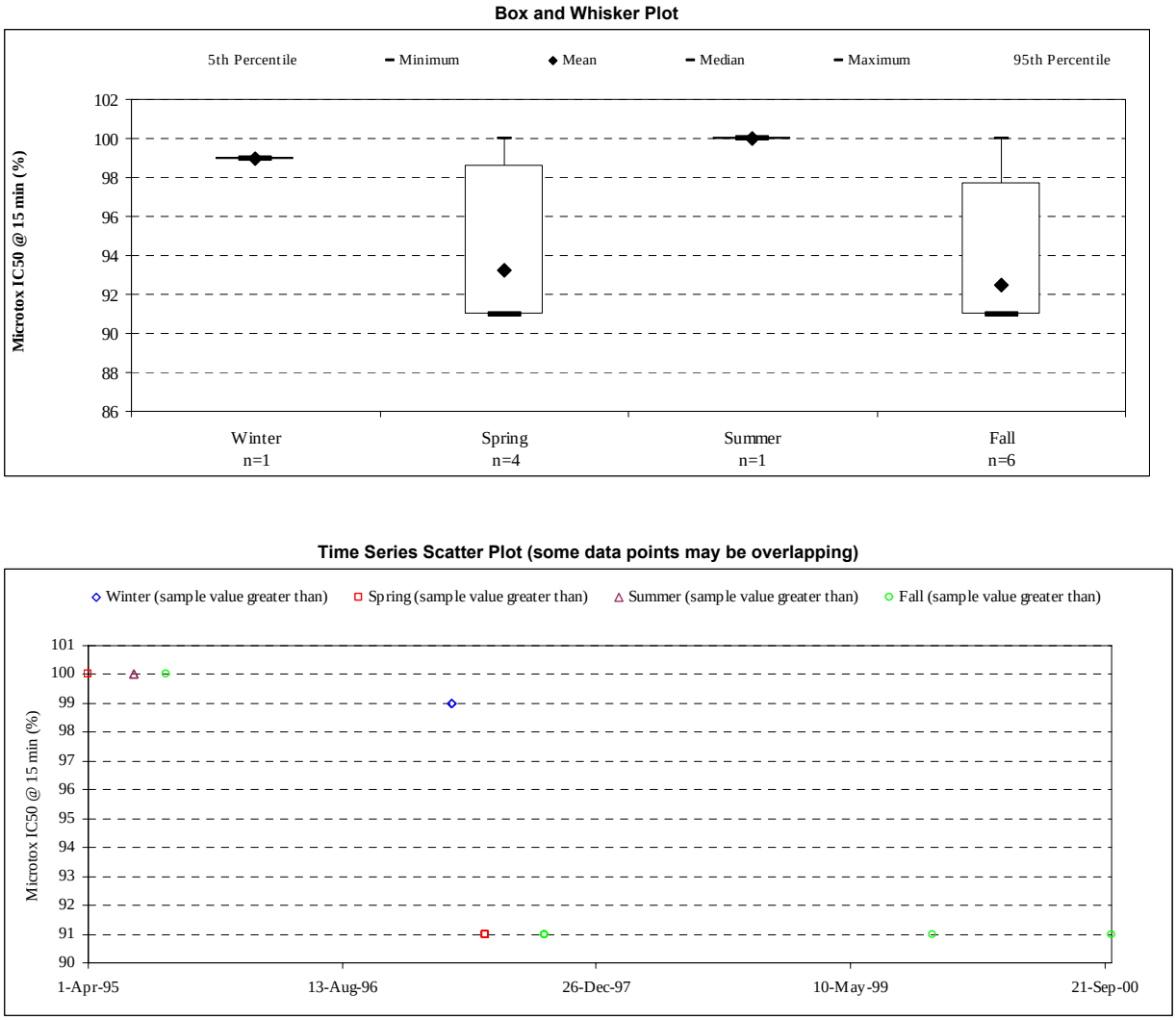


Figure G-2-4-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Jackpine Creek

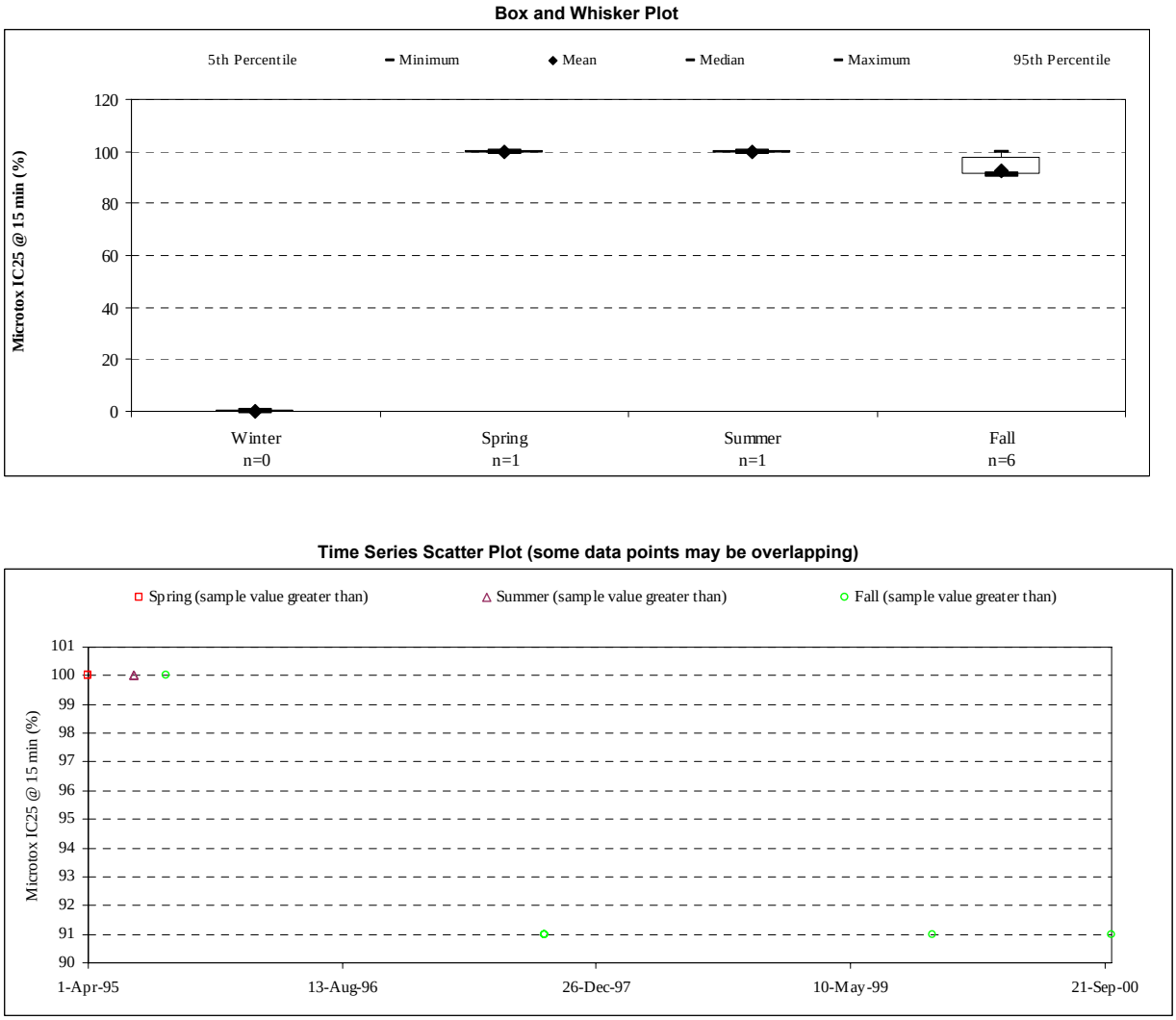
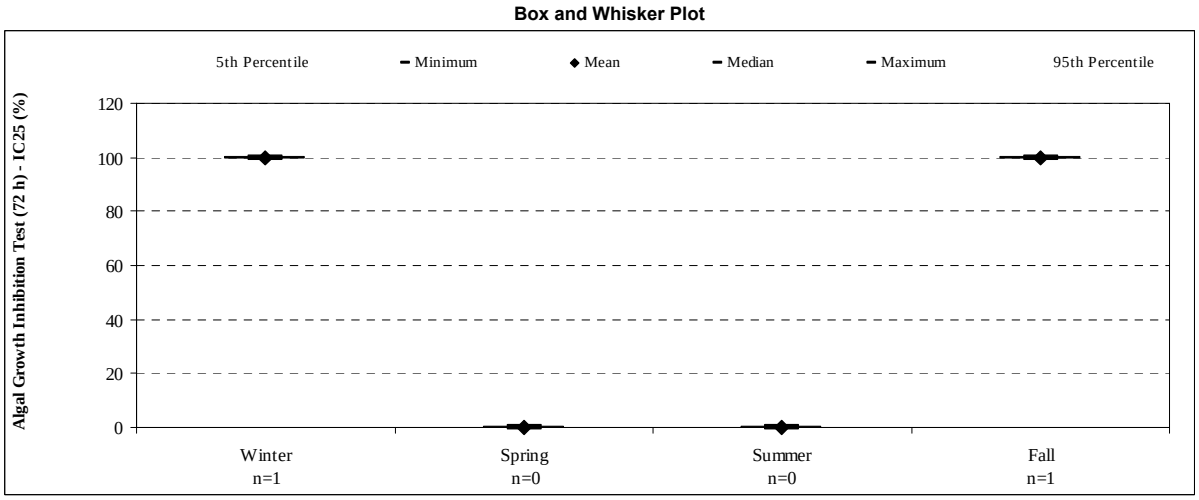


Figure G-2-4-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Jackpine Creek



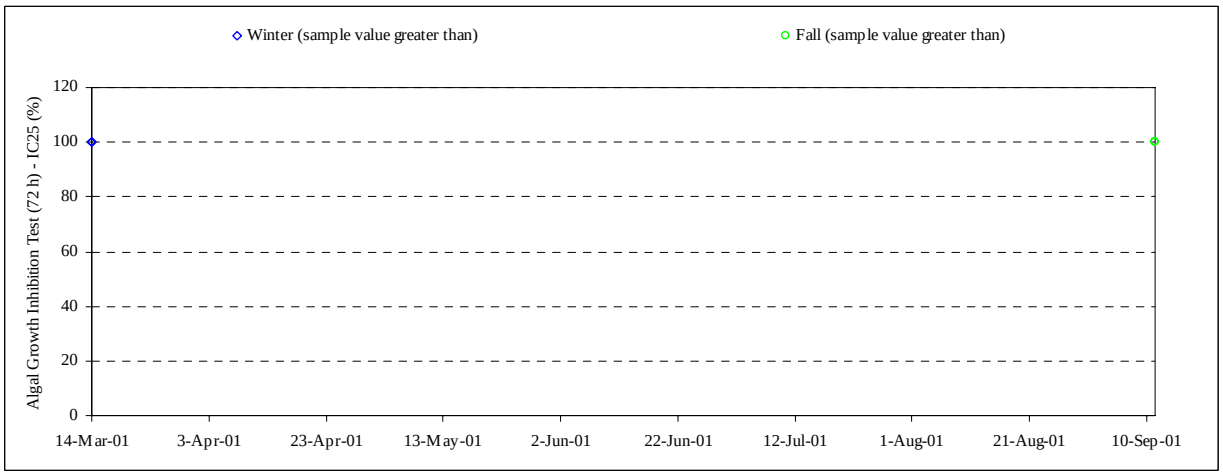
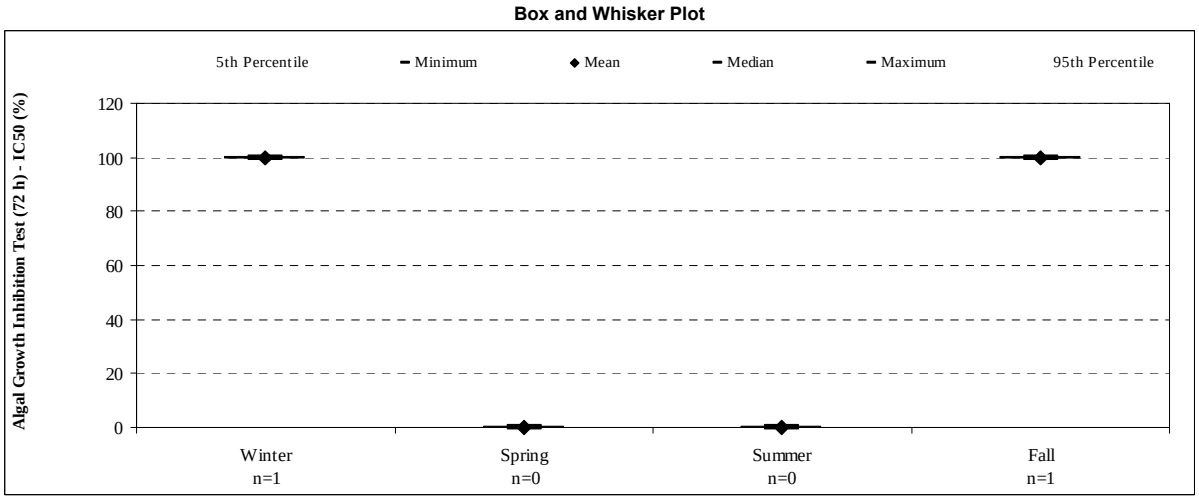


Figure G-2-4-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Jackpine Creek



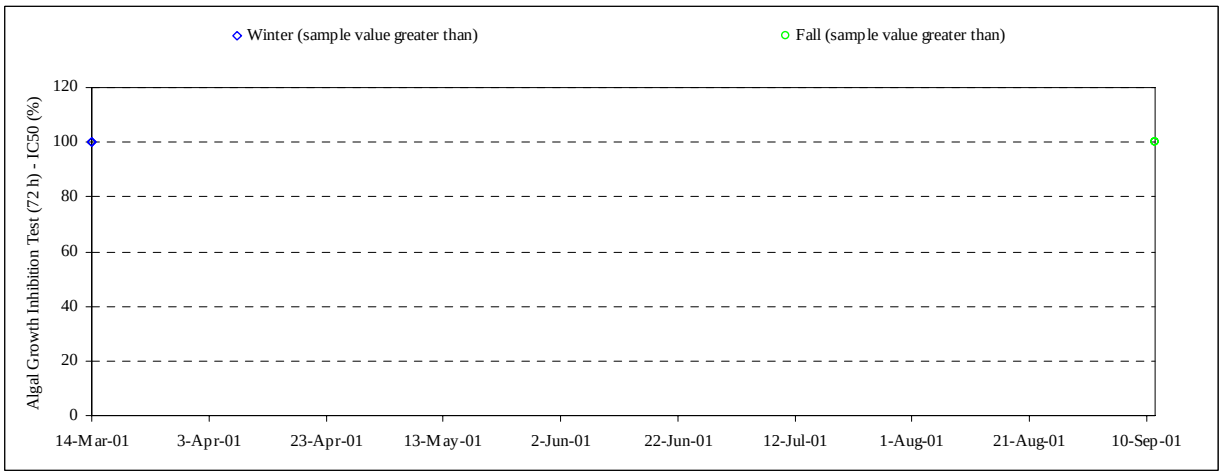
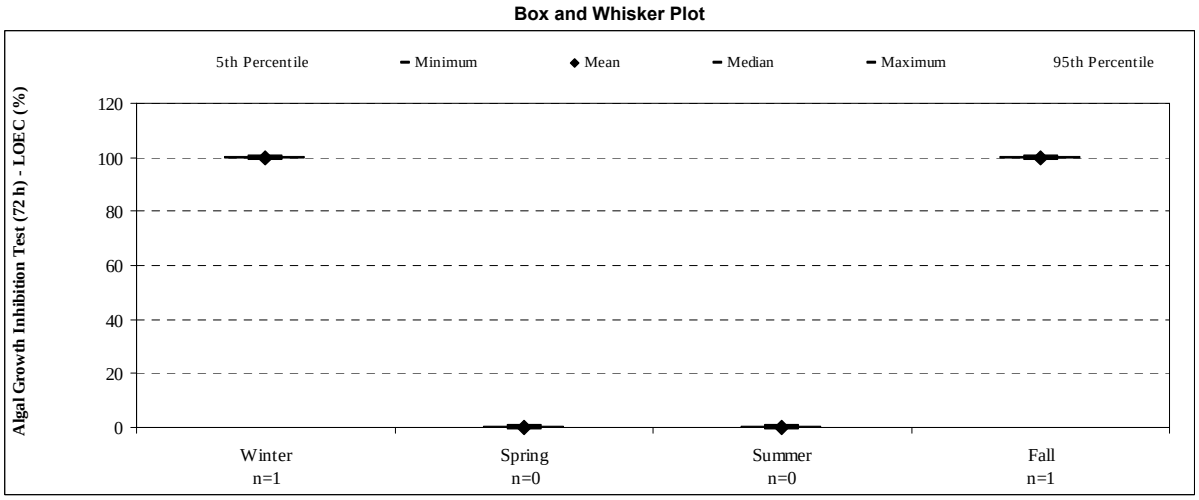


Figure G-2-4-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Jackpine Creek



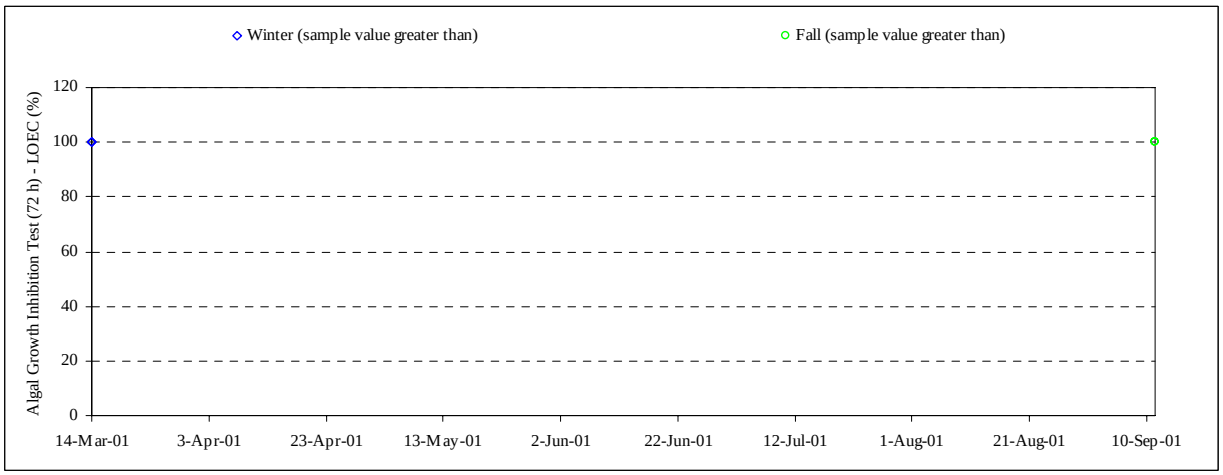
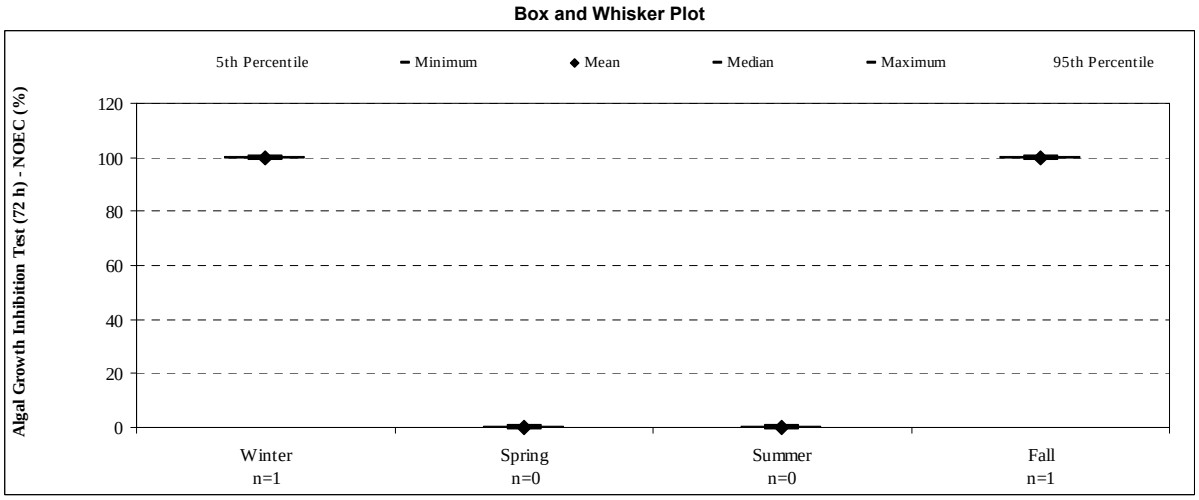


Figure G-2-4-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Jackpine Creek



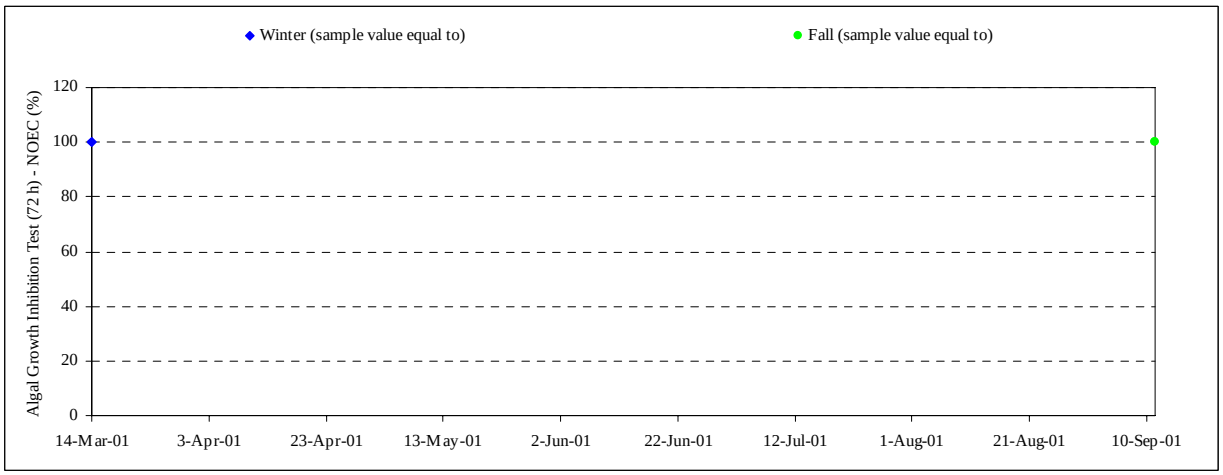
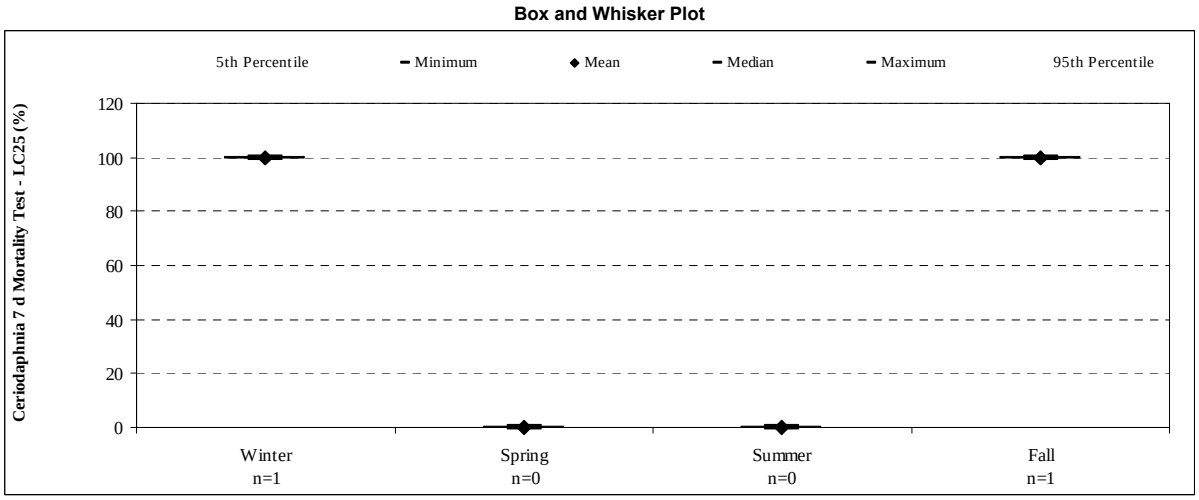


Figure G-2-4-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Jackpine Creek



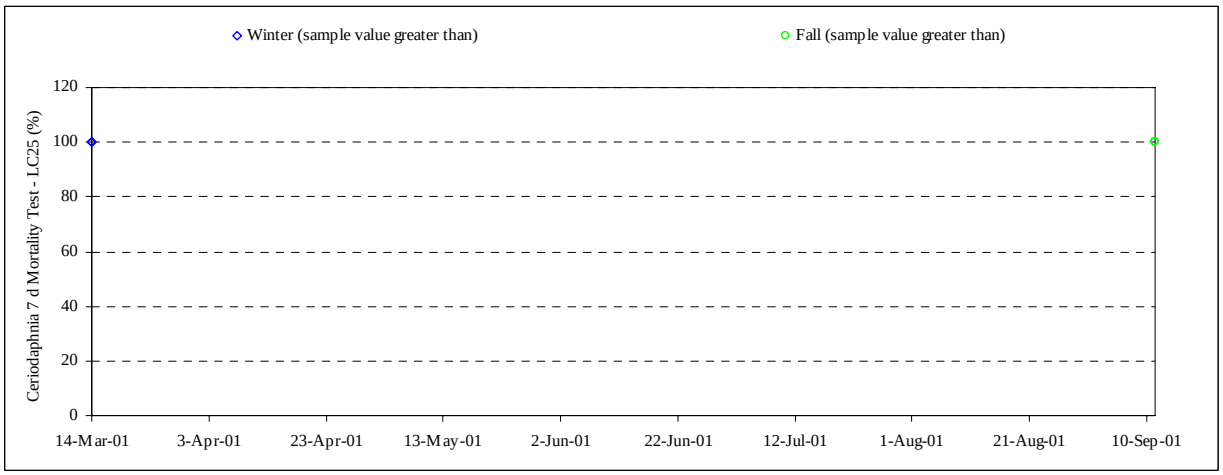
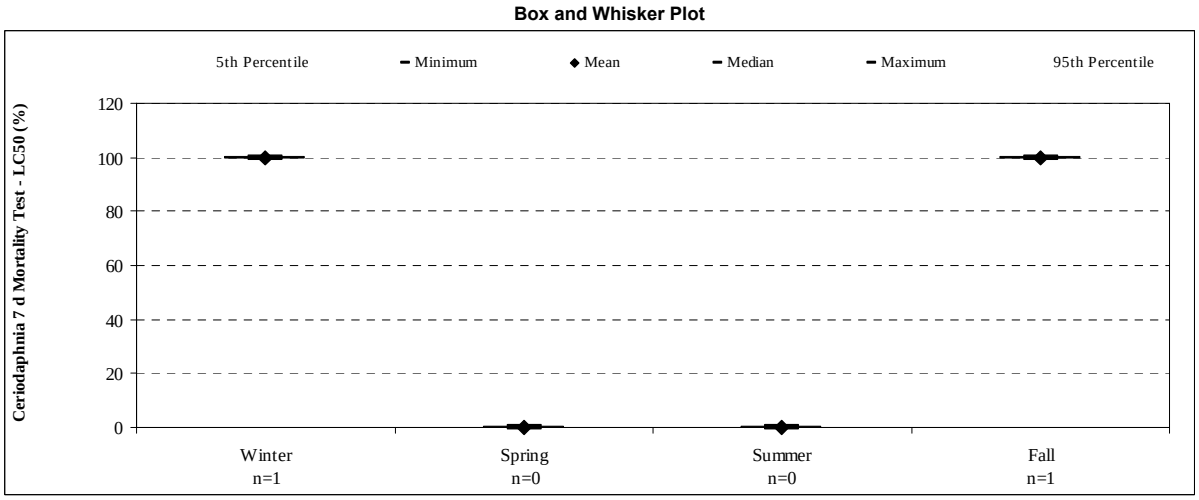


Figure G-2-4-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Jackpine Creek



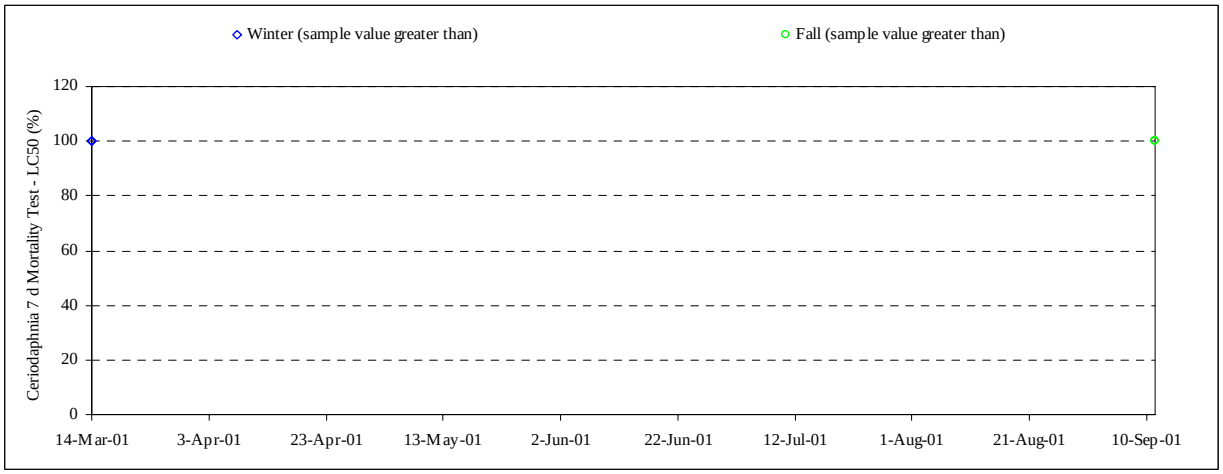
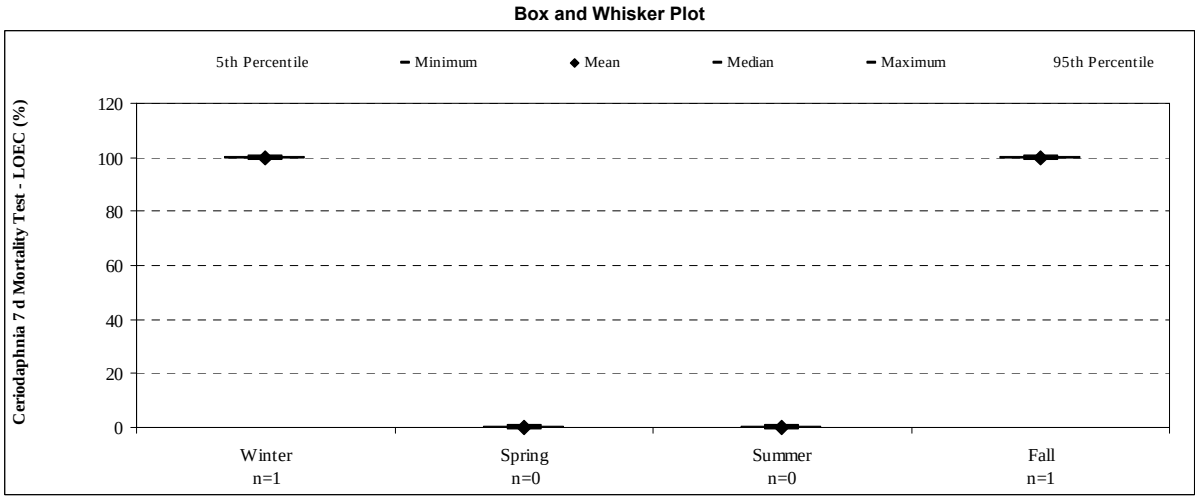


Figure G-2-4-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Jackpine Creek



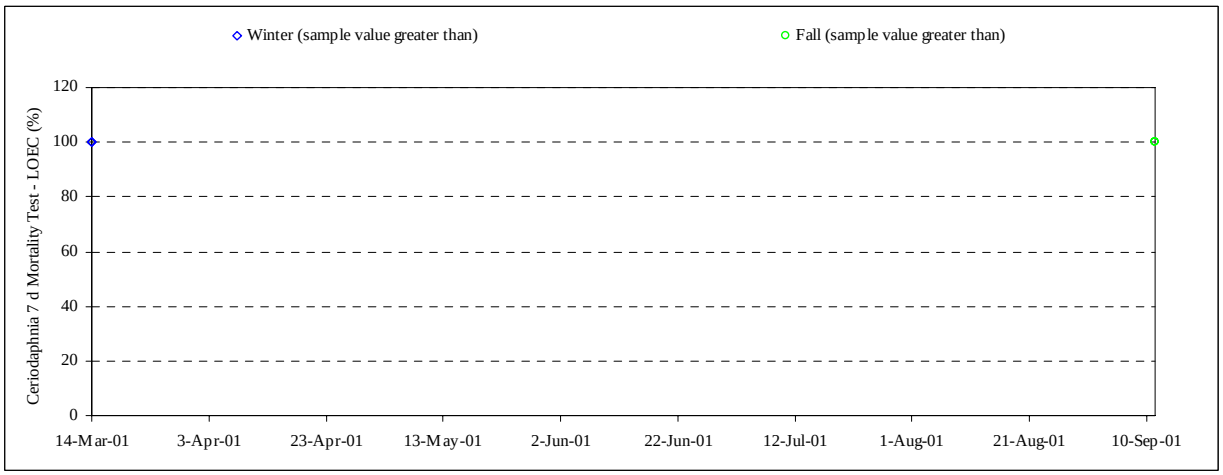
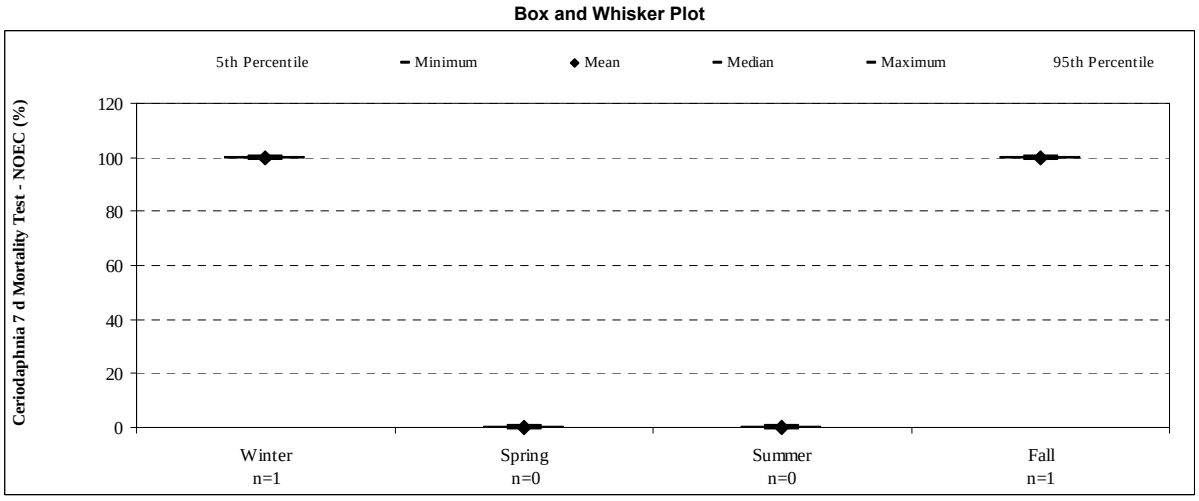


Figure G-2-4-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Jackpine Creek



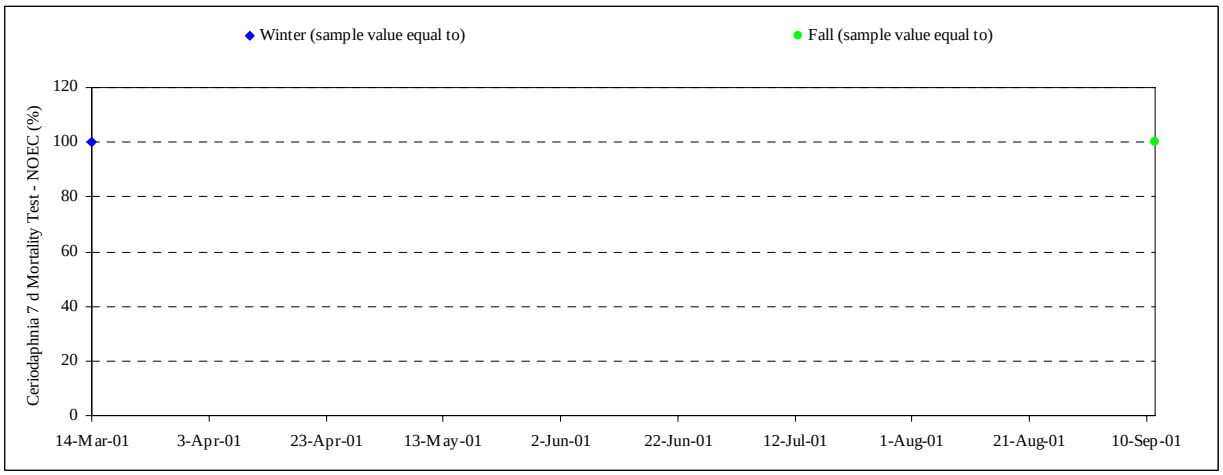
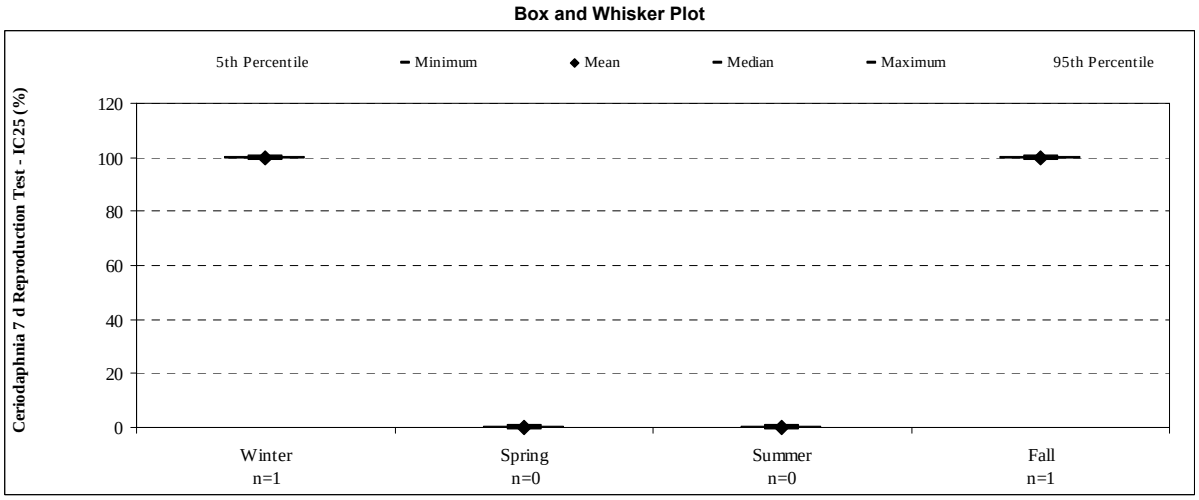


Figure G-2-4-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Jackpine Creek



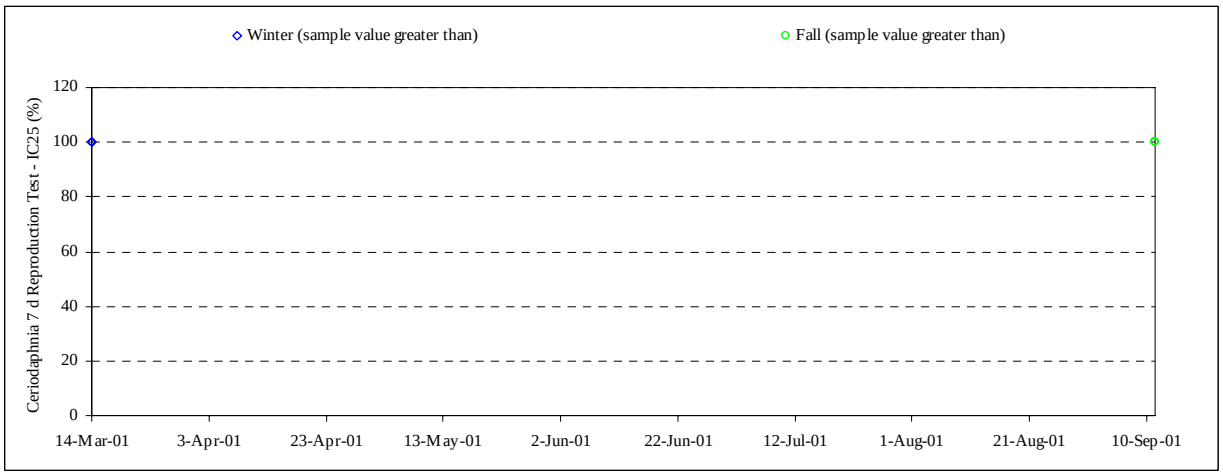
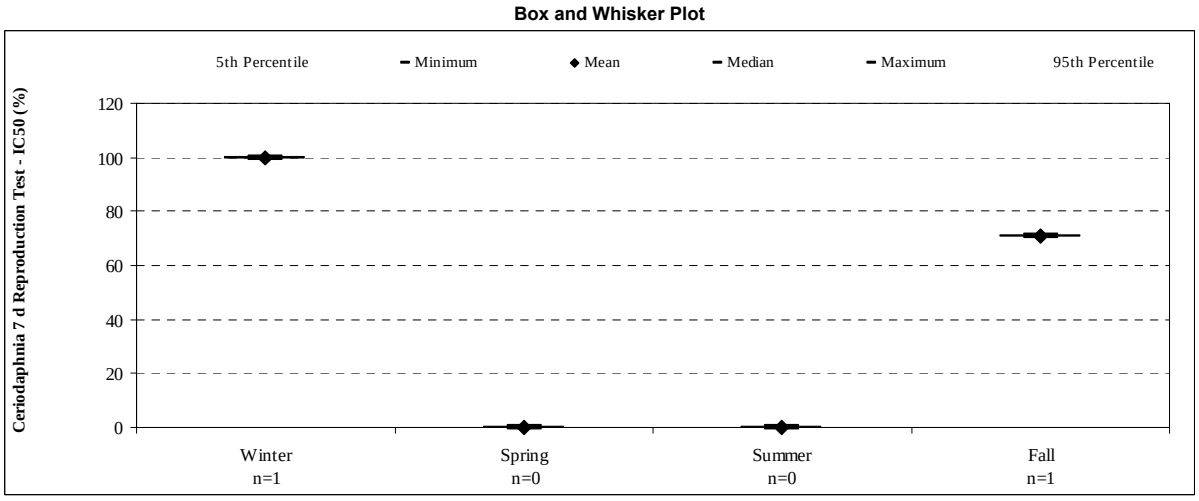


Figure G-2-4-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Jackpine Creek



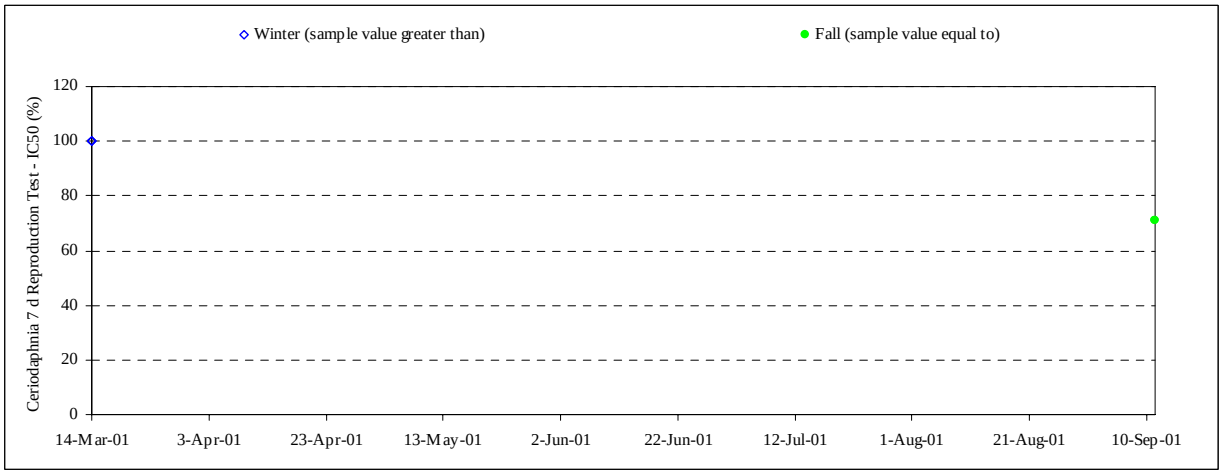
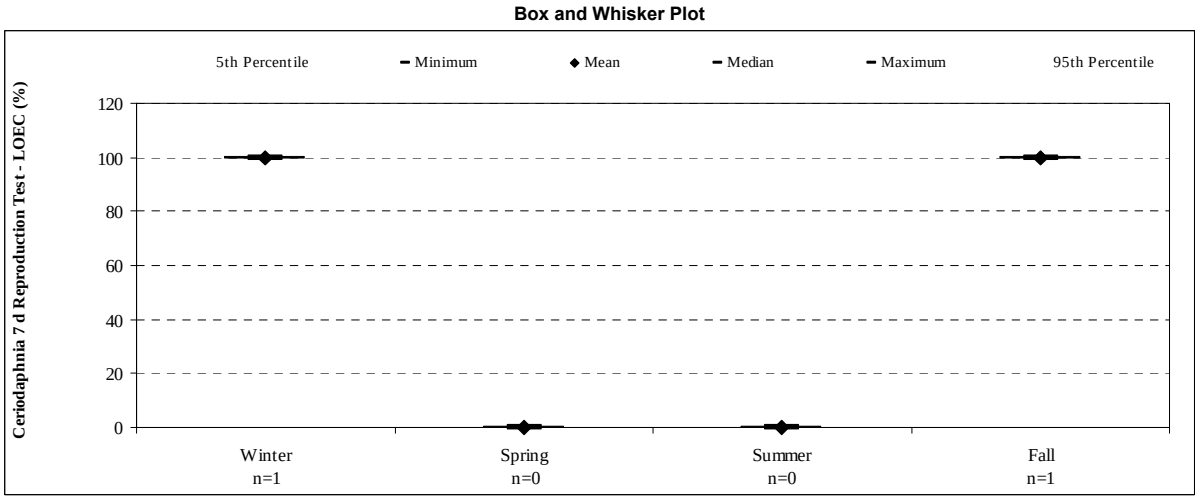


Figure G-2-4-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Jackpine Creek



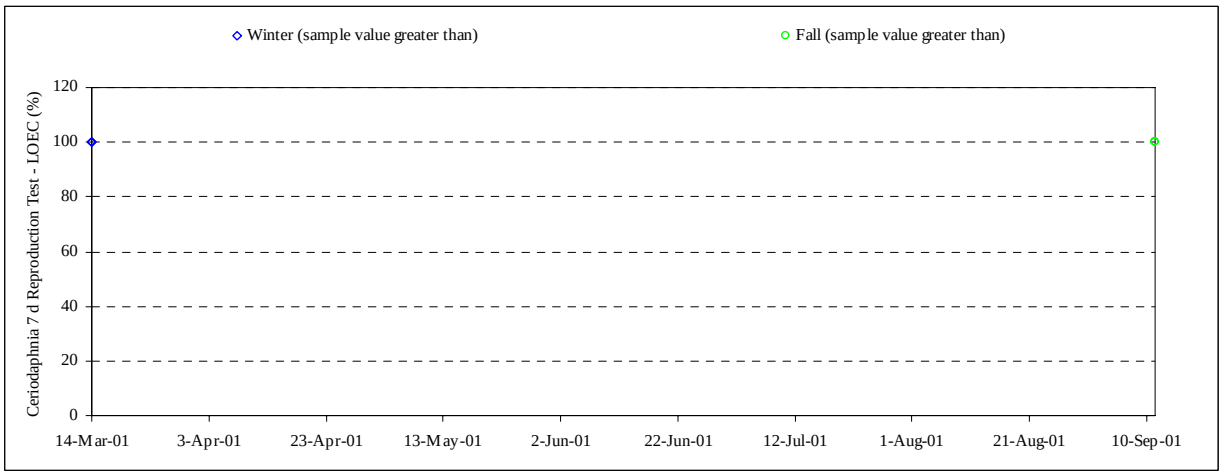
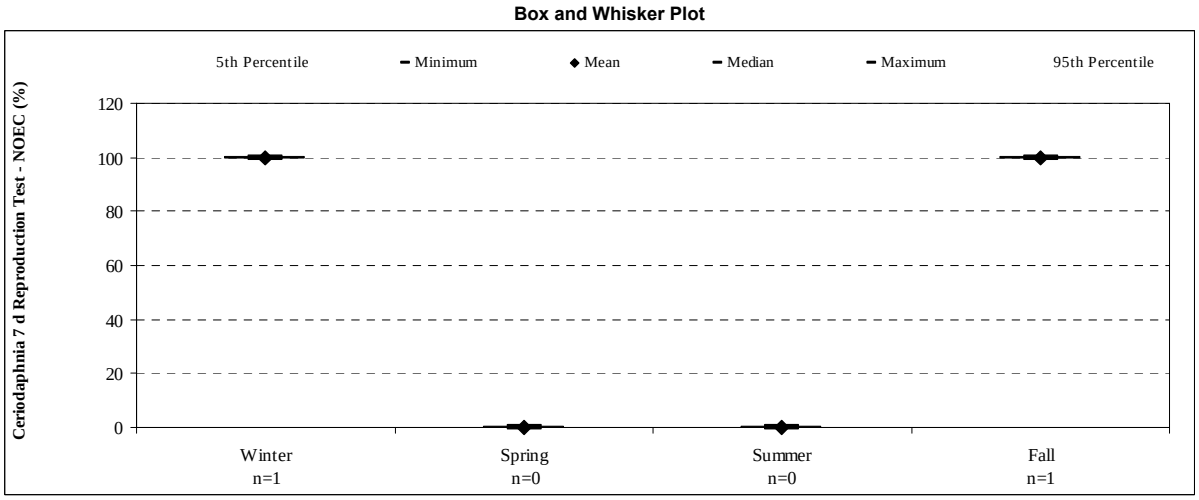


Figure G-2-4-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Jackpine Creek



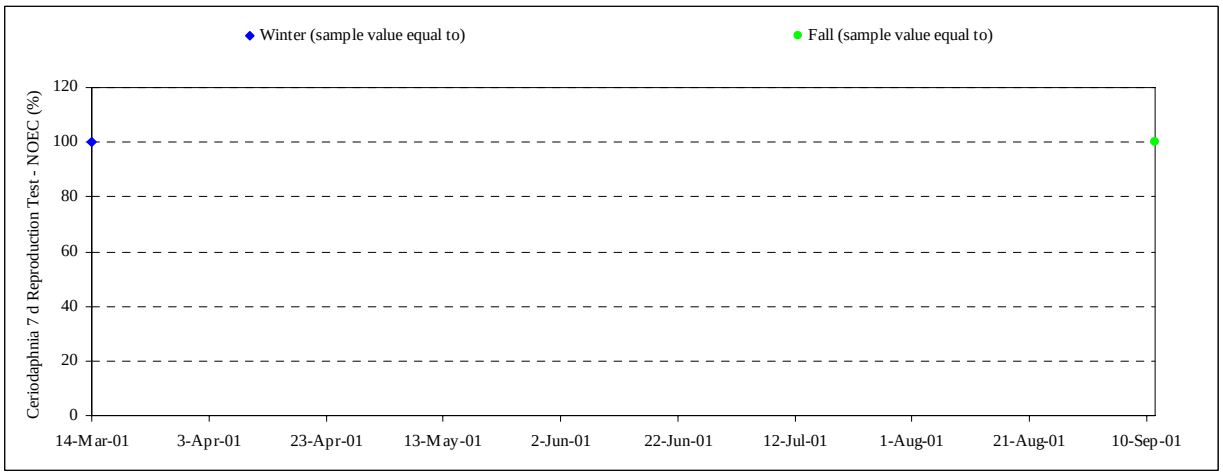


Figure G-2-4-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Jackpine Creek

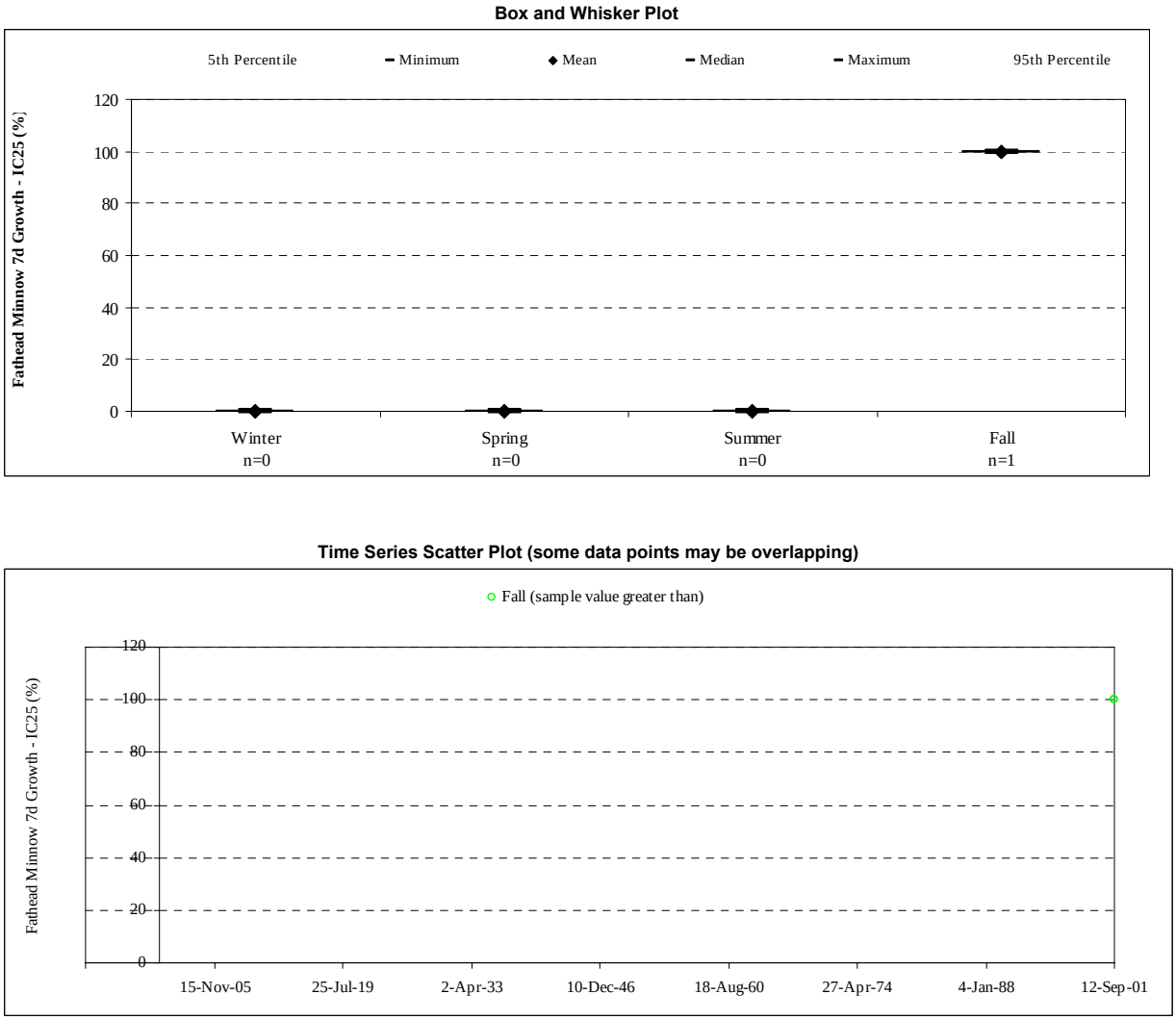
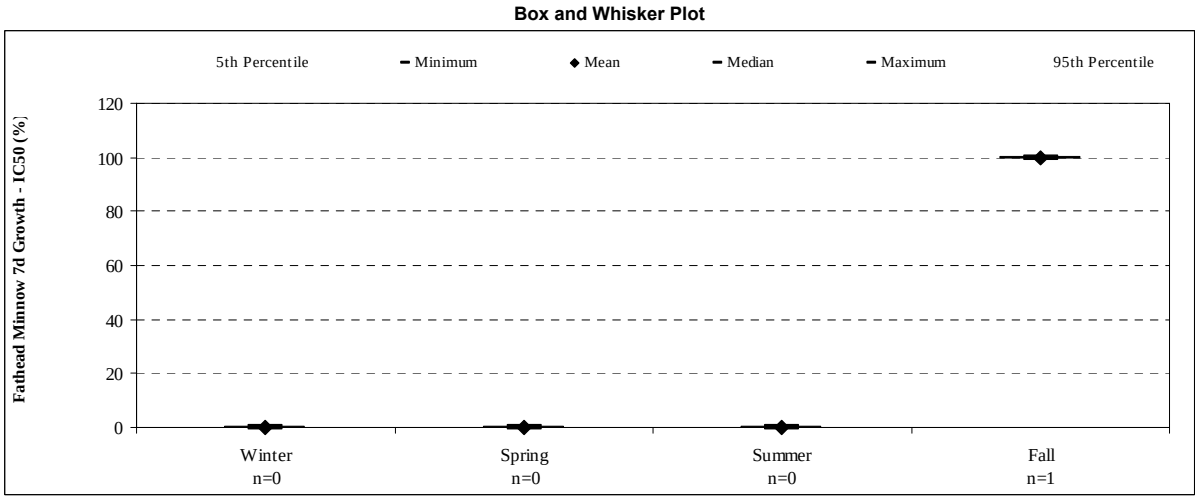


Figure G-2-4-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Jackpine Creek



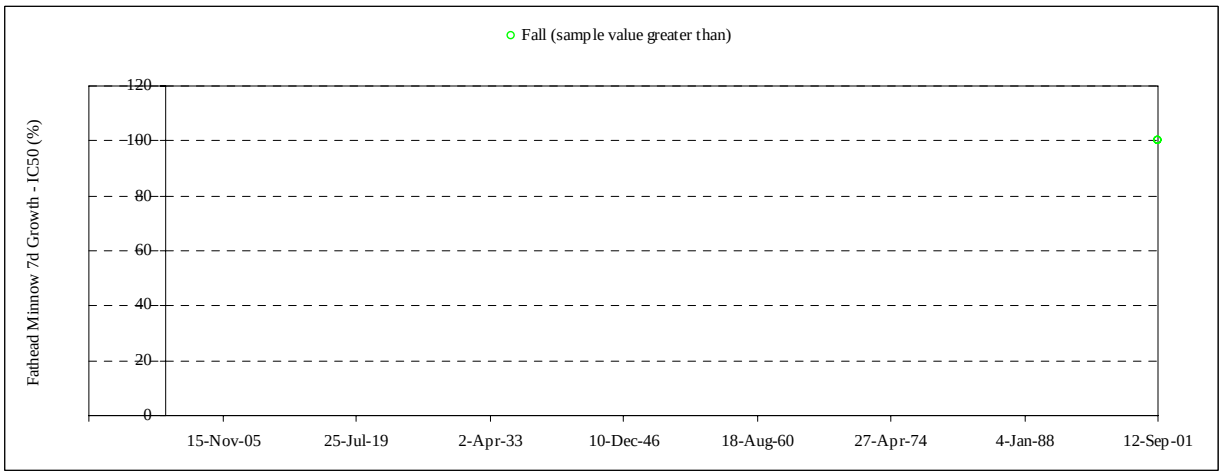
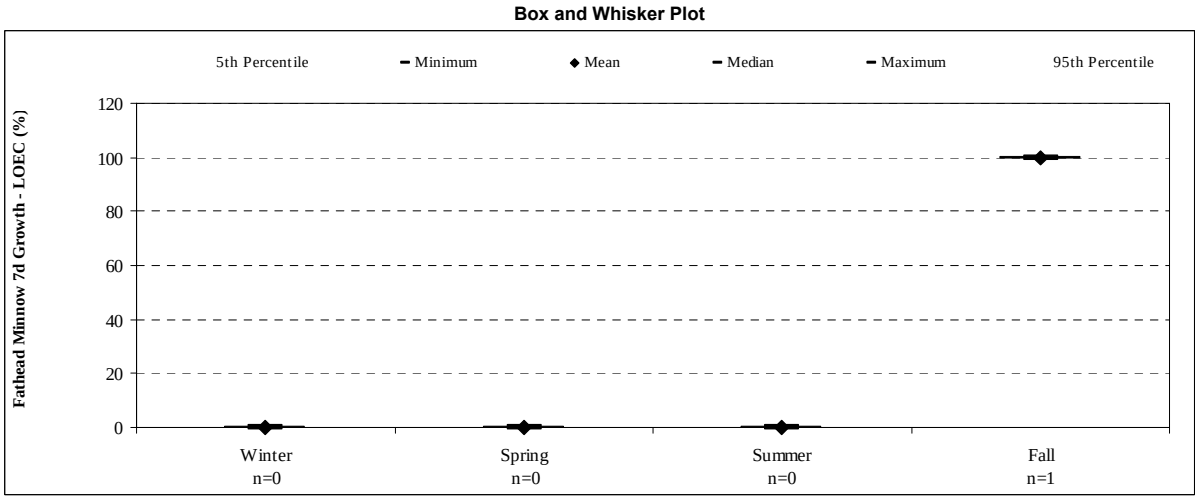


Figure G-2-4-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Jackpine Creek



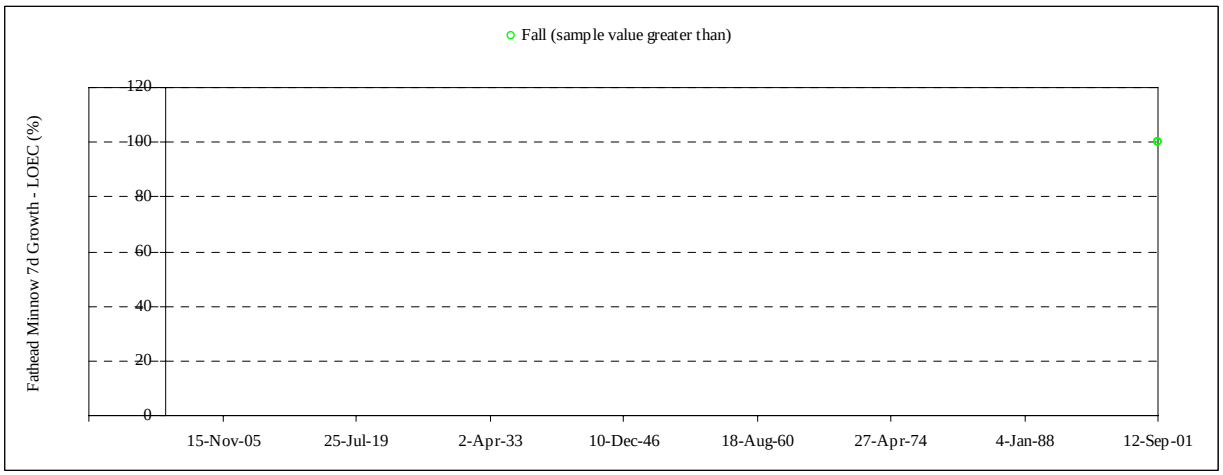
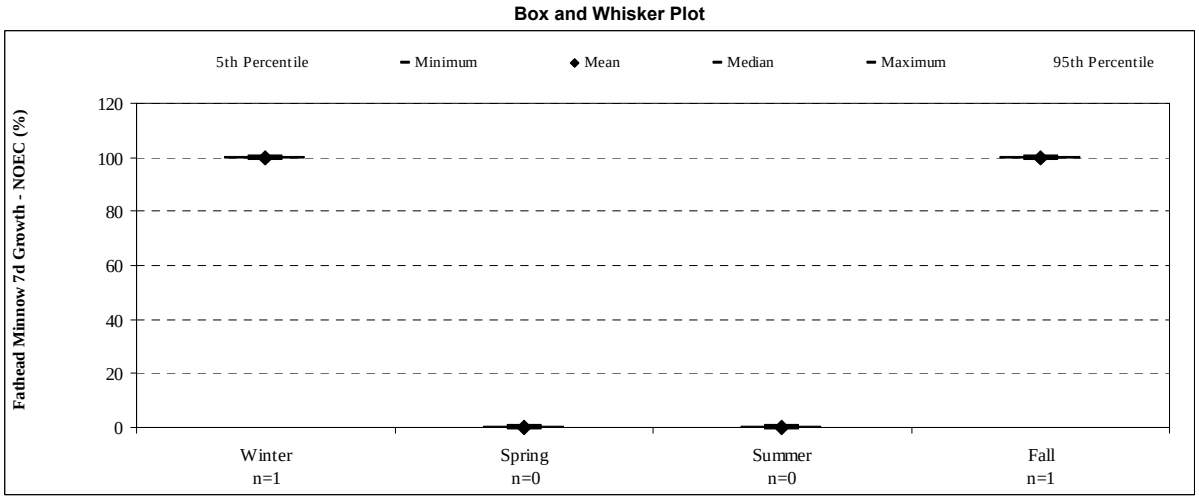


Figure G-2-4-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Jackpine Creek



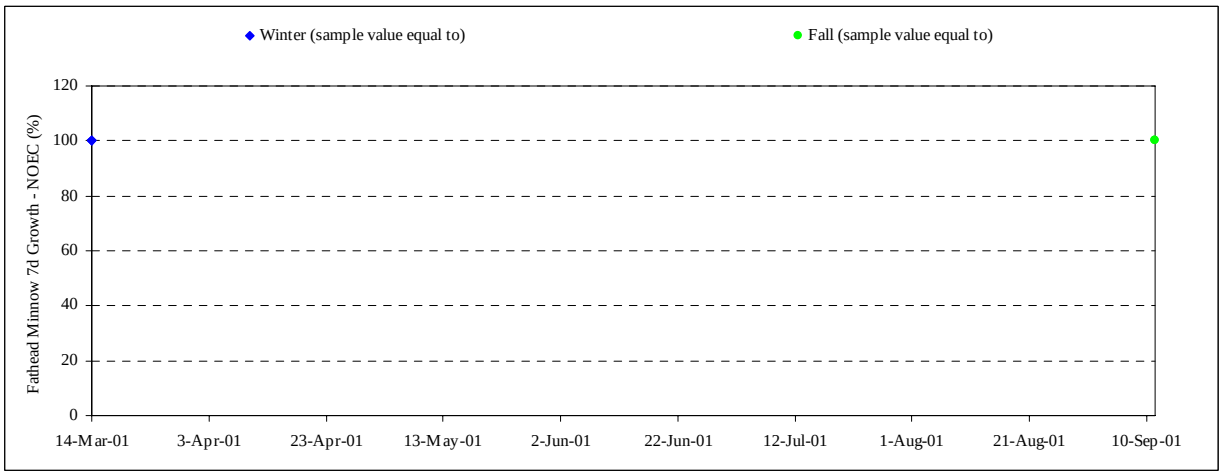


Figure G-2-4-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Jackpine Creek

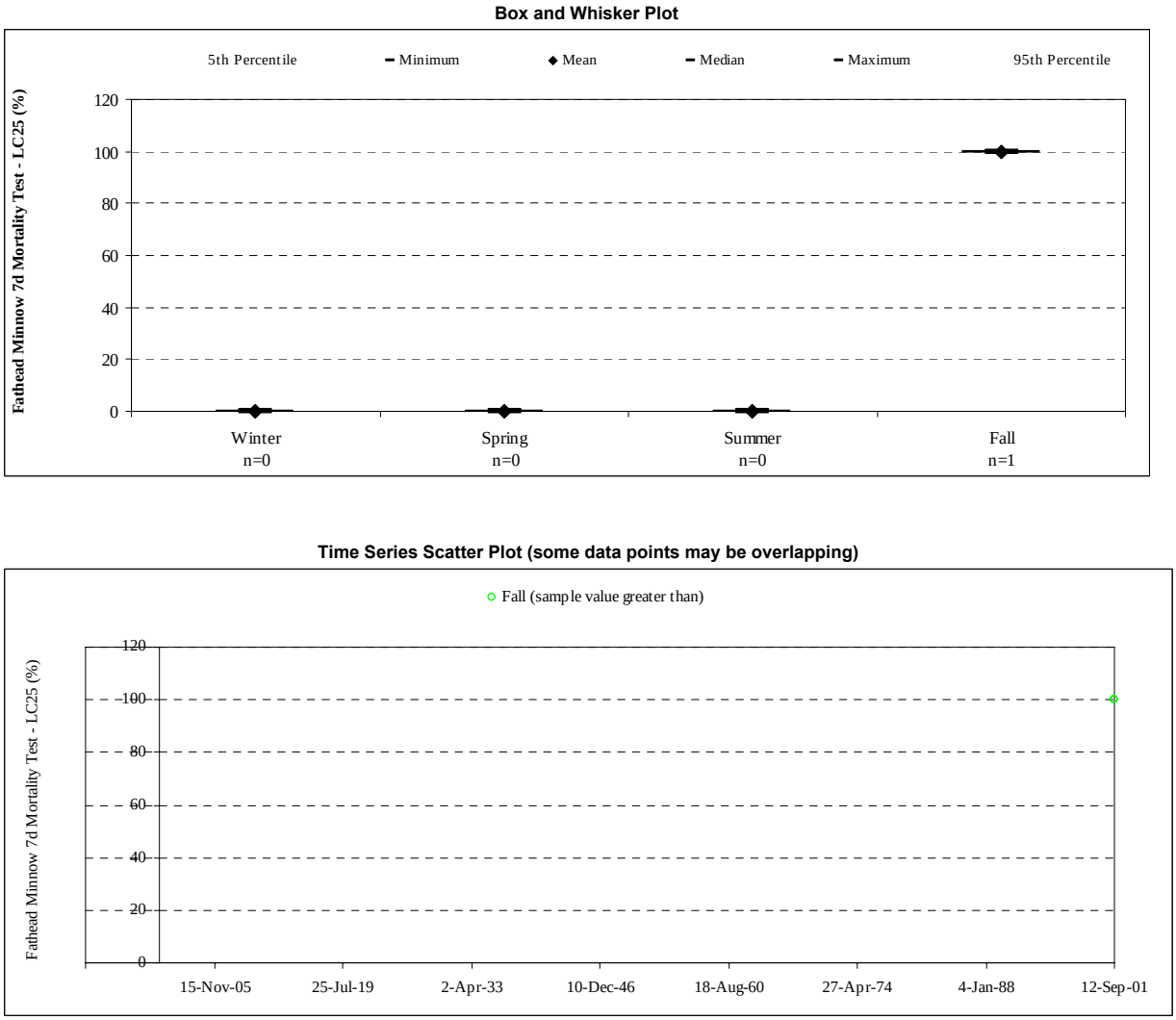
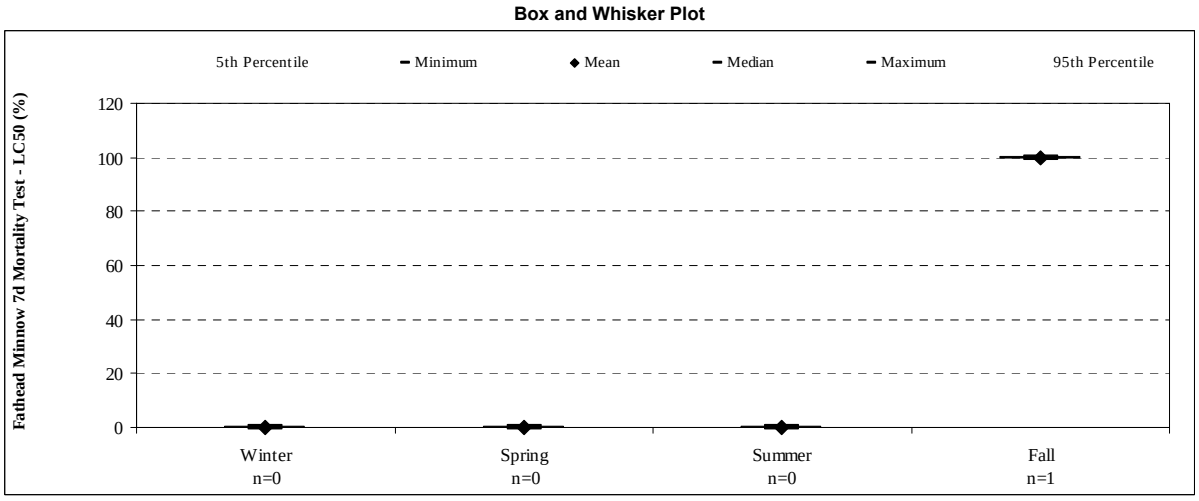


Figure G-2-4-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Jackpine Creek



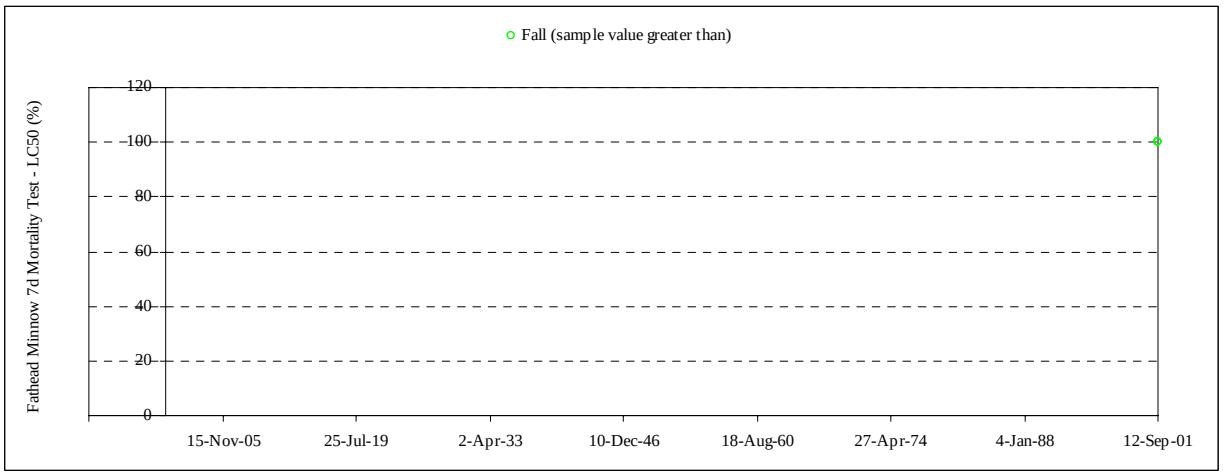


Figure G-2-4-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Jackpine Creek

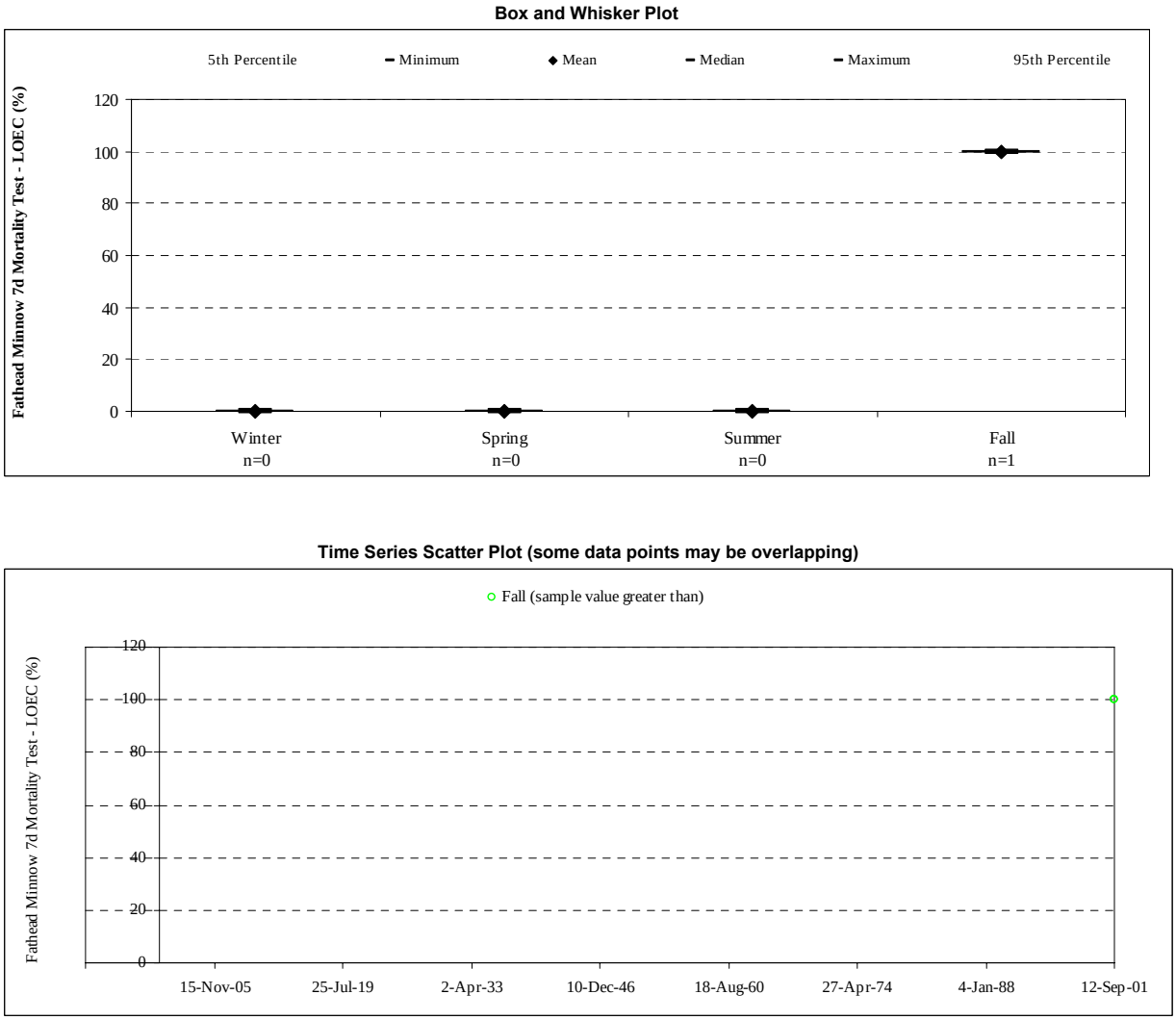
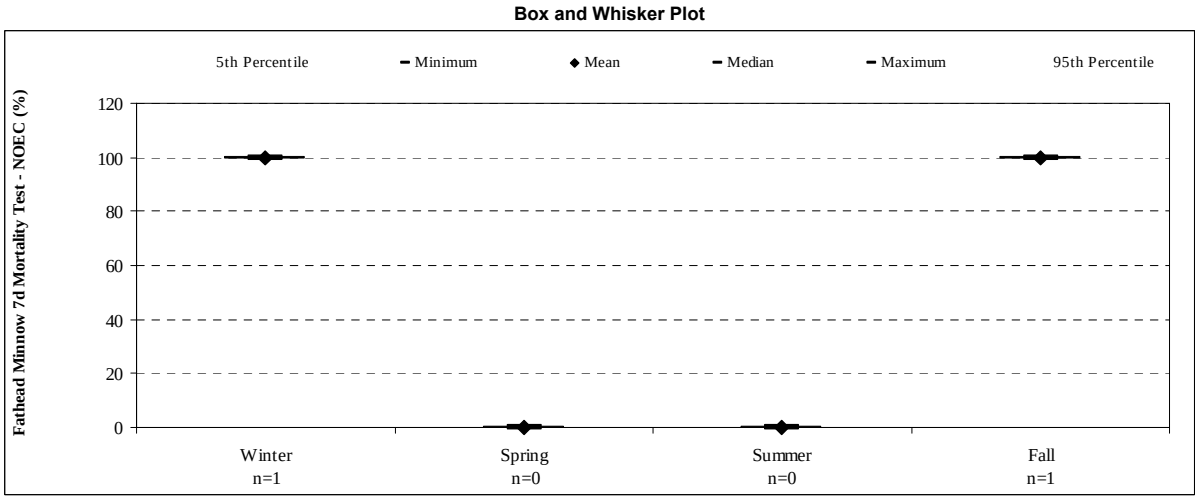


Figure G-2-4-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Jackpine Creek



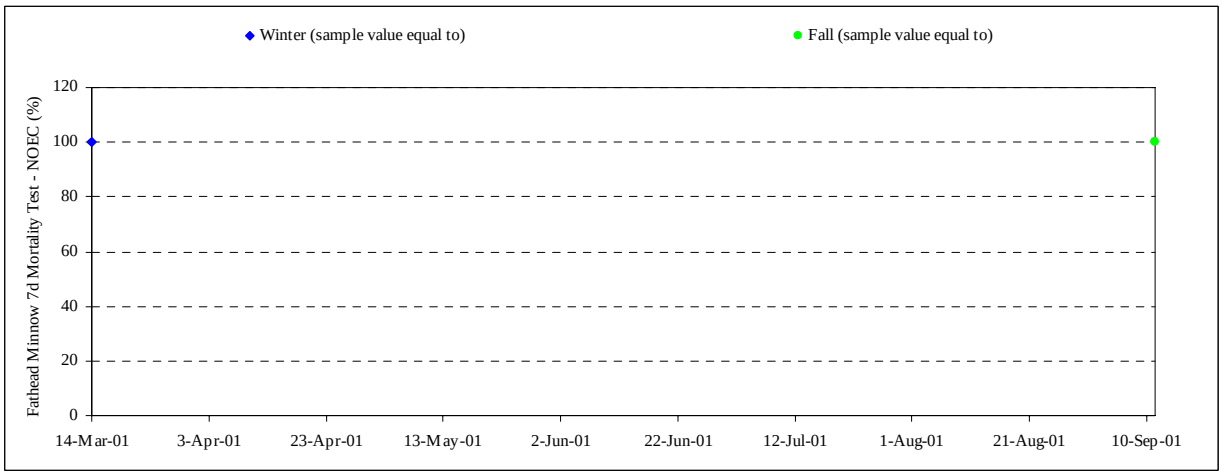
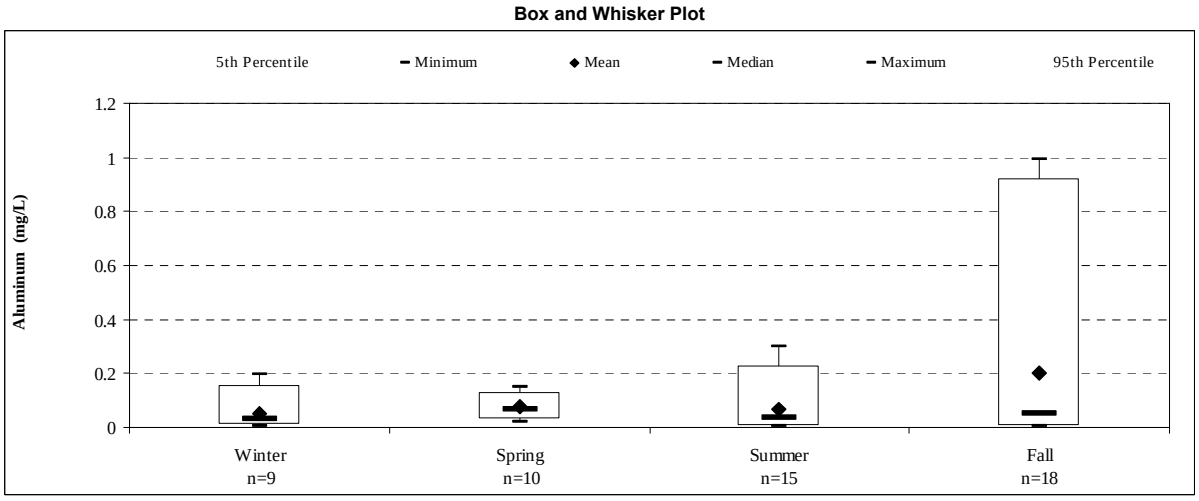


Figure G-2-4-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Jackpine Creek



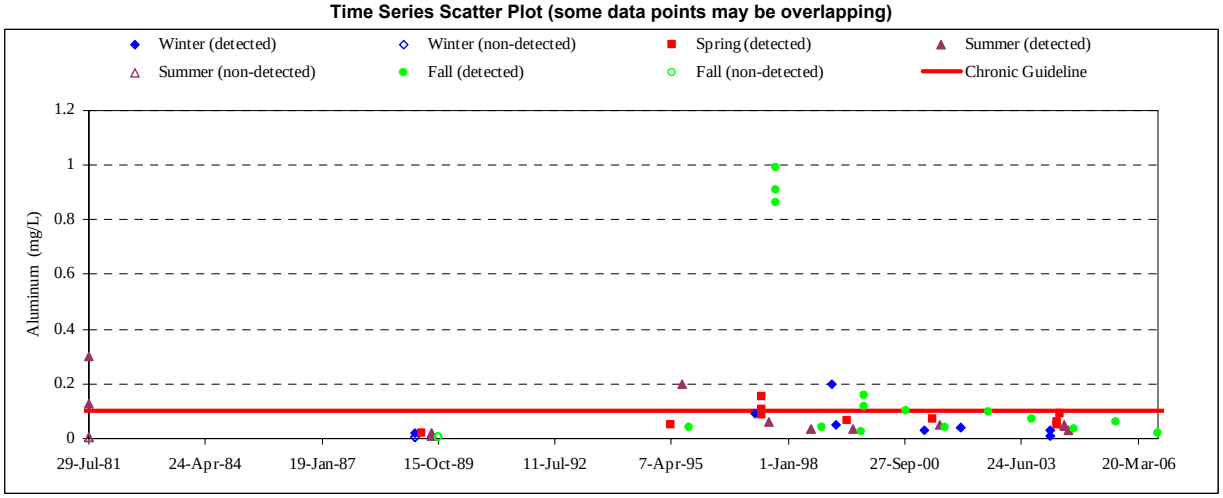


Figure G-2-4-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Jackpine Creek

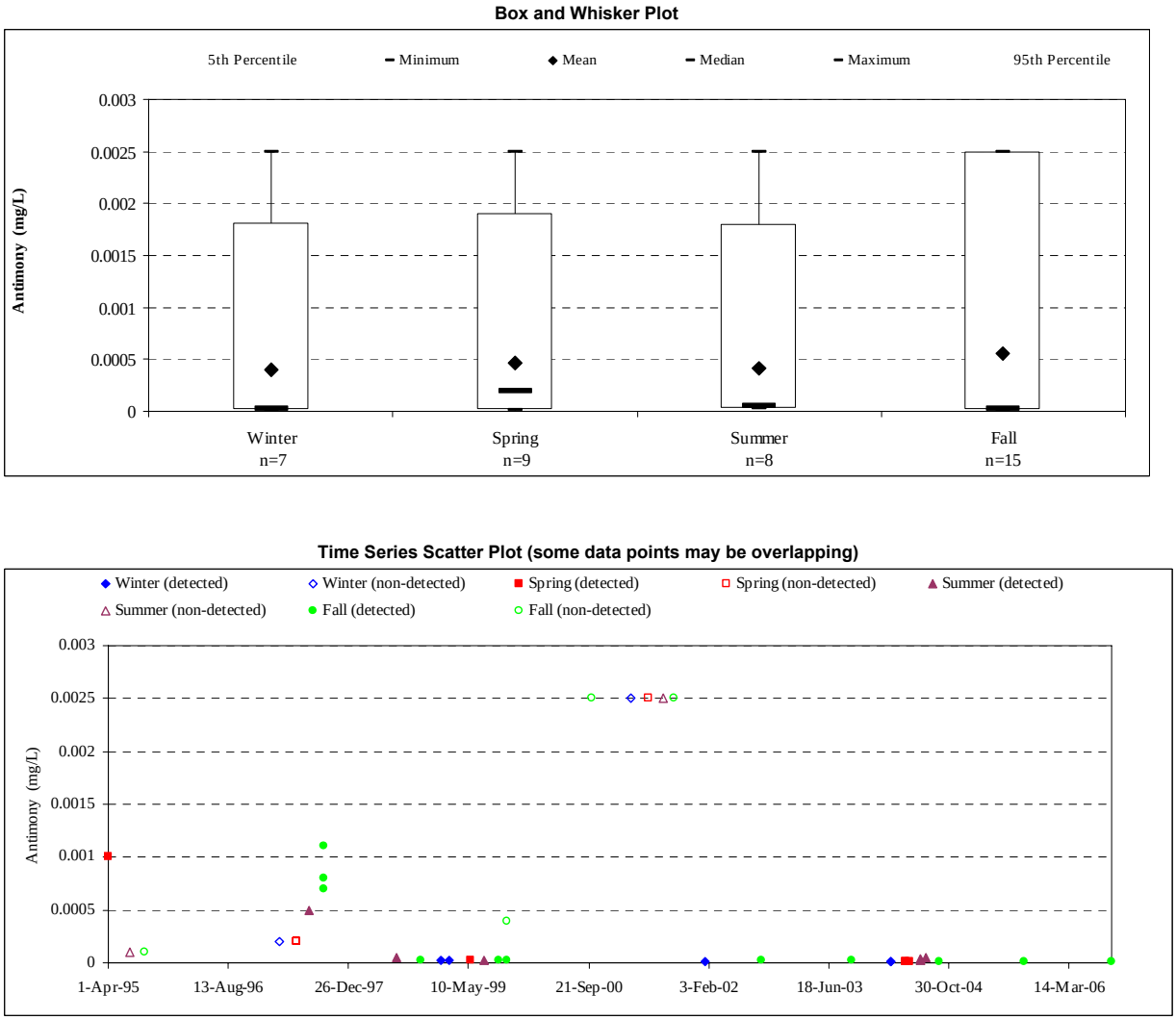
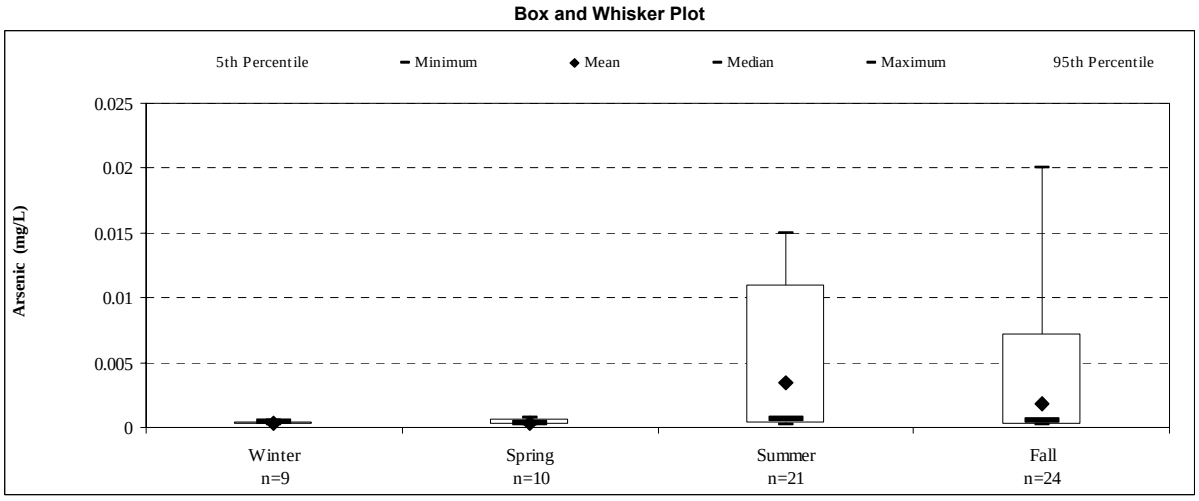


Figure G-2-4-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Jackpine Creek



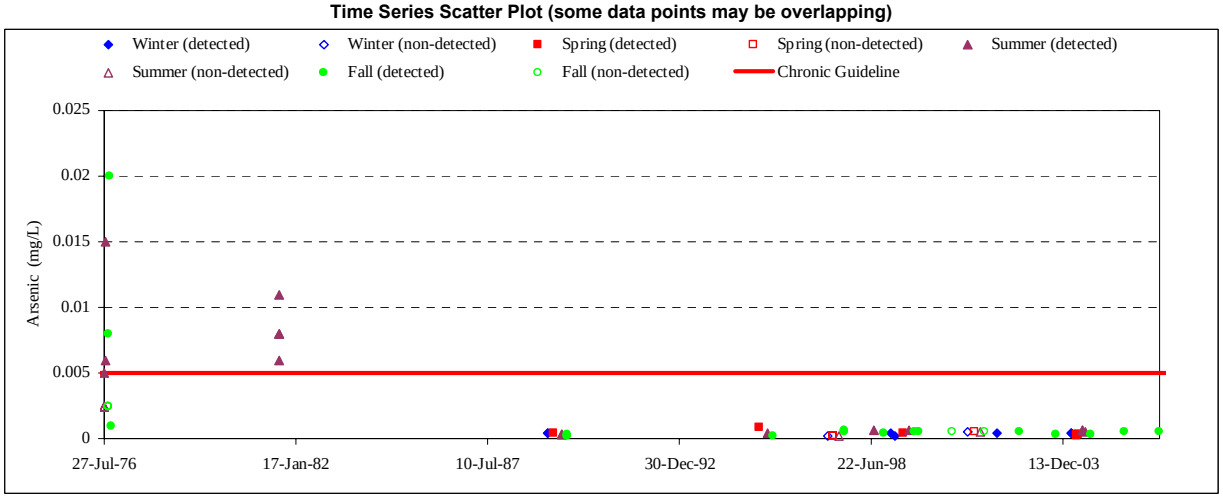
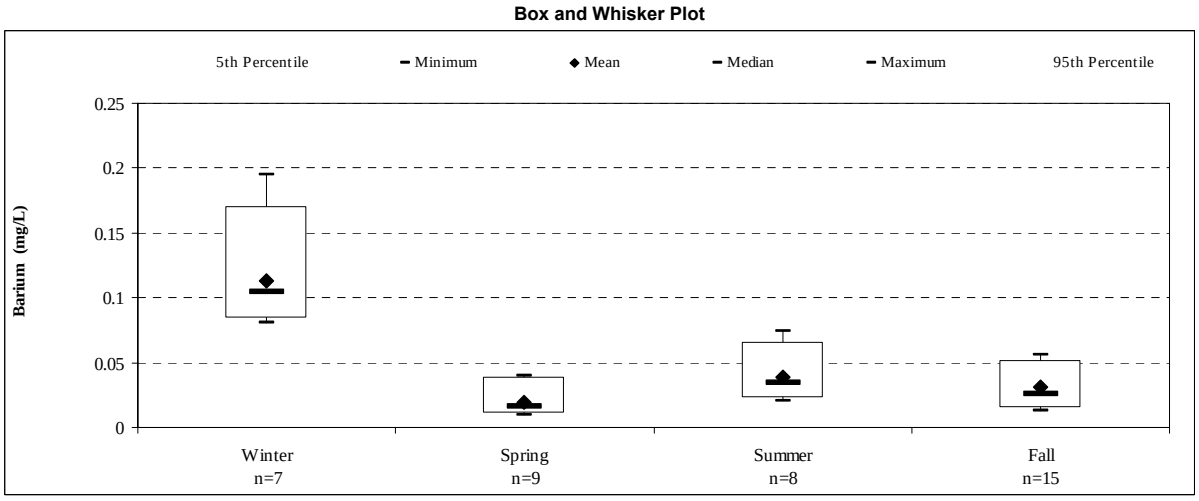


Figure G-2-4-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Jackpine Creek



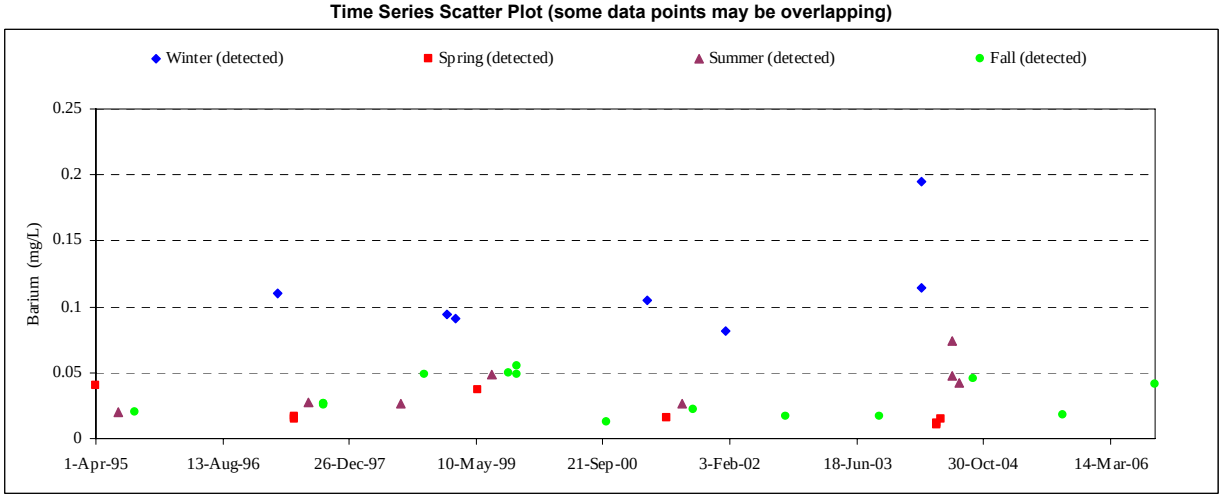
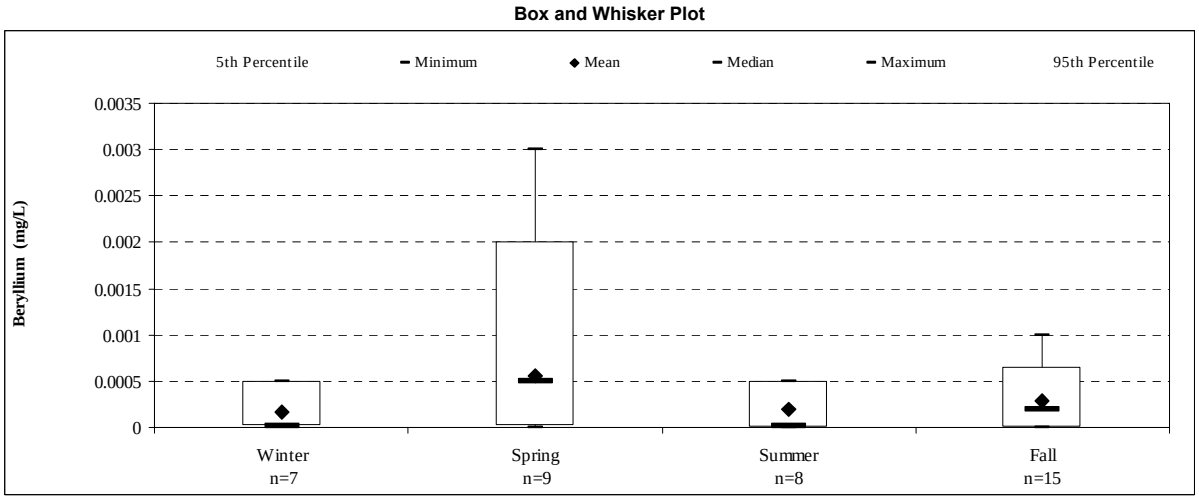


Figure G-2-4-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Jackpine Creek



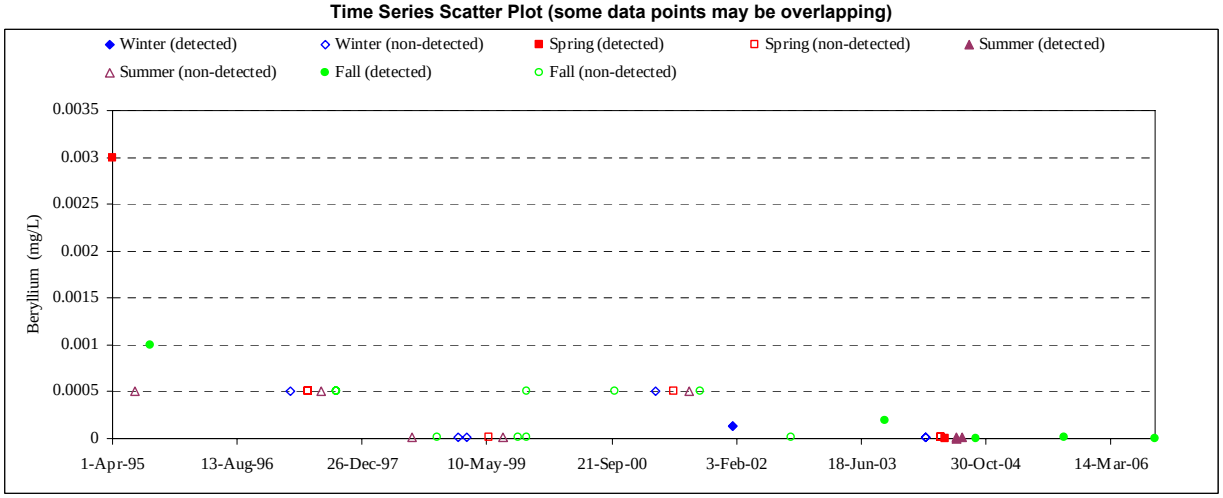
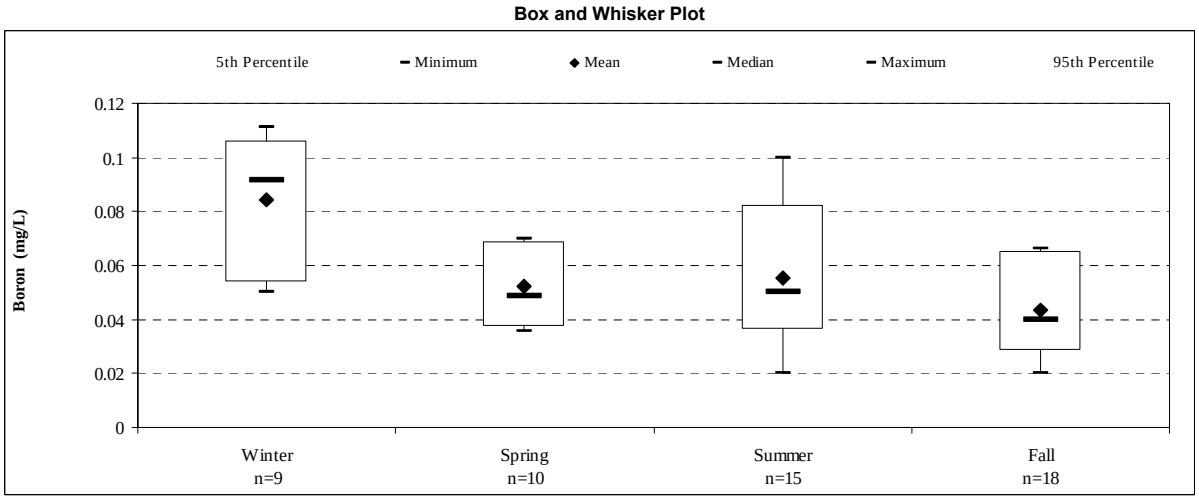


Figure G-2-4-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Jackpine Creek



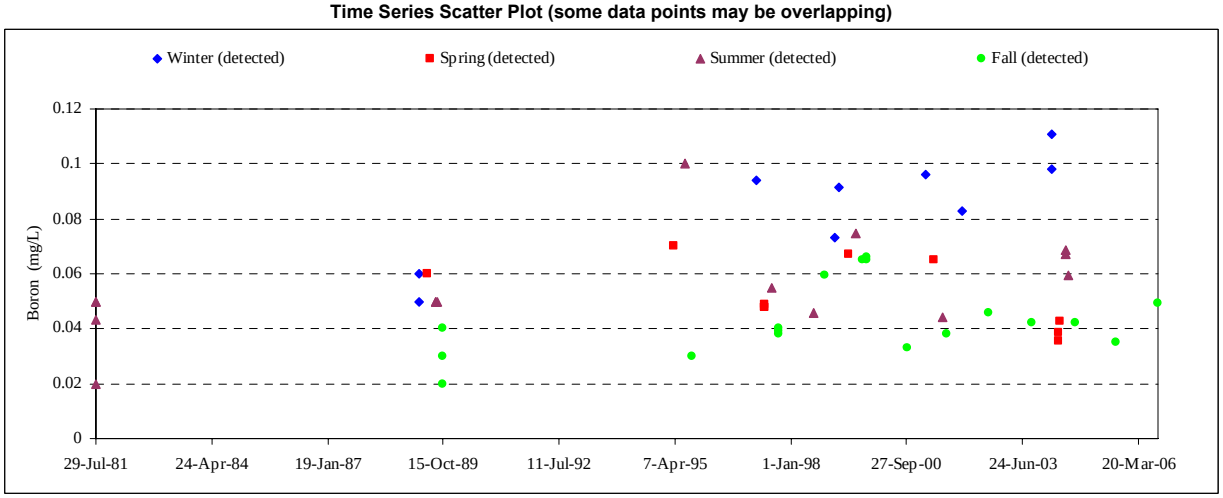
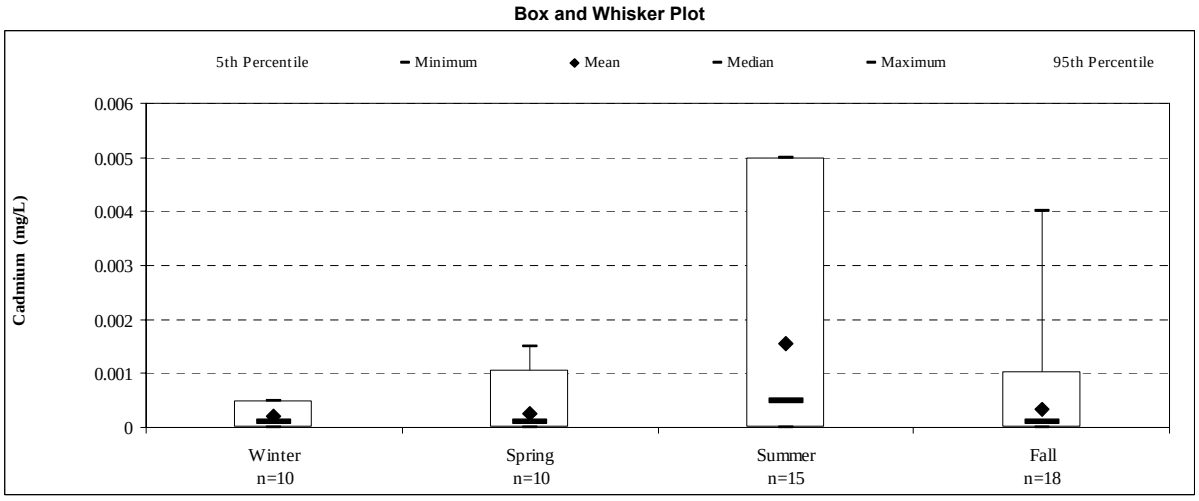


Figure G-2-4-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Jackpine Creek



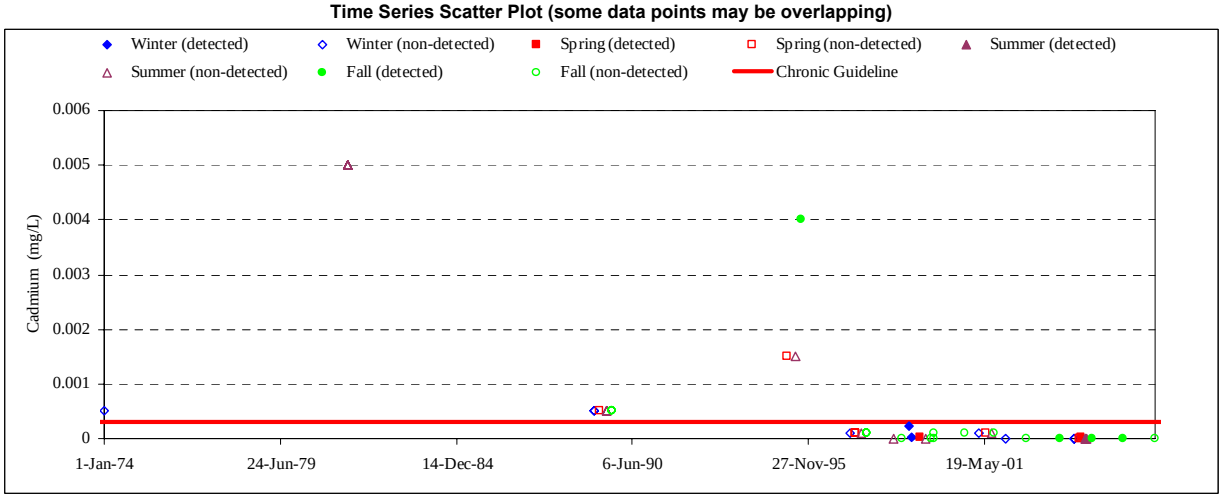
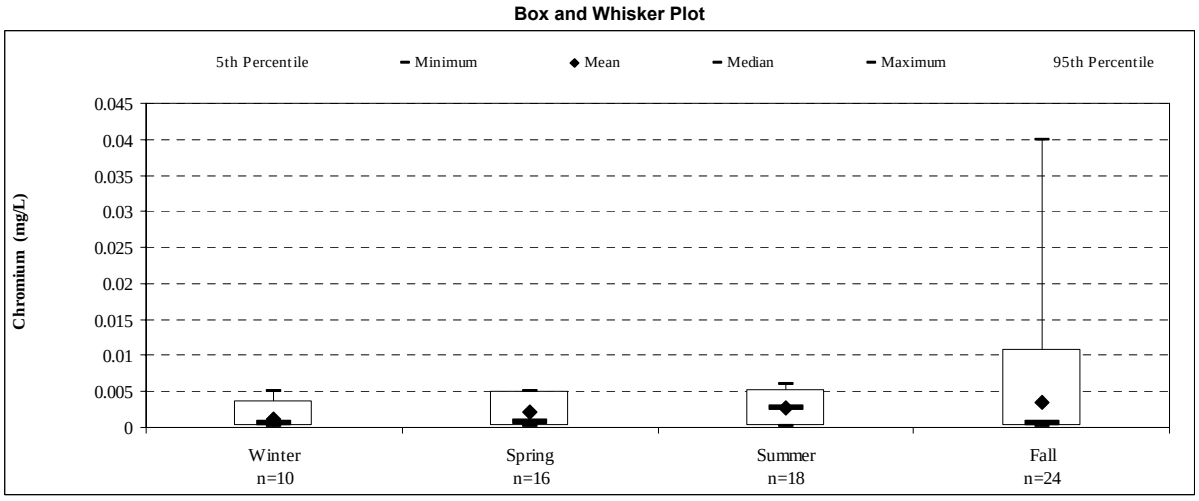


Figure G-2-4-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Jackpine Creek



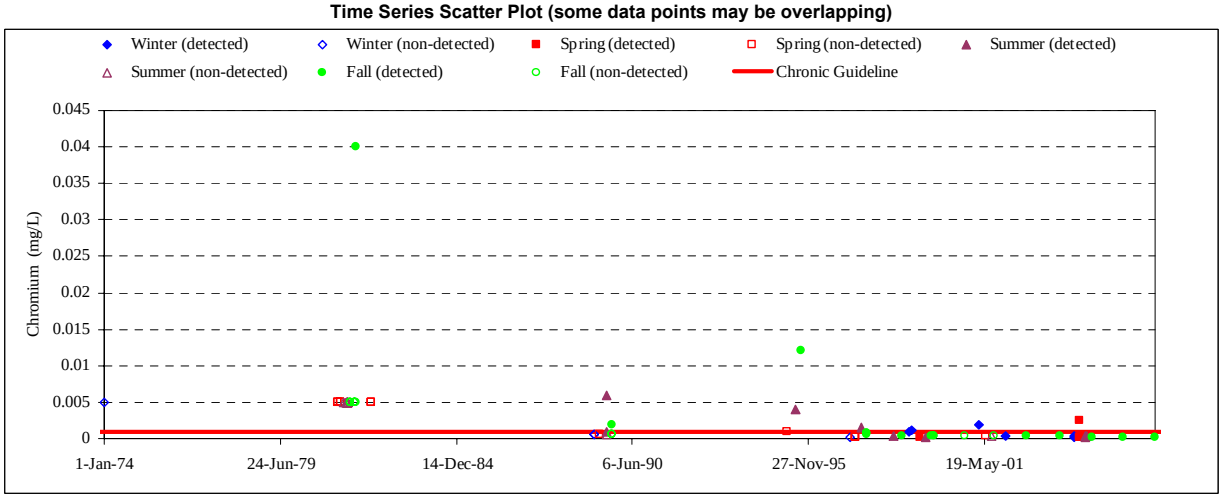
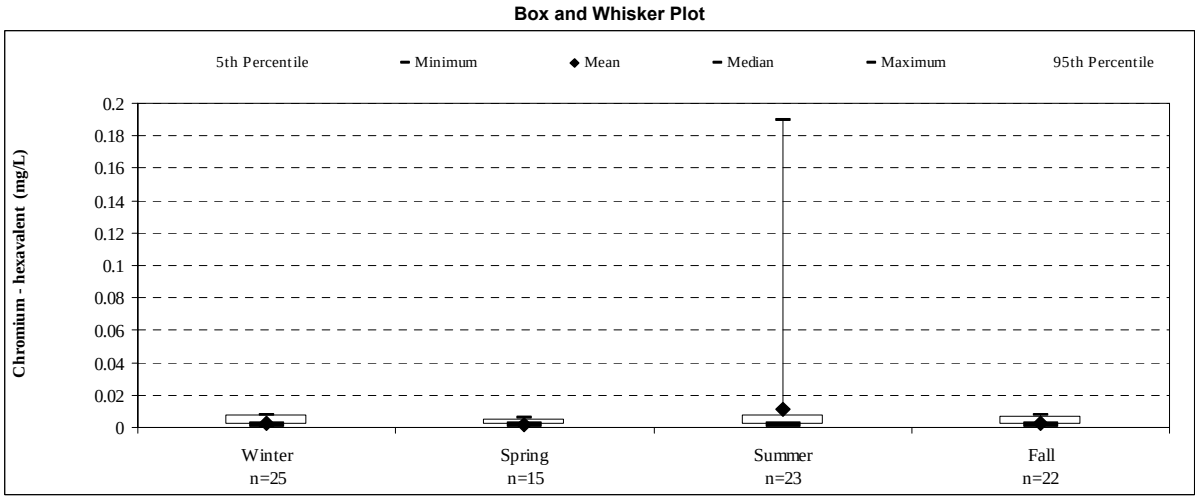


Figure G-2-4-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Jackpine Creek



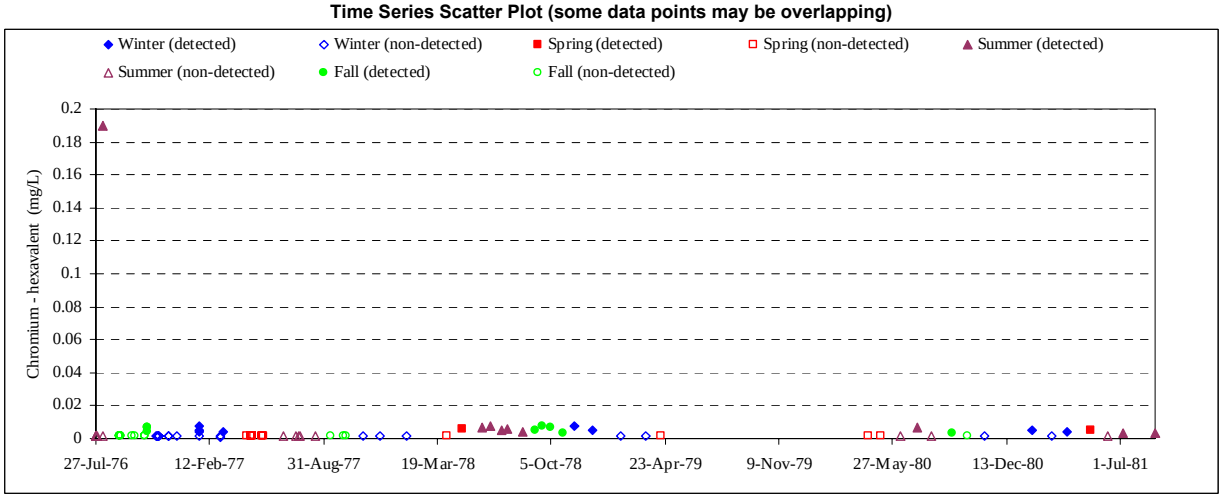
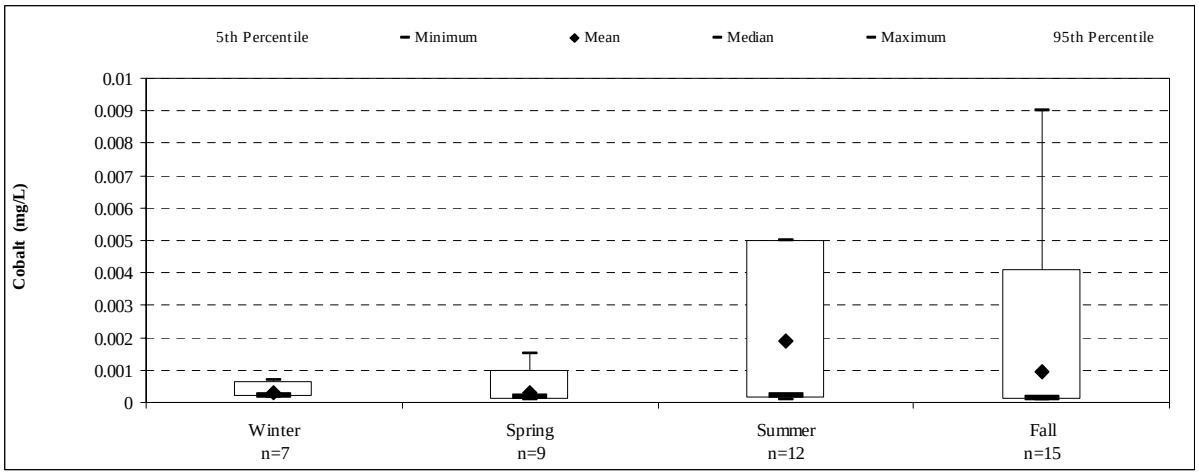


Figure G-2-4-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Jackpine Creek

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

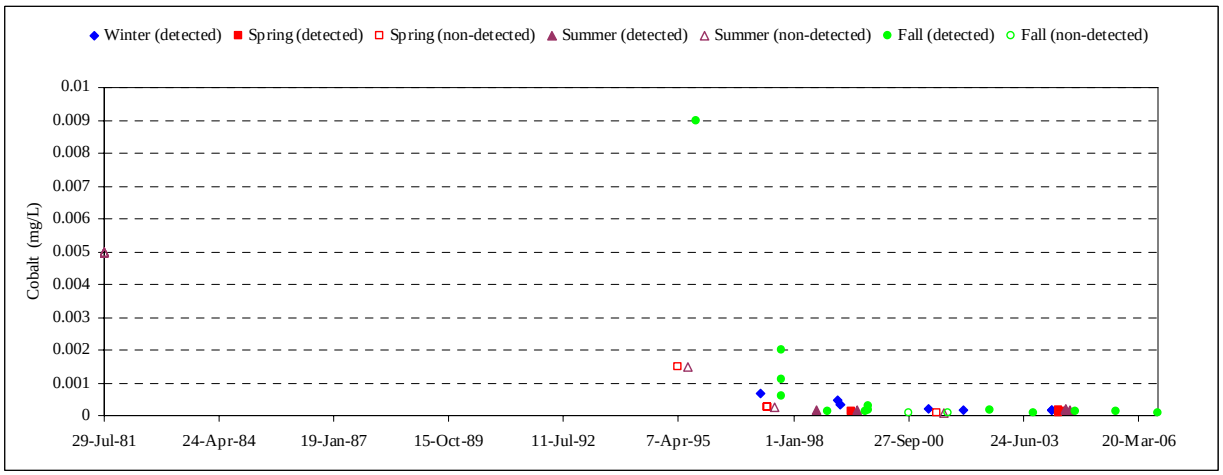
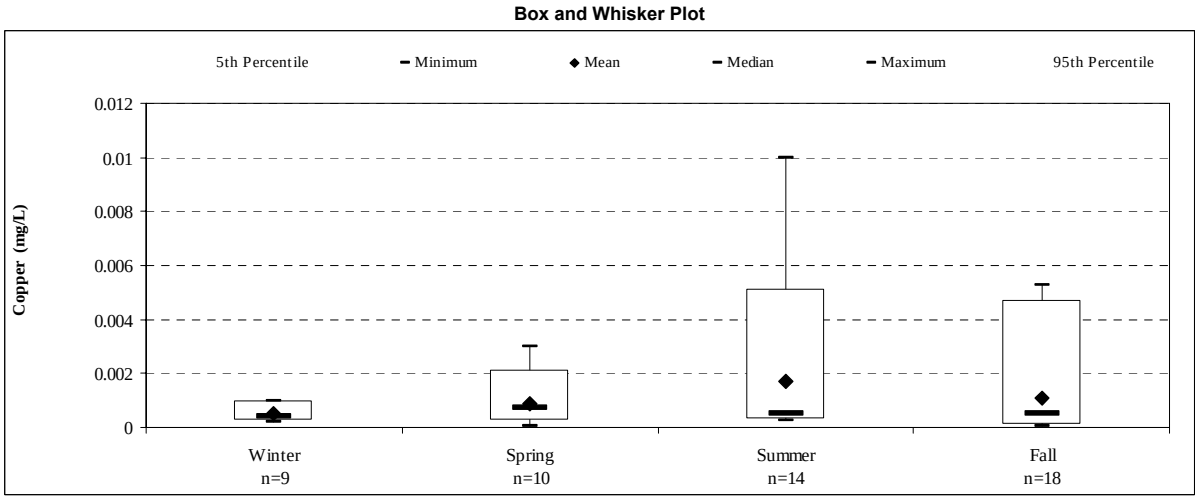


Figure G-2-4-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Jackpine Creek



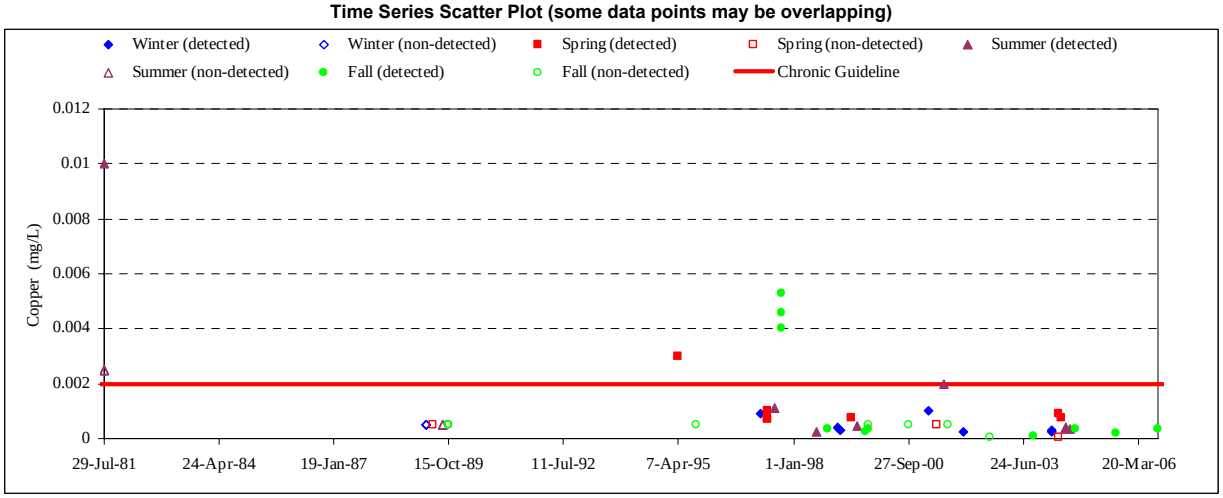
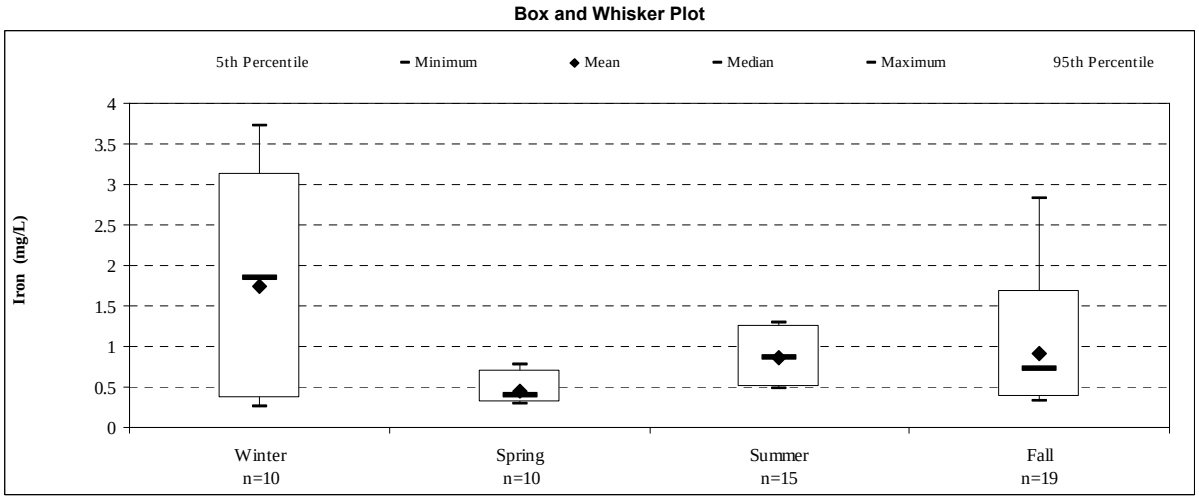


Figure G-2-4-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Jackpine Creek



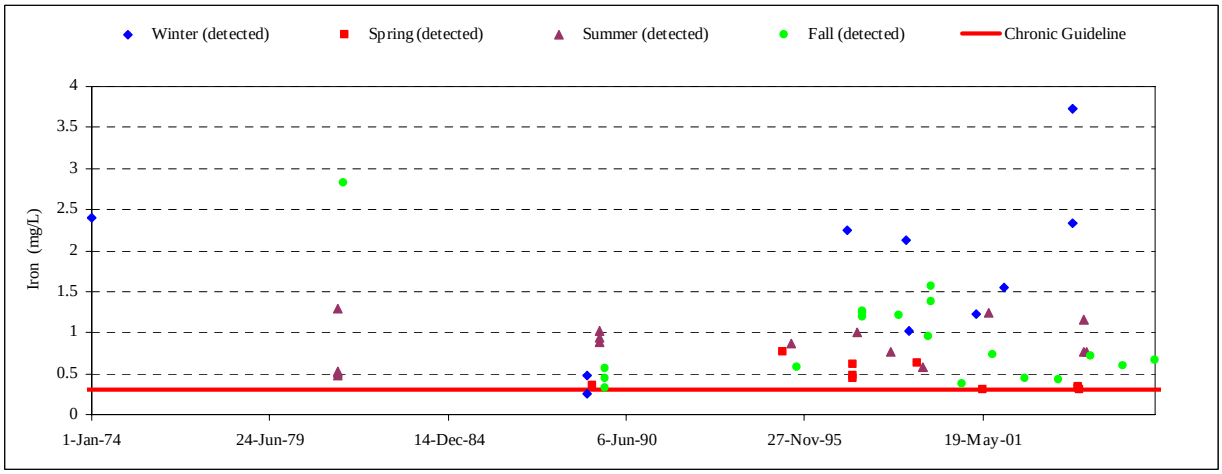
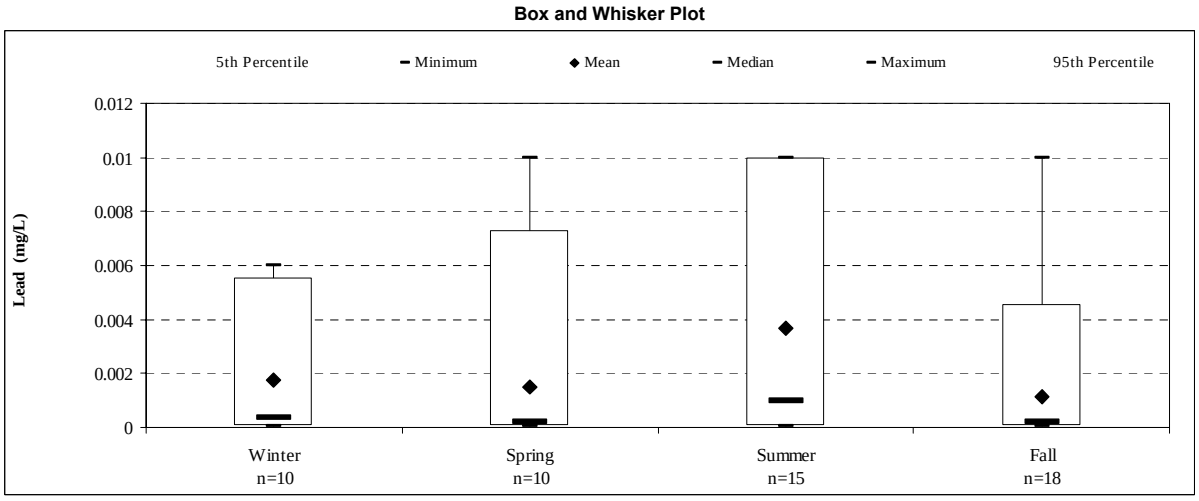


Figure G-2-4-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Jackpine Creek



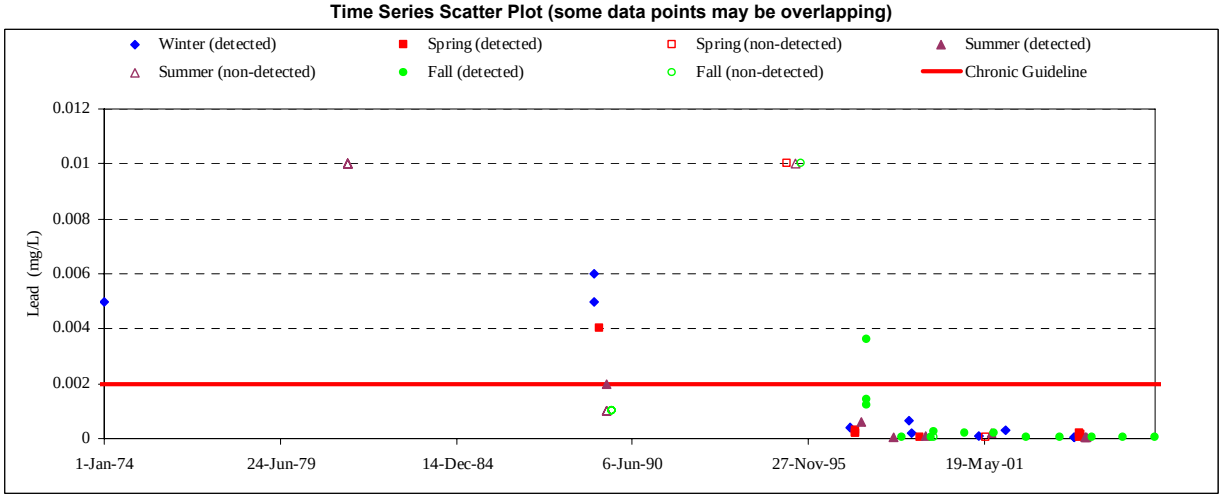
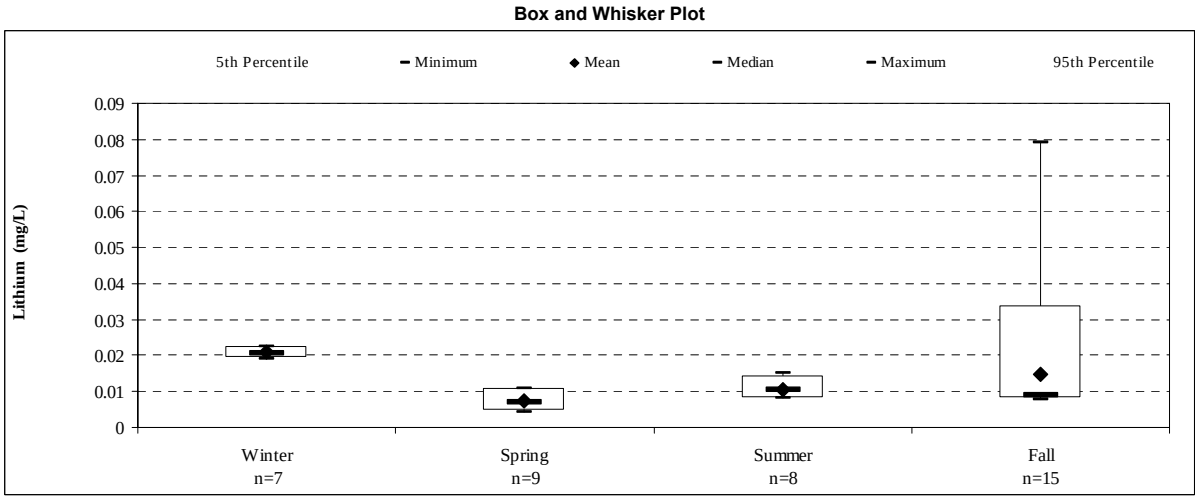


Figure G-2-4-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Jackpine Creek



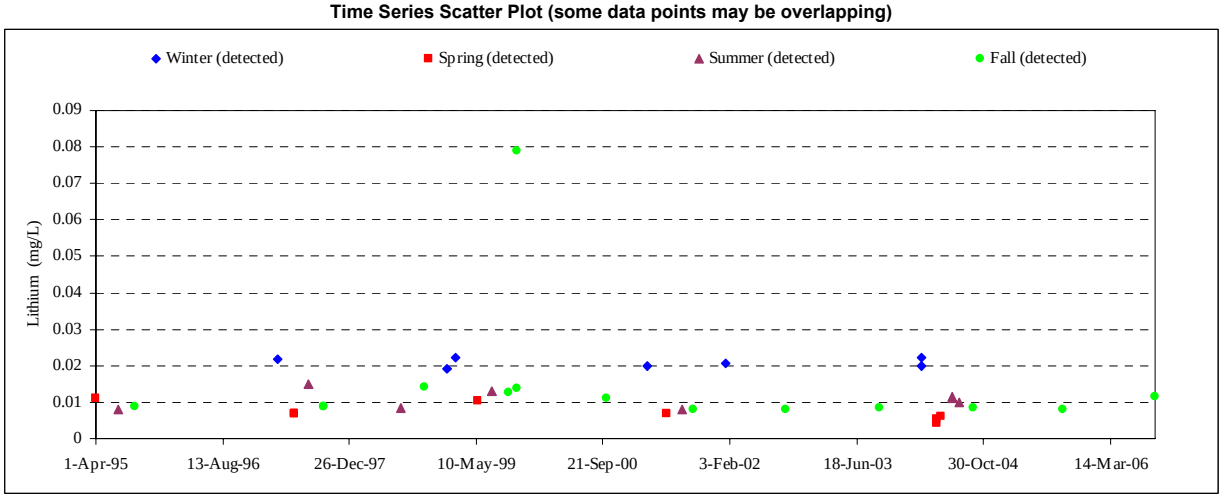
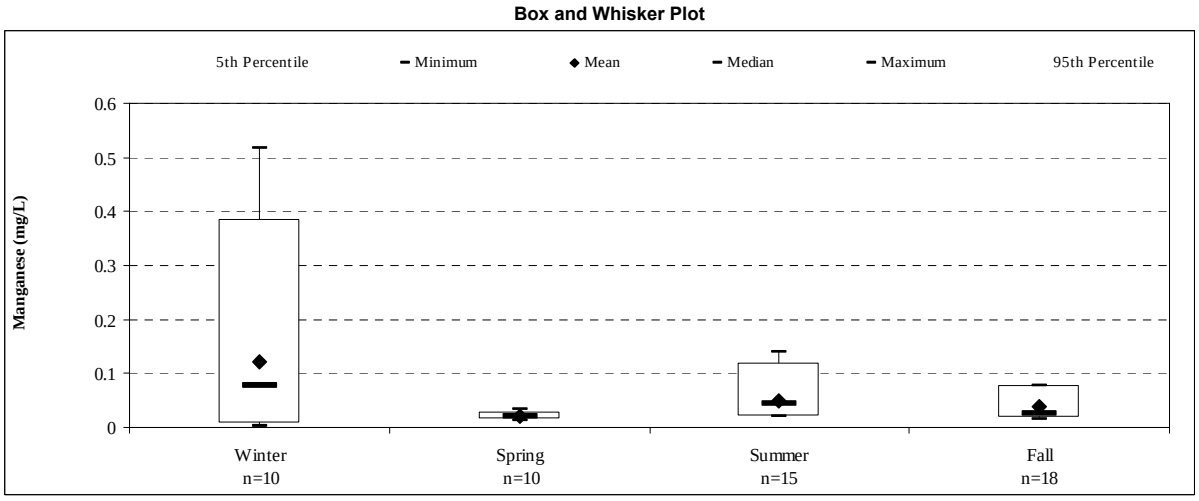


Figure G-2-4-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Jackpine Creek



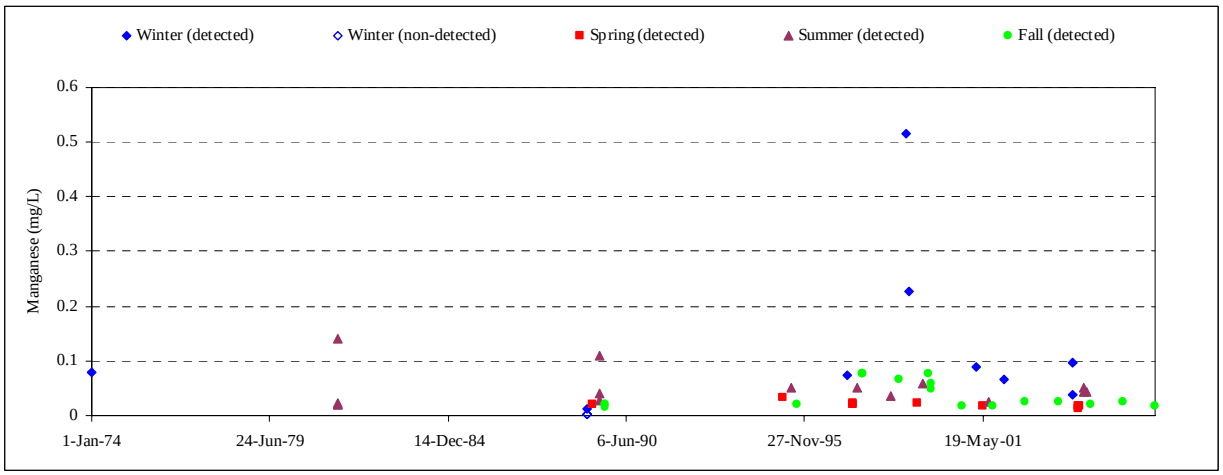
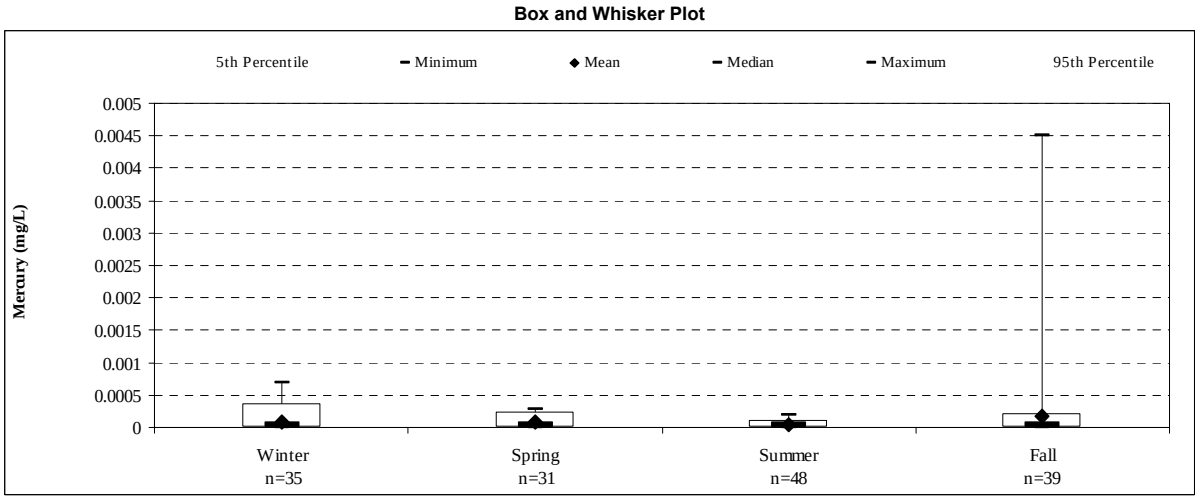


Figure G-2-4-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Jackpine Creek



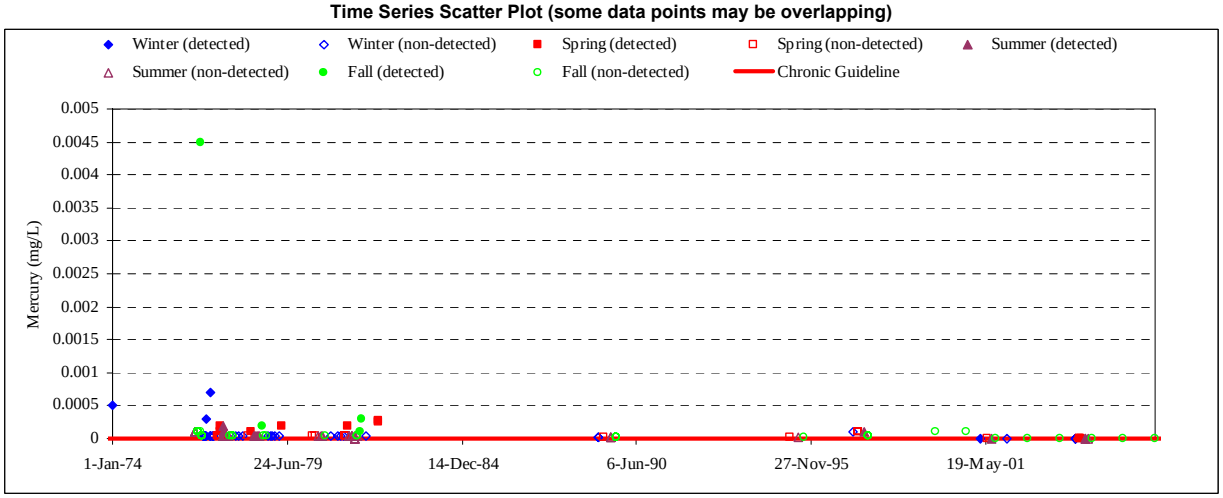
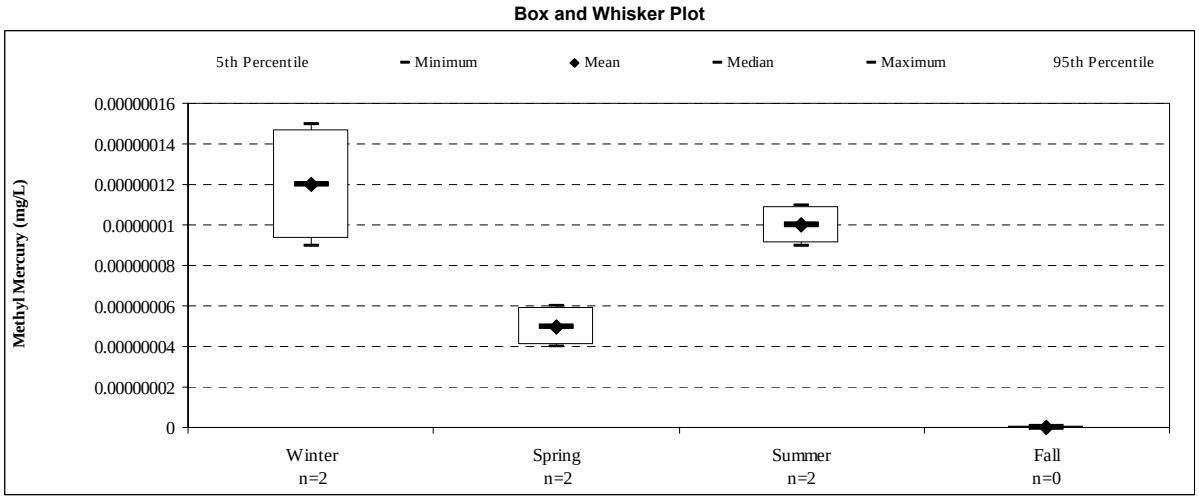


Figure G-2-4-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Jackpine Creek



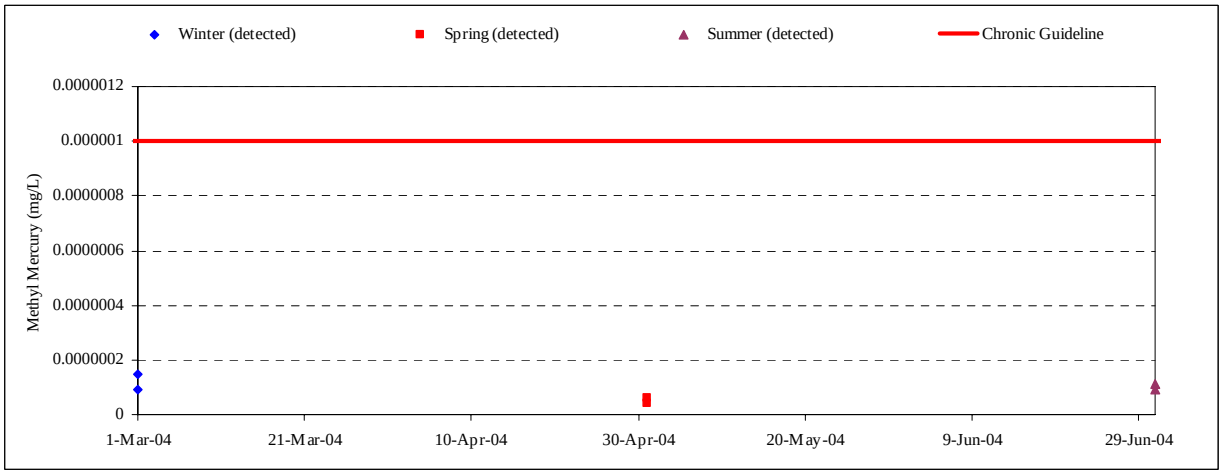


Figure G-2-4-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Jackpine Creek

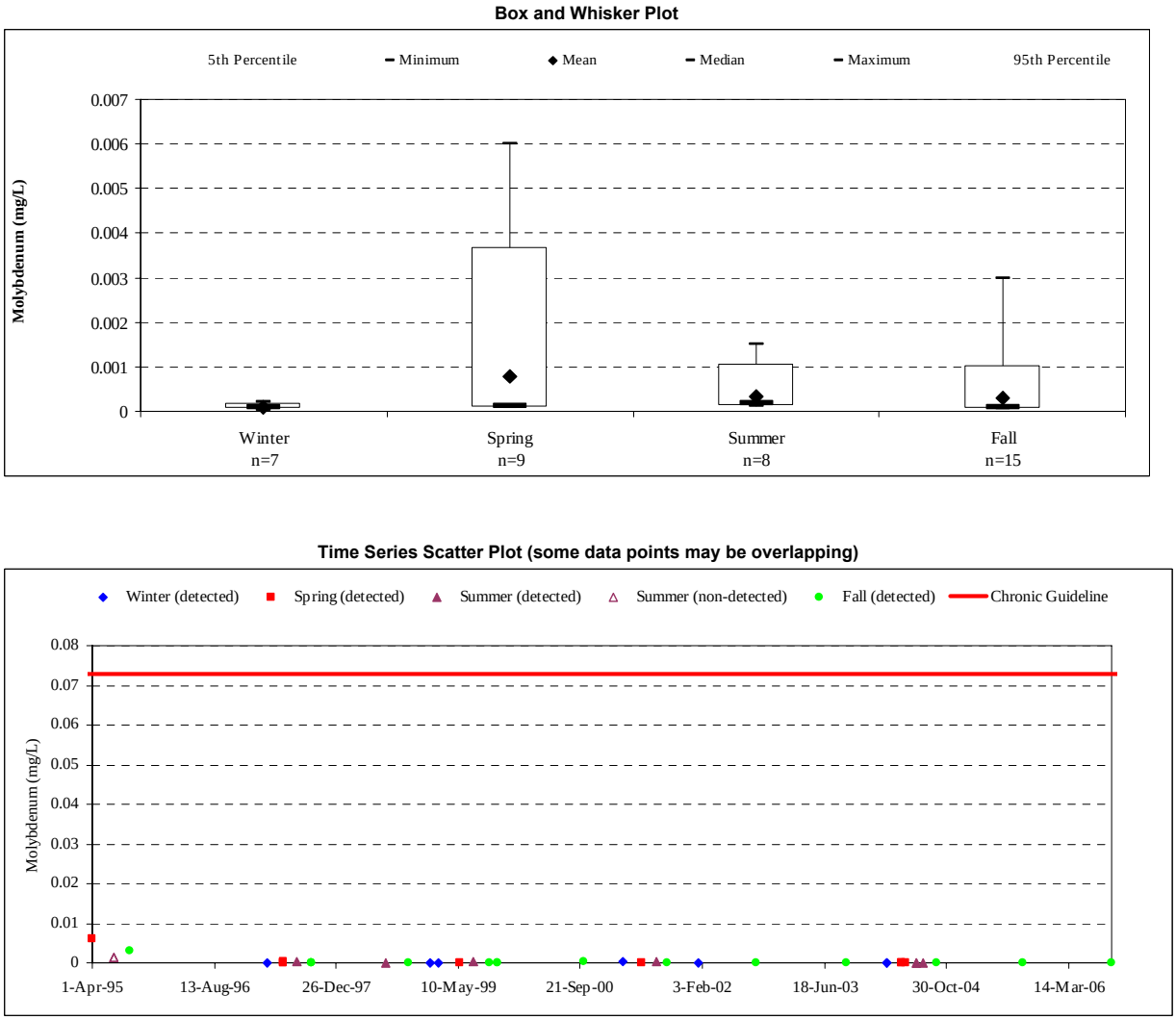
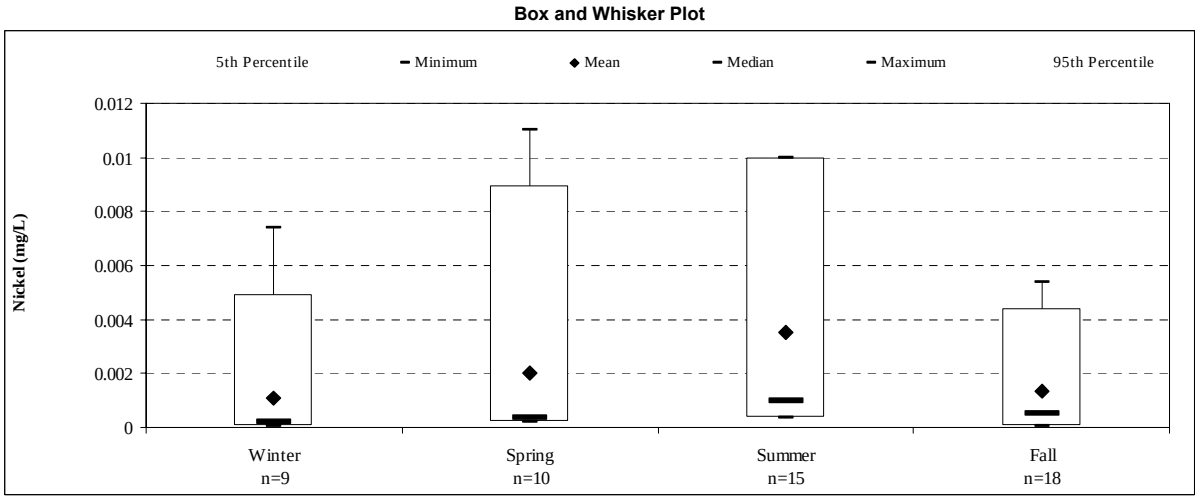


Figure G-2-4-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Jackpine Creek



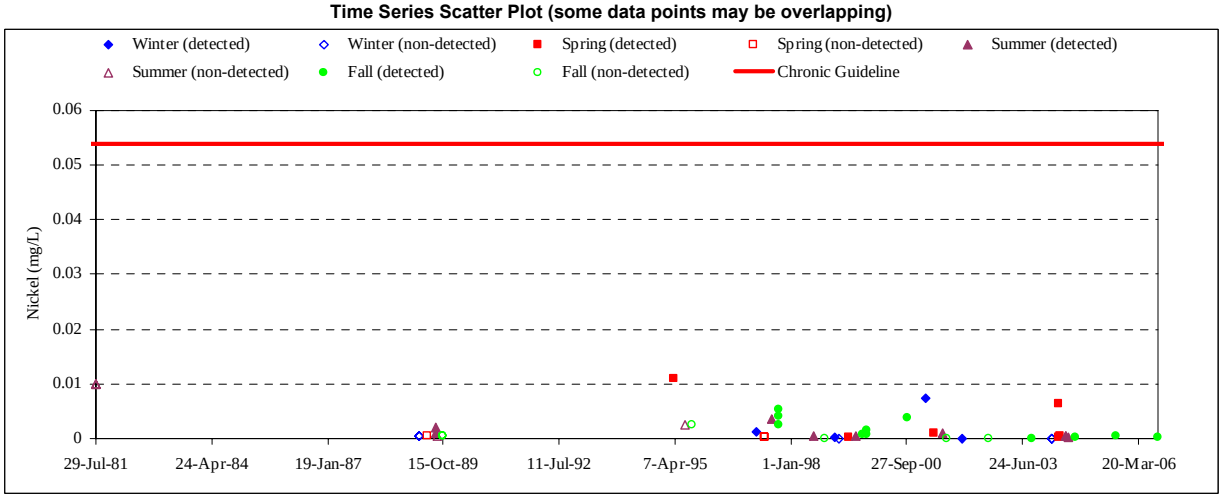
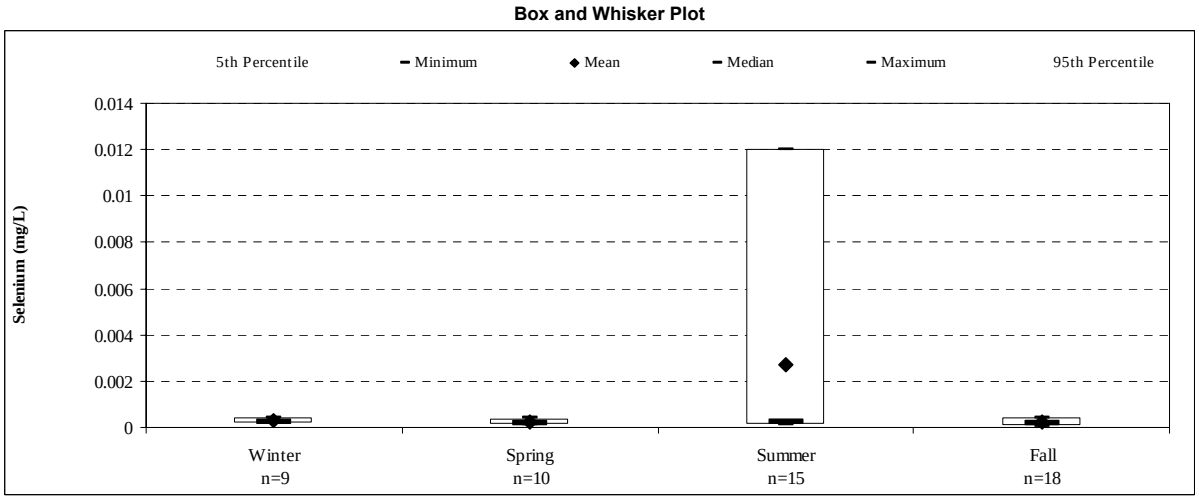


Figure G-2-4-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Jackpine Creek



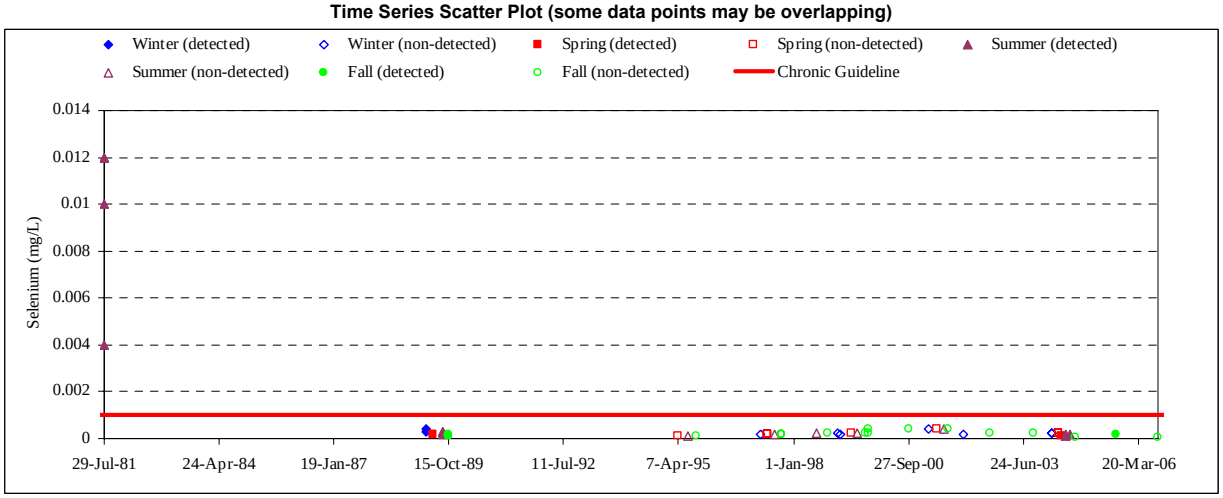
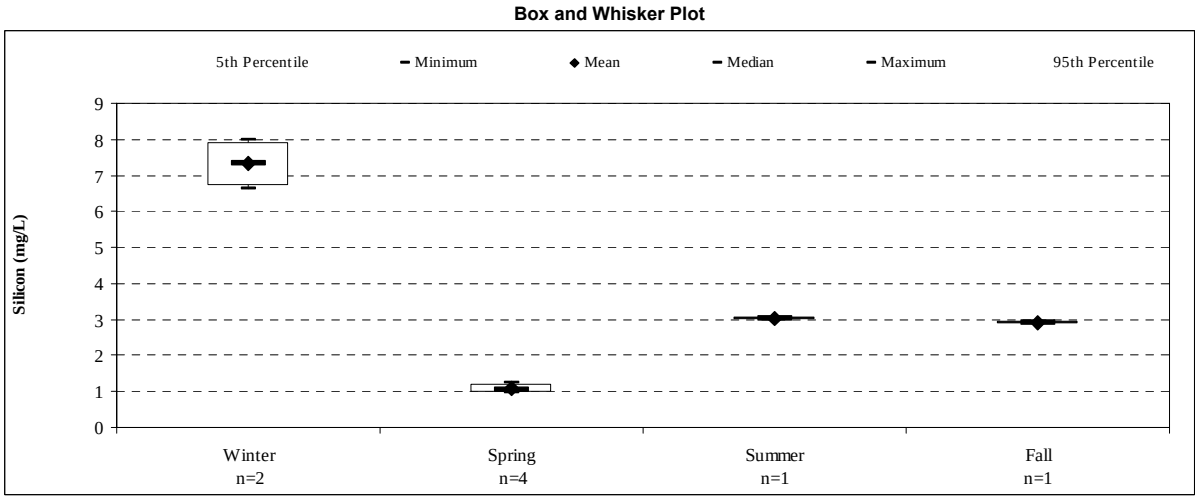


Figure G-2-4-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Jackpine Creek



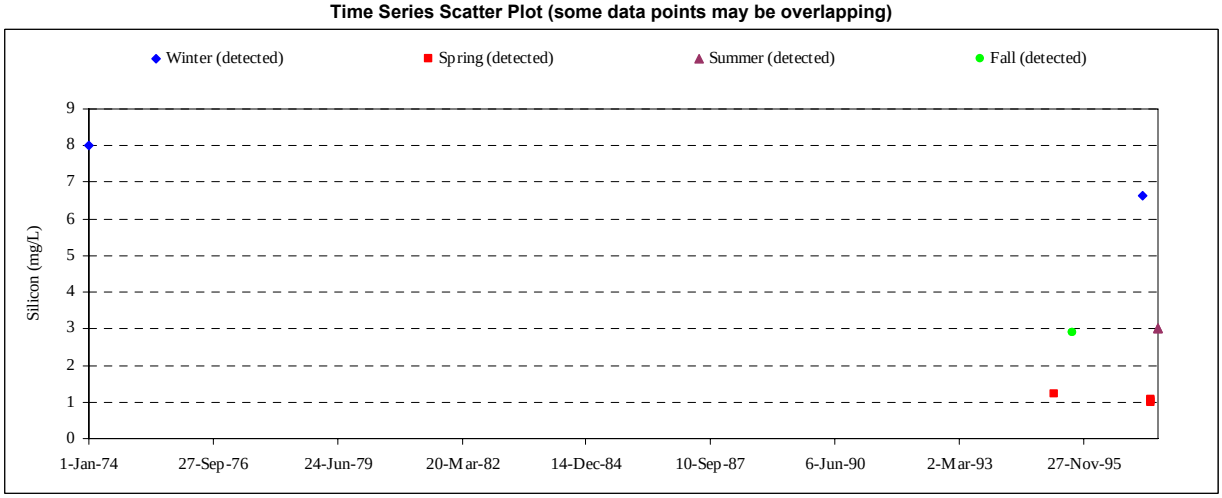
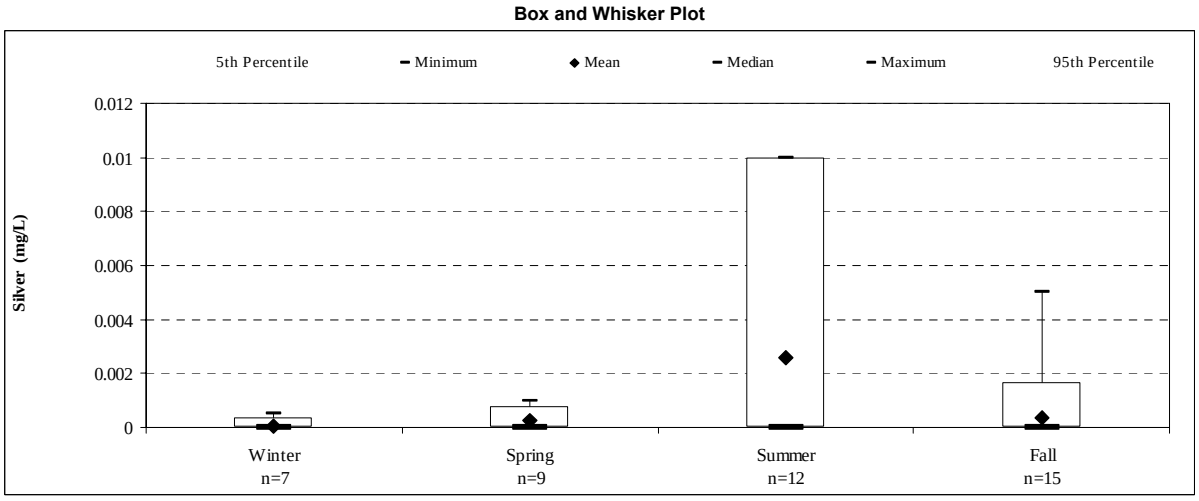


Figure G-2-4-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Jackpine Creek



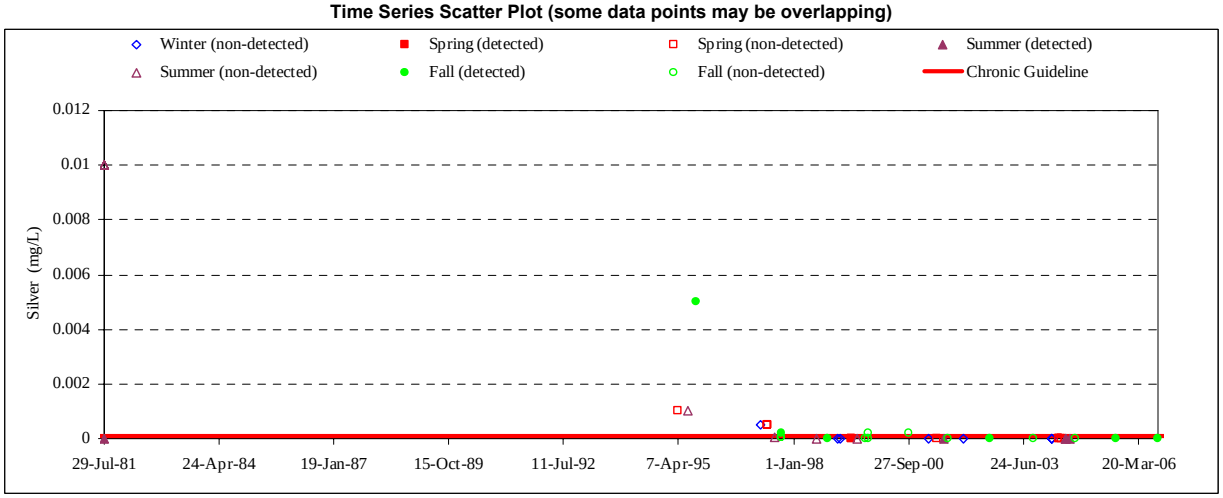
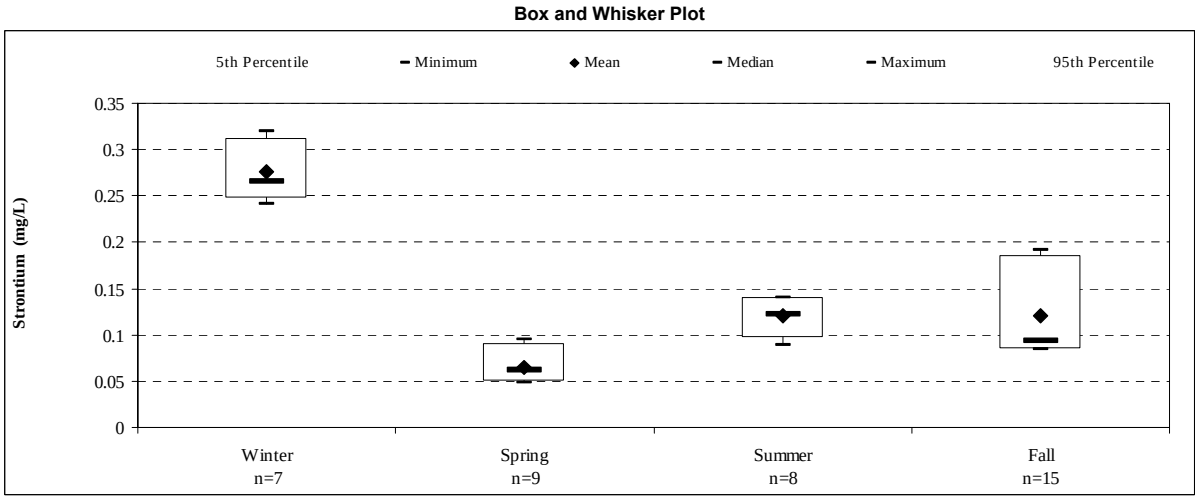


Figure G-2-4-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Jackpine Creek



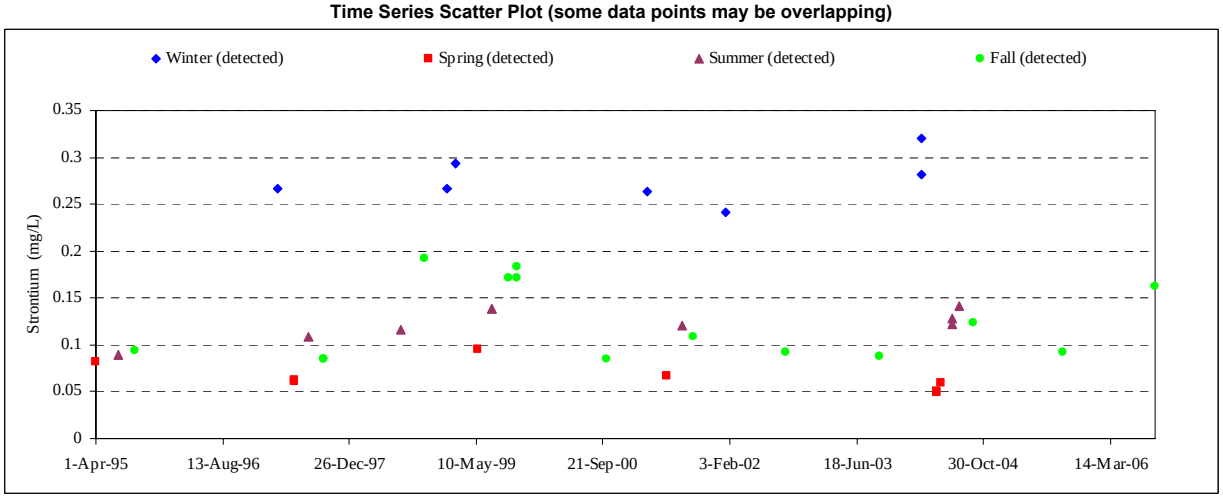
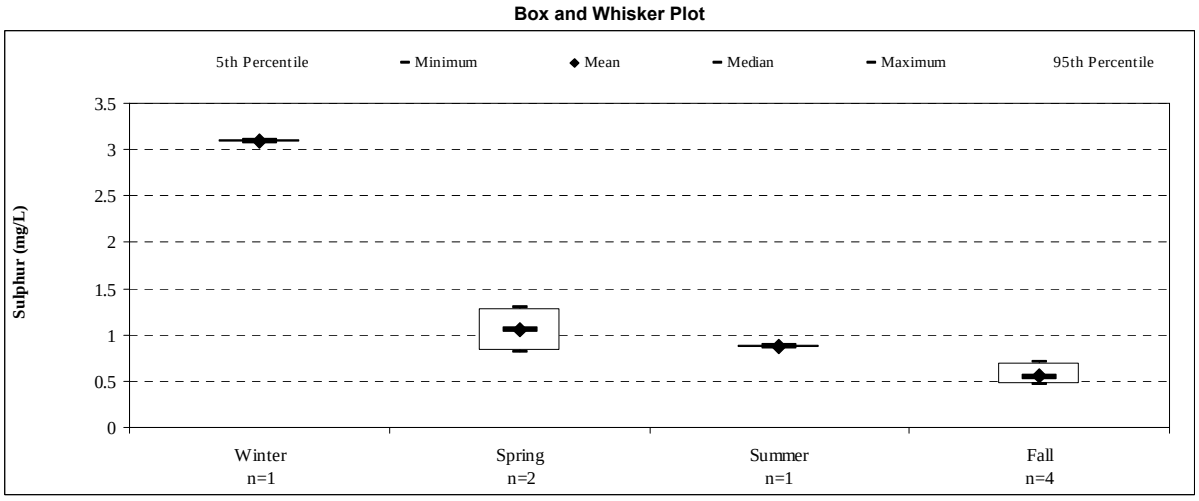


Figure G-2-4-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Jackpine Creek



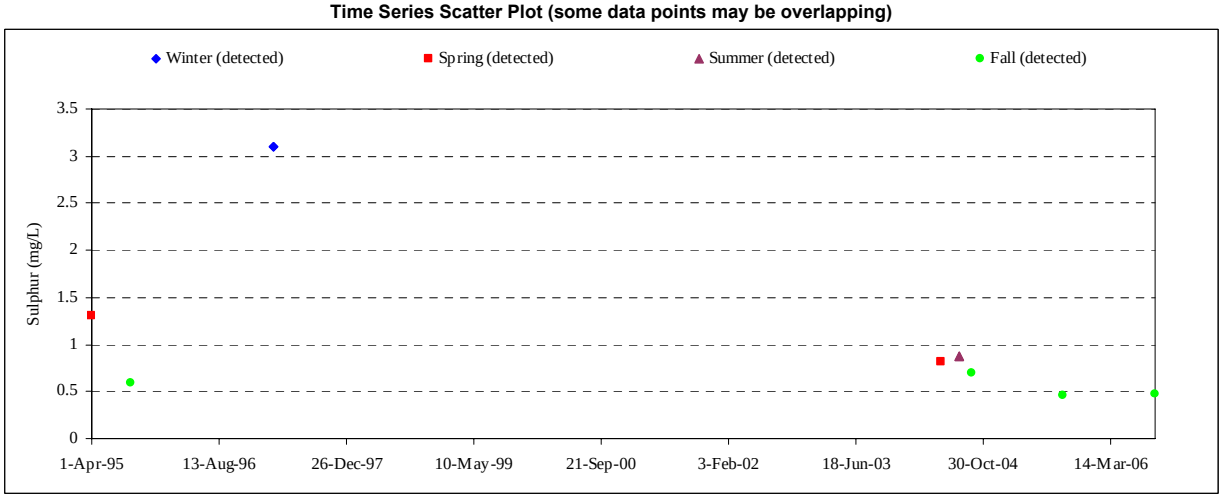
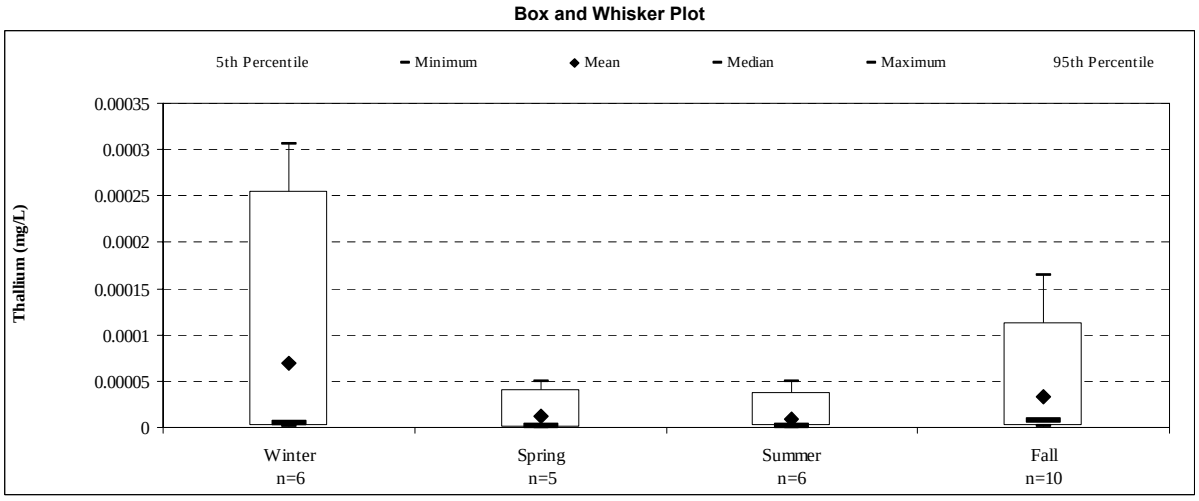


Figure G-2-4-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Jackpine Creek



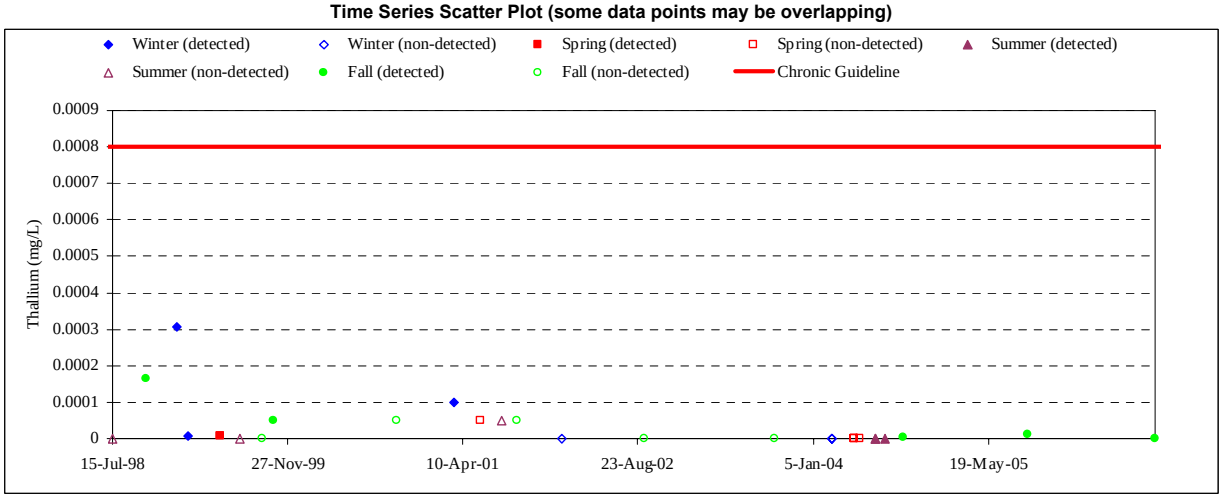


Figure G-2-4-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Jackpine Creek

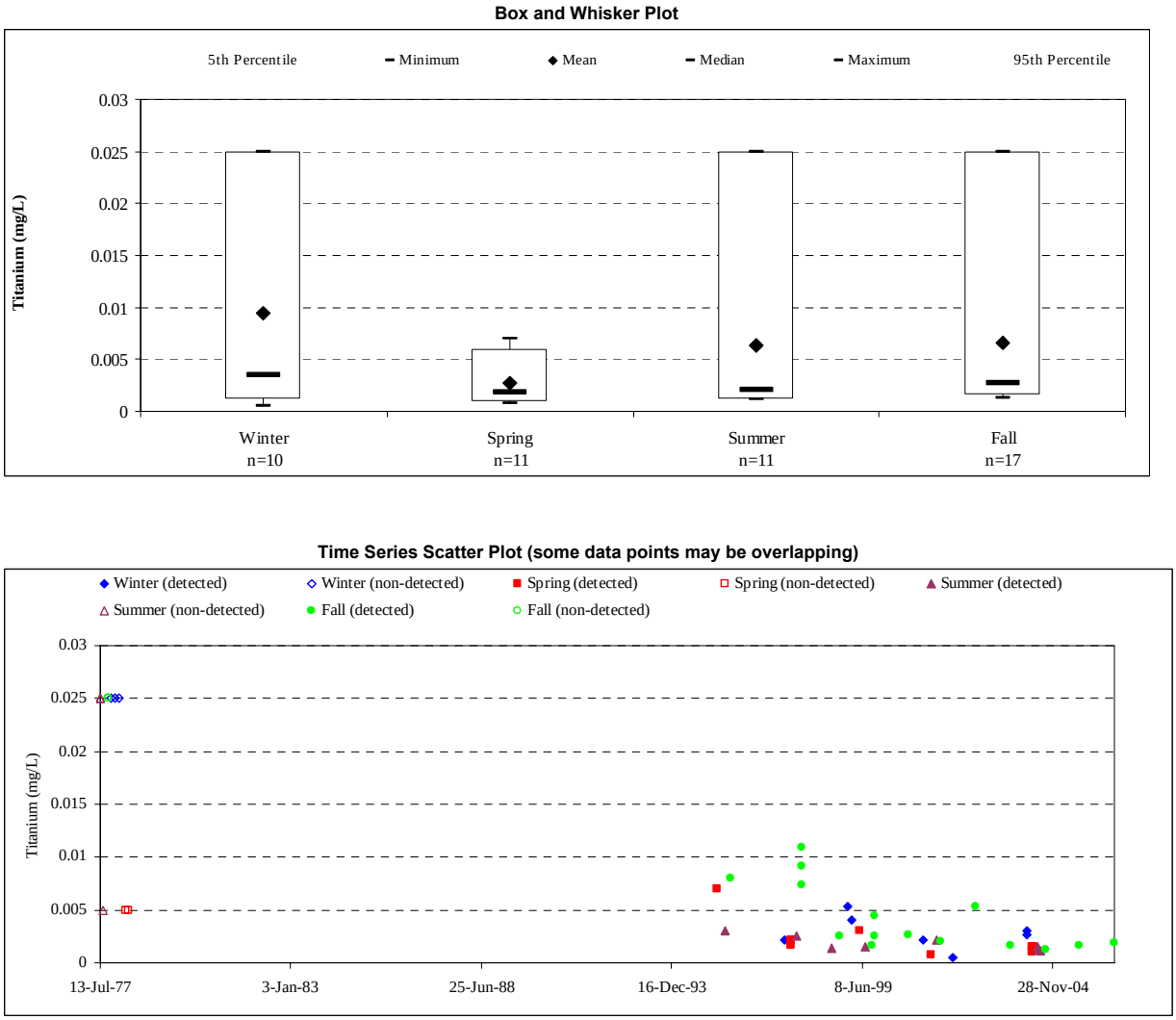
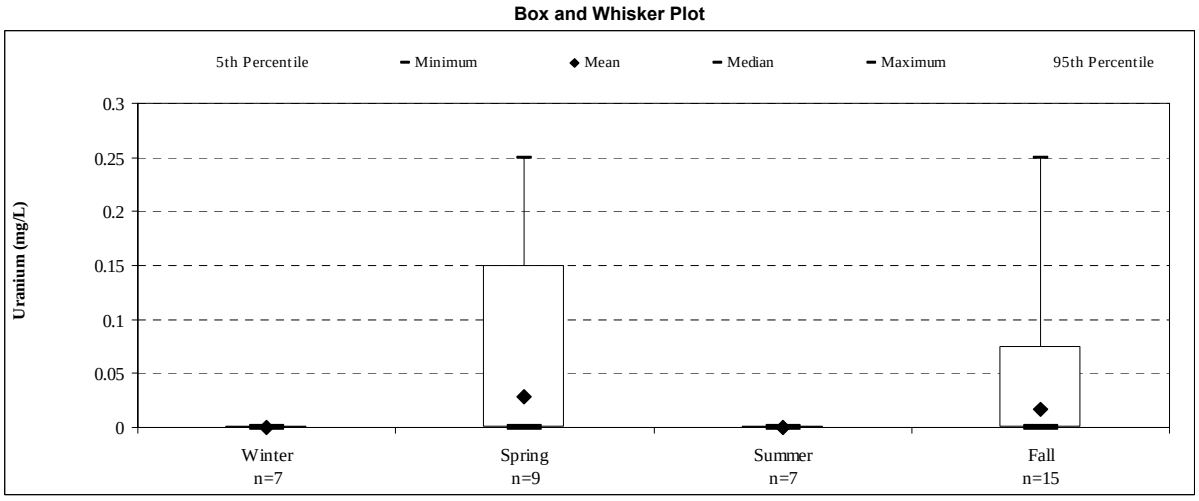


Figure G-2-4-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Jackpine Creek



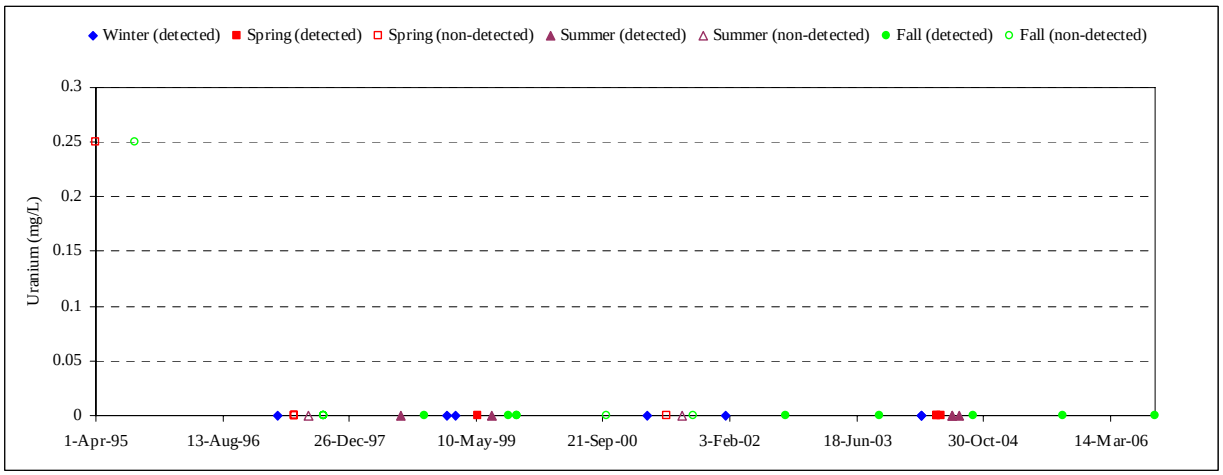
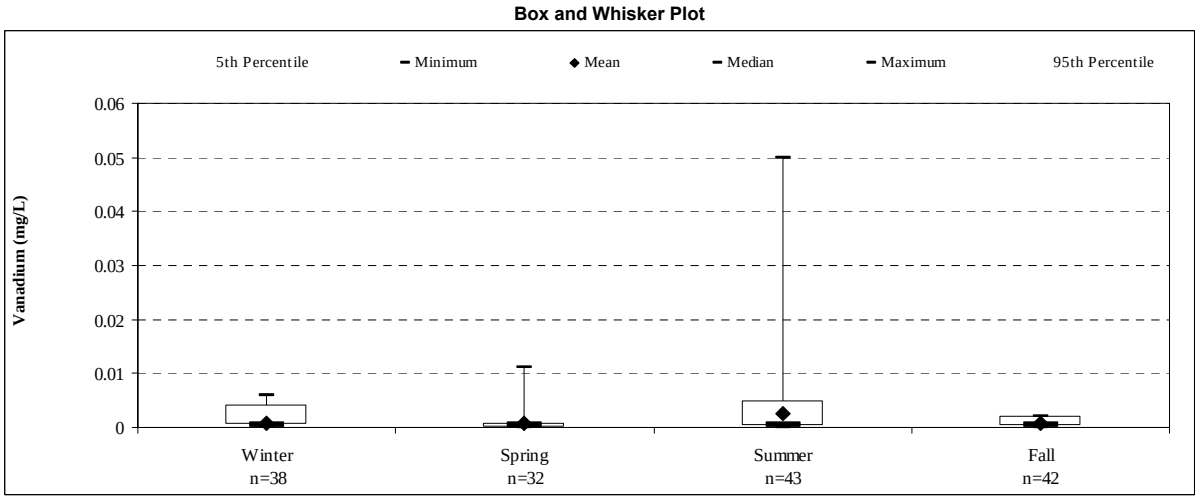


Figure G-2-4-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Jackpine Creek



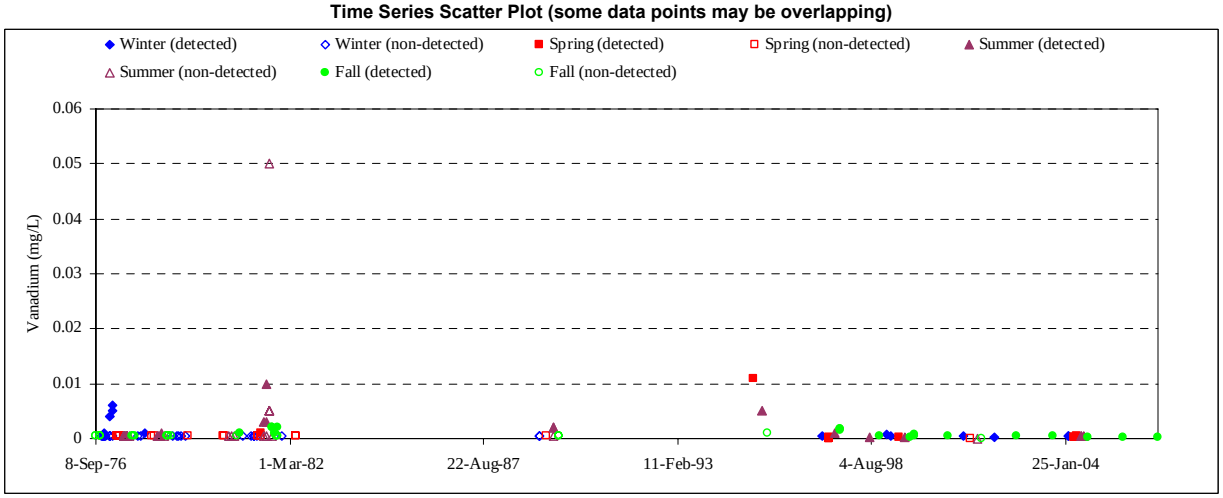
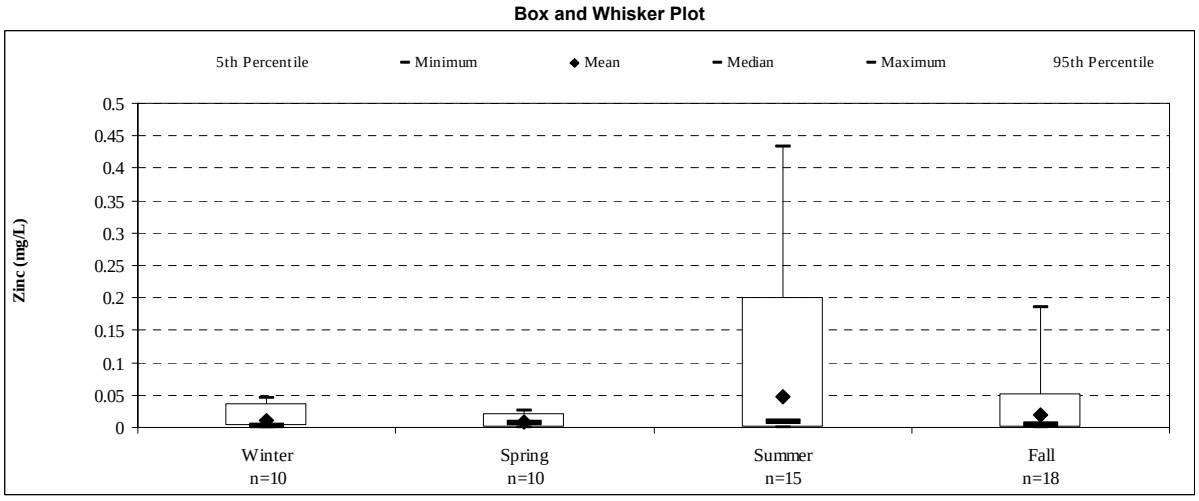


Figure G-2-4-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Jackpine Creek



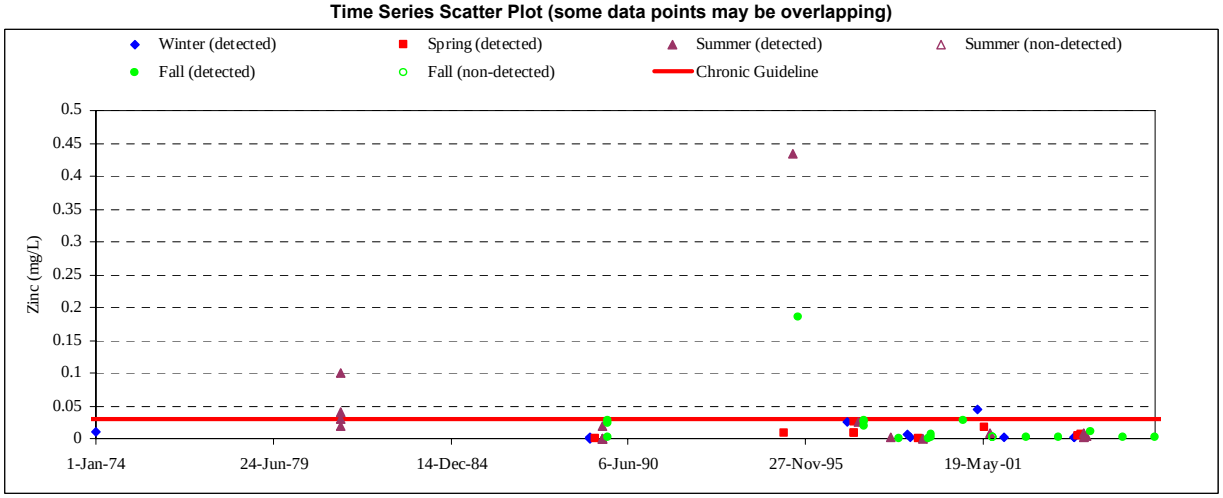
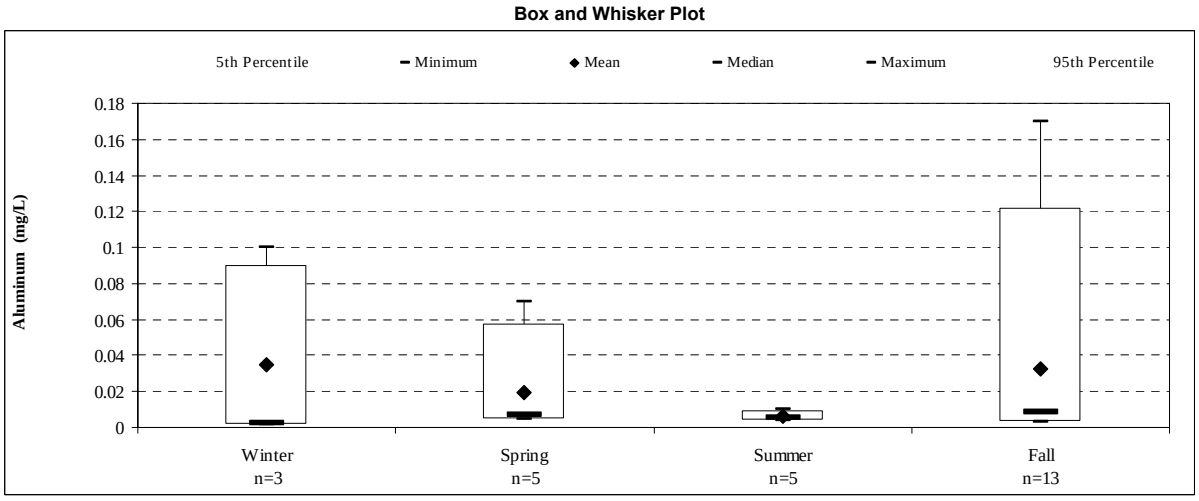


Figure G-2-4-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Jackpine Creek



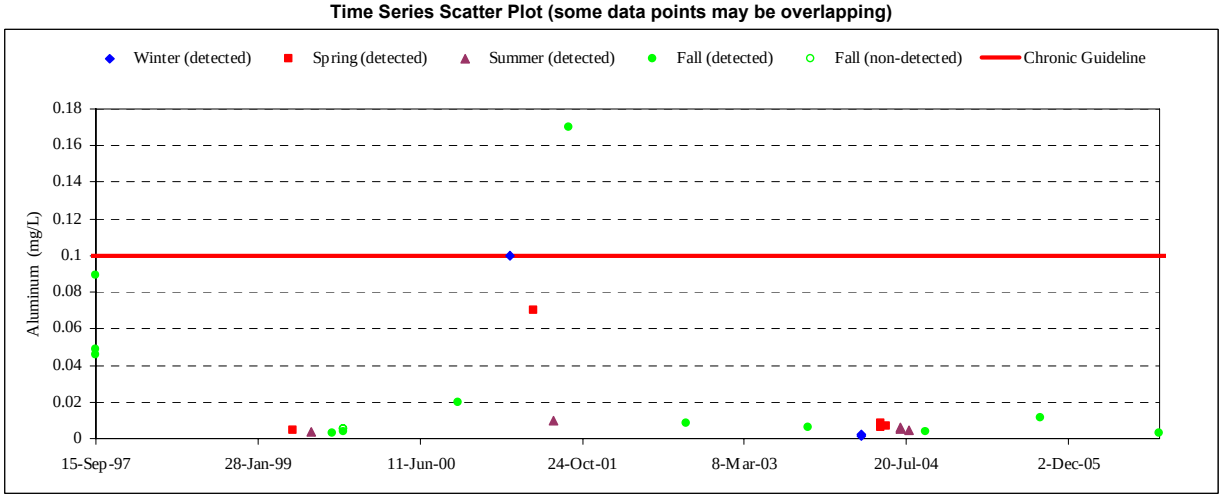
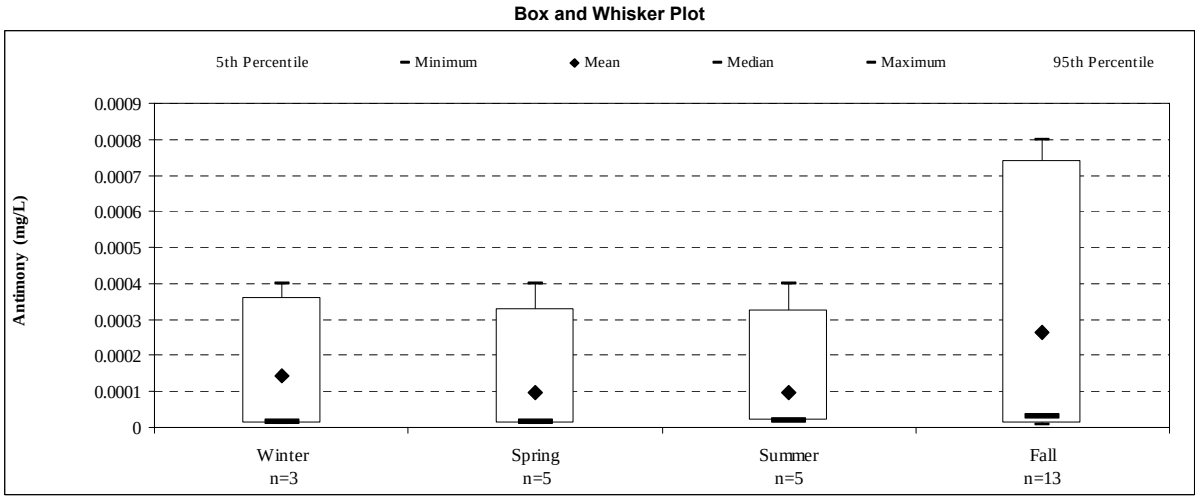


Figure G-2-4-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Jackpine Creek



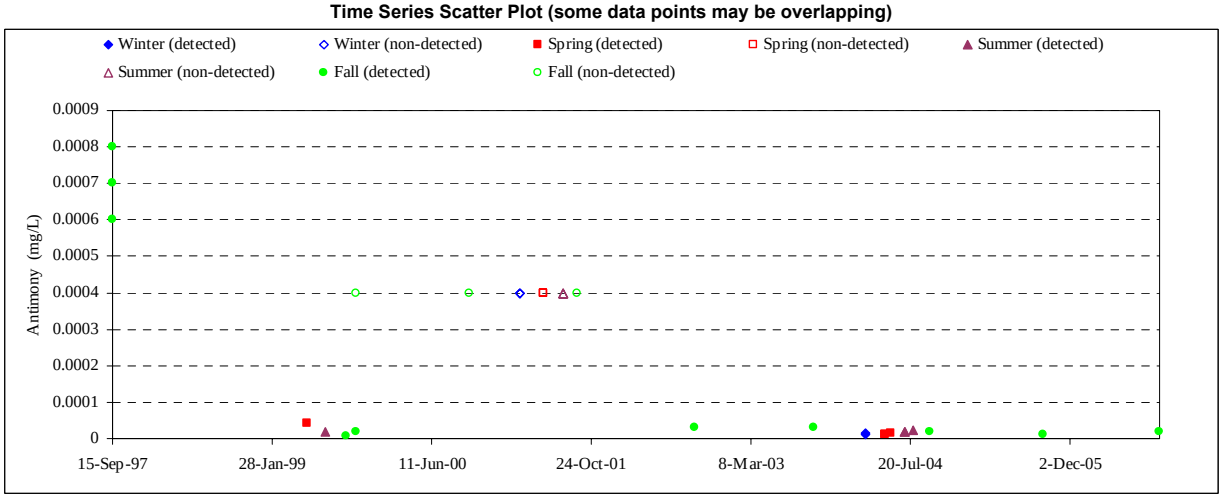
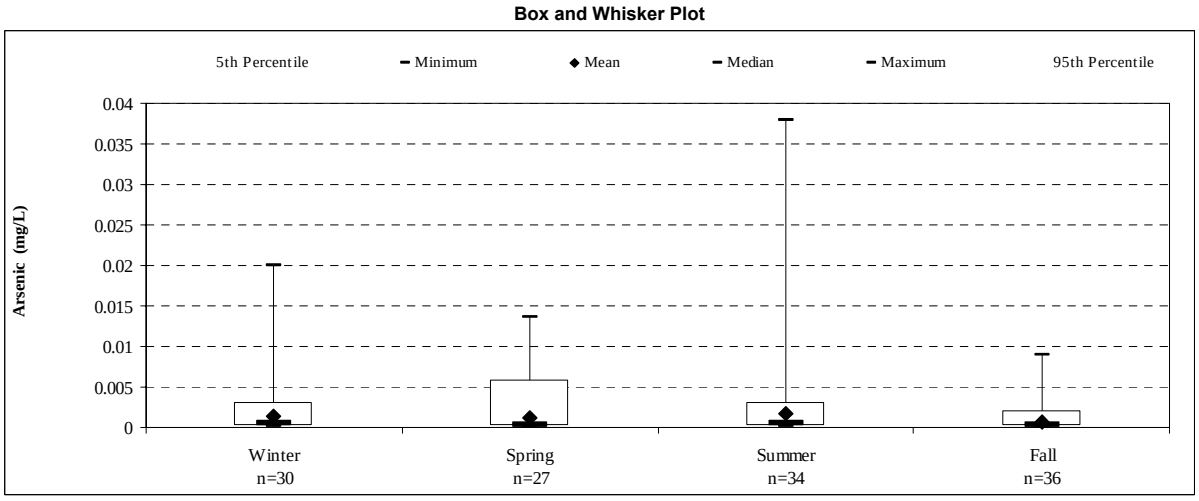


Figure G-2-4-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Jackpine Creek



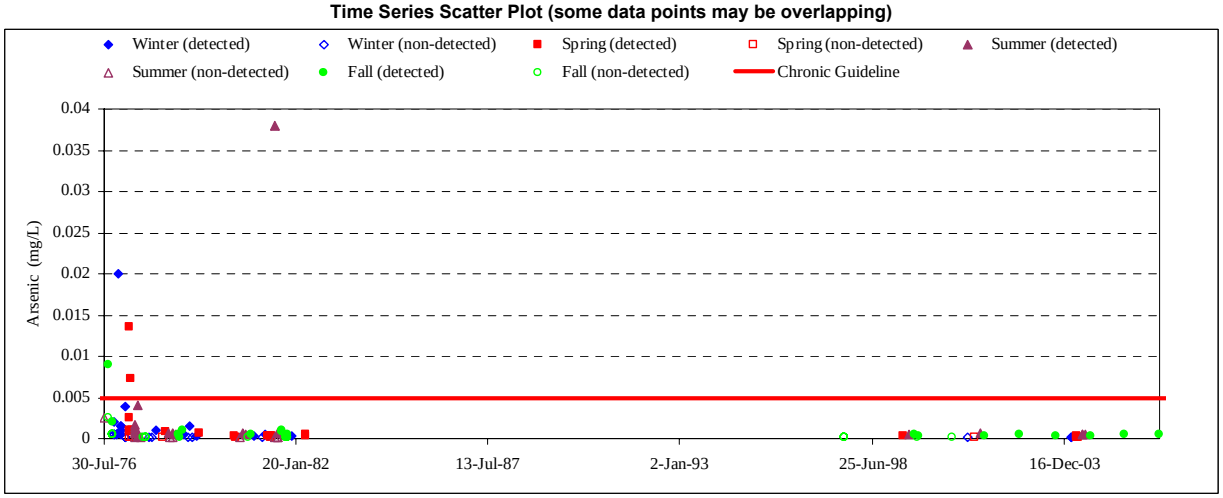
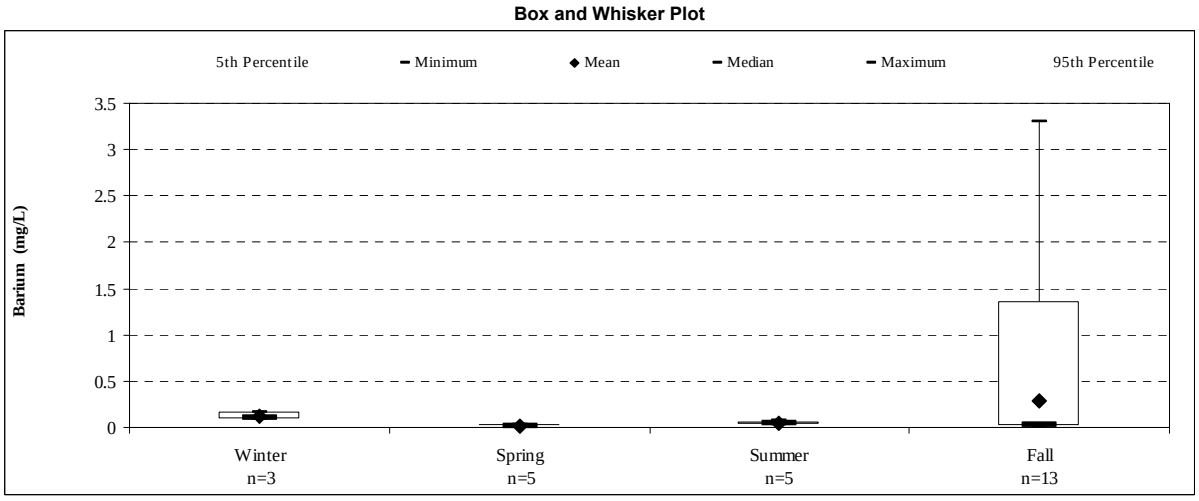


Figure G-2-4-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Jackpine Creek



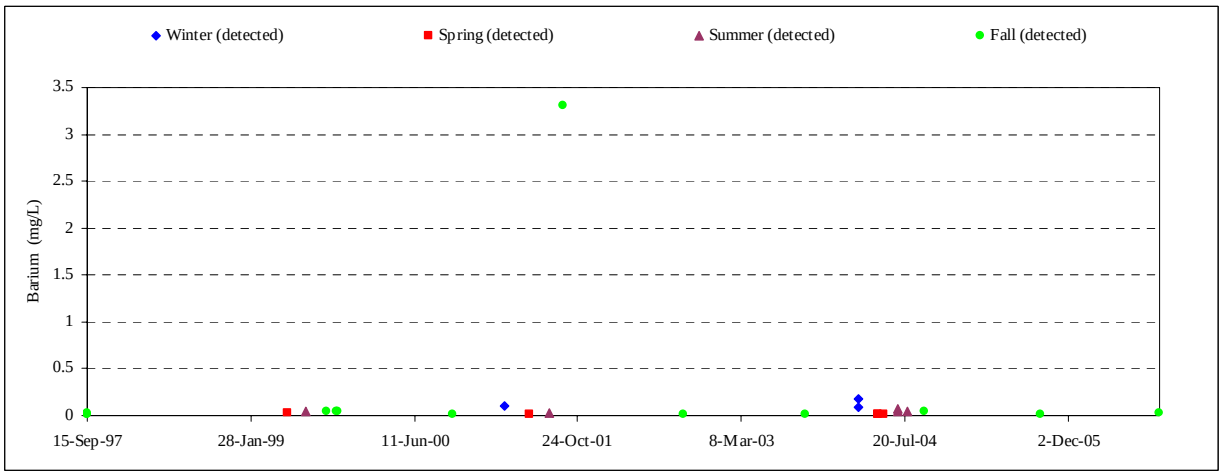
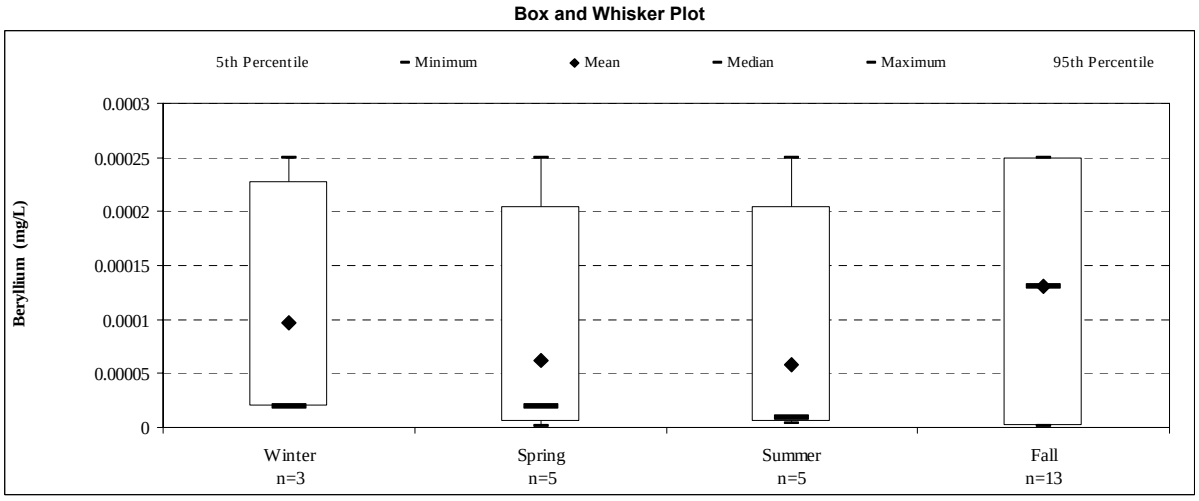


Figure G-2-4-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Jackpine Creek



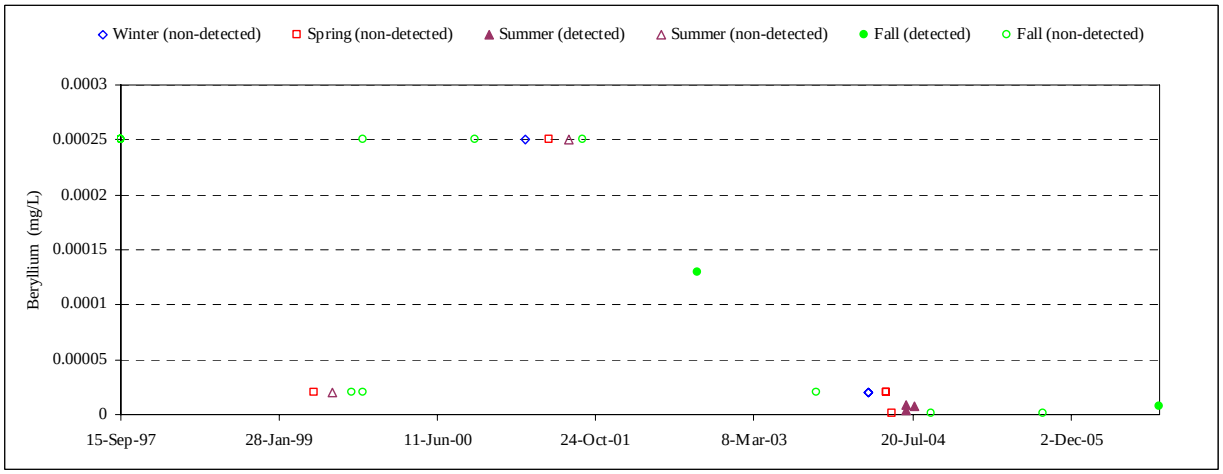
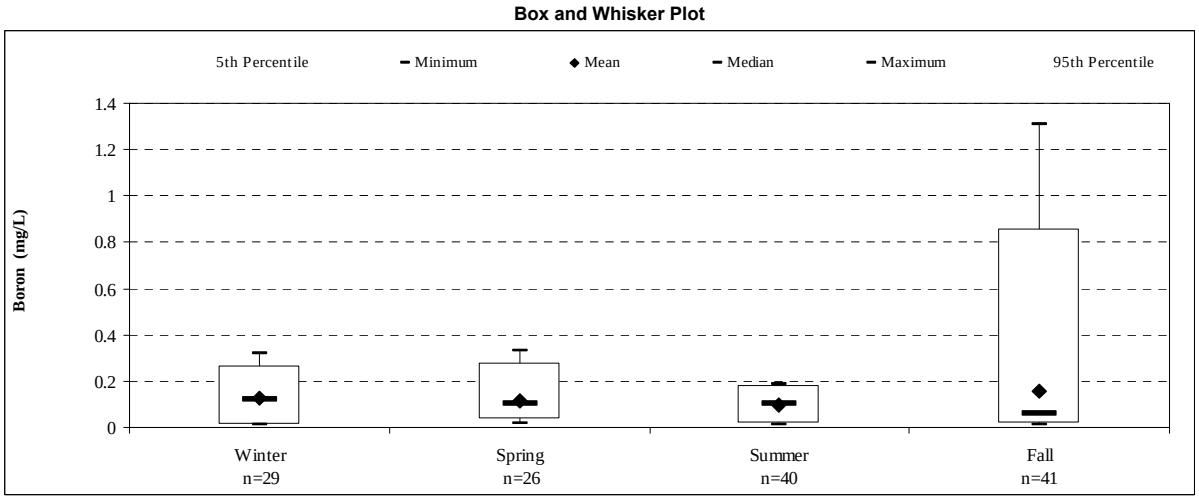


Figure G-2-4-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Jackpine Creek



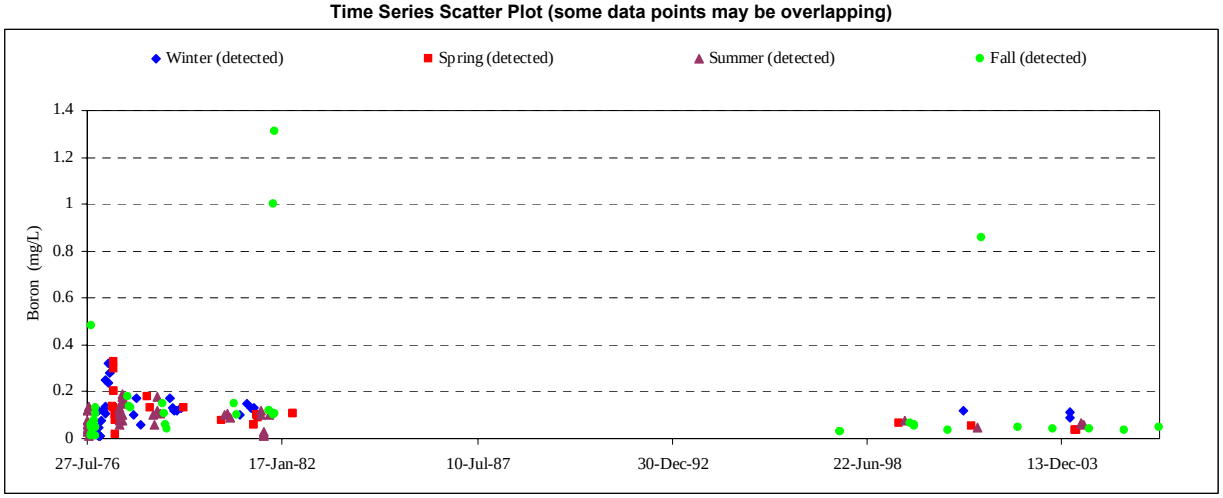
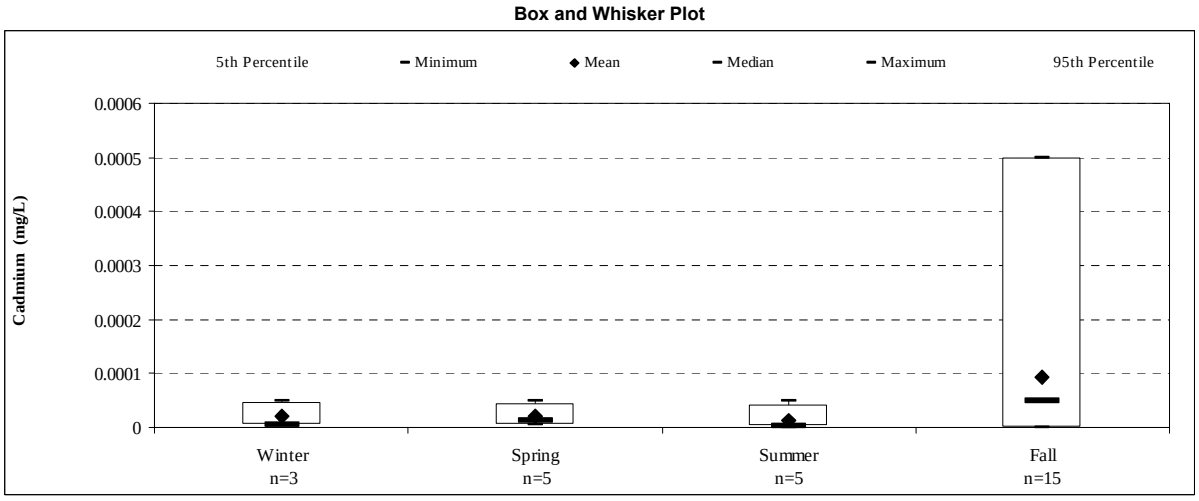


Figure G-2-4-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Jackpine Creek



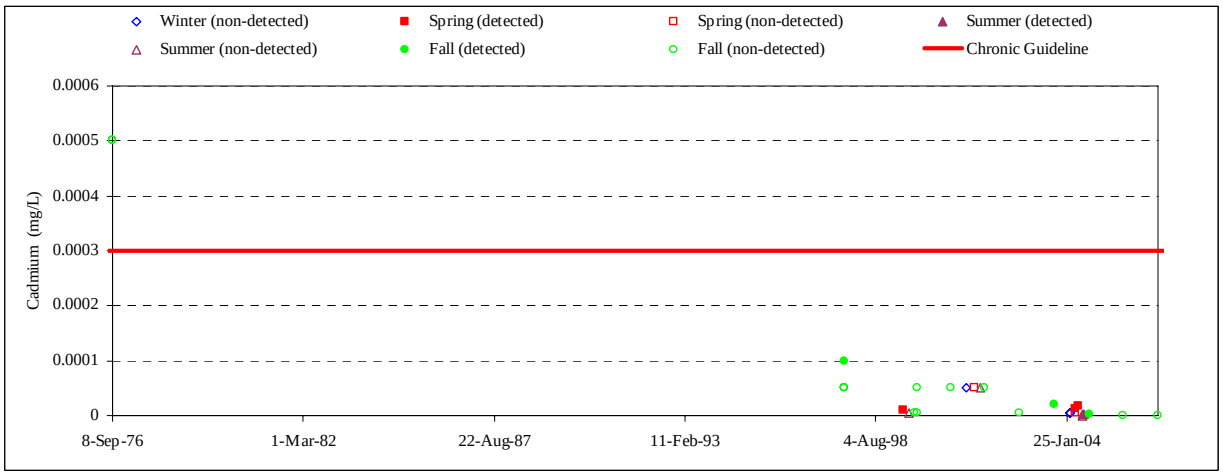


Figure G-2-4-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Jackpine Creek

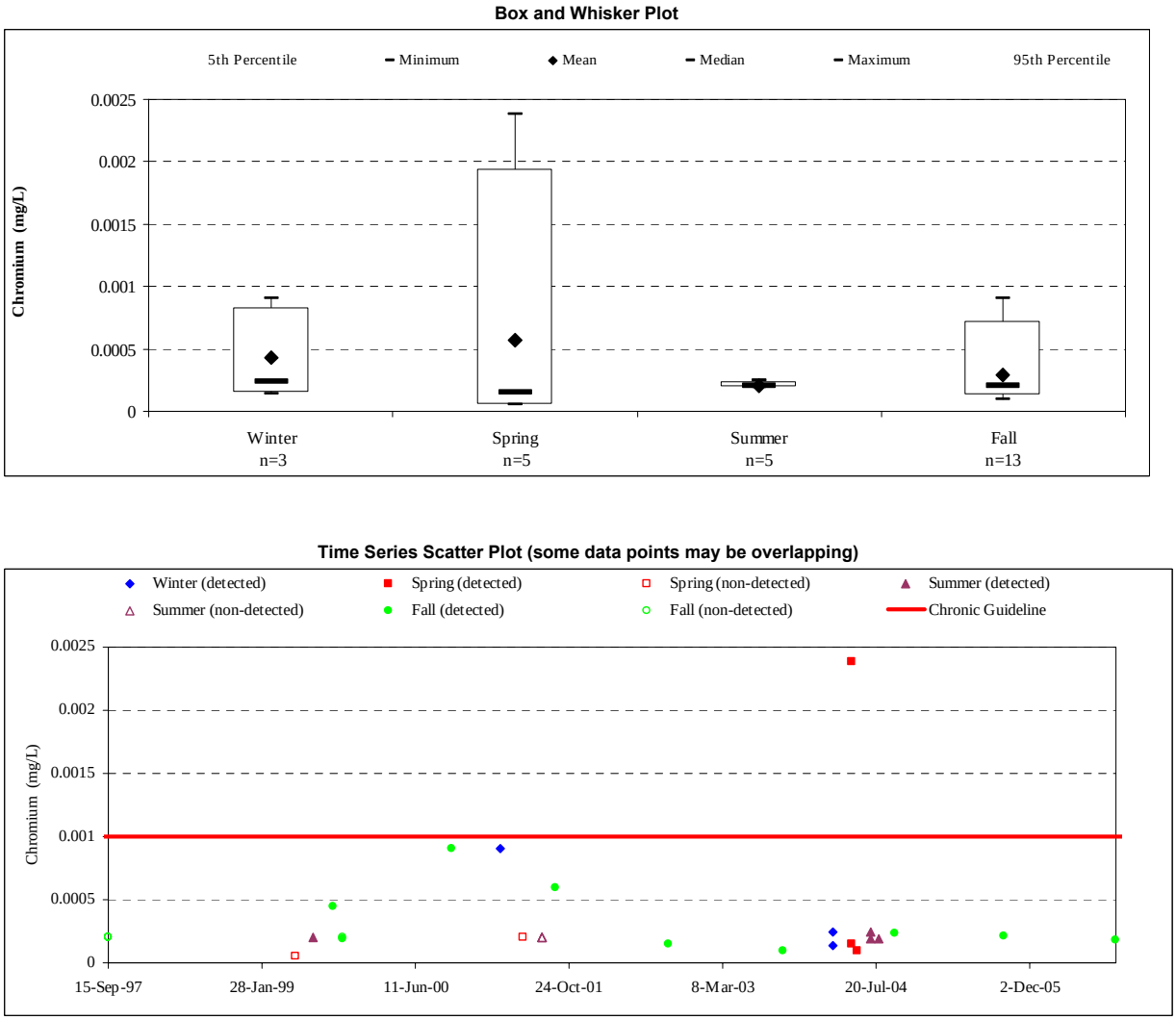
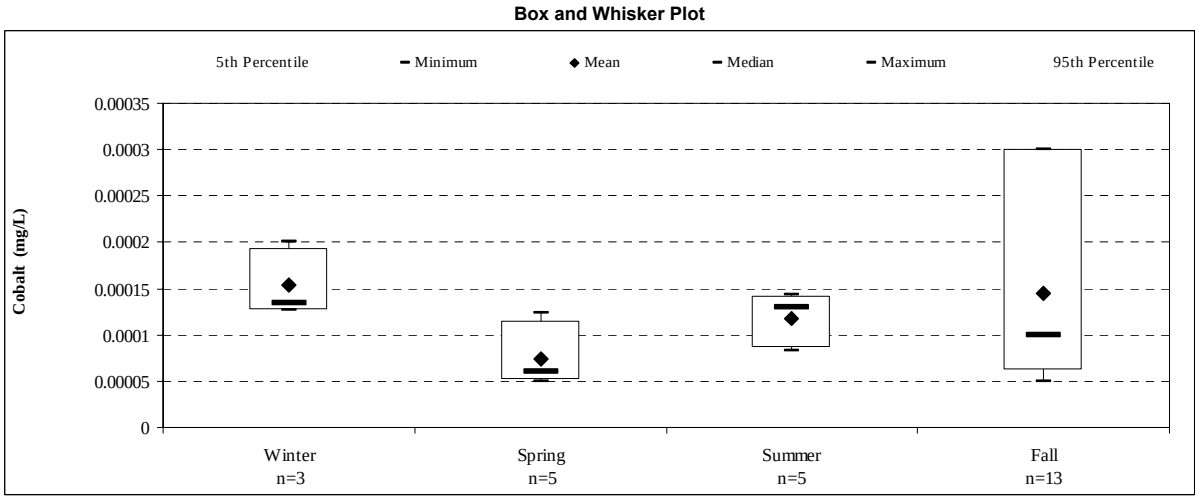


Figure G-2-4-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Jackpine Creek



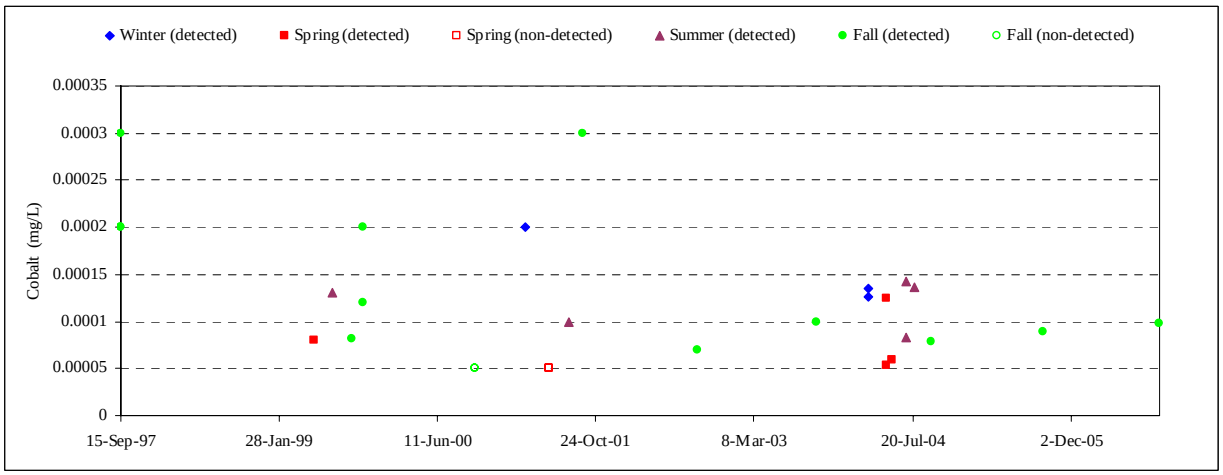
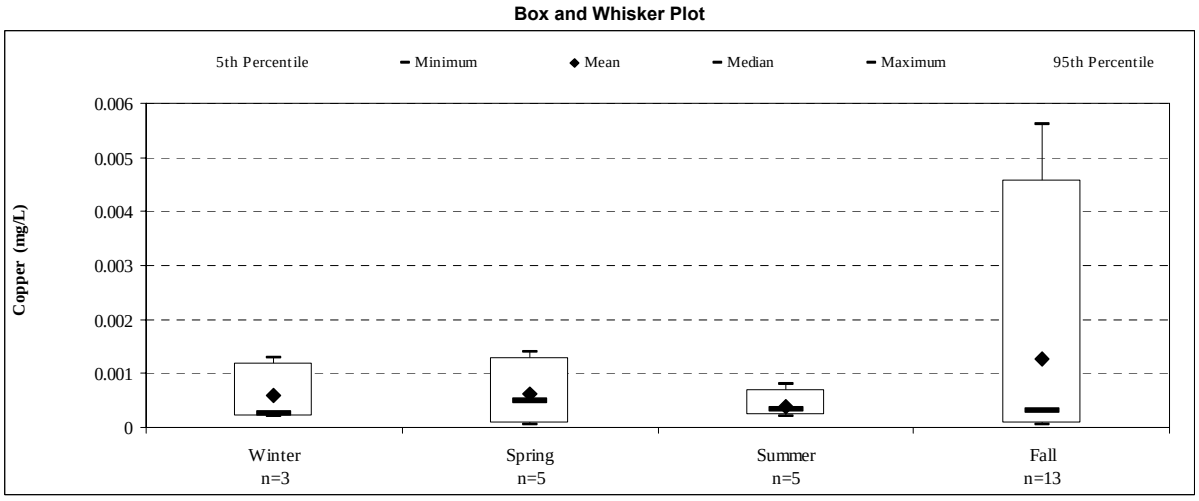


Figure G-2-4-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Jackpine Creek



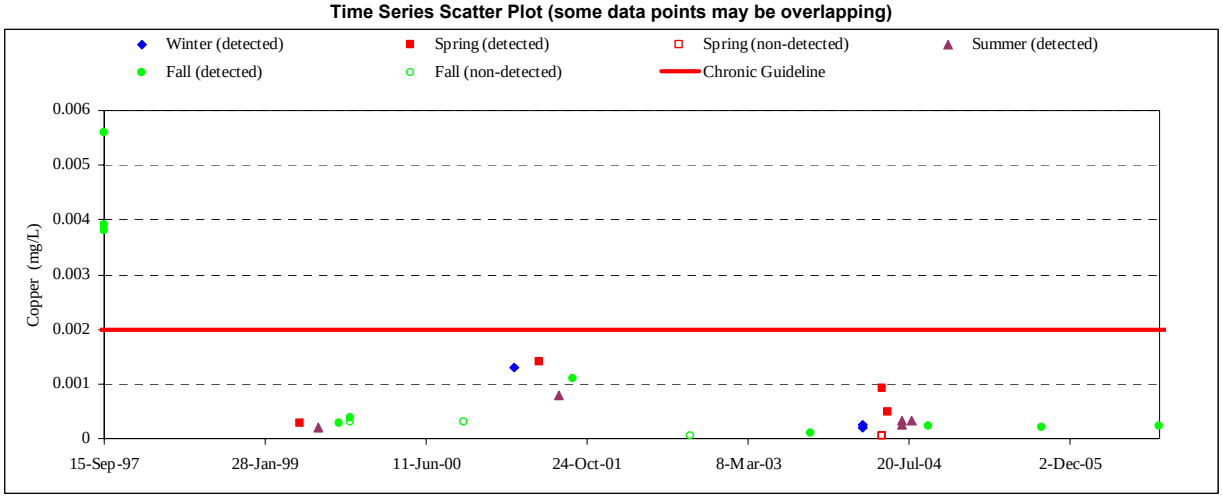
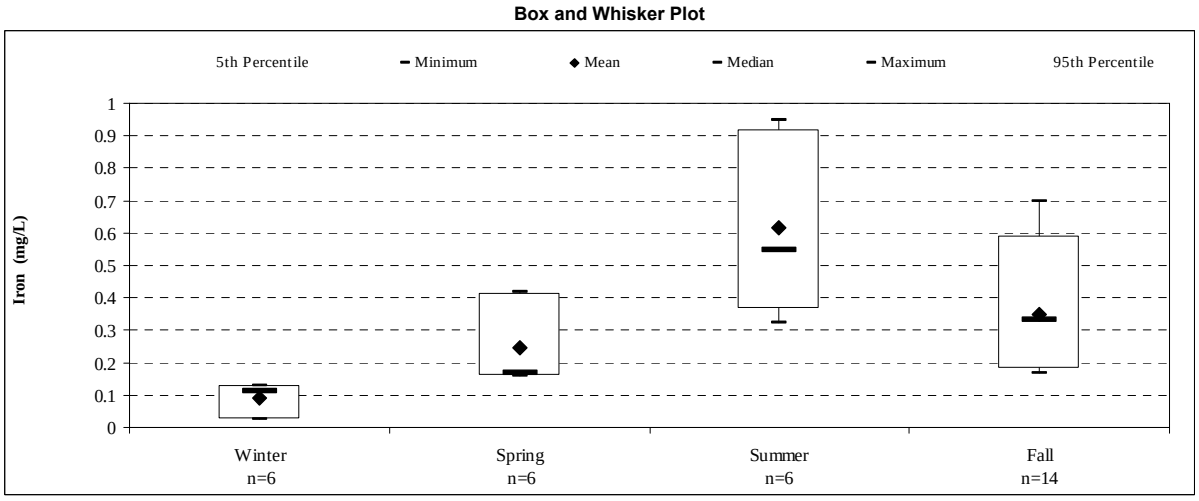


Figure G-2-4-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Jackpine Creek



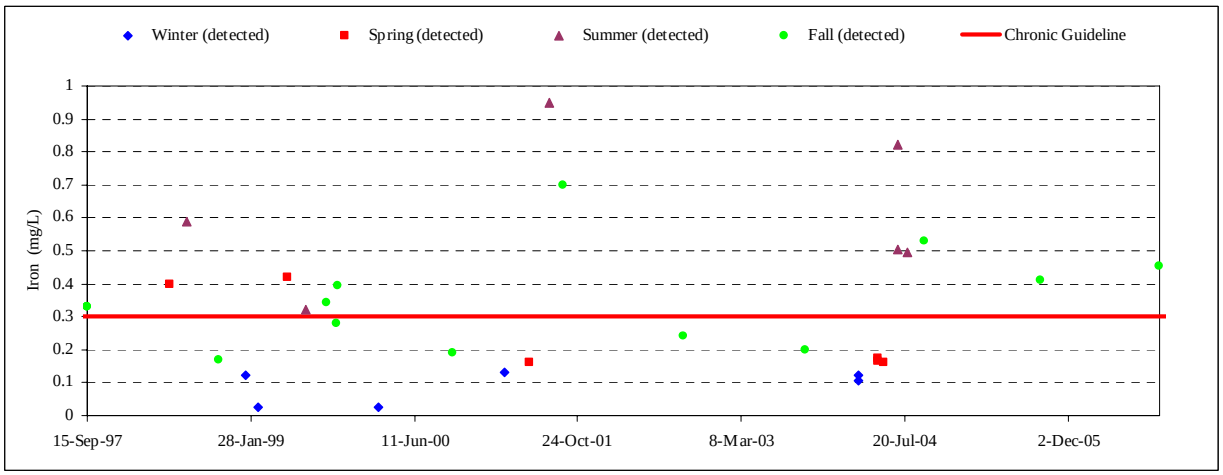


Figure G-2-4-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Jackpine Creek

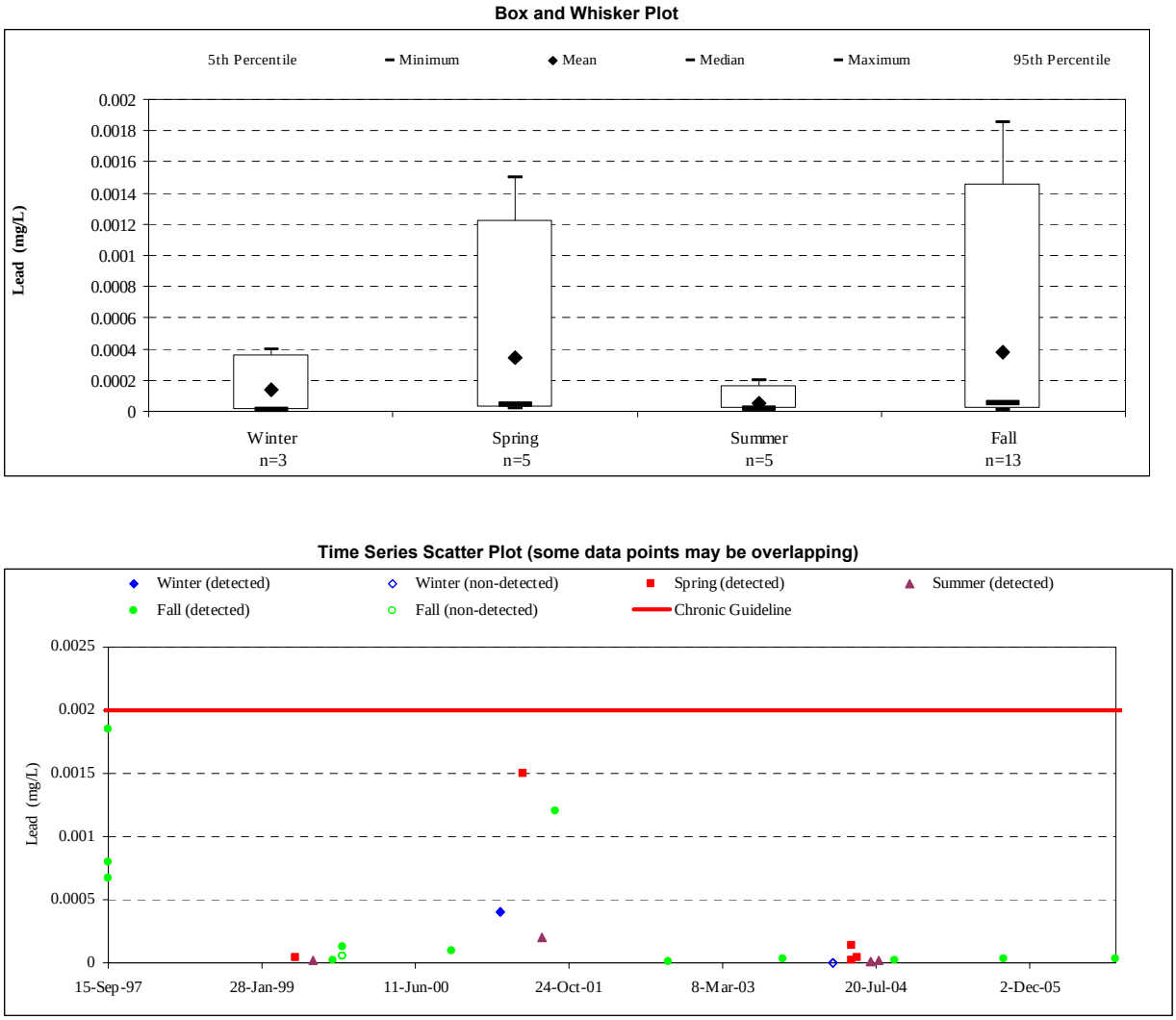
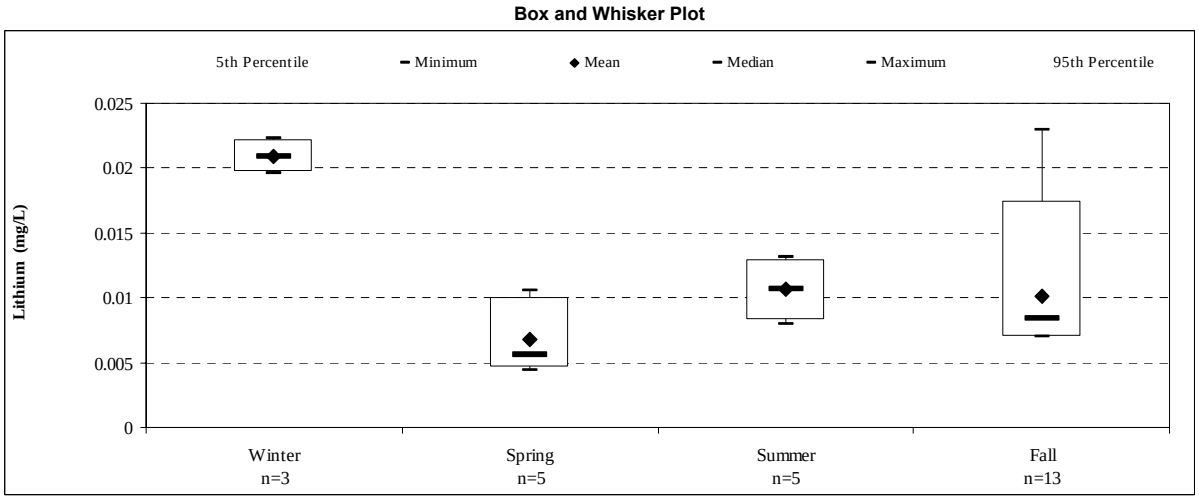


Figure G-2-4-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Jackpine Creek



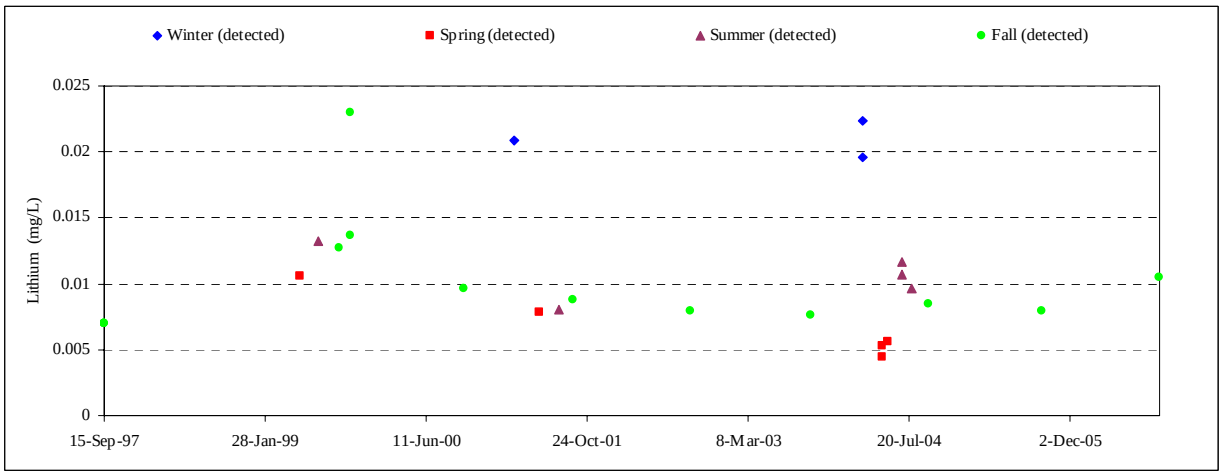
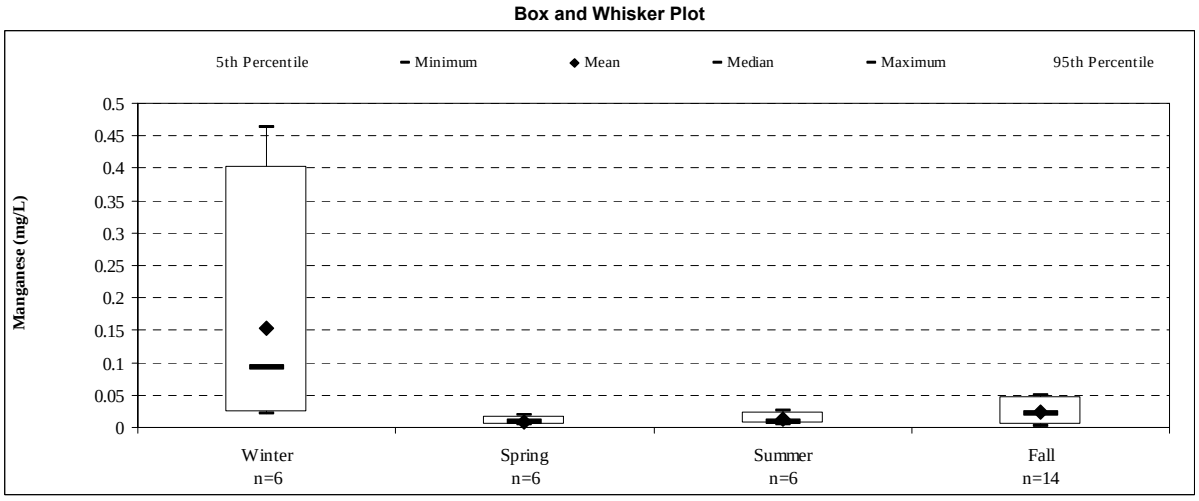


Figure G-2-4-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Jackpine Creek



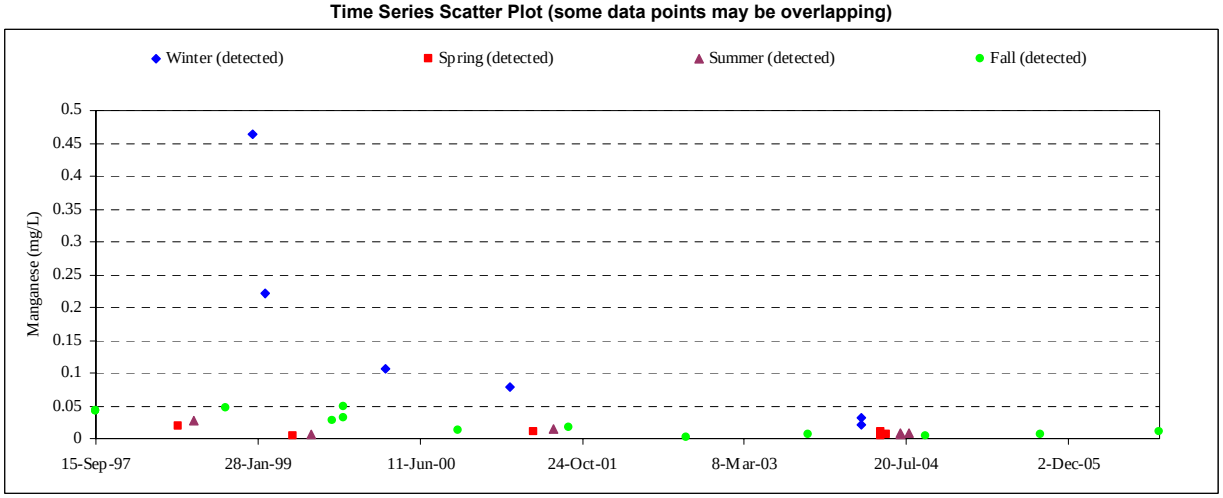
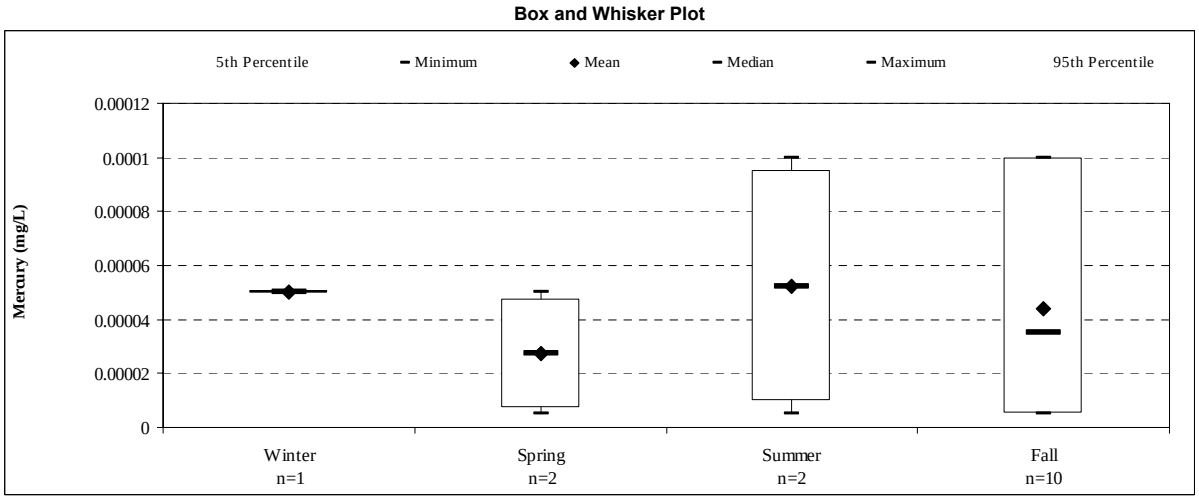


Figure G-2-4-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Jackpine Creek



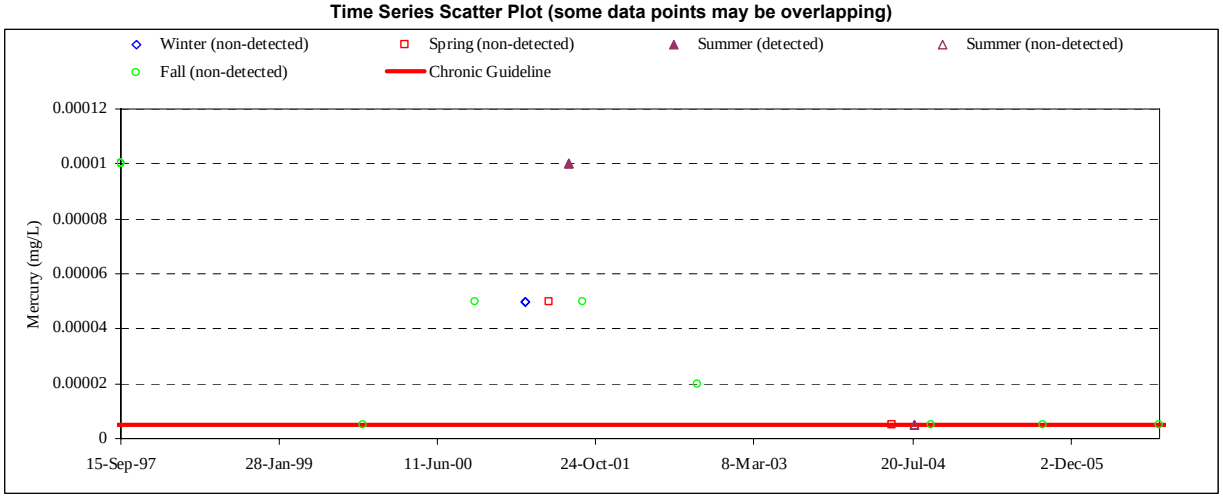
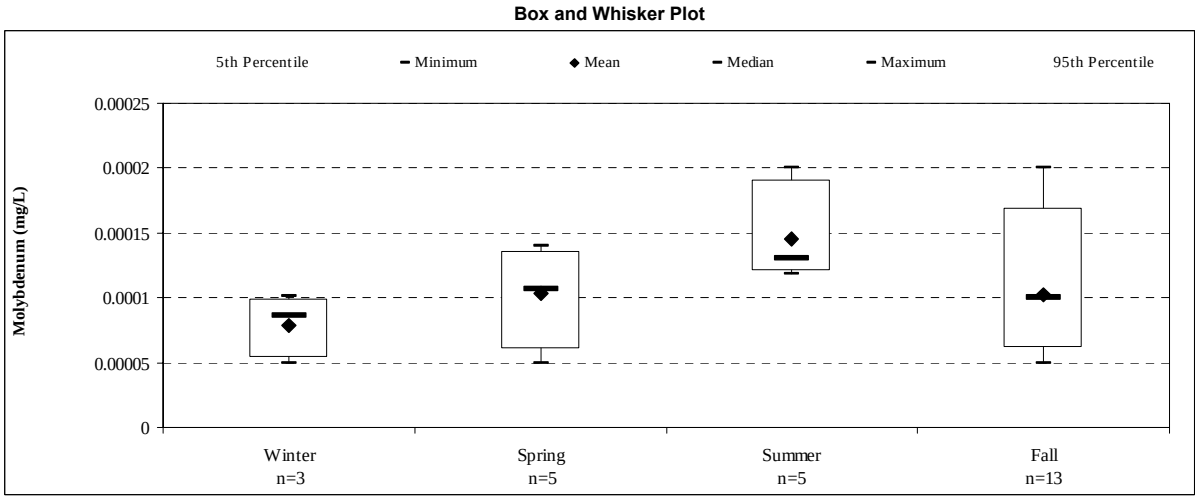


Figure G-2-4-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Jackpine Creek



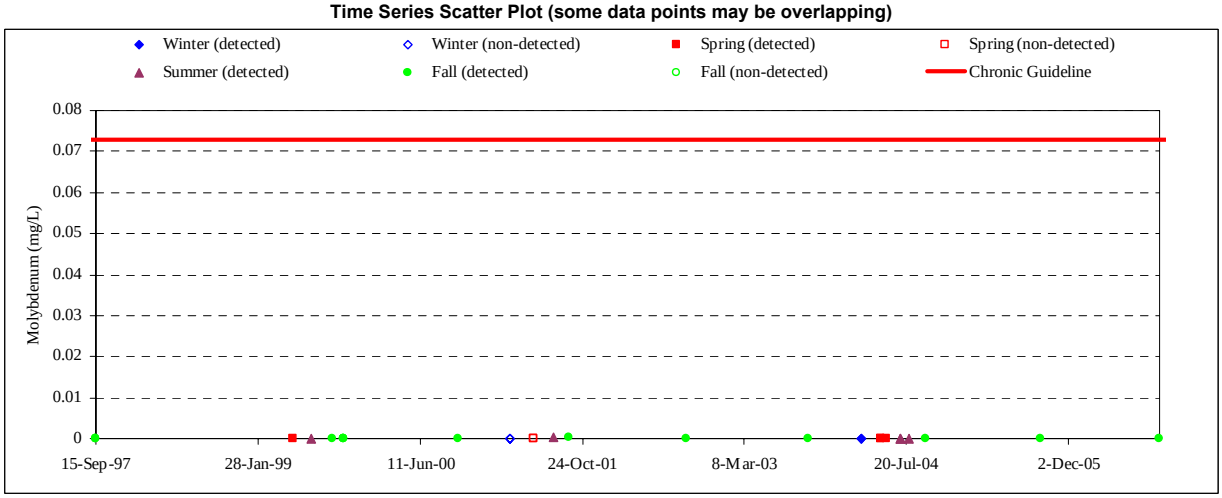
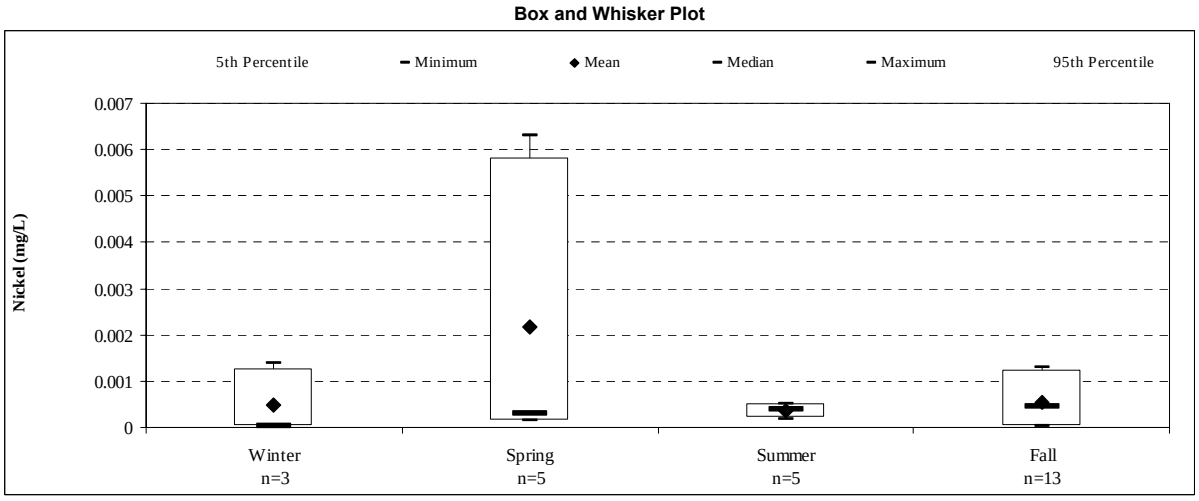


Figure G-2-4-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Jackpine Creek



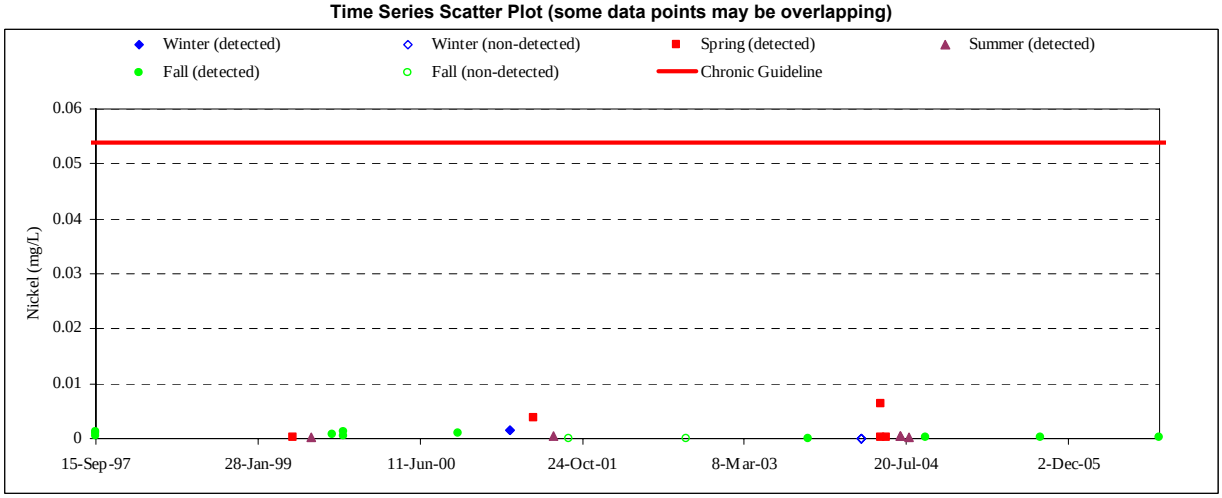
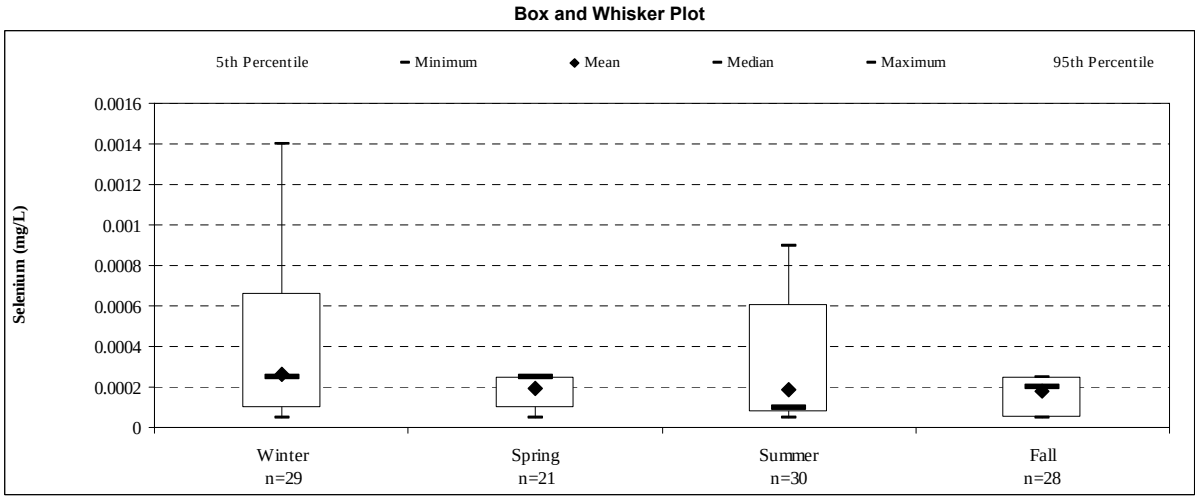


Figure G-2-4-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Jackpine Creek



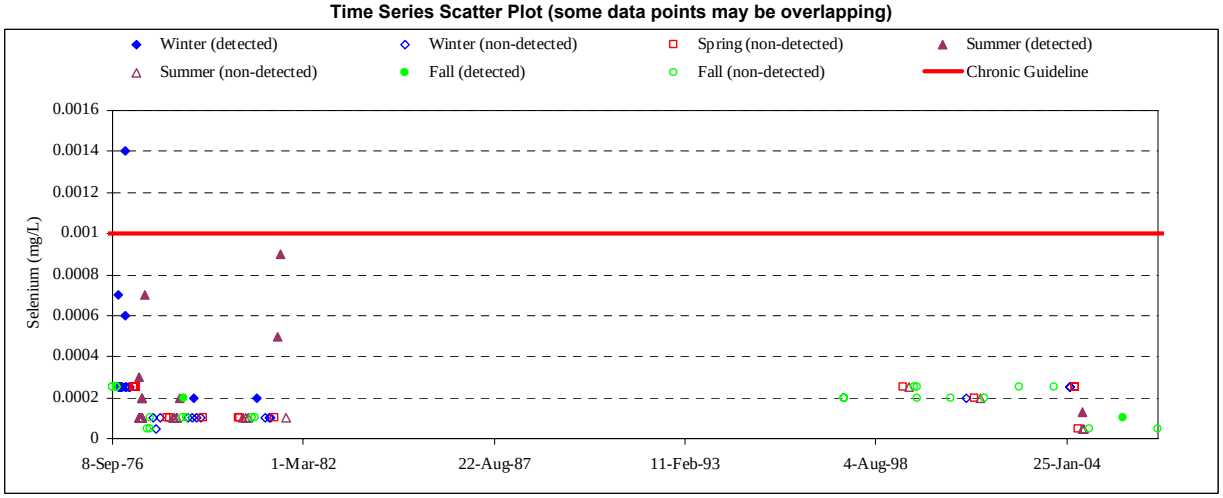
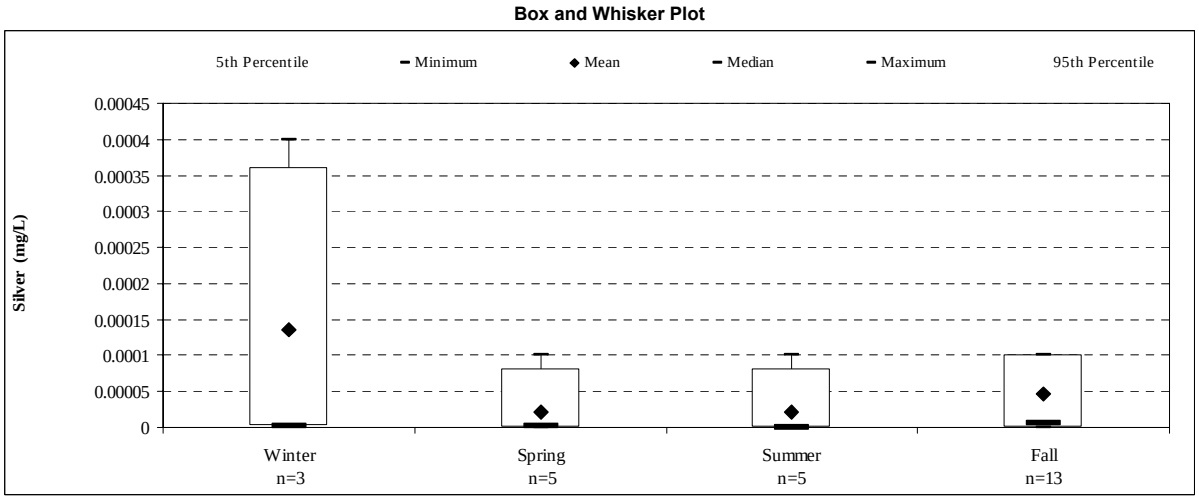


Figure G-2-4-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Jackpine Creek



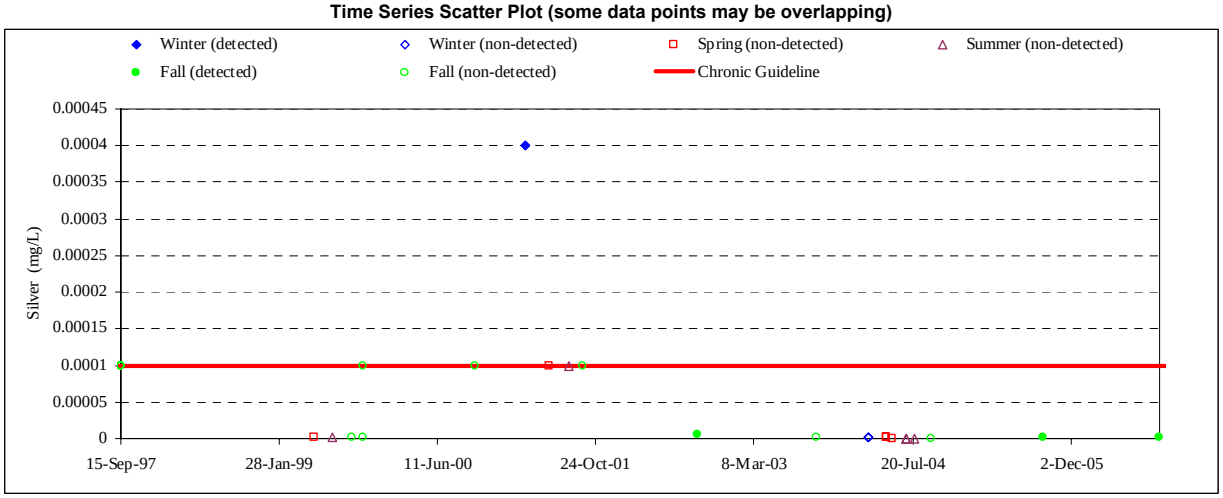
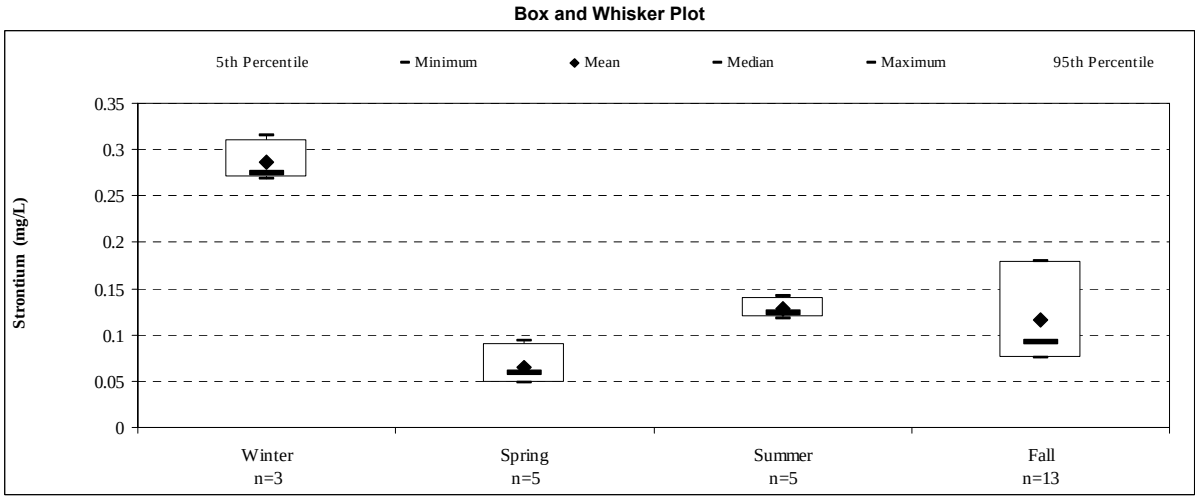


Figure G-2-4-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Jackpine Creek



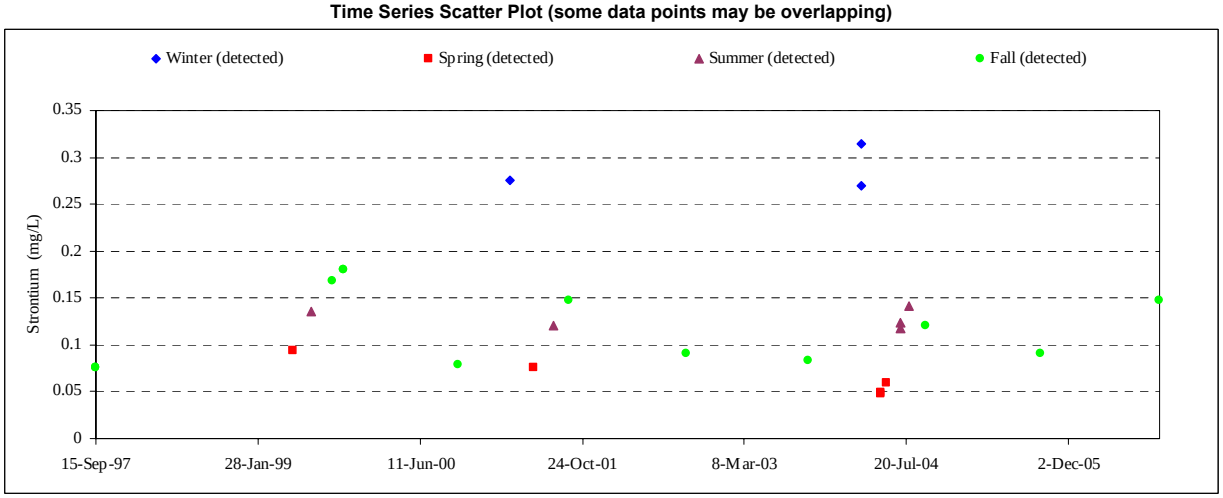
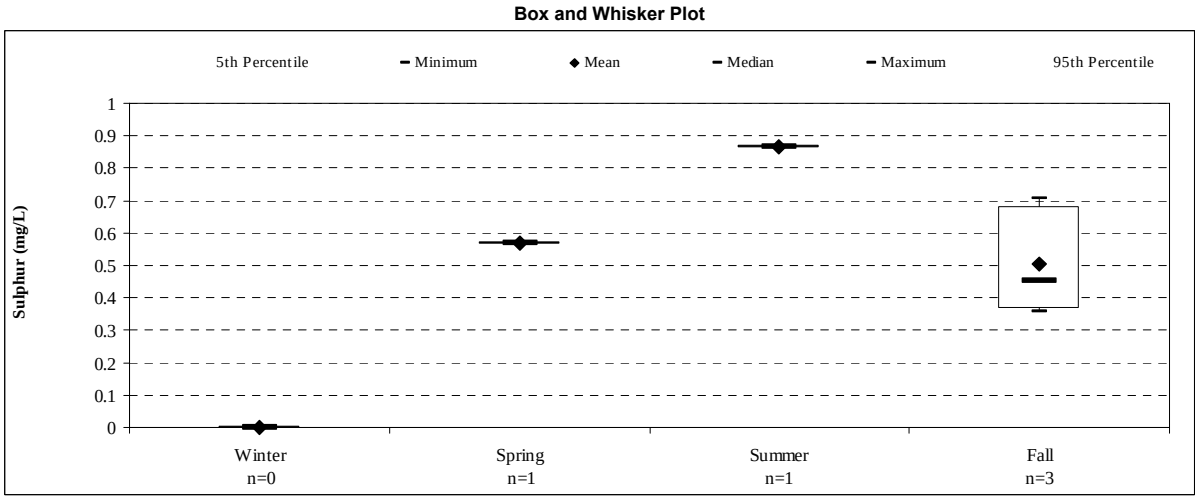


Figure G-2-4-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Jackpine Creek



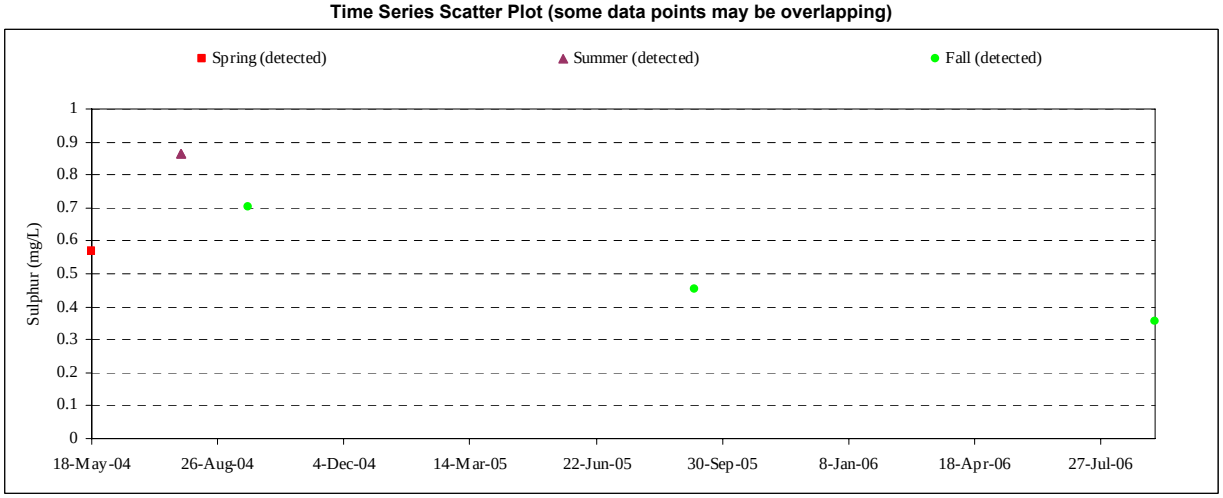
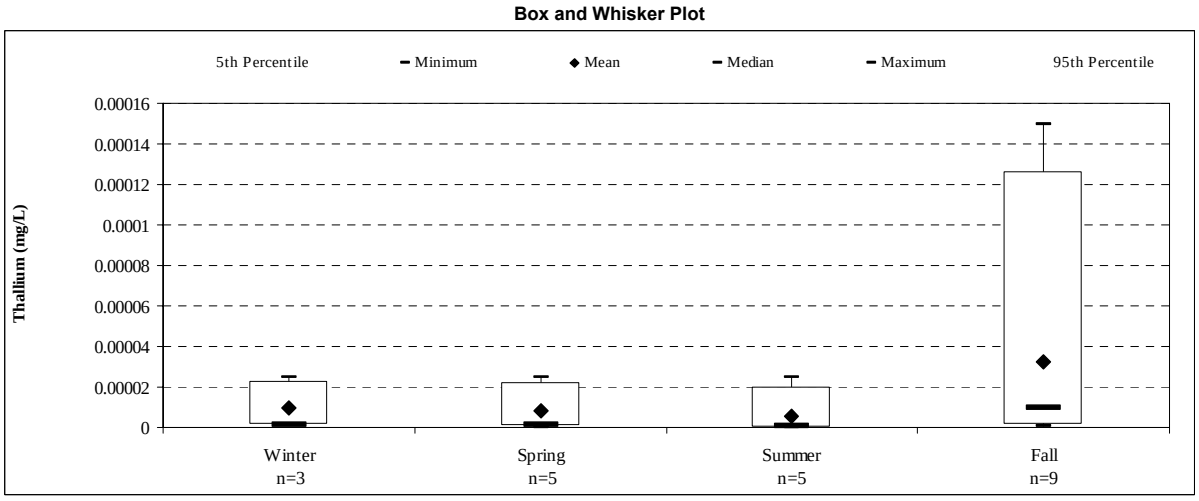


Figure G-2-4-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Jackpine Creek



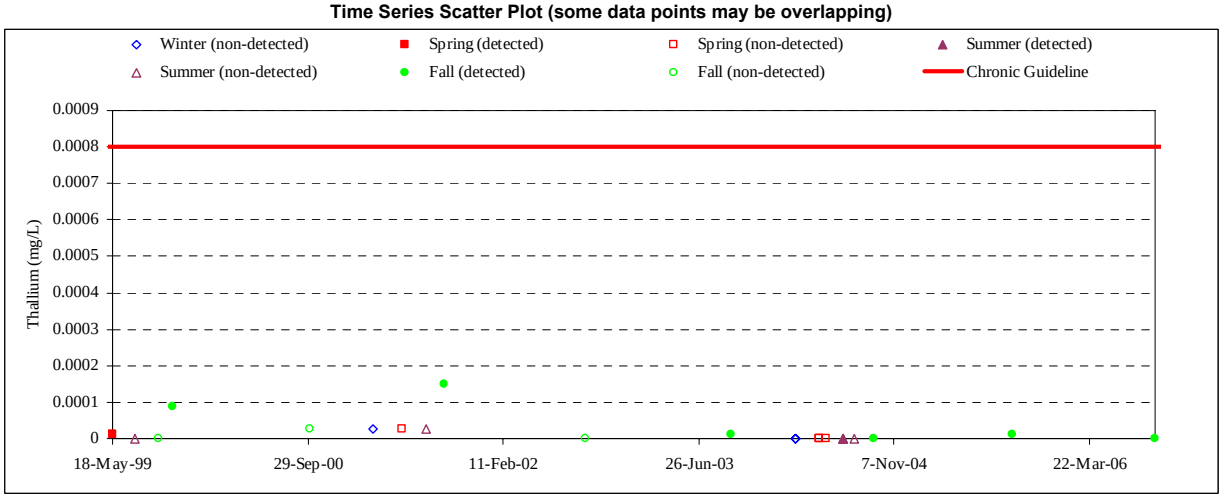
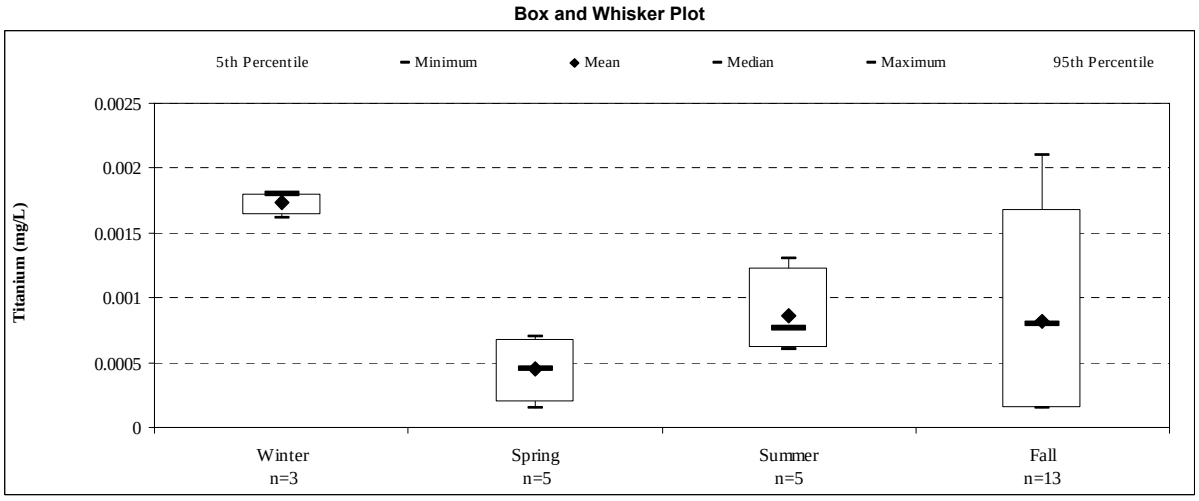


Figure G-2-4-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Jackpine Creek



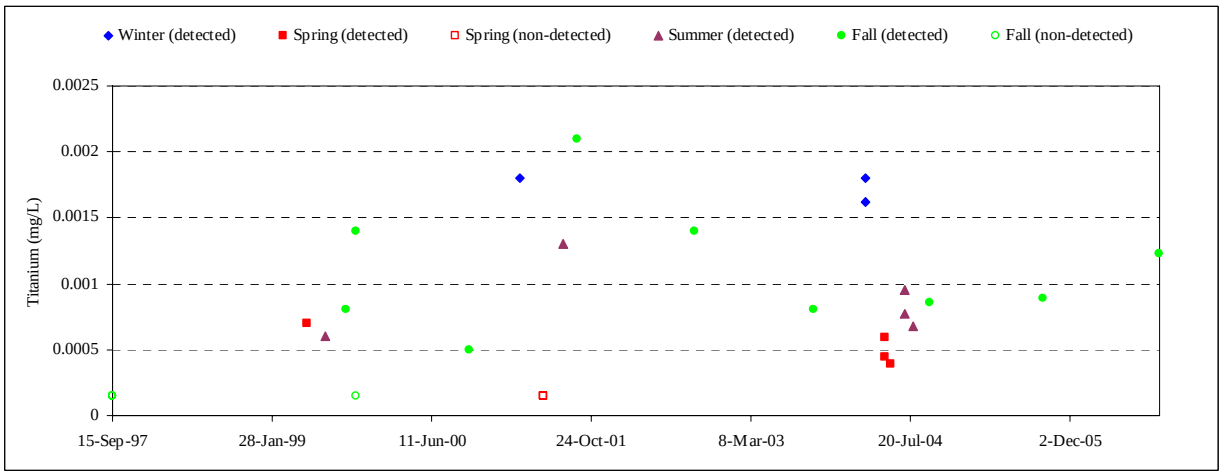
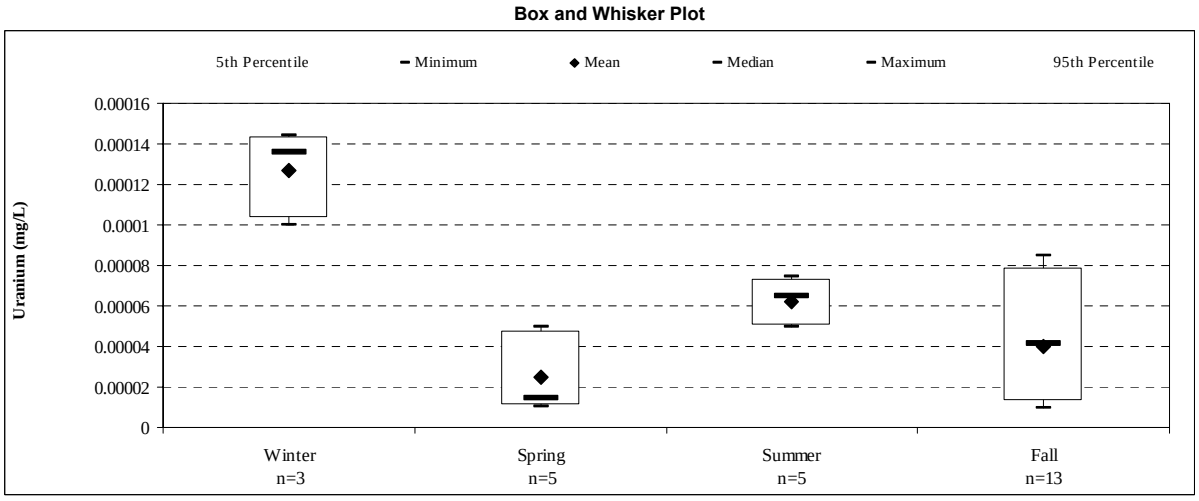


Figure G-2-4-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Jackpine Creek



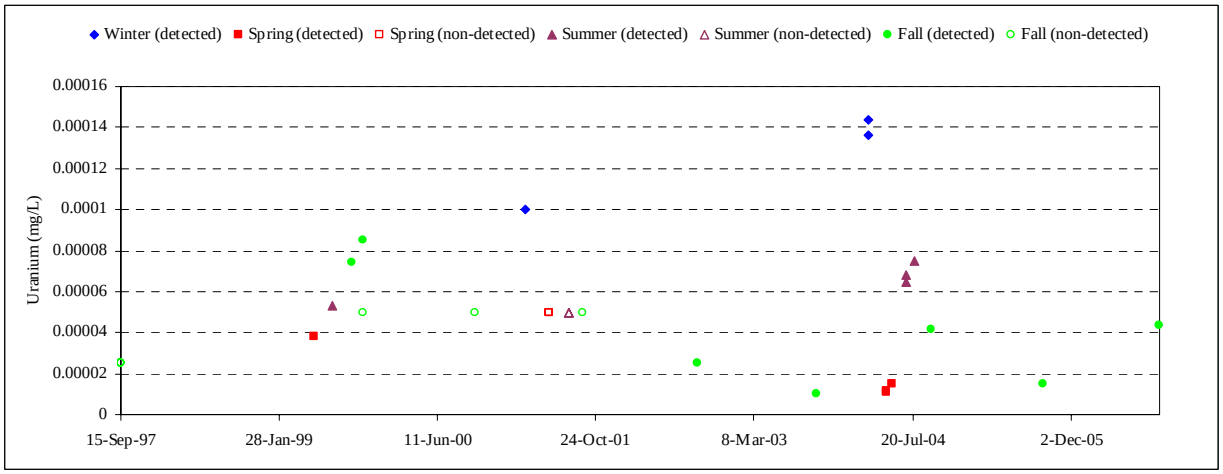
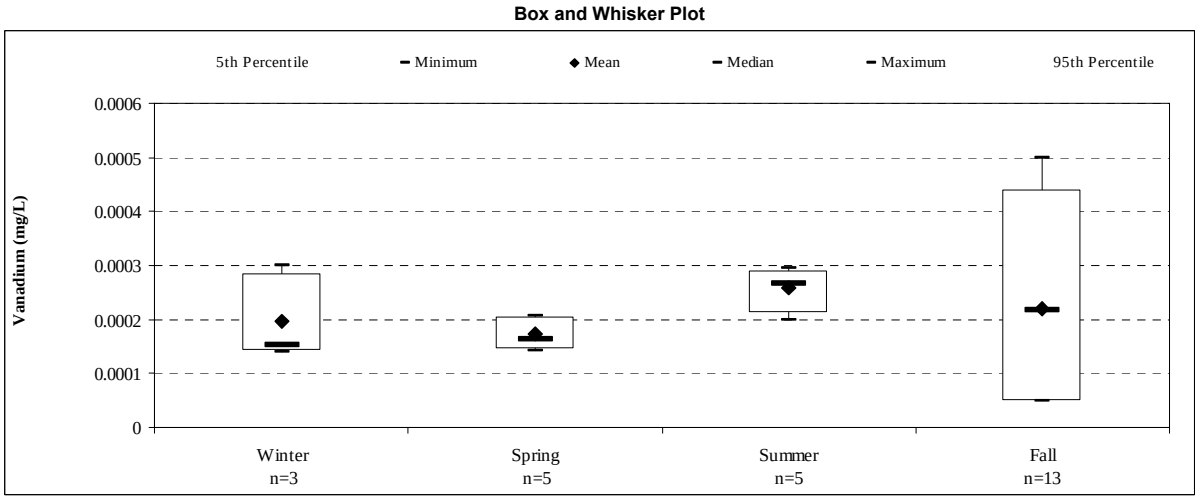


Figure G-2-4-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Jackpine Creek



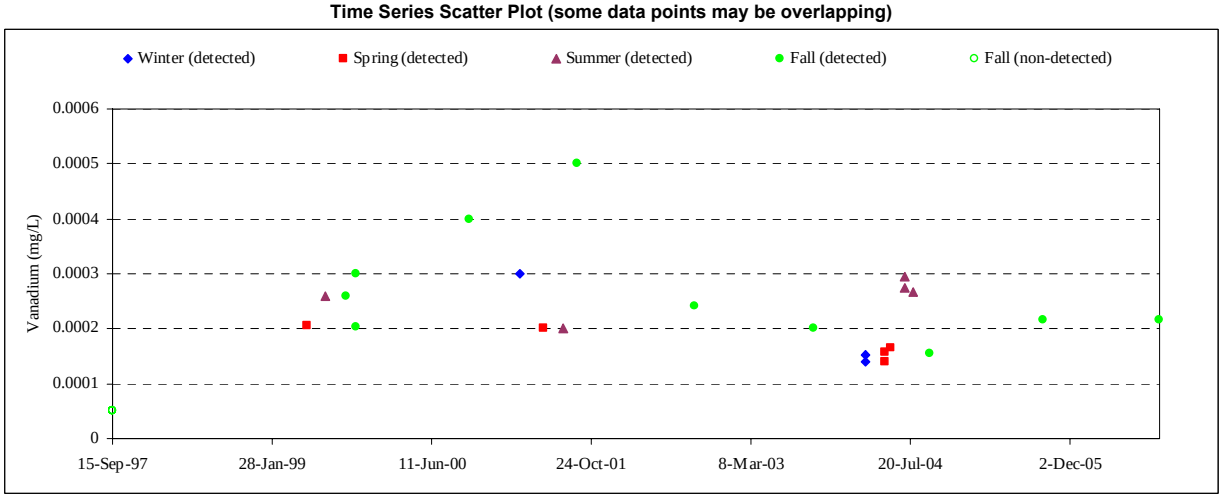
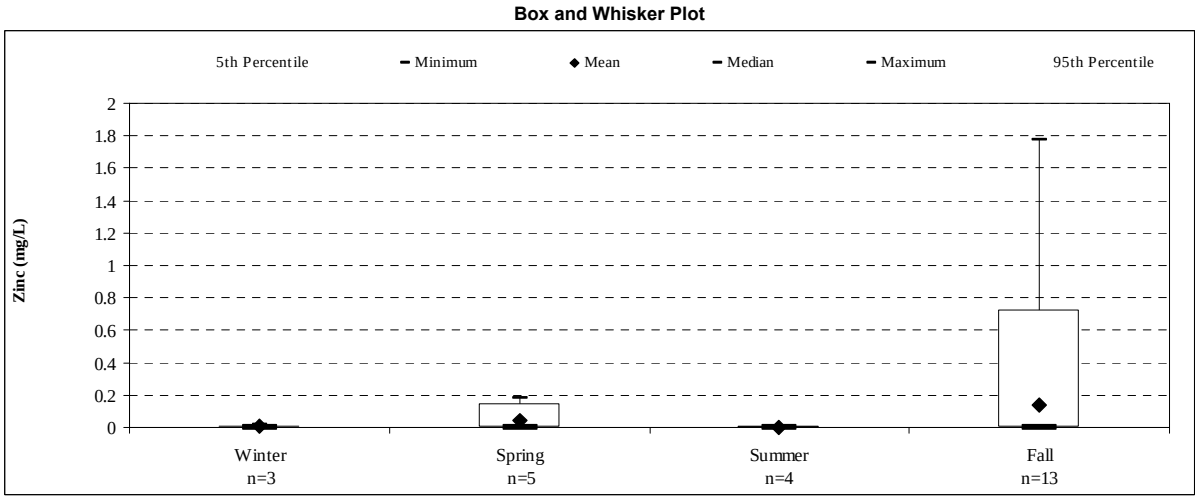


Figure G-2-4-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Jackpine Creek



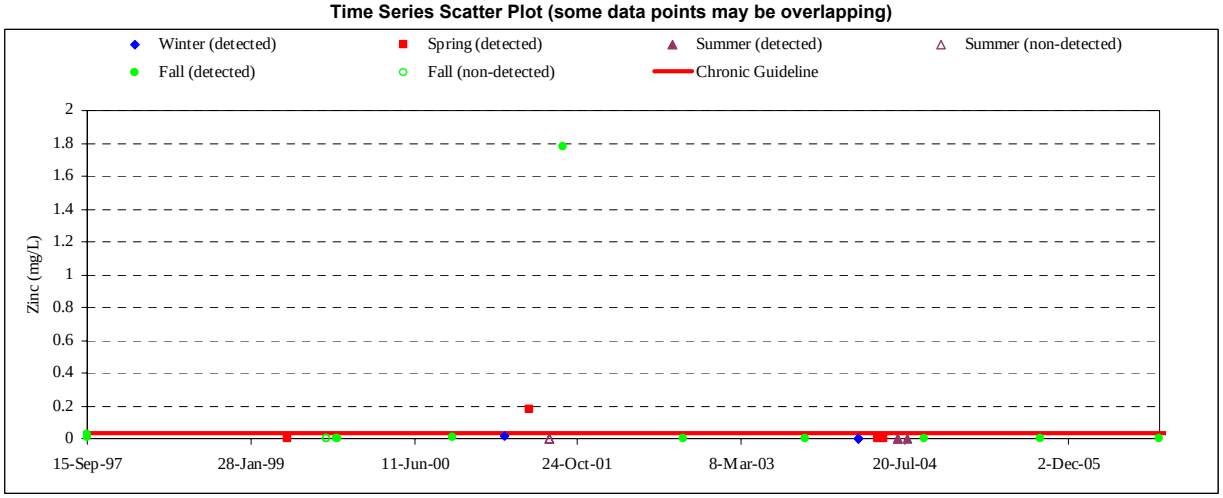
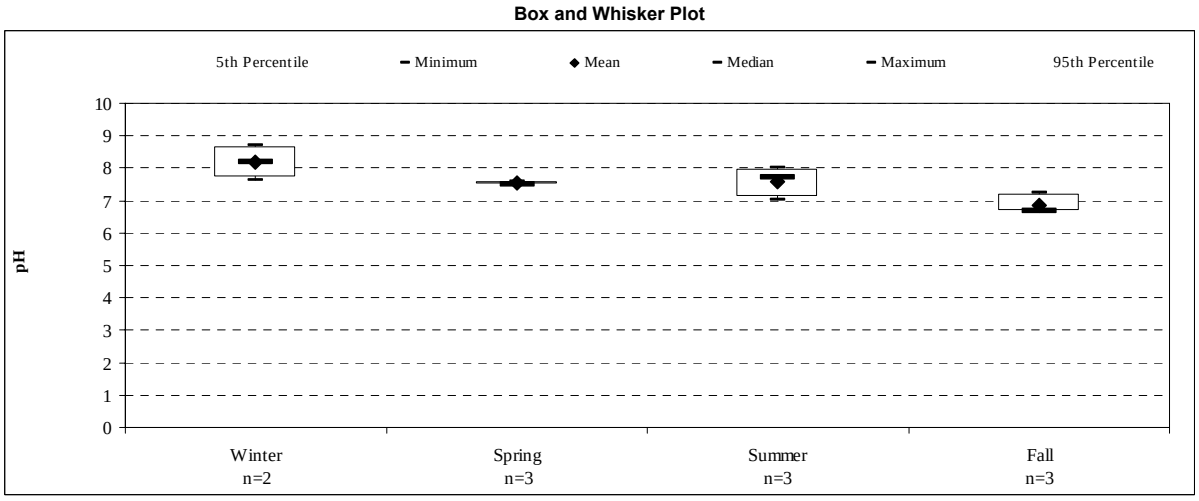


Figure G-2-5-1 Box Whisker and Time Series Scatter Plots of Observed pH in Shelley Creek



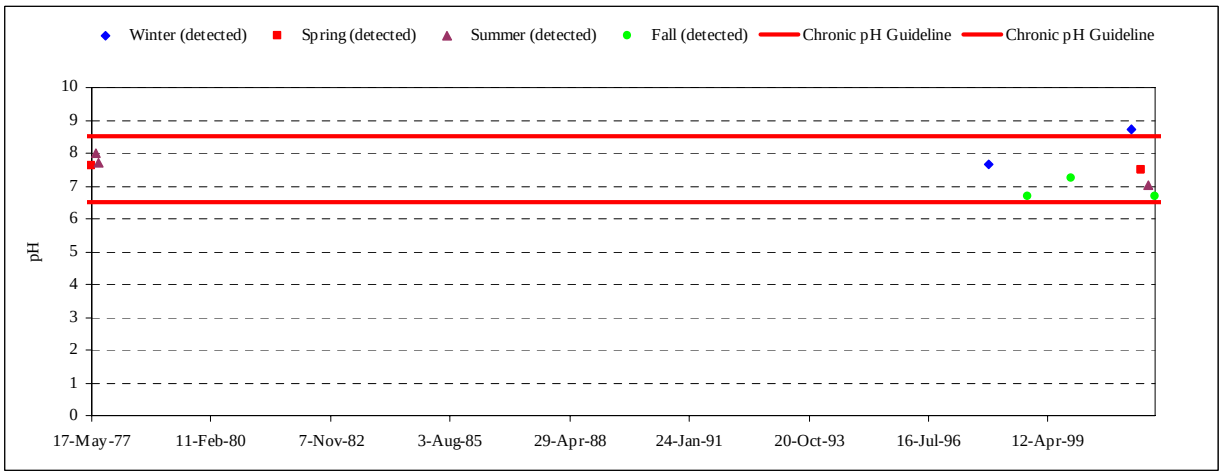


Figure G-2-5-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Shelley Creek

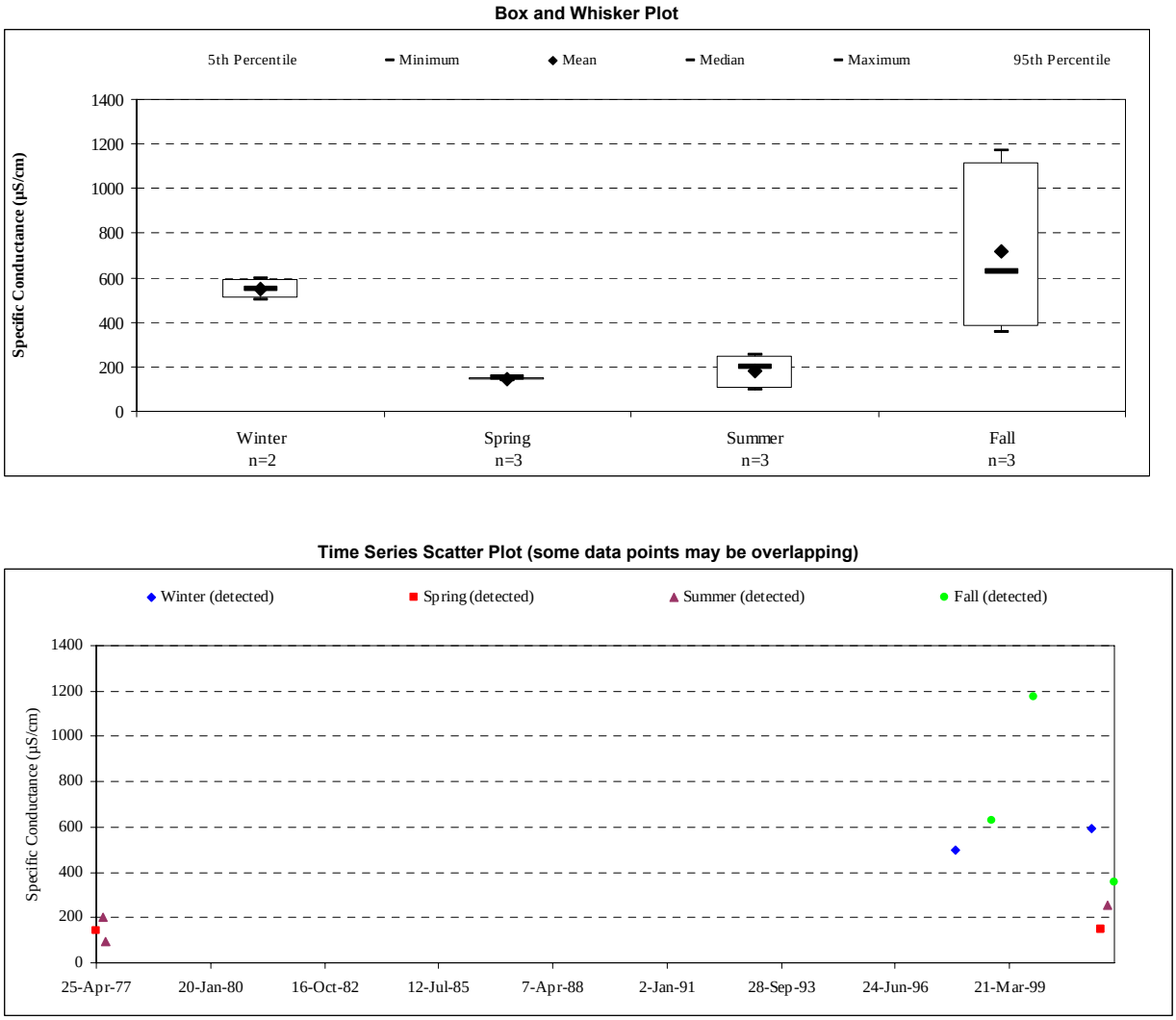
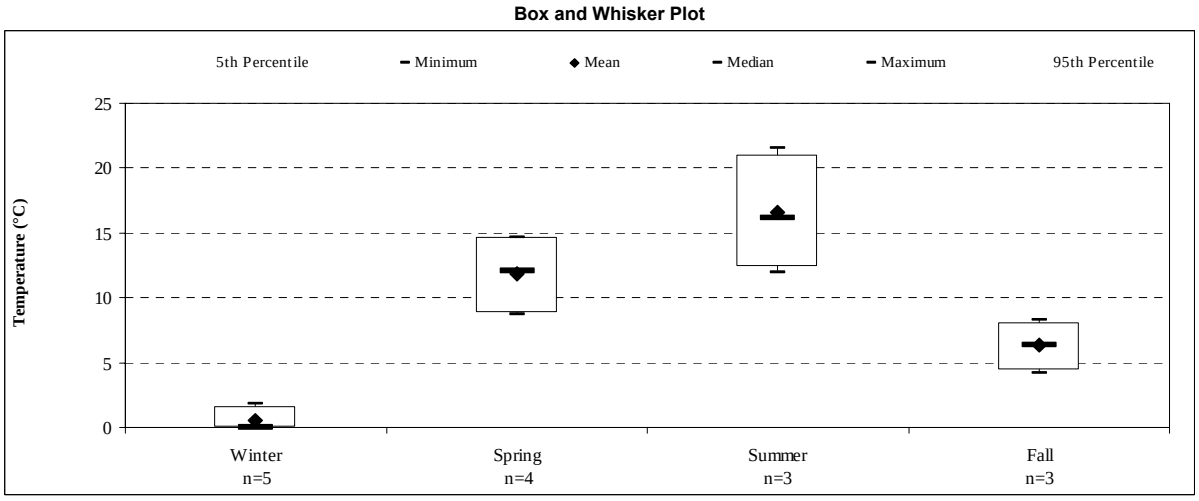


Figure G-2-5-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Shelley Creek



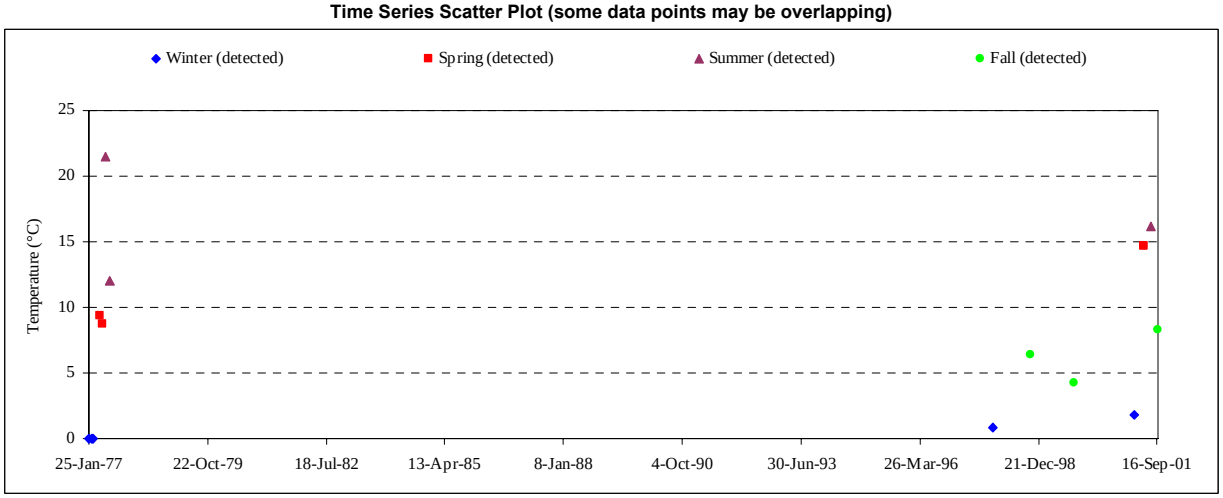
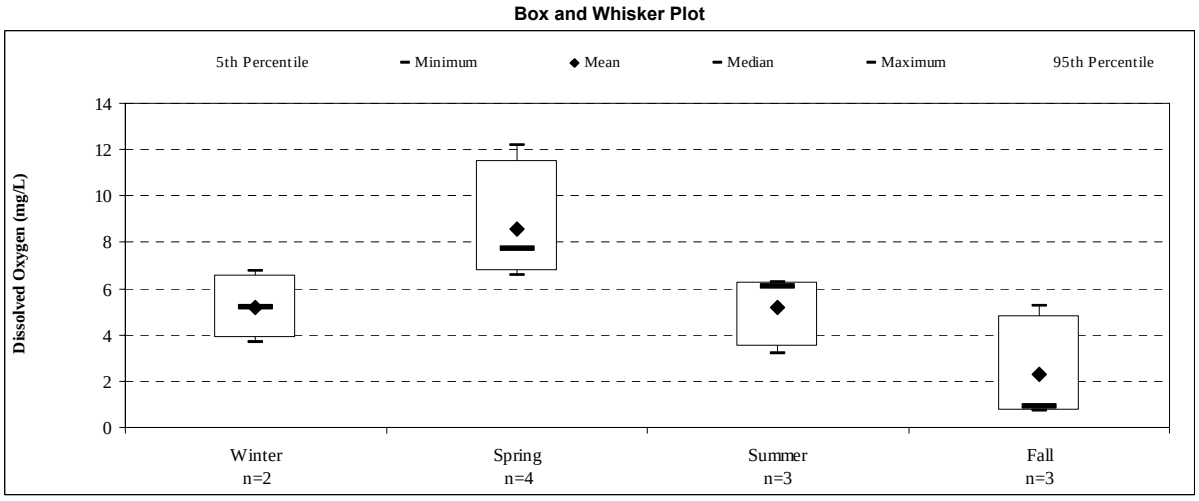


Figure G-2-5-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Shelley Creek



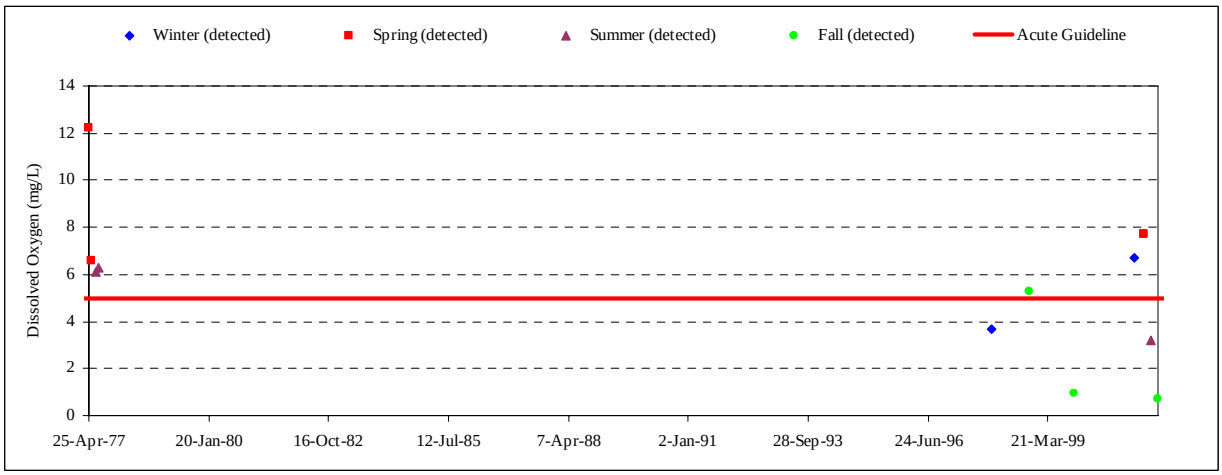
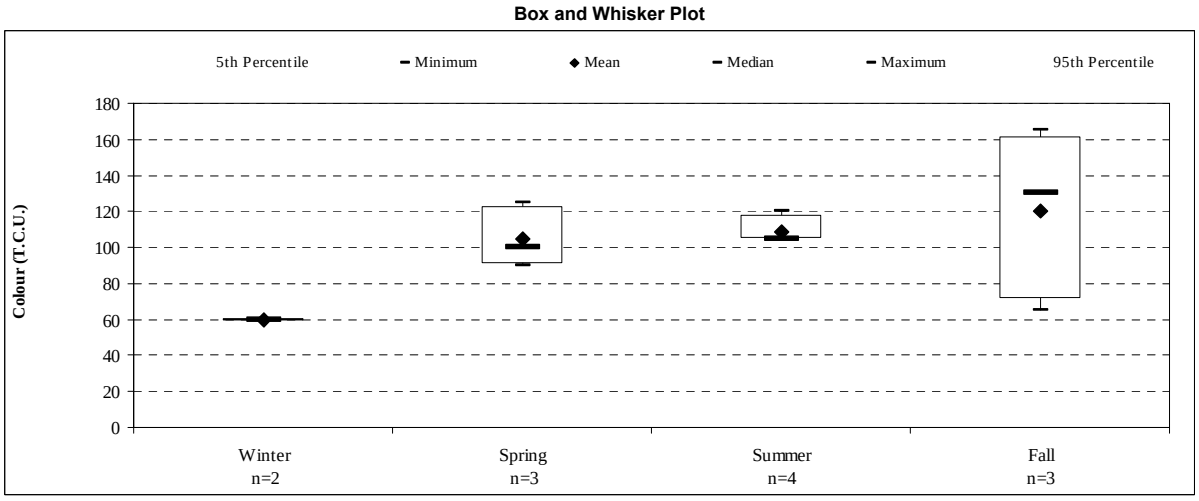


Figure G-2-5-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Shelley Creek



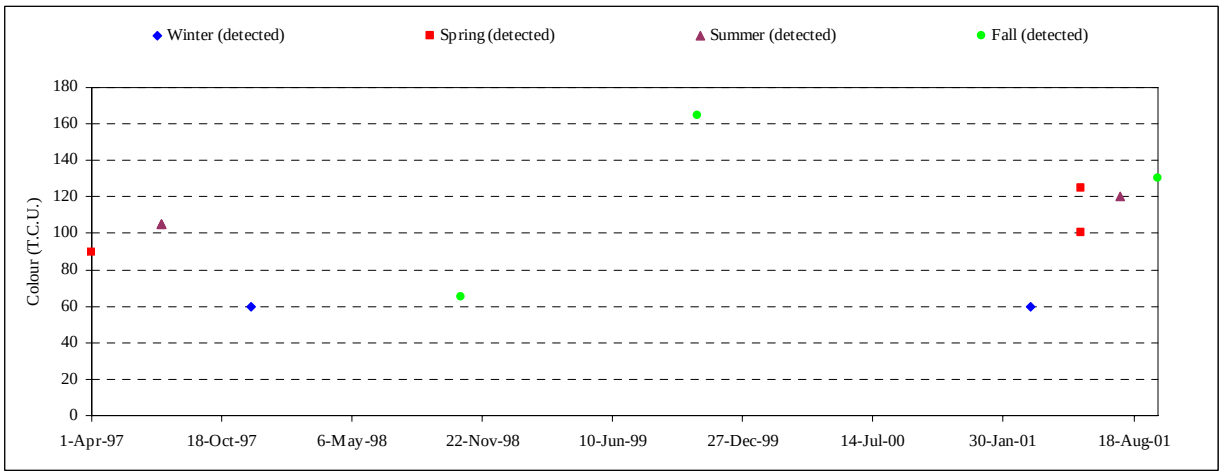
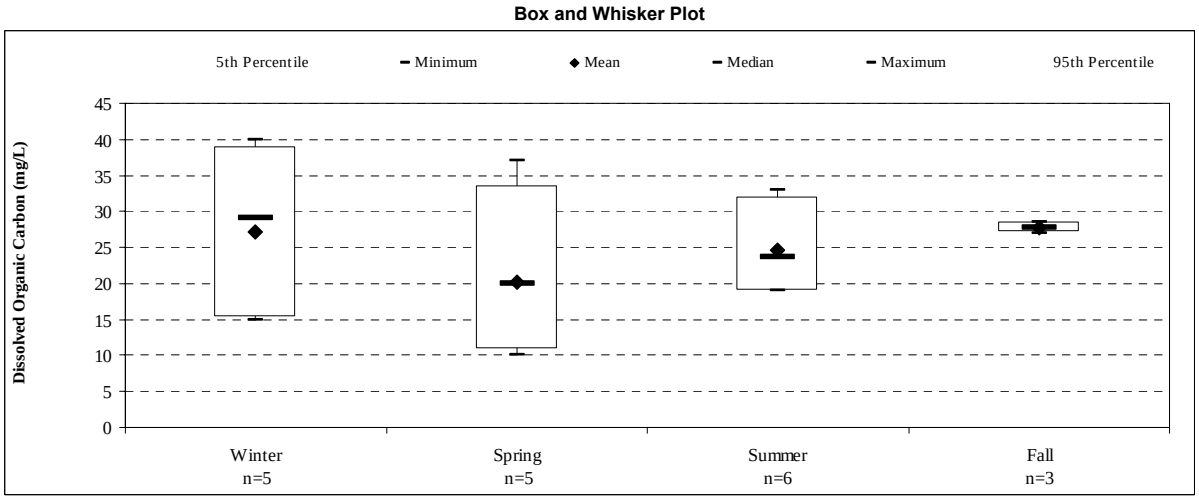


Figure G-2-5-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Shelley Creek



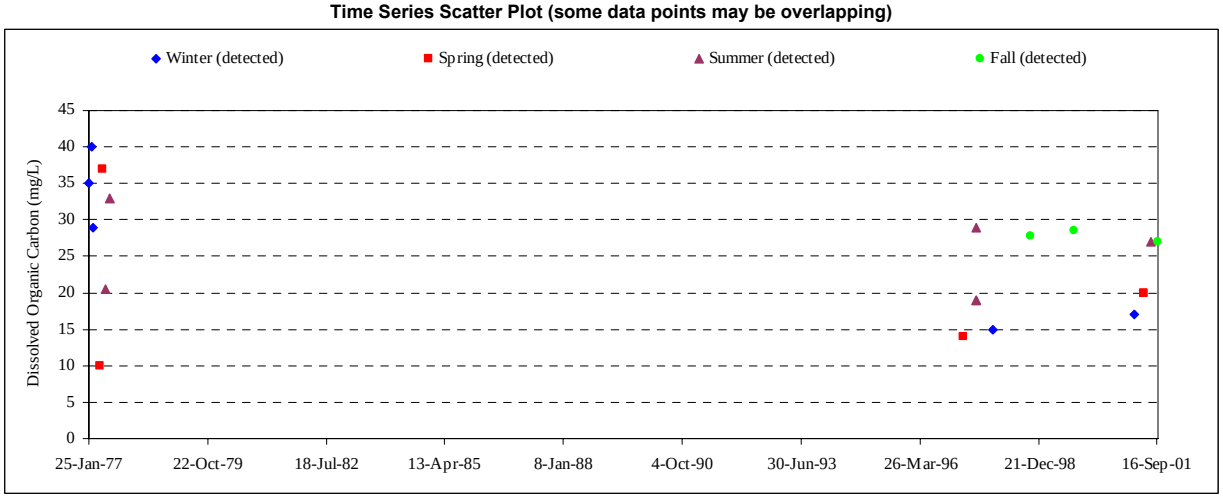
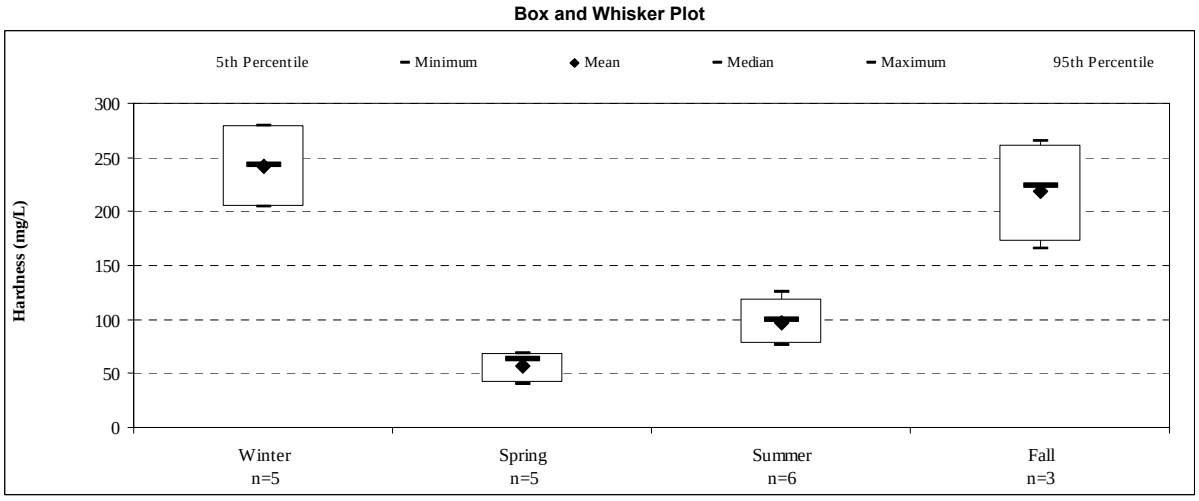


Figure G-2-5-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Shelley Creek



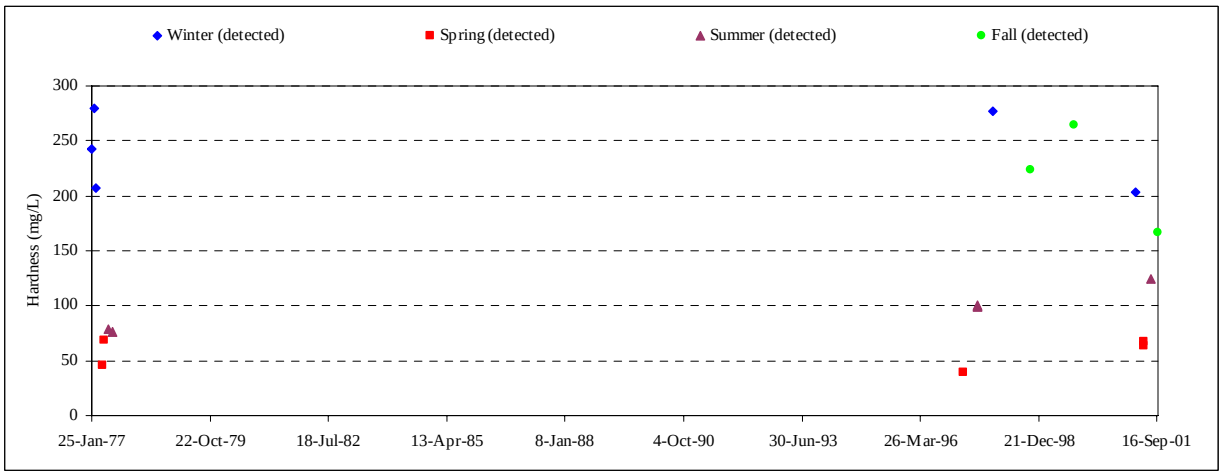
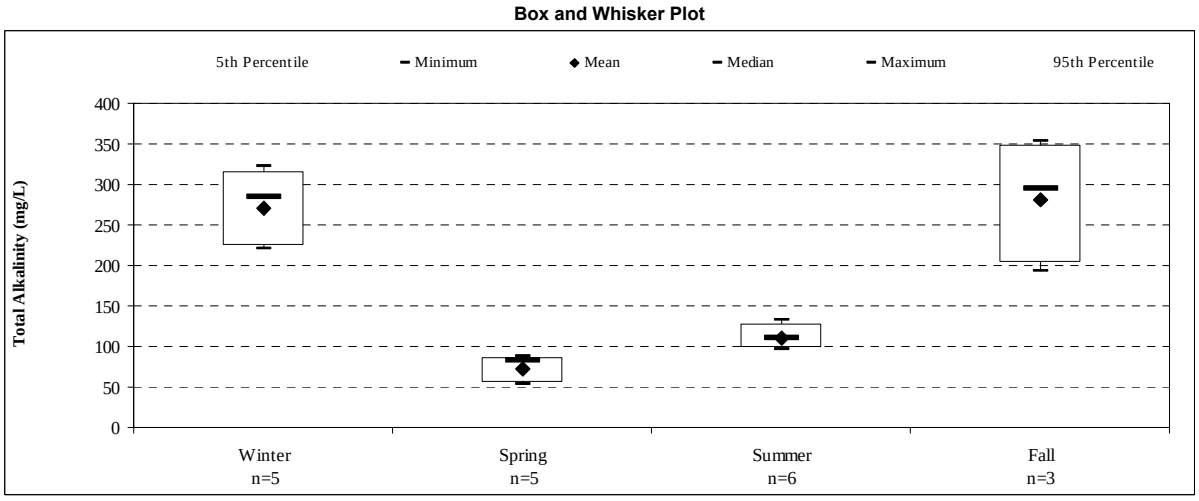


Figure G-2-5-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Shelley Creek



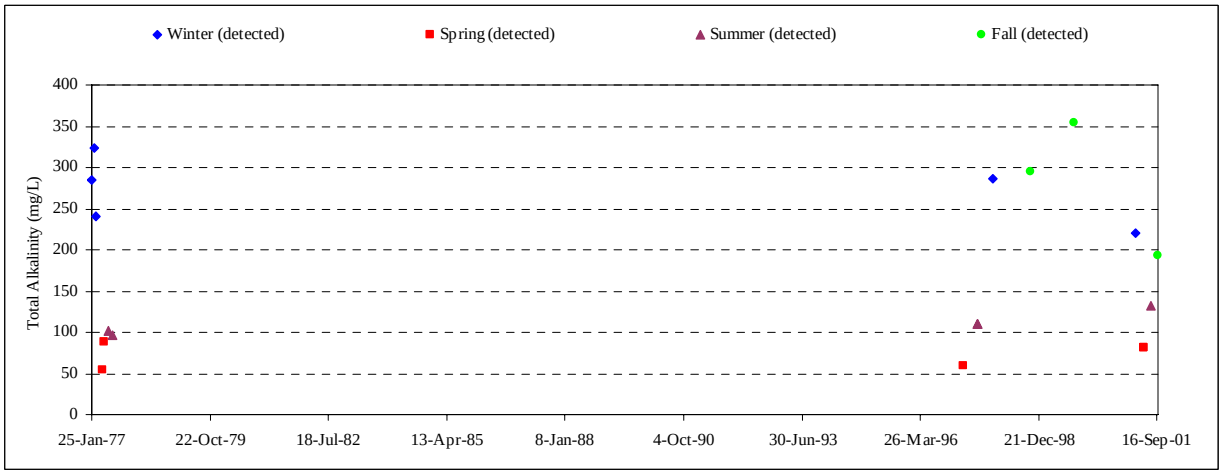
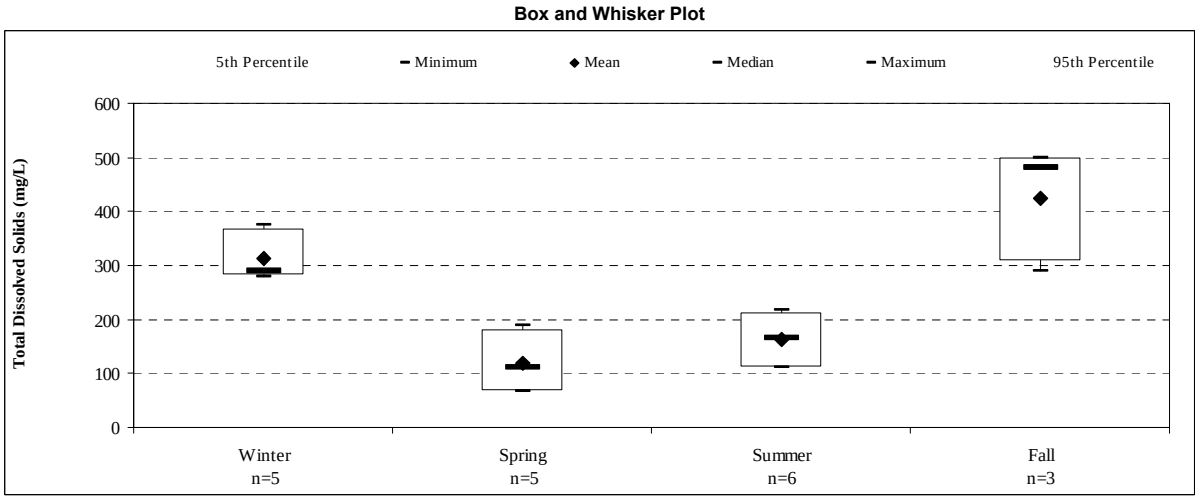


Figure G-2-5-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Shelley Creek



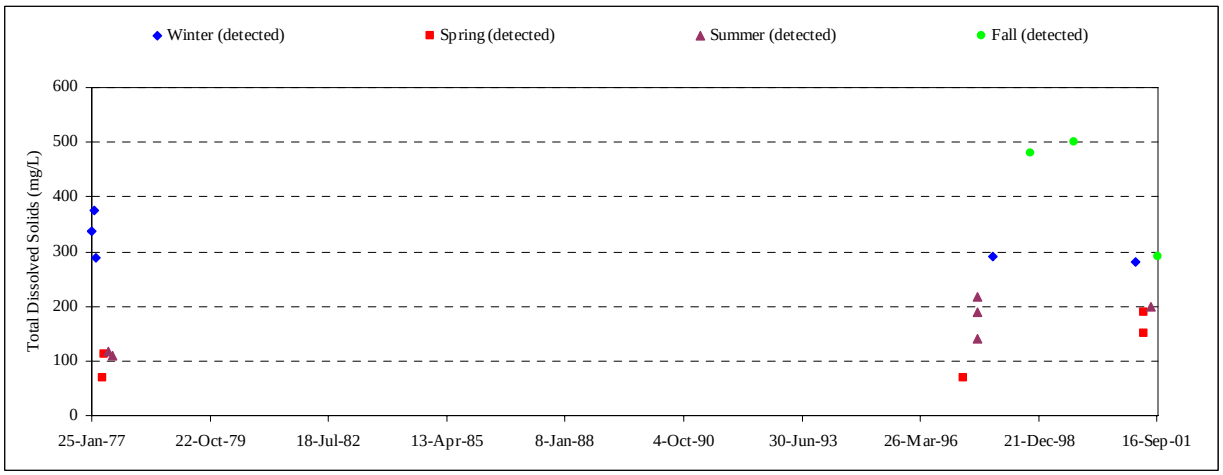
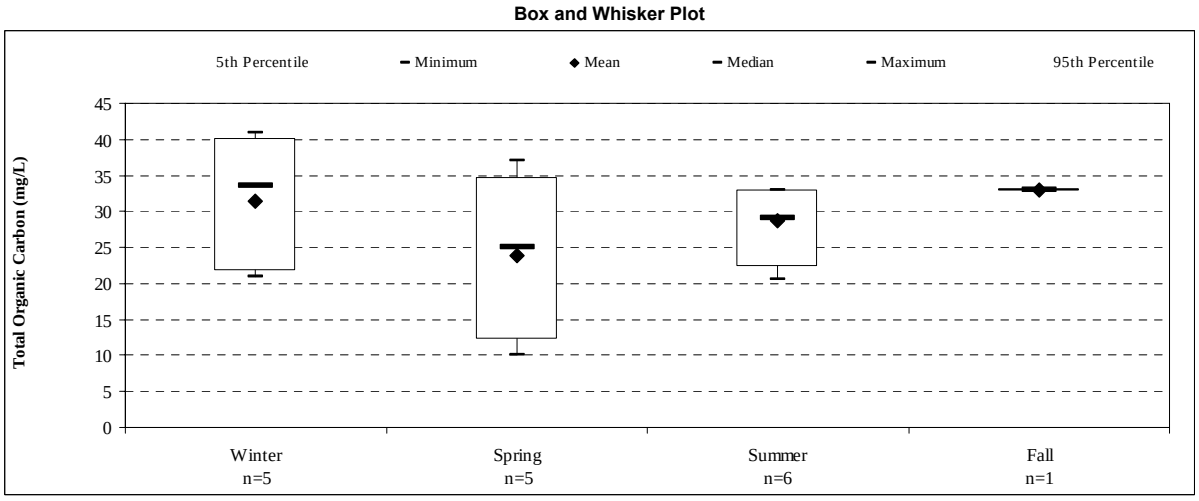


Figure G-2-5-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Shelley Creek



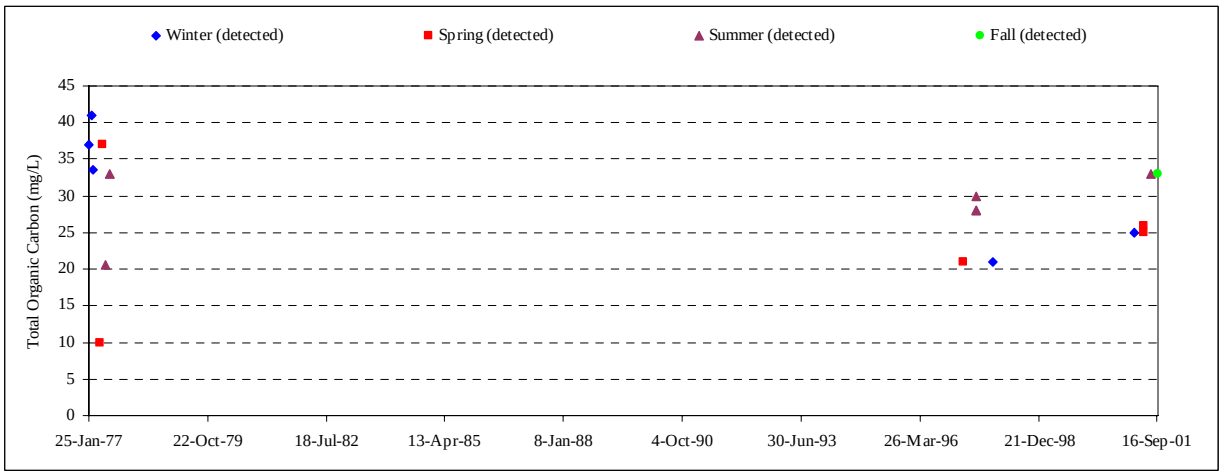
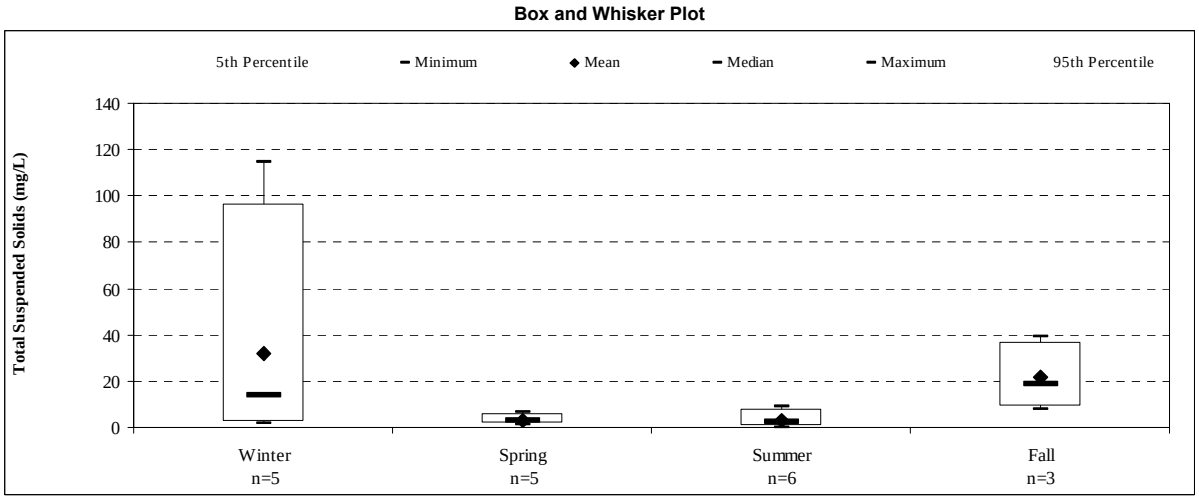


Figure G-2-5-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Shelley Creek



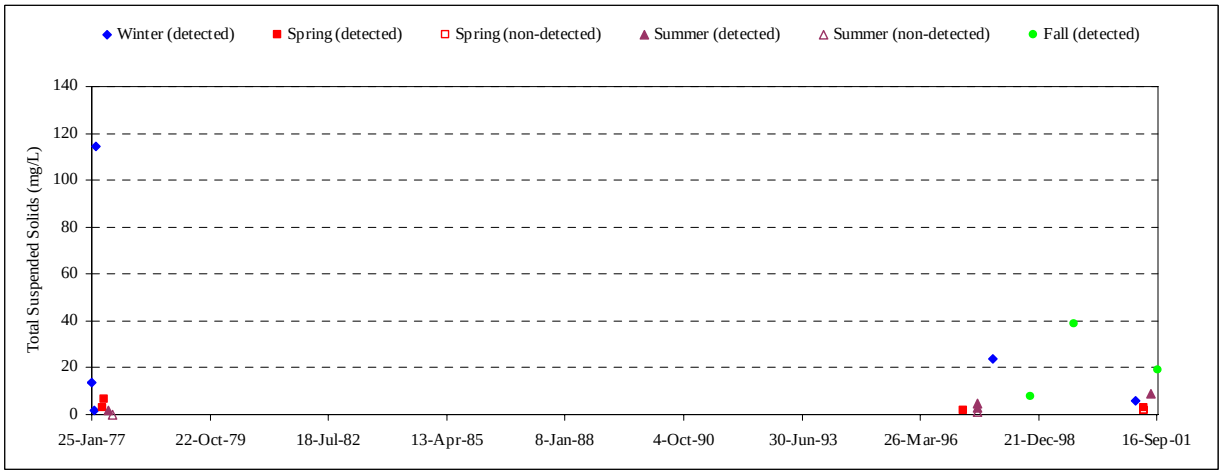
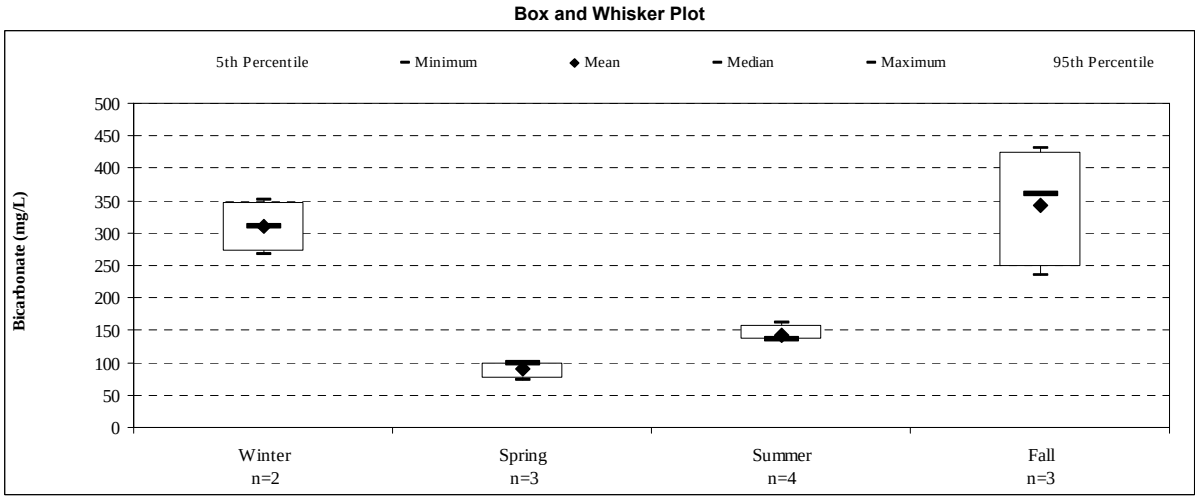


Figure G-2-5-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Shelley Creek



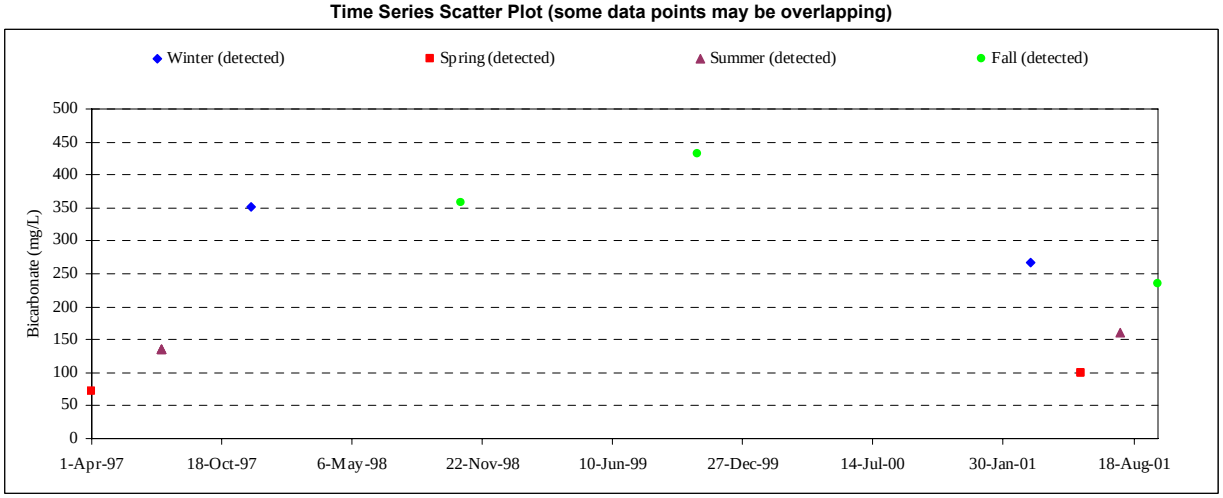
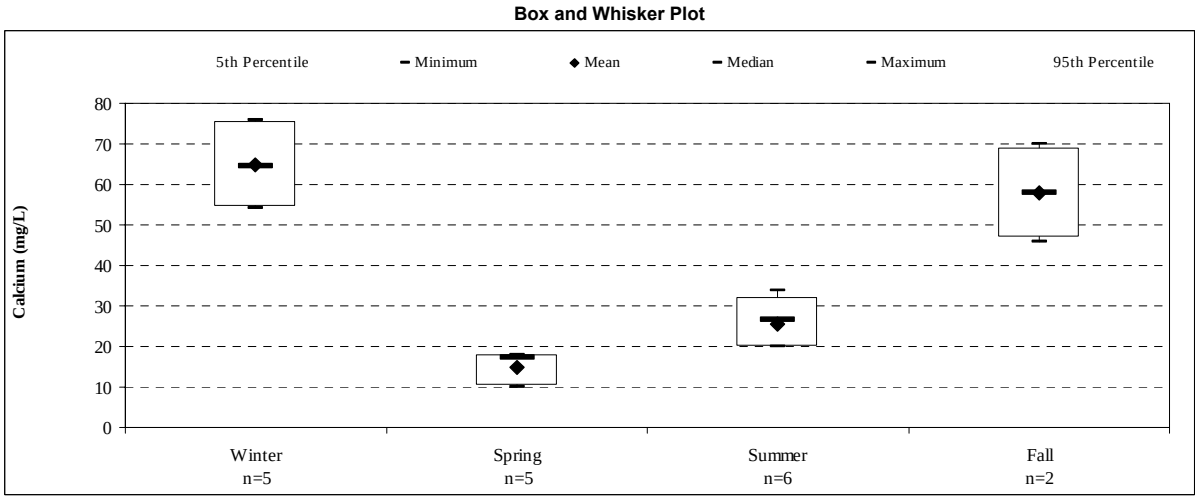


Figure G-2-5-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Shelley Creek



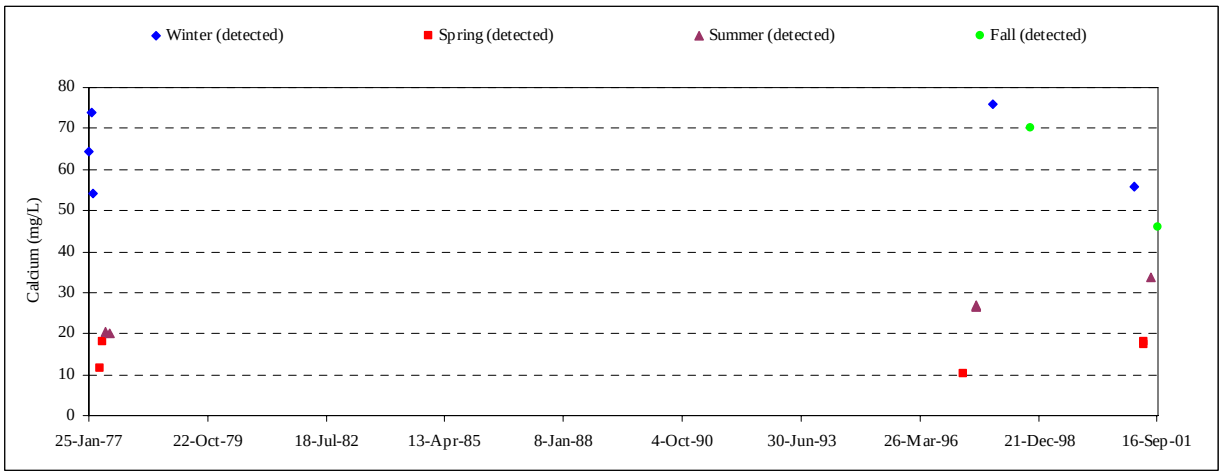
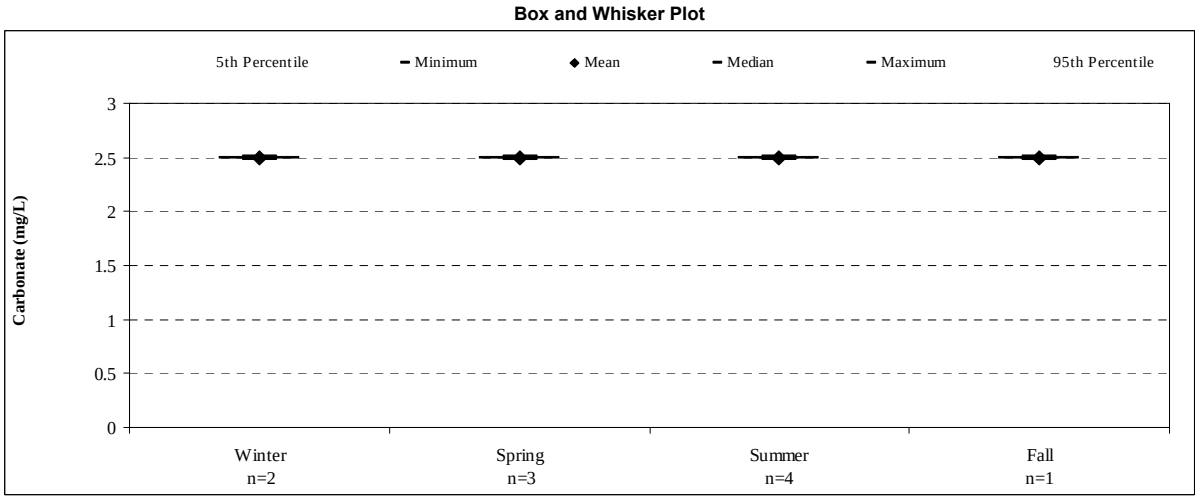


Figure G-2-5-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Shelley Creek



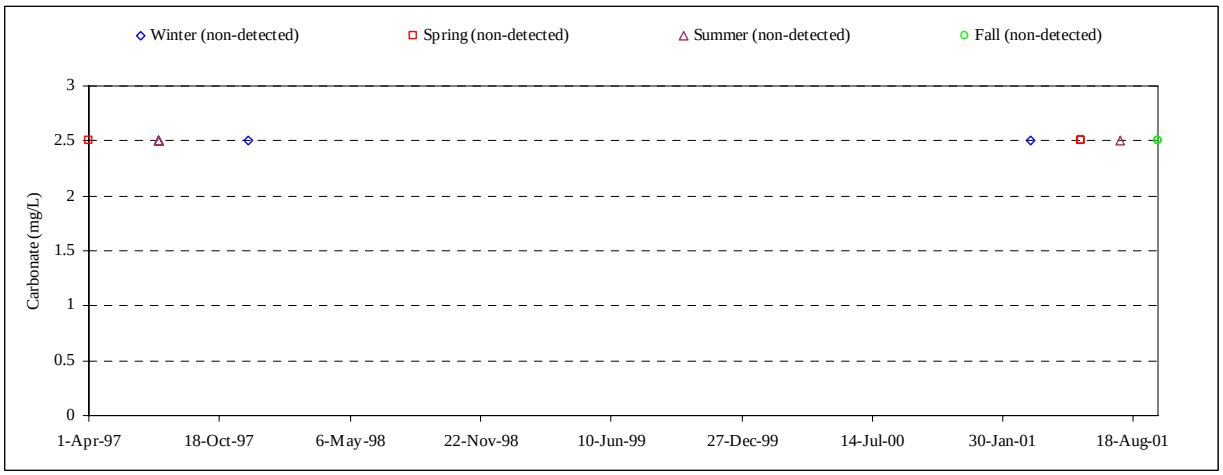
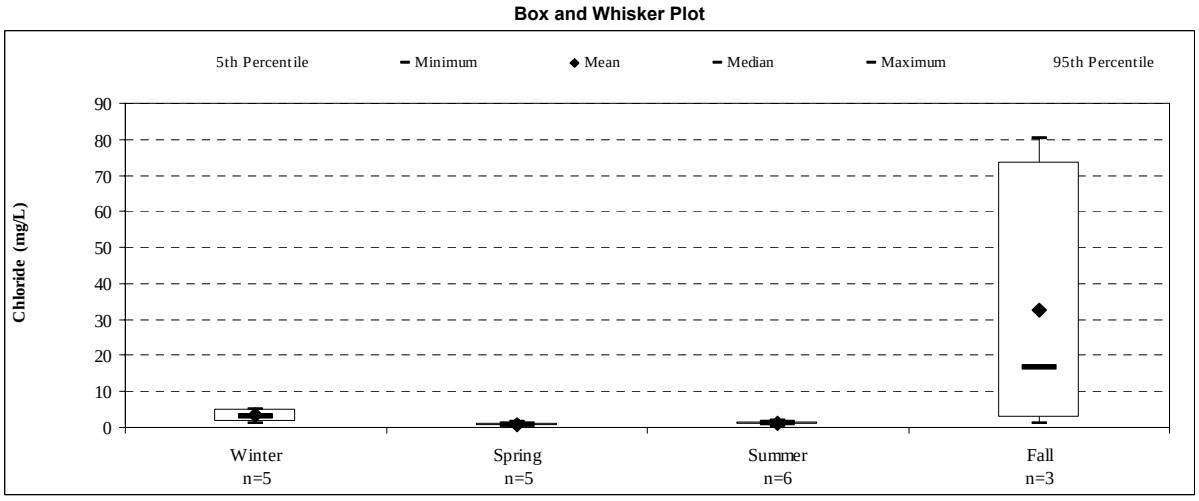


Figure G-2-5-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Shelley Creek



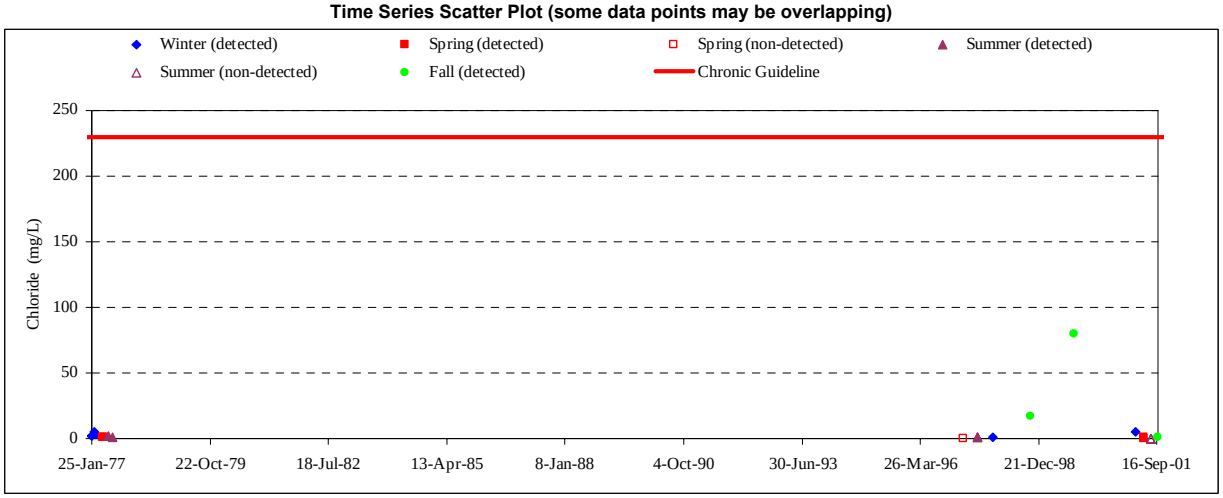
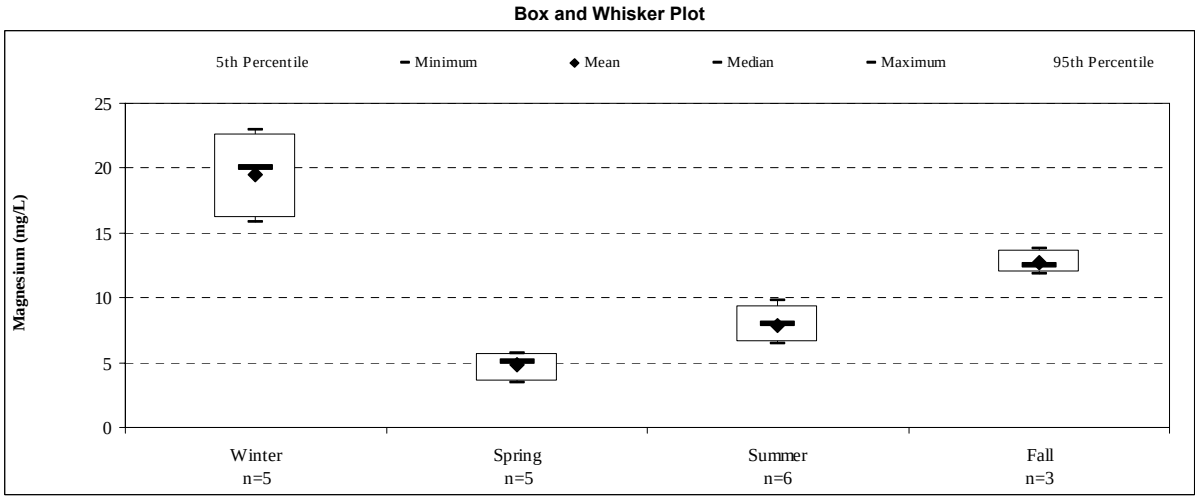


Figure G-2-5-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Shelley Creek



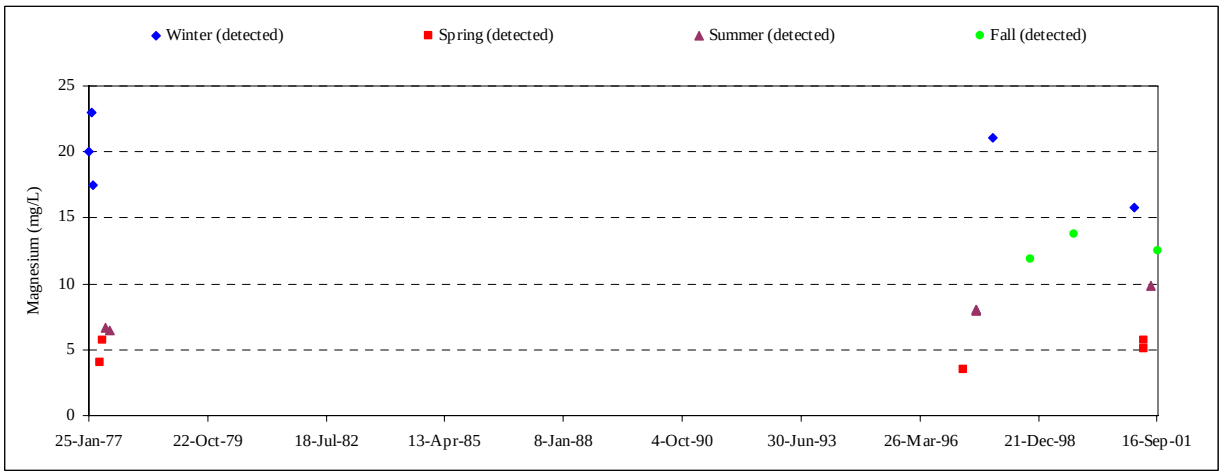
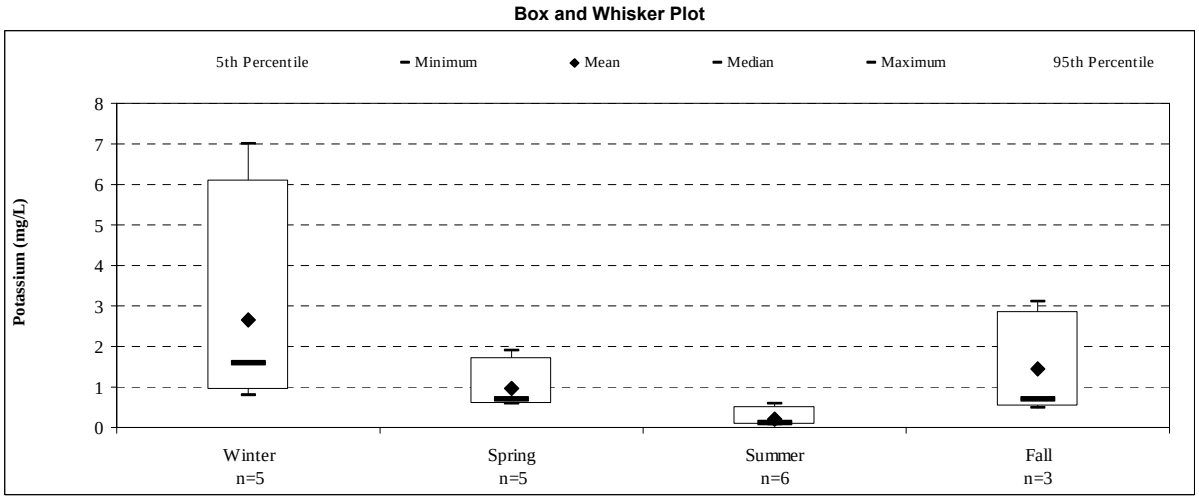


Figure G-2-5-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Shelley Creek



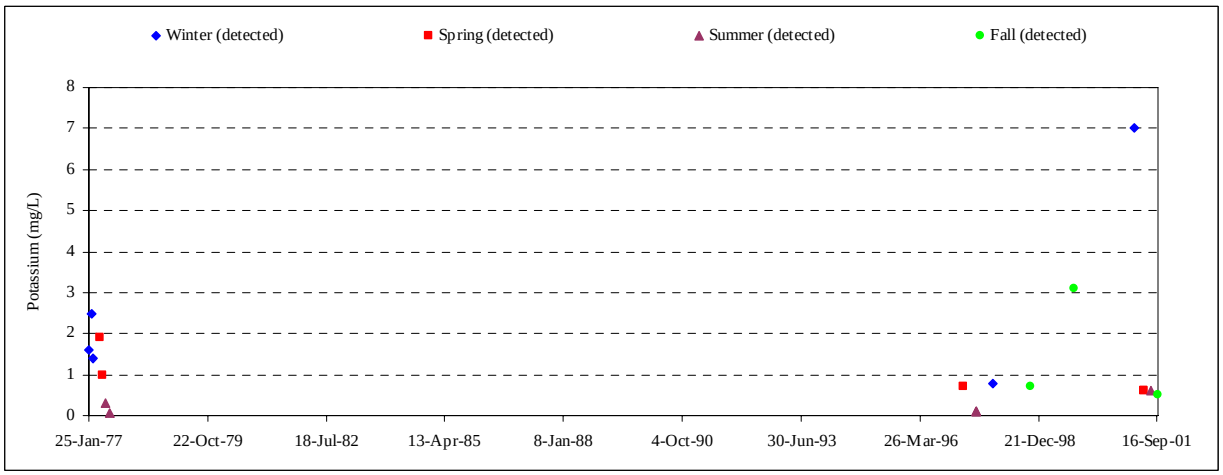
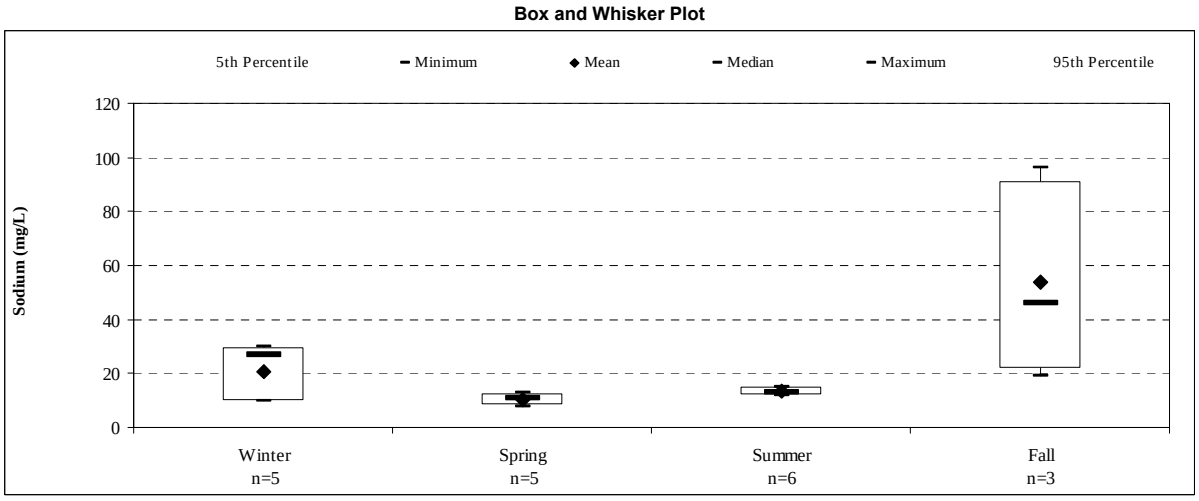


Figure G-2-5-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Shelley Creek



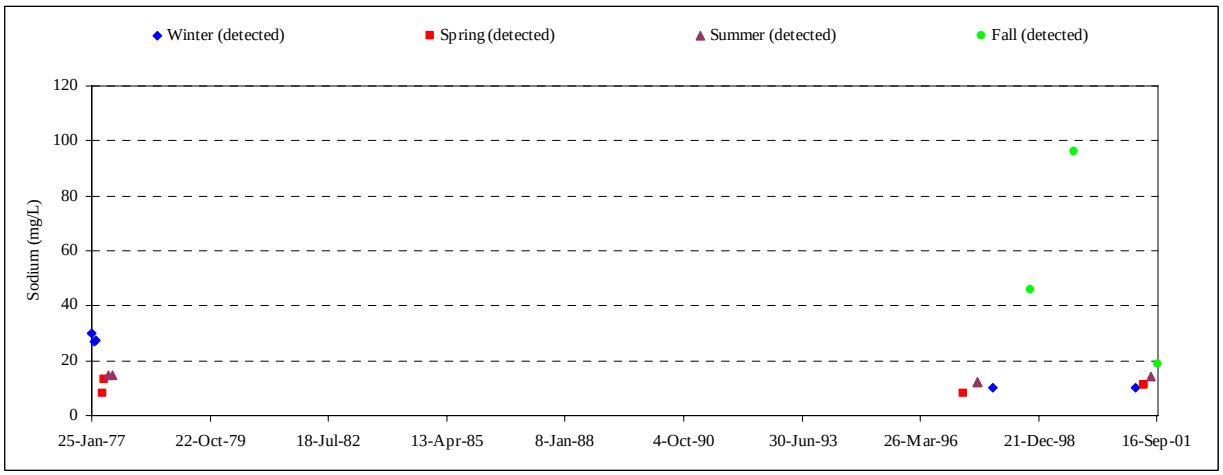
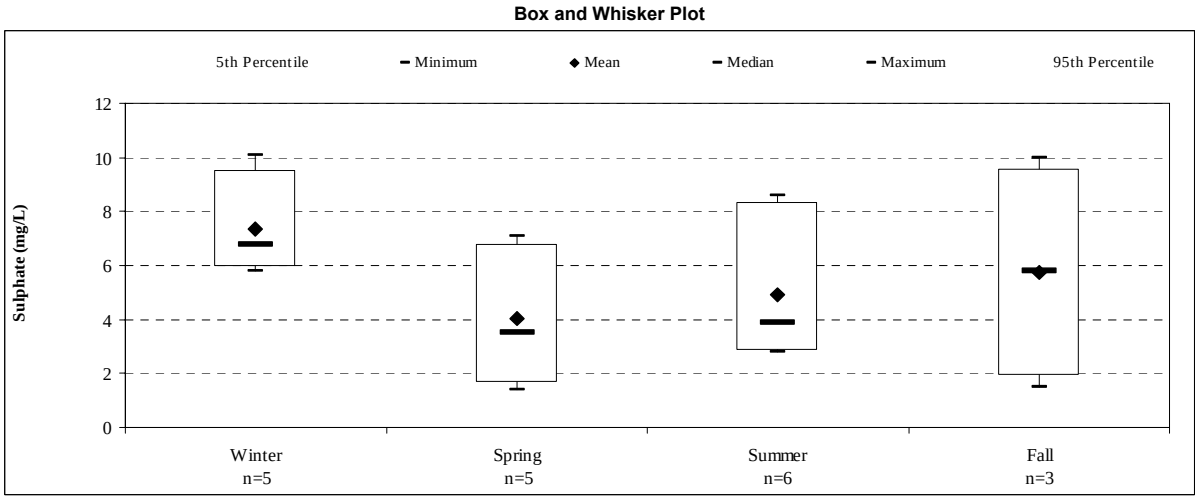


Figure G-2-5-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Shelley Creek



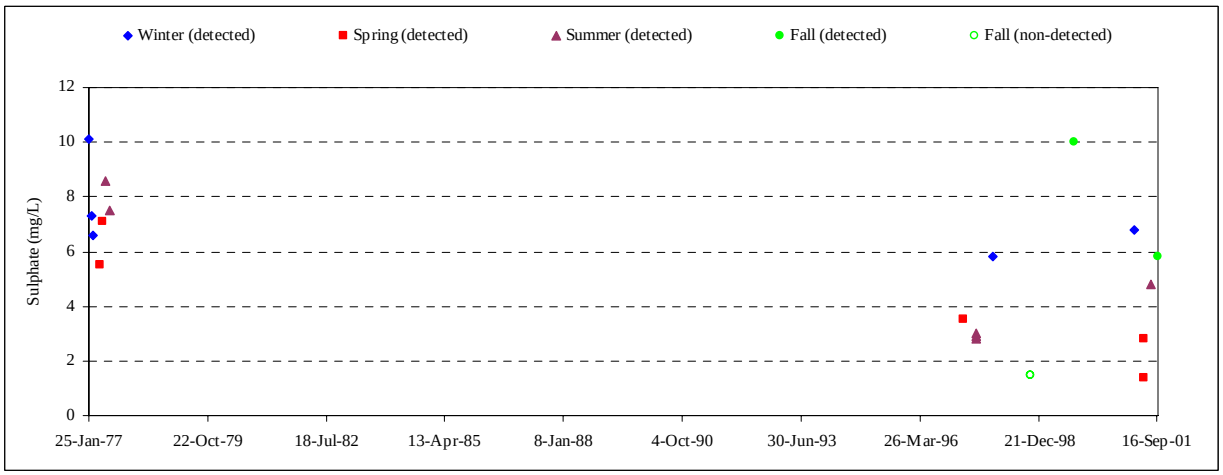
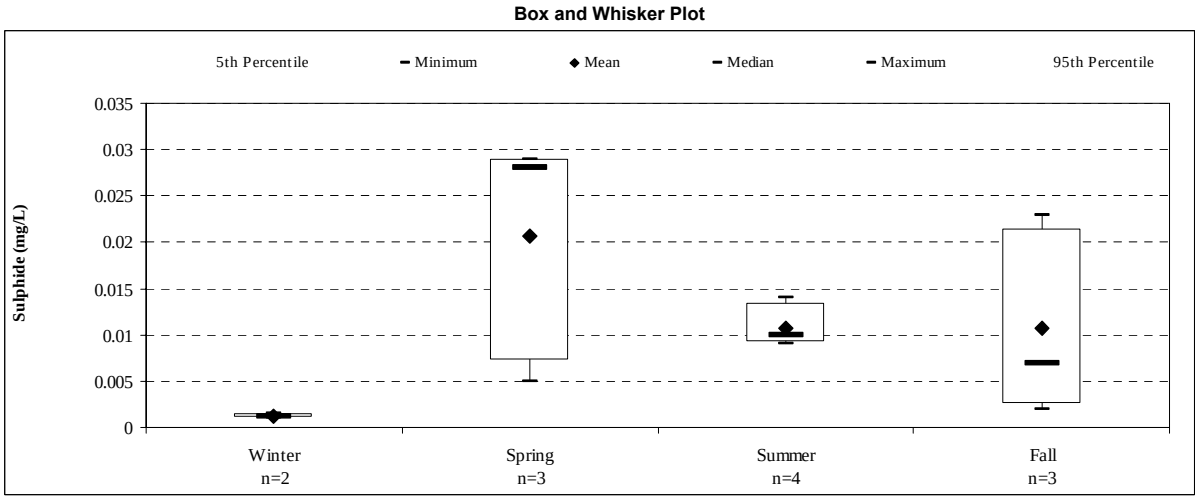


Figure G-2-5-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Shelley Creek



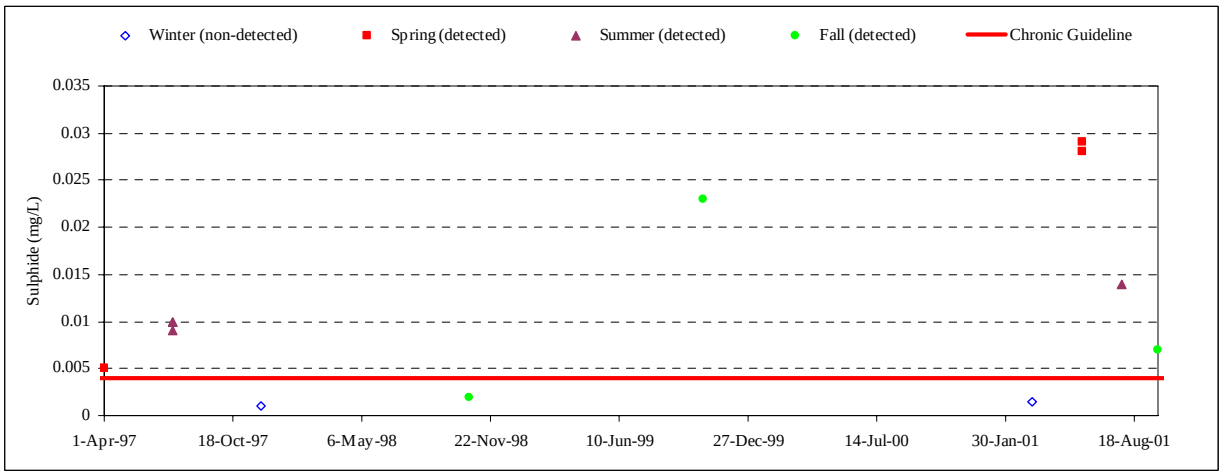
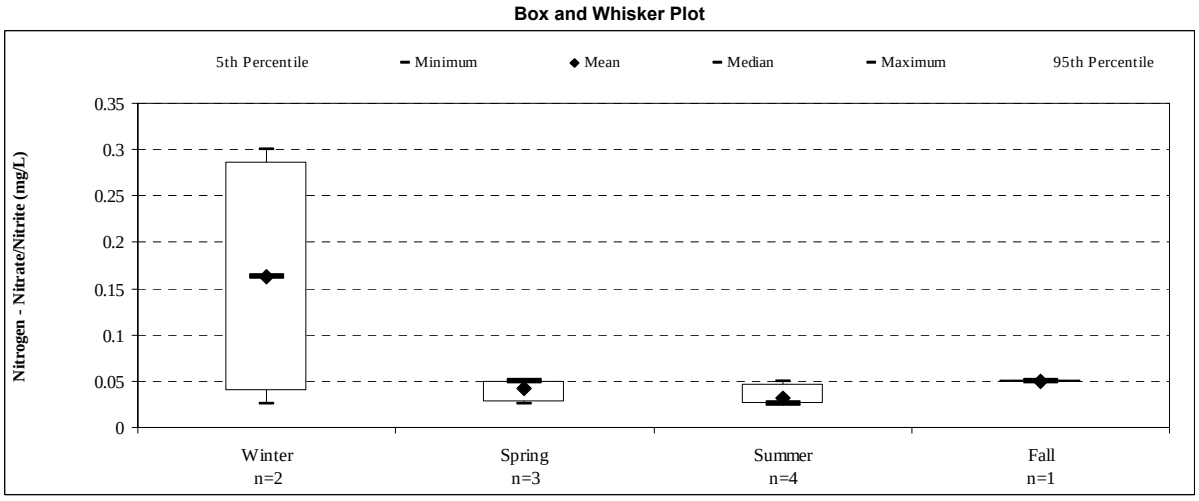


Figure G-2-5-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Shelley Creek



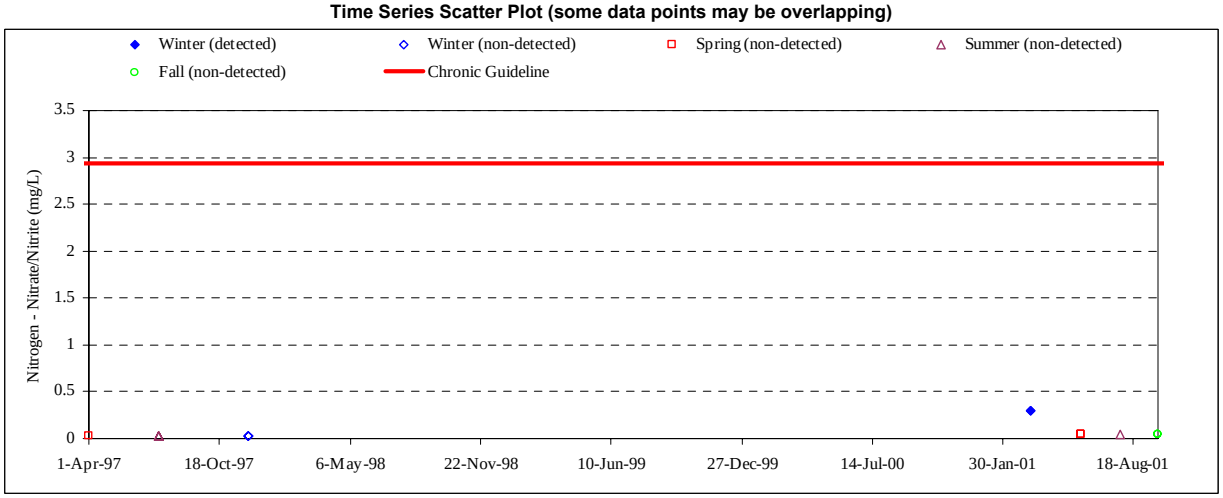
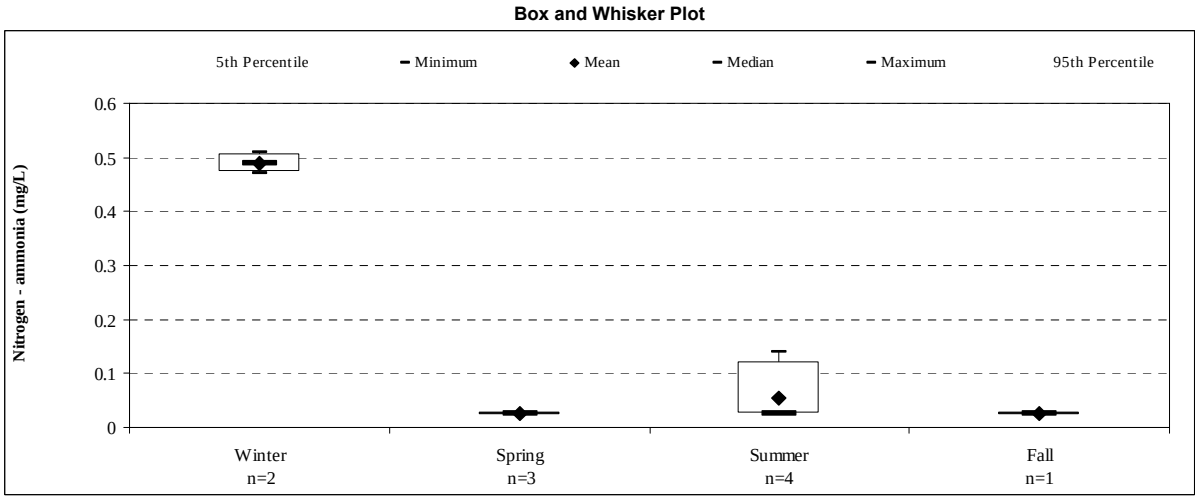


Figure G-2-5-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Shelley Creek



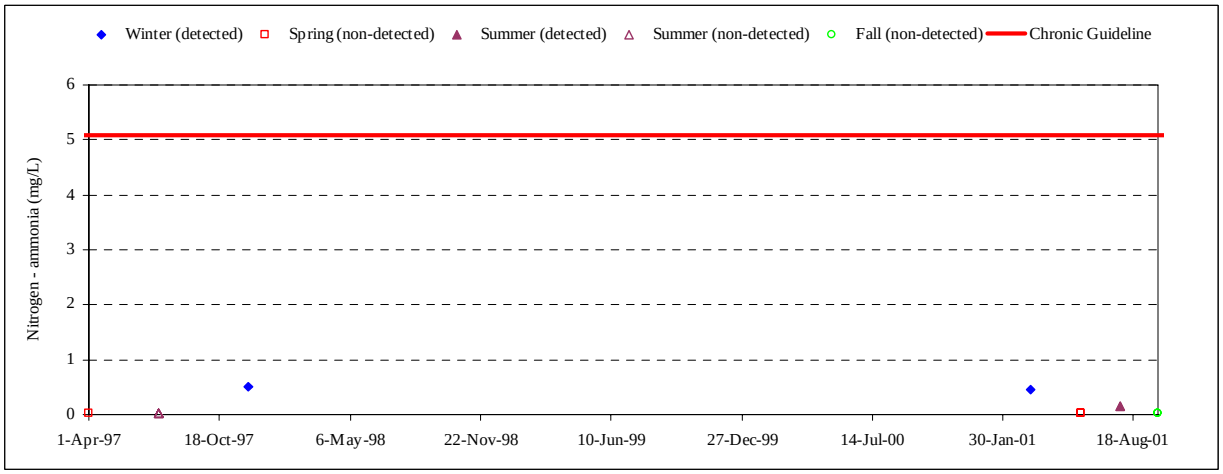
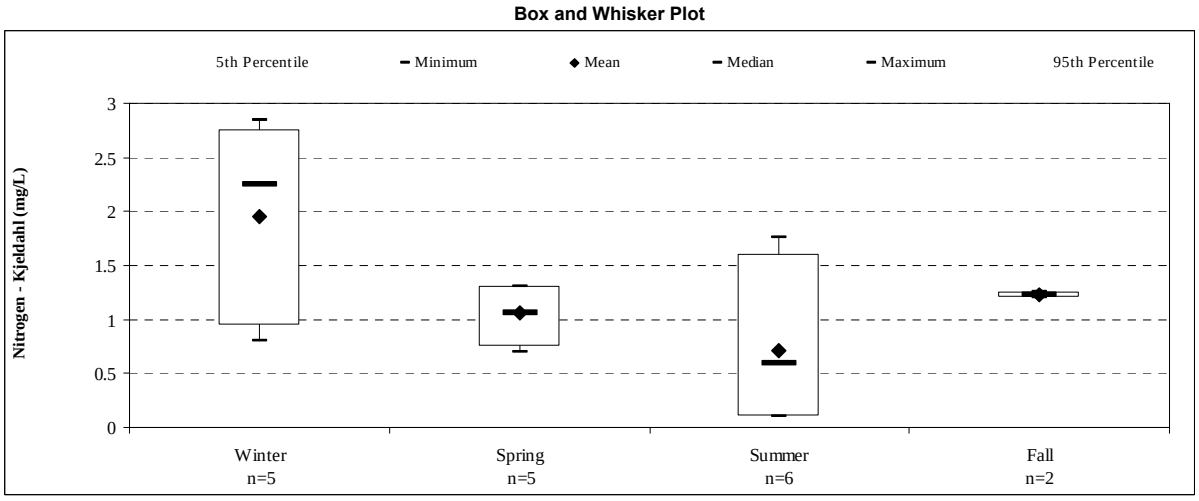


Figure G-2-5-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Shelley Creek



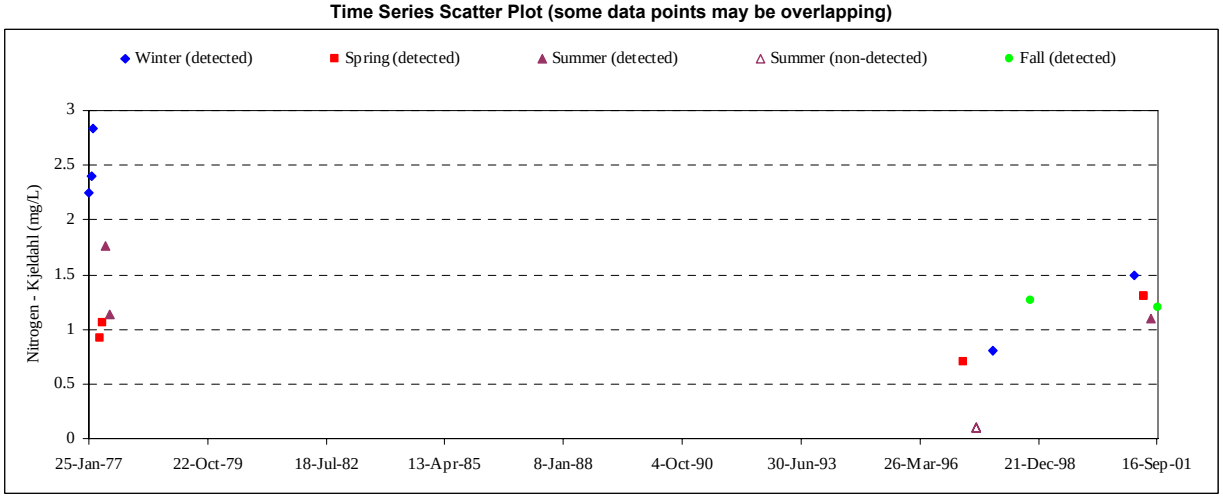
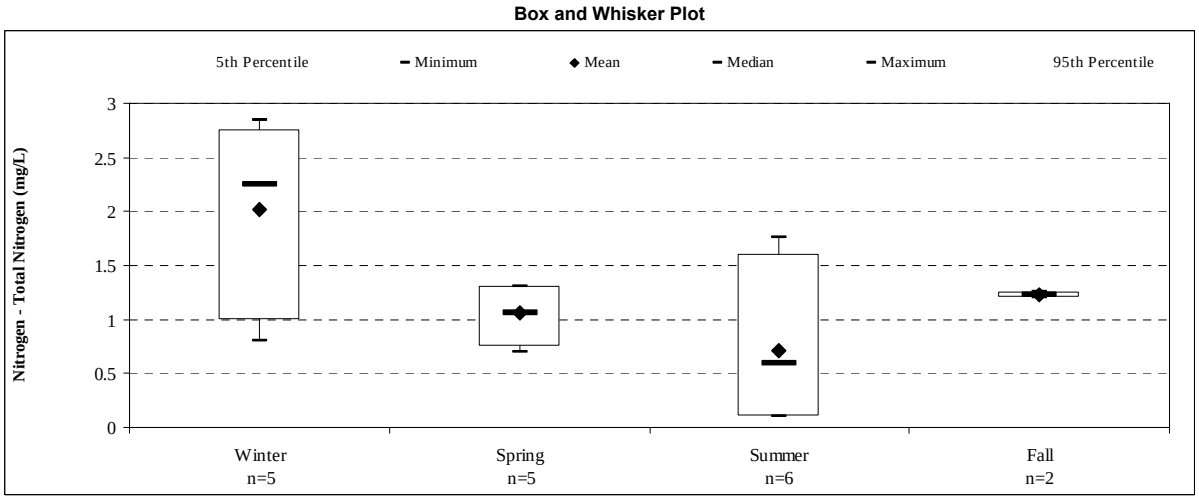


Figure G-2-5-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Shelley Creek



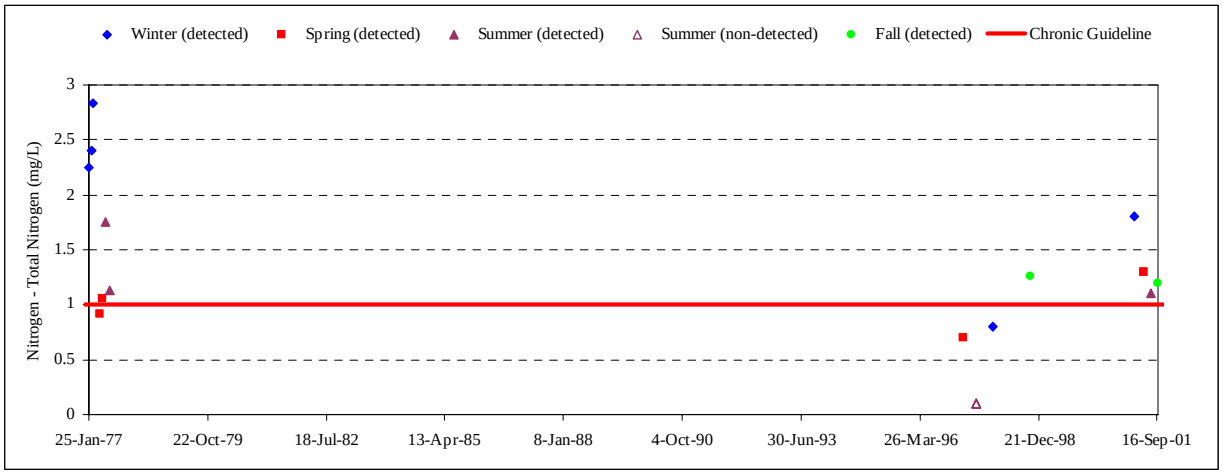
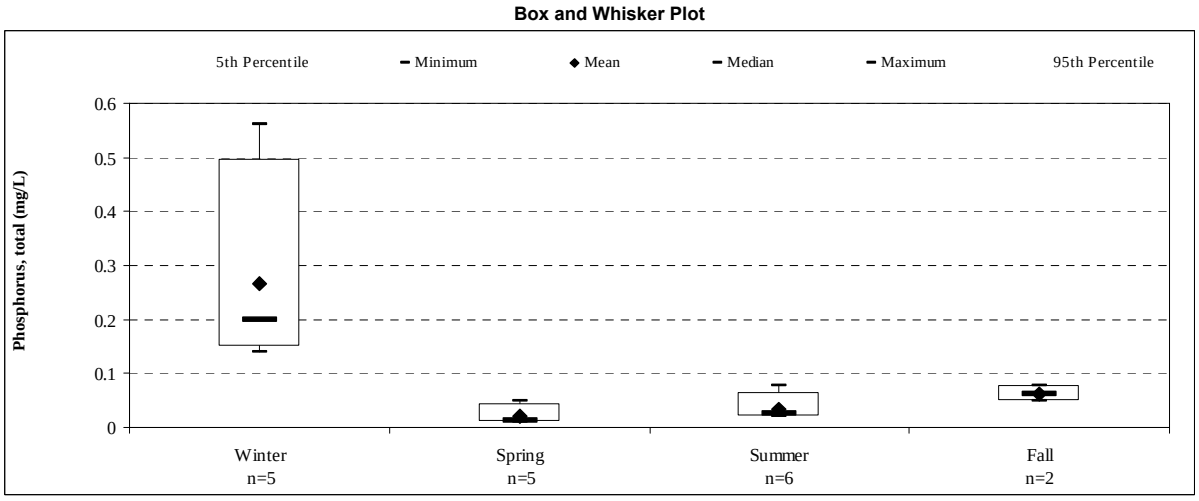


Figure G-2-5-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Shelley Creek



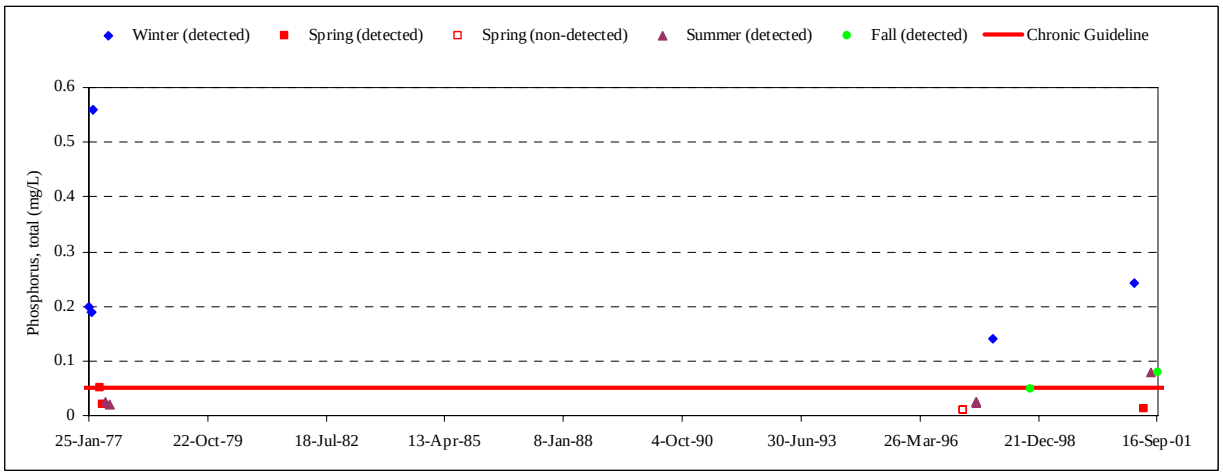
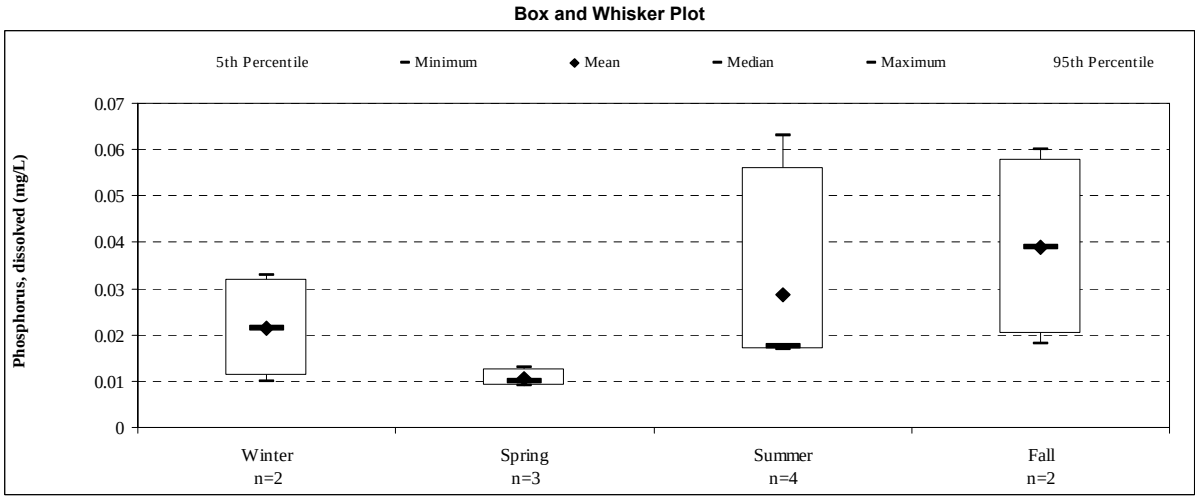


Figure G-2-5-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Shelley Creek



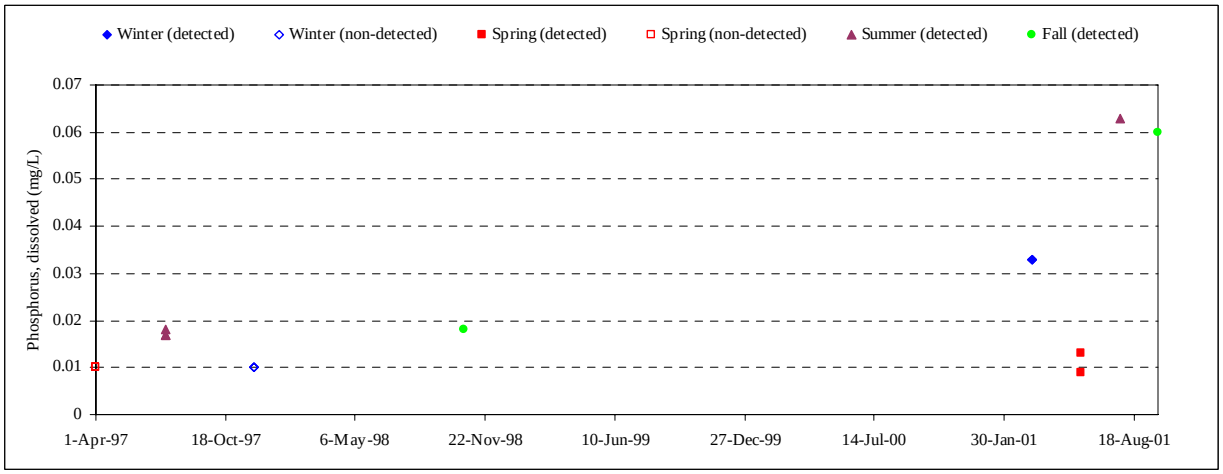
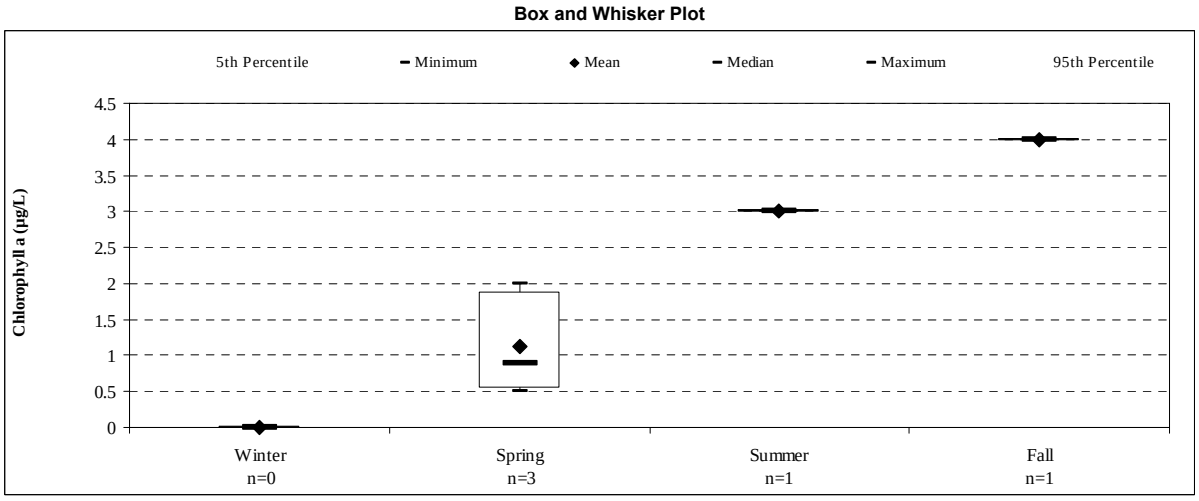


Figure G-2-5-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Shelley Creek



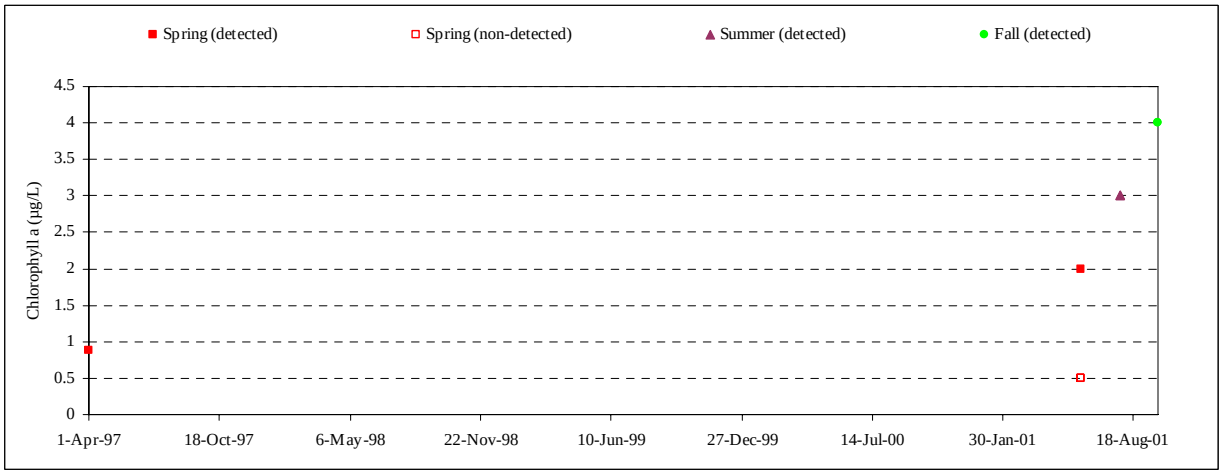
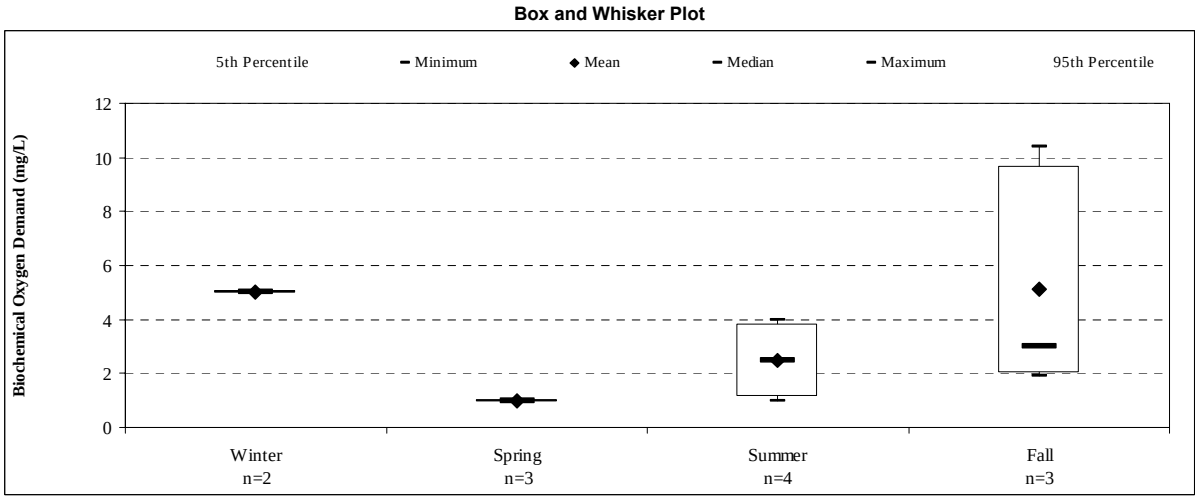


Figure G-2-5-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Shelley Creek



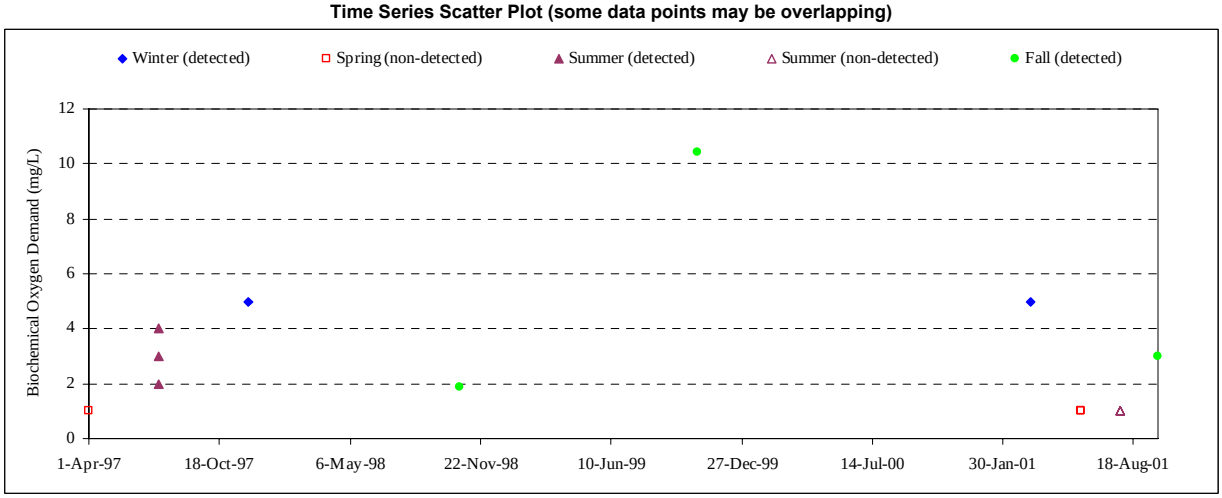
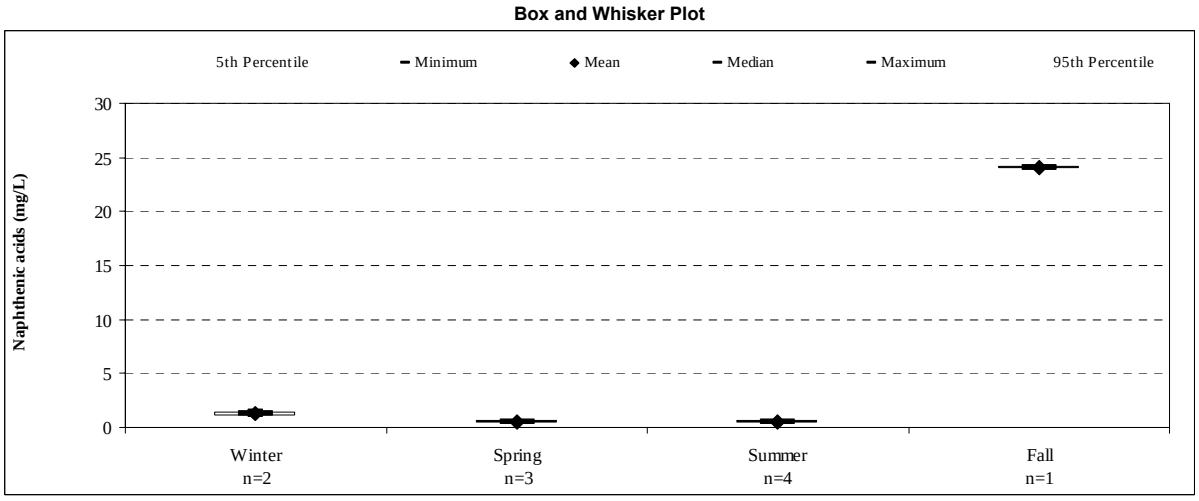


Figure G-2-5-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Shelley Creek



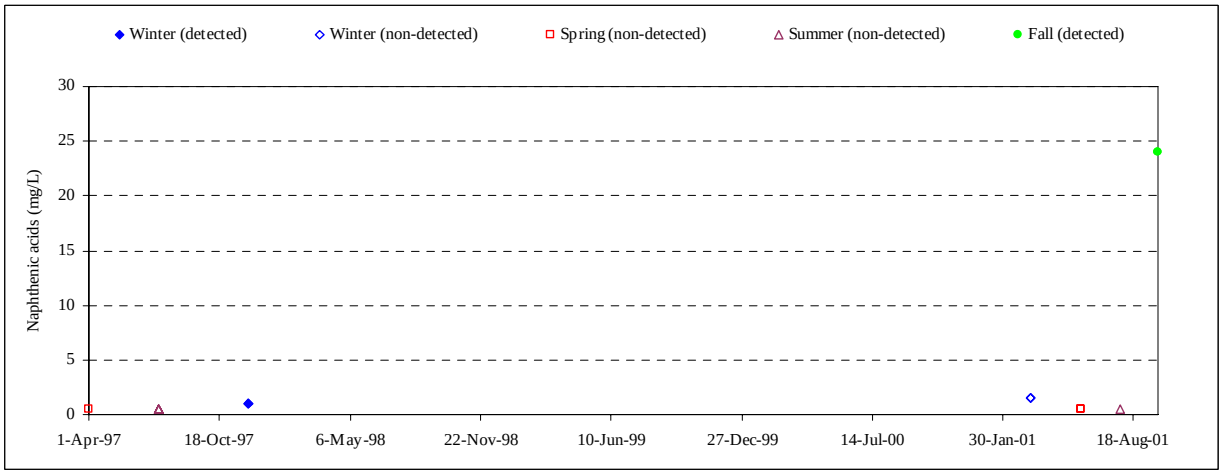


Figure G-2-5-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Shelley Creek

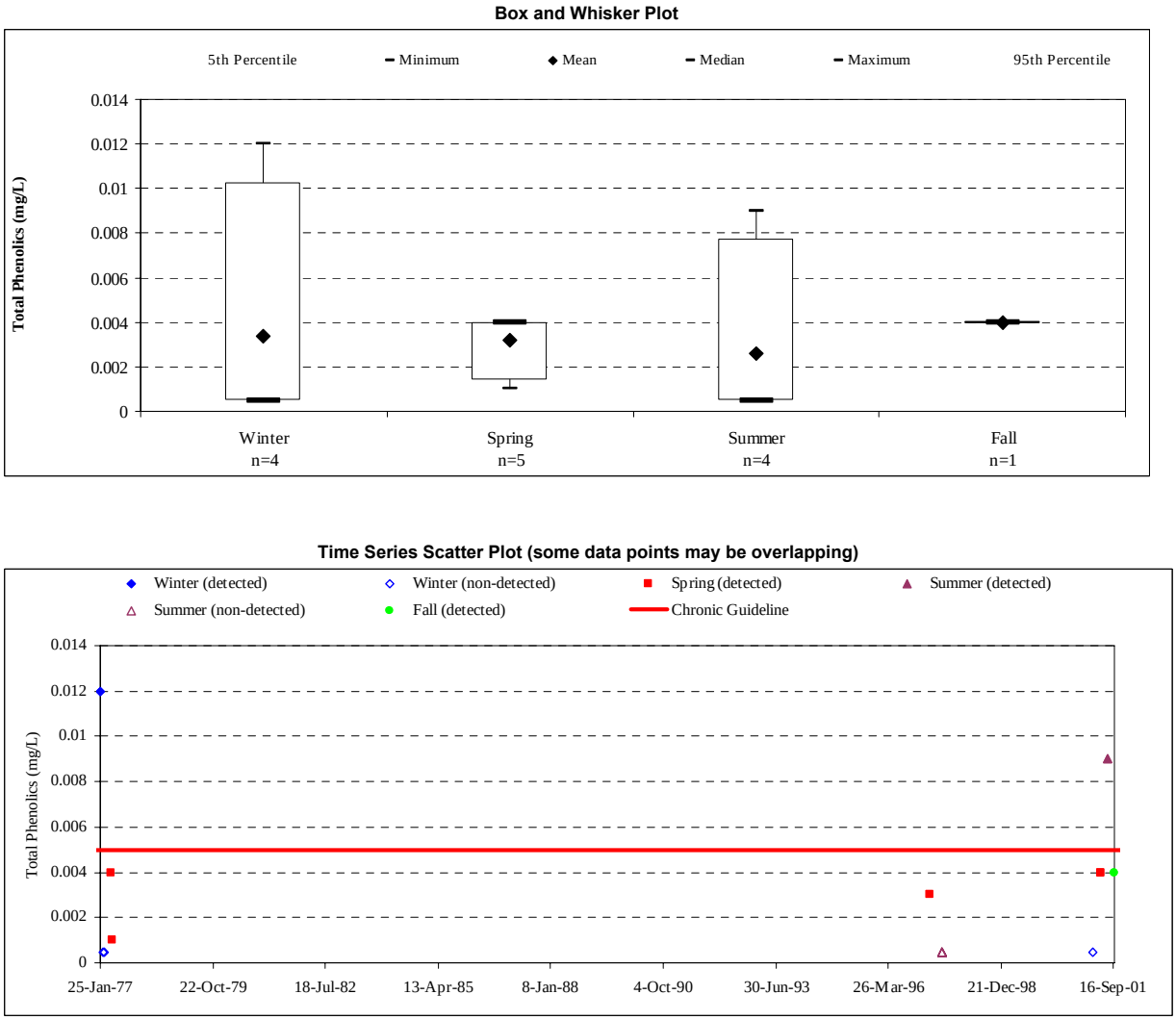
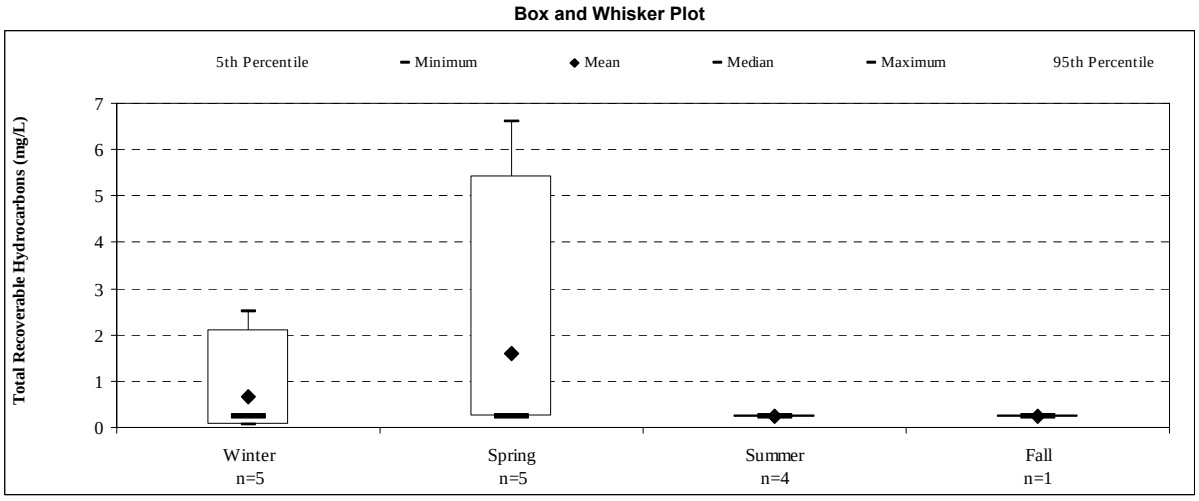


Figure G-2-5-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Shelley Creek



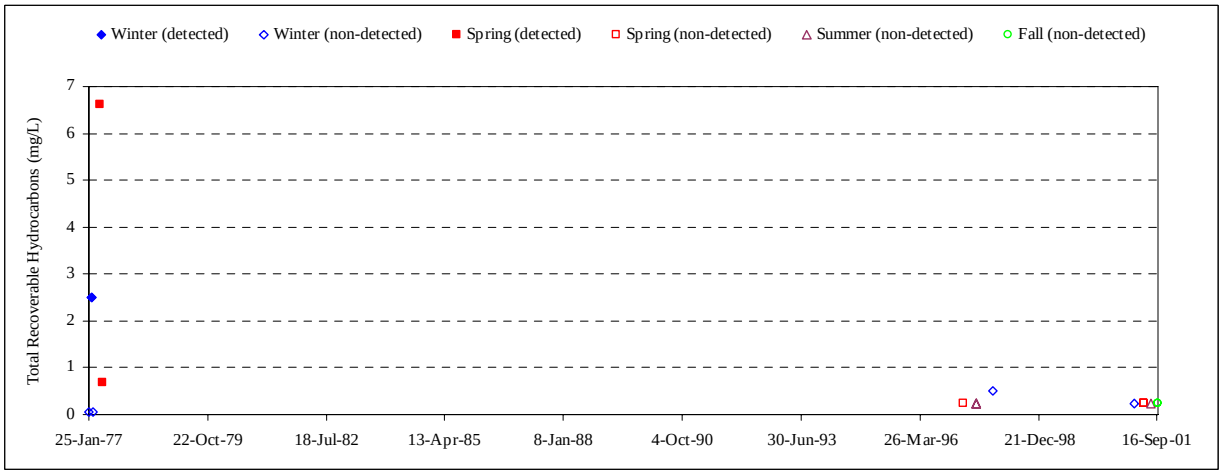
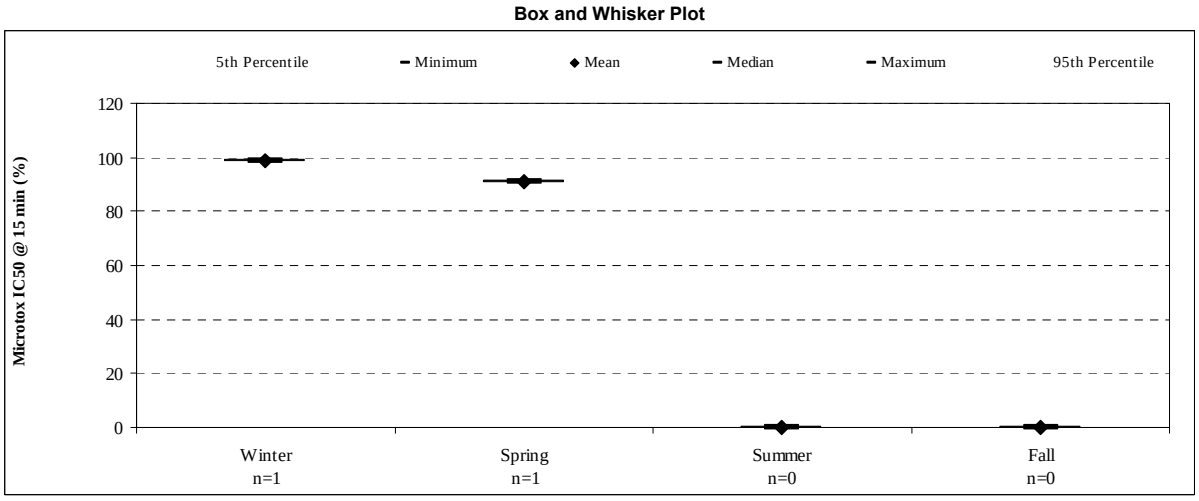


Figure G-2-5-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Shelley Creek



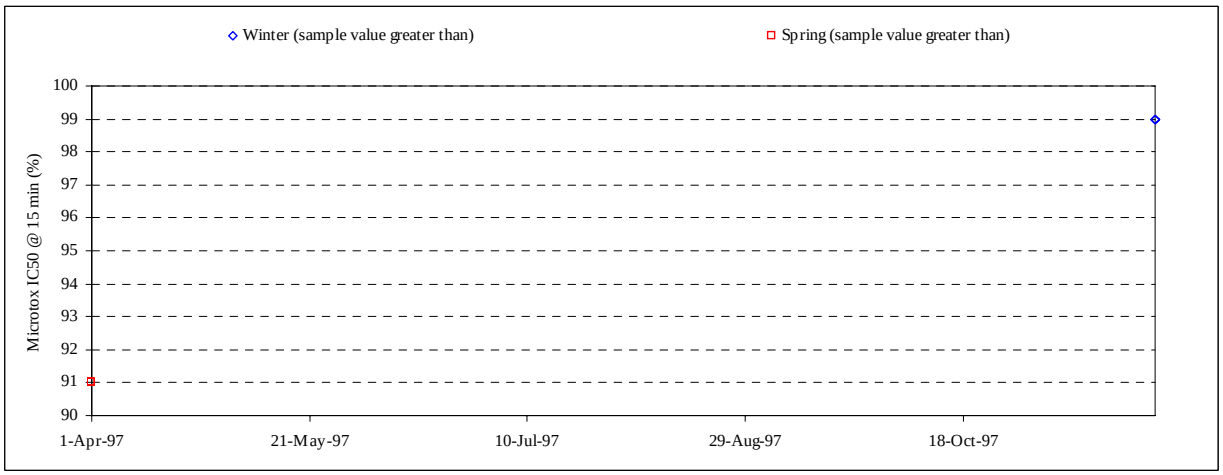
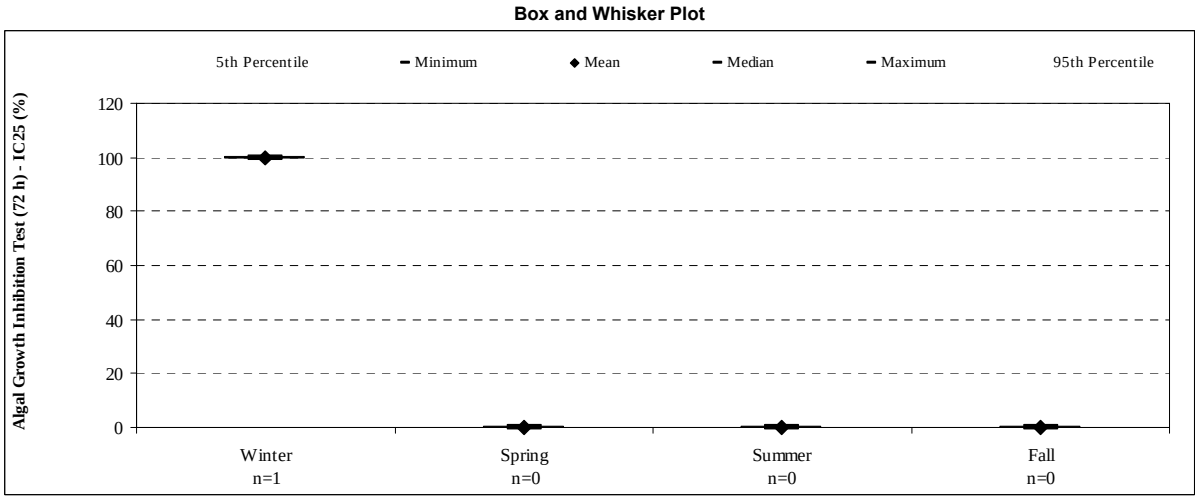


Figure G-2-5-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Shelley Creek



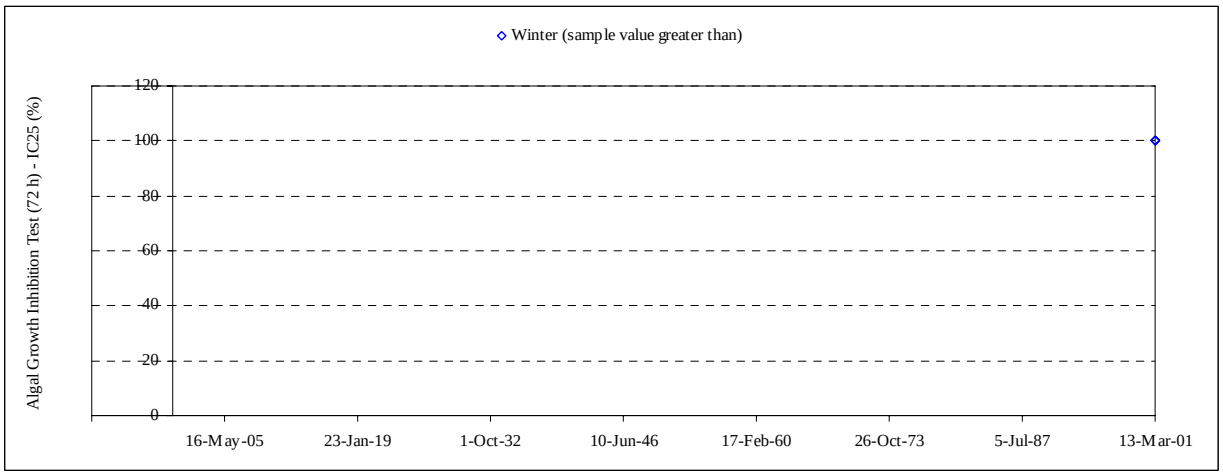
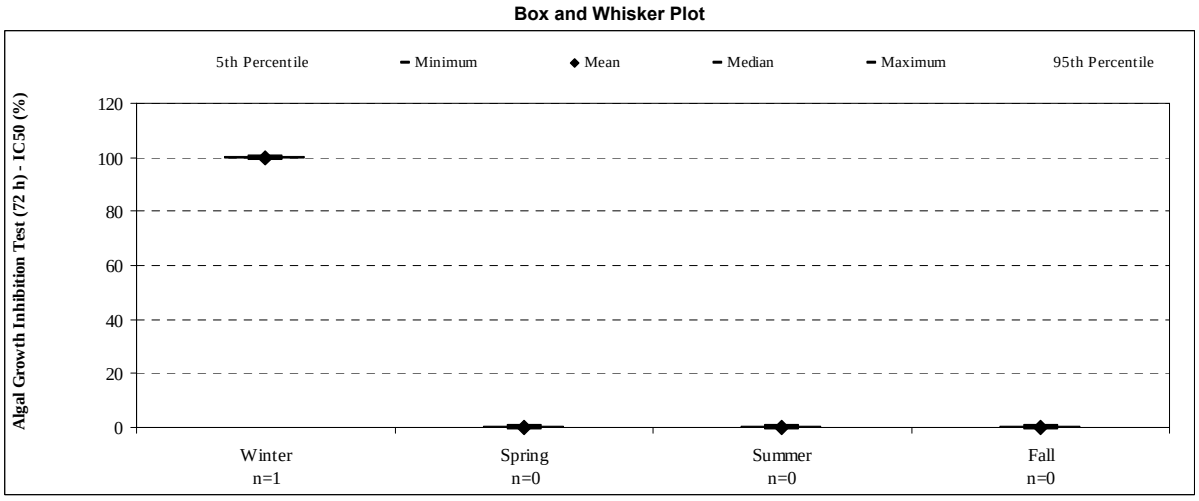


Figure G-2-5-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Shelley Creek



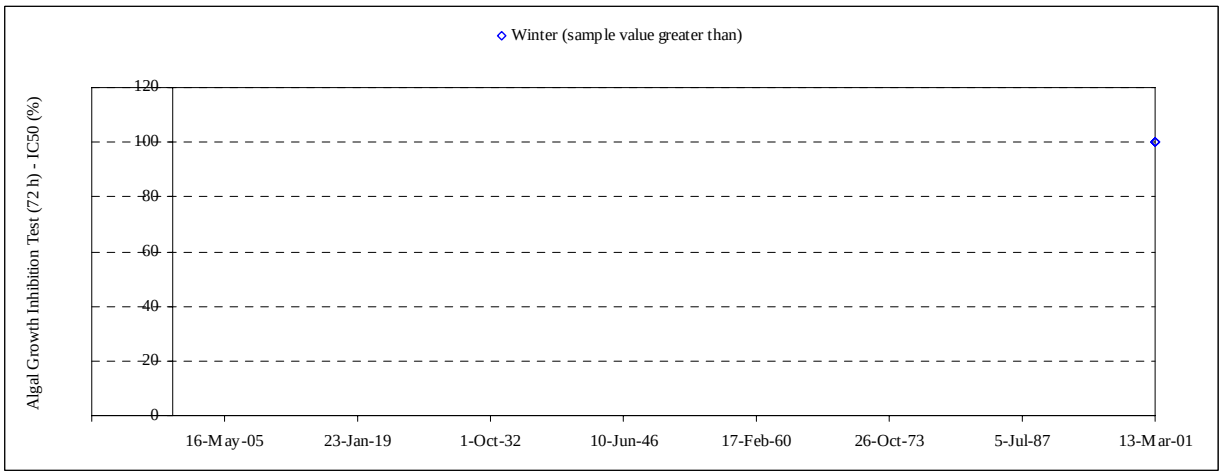
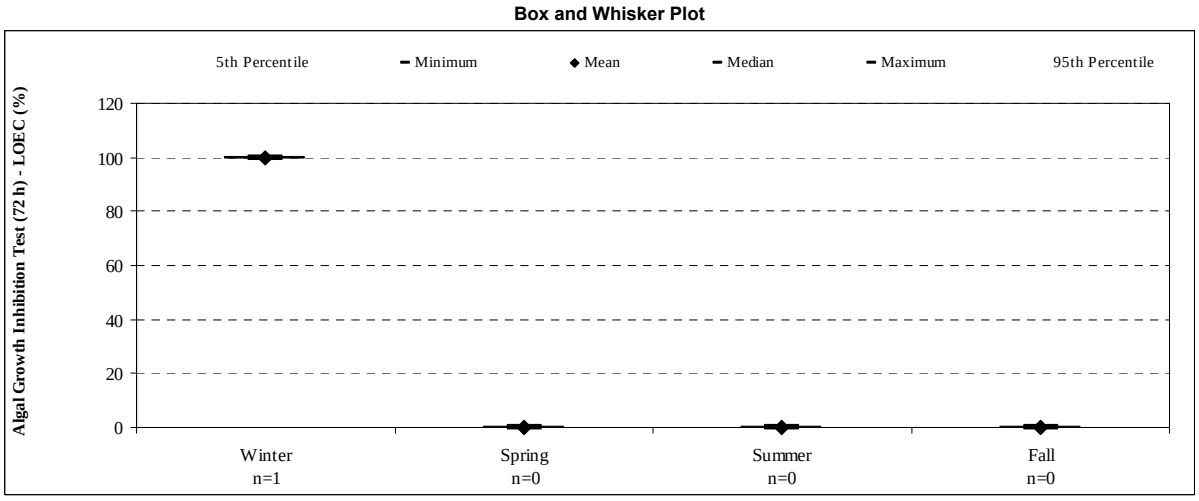


Figure G-2-5-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Shelley Creek



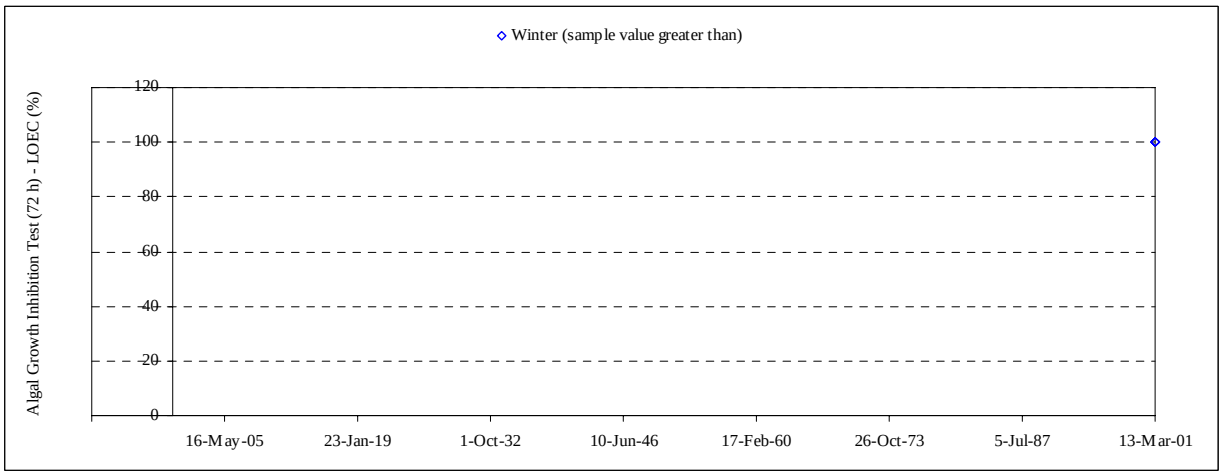
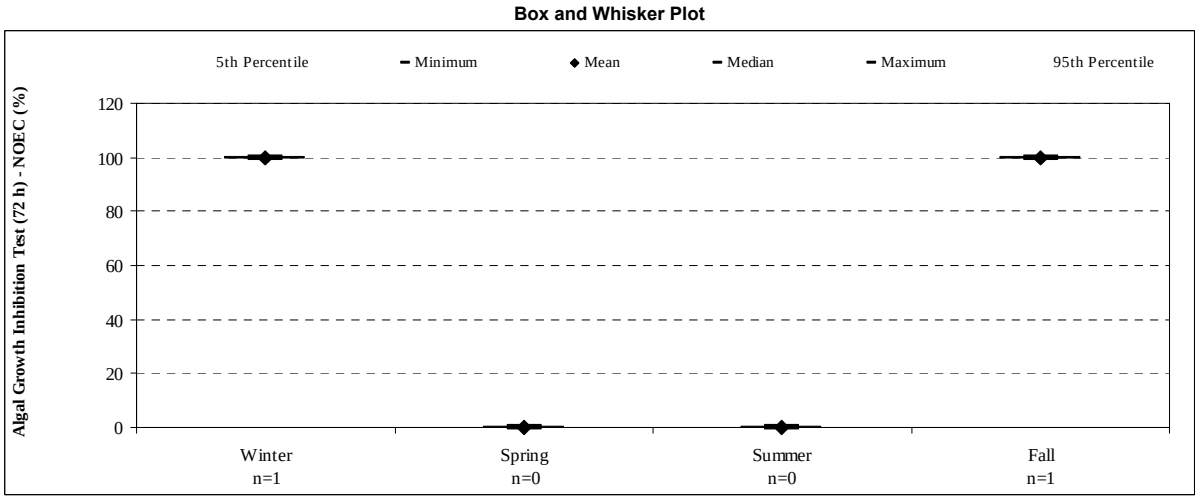


Figure G-2-5-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Shelley Creek



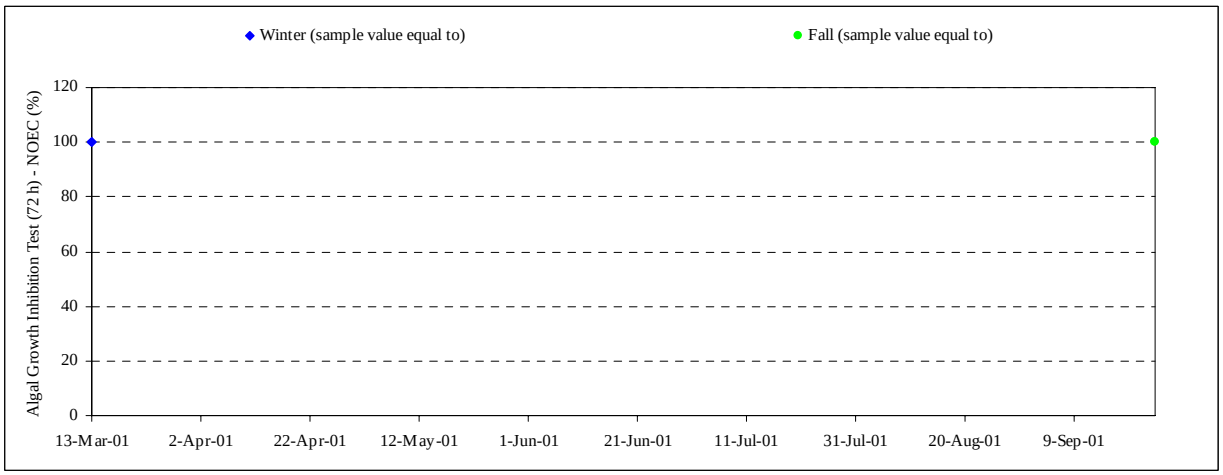
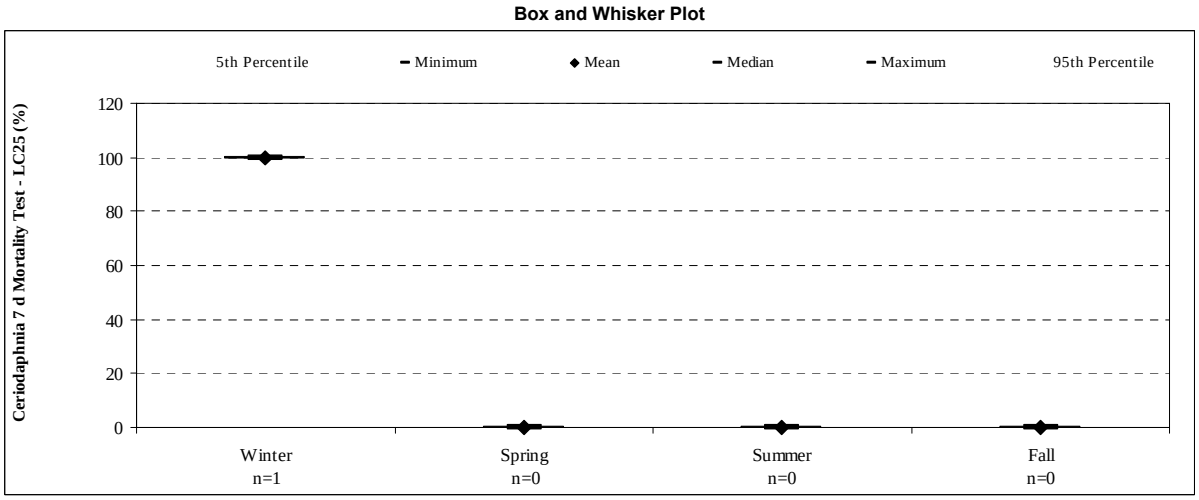


Figure G-2-5-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Shelley Creek



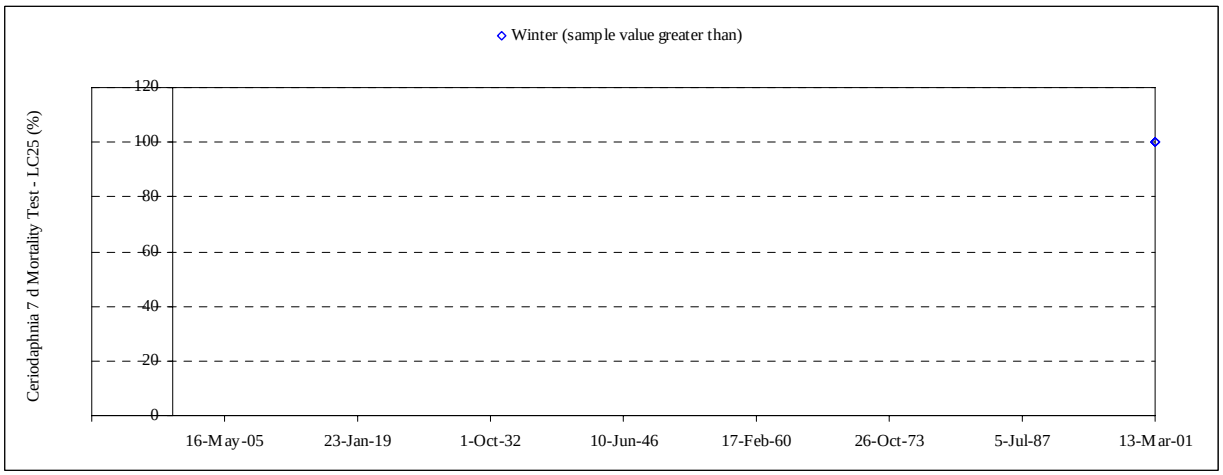
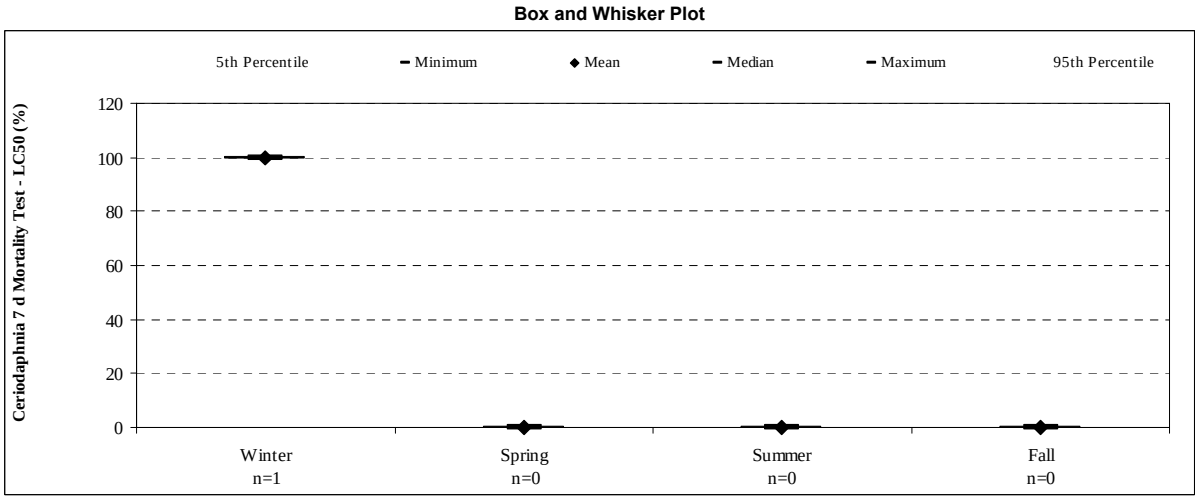


Figure G-2-5-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Shelley Creek



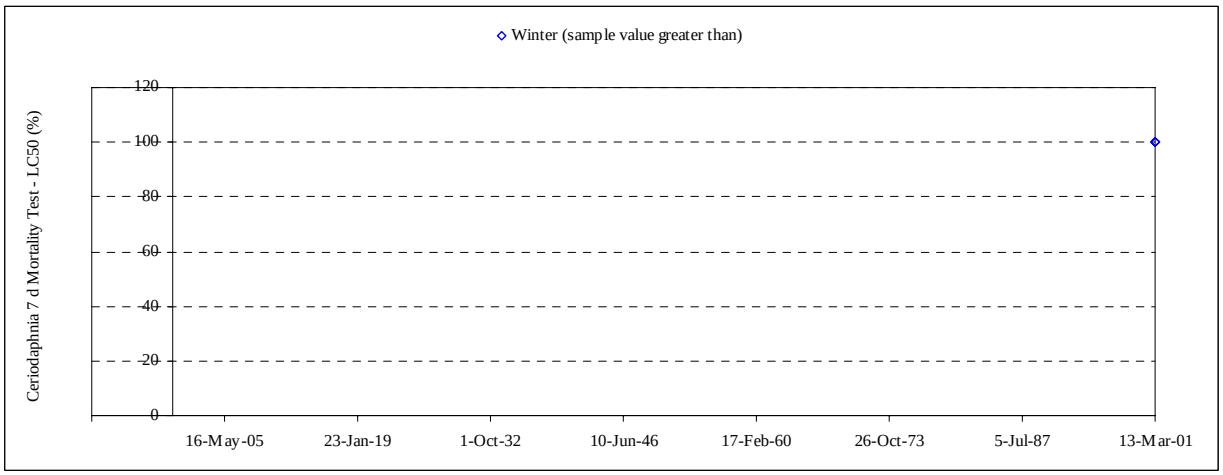
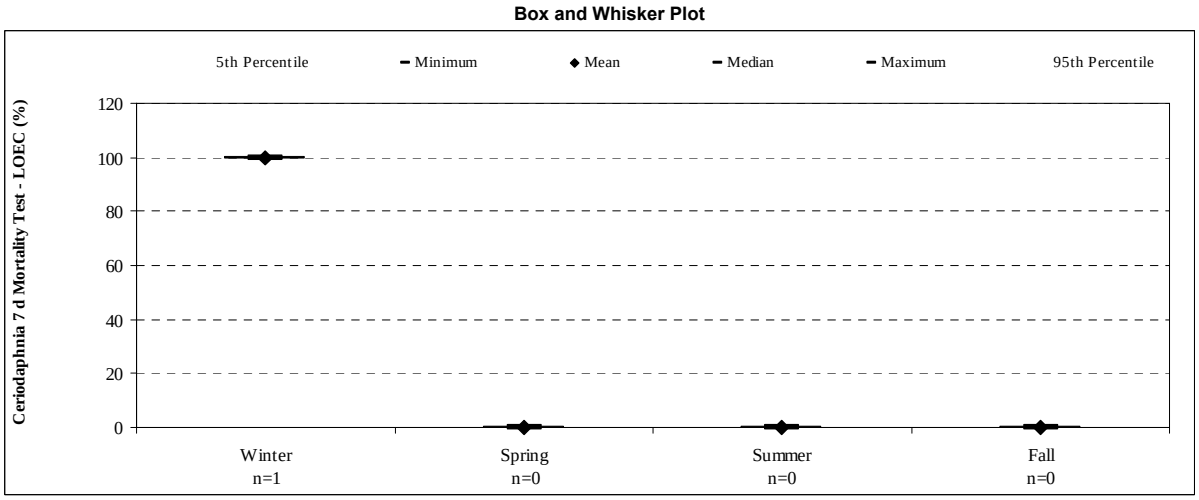


Figure G-2-5-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Shelley Creek



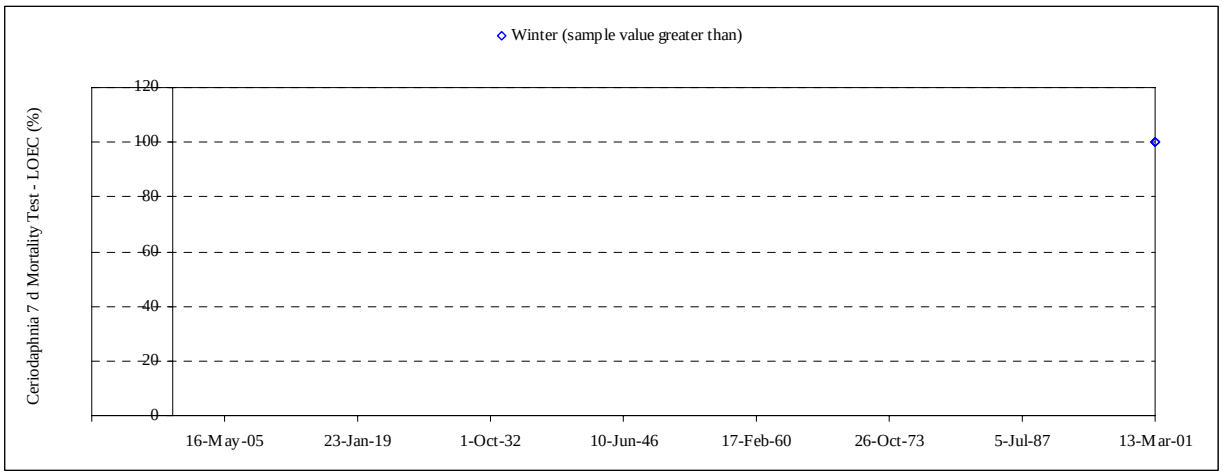
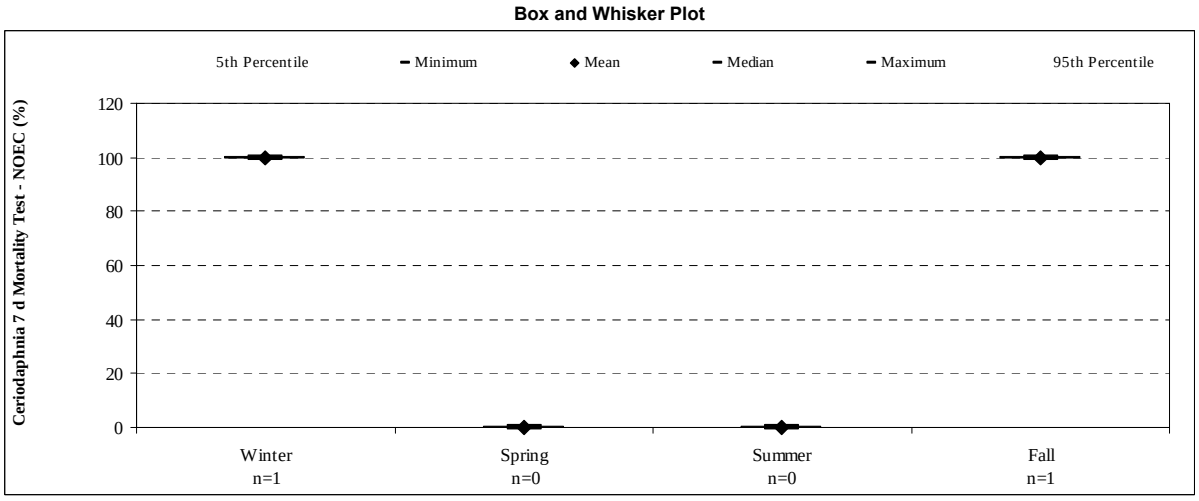


Figure G-2-5-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Shelley Creek



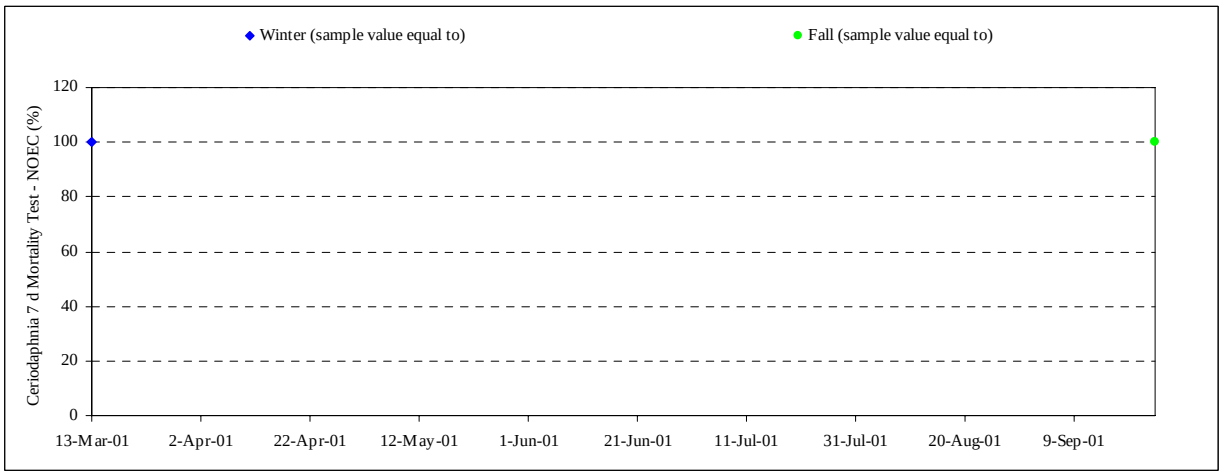
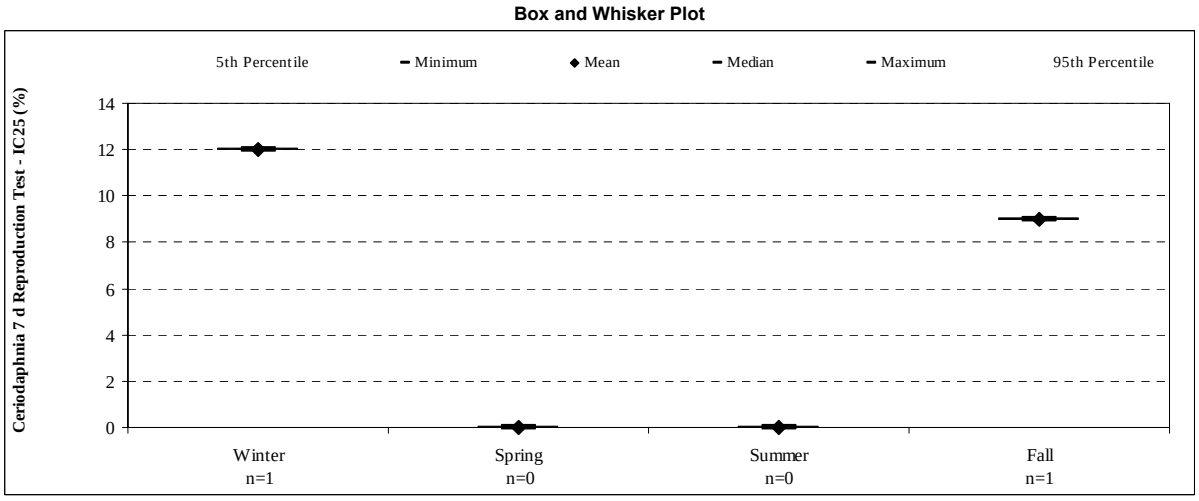


Figure G-2-5-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Shelley Creek



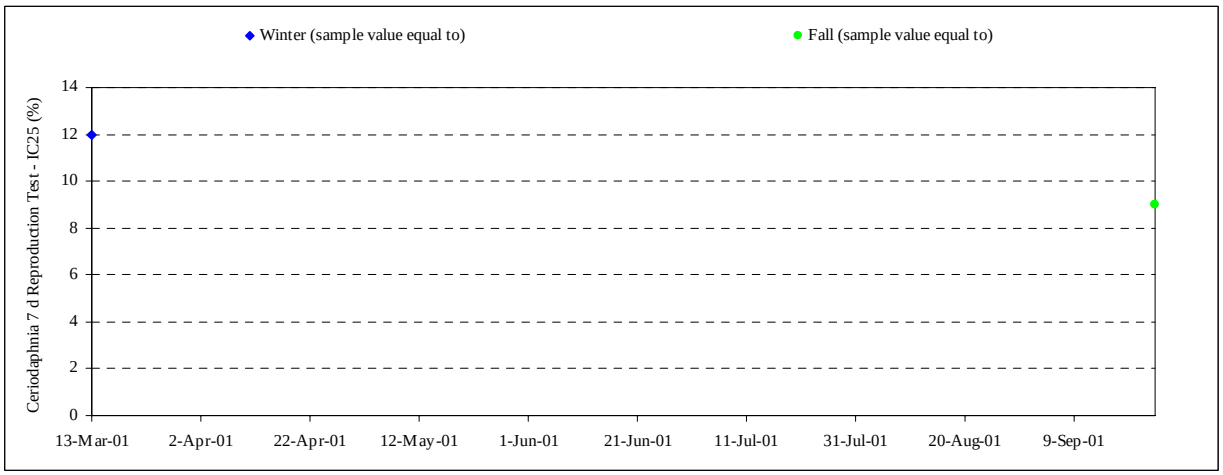
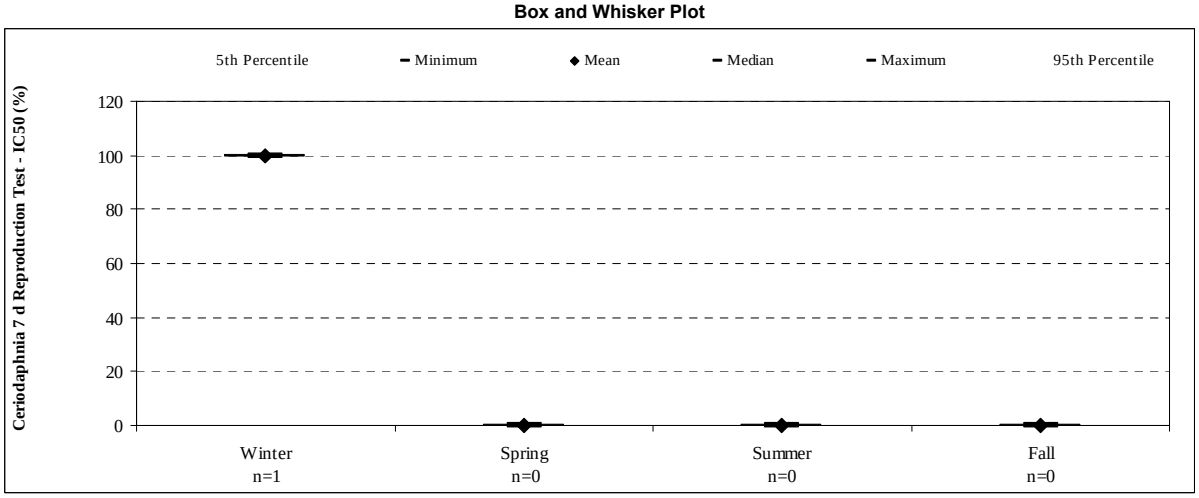


Figure G-2-5-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Shelley Creek



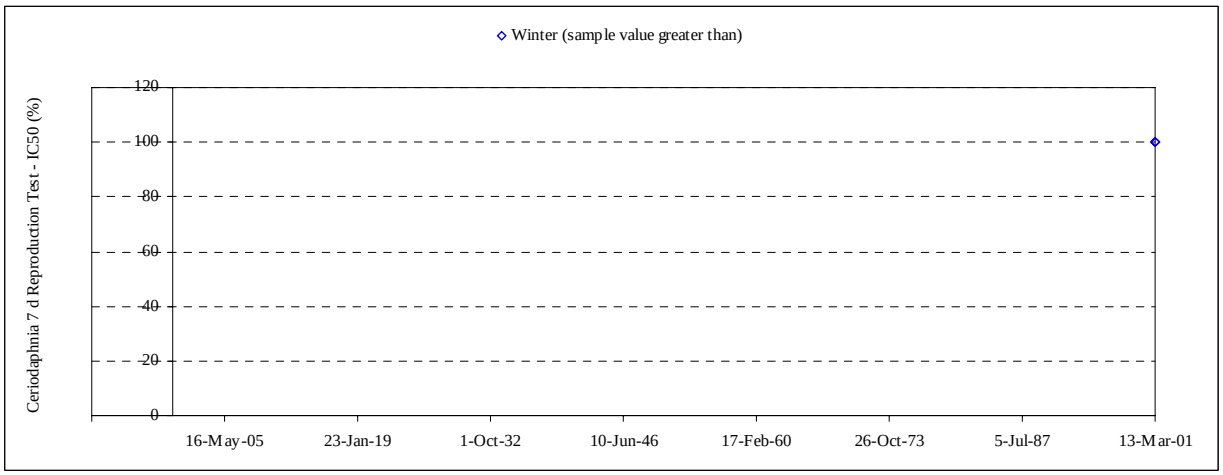
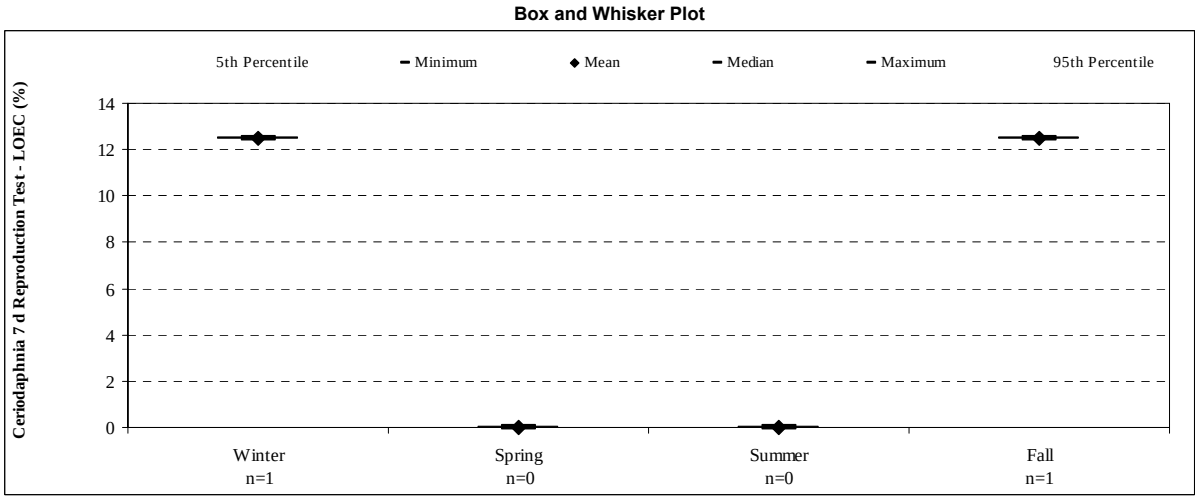


Figure G-2-5-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Shelley Creek



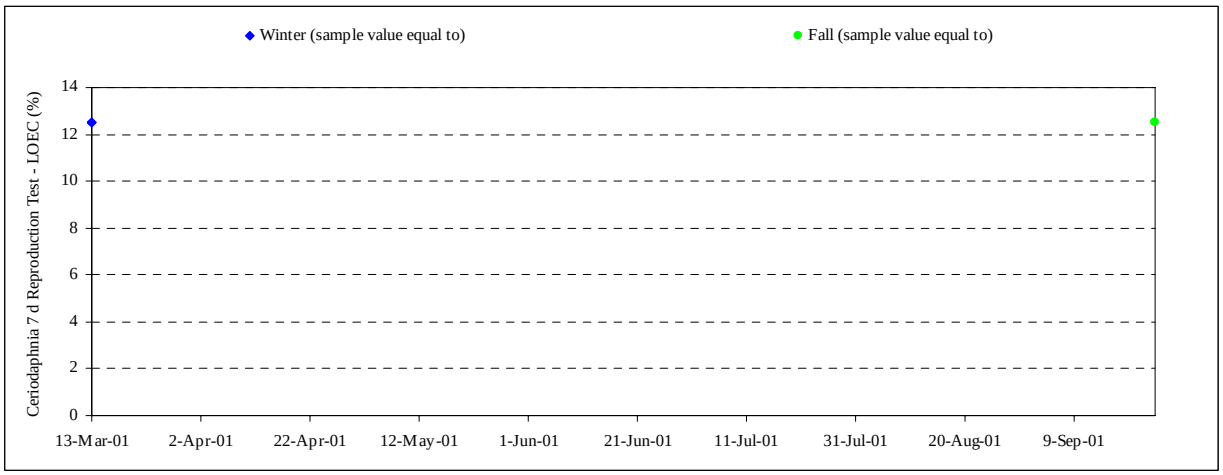
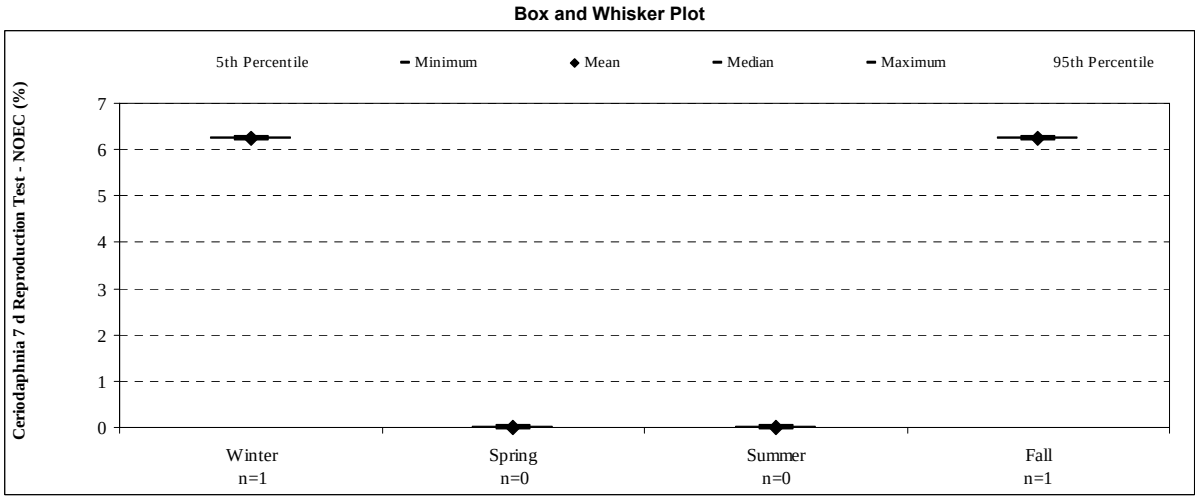


Figure G-2-5-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Shelley Creek



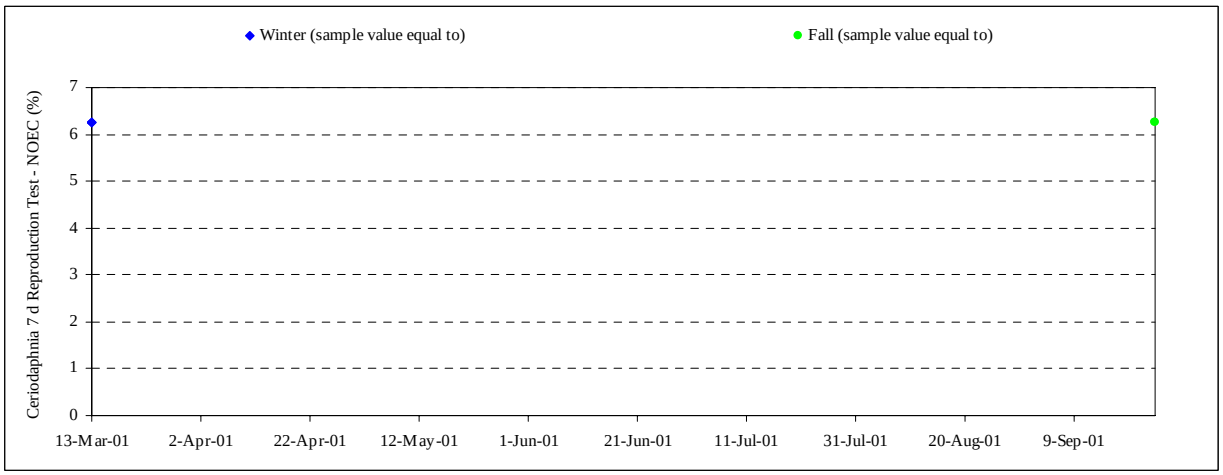
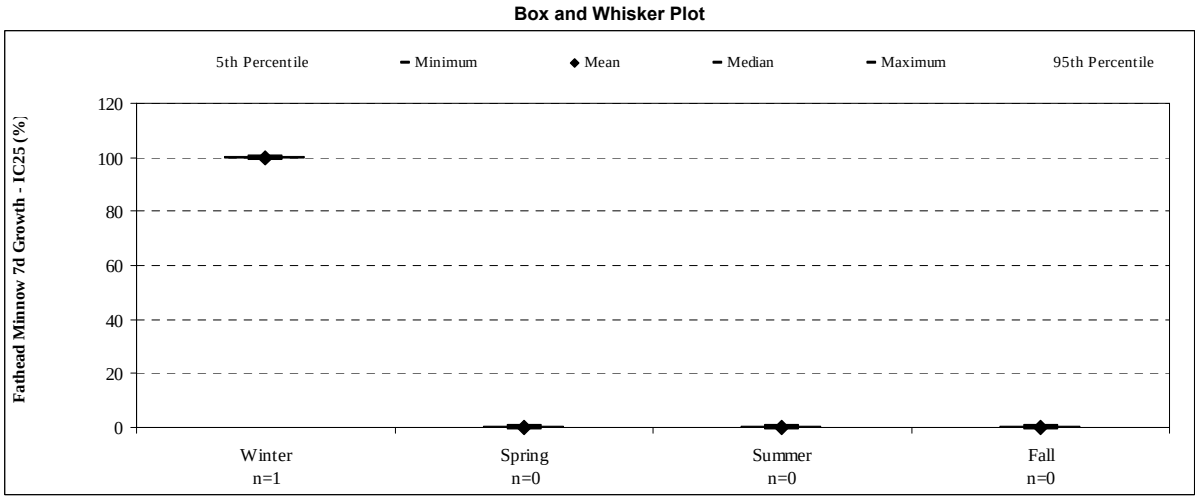


Figure G-2-5-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Shelley Creek



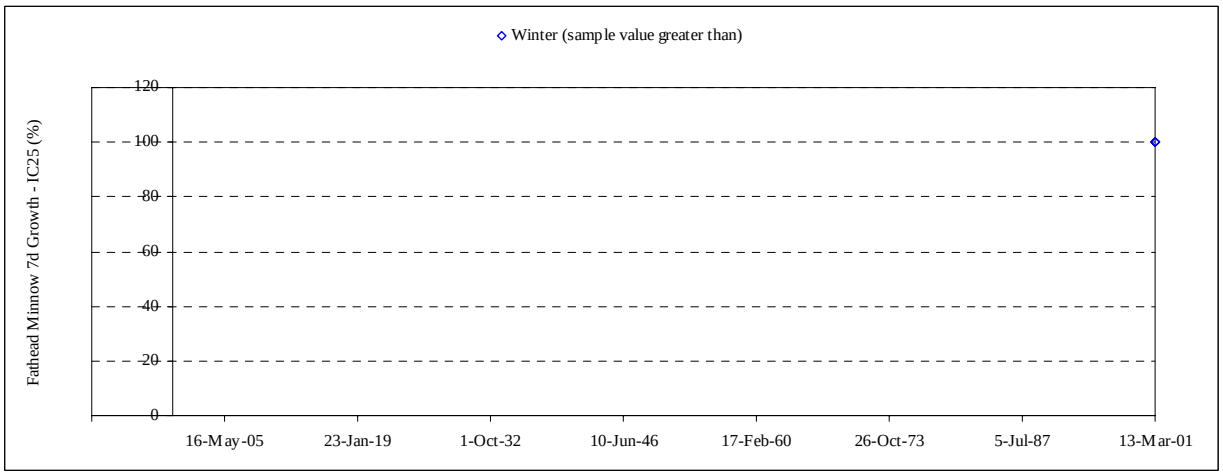
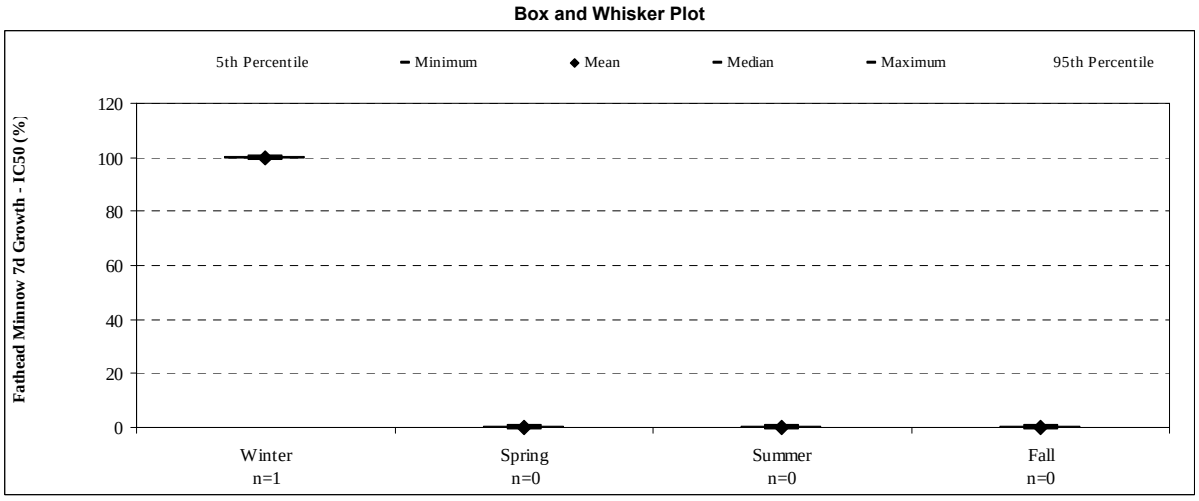


Figure G-2-5-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Shelley Creek



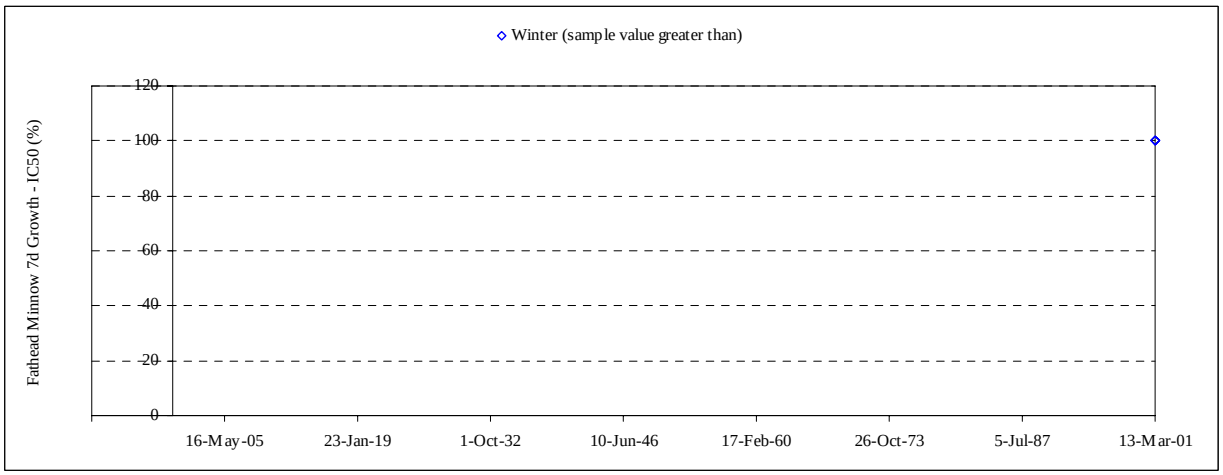
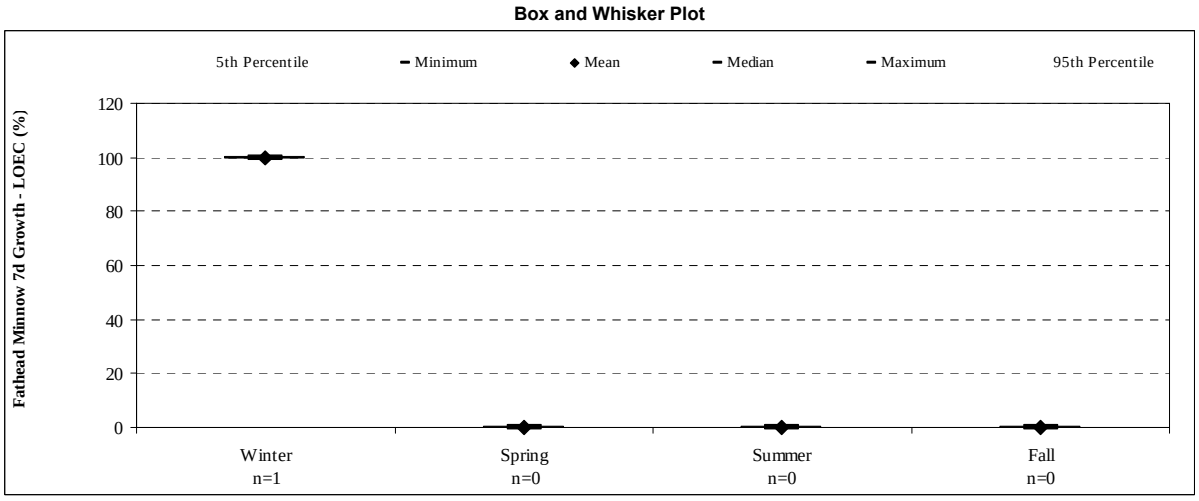


Figure G-2-5-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Shelley Creek



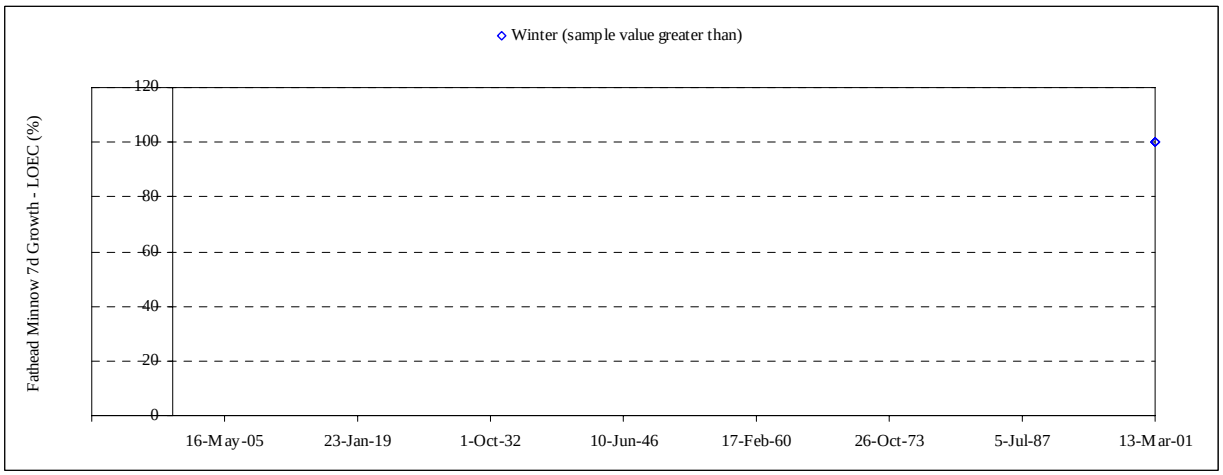
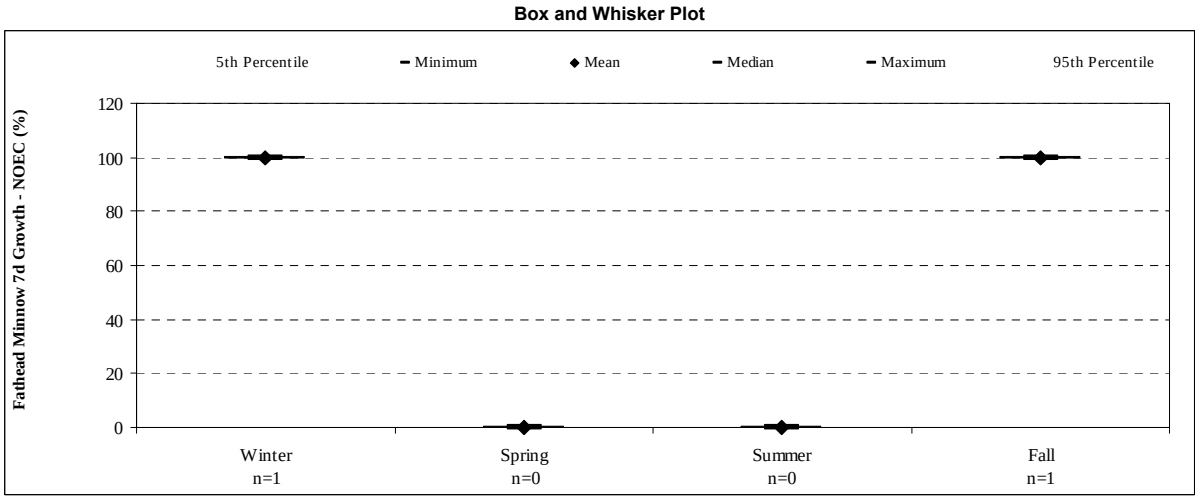


Figure G-2-5-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Shelley Creek



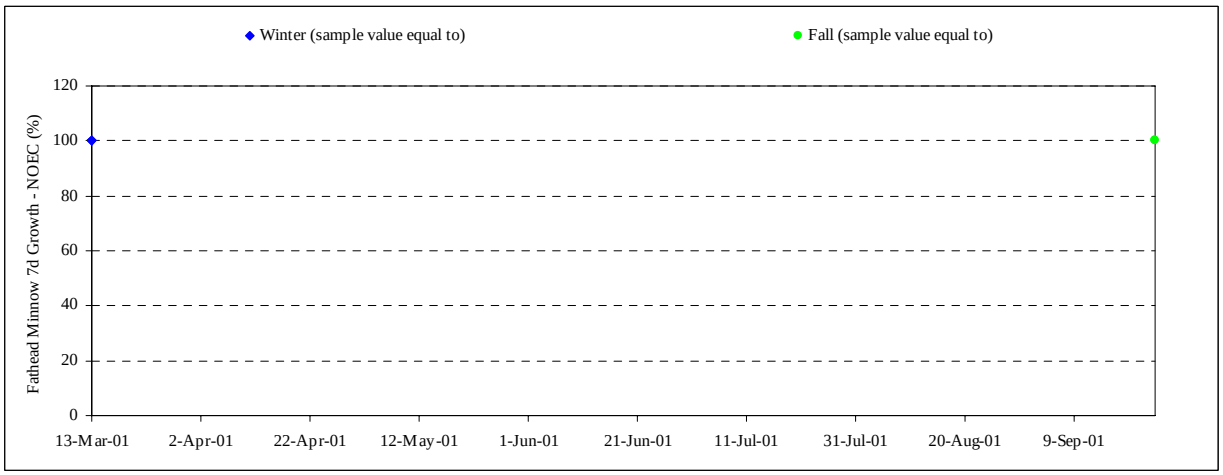
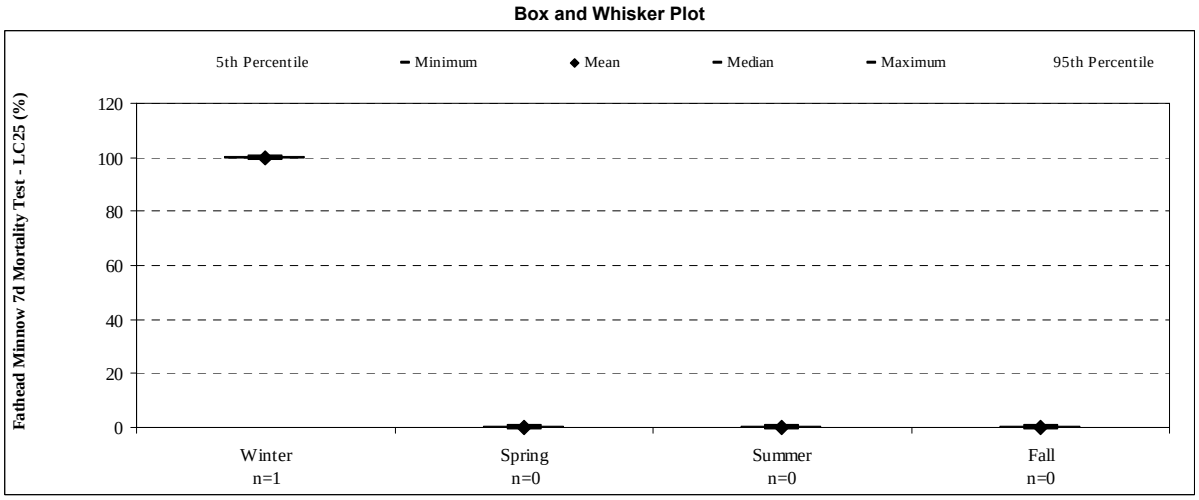


Figure G-2-5-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Shelley Creek



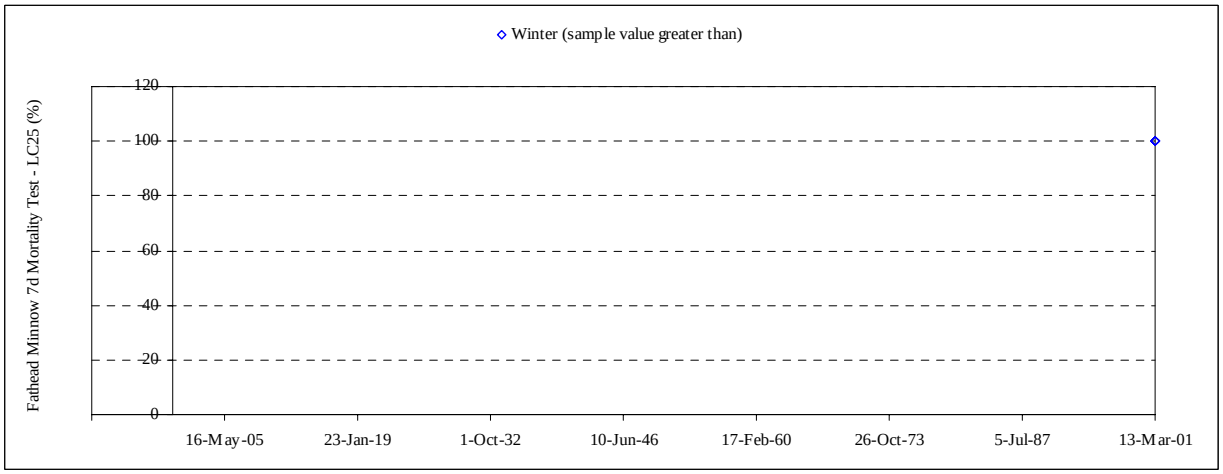
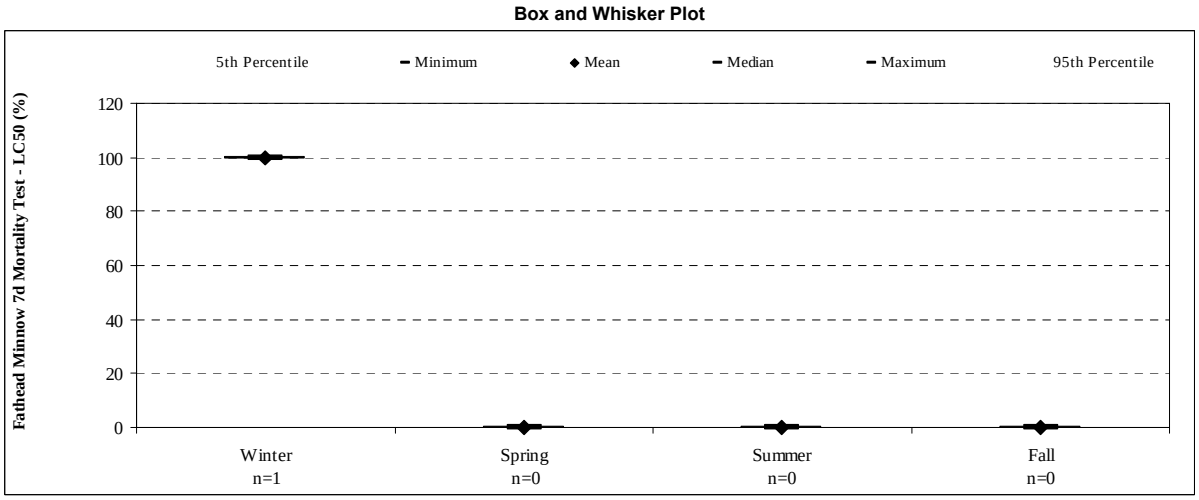


Figure G-2-5-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Shelley Creek



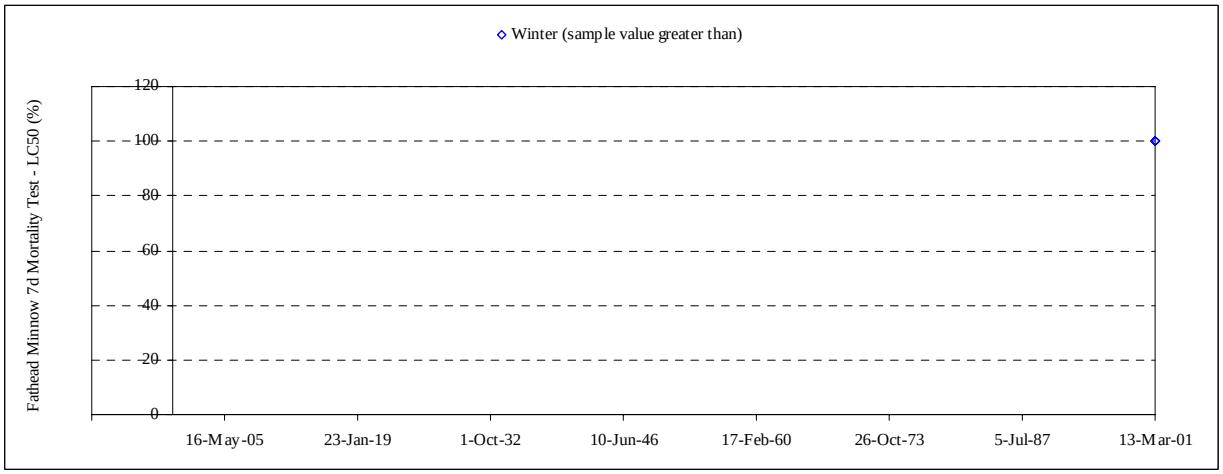
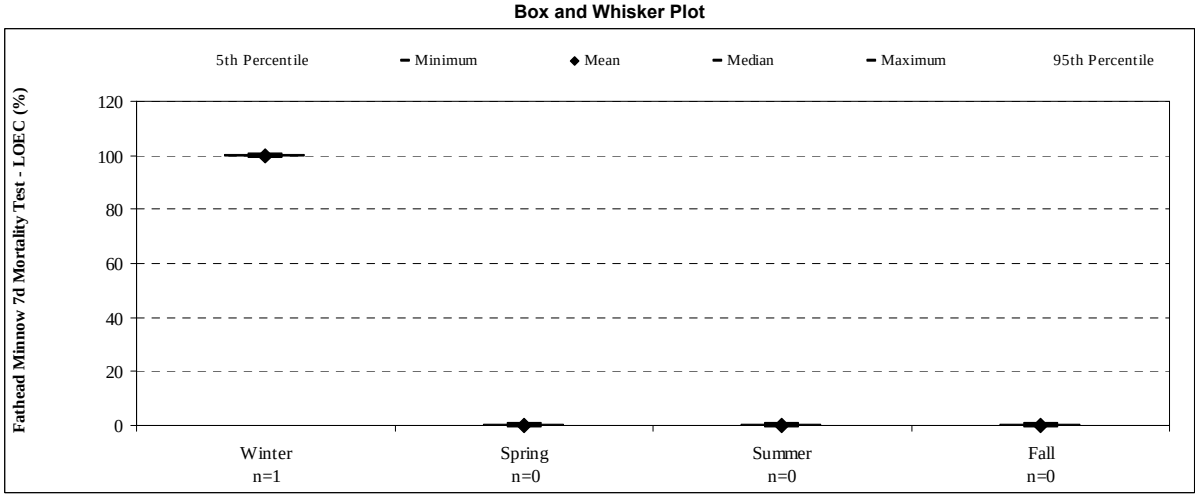


Figure G-2-5-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Shelley Creek



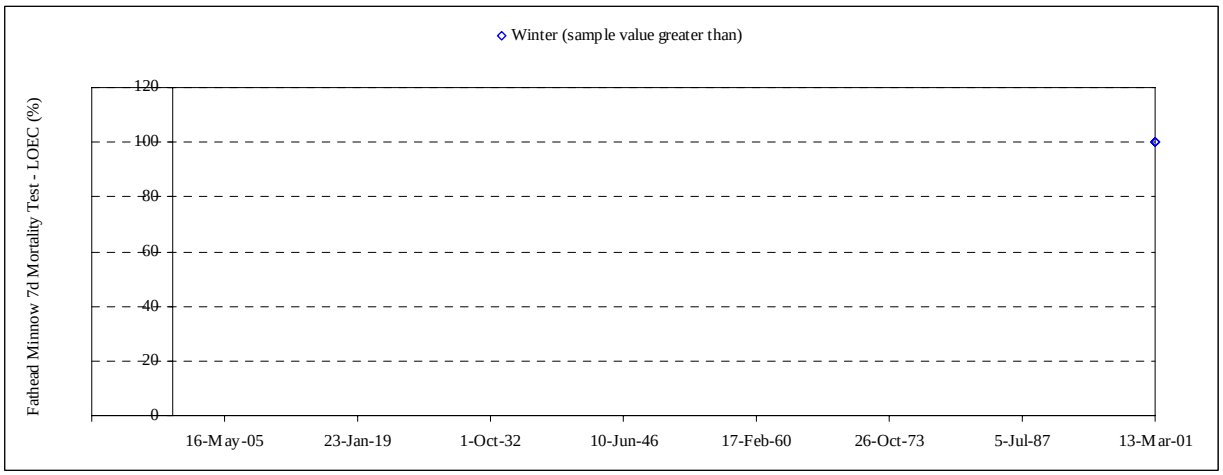


Figure G-2-5-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Shelley Creek

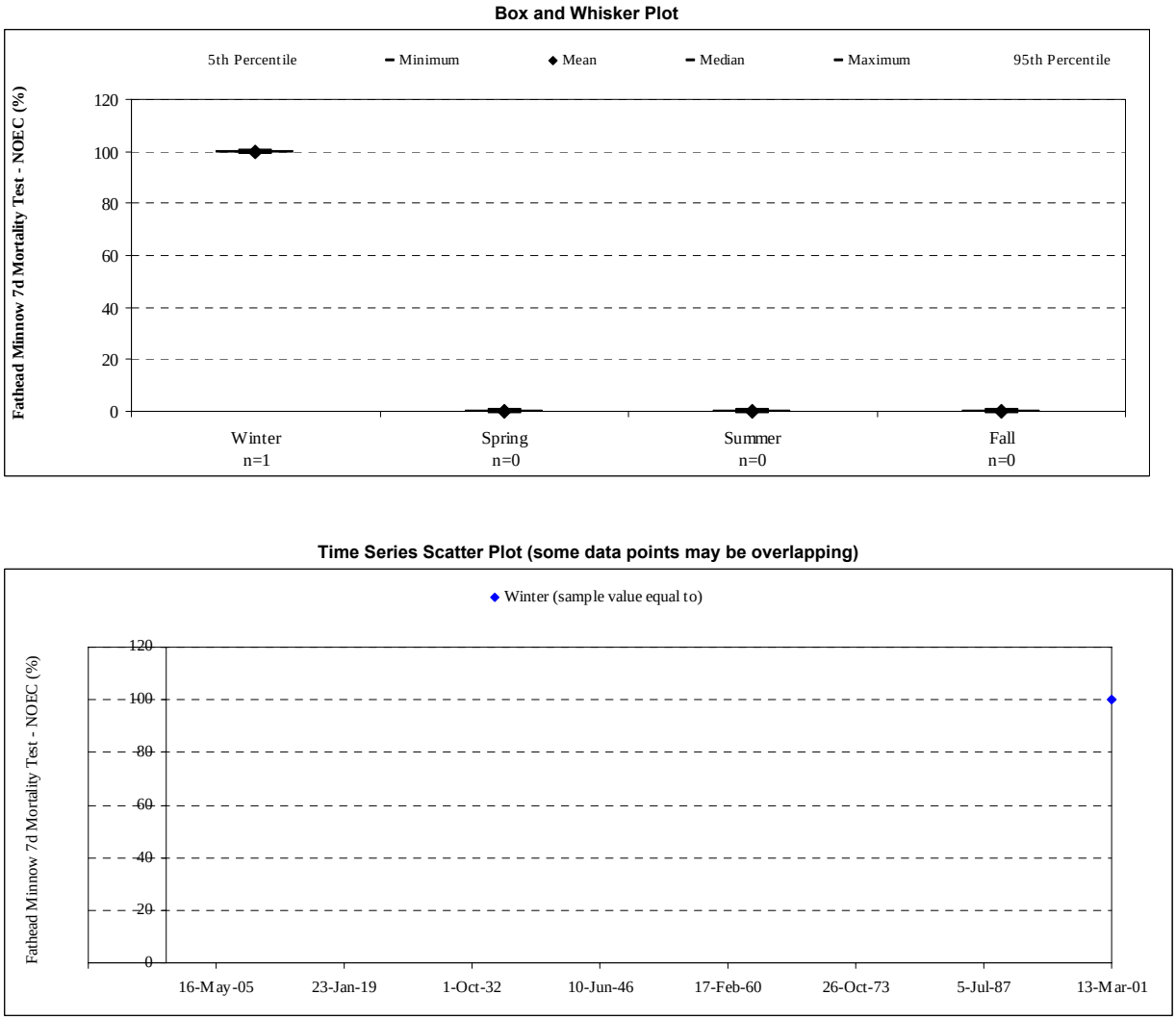
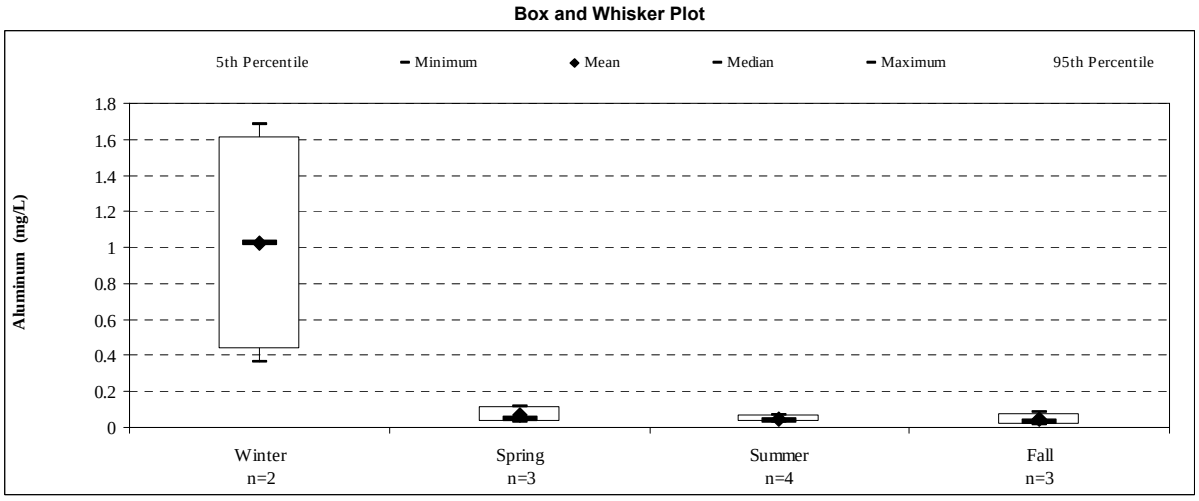


Figure G-2-5-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Shelley Creek



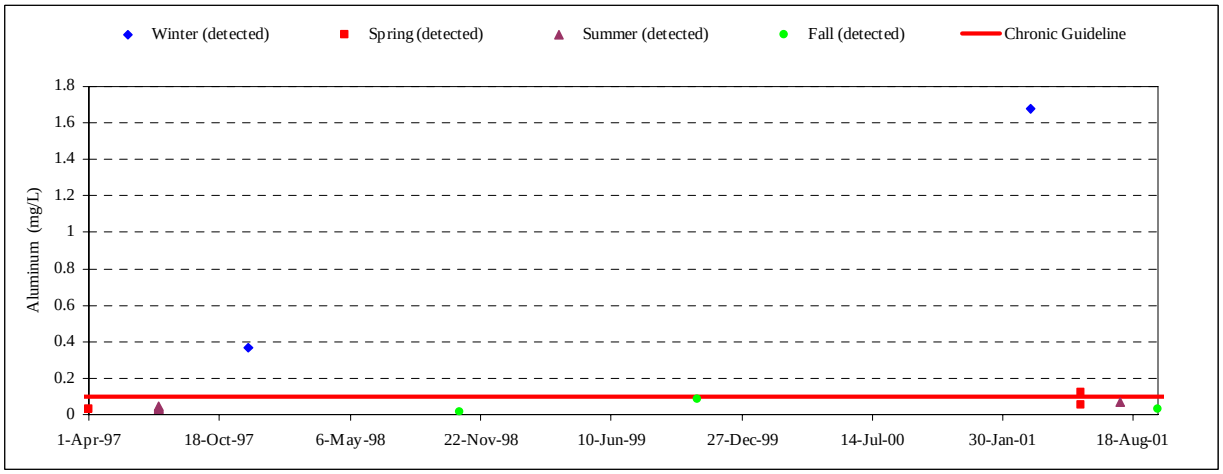
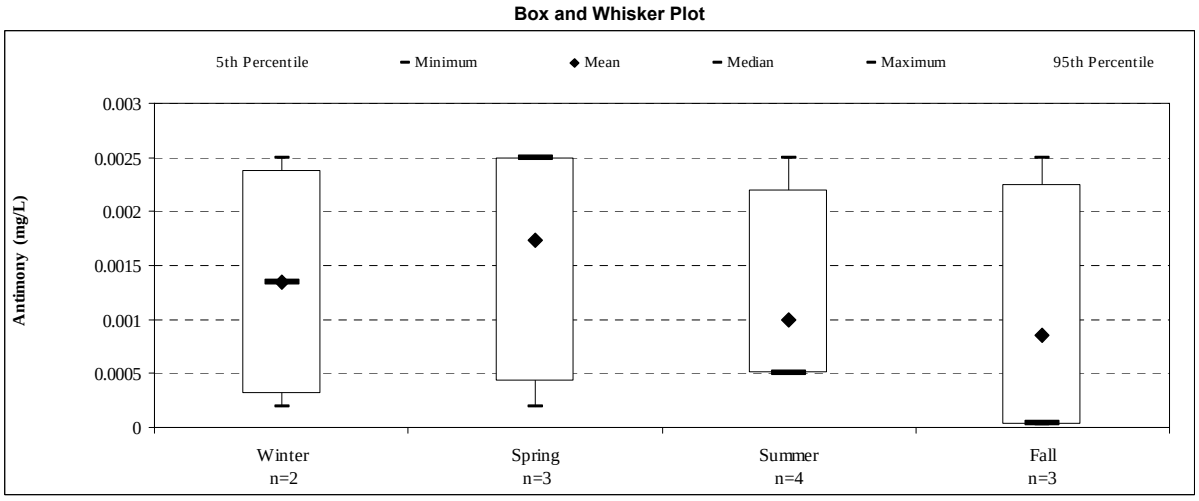


Figure G-2-5-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Shelley Creek



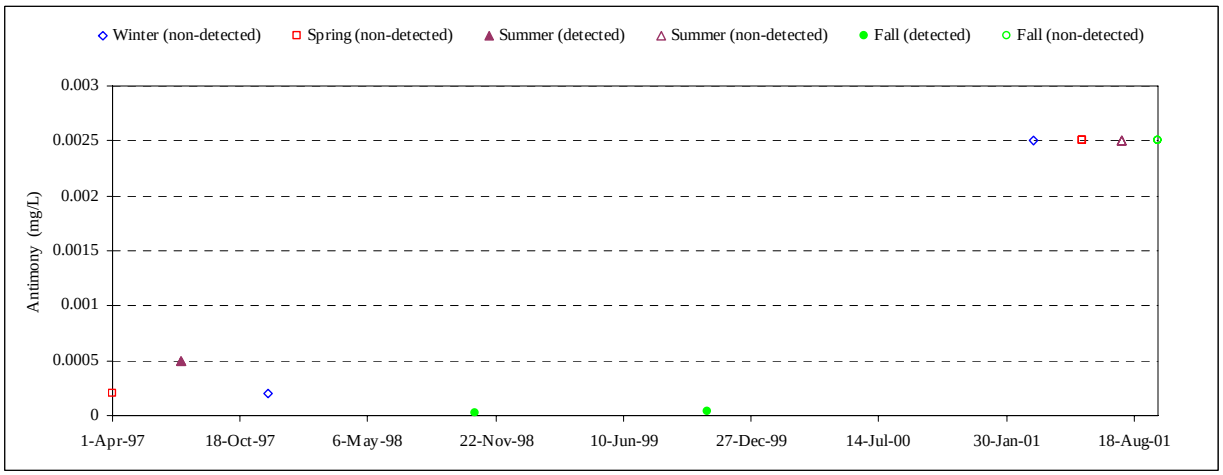
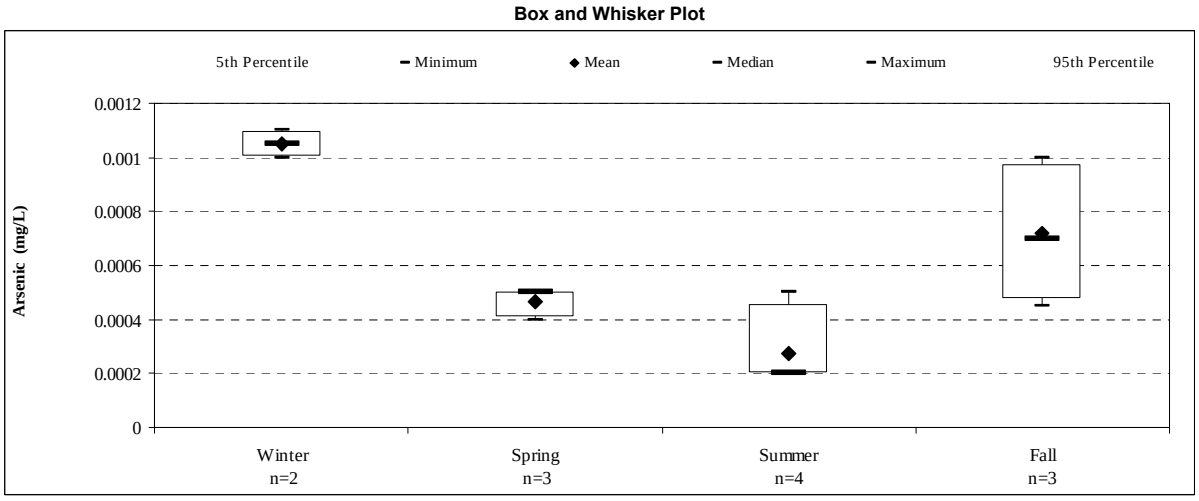


Figure G-2-5-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Shelley Creek



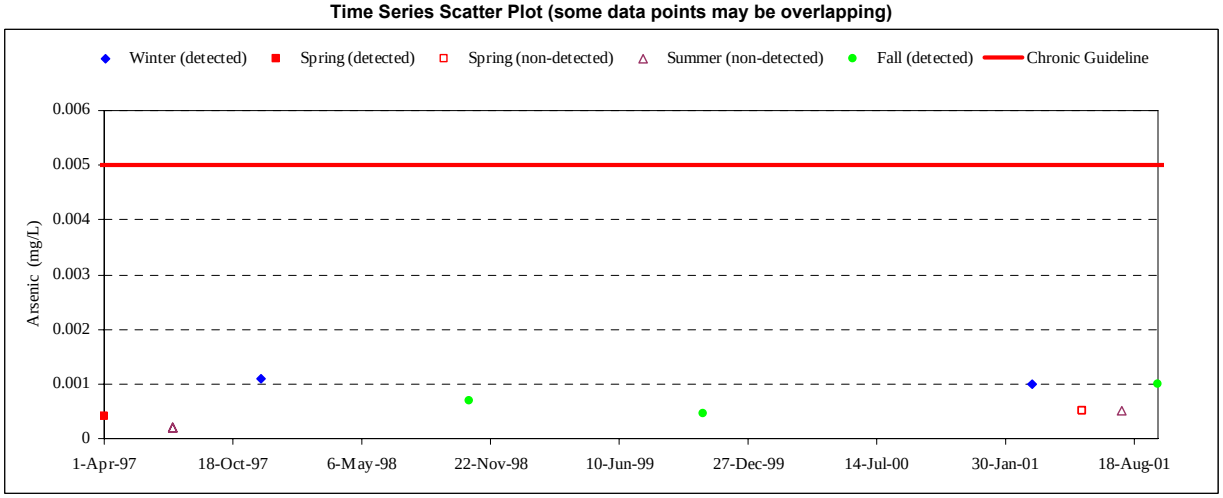
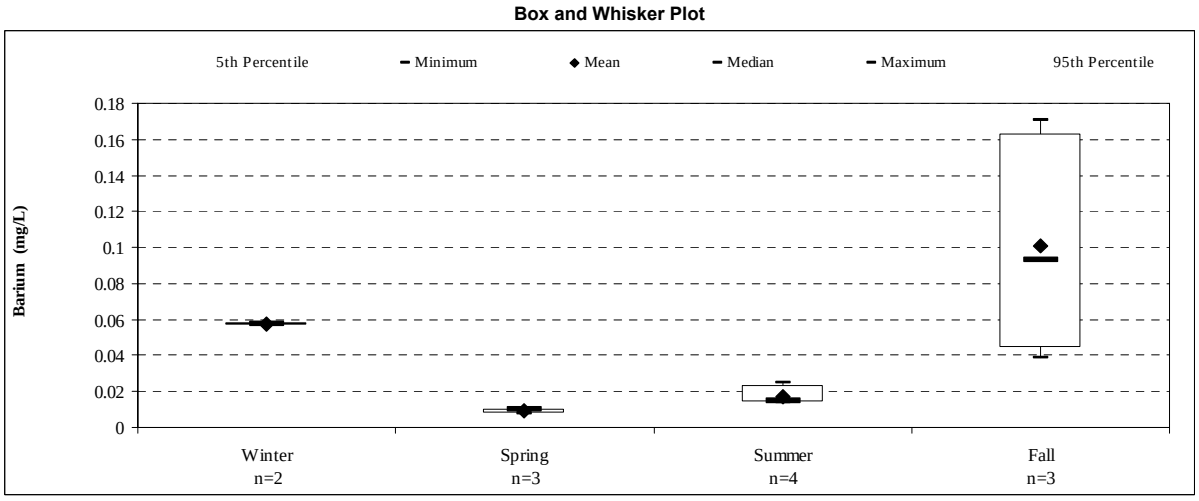


Figure G-2-5-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Shelley Creek



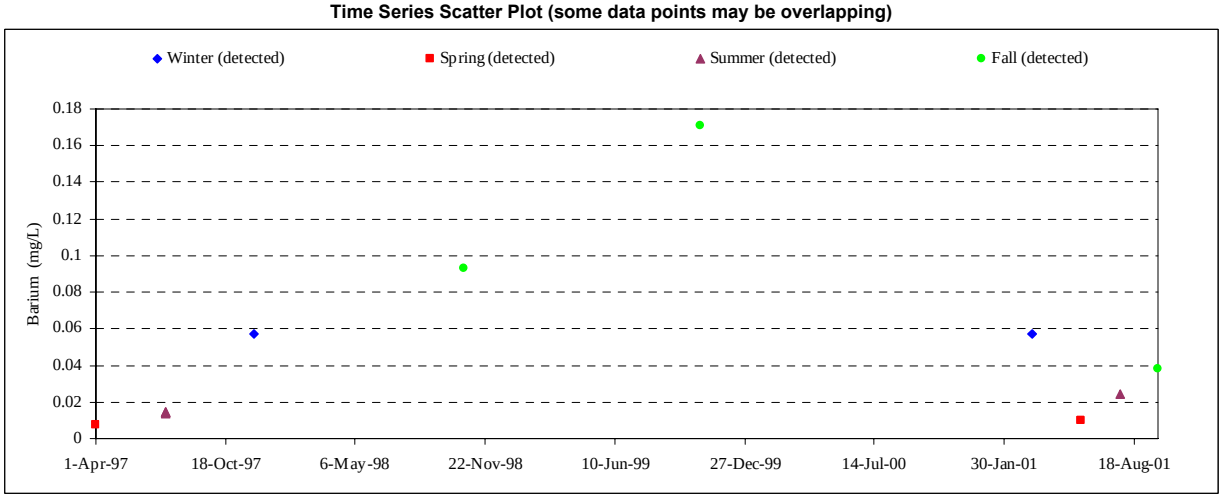
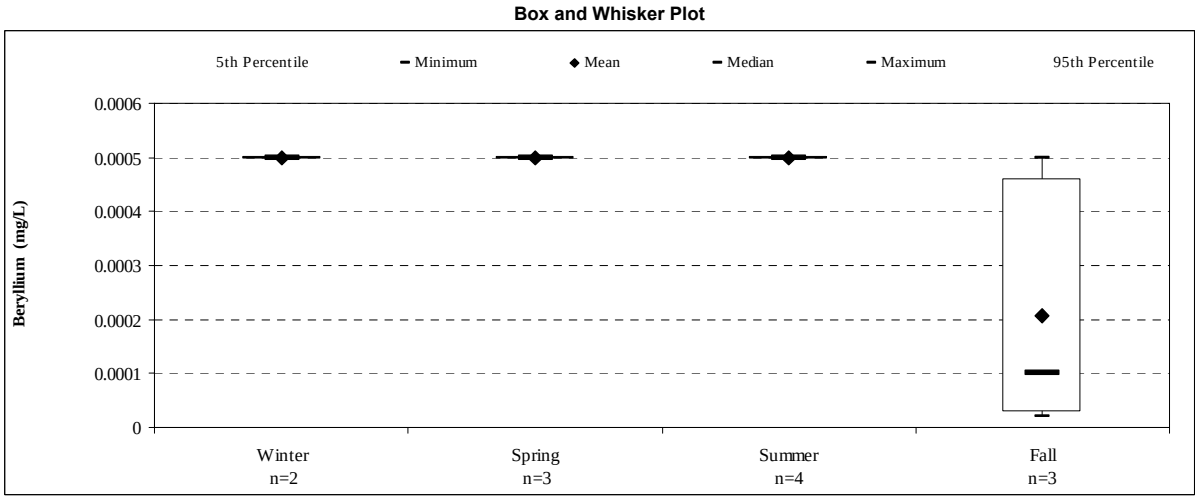


Figure G-2-5-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Shelley Creek



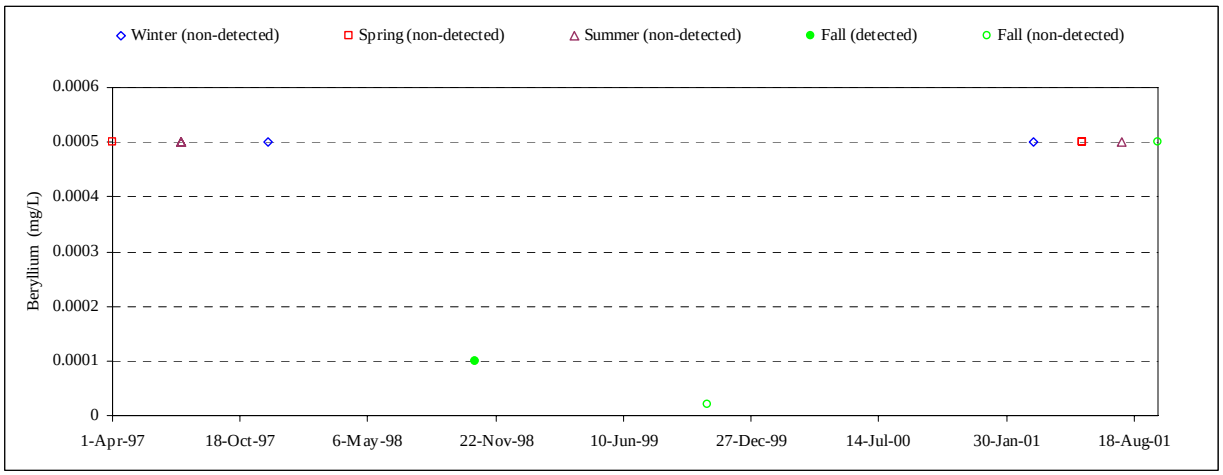
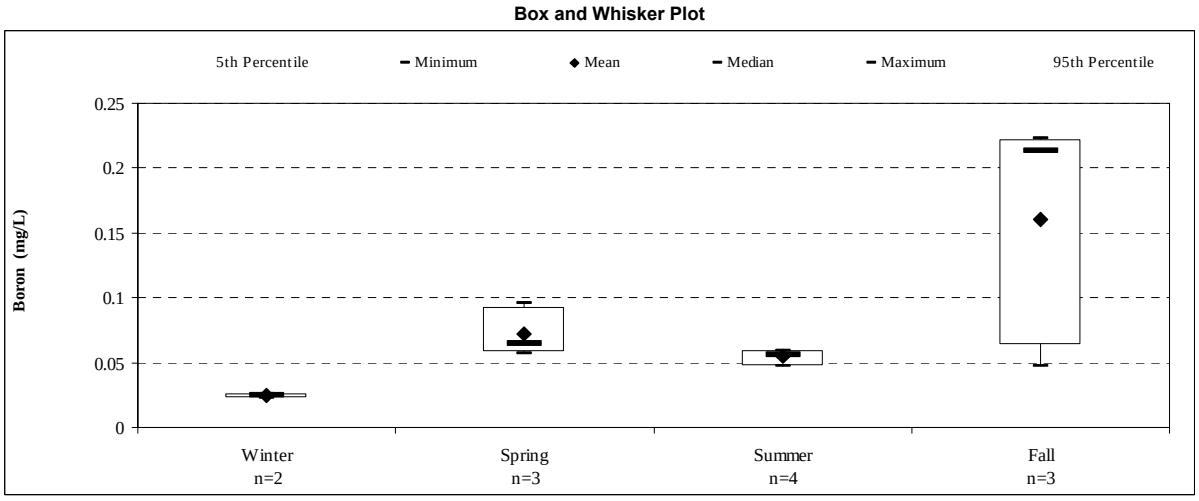


Figure G-2-5-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Shelley Creek



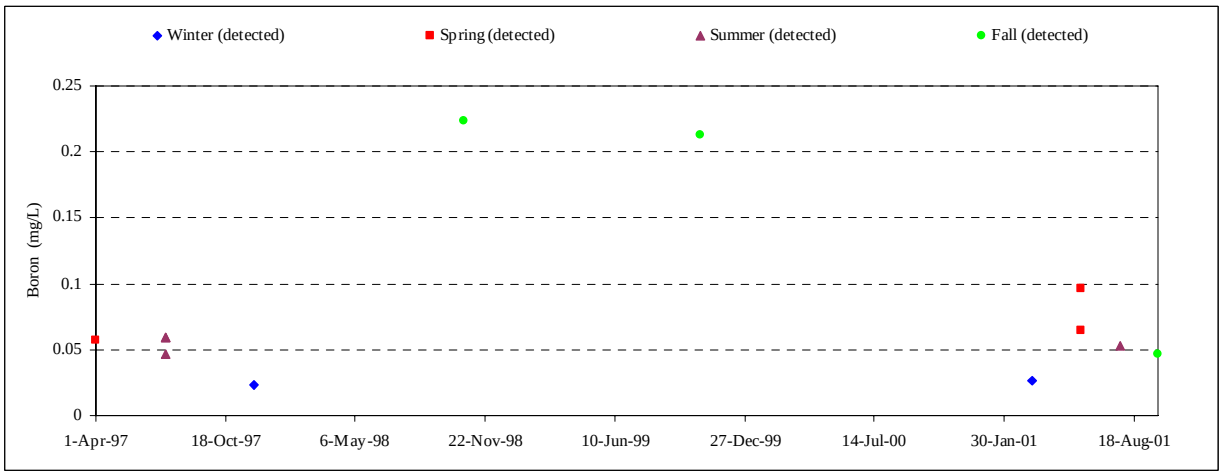
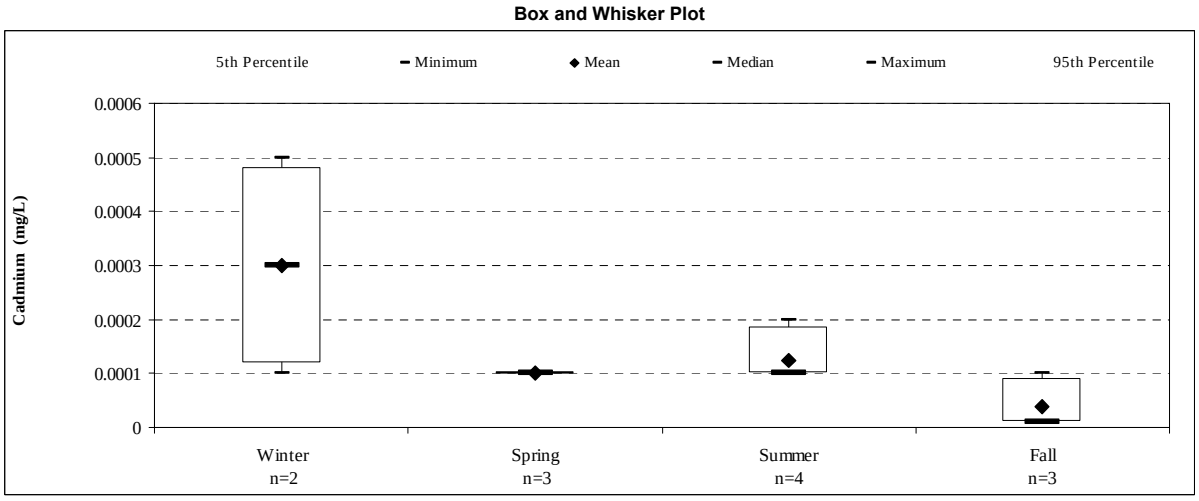


Figure G-2-5-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Shelley Creek



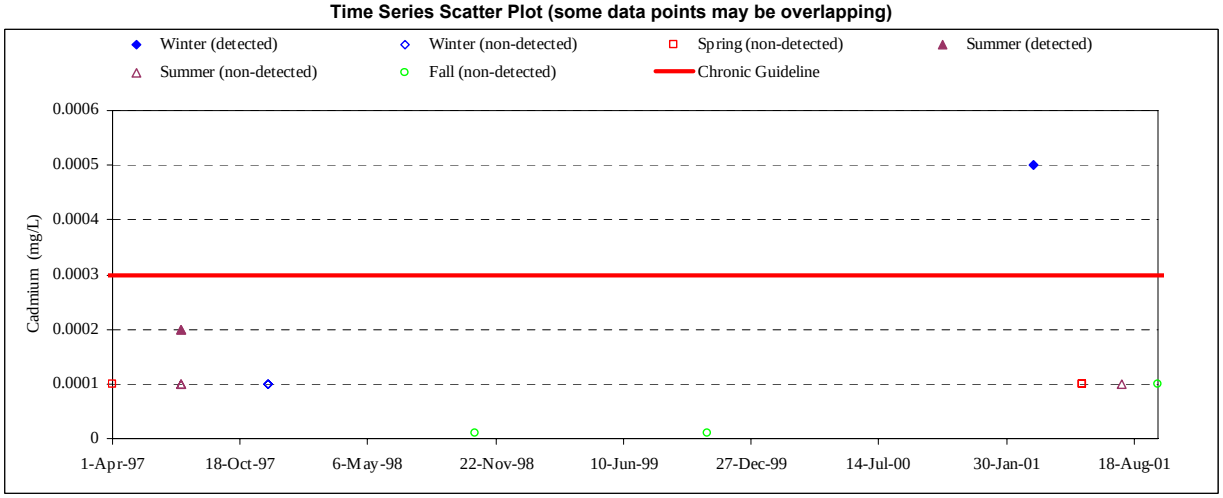


Figure G-2-5-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Shelley Creek

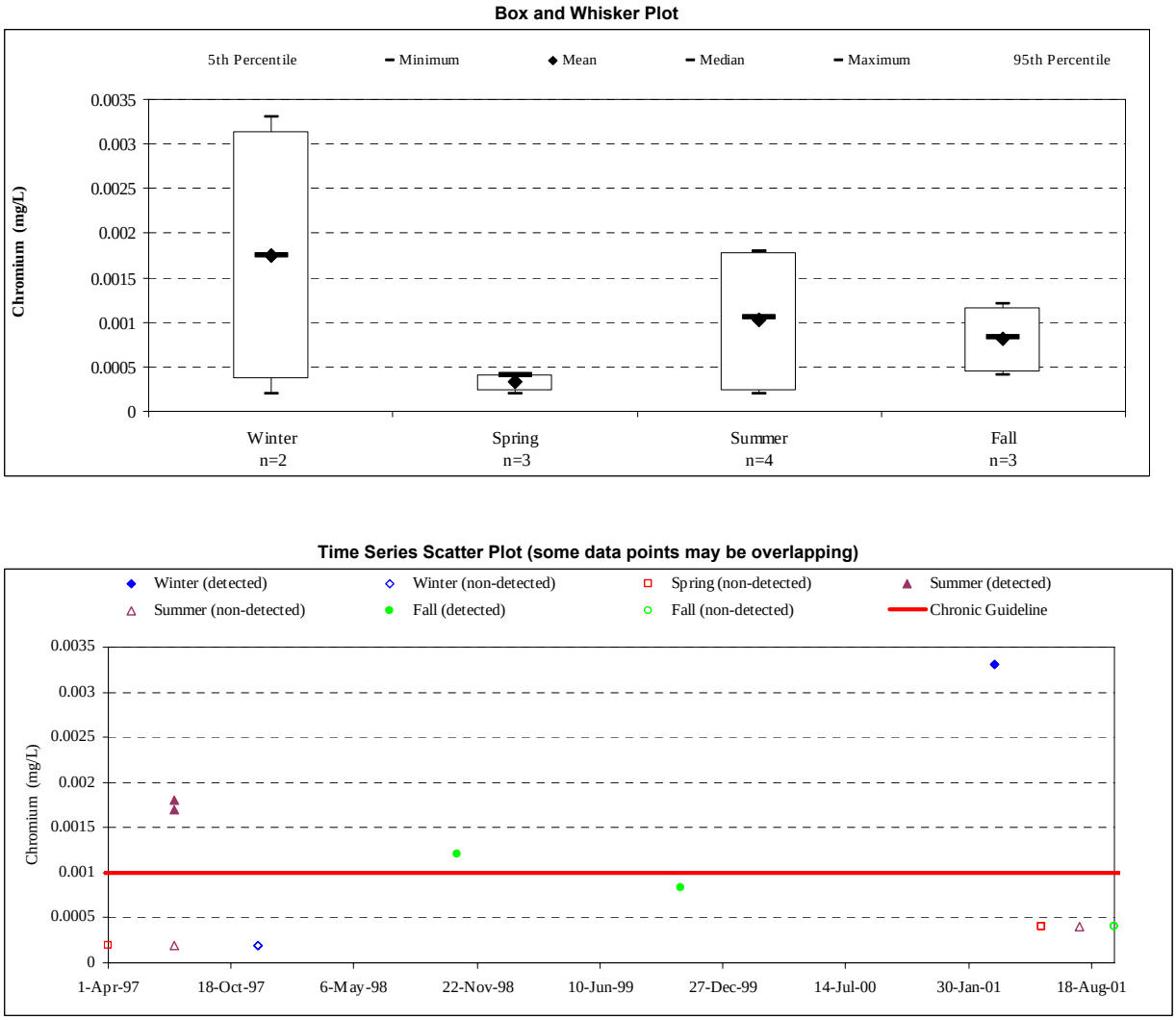
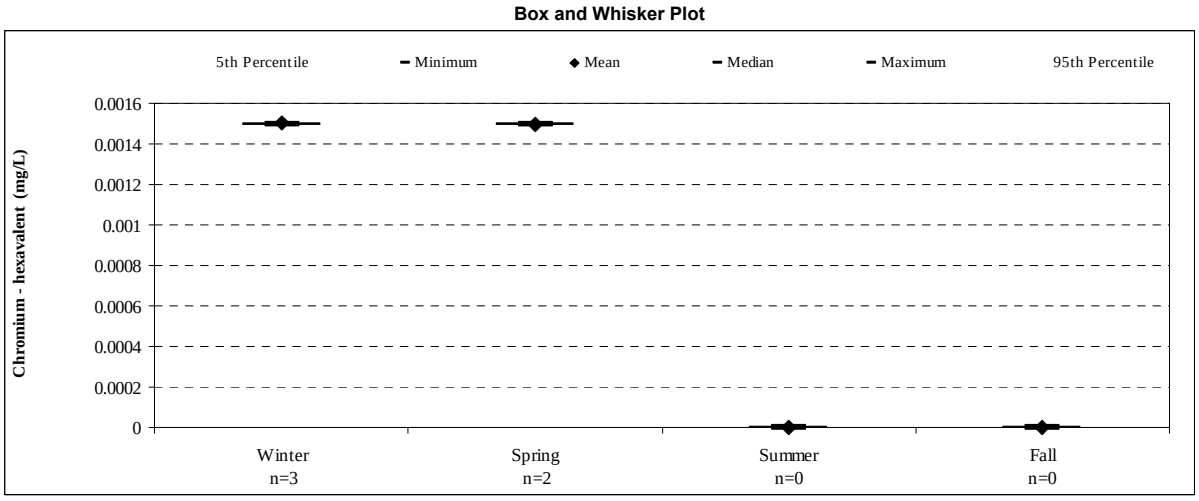


Figure G-2-5-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Shelley Creek



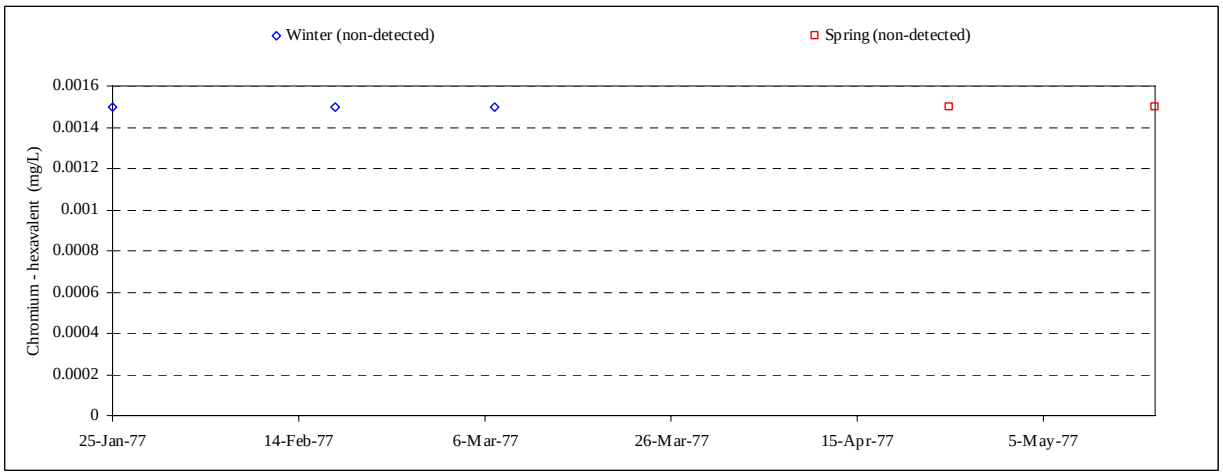
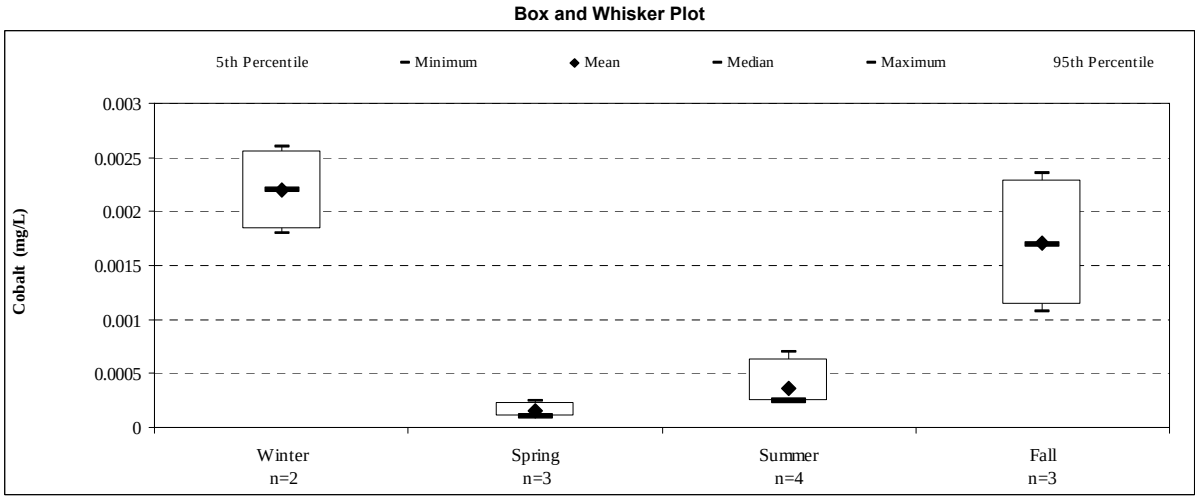


Figure G-2-5-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Shelley Creek



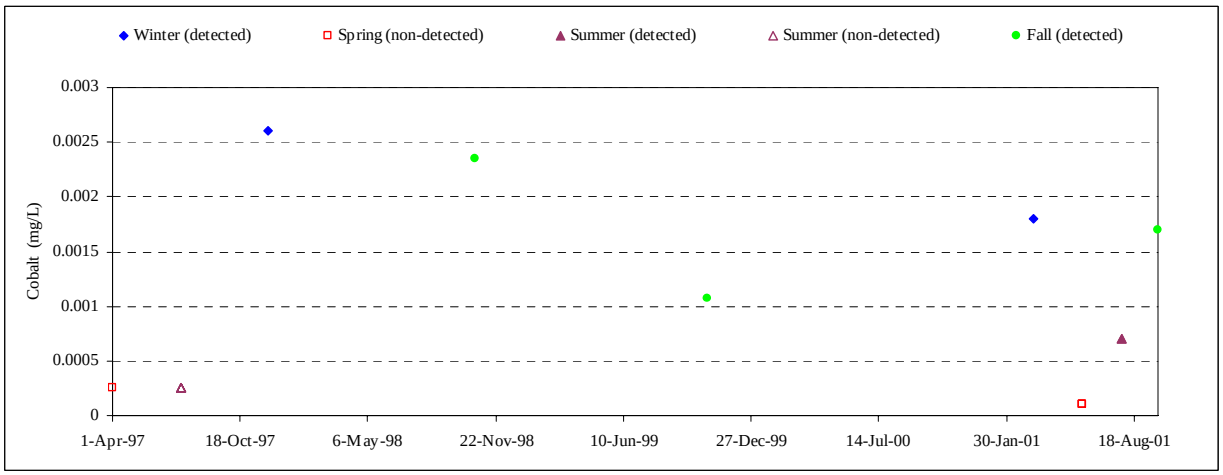
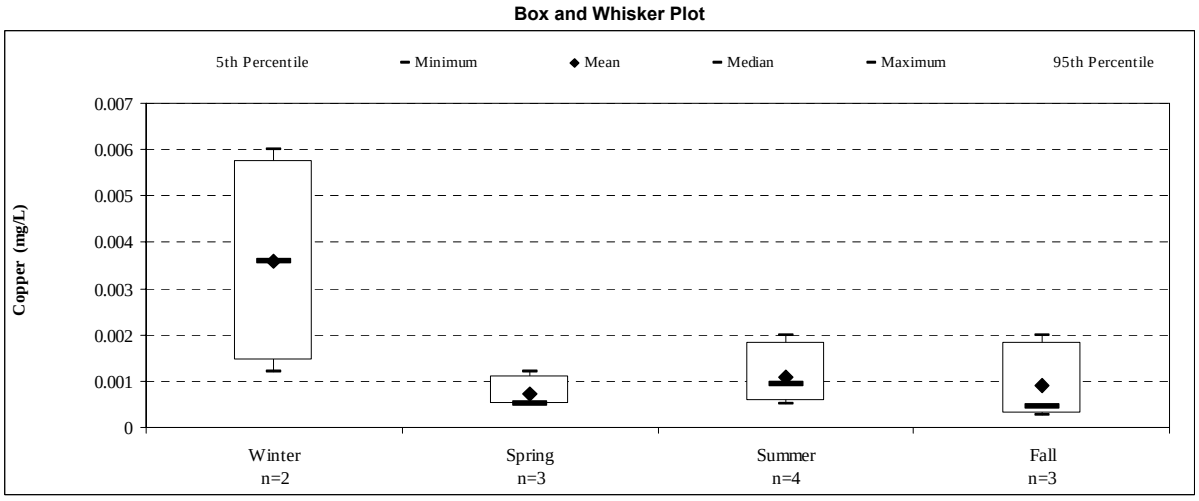


Figure G-2-5-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Shelley Creek



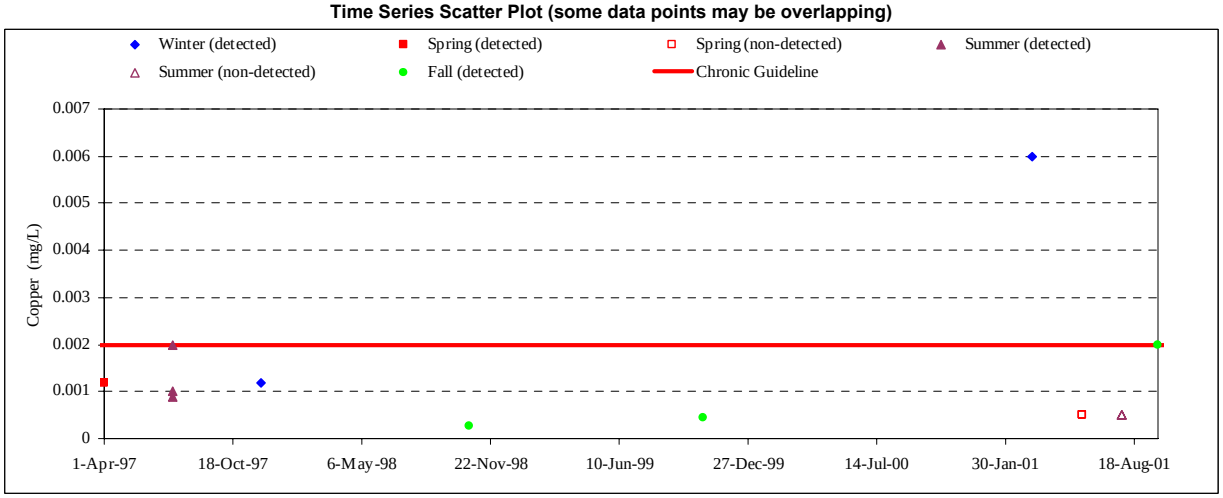
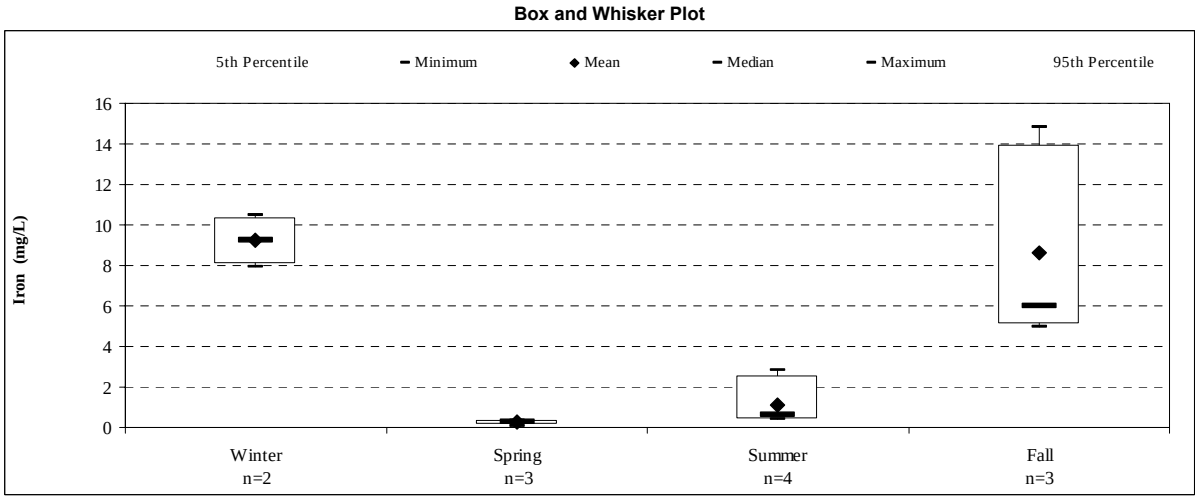


Figure G-2-5-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Shelley Creek



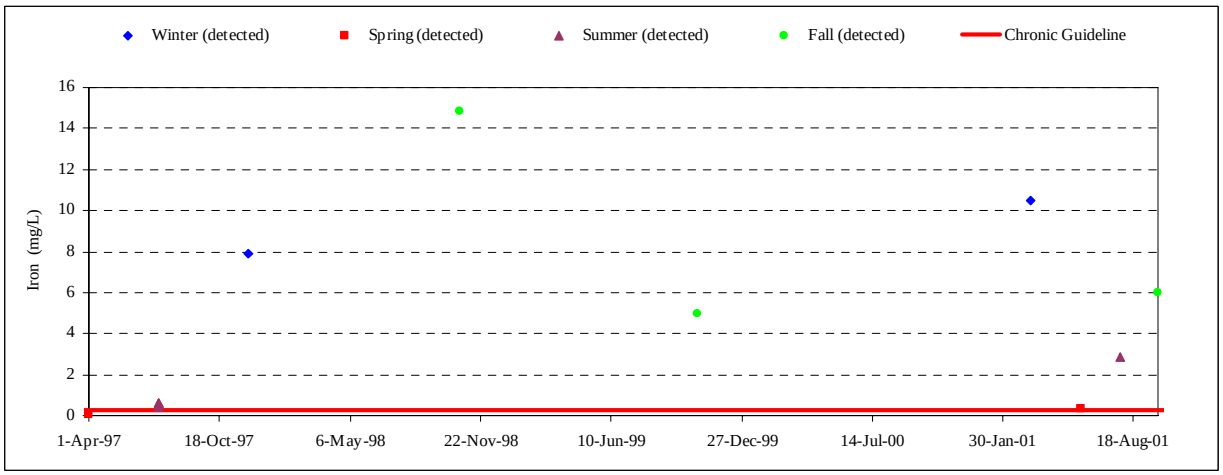
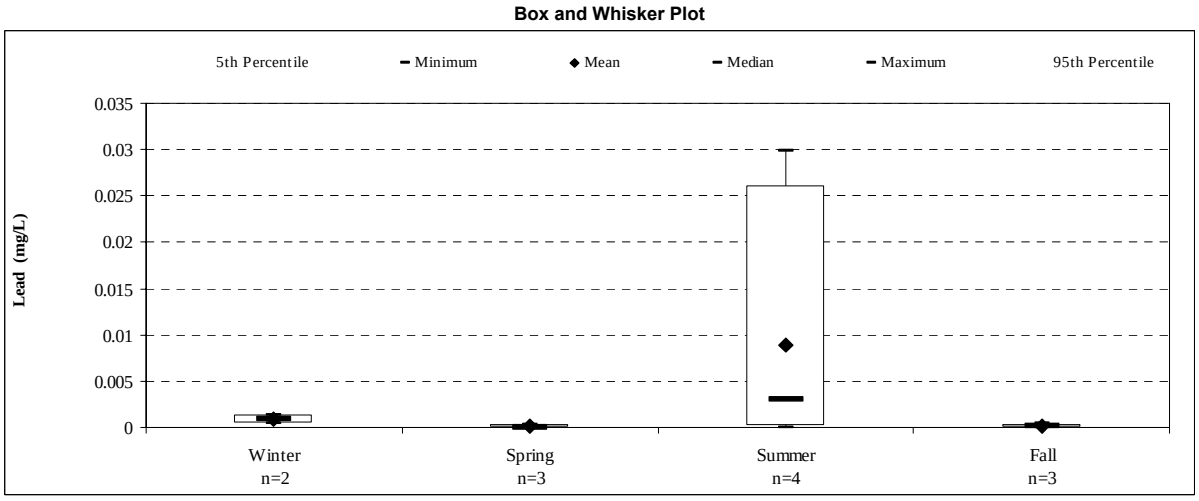


Figure G-2-5-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Shelley Creek



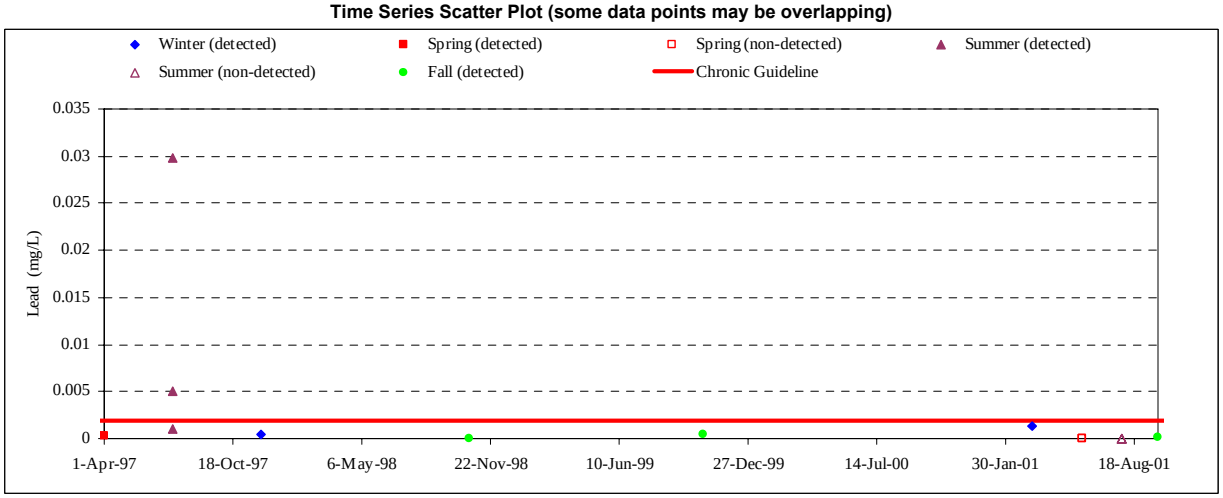
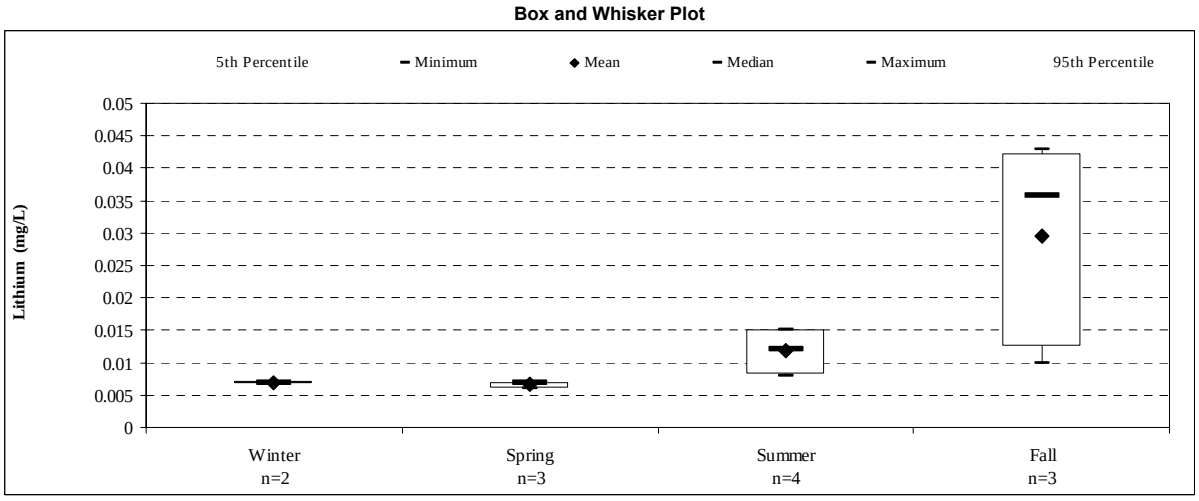


Figure G-2-5-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Shelley Creek



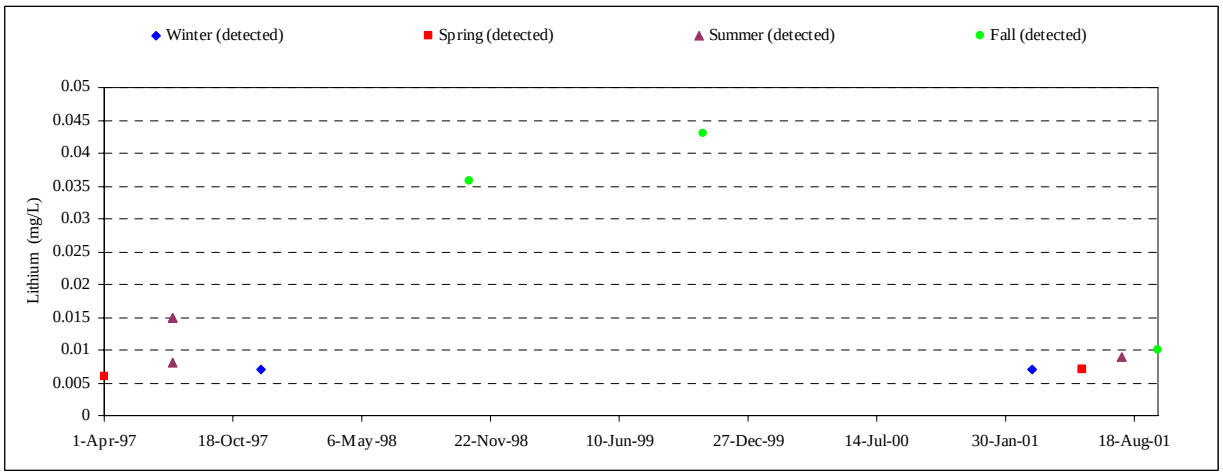
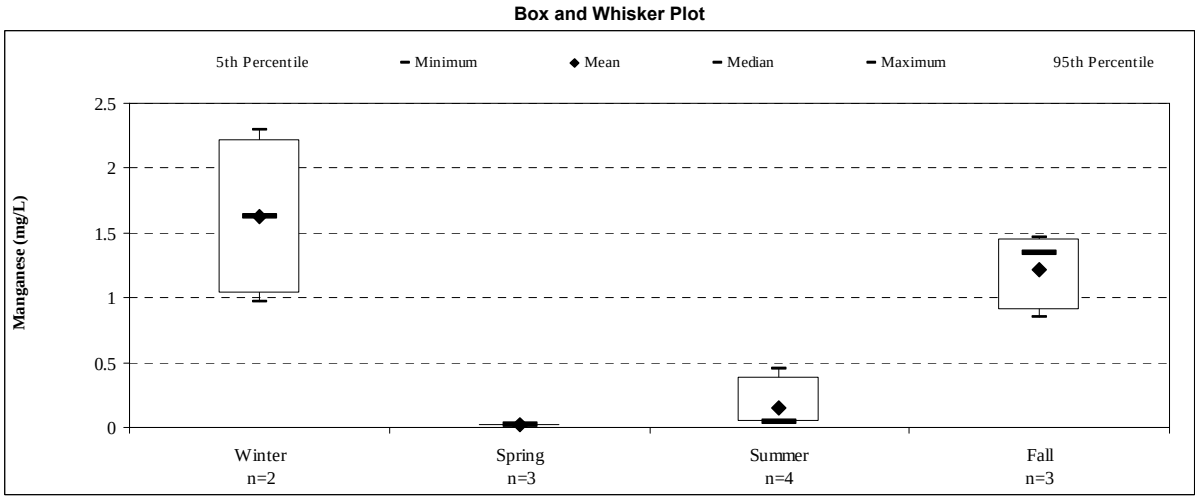


Figure G-2-5-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Shelley Creek



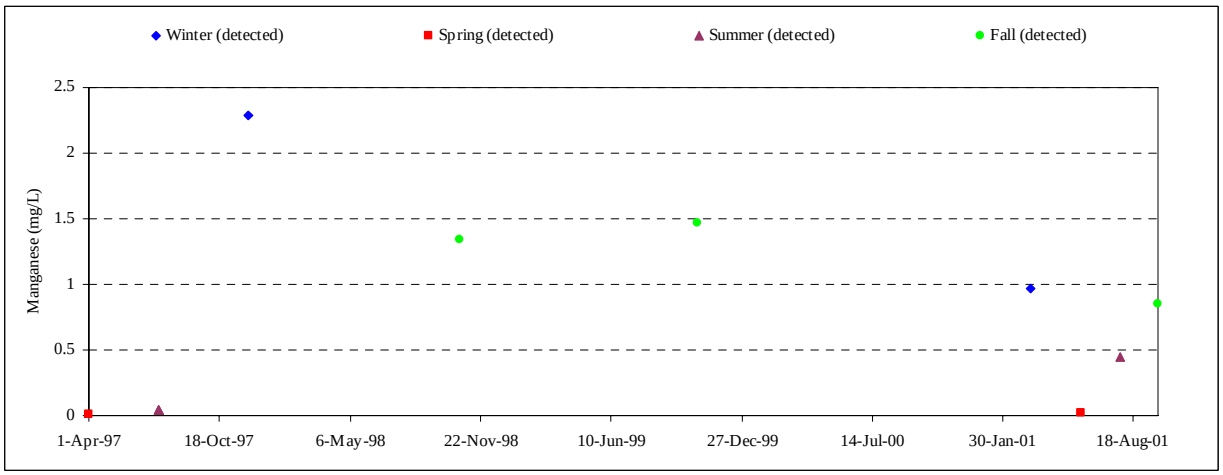
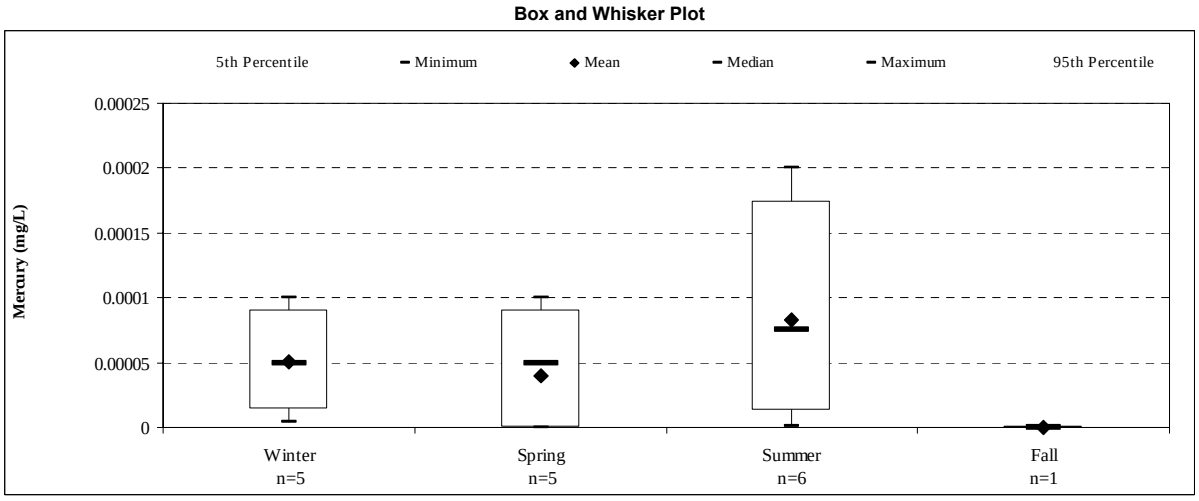


Figure G-2-5-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Shelley Creek



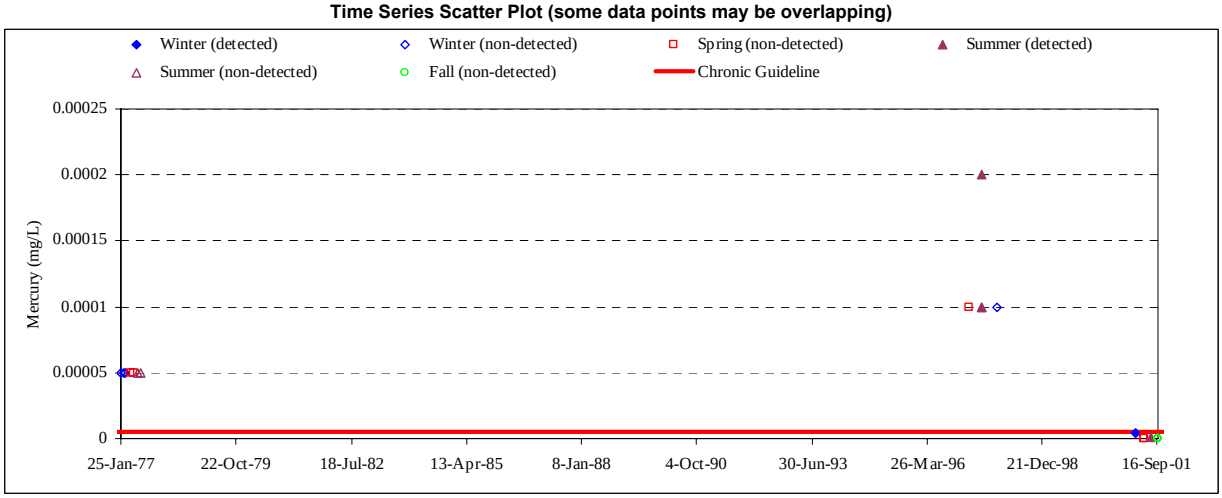


Figure G-2-5-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Shelley Creek

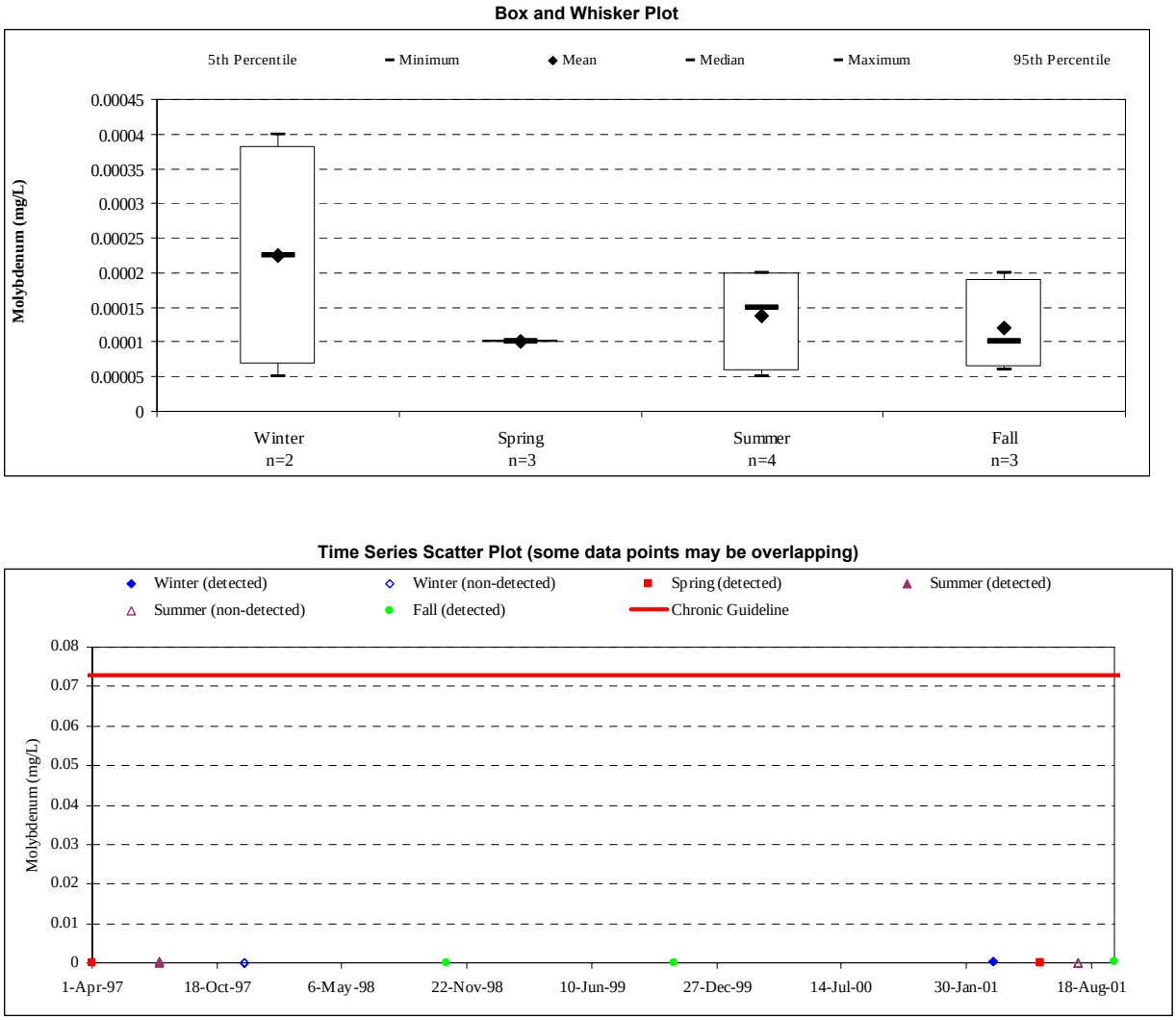
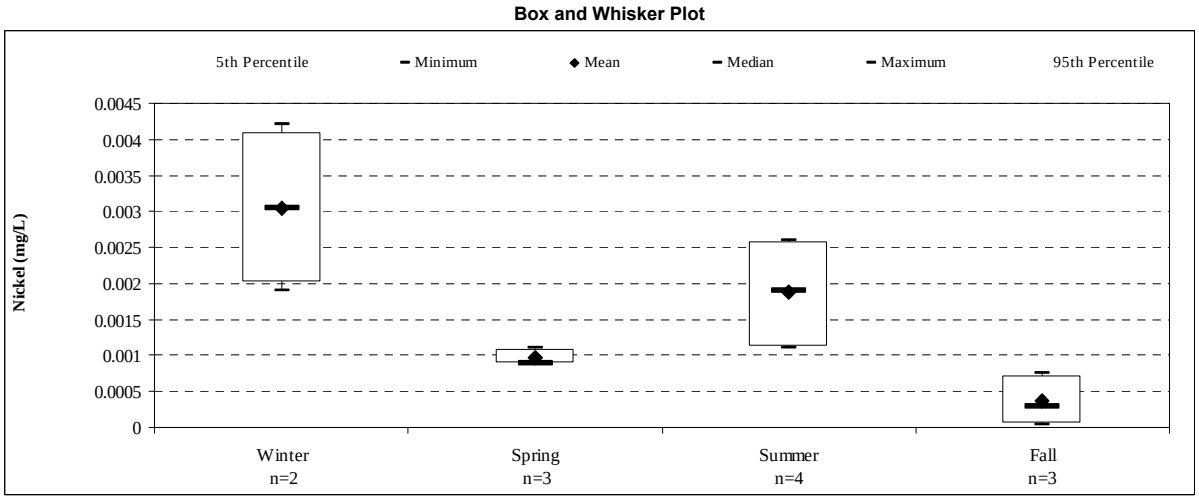


Figure G-2-5-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Shelley Creek



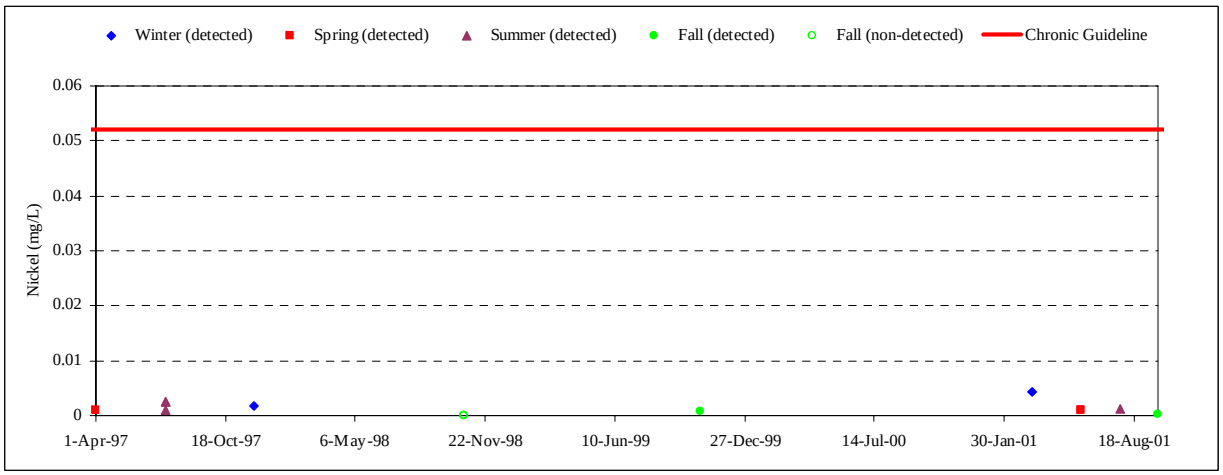
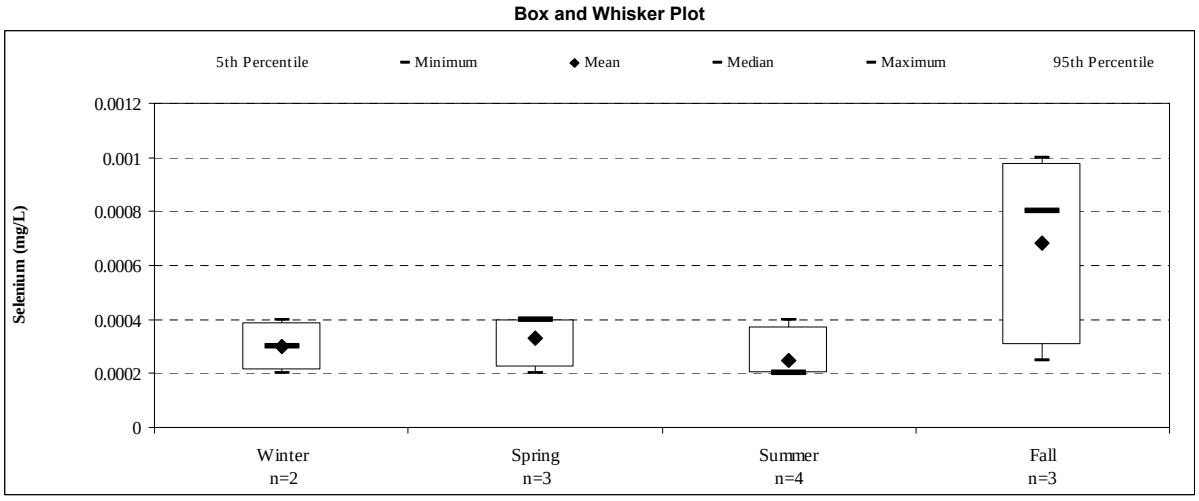


Figure G-2-5-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Shelley Creek



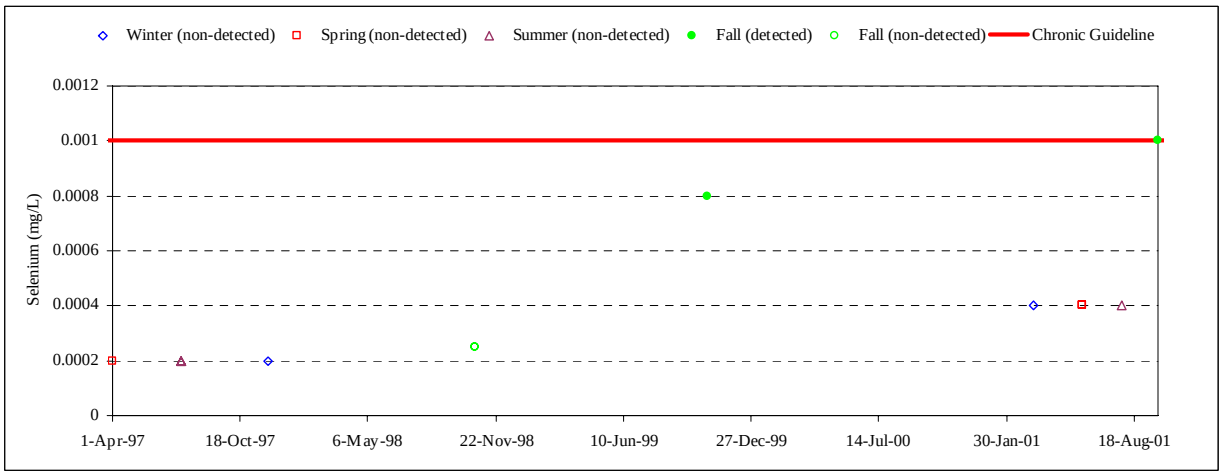
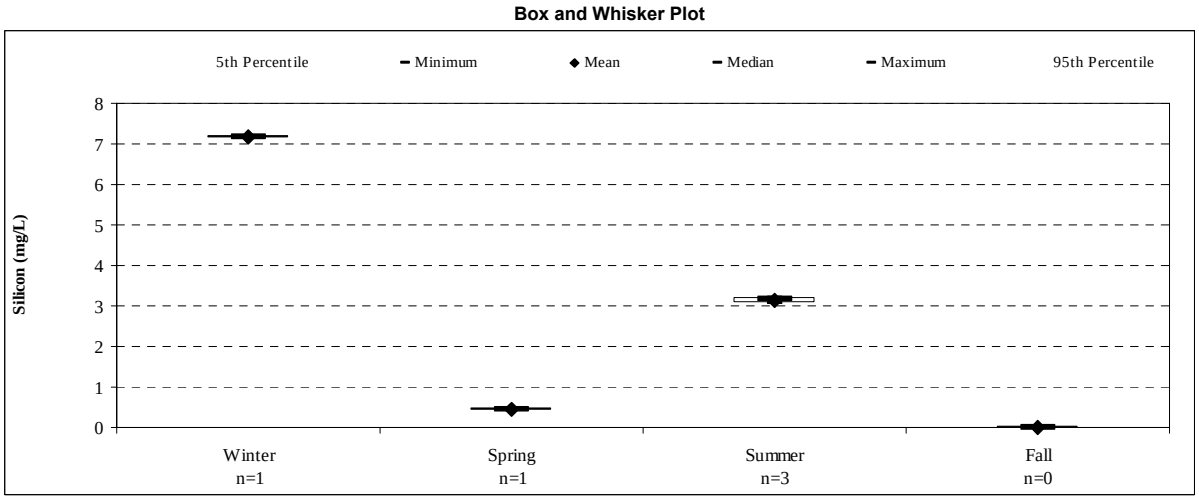


Figure G-2-5-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Shelley Creek



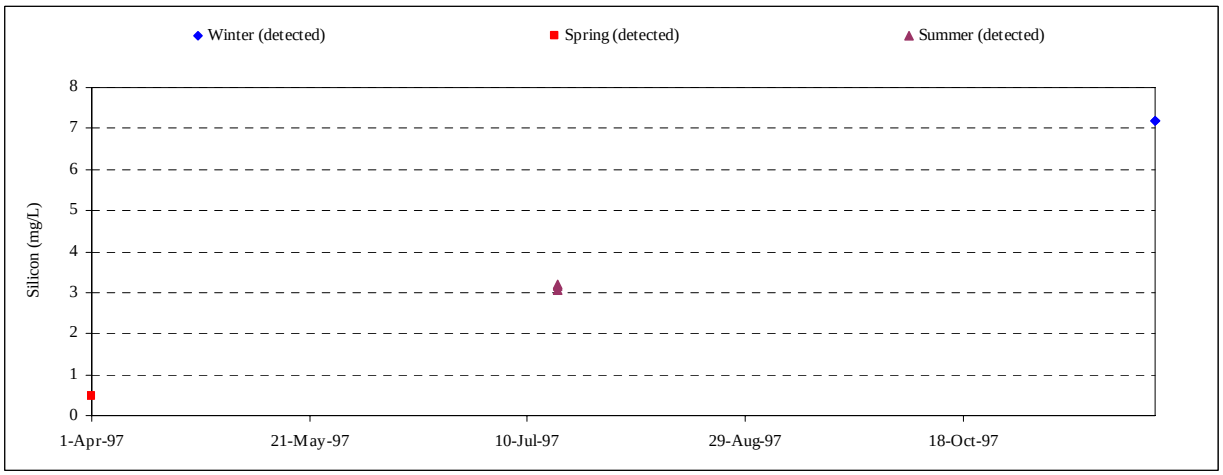
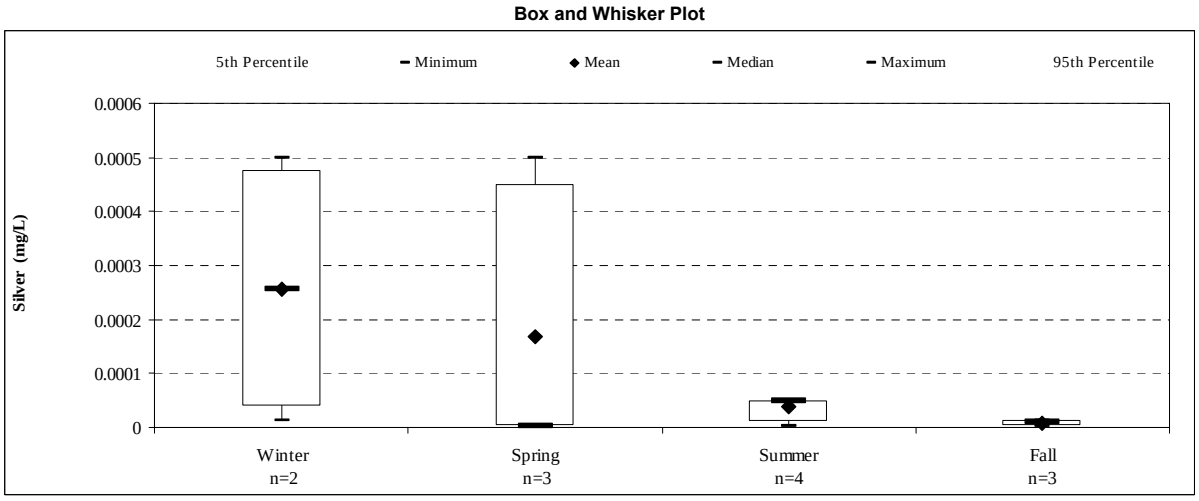


Figure G-2-5-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Shelley Creek



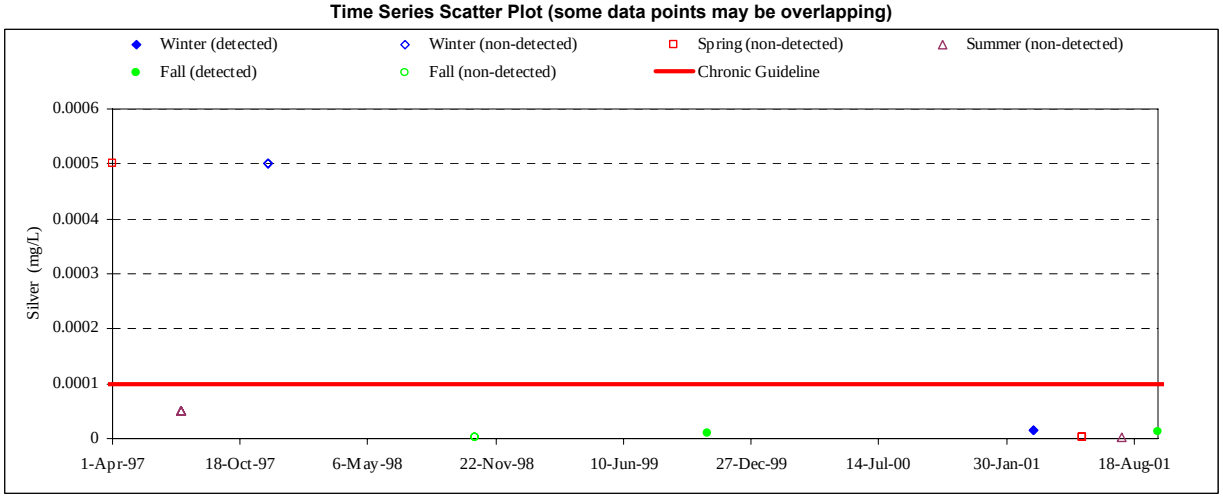
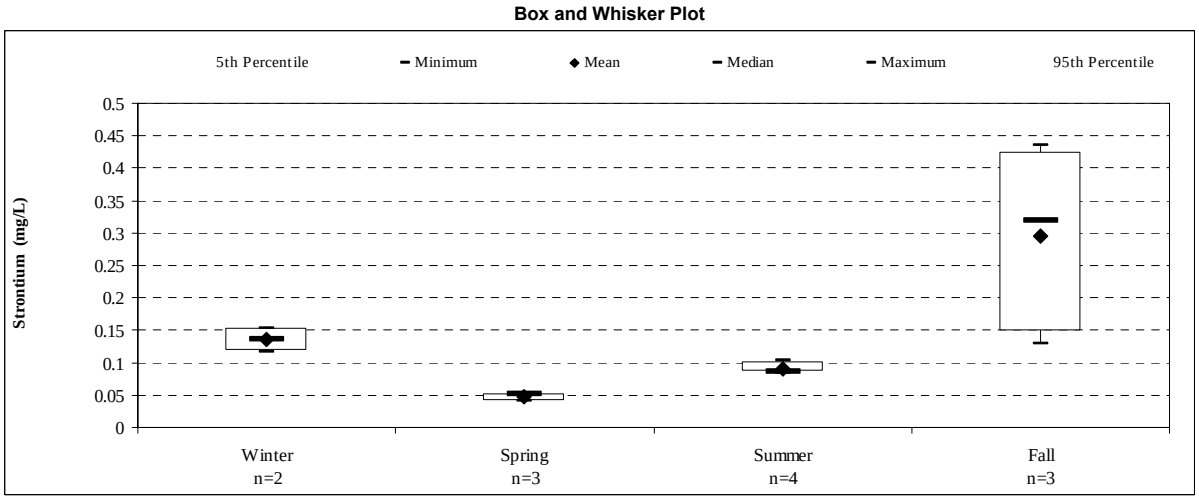


Figure G-2-5-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Shelley Creek



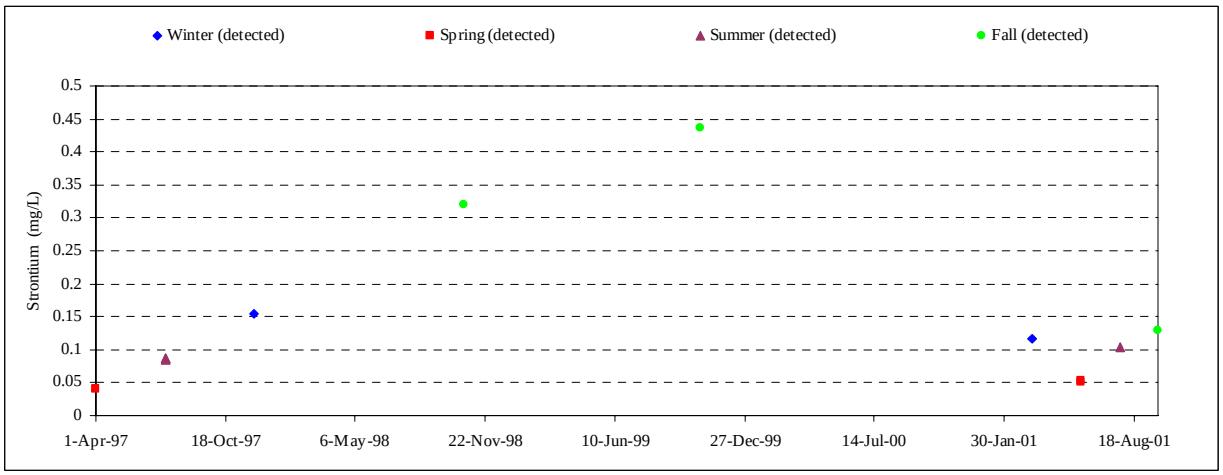
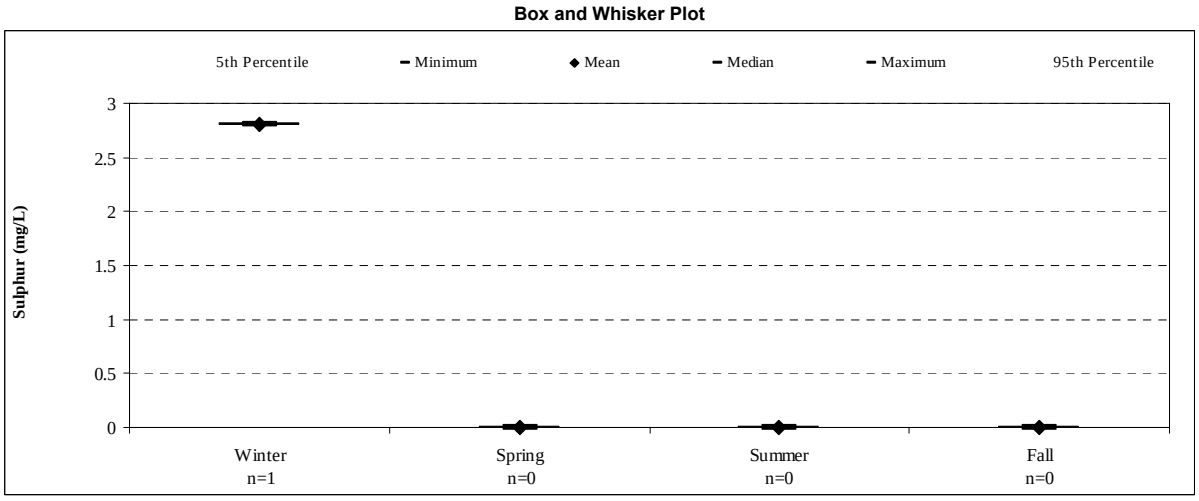


Figure G-2-5-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Shelley Creek



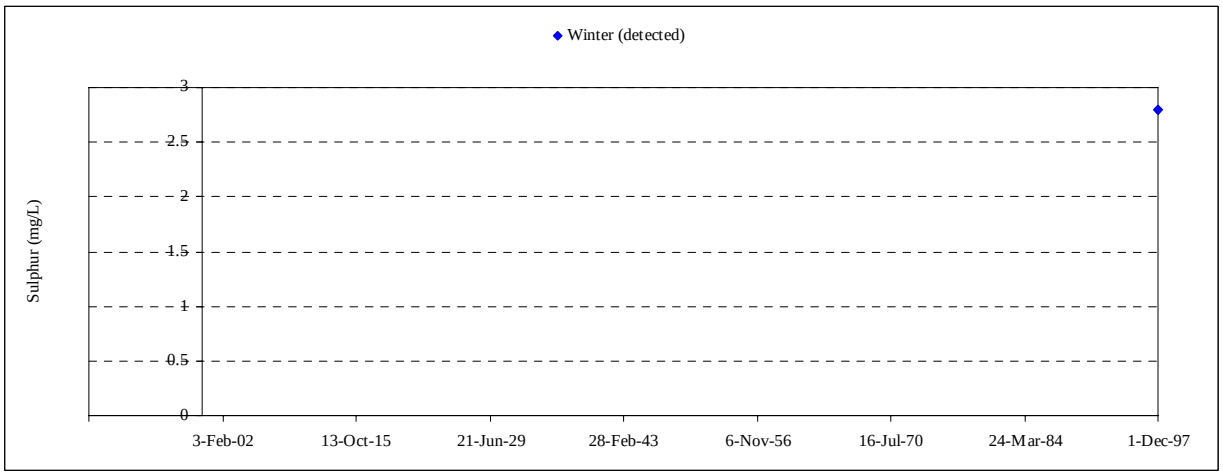
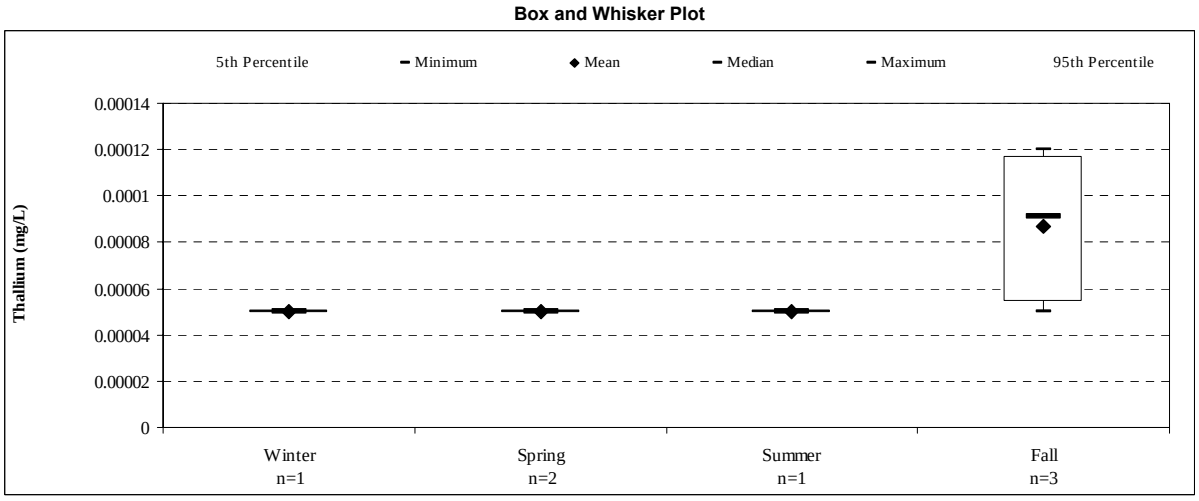


Figure G-2-5-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Shelley Creek



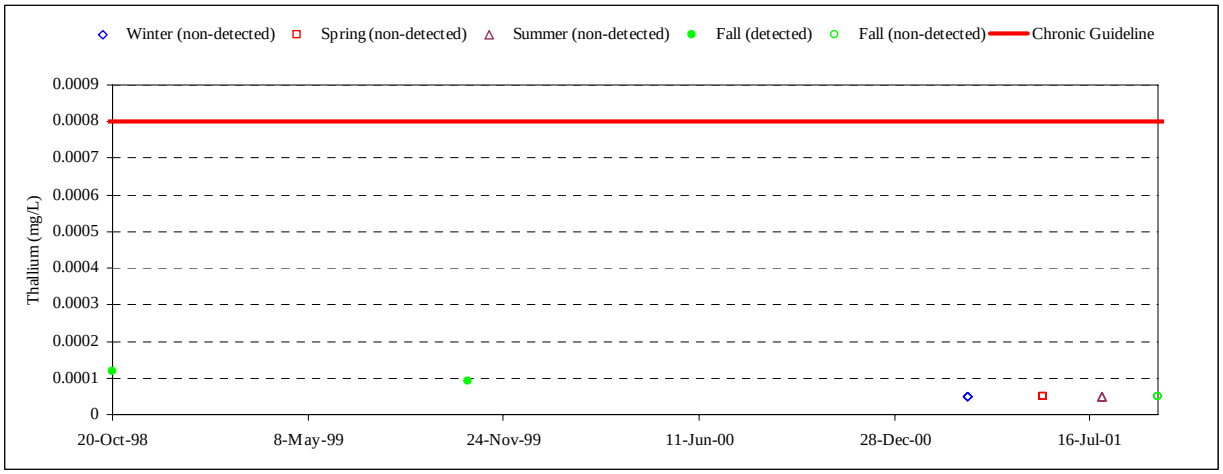
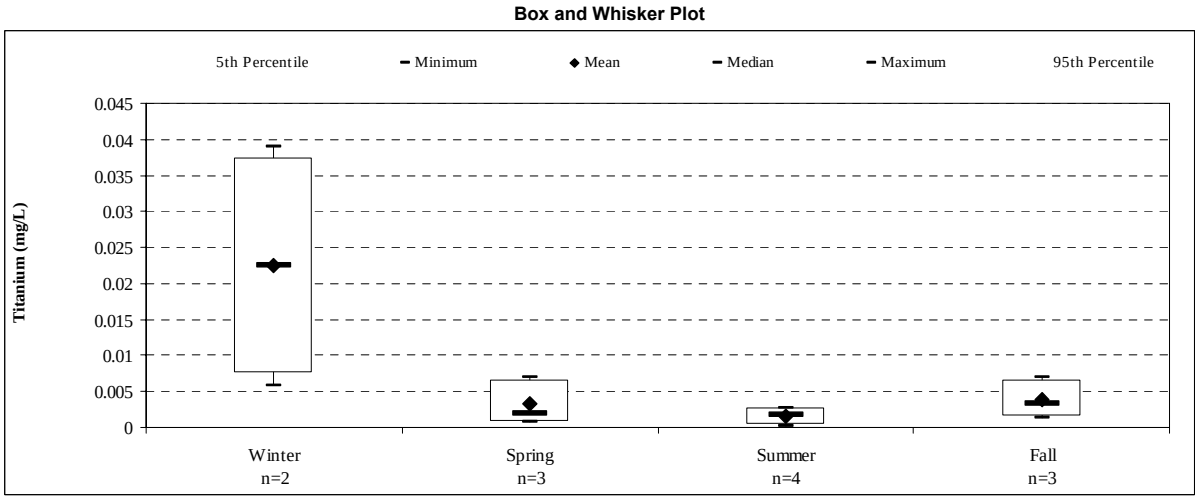


Figure G-2-5-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Shelley Creek



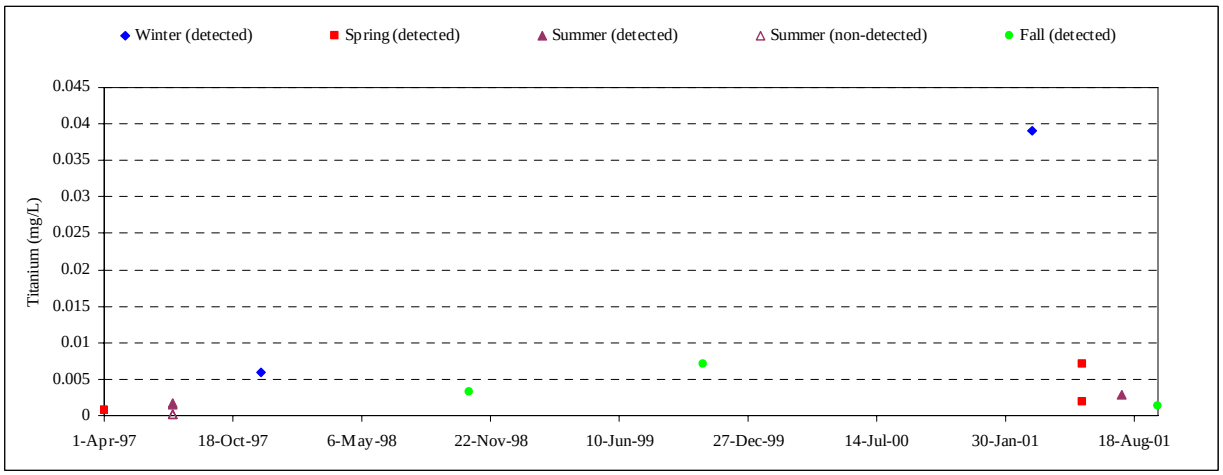
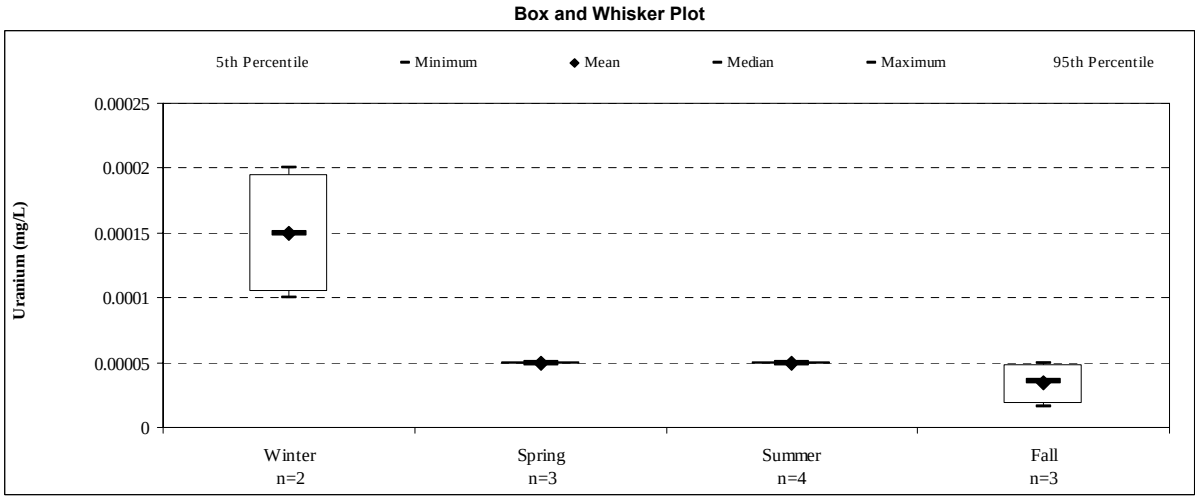


Figure G-2-5-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Shelley Creek



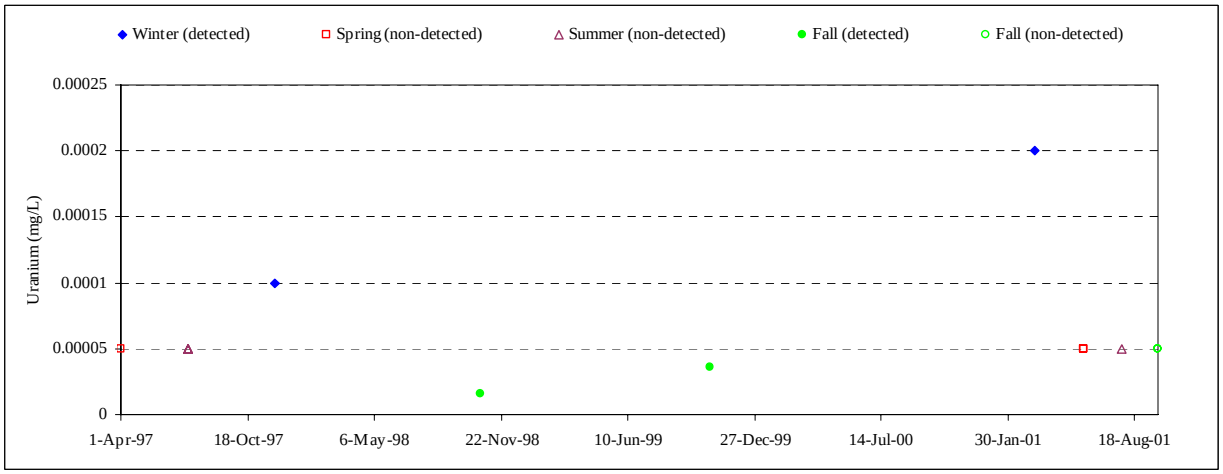
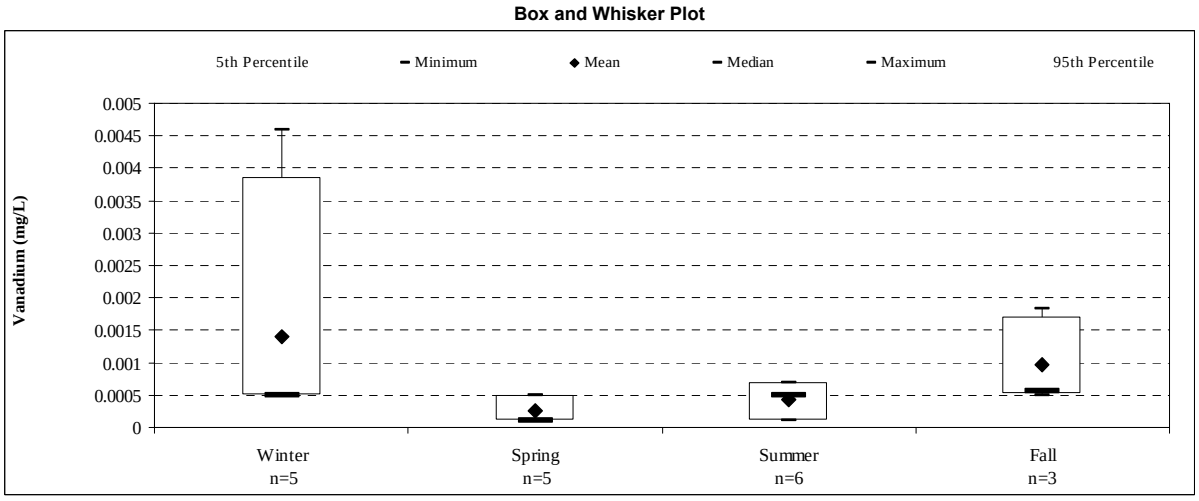


Figure G-2-5-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Shelley Creek



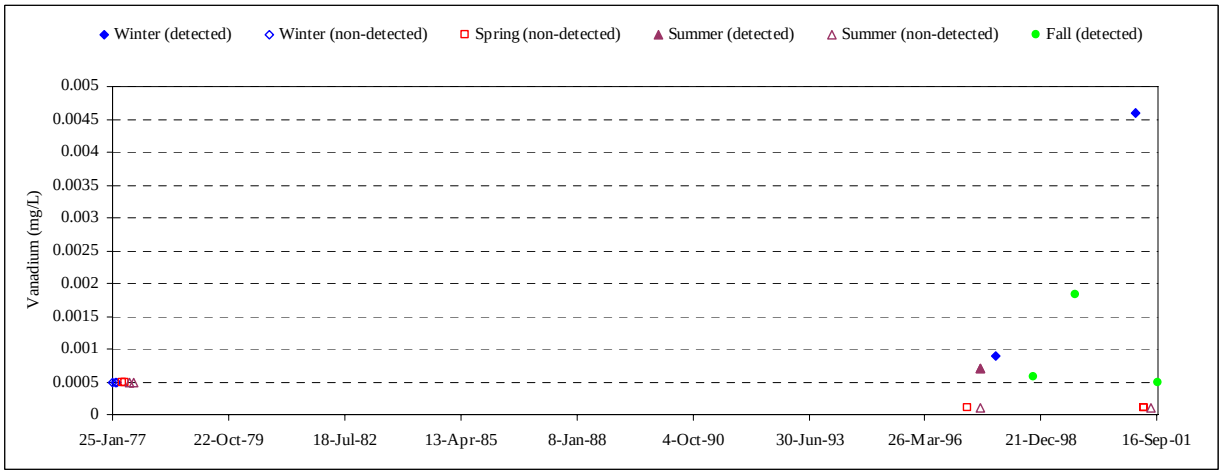
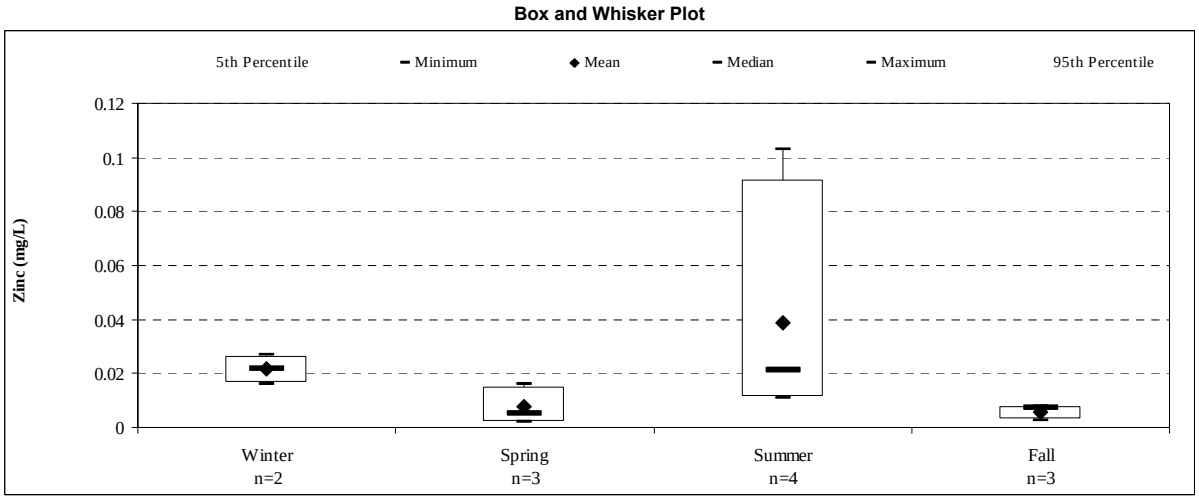


Figure G-2-5-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Shelley Creek



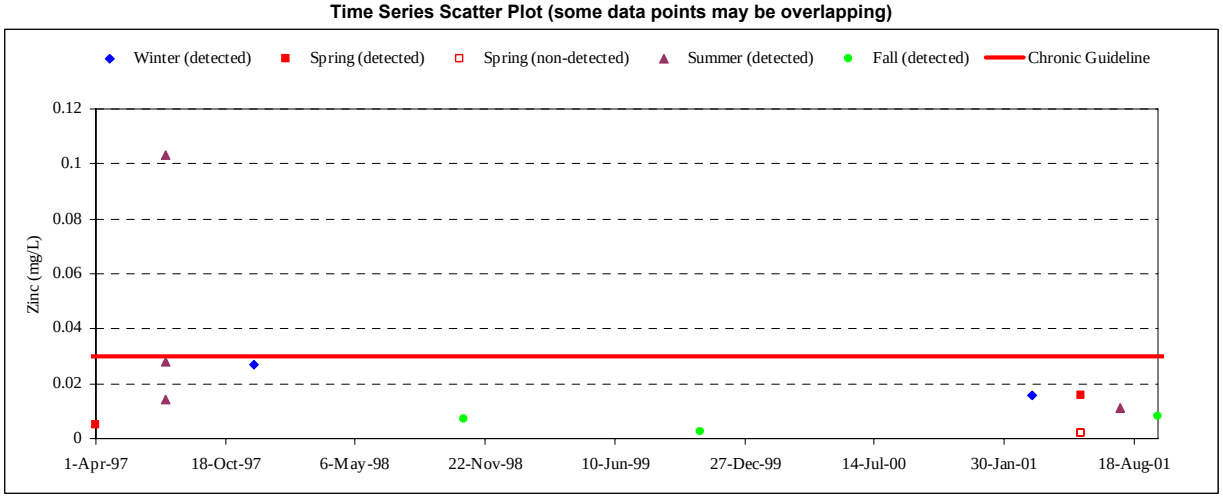
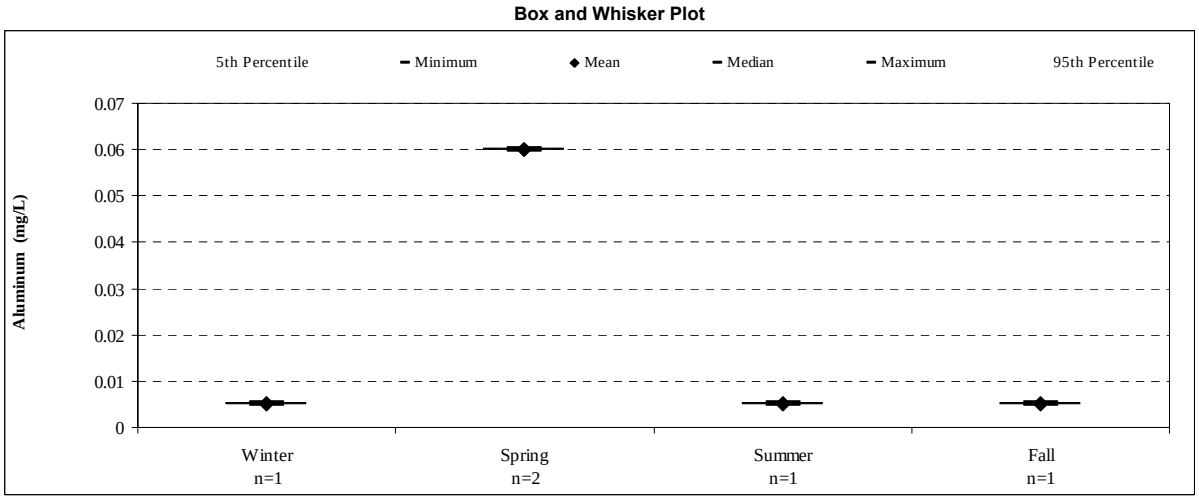


Figure G-2-5-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Shelley Creek



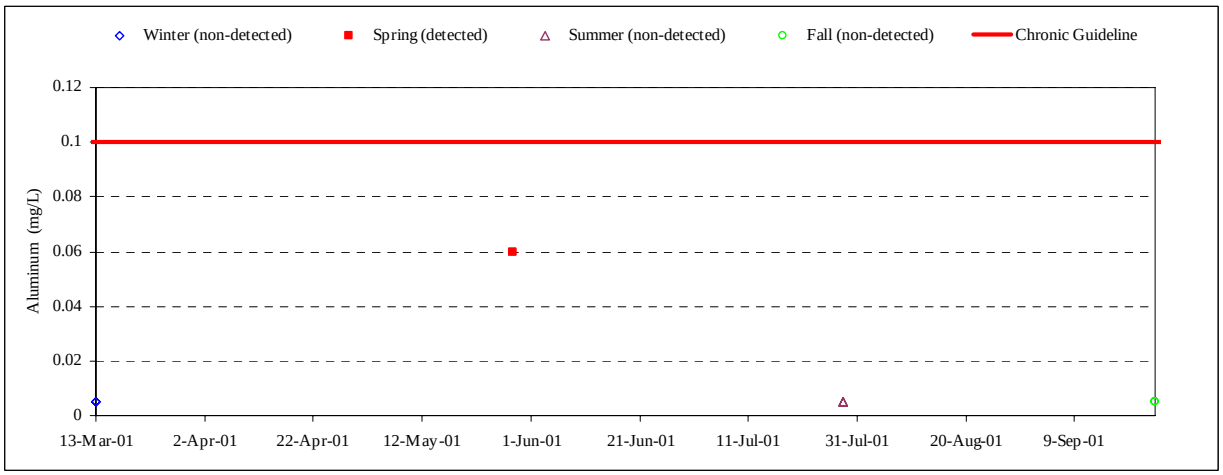
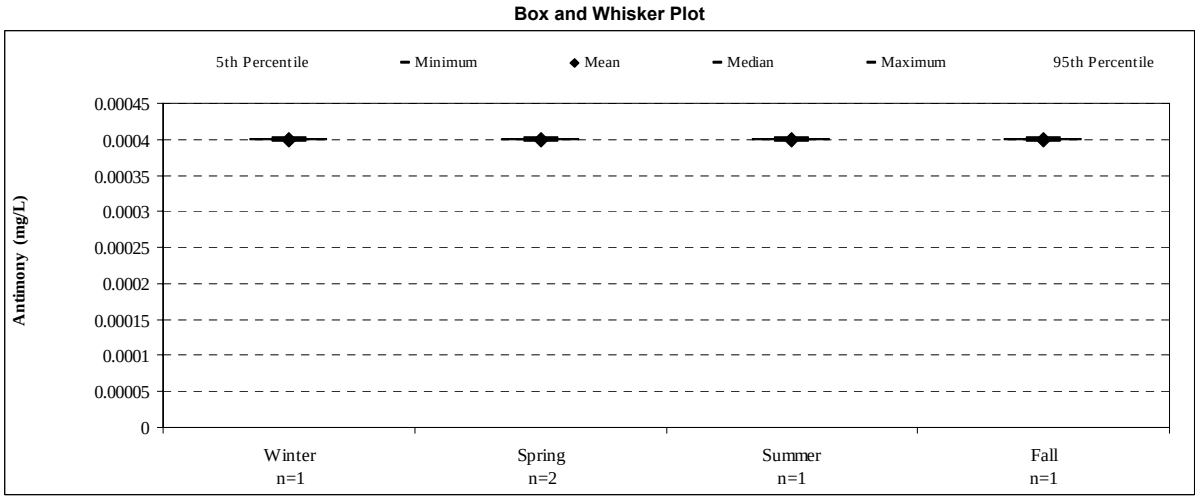


Figure G-2-5-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Shelley Creek



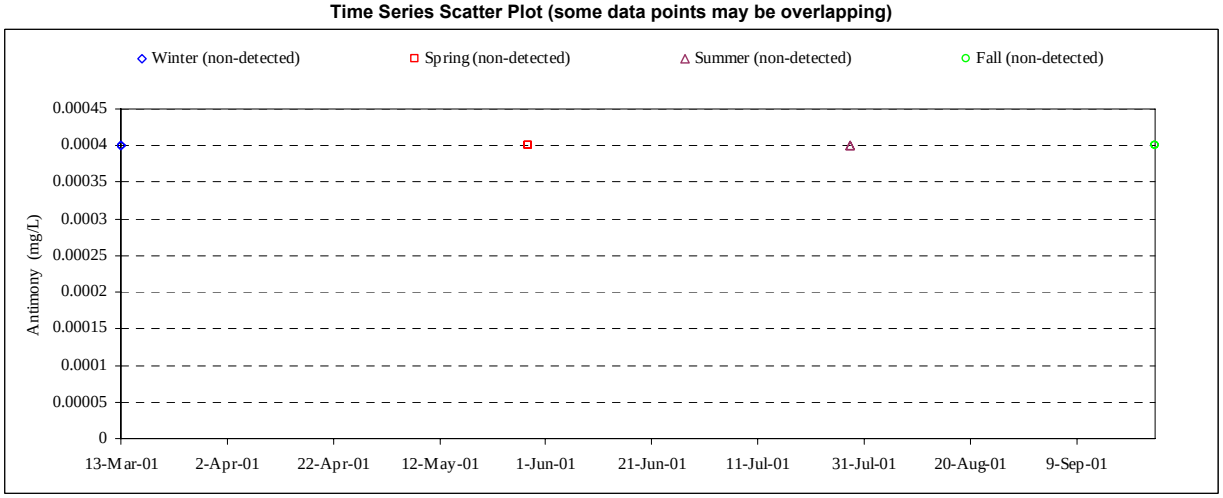
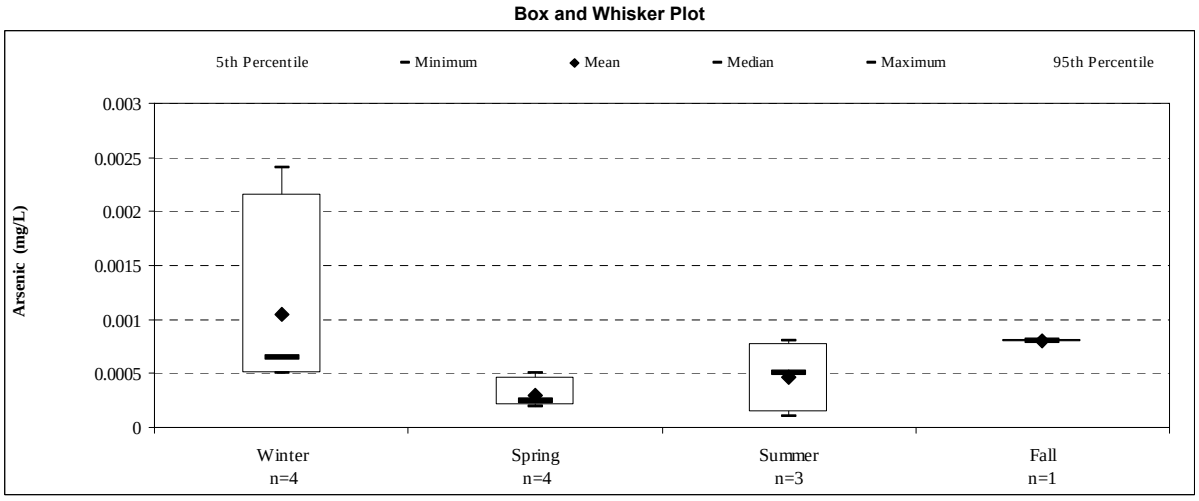


Figure G-2-5-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Shelley Creek



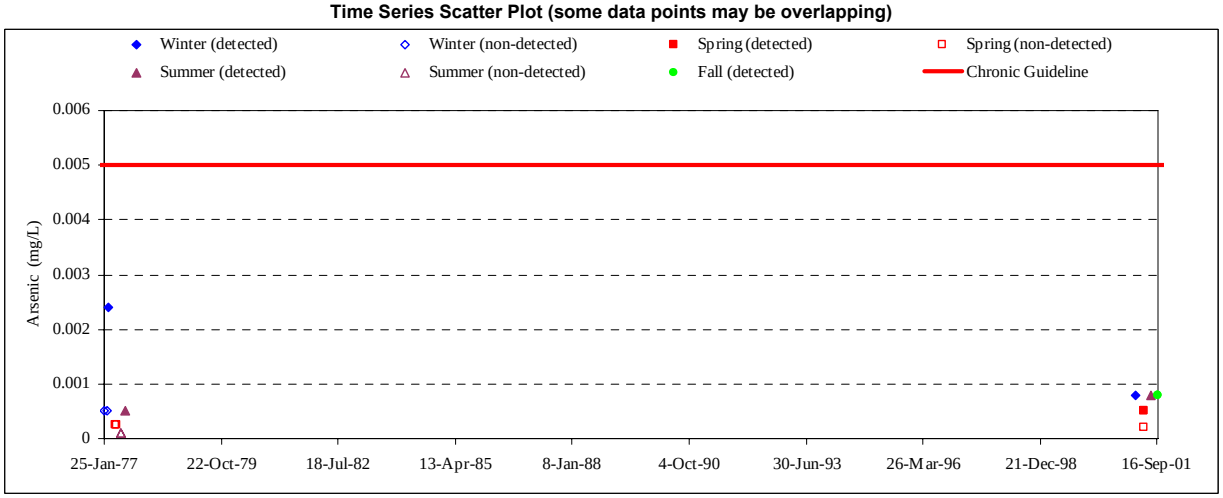
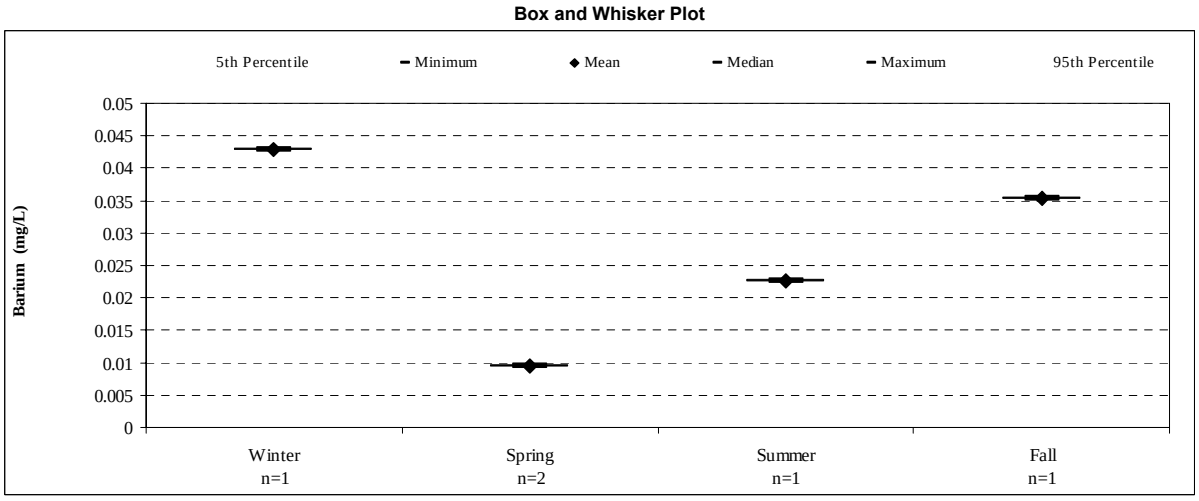


Figure G-2-5-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Shelley Creek



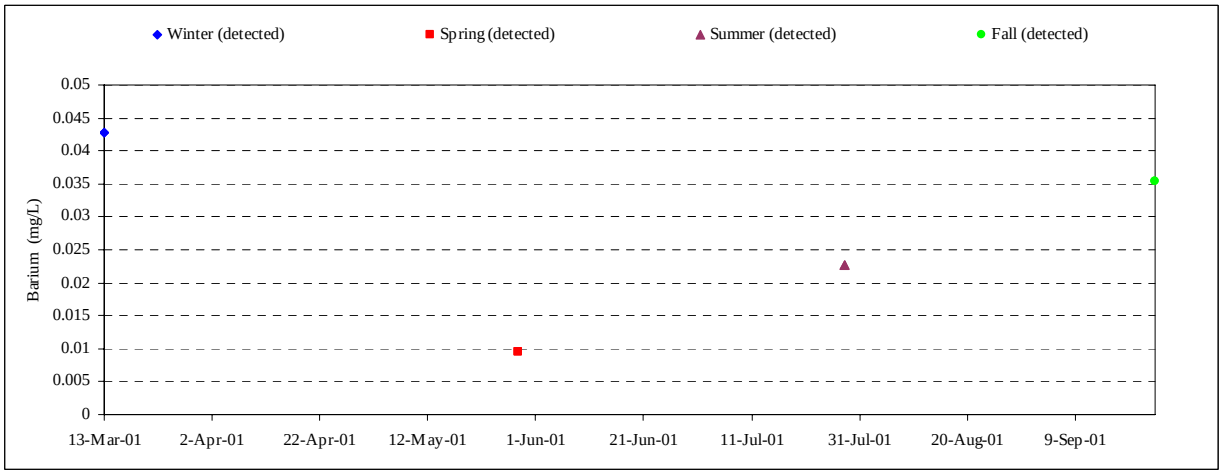
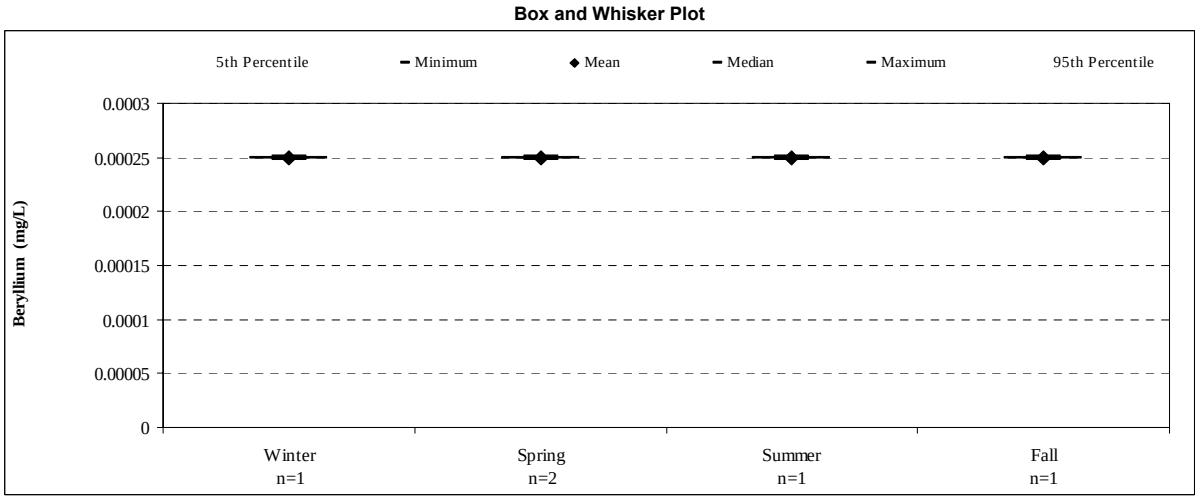


Figure G-2-5-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Shelley Creek



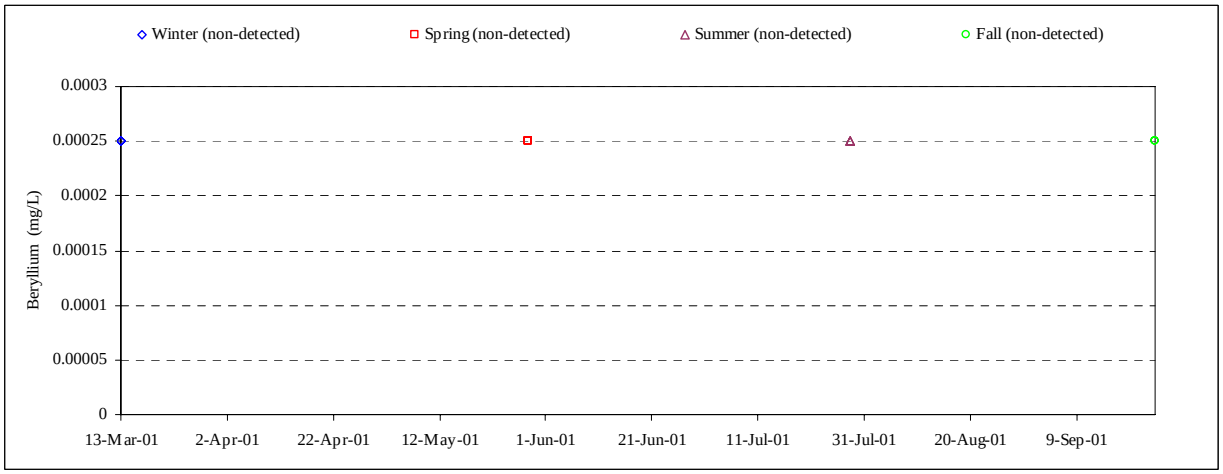
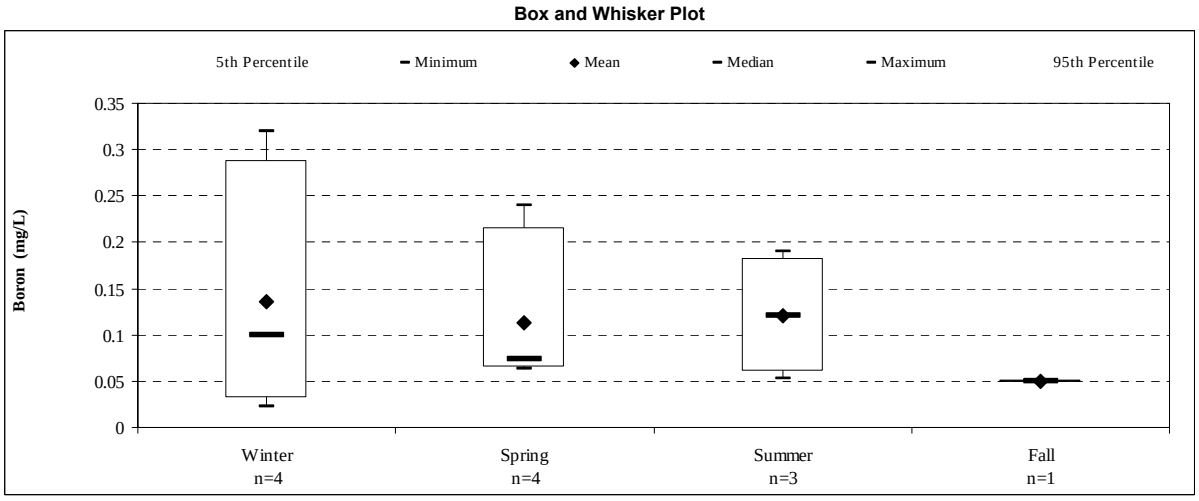


Figure G-2-5-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Shelley Creek



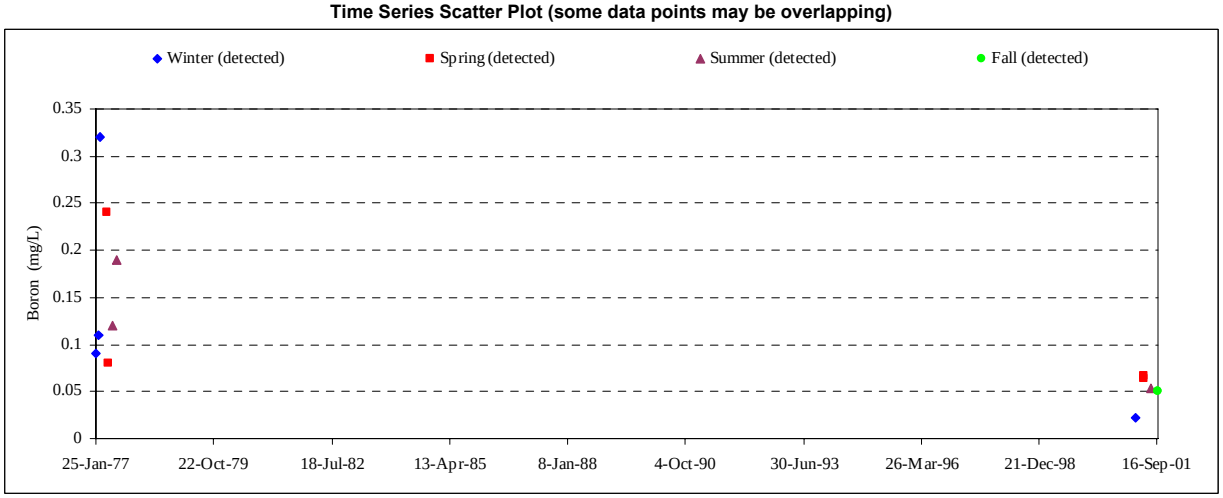
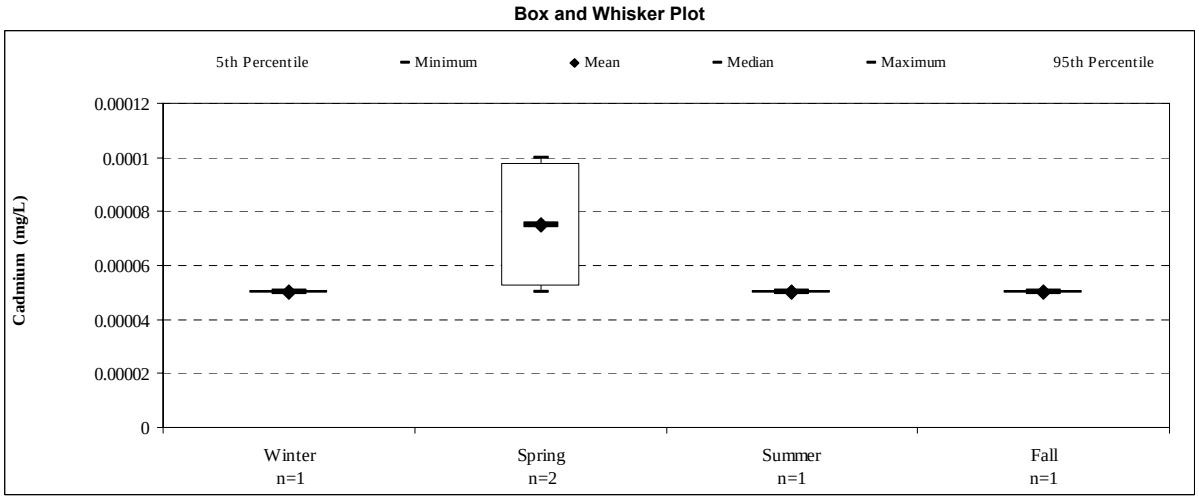


Figure G-2-5-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Shelley Creek



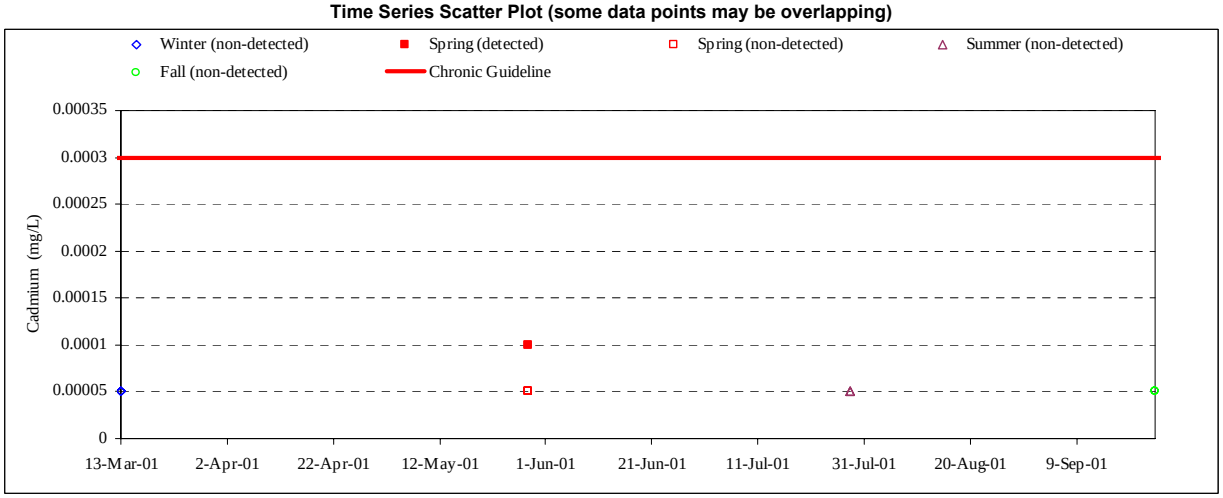
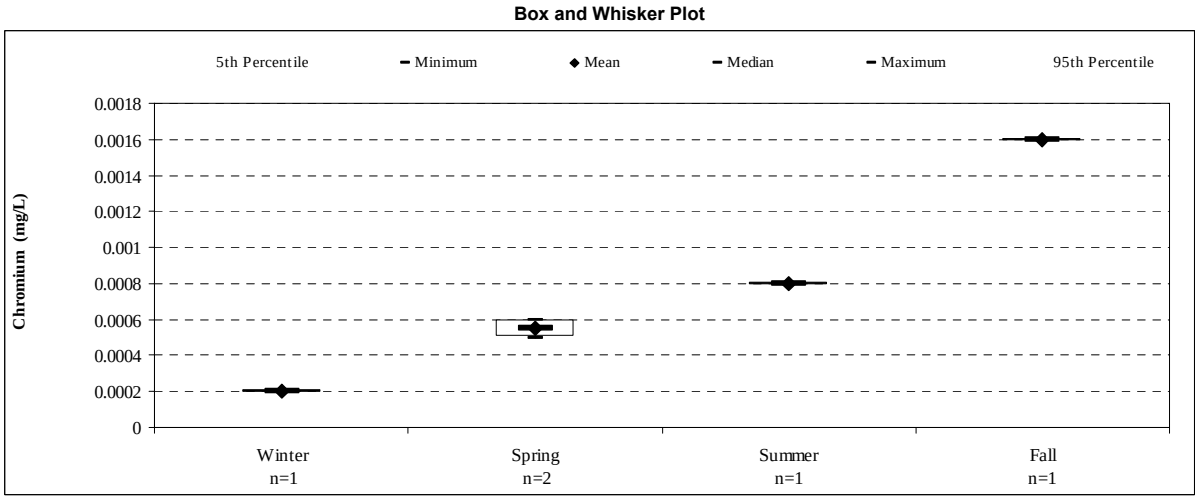


Figure G-2-5-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Shelley Creek



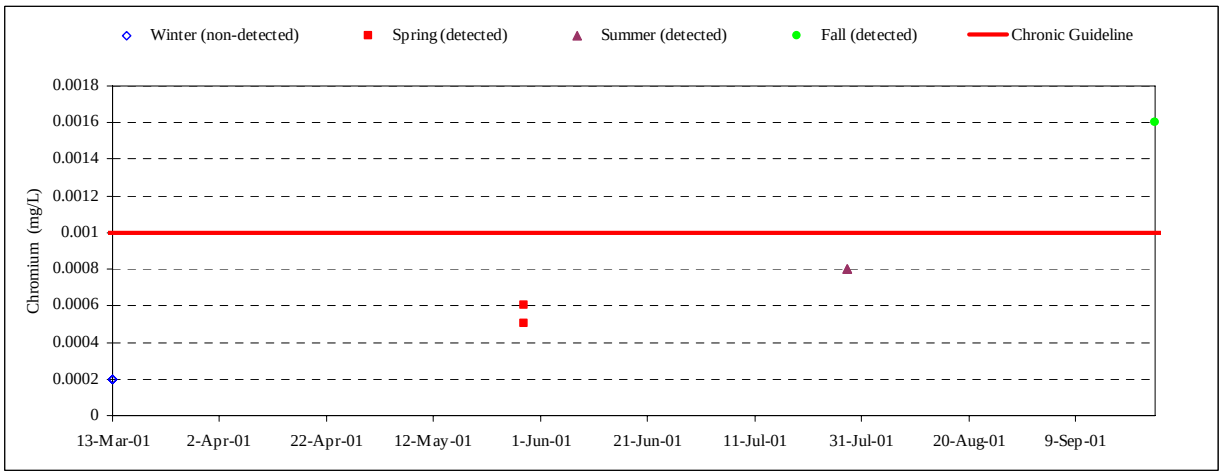
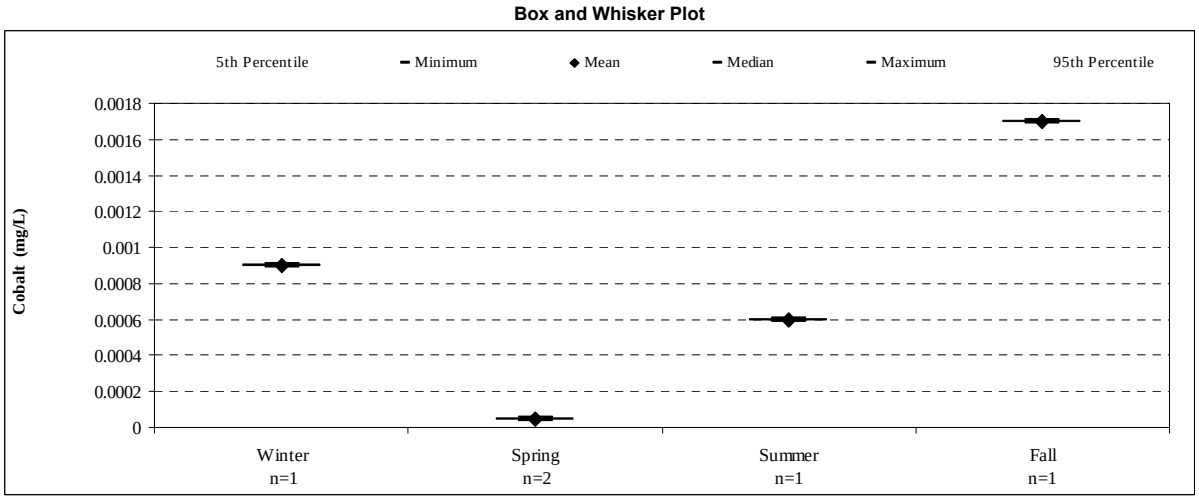


Figure G-2-5-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Shelley Creek



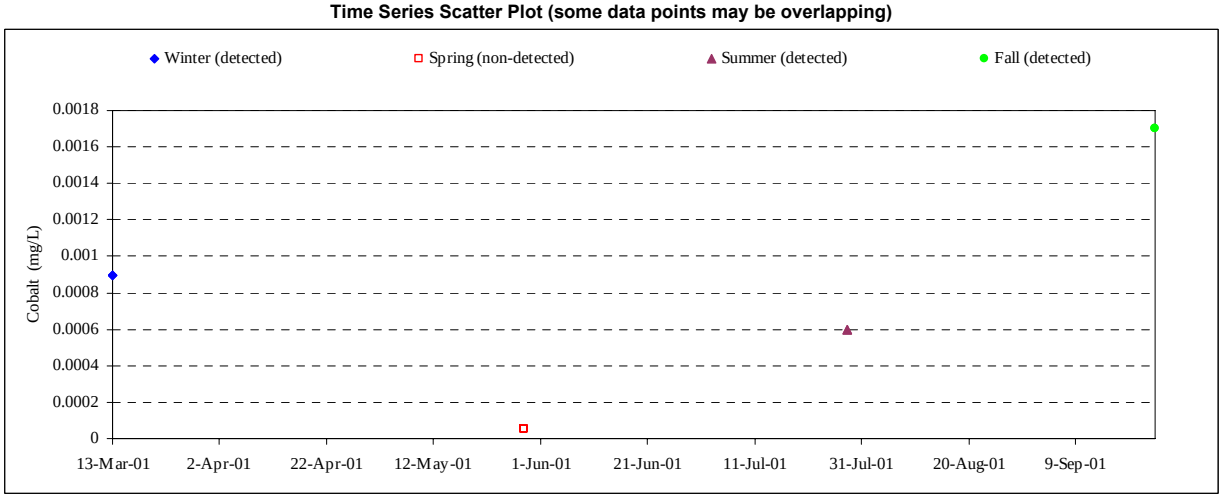
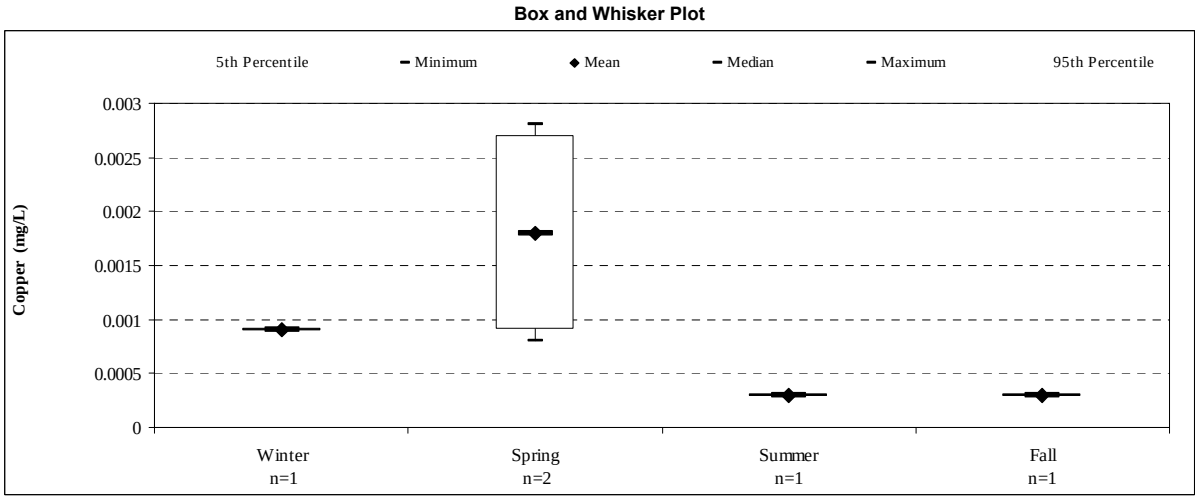


Figure G-2-5-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Shelley Creek



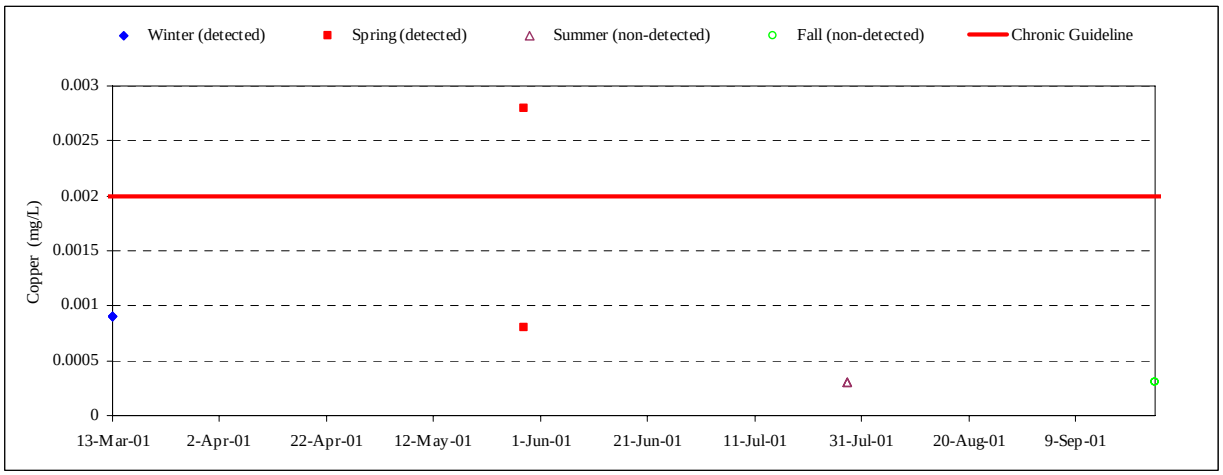
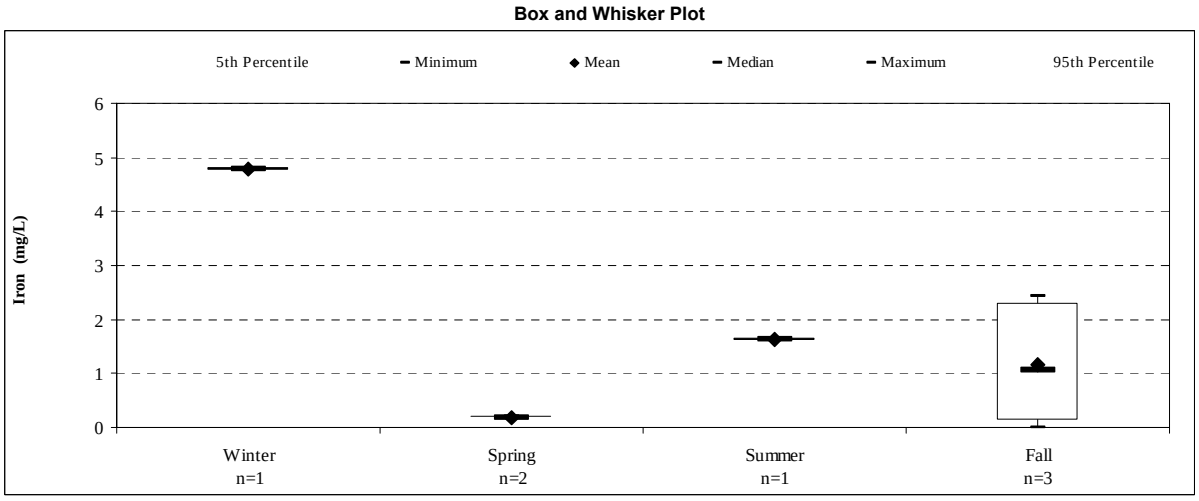


Figure G-2-5-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Shelley Creek



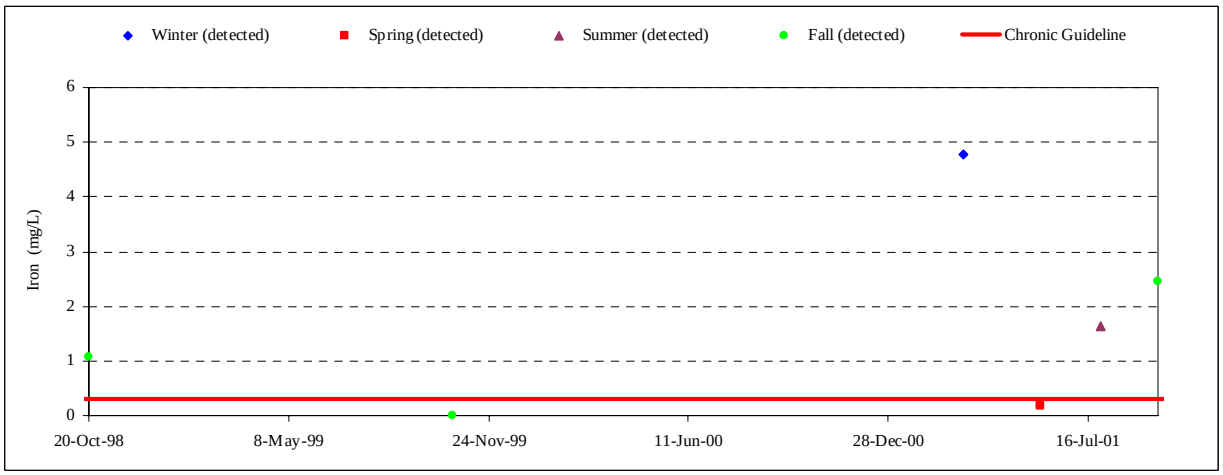
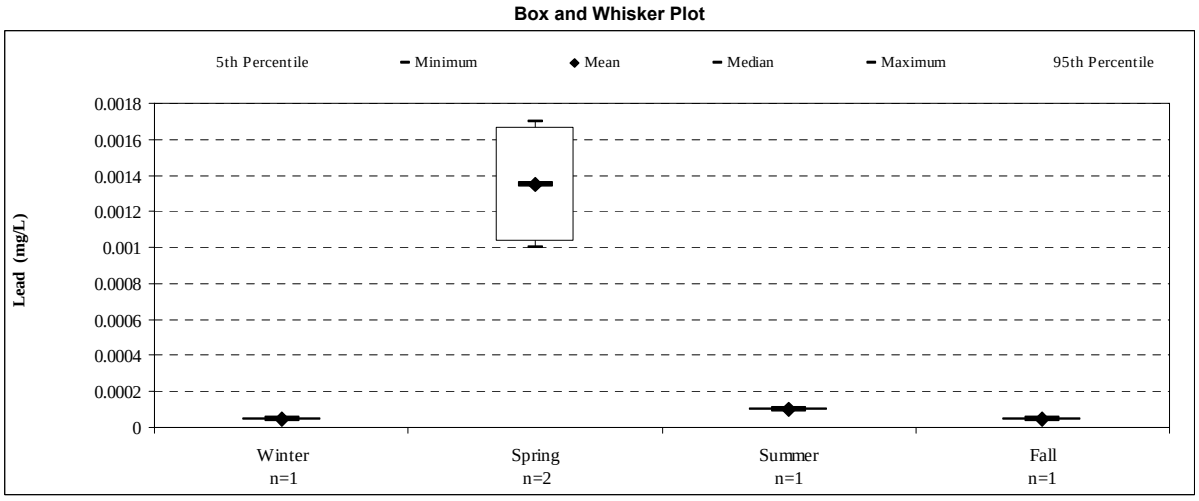


Figure G-2-5-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Shelley Creek



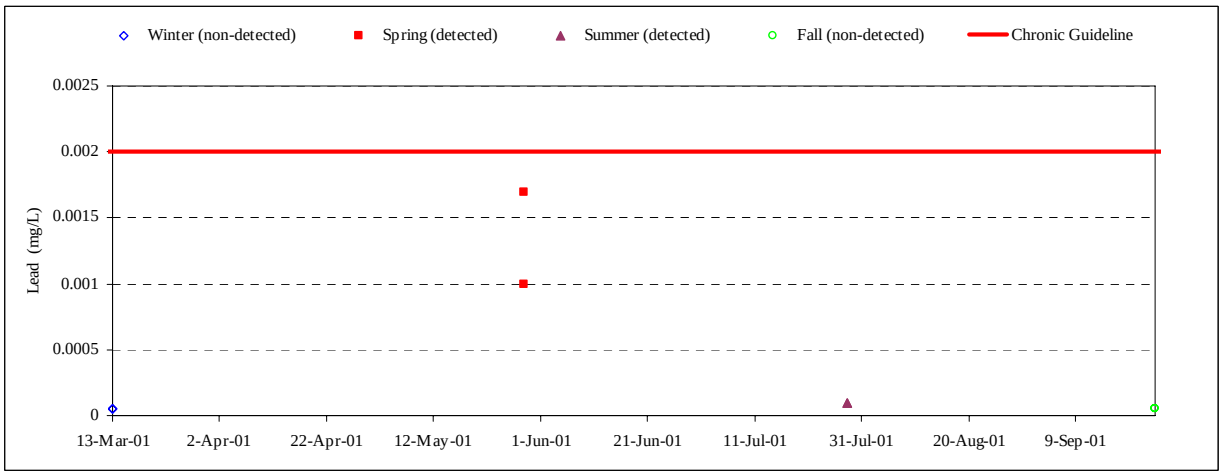
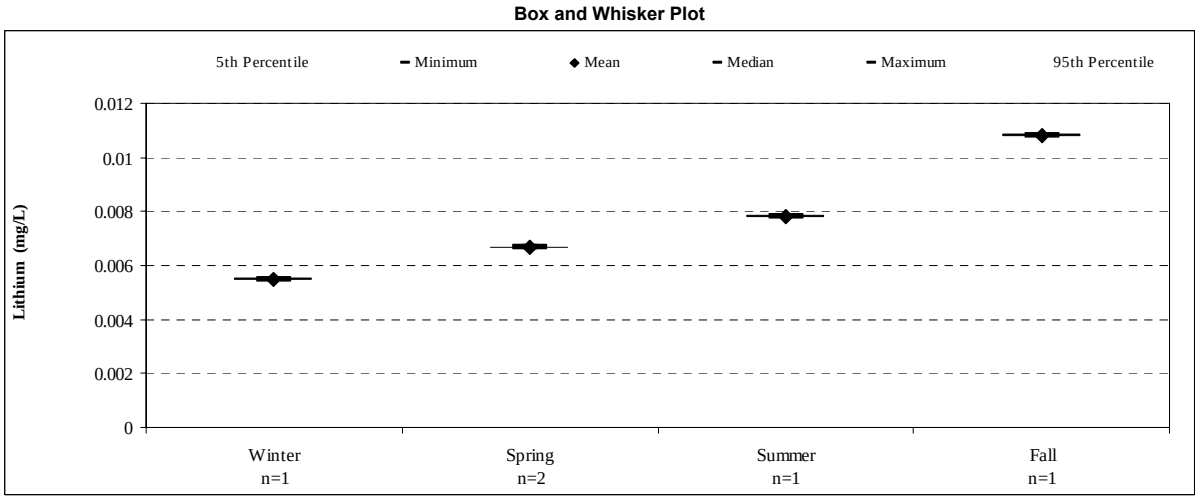


Figure G-2-5-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Shelley Creek



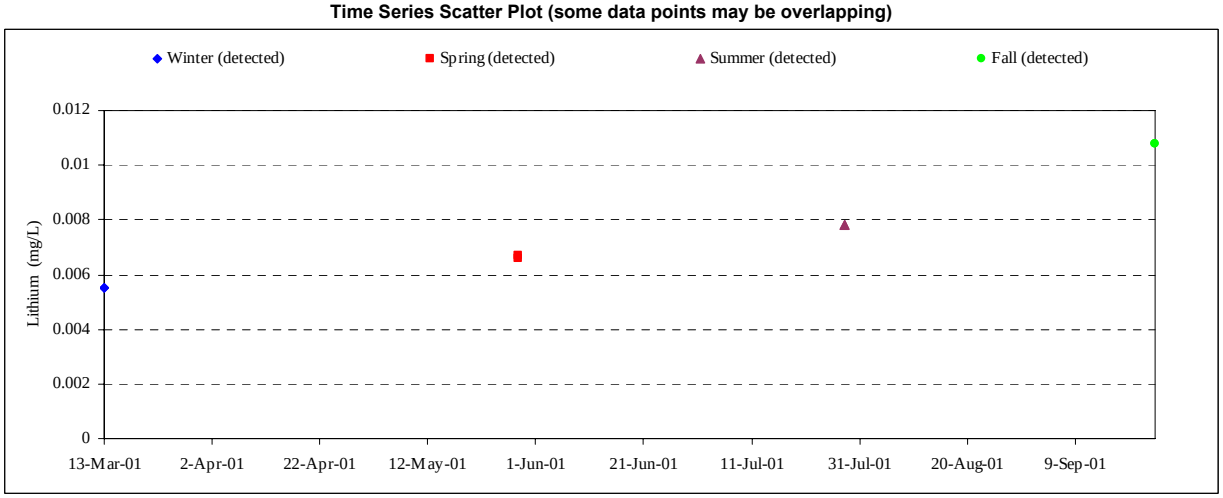
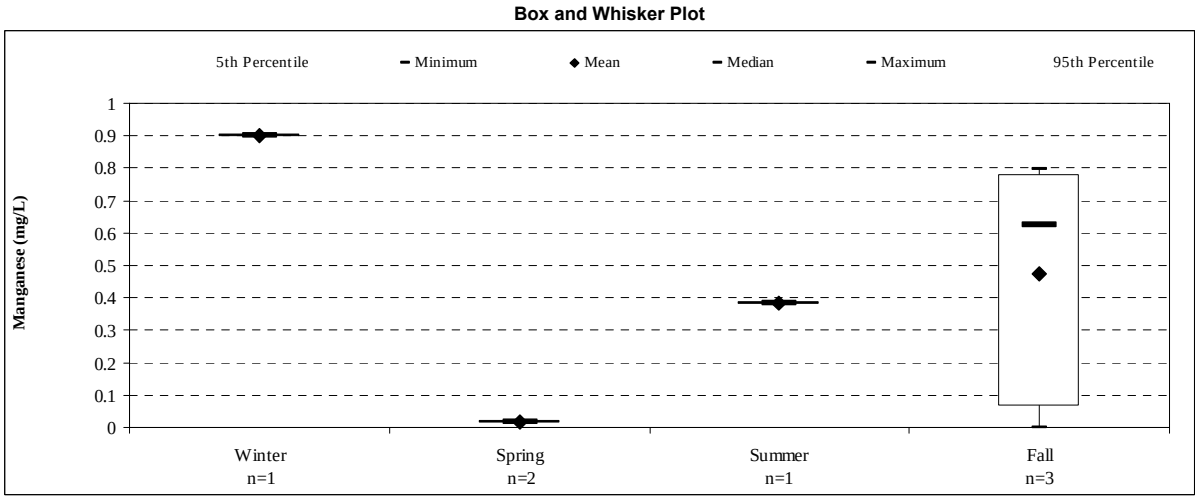


Figure G-2-5-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Shelley Creek



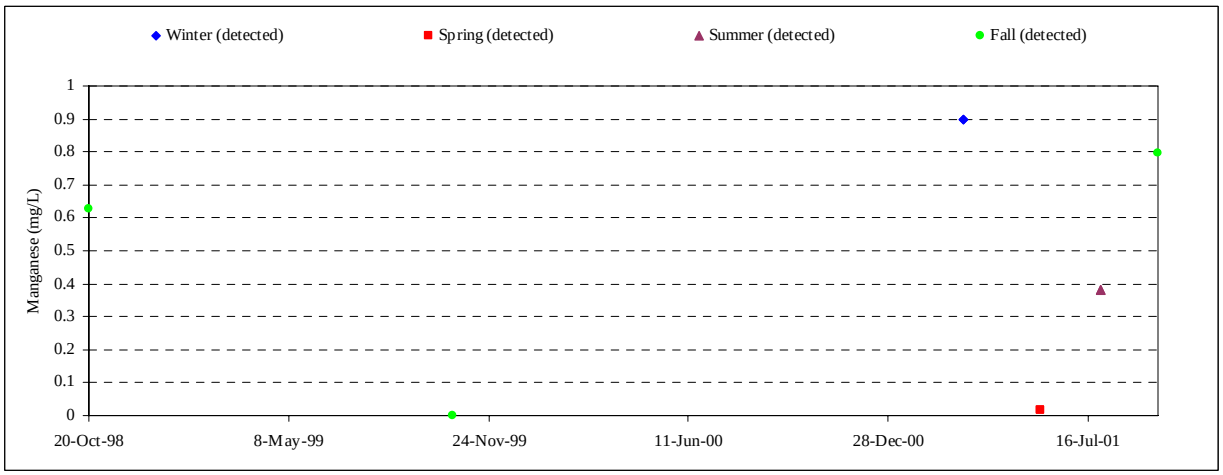
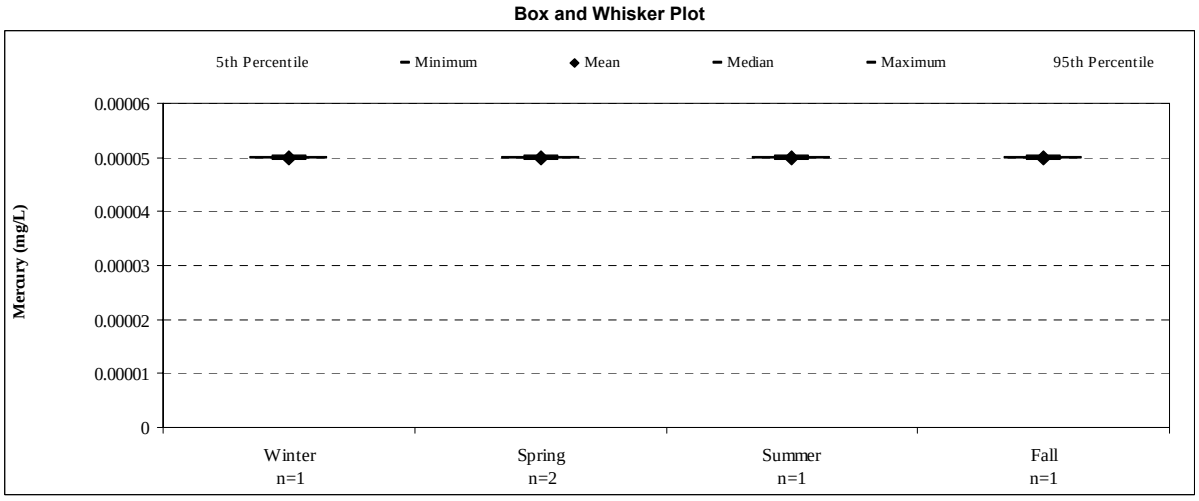


Figure G-2-5-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Shelley Creek



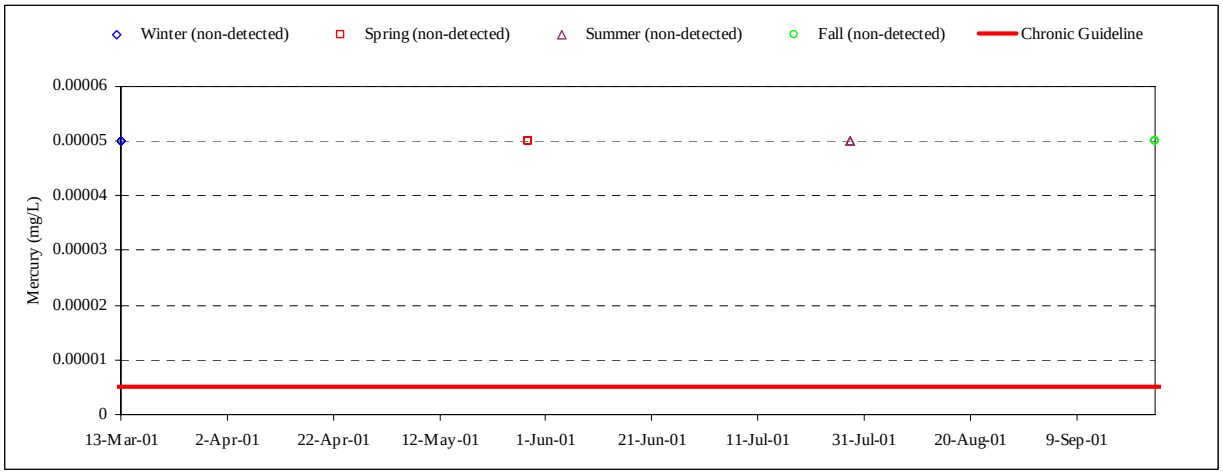
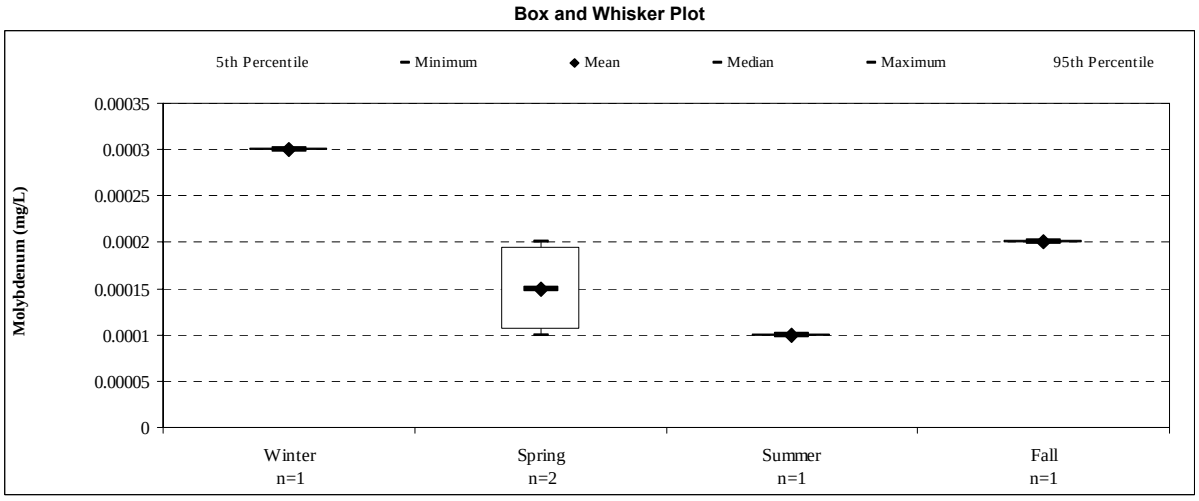


Figure G-2-5-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Shelley Creek



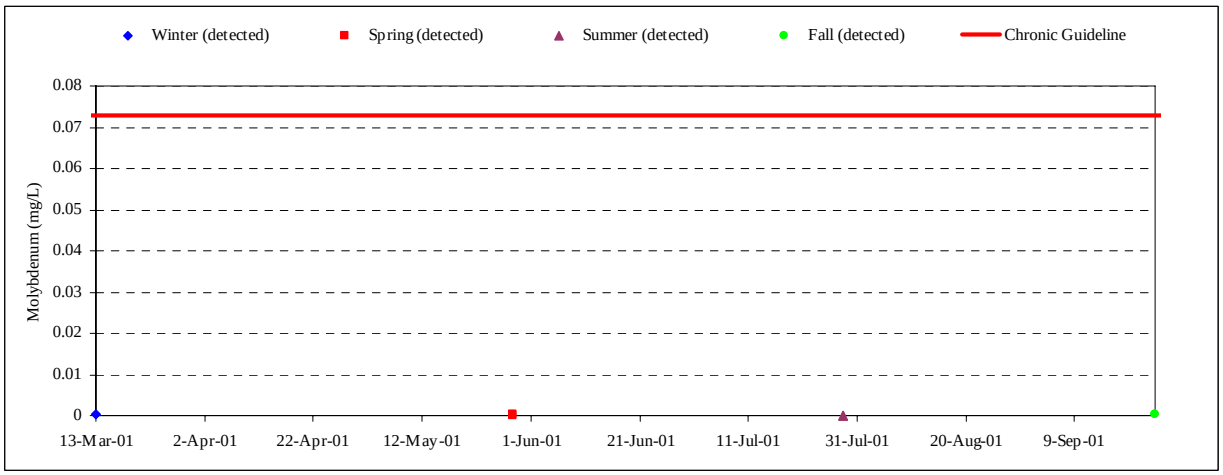
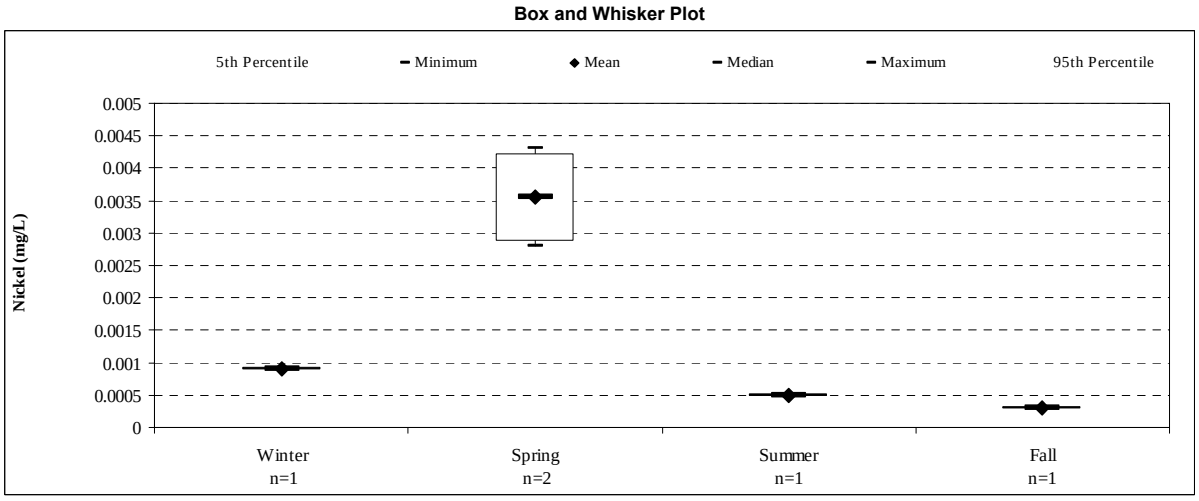


Figure G-2-5-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Shelley Creek



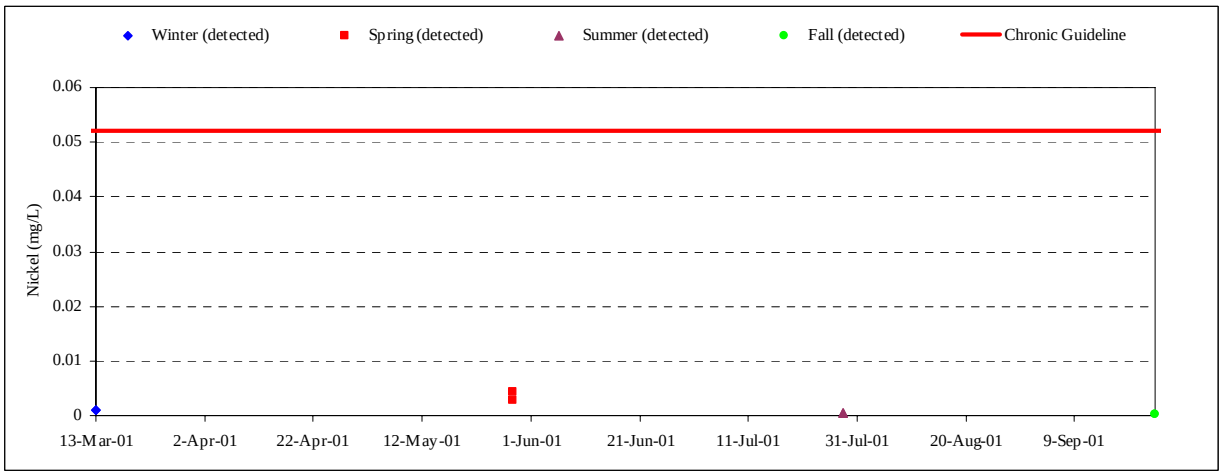
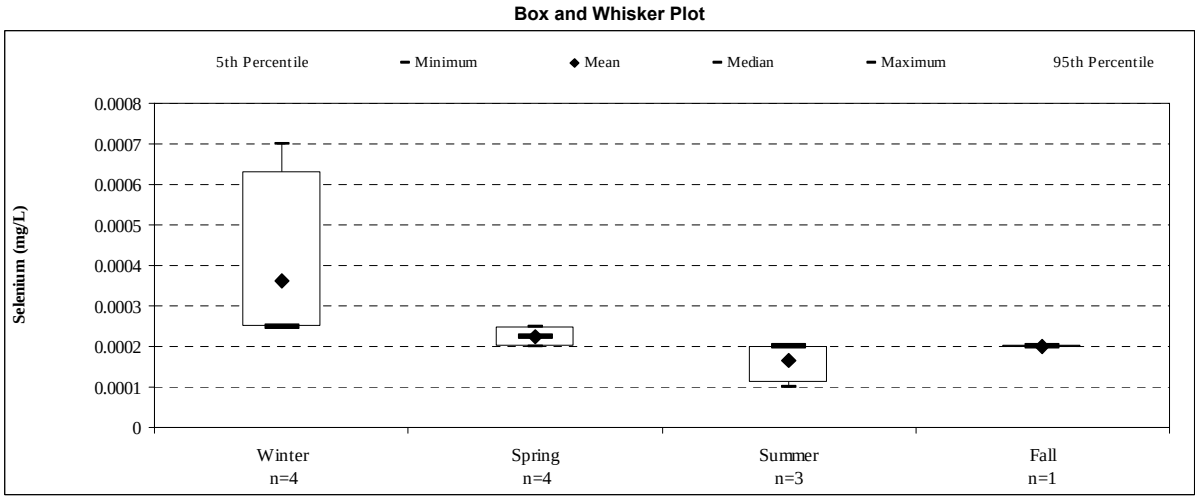


Figure G-2-5-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Shelley Creek



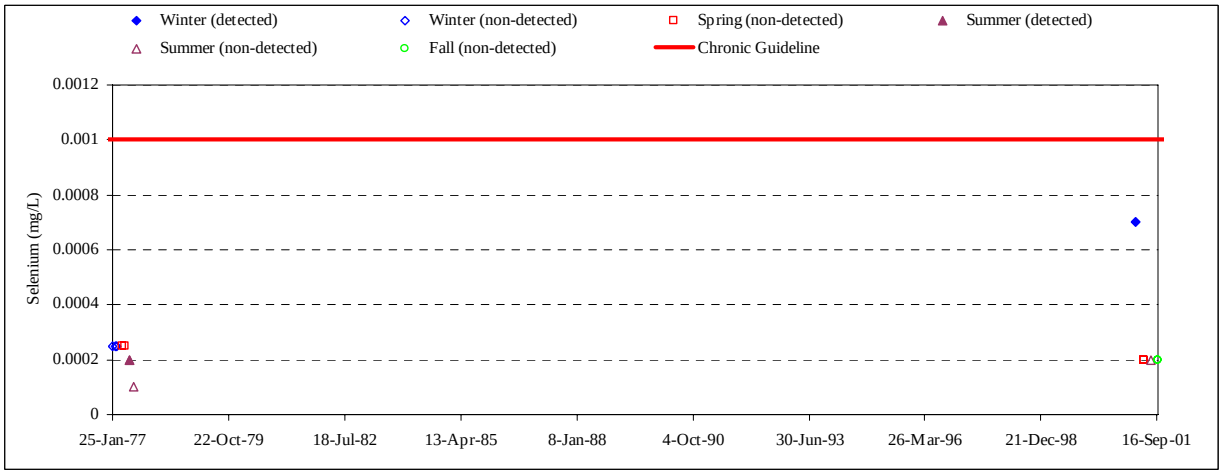
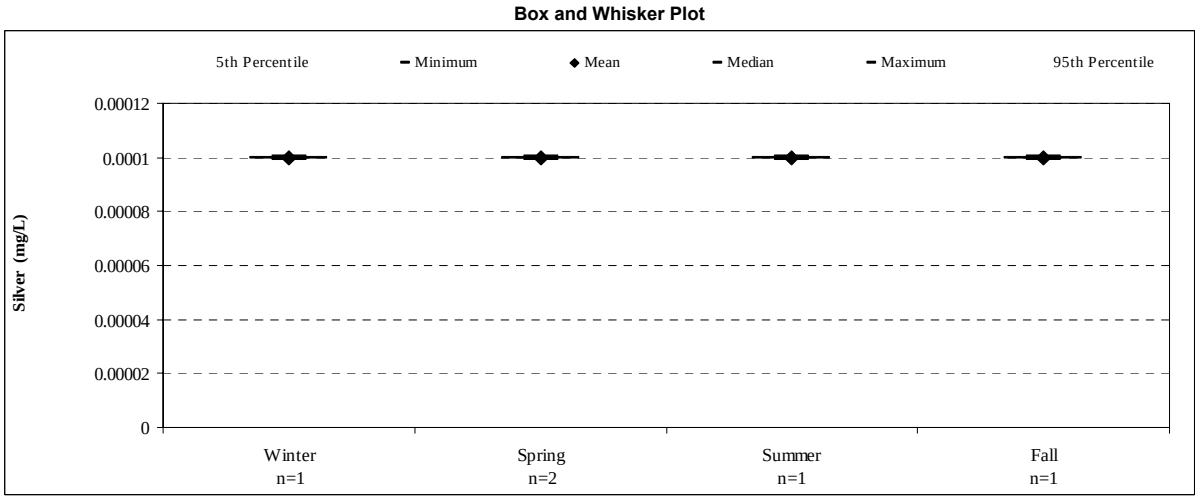


Figure G-2-5-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Shelley Creek



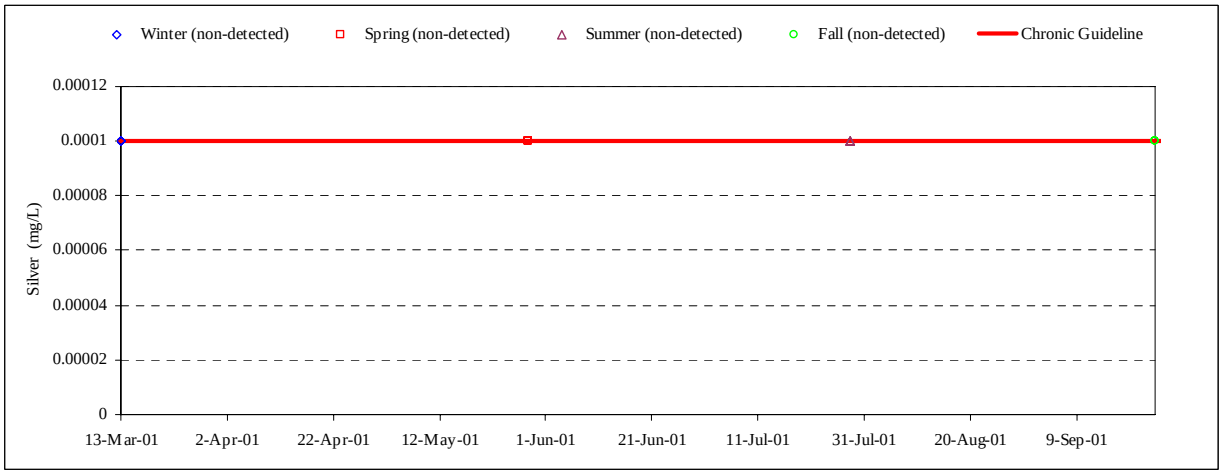
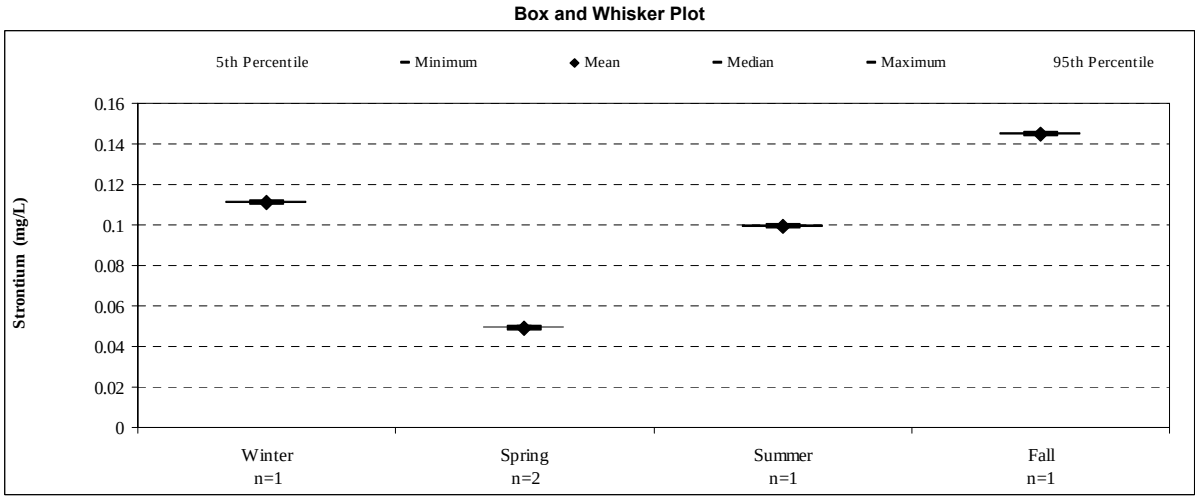


Figure G-2-5-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Shelley Creek



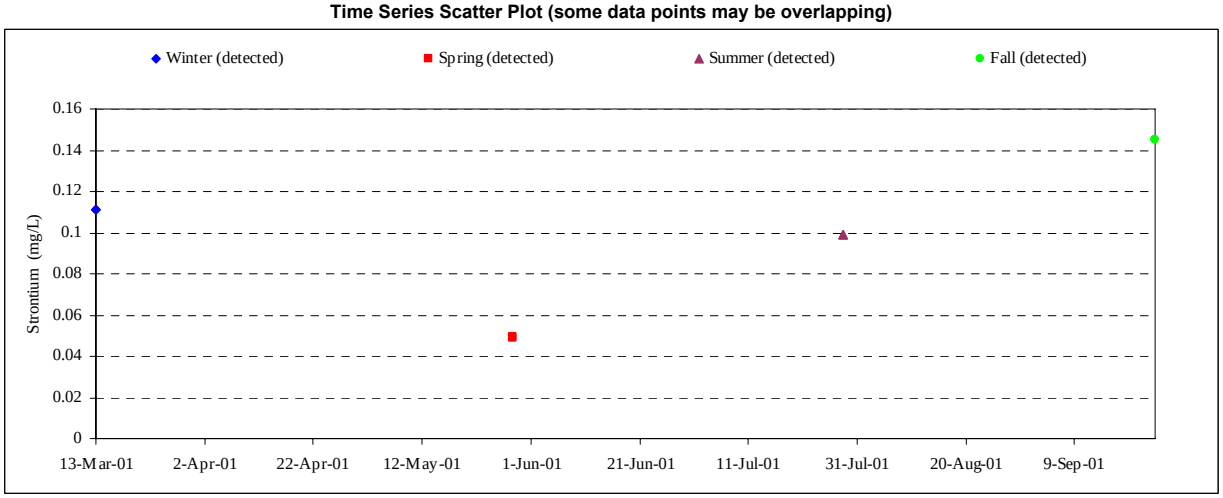
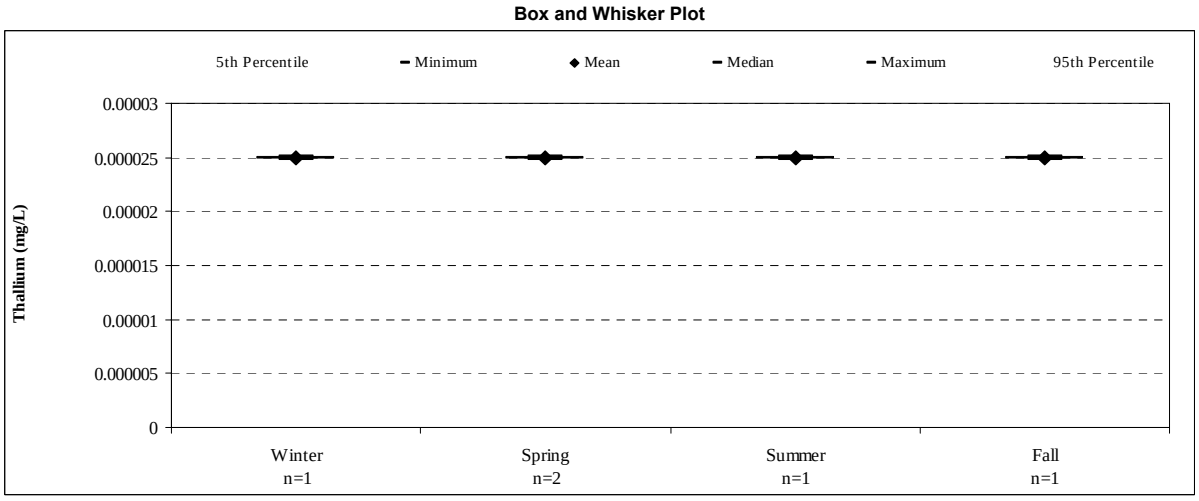


Figure G-2-5-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Shelley Creek



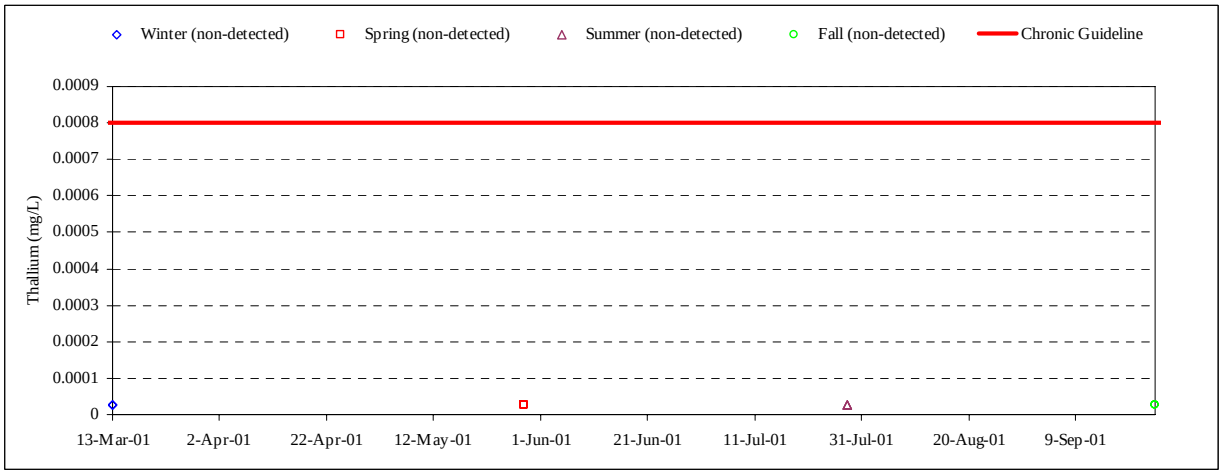
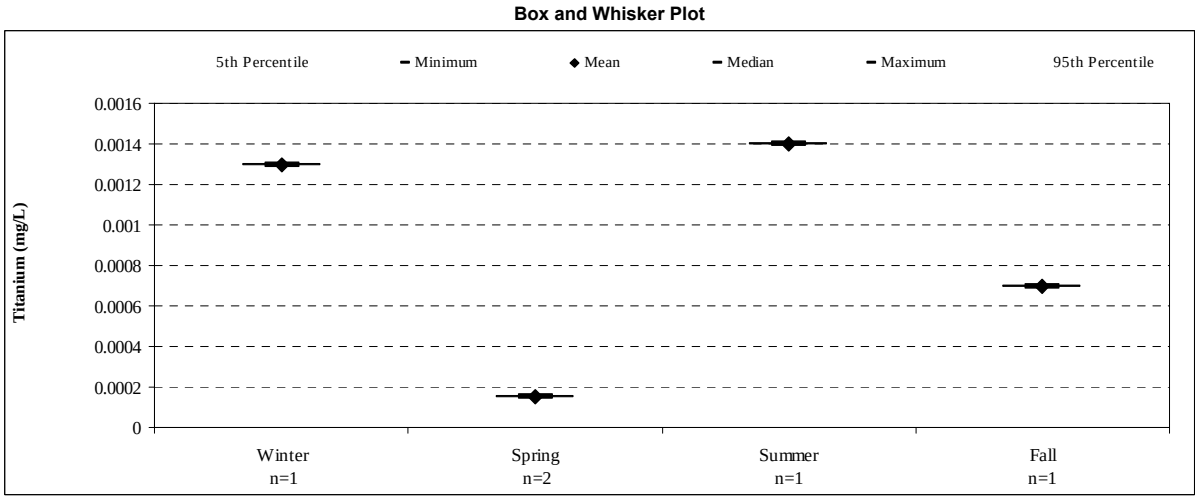


Figure G-2-5-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Shelley Creek



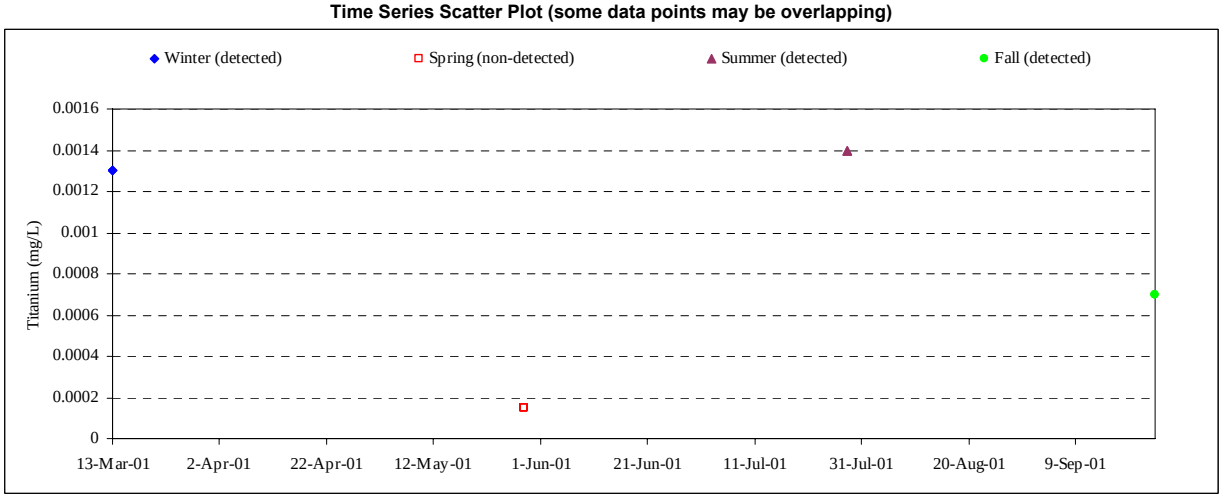
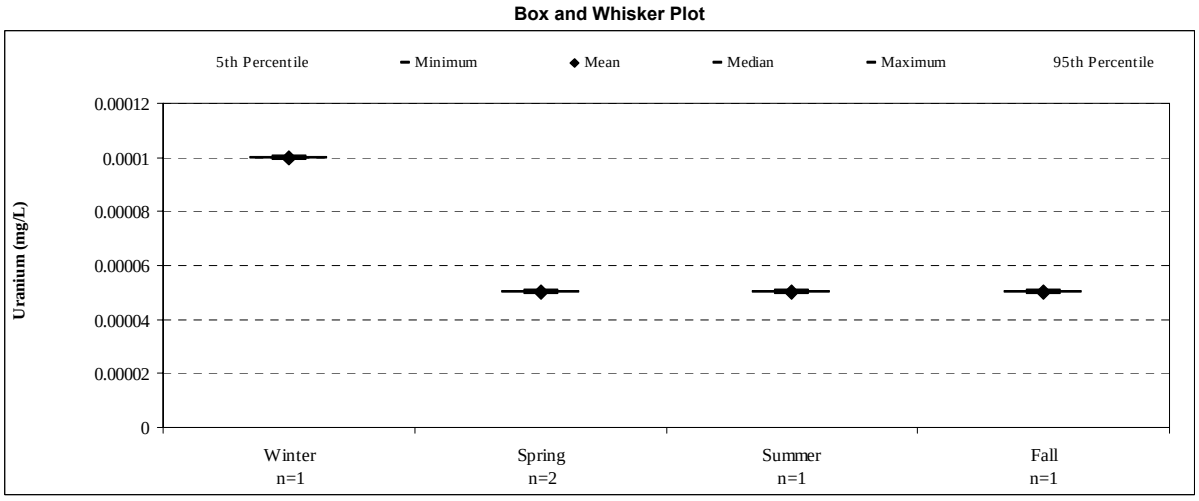


Figure G-2-5-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Shelley Creek



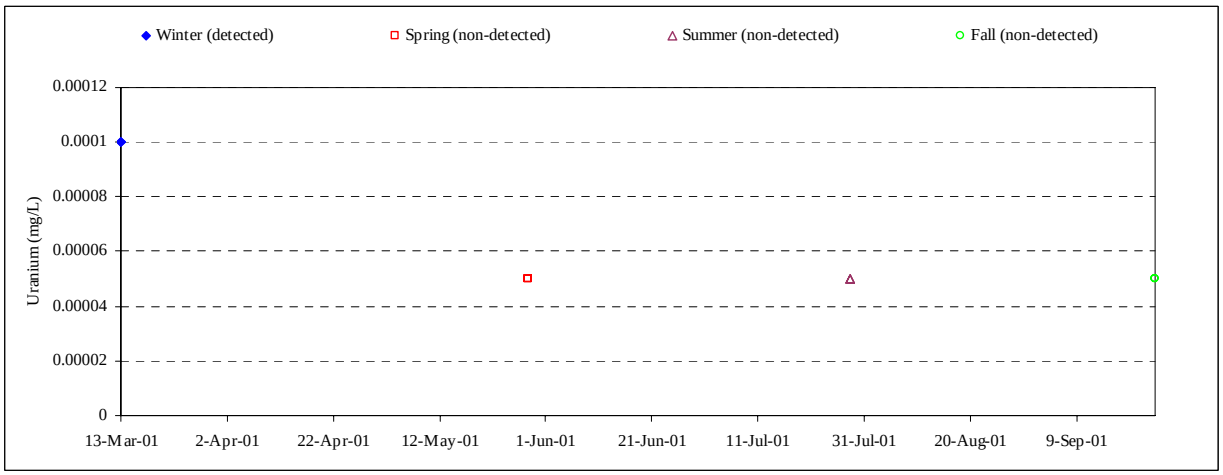
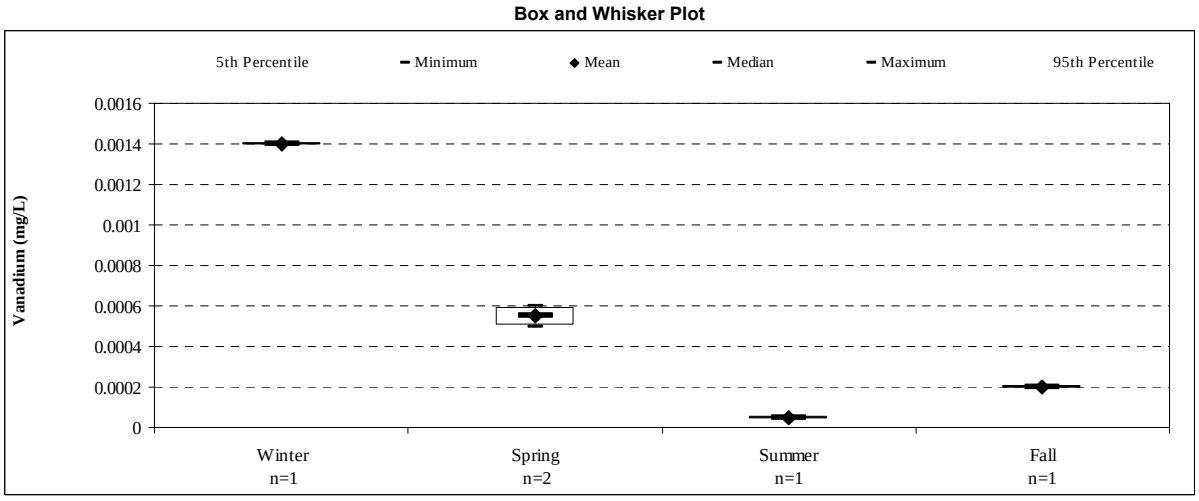


Figure G-2-5-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Shelley Creek



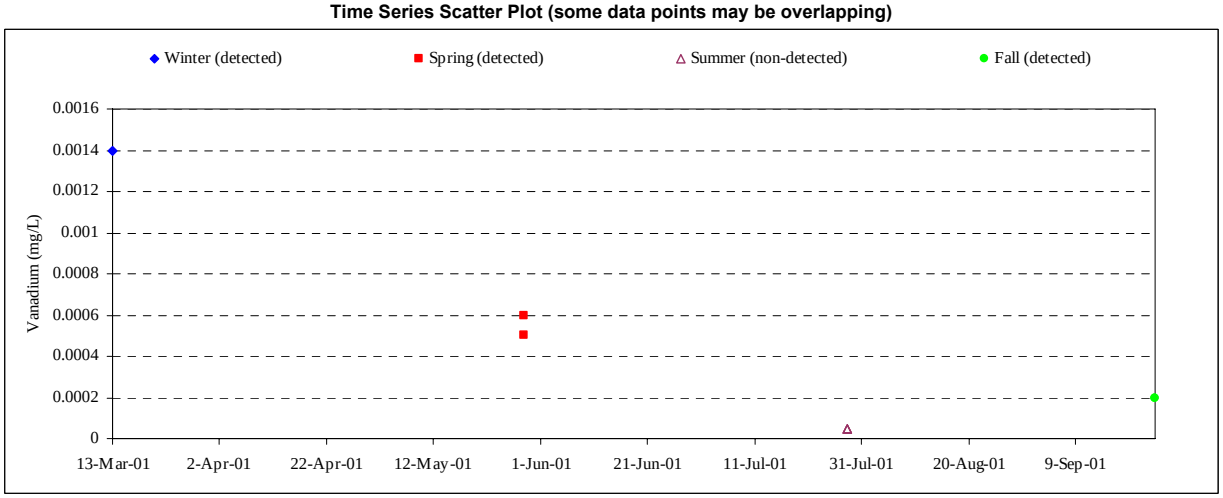
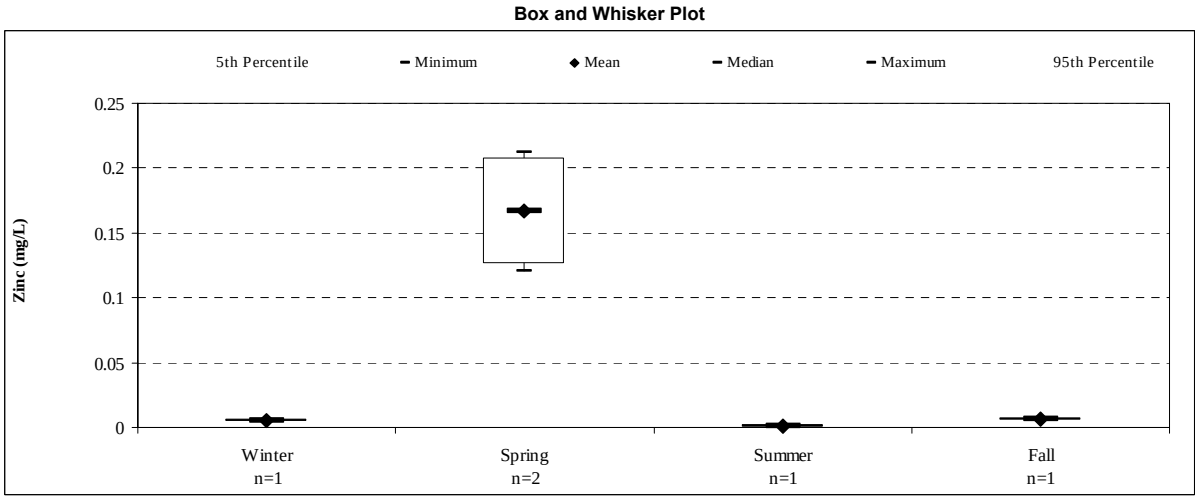


Figure G-2-5-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Shelley Creek



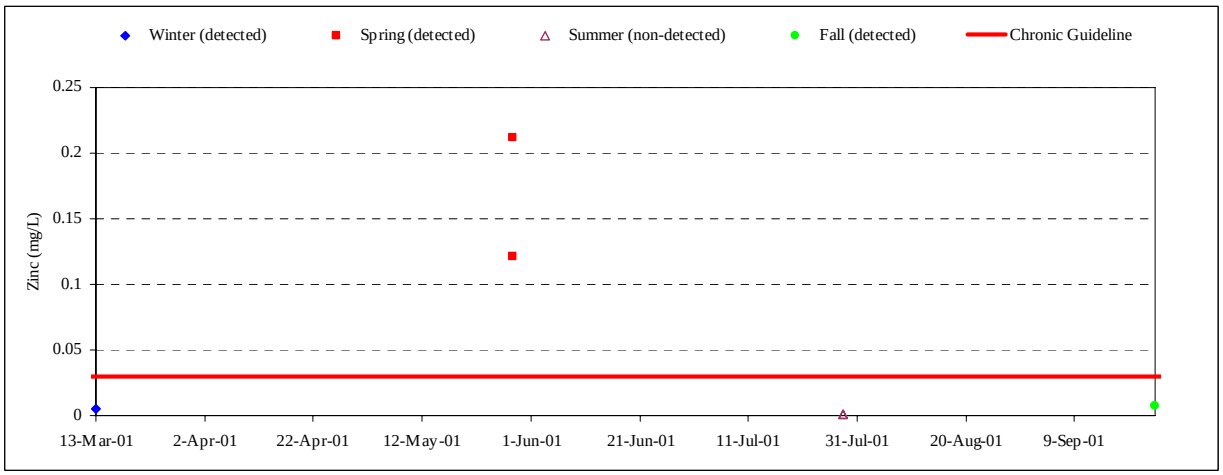
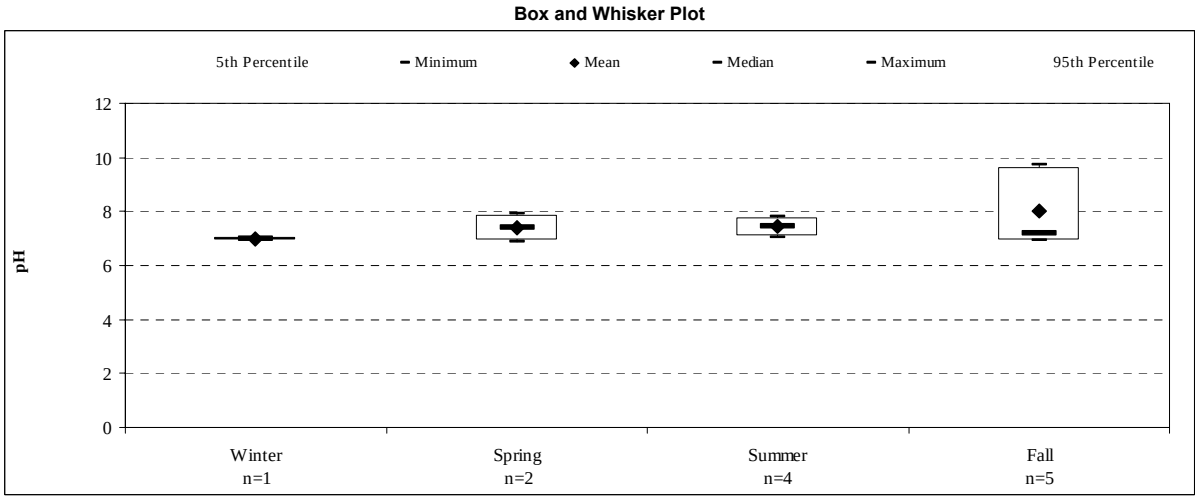


Figure G-2-6-1 Box Whisker and Time Series Scatter Plots of Observed pH in Stanley Creek



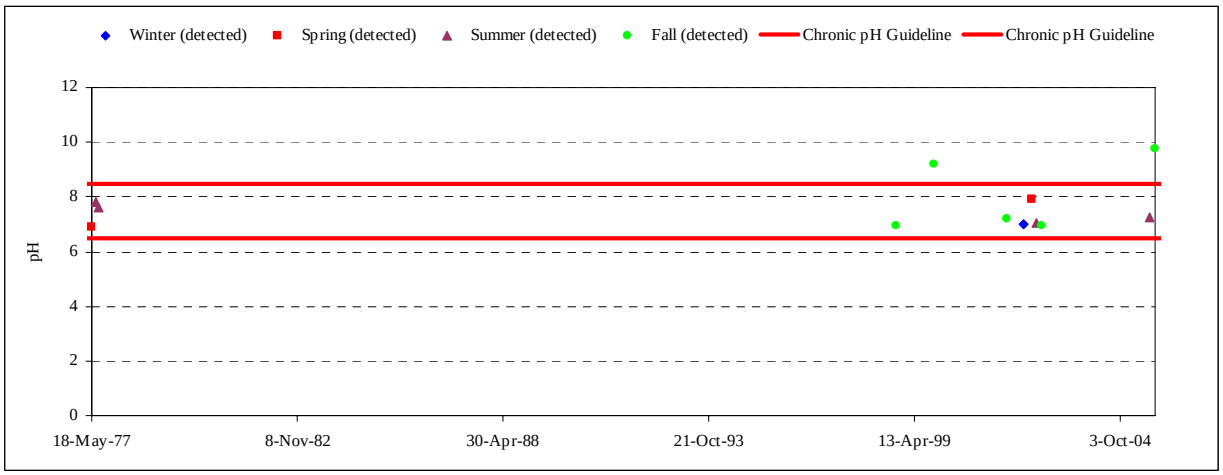
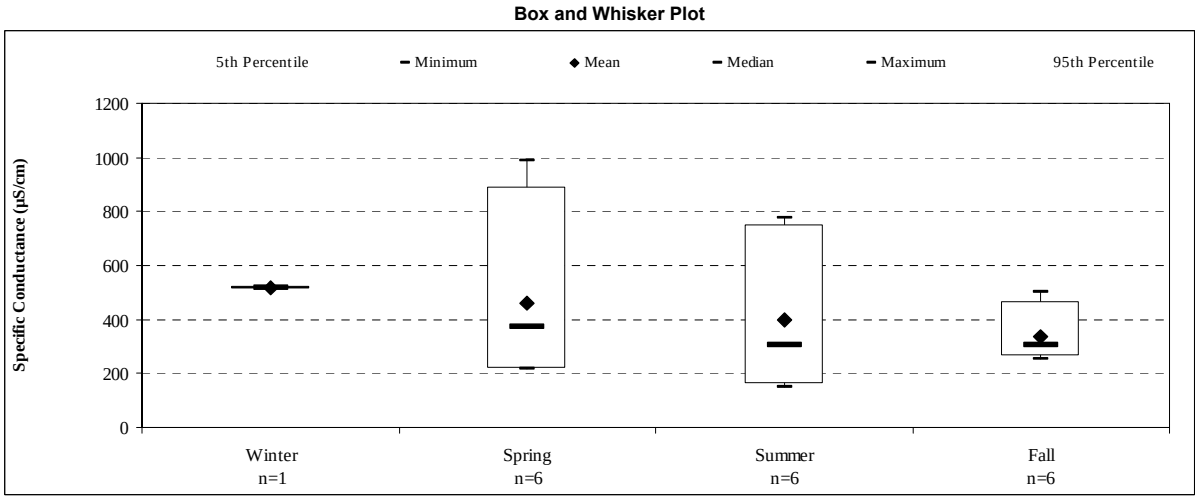


Figure G-2-6-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Stanley Creek



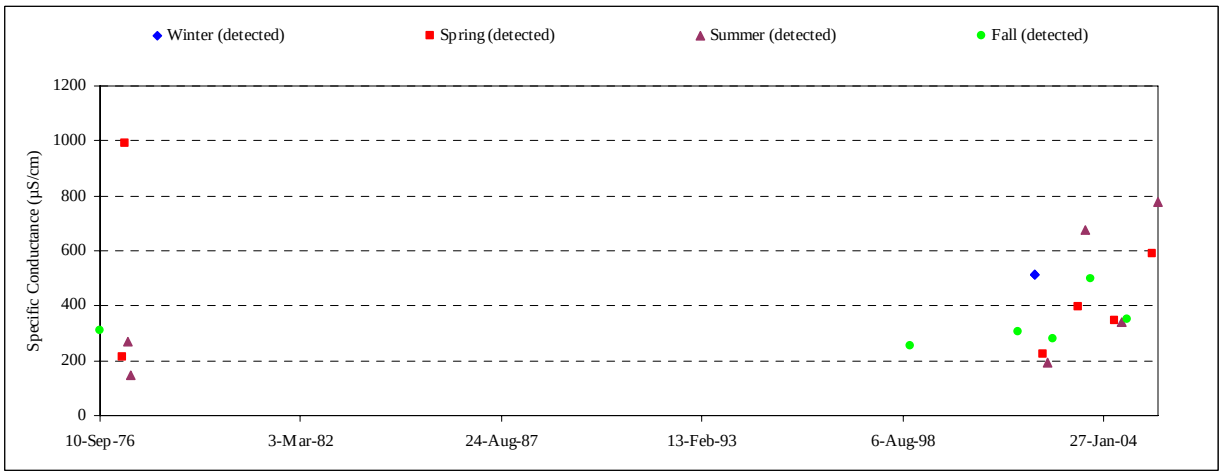
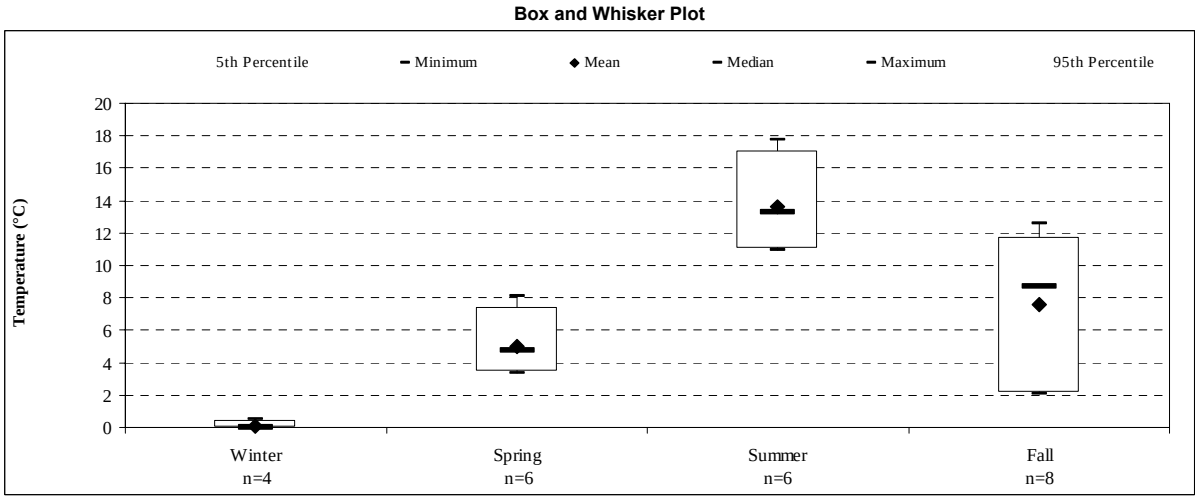


Figure G-2-6-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Stanley Creek



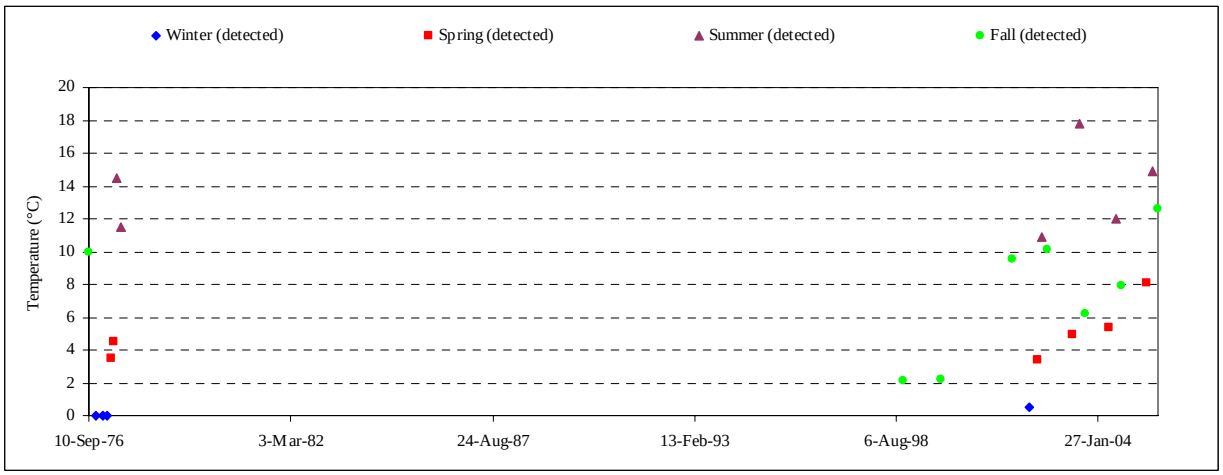
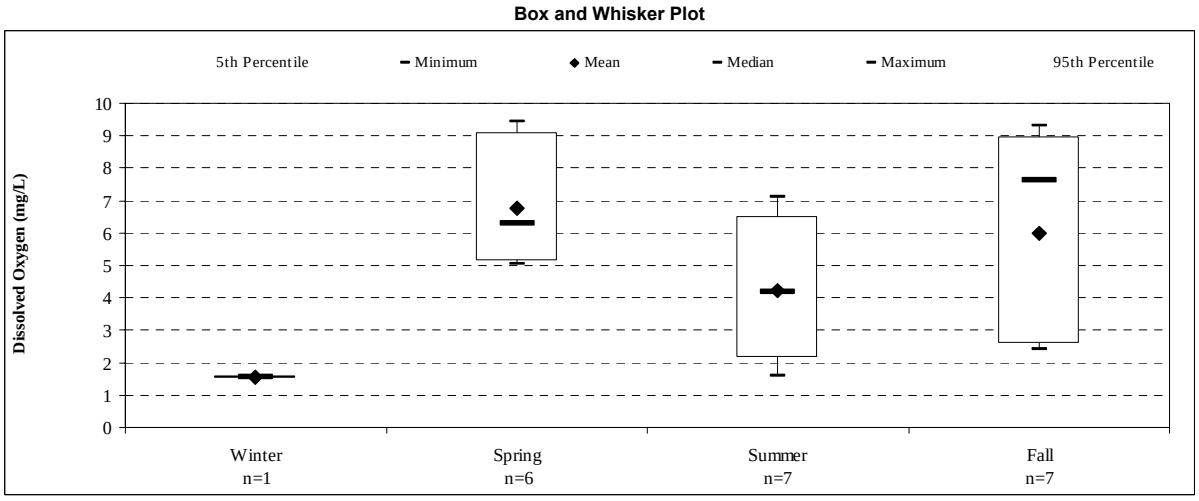


Figure G-2-6-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Stanley Creek



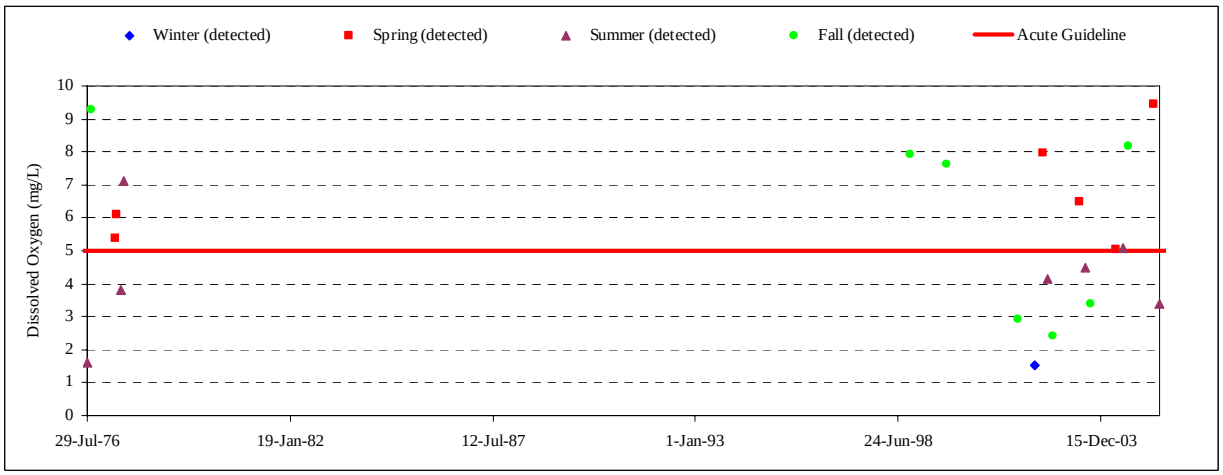
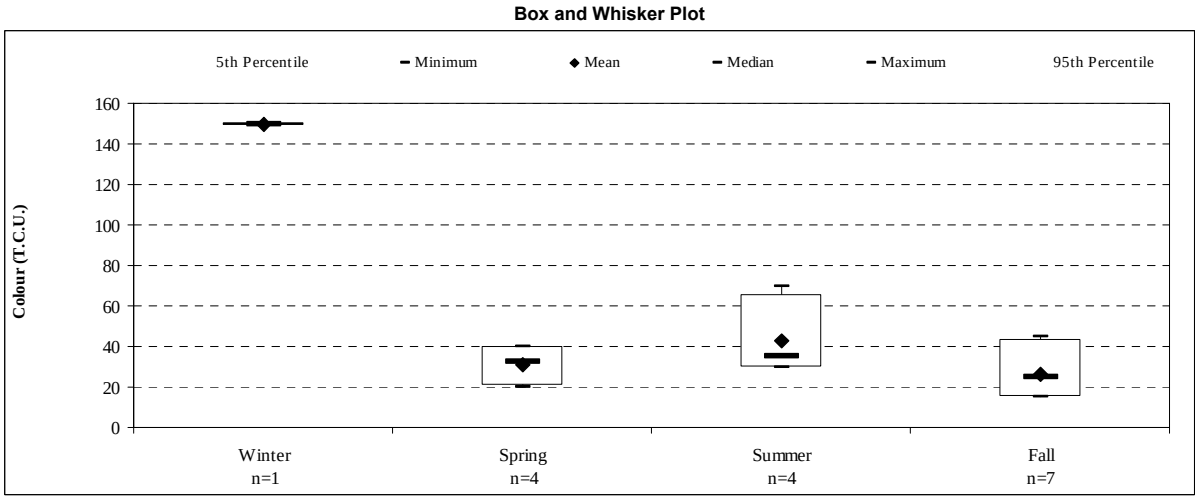


Figure G-2-6-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Stanley Creek



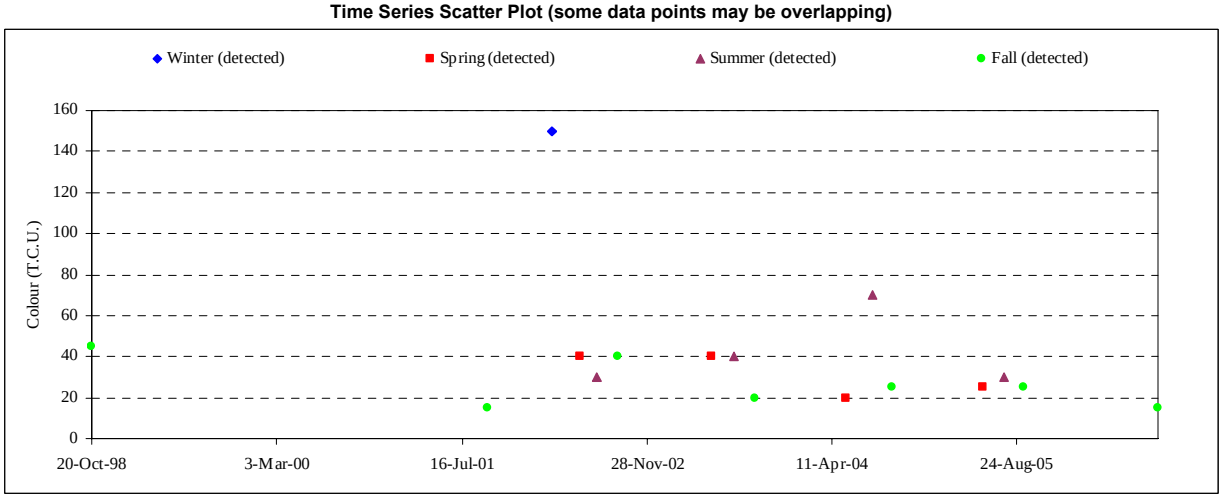
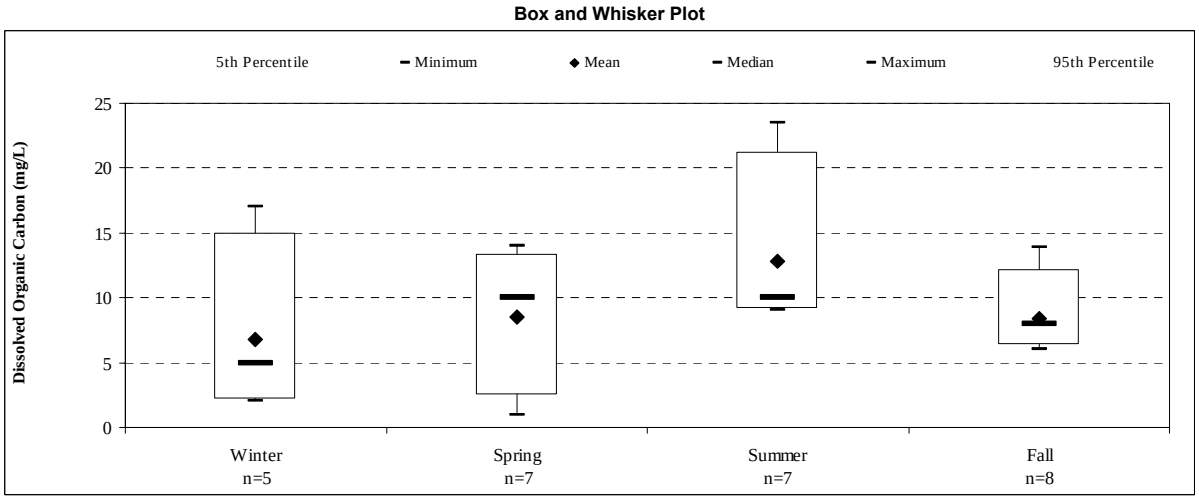


Figure G-2-6-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Stanley Creek



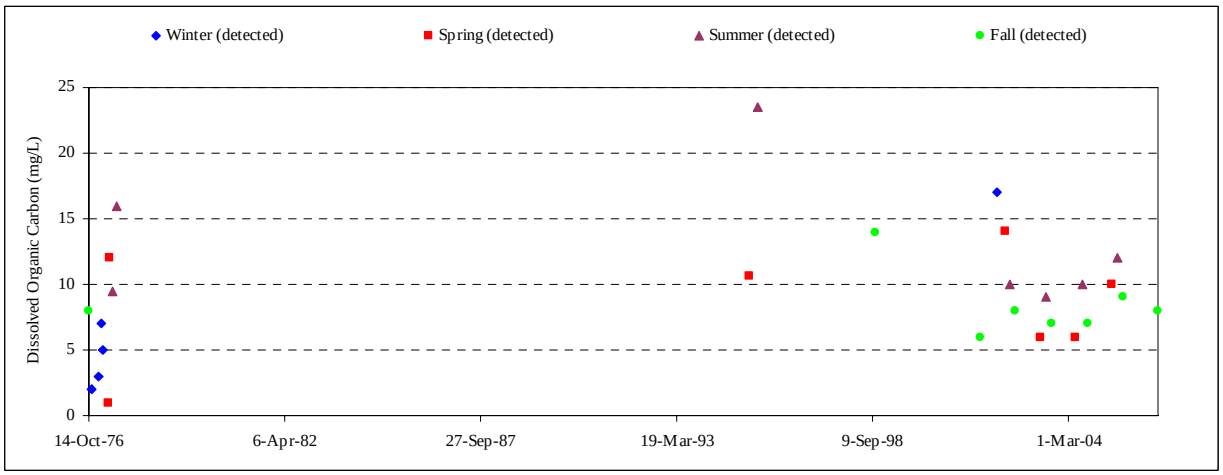
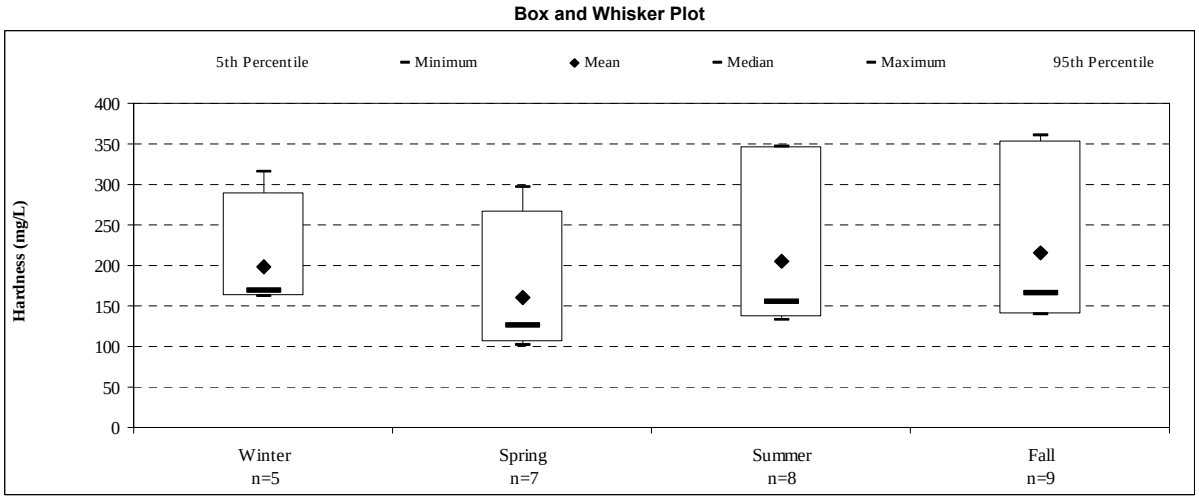


Figure G-2-6-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Stanley Creek



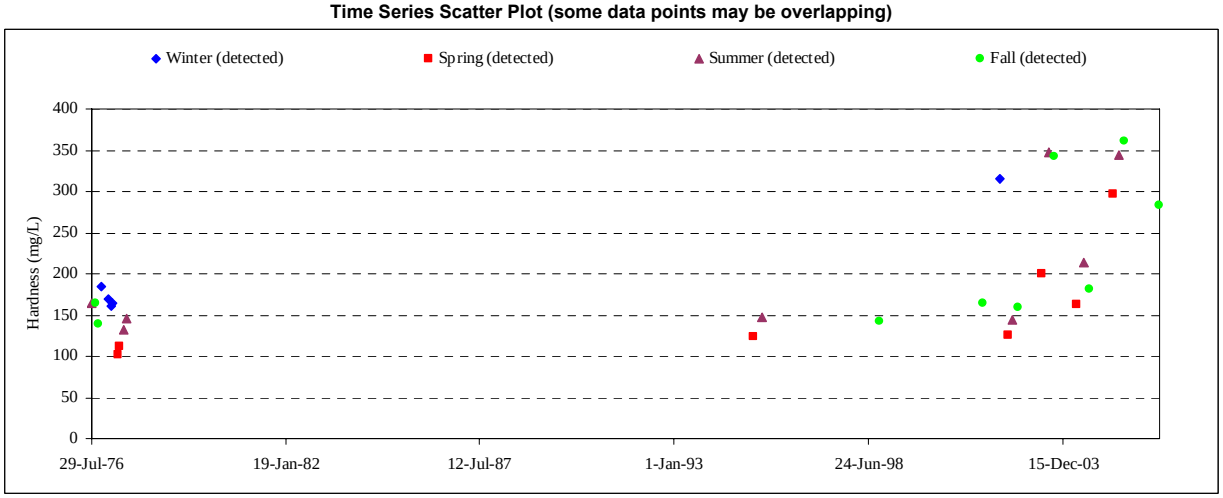
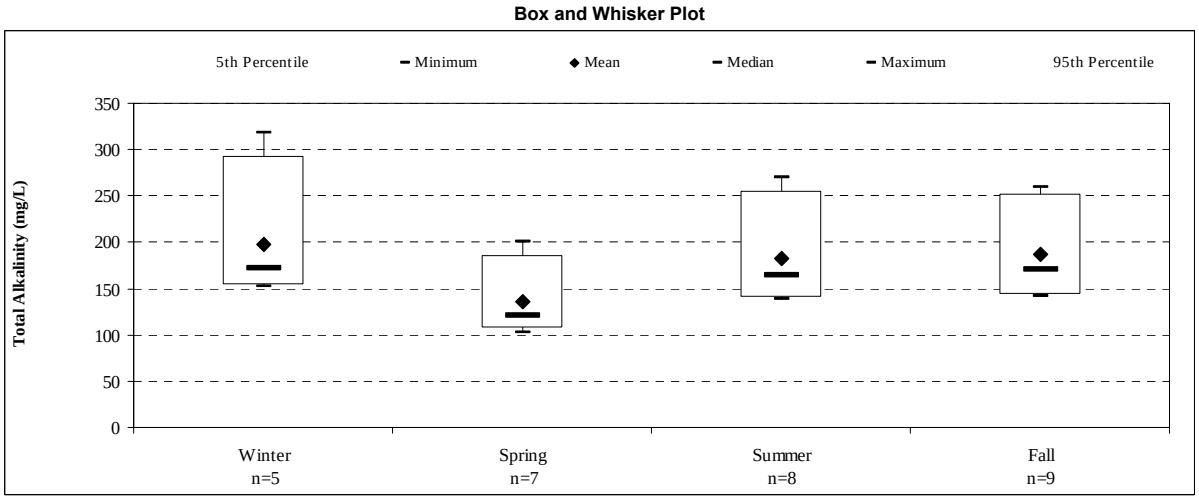


Figure G-2-6-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Stanley Creek



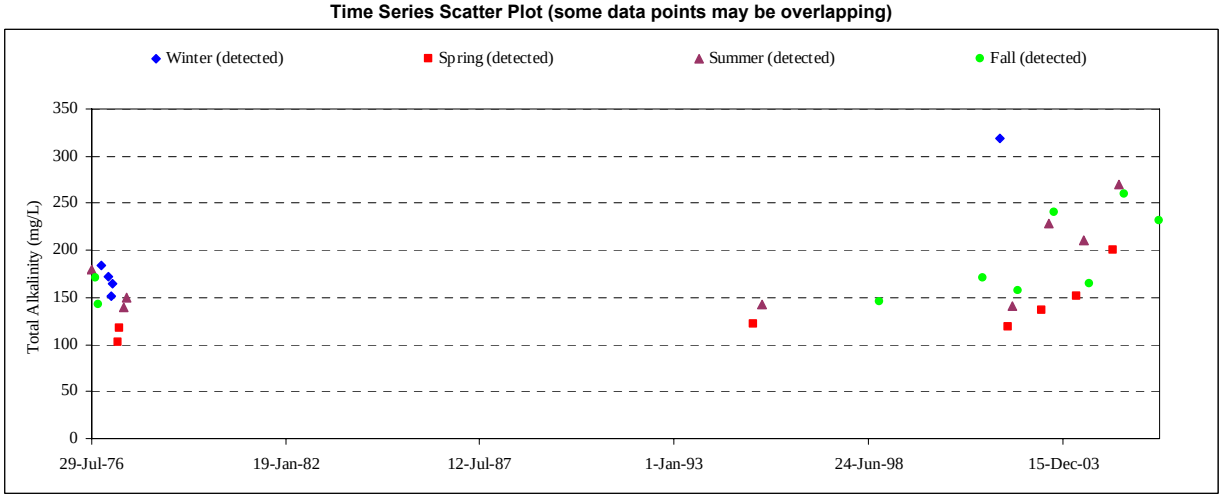
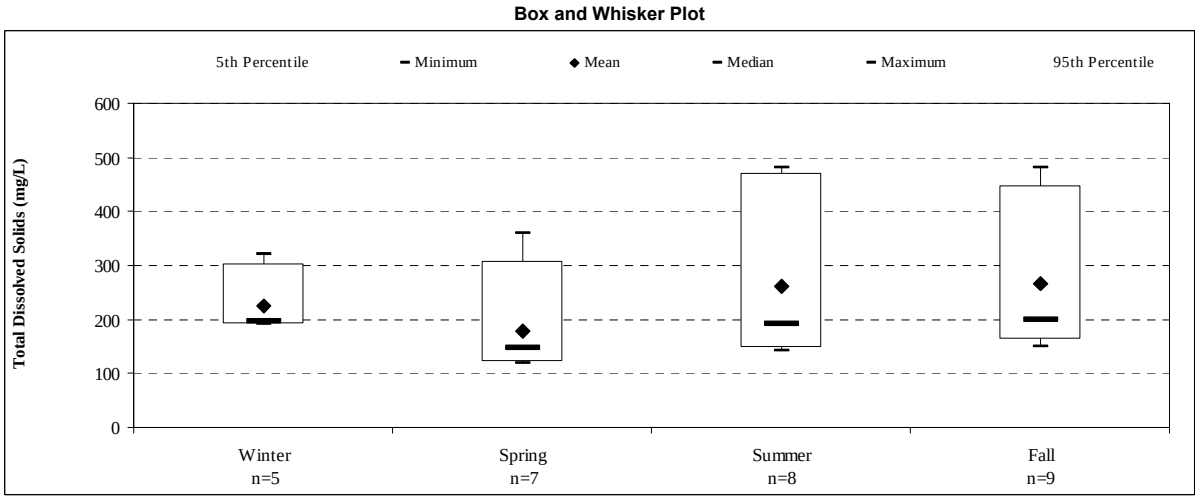


Figure G-2-6-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Stanley Creek



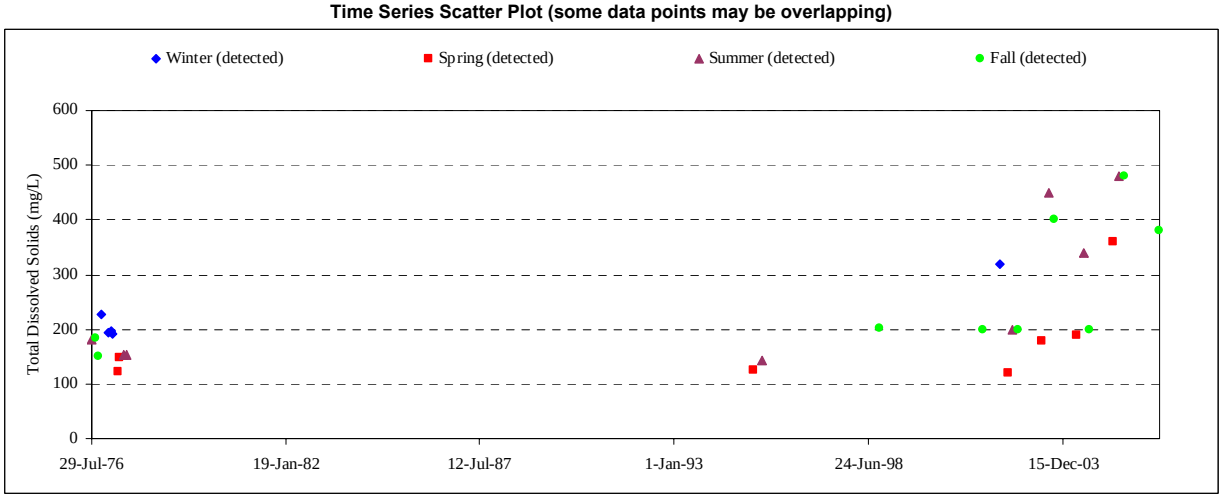
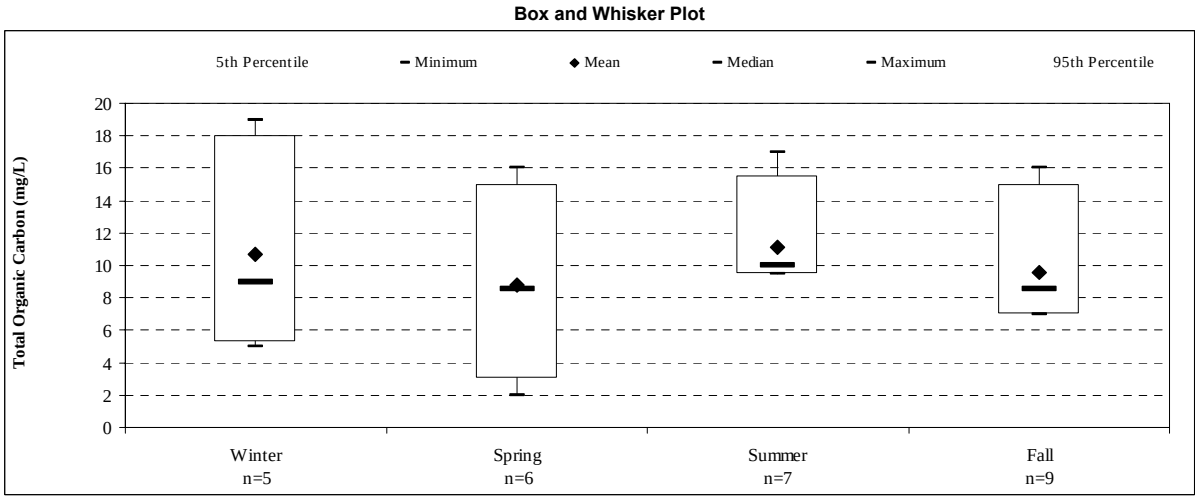


Figure G-2-6-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Stanley Creek



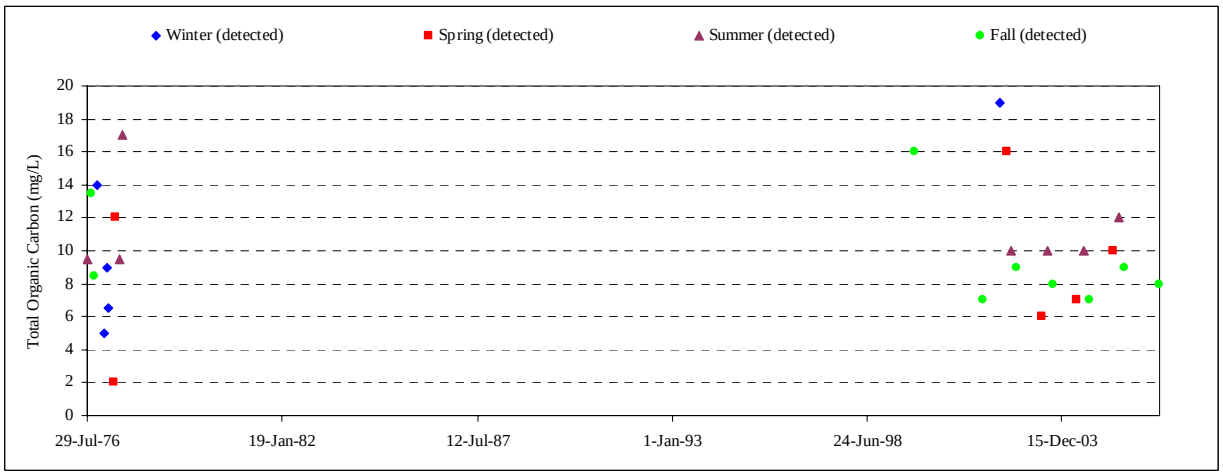
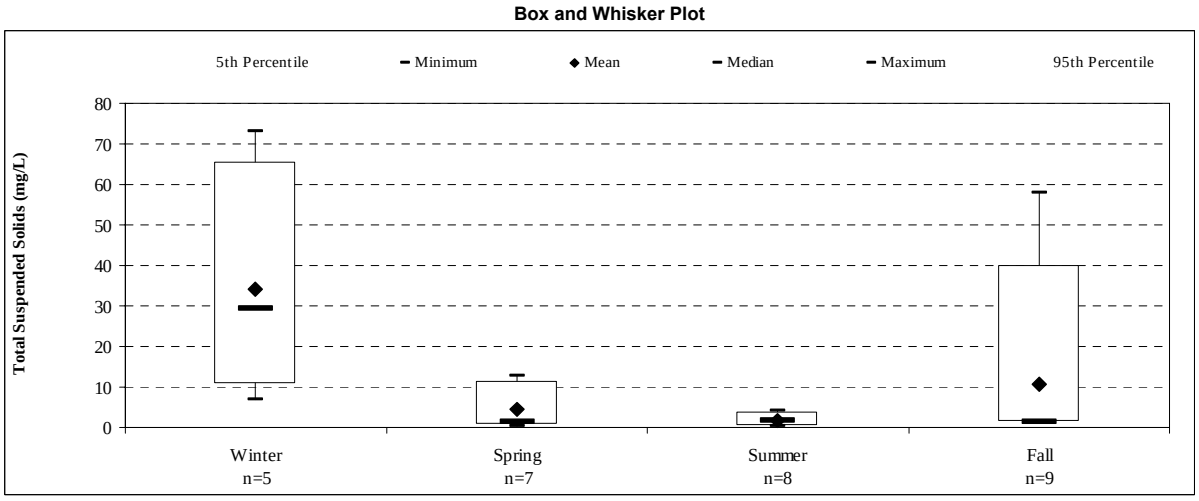


Figure G-2-6-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Stanley Creek



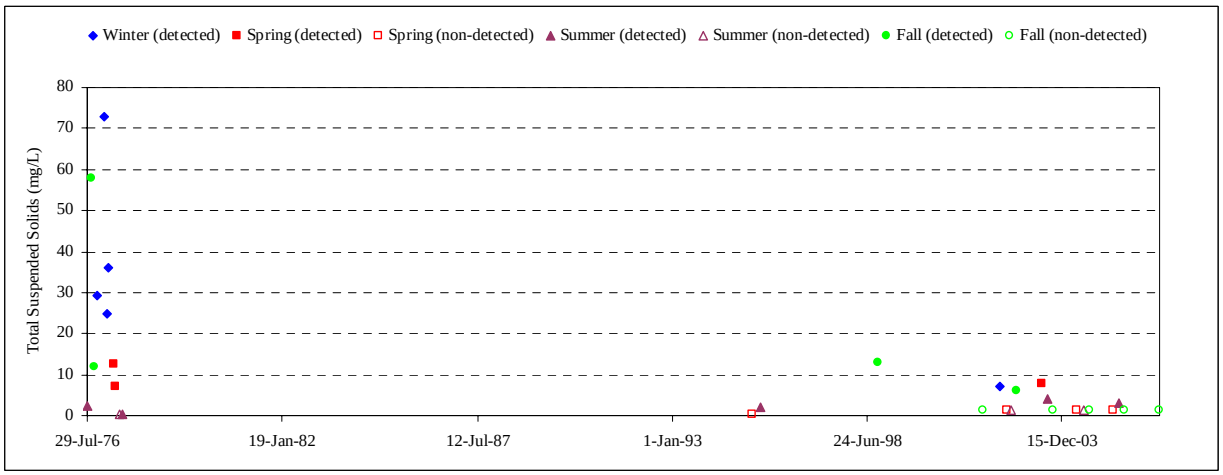
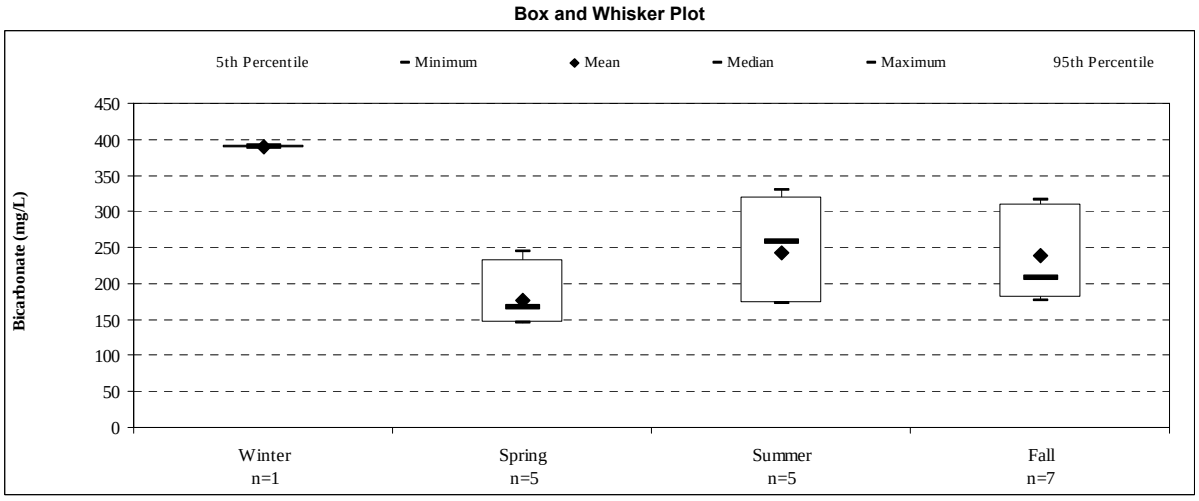


Figure G-2-6-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Stanley Creek



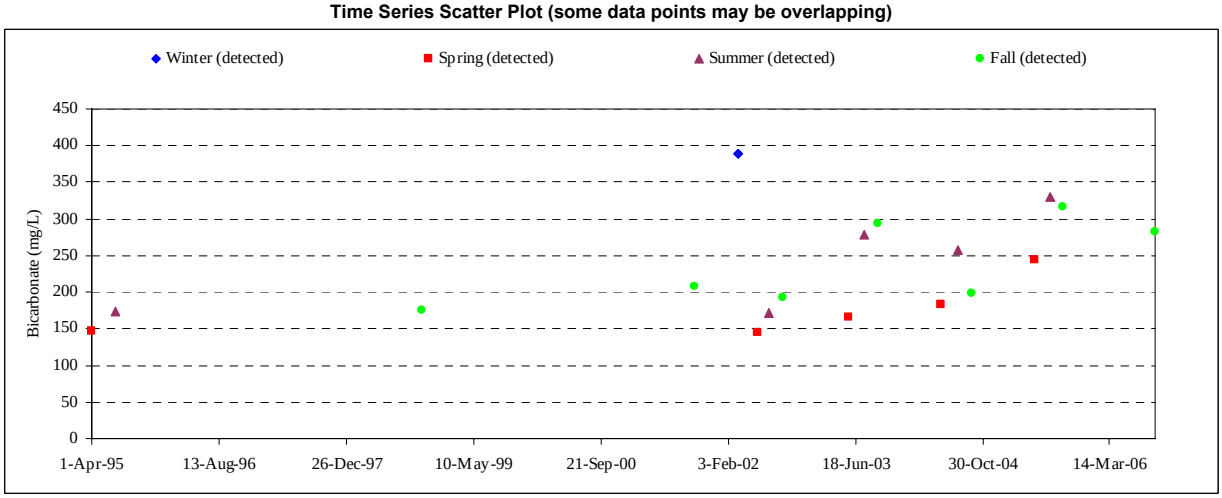
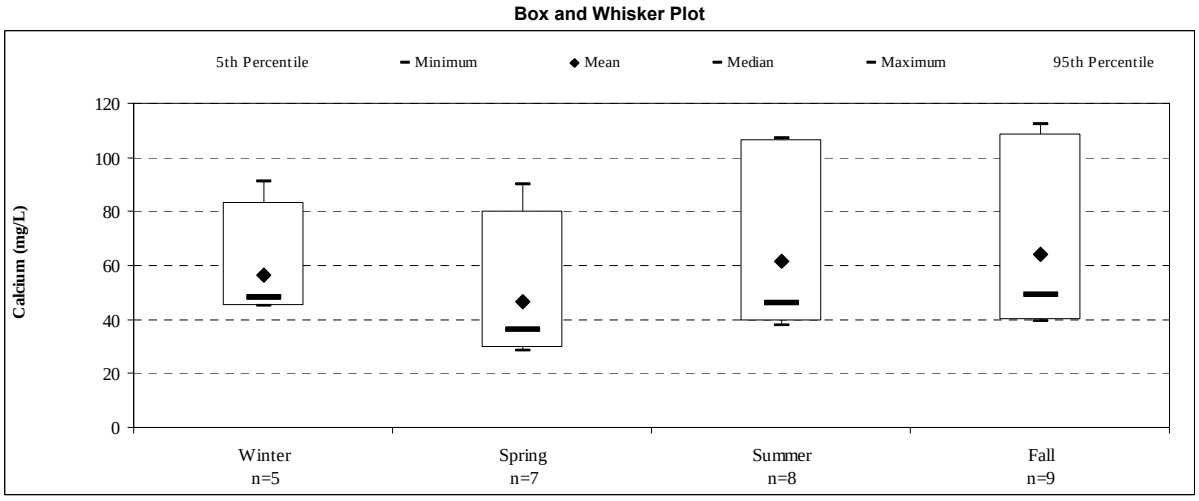


Figure G-2-6-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Stanley Creek



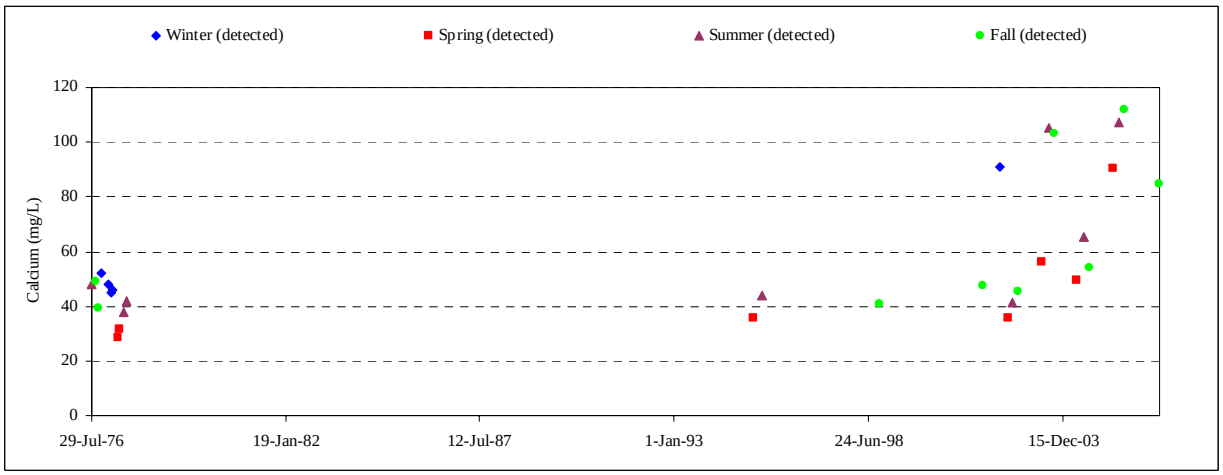
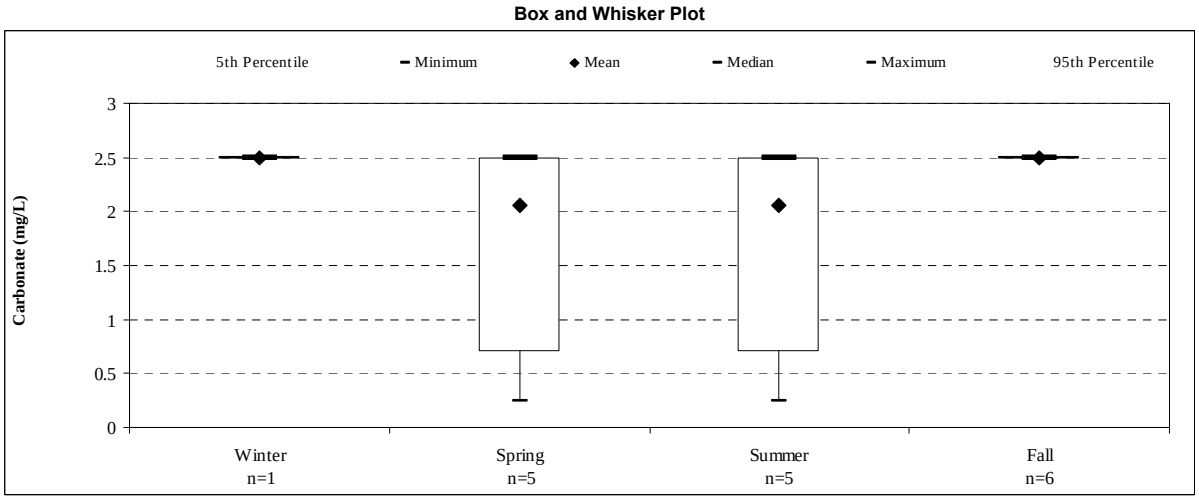


Figure G-2-6-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Stanley Creek



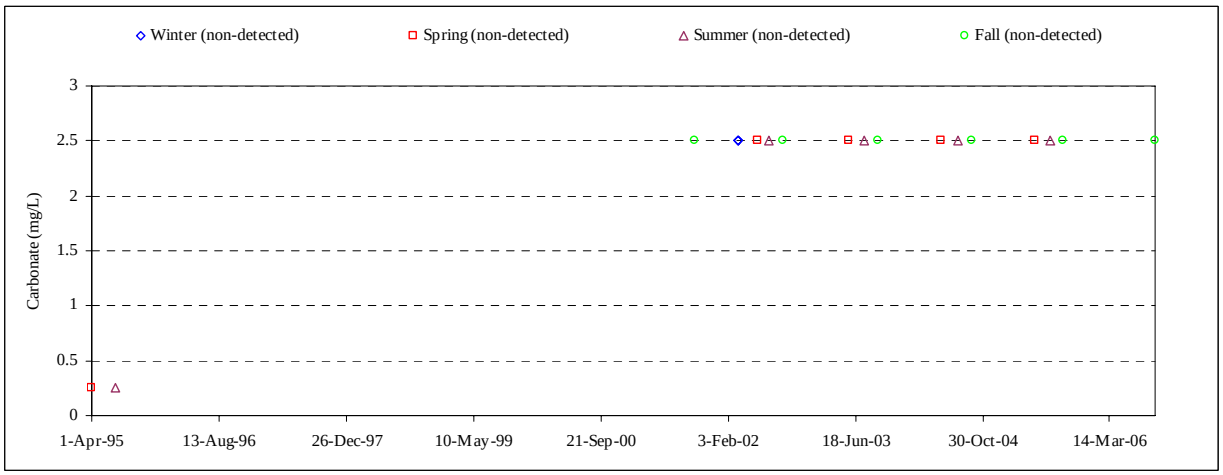
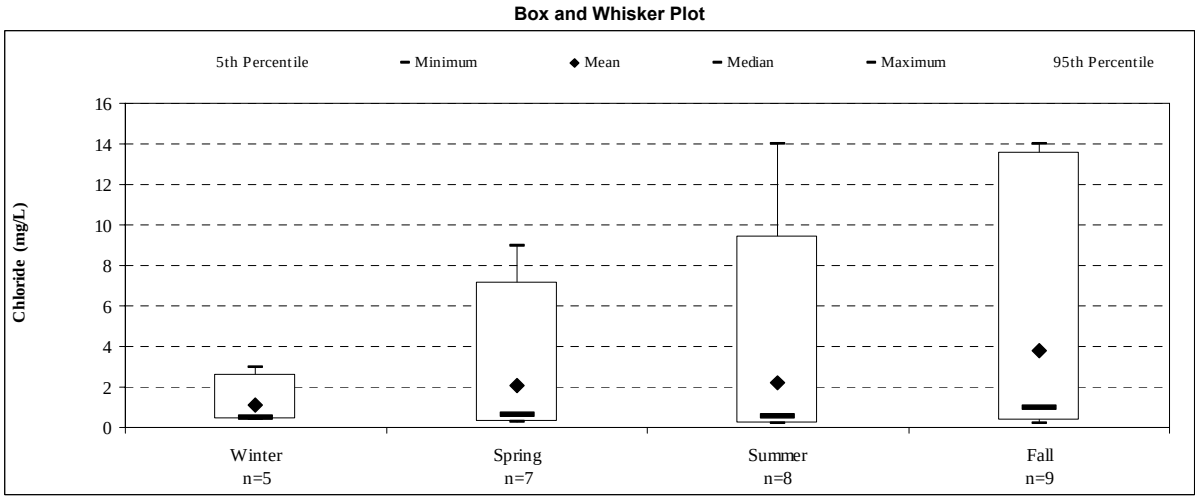


Figure G-2-6-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Stanley Creek



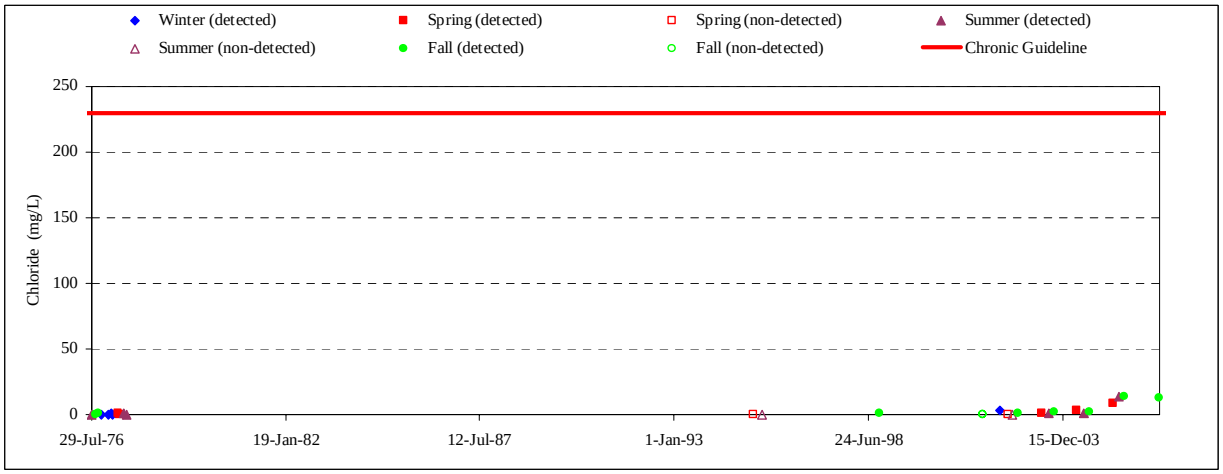
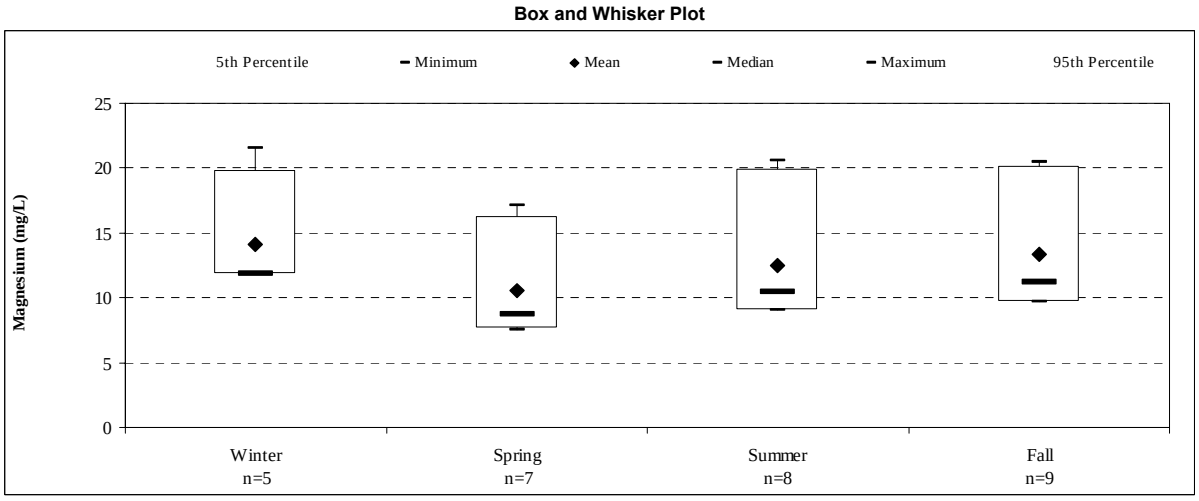


Figure G-2-6-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Stanley Creek



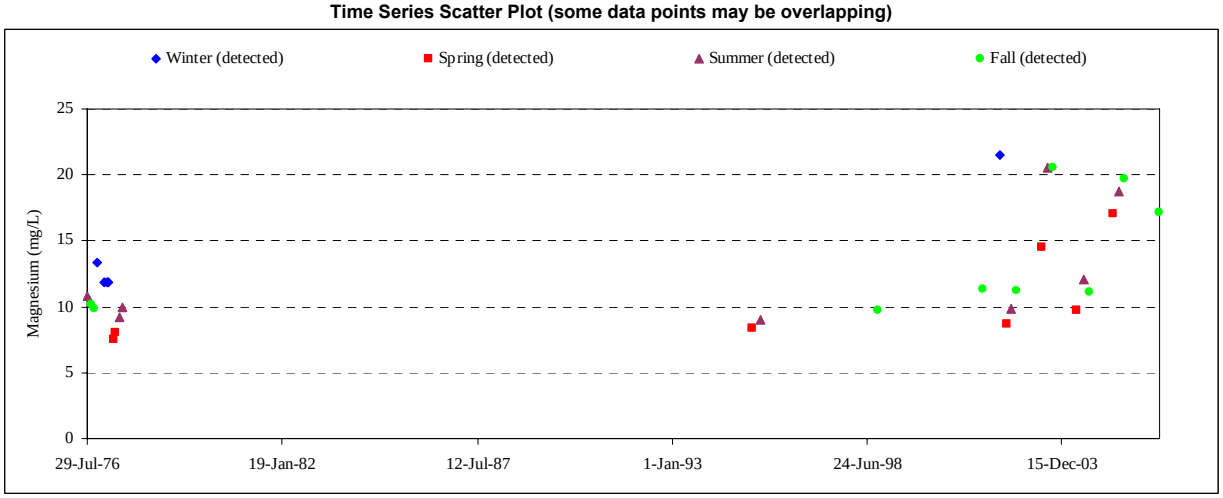
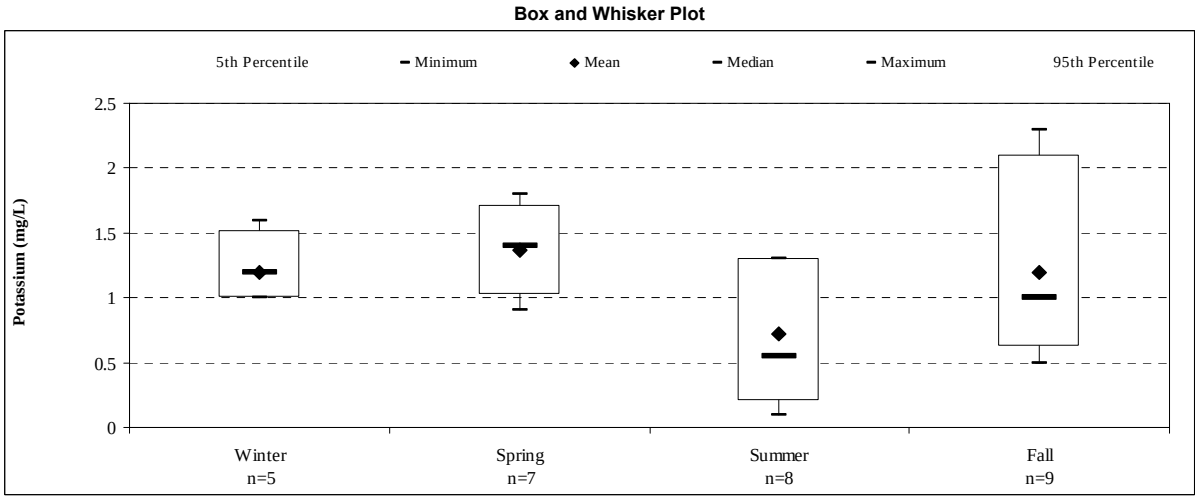


Figure G-2-6-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Stanley Creek



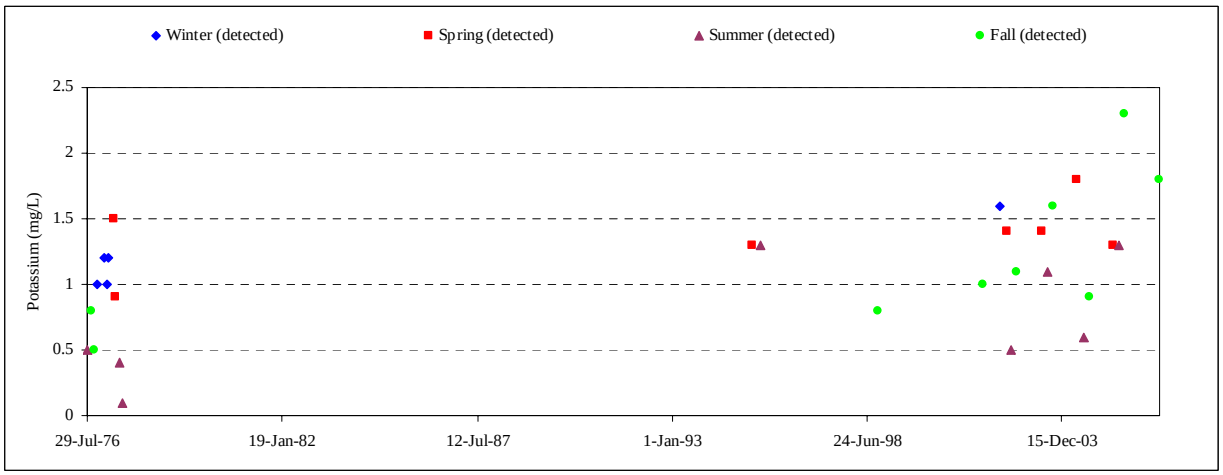
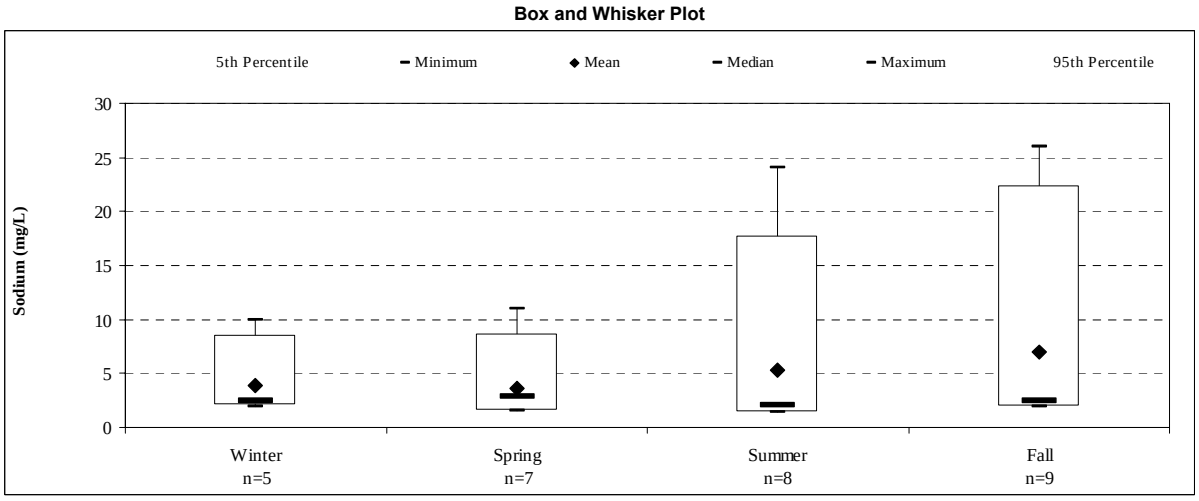


Figure G-2-6-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Stanley Creek



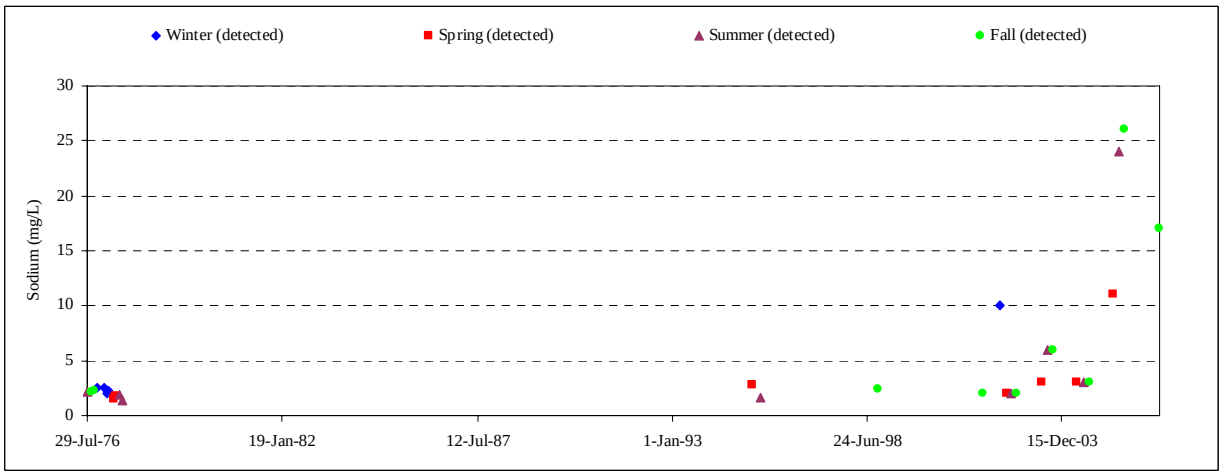


Figure G-2-6-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Stanley Creek

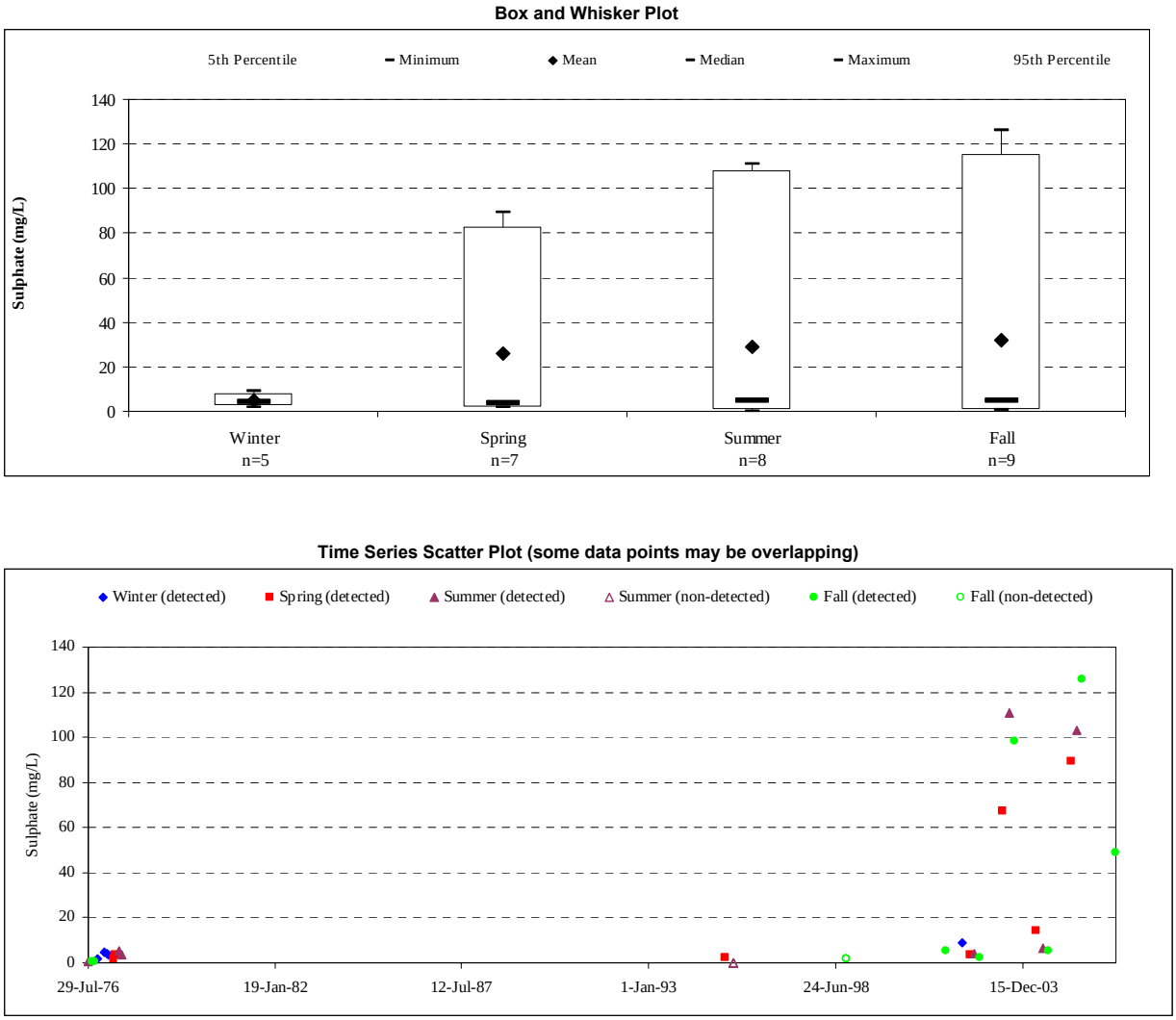
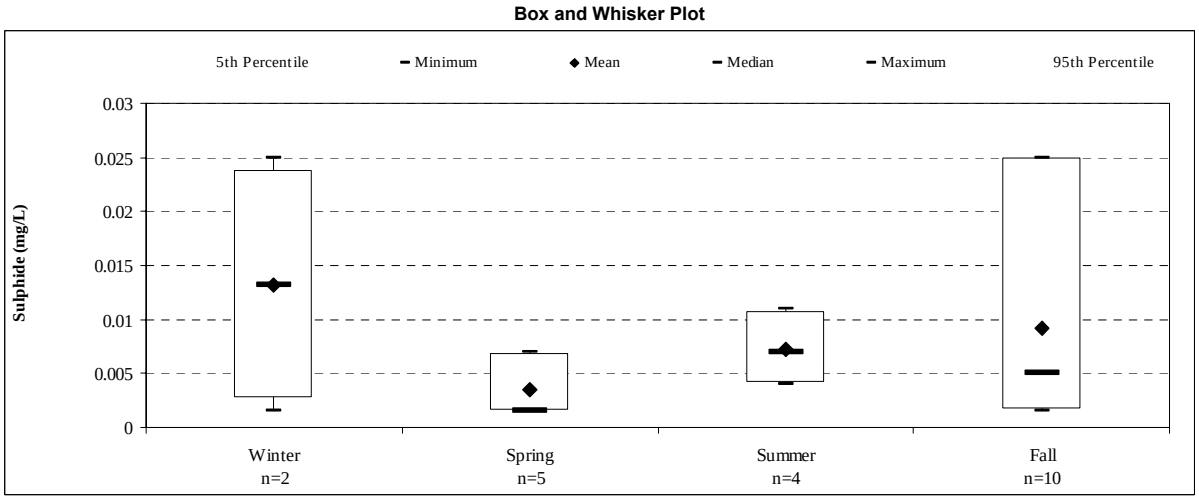


Figure G-2-6-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Stanley Creek



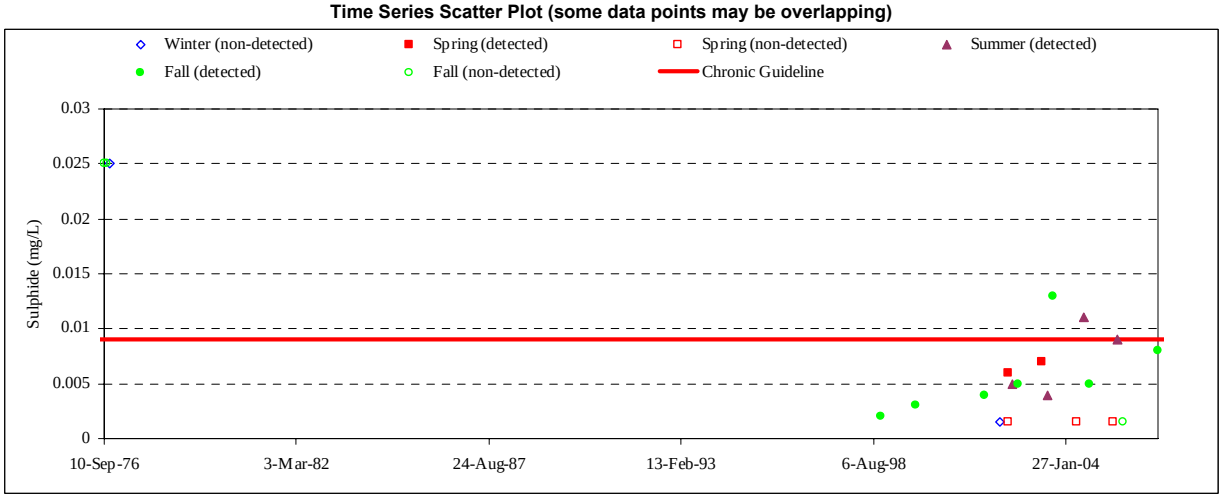
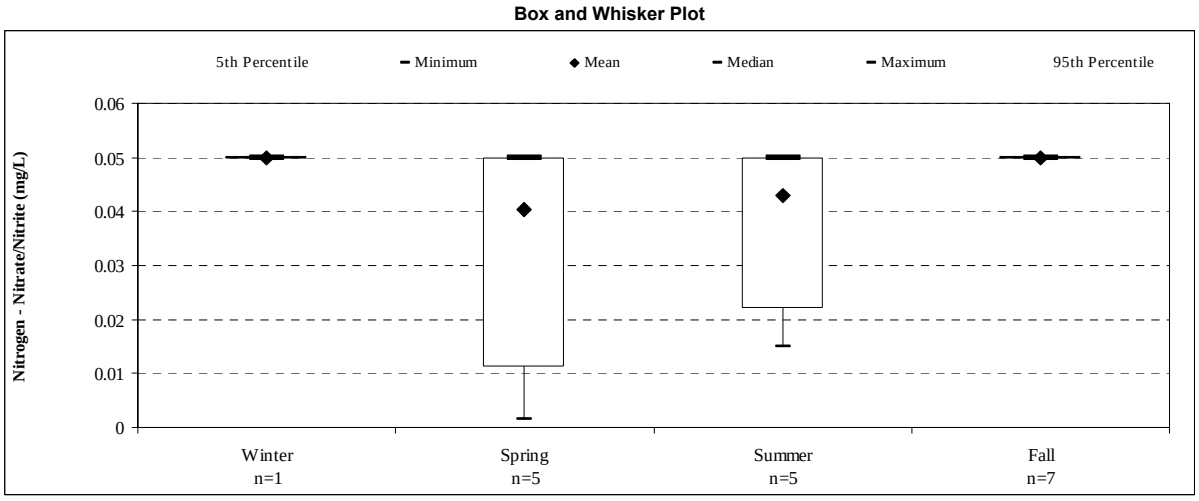


Figure G-2-6-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Stanley Creek



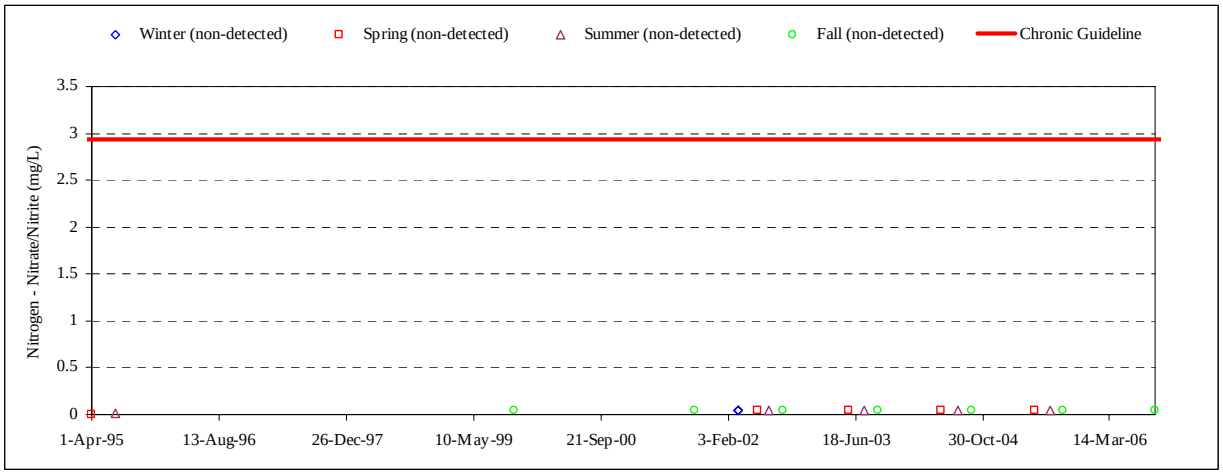
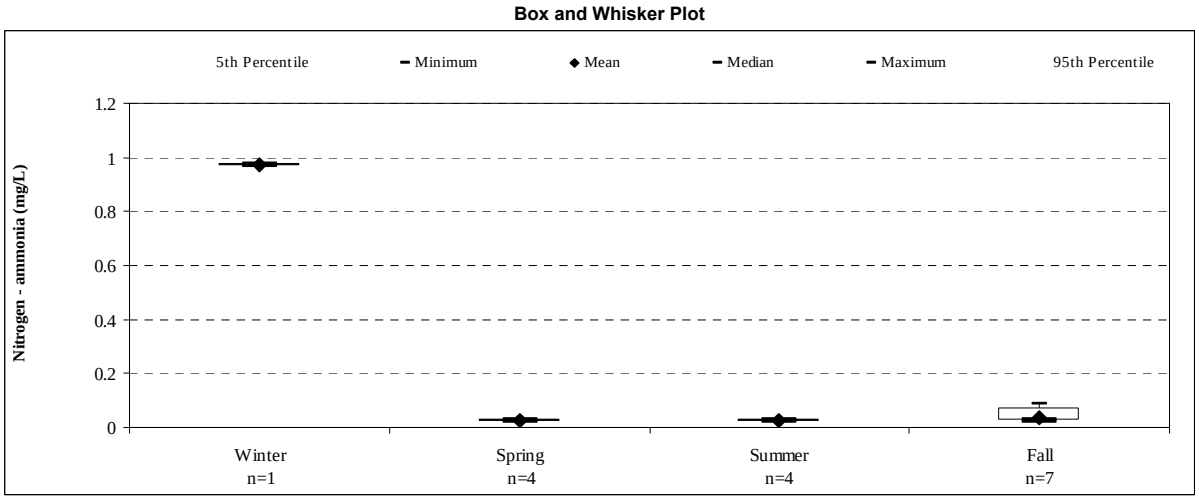


Figure G-2-6-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Stanley Creek



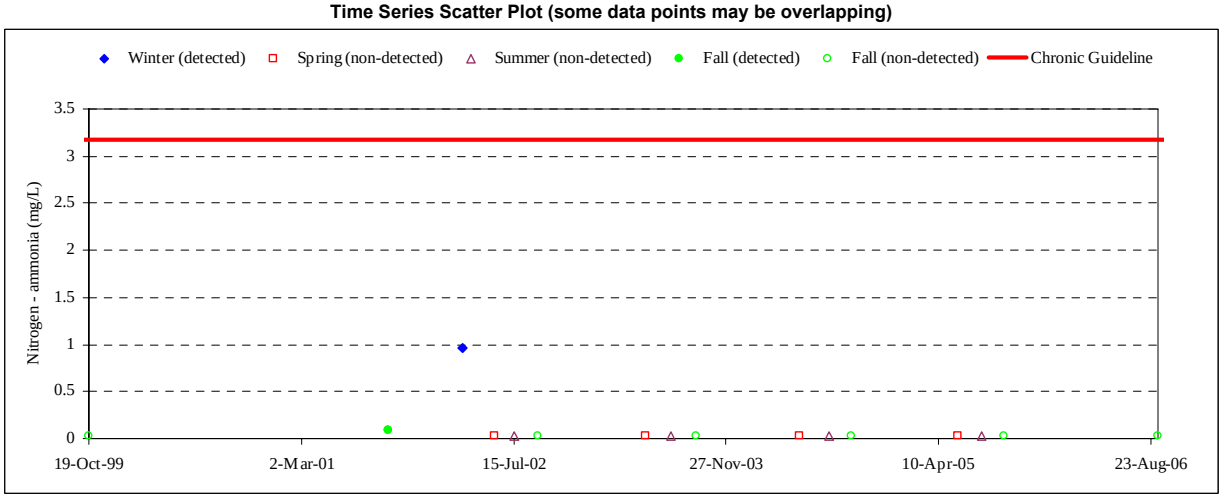
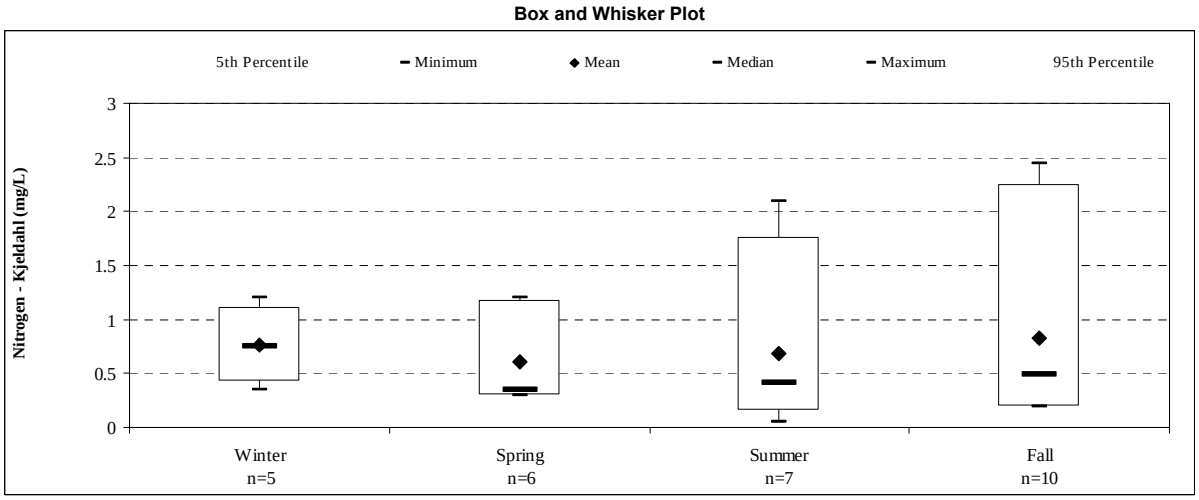


Figure G-2-6-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Stanley Creek



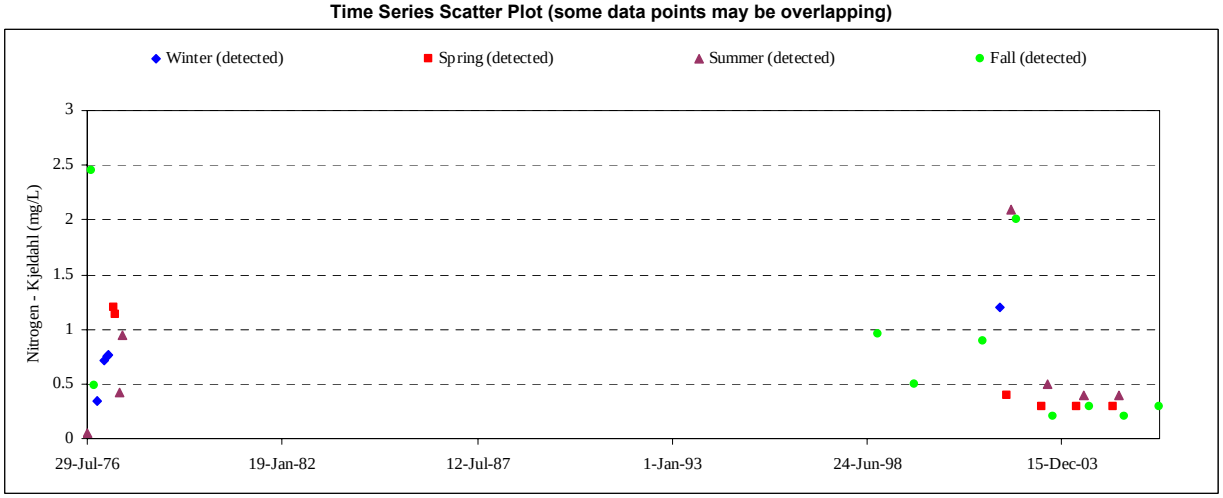
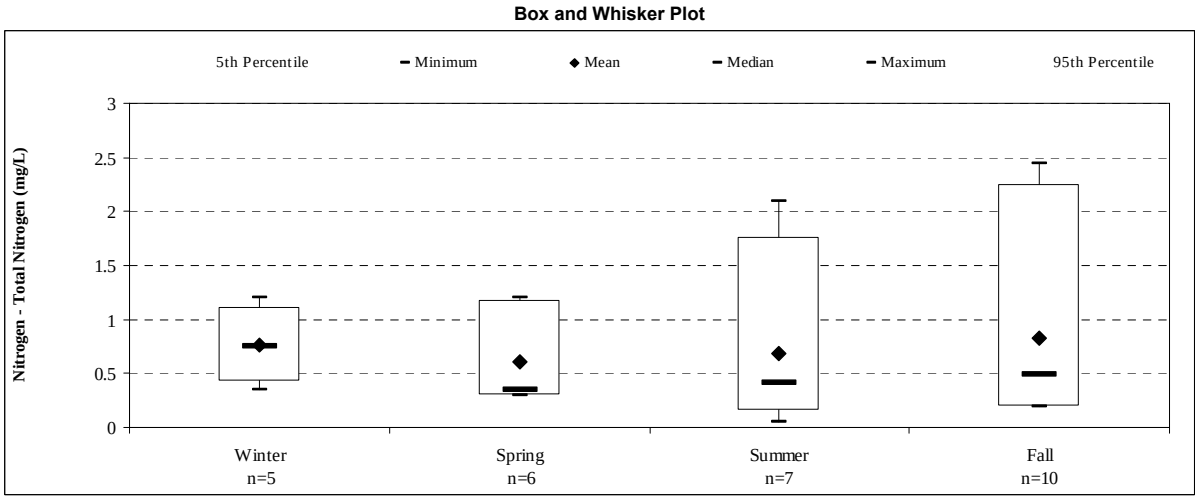


Figure G-2-6-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Stanley Creek



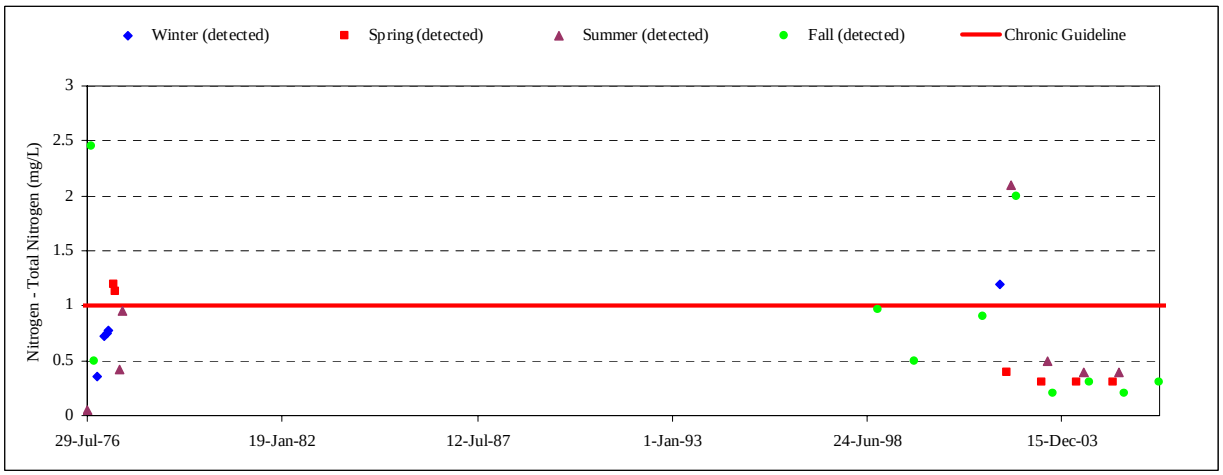
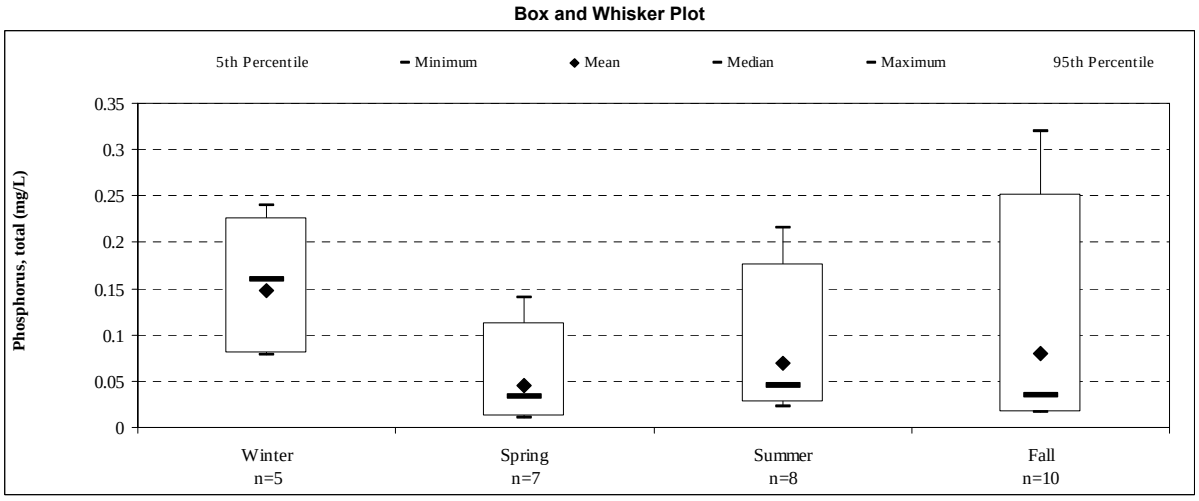


Figure G-2-6-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Stanley Creek



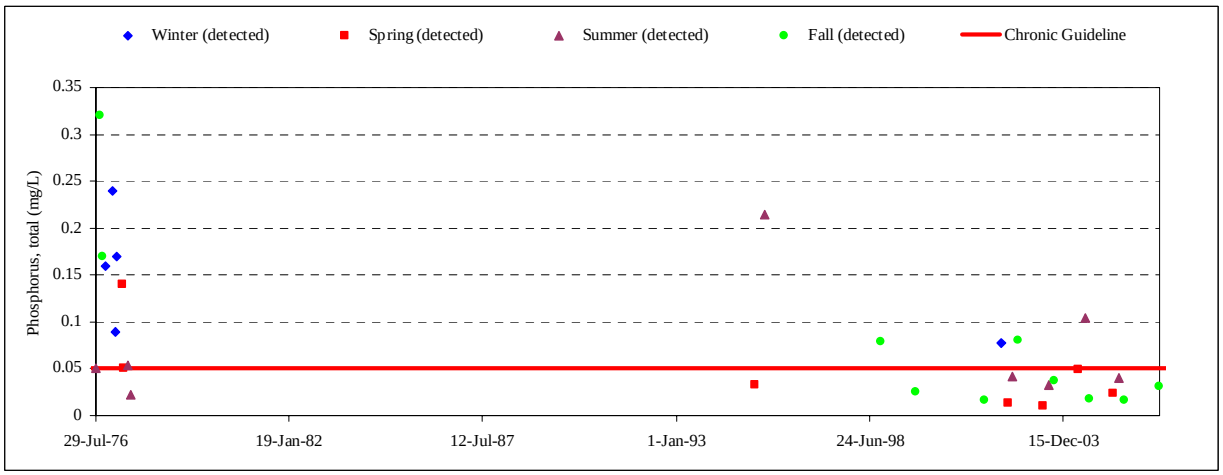
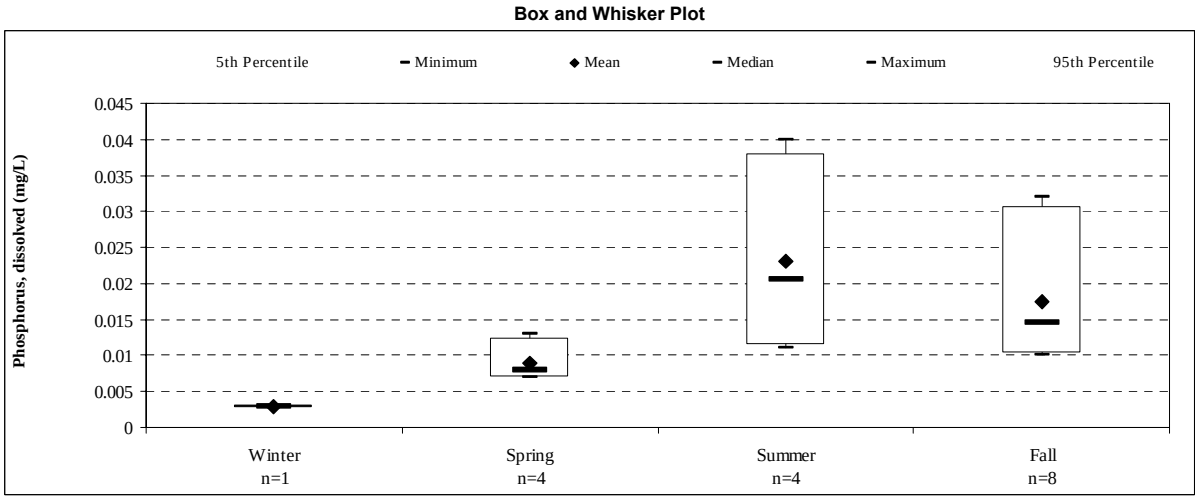


Figure G-2-6-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Stanley Creek



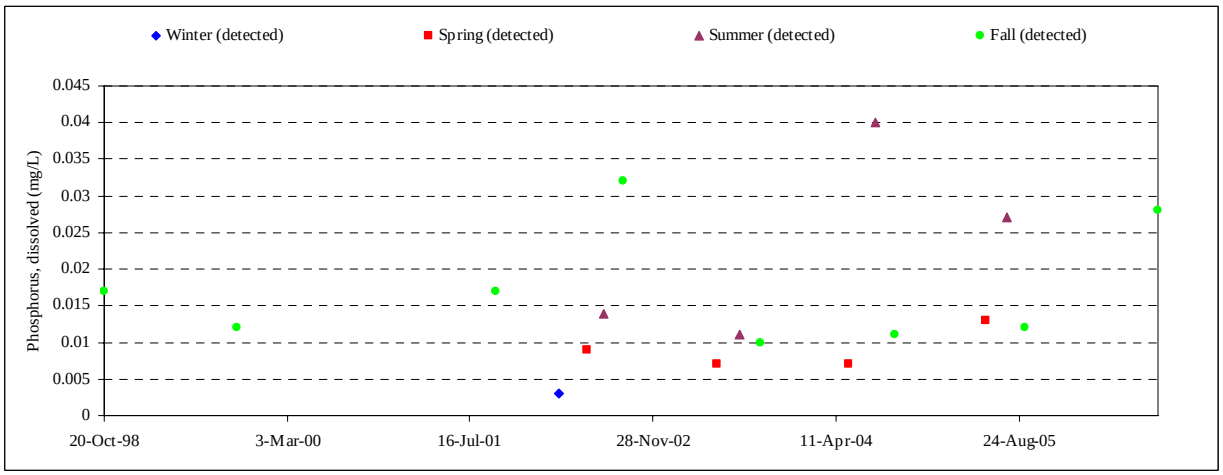
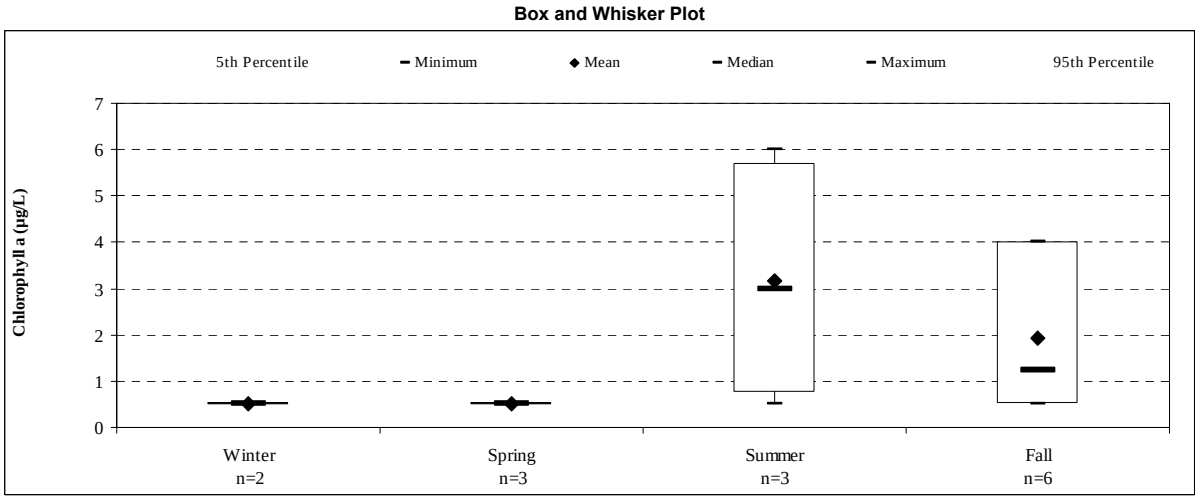


Figure G-2-6-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Stanley Creek



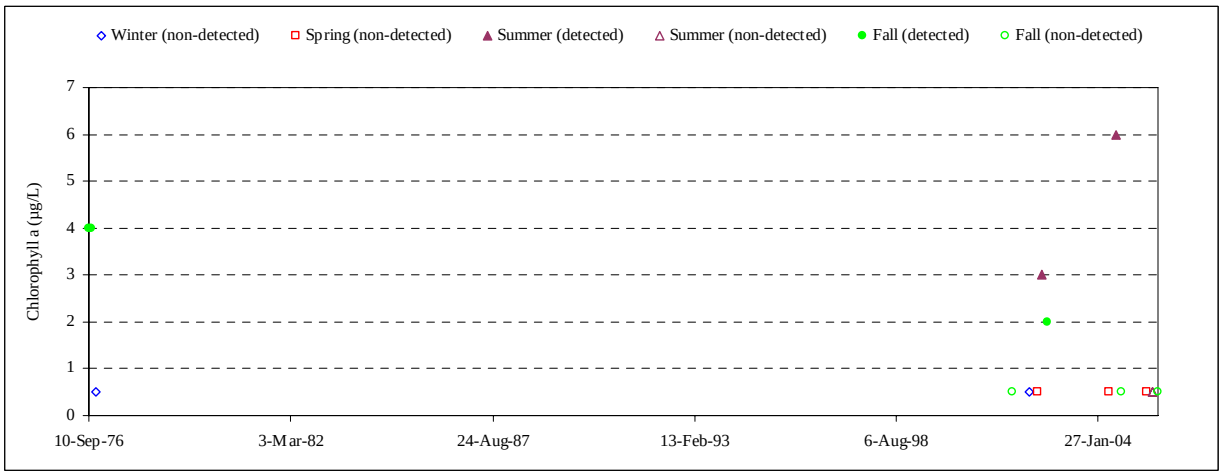
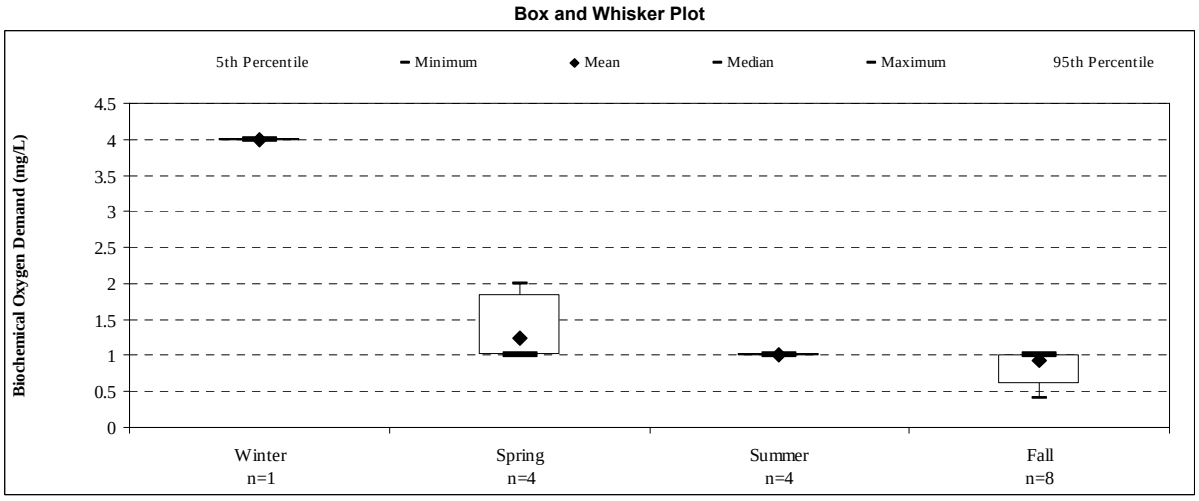


Figure G-2-6-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Stanley Creek



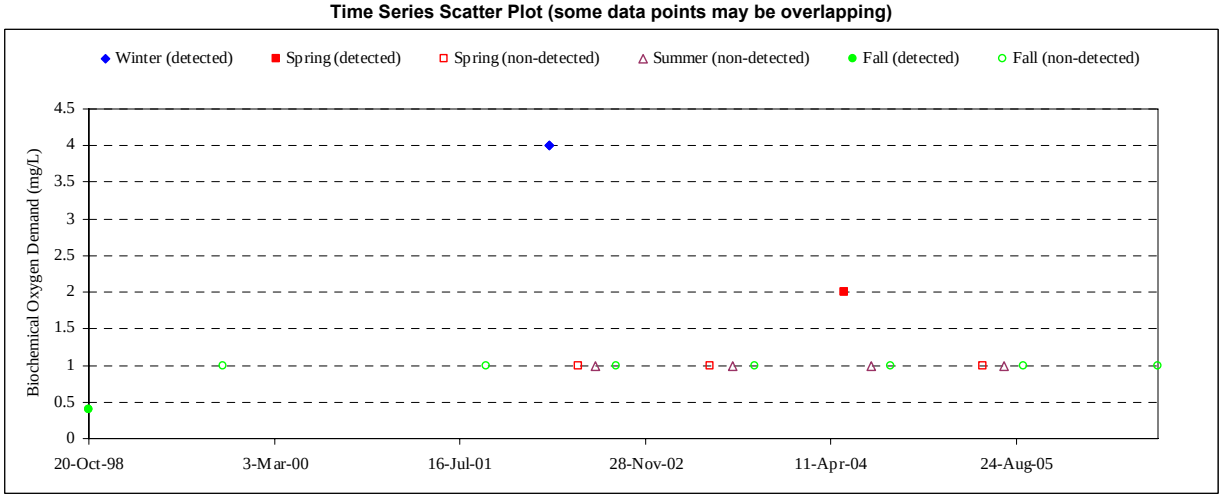
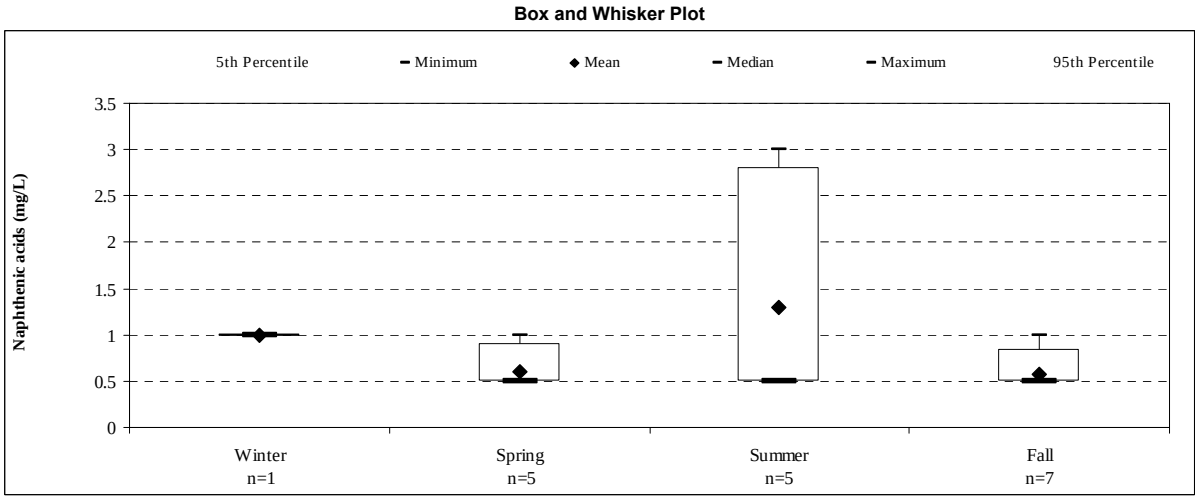


Figure G-2-6-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Stanley Creek



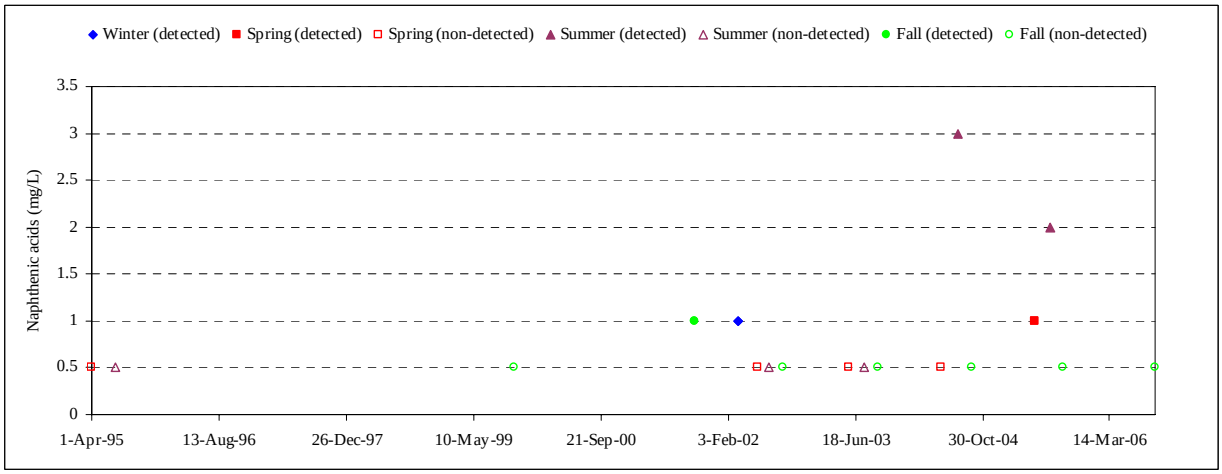
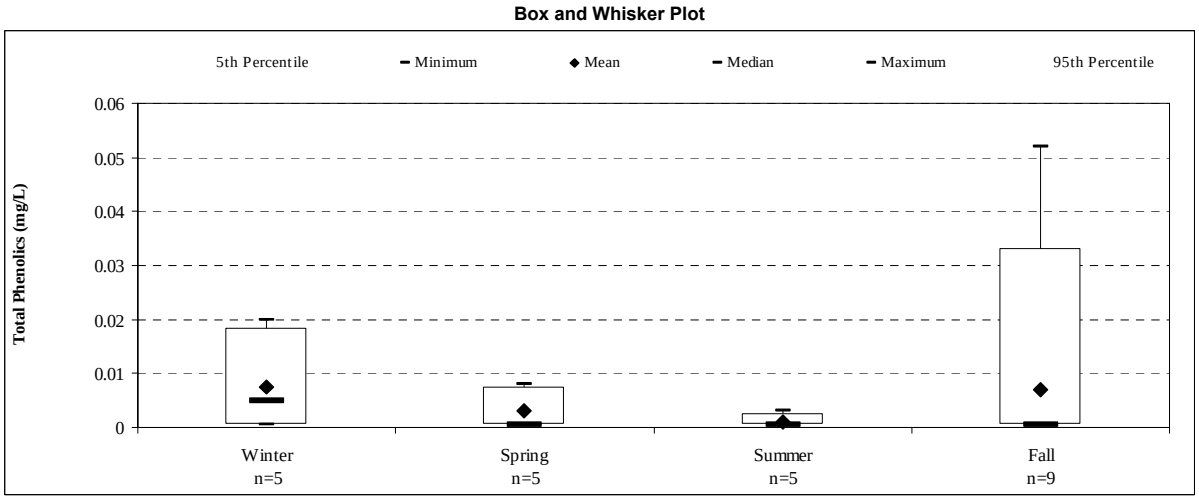


Figure G-2-6-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Stanley Creek



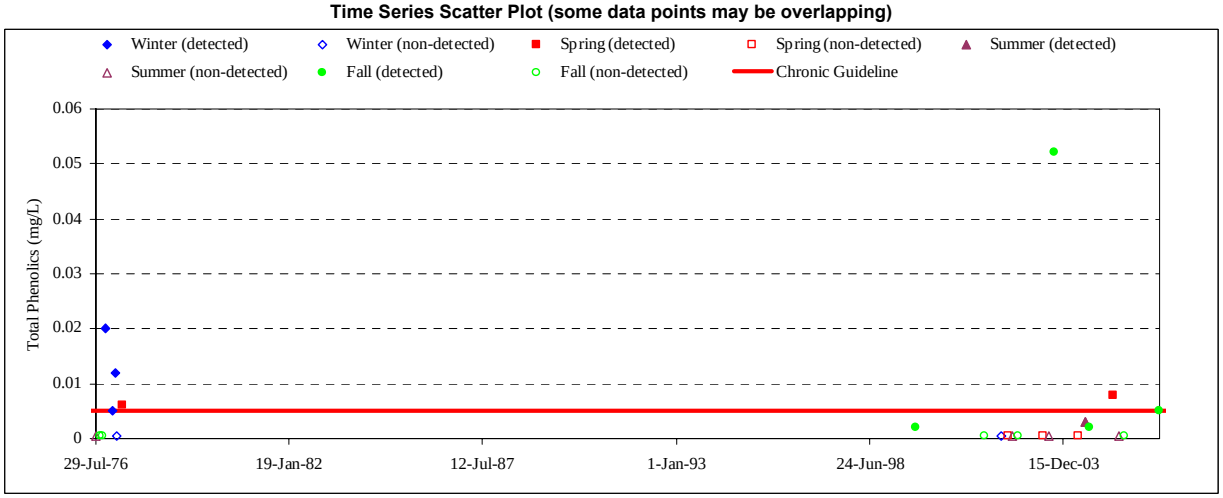


Figure G-2-6-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Stanley Creek

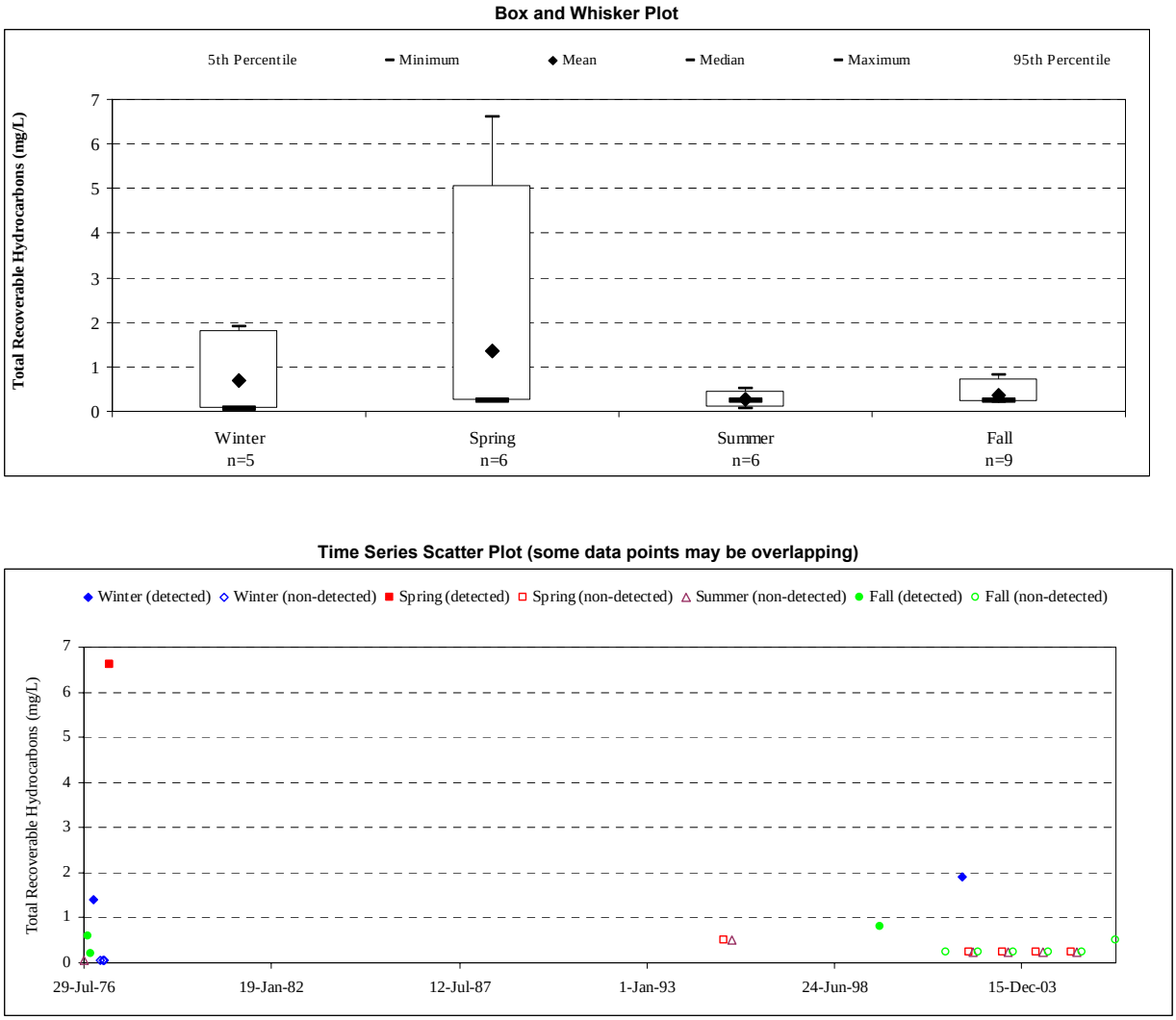
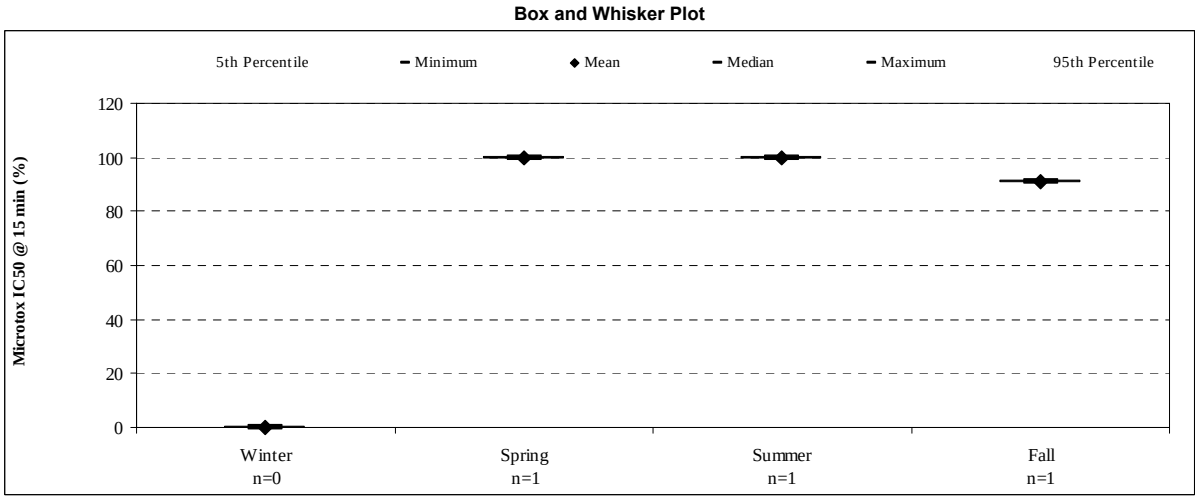


Figure G-2-6-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Stanley Creek



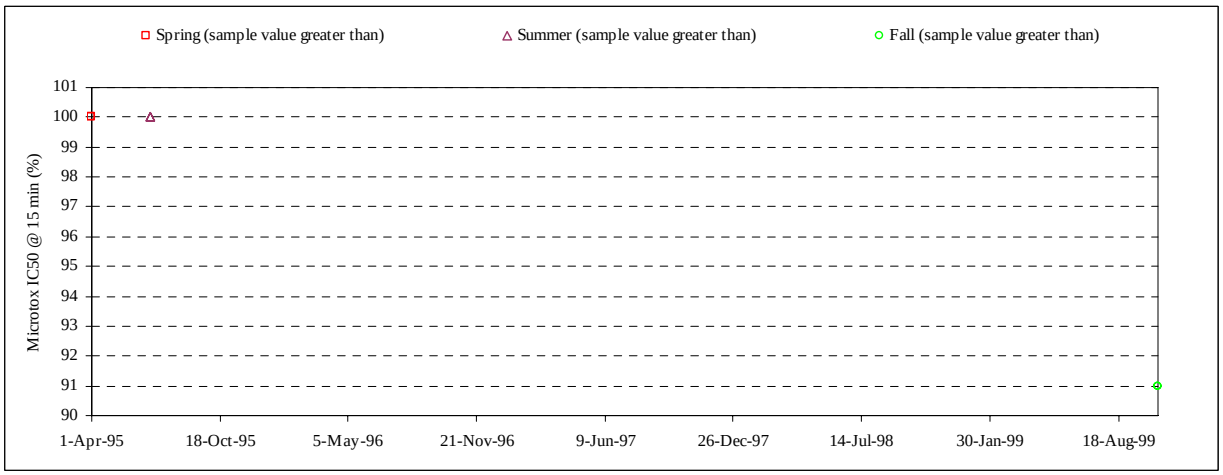
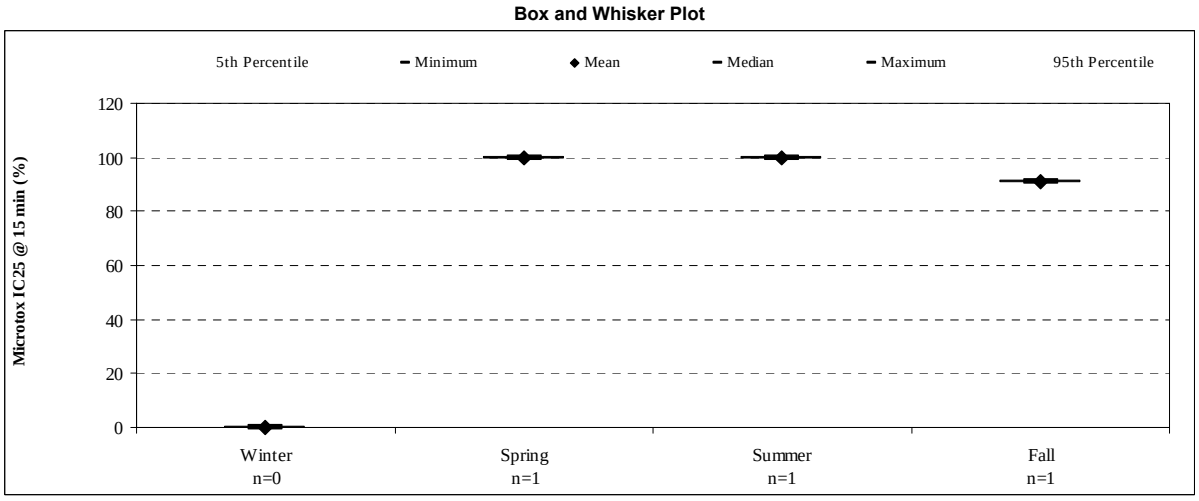


Figure G-2-6-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Stanley Creek



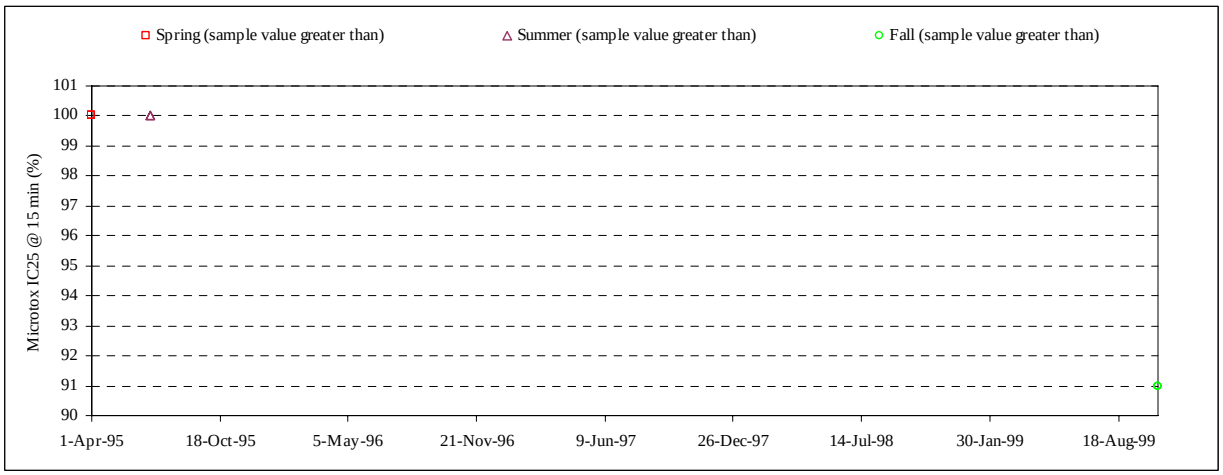
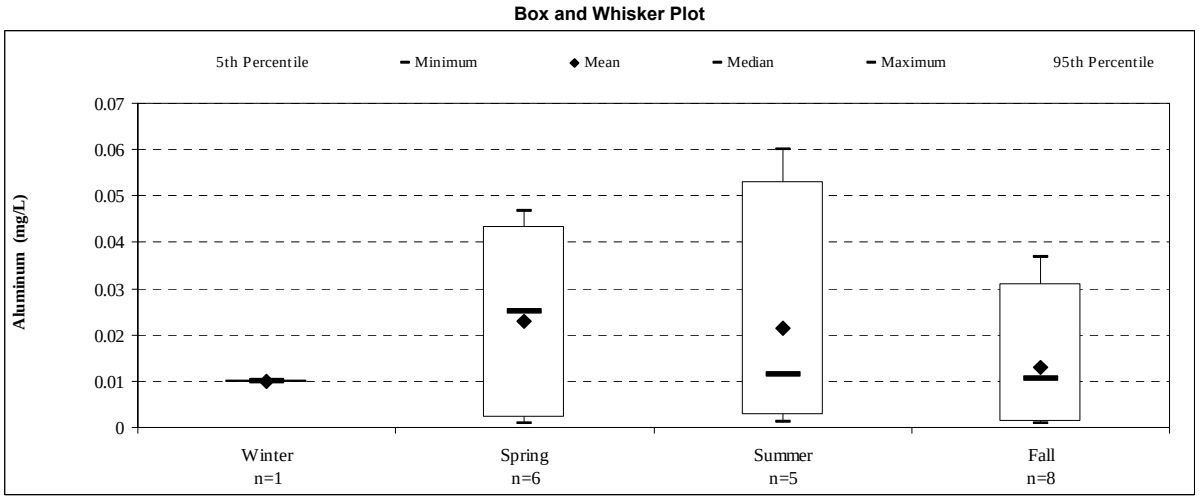


Figure G-2-6-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Stanley Creek



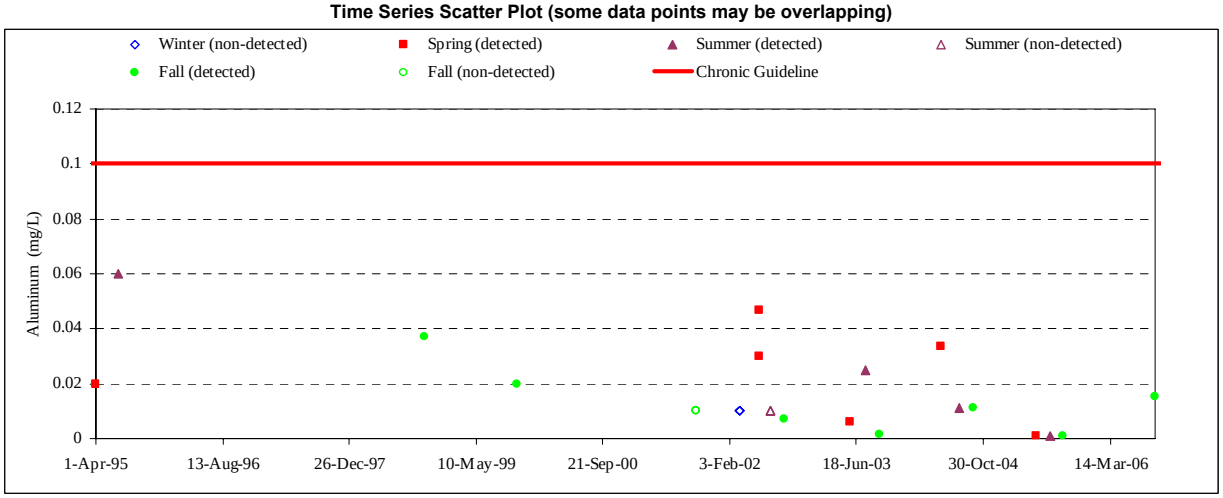
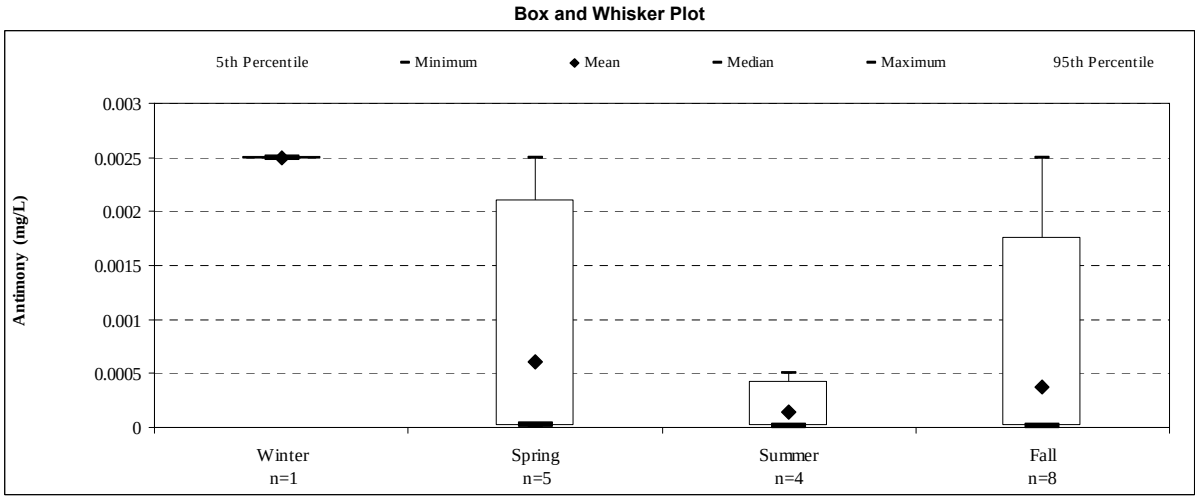


Figure G-2-6-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Stanley Creek



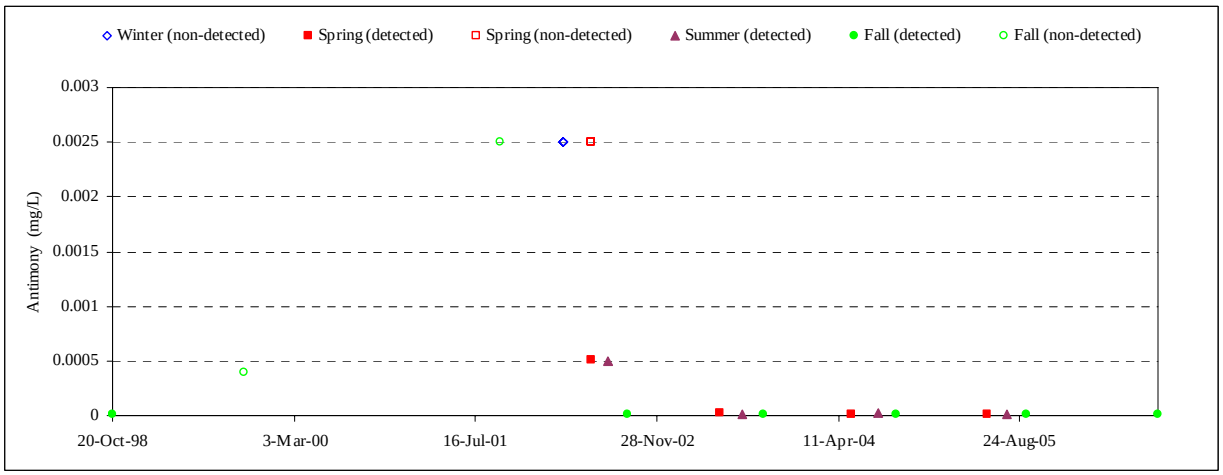
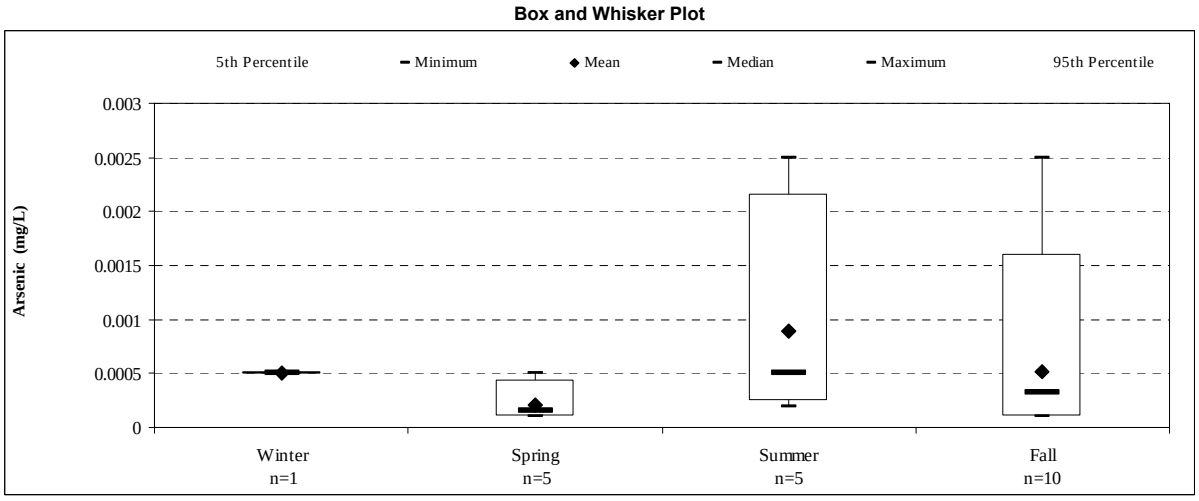


Figure G-2-6-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Stanley Creek



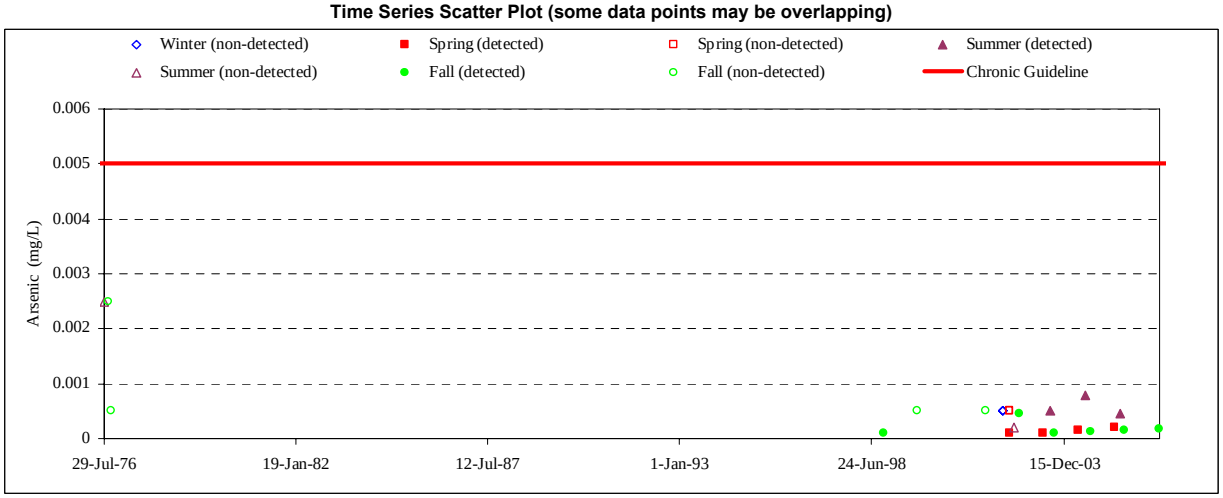
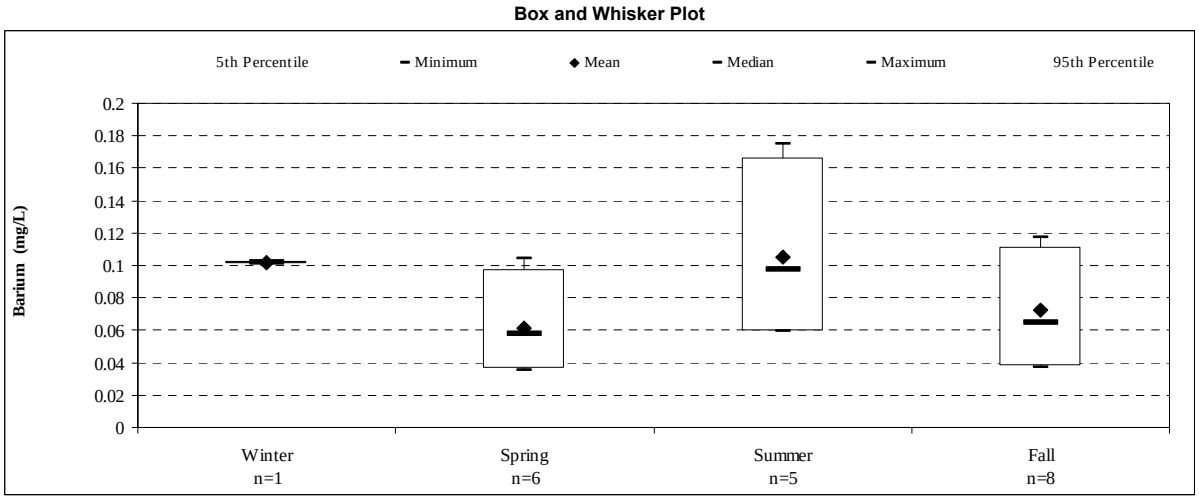


Figure G-2-6-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Stanley Creek



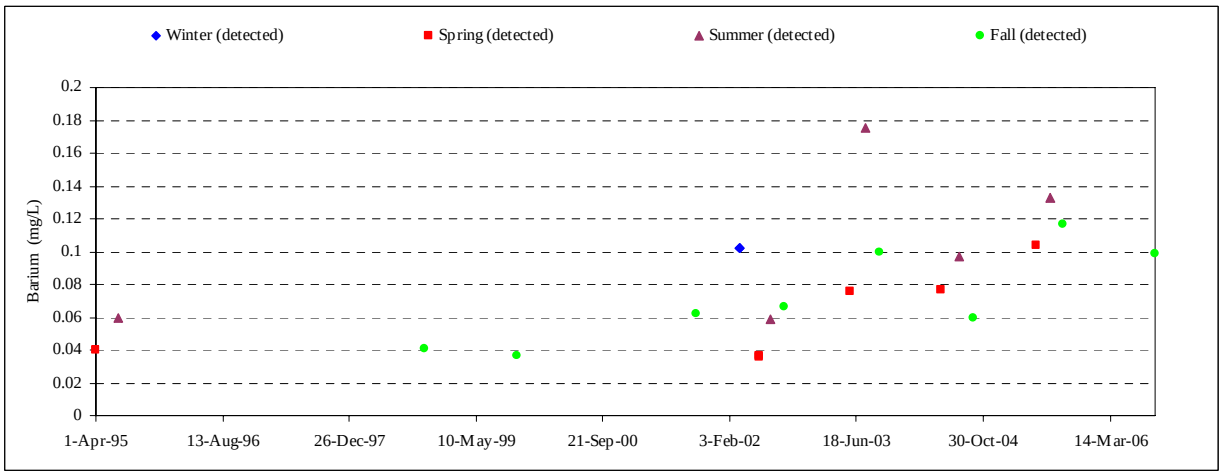
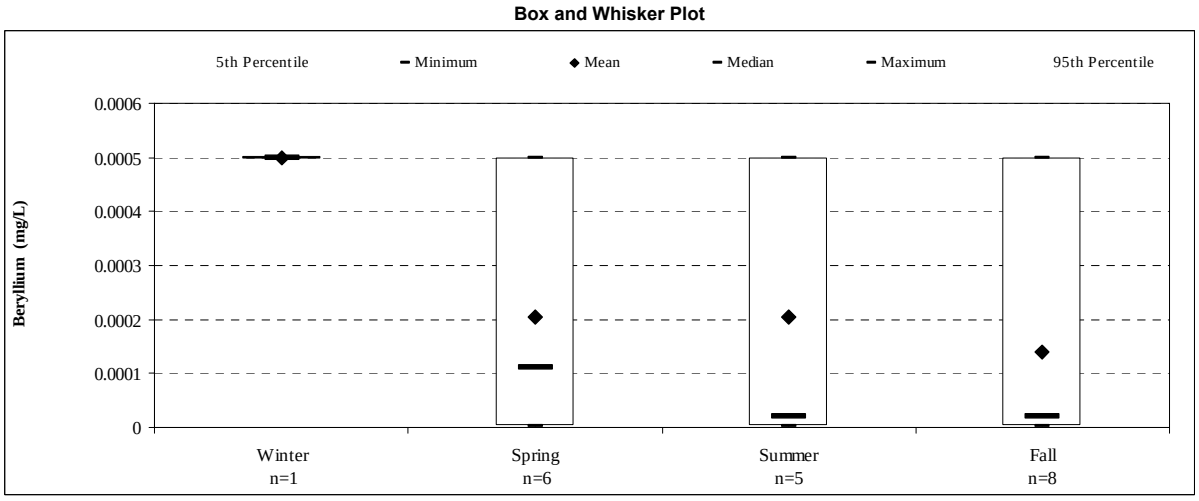


Figure G-2-6-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Stanley Creek



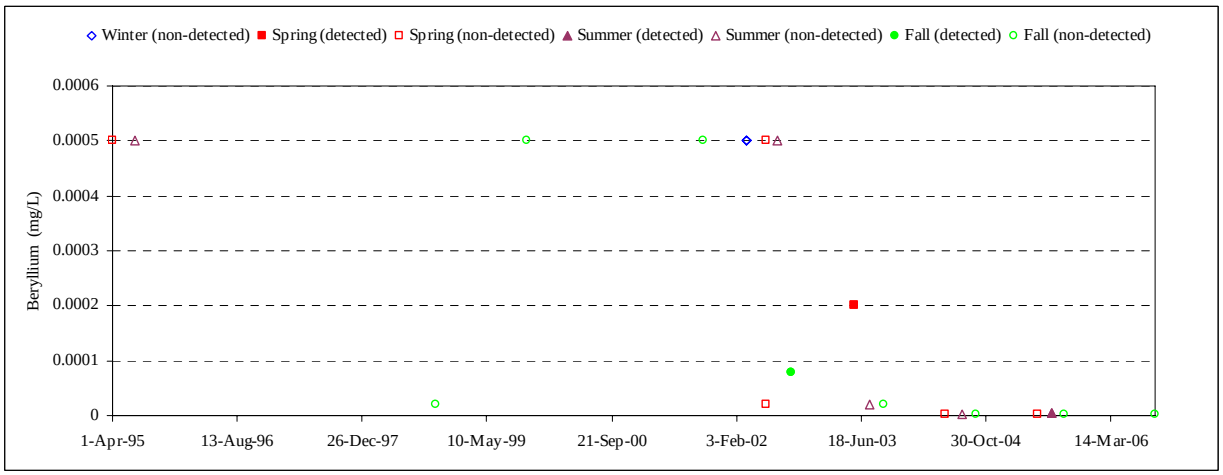
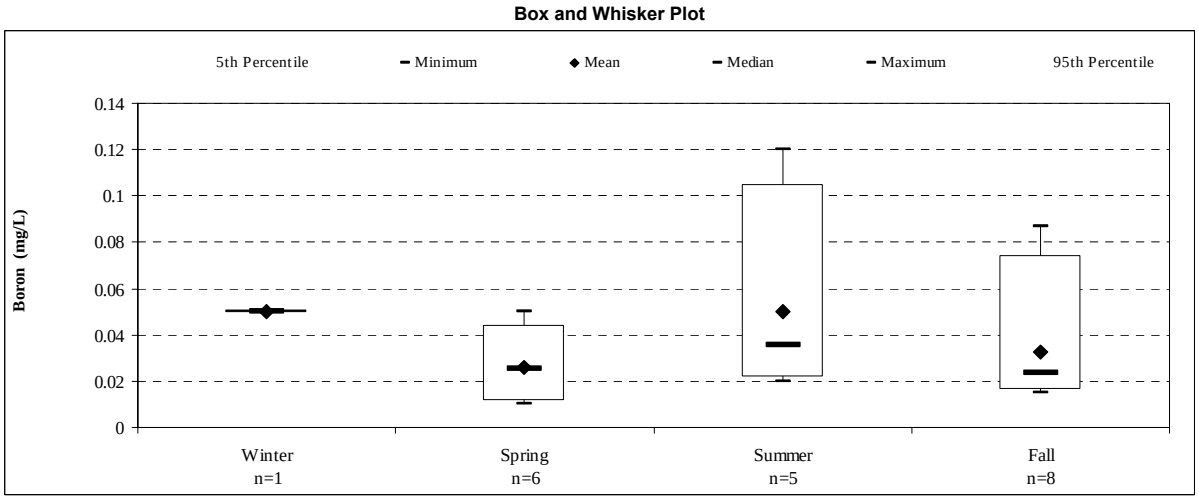


Figure G-2-6-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Stanley Creek



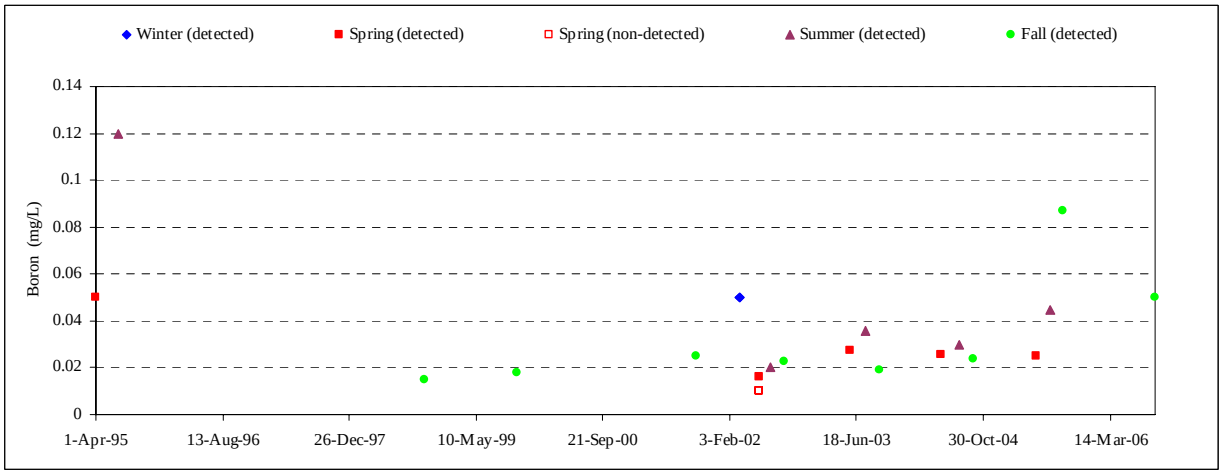
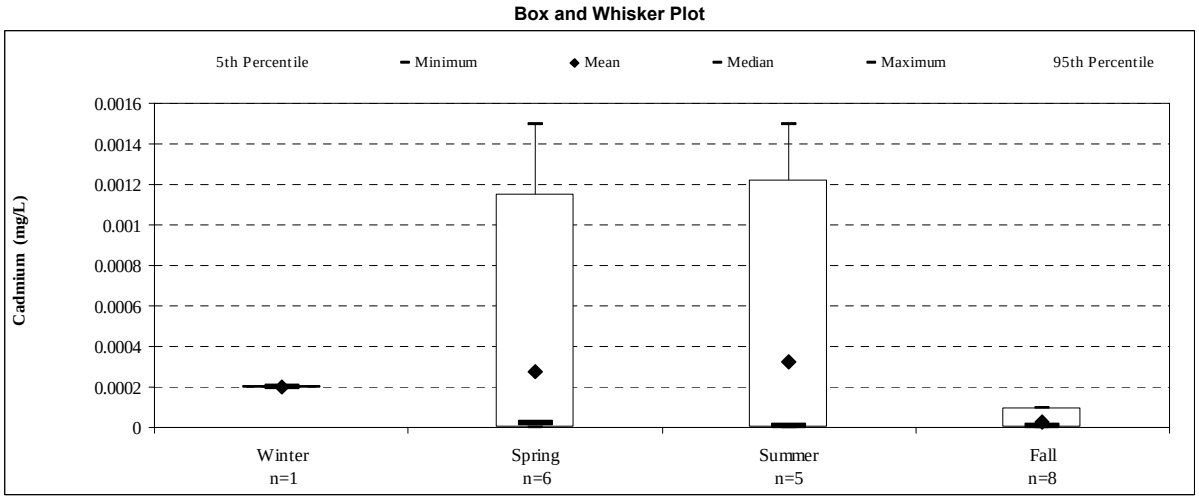


Figure G-2-6-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Stanley Creek



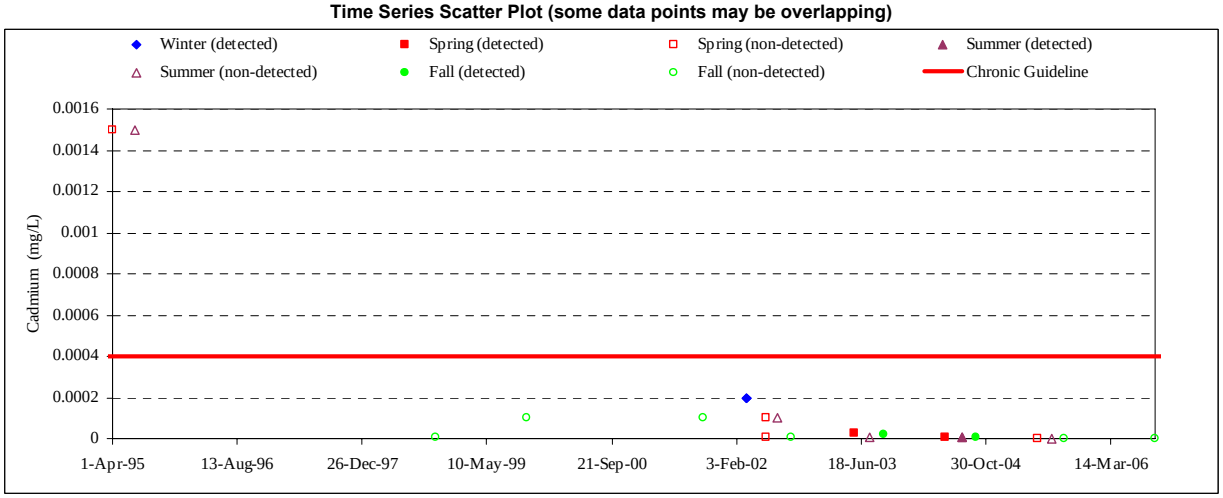
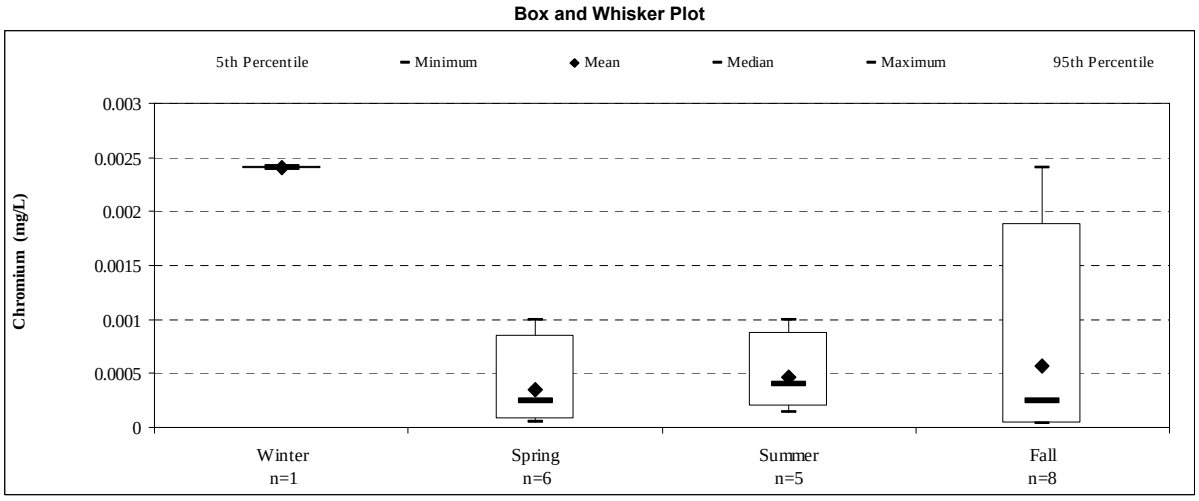


Figure G-2-6-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Stanley Creek



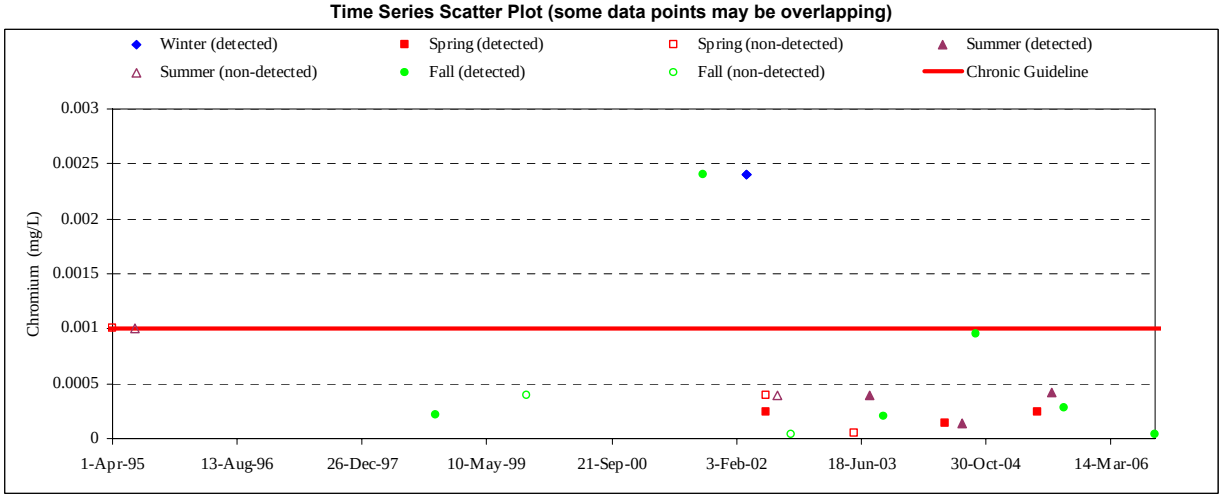
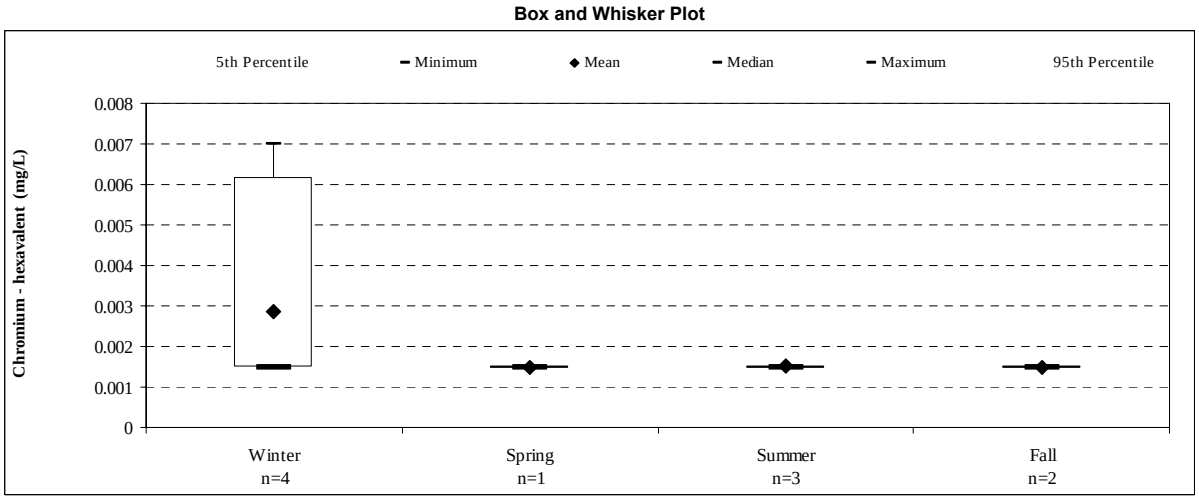


Figure G-2-6-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Stanley Creek



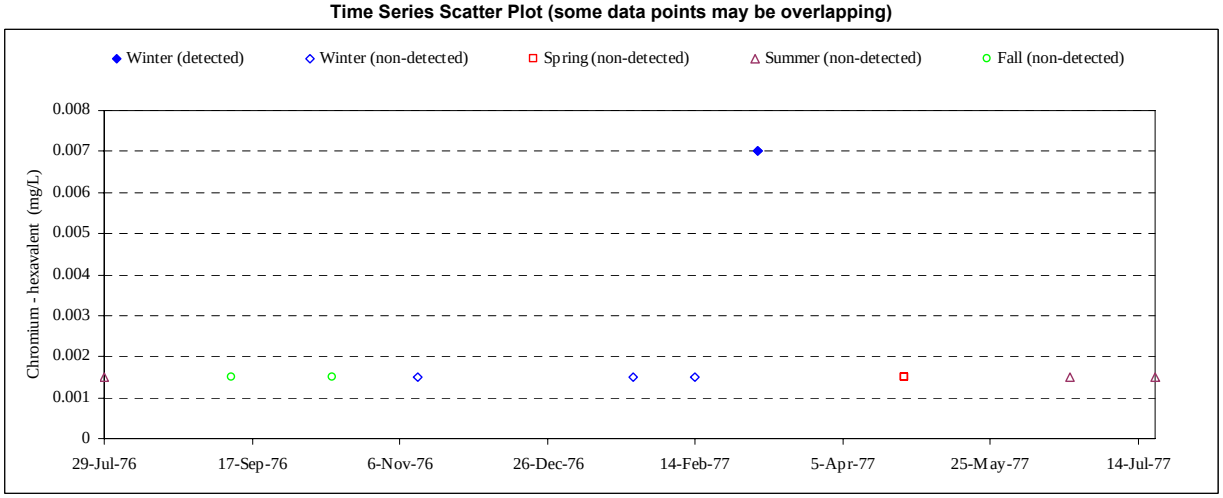
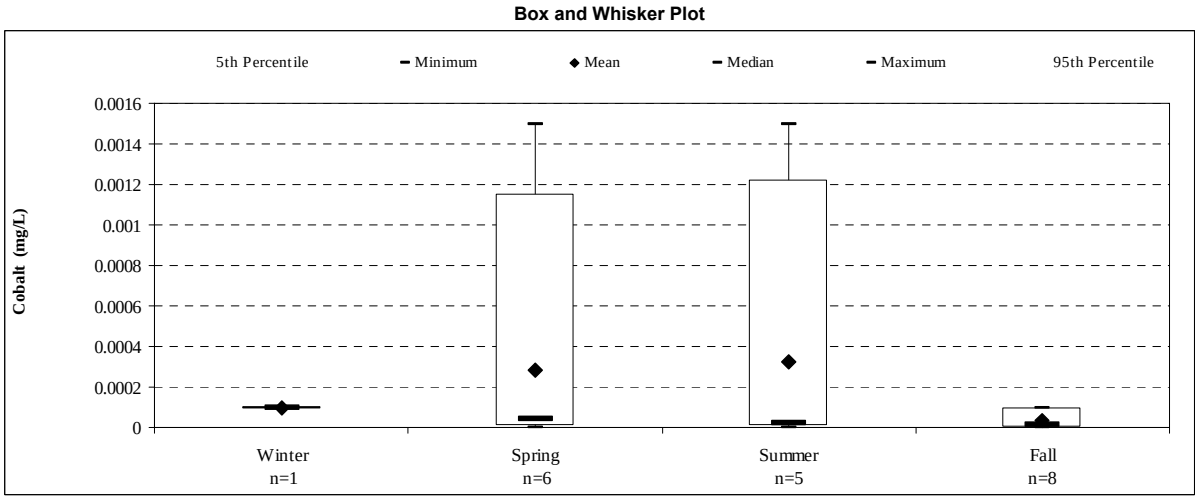


Figure G-2-6-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Stanley Creek



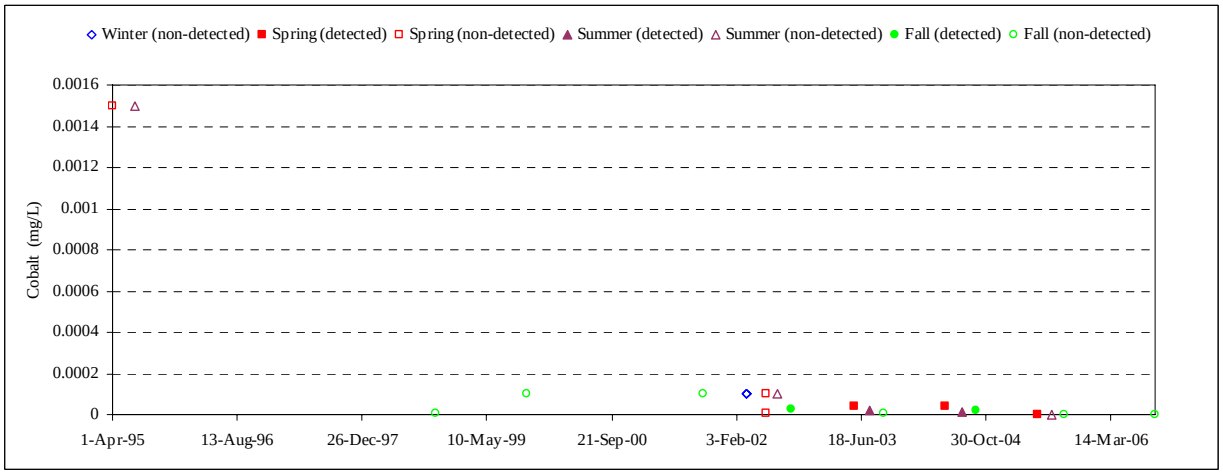
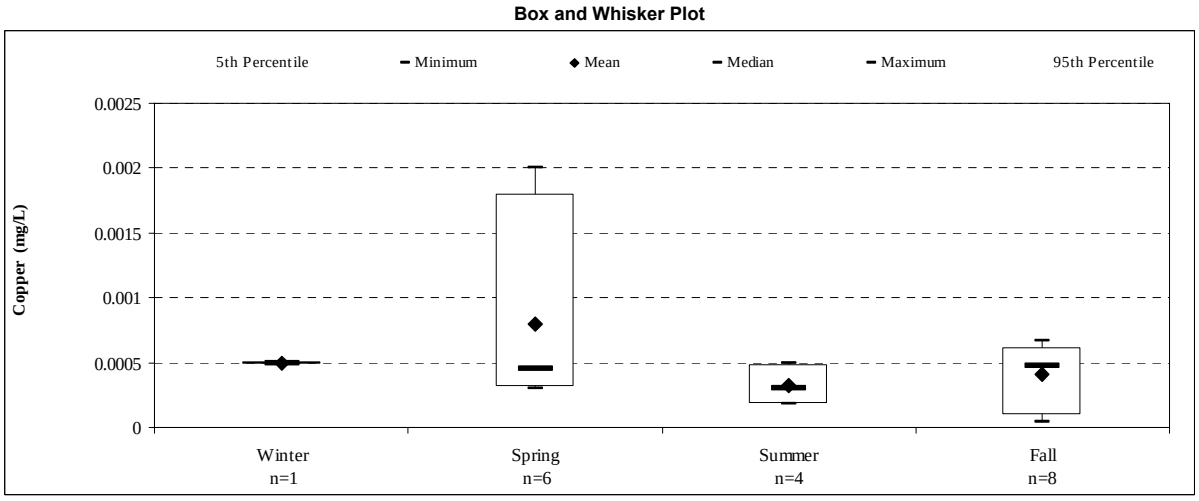


Figure G-2-6-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Stanley Creek



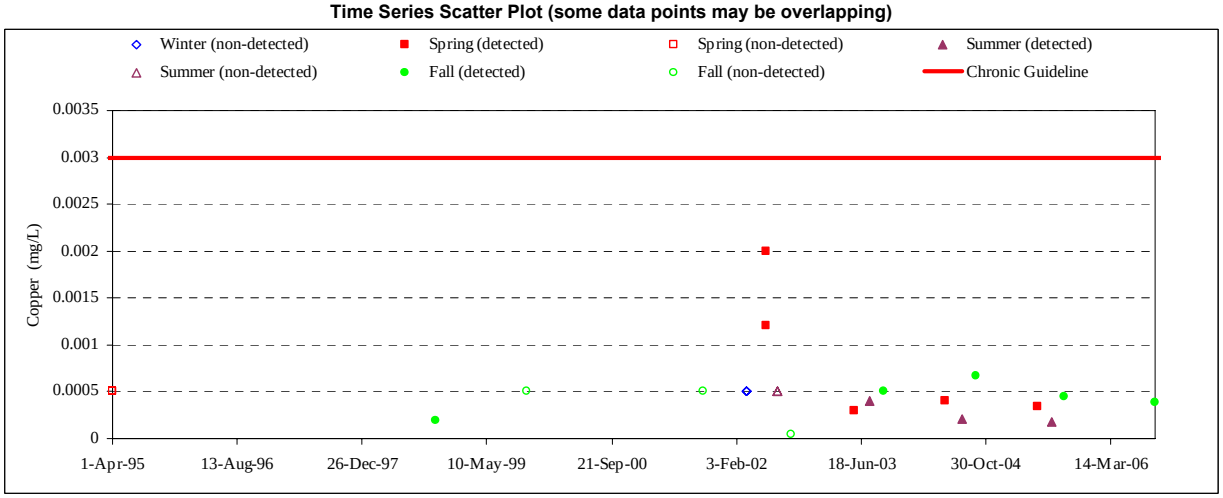
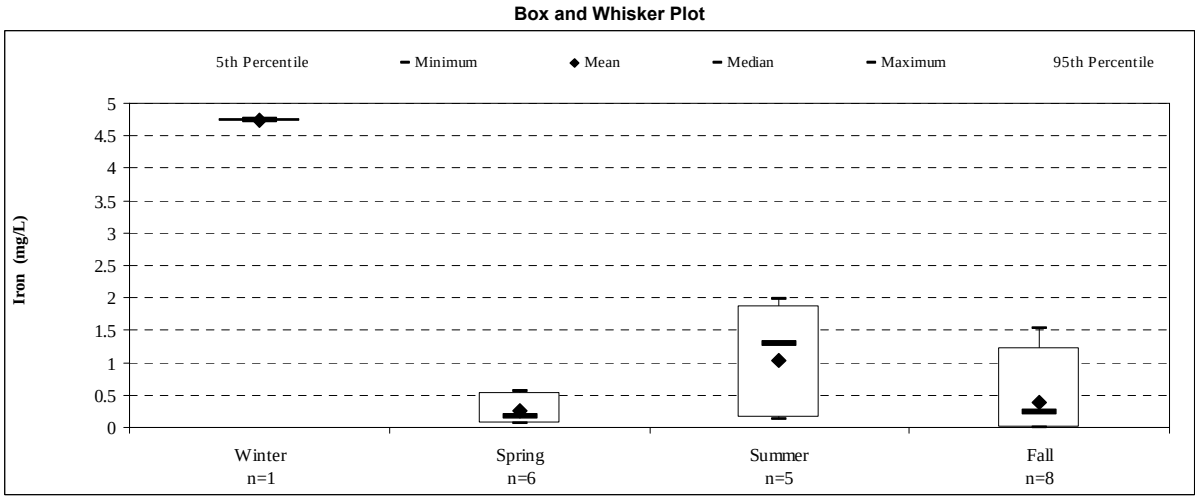


Figure G-2-6-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Stanley Creek



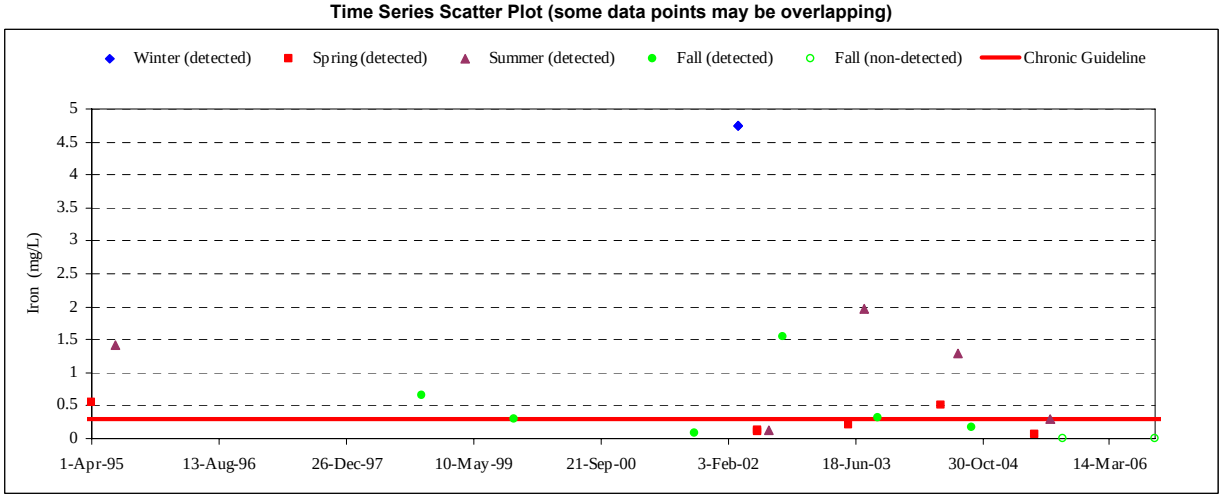
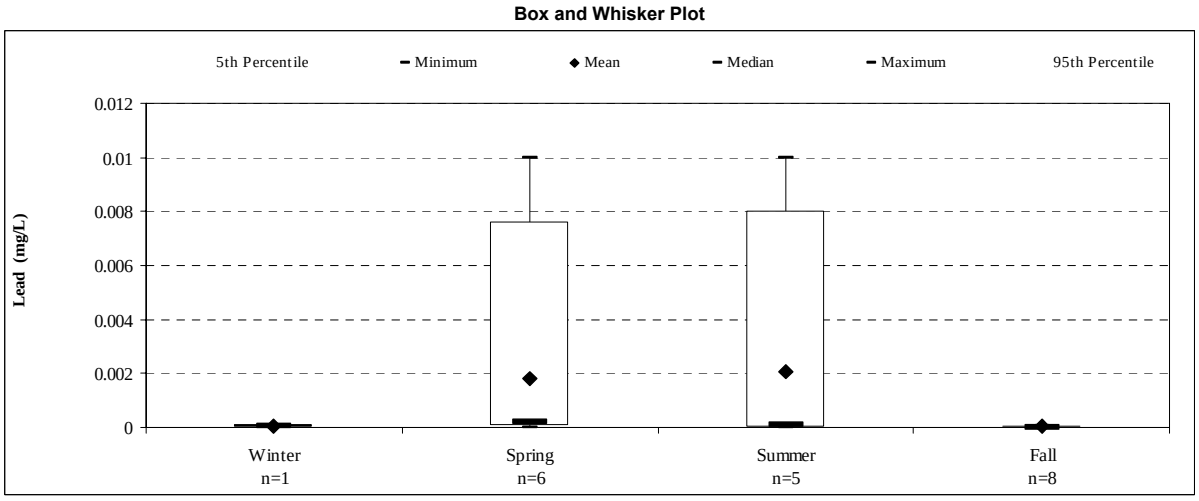


Figure G-2-6-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Stanley Creek



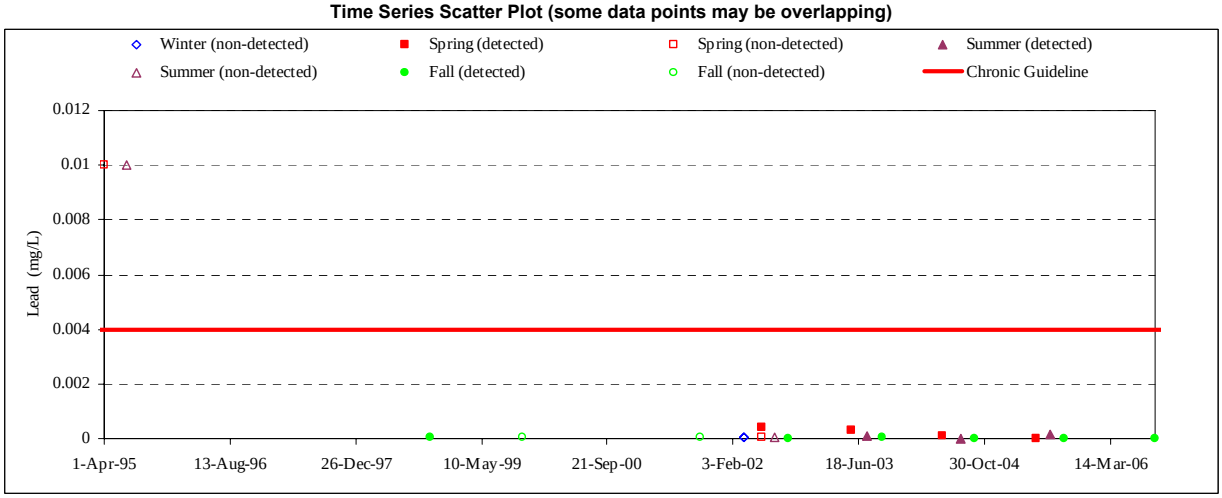
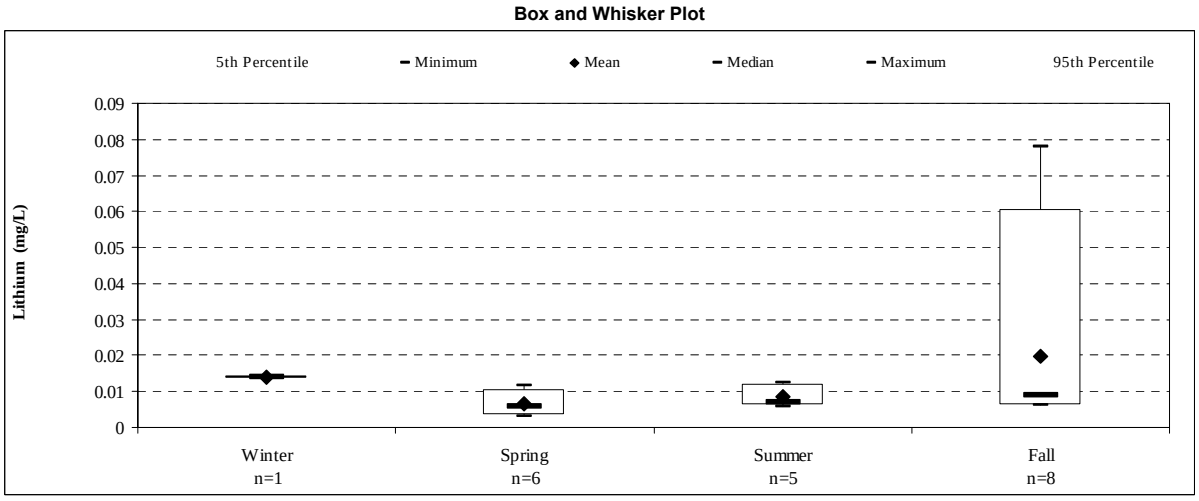


Figure G-2-6-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Stanley Creek



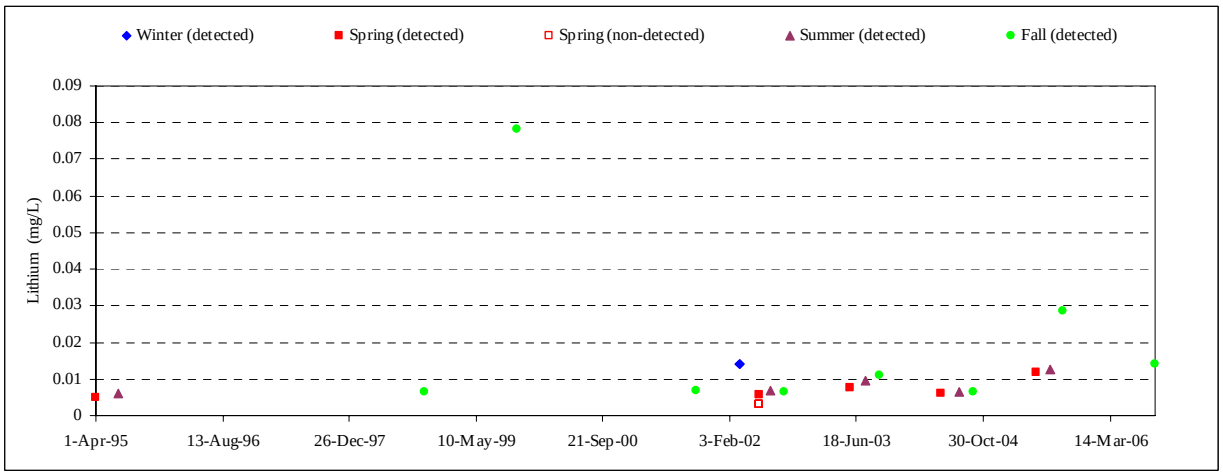
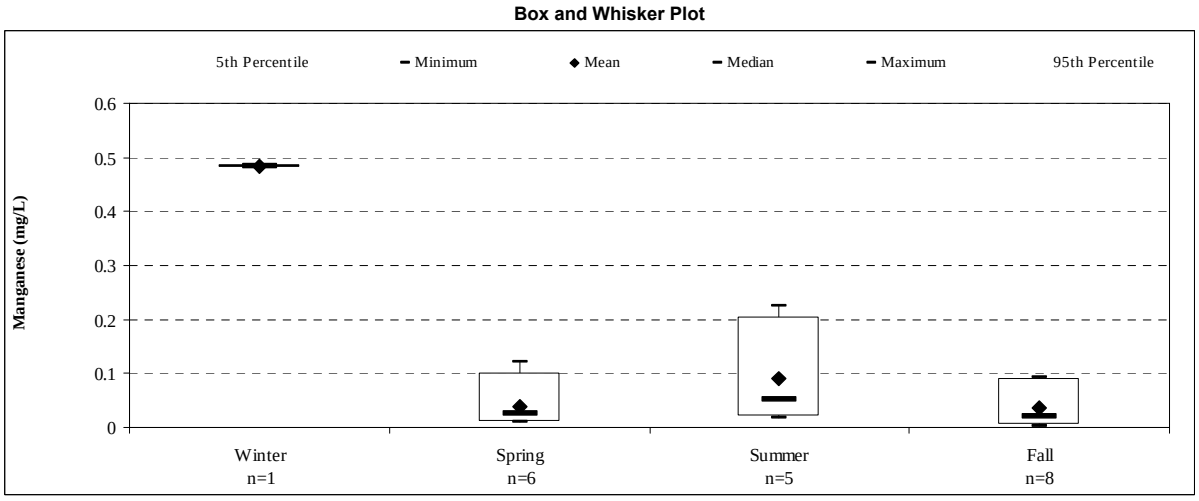


Figure G-2-6-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Stanley Creek



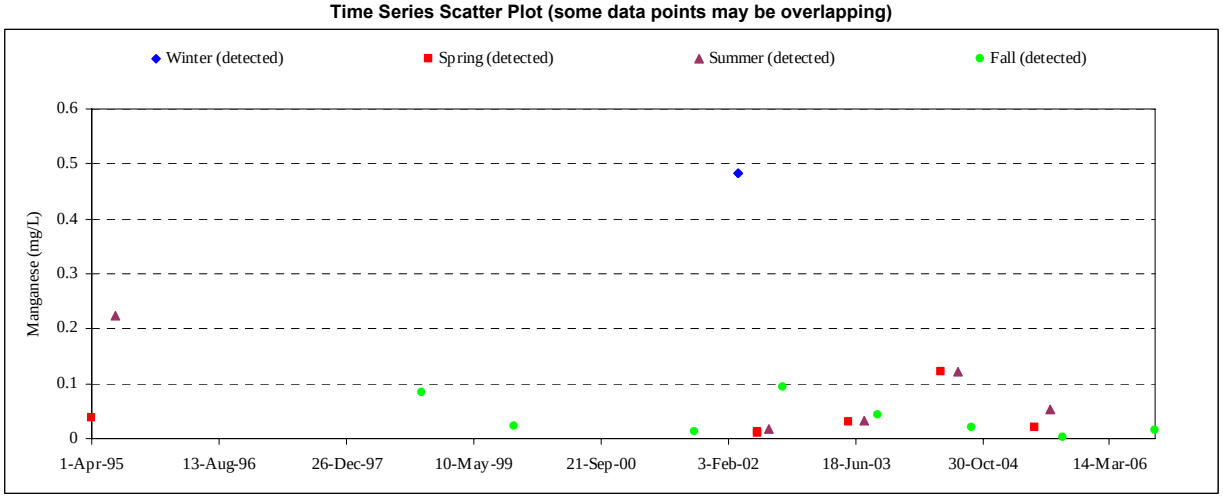
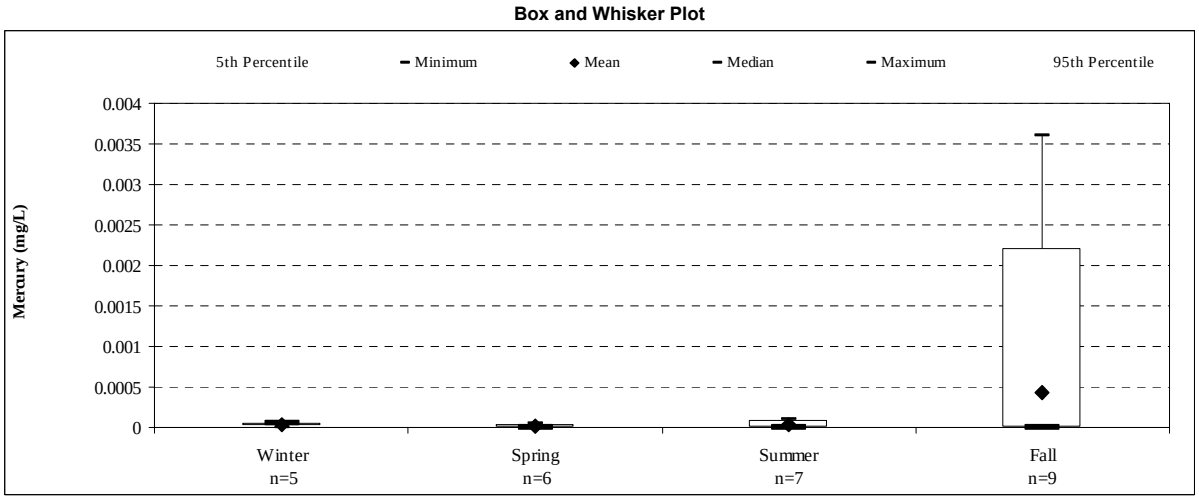


Figure G-2-6-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Stanley Creek



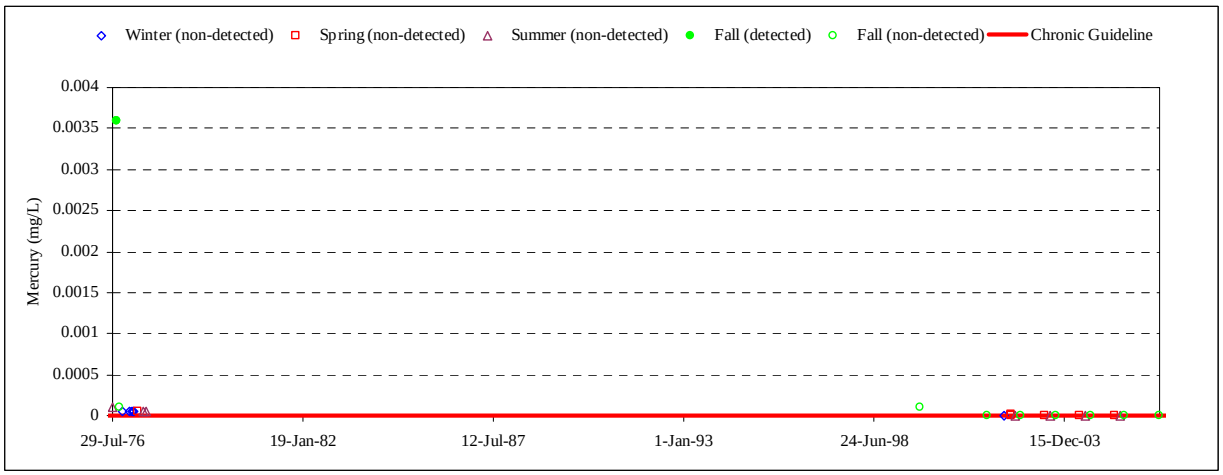
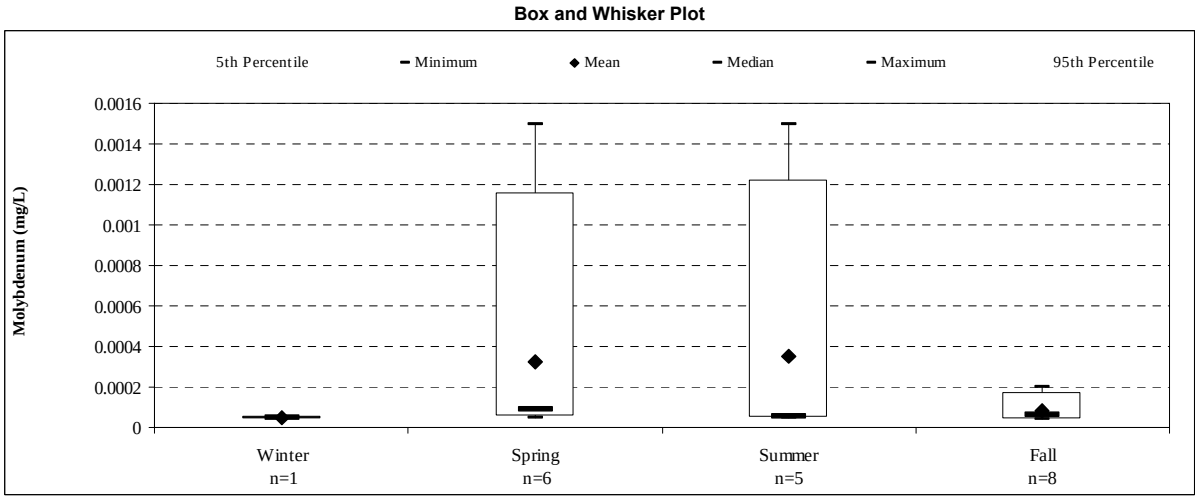


Figure G-2-6-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Stanley Creek



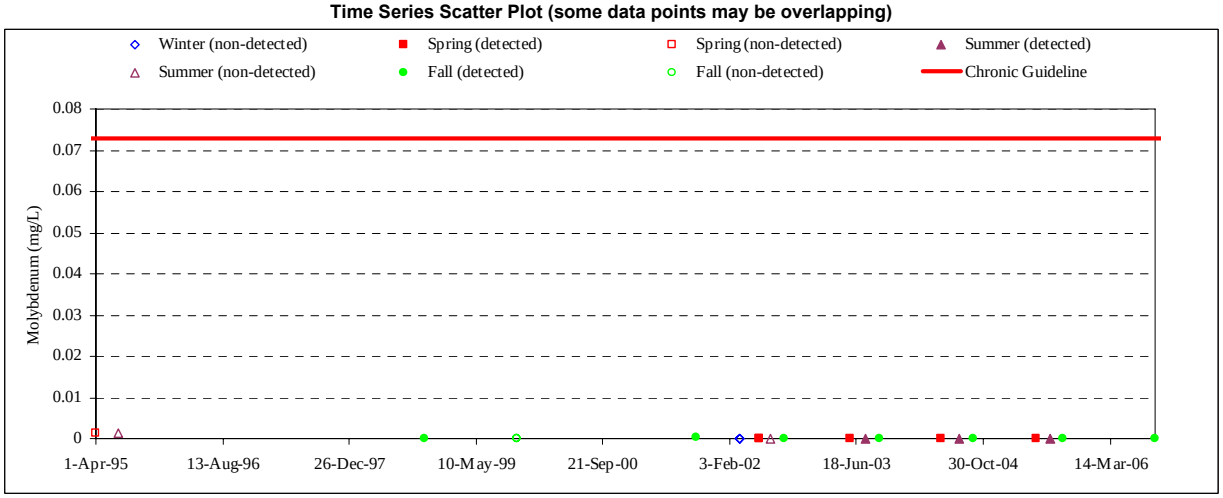
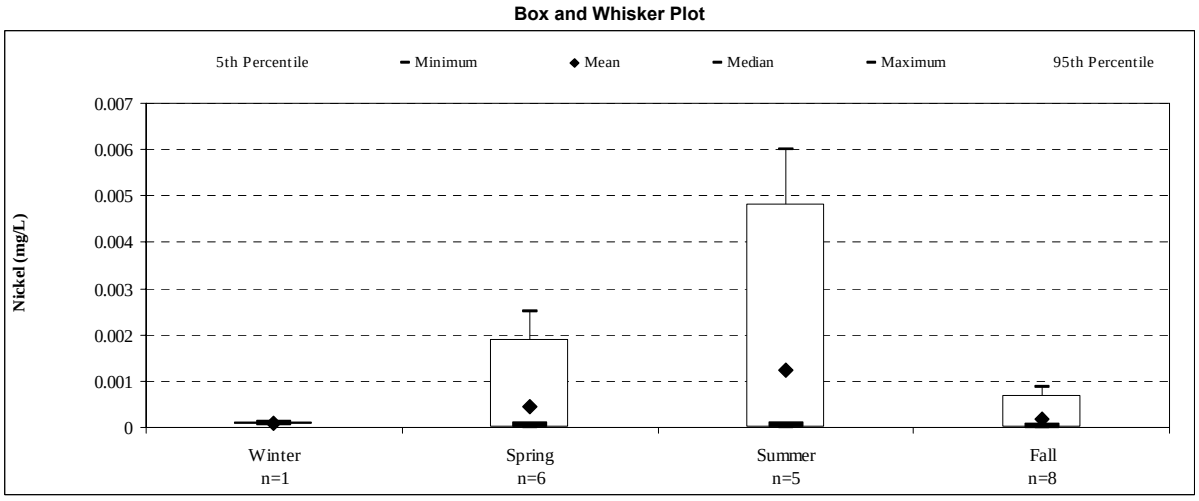


Figure G-2-6-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Stanley Creek



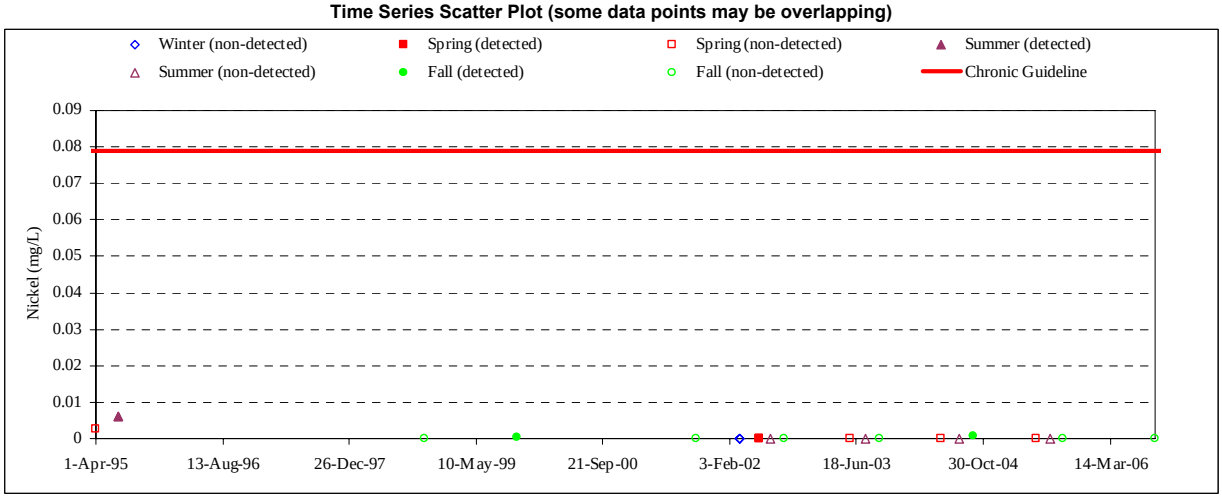
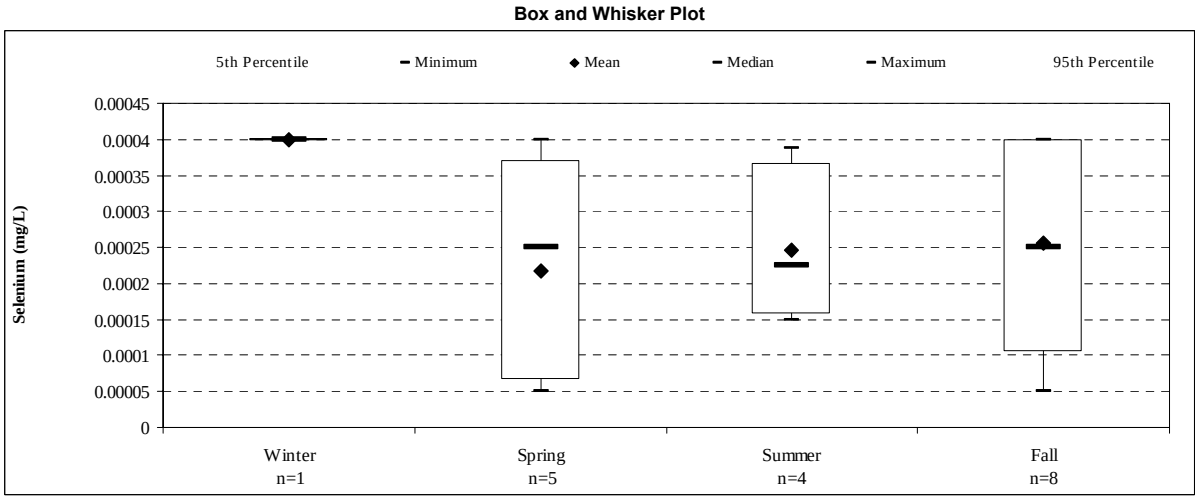


Figure G-2-6-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Stanley Creek



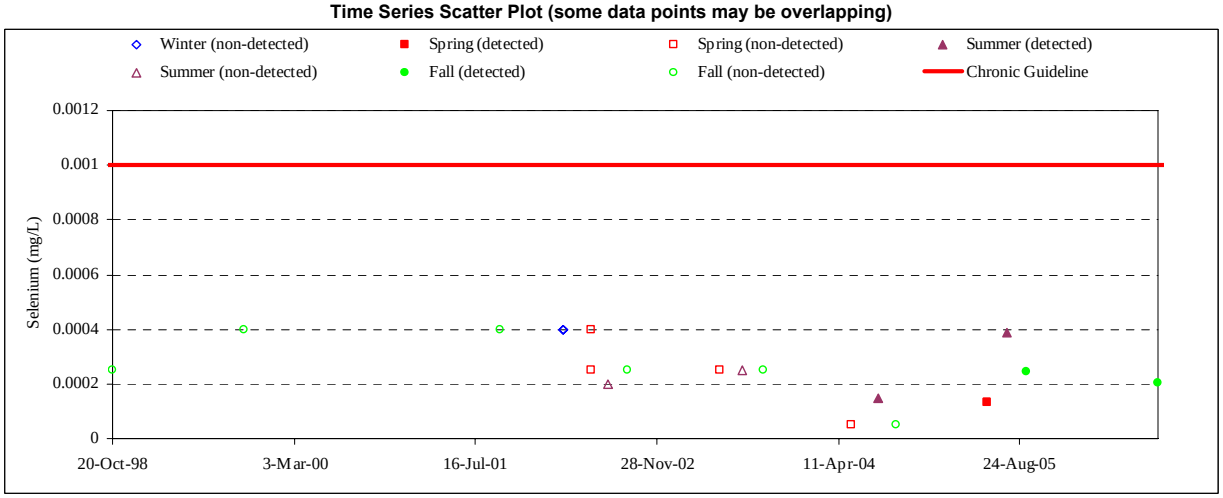
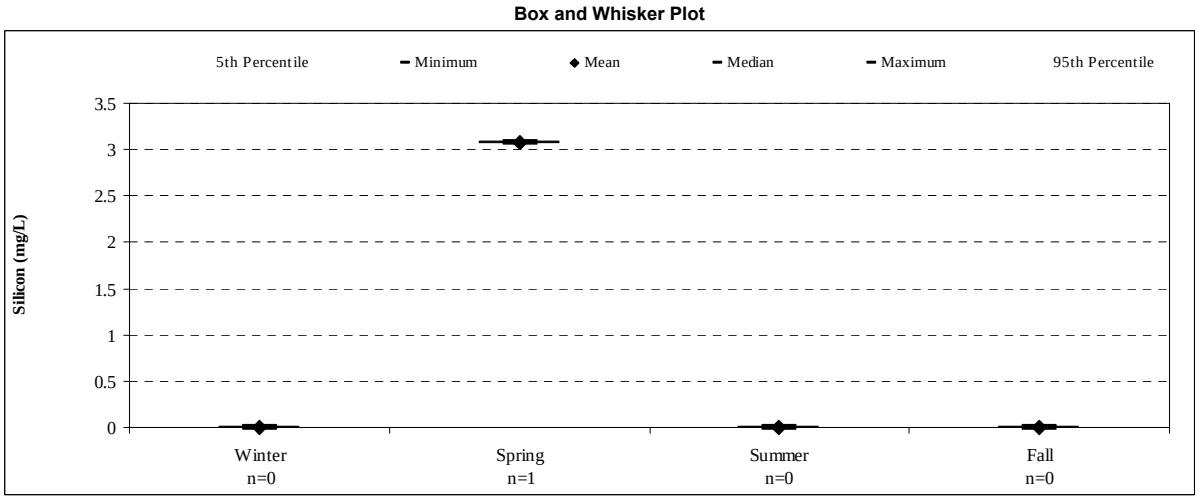


Figure G-2-6-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Stanley Creek



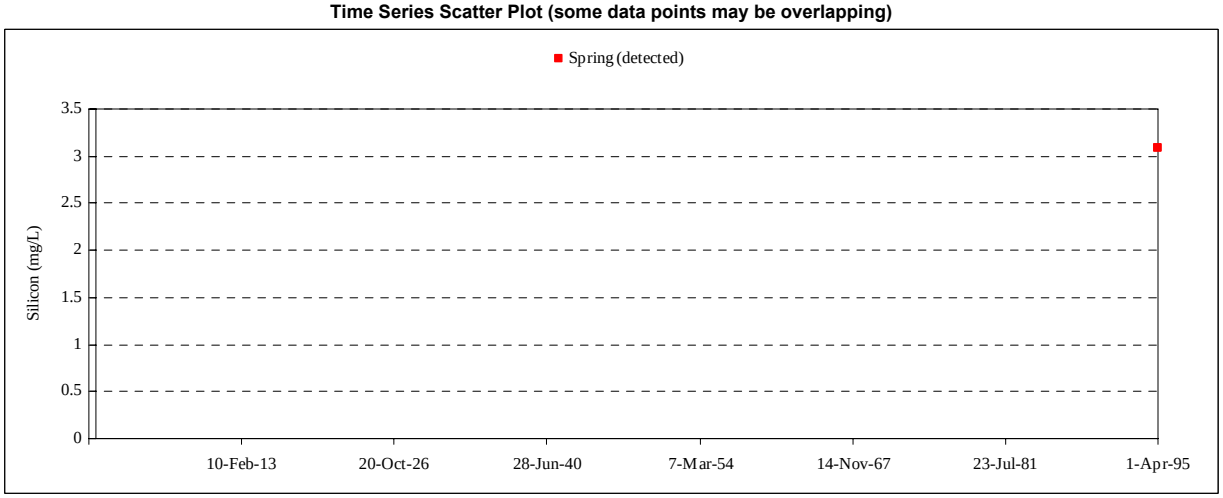
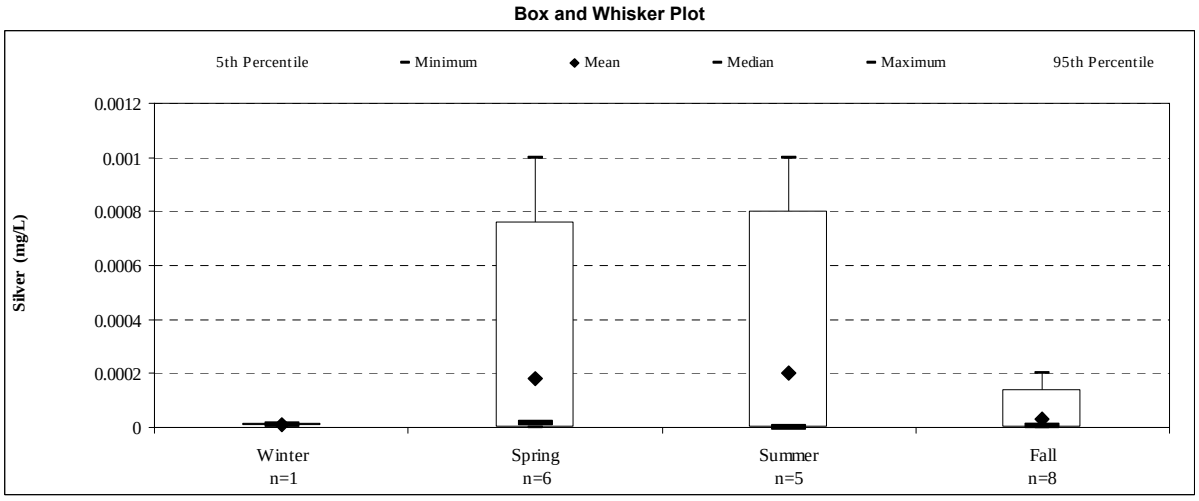


Figure G-2-6-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Stanley Creek



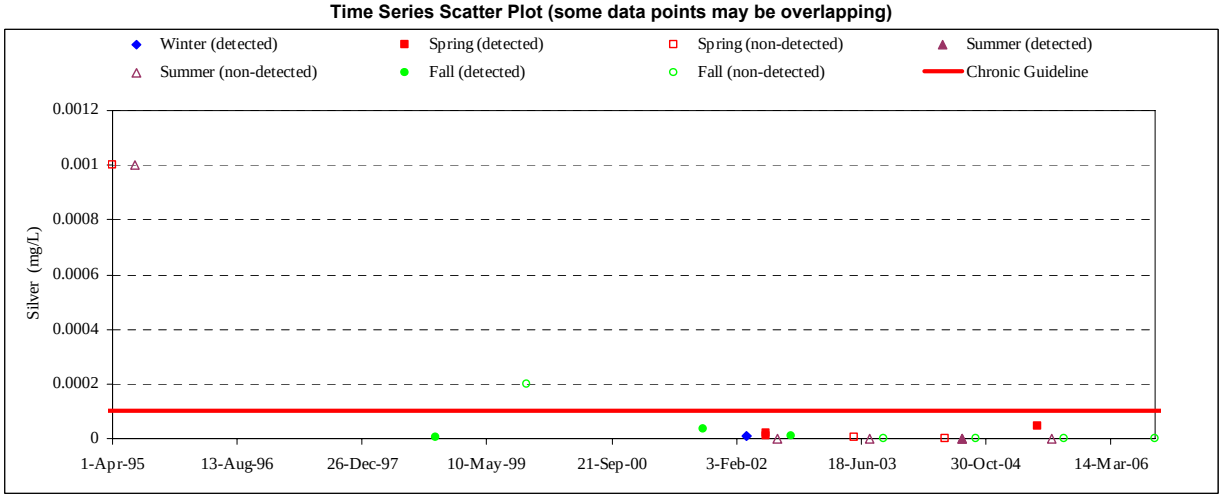
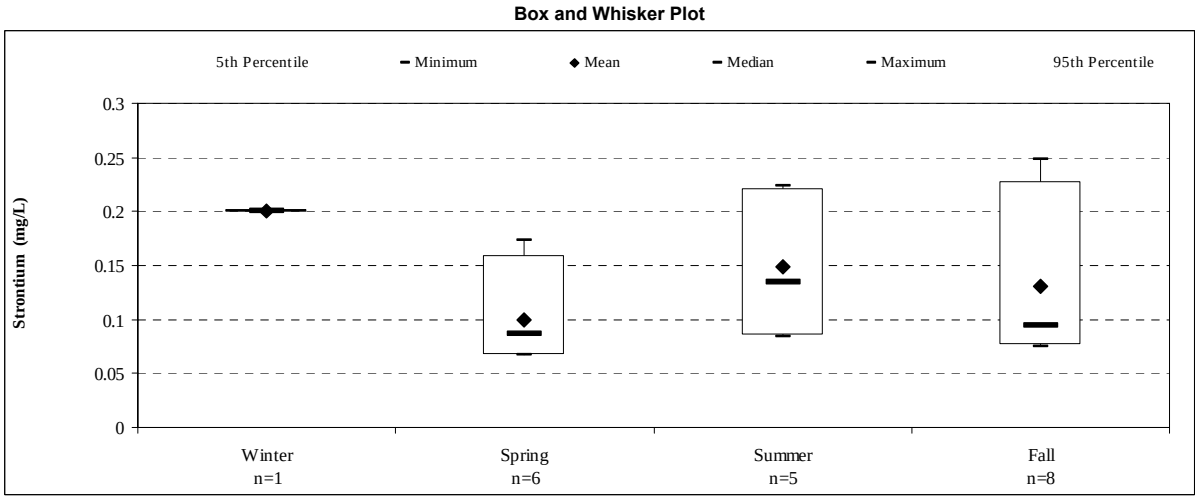


Figure G-2-6-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Stanley Creek



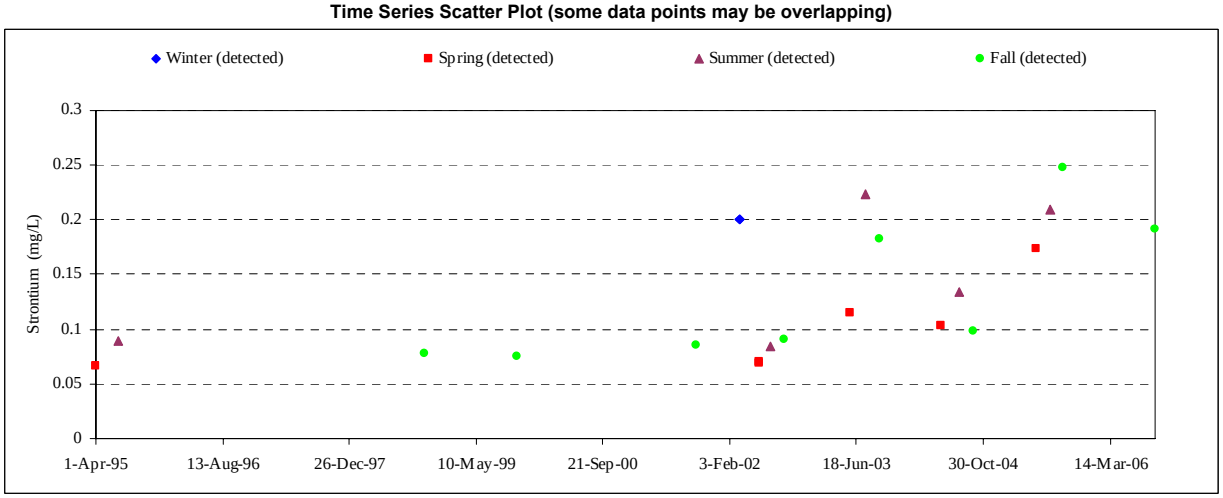
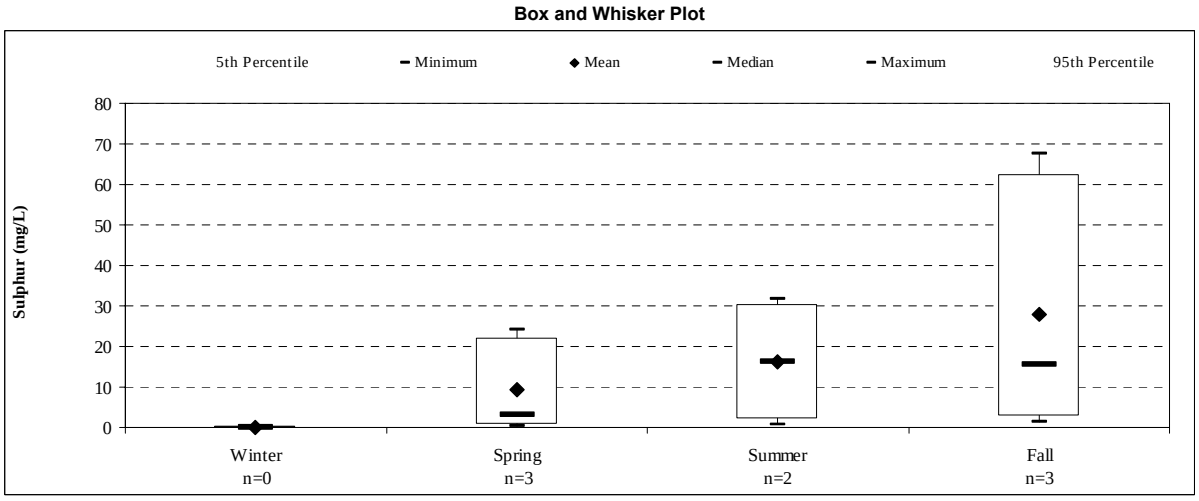


Figure G-2-6-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Stanley Creek



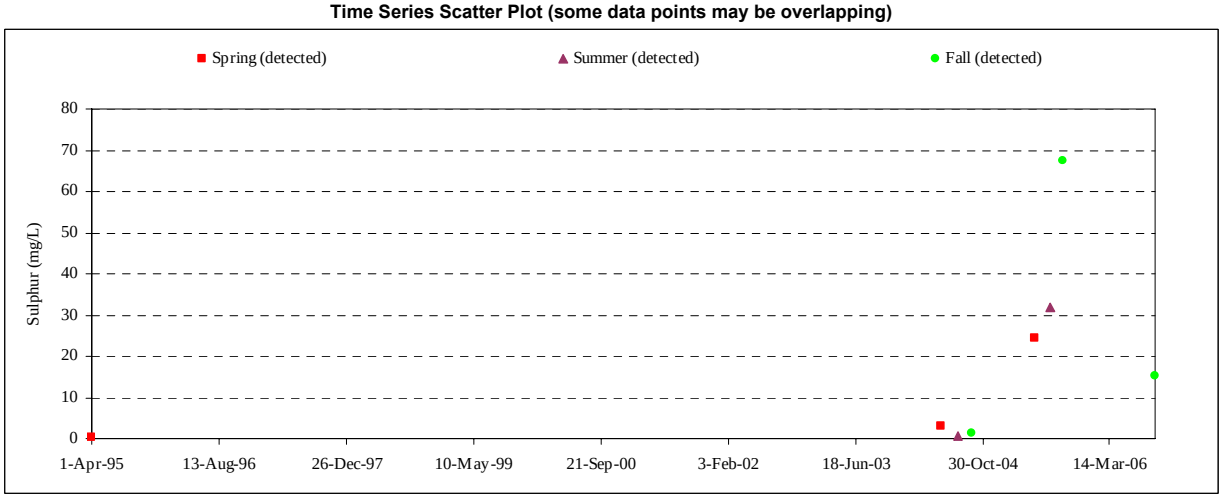
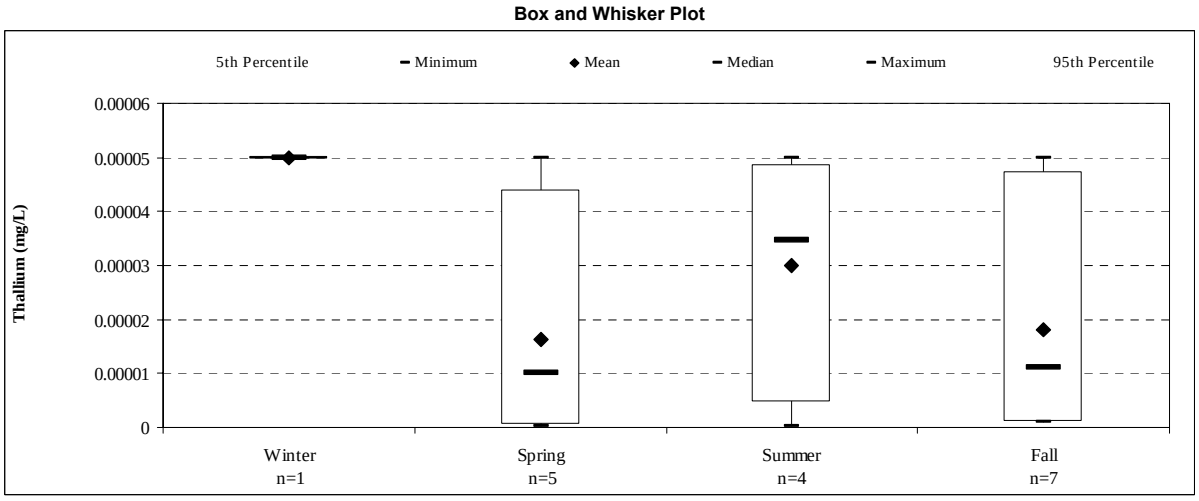


Figure G-2-6-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Stanley Creek



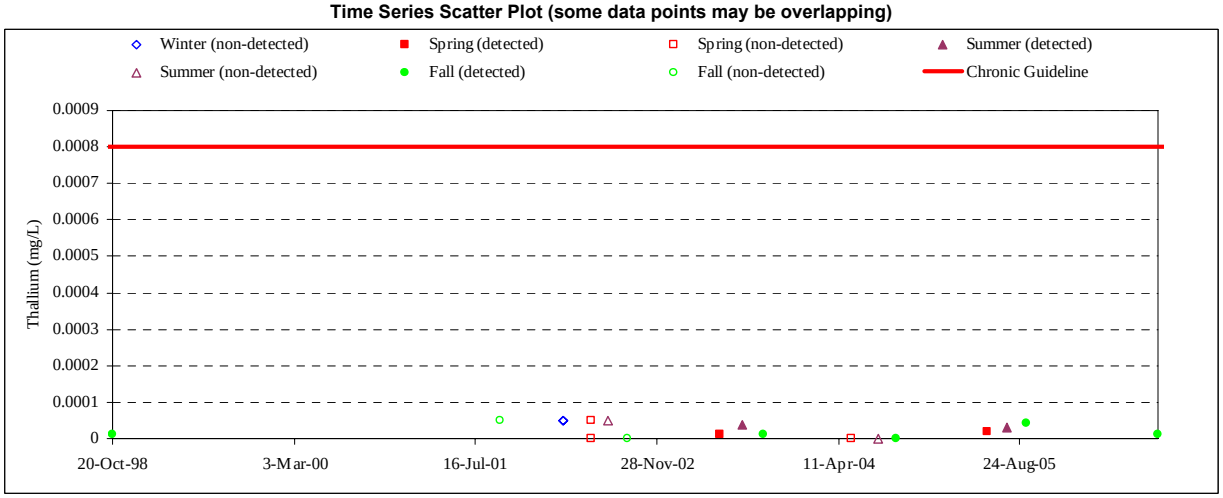
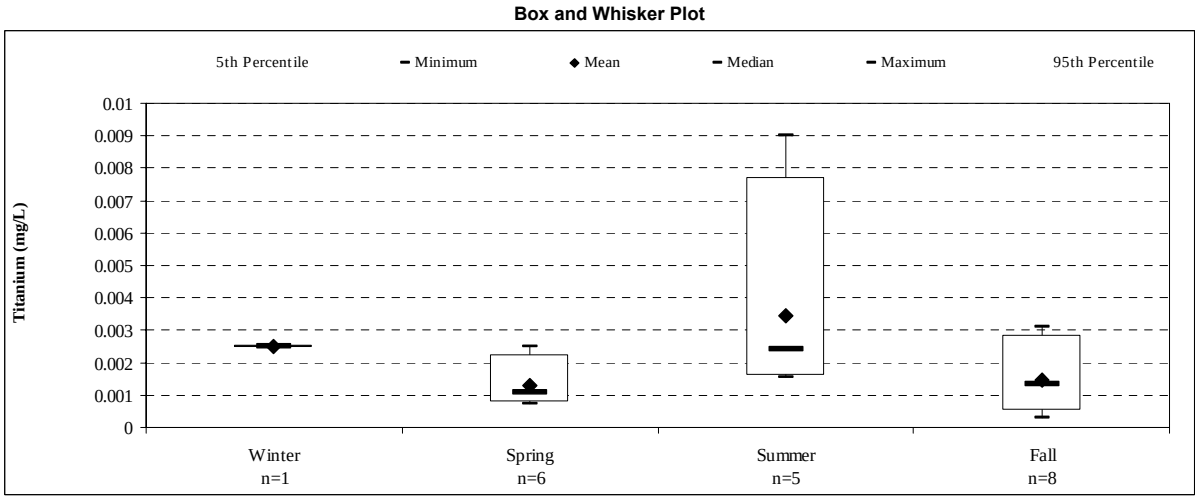


Figure G-2-6-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Stanley Creek



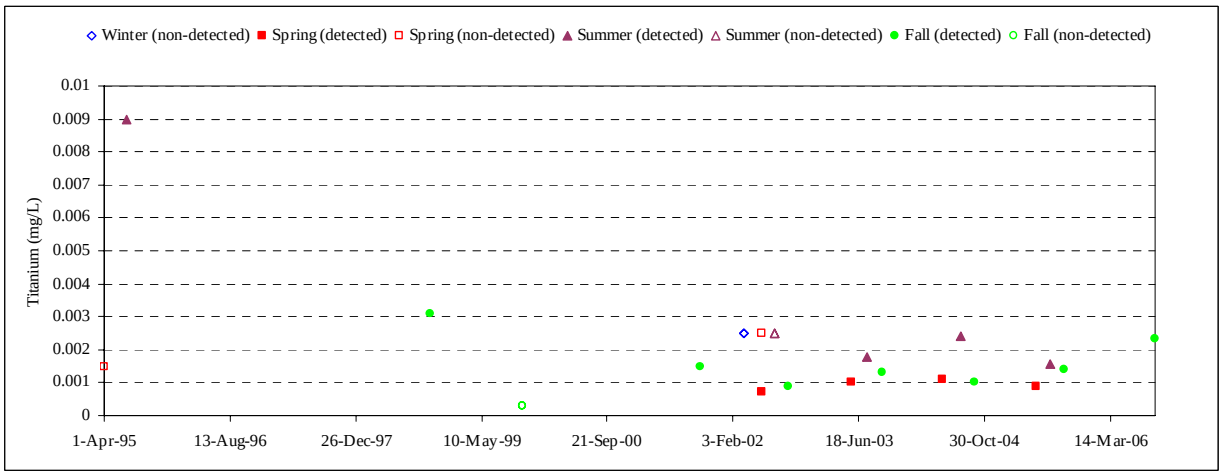
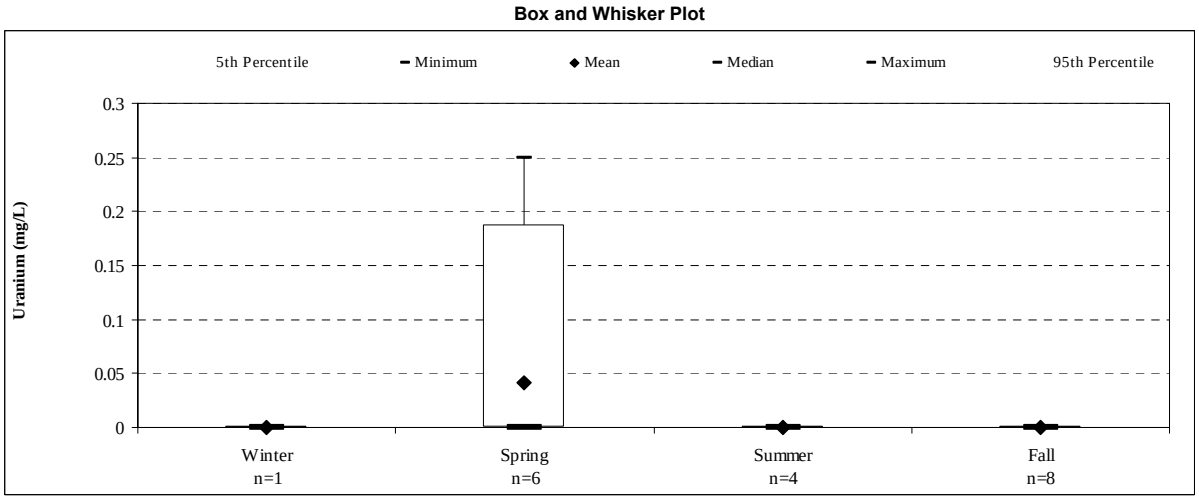


Figure G-2-6-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Stanley Creek



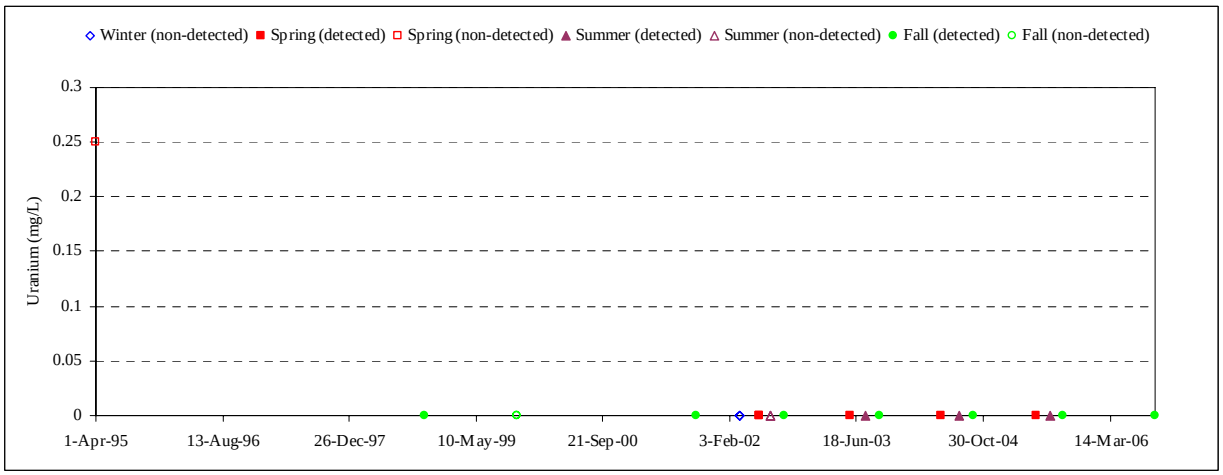
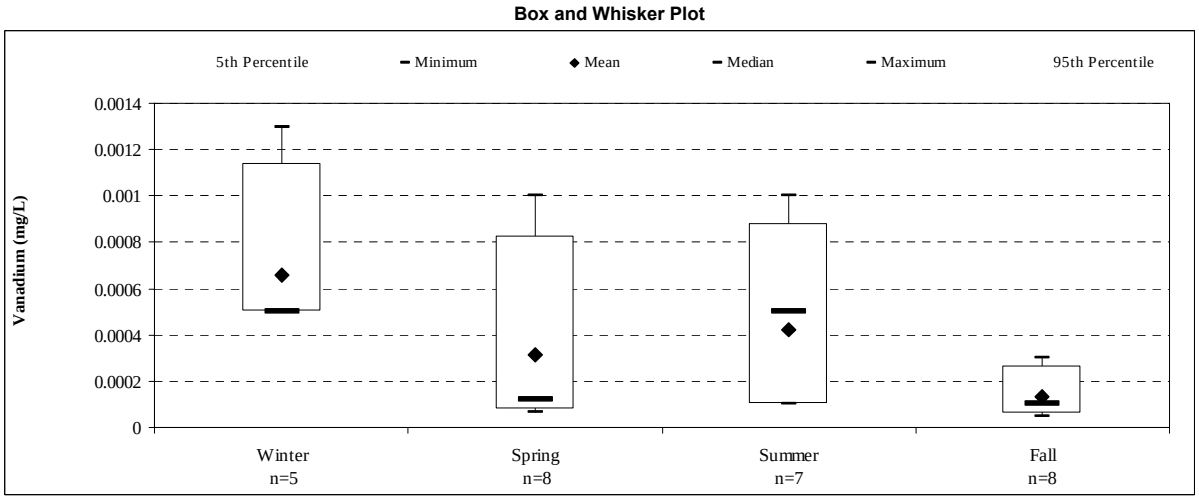


Figure G-2-6-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Stanley Creek



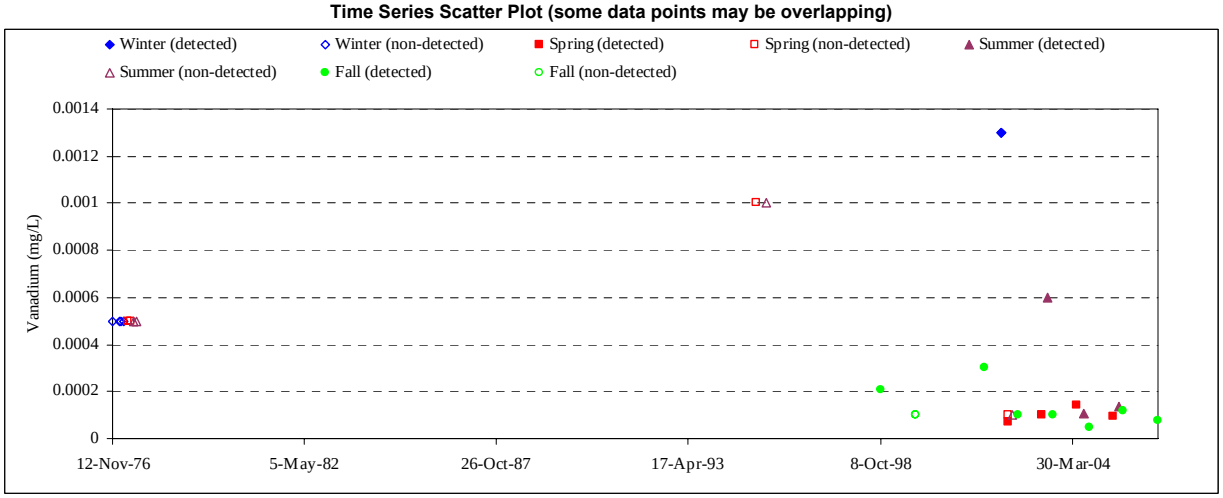
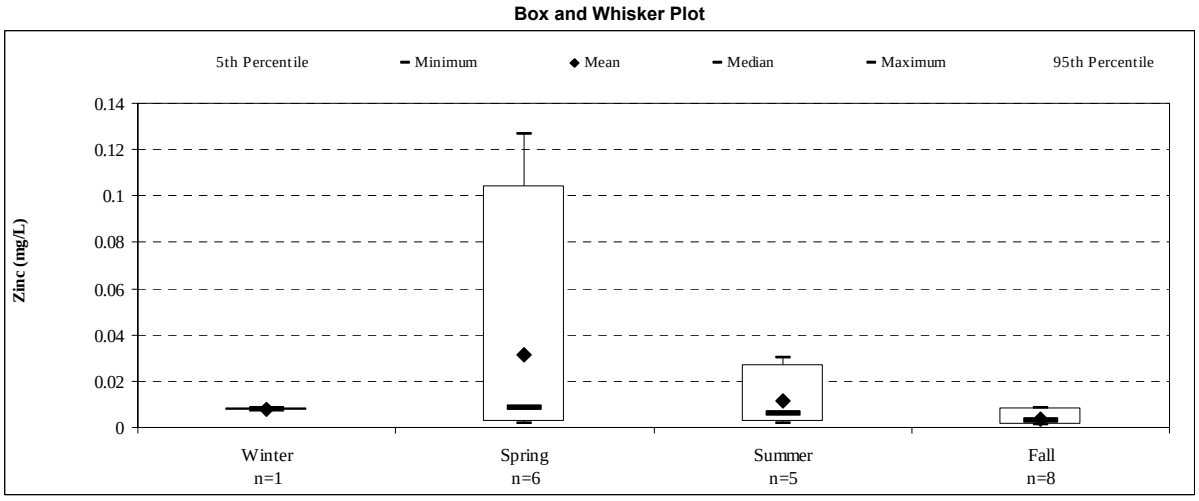


Figure G-2-6-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Stanley Creek



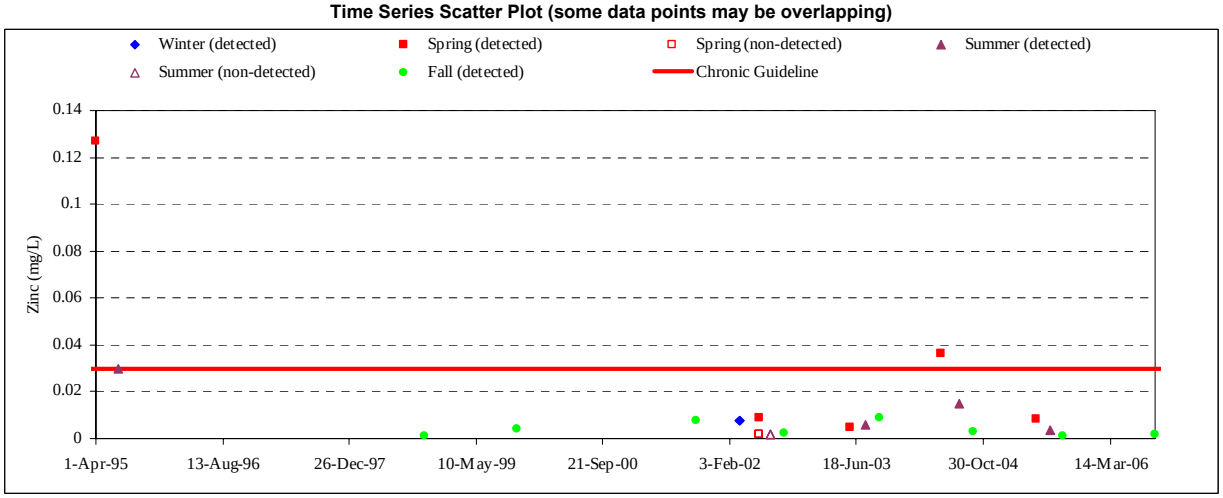
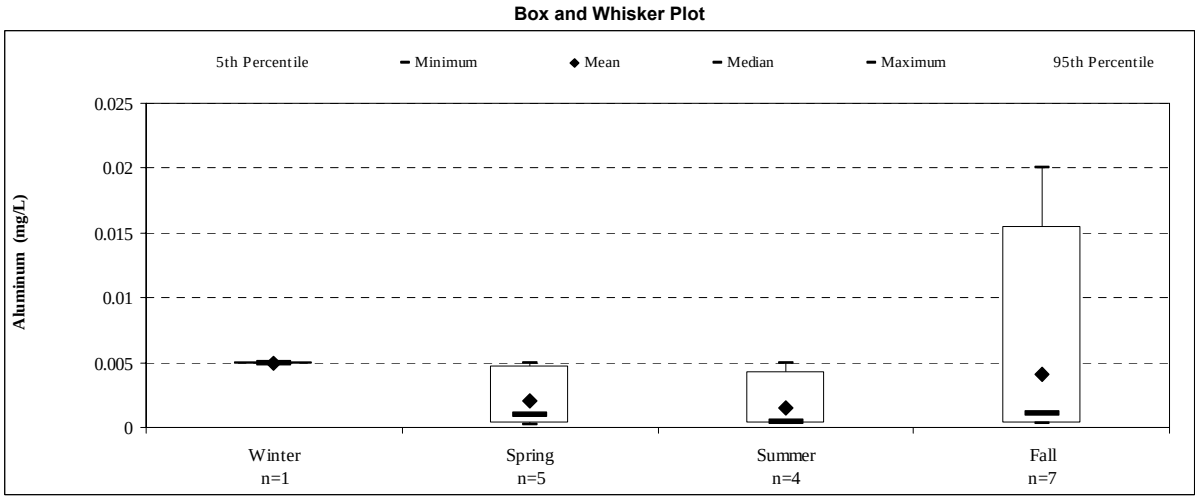


Figure G-2-6-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Stanley Creek



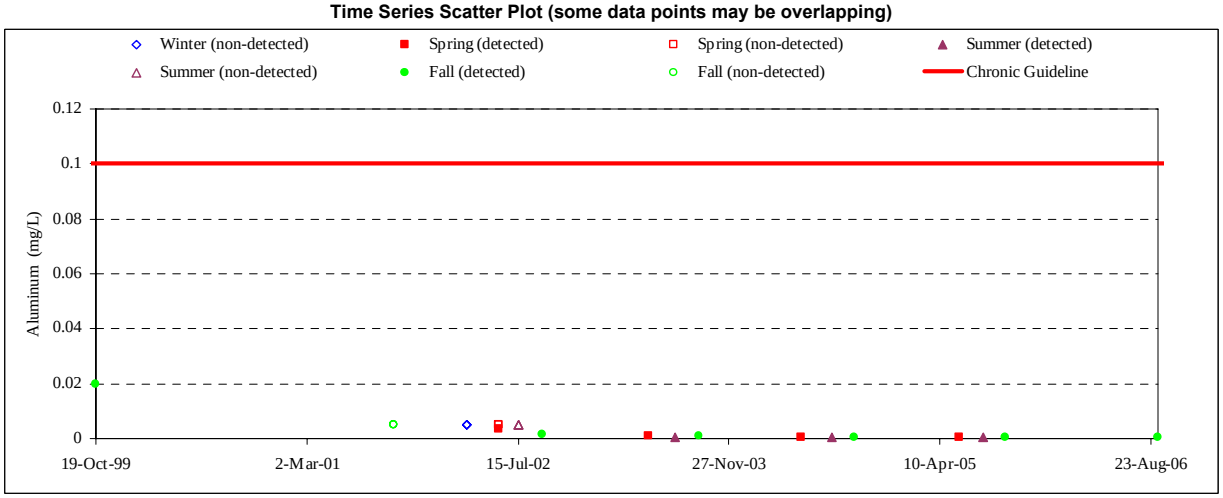
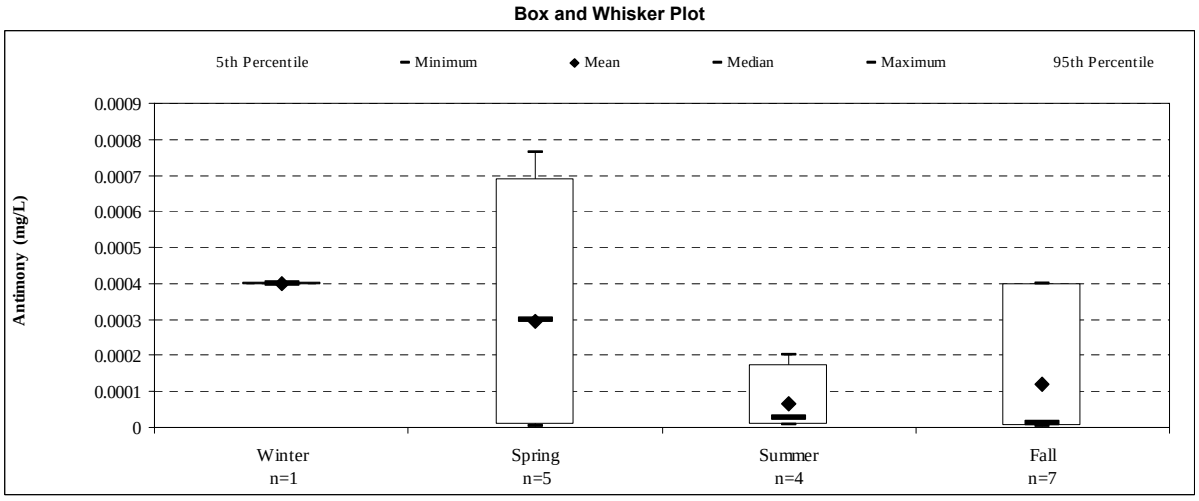


Figure G-2-6-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Stanley Creek



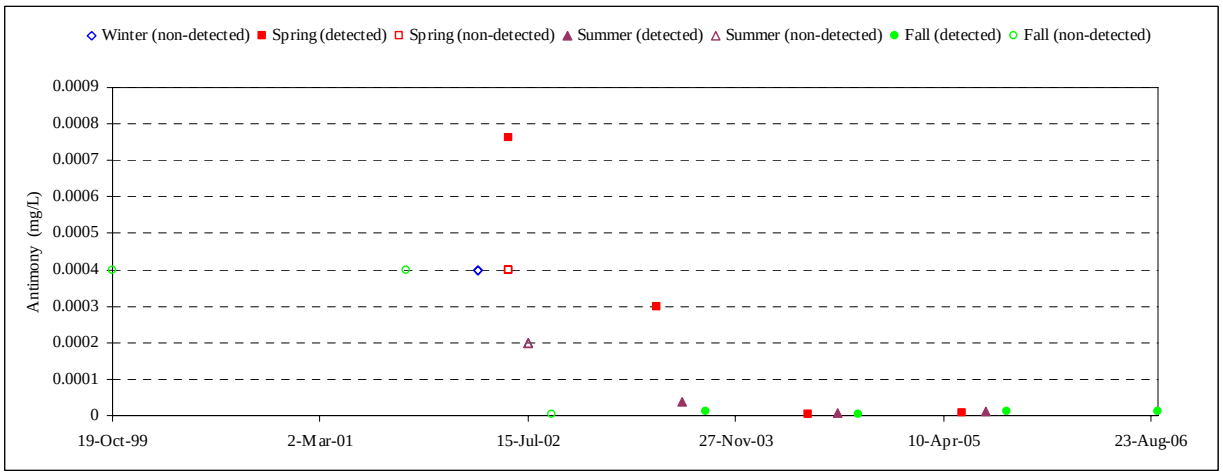
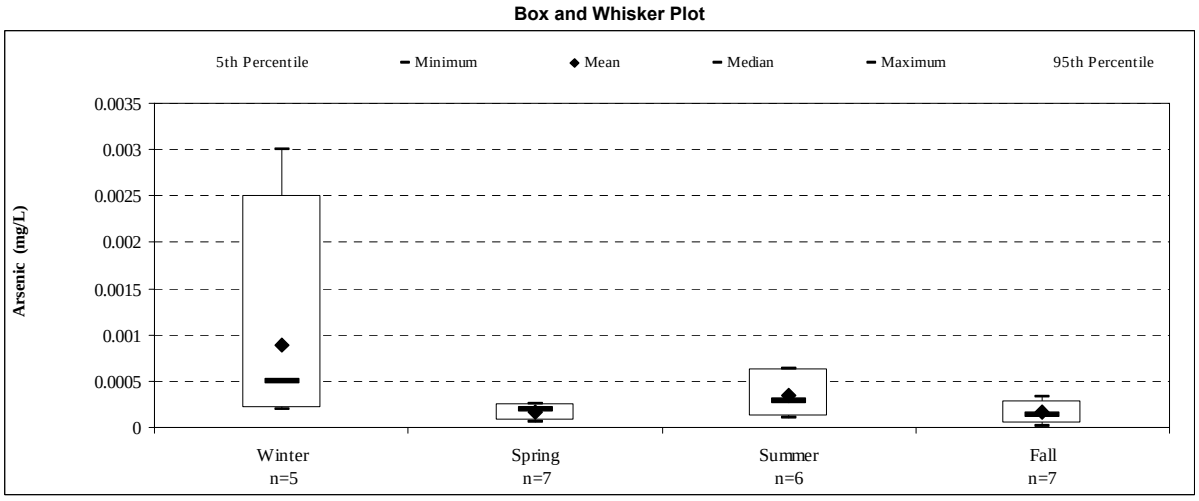


Figure G-2-6-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Stanley Creek



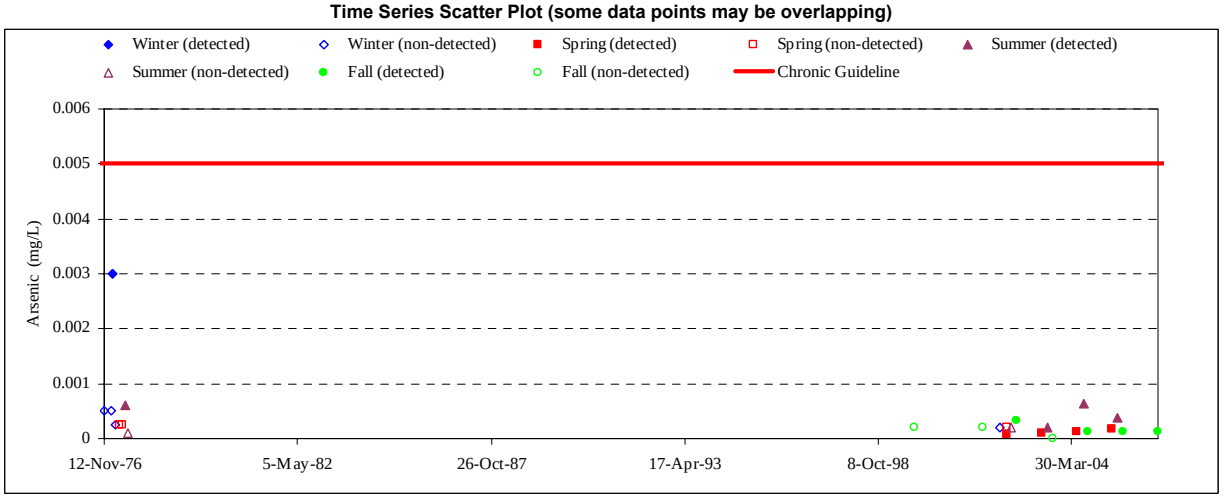
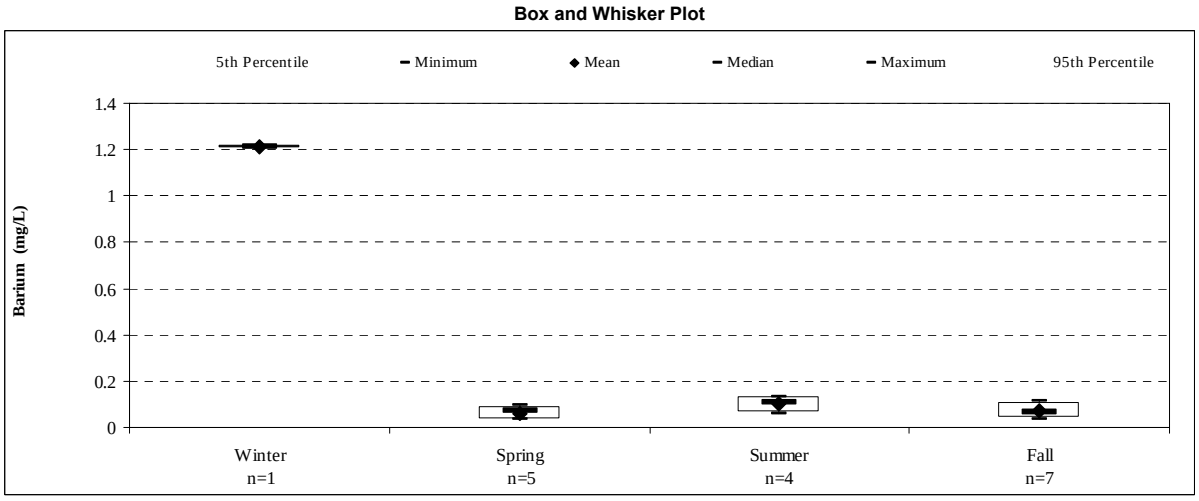


Figure G-2-6-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Stanley Creek



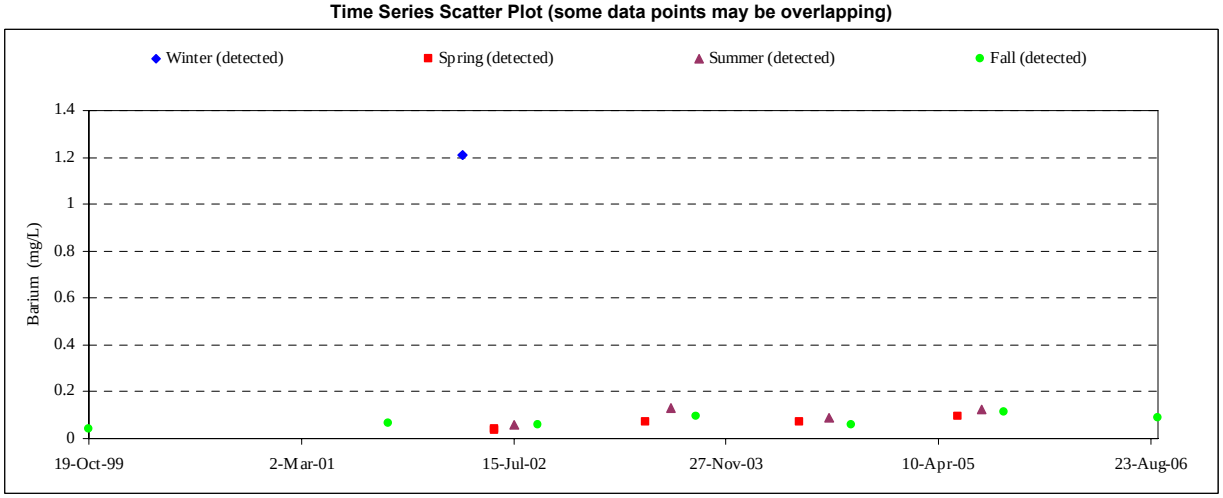
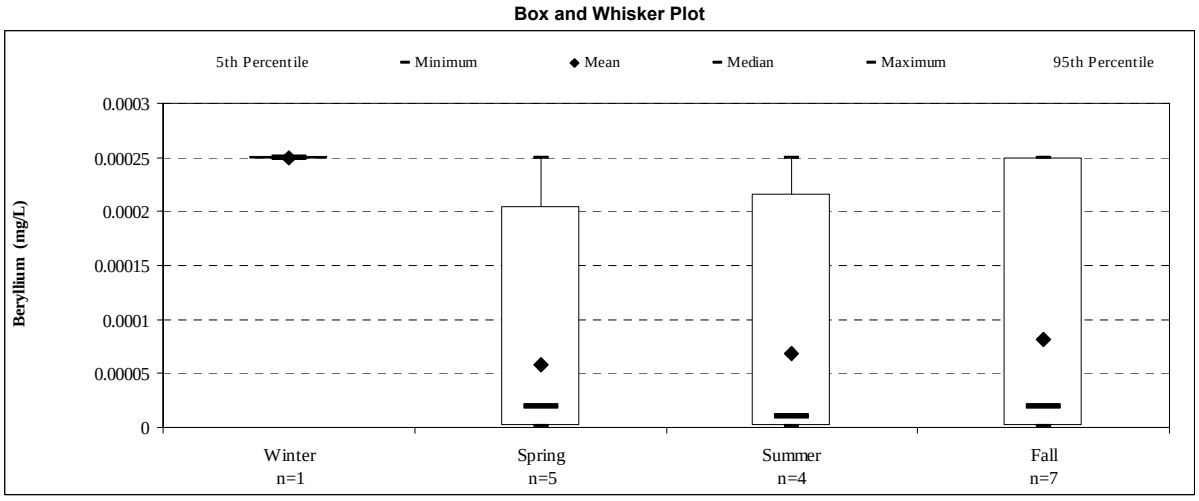


Figure G-2-6-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Stanley Creek



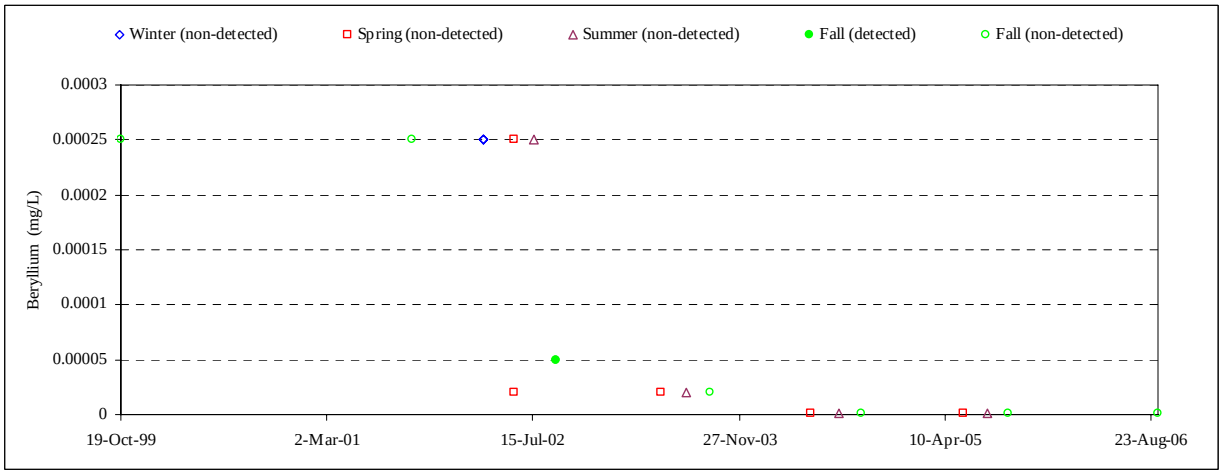
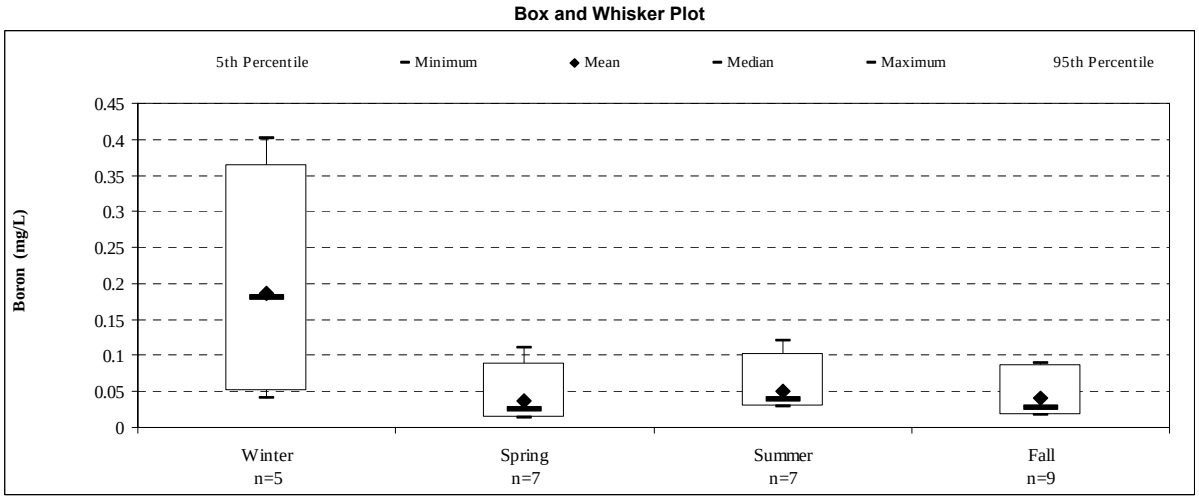


Figure G-2-6-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Stanley Creek



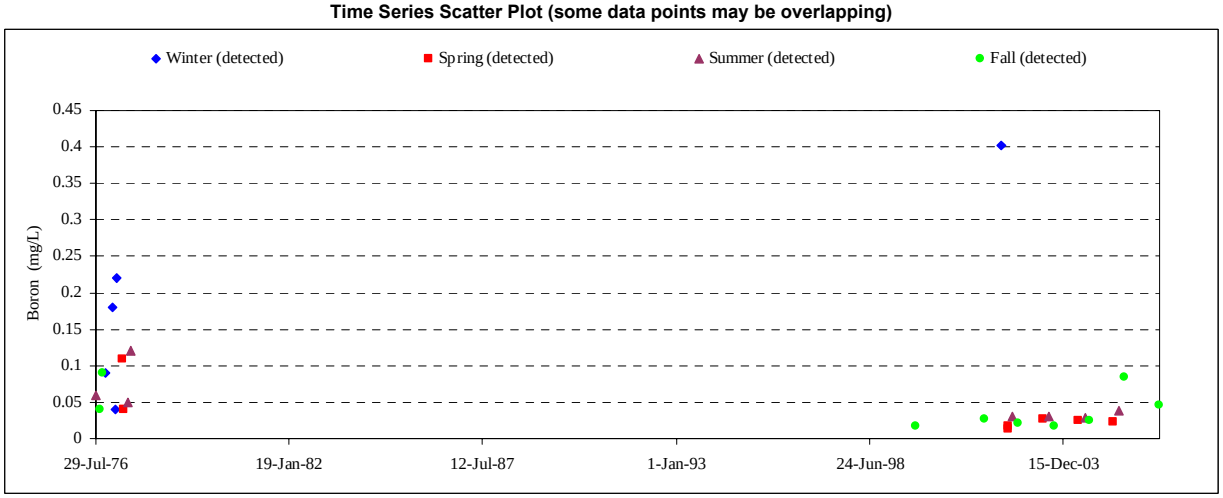
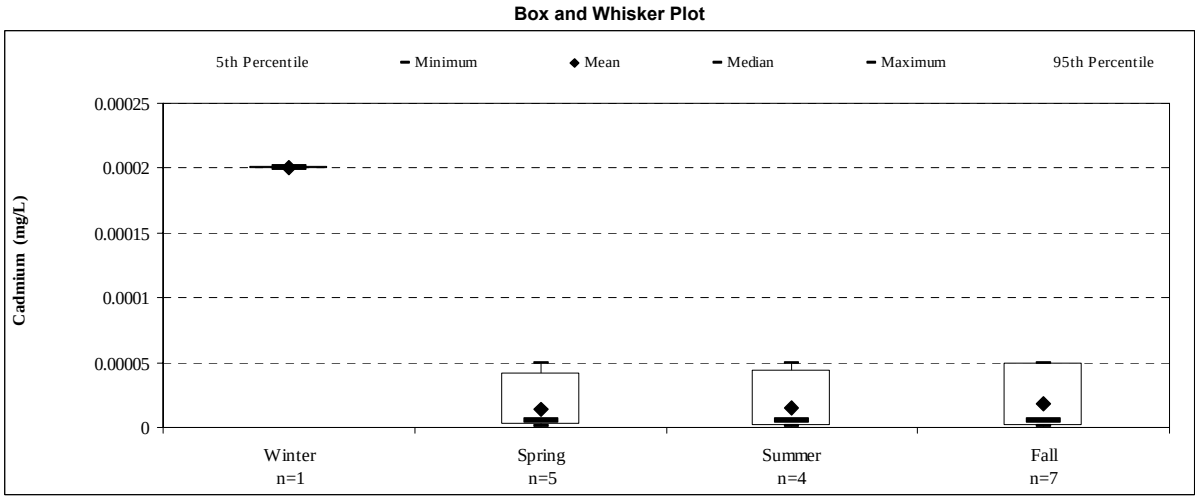


Figure G-2-6-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Stanley Creek



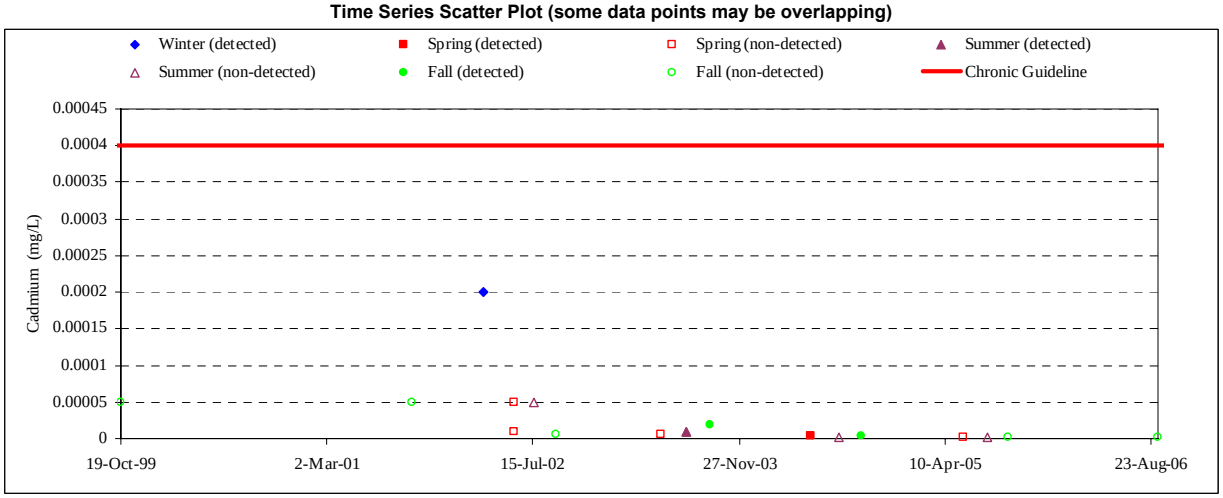
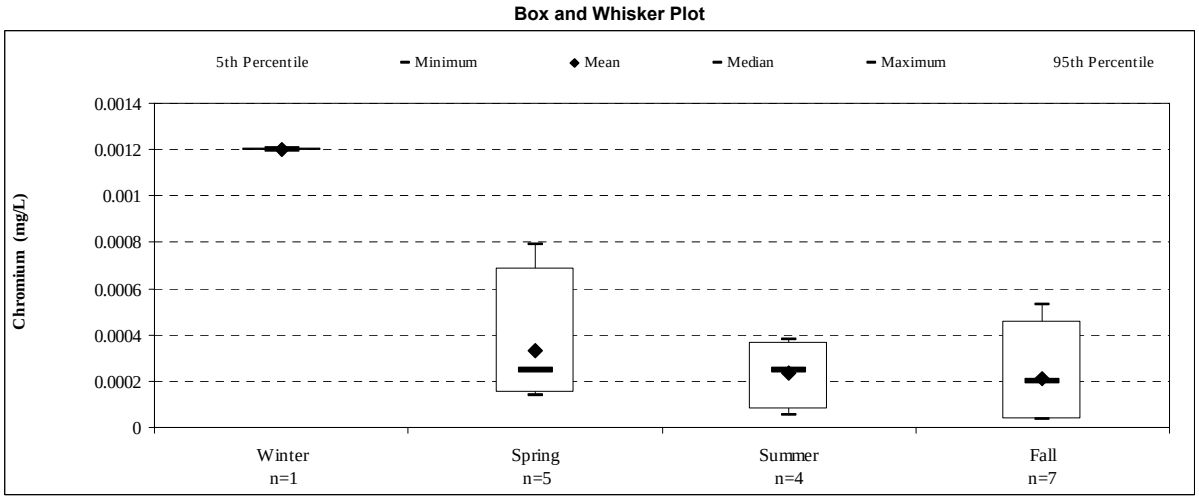


Figure G-2-6-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Stanley Creek



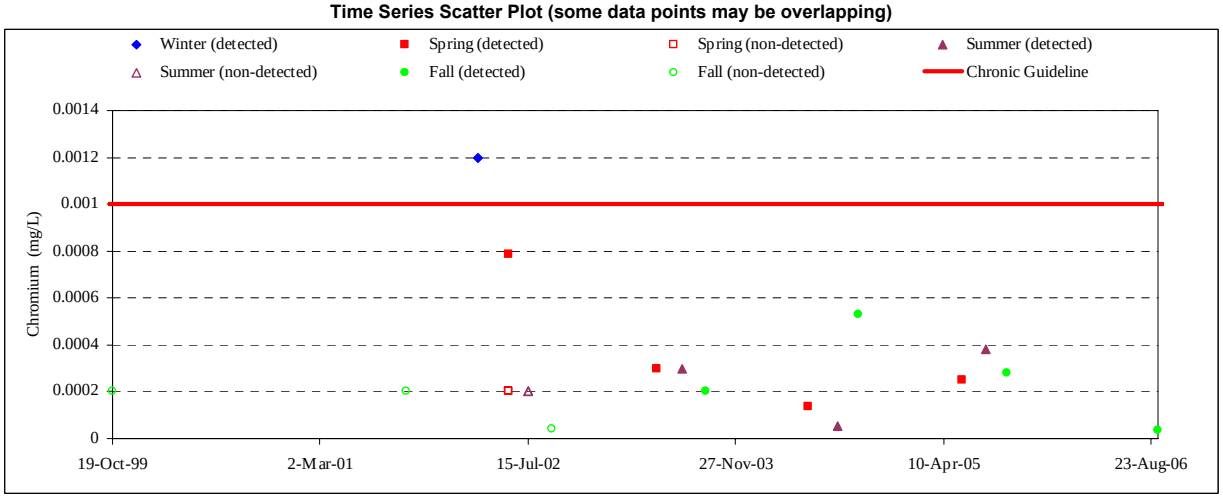
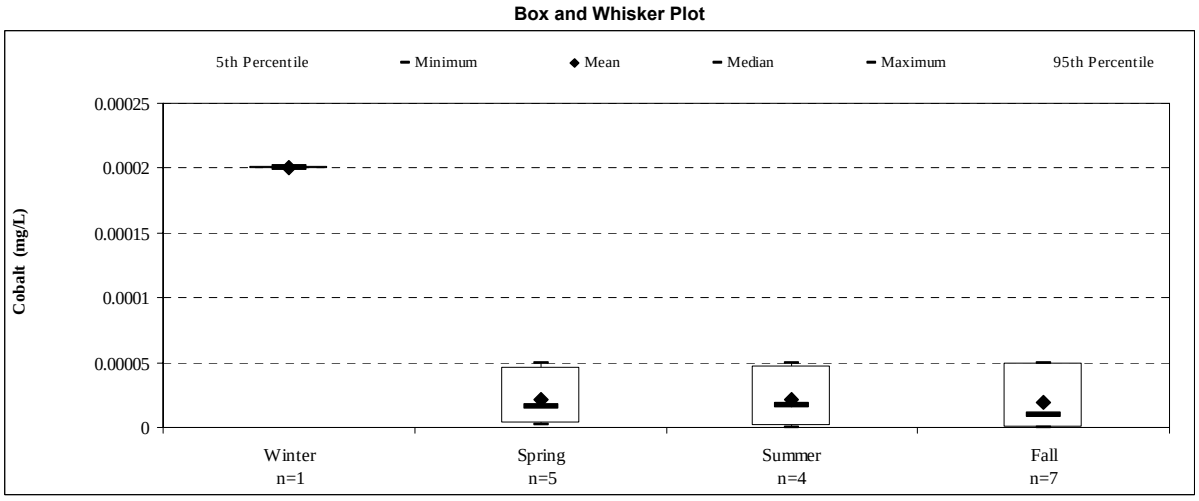


Figure G-2-6-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Stanley Creek



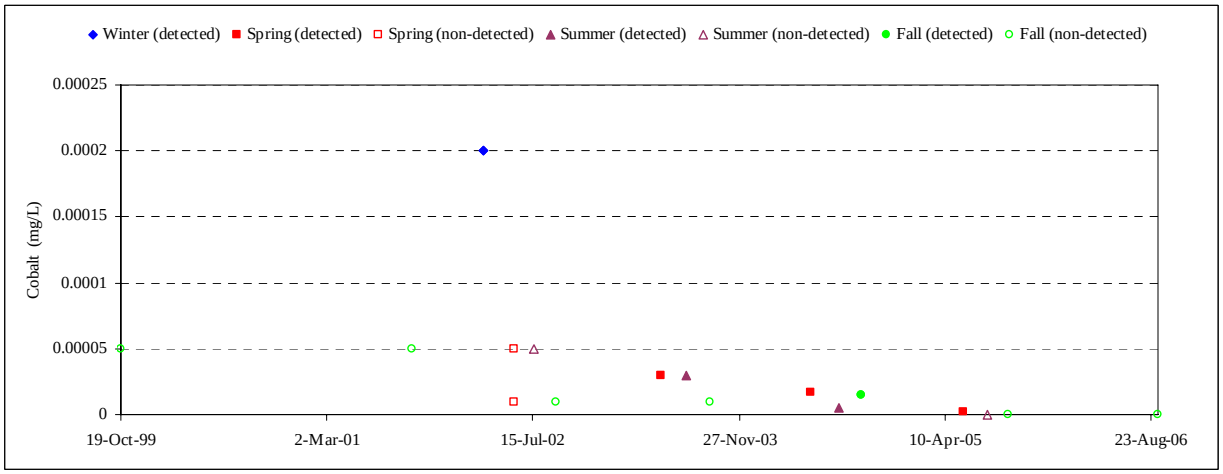
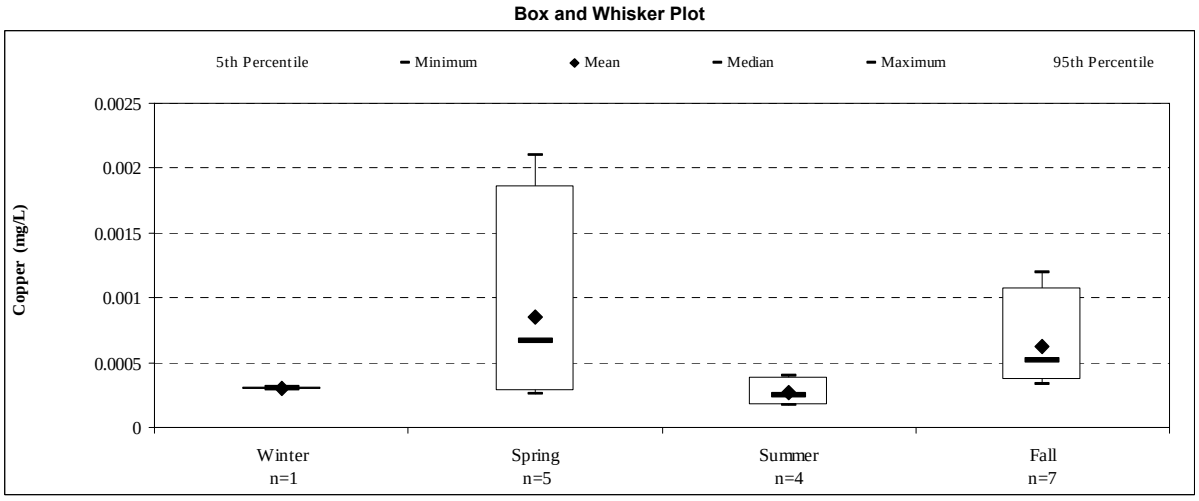


Figure G-2-6-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Stanley Creek



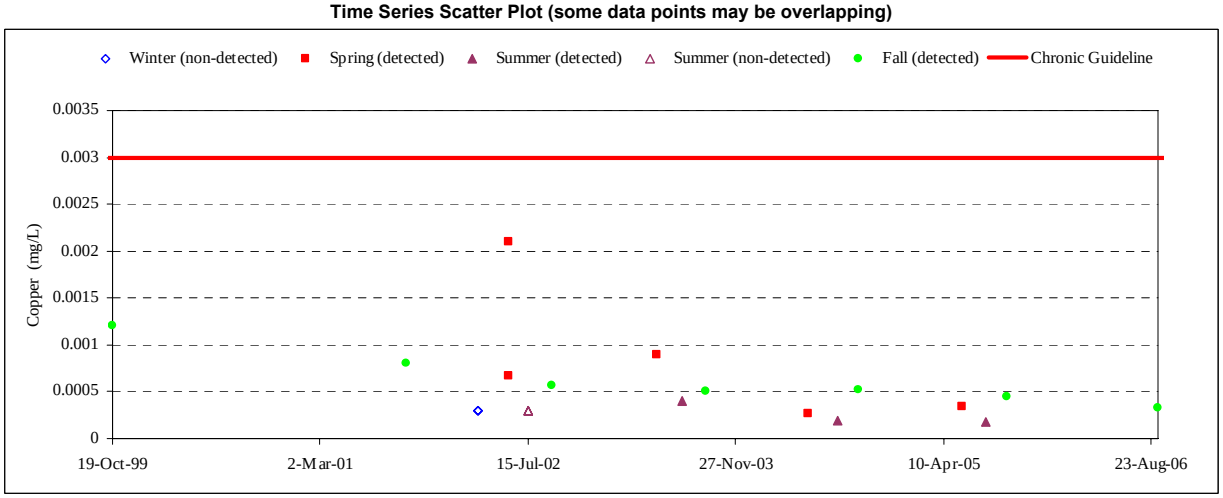
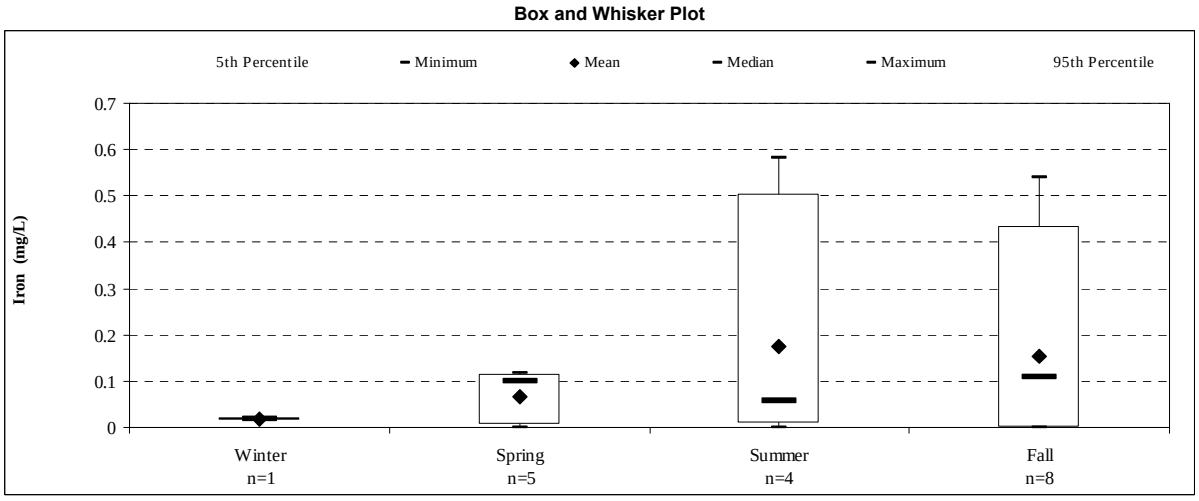


Figure G-2-6-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Stanley Creek



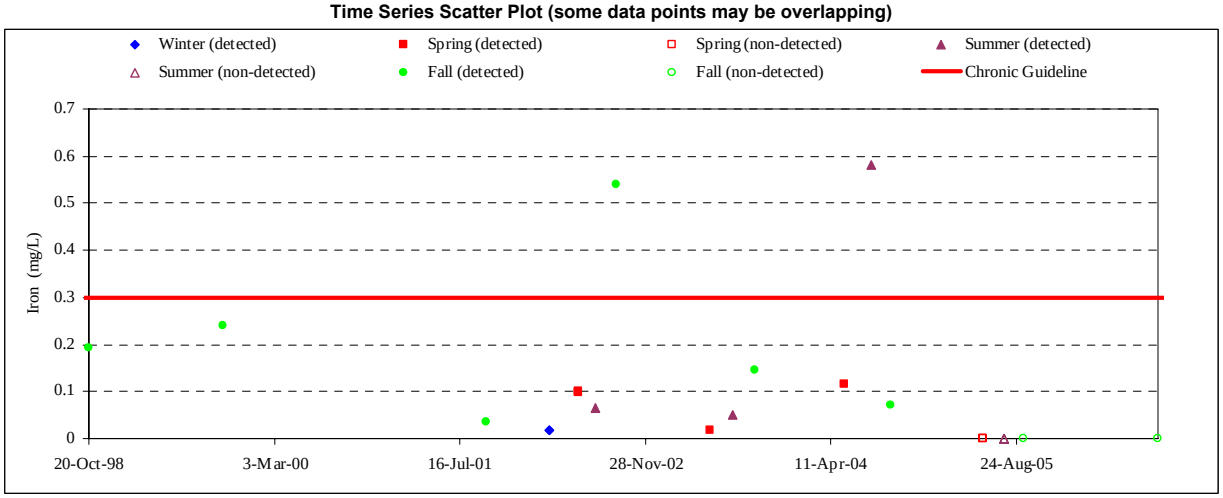
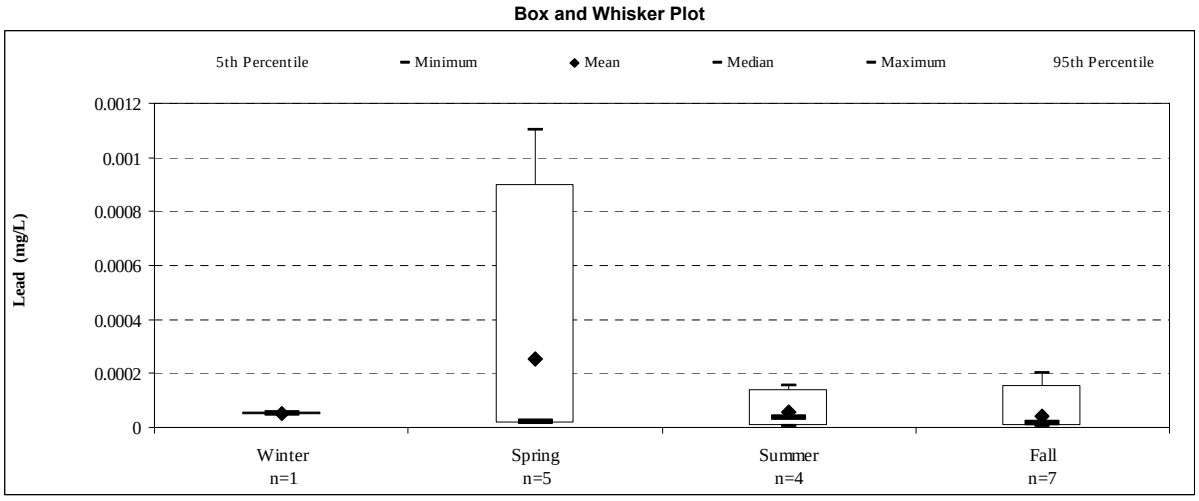


Figure G-2-6-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Stanley Creek



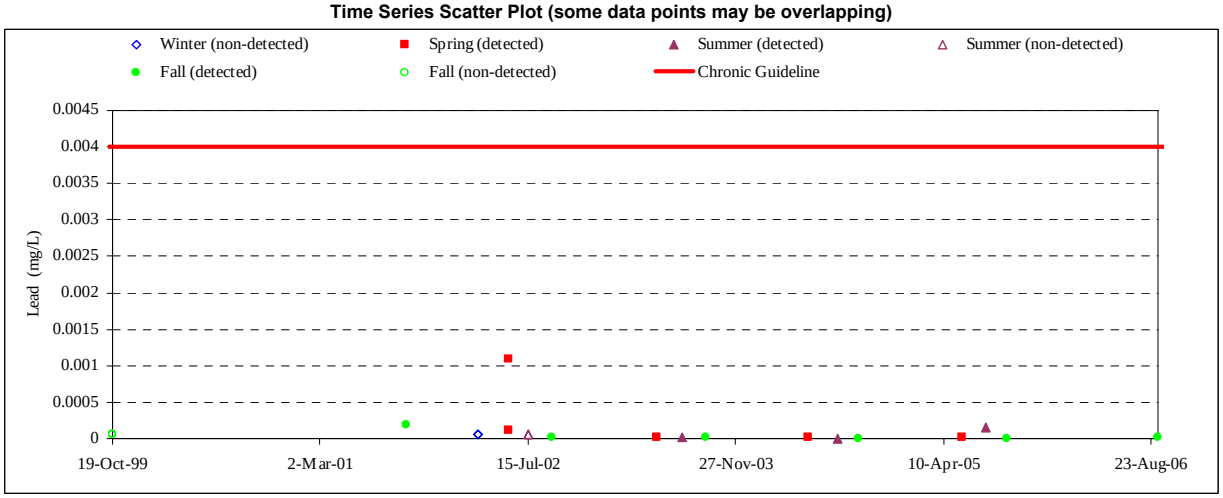
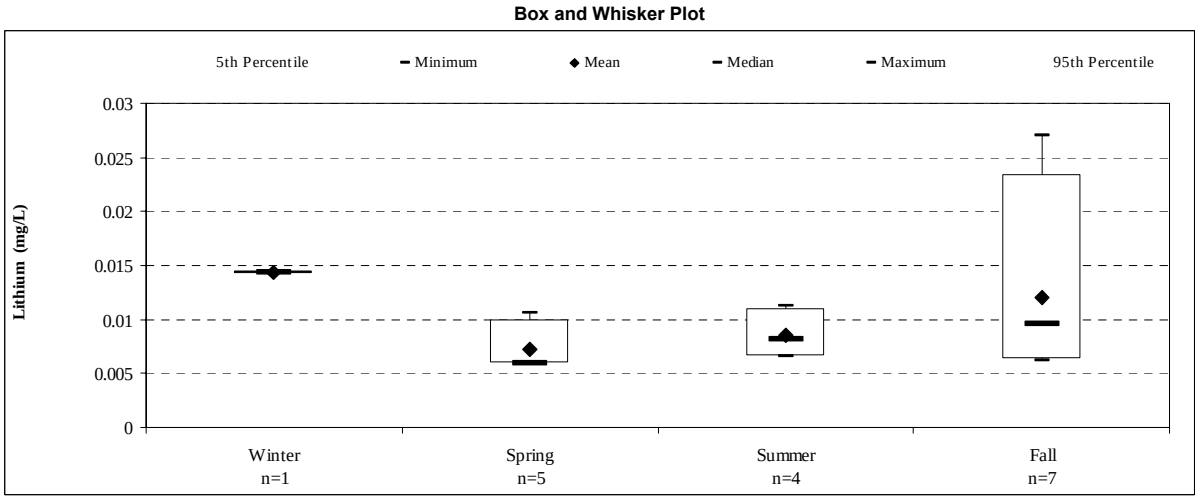


Figure G-2-6-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Stanley Creek



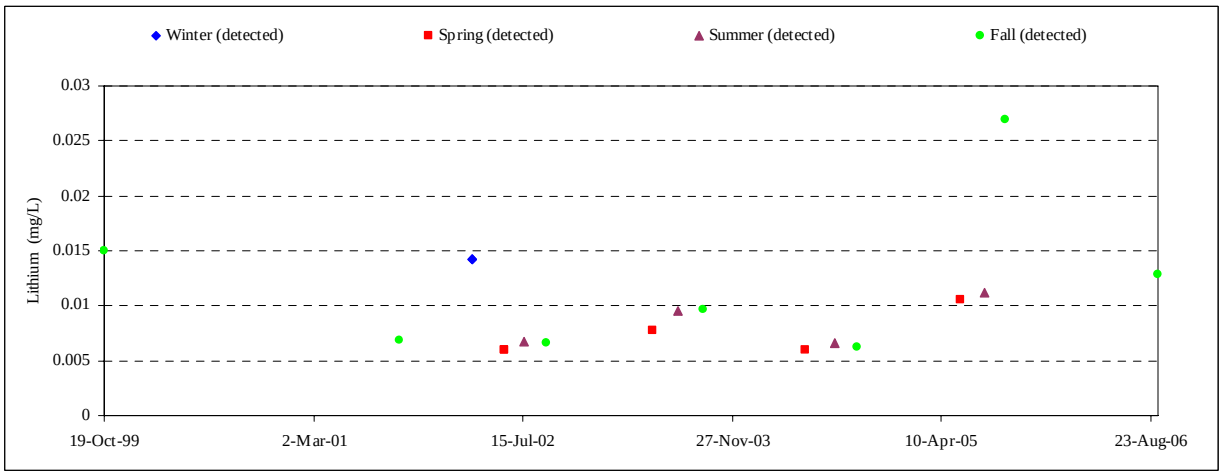
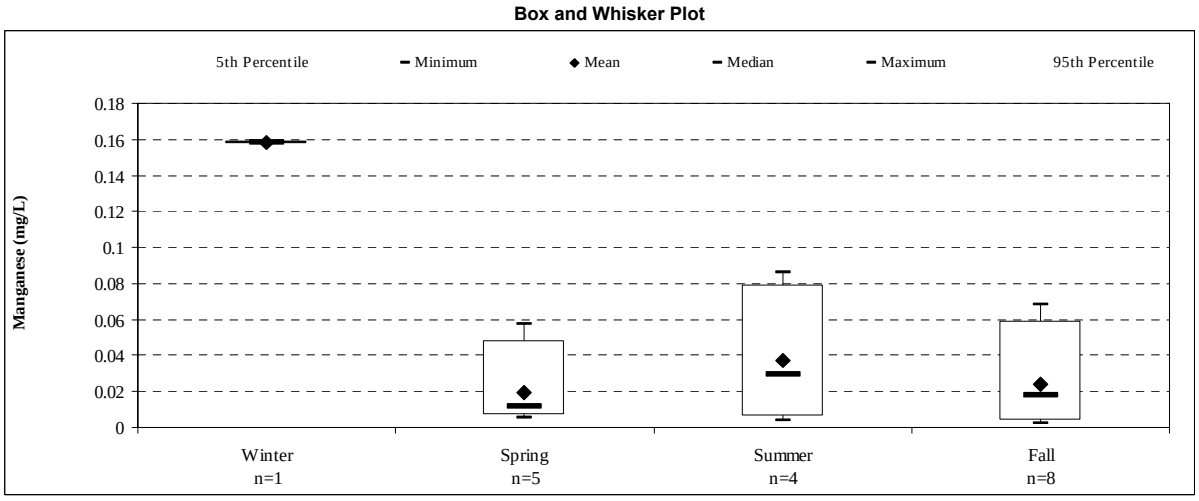


Figure G-2-6-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Stanley Creek



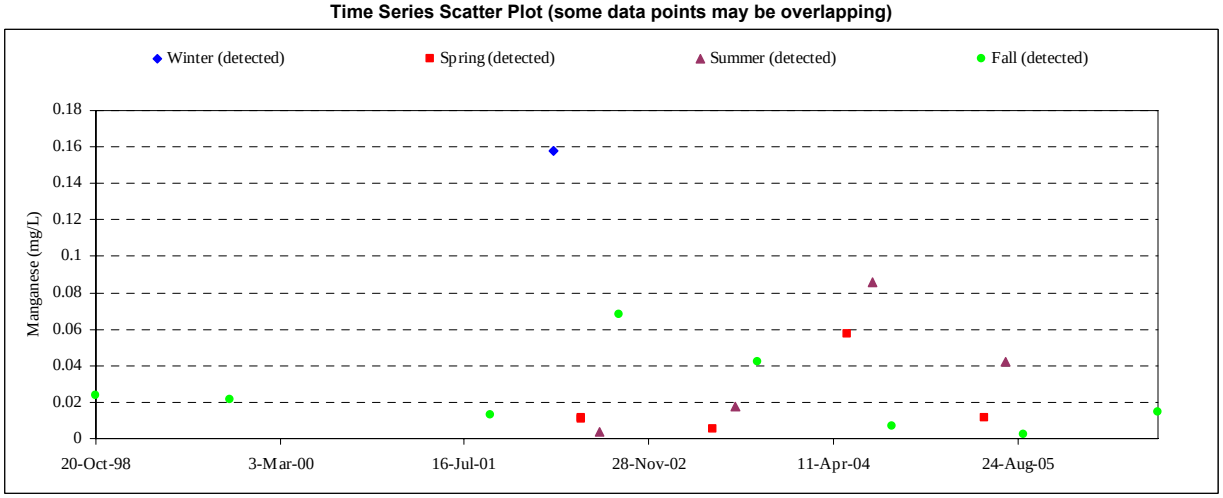
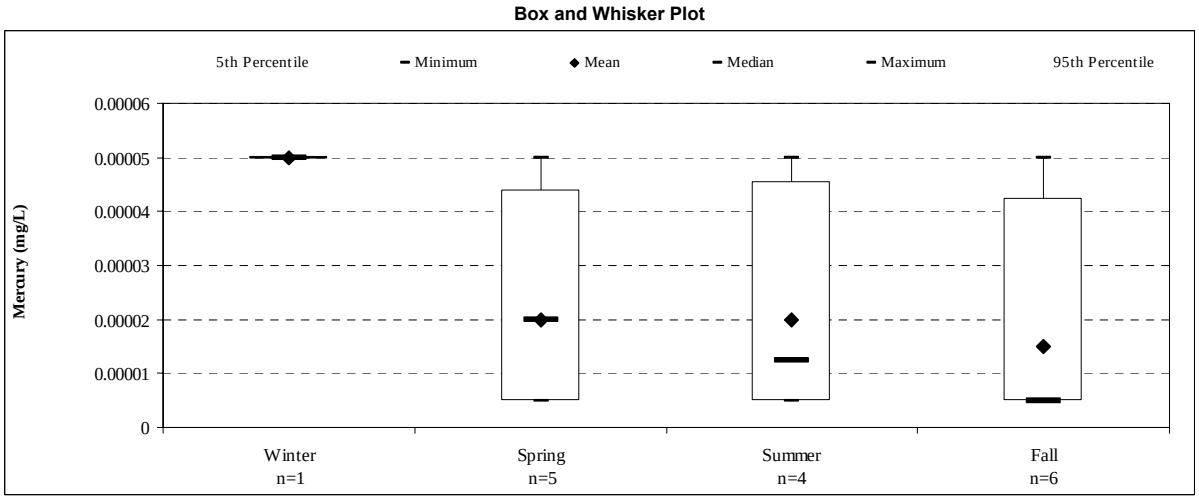


Figure G-2-6-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Stanley Creek



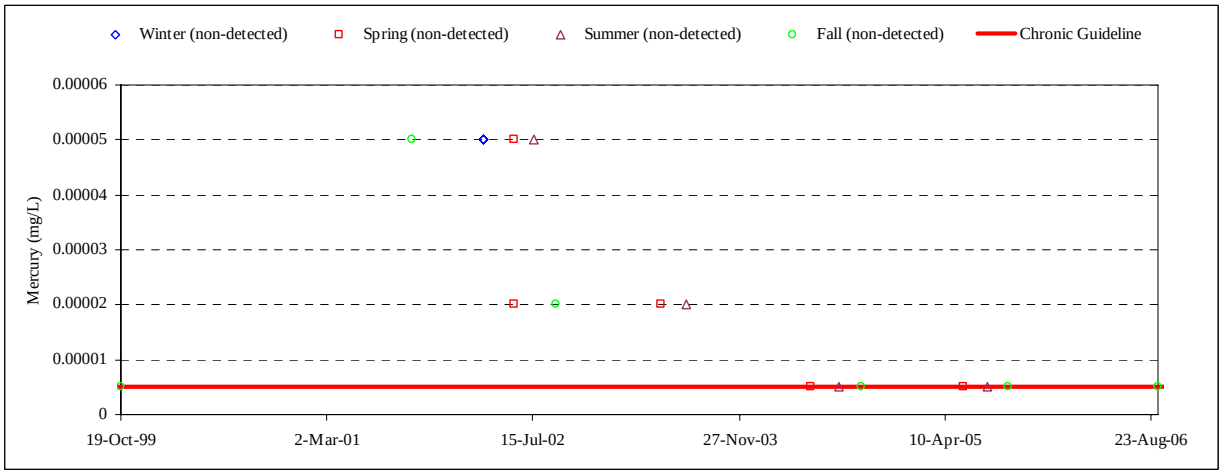
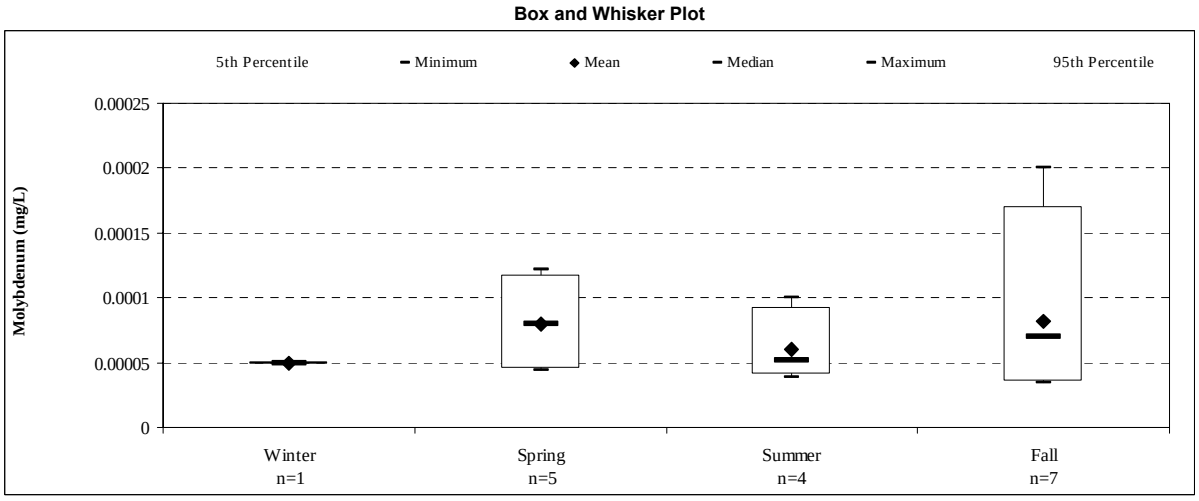


Figure G-2-6-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Stanley Creek



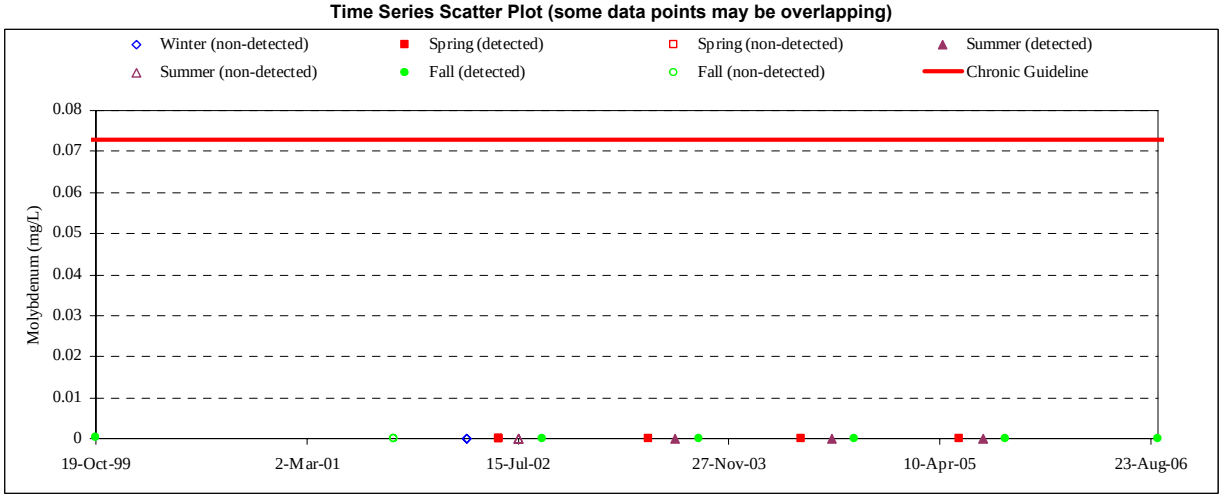
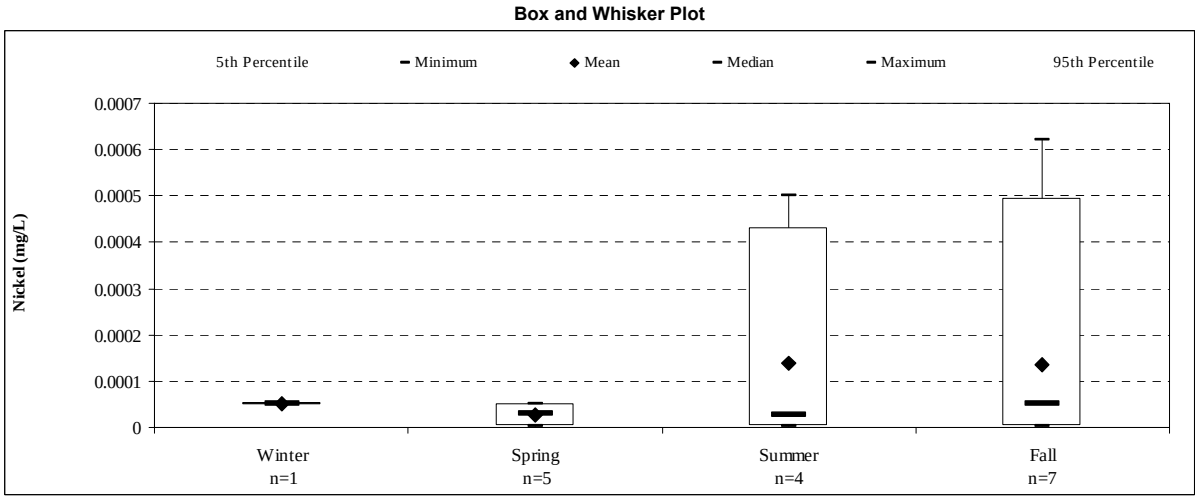


Figure G-2-6-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Stanley Creek



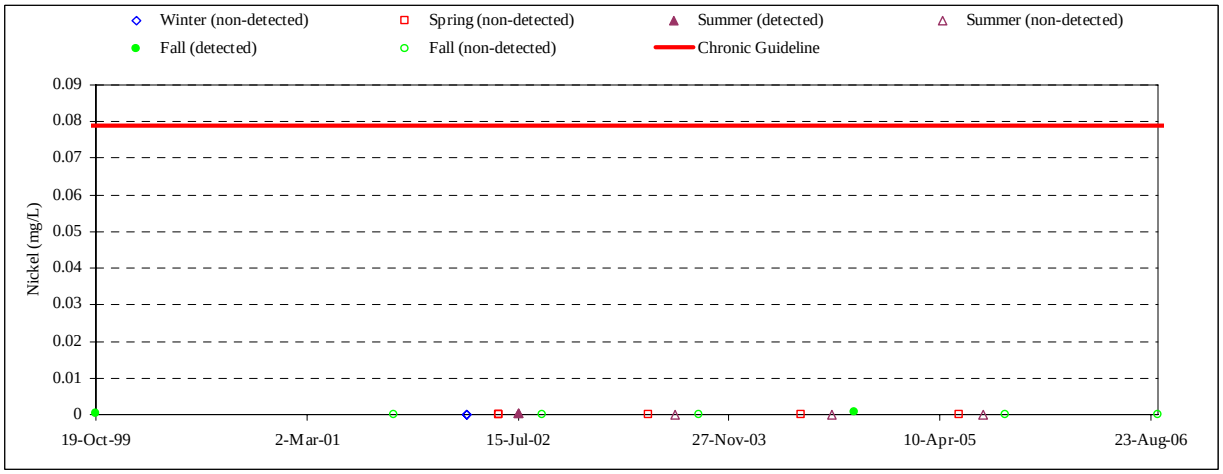
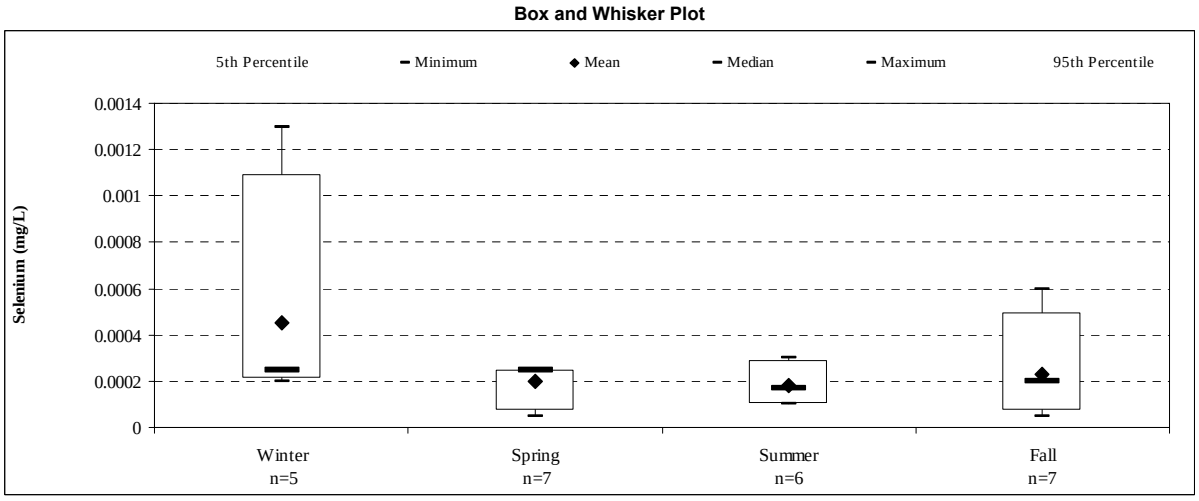


Figure G-2-6-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Stanley Creek



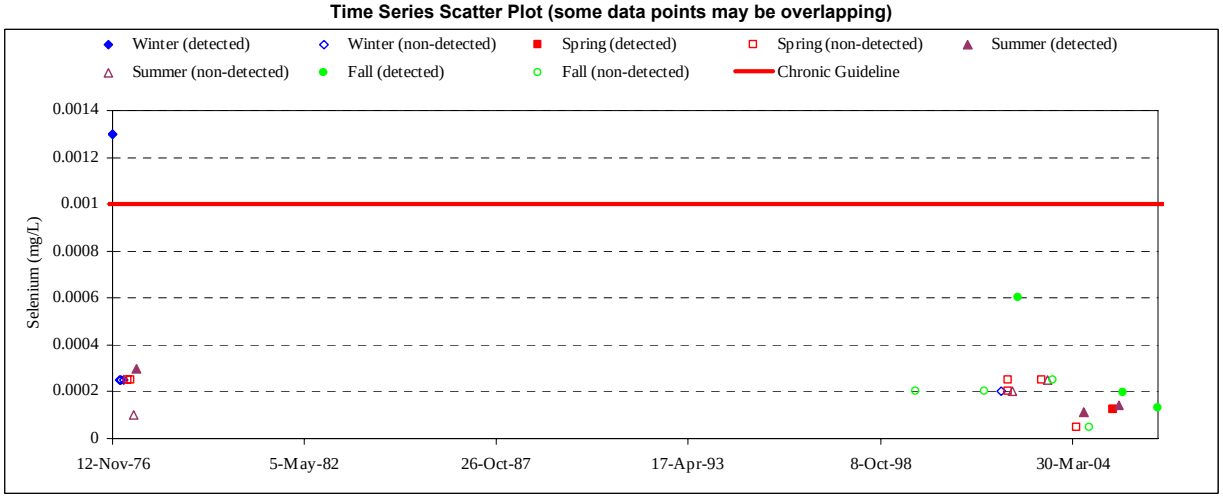
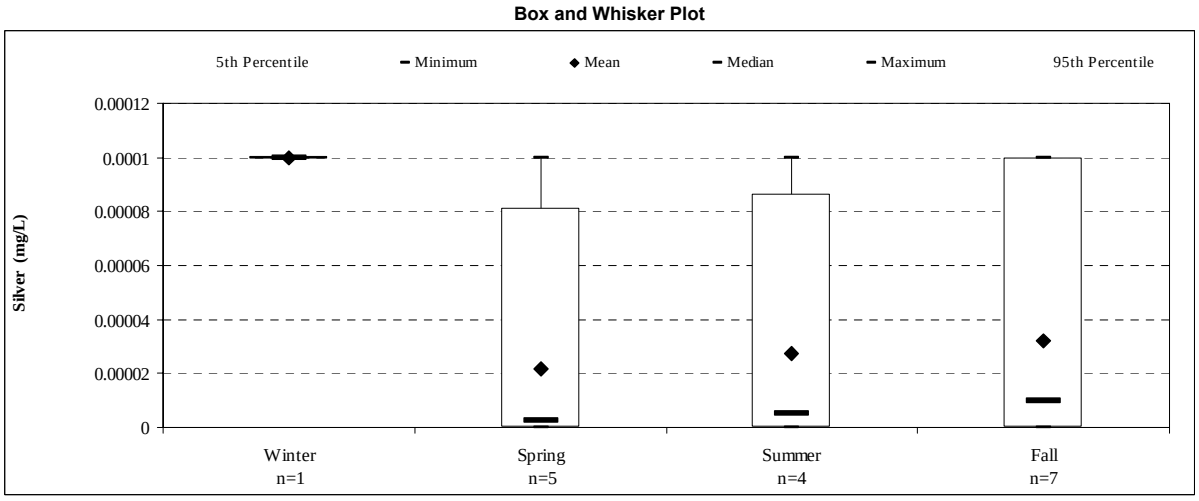


Figure G-2-6-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Stanley Creek



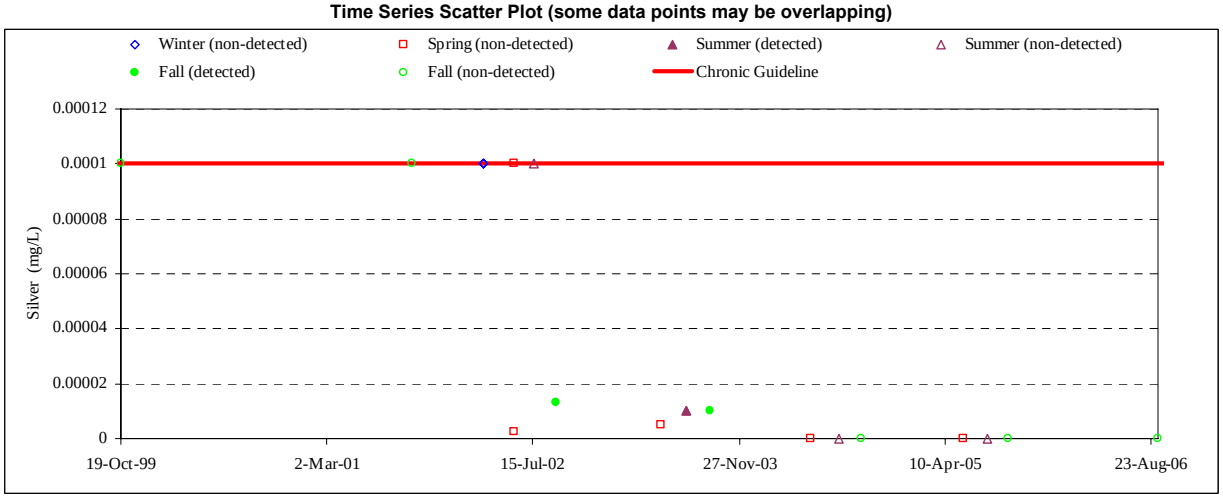
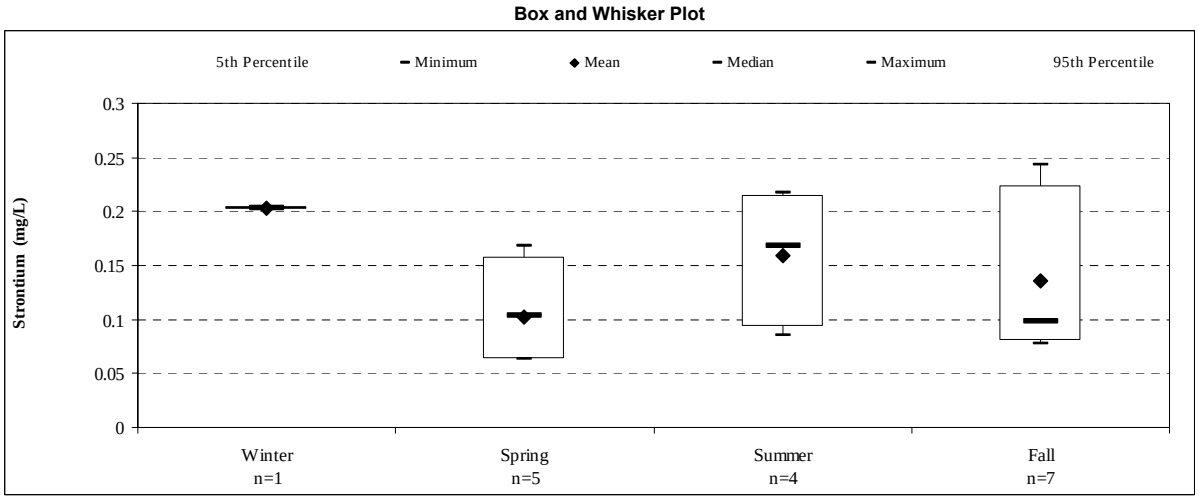


Figure G-2-6-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Stanley Creek



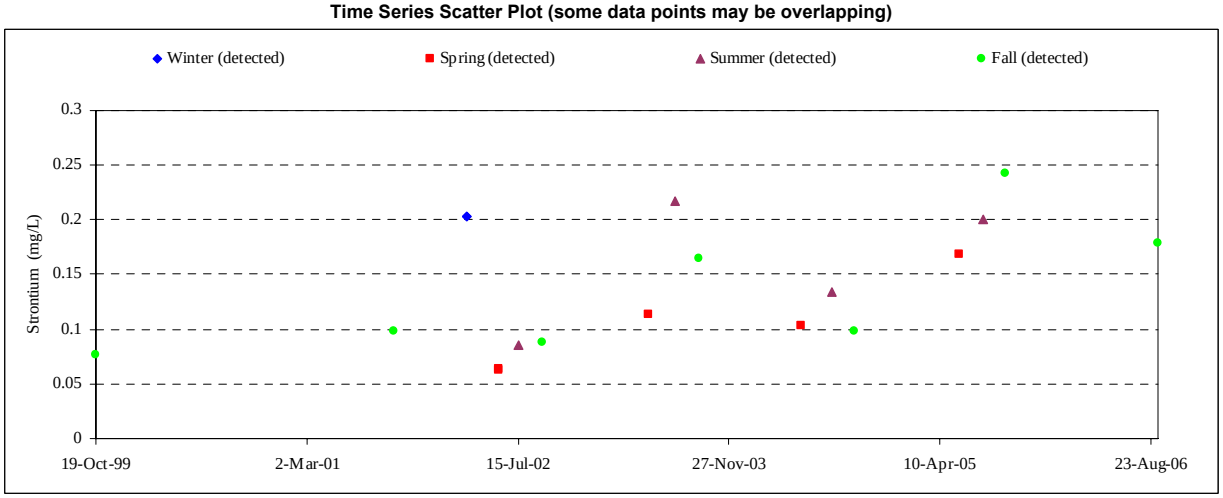
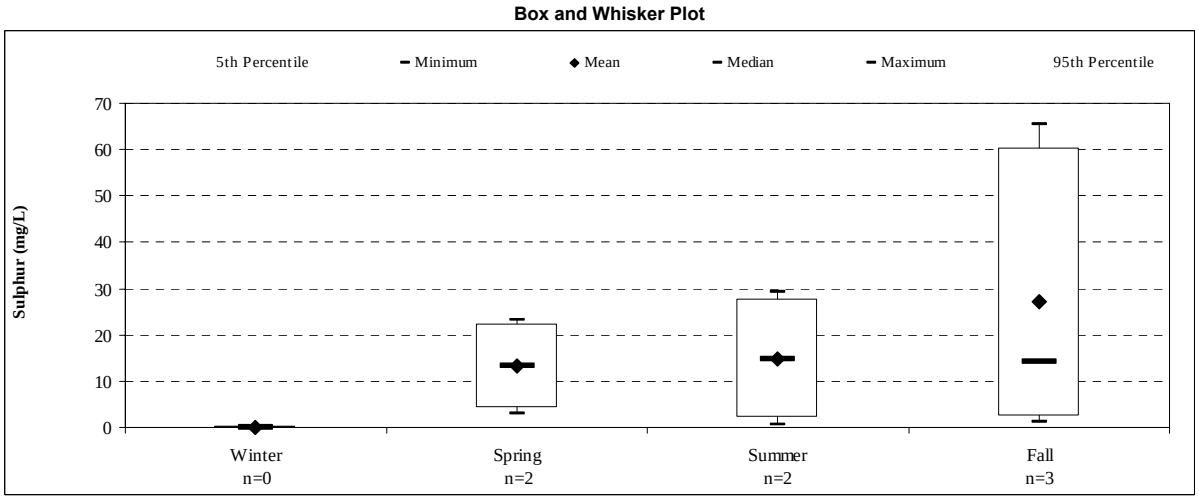


Figure G-2-6-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Stanley Creek



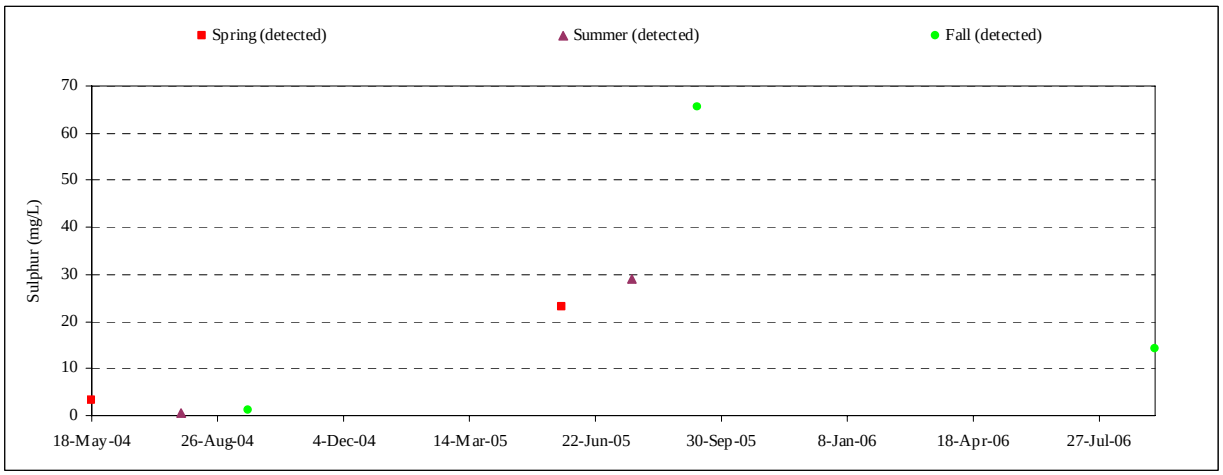
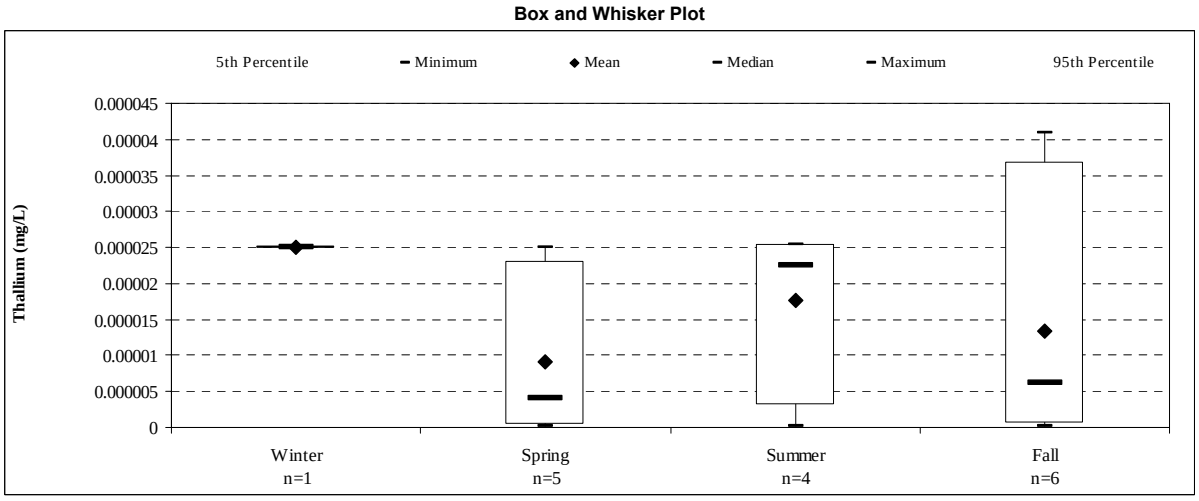


Figure G-2-6-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Stanley Creek



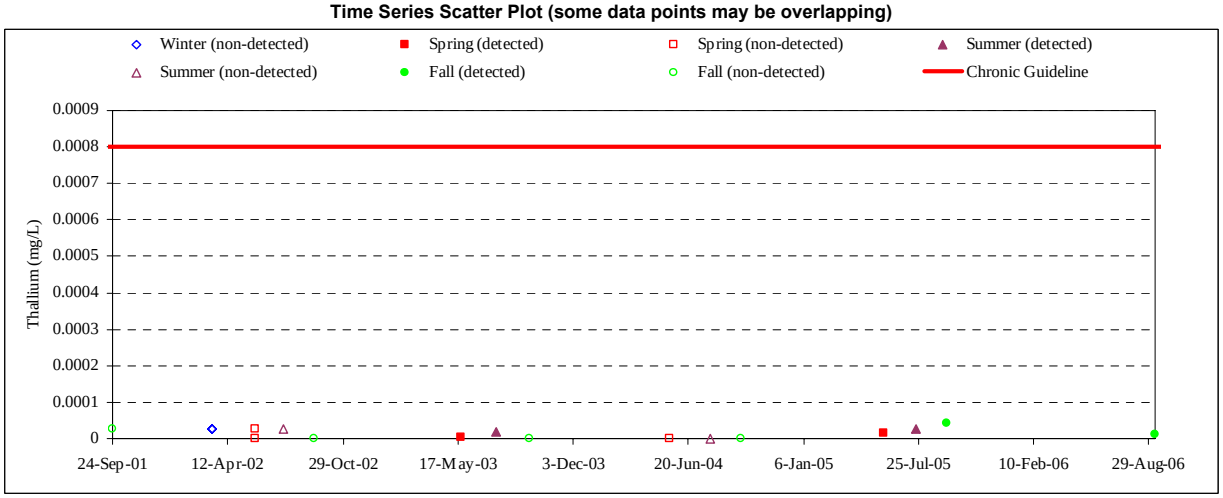
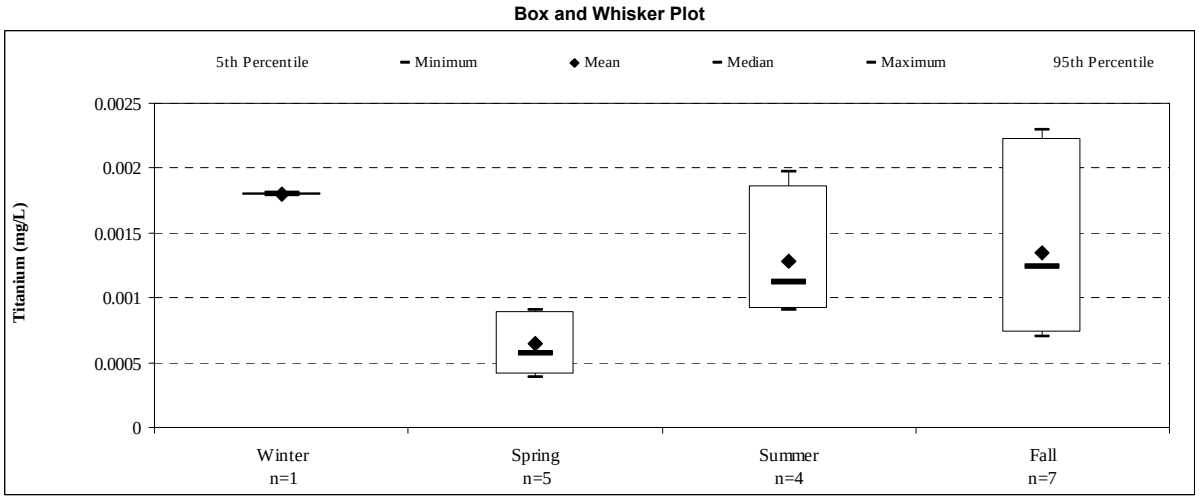


Figure G-2-6-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Stanley Creek



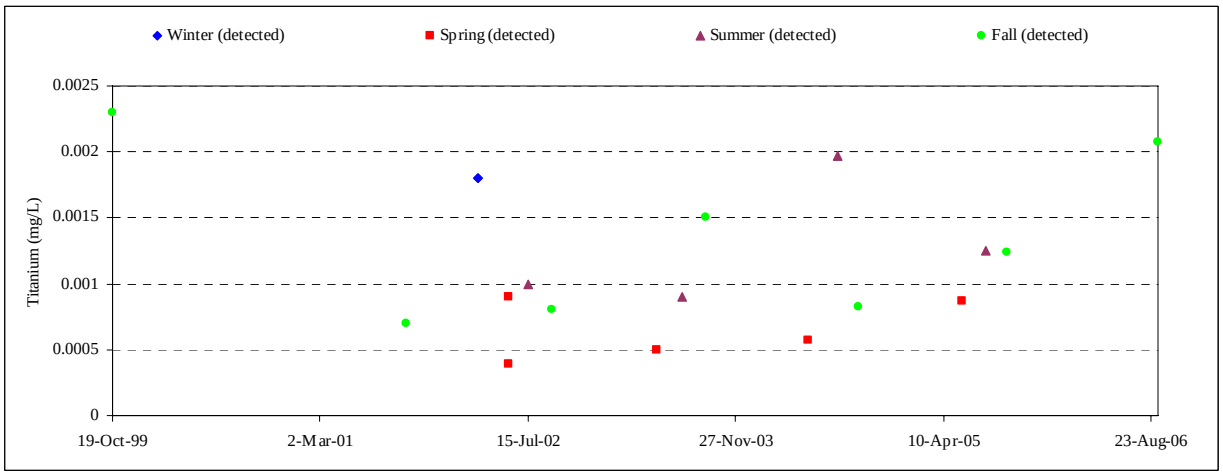
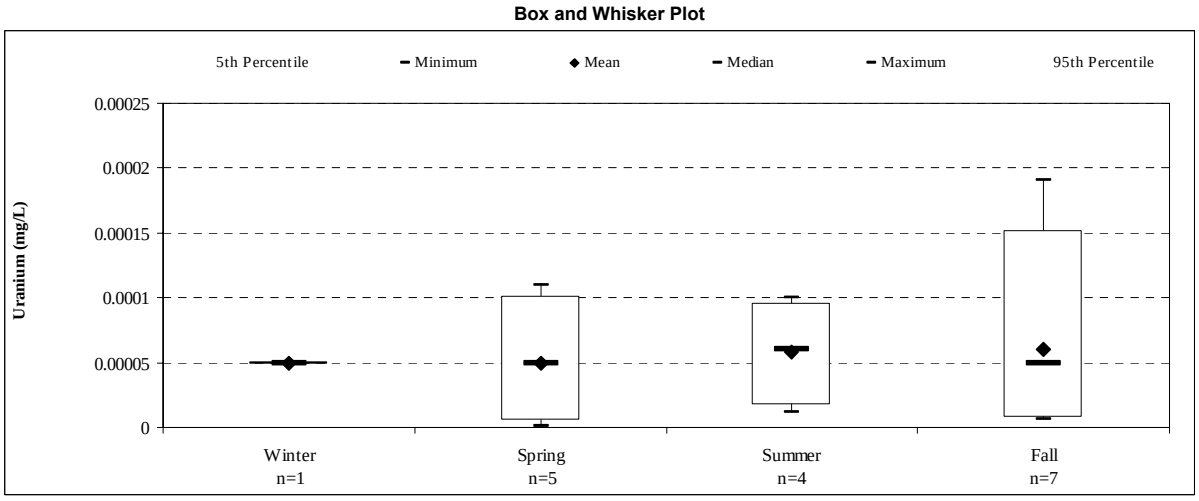


Figure G-2-6-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Stanley Creek



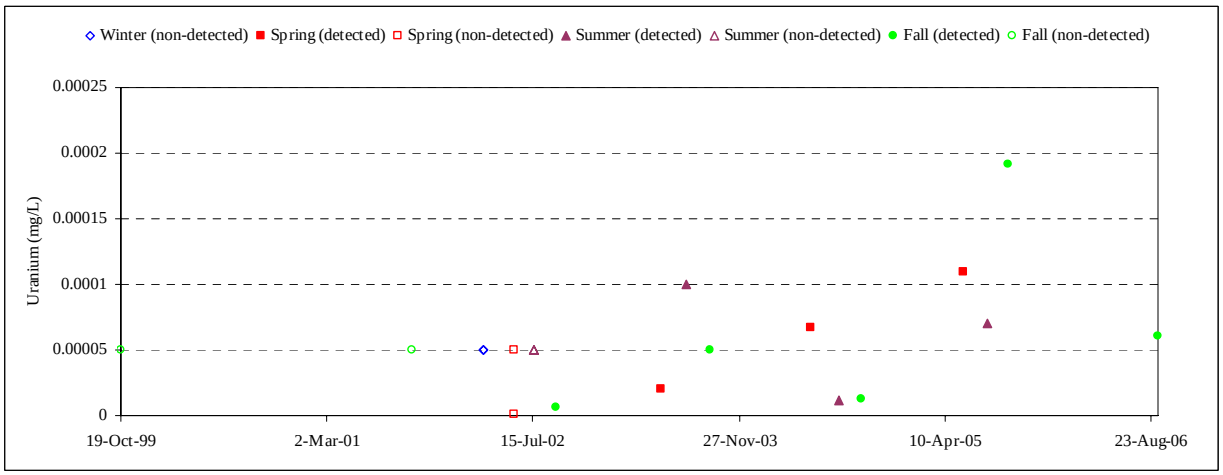
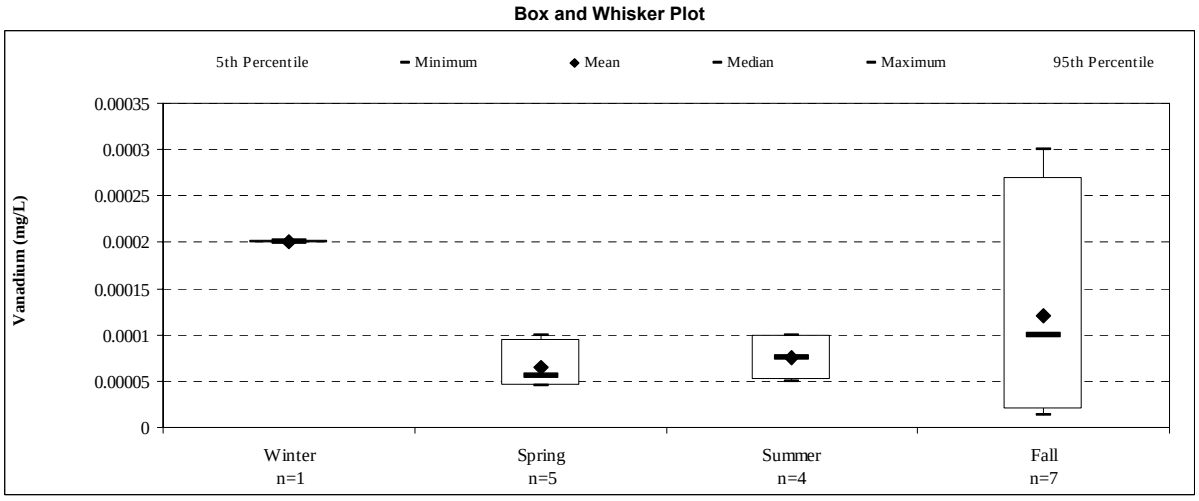


Figure G-2-6-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Stanley Creek



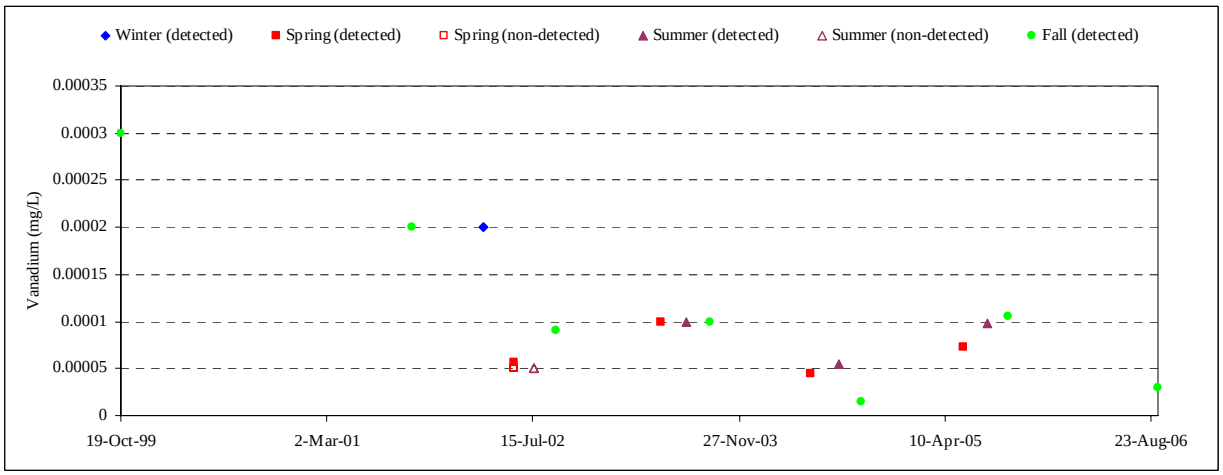
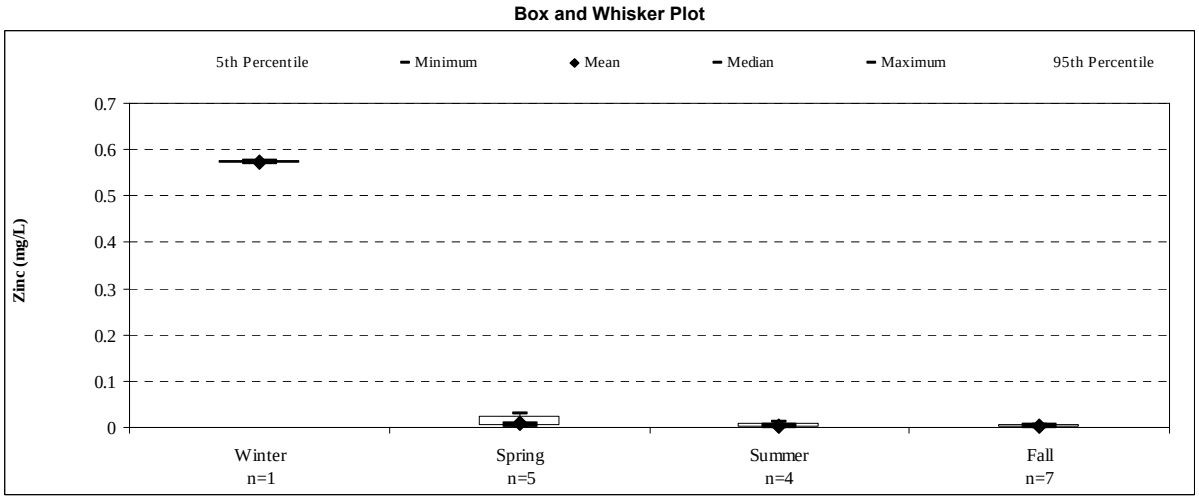


Figure G-2-6-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Stanley Creek



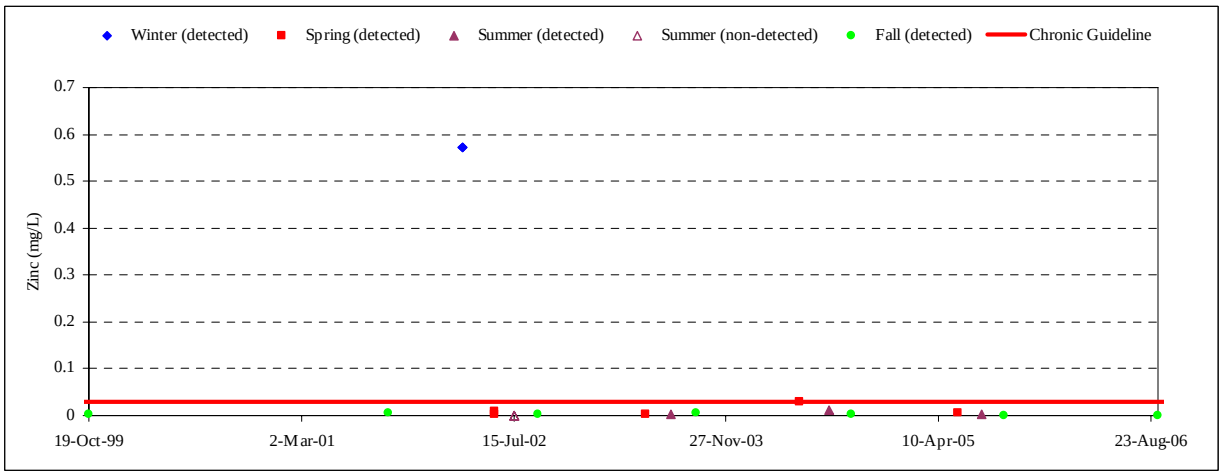
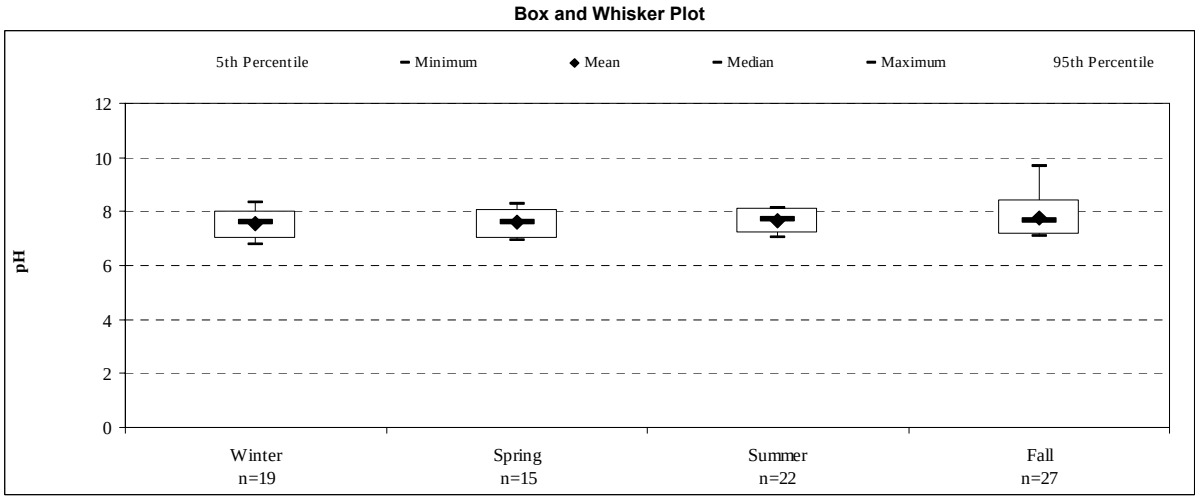


Figure G-2-7-1 Box Whisker and Time Series Scatter Plots of Observed pH in Muskeg Creek



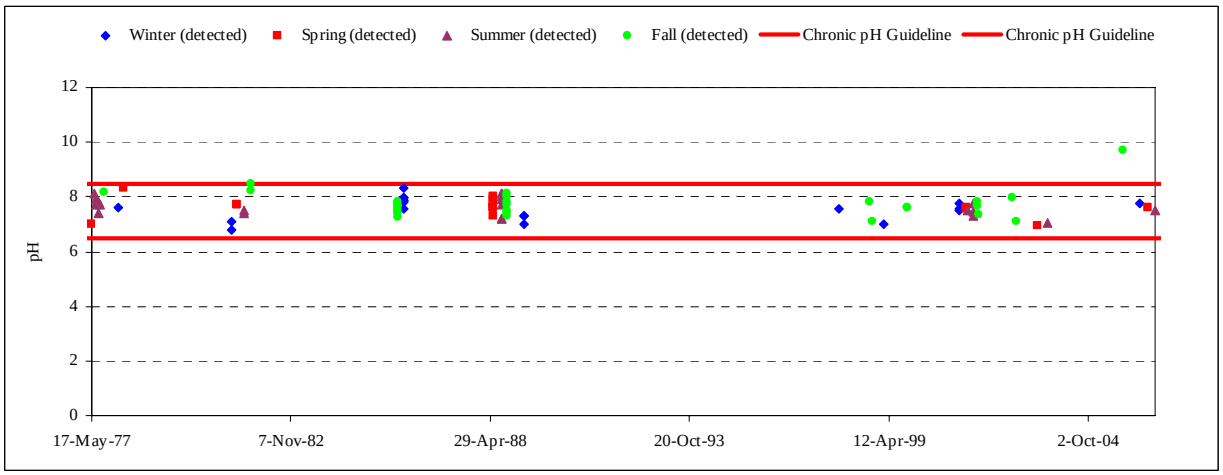
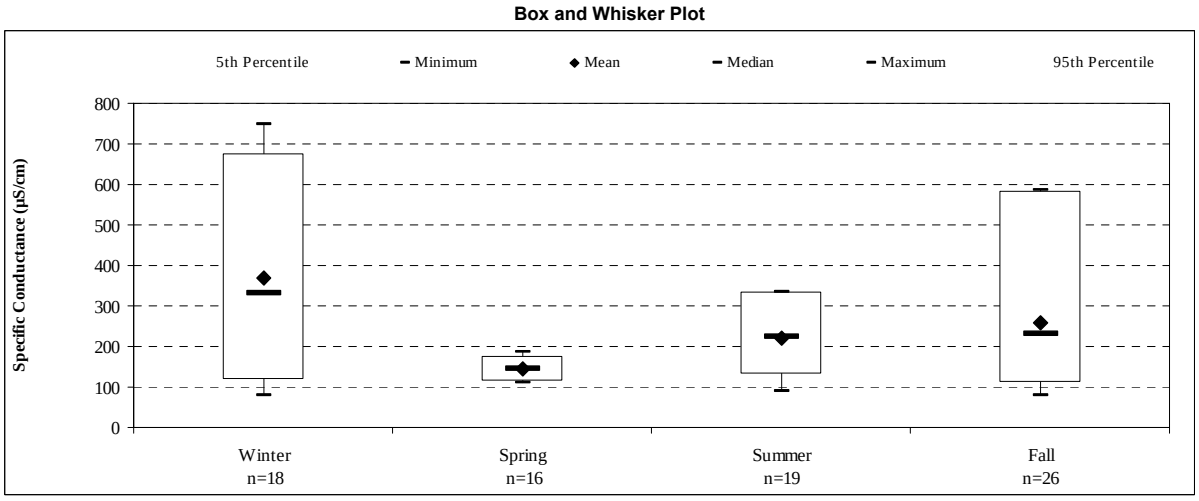


Figure G-2-7-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Muskeg Creek



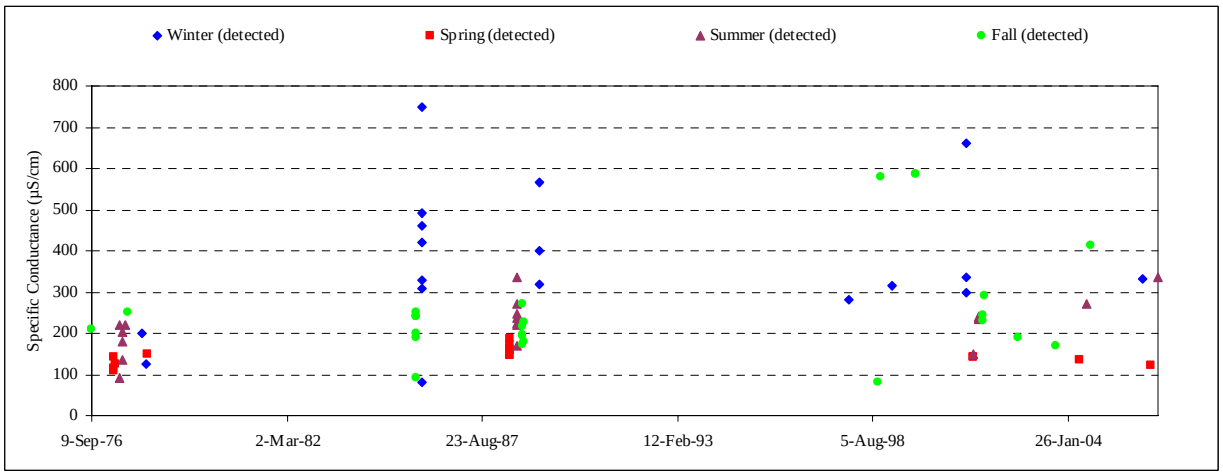
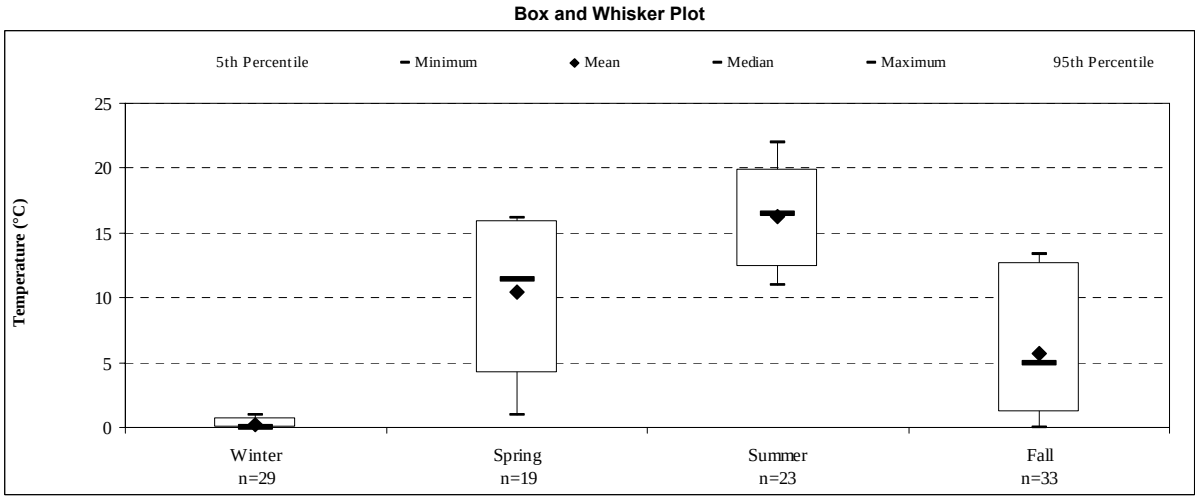


Figure G-2-7-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Muskeg Creek



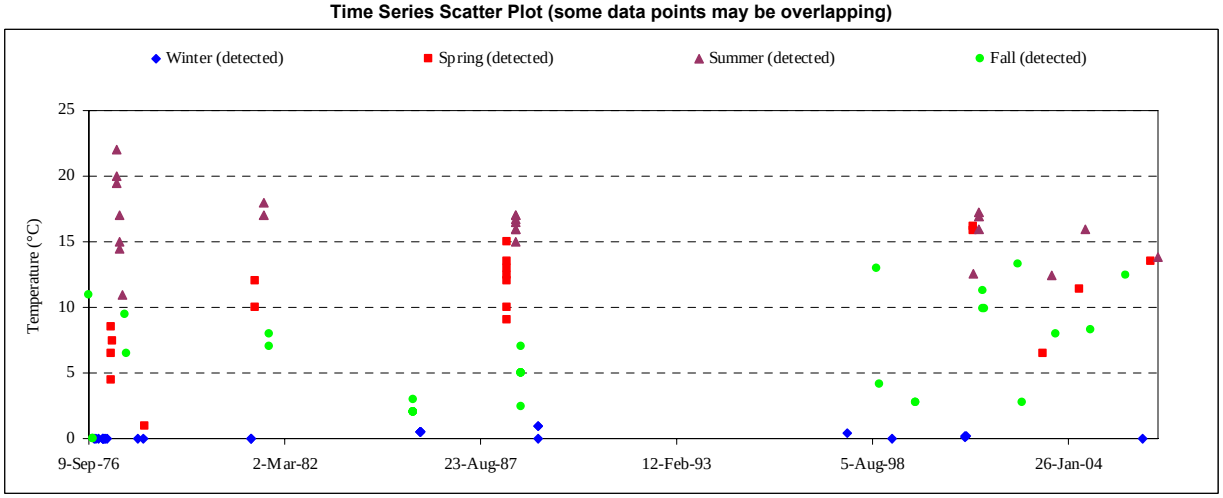
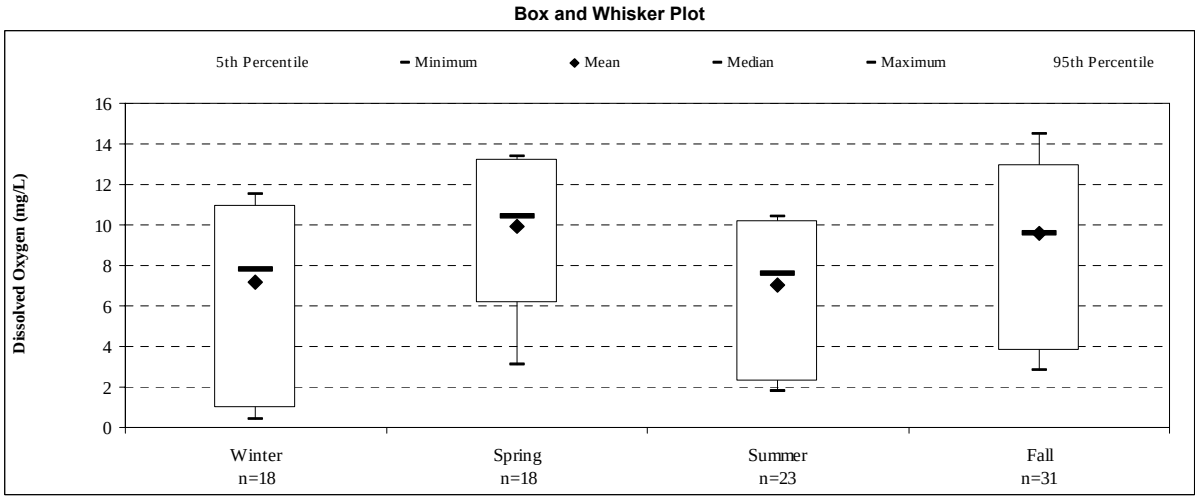


Figure G-2-7-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Muskeg Creek



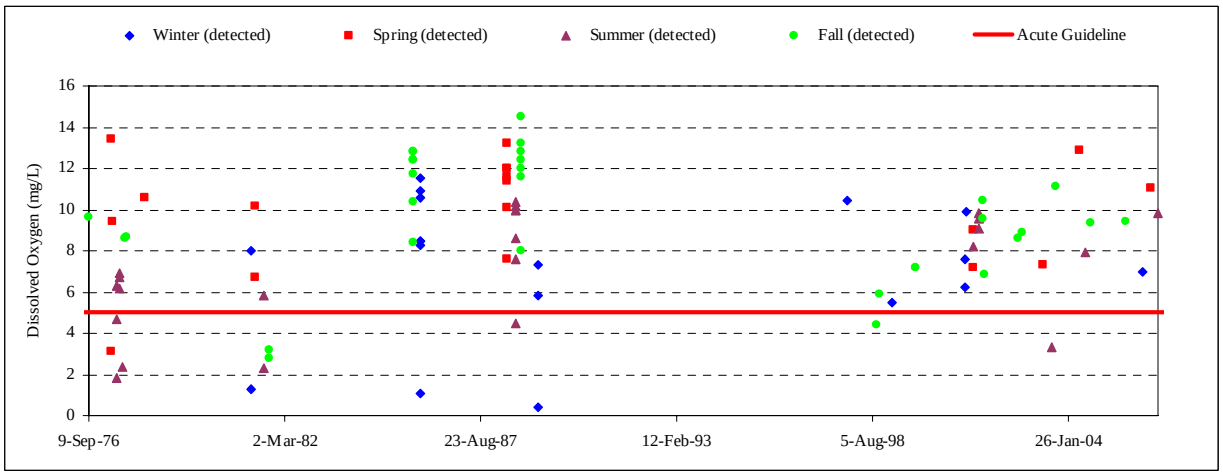
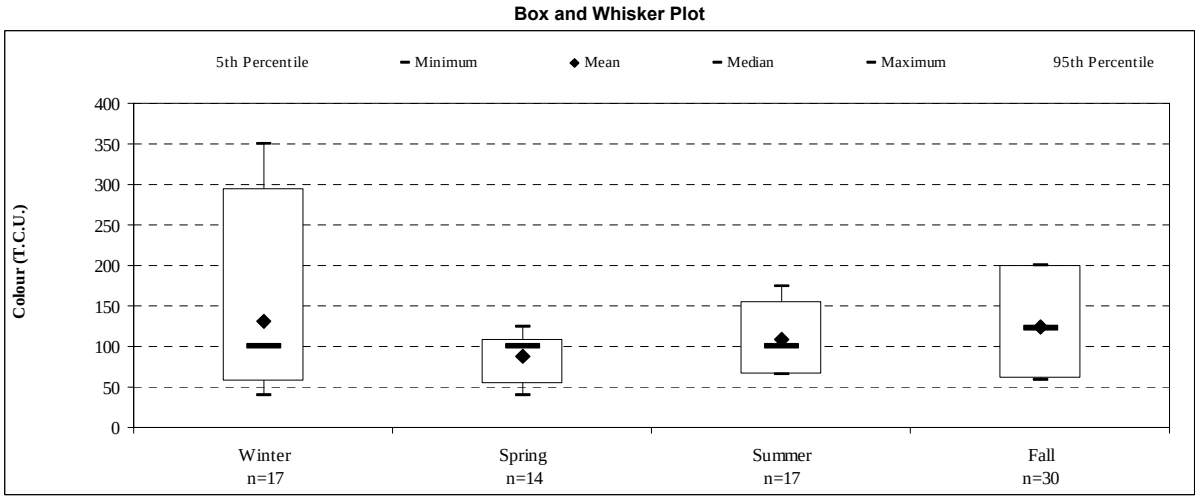


Figure G-2-7-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Muskeg Creek



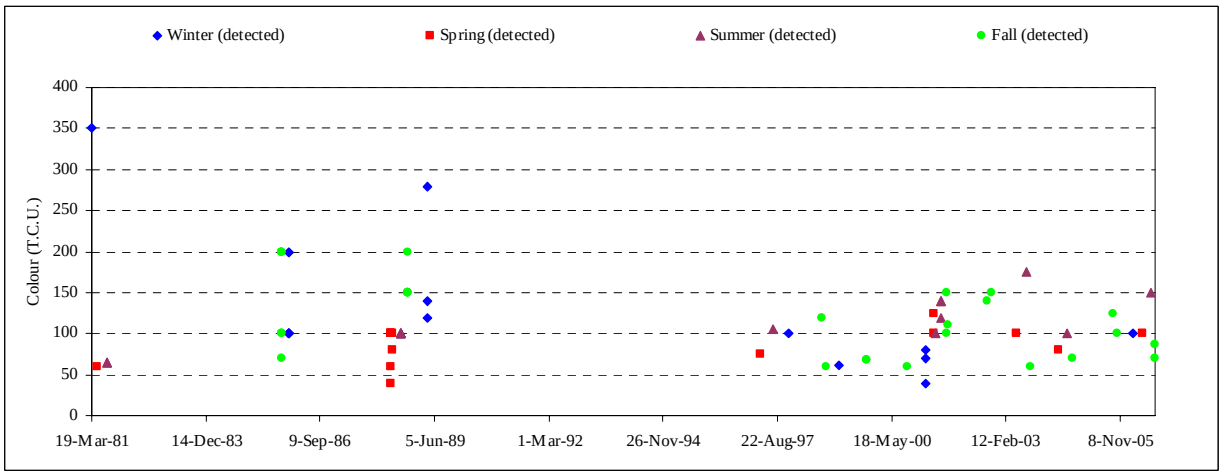
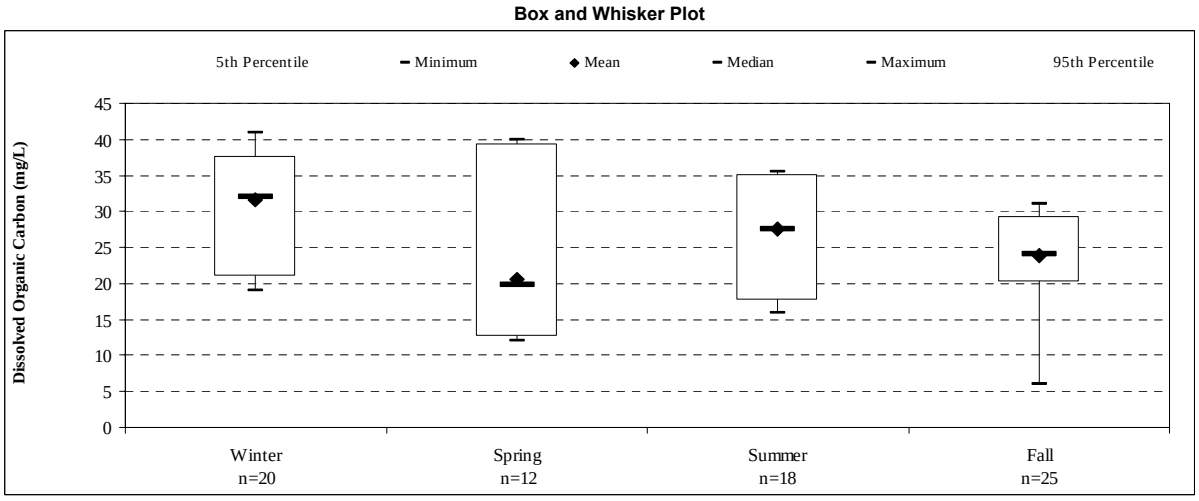


Figure G-2-7-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Muskeg Creek



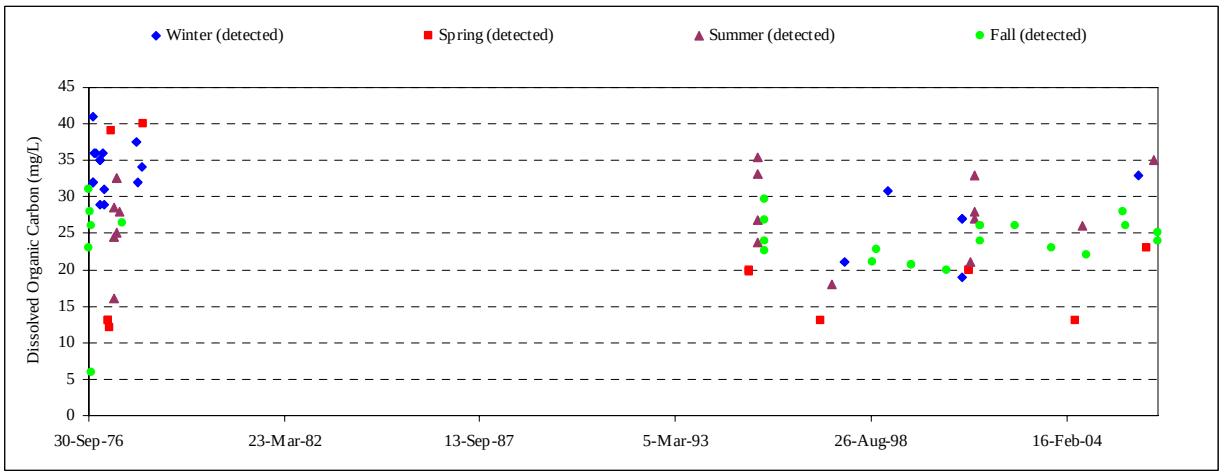
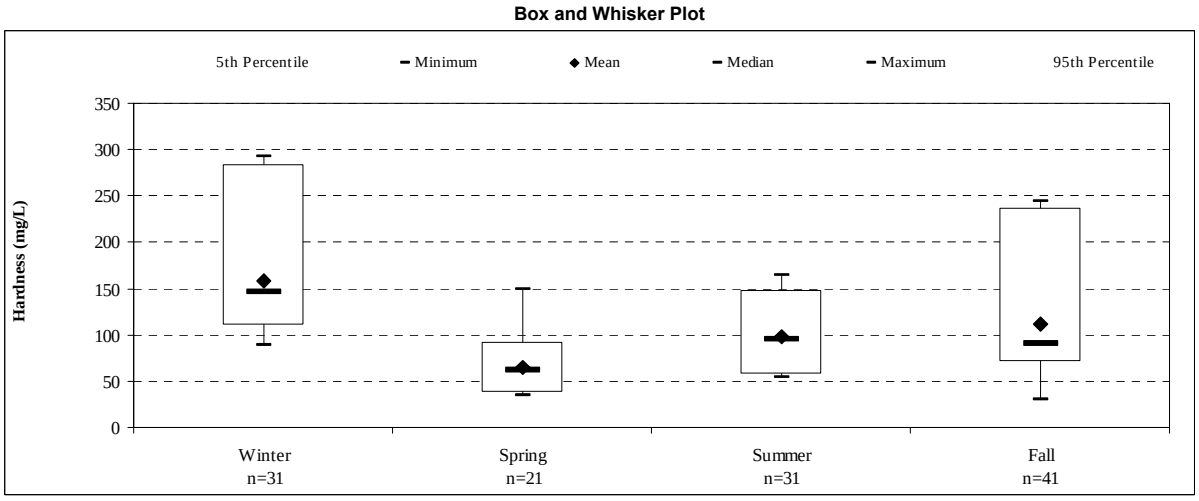


Figure G-2-7-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Muskeg Creek



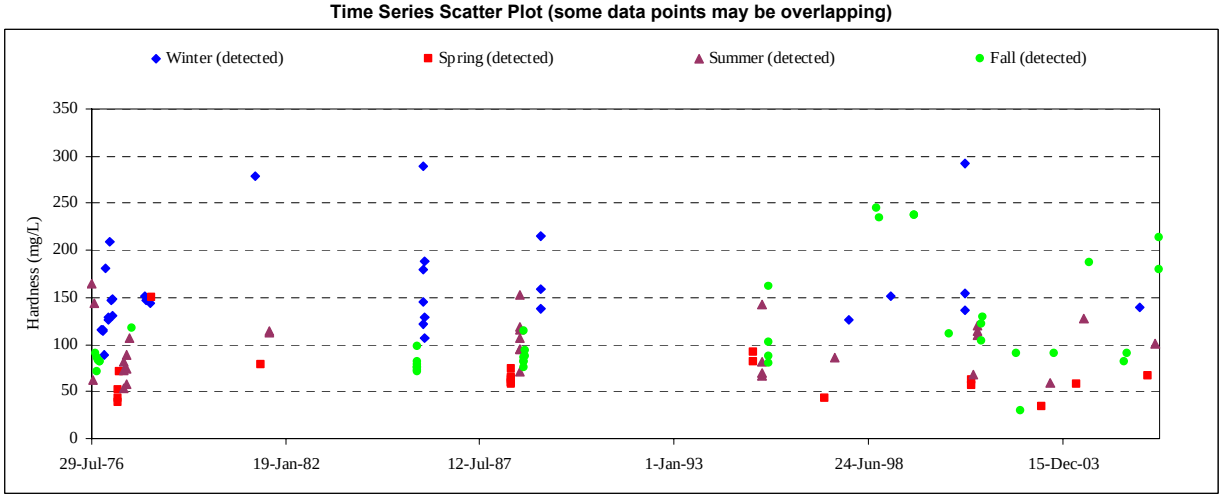
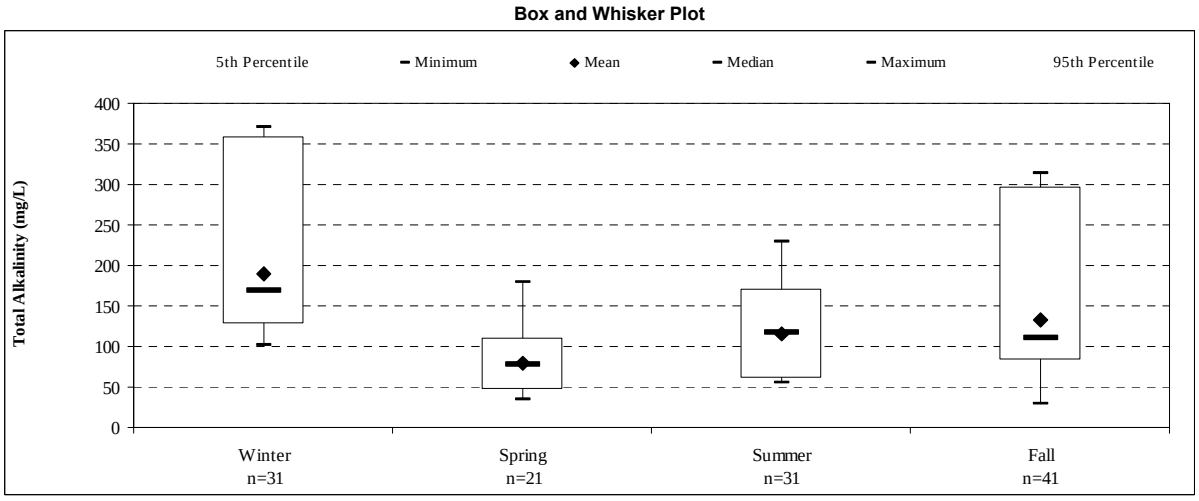


Figure G-2-7-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Muskeg Creek



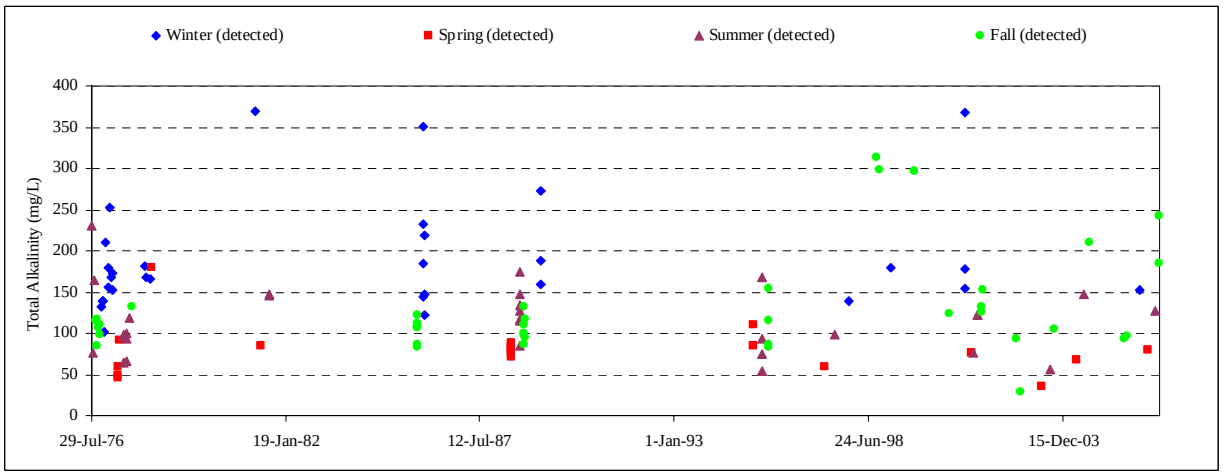
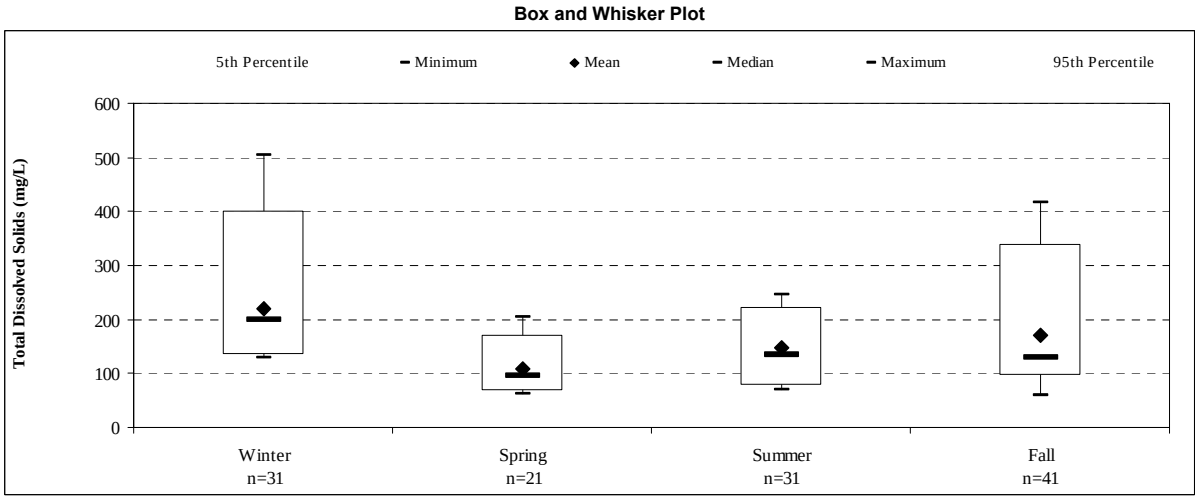


Figure G-2-7-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Muskeg Creek



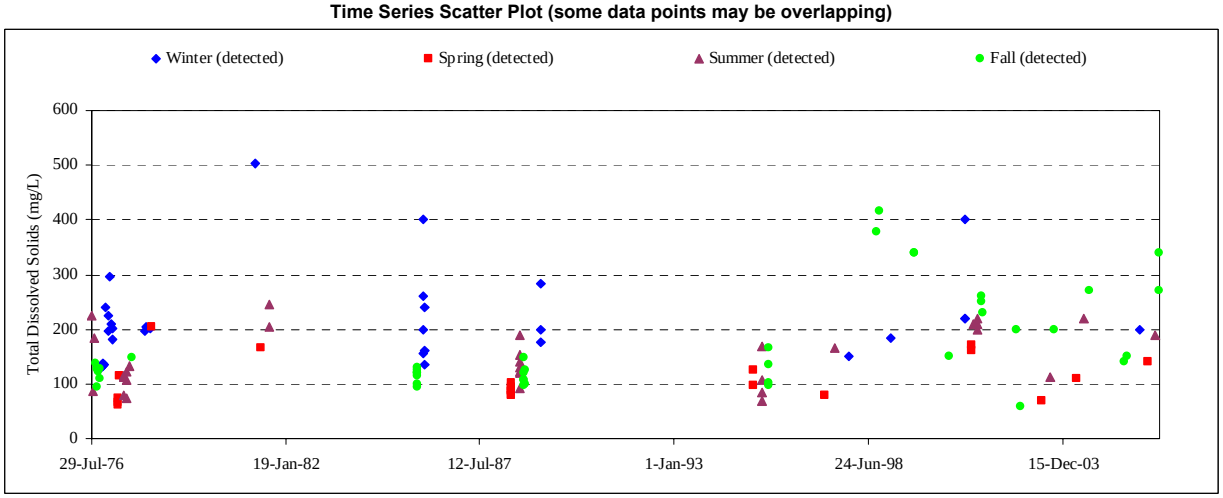
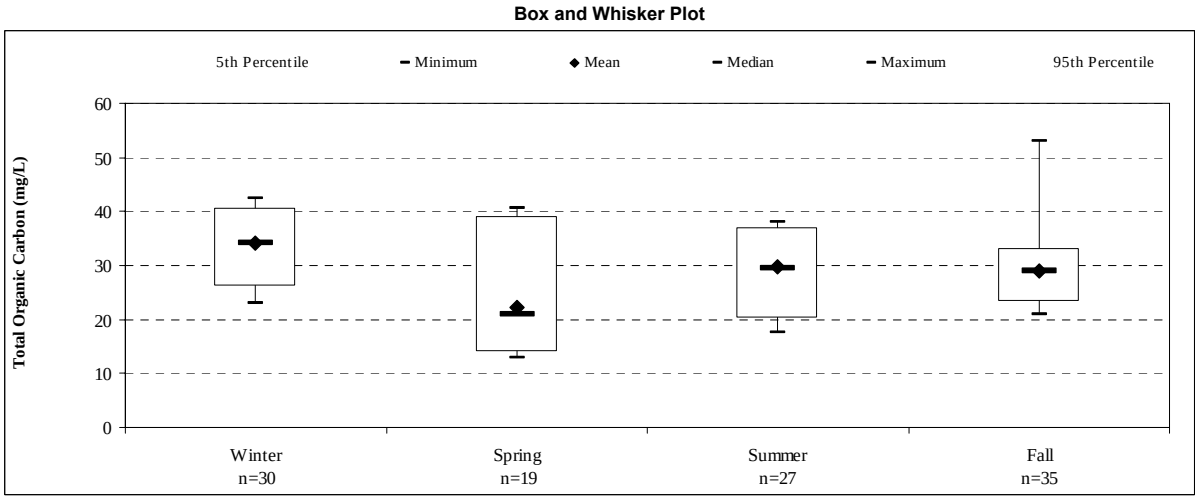


Figure G-2-7-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Muskeg Creek



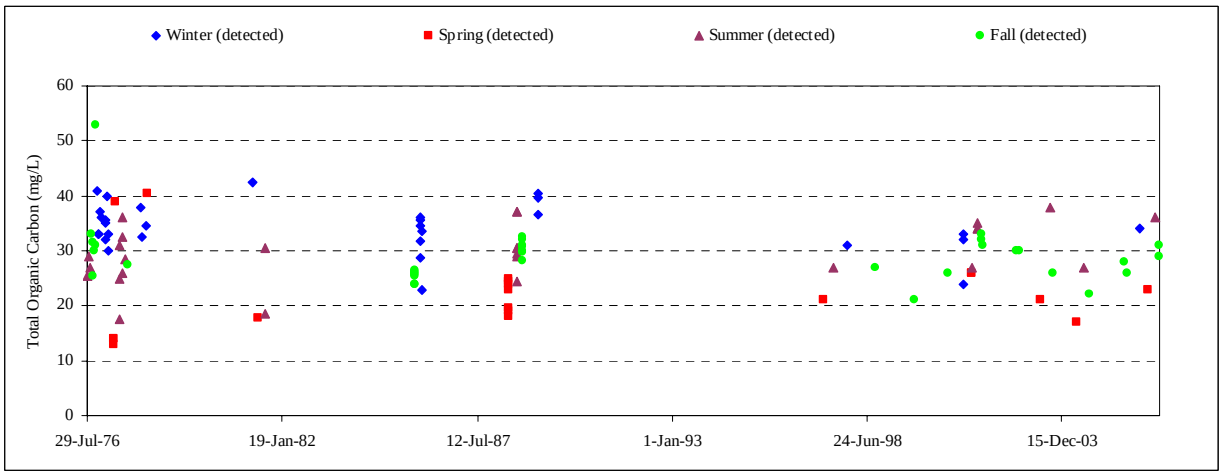


Figure G-2-7-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Muskeg Creek

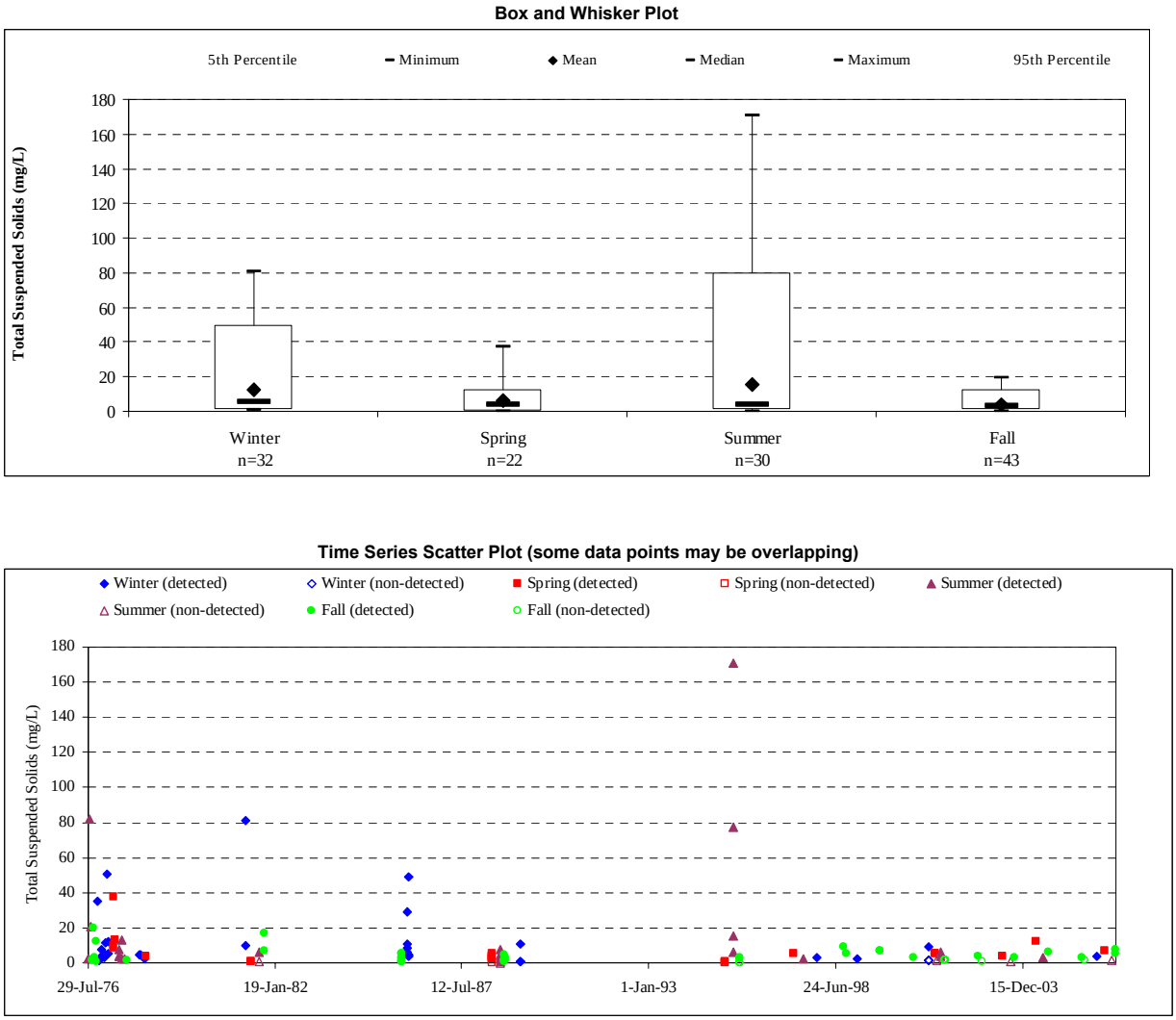
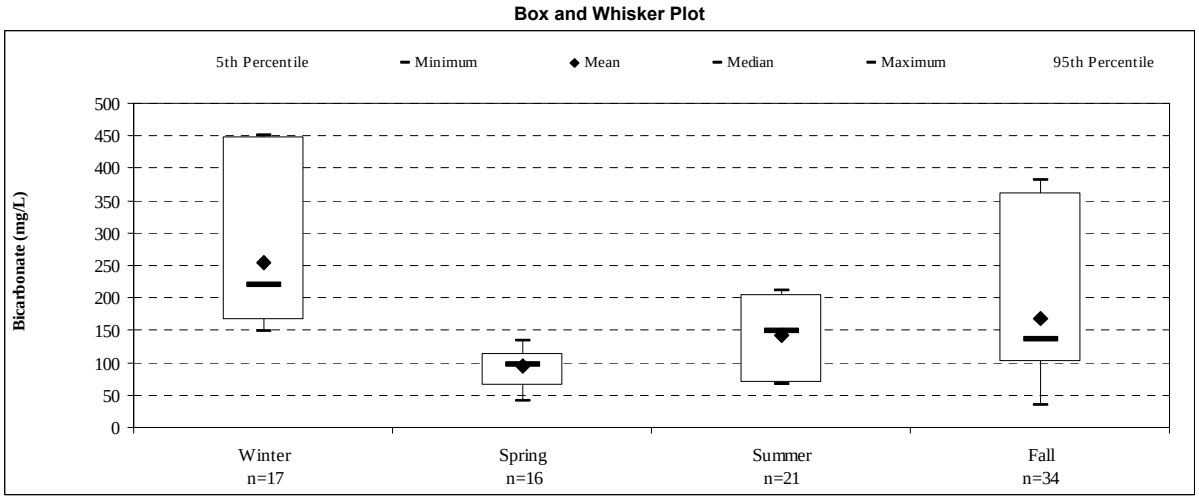


Figure G-2-7-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Muskeg Creek



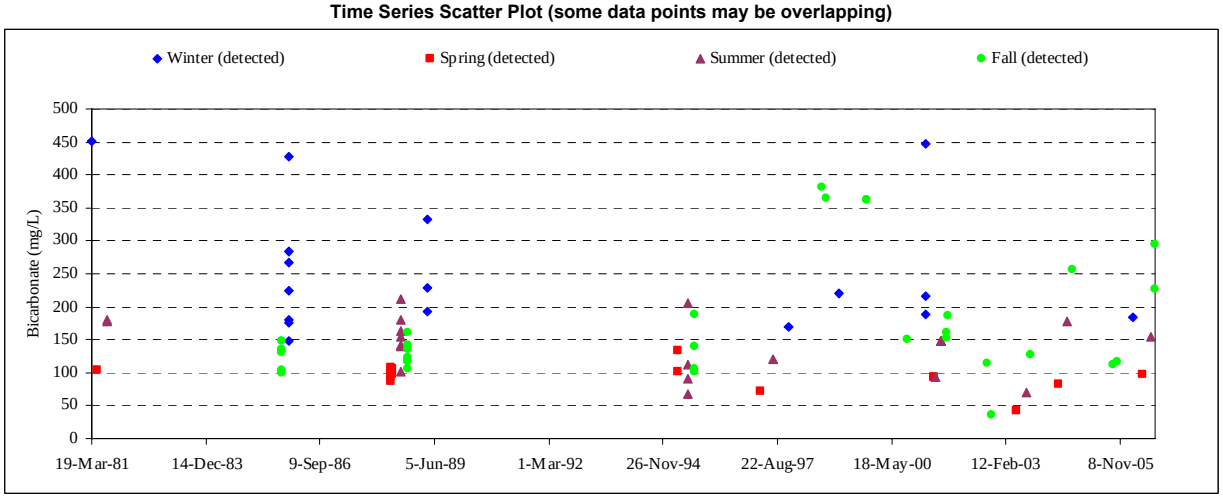
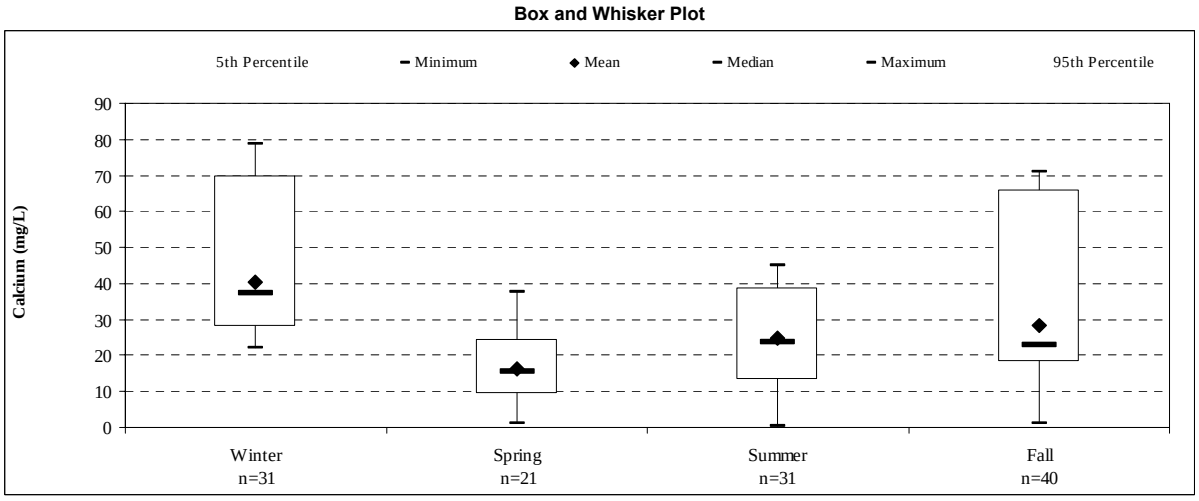


Figure G-2-7-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Muskeg Creek



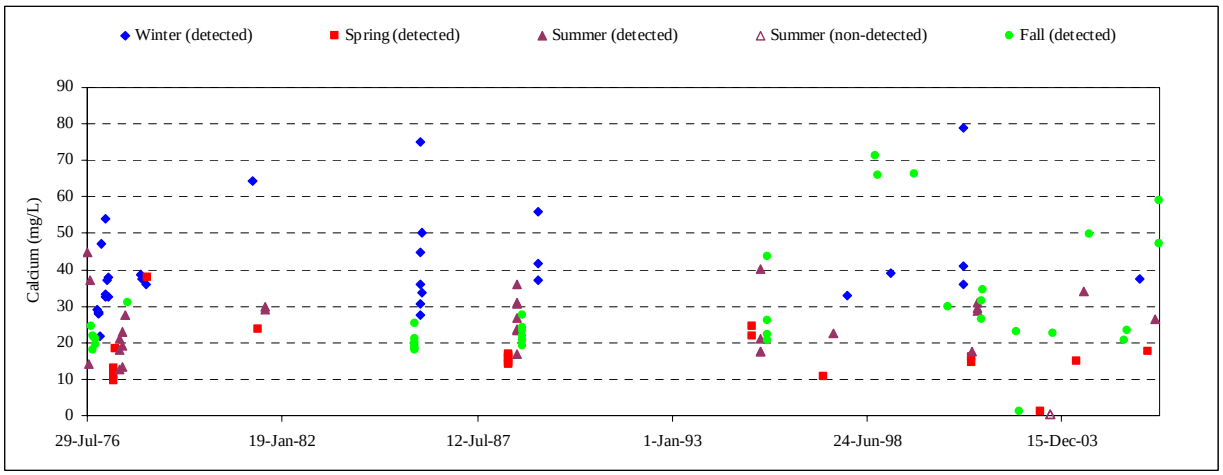
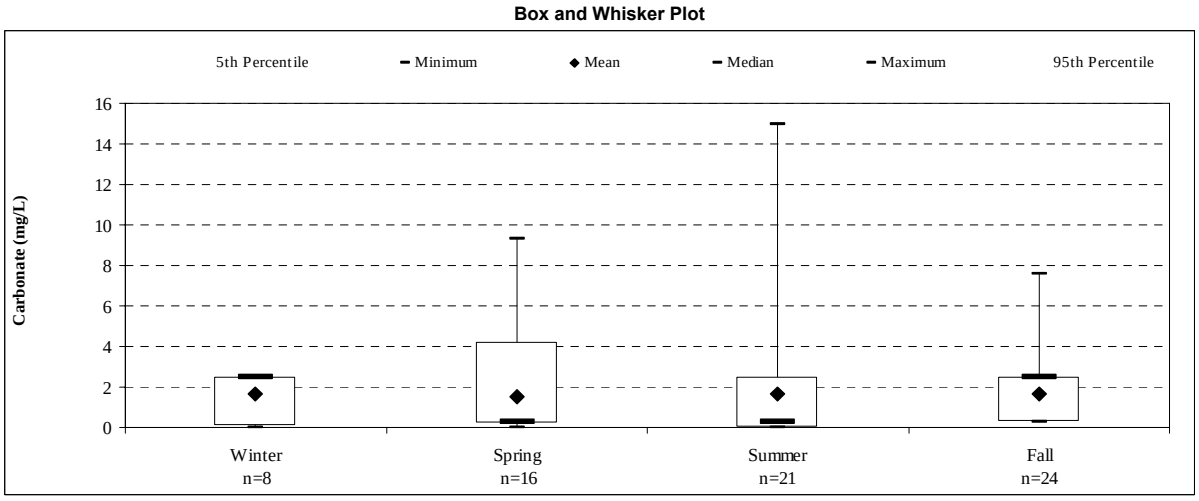


Figure G-2-7-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Muskeg Creek



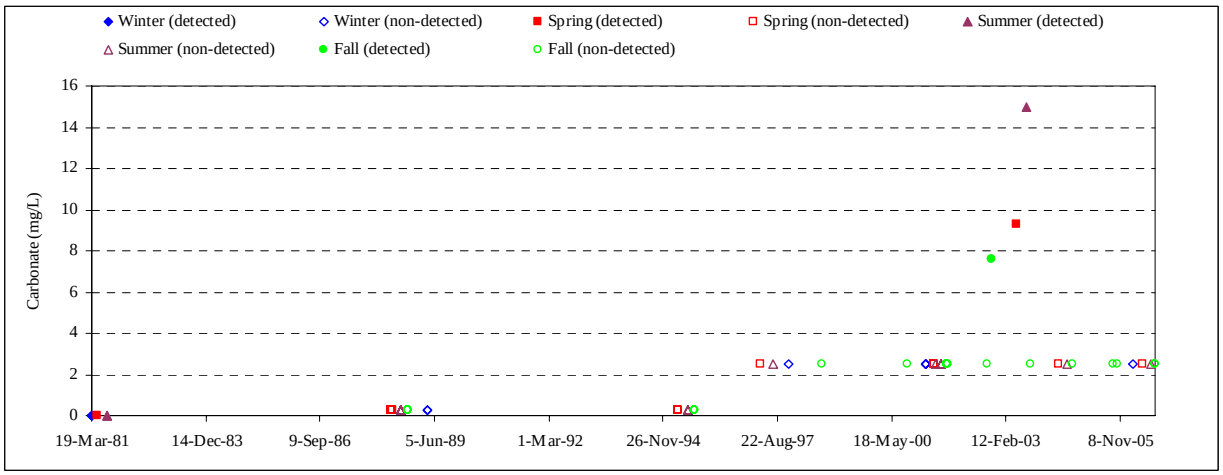
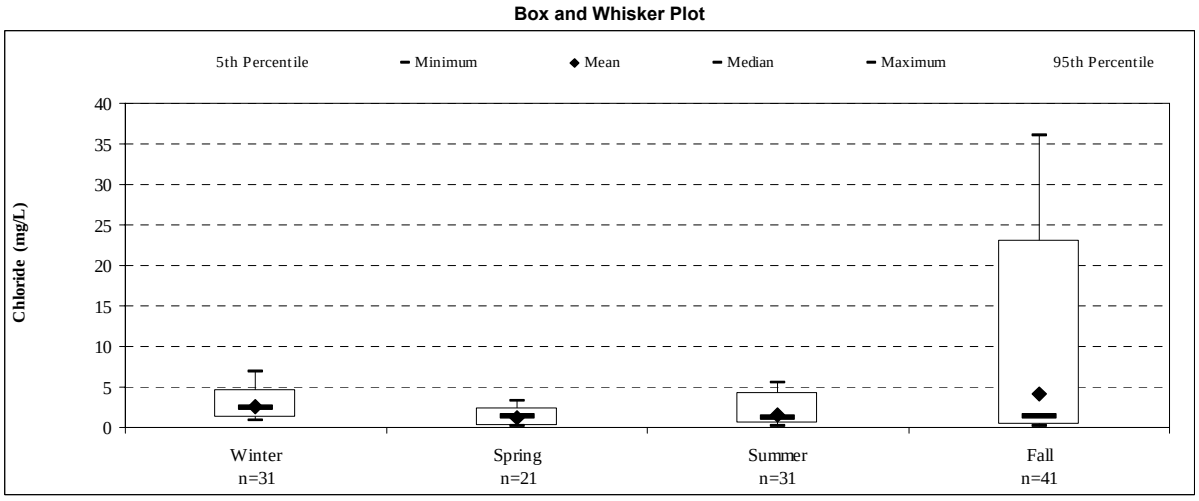


Figure G-2-7-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Muskeg Creek



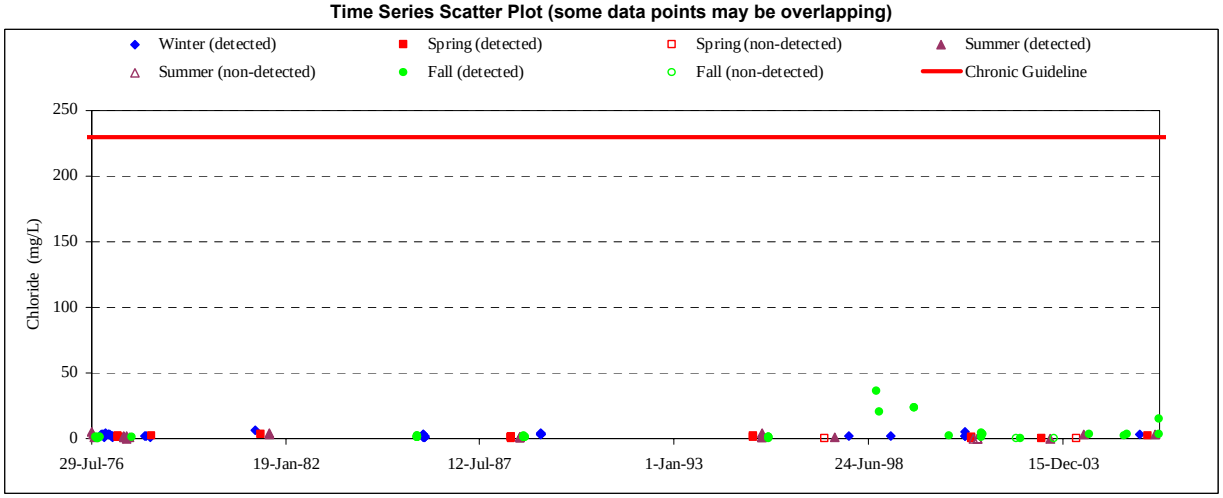
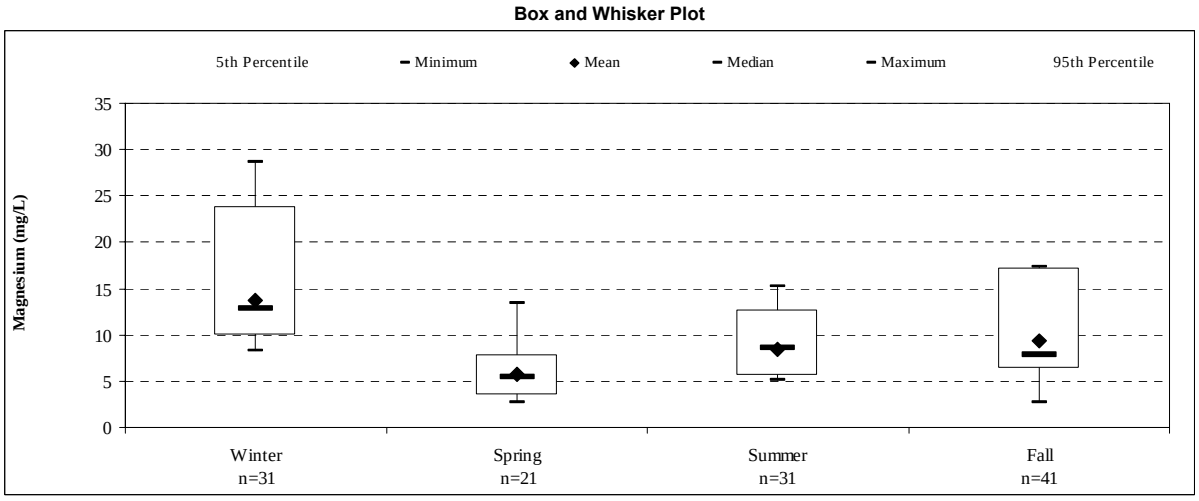


Figure G-2-7-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Muskeg Creek



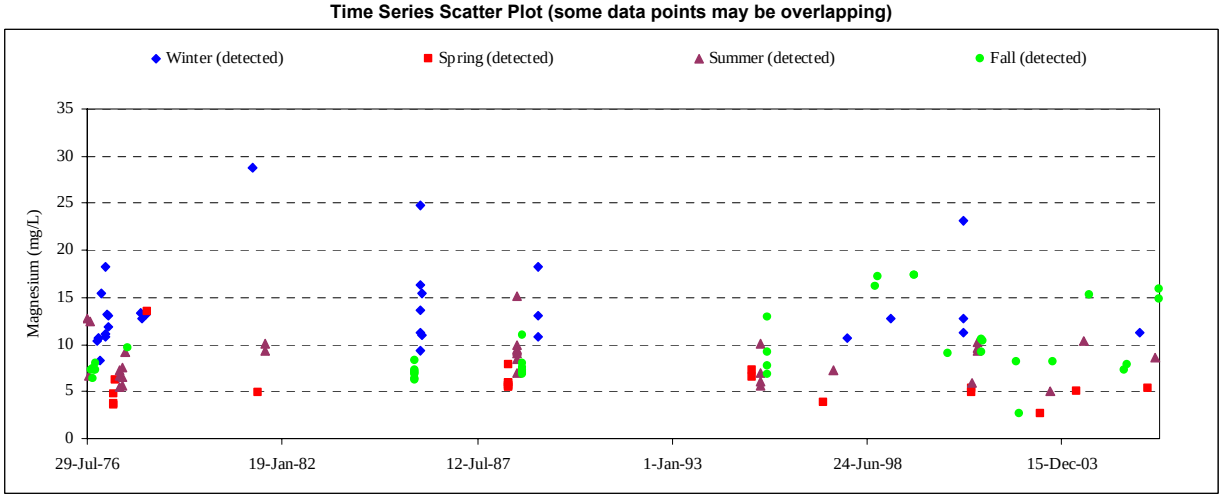
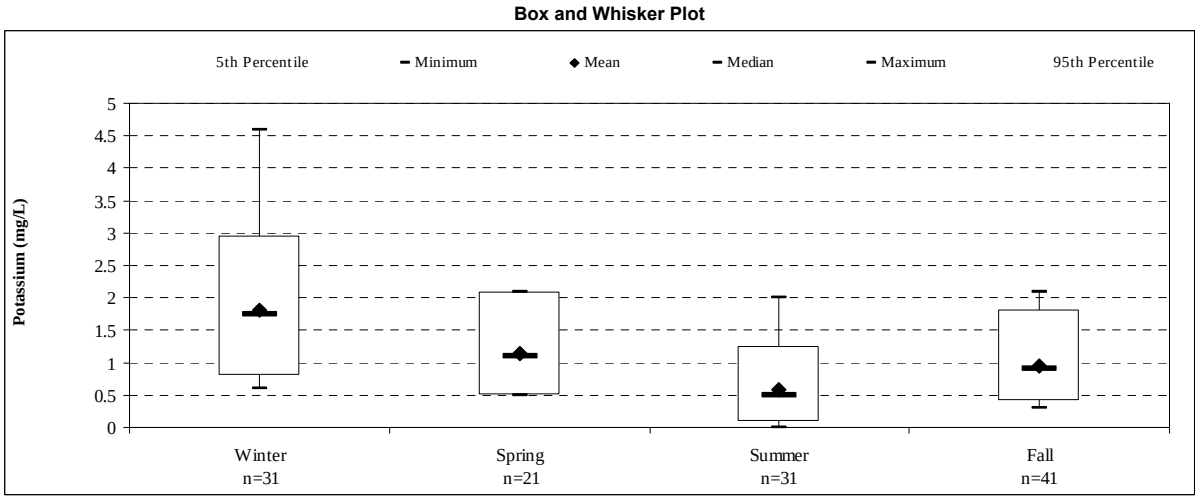


Figure G-2-7-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Muskeg Creek



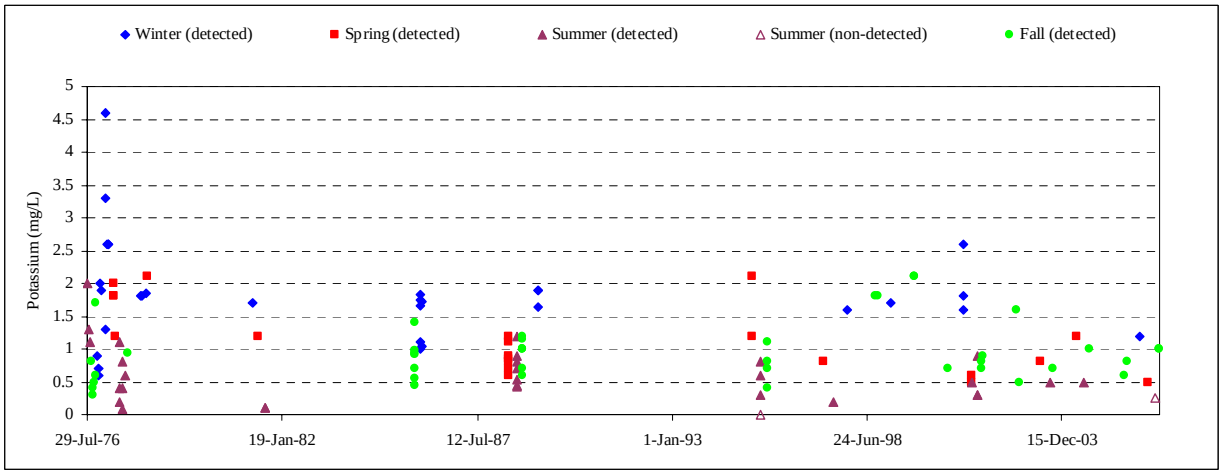
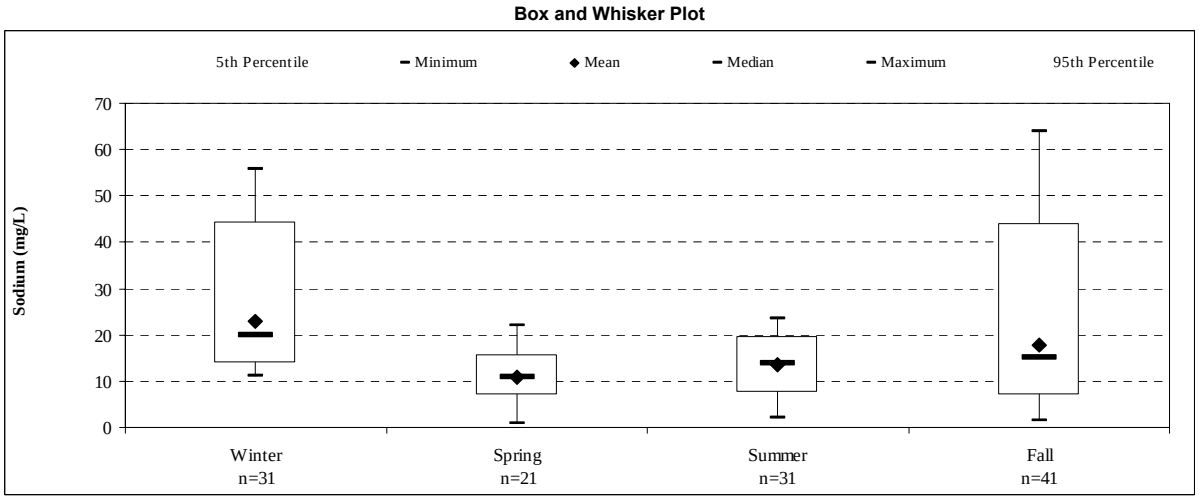


Figure G-2-7-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Muskeg Creek



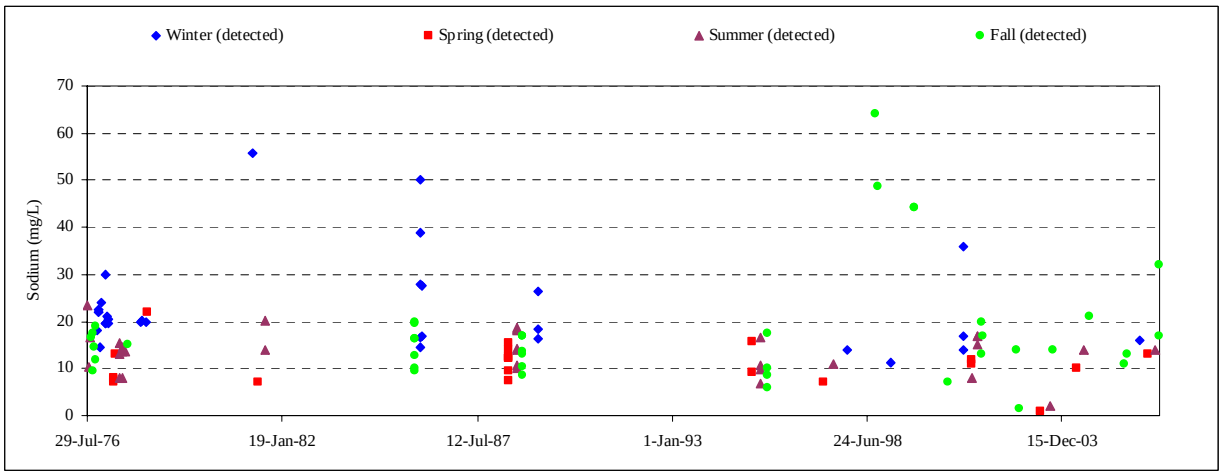
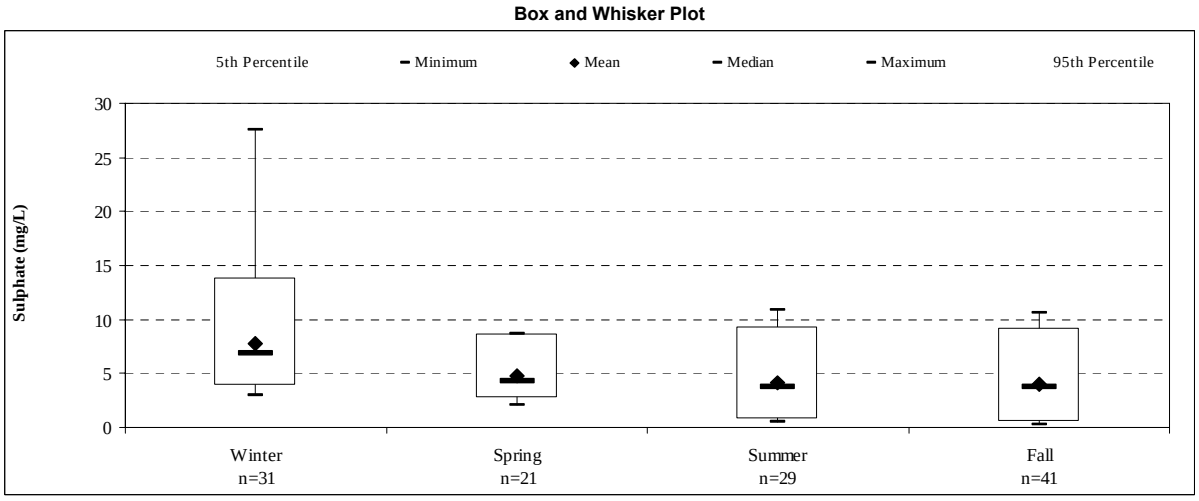


Figure G-2-7-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Muskeg Creek



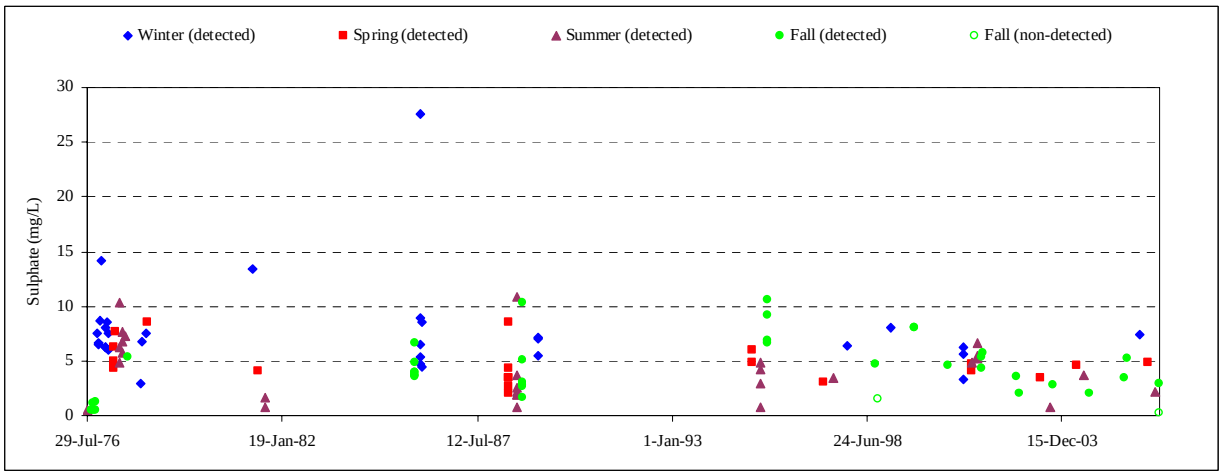
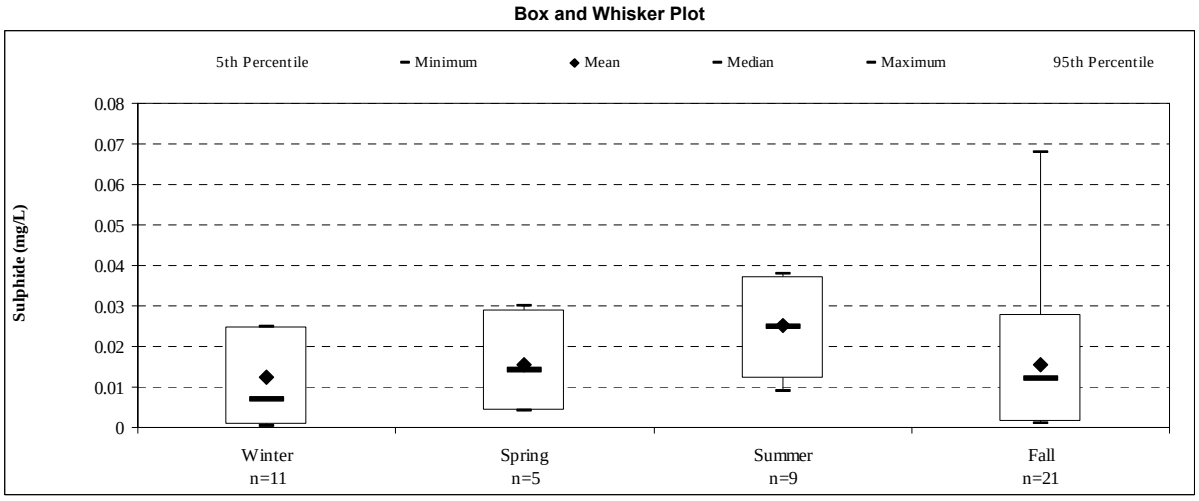


Figure G-2-7-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Muskeg Creek



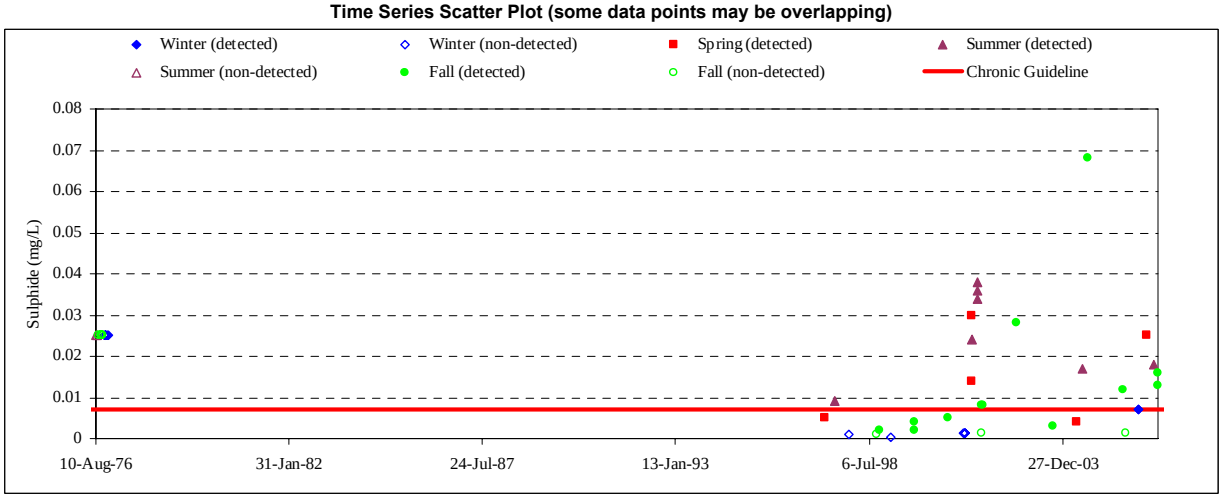


Figure G-2-7-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Muskeg Creek

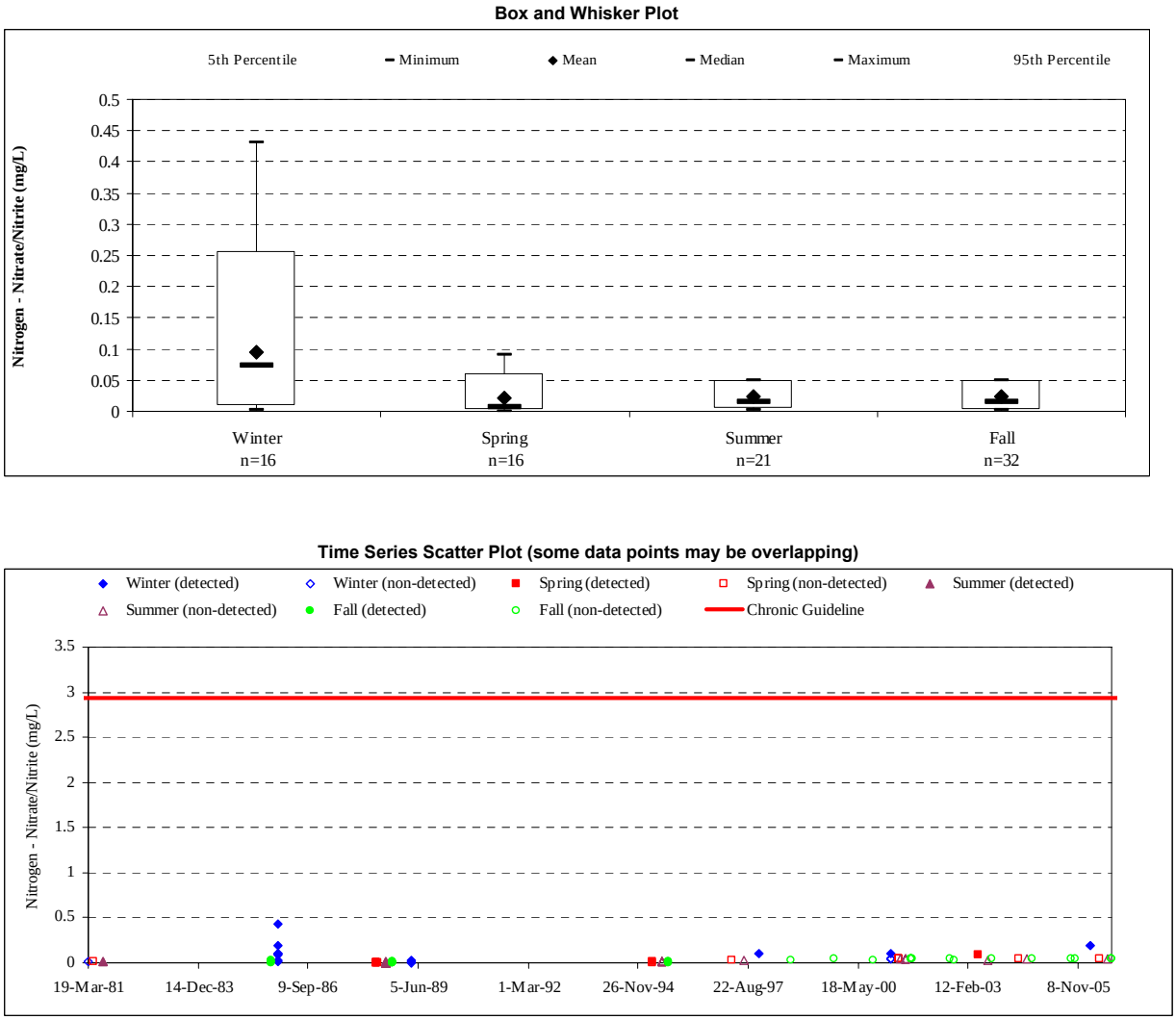
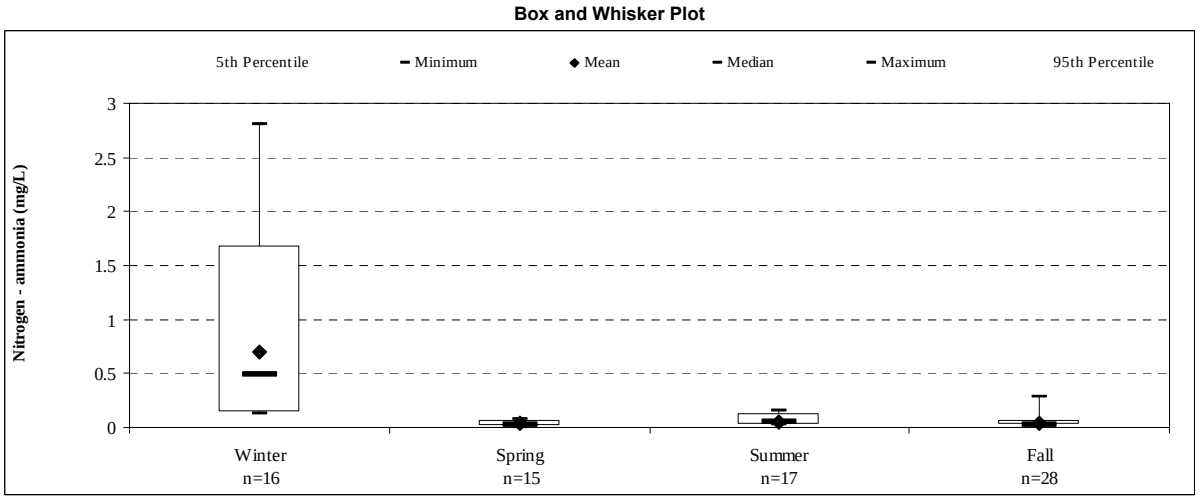


Figure G-2-7-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Muskeg Creek



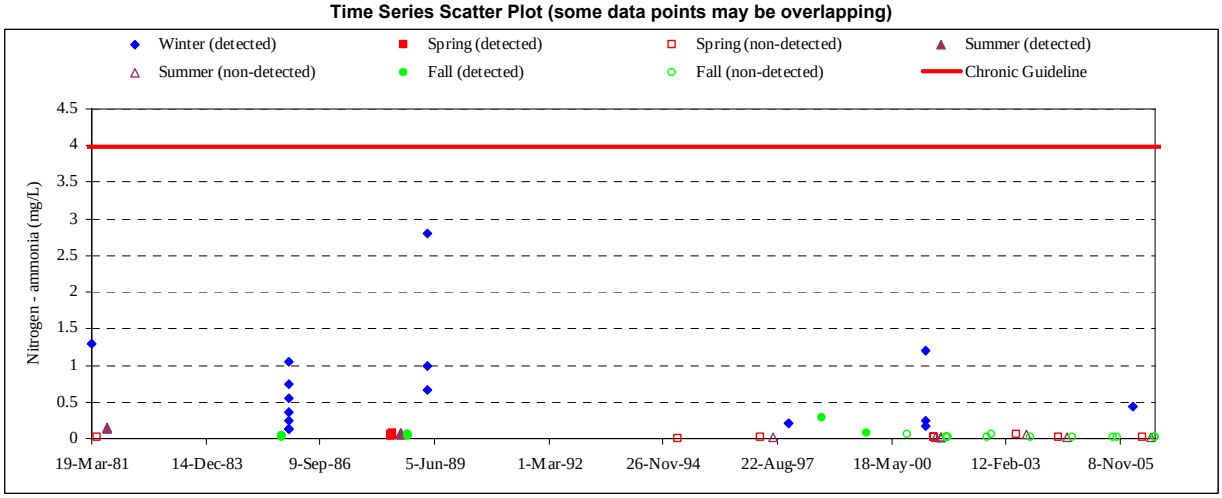
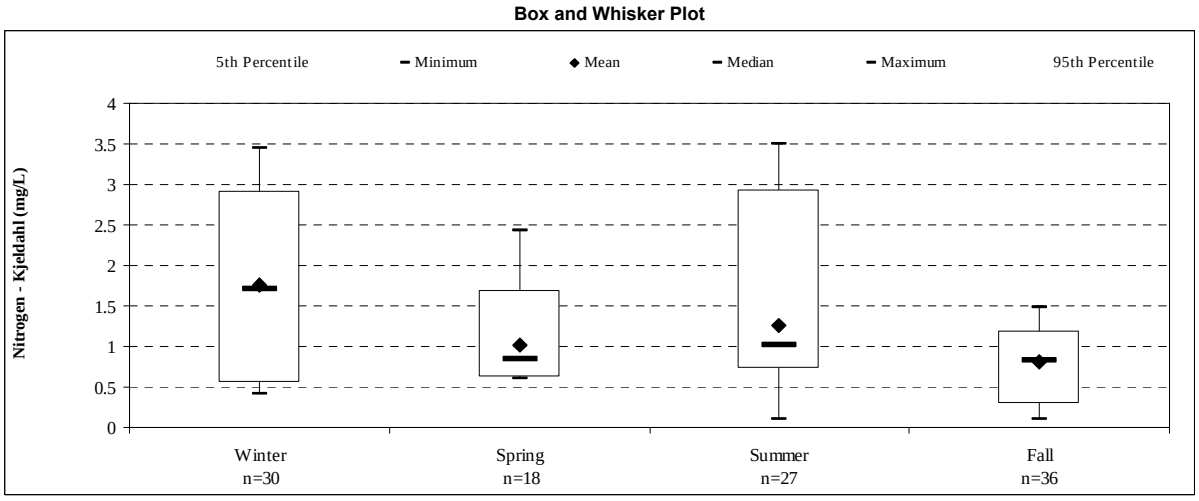


Figure G-2-7-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Muskeg Creek



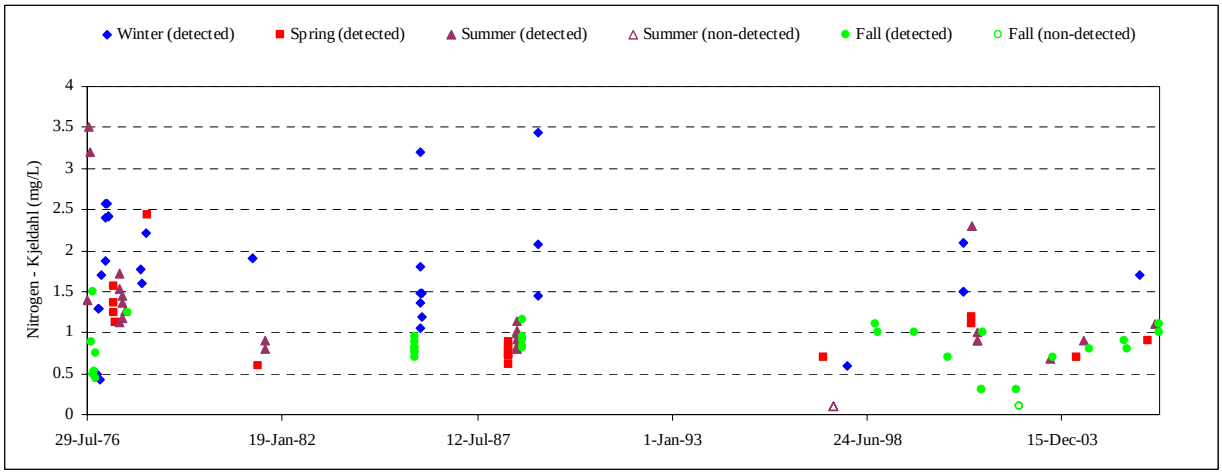
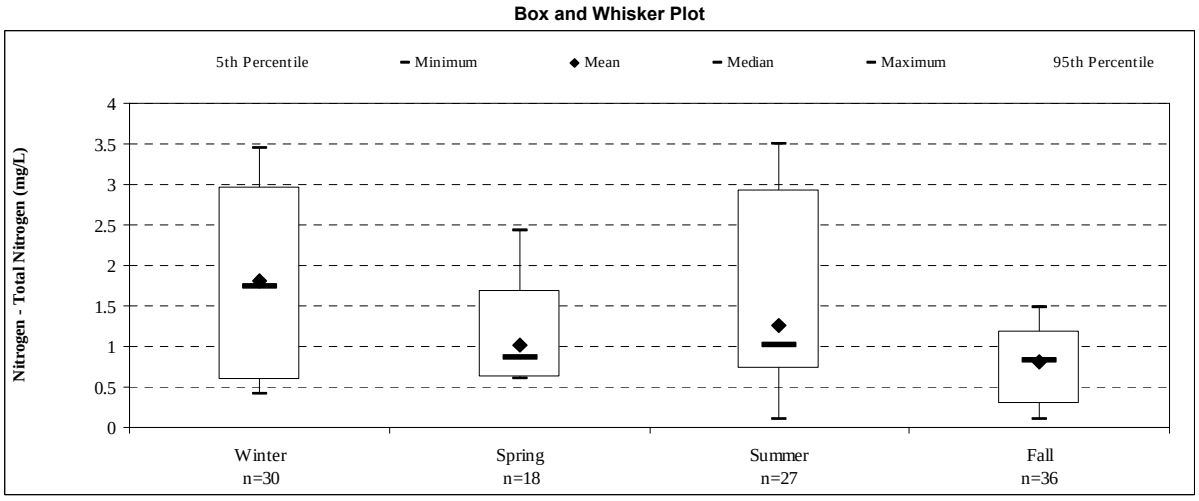


Figure G-2-7-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Muskeg Creek



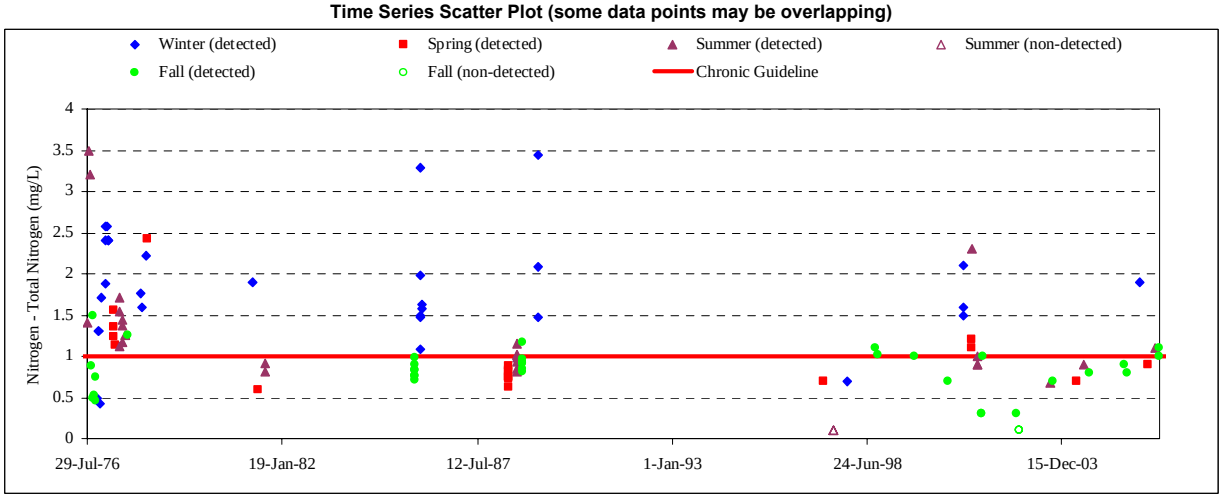
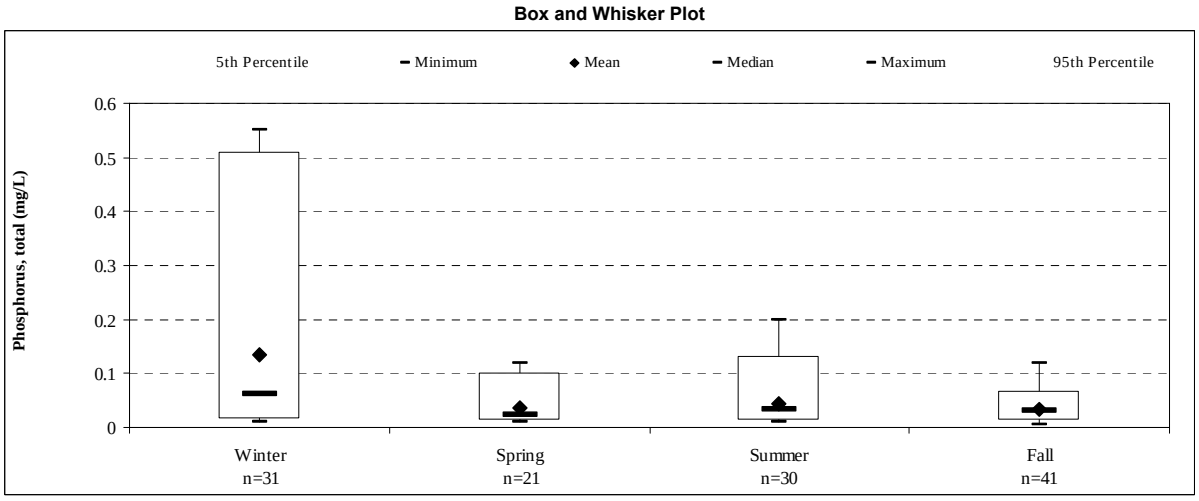


Figure G-2-7-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Muskeg Creek



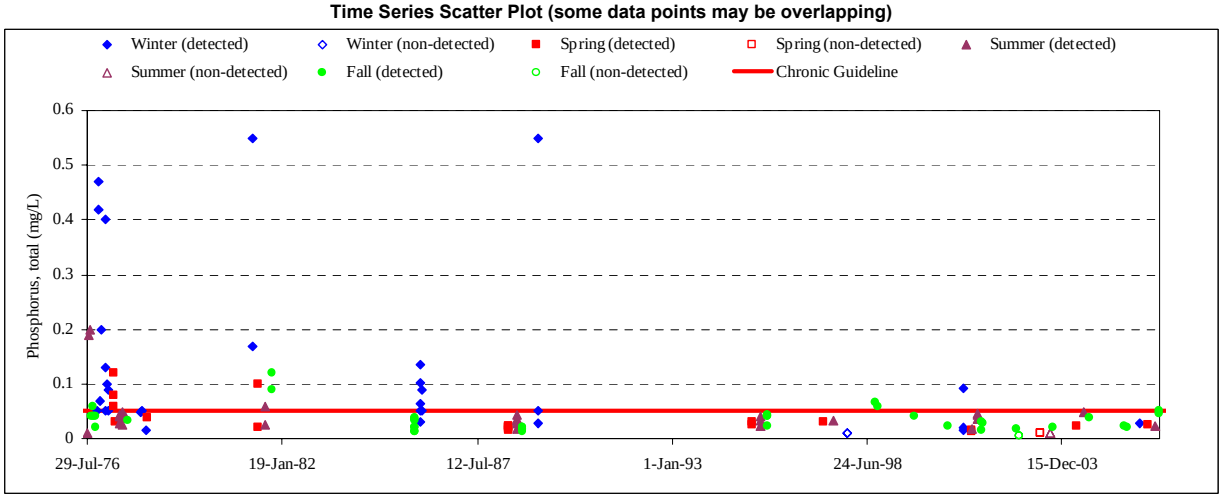
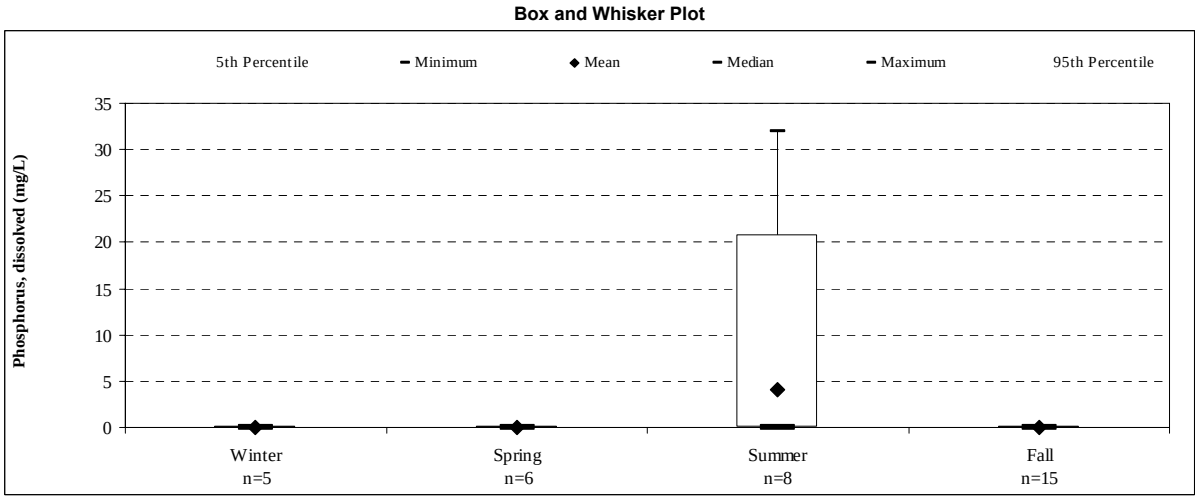


Figure G-2-7-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Muskeg Creek



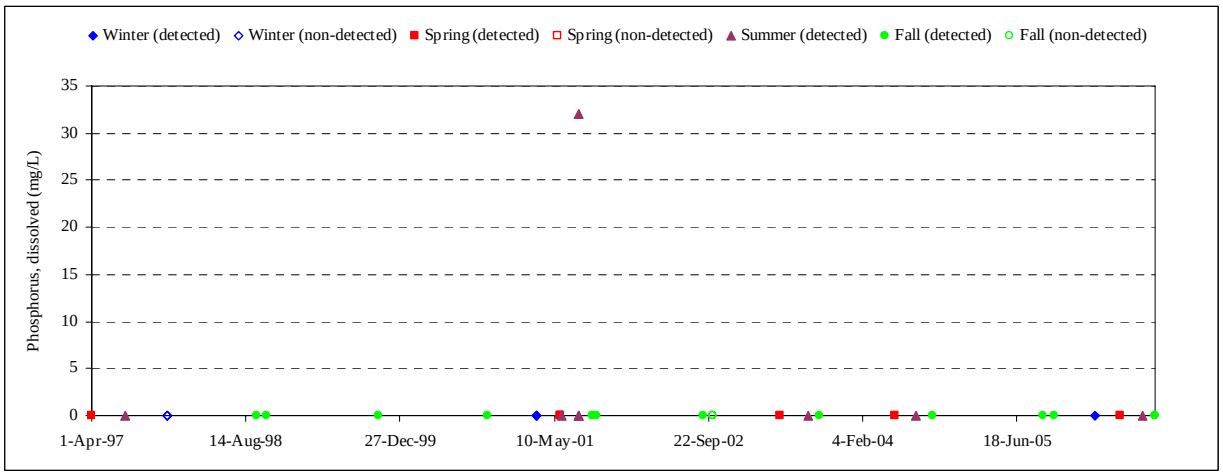
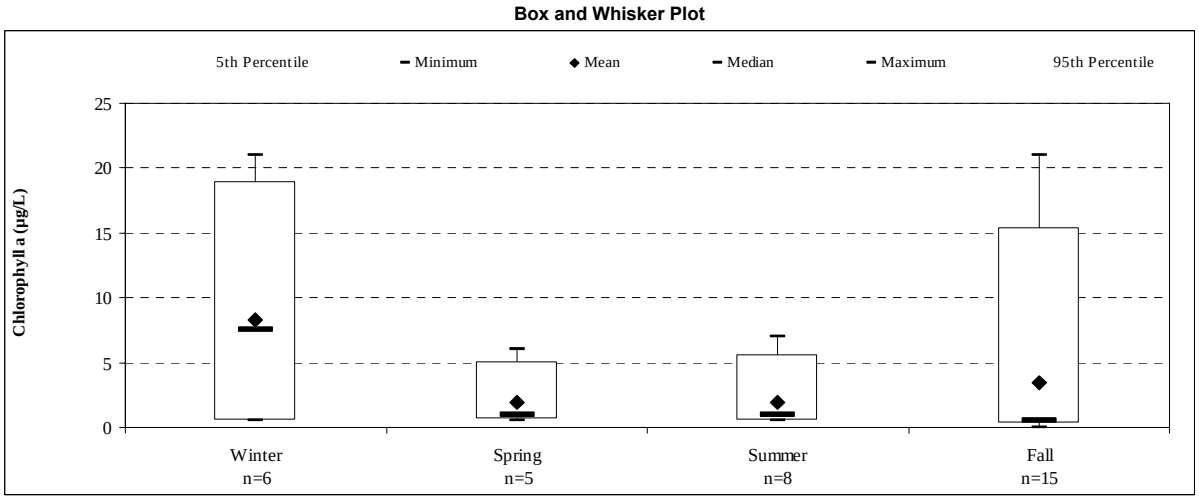


Figure G-2-7-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Muskeg Creek



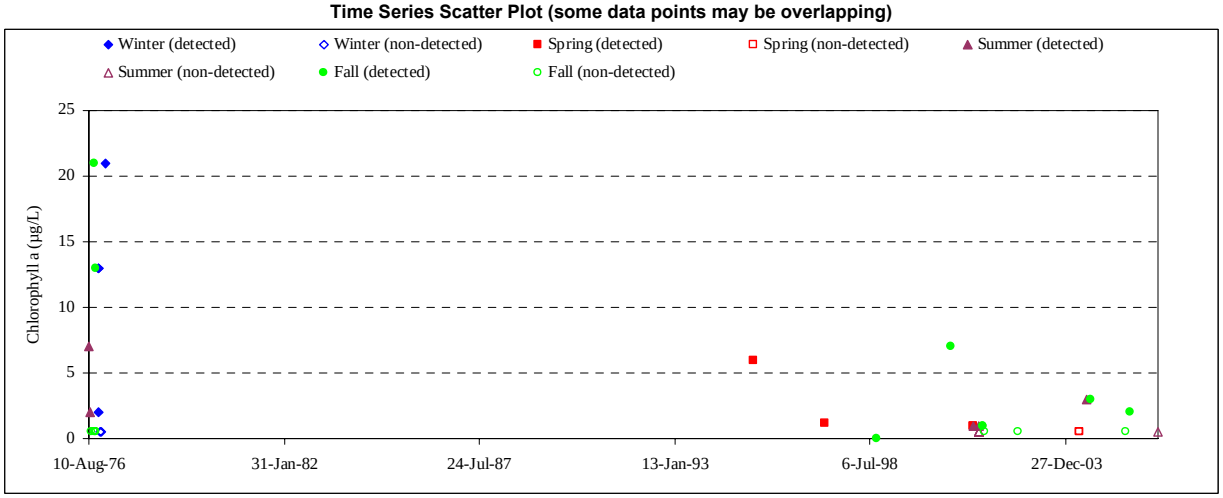


Figure G-2-7-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Muskeg Creek

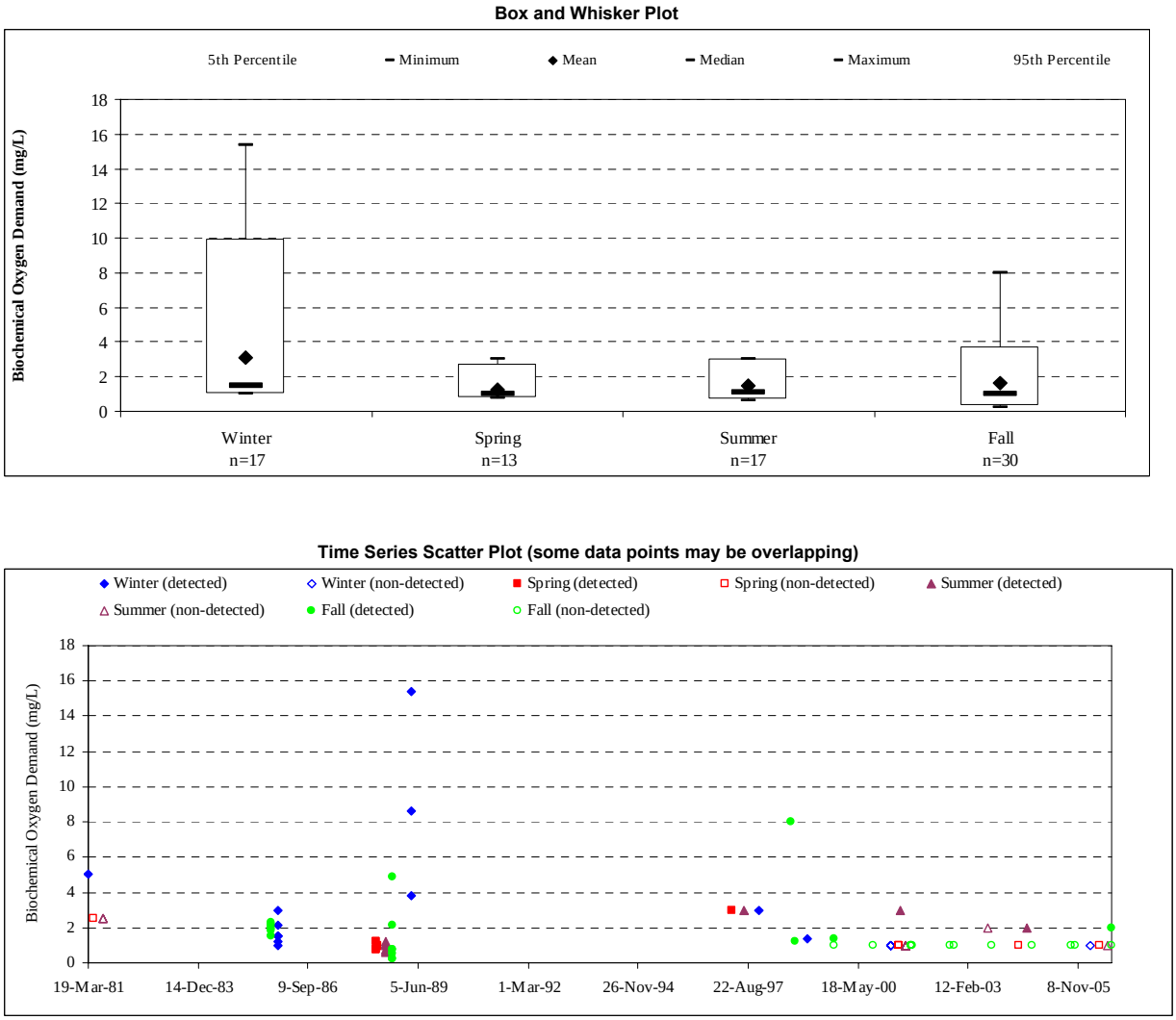
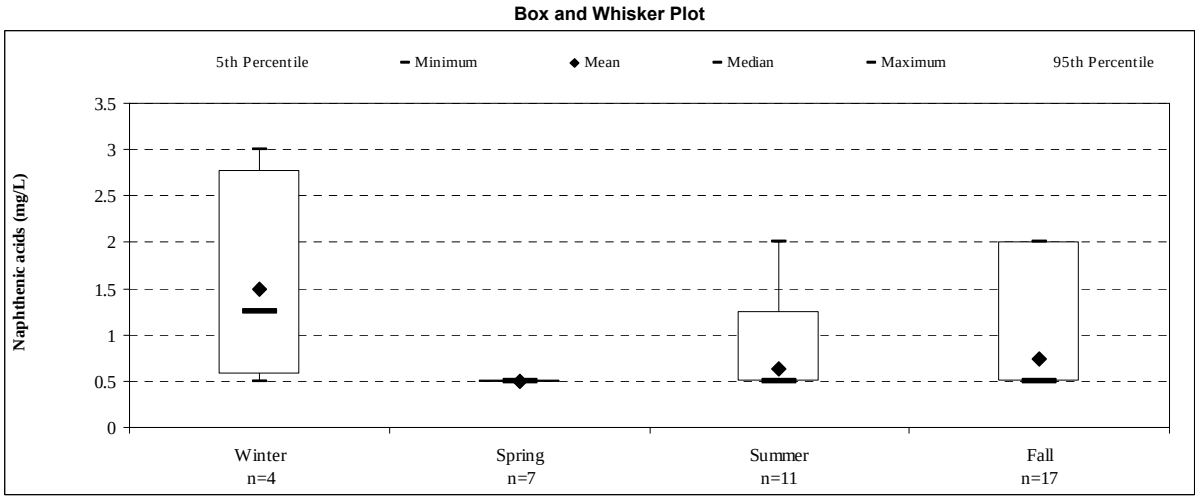


Figure G-2-7-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Muskeg Creek



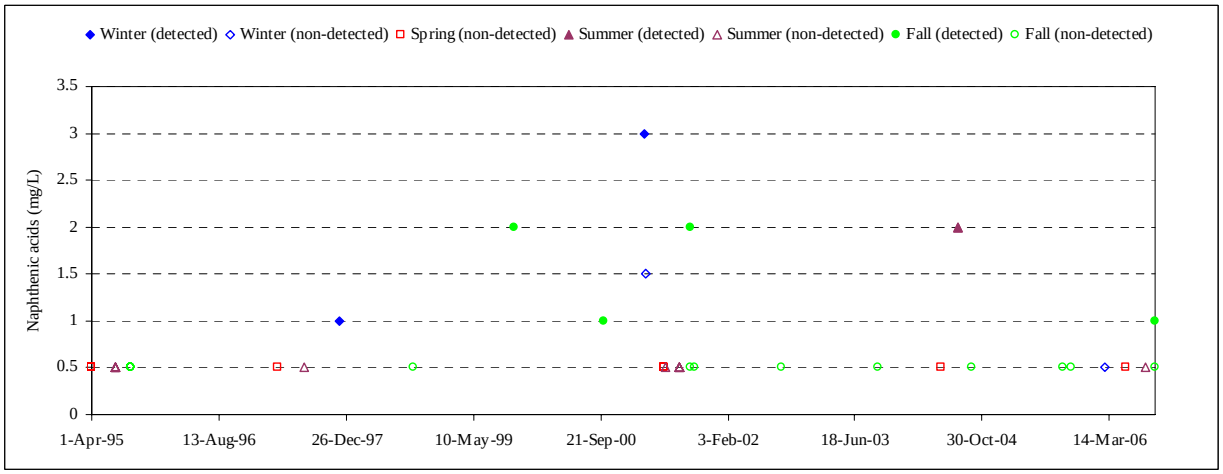


Figure G-2-7-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Muskeg Creek

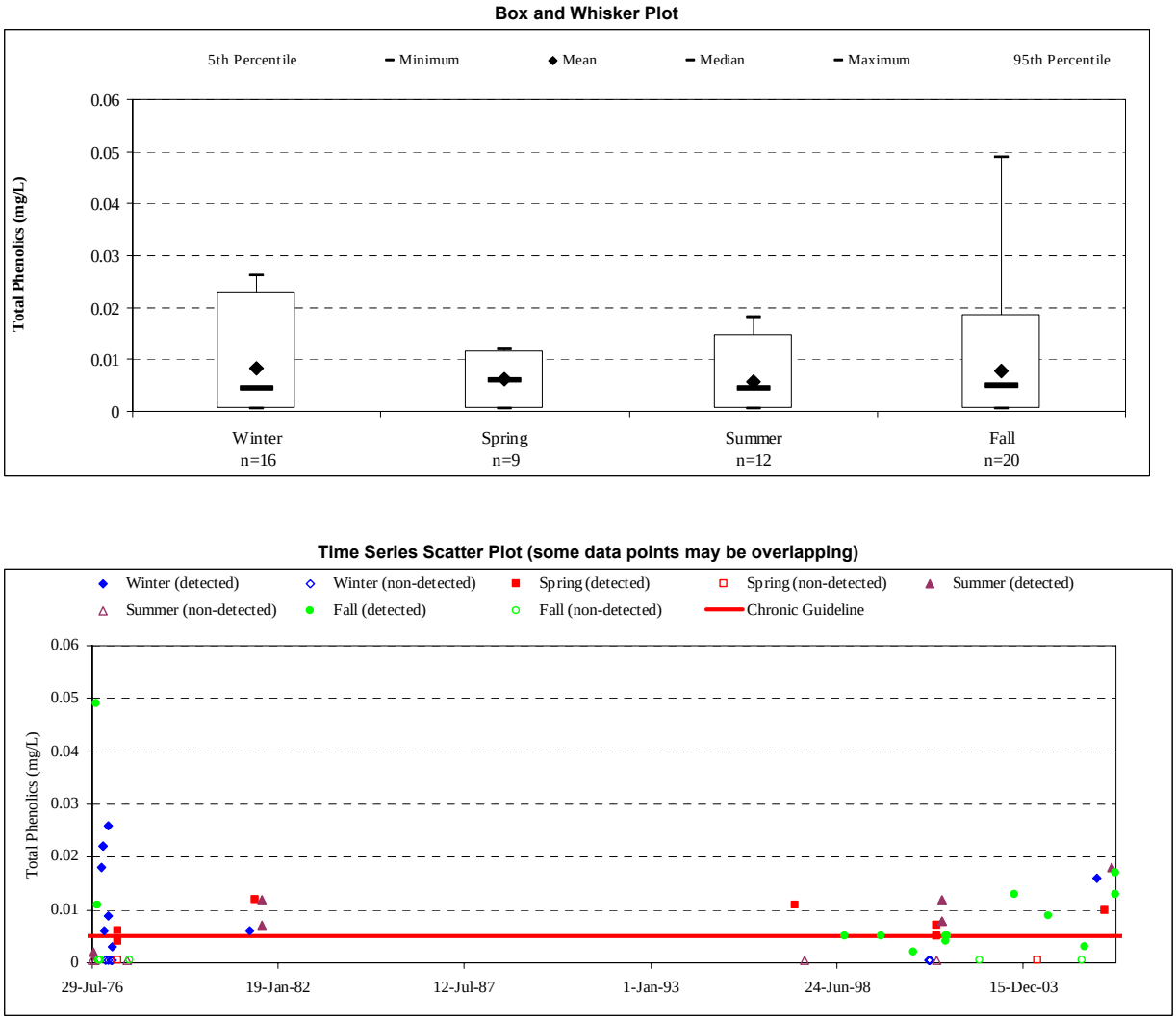
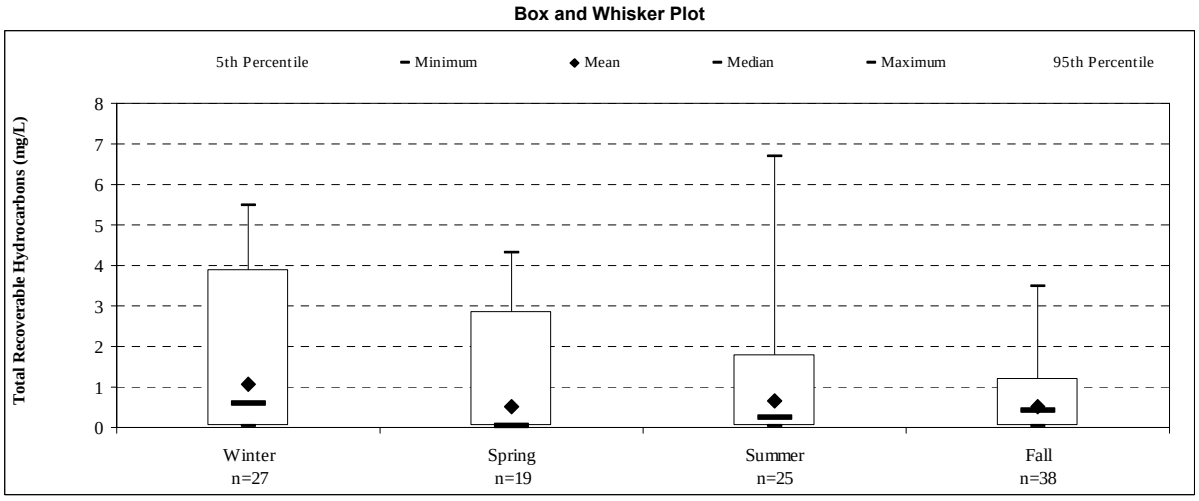


Figure G-2-7-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Muskeg Creek



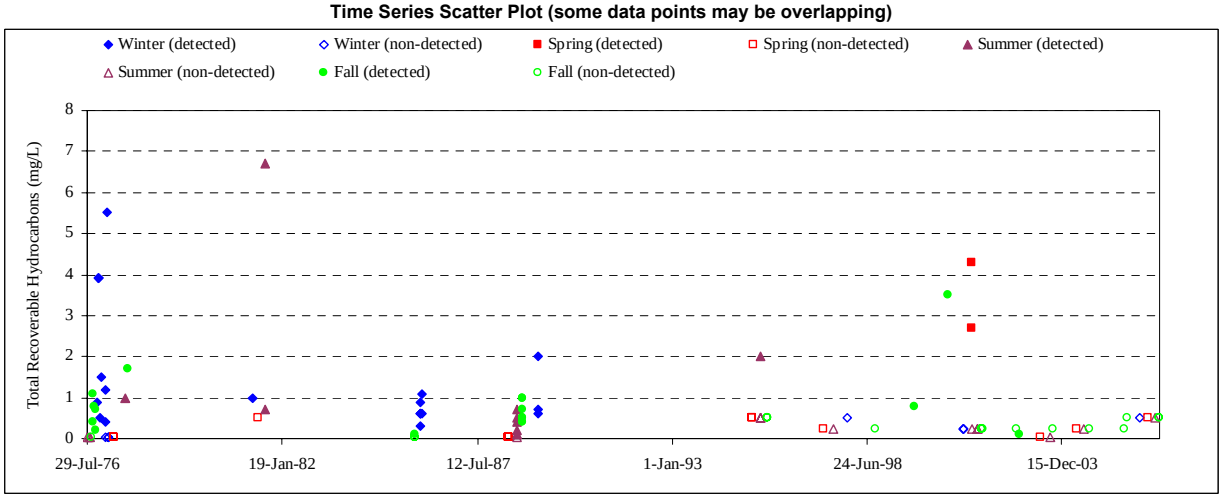


Figure G-2-7-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Muskeg Creek

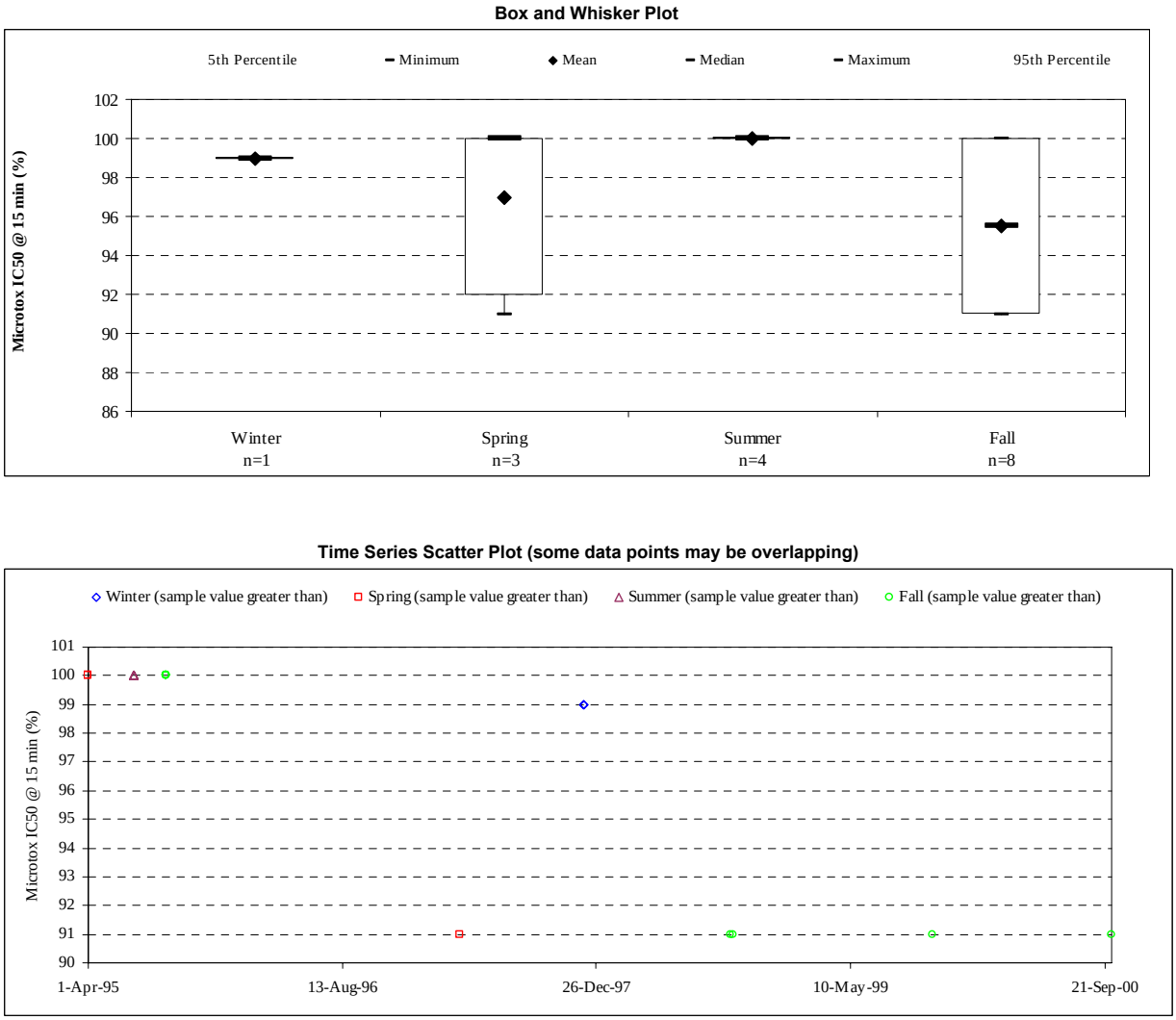
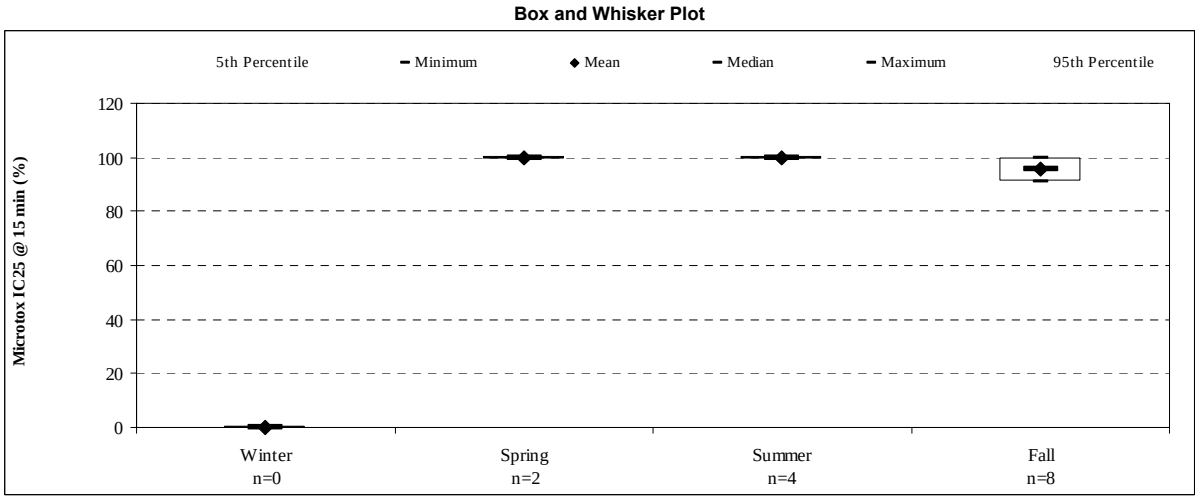


Figure G-2-7-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Muskeg Creek



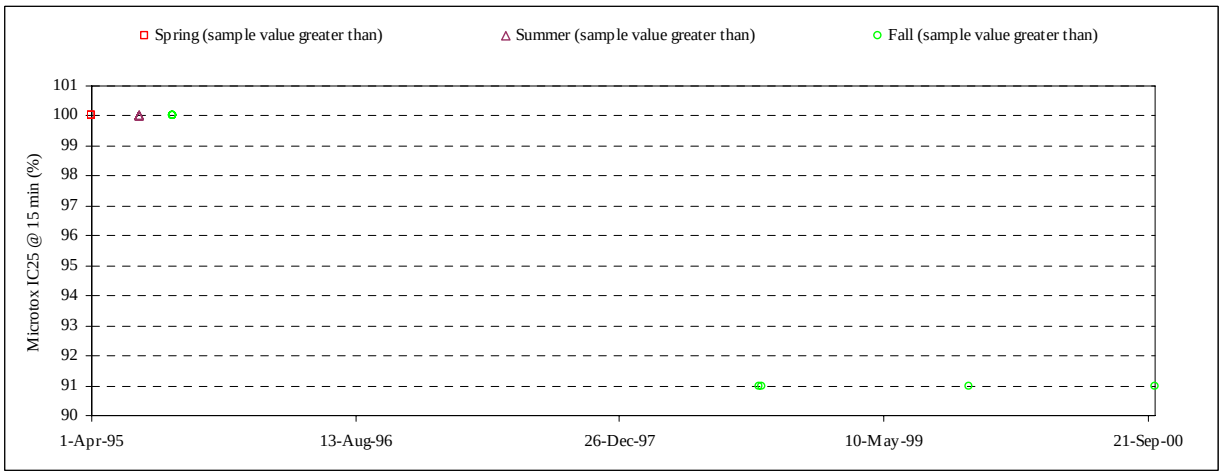
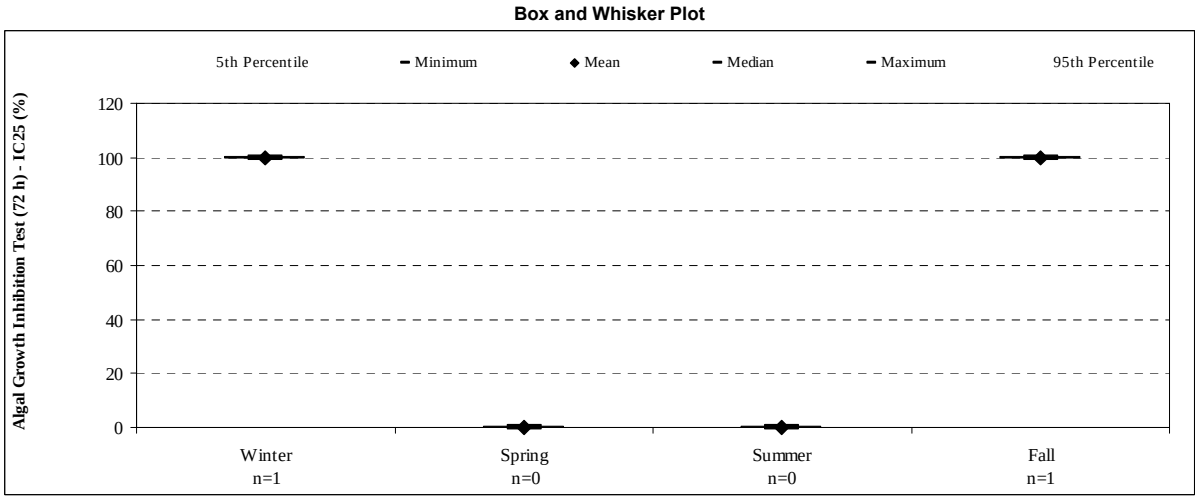


Figure G-2-7-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Muskeg Creek



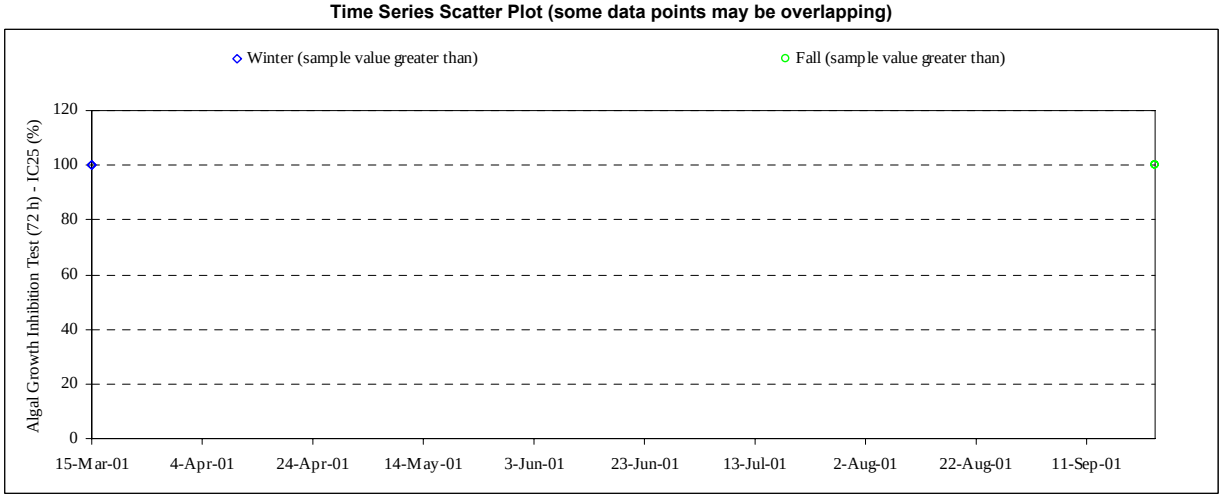
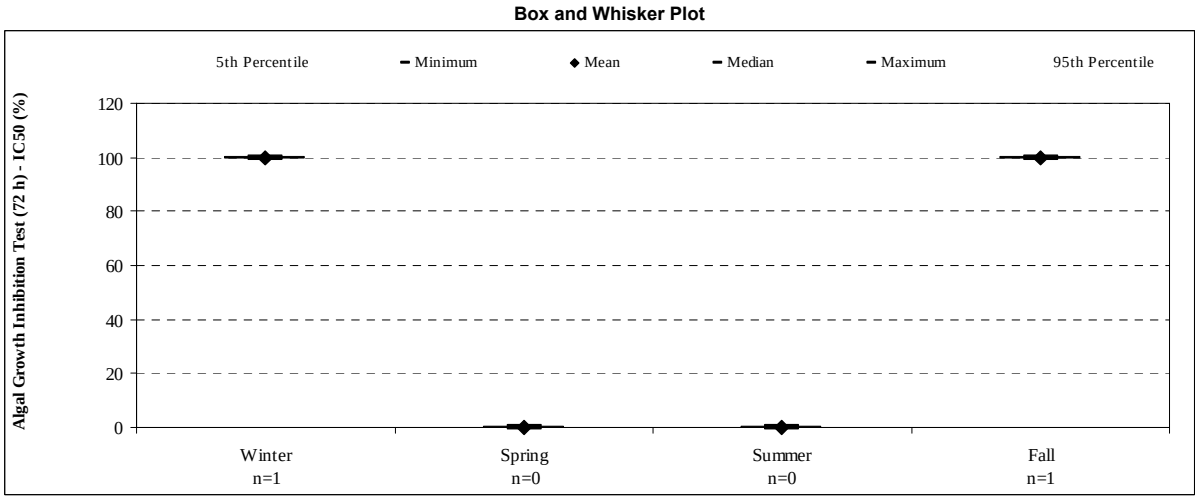


Figure G-2-7-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Muskeg Creek



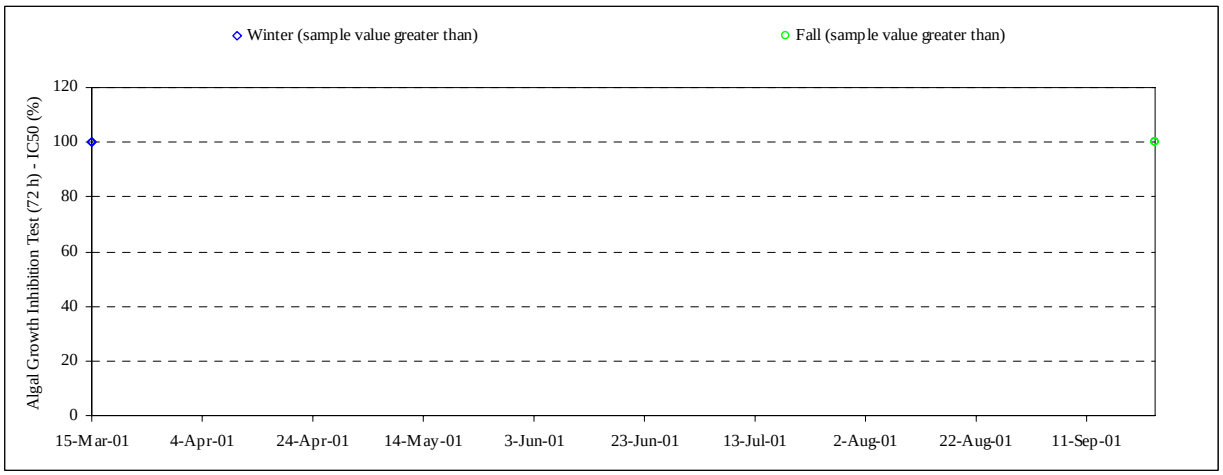
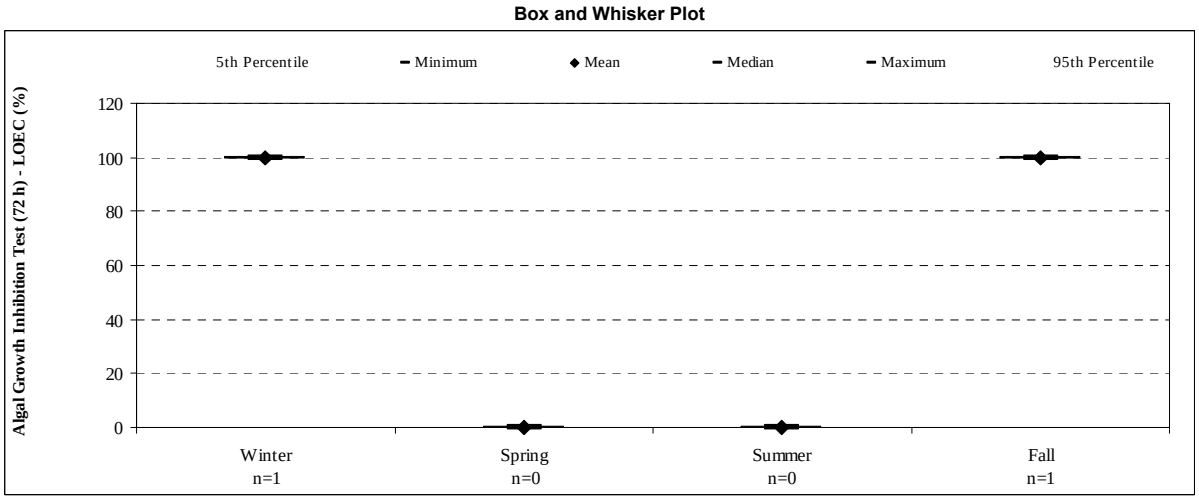


Figure G-2-7-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Muskeg Creek



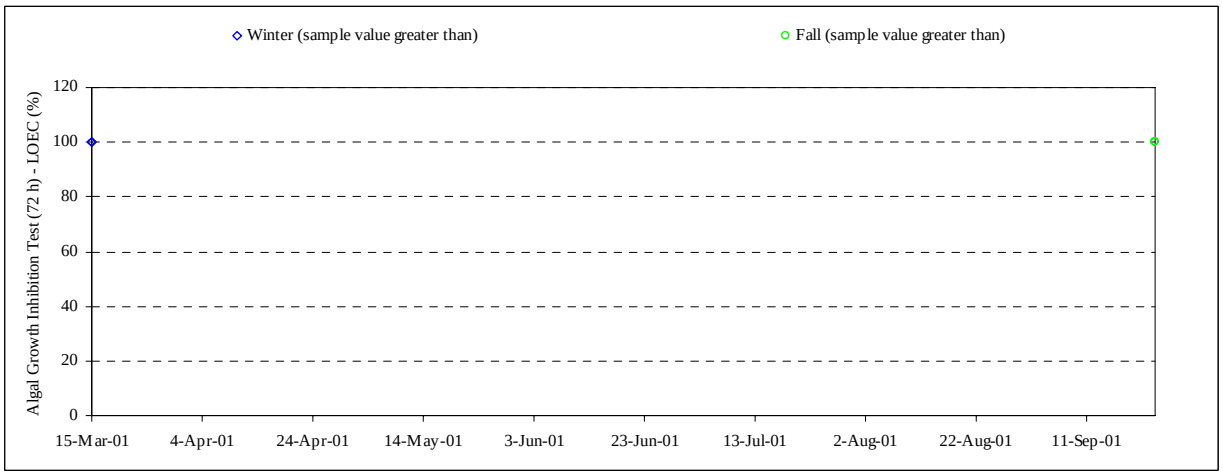
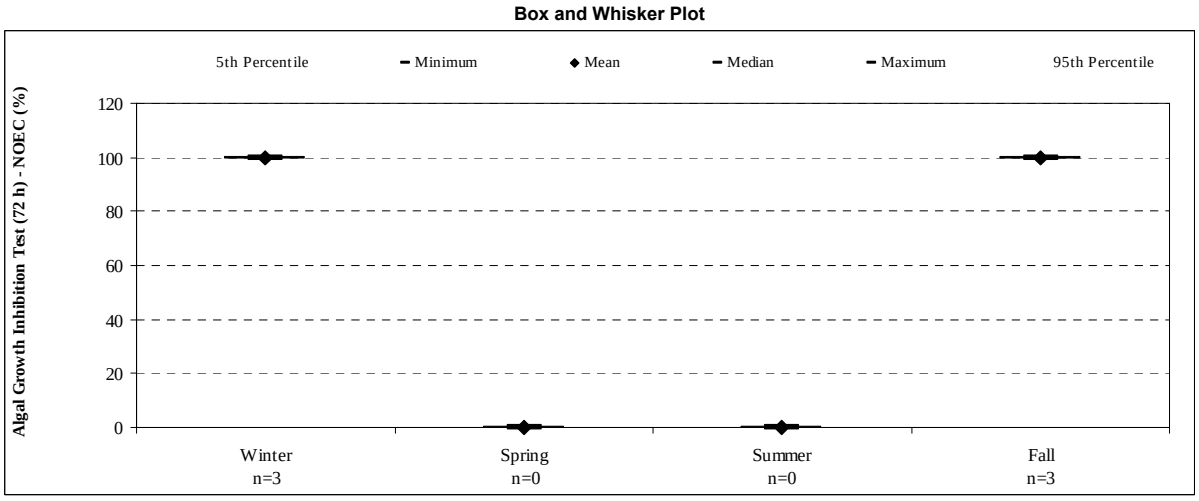


Figure G-2-7-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Muskeg Creek



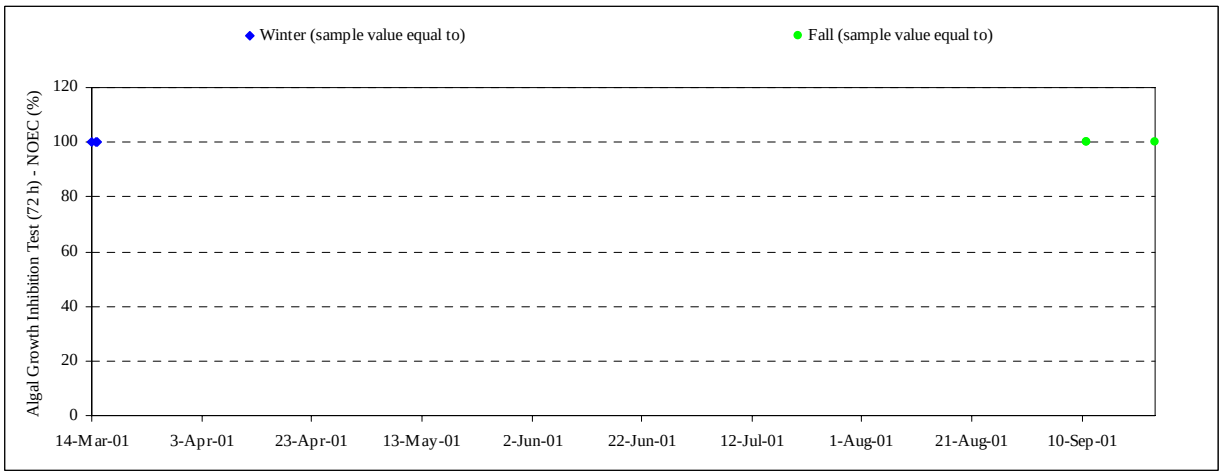
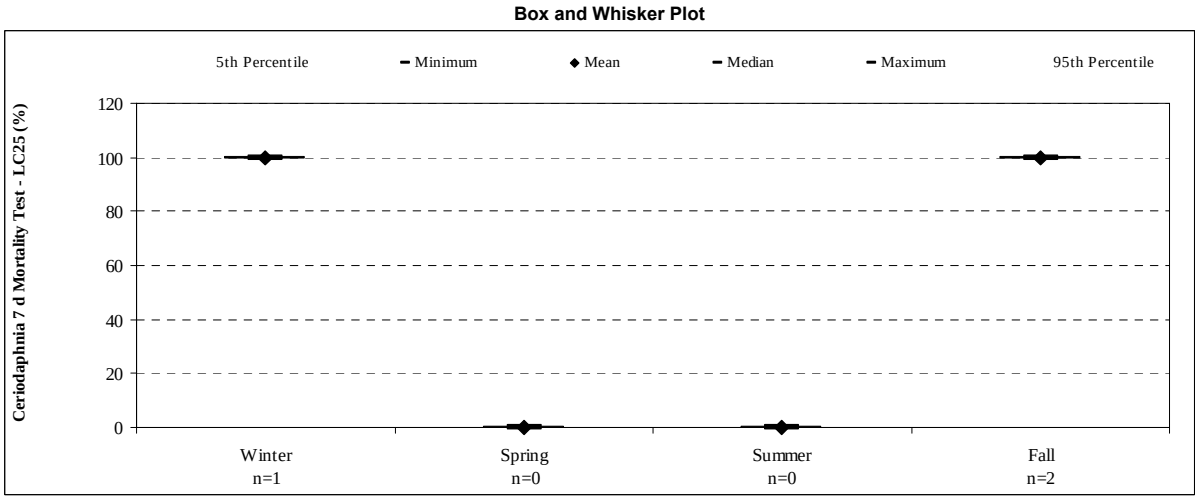


Figure G-2-7-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Muskeg Creek



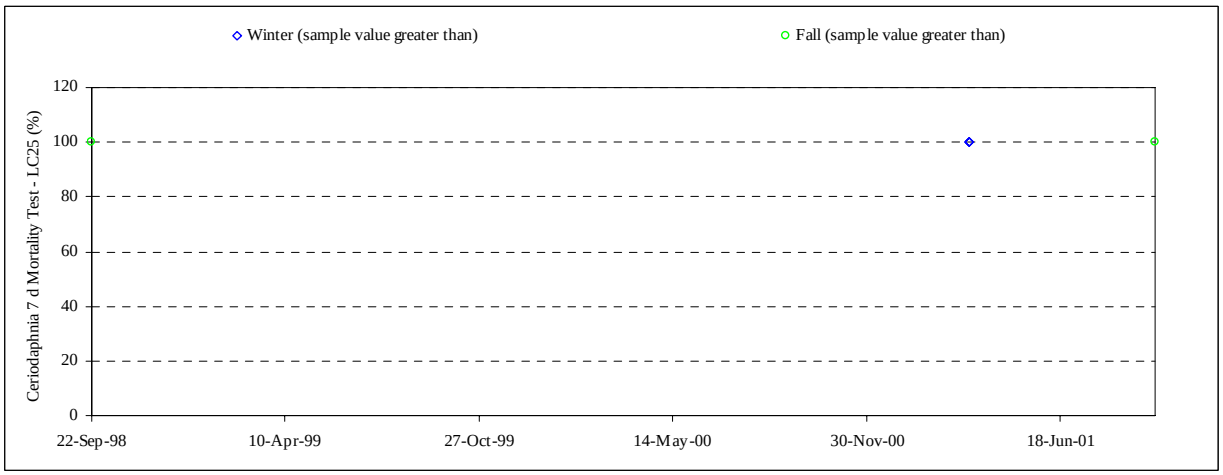
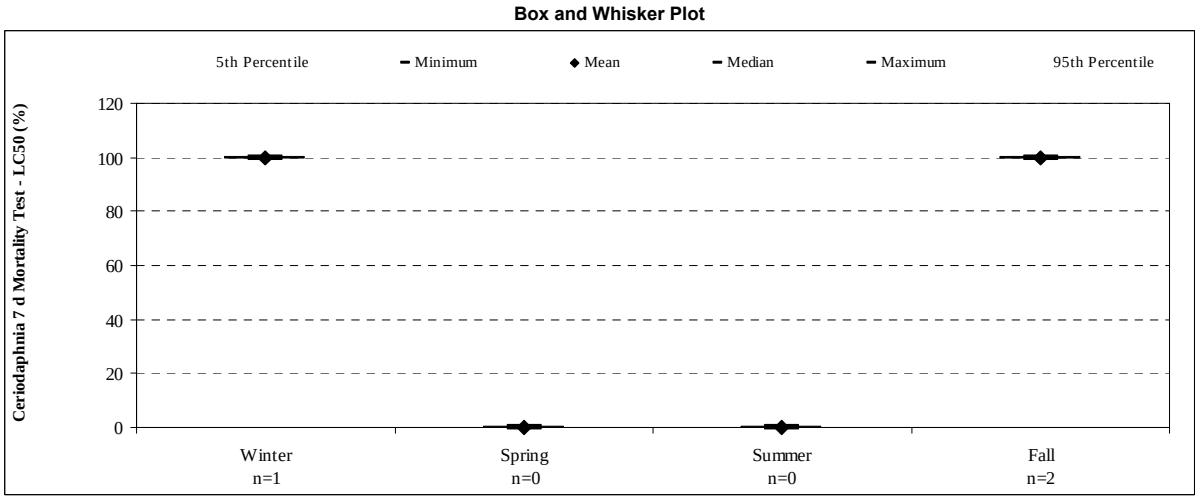


Figure G-2-7-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Muskeg Creek



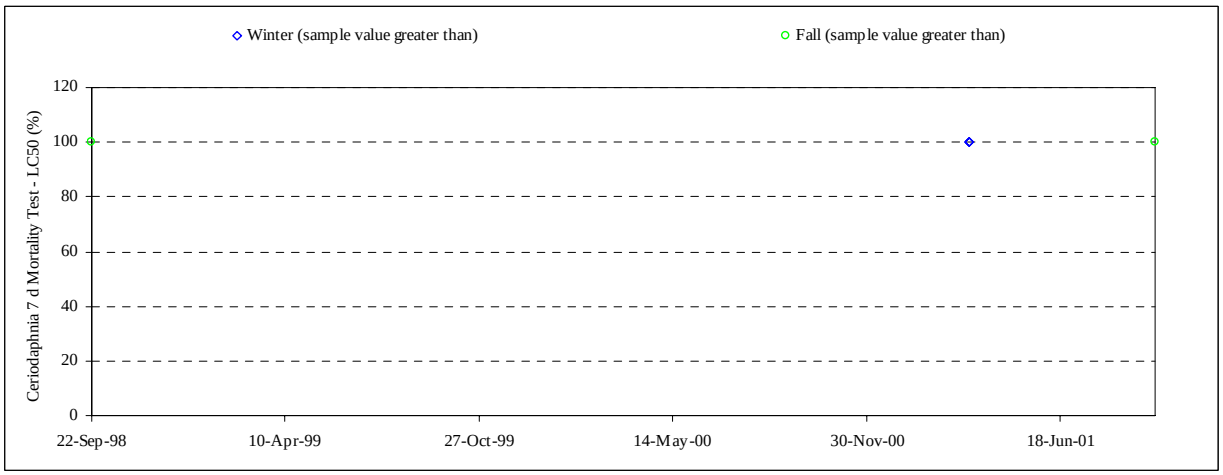
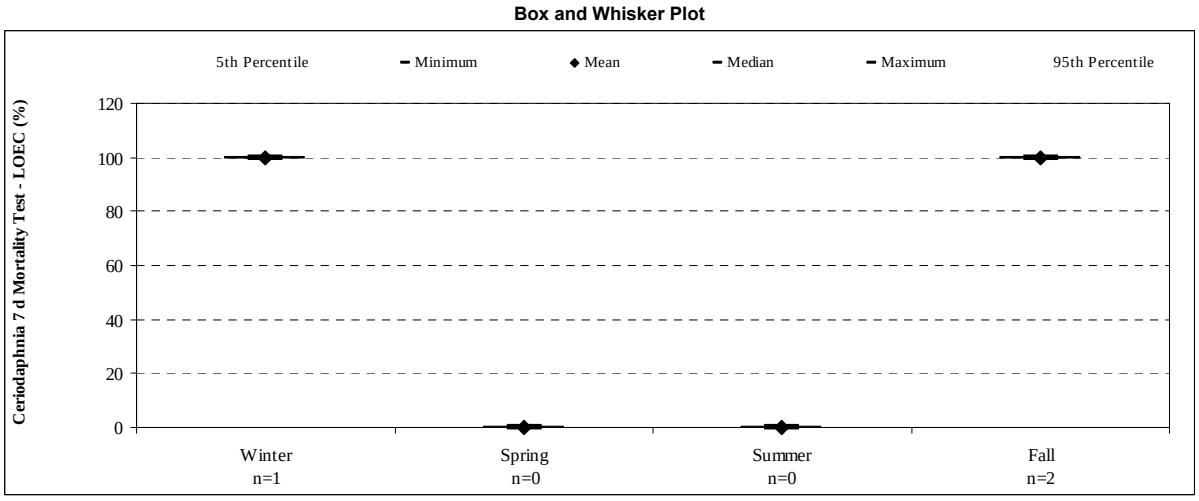


Figure G-2-7-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Muskeg Creek



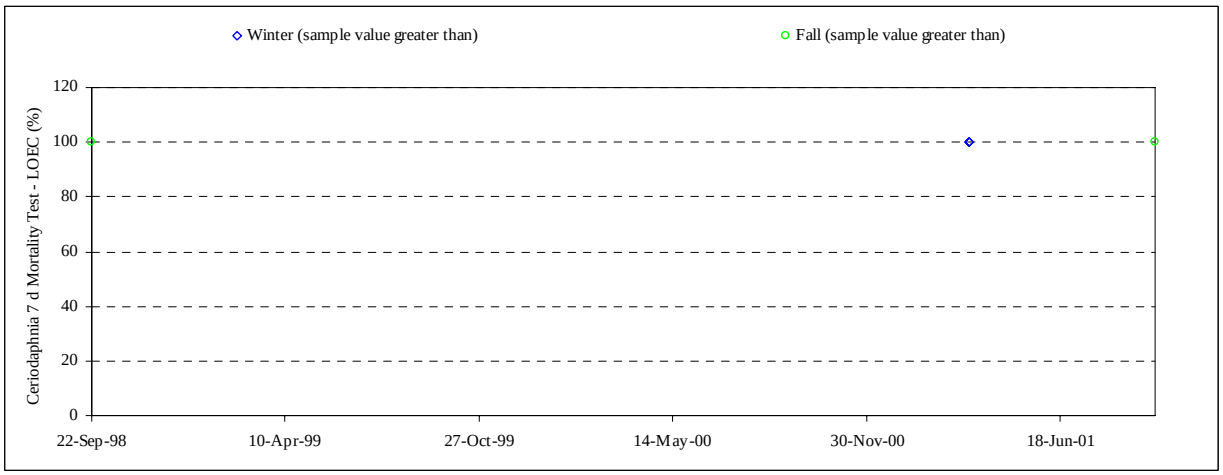
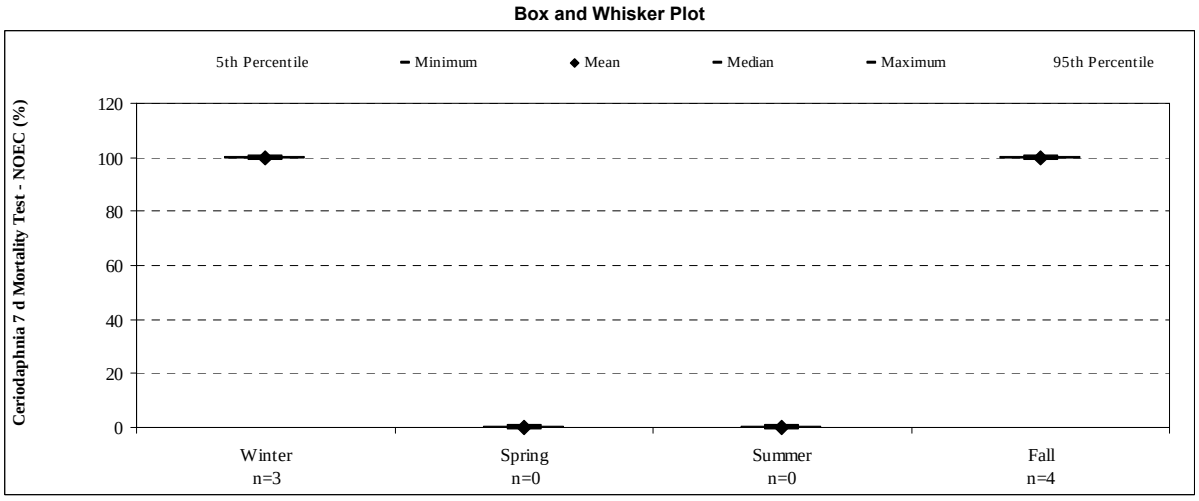


Figure G-2-7-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Muskeg Creek



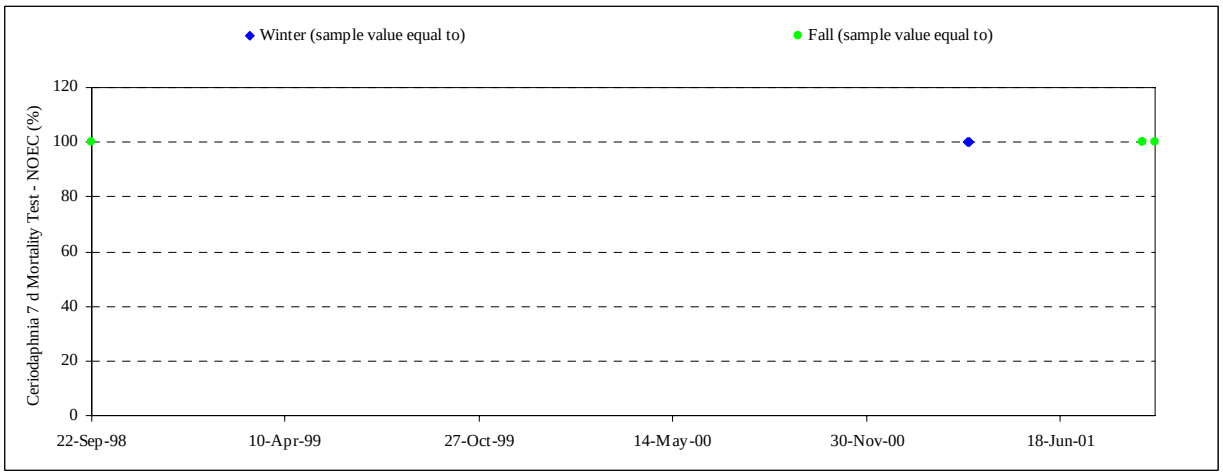
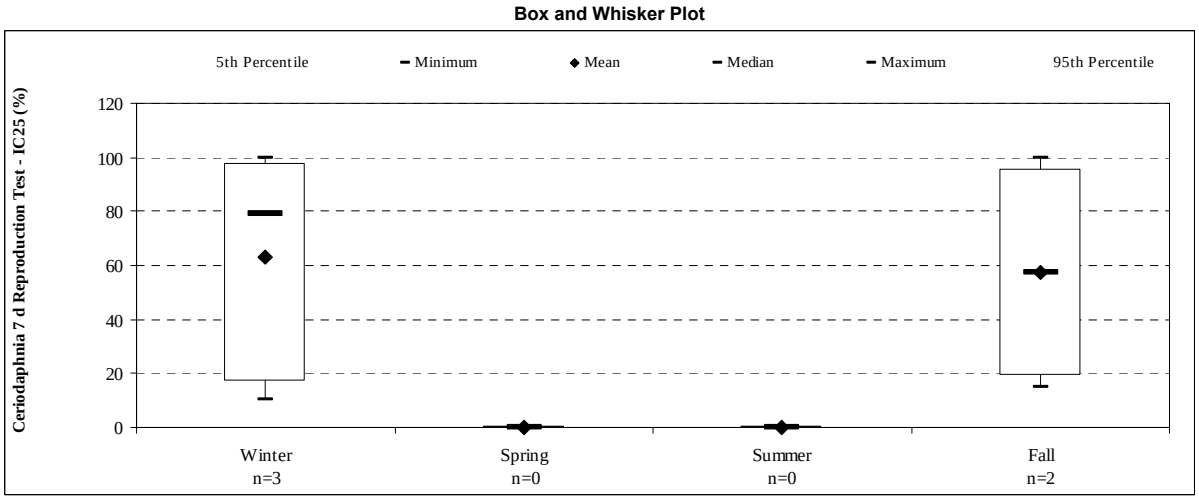


Figure G-2-7-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Muskeg Creek



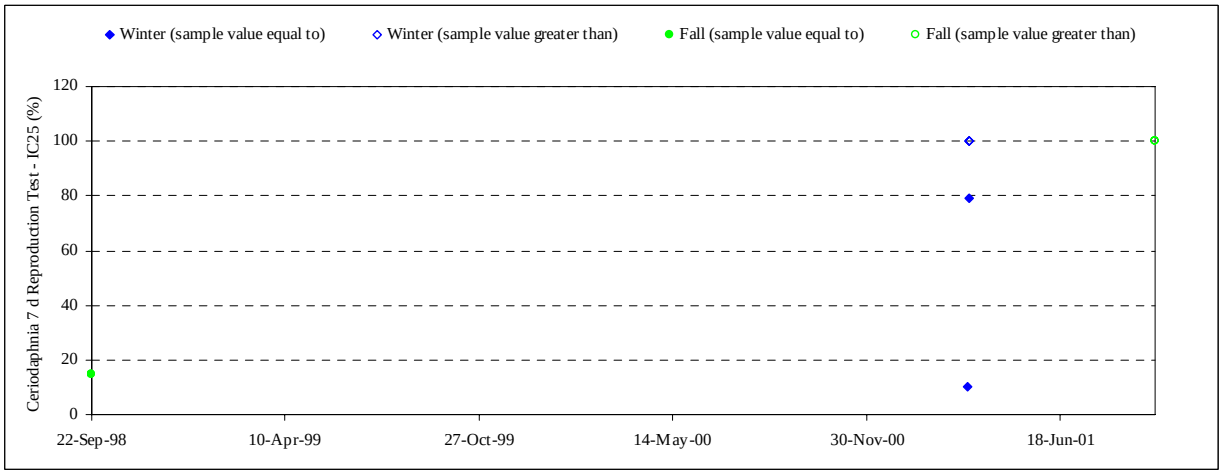
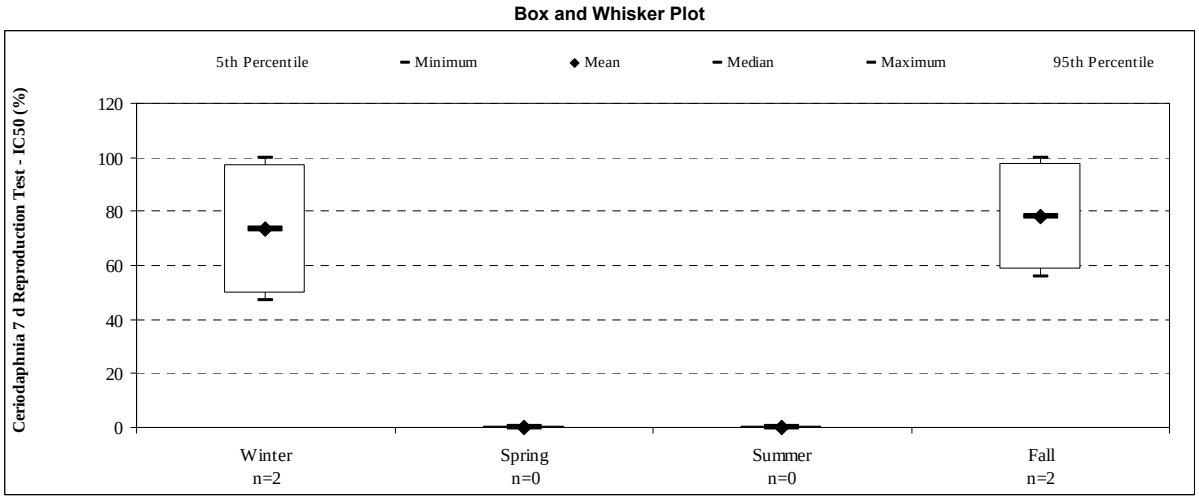


Figure G-2-7-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Muskeg Creek



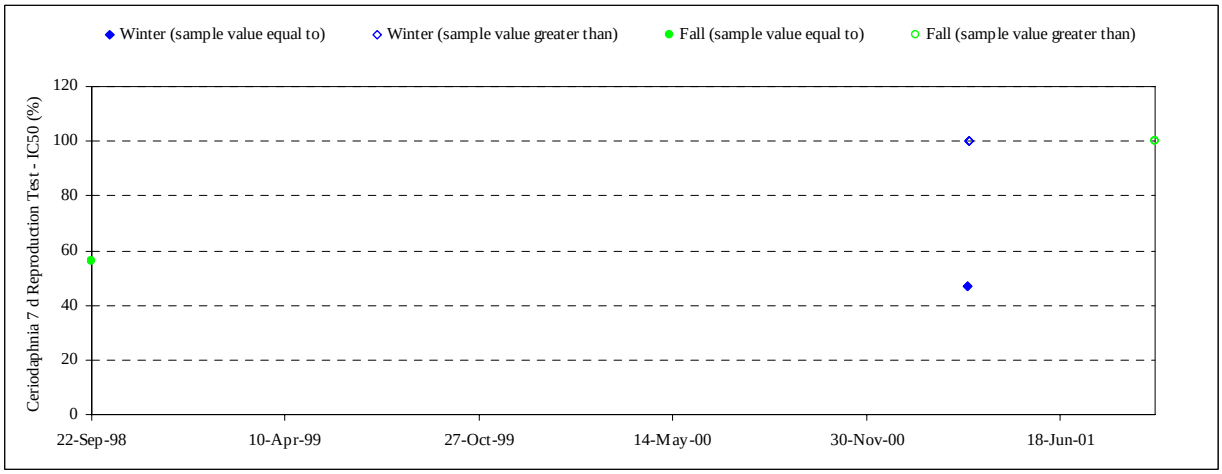
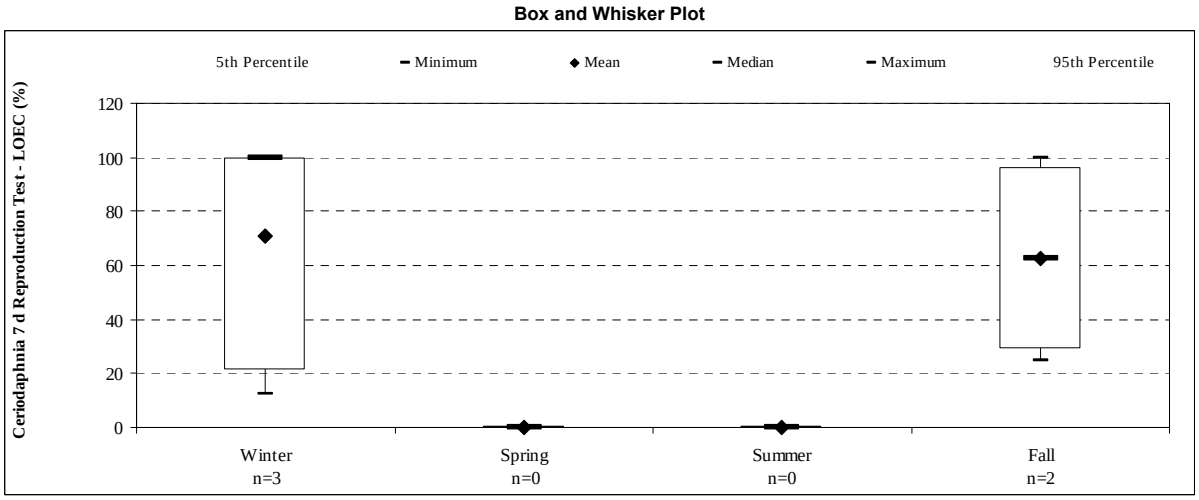


Figure G-2-7-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Muskeg Creek



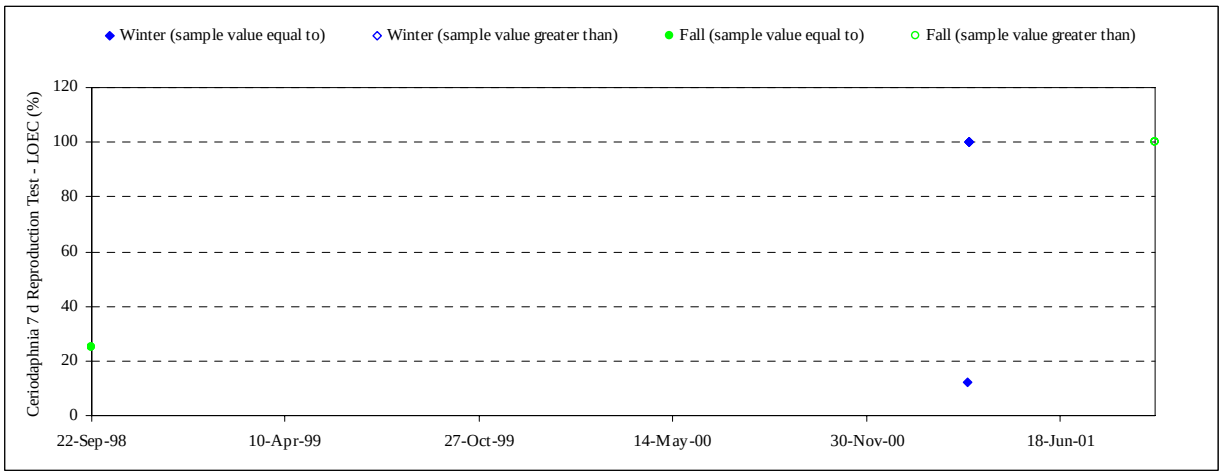
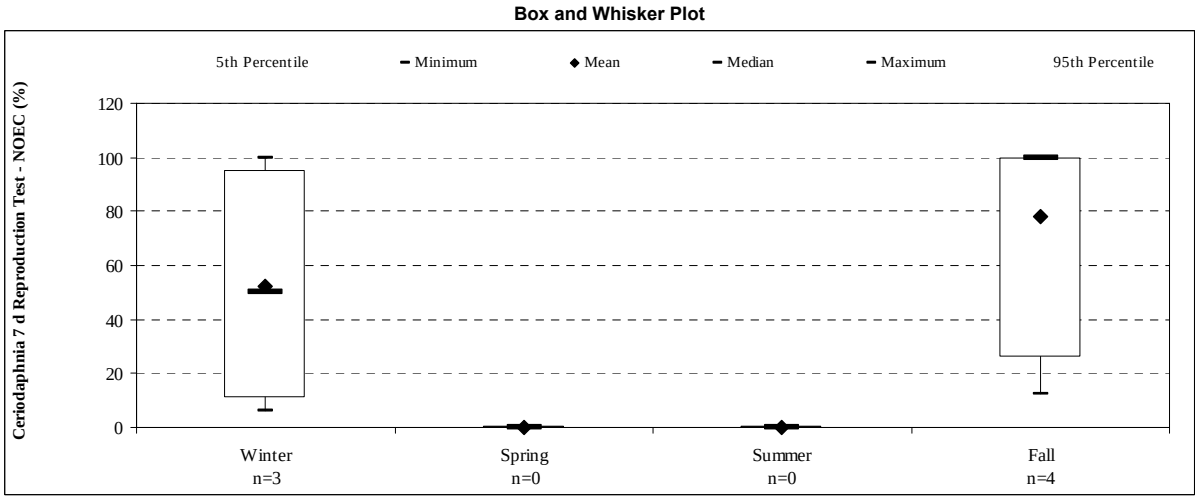


Figure G-2-7-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Muskeg Creek



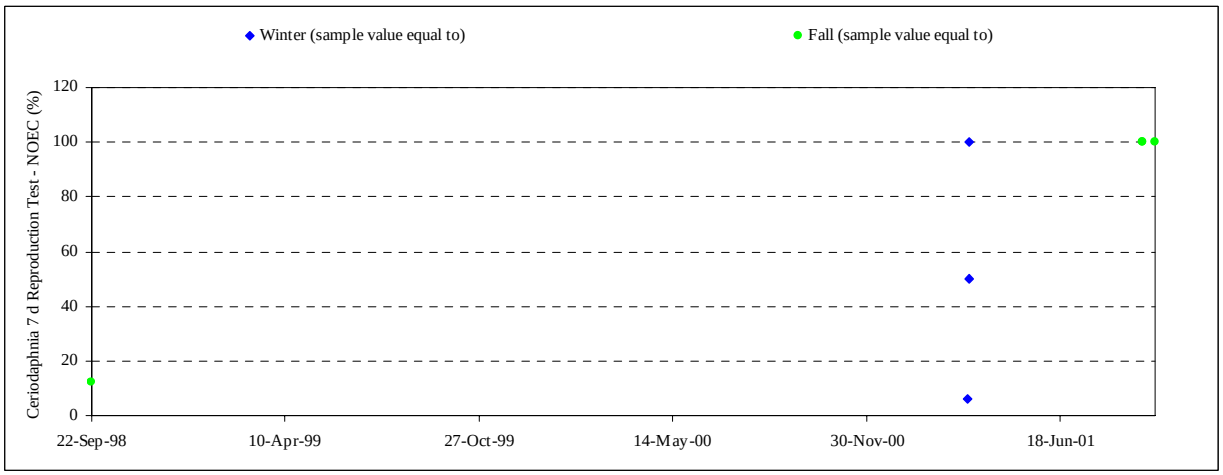
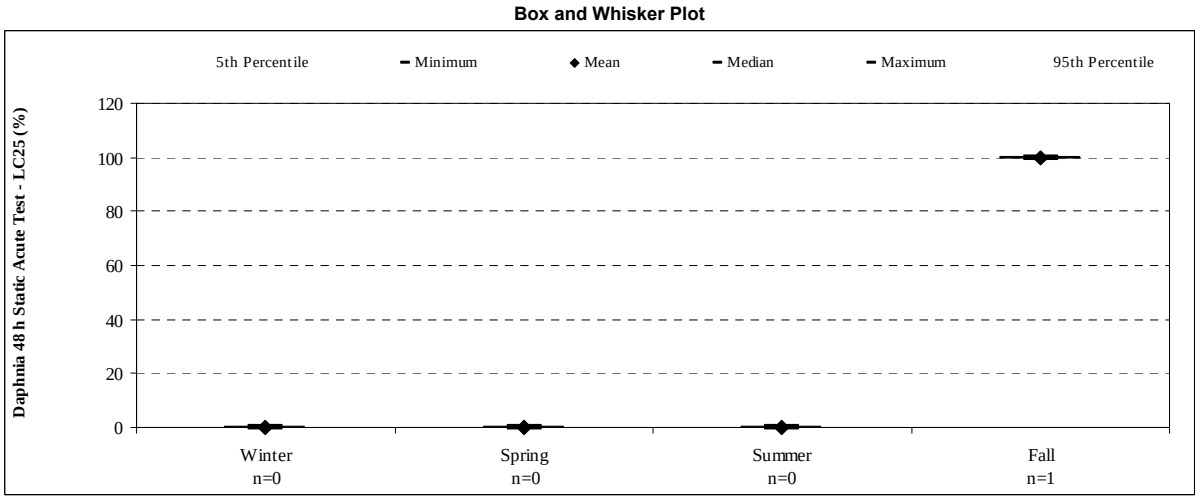


Figure G-2-7-46 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - LC25 in Muskeg Creek



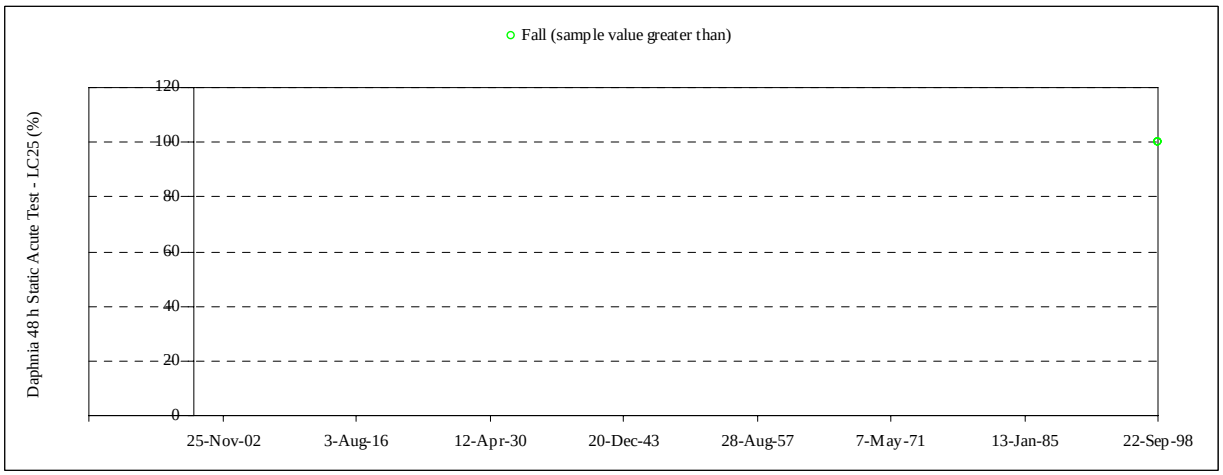
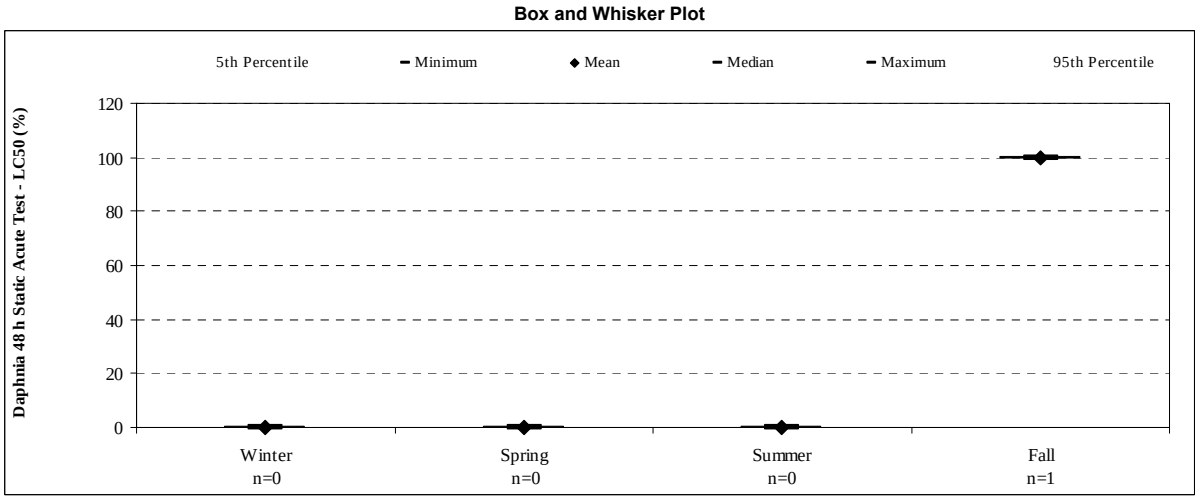
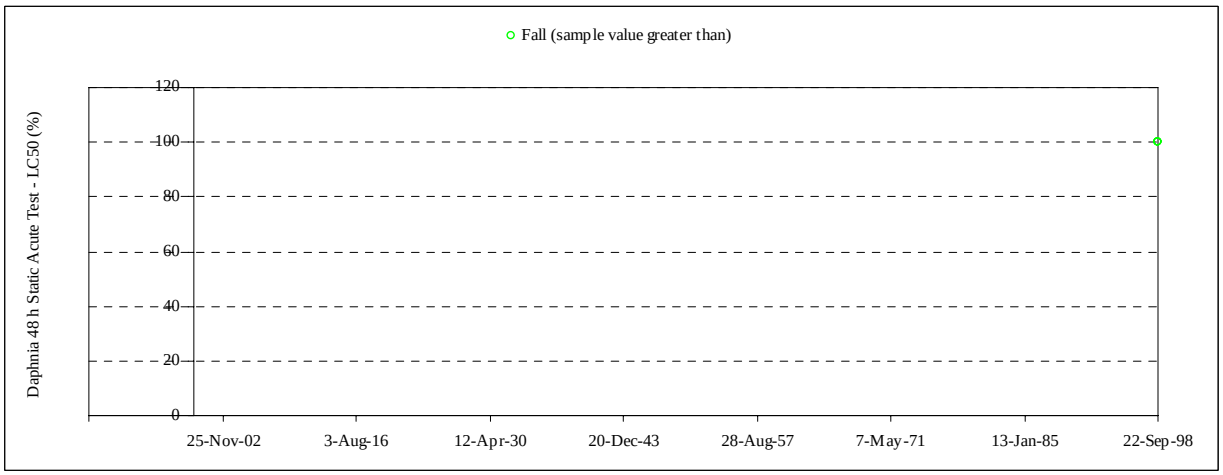


Figure G-2-7-47 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - LC50 in Muskeg Creek





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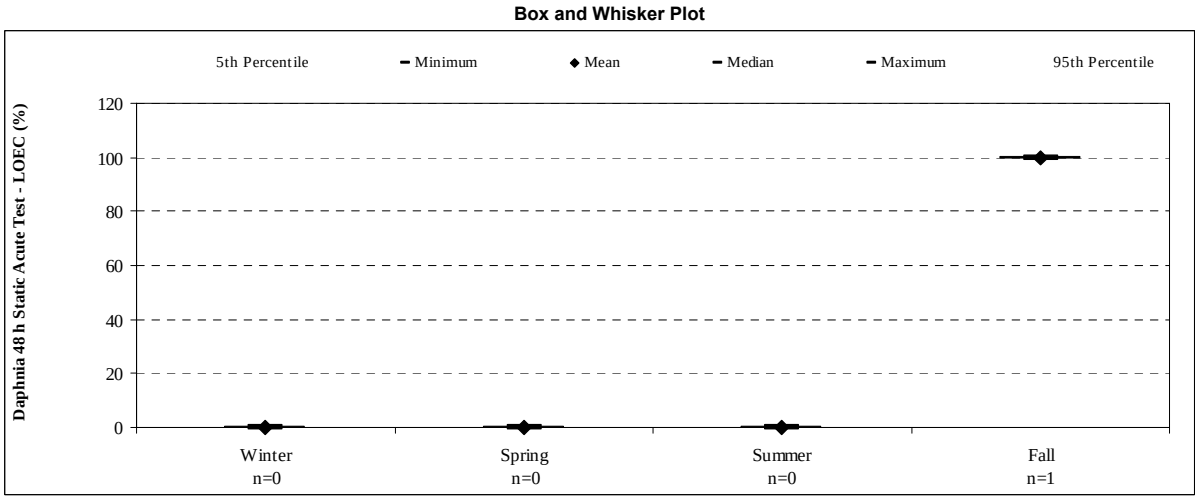


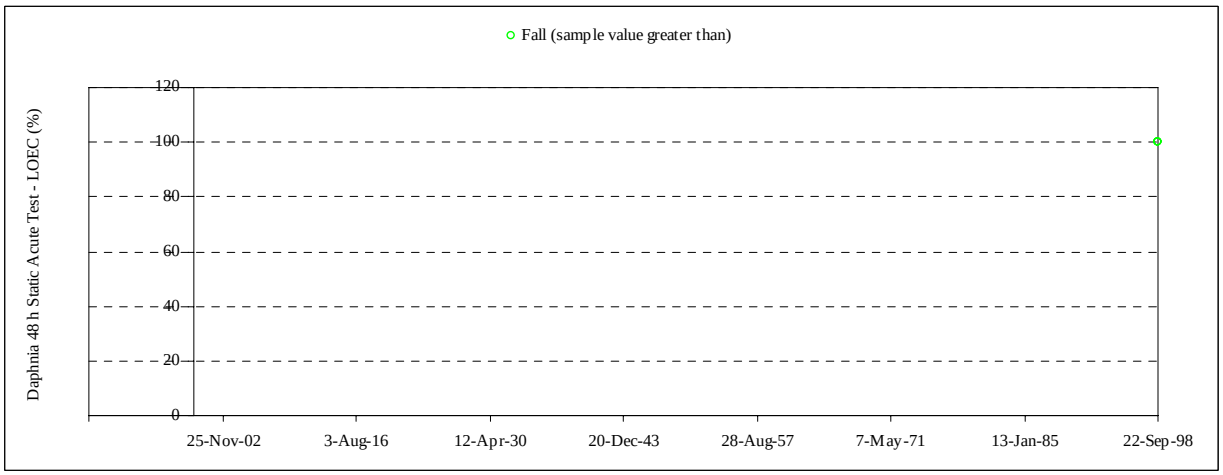
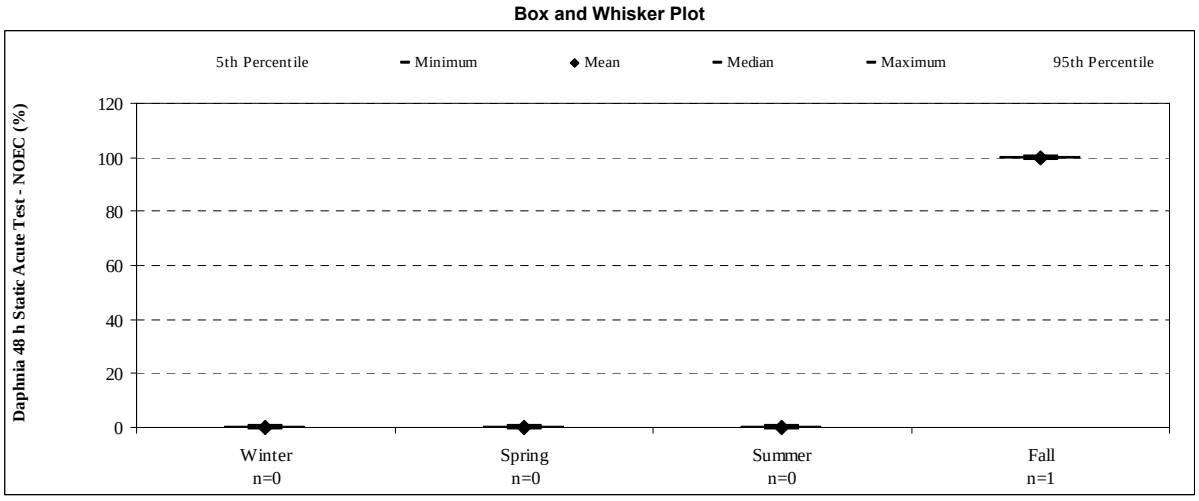


Figure G-2-7-49 Box Whisker and Time Series Scatter Plots of Observed Daphnia 48 h Static Acute Test - NOEC in Muskeg Creek



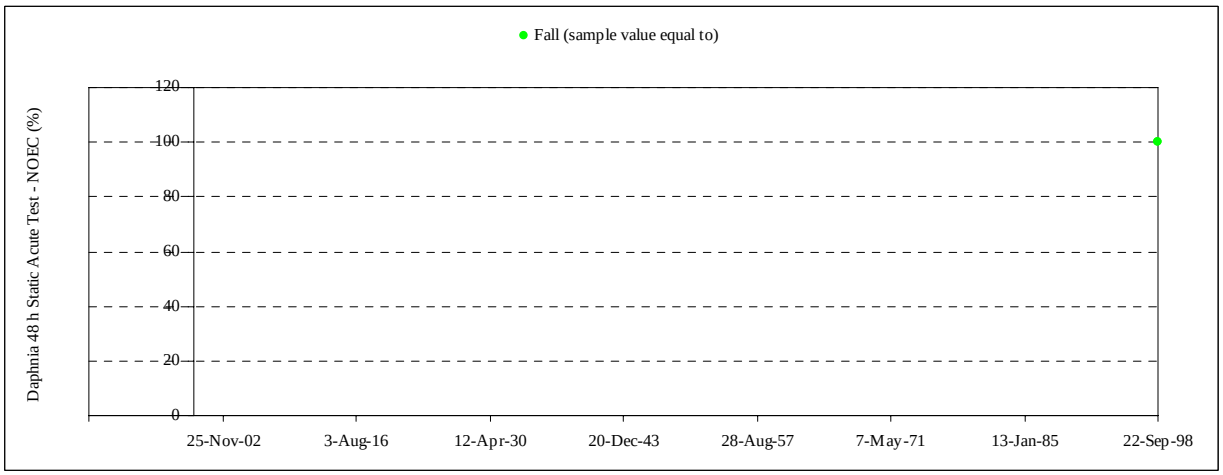
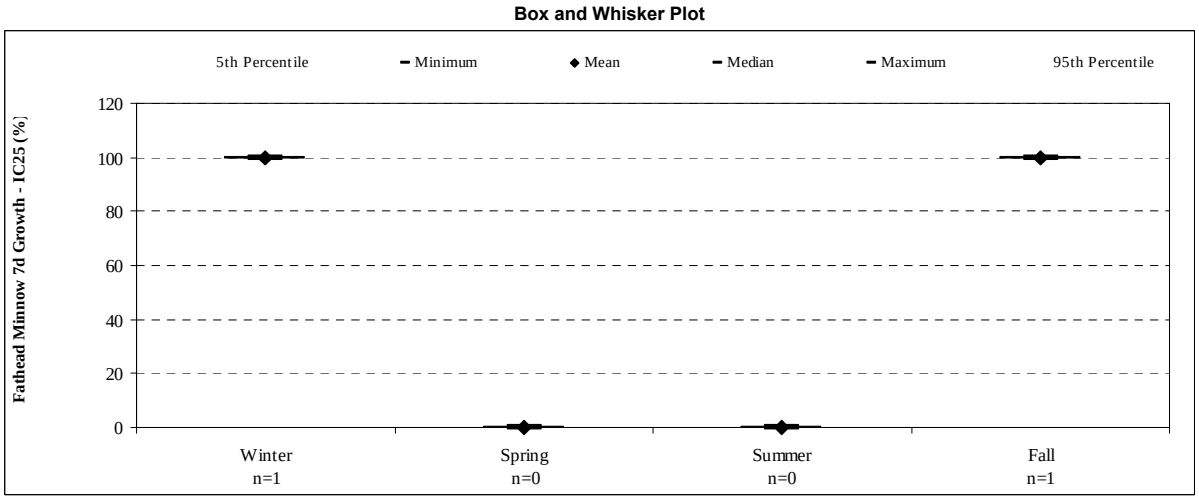


Figure G-2-7-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Muskeg Creek



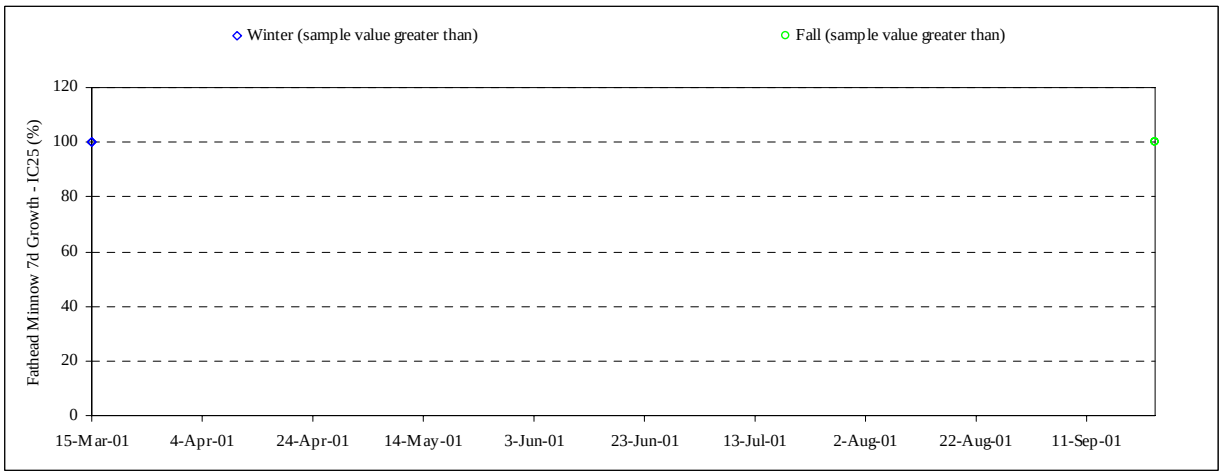
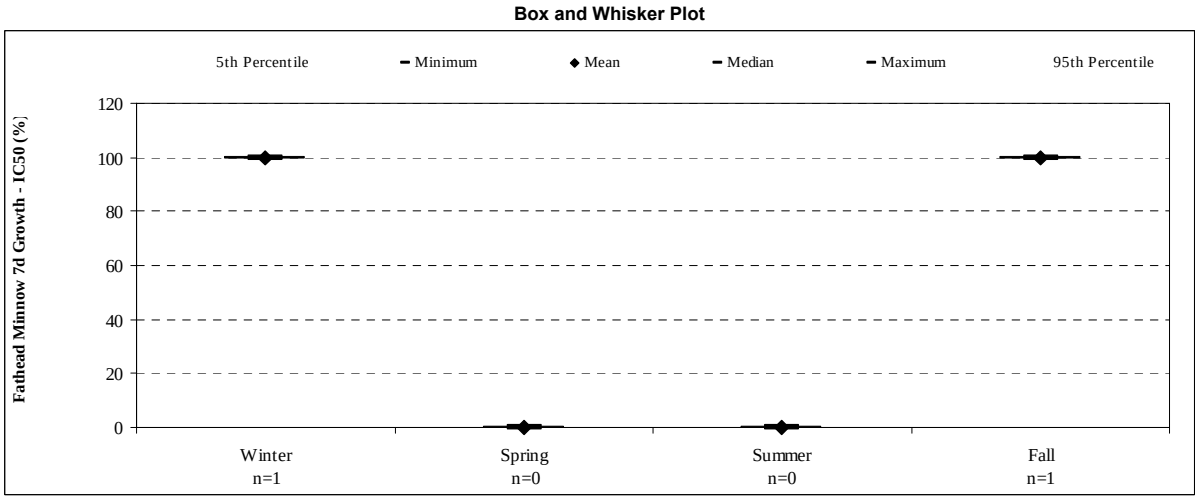


Figure G-2-7-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Muskeg Creek



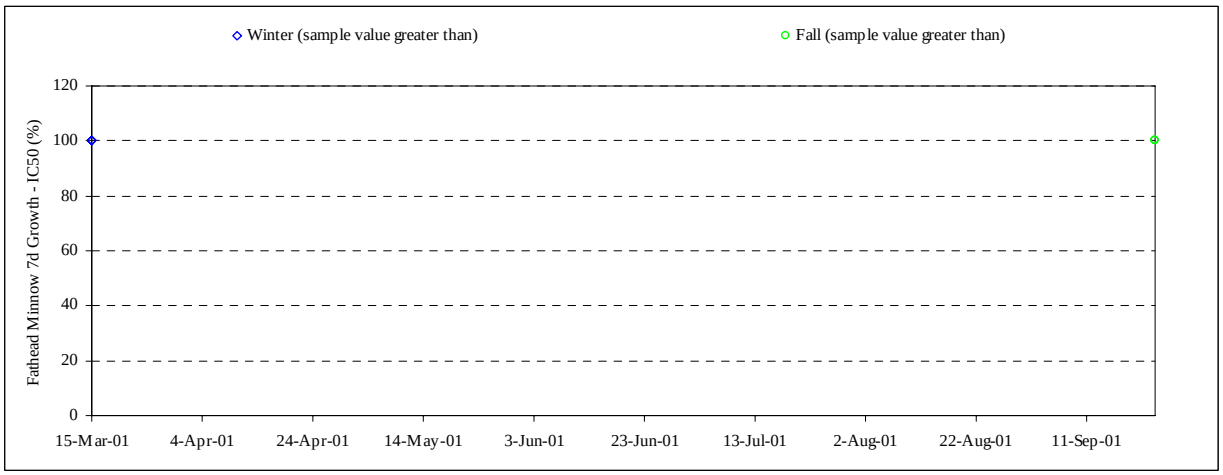
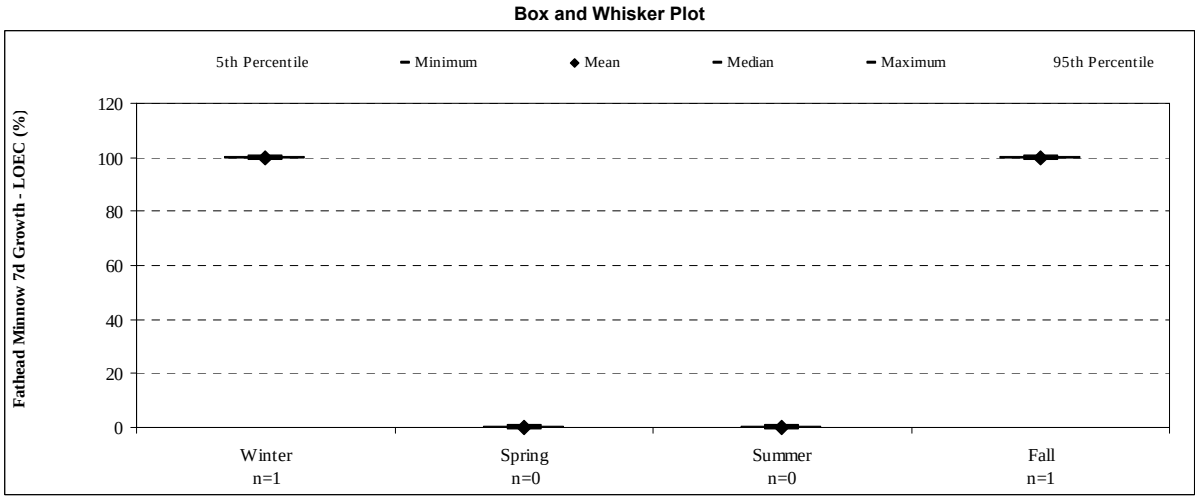


Figure G-2-7-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Muskeg Creek



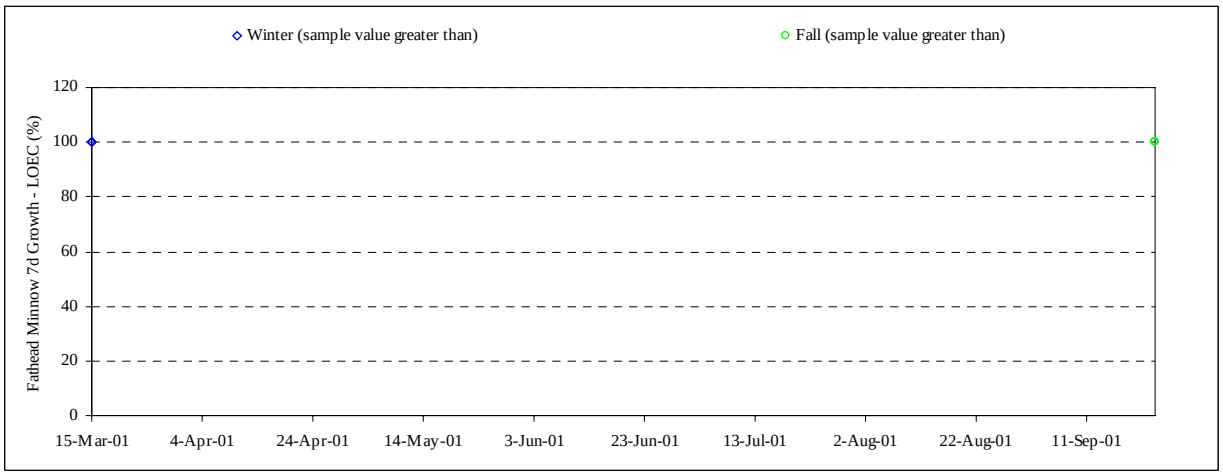
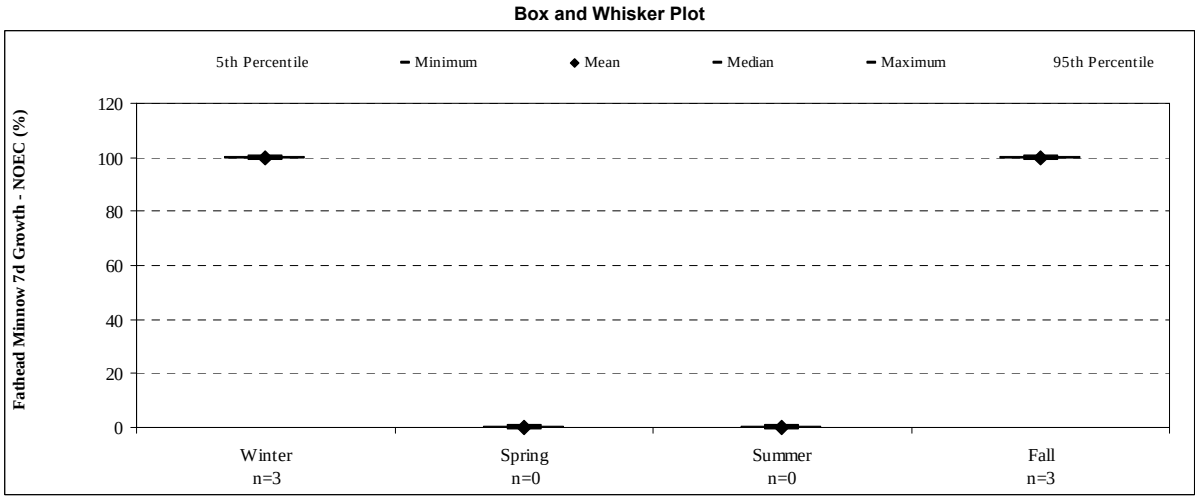


Figure G-2-7-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Muskeg Creek



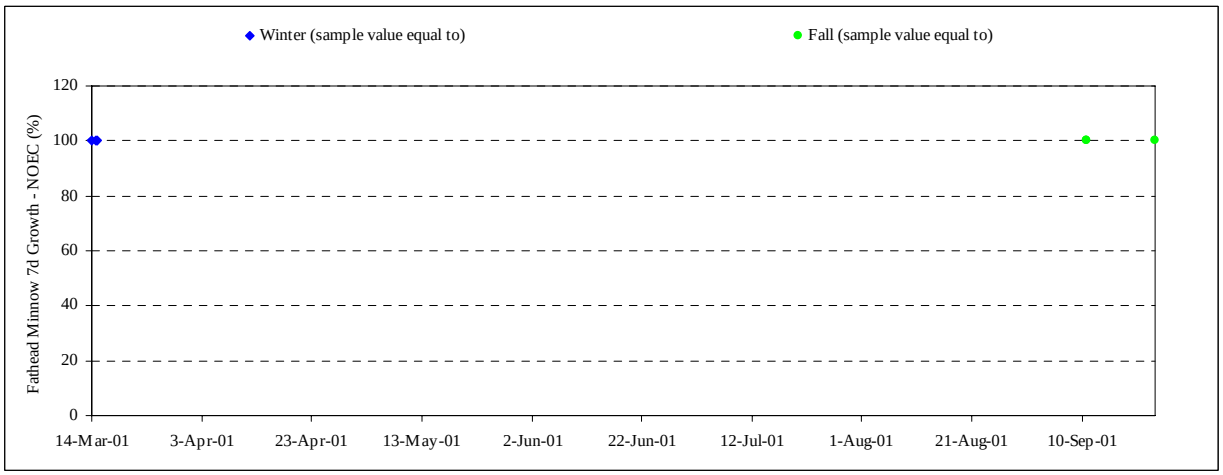
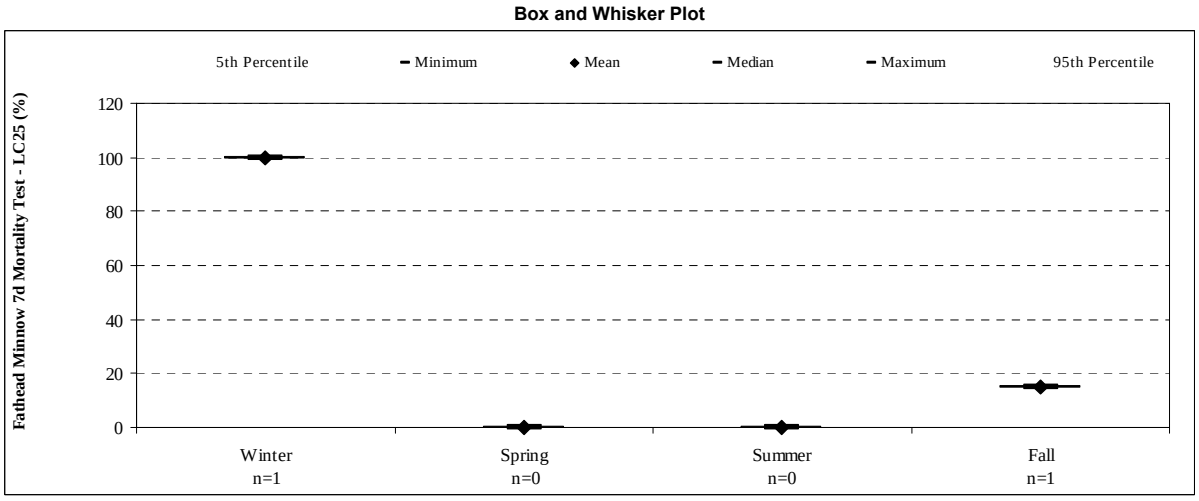


Figure G-2-7-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Muskeg Creek



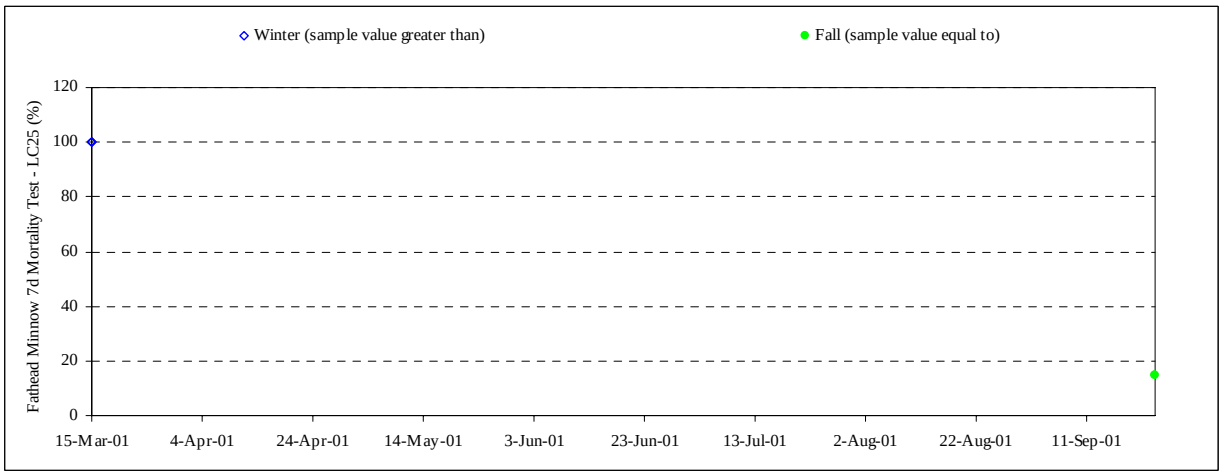
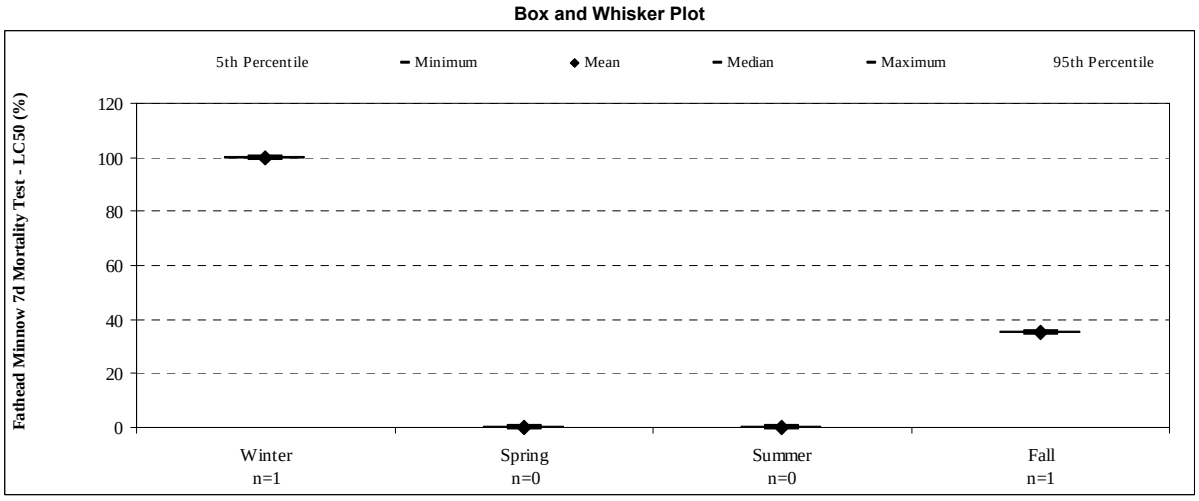


Figure G-2-7-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Muskeg Creek



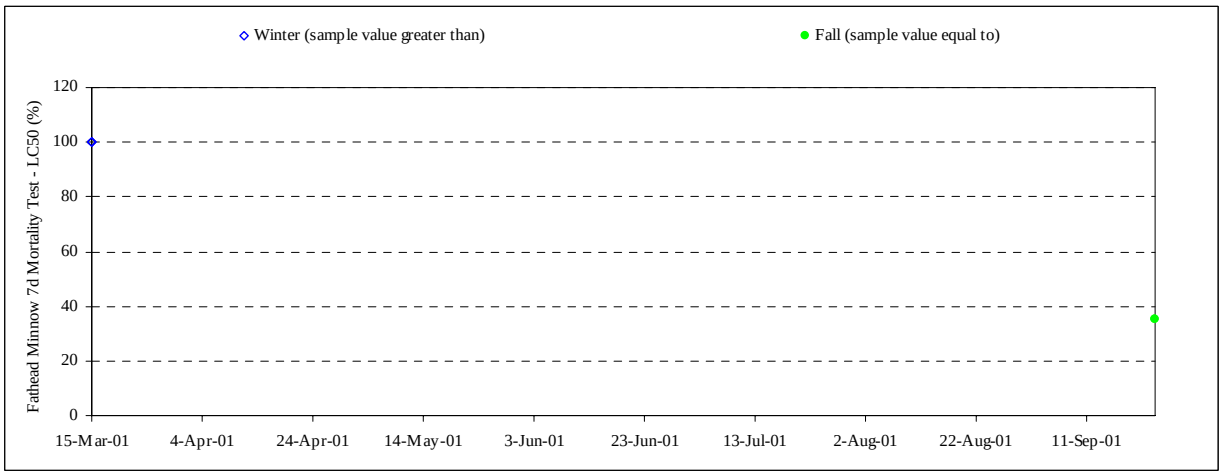
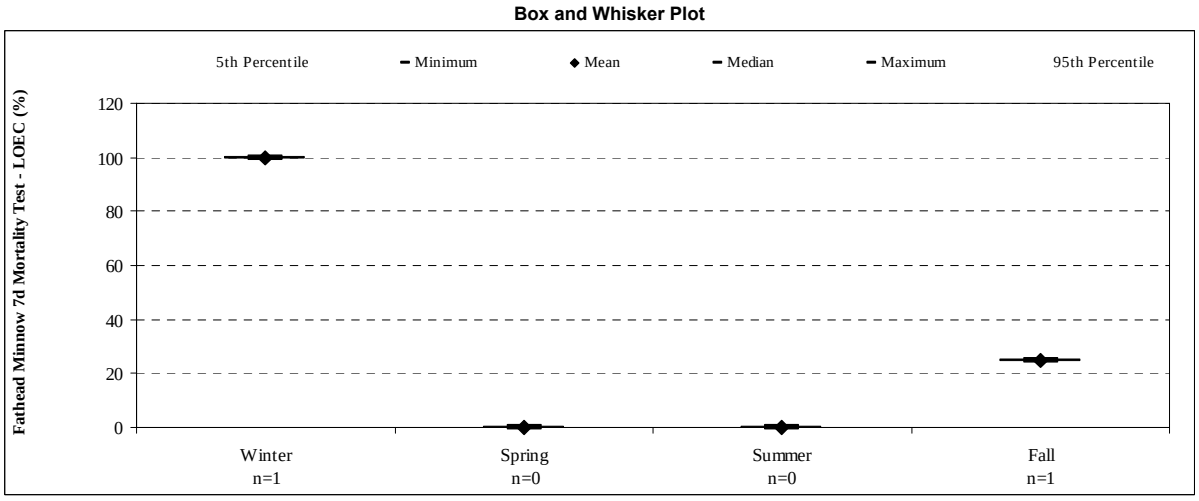


Figure G-2-7-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Muskeg Creek



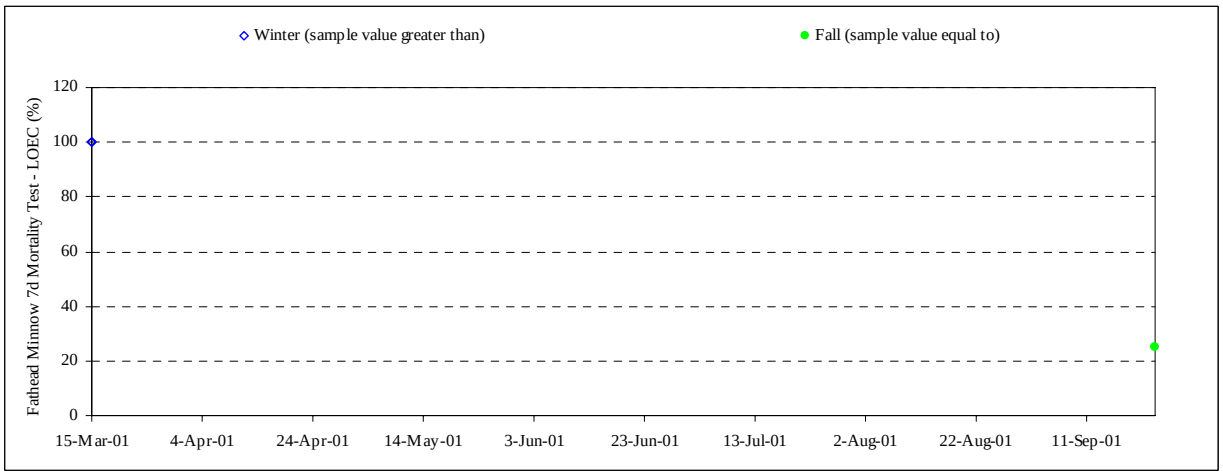
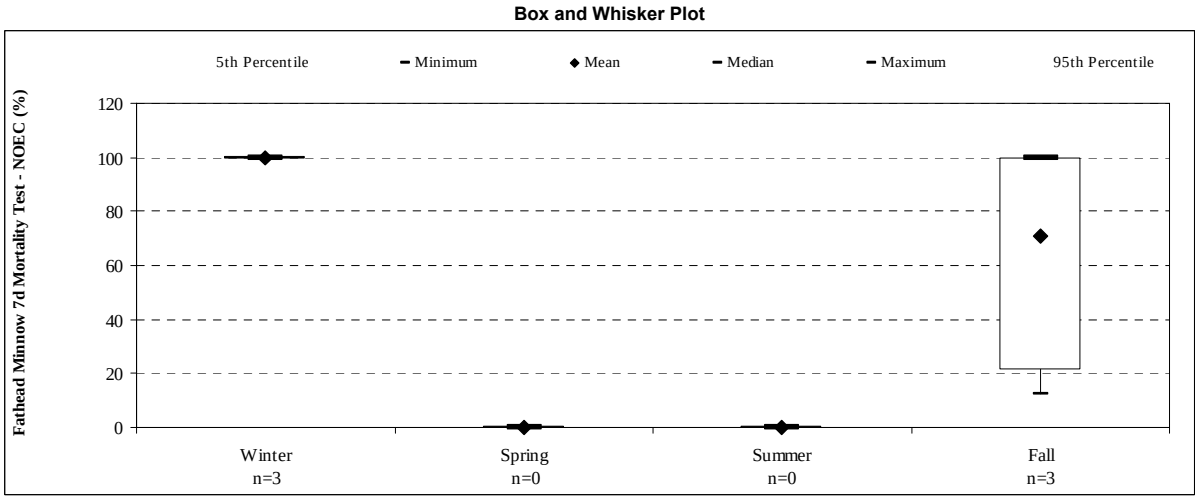


Figure G-2-7-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Muskeg Creek



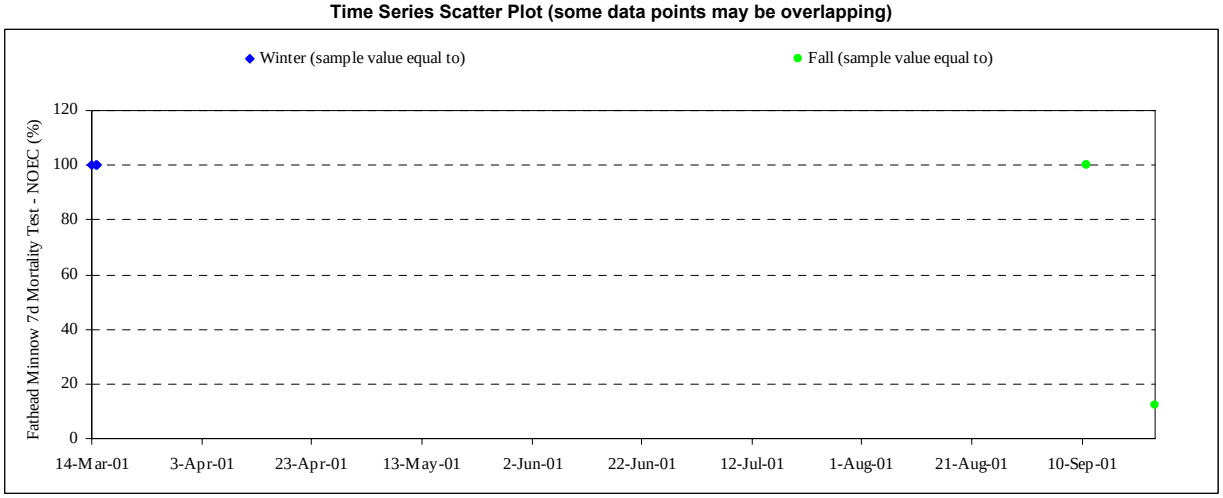
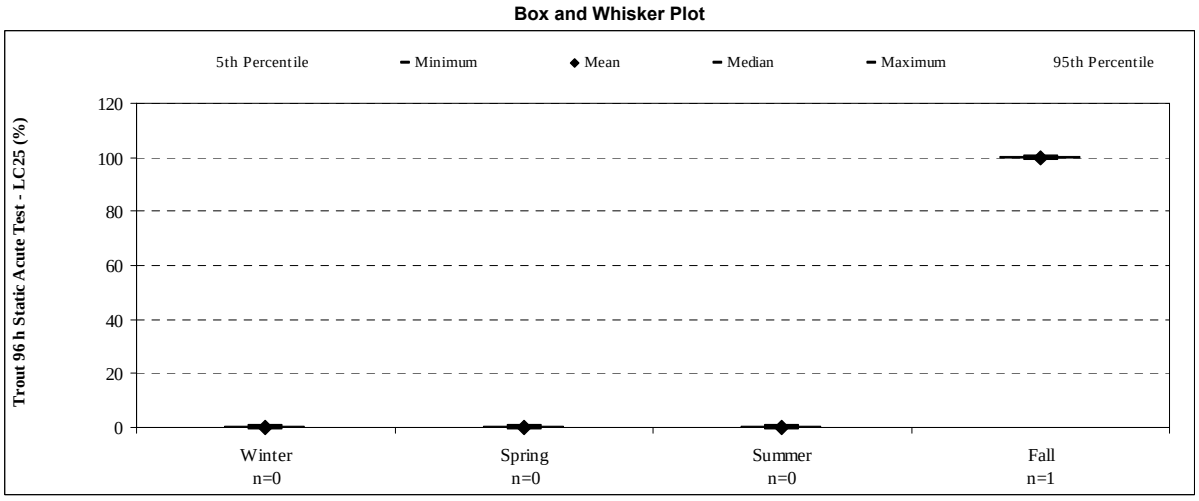


Figure G-2-7-58 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LC25 in Muskeg Creek



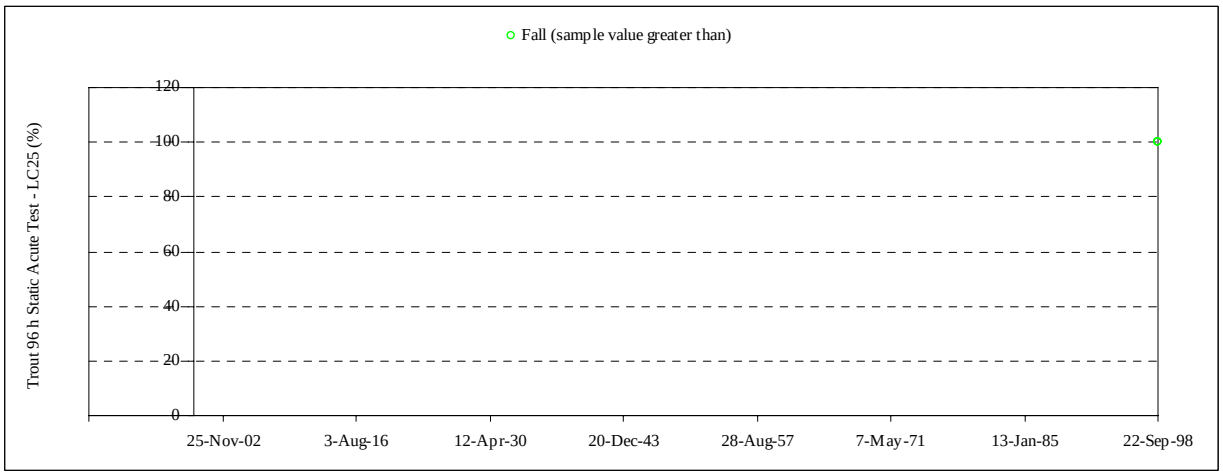
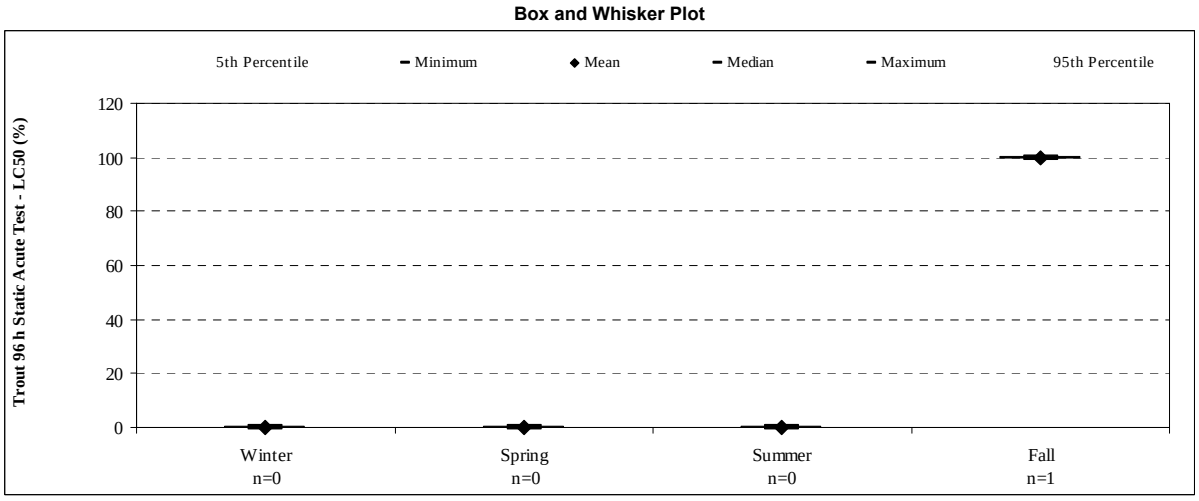


Figure G-2-7-59 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LC50 in Muskeg Creek



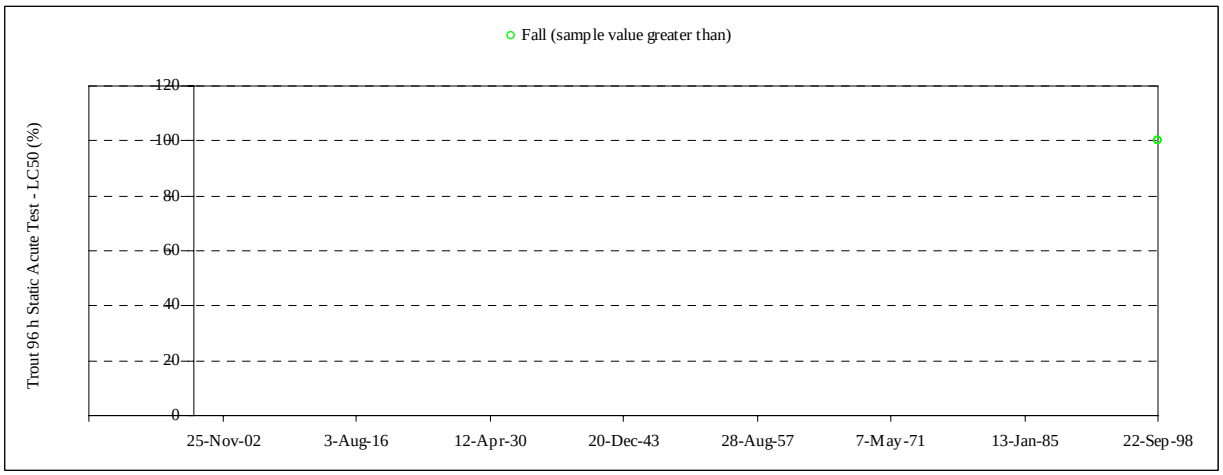
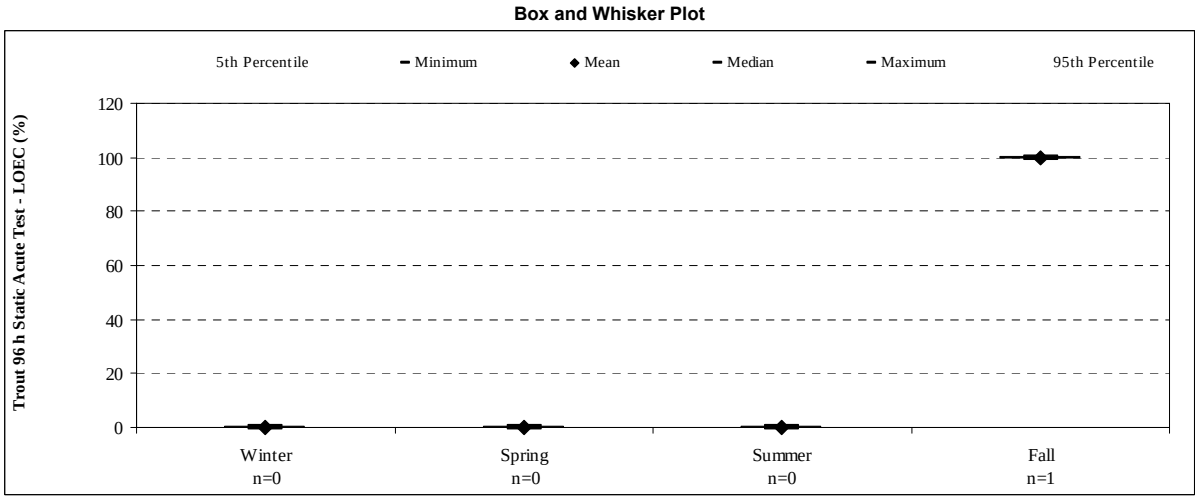


Figure G-2-7-60 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - LOEC in Muskeg Creek



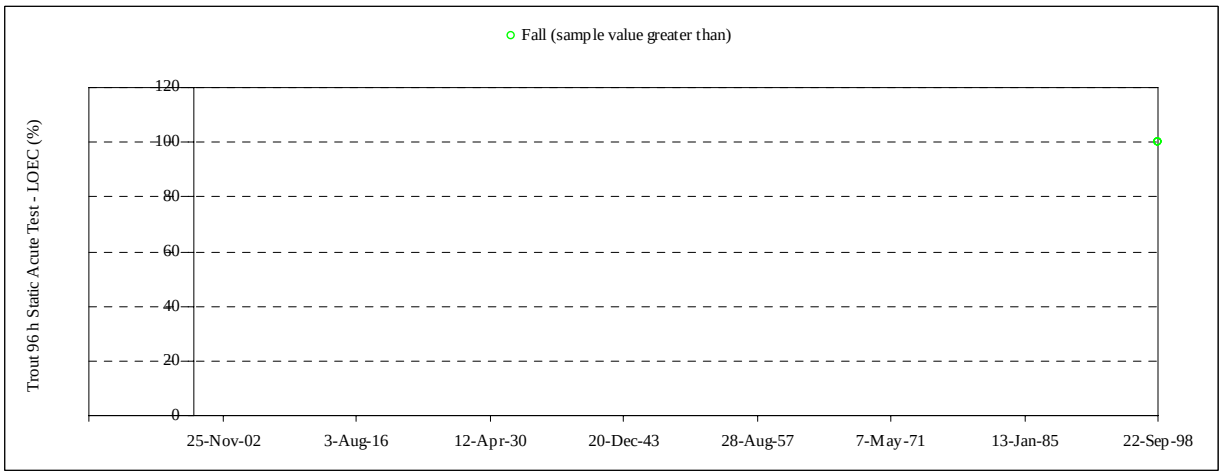
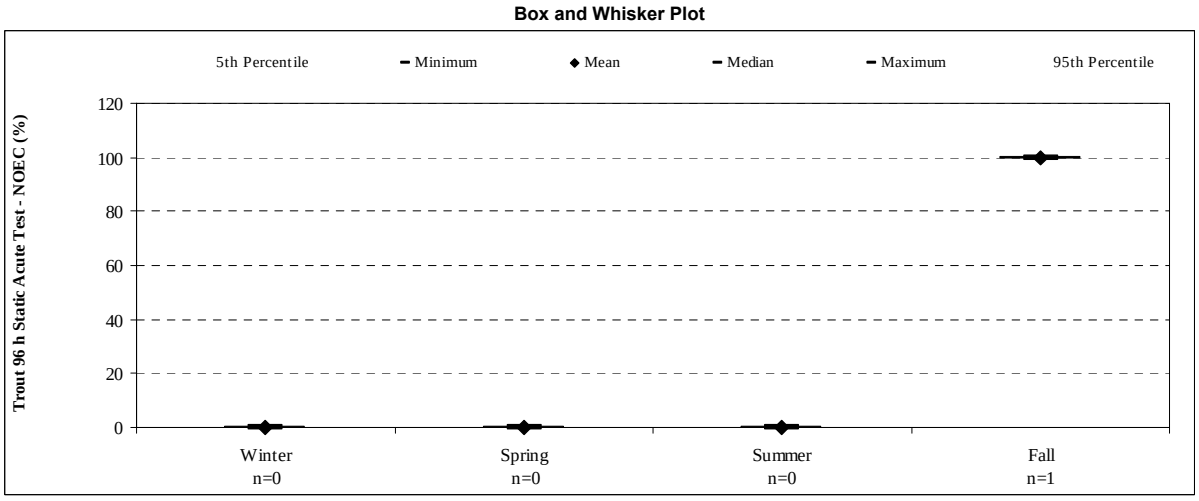


Figure G-2-7-61 Box Whisker and Time Series Scatter Plots of Observed Trout 96 h Static Acute Test - NOEC in Muskeg Creek



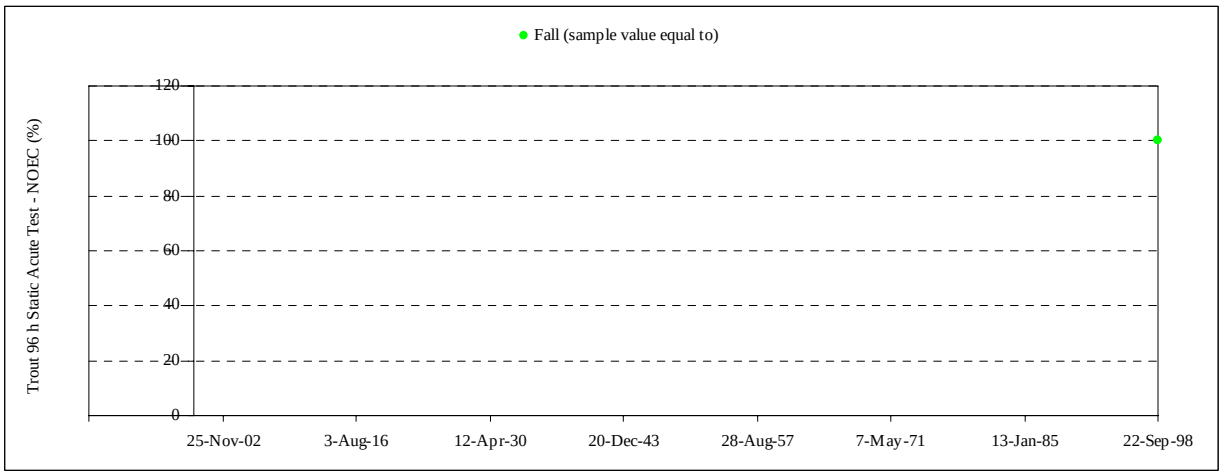
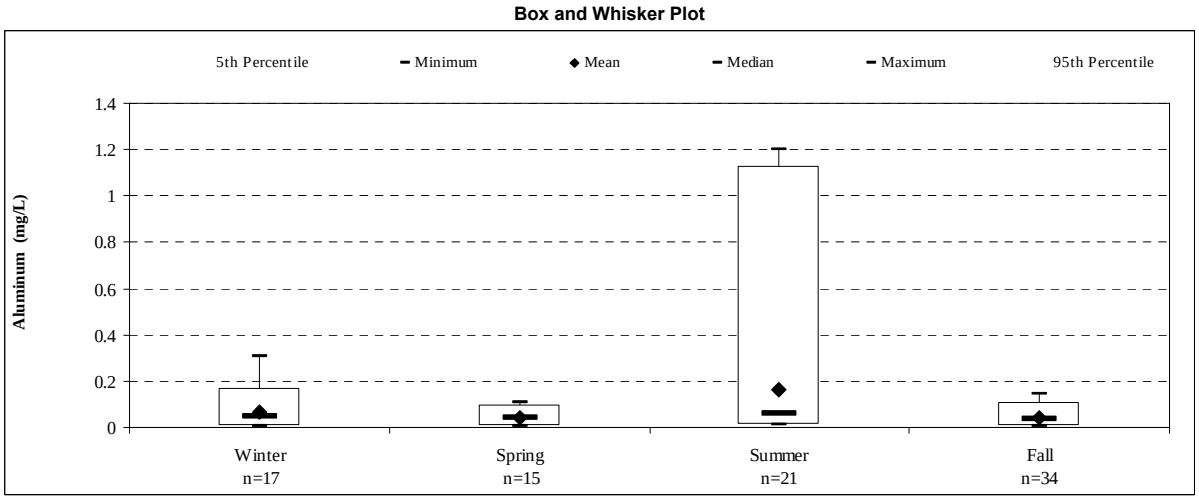


Figure G-2-7-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Muskeg Creek



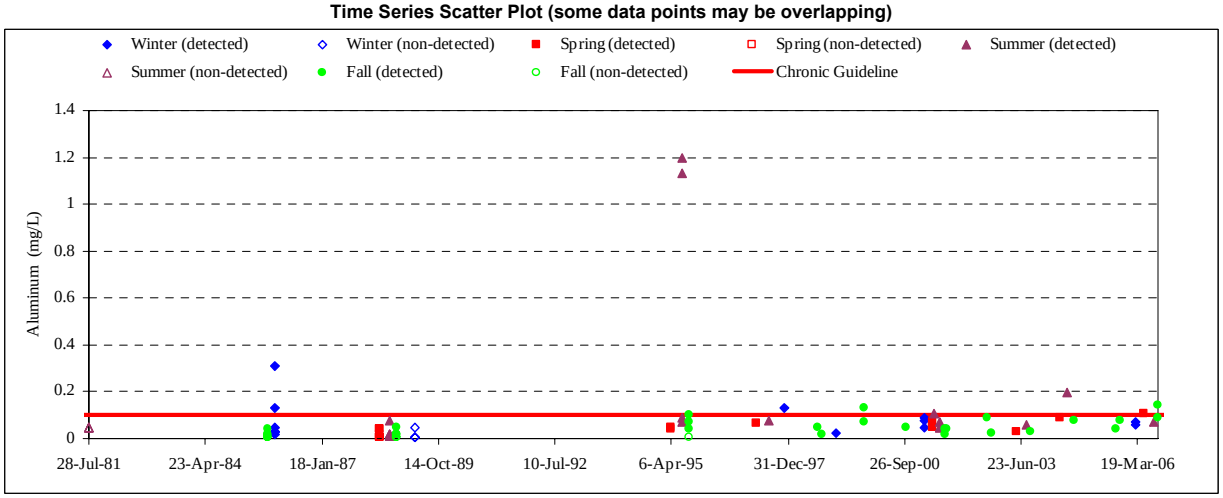
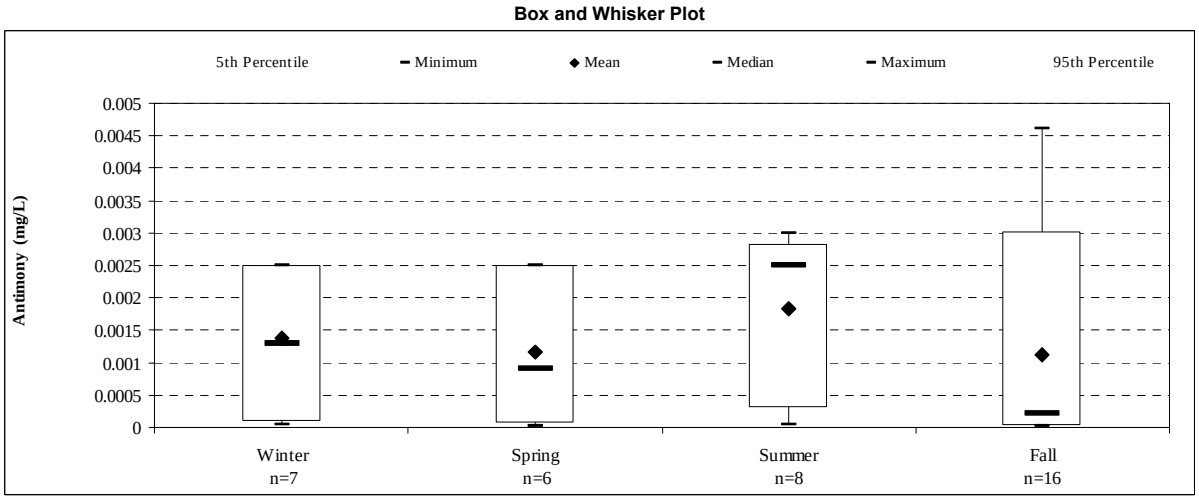


Figure G-2-7-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Muskeg Creek



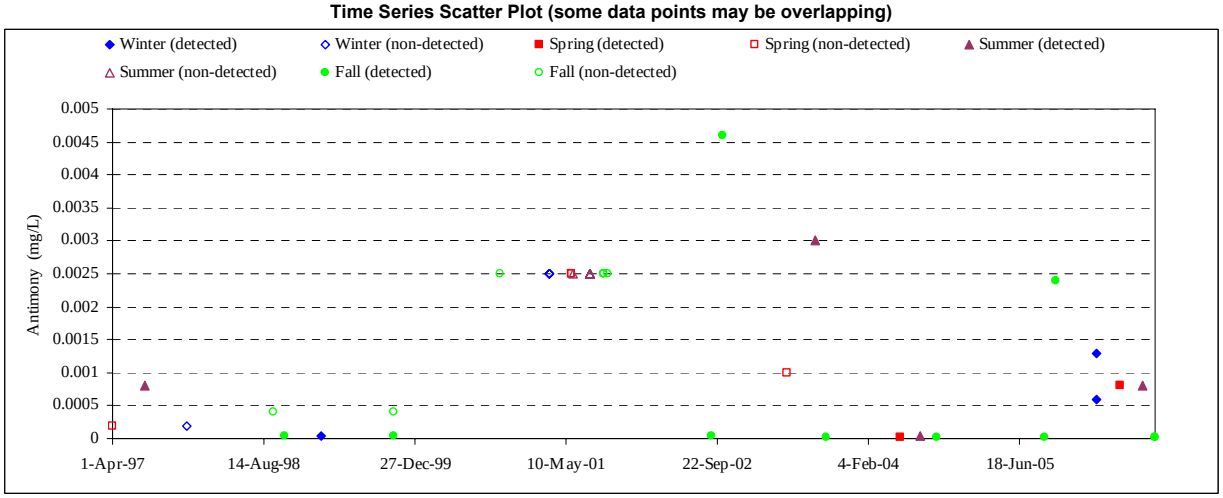


Figure G-2-7-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Muskeg Creek

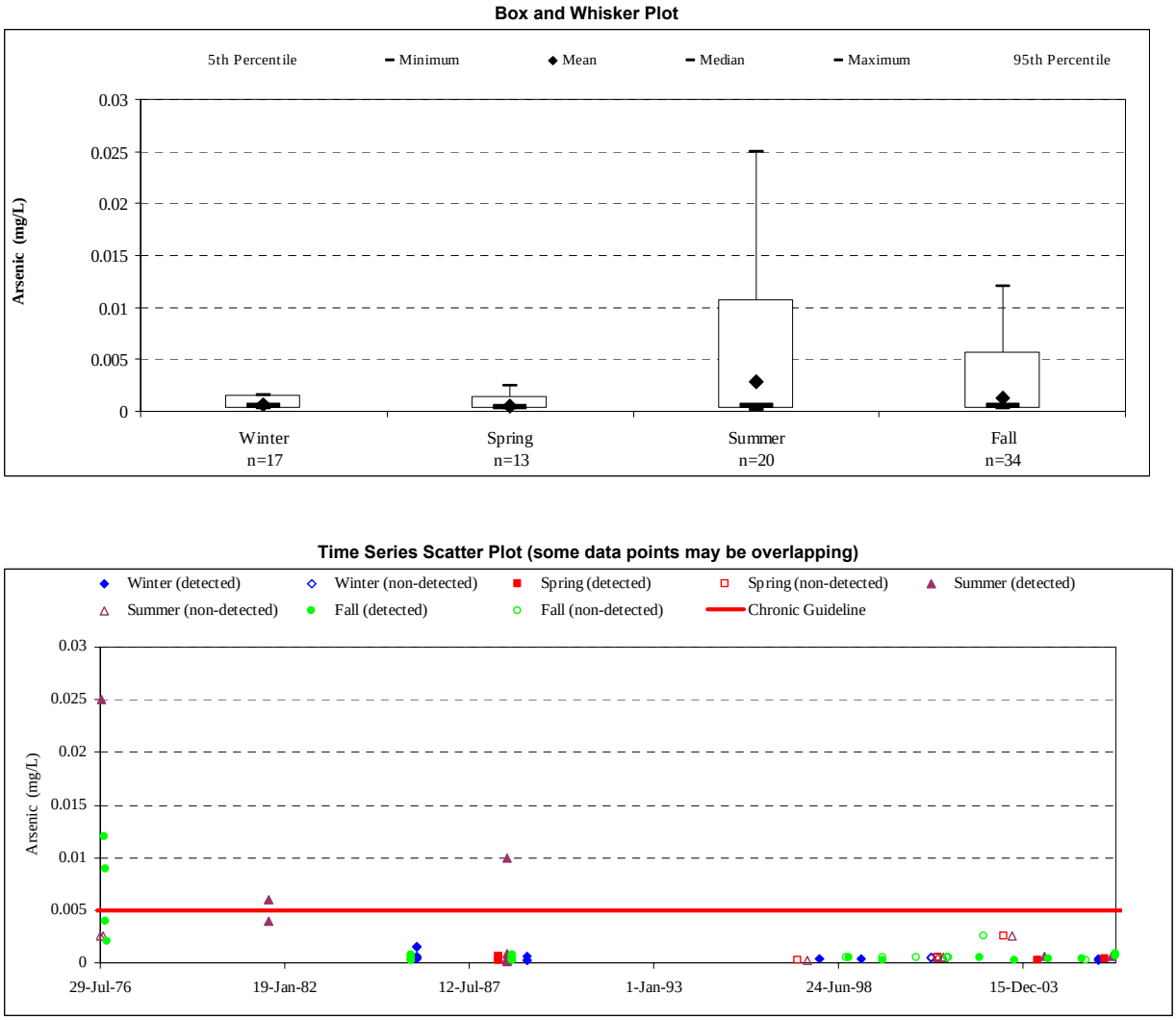
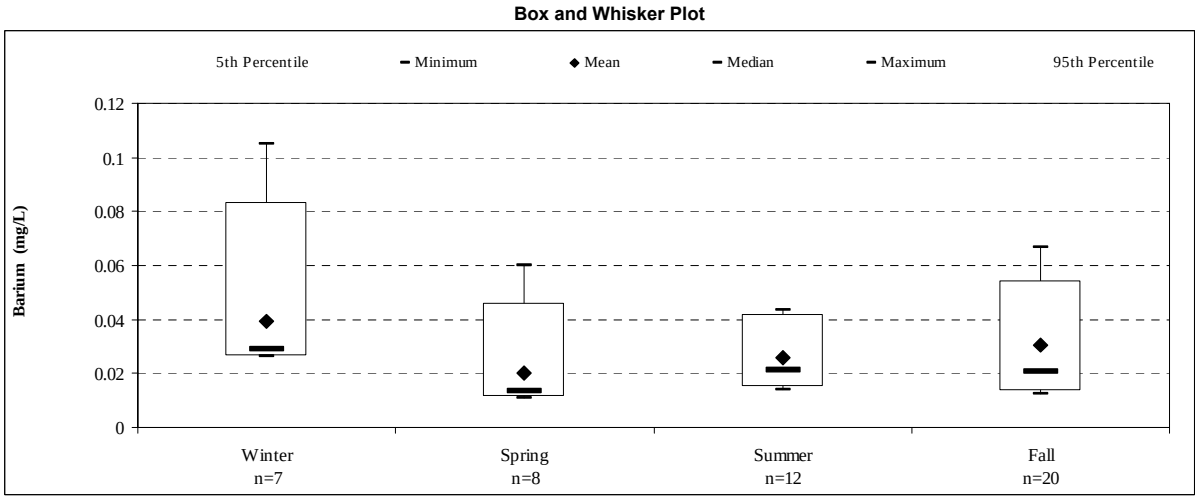


Figure G-2-7-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Muskeg Creek



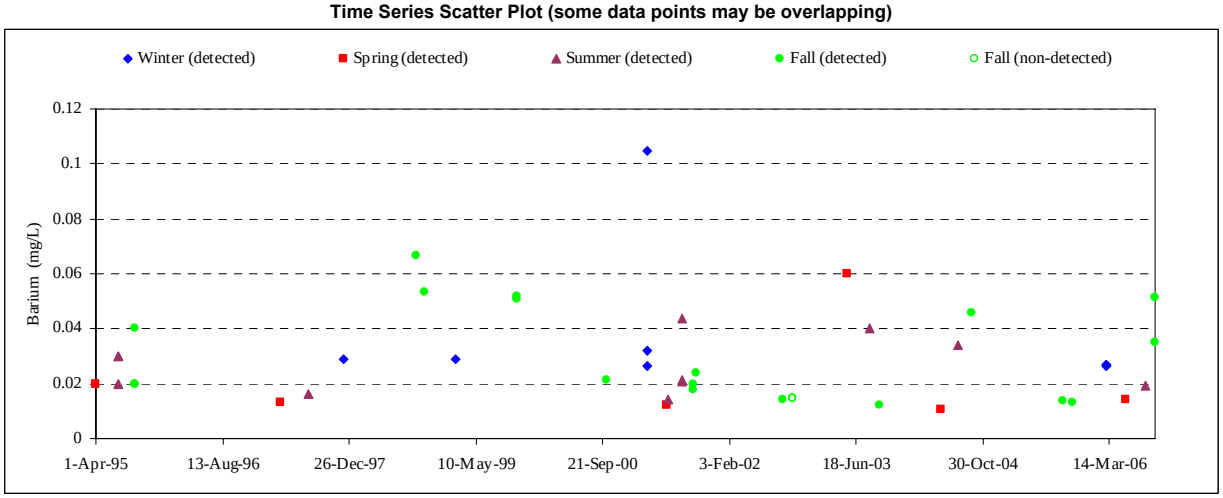
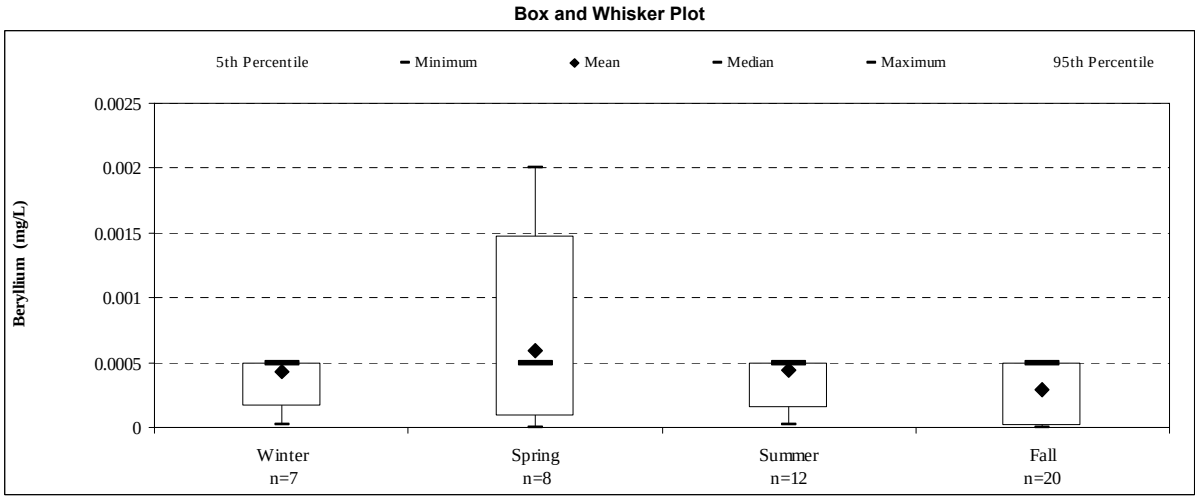


Figure G-2-7-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Muskeg Creek



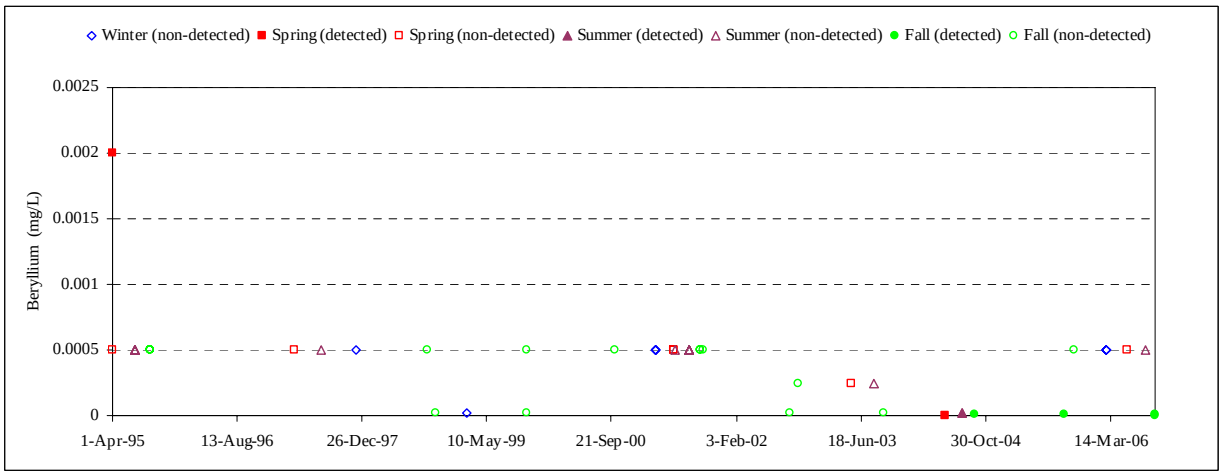
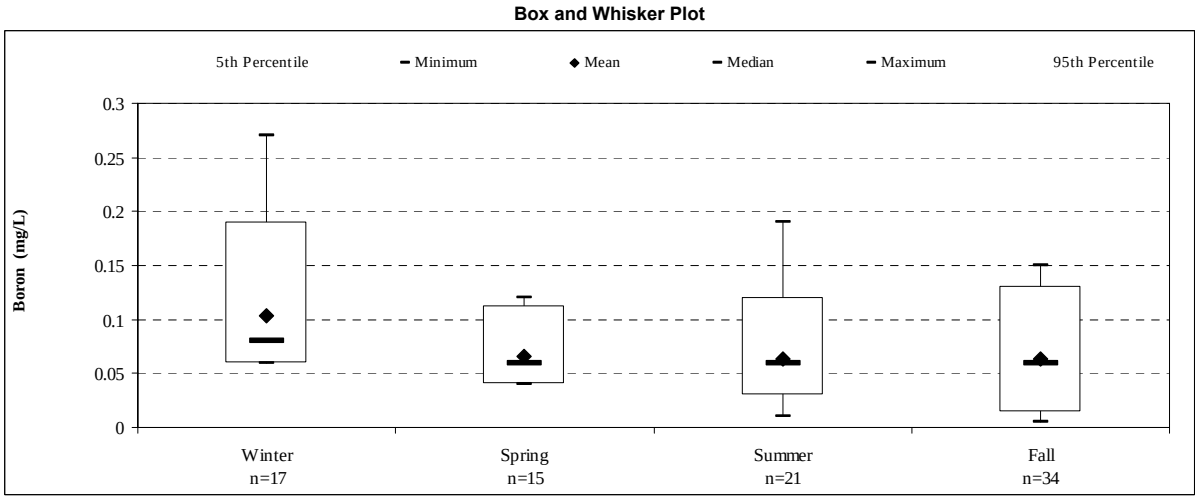


Figure G-2-7-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Muskeg Creek



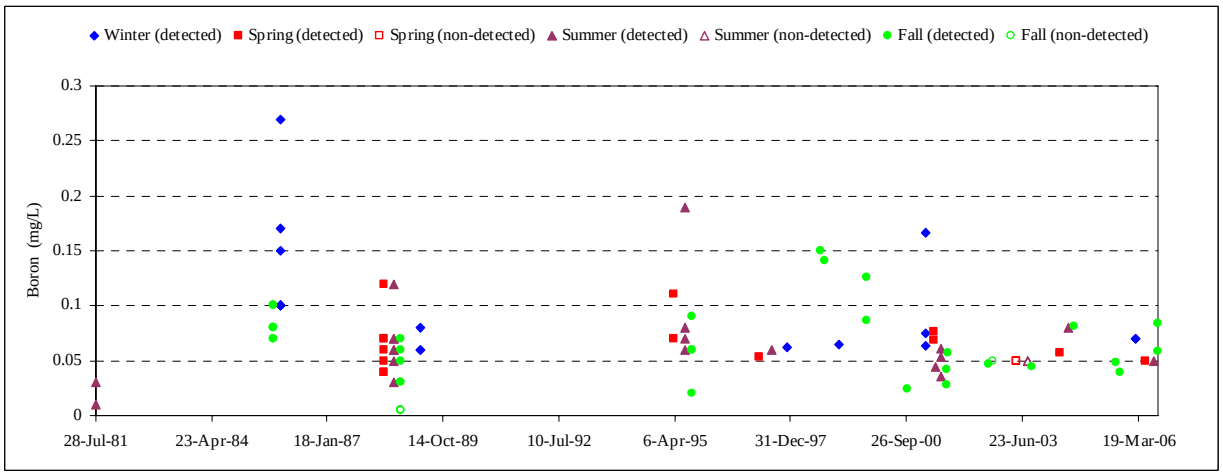
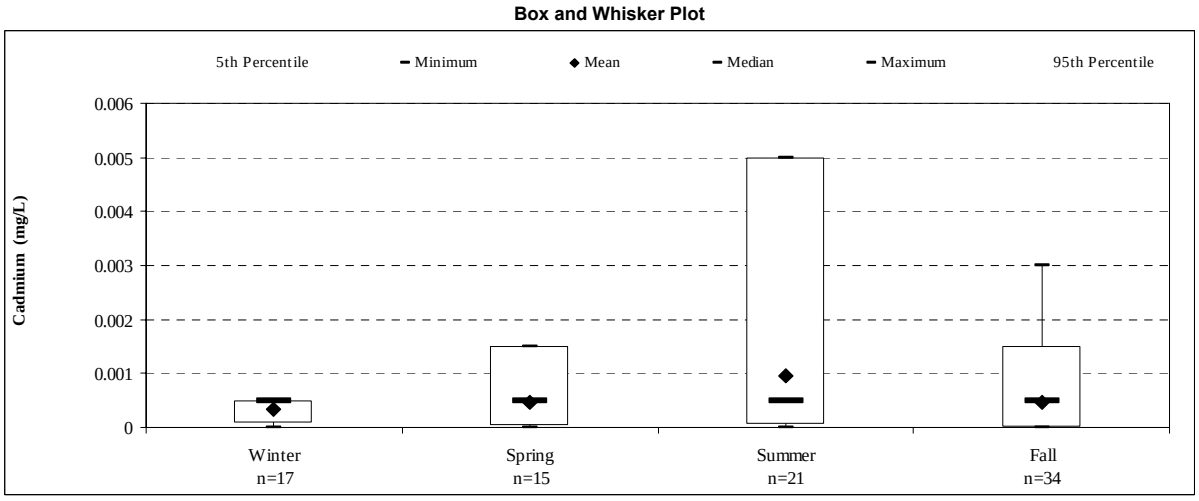


Figure G-2-7-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Muskeg Creek



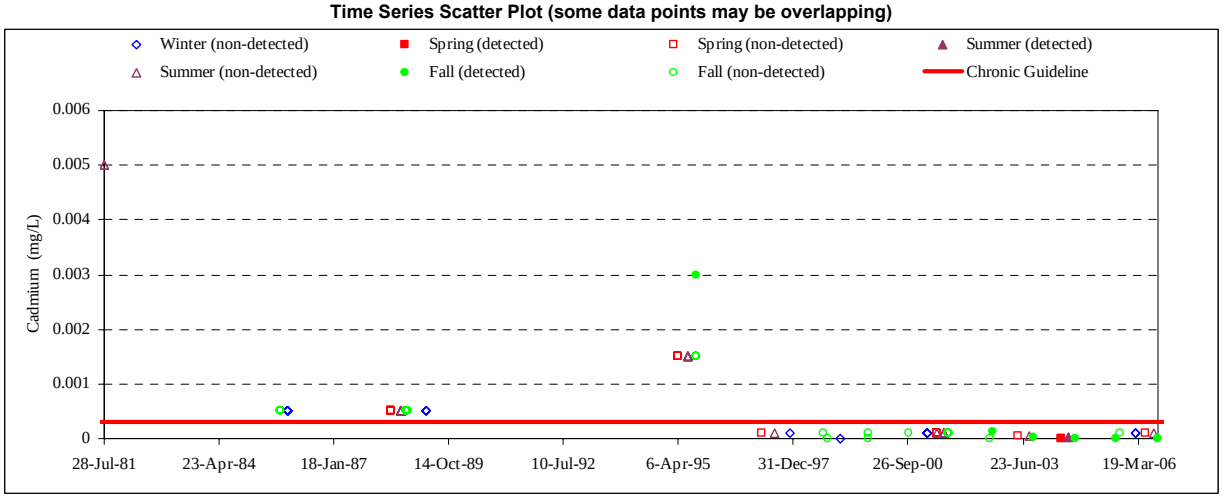
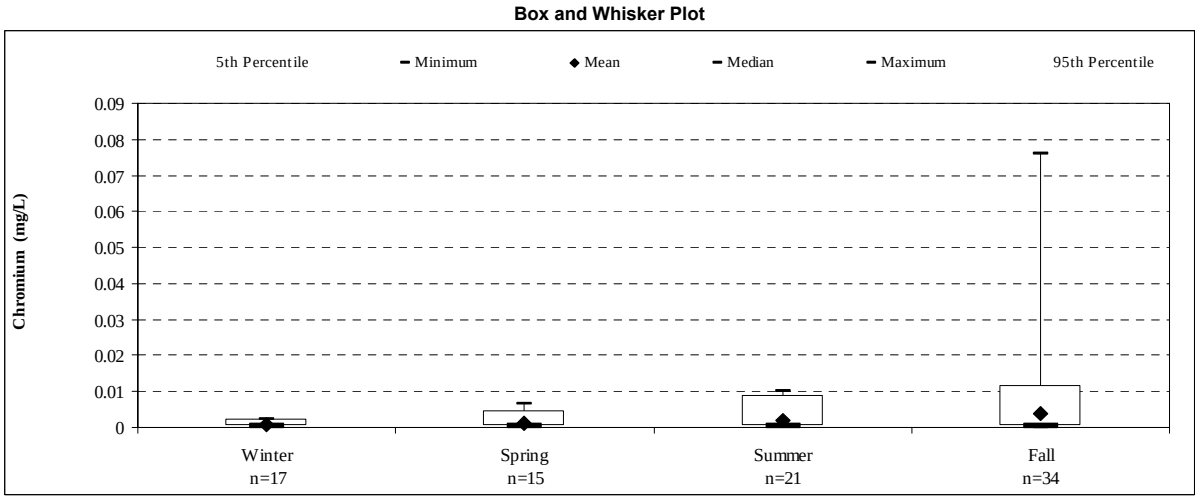


Figure G-2-7-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Muskeg Creek



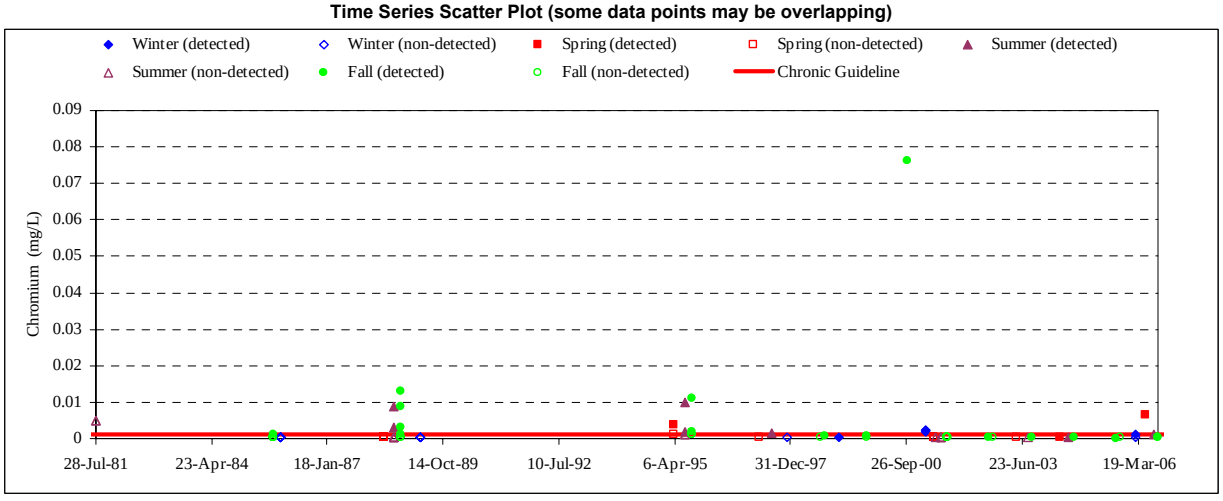


Figure G-2-7-70 Box Whisker and Time Series Scatter Plots of Observed Chromium - hexavalent (Total) Concentration in Muskeg Creek

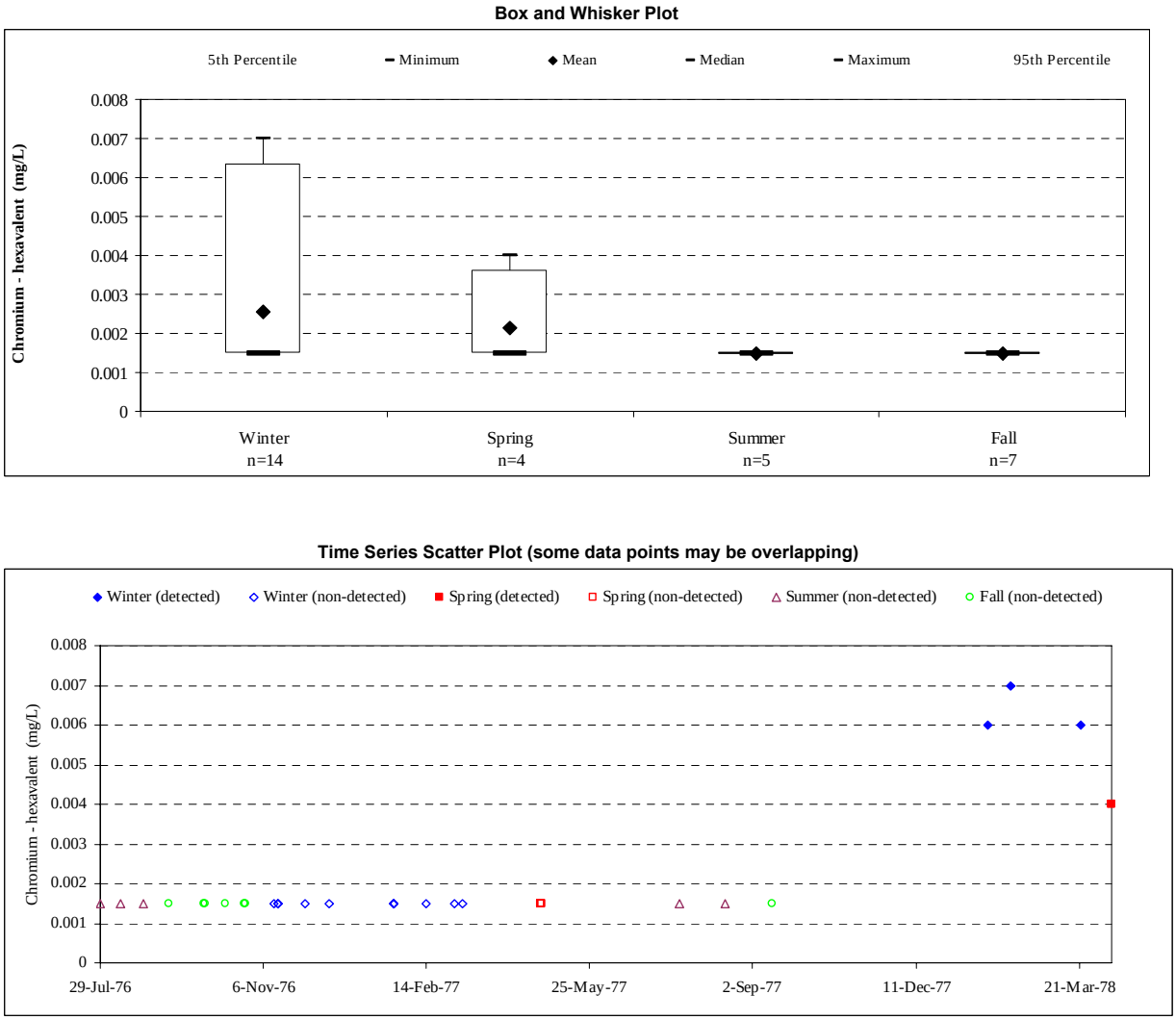


Figure G-2-7-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Muskeg Creek

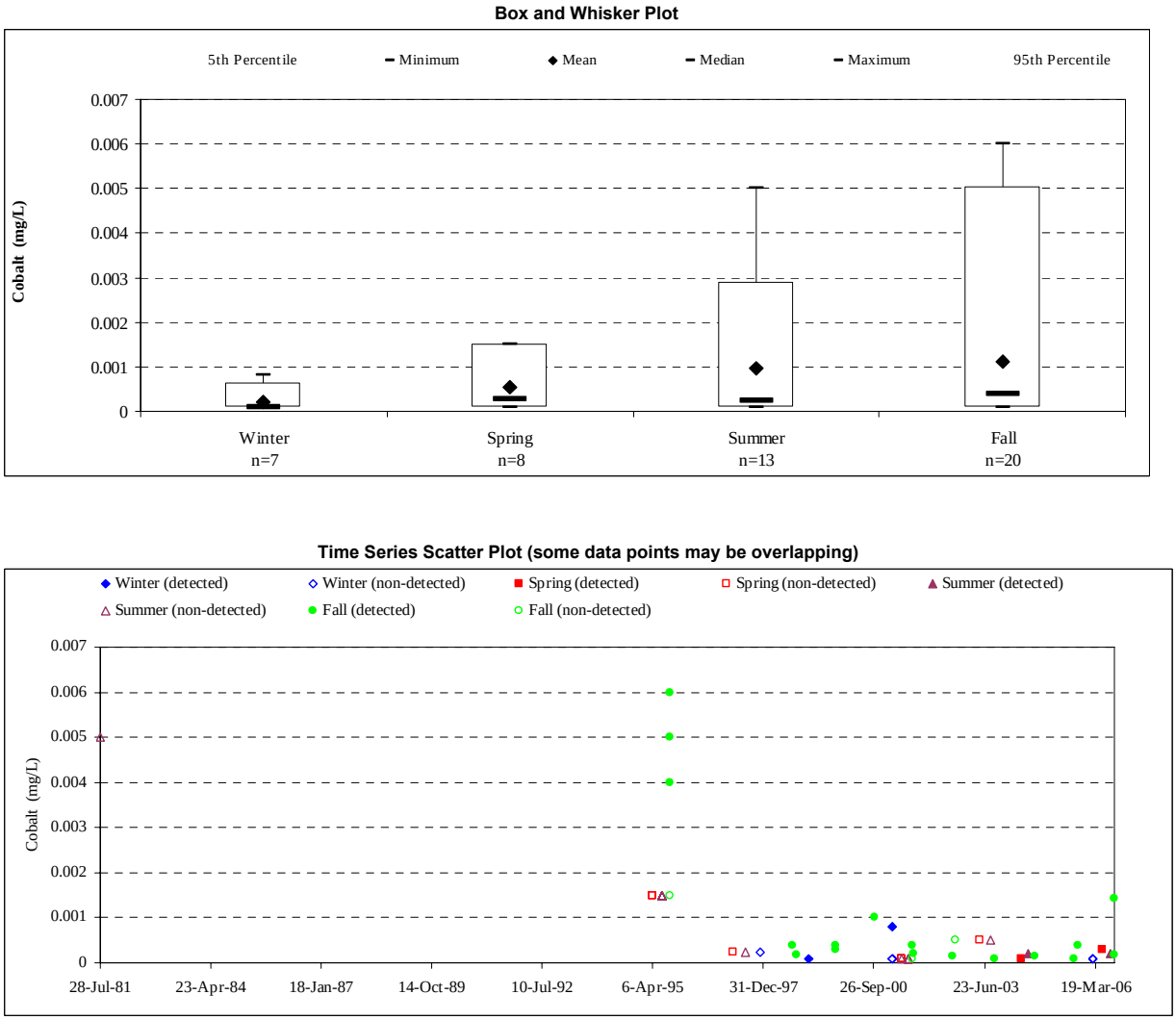
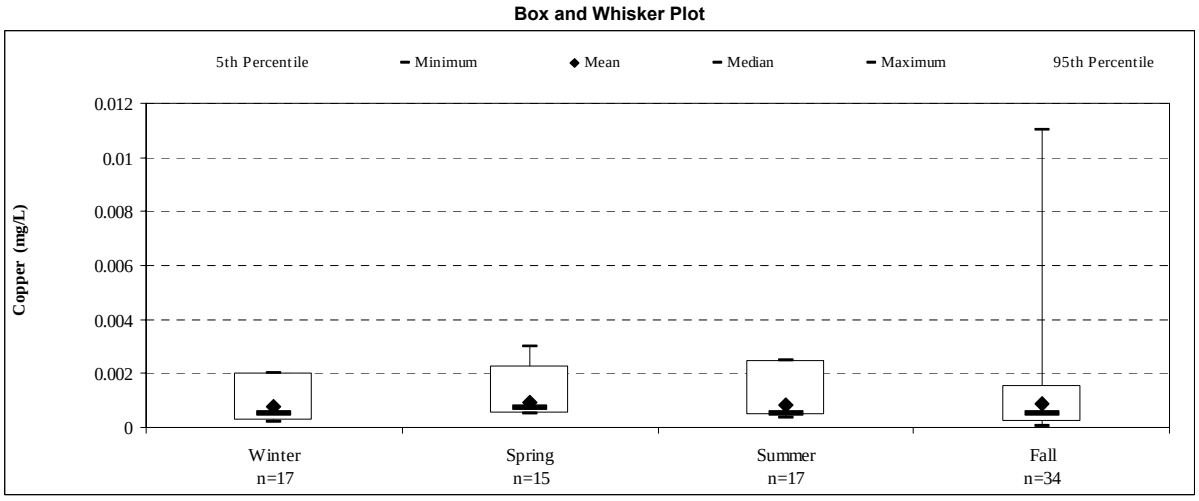


Figure G-2-7-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Muskeg Creek



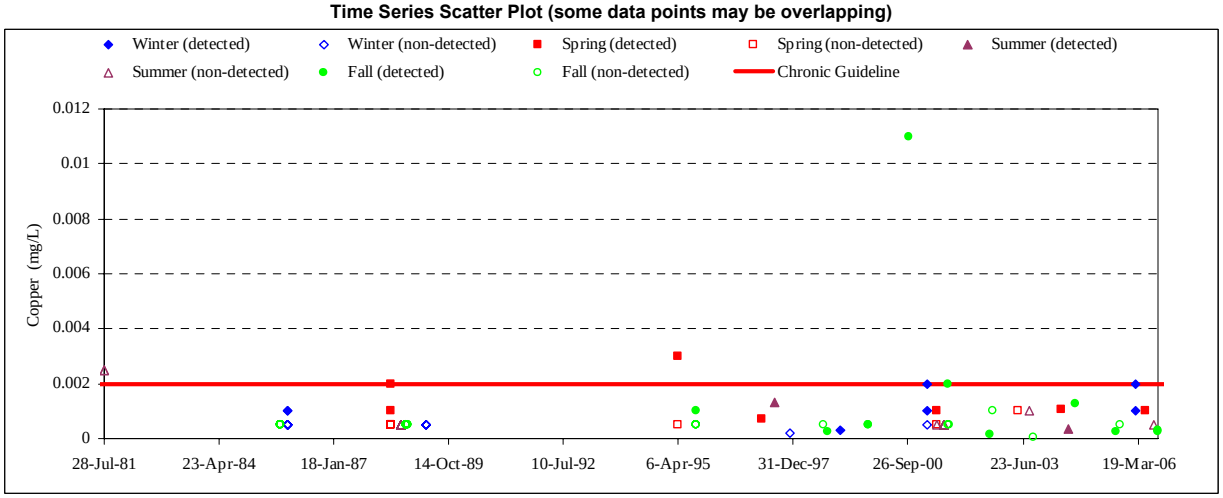
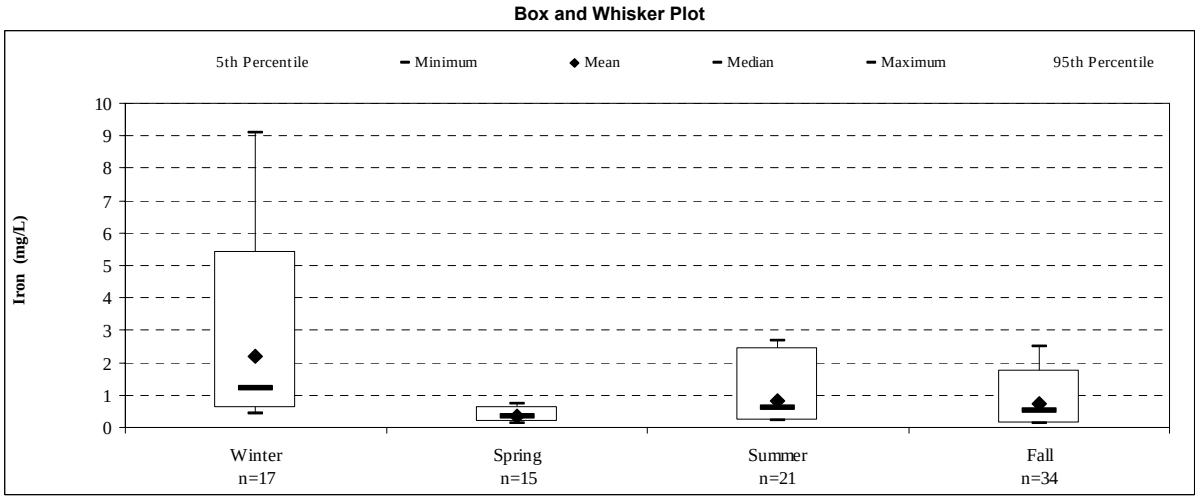


Figure G-2-7-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Muskeg Creek



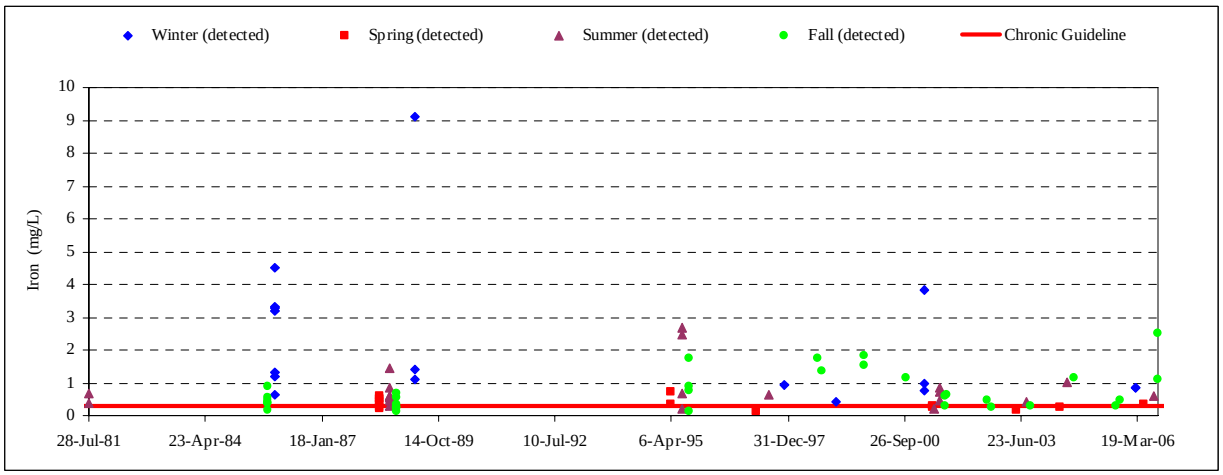
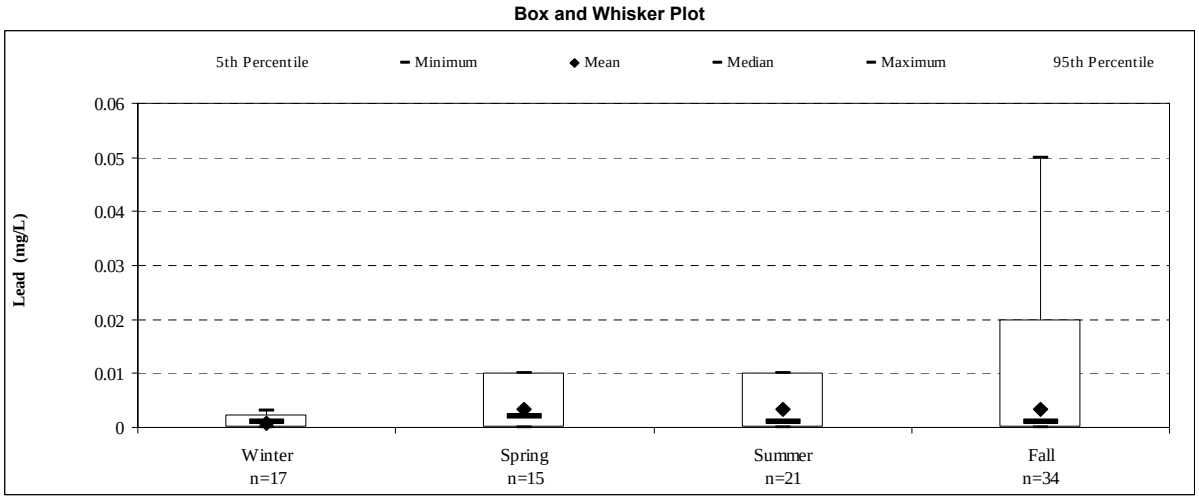


Figure G-2-7-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Muskeg Creek



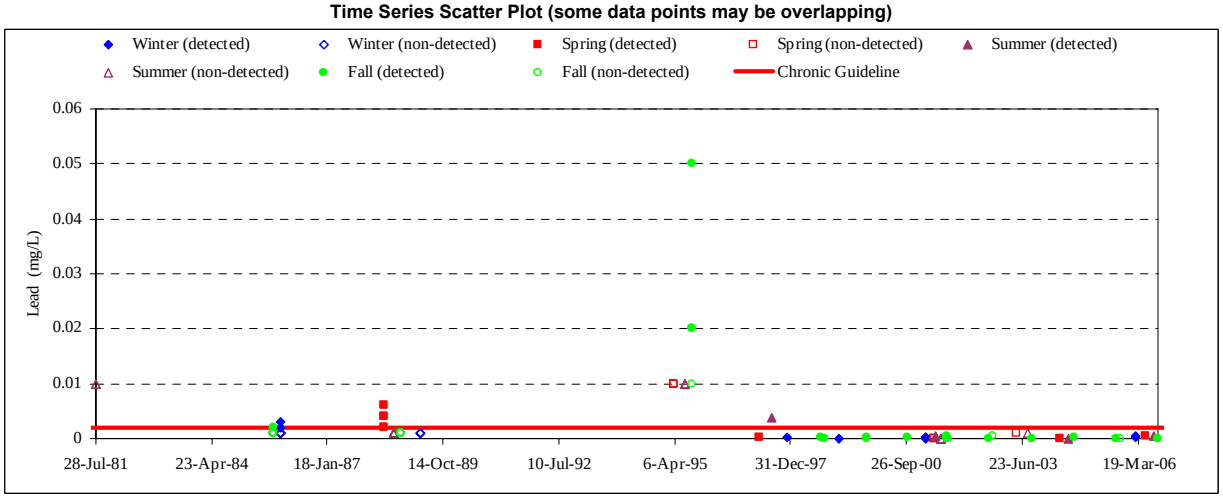
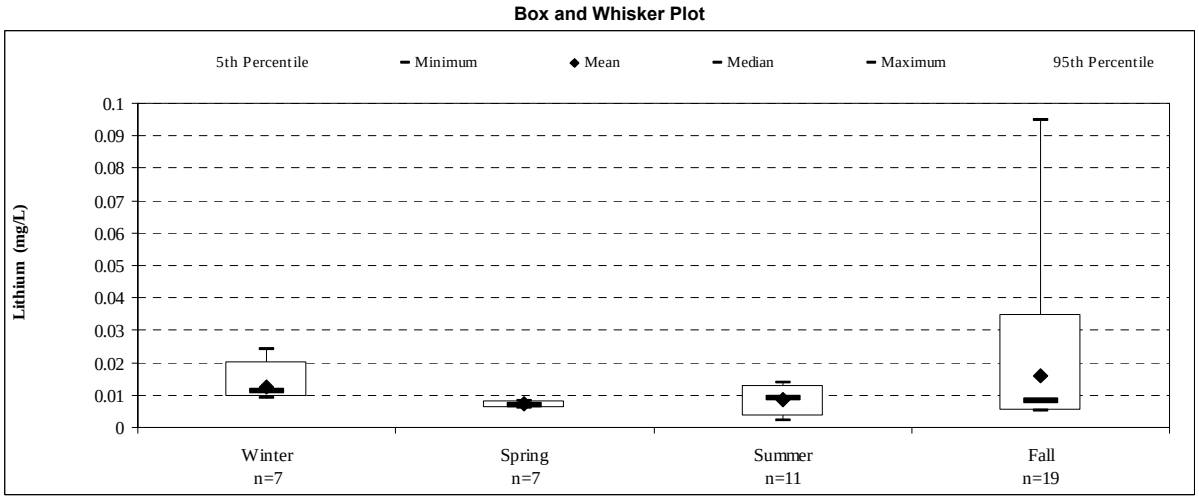


Figure G-2-7-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Muskeg Creek



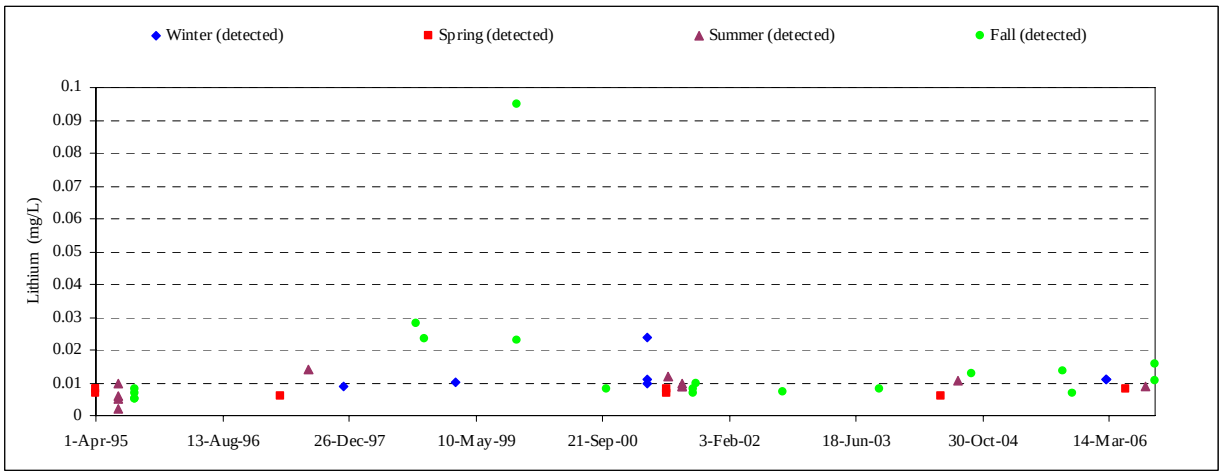
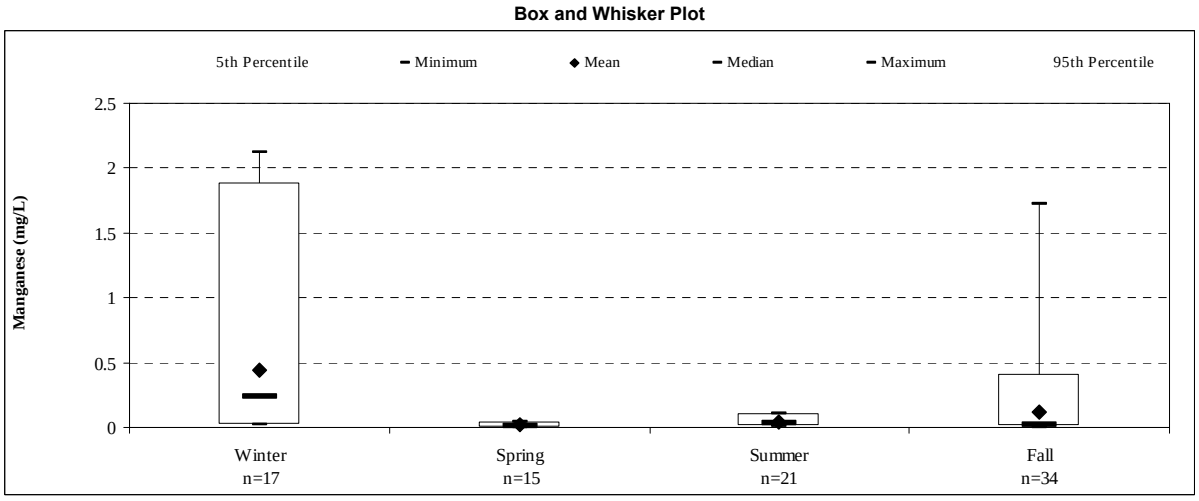


Figure G-2-7-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Muskeg Creek



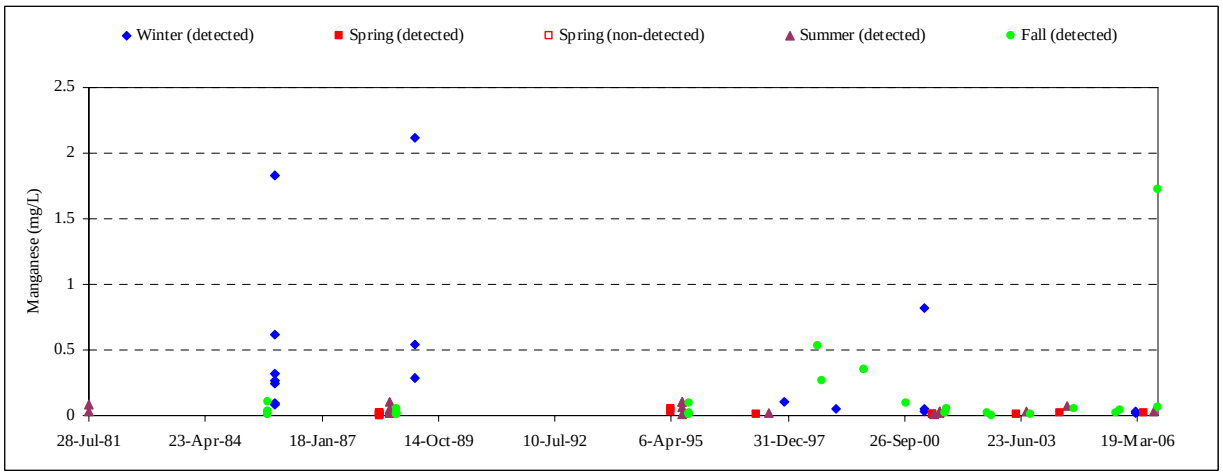
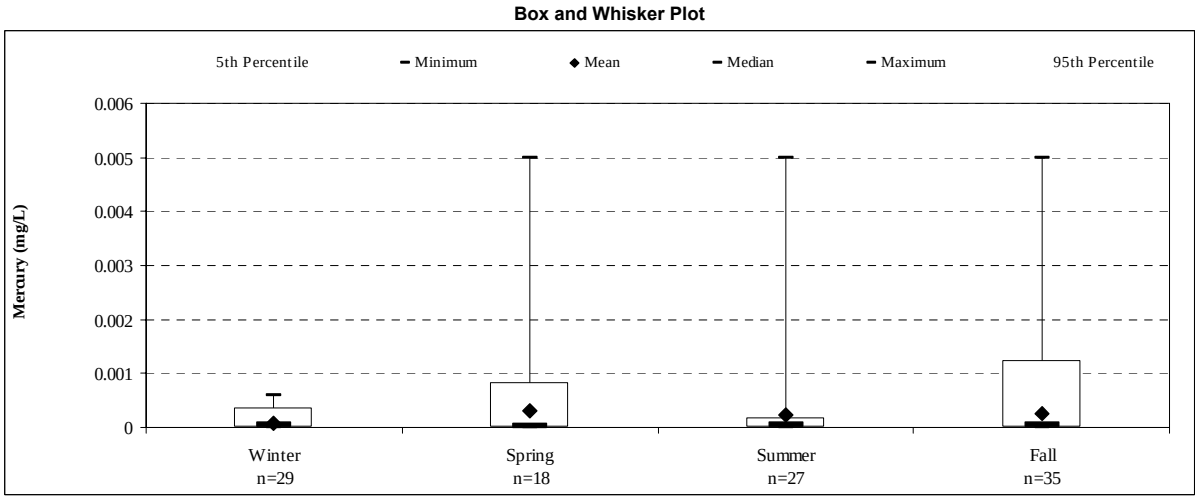


Figure G-2-7-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Muskeg Creek



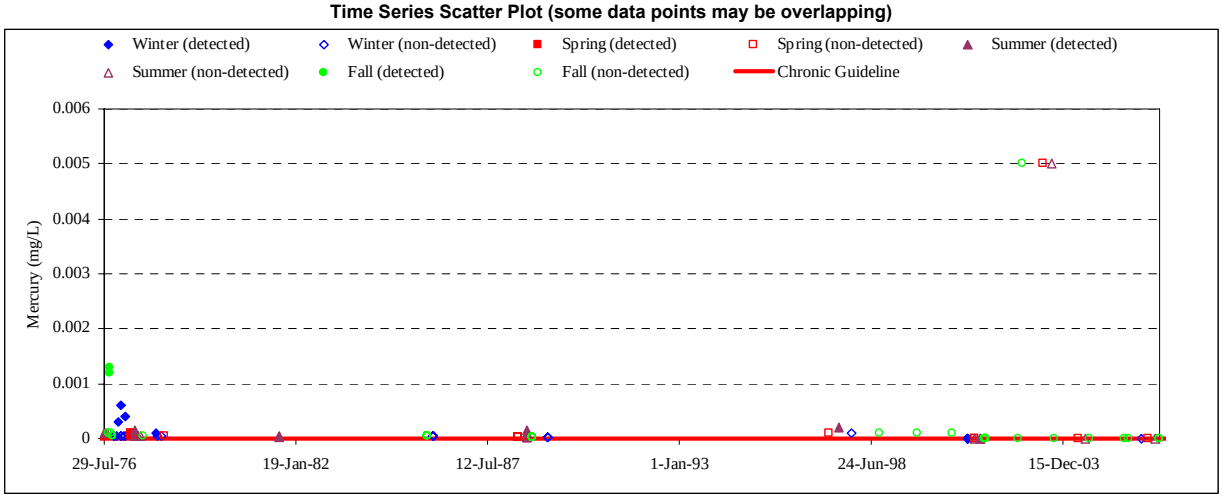
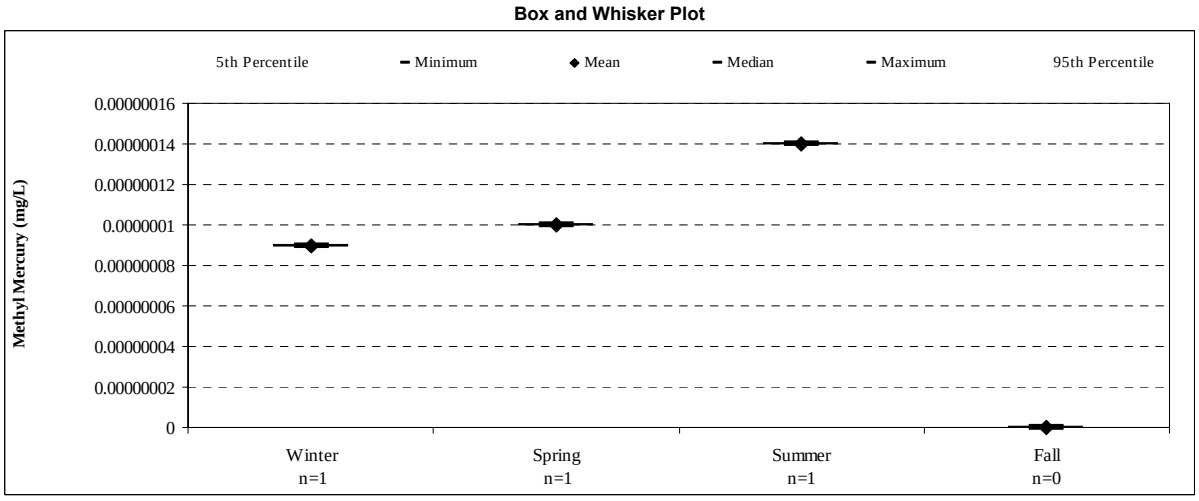


Figure G-2-7-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Muskeg Creek



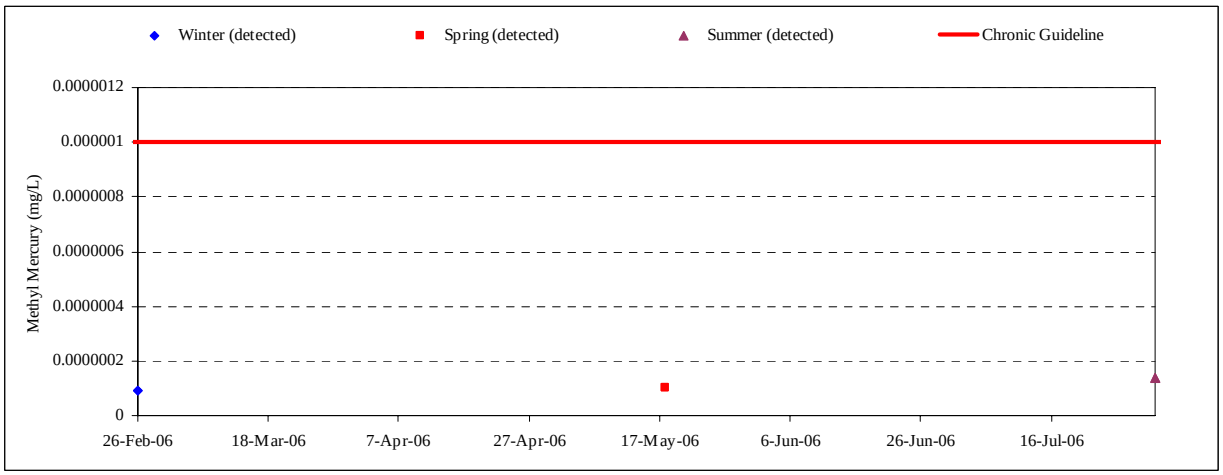


Figure G-2-7-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Muskeg Creek

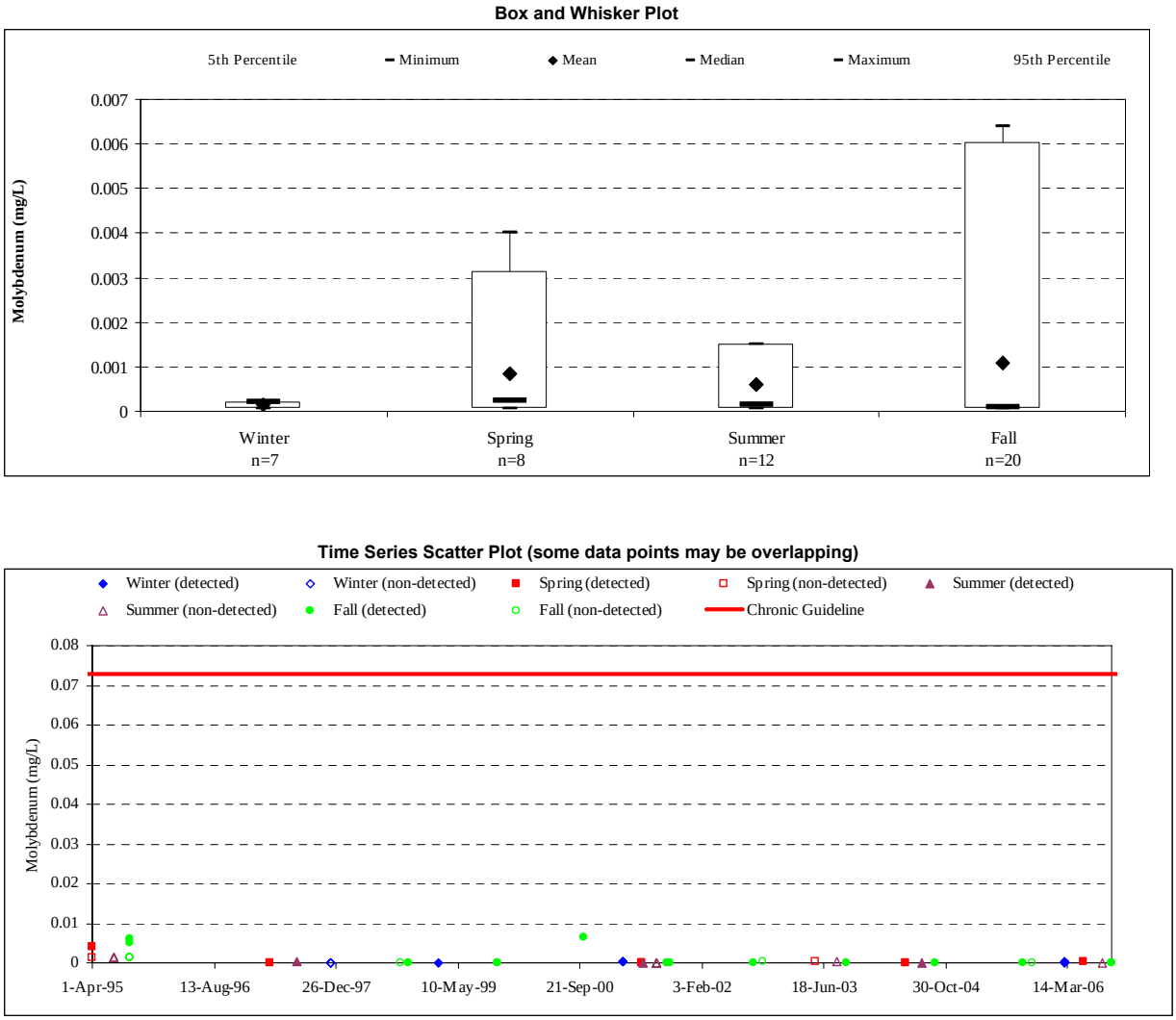
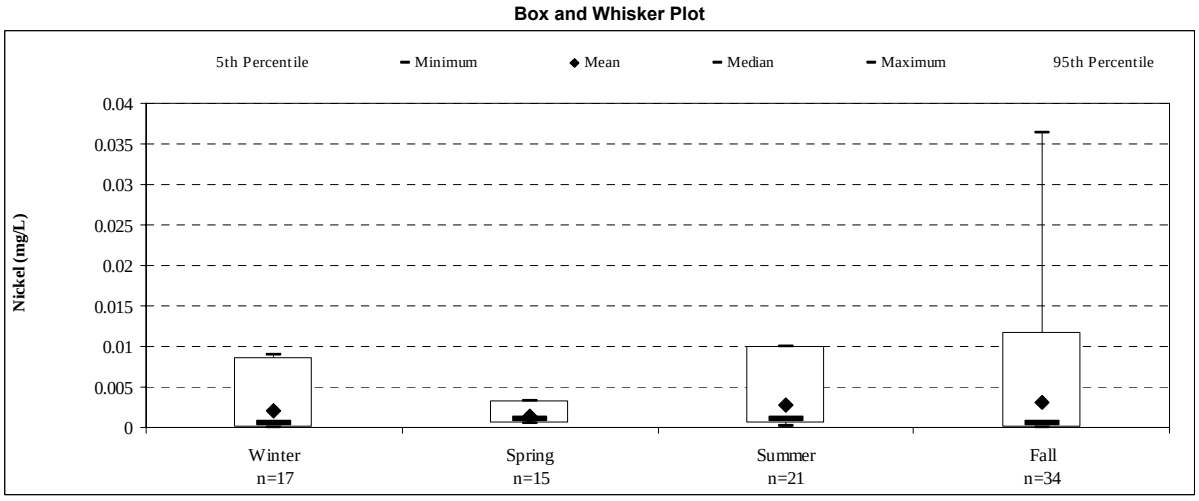


Figure G-2-7-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Muskeg Creek



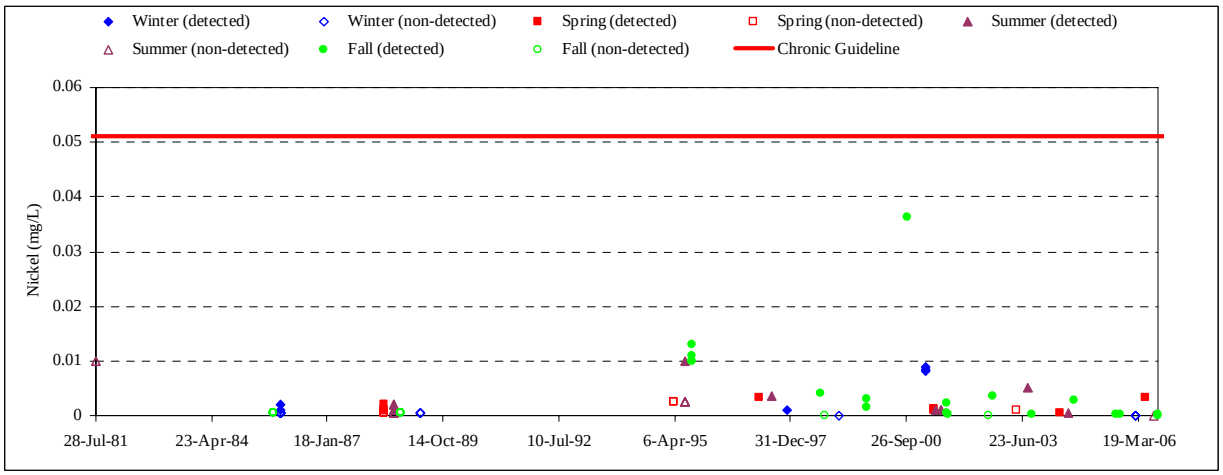
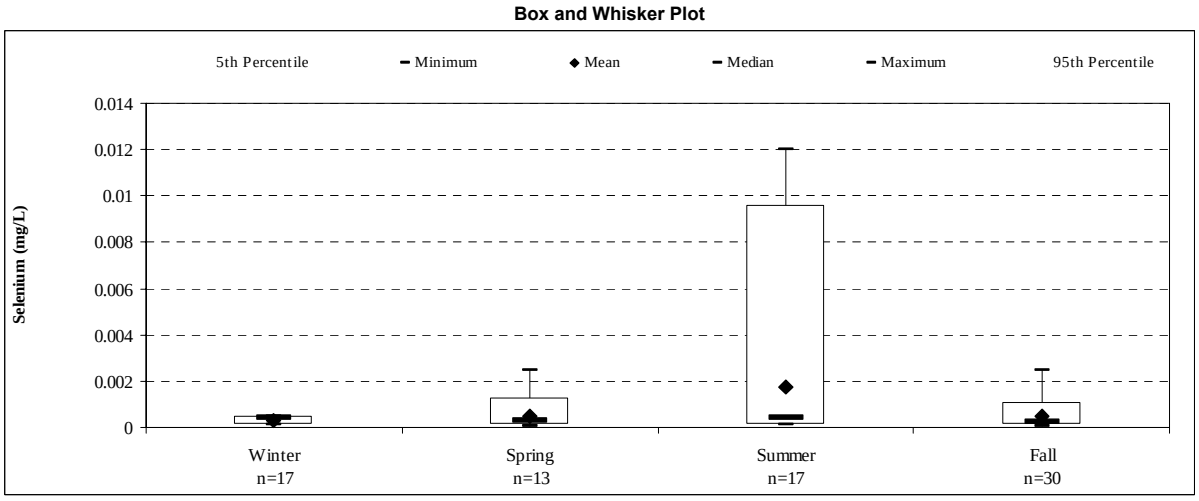


Figure G-2-7-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Muskeg Creek



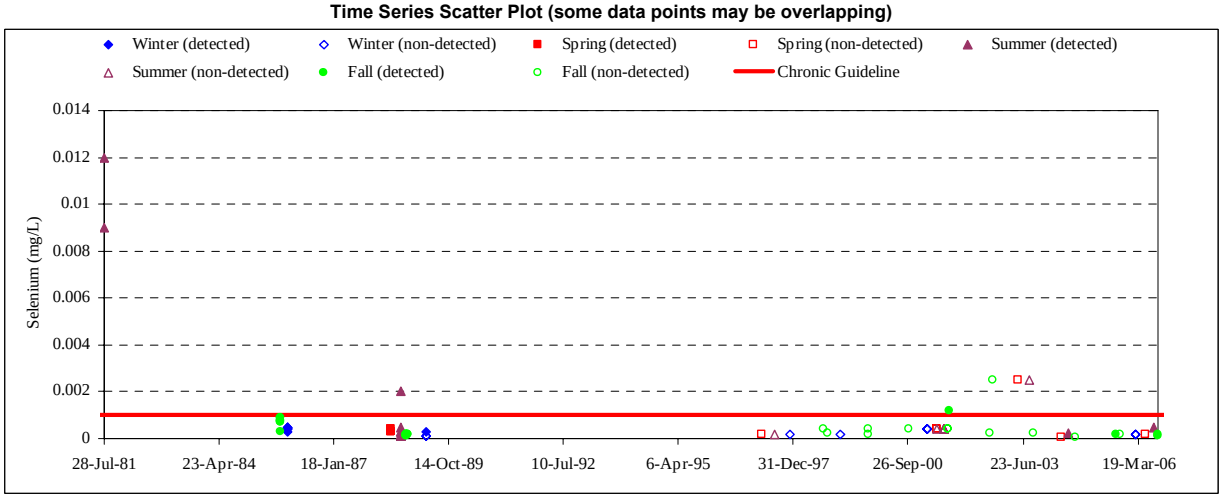
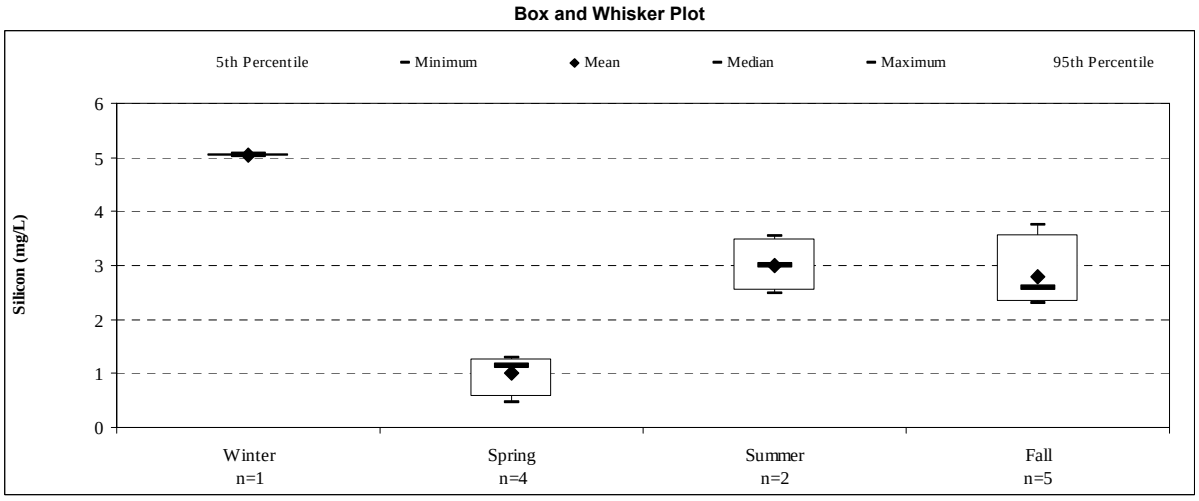


Figure G-2-7-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Muskeg Creek



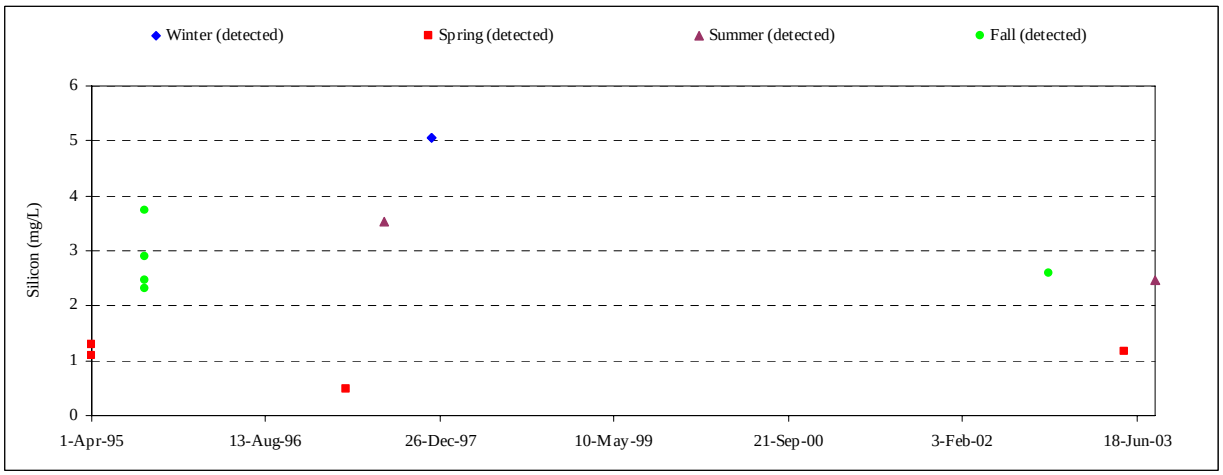
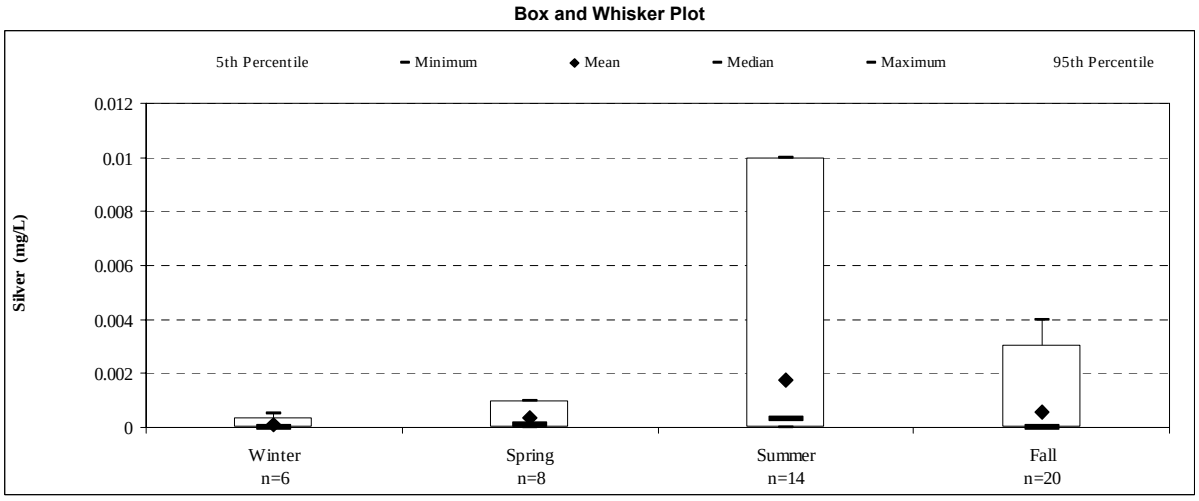


Figure G-2-7-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Muskeg Creek



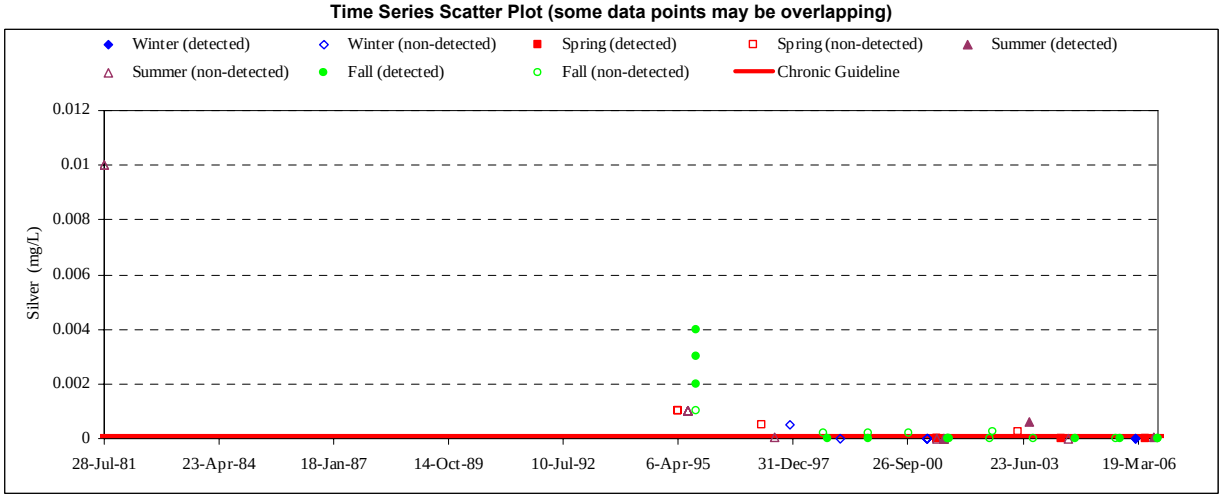
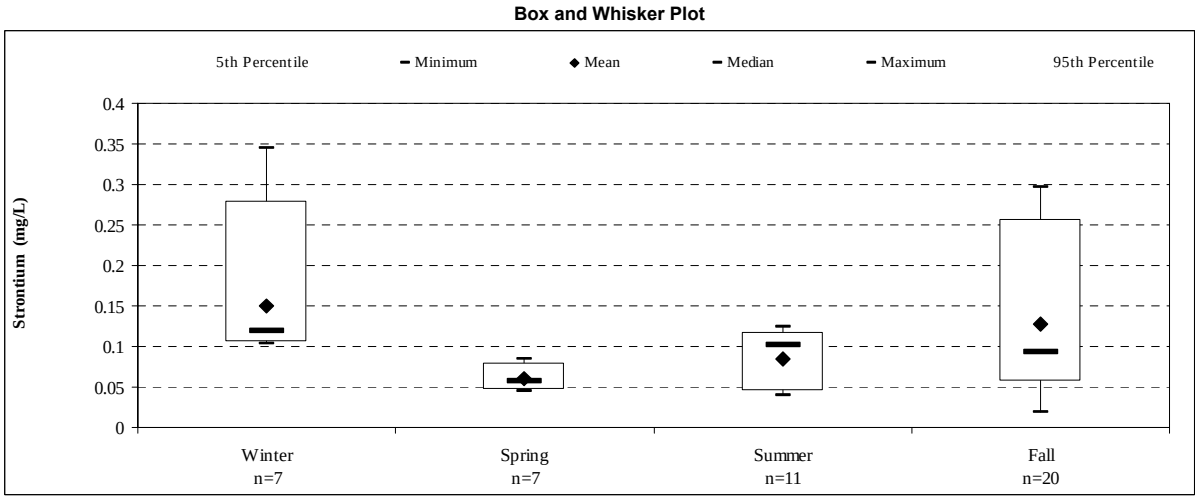


Figure G-2-7-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Muskeg Creek



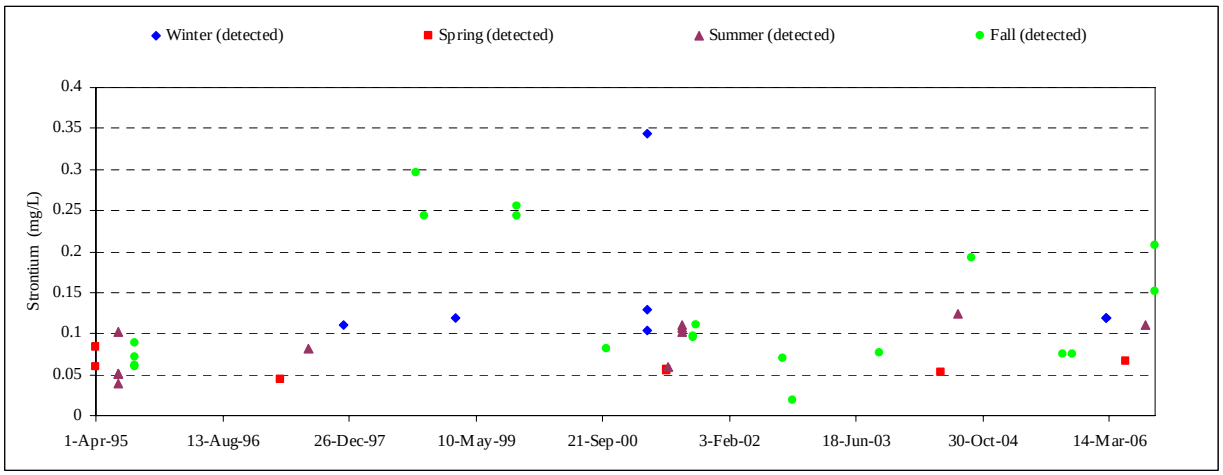
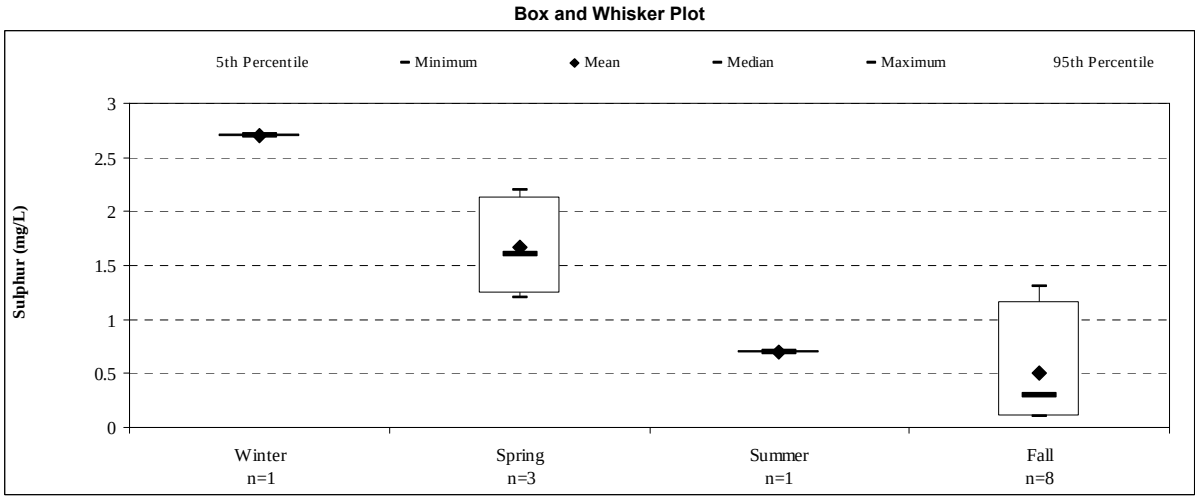


Figure G-2-7-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Muskeg Creek



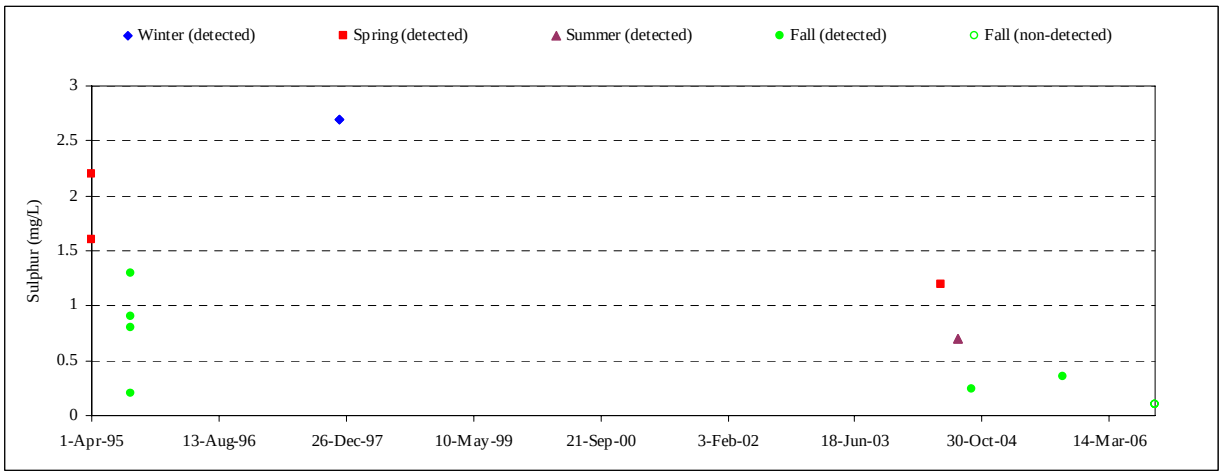


Figure G-2-7-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Muskeg Creek

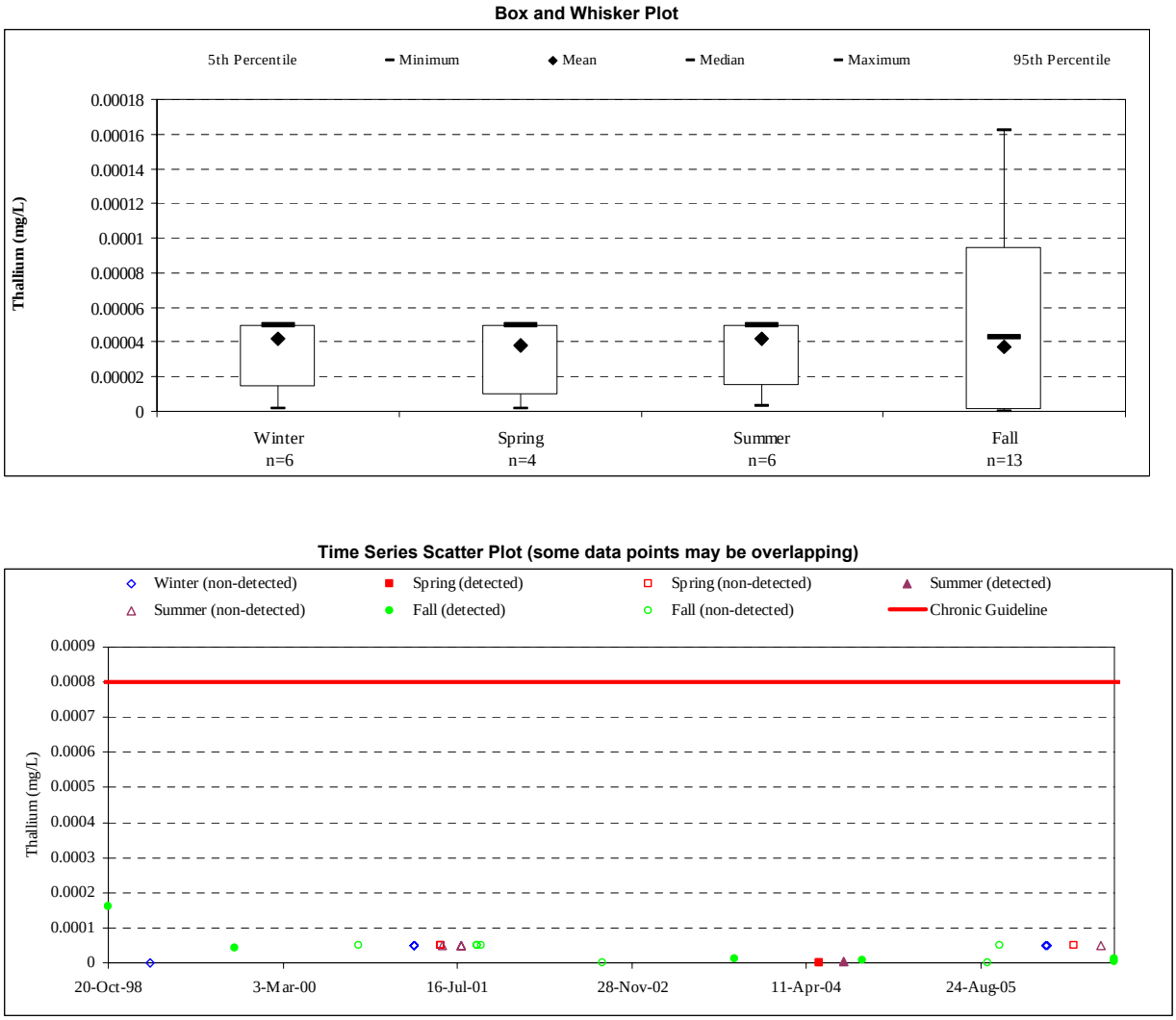
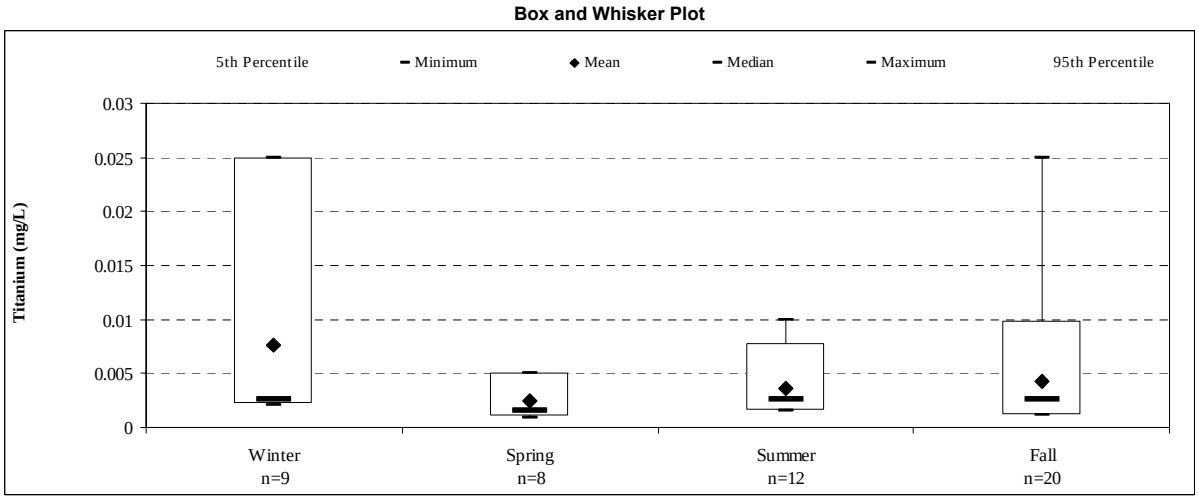


Figure G-2-7-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Muskeg Creek



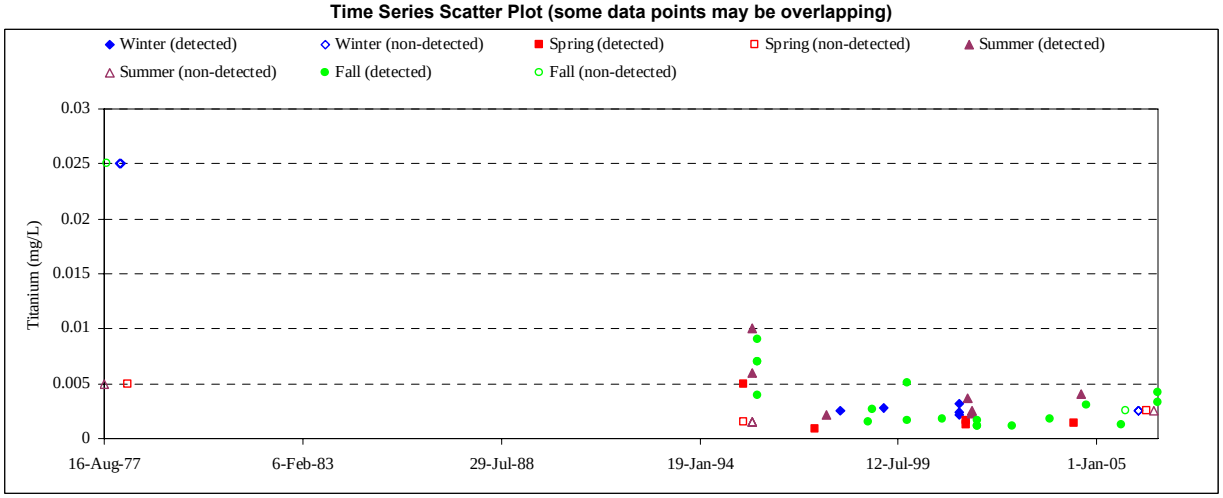
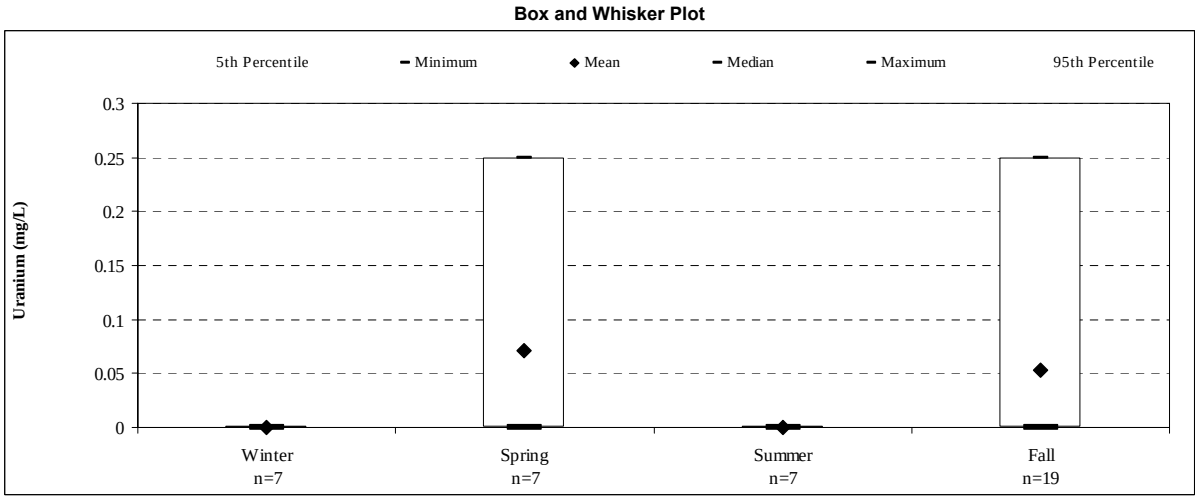


Figure G-2-7-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Muskeg Creek



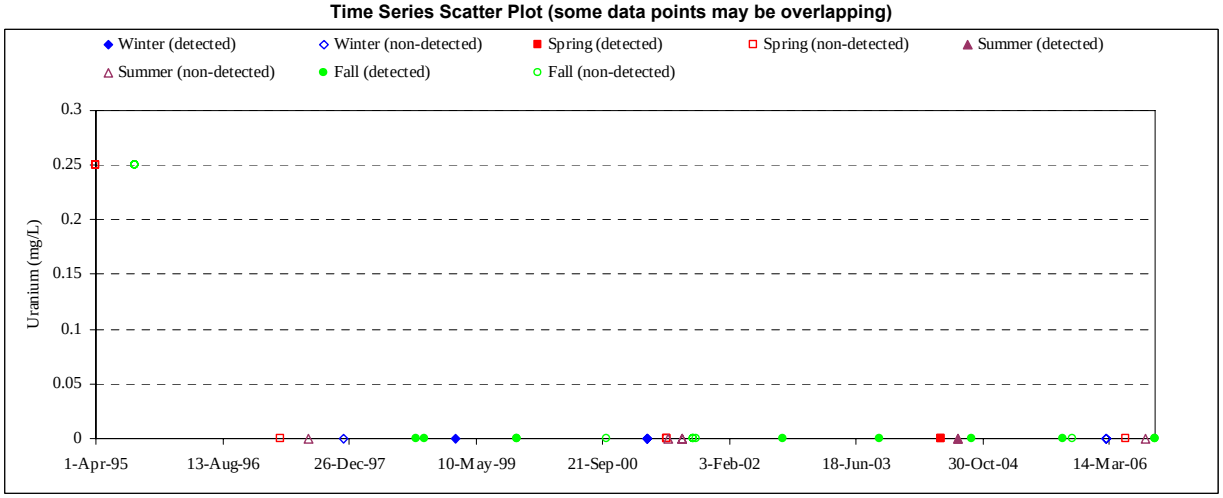
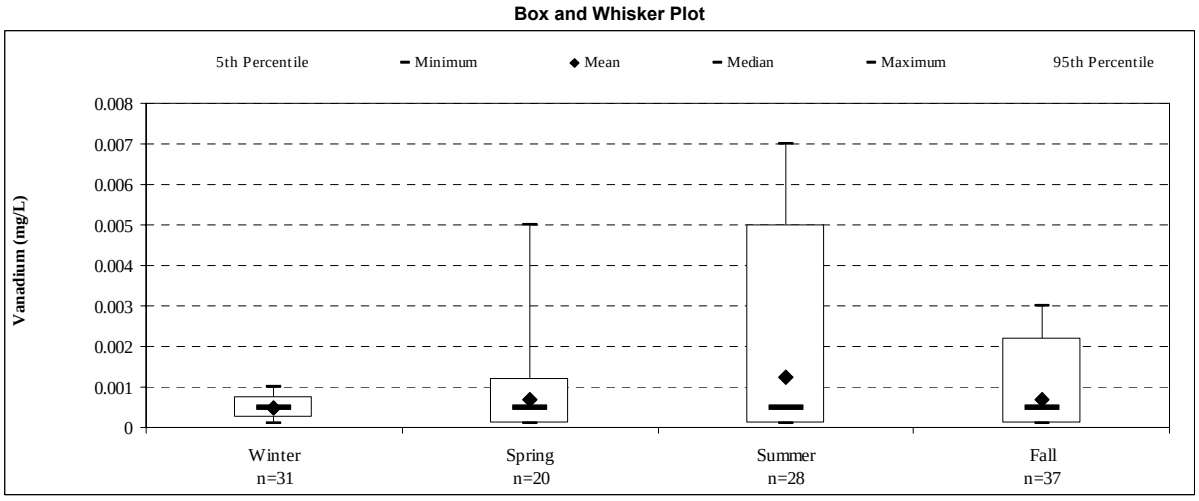


Figure G-2-7-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Muskeg Creek



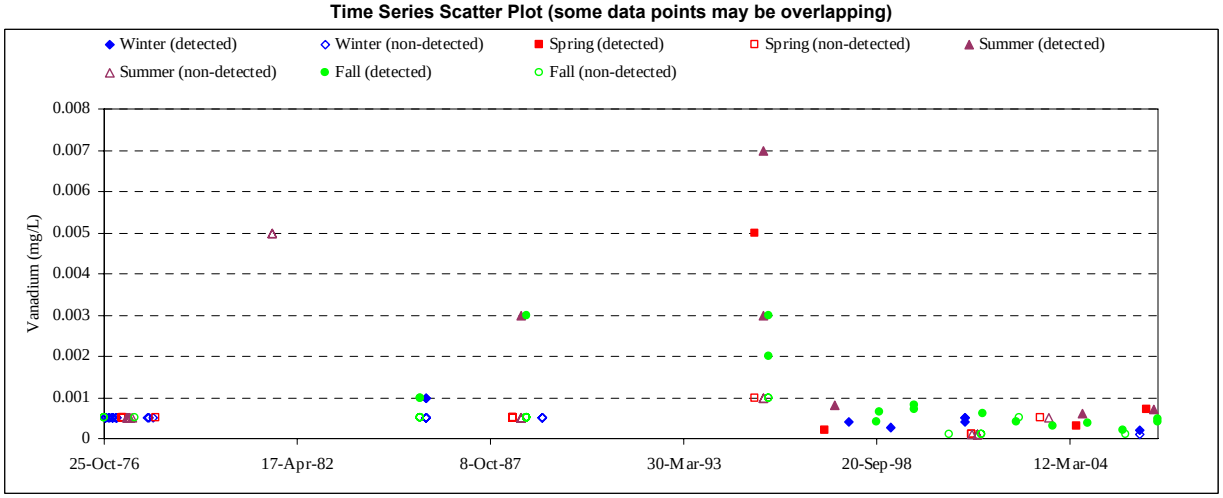
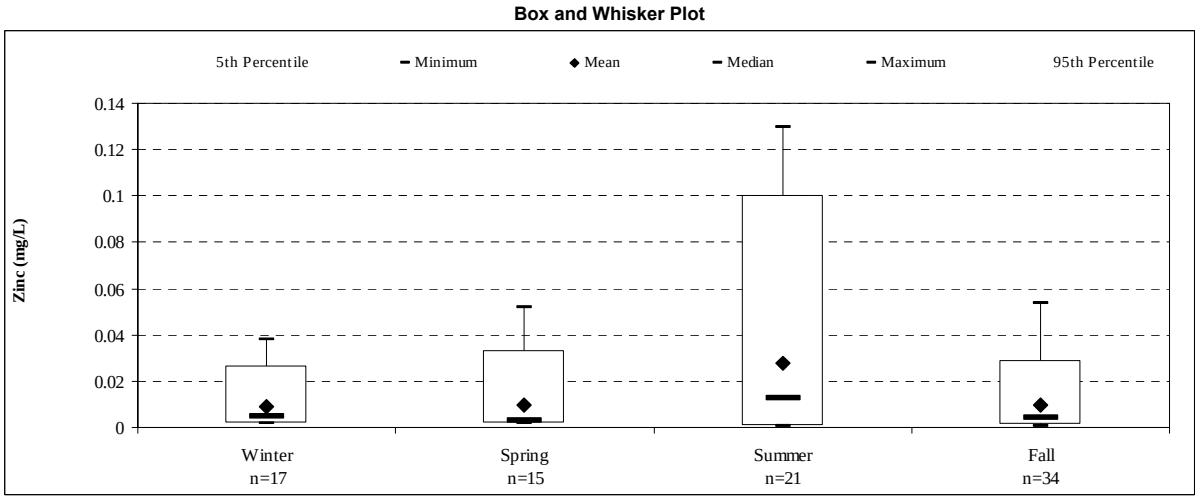


Figure G-2-7-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Muskeg Creek



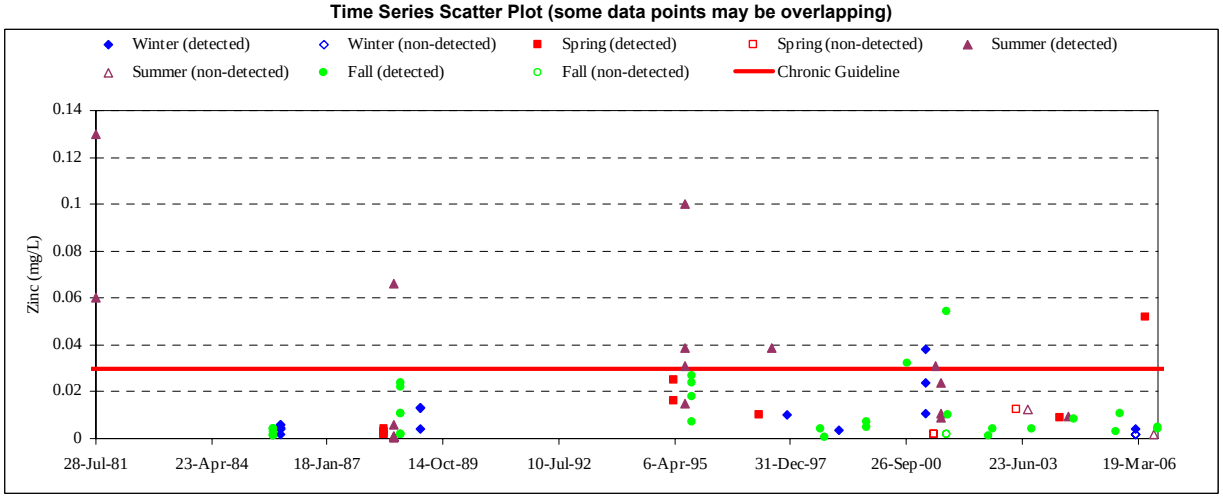
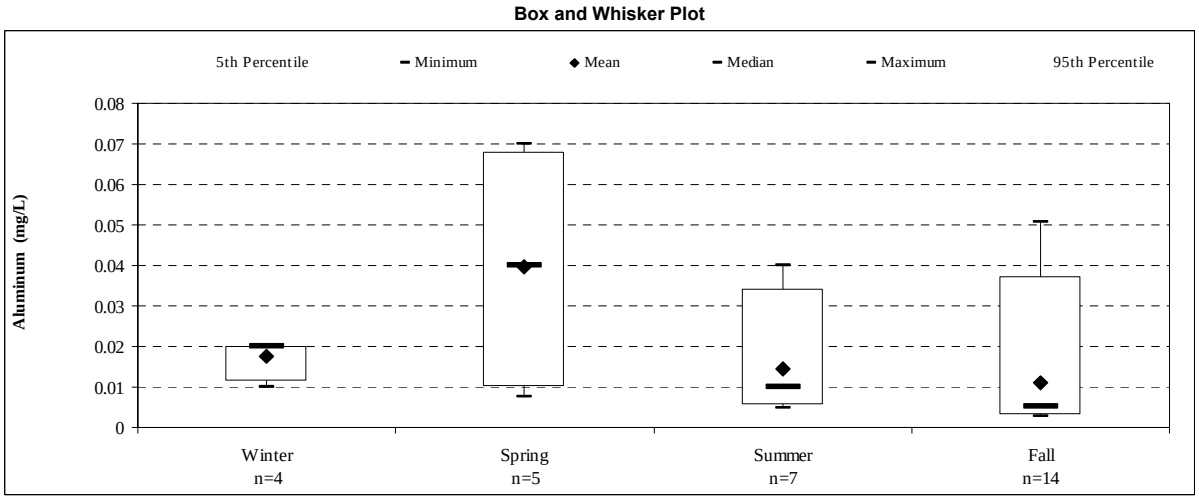


Figure G-2-7-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Muskeg Creek



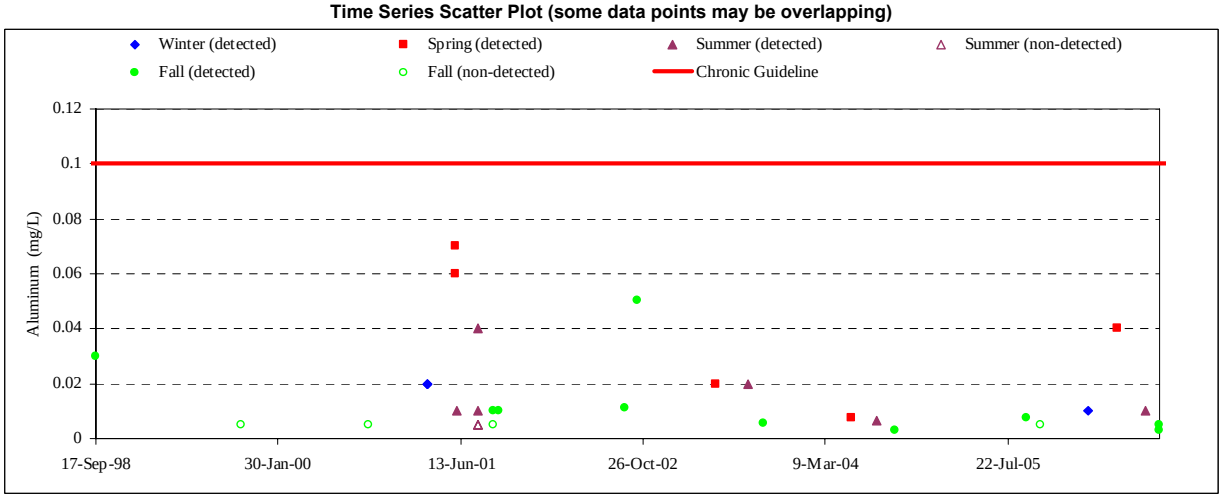
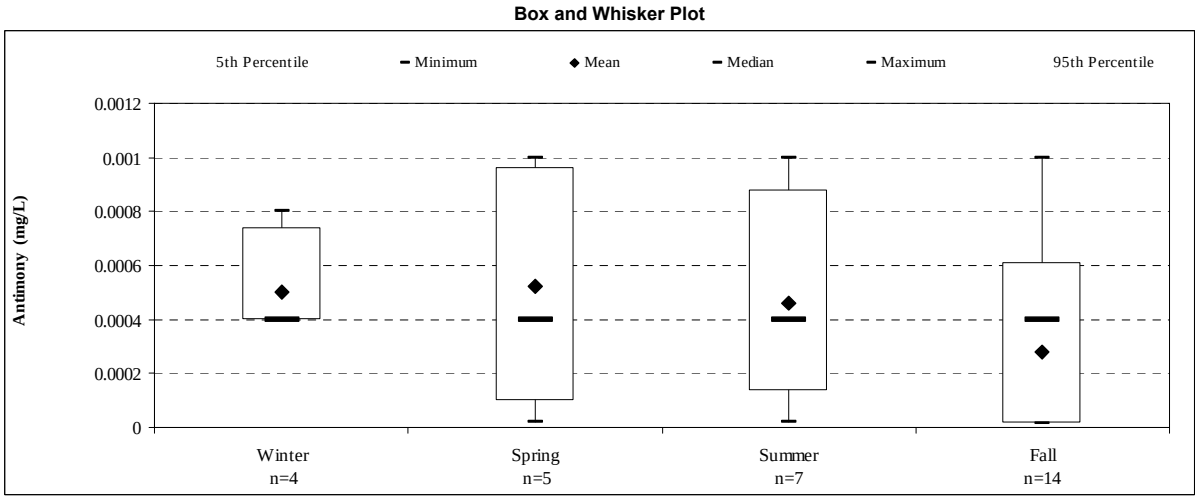


Figure G-2-7-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Muskeg Creek



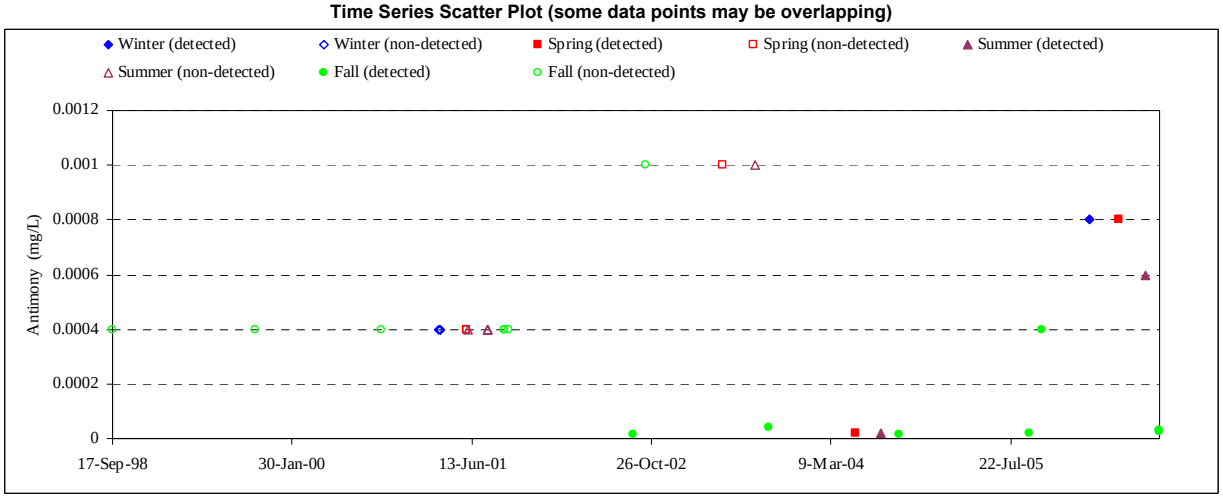
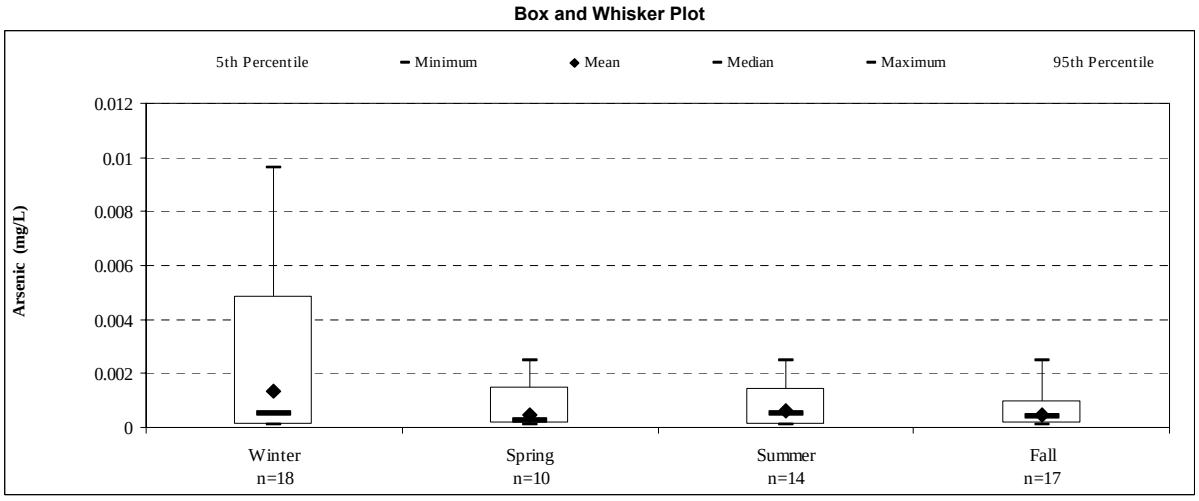


Figure G-2-7-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Muskeg Creek



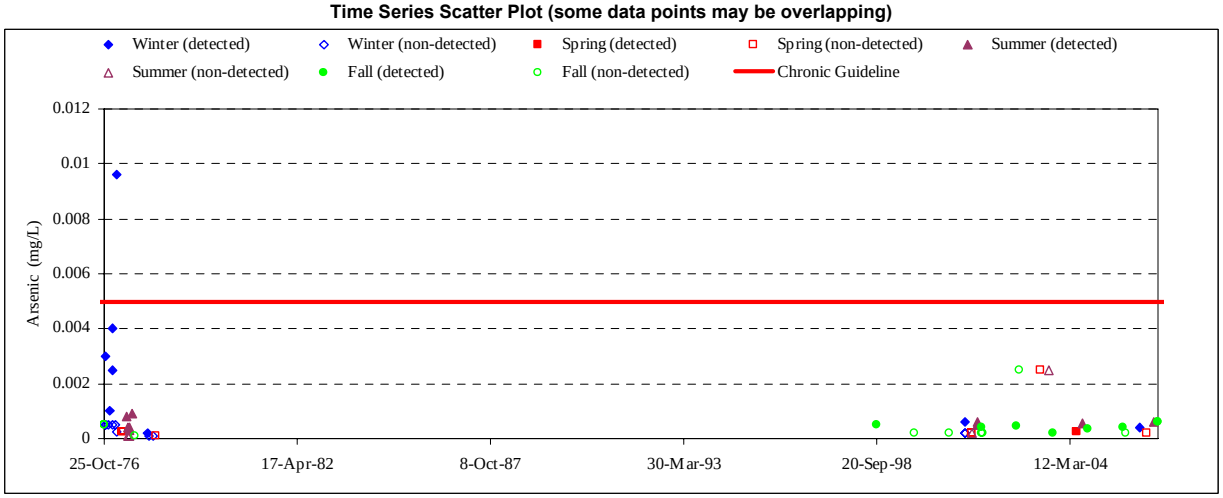
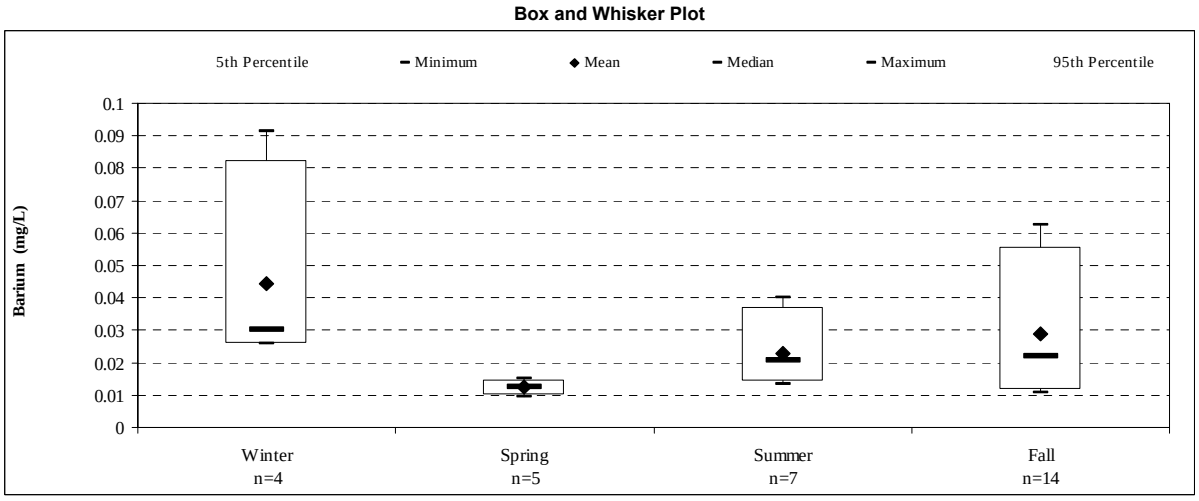


Figure G-2-7-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Muskeg Creek



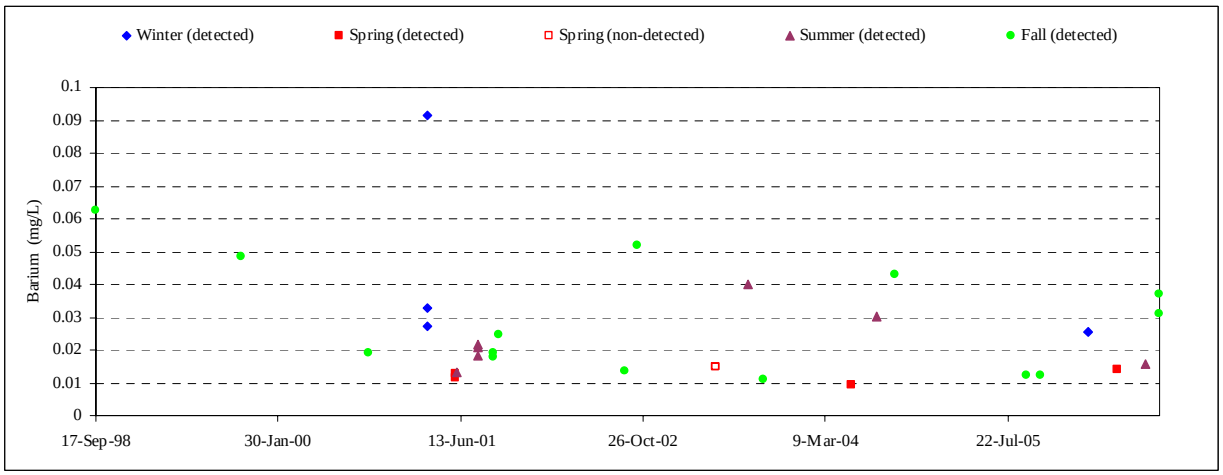
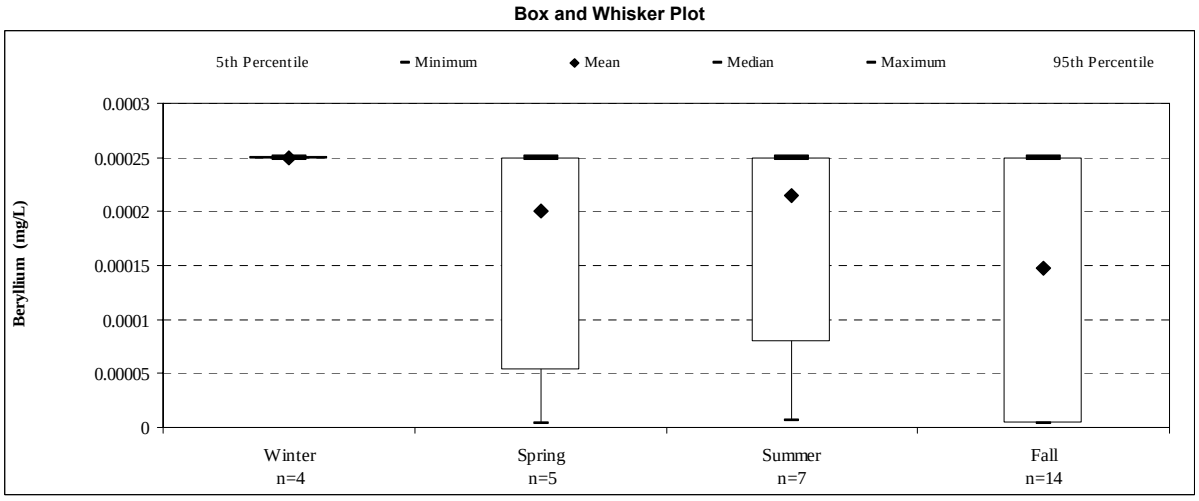


Figure G-2-7-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Muskeg Creek



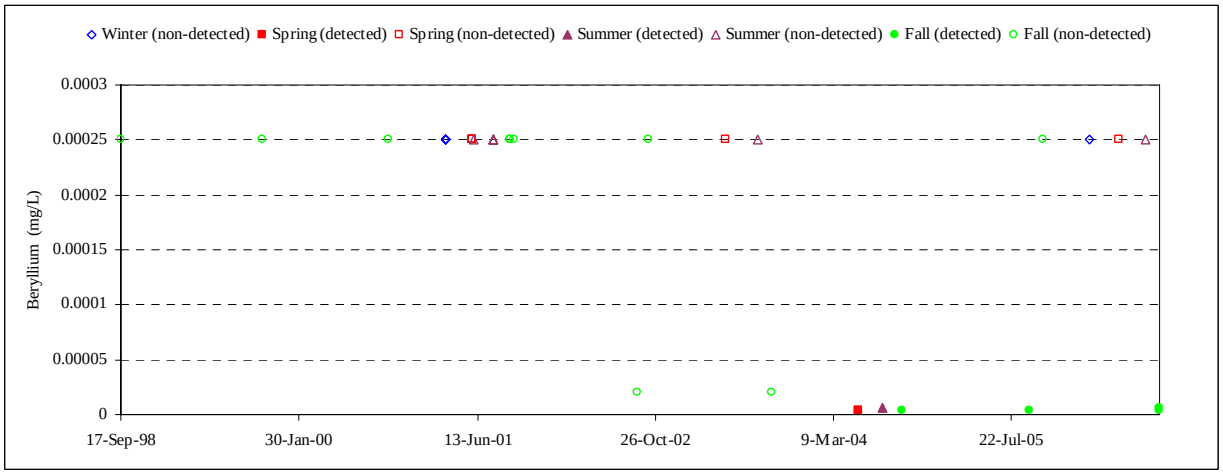
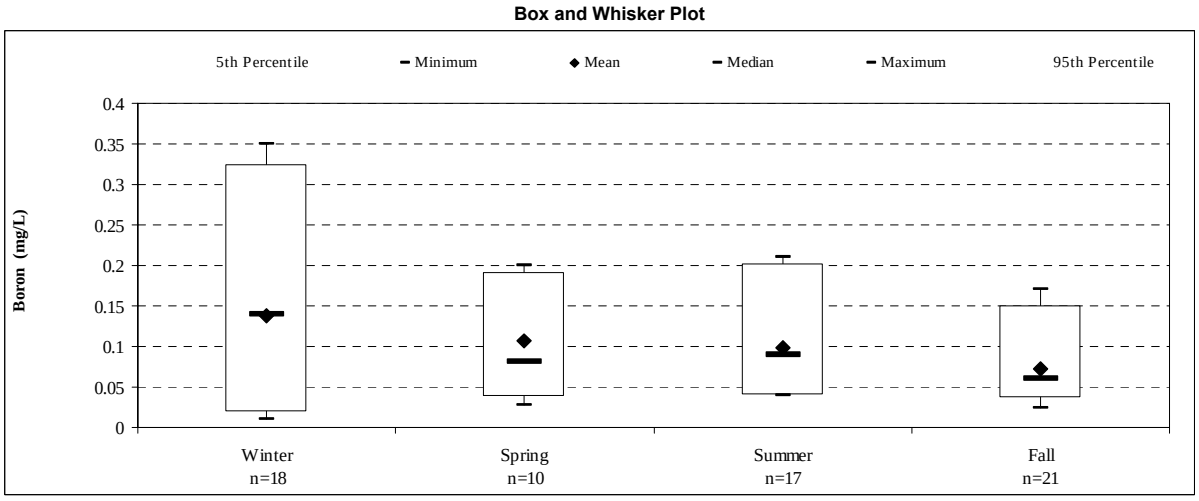


Figure G-2-7-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Muskeg Creek



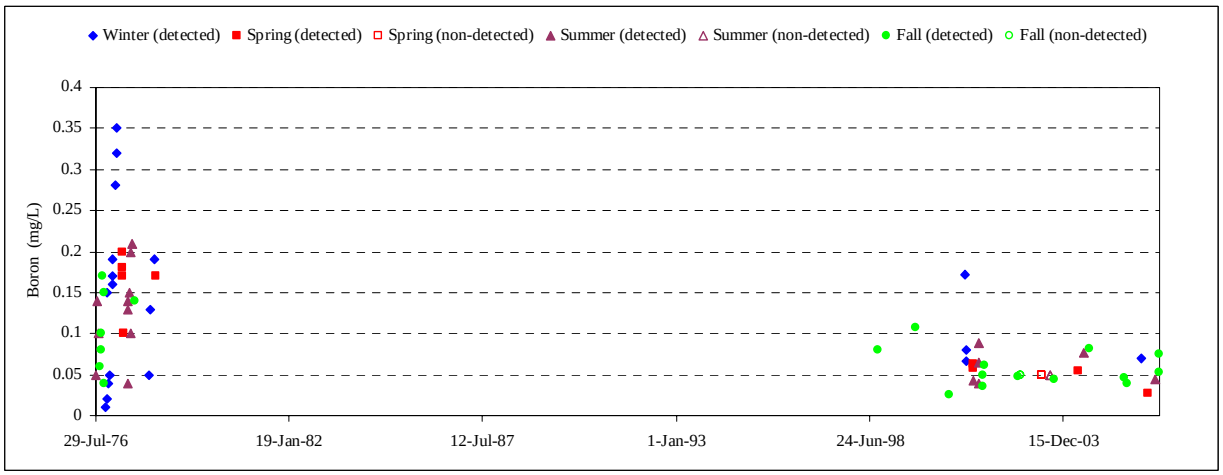
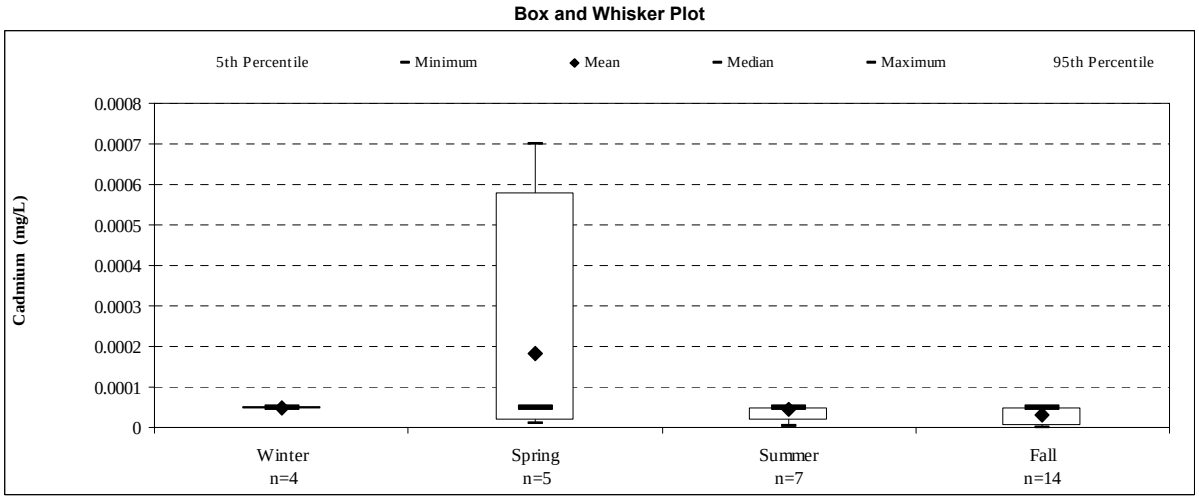


Figure G-2-7-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Muskeg Creek



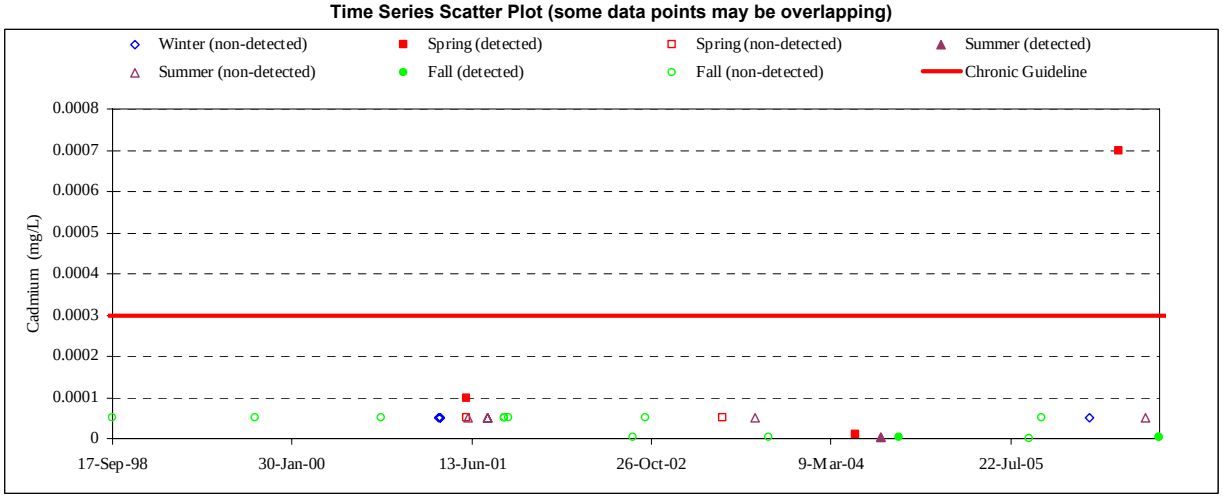
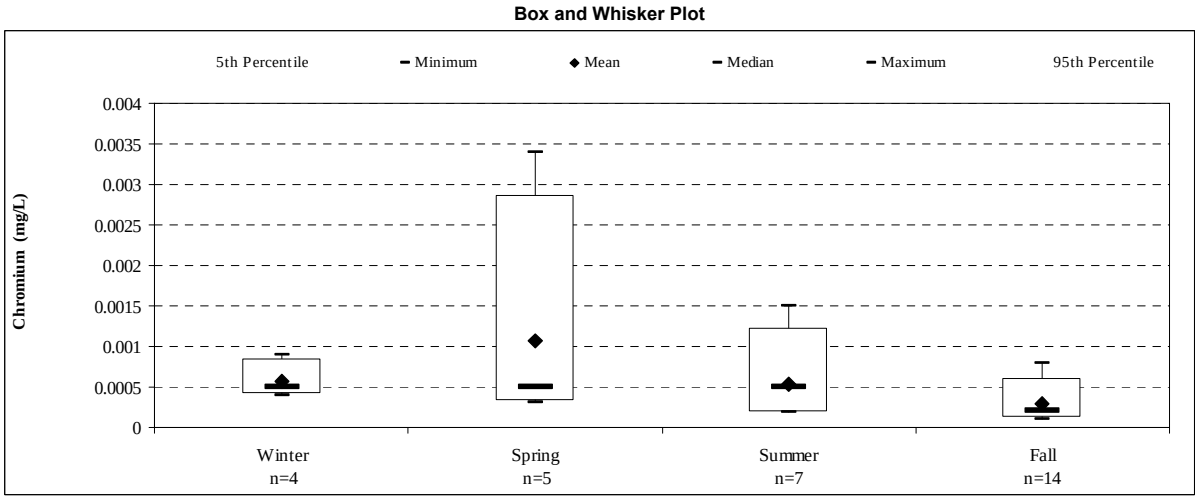


Figure G-2-7-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Muskeg Creek



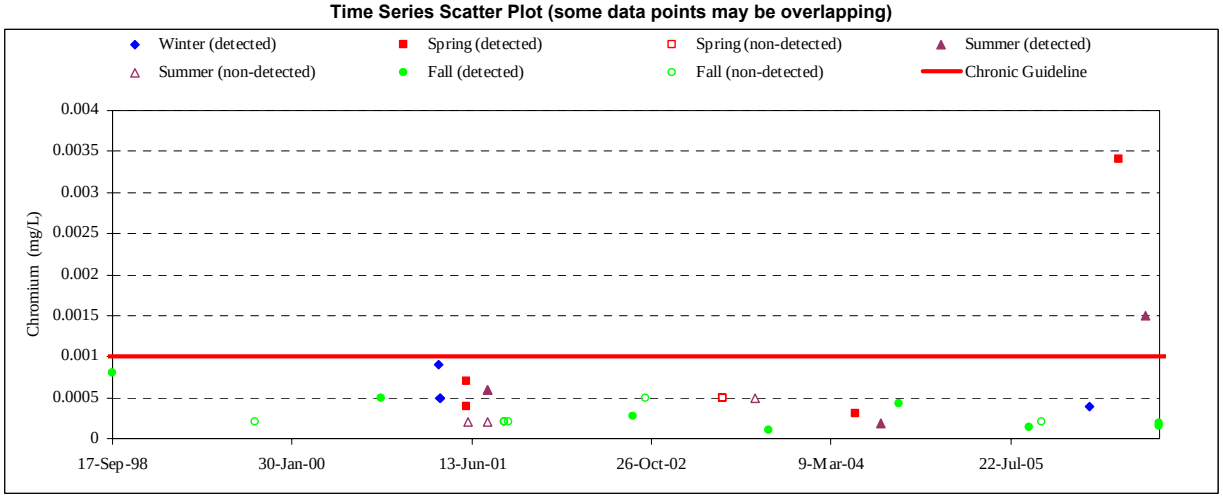
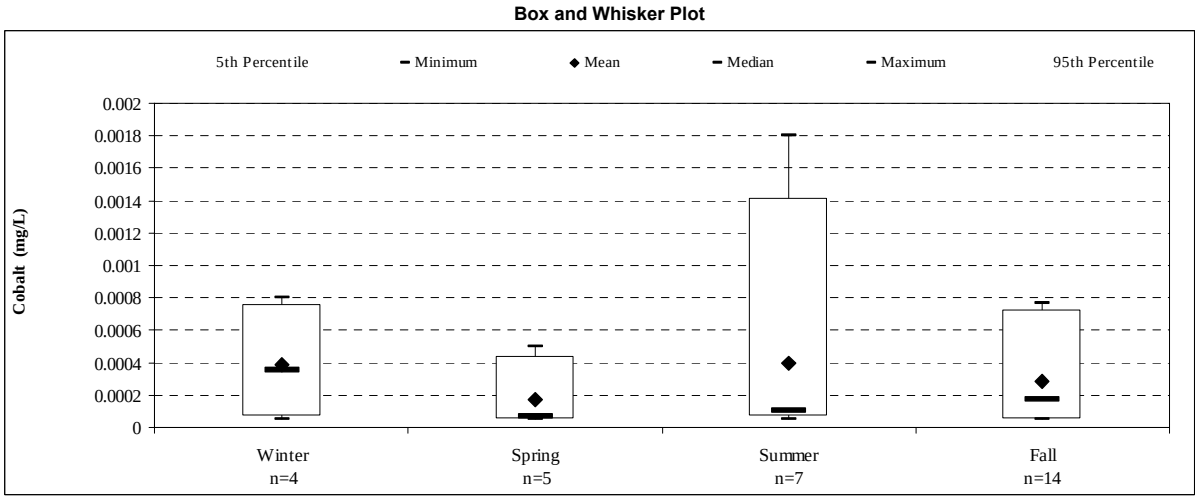


Figure G-2-7-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Muskeg Creek



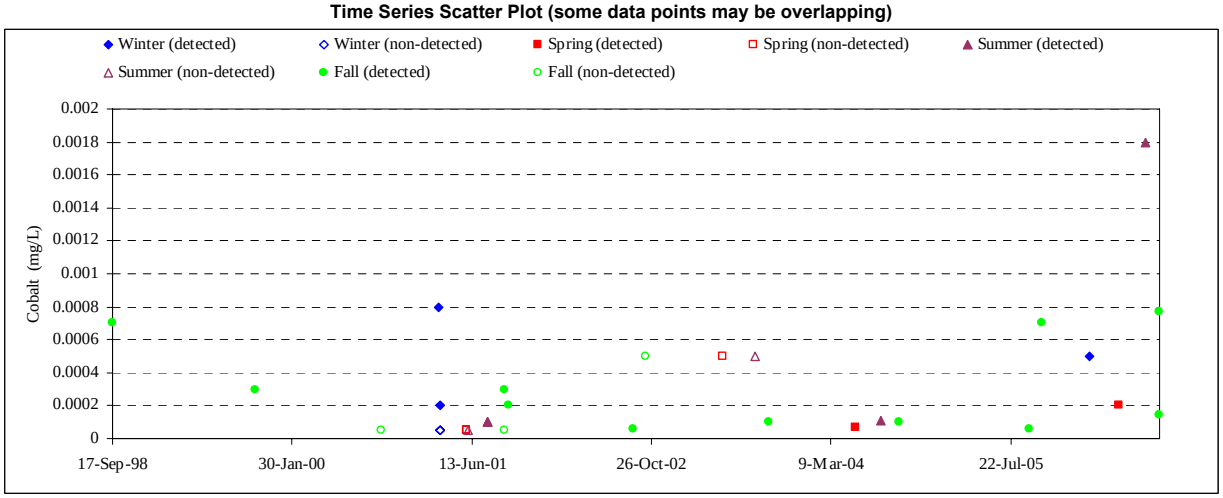
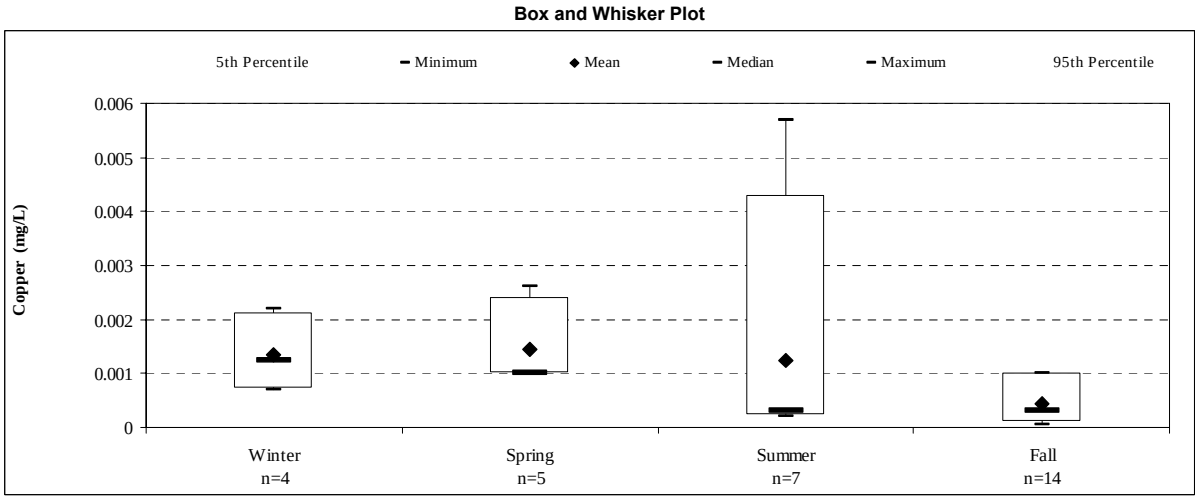


Figure G-2-7-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Muskeg Creek



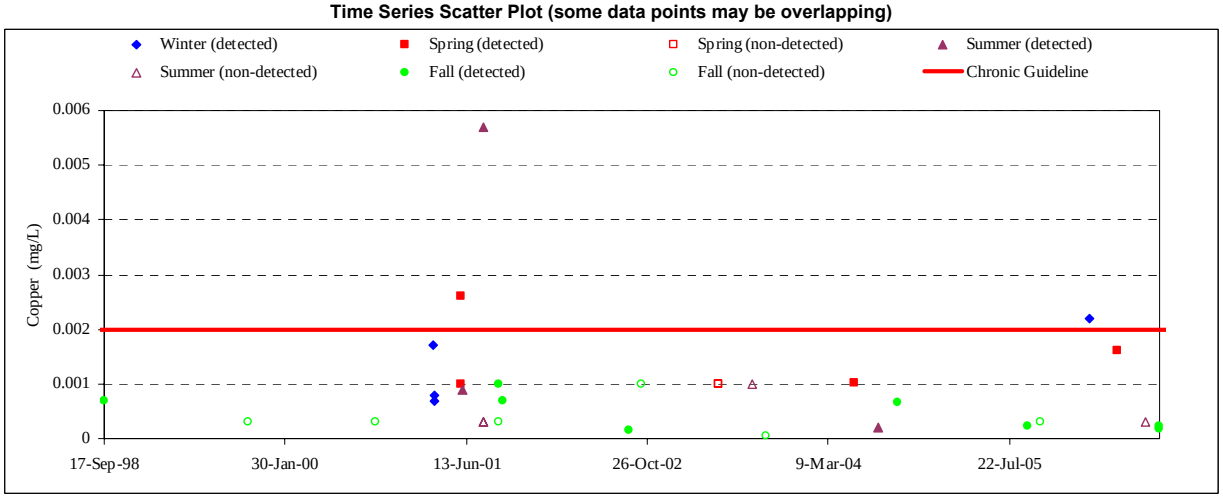
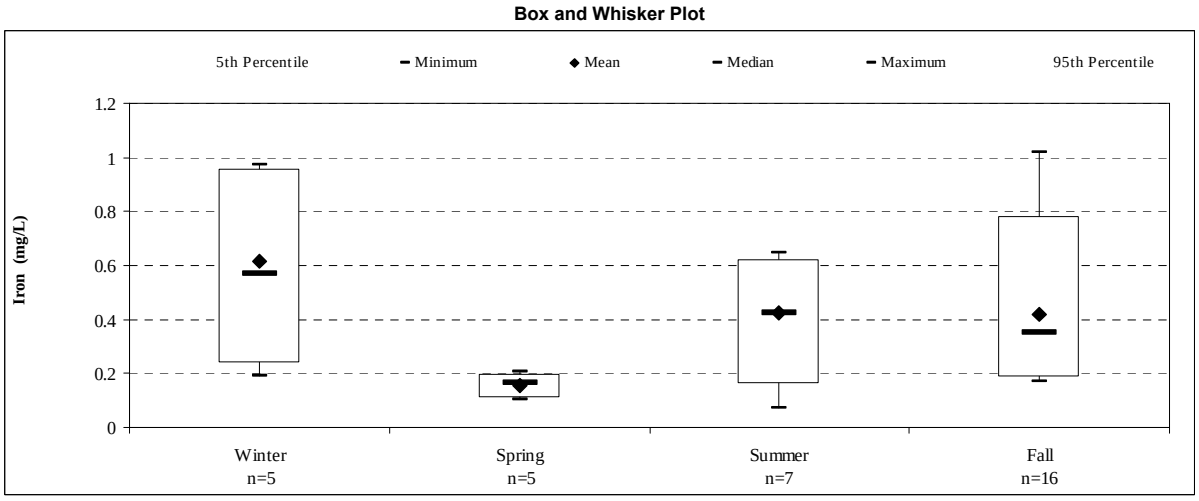


Figure G-2-7-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Muskeg Creek



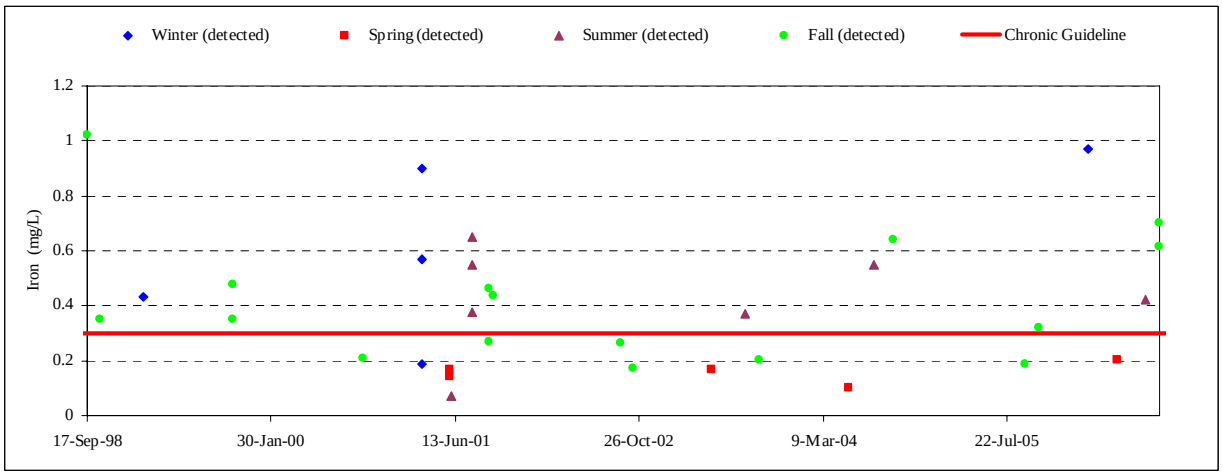
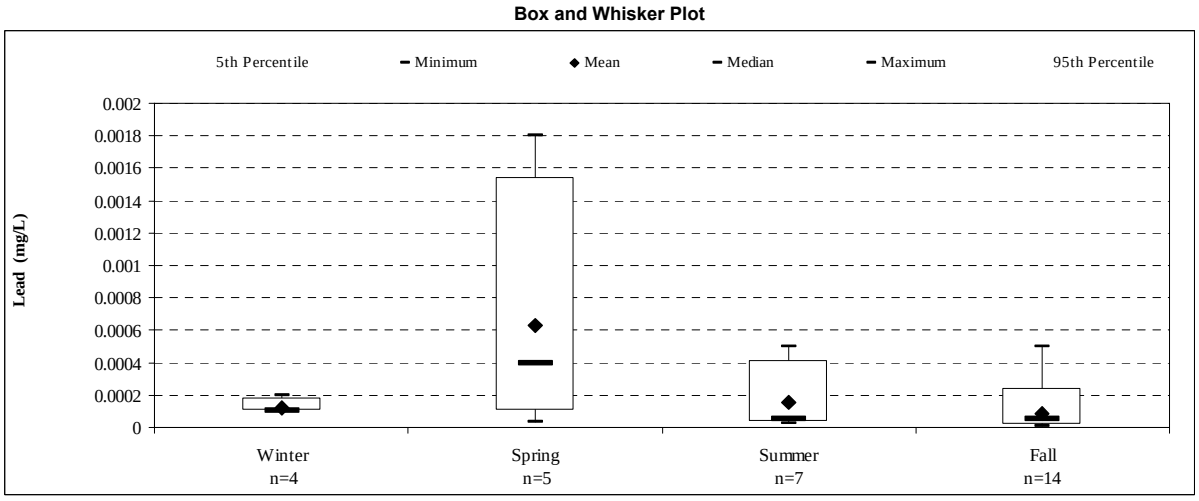


Figure G-2-7-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Muskeg Creek



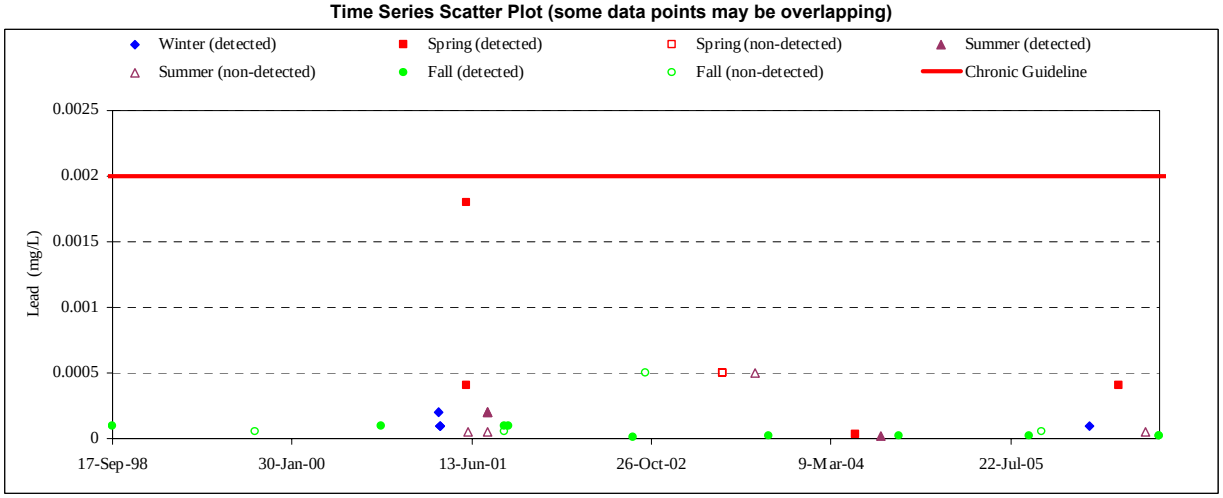
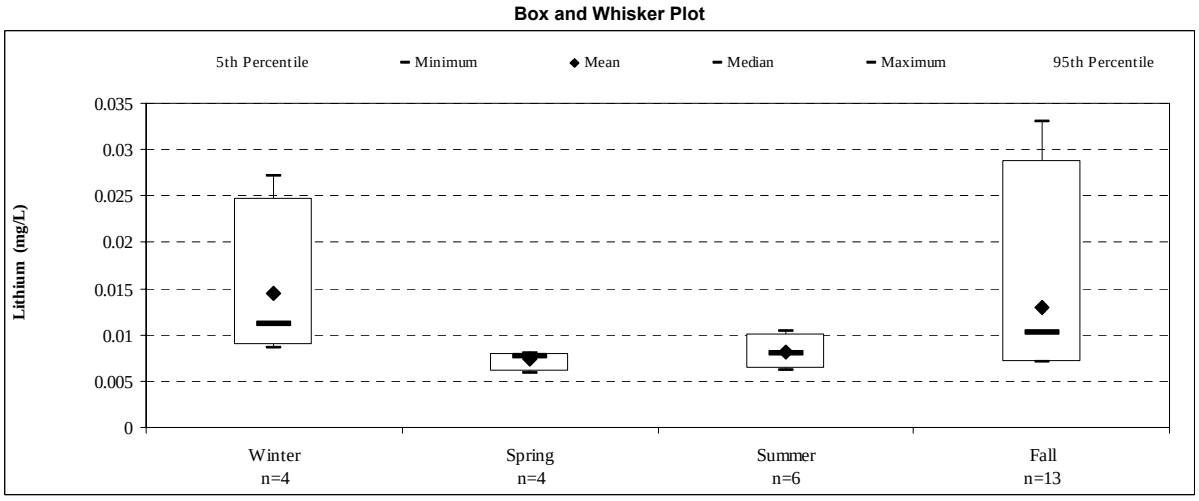


Figure G-2-7-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Muskeg Creek



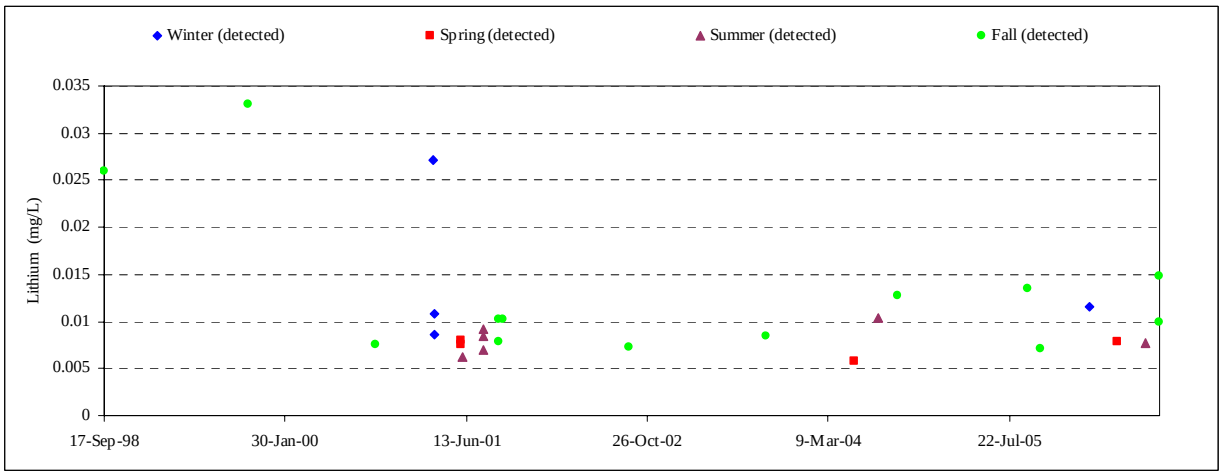
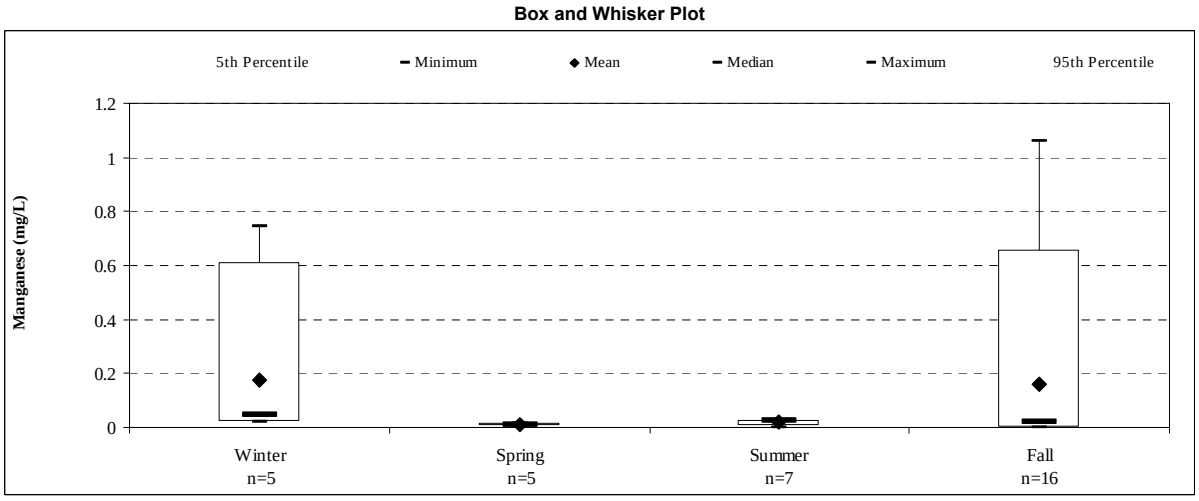


Figure G-2-7-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Muskeg Creek



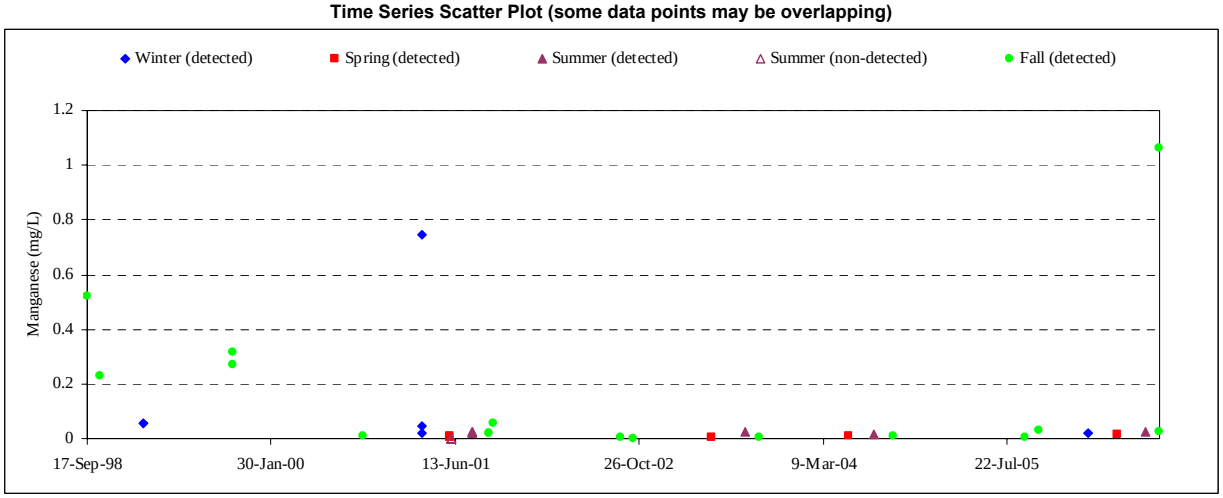
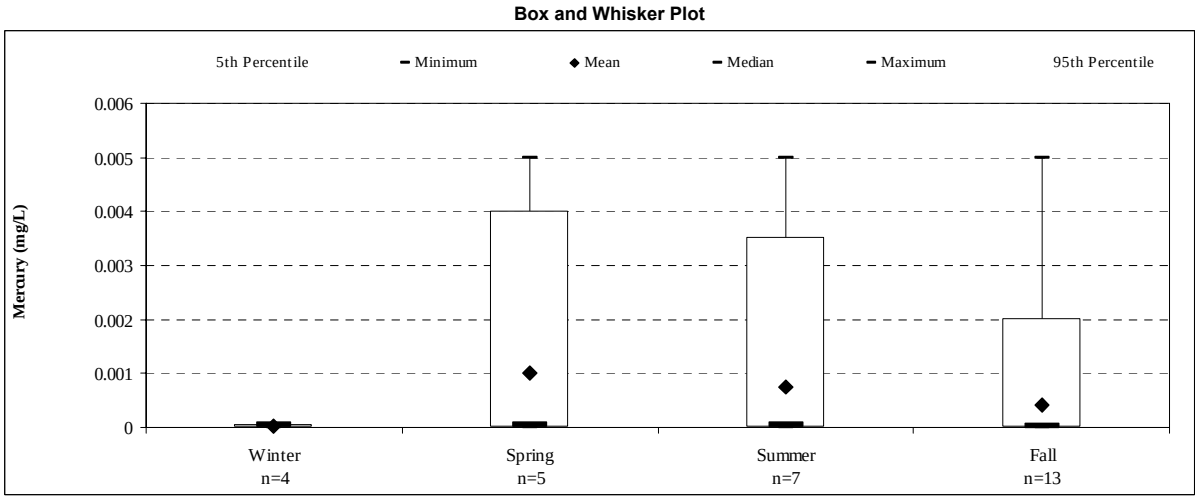


Figure G-2-7-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Muskeg Creek



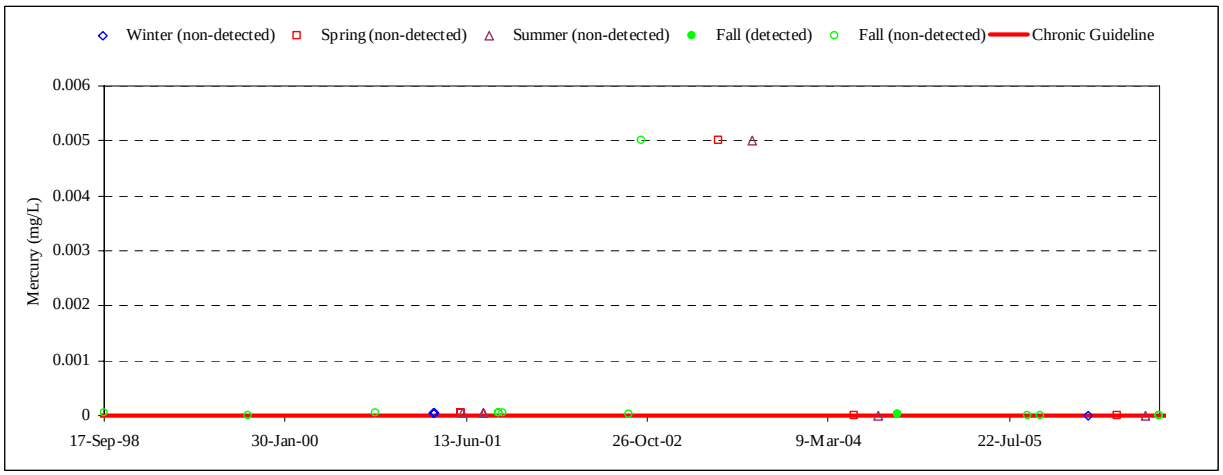
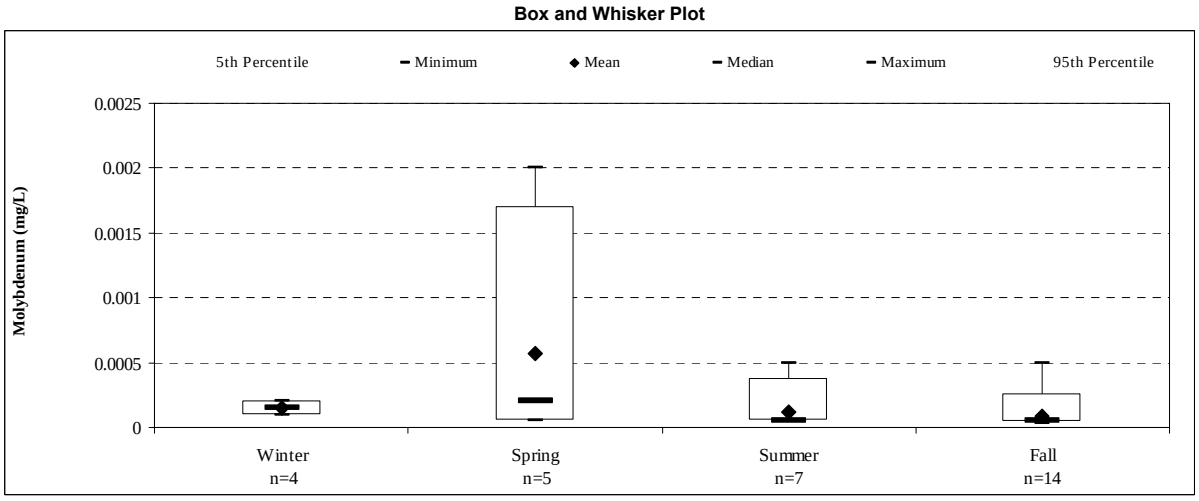


Figure G-2-7-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Muskeg Creek



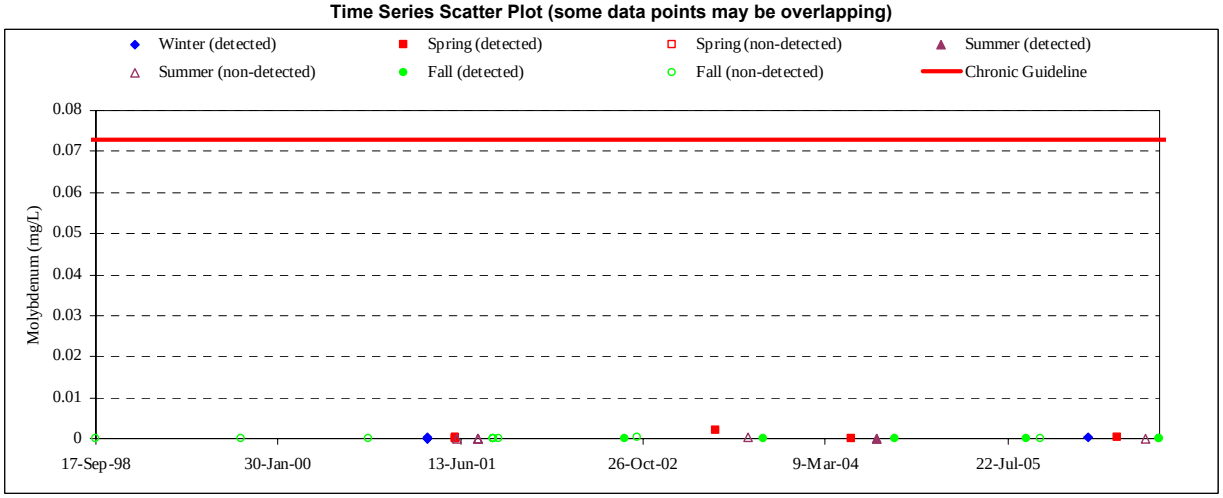
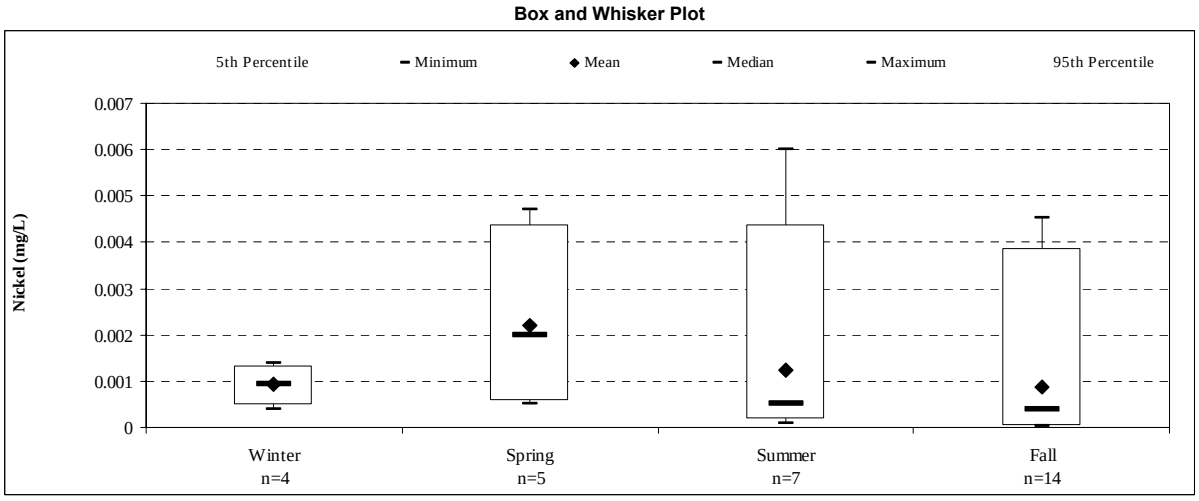


Figure G-2-7-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Muskeg Creek



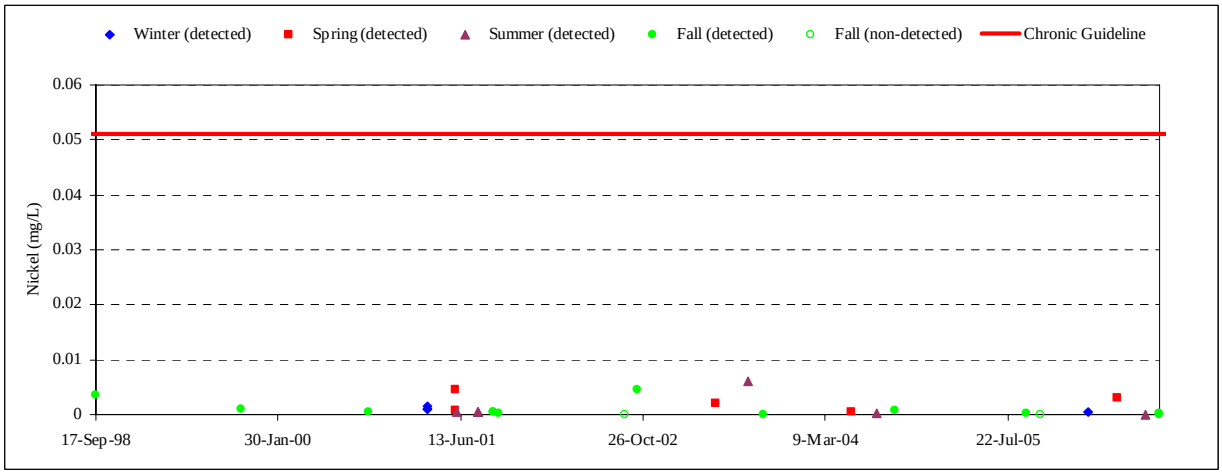
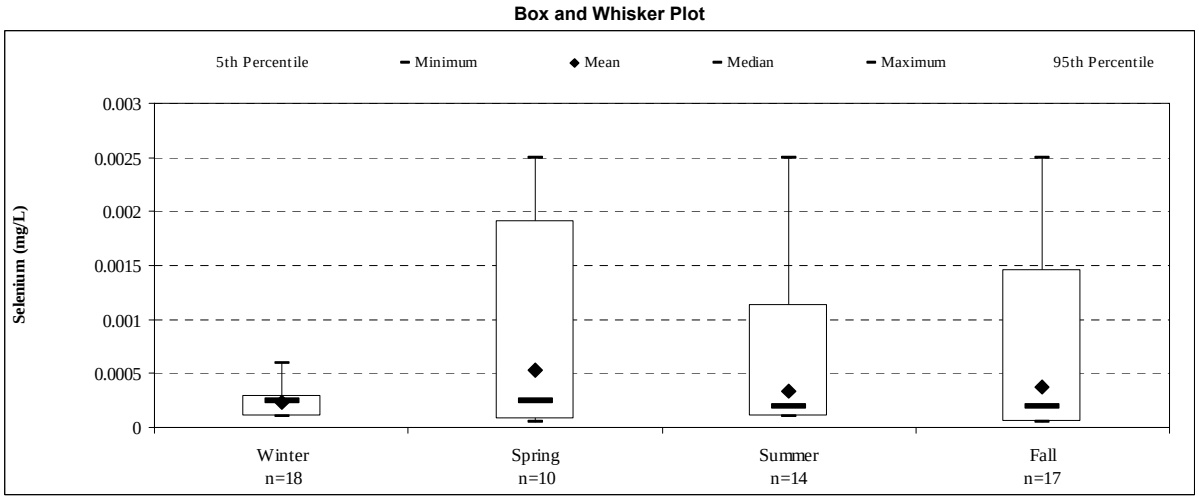


Figure G-2-7-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Muskeg Creek



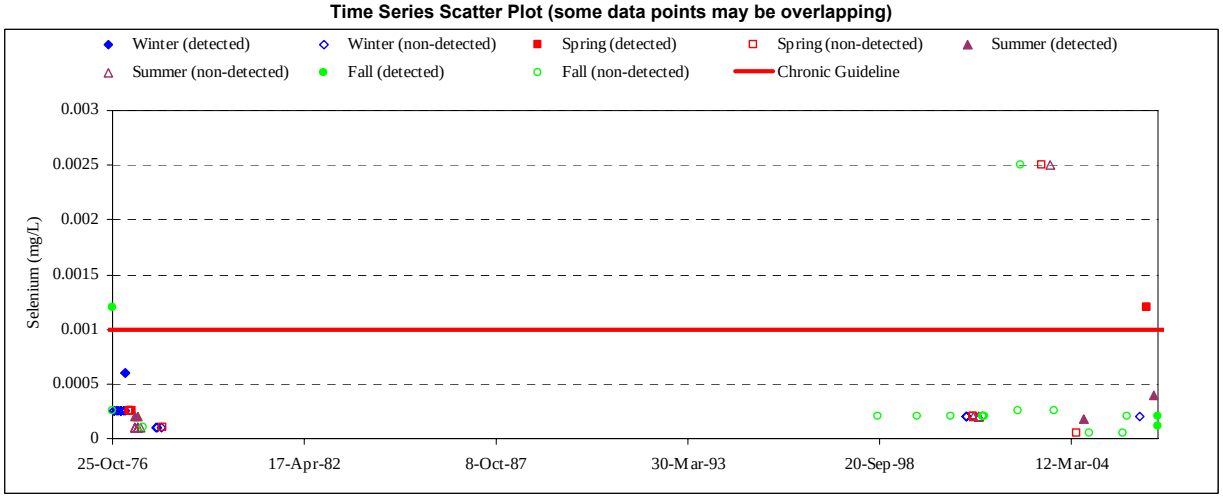
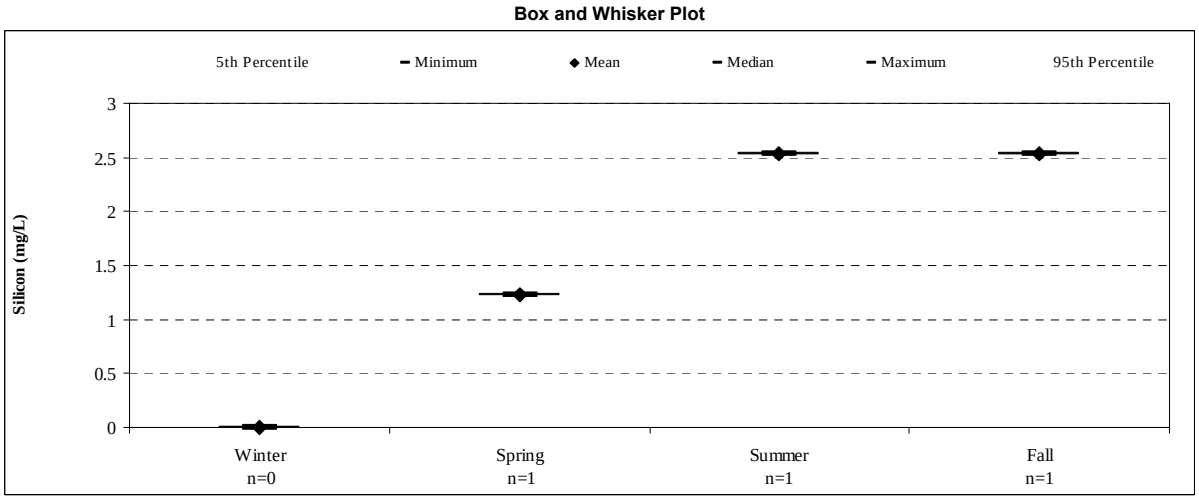


Figure G-2-7-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Muskeg Creek



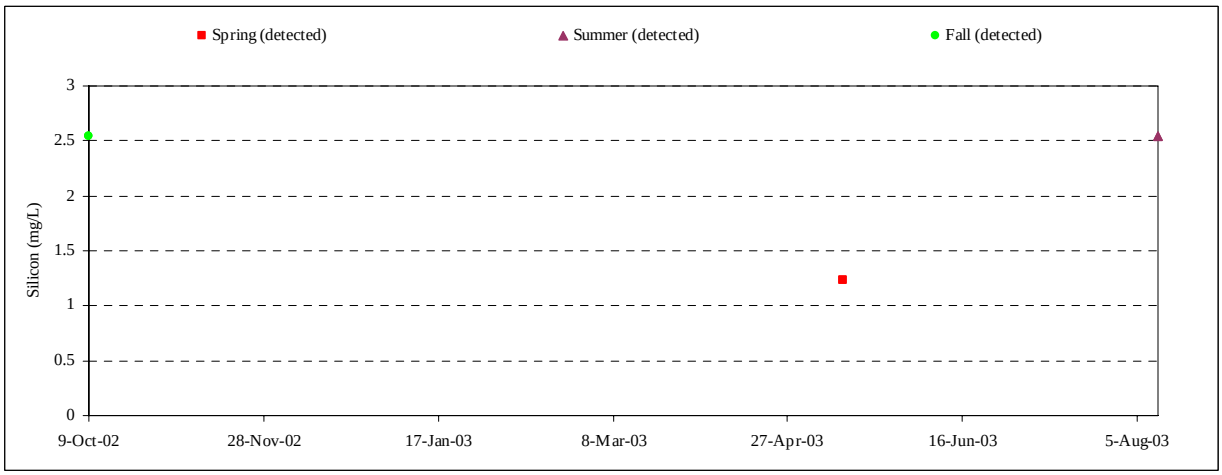
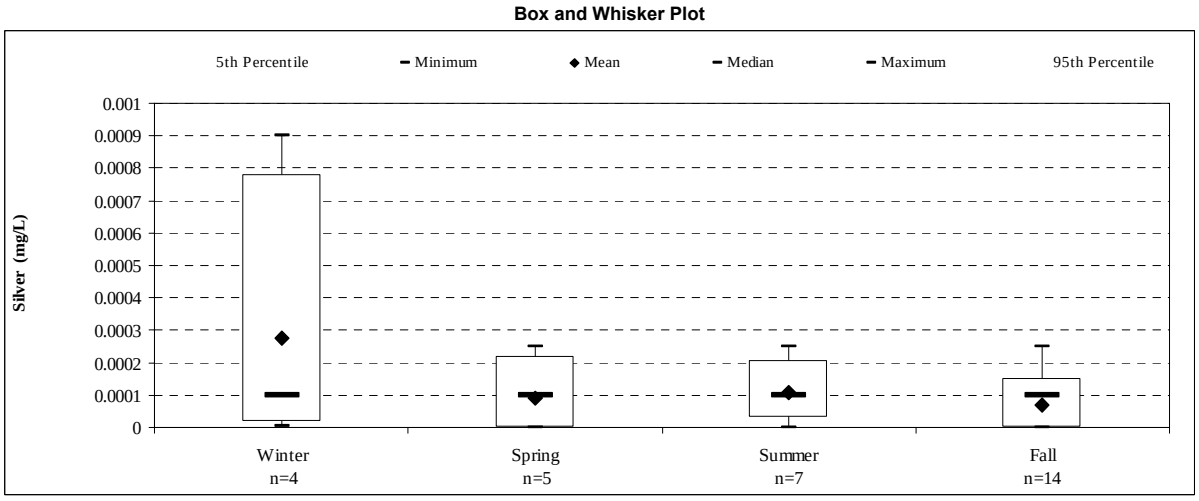


Figure G-2-7-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Muskeg Creek



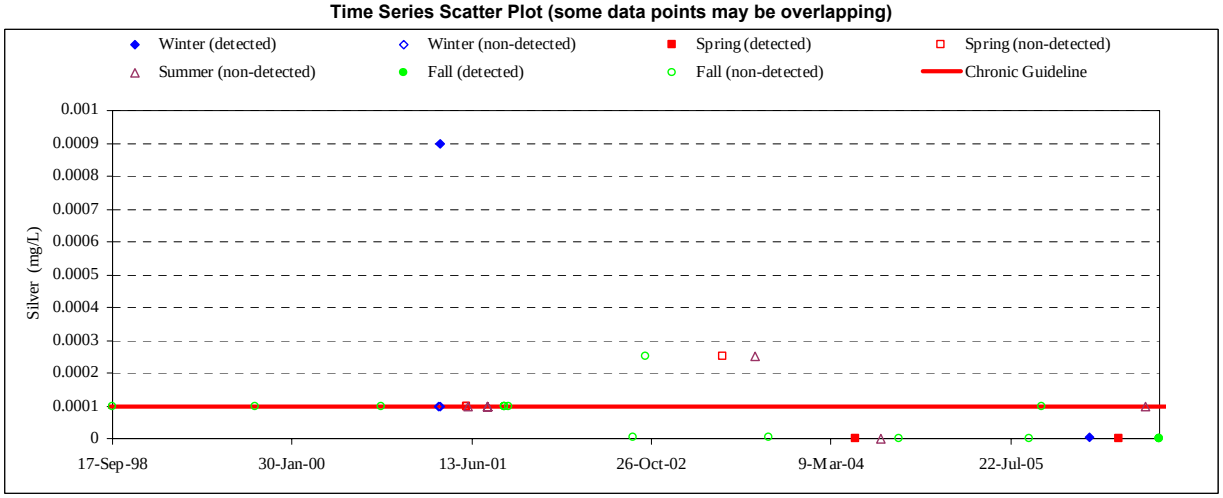
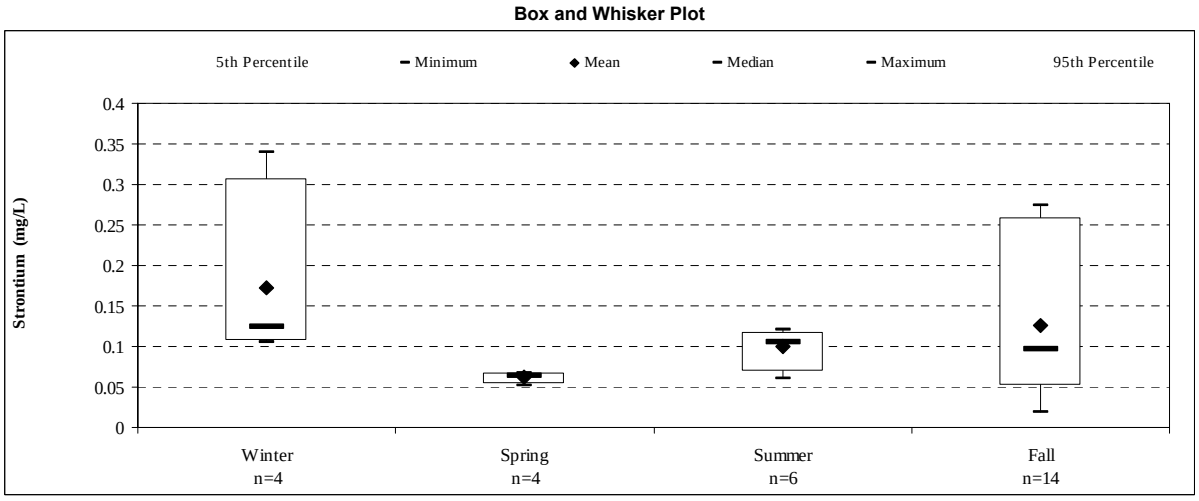


Figure G-2-7-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Muskeg Creek



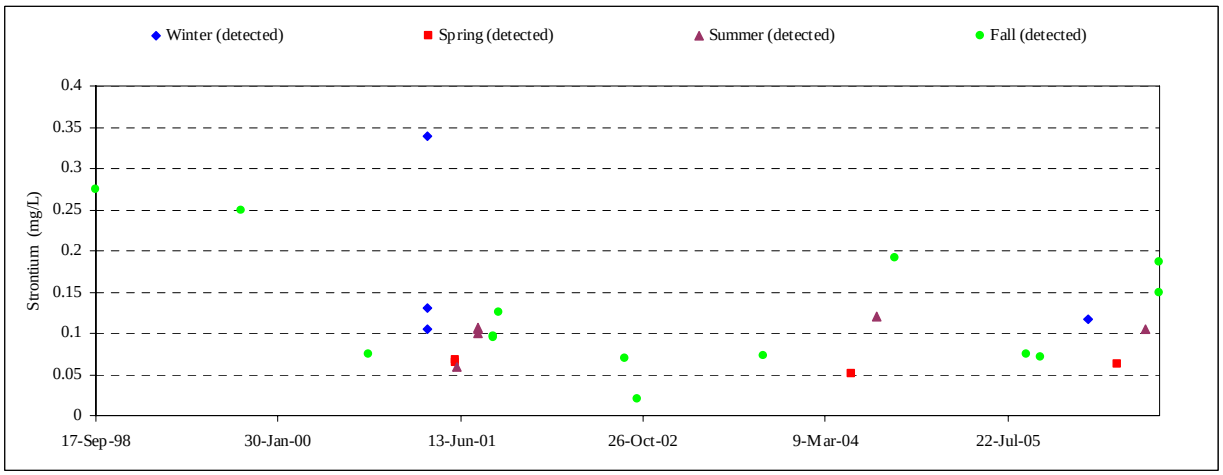
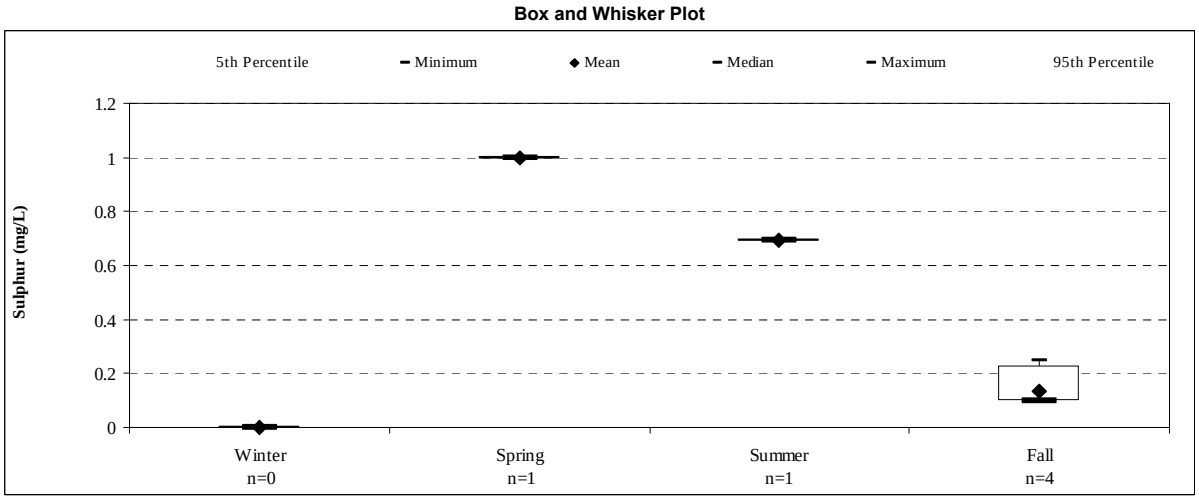


Figure G-2-7-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Muskeg Creek



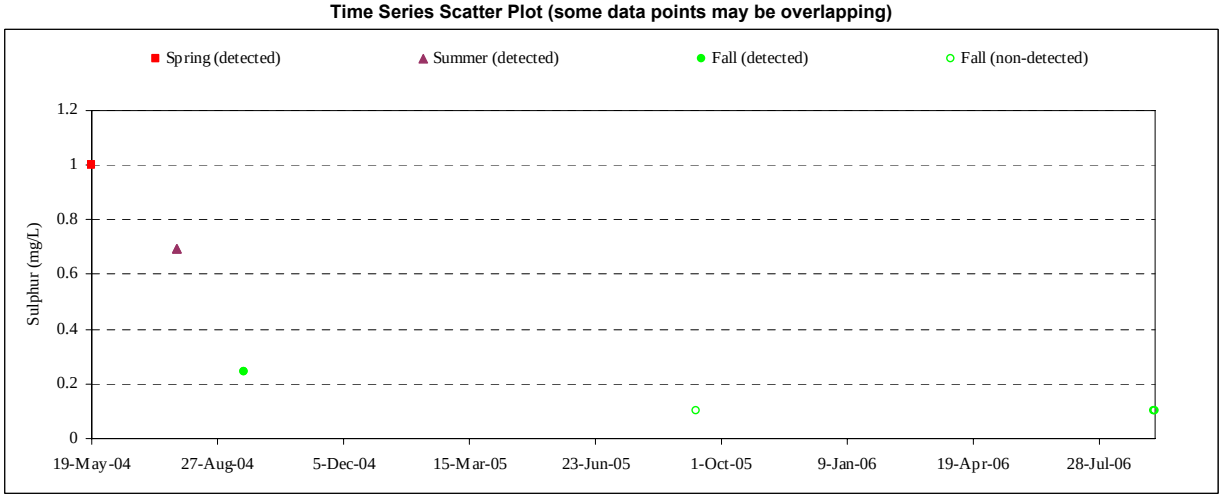
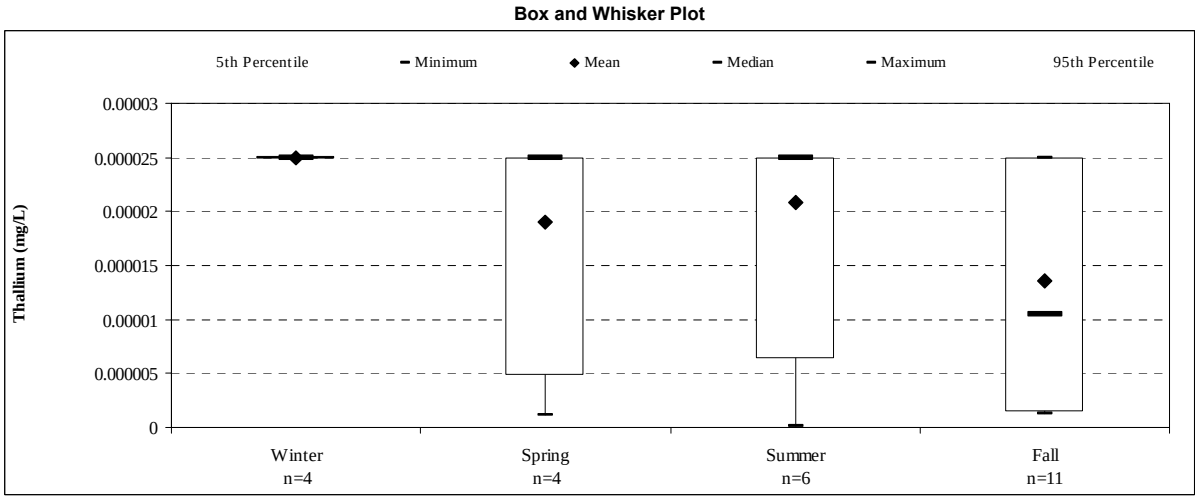


Figure G-2-7-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Muskeg Creek



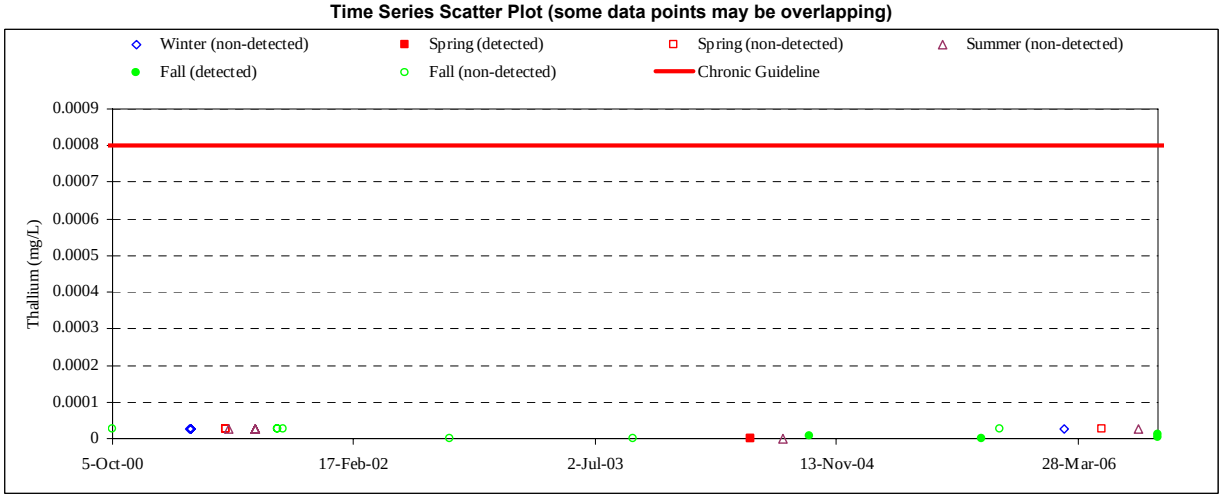
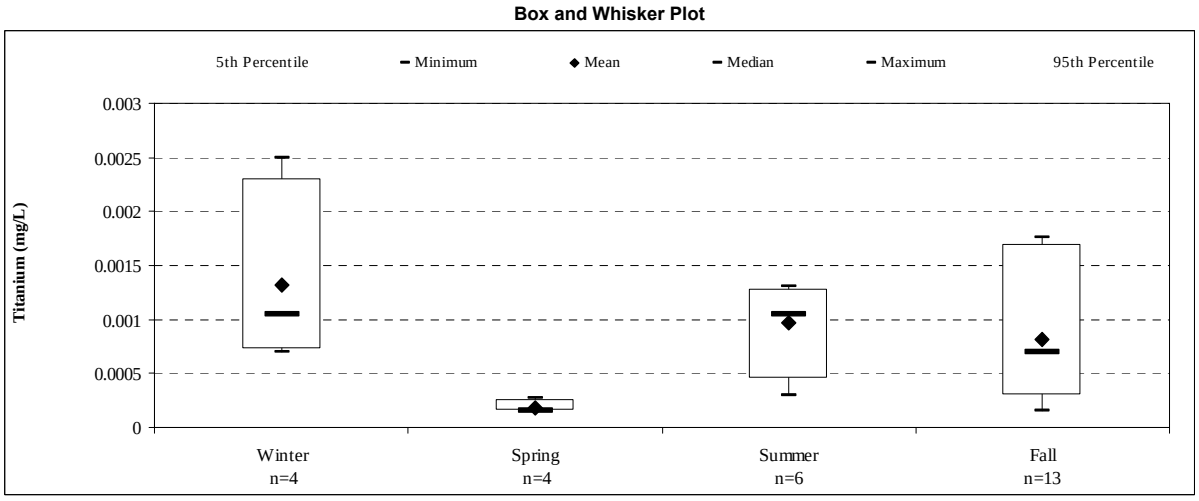


Figure G-2-7-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Muskeg Creek



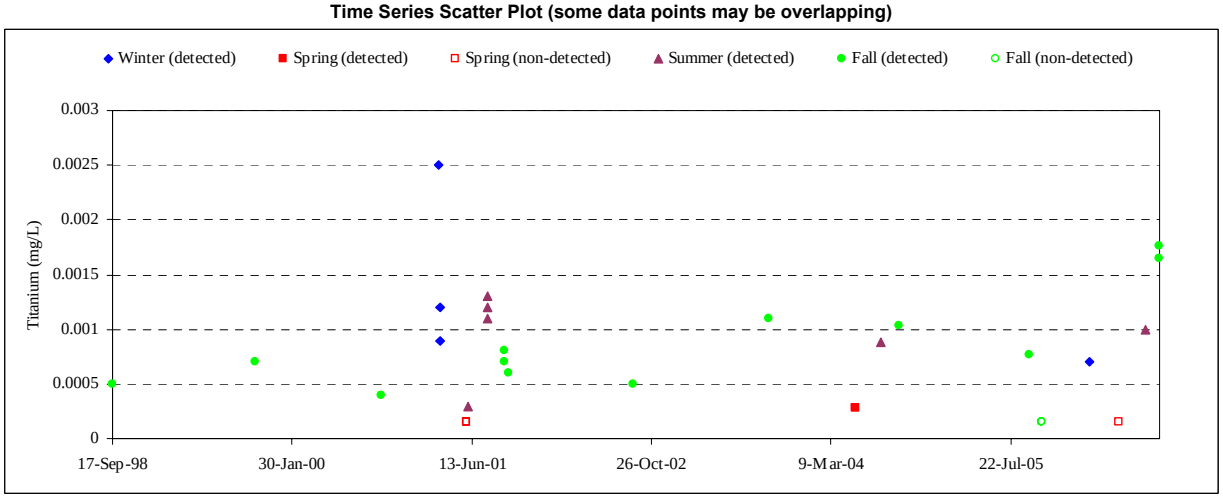
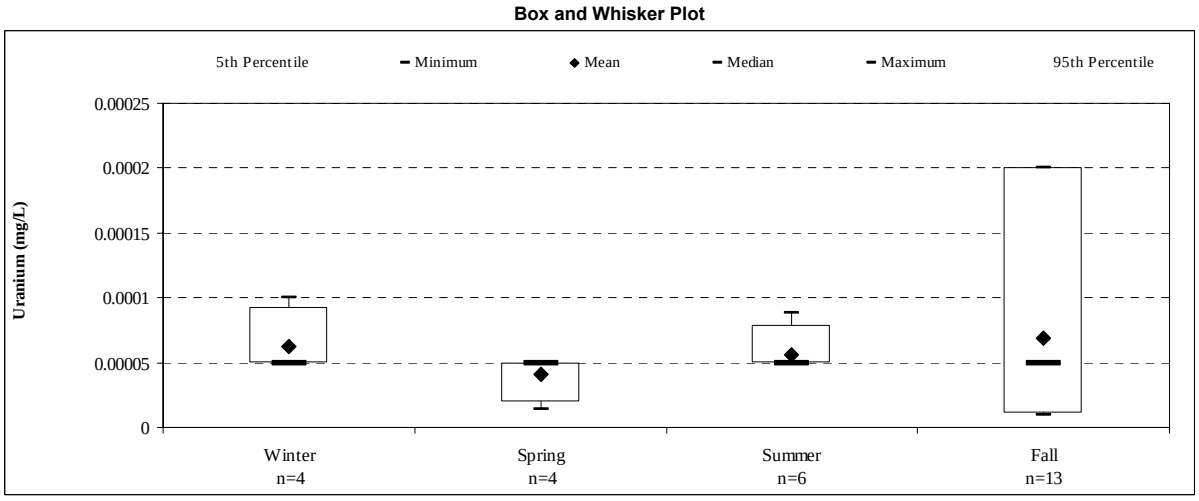


Figure G-2-7-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Muskeg Creek



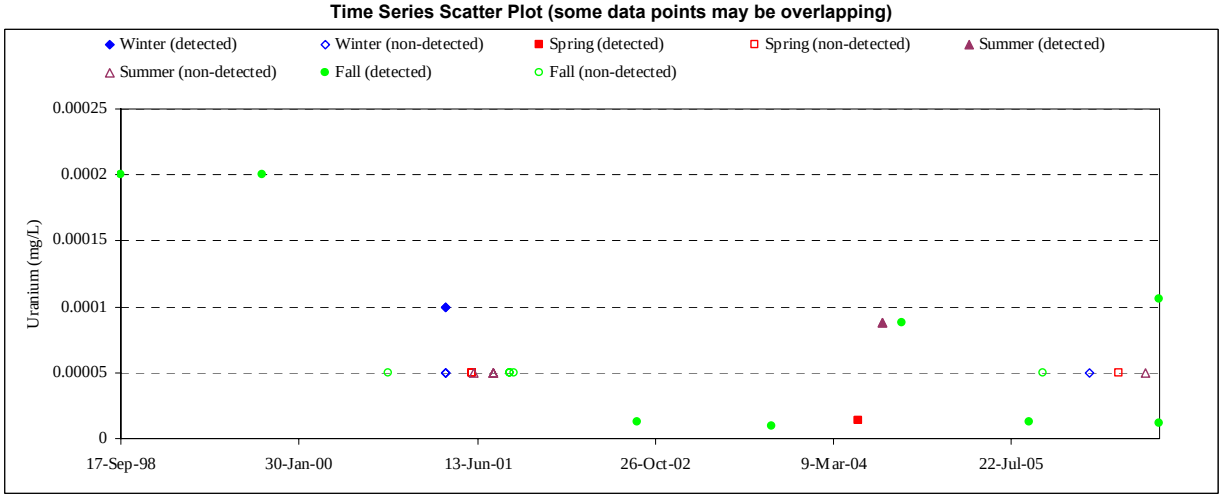
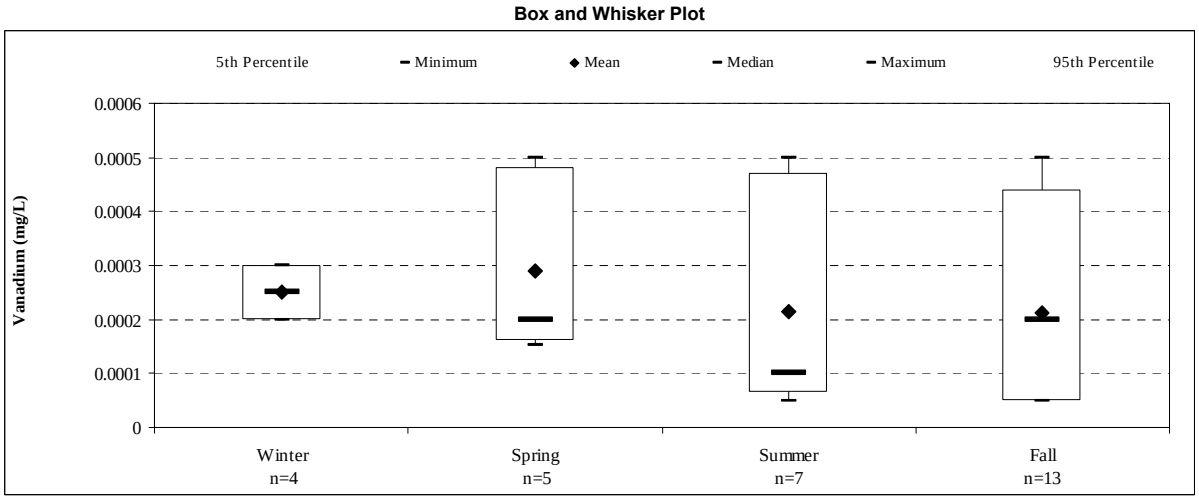


Figure G-2-7-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Muskeg Creek



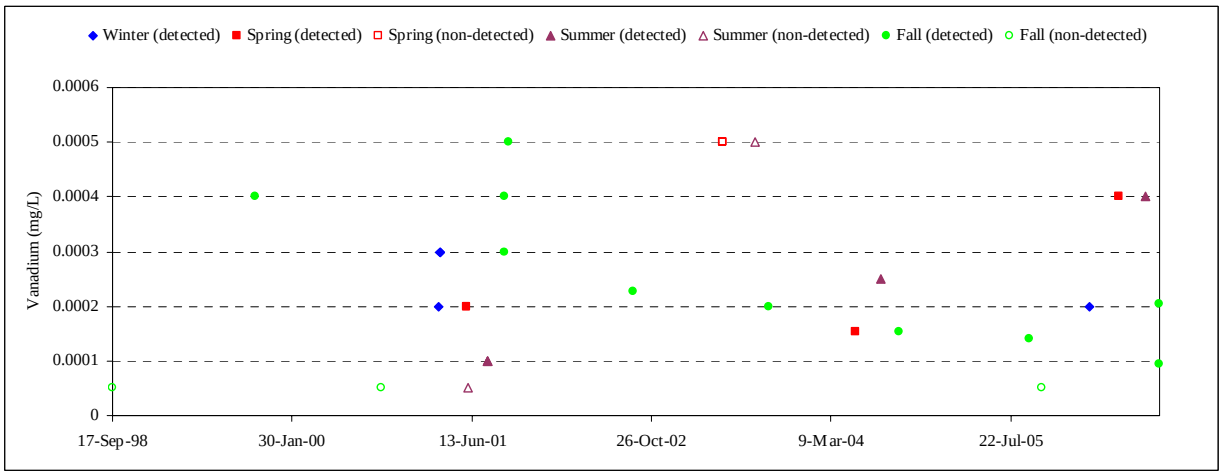


Figure G-2-7-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Muskeg Creek

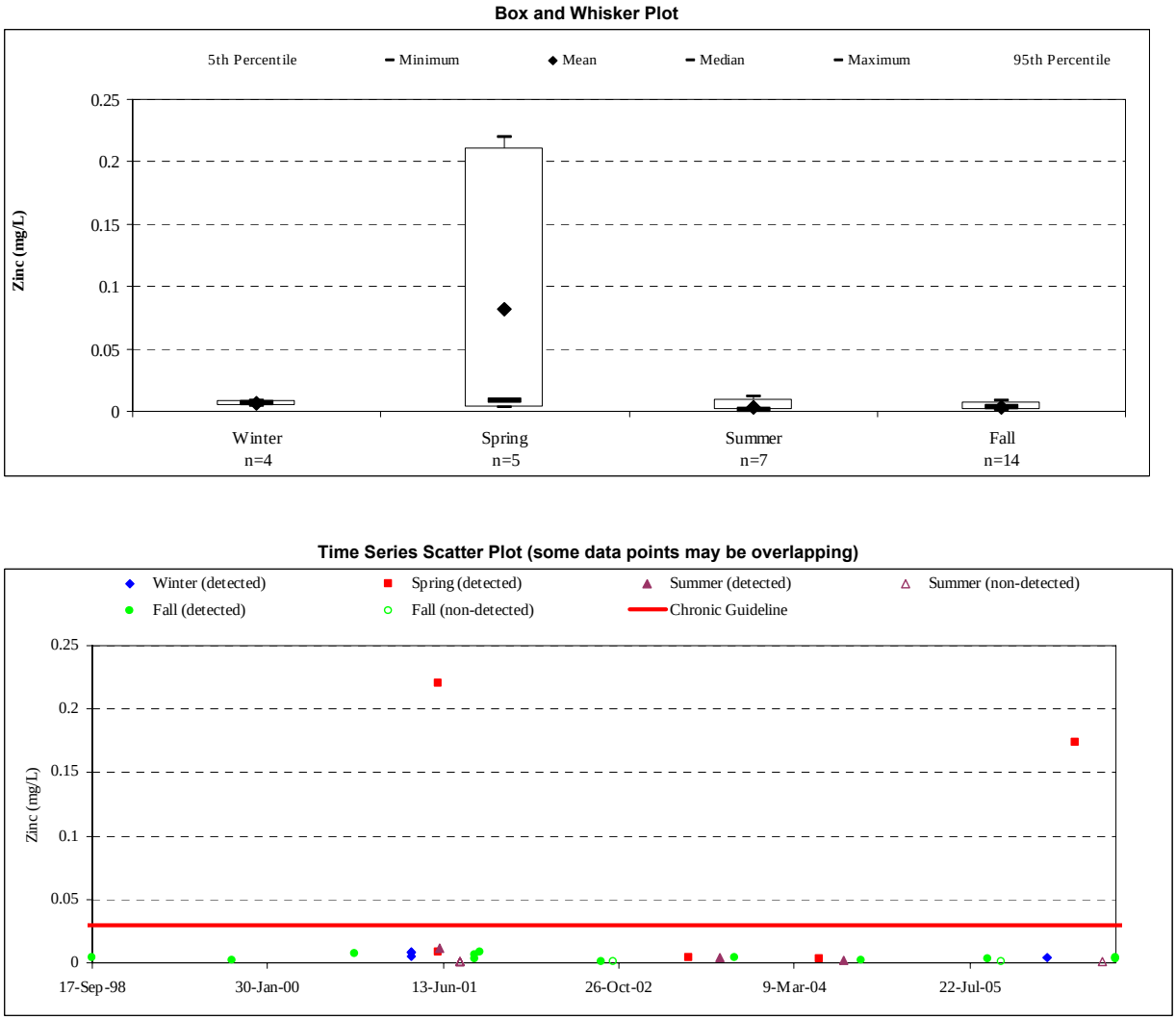
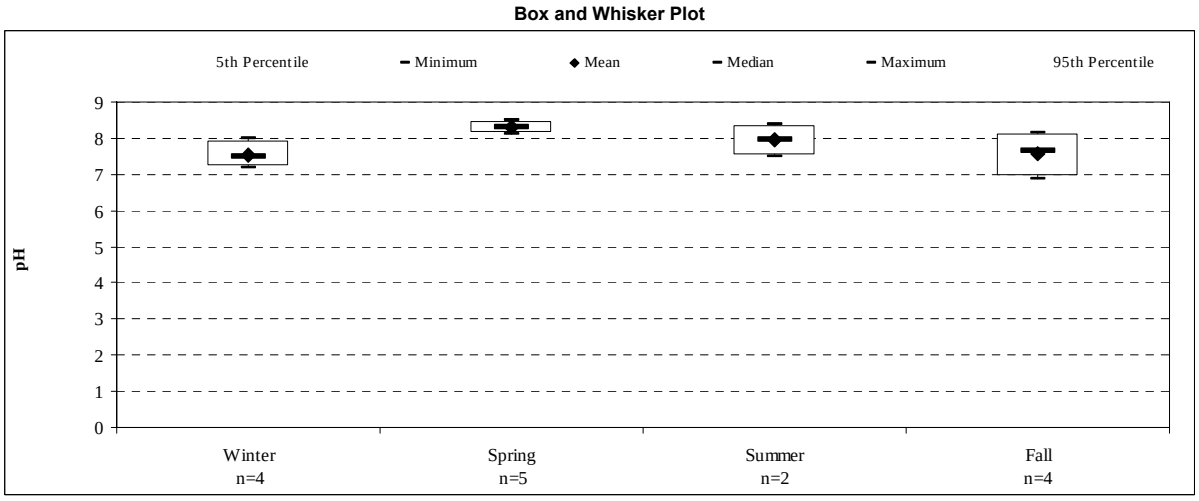


Figure G-2-8-1 Box Whisker and Time Series Scatter Plots of Observed pH in Kearl Lake



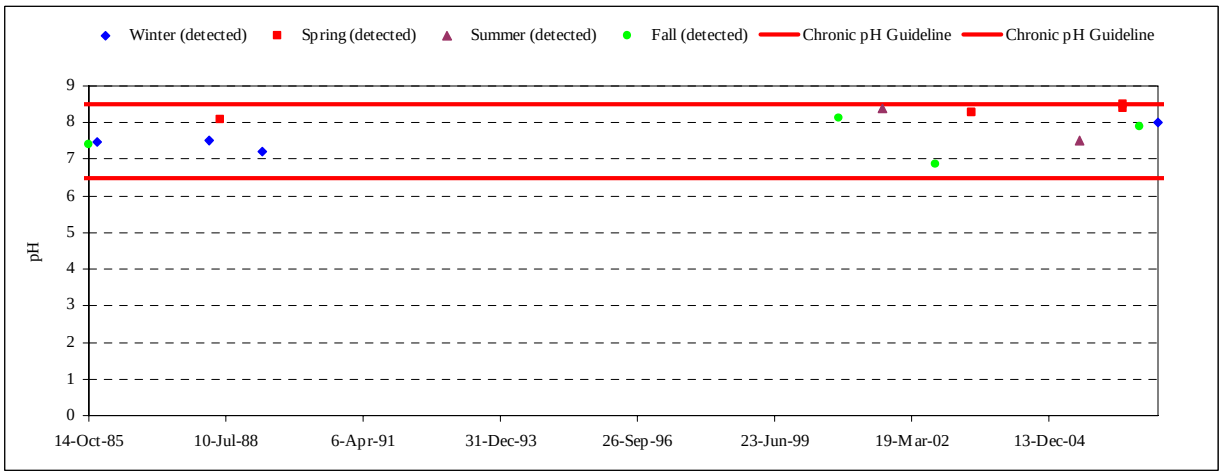
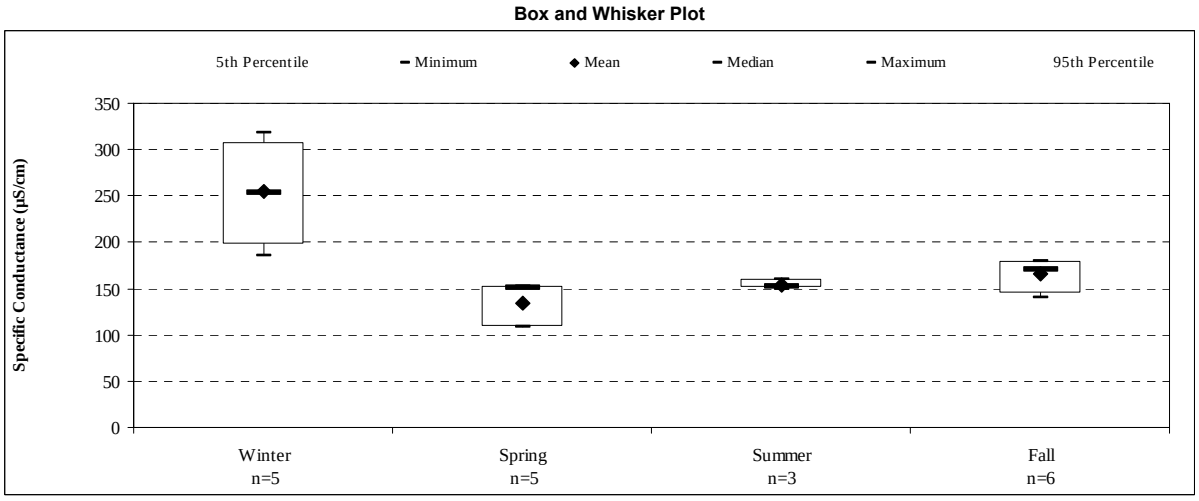


Figure G-2-8-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Kearl Lake



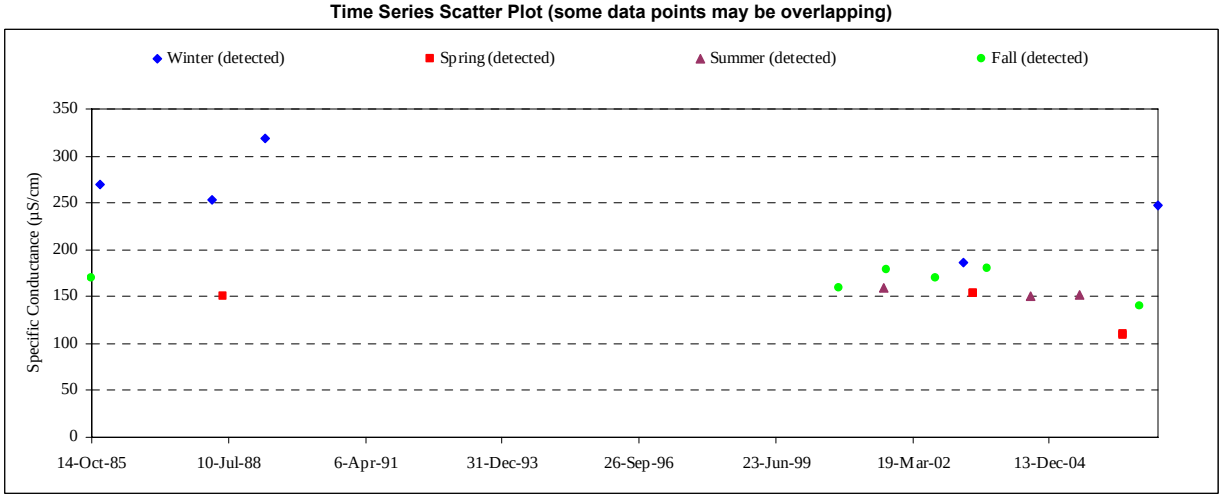
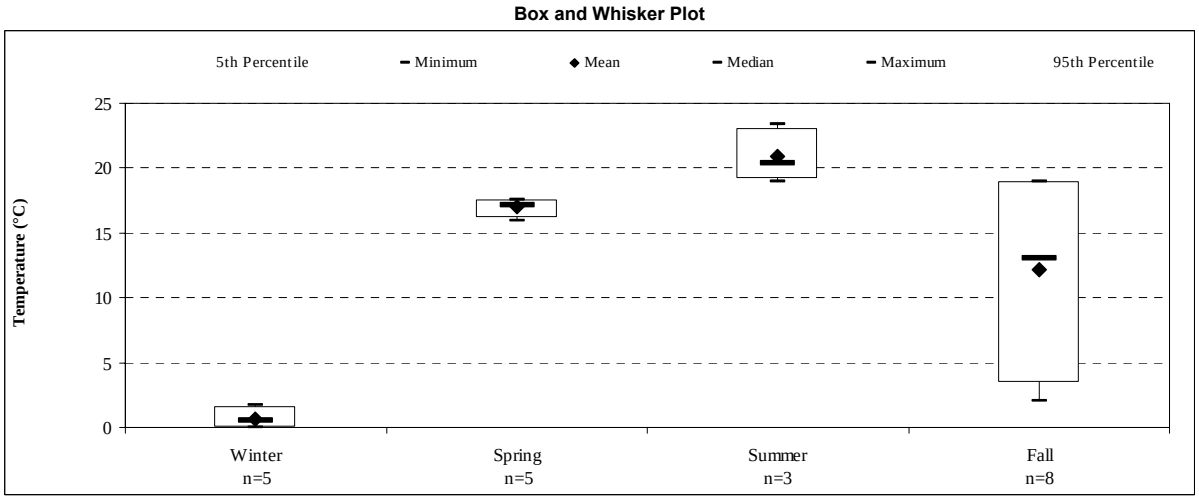


Figure G-2-8-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Kearl Lake



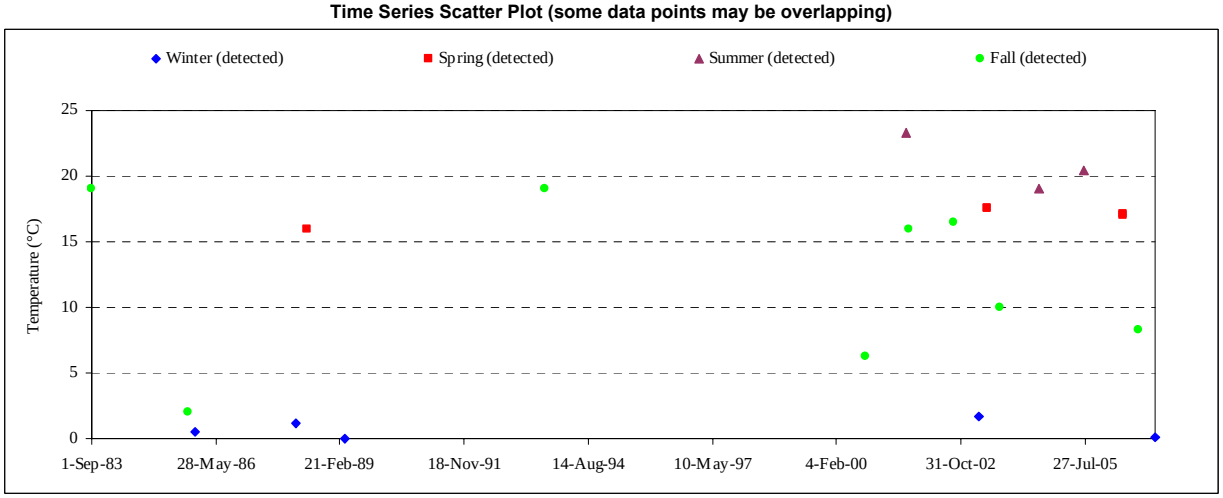
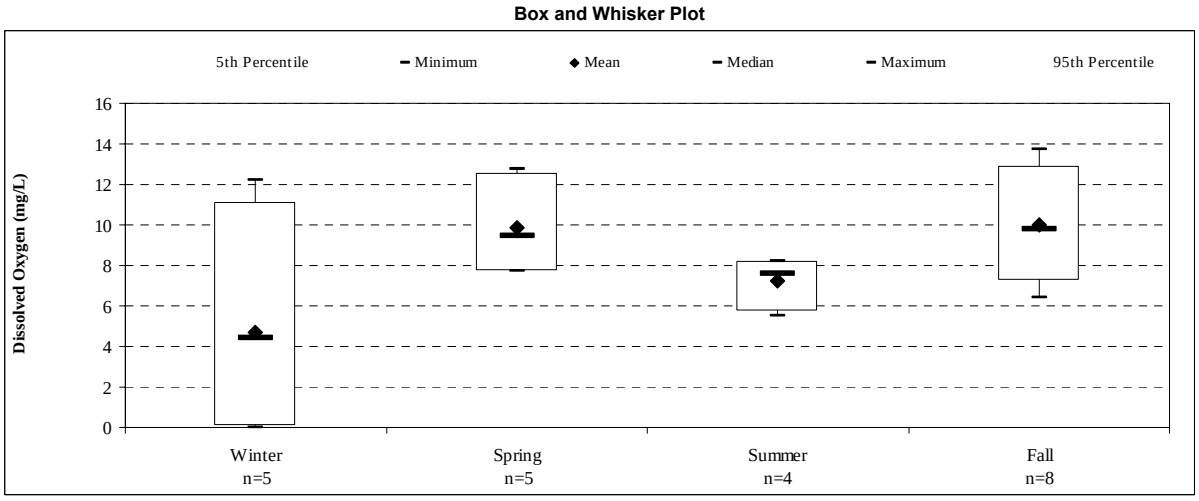


Figure G-2-8-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Kearl Lake



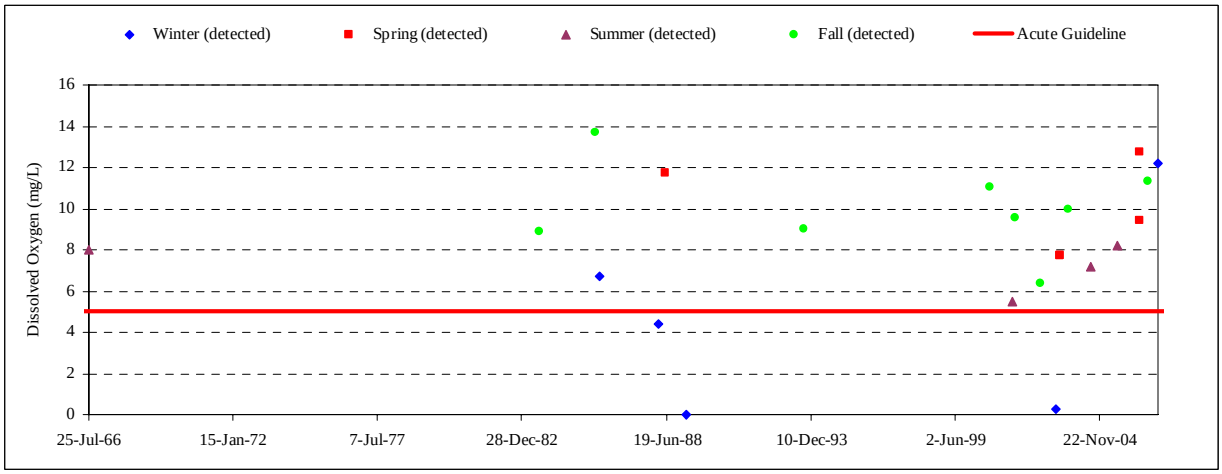
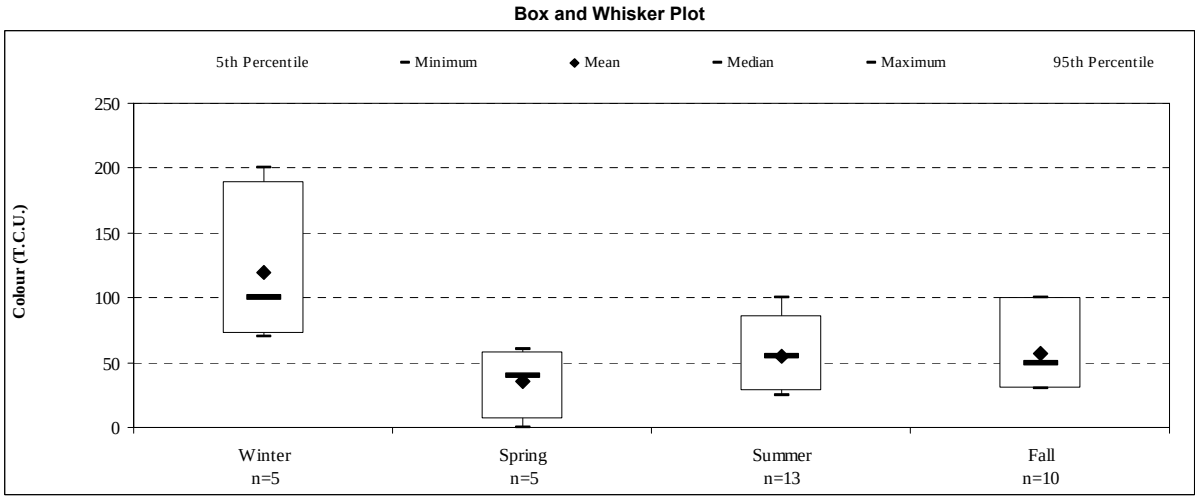


Figure G-2-8-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Kearl Lake



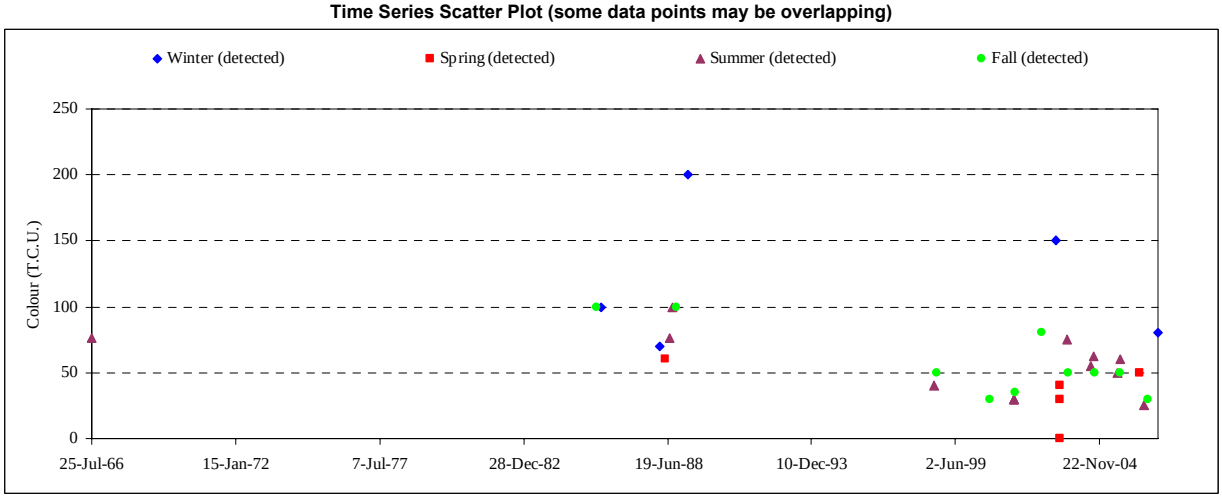
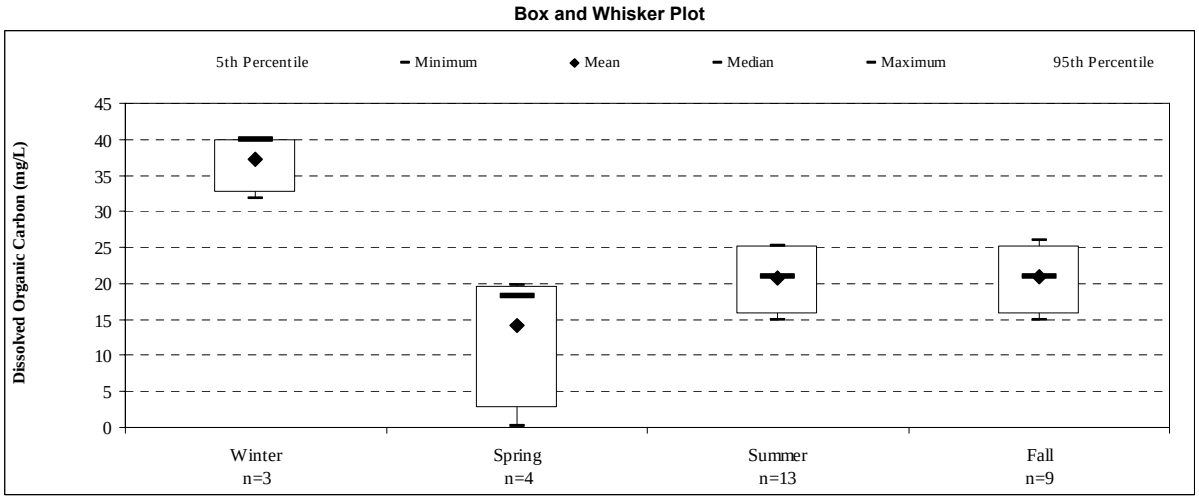


Figure G-2-8-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Kearl Lake



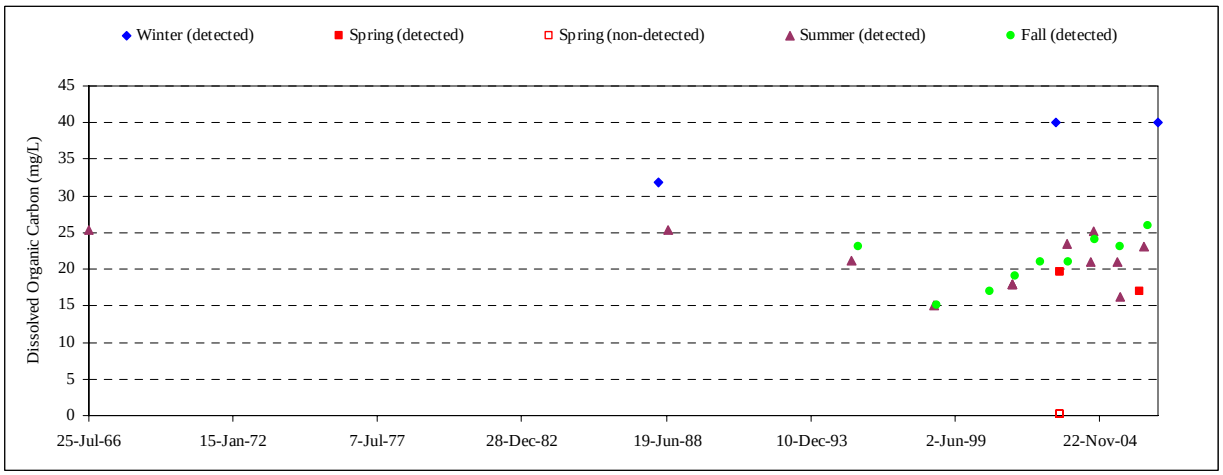
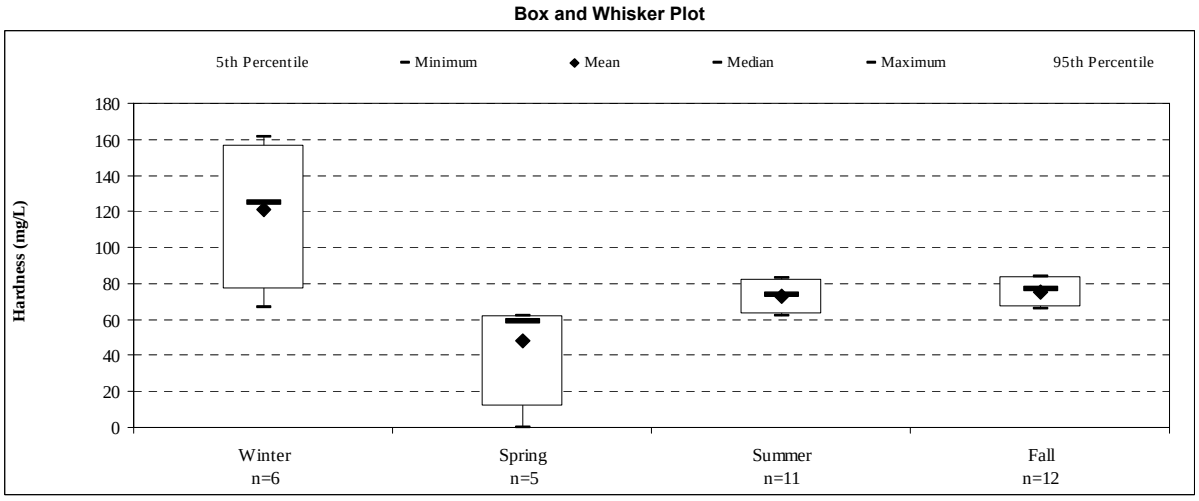


Figure G-2-8-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Kearl Lake



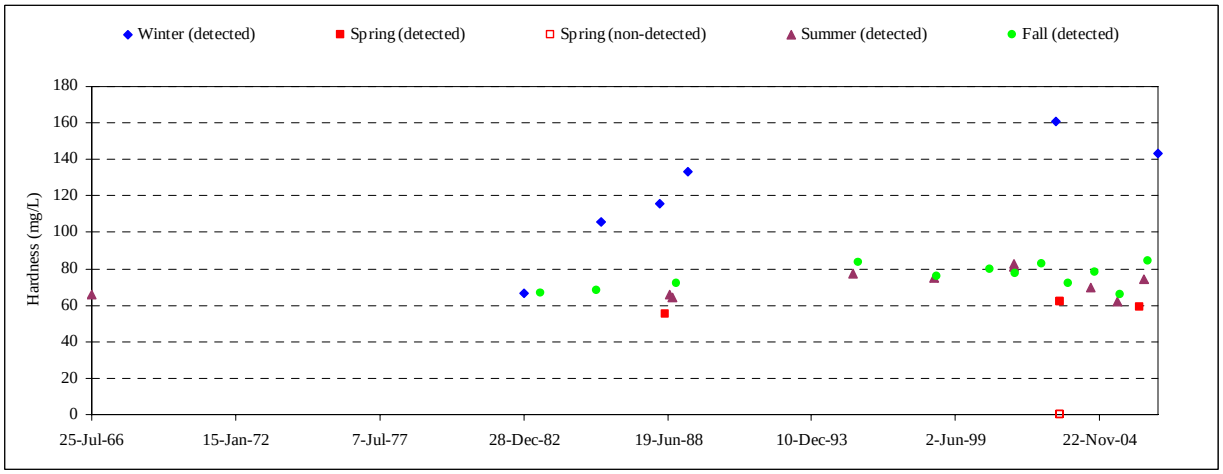
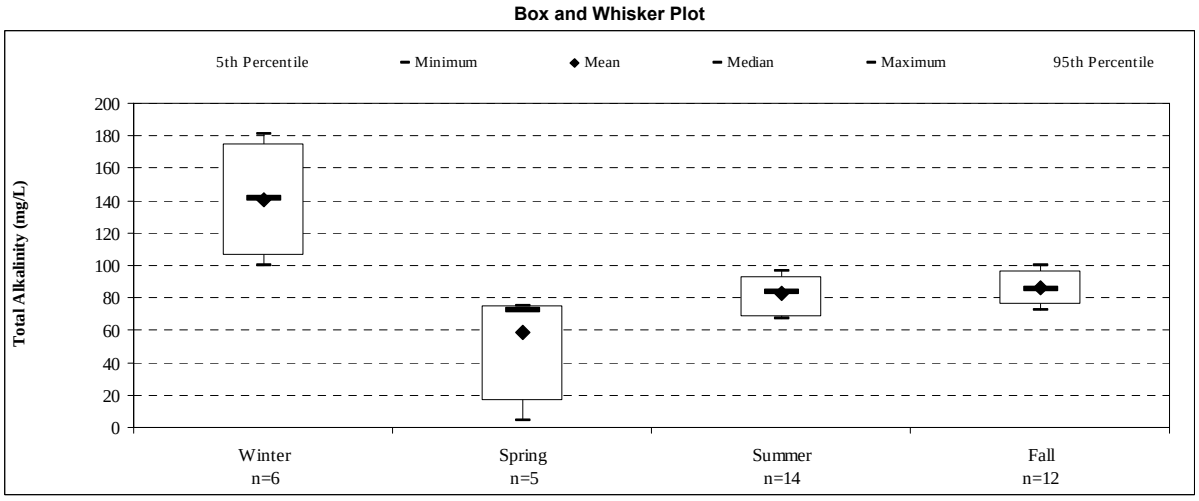


Figure G-2-8-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Kearl Lake



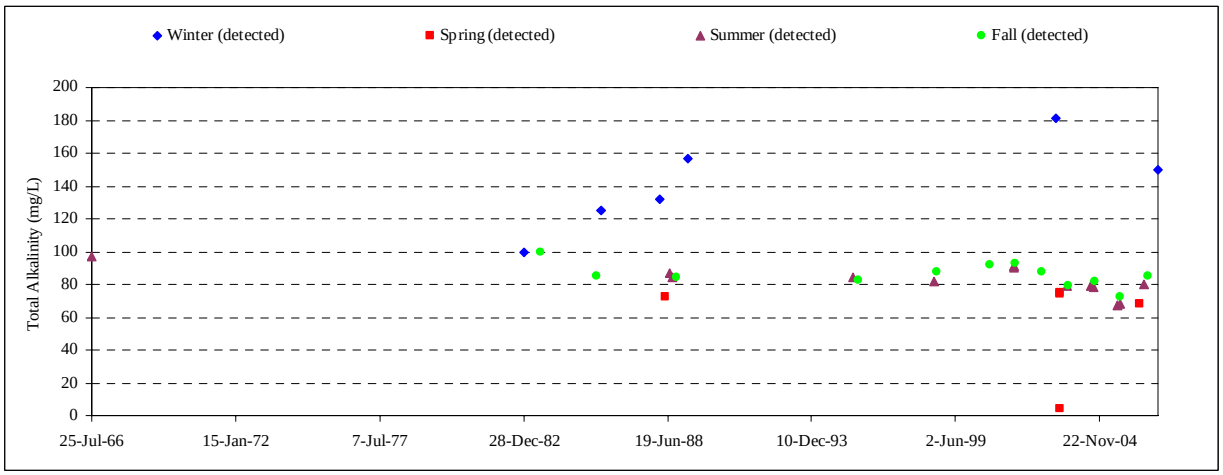
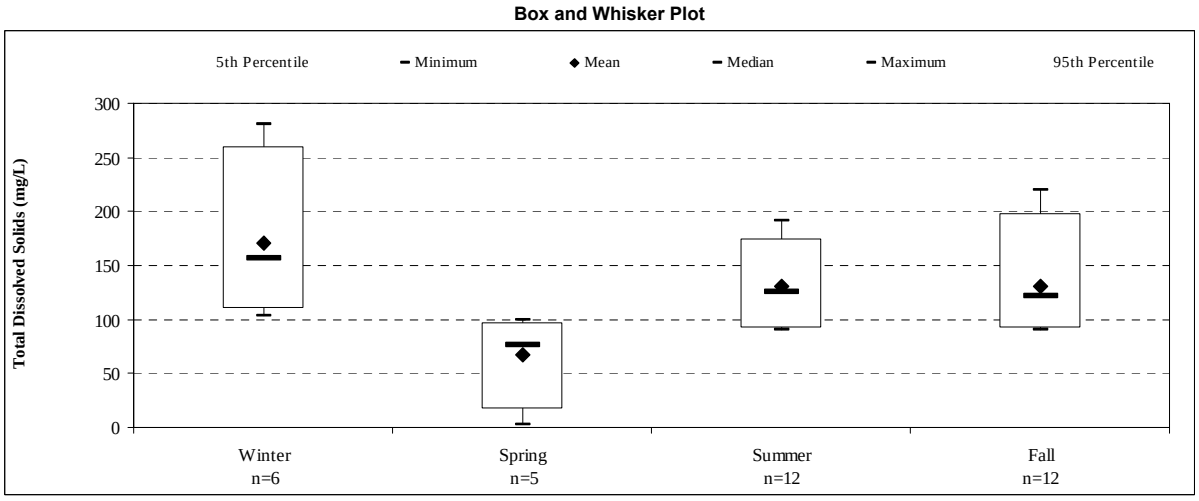


Figure G-2-8-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Kearl Lake



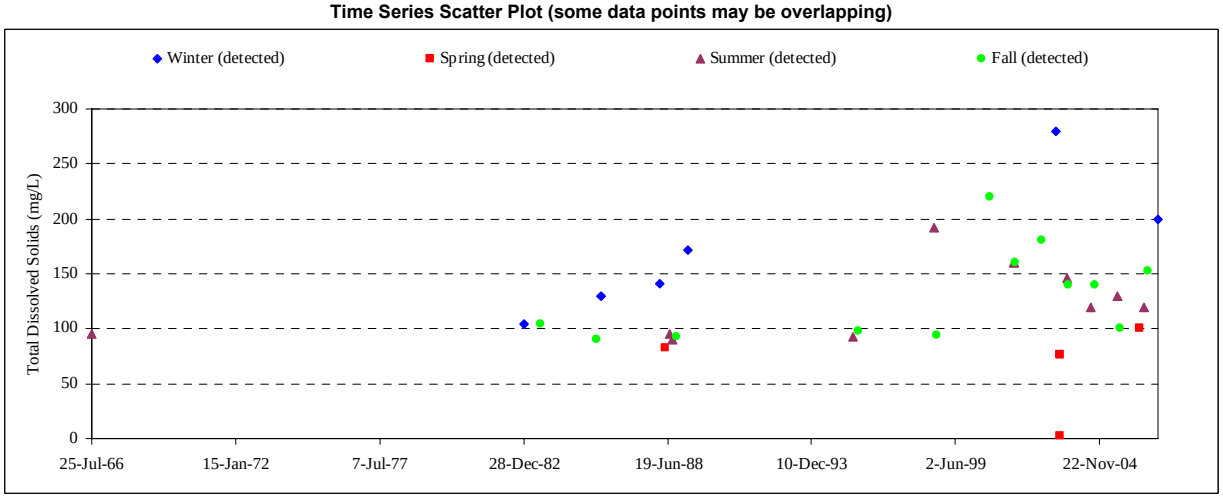
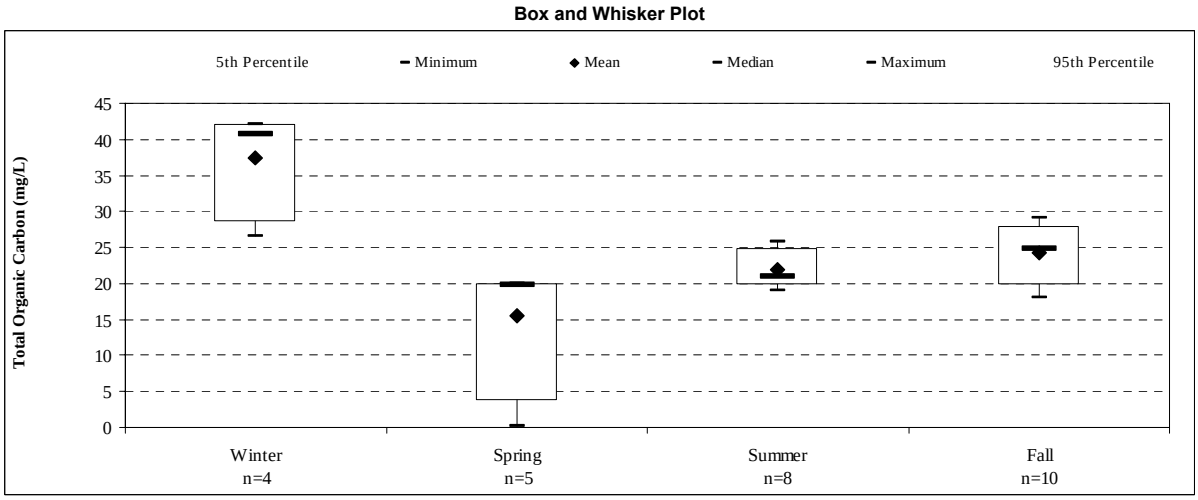


Figure G-2-8-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Kearl Lake



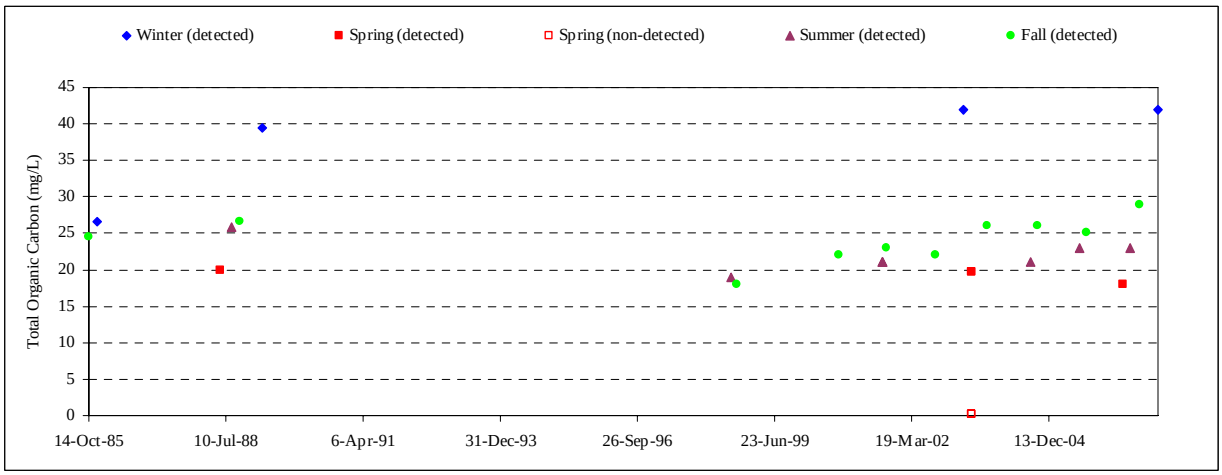
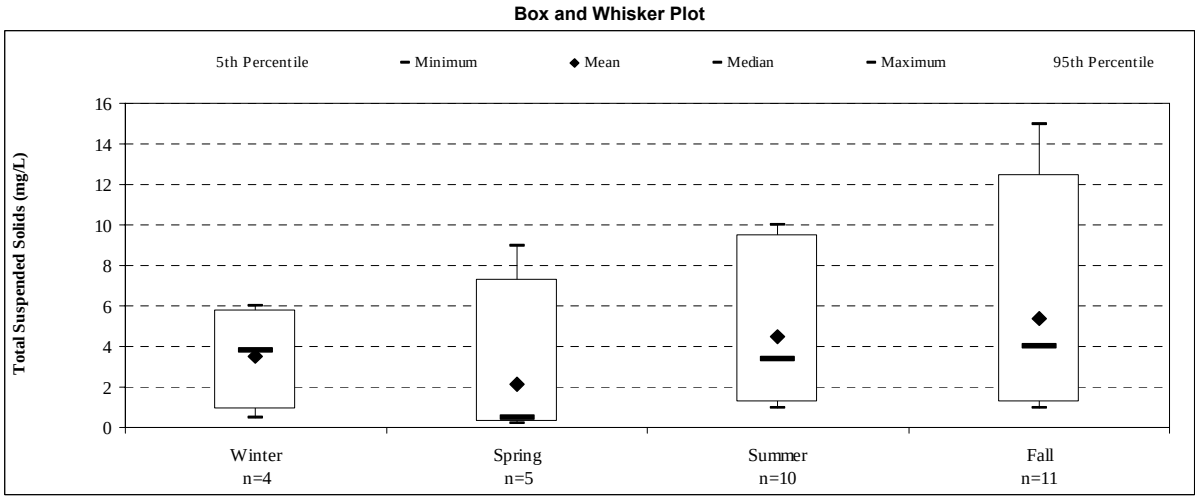


Figure G-2-8-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Kearl Lake



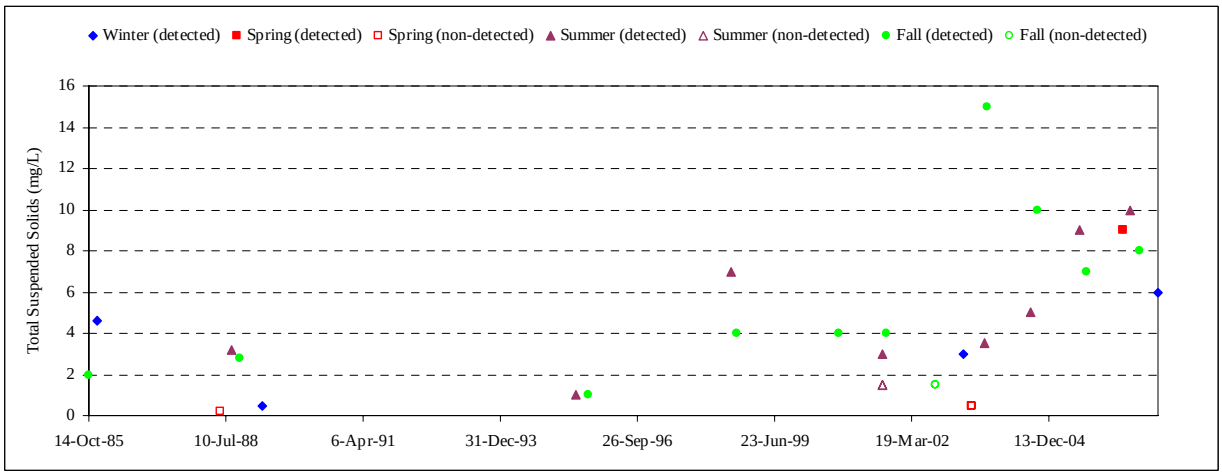
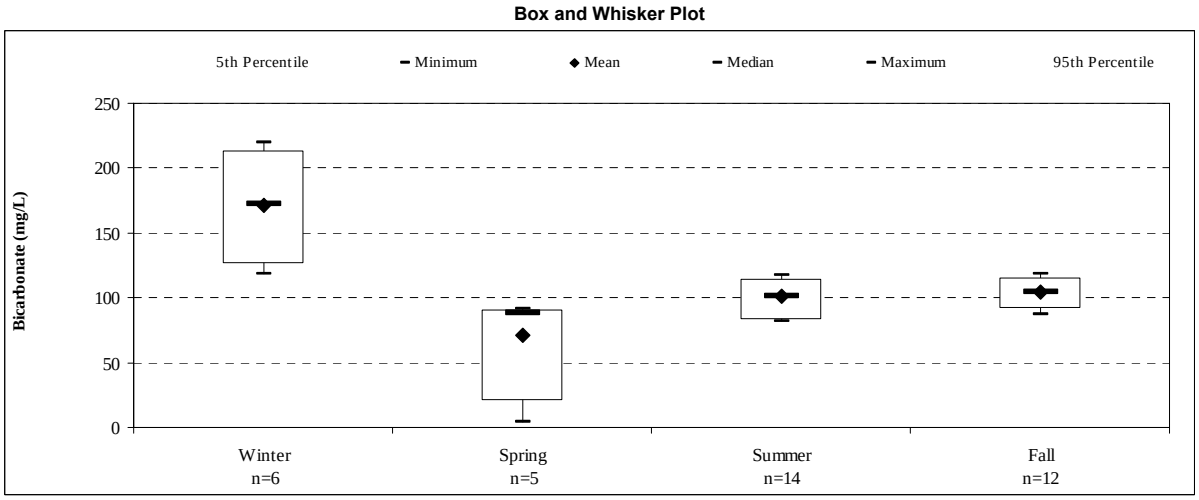


Figure G-2-8-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Kearl Lake



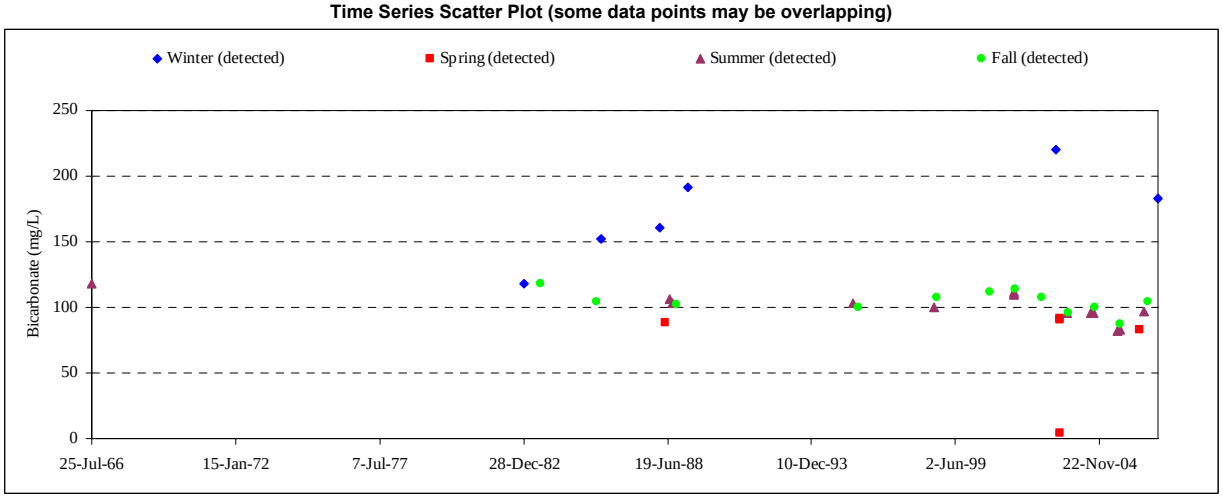
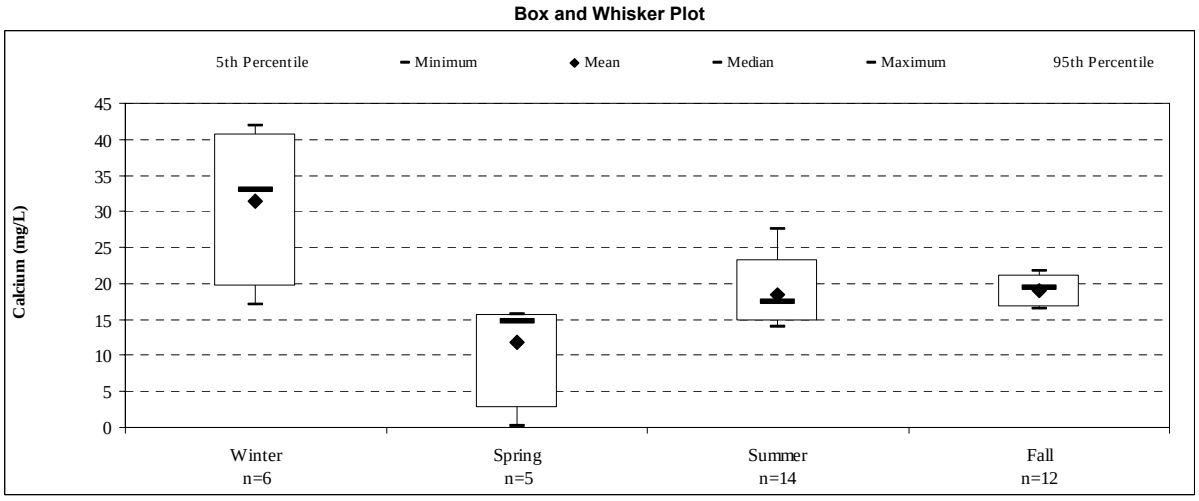


Figure G-2-8-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Kearl Lake



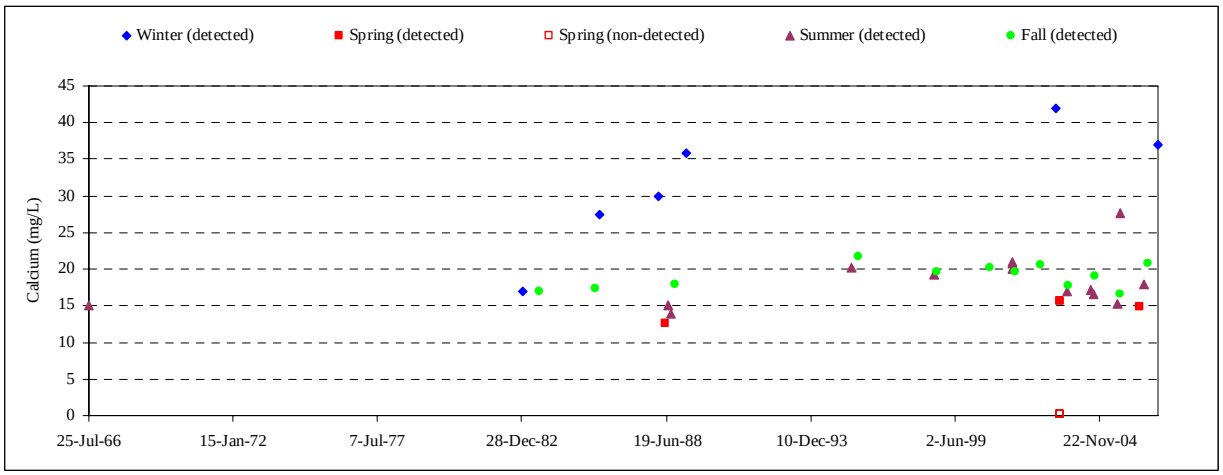
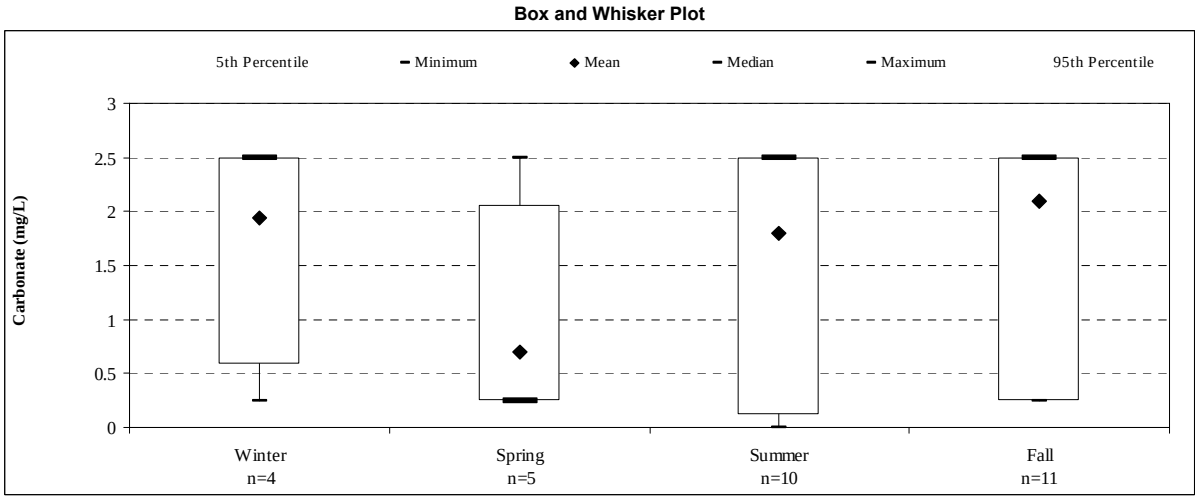


Figure G-2-8-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Kearl Lake



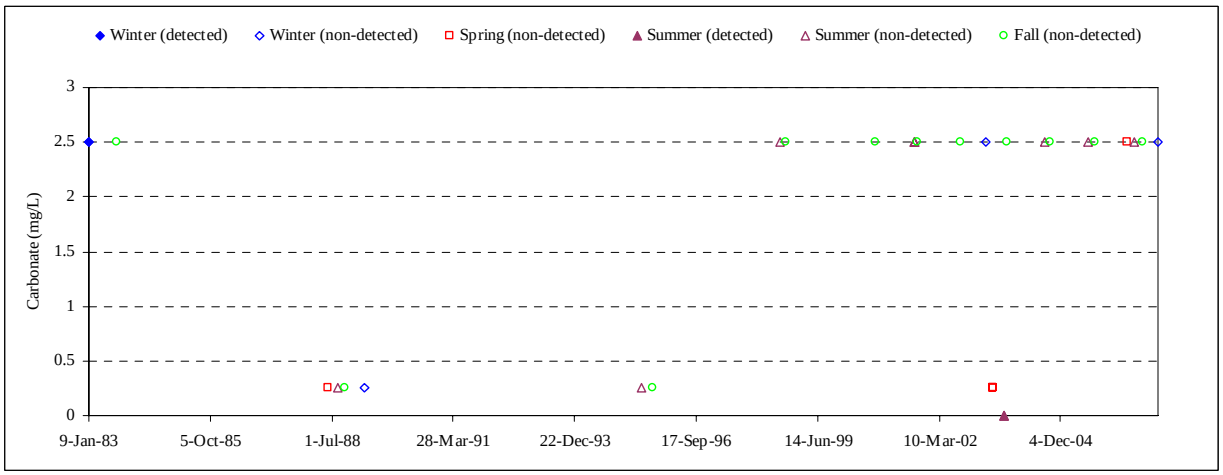


Figure G-2-8-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Kearl Lake

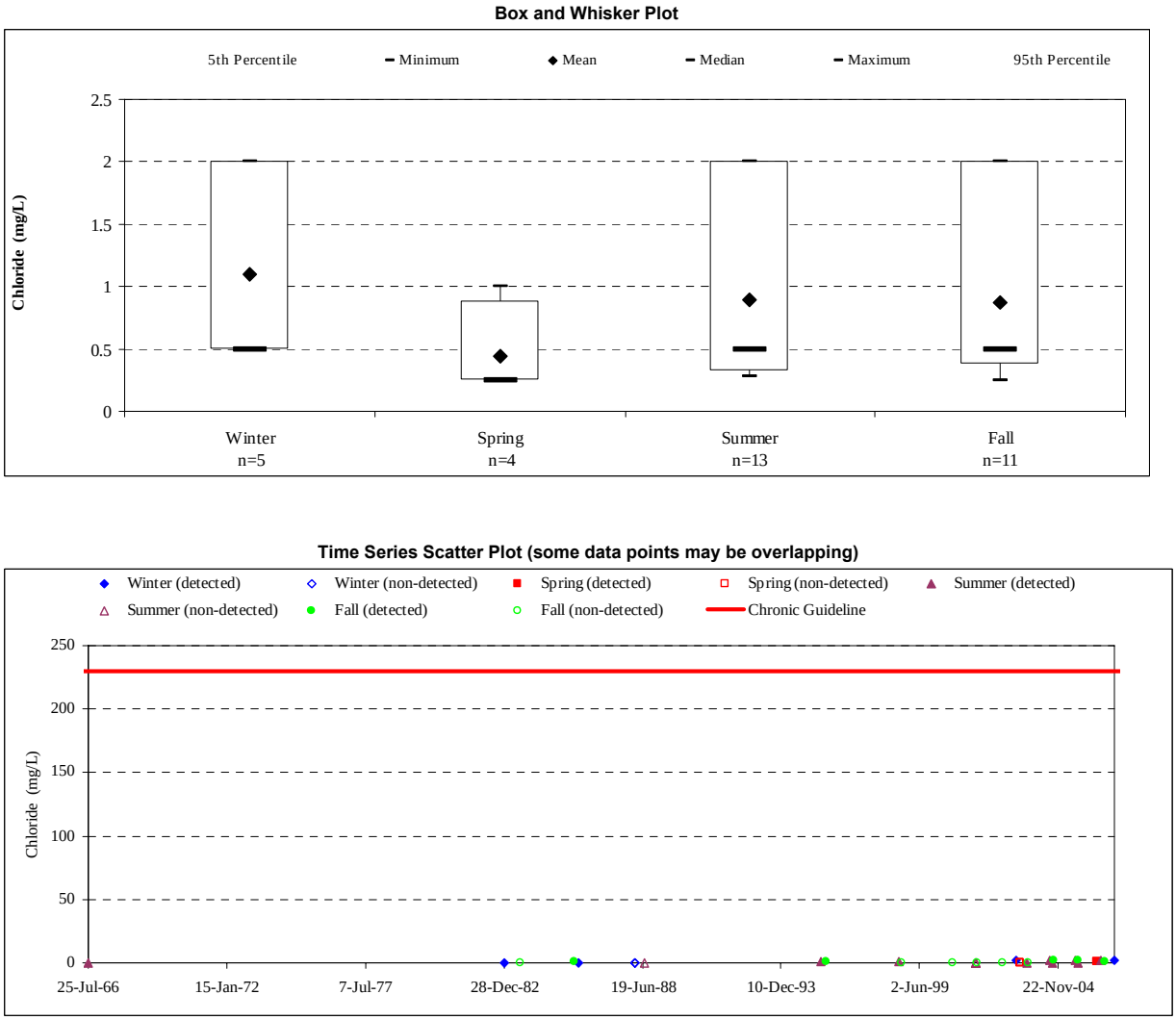
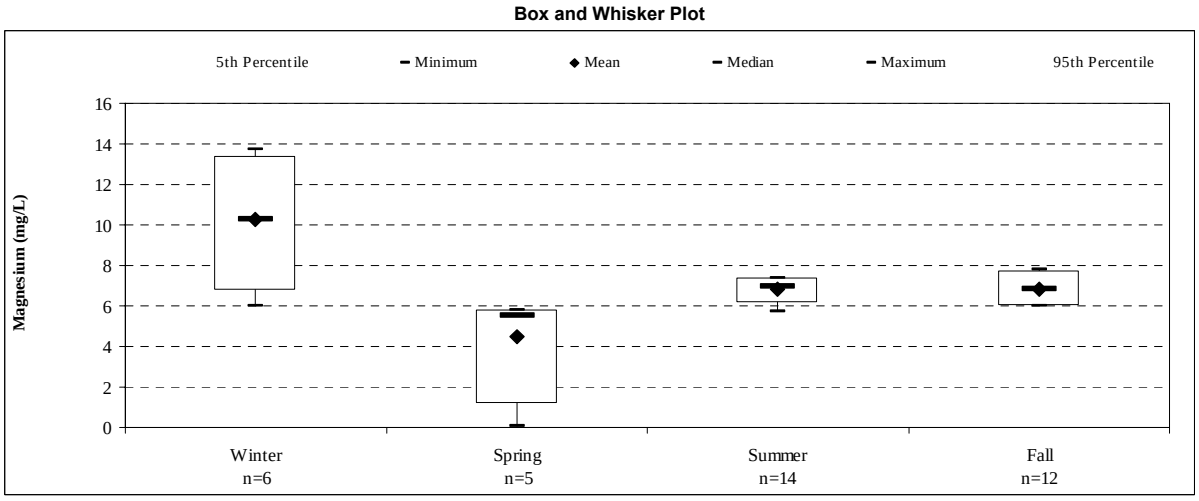


Figure G-2-8-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Kearl Lake



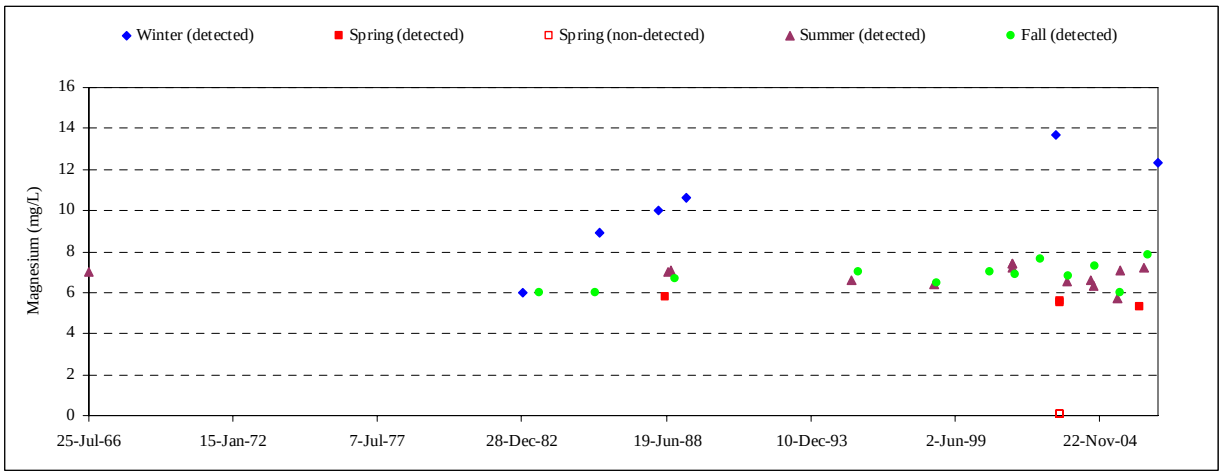


Figure G-2-8-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Kearl Lake

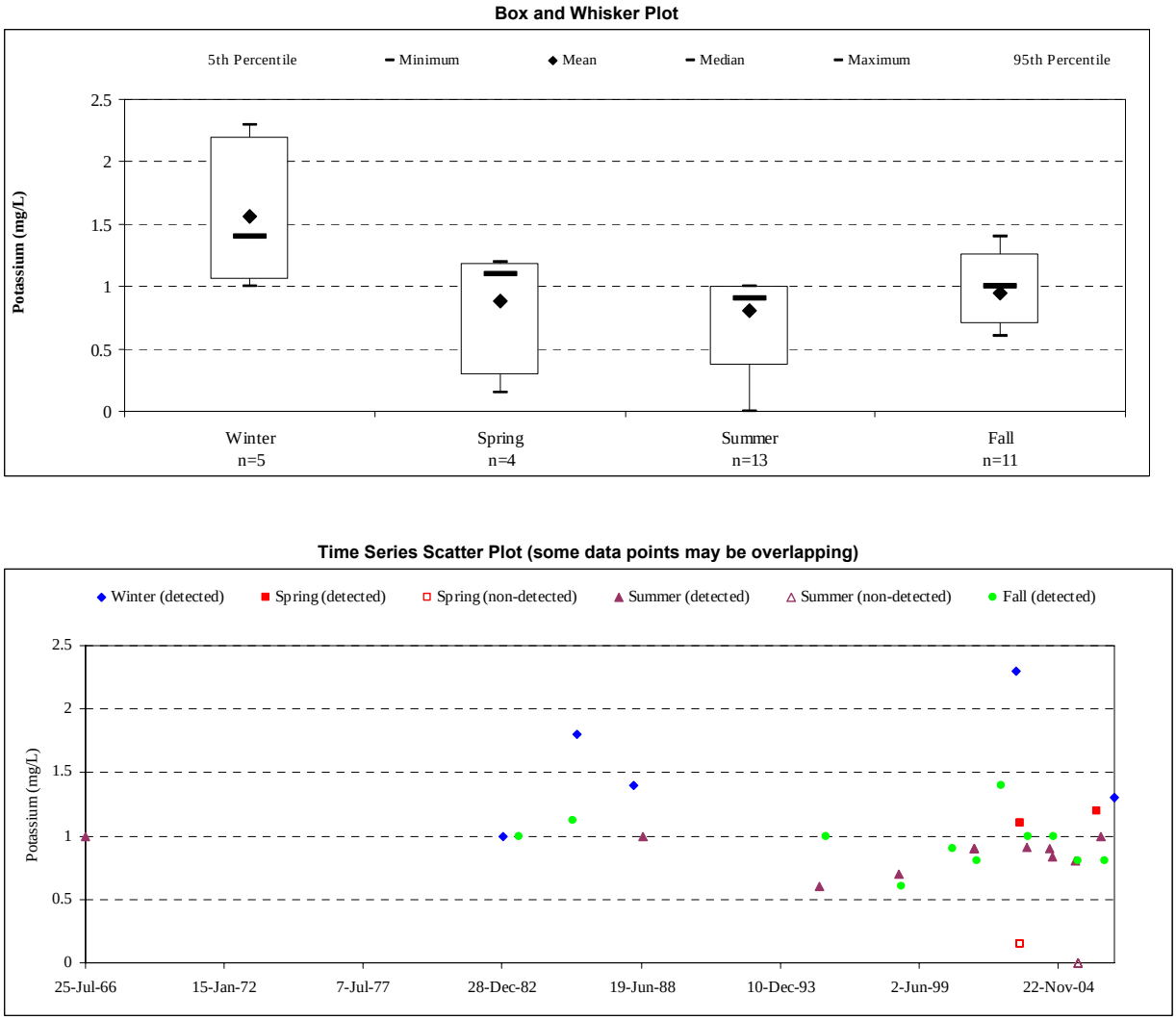
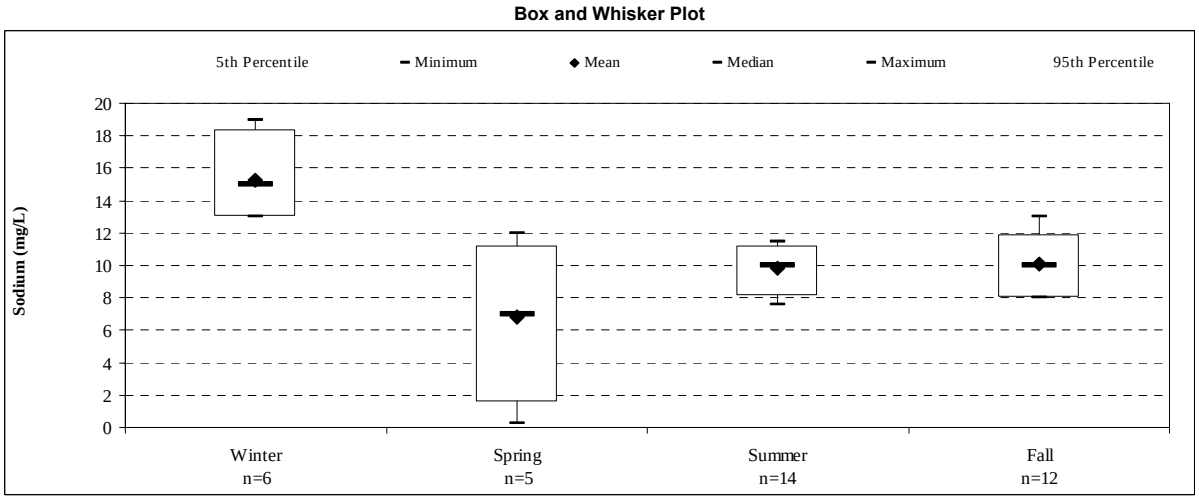


Figure G-2-8-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Kearl Lake



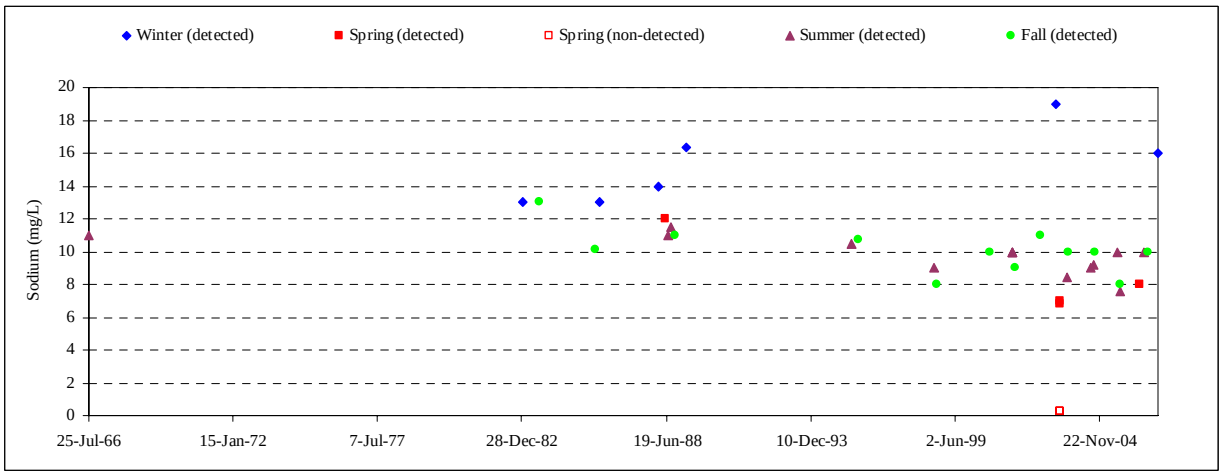
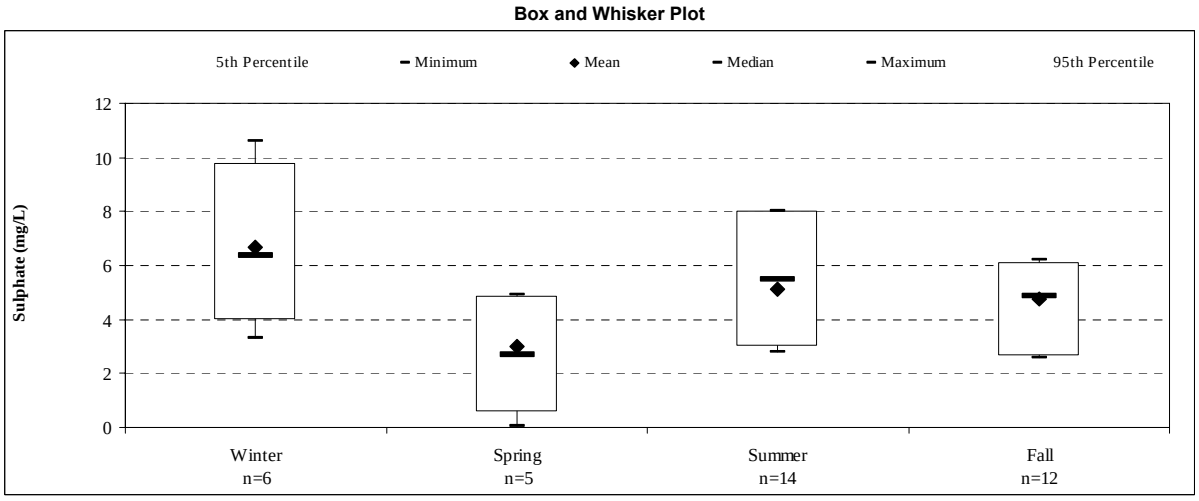


Figure G-2-8-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Kearl Lake



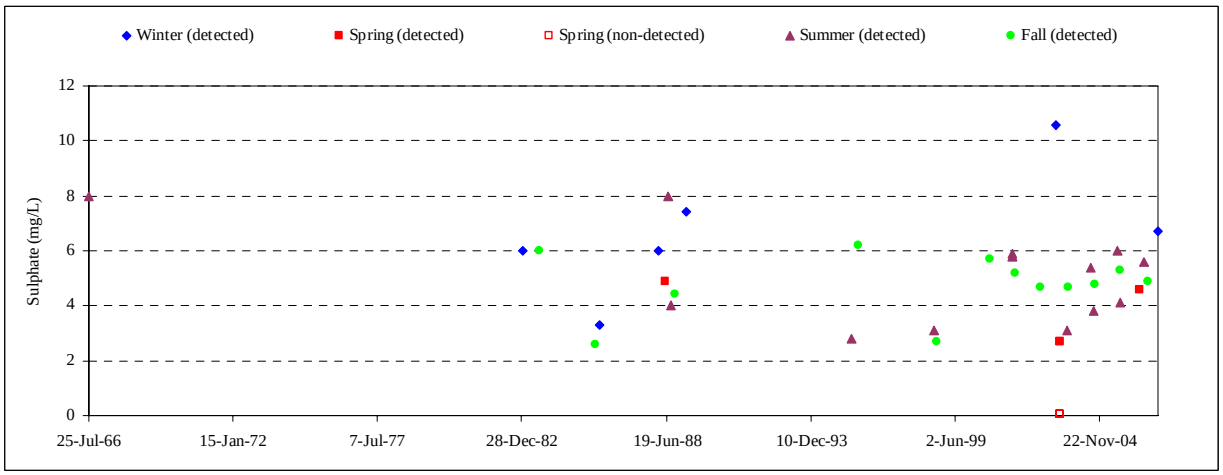


Figure G-2-8-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Kearl Lake

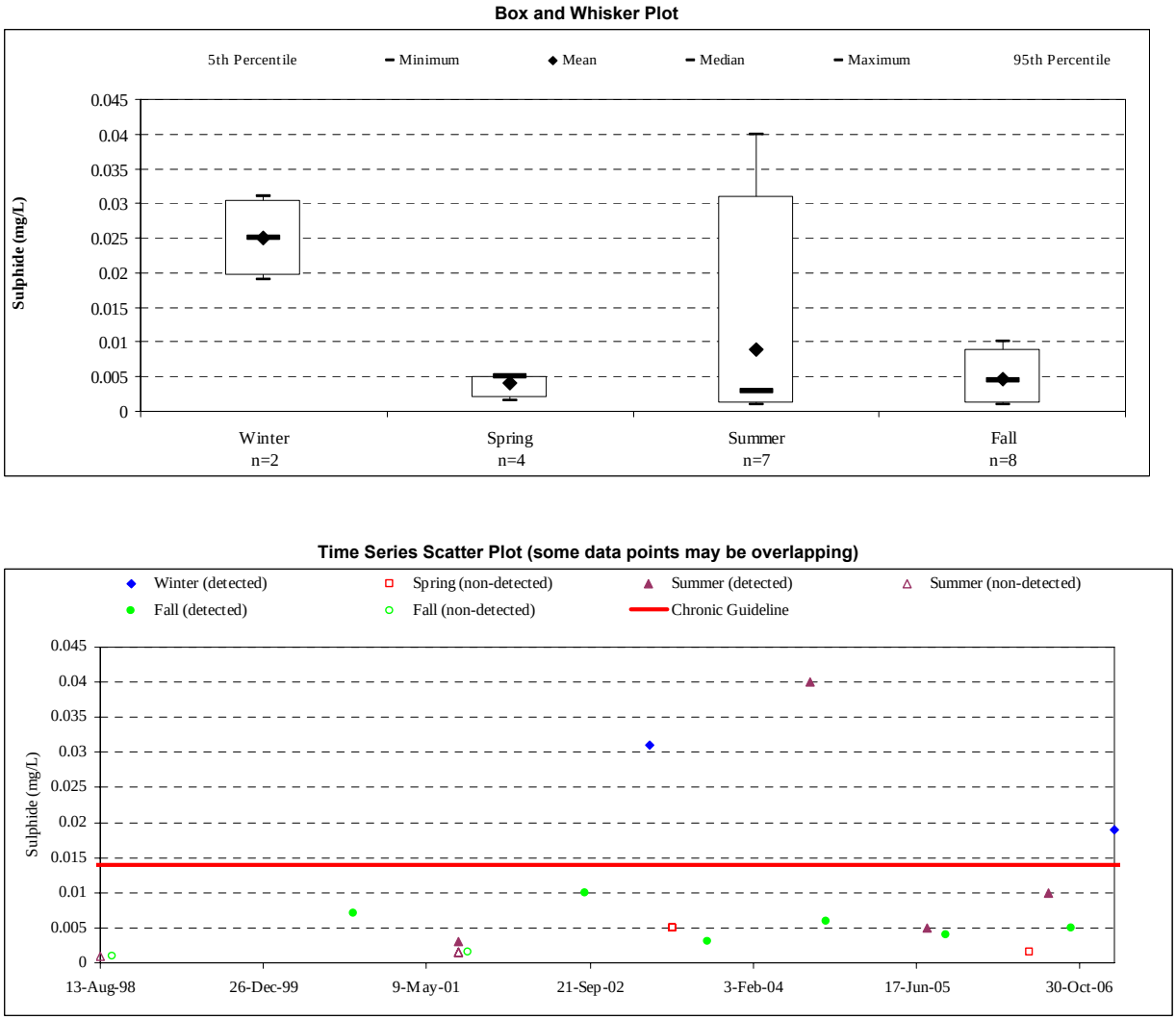


Figure G-2-8-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Kearl Lake

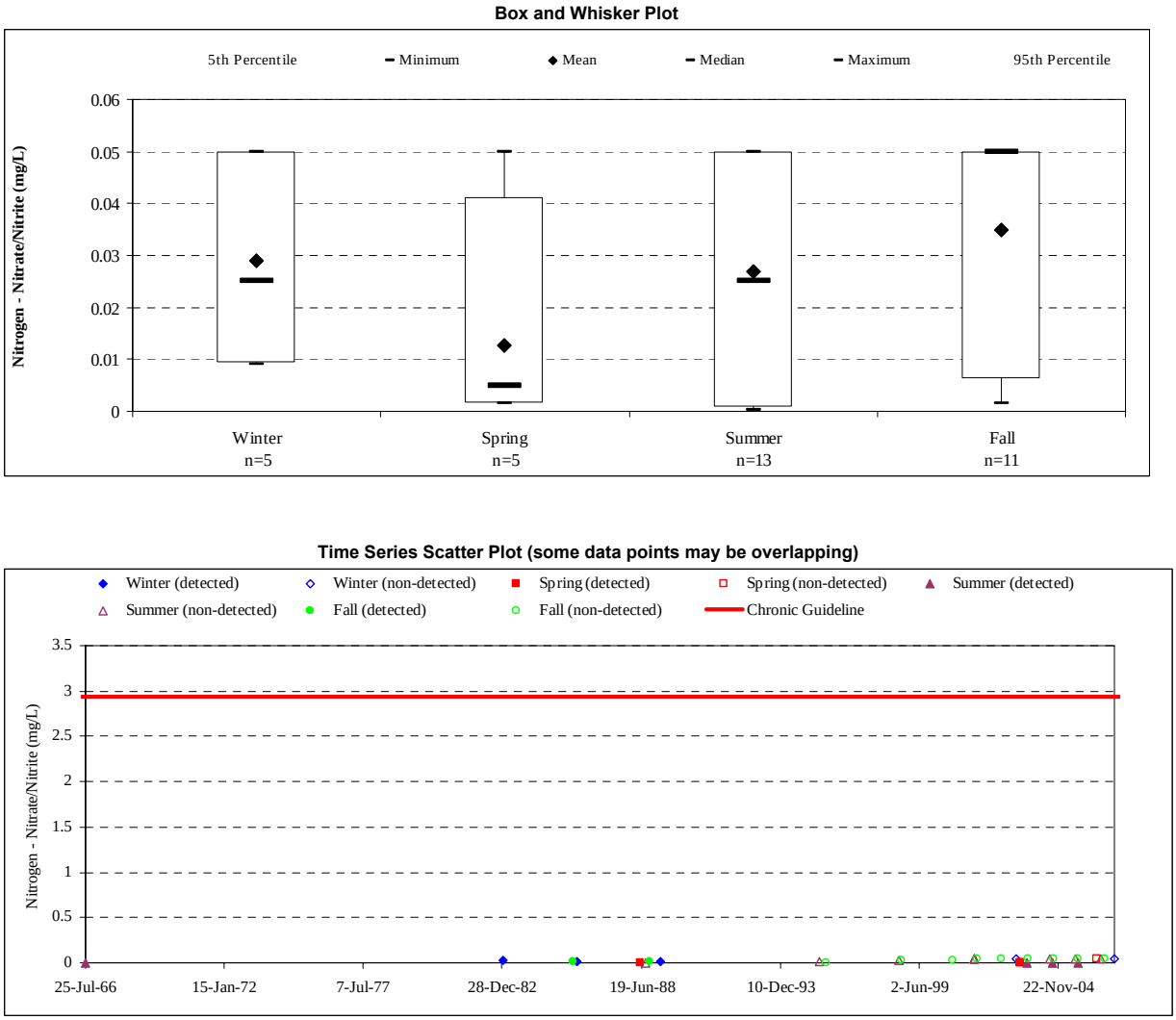
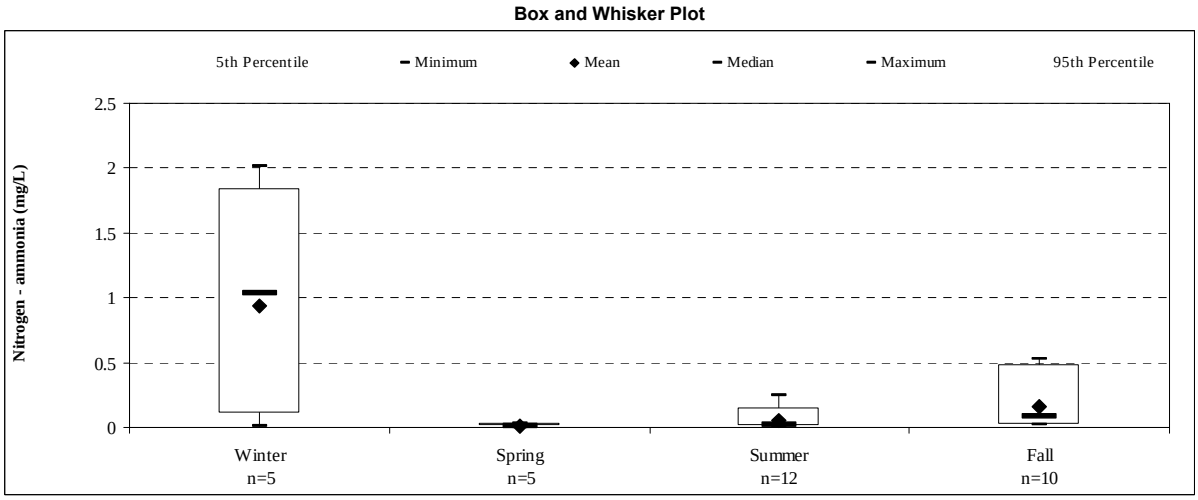


Figure G-2-8-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Kearl Lake



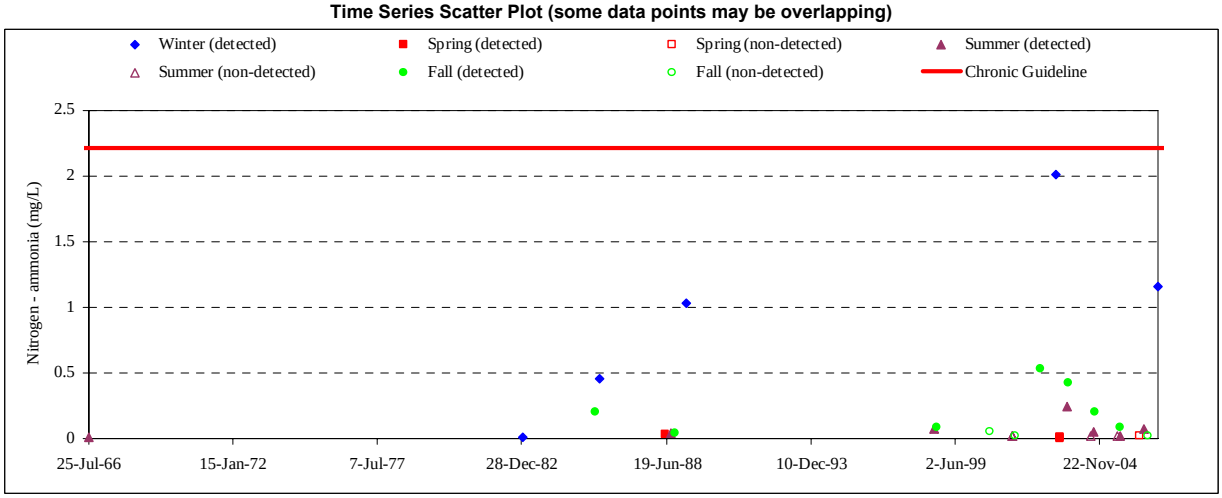
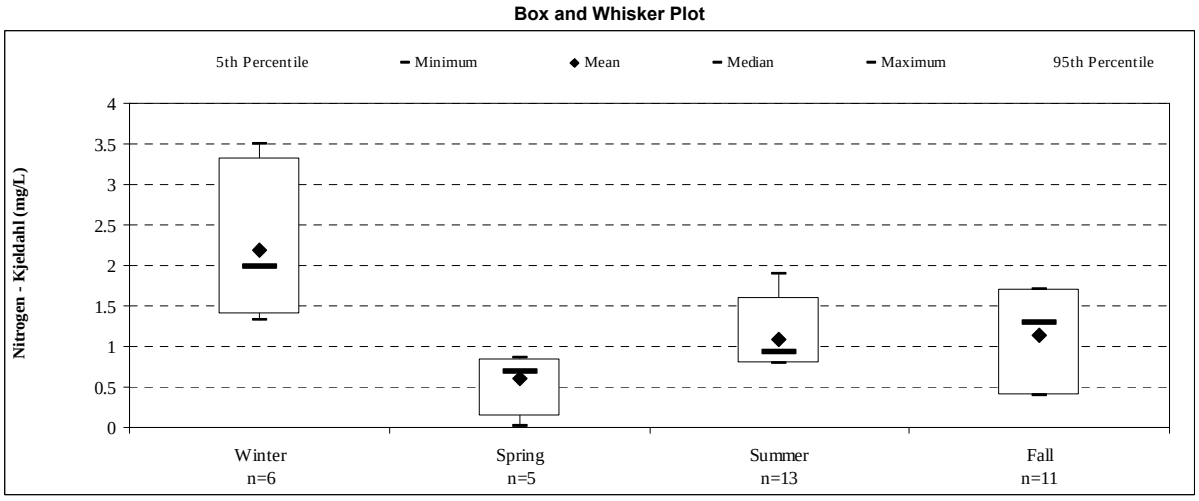


Figure G-2-8-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Kearl Lake



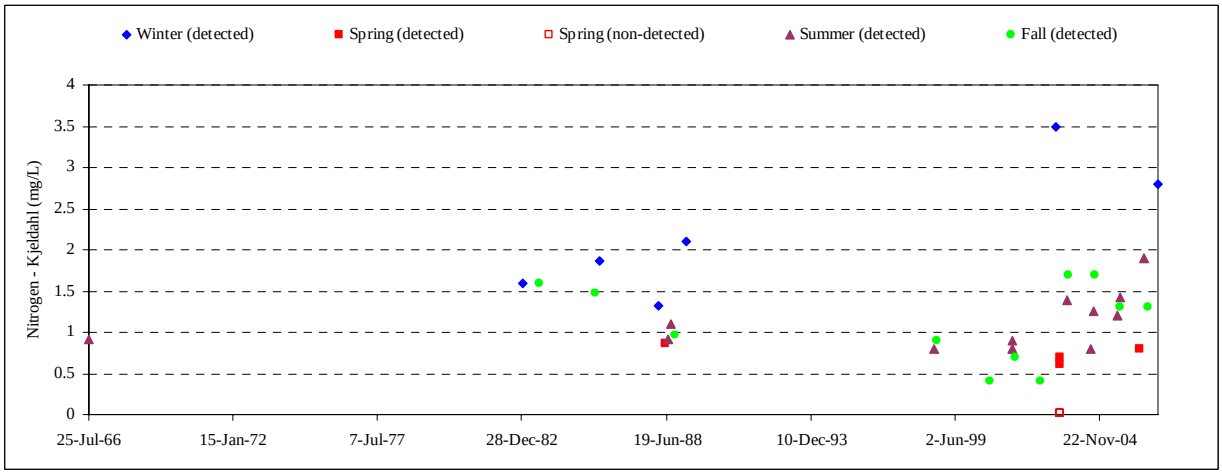
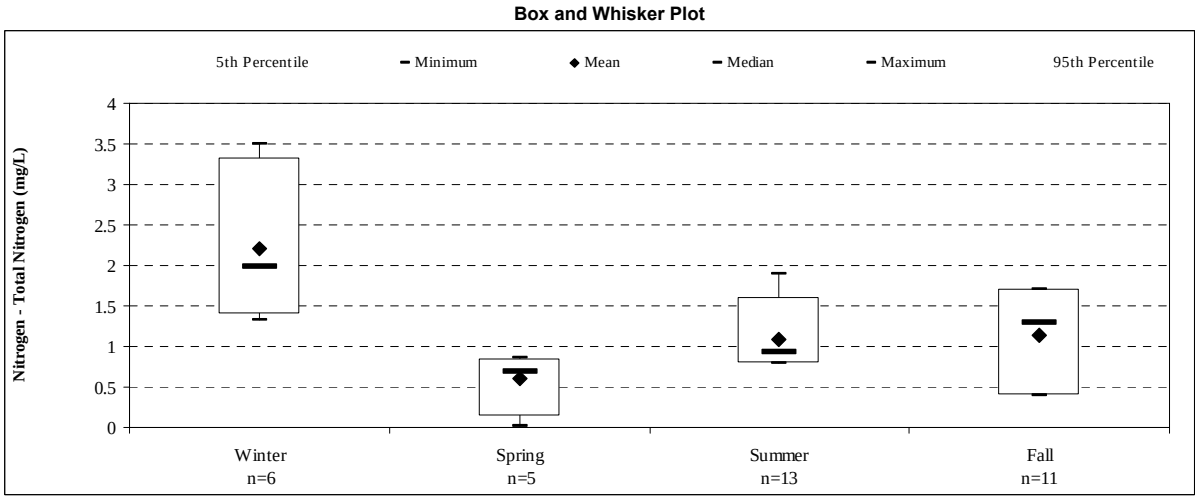


Figure G-2-8-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Kearl Lake



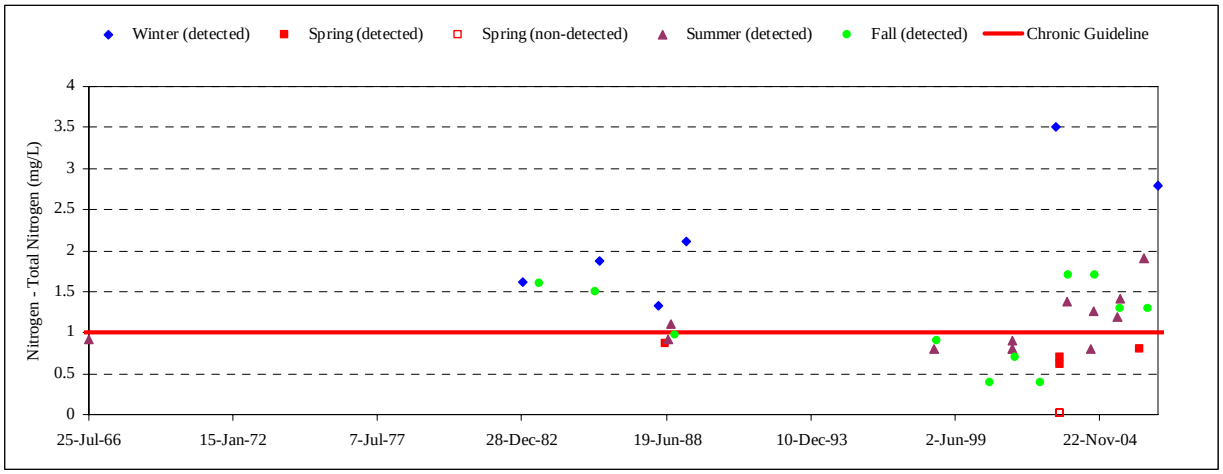
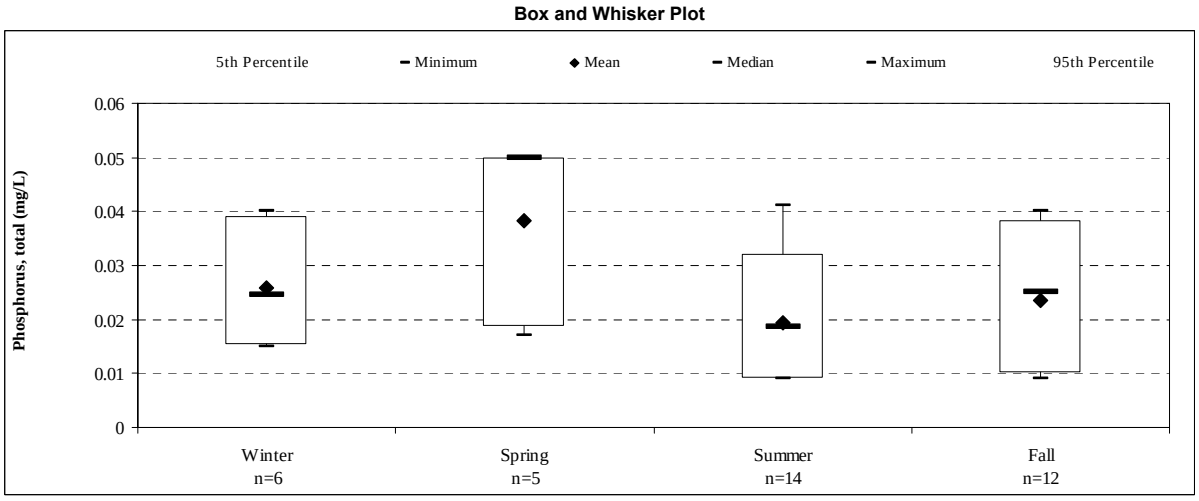


Figure G-2-8-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Kearl Lake



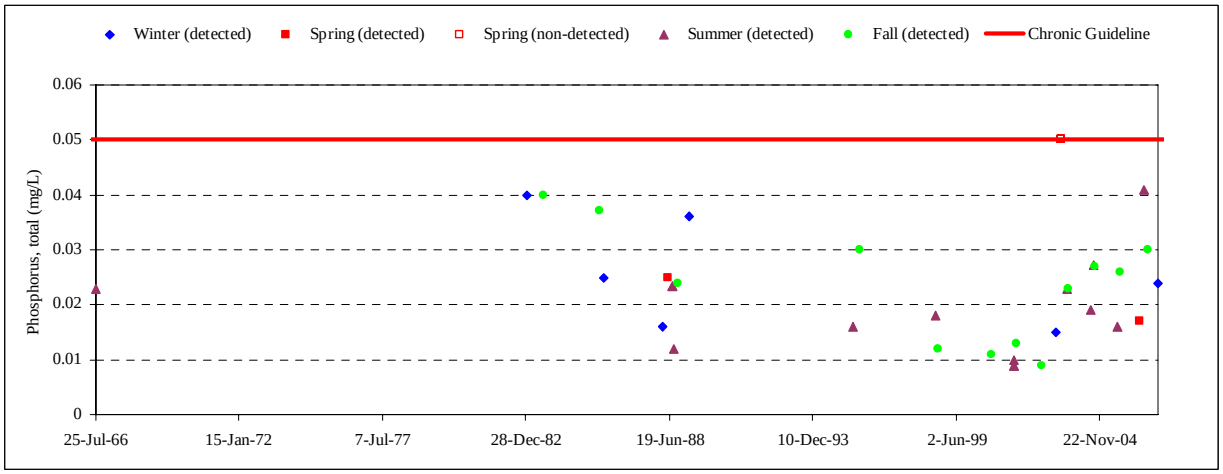
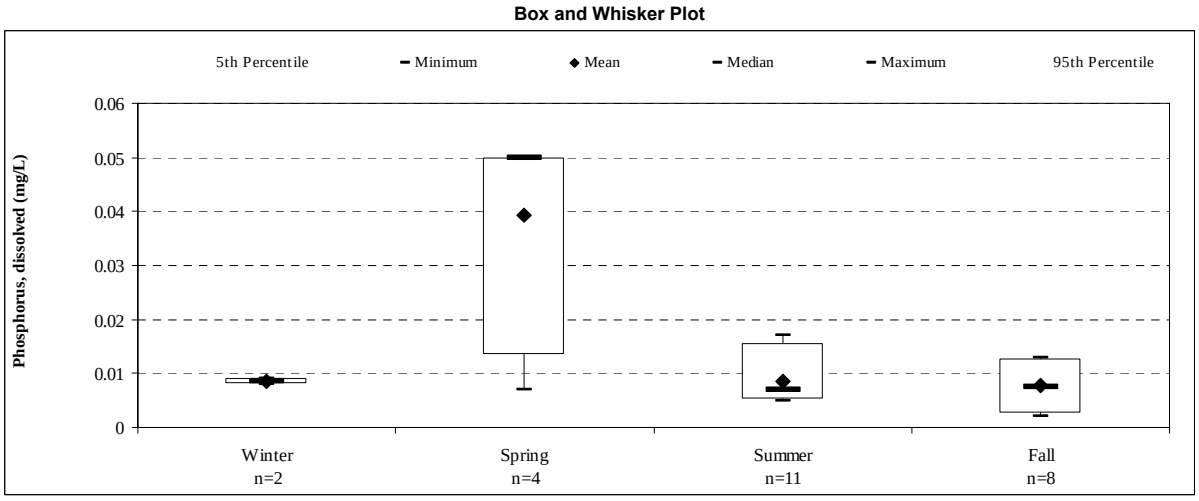


Figure G-2-8-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Kearl Lake



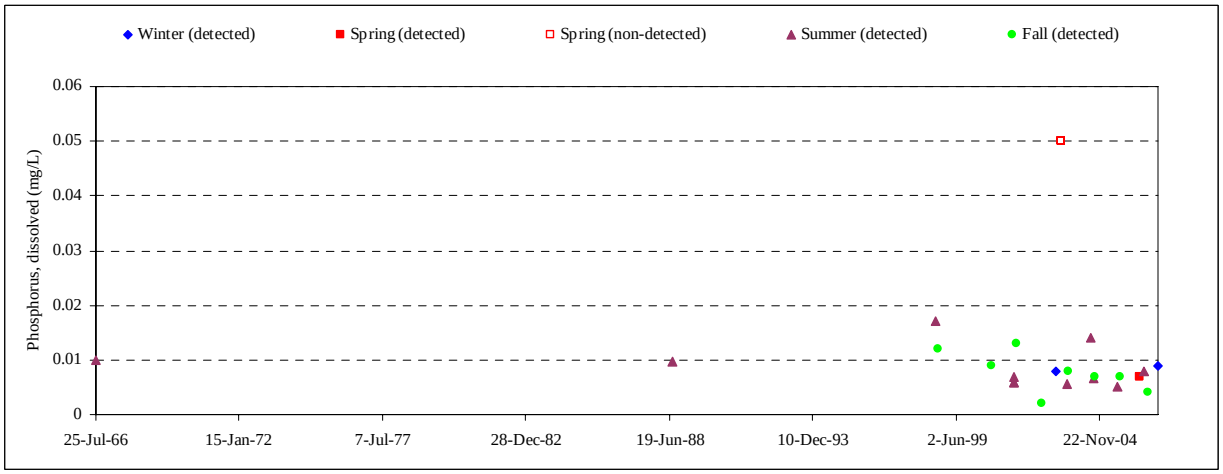
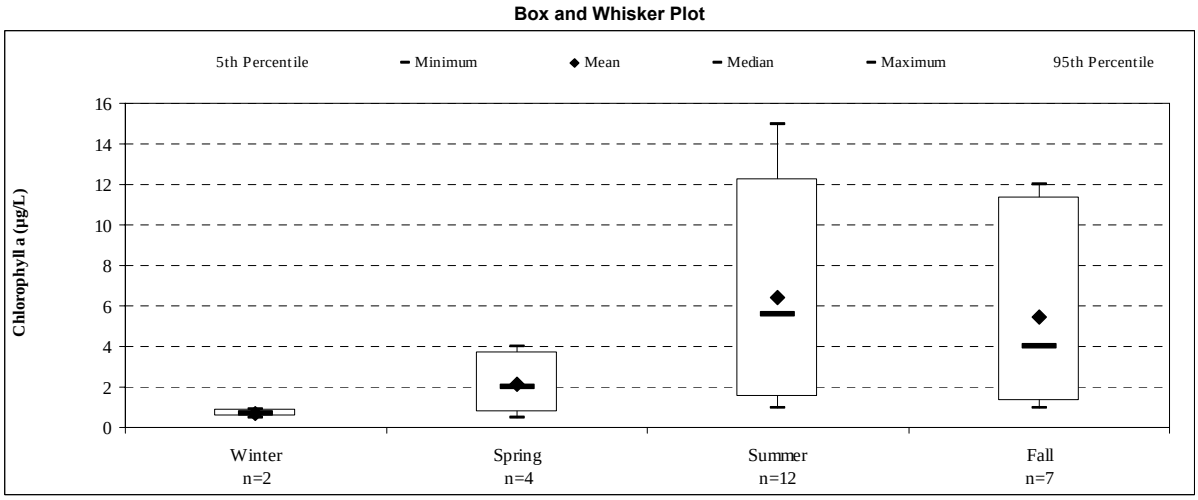


Figure G-2-8-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Kearl Lake



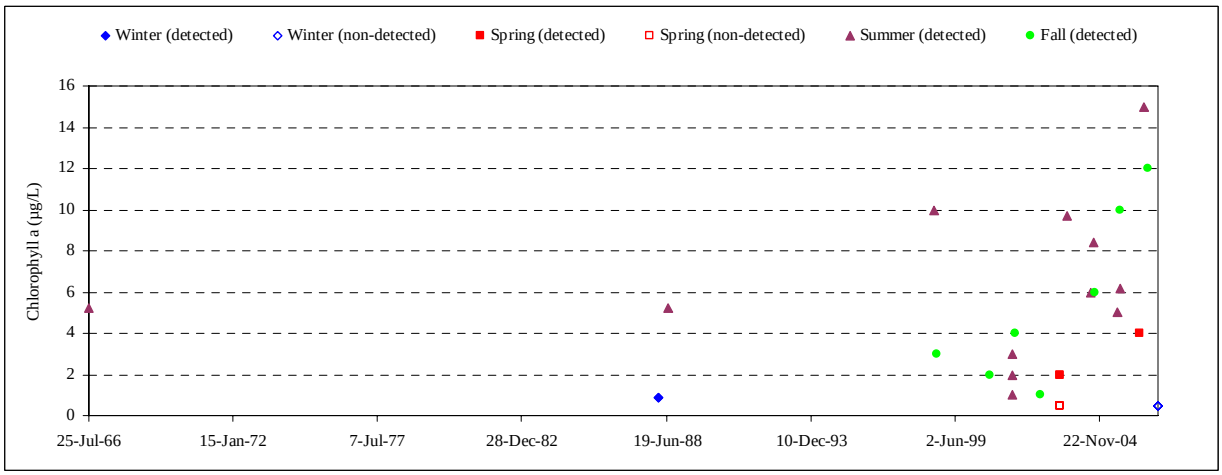
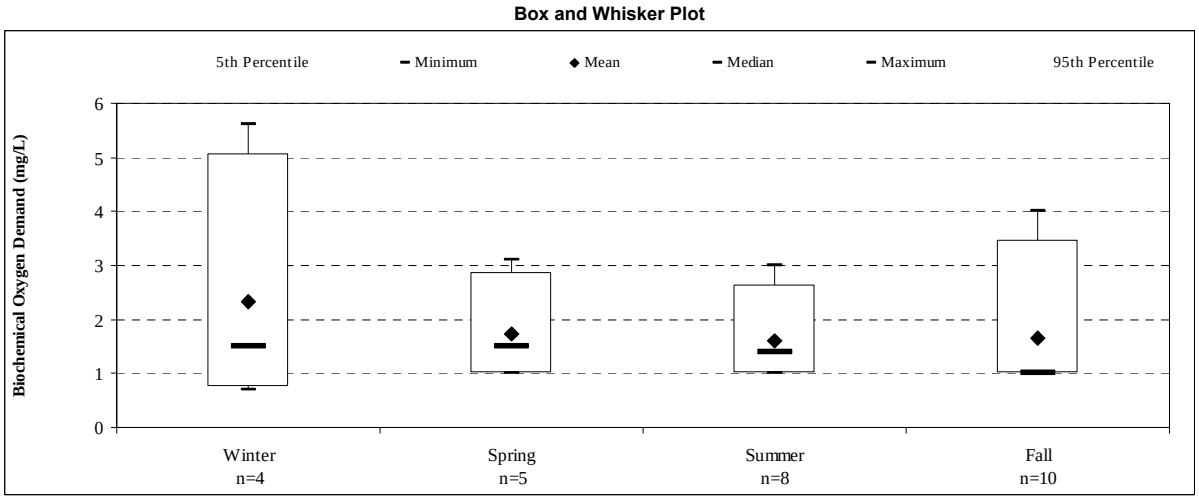


Figure G-2-8-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Kearl Lake



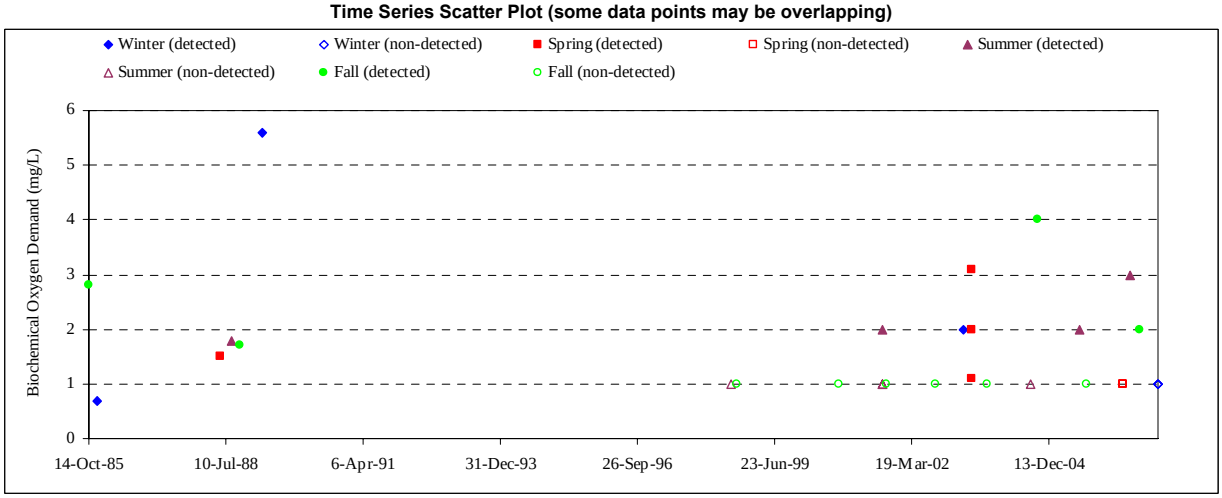
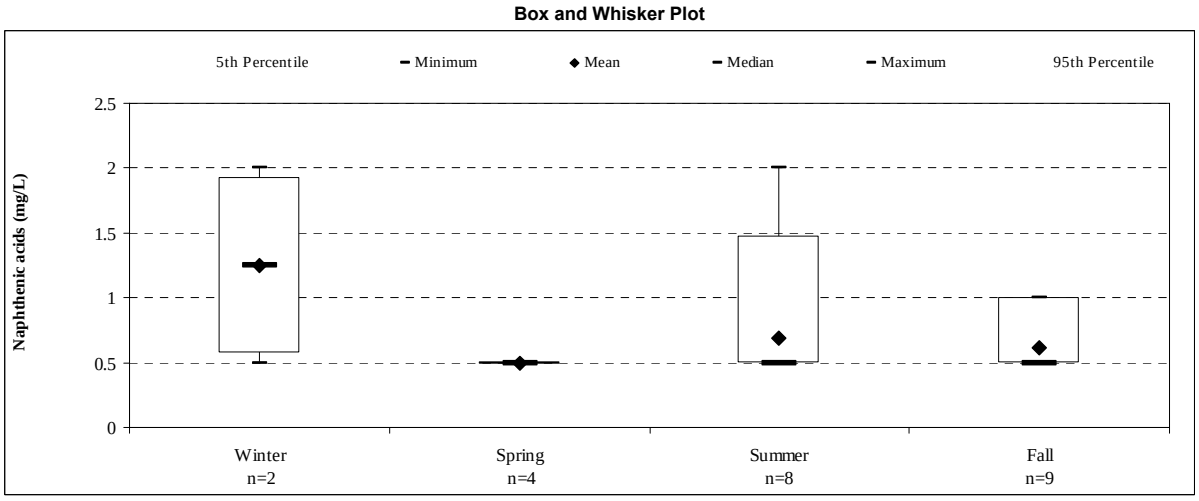


Figure G-2-8-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Kearl Lake



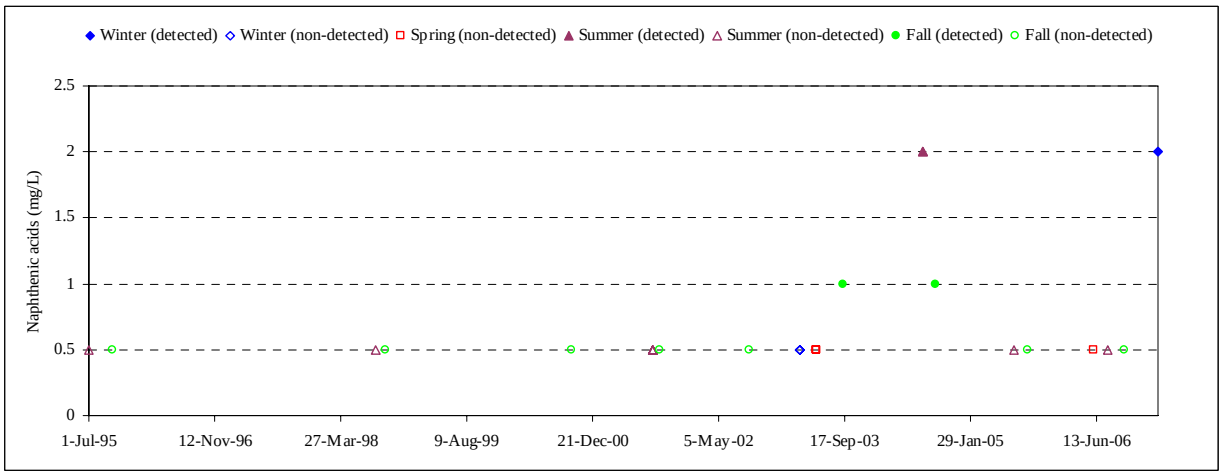


Figure G-2-8-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Kearl Lake

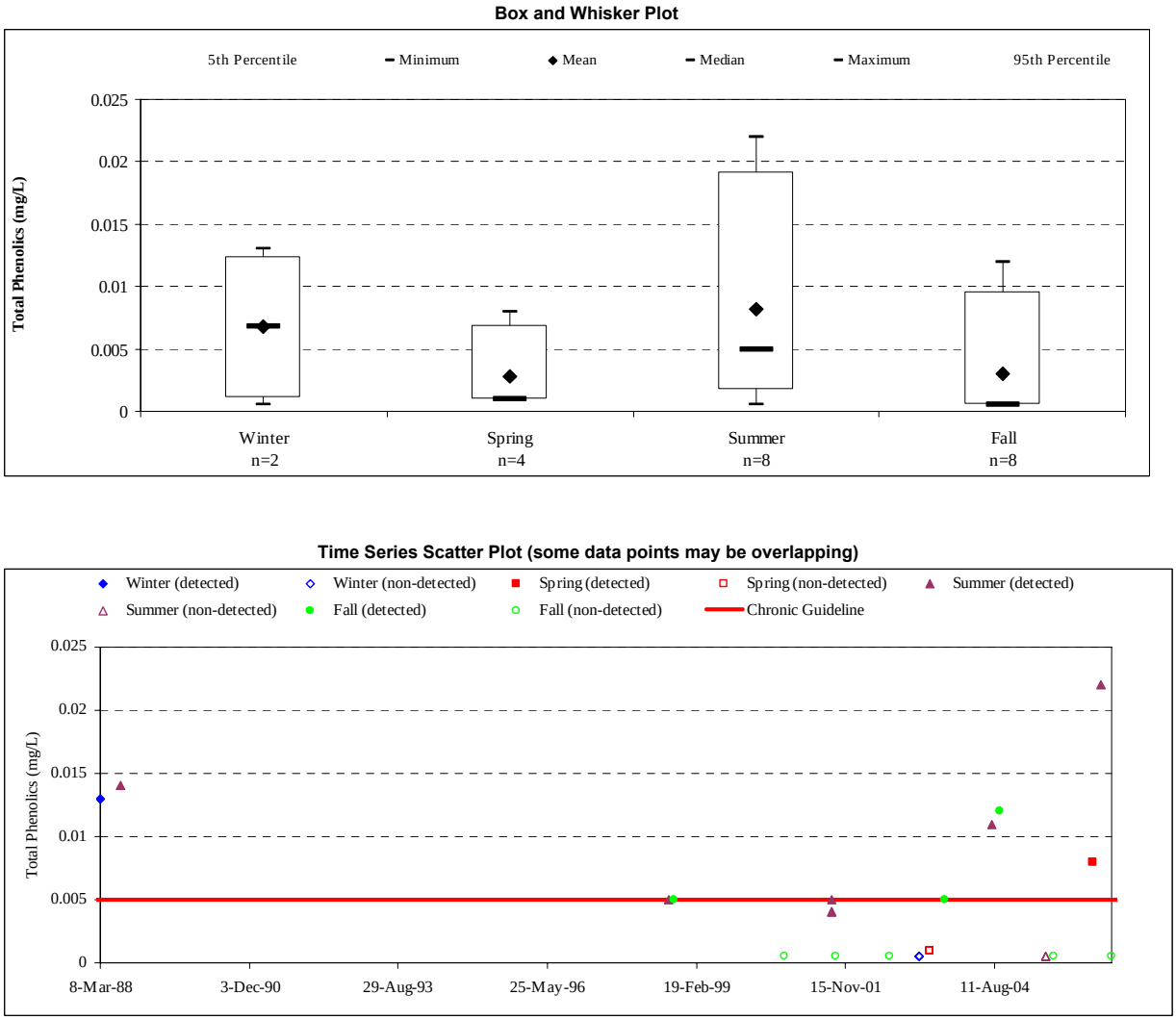


Figure G-2-8-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Kearl Lake

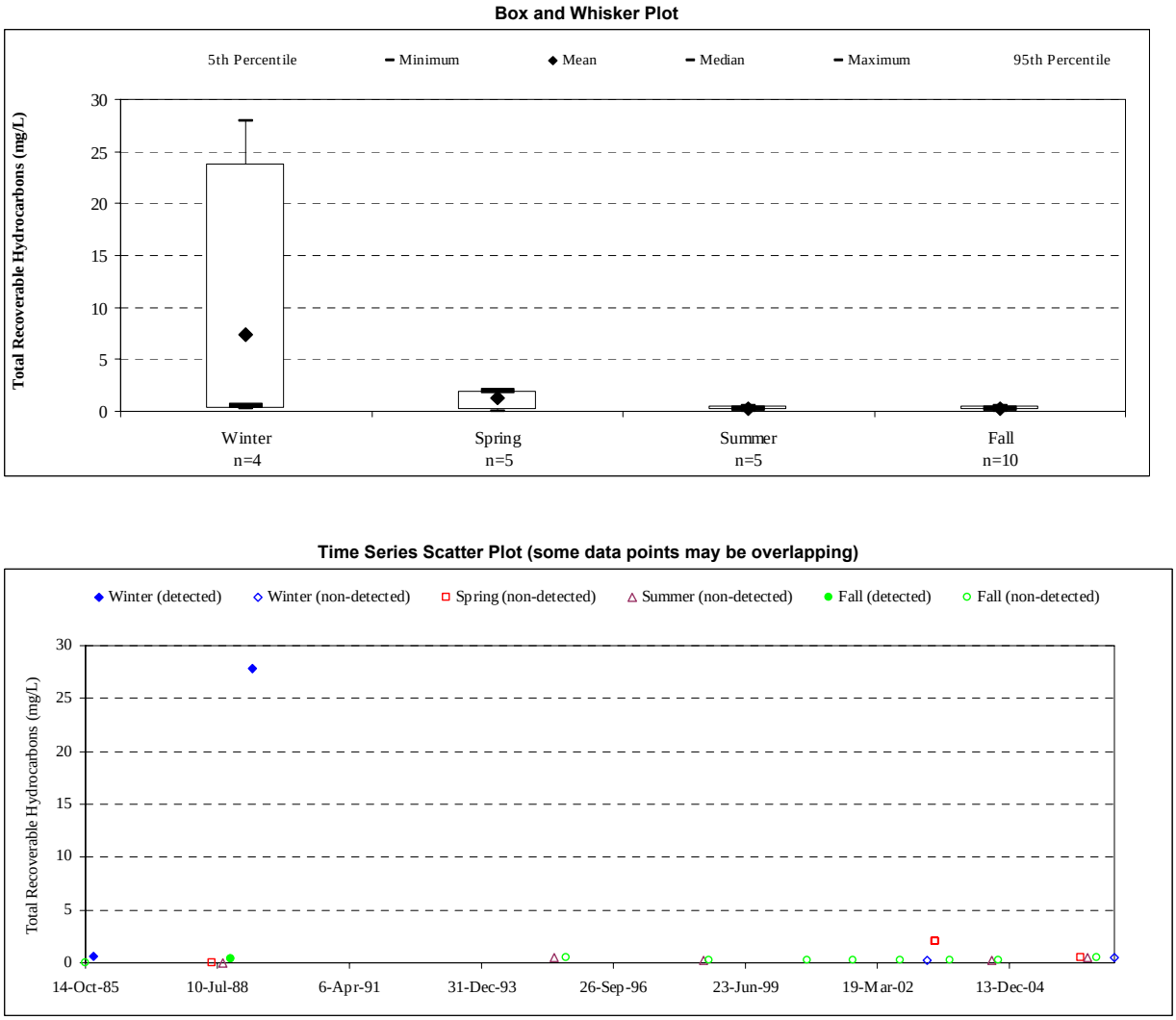
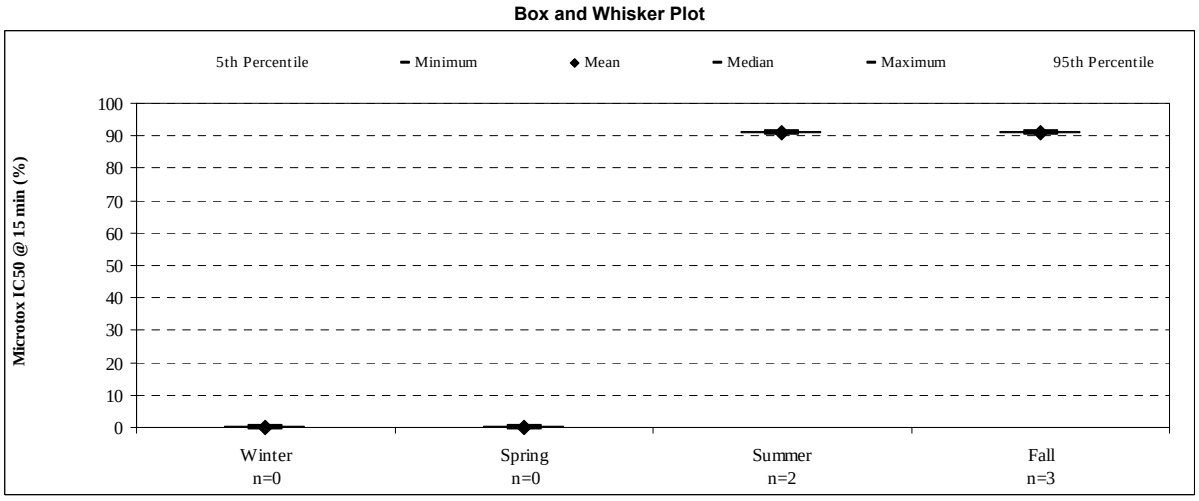


Figure G-2-8-32 Box Whisker and Time Series Scatter Plots of Observed Microtox IC50 @ 15 min in Kearl Lake



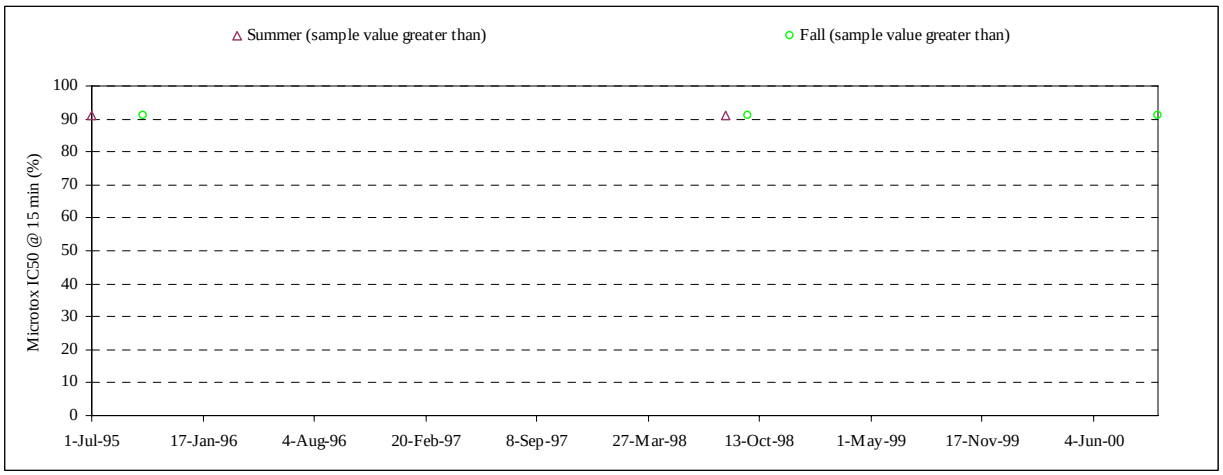
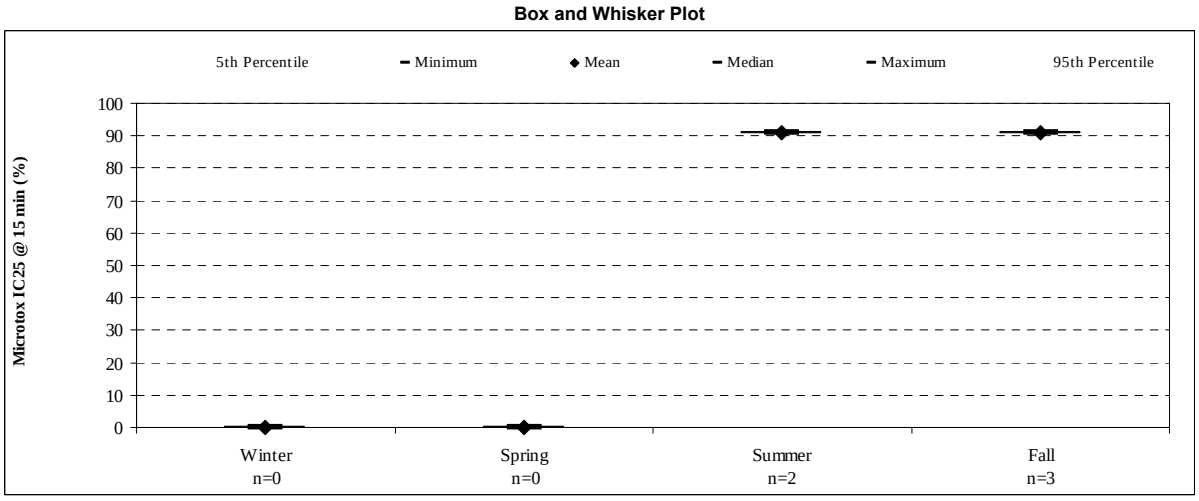


Figure G-2-8-33 Box Whisker and Time Series Scatter Plots of Observed Microtox IC25 @ 15 min in Kearl Lake



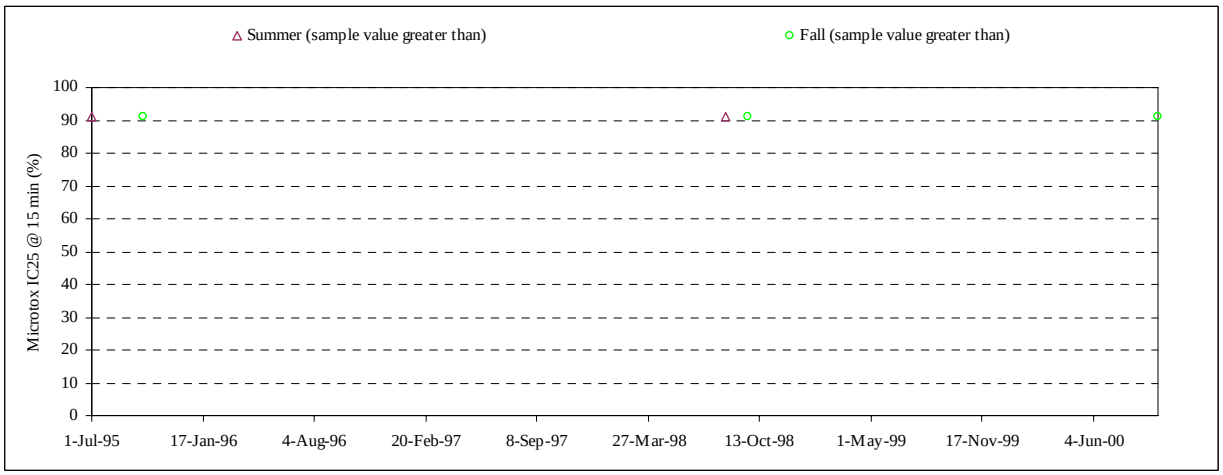
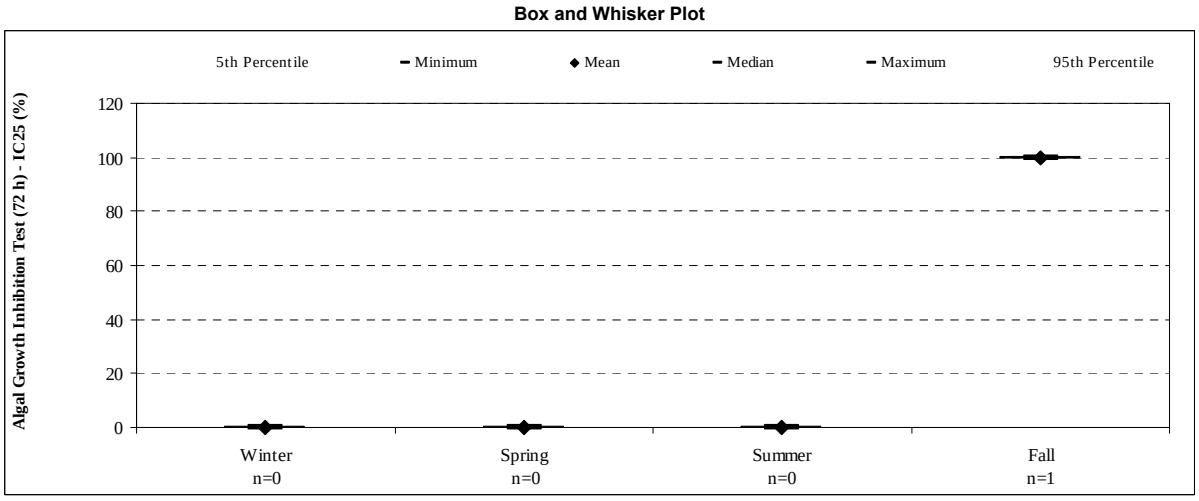


Figure G-2-8-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Kearl Lake



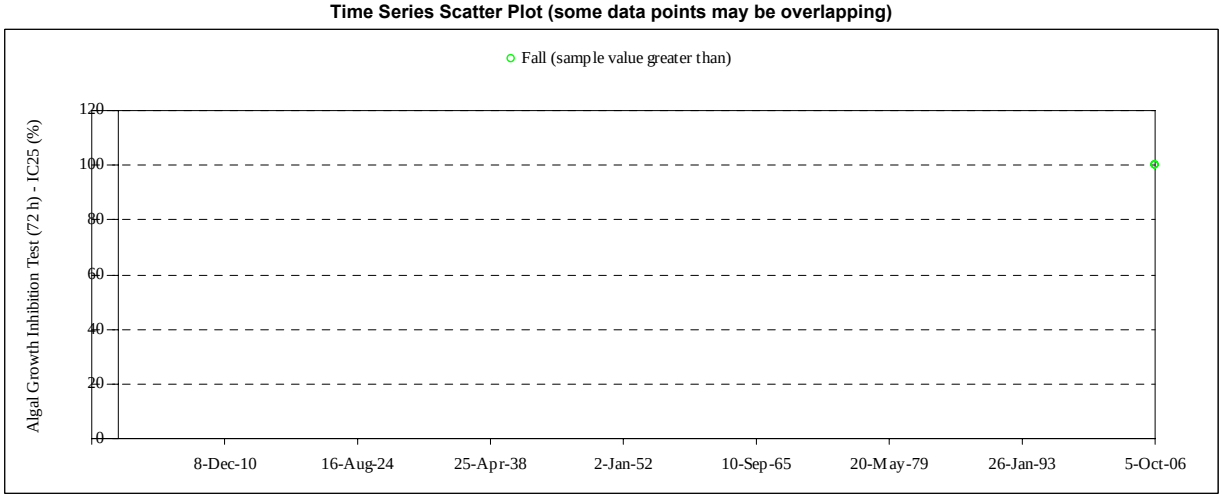
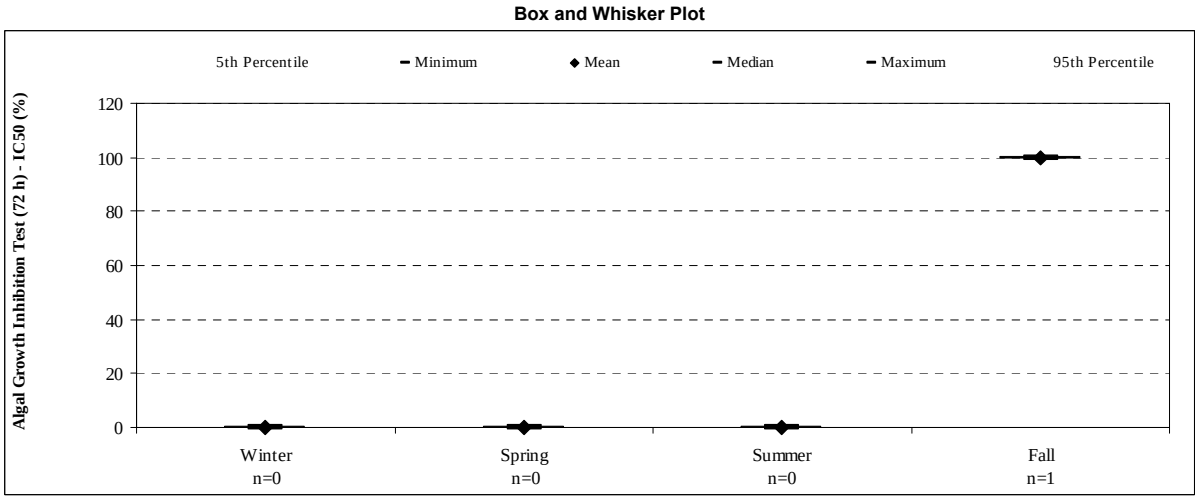


Figure G-2-8-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Kearl Lake



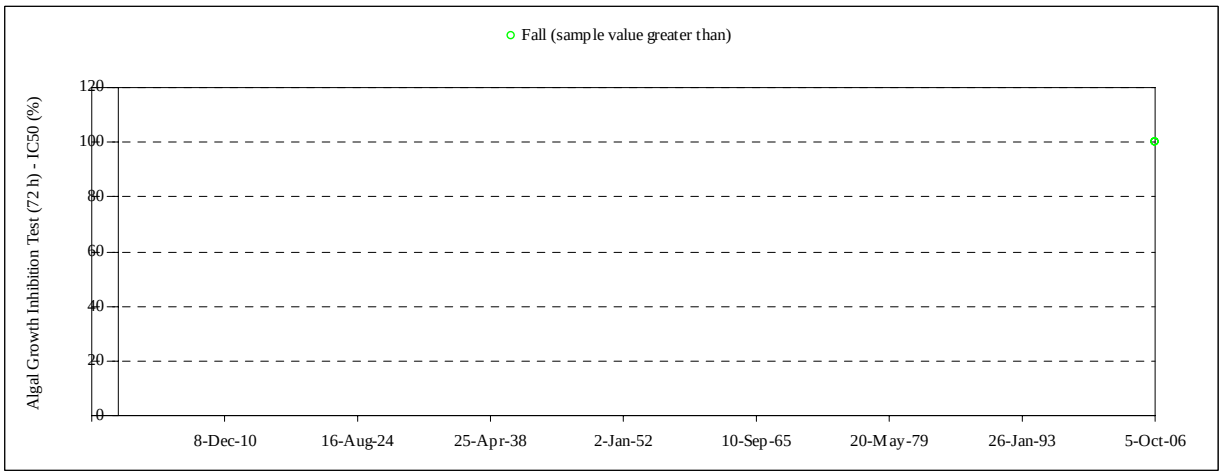
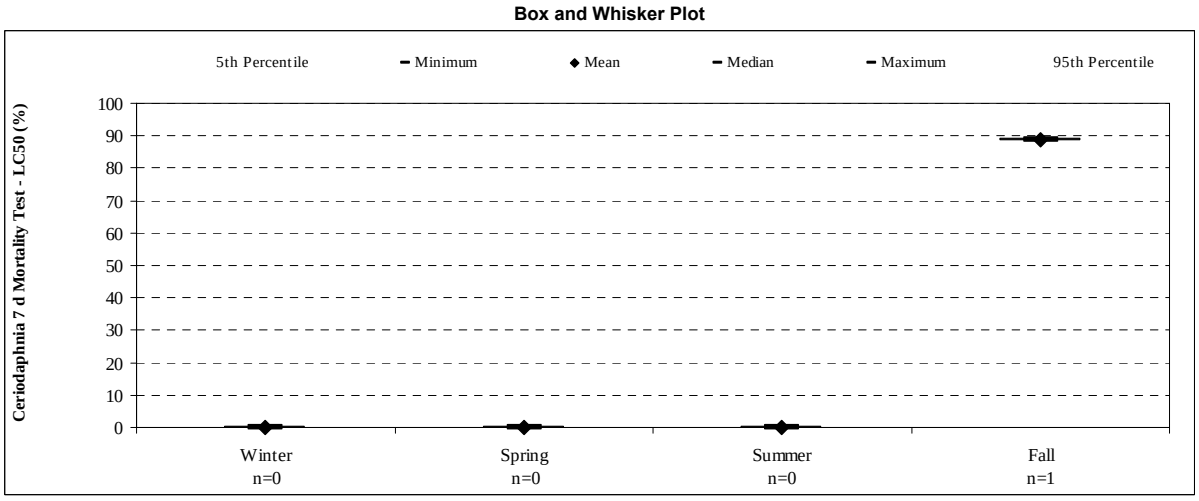


Figure G-2-8-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Kearl Lake



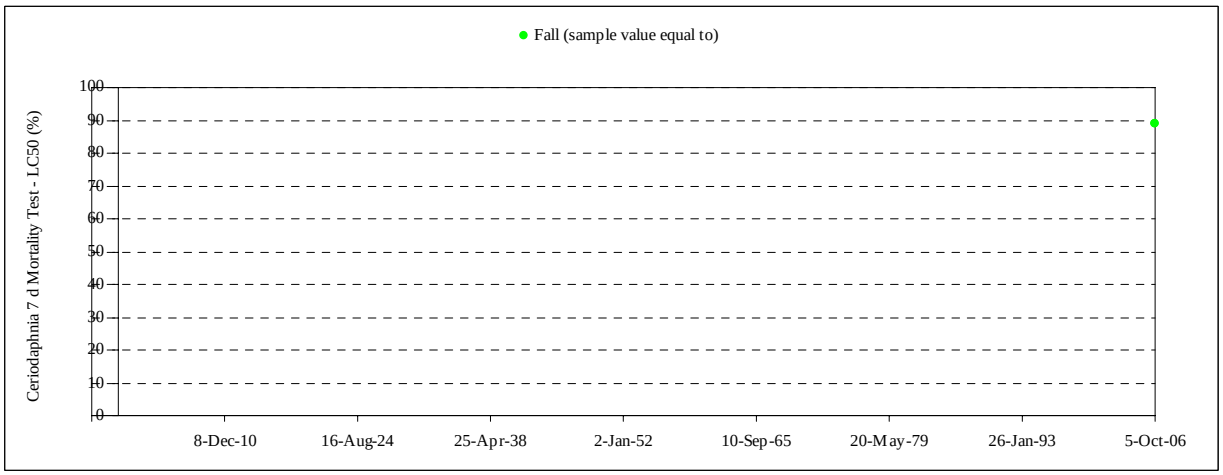
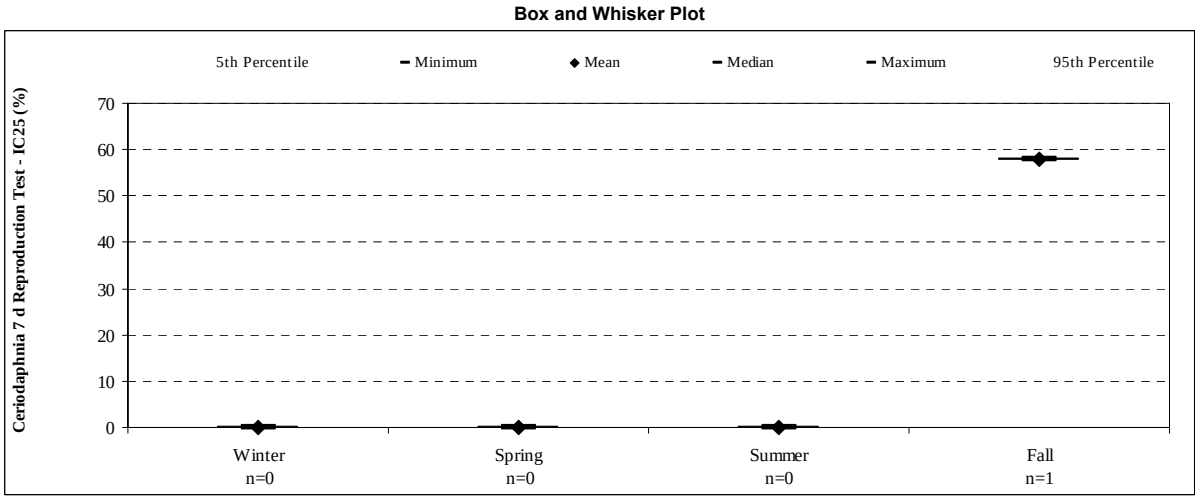


Figure G-2-8-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Kearl Lake



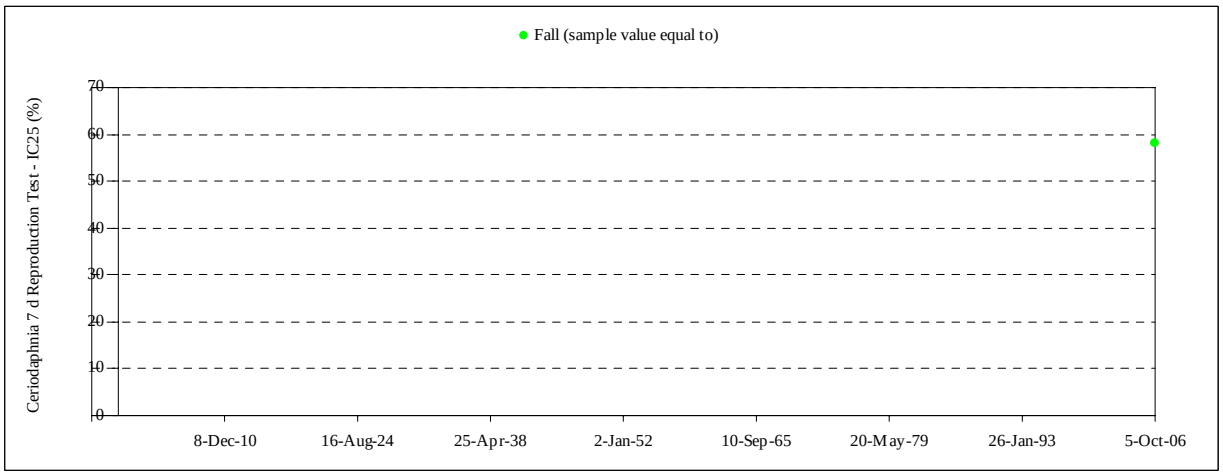
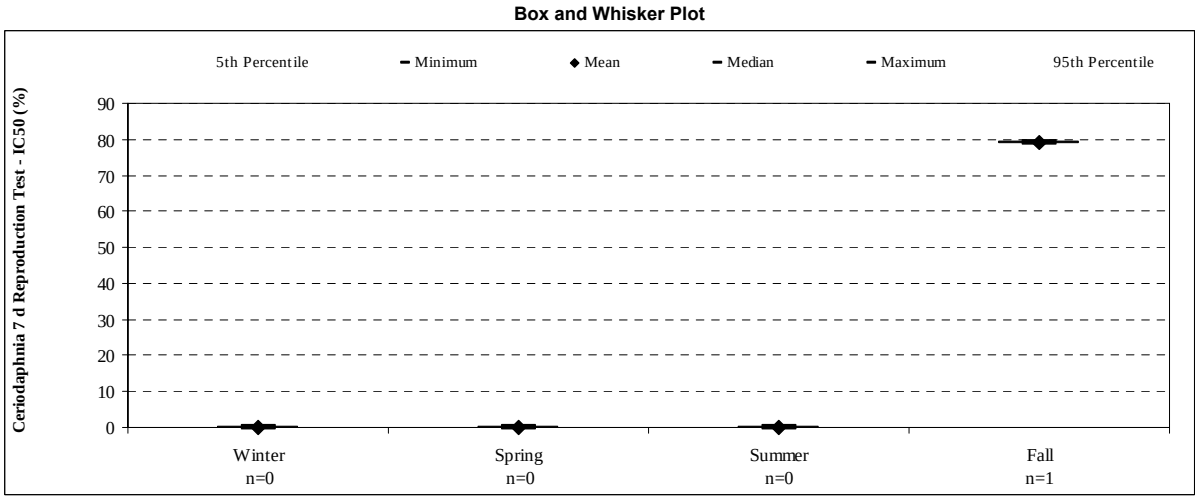


Figure G-2-8-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Kearl Lake



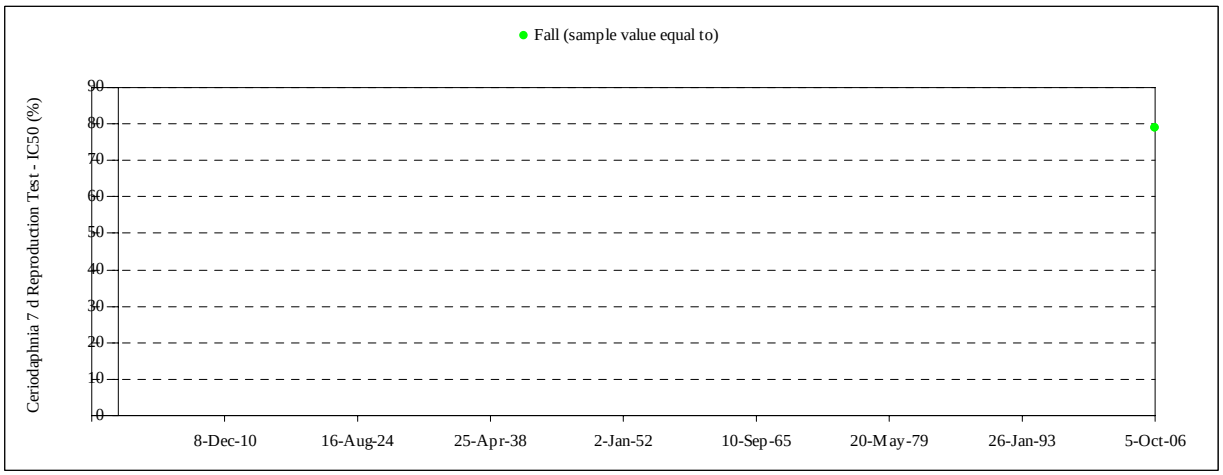


Figure G-2-8-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Kearl Lake

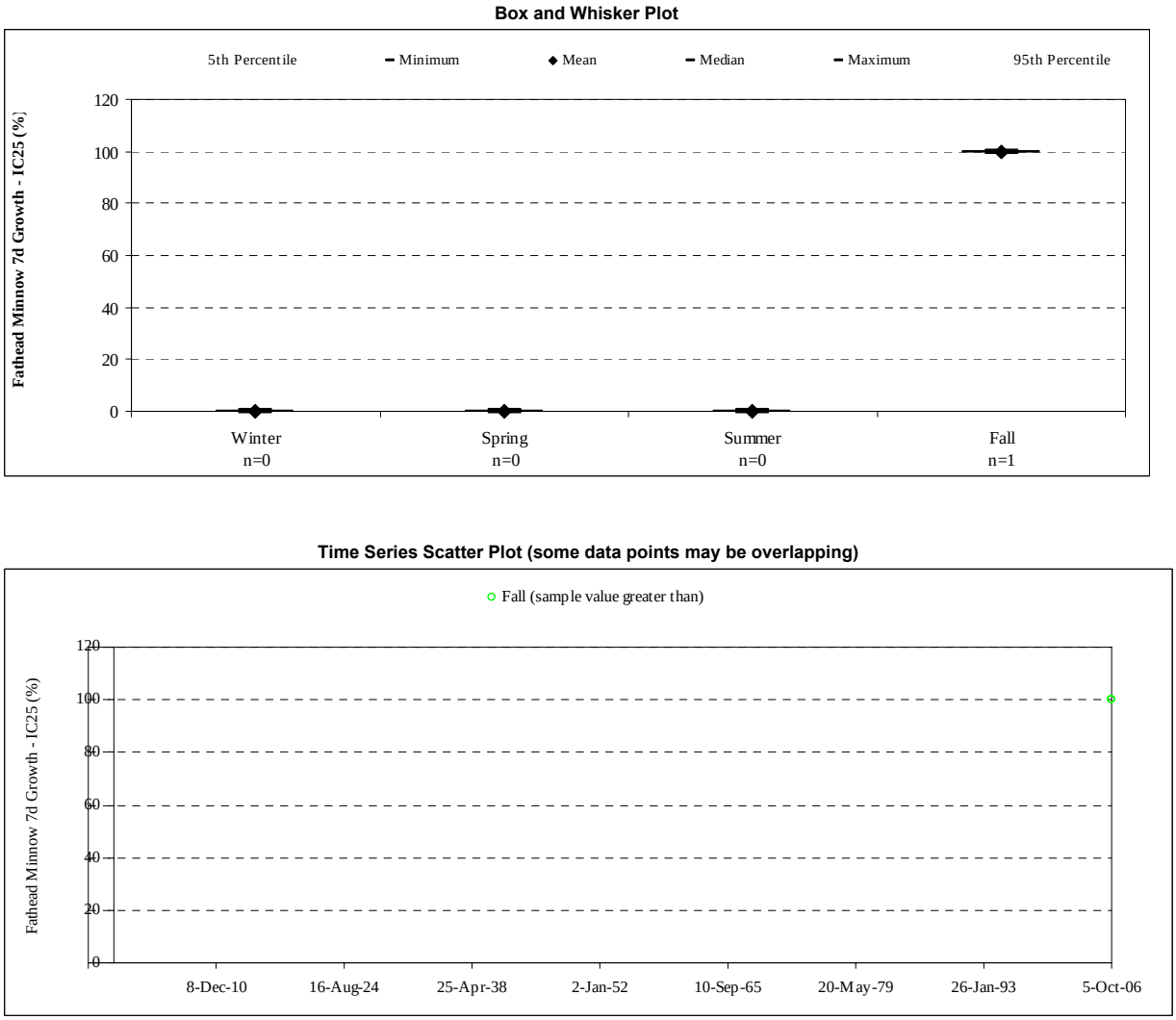
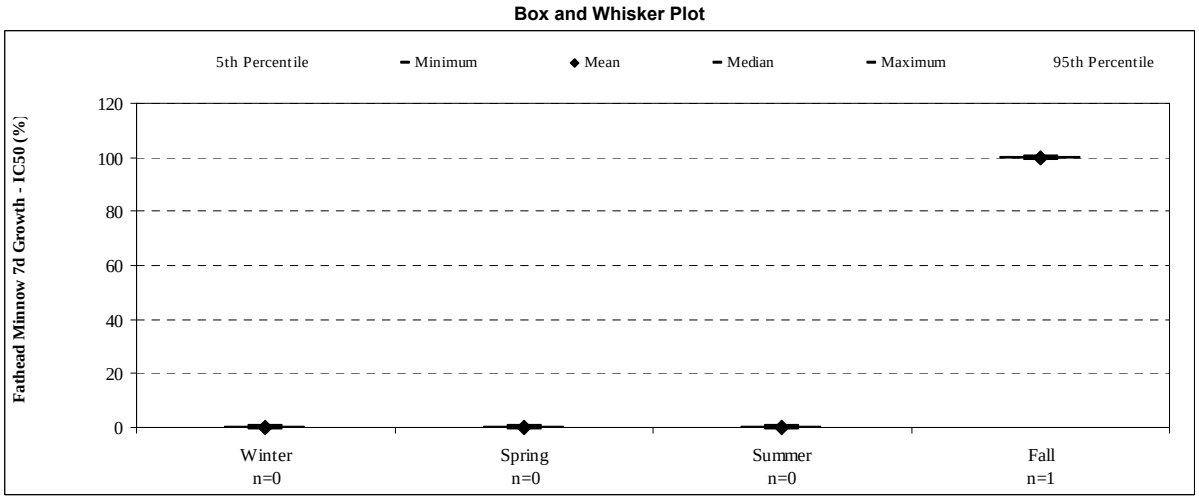


Figure G-2-8-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Kearl Lake



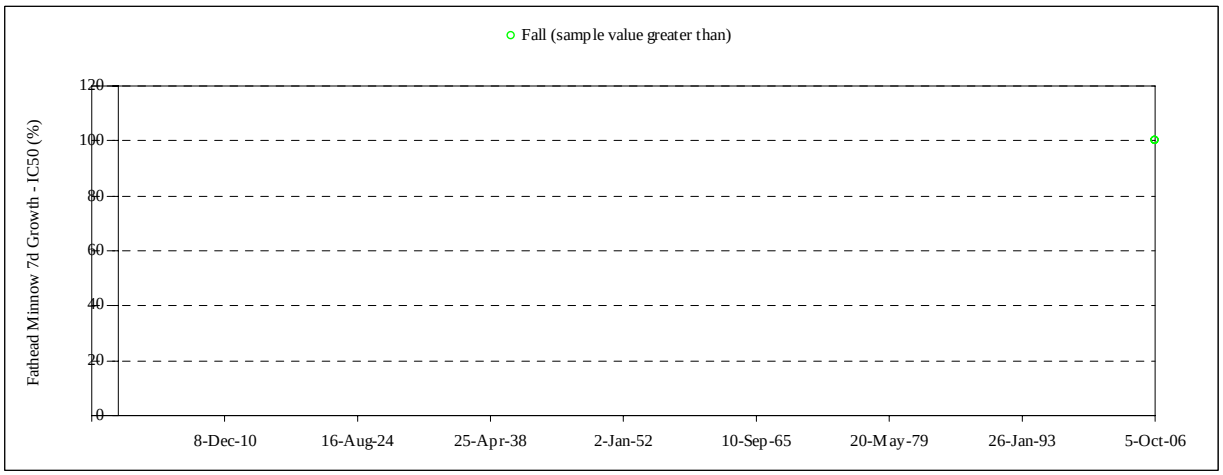
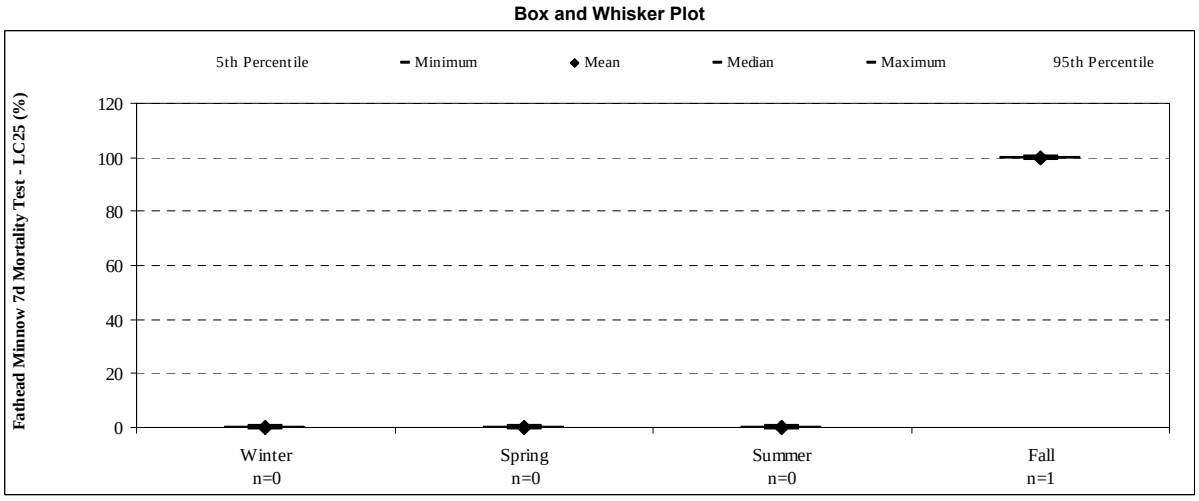


Figure G-2-8-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Kearl Lake



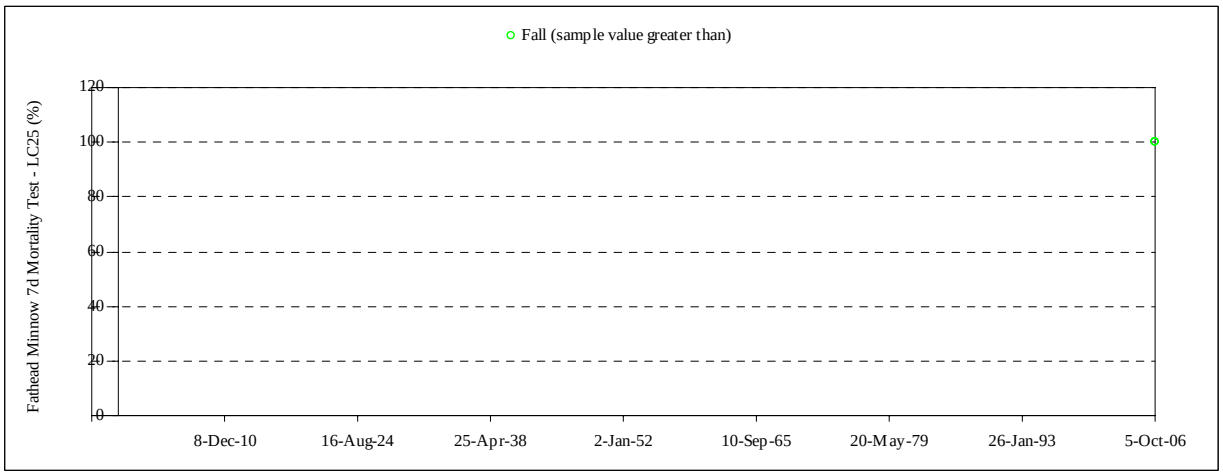
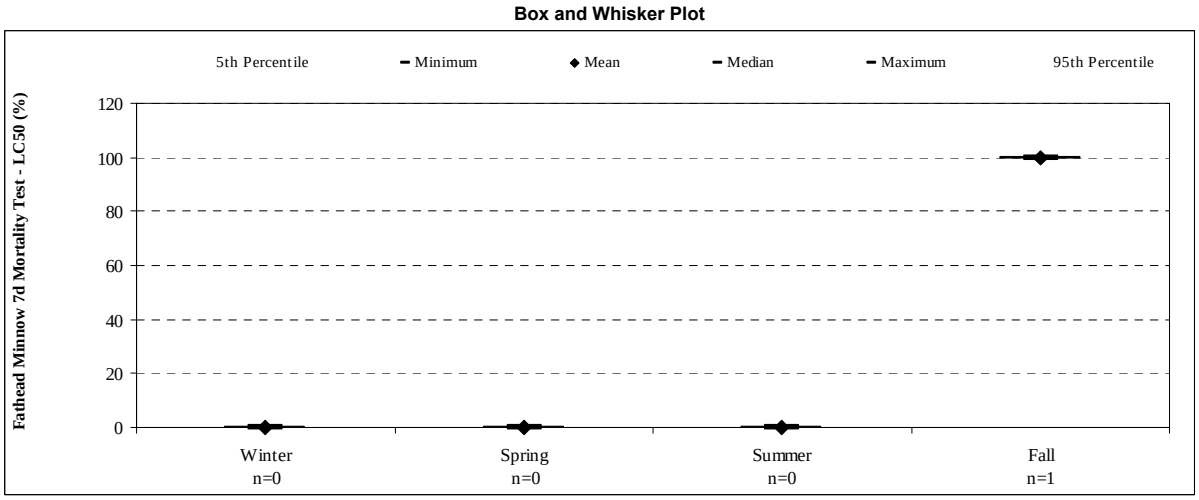


Figure G-2-8-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Kearl Lake



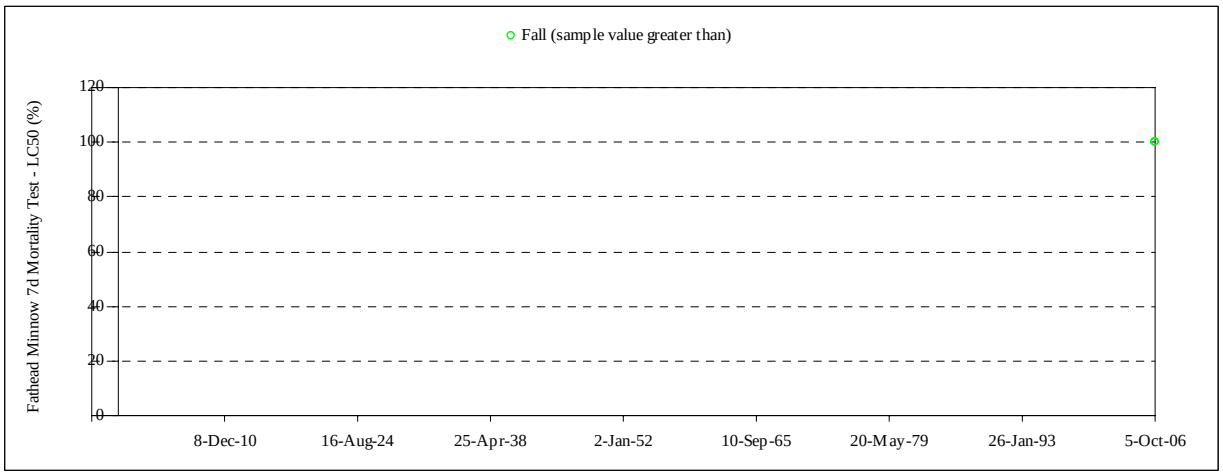
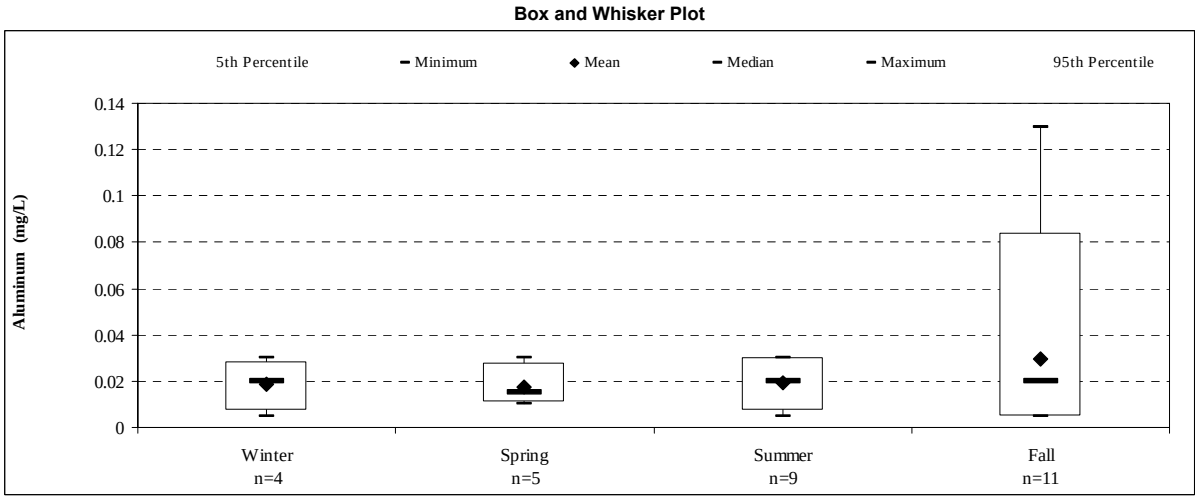


Figure G-2-8-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Kearl Lake



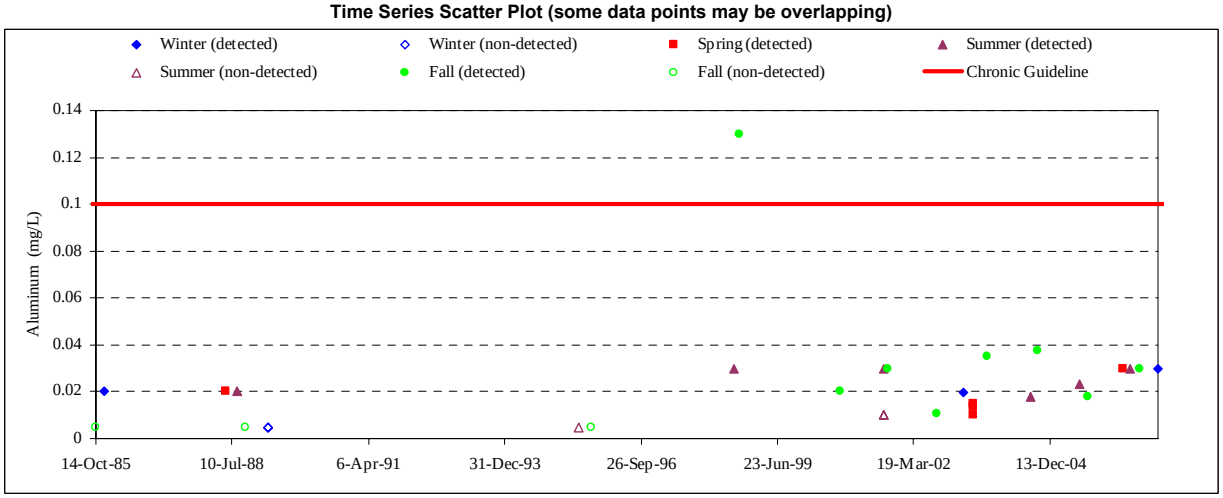
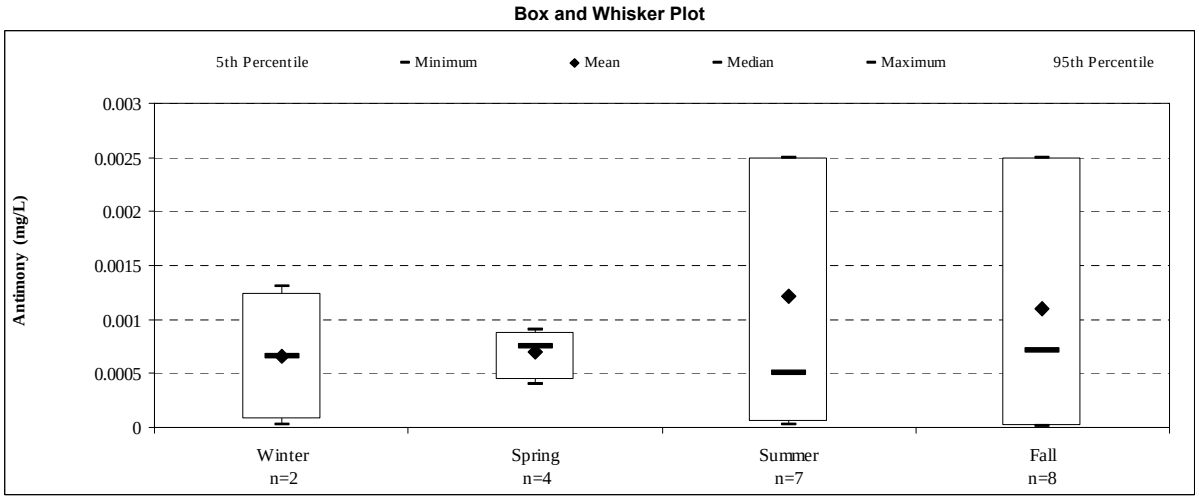


Figure G-2-8-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Kearl Lake



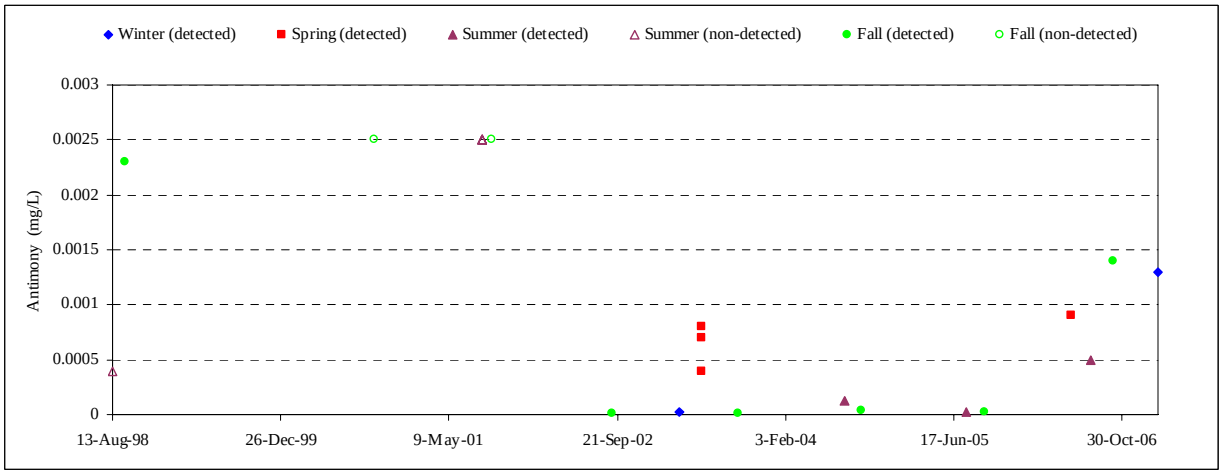
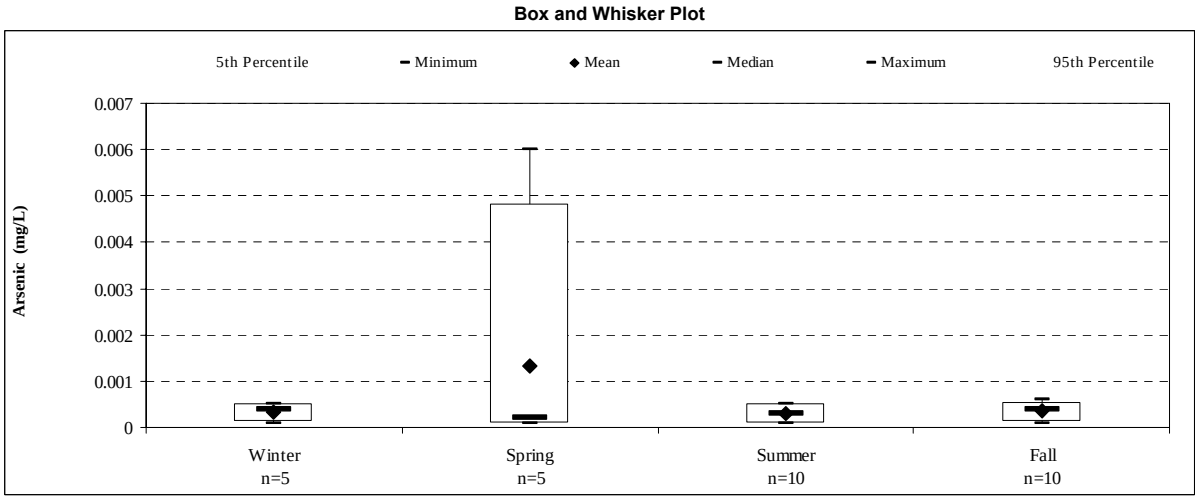


Figure G-2-8-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Kearl Lake



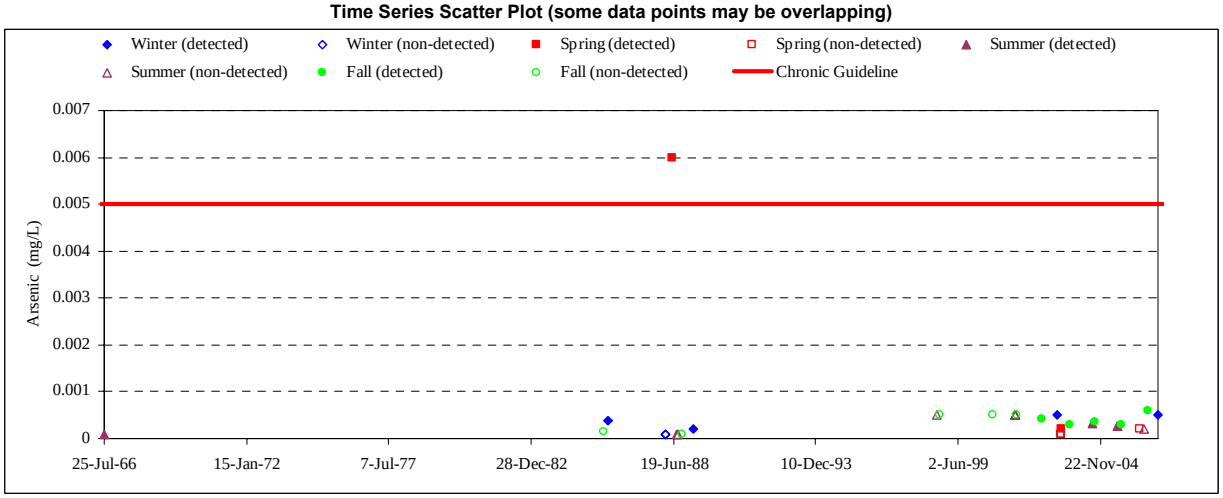
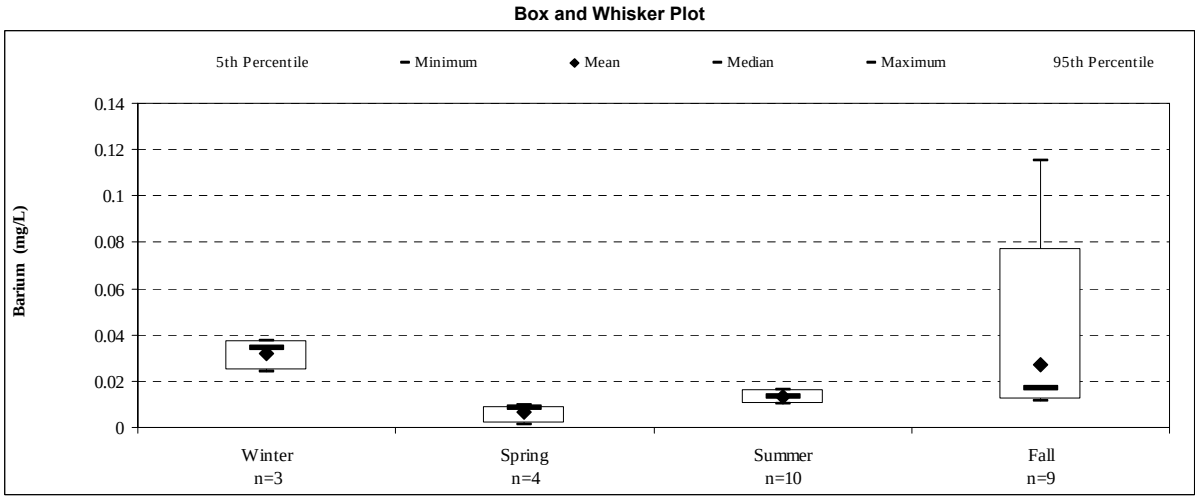


Figure G-2-8-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Kearl Lake



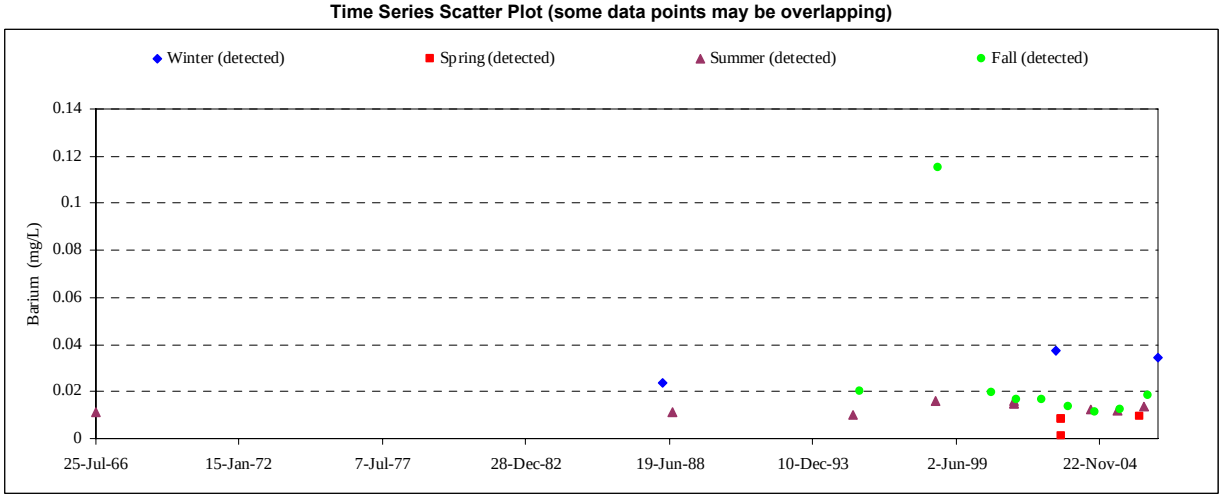
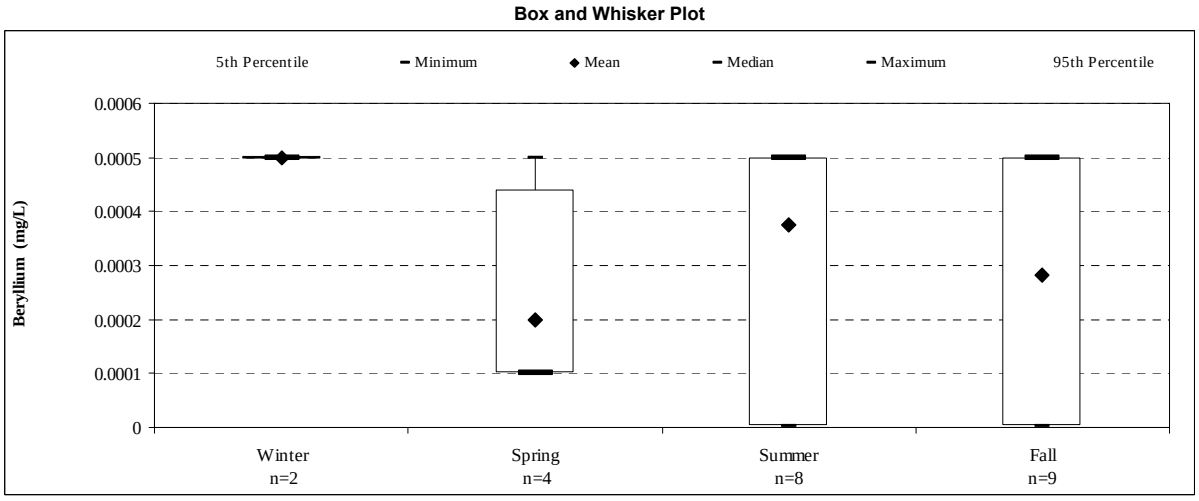


Figure G-2-8-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Kearl Lake



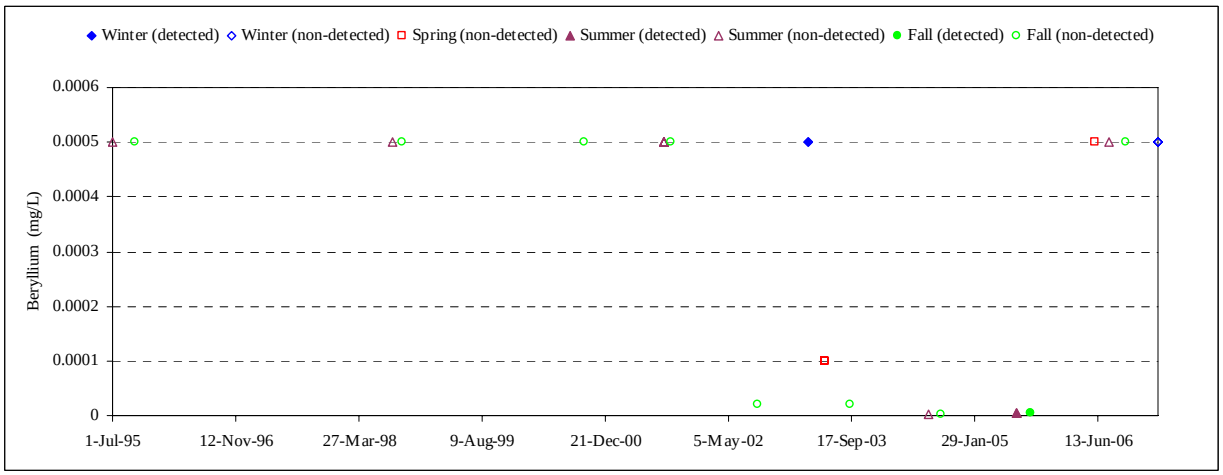


Figure G-2-8-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Kearl Lake

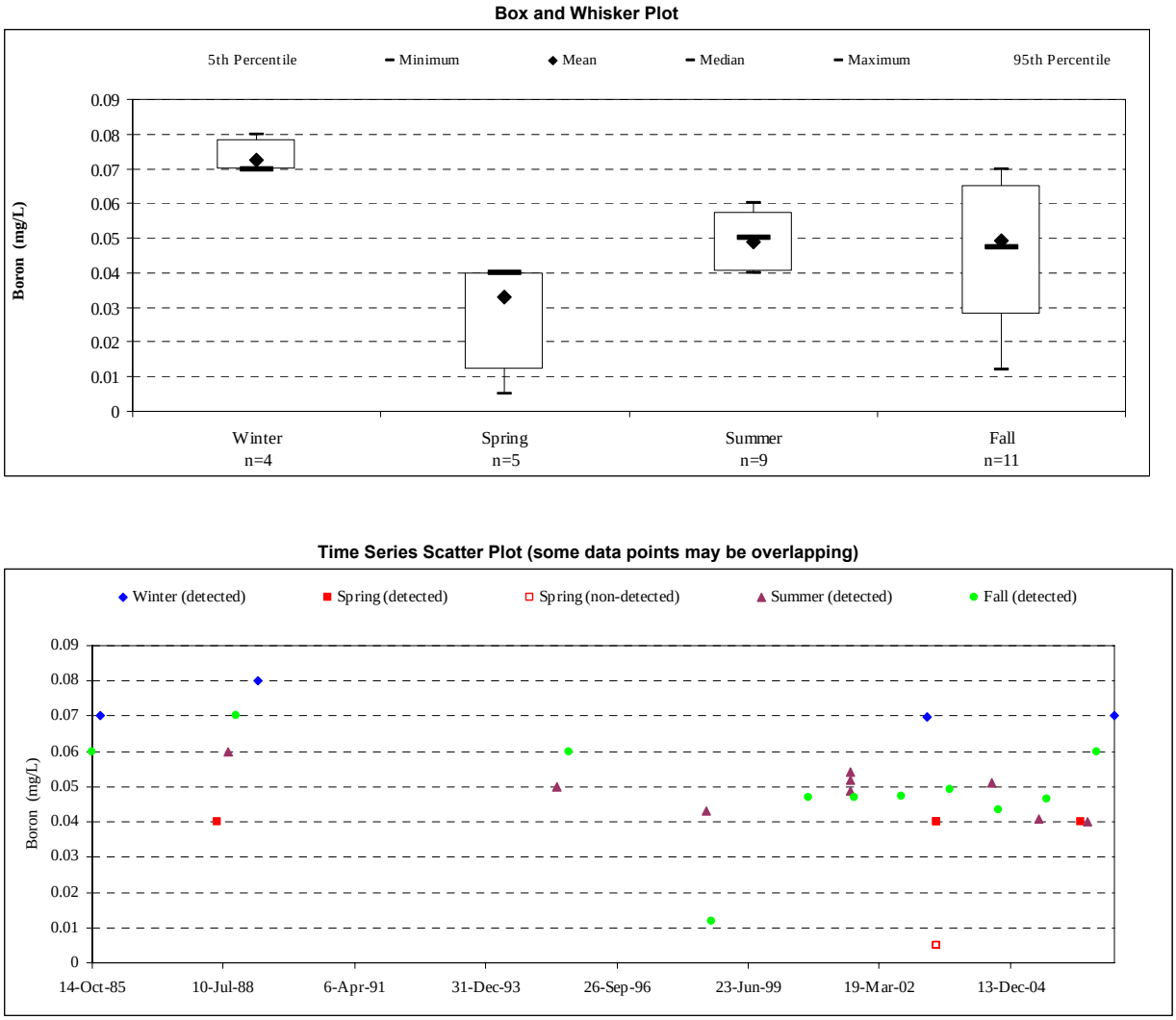
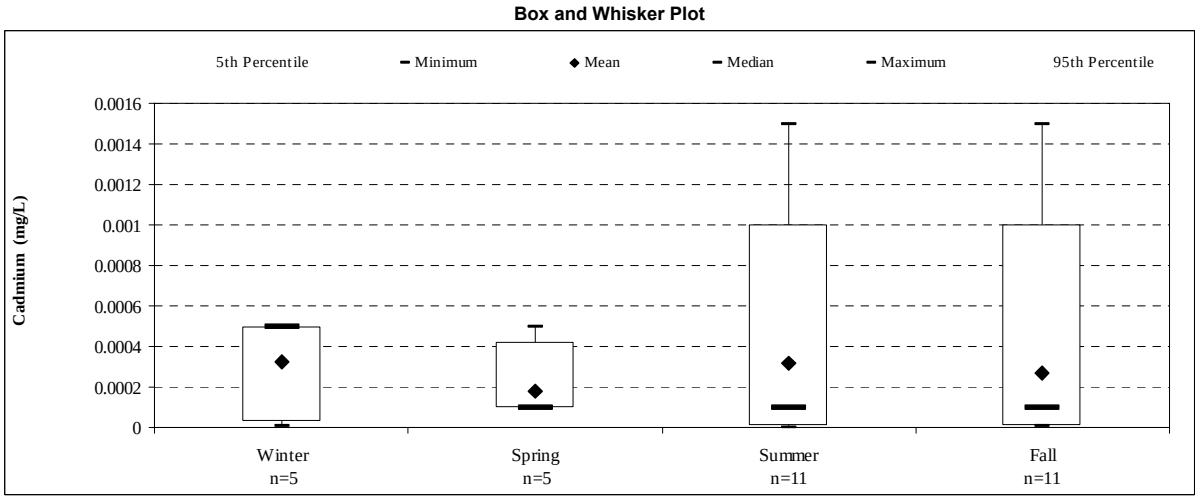


Figure G-2-8-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Kearl Lake



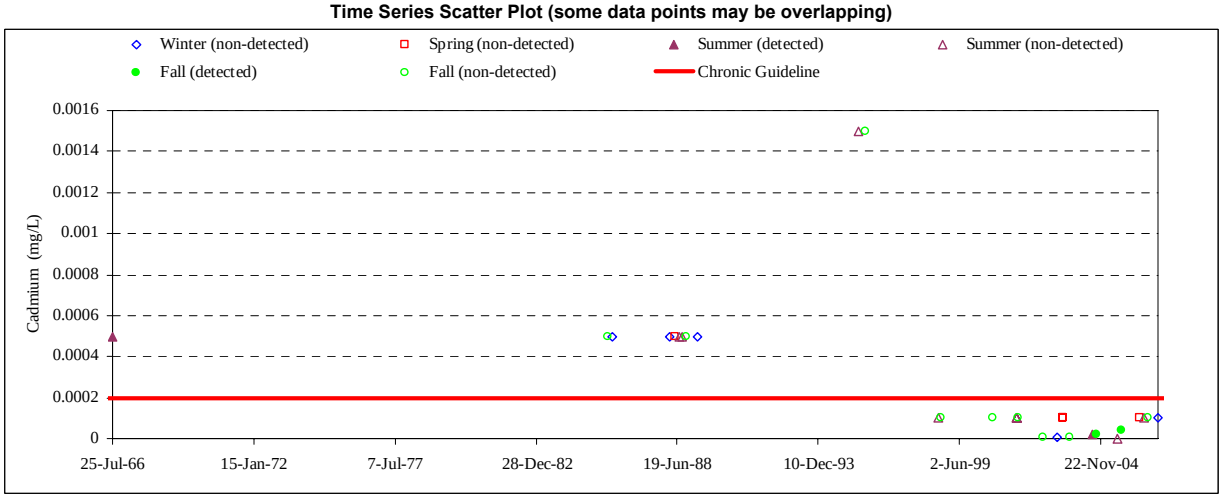
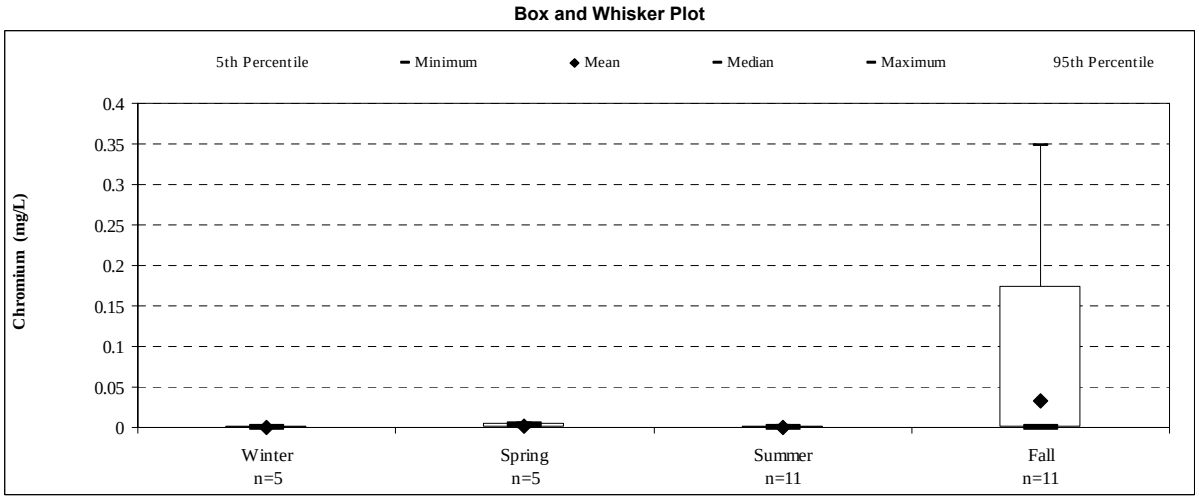


Figure G-2-8-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Kearl Lake



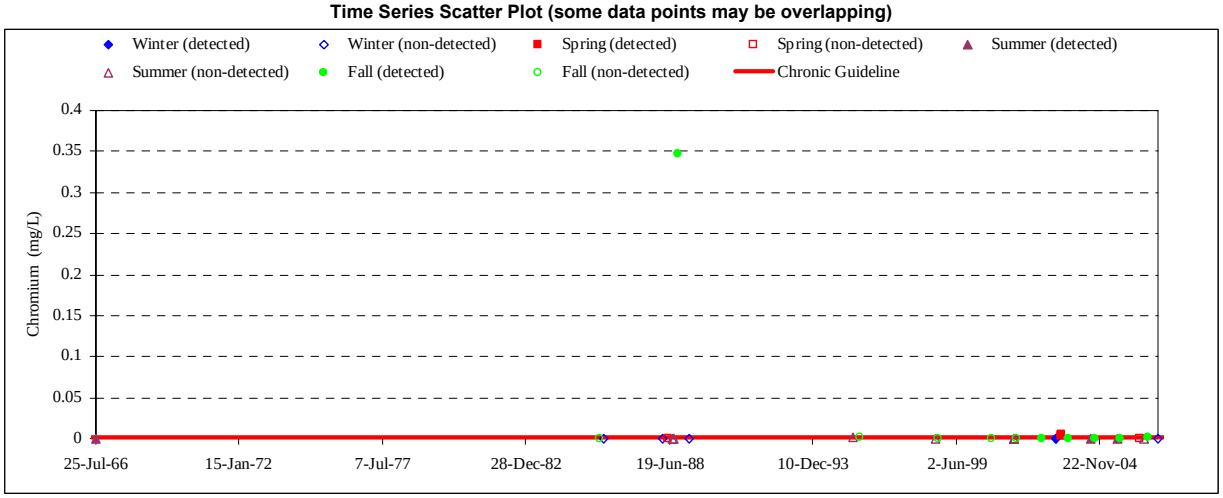
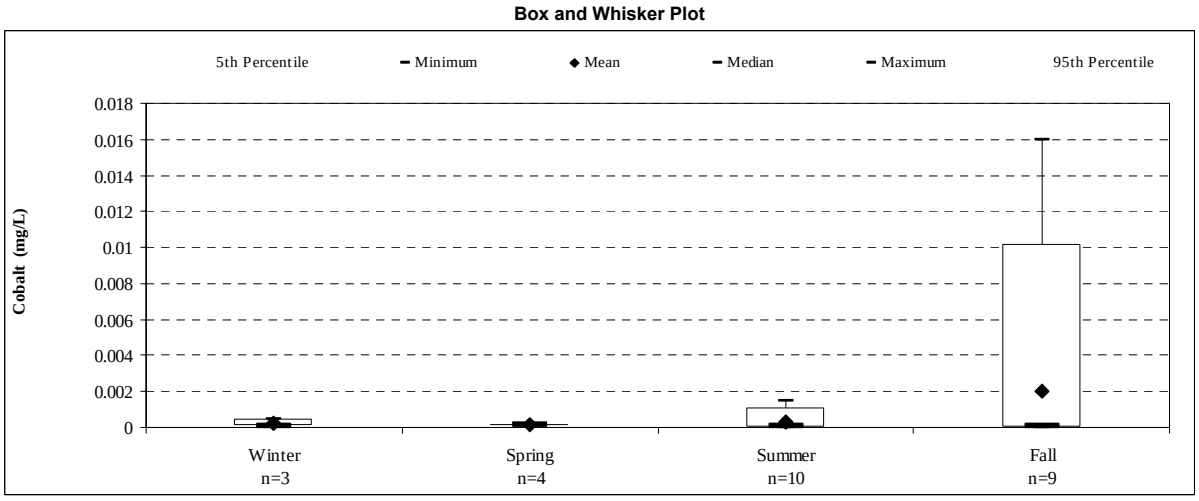


Figure G-2-8-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Kearl Lake



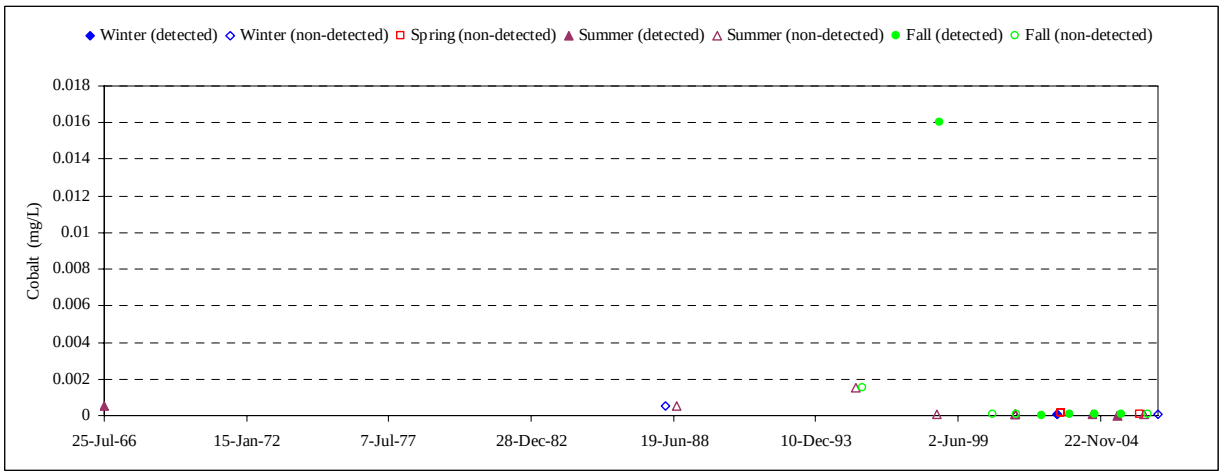
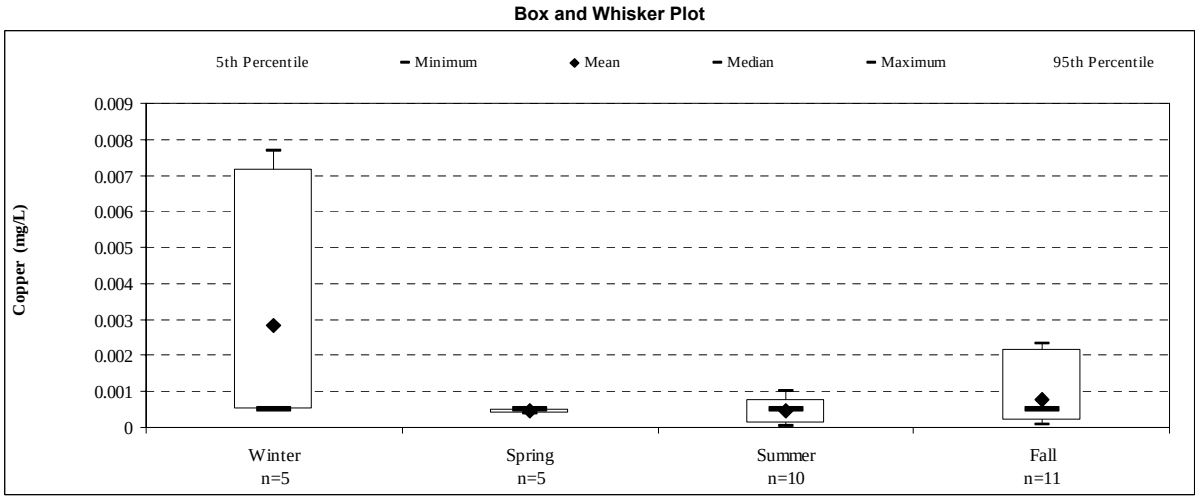


Figure G-2-8-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Kearl Lake



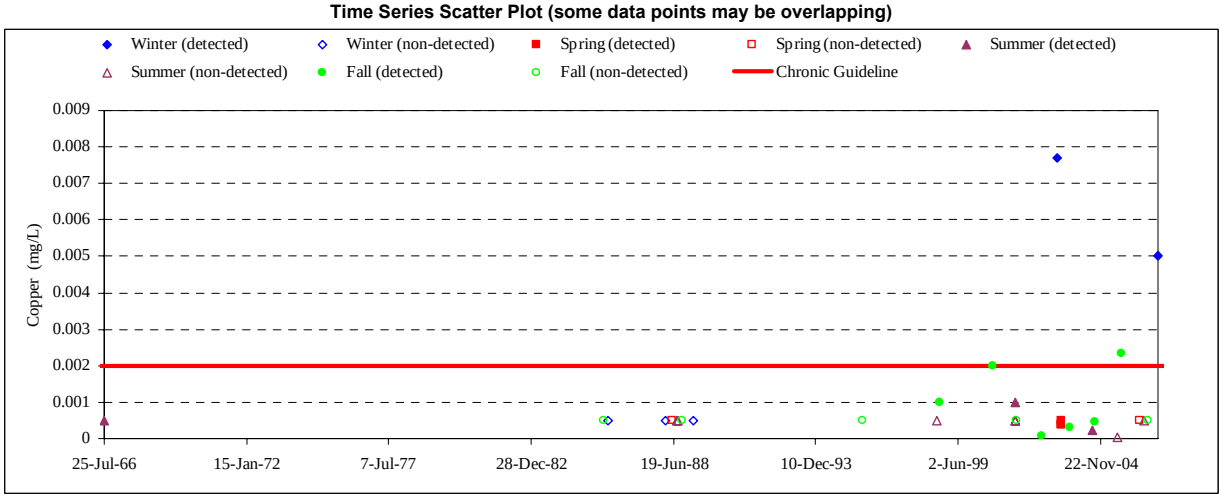
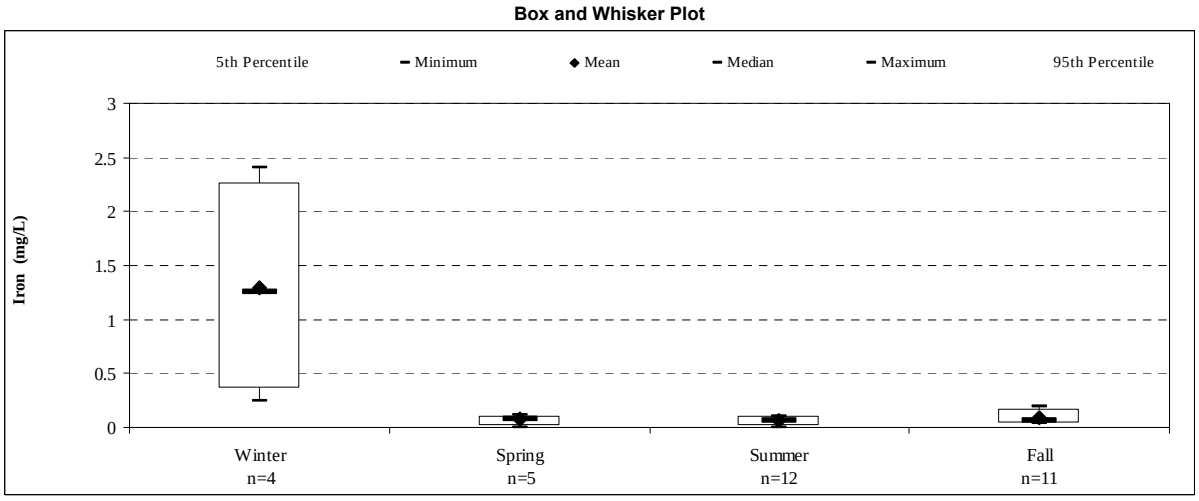


Figure G-2-8-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Kearl Lake



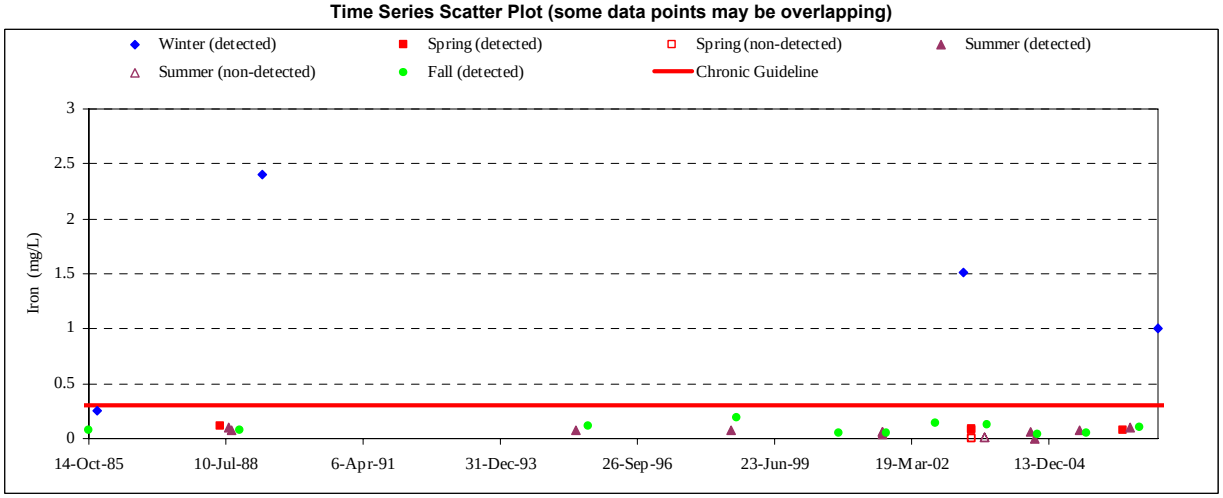
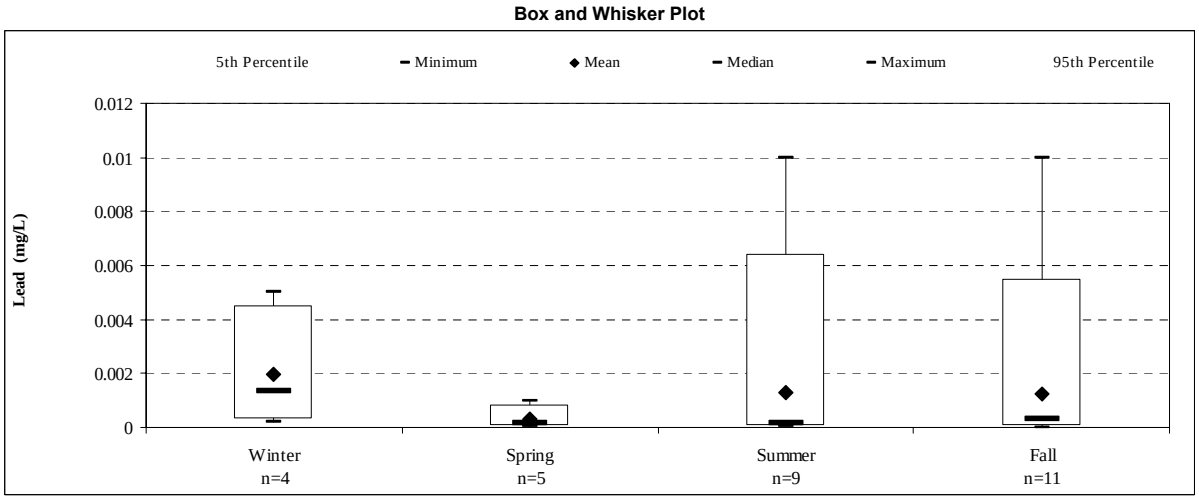


Figure G-2-8-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Kearl Lake



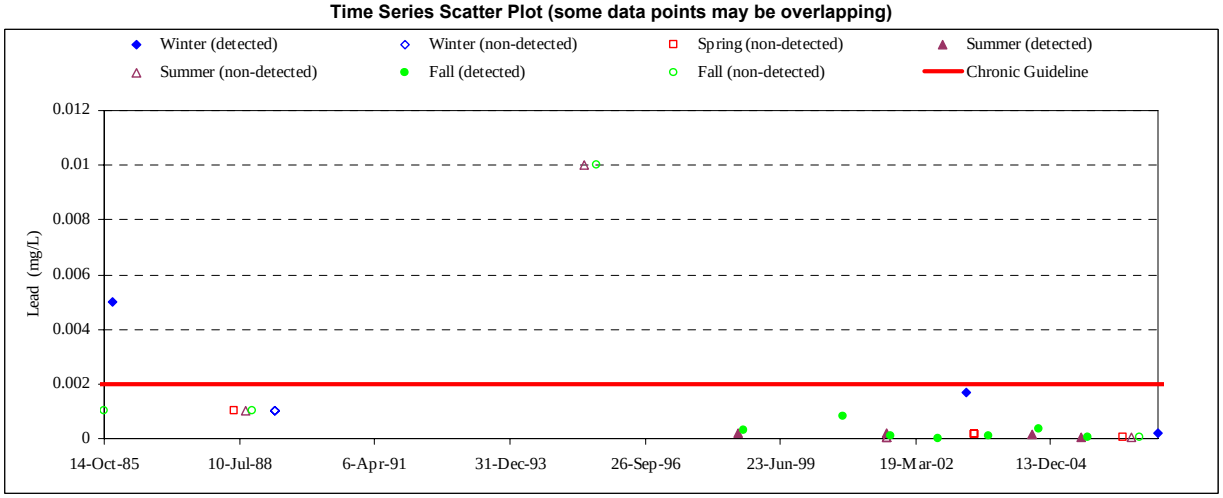
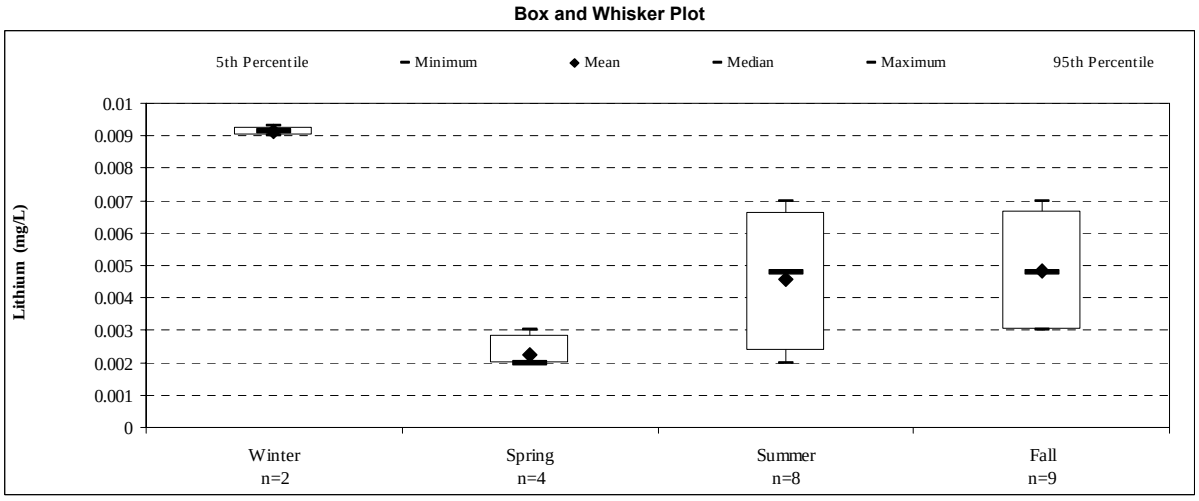


Figure G-2-8-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Kearl Lake



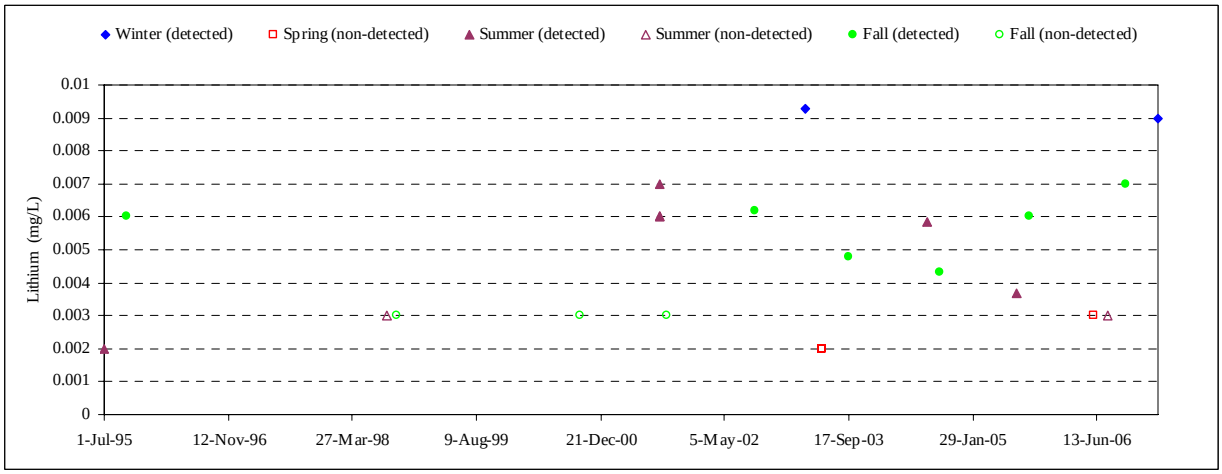
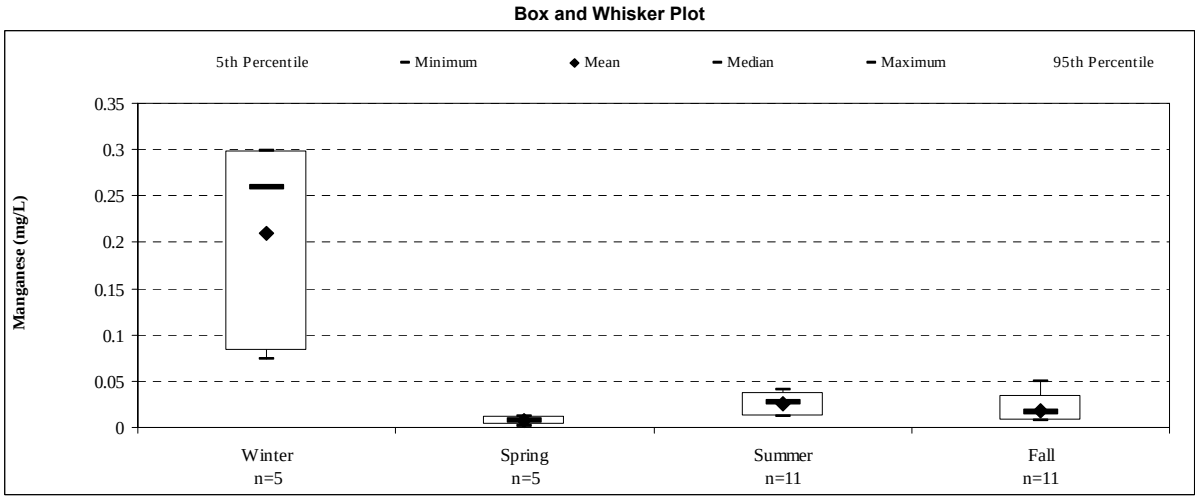


Figure G-2-8-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Kearl Lake



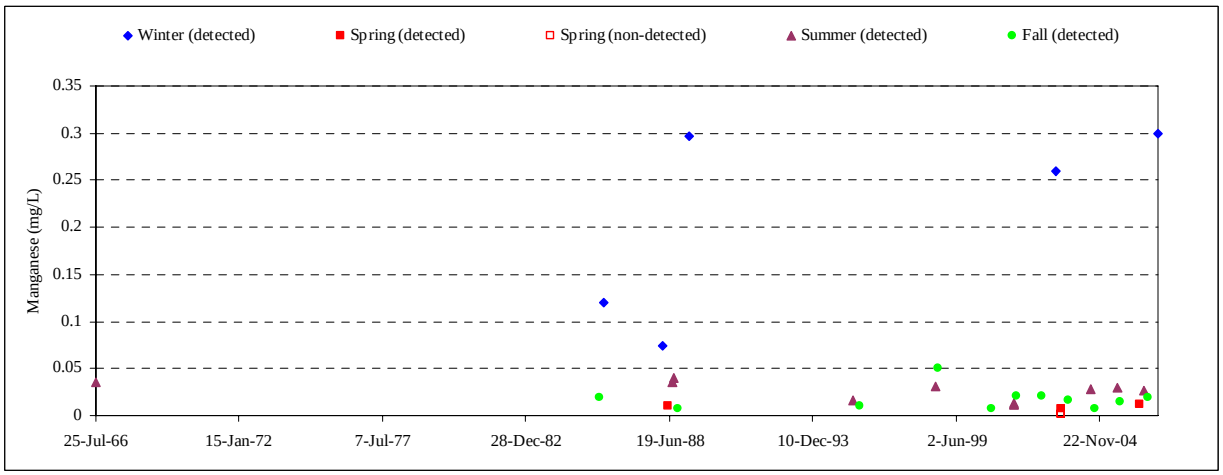
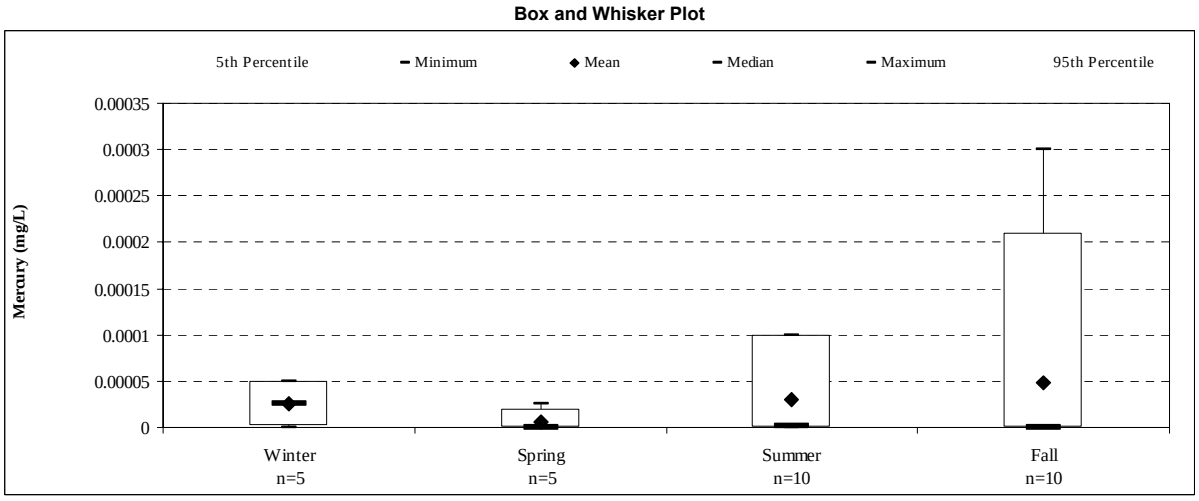


Figure G-2-8-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Kearl Lake



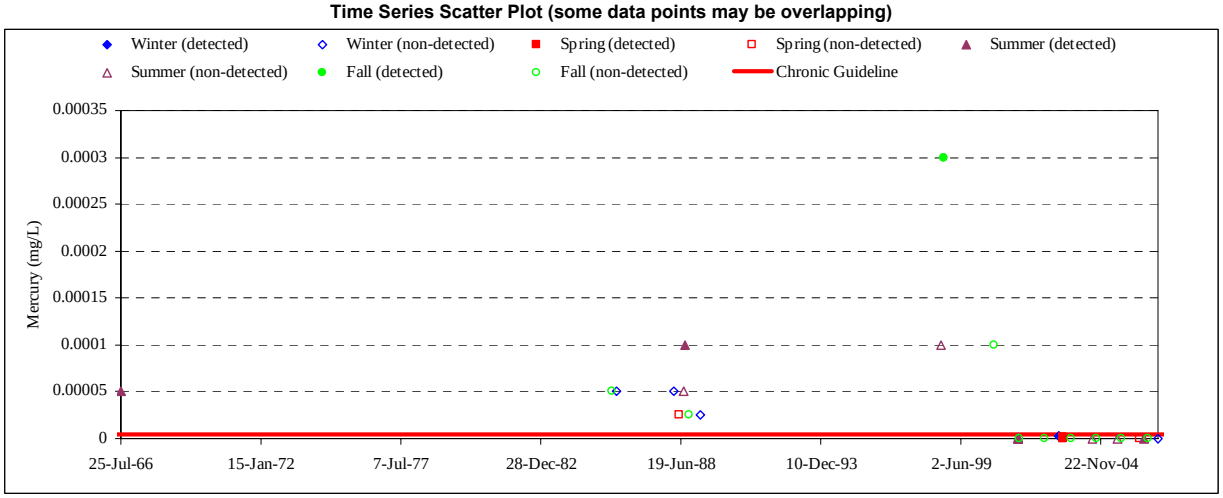
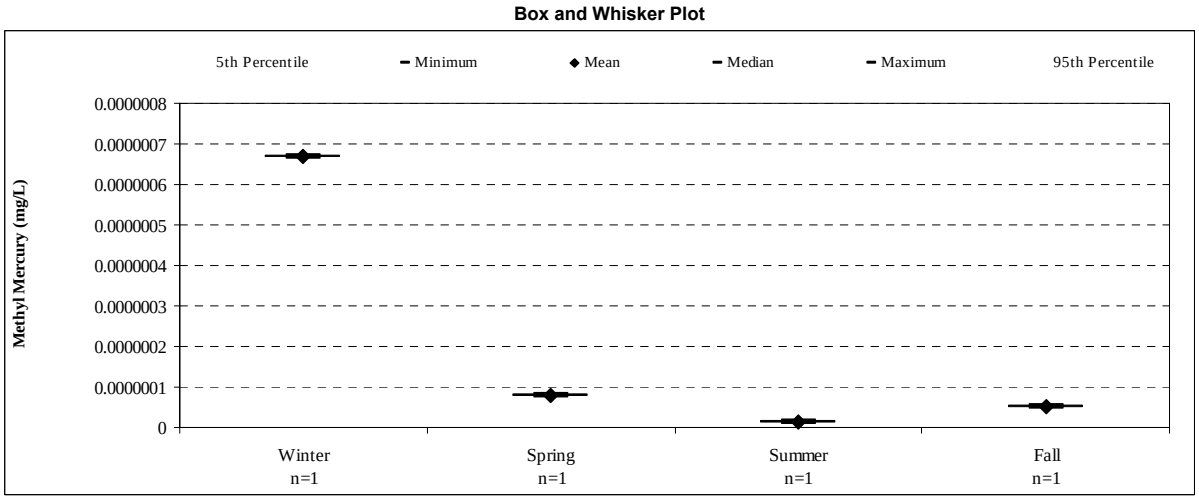


Figure G-2-8-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Kearl Lake



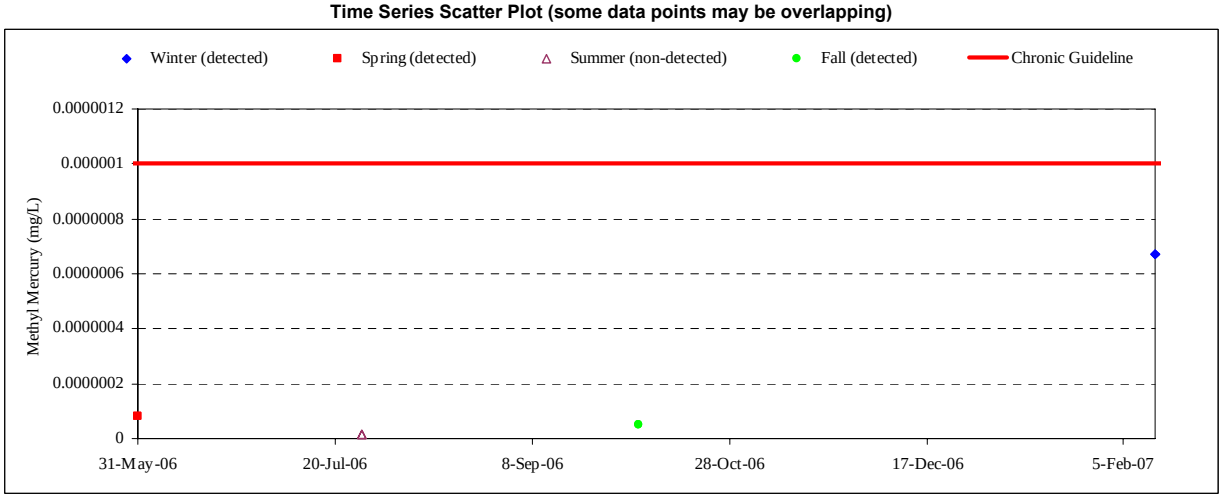
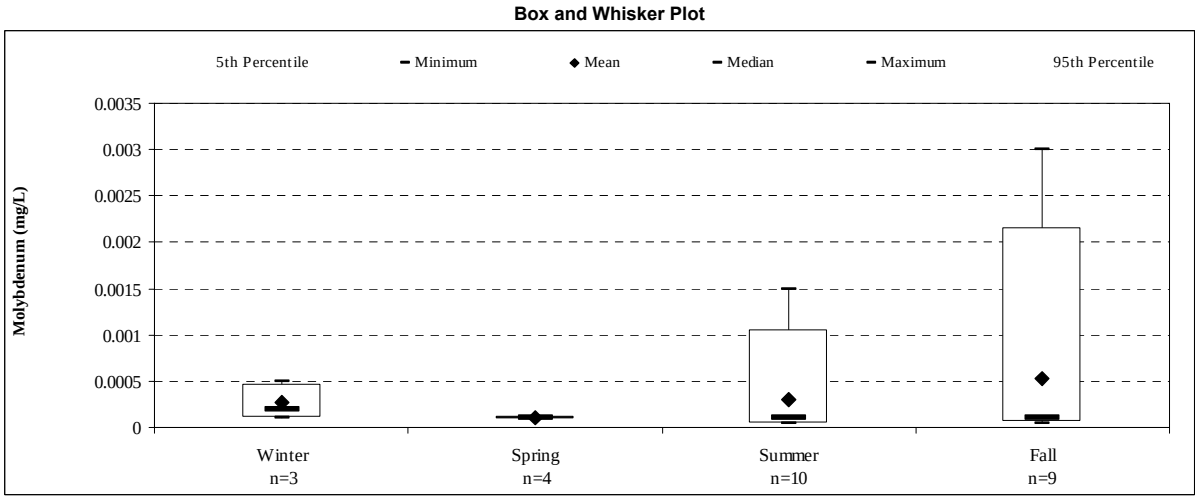


Figure G-2-8-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Kearl Lake



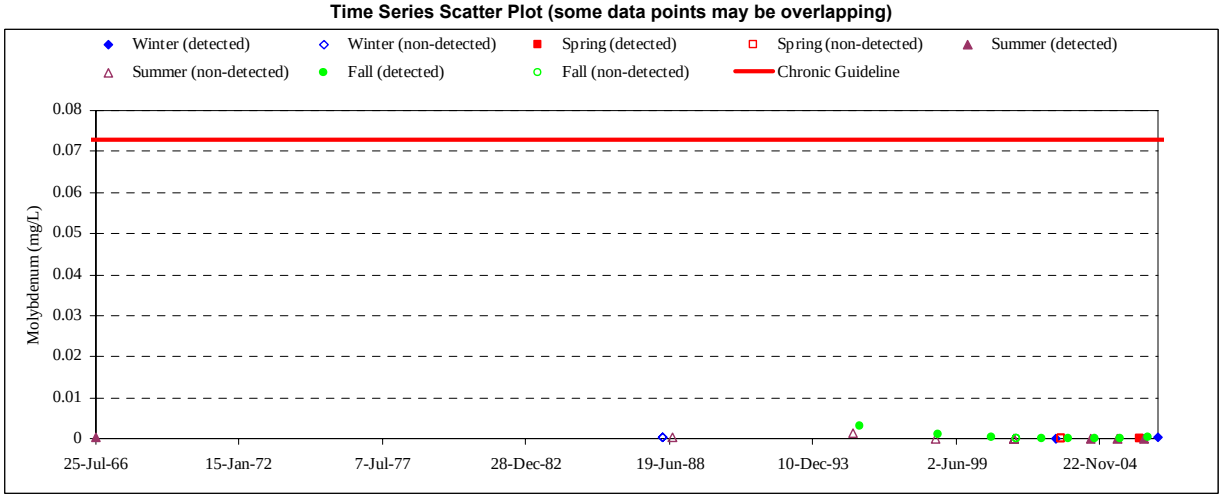
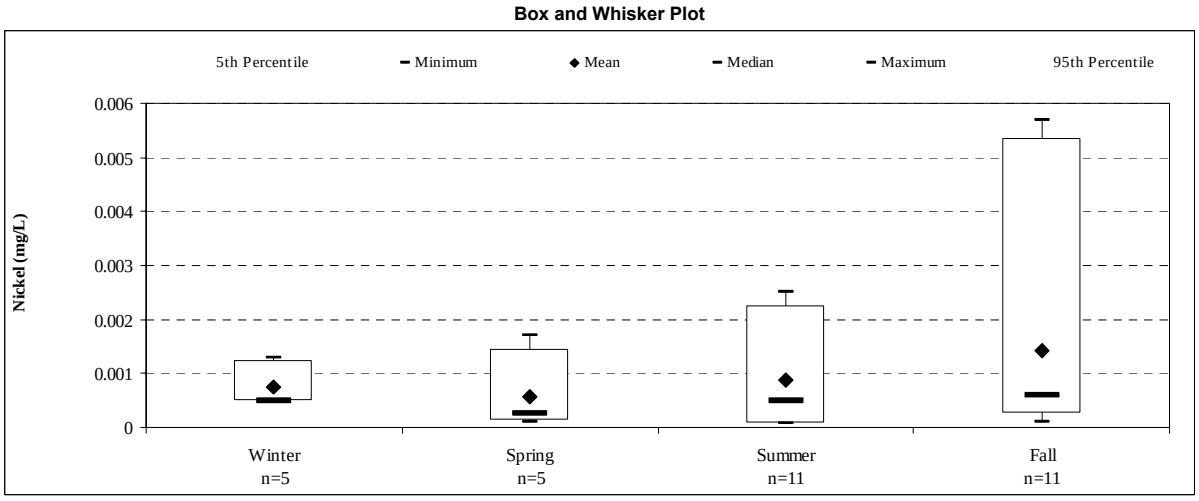


Figure G-2-8-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Kearl Lake



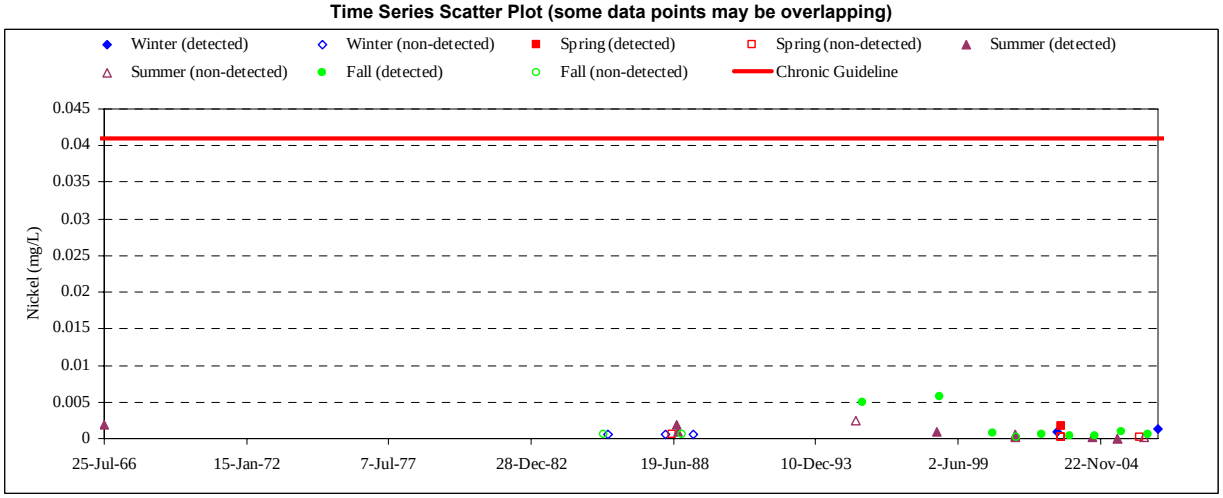
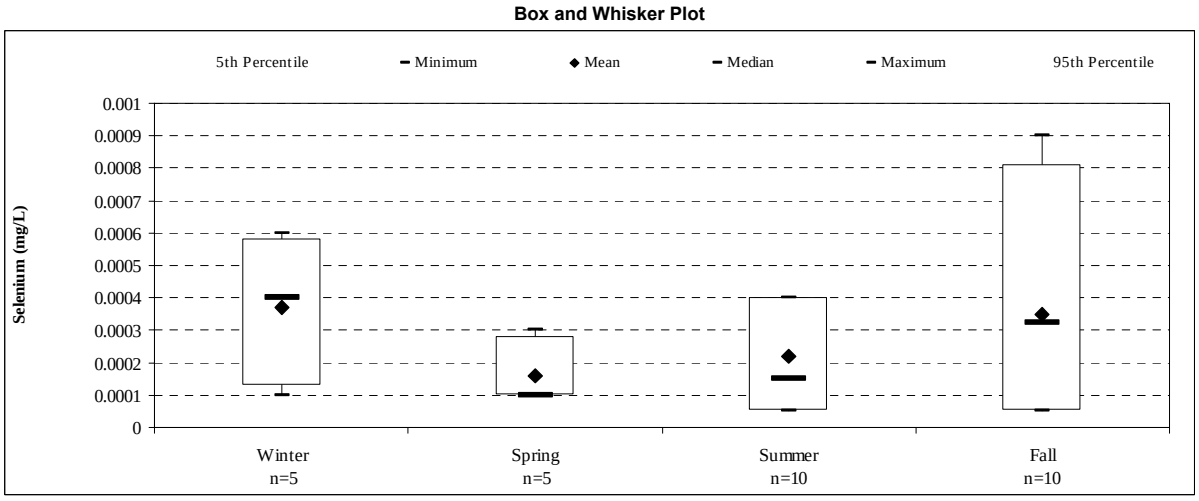


Figure G-2-8-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Kearl Lake



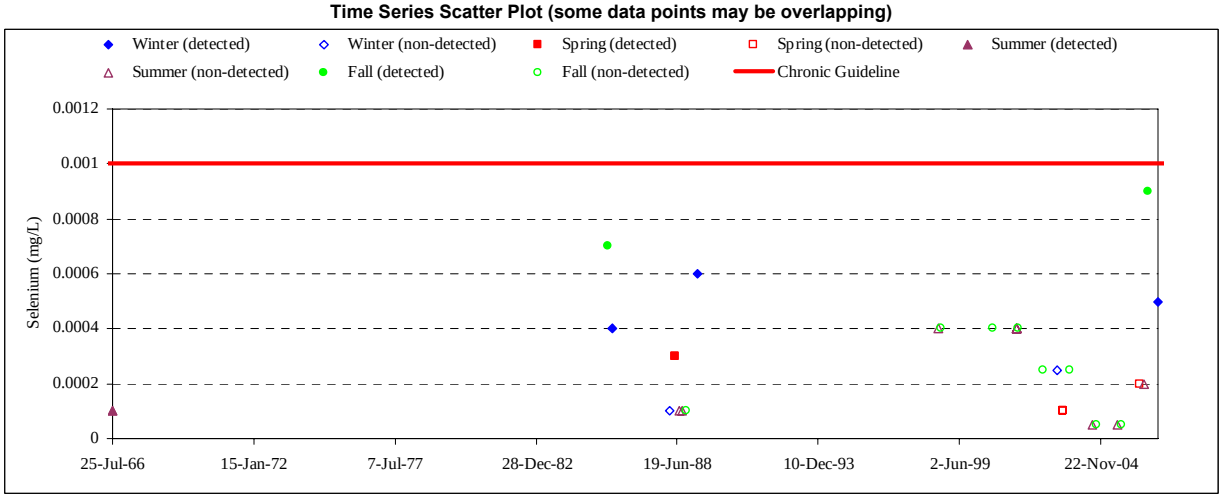
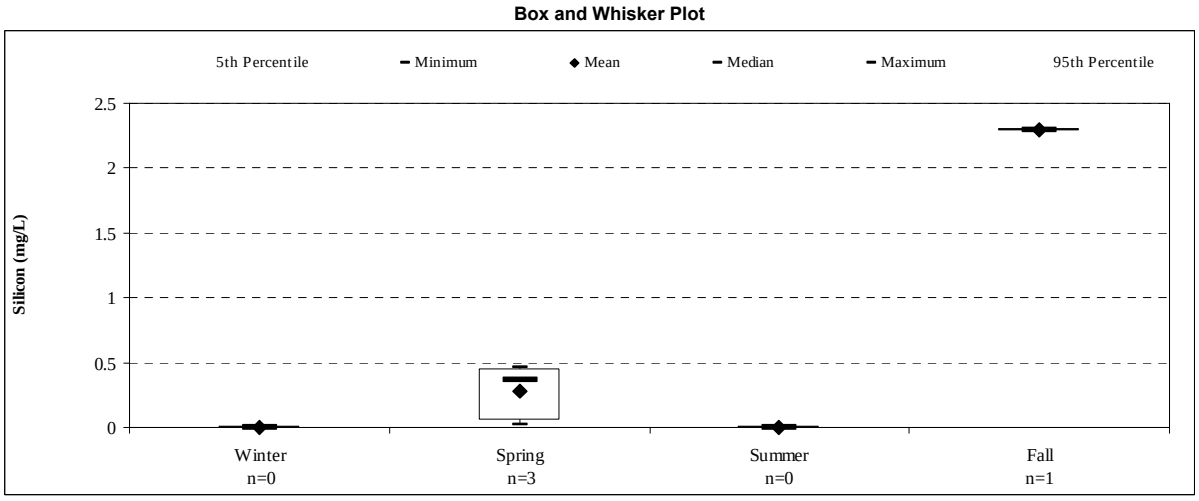


Figure G-2-8-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Kearl Lake



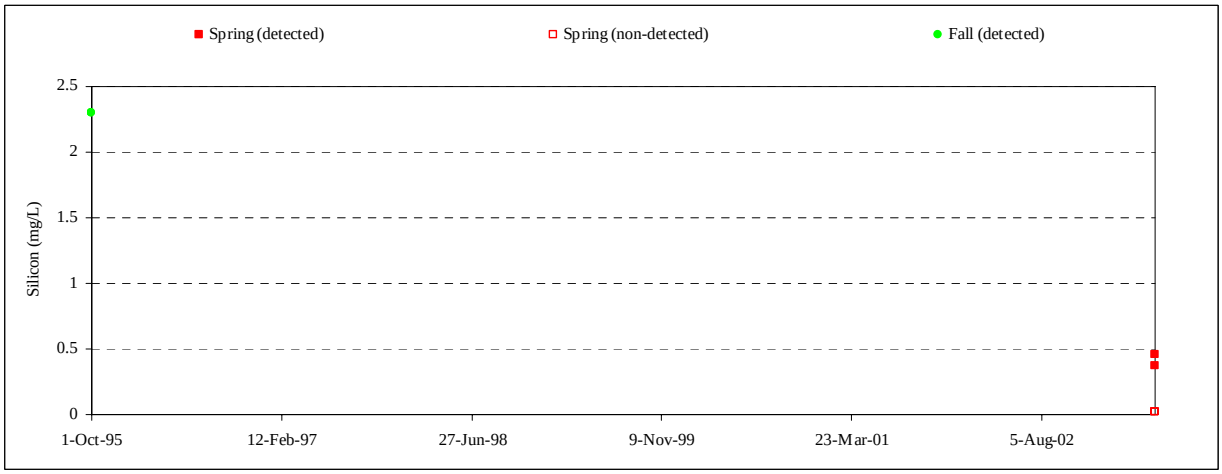
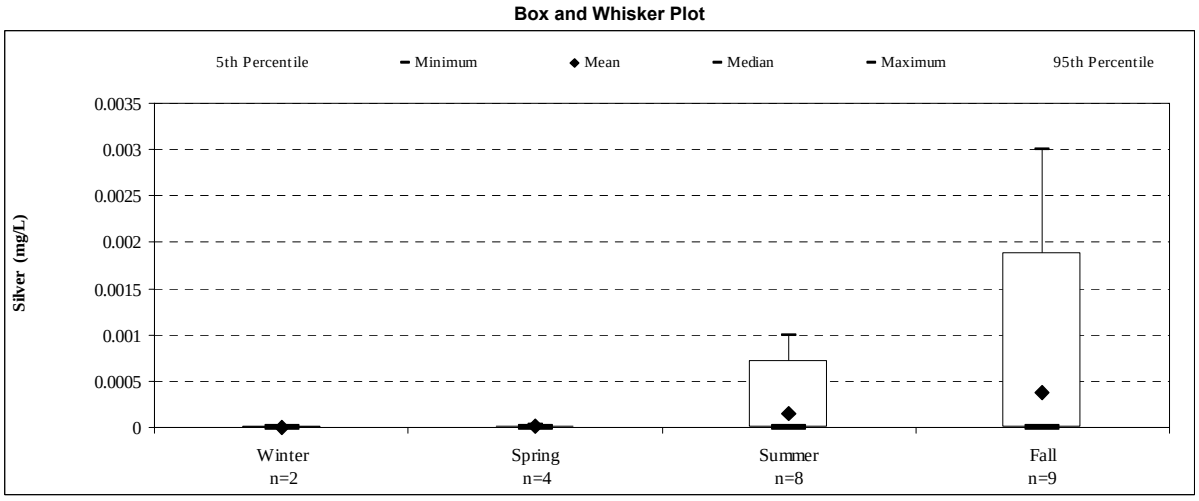


Figure G-2-8-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Kearl Lake



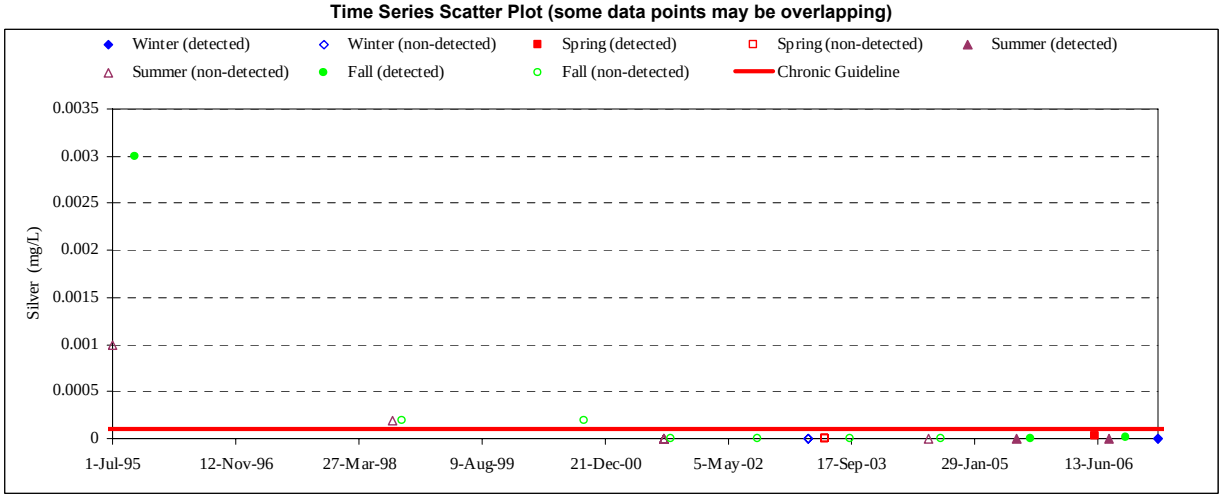
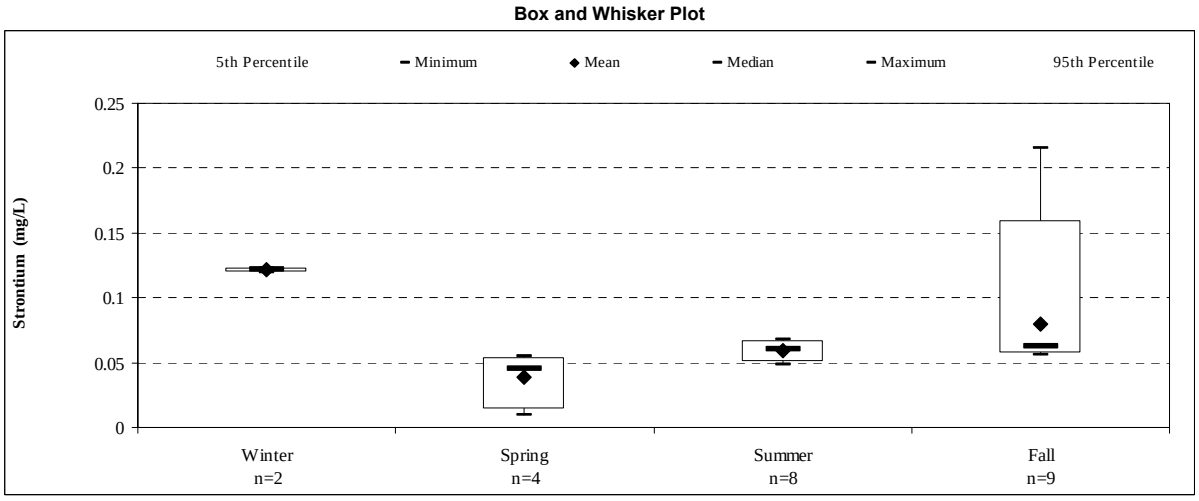


Figure G-2-8-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Kearl Lake



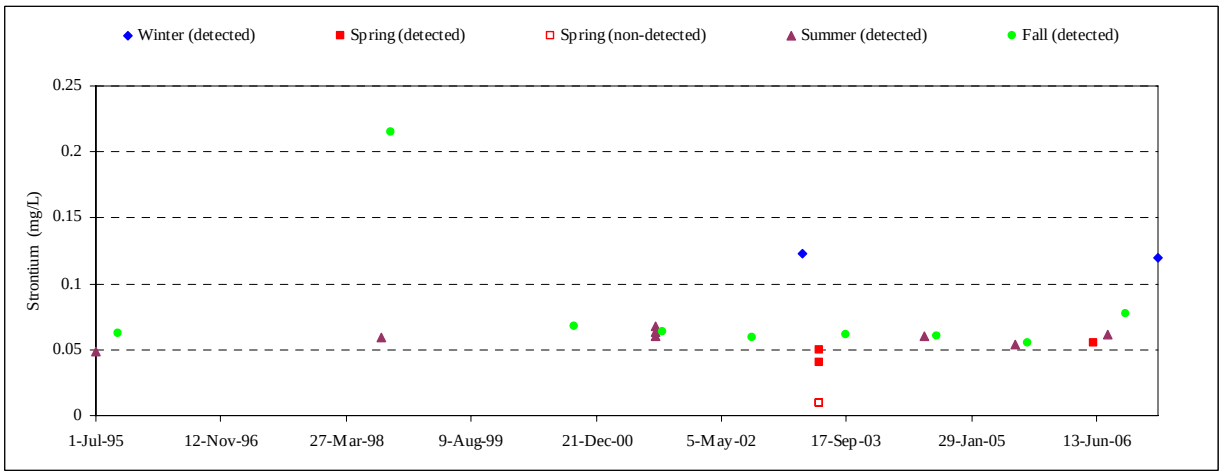


Figure G-2-8-85 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Total) Concentration in Kearl Lake

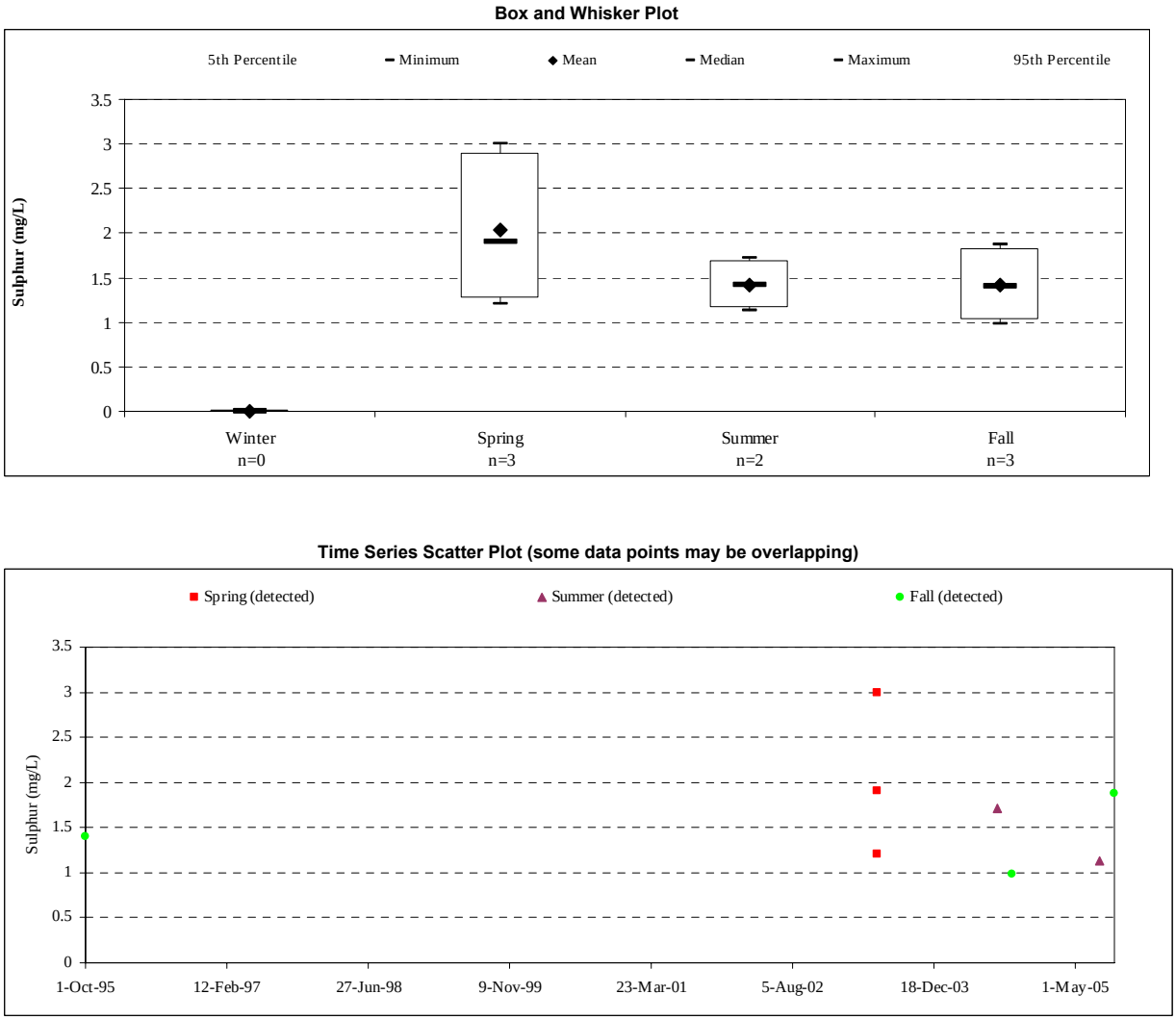
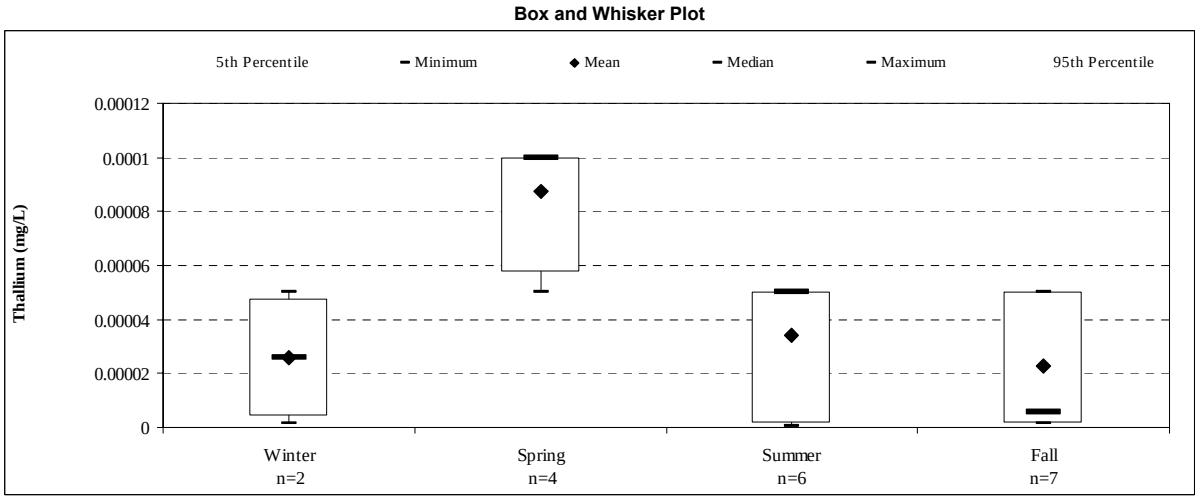


Figure G-2-8-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Kearl Lake



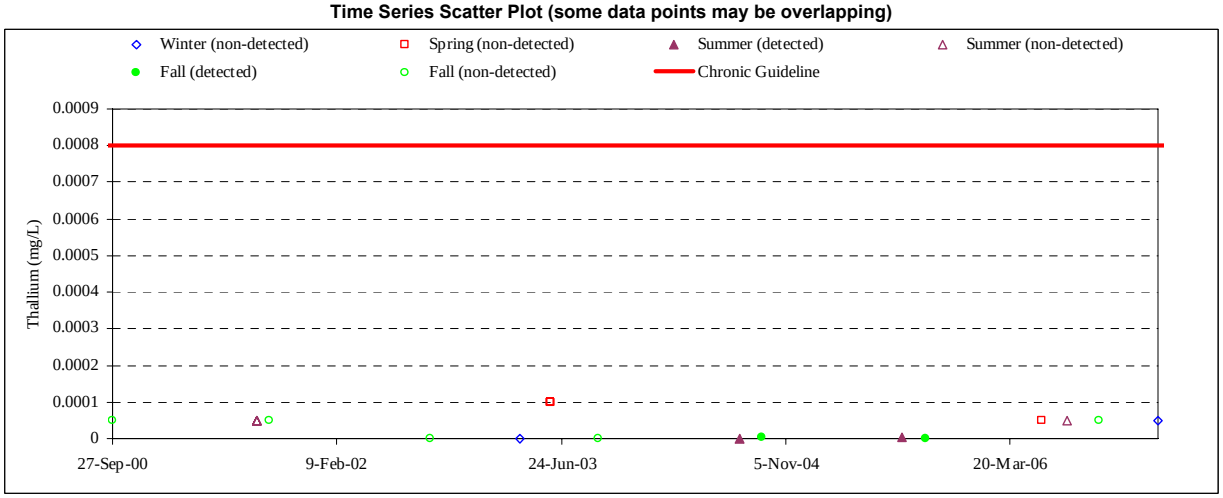
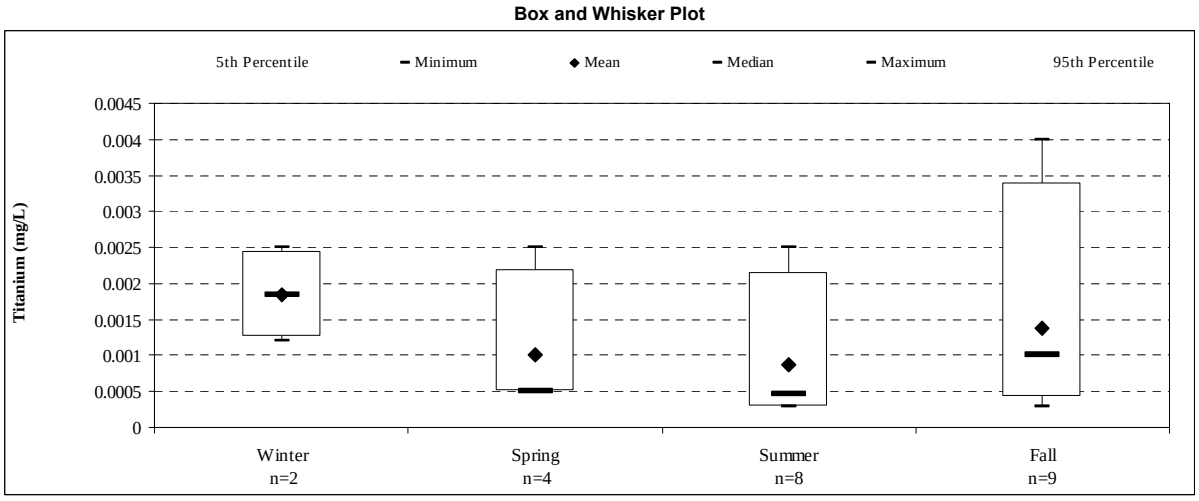


Figure G-2-8-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Kearl Lake



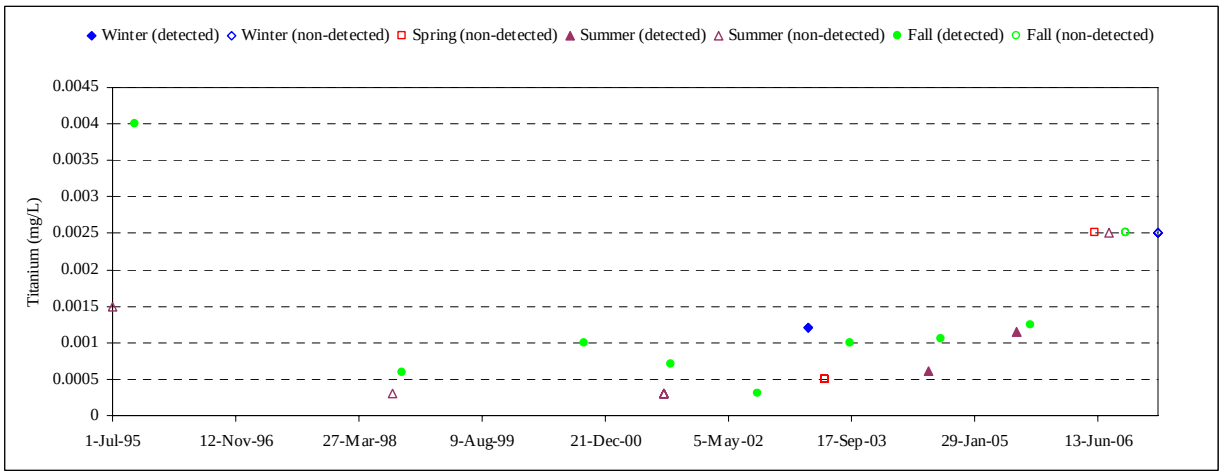
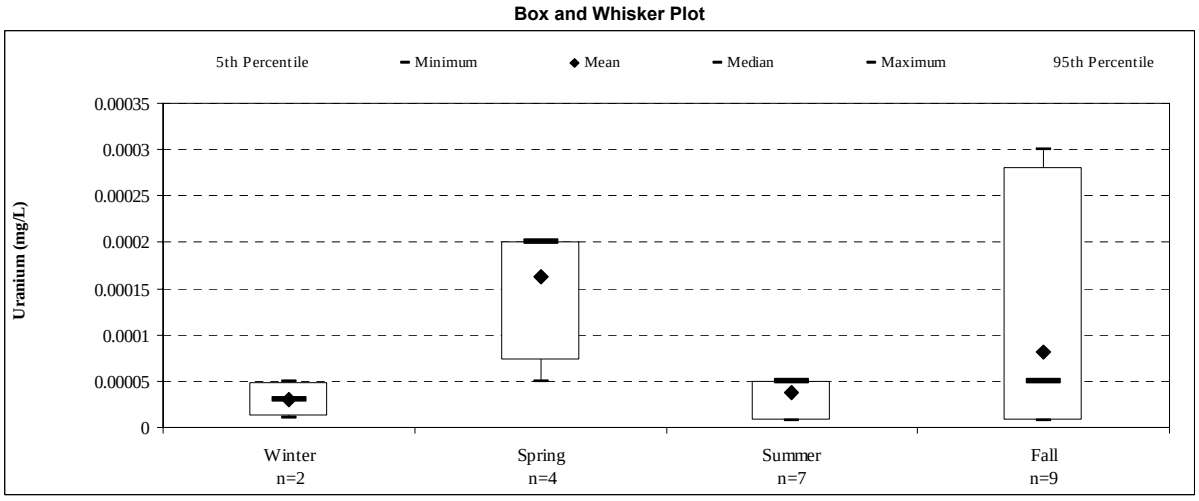


Figure G-2-8-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Kearl Lake



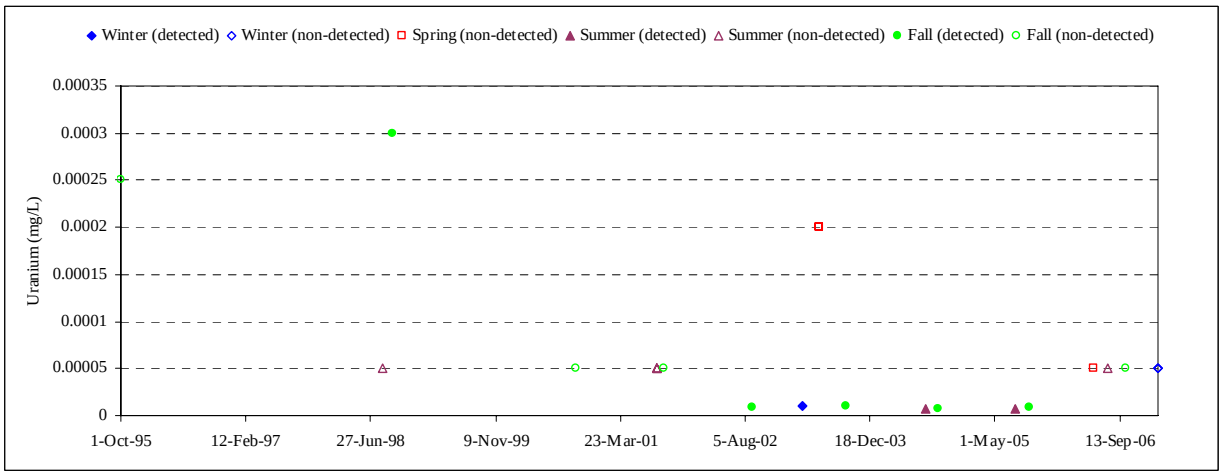
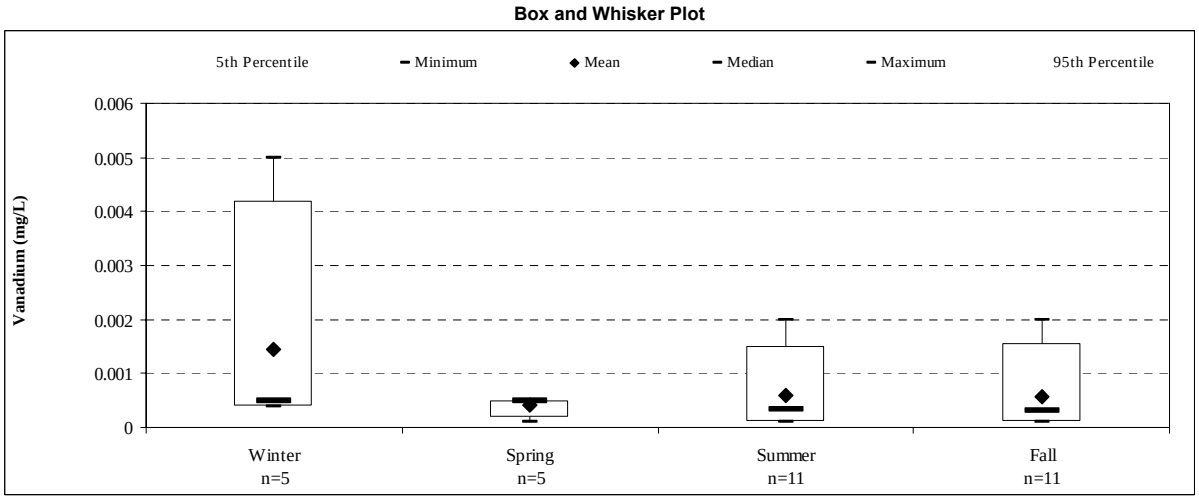


Figure G-2-8-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Kearl Lake



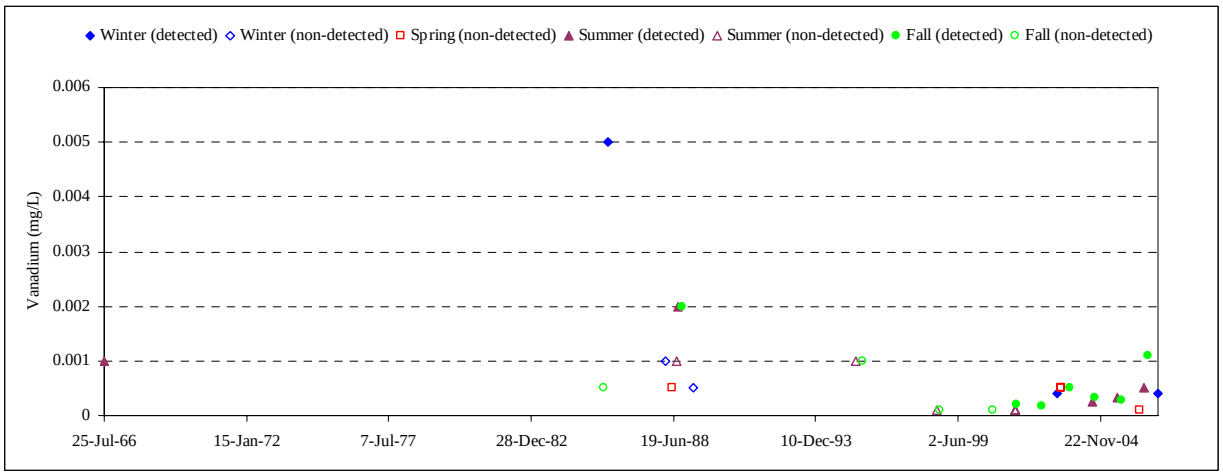


Figure G-2-8-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Kearl Lake

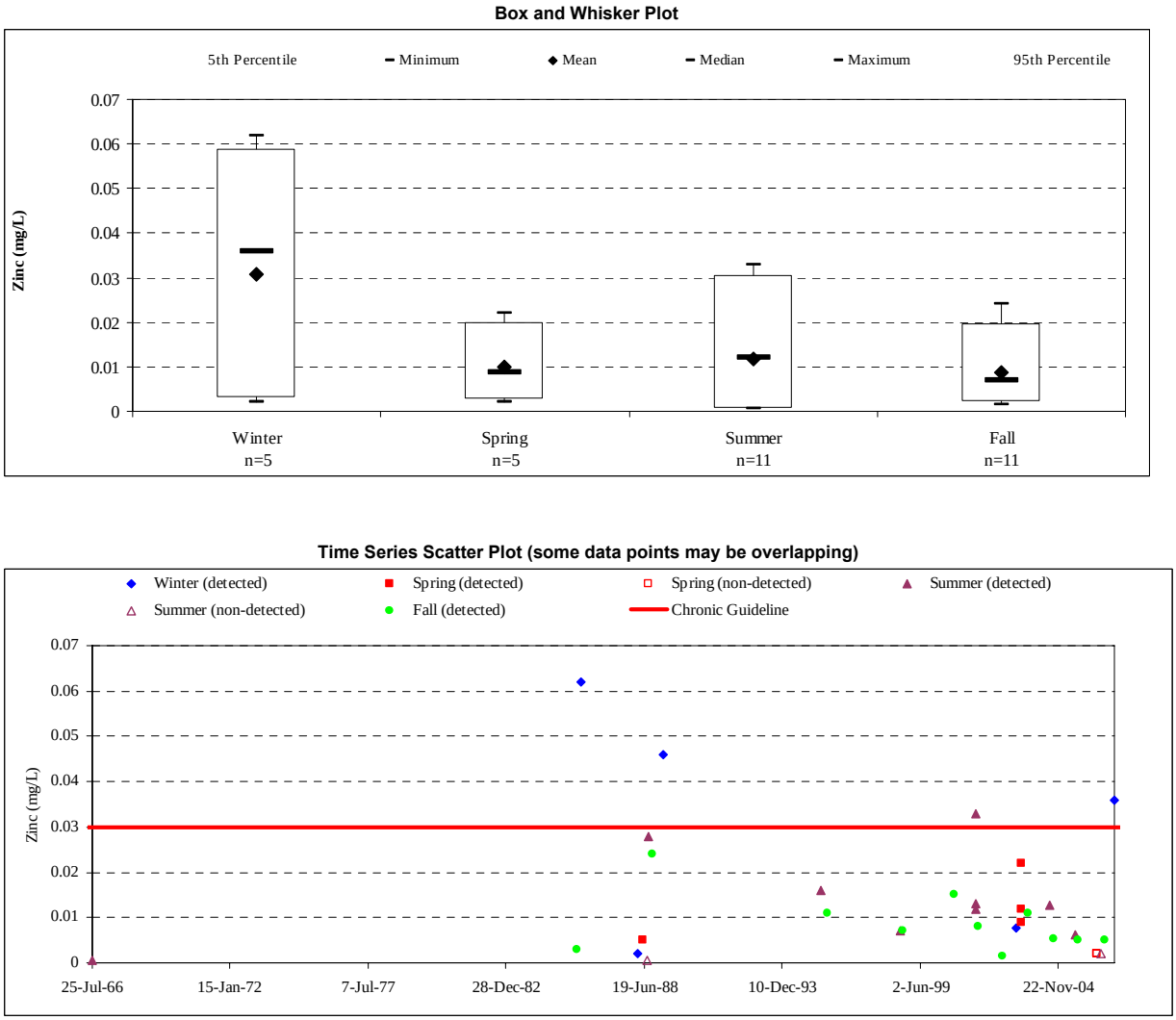
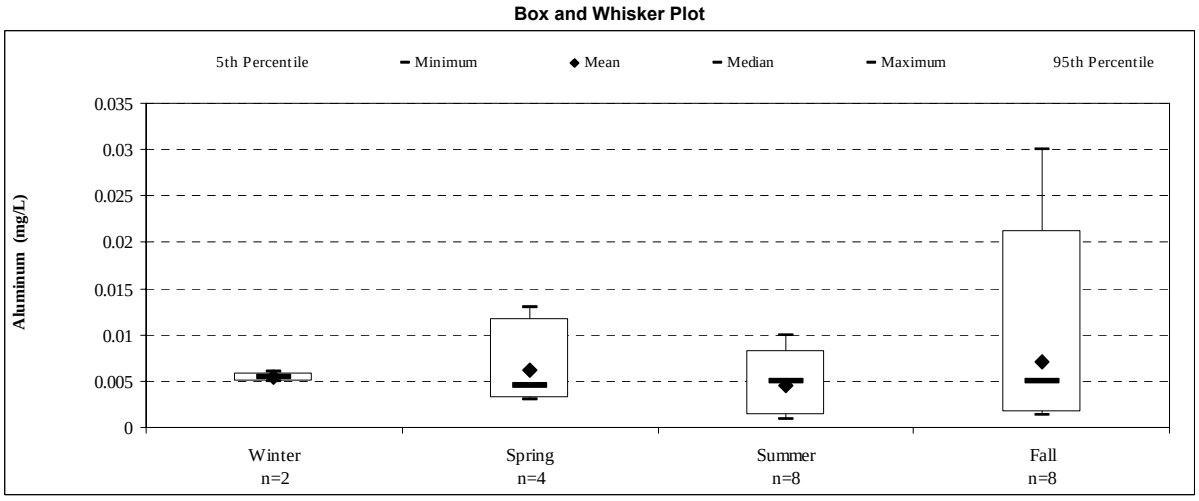


Figure G-2-8-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Kearl Lake



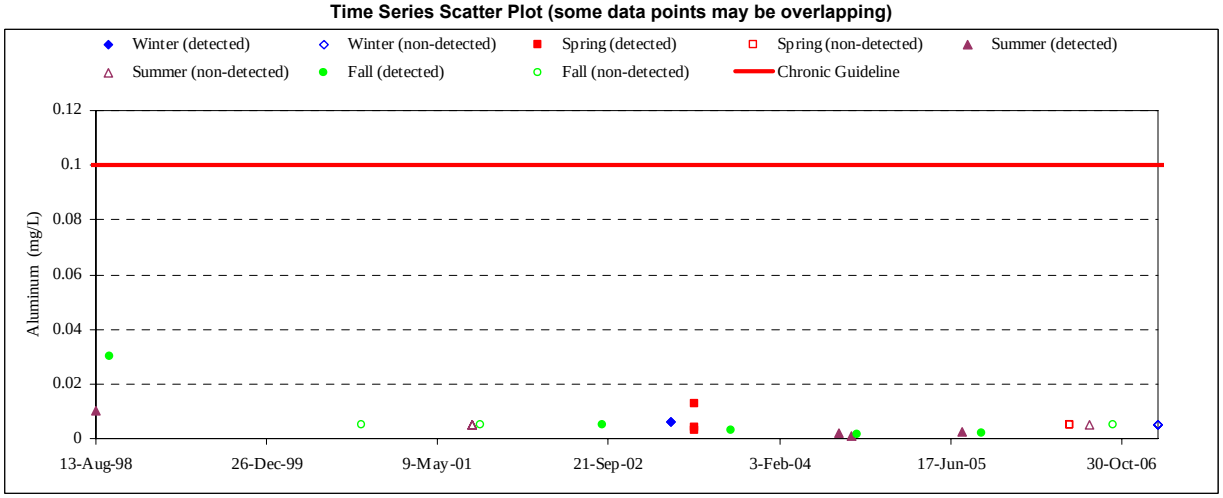
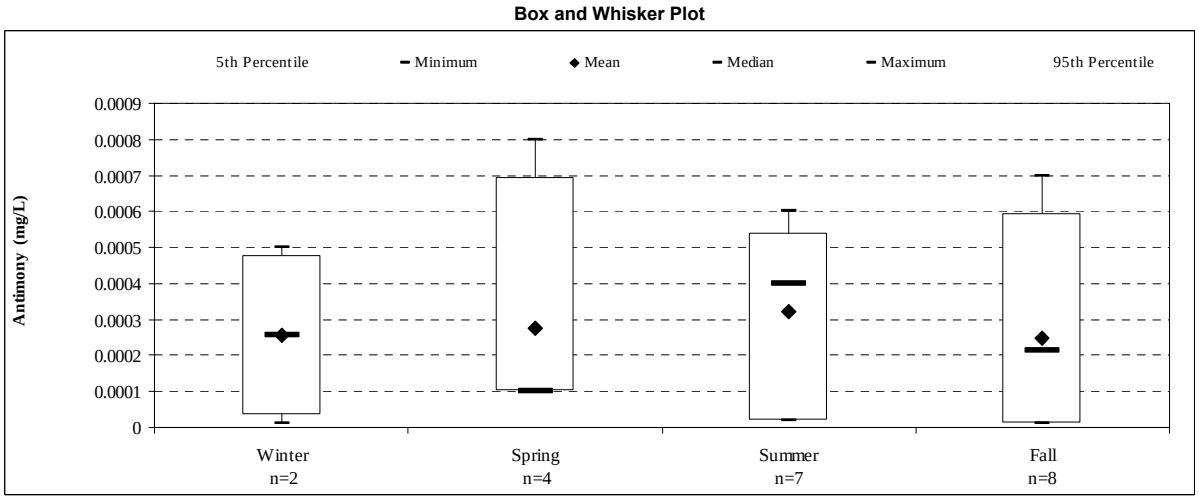


Figure G-2-8-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Kearl Lake



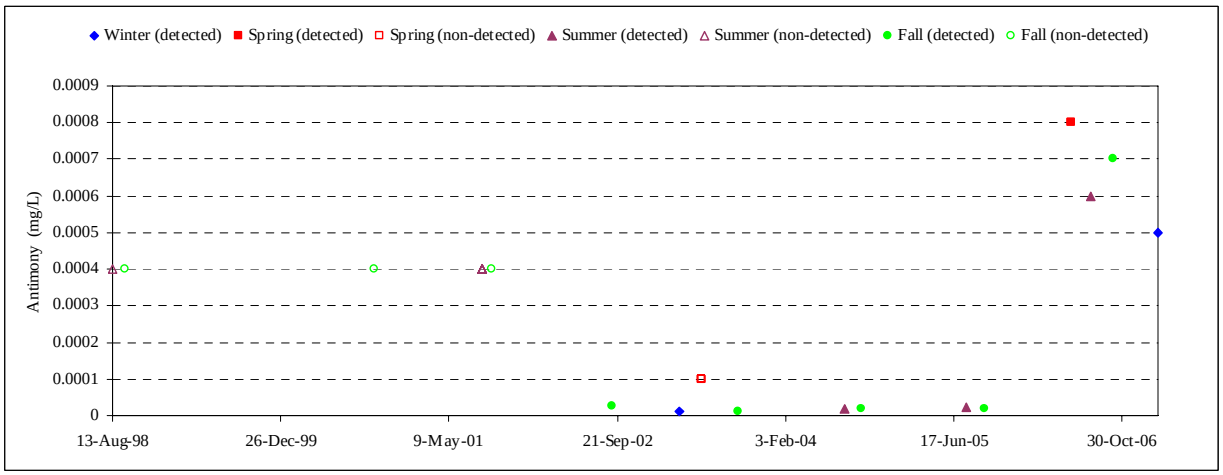
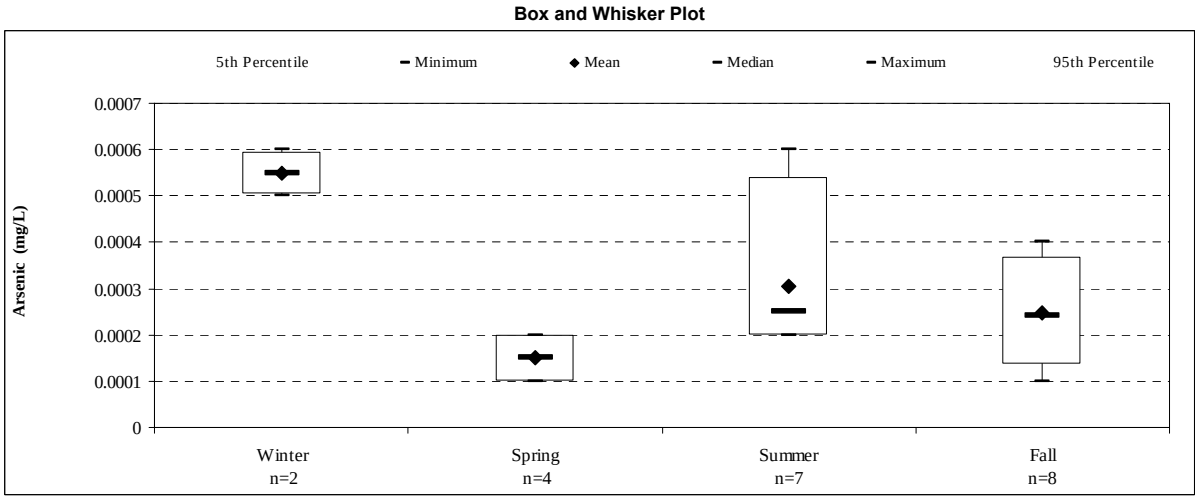


Figure G-2-8-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Kearl Lake



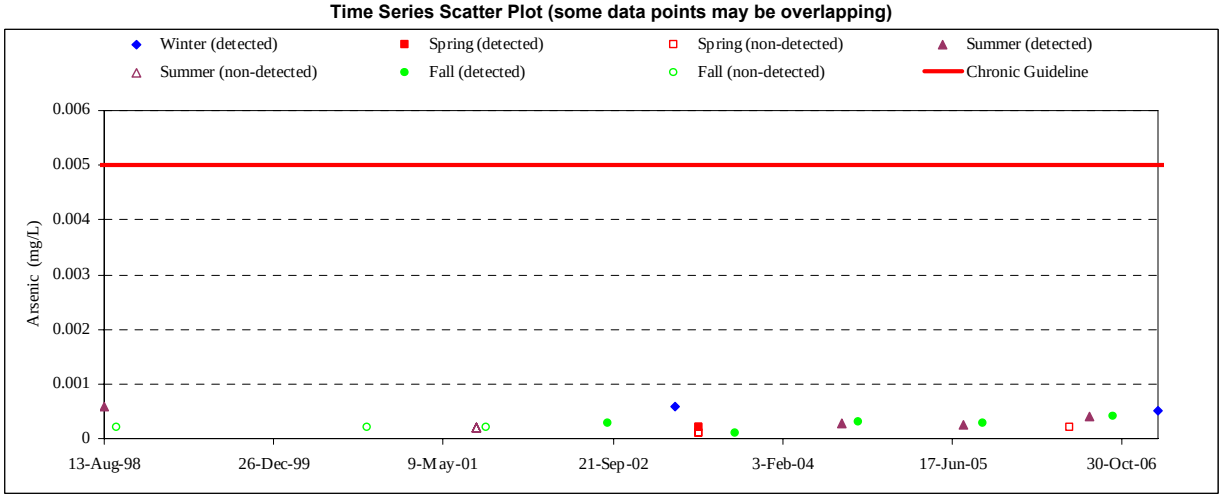
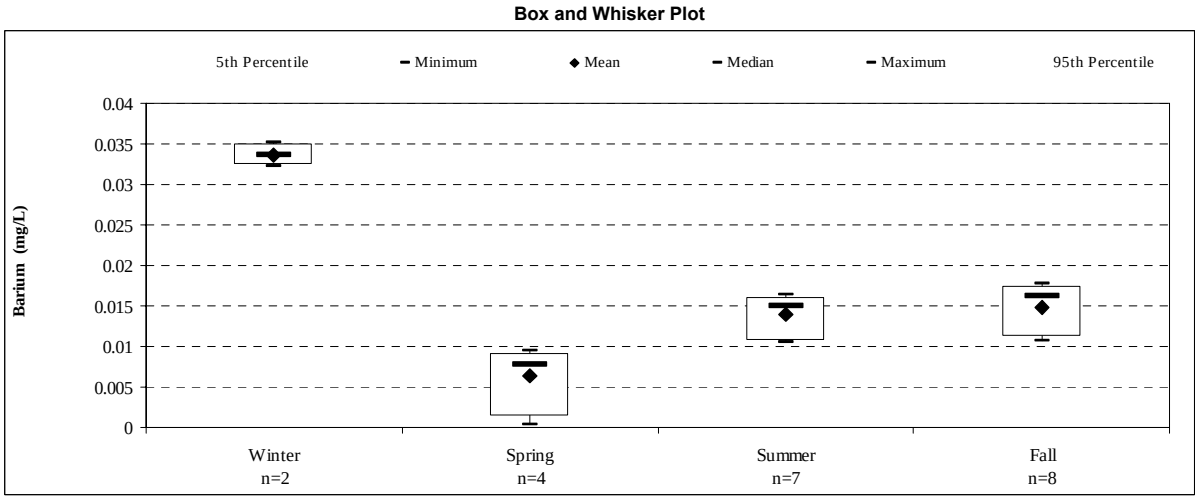


Figure G-2-8-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Kearl Lake



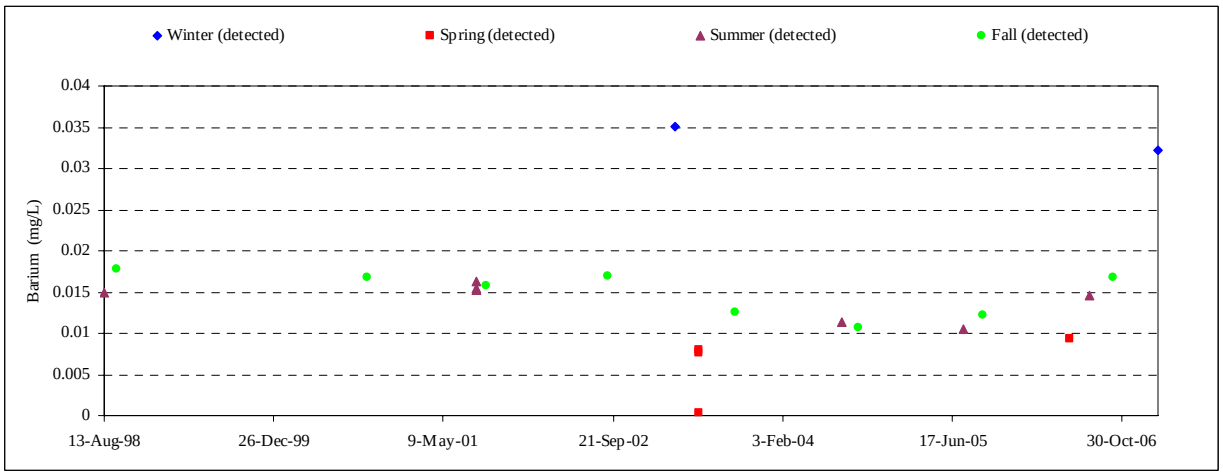
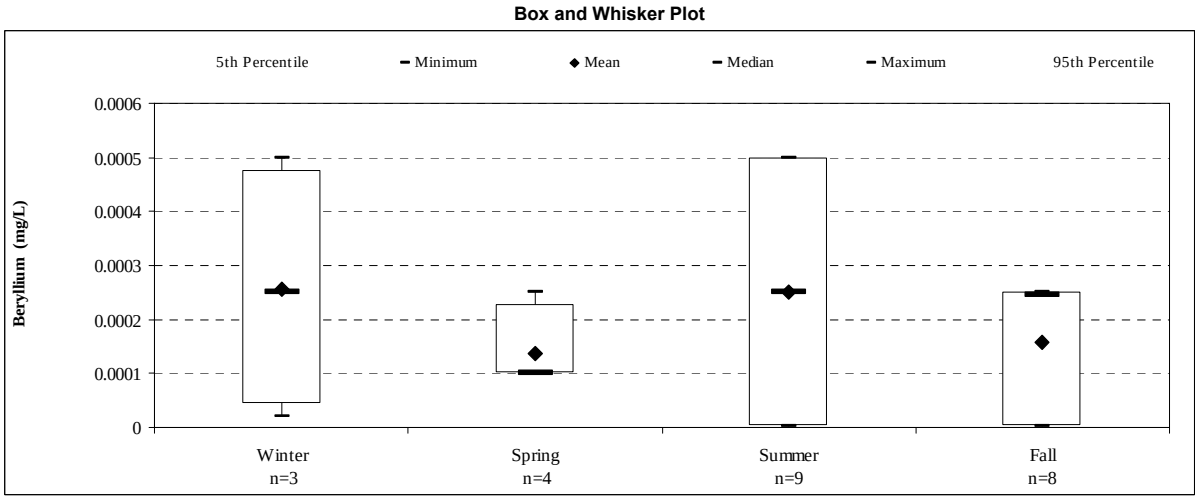


Figure G-2-8-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Kearl Lake



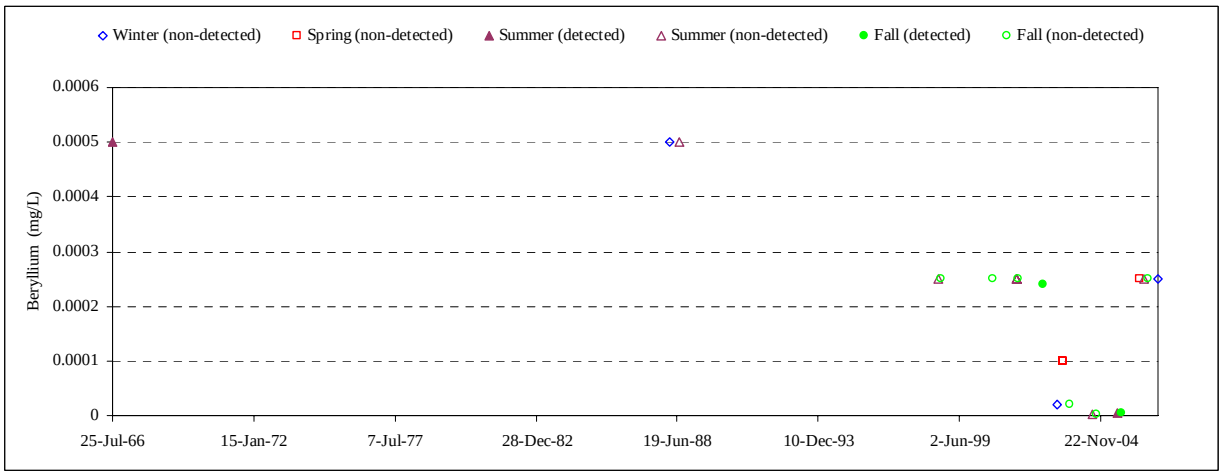
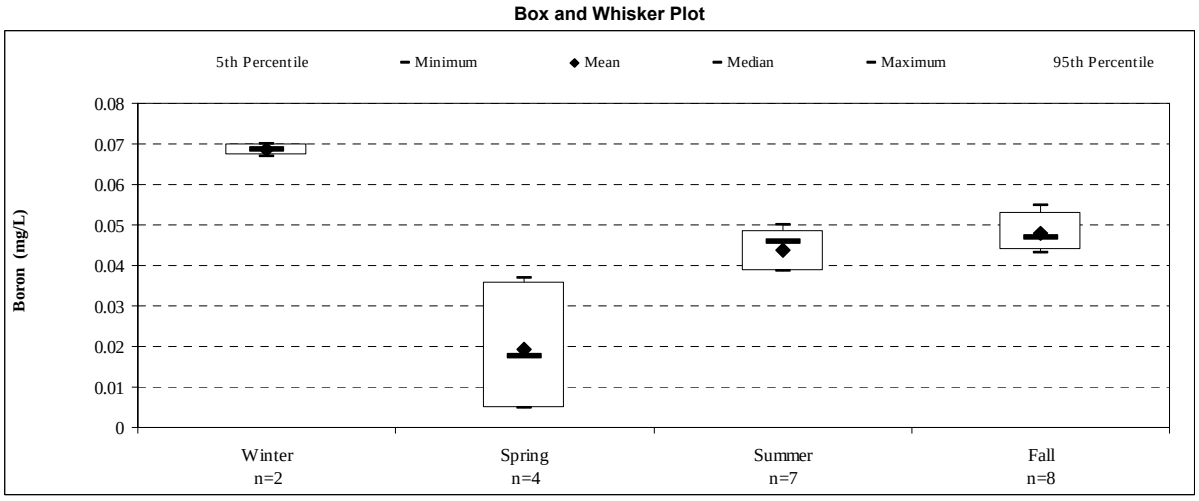


Figure G-2-8-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Kearl Lake



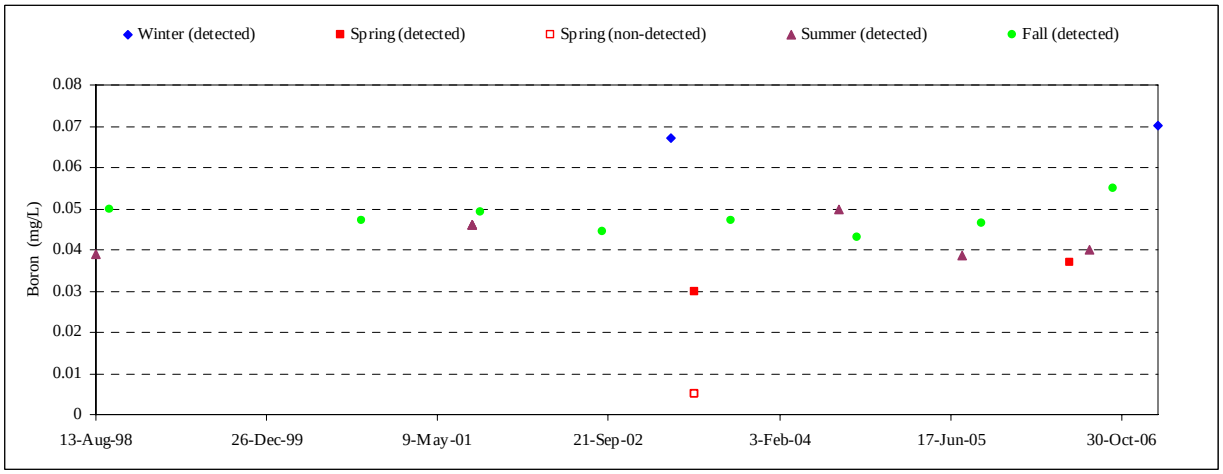
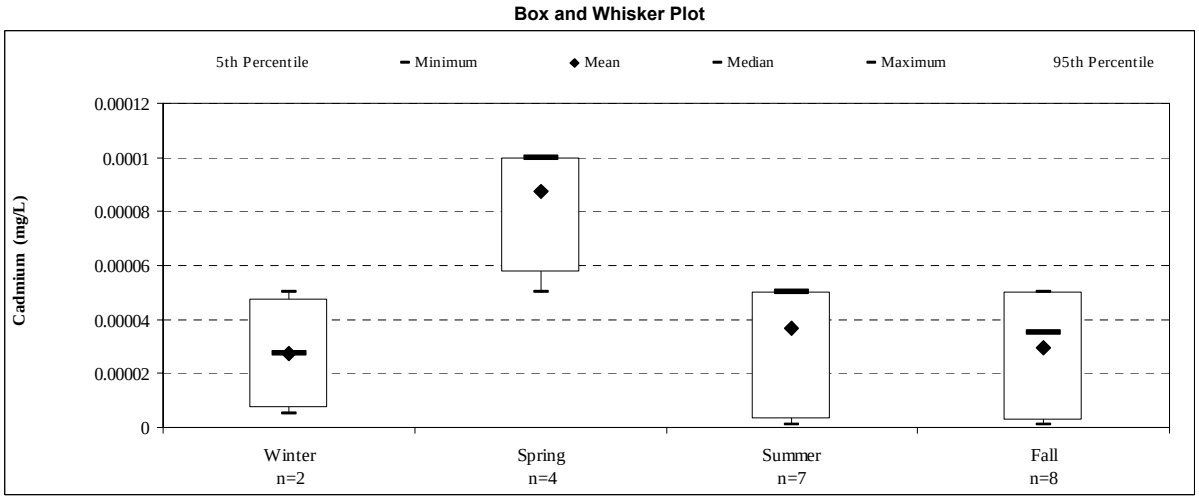


Figure G-2-8-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Kearl Lake



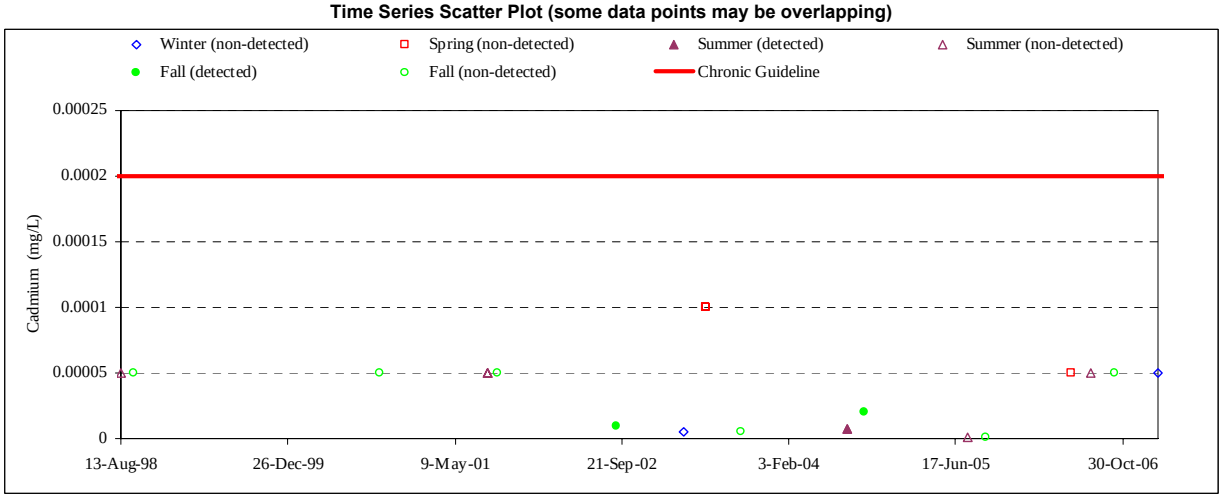
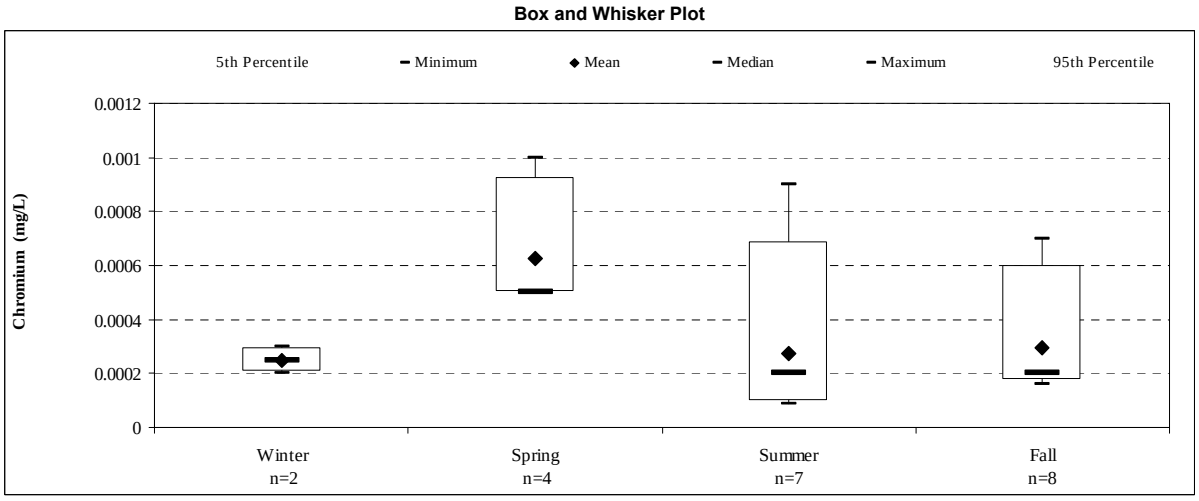


Figure G-2-8-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Kearl Lake



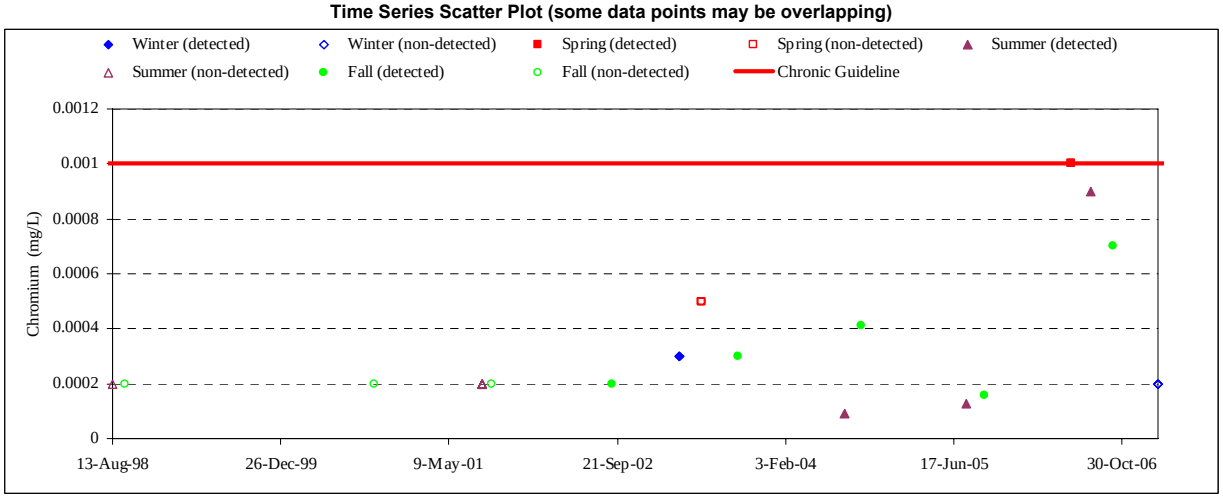
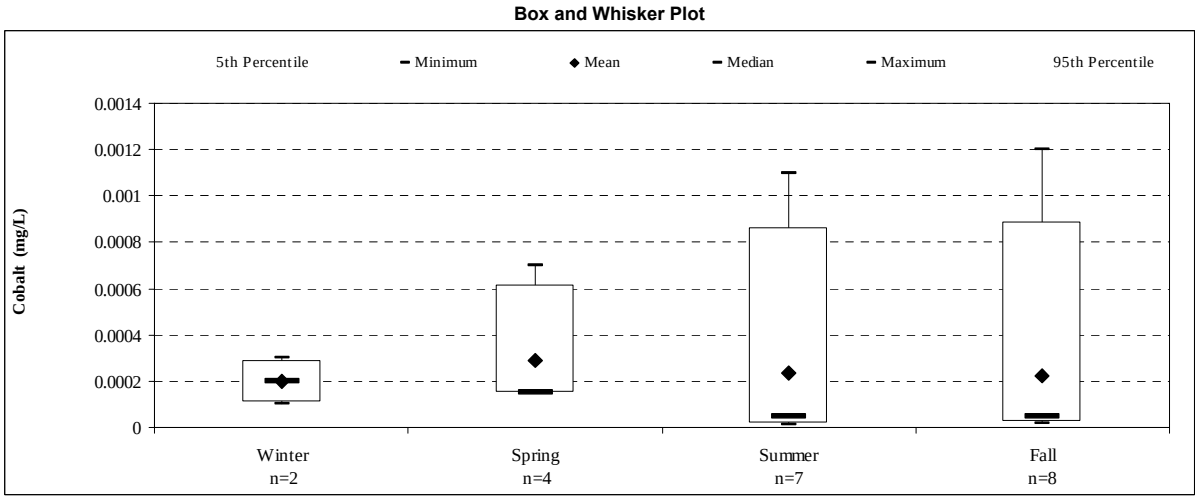


Figure G-2-8-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Kearl Lake



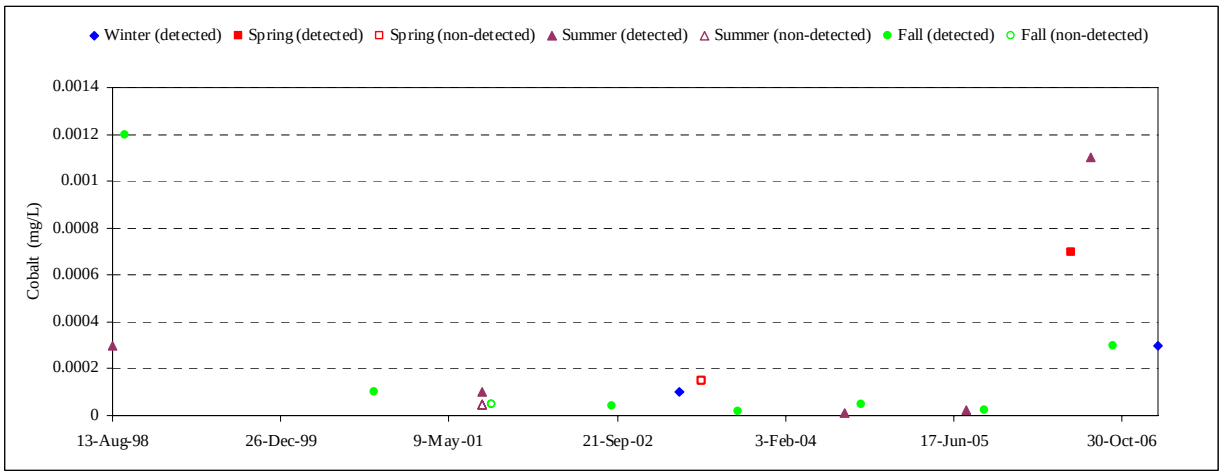
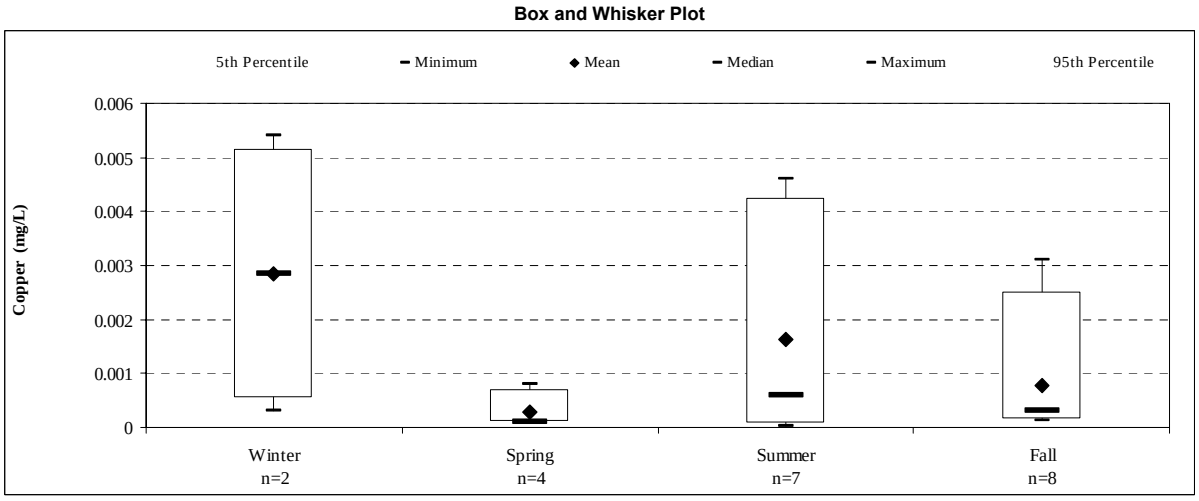


Figure G-2-8-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Kearl Lake



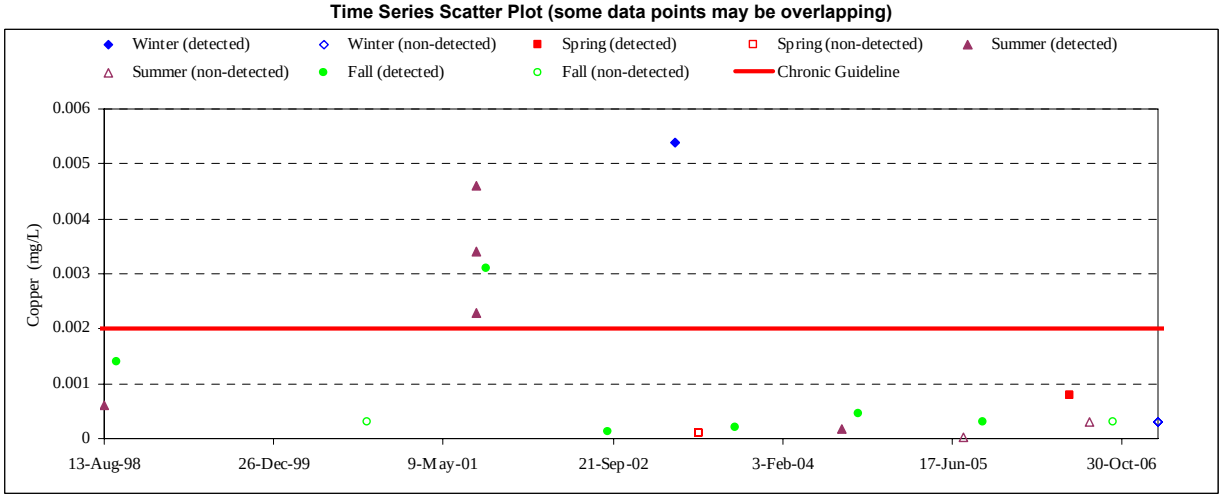
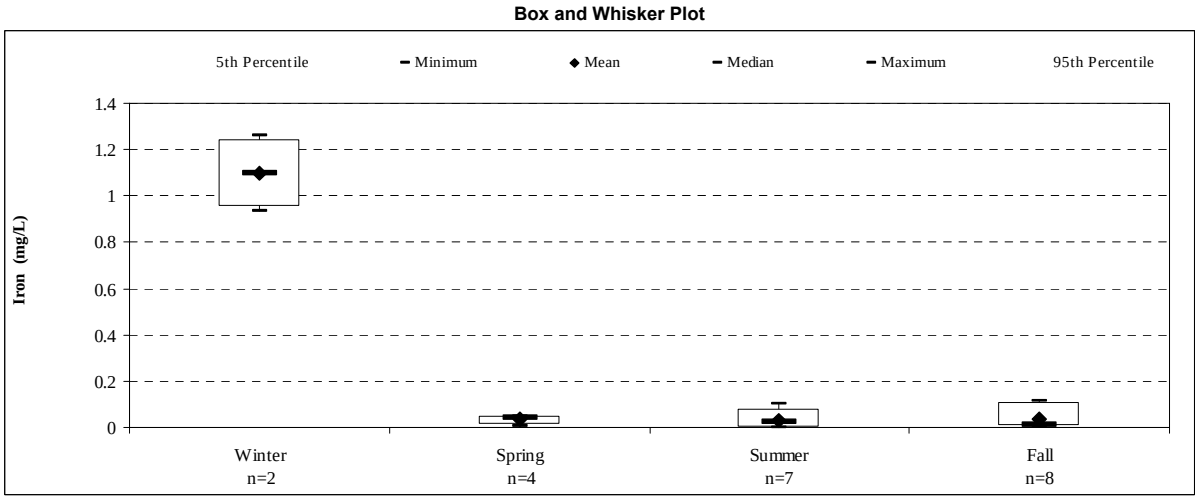


Figure G-2-8-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Kearl Lake



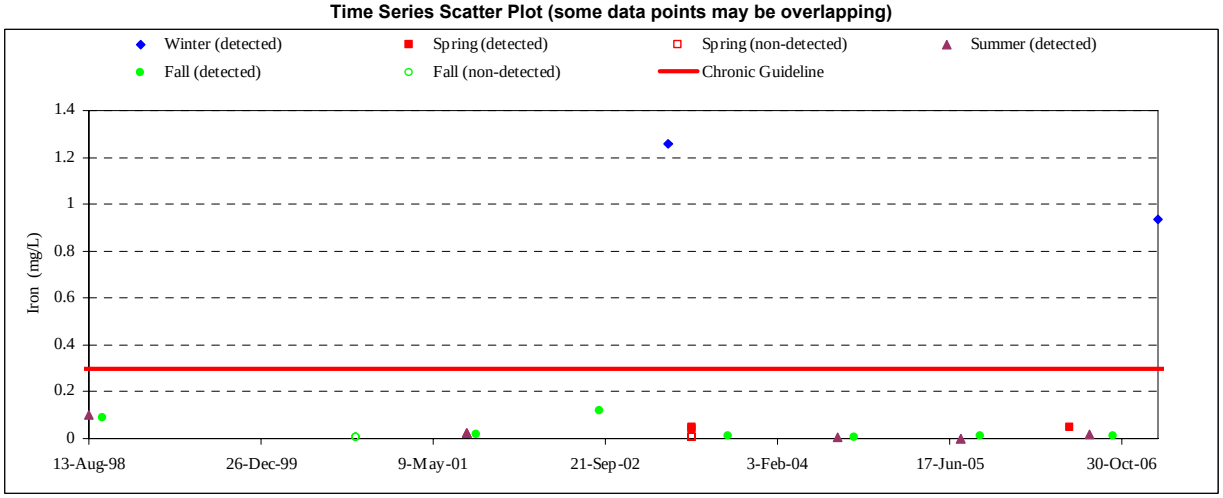
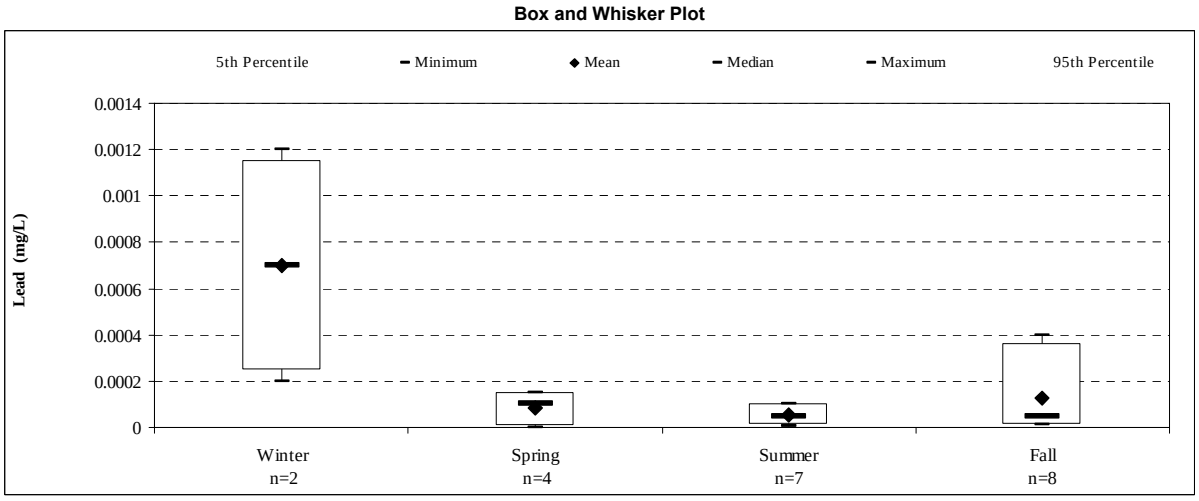


Figure G-2-8-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Kearl Lake



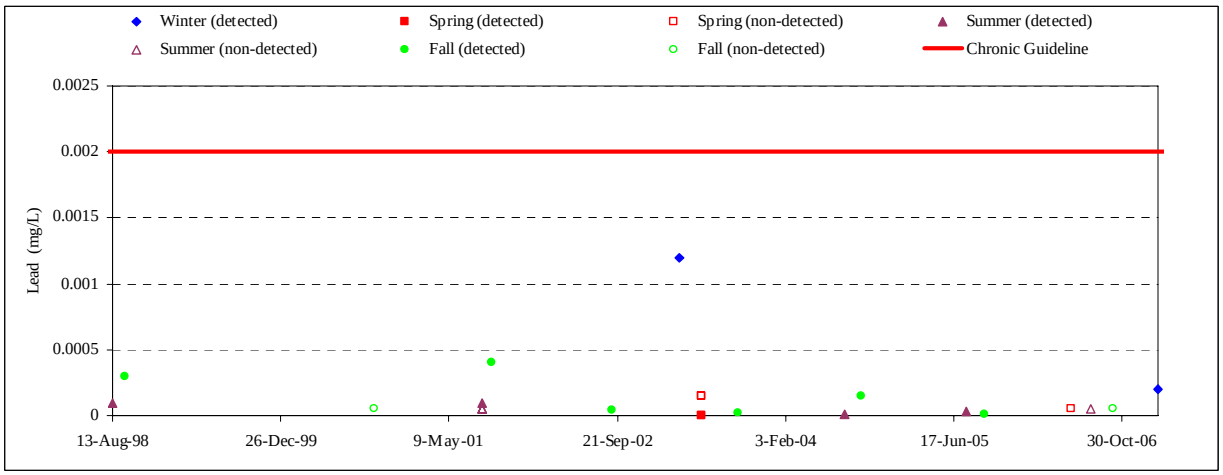
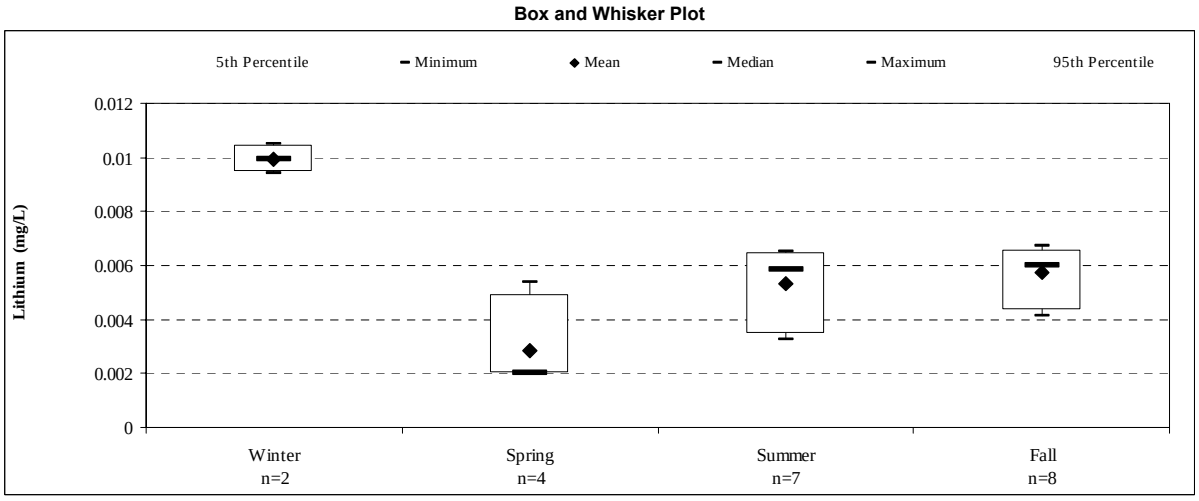


Figure G-2-8-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Kearl Lake



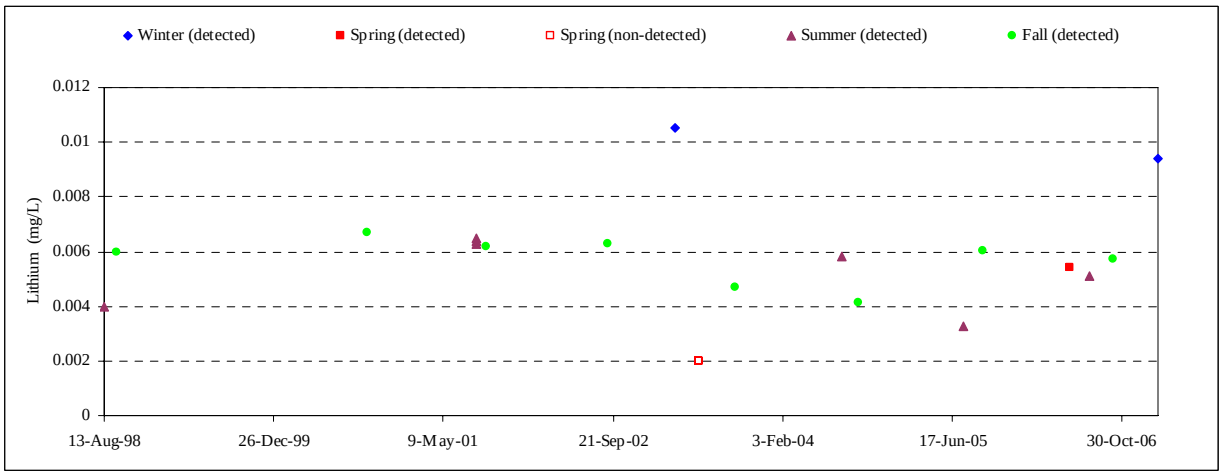
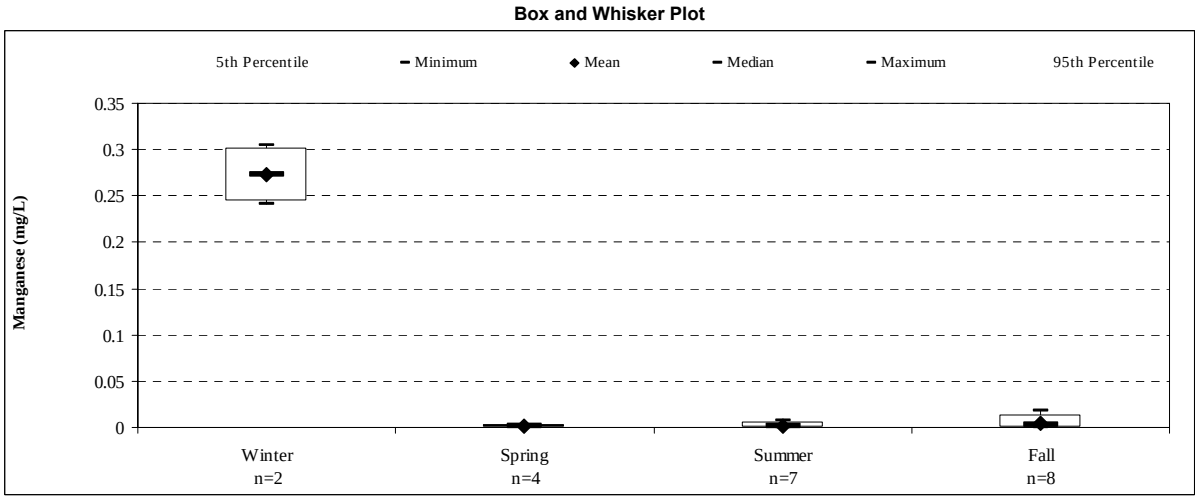


Figure G-2-8-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Kearl Lake



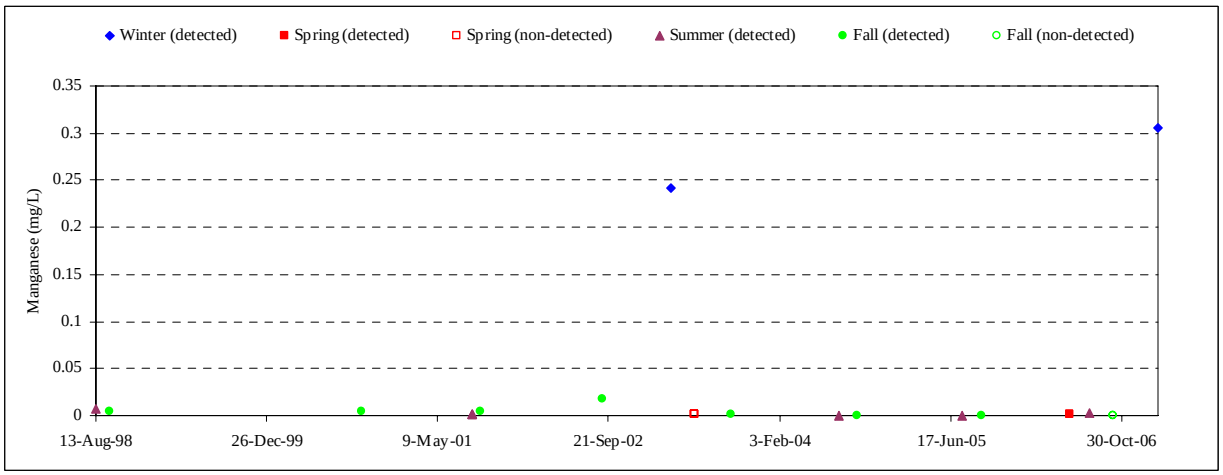
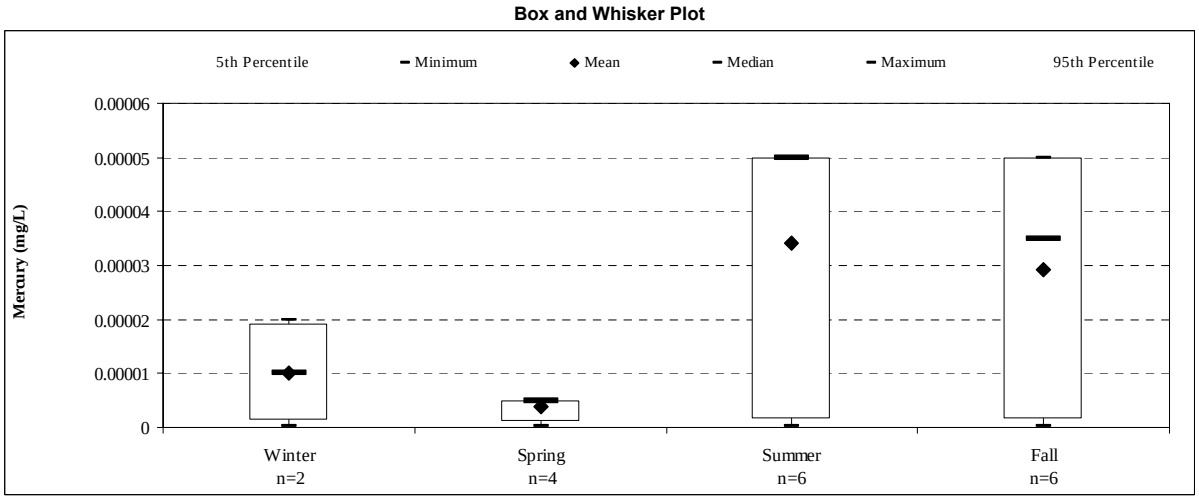


Figure G-2-8-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Kearl Lake



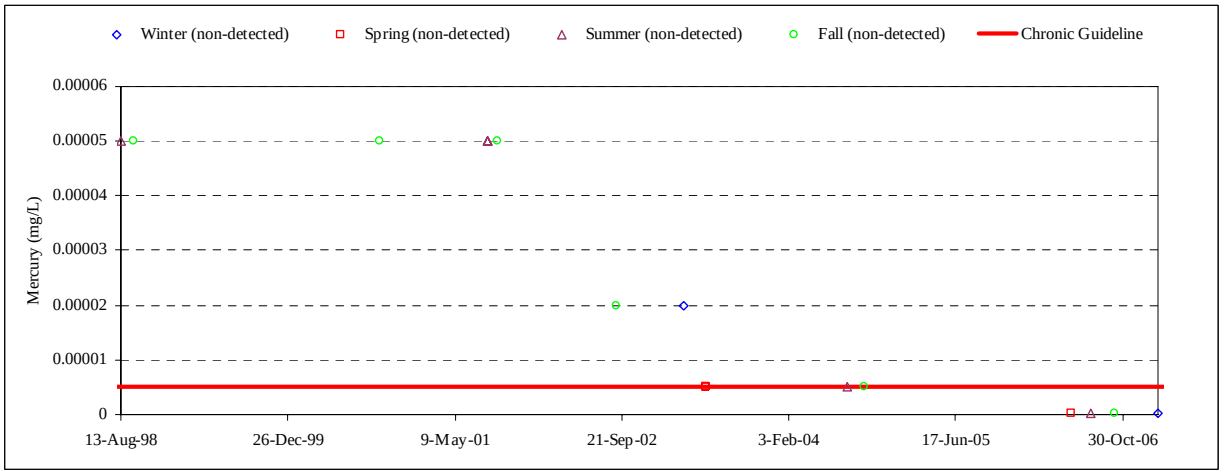
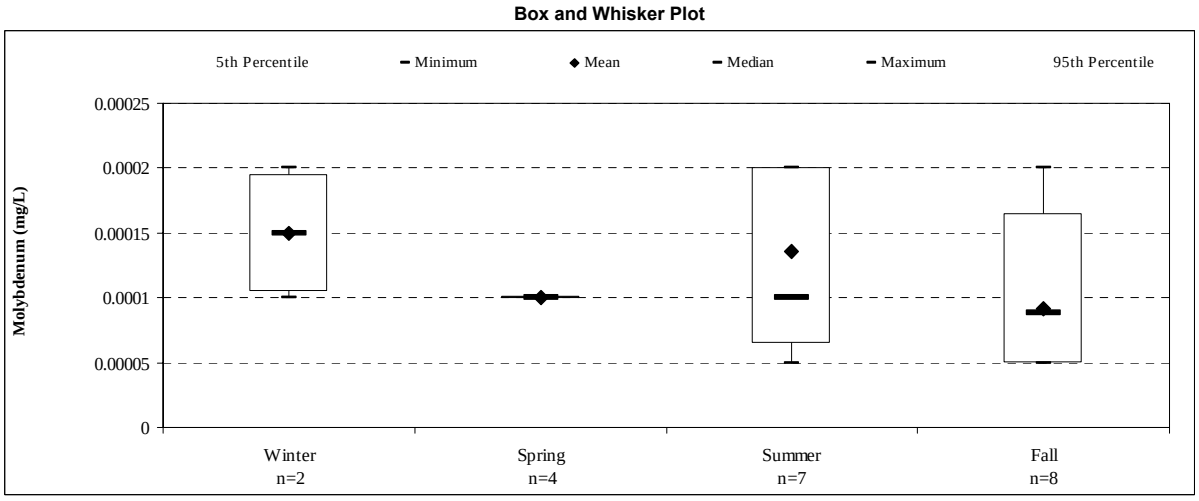


Figure G-2-8-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Kearl Lake



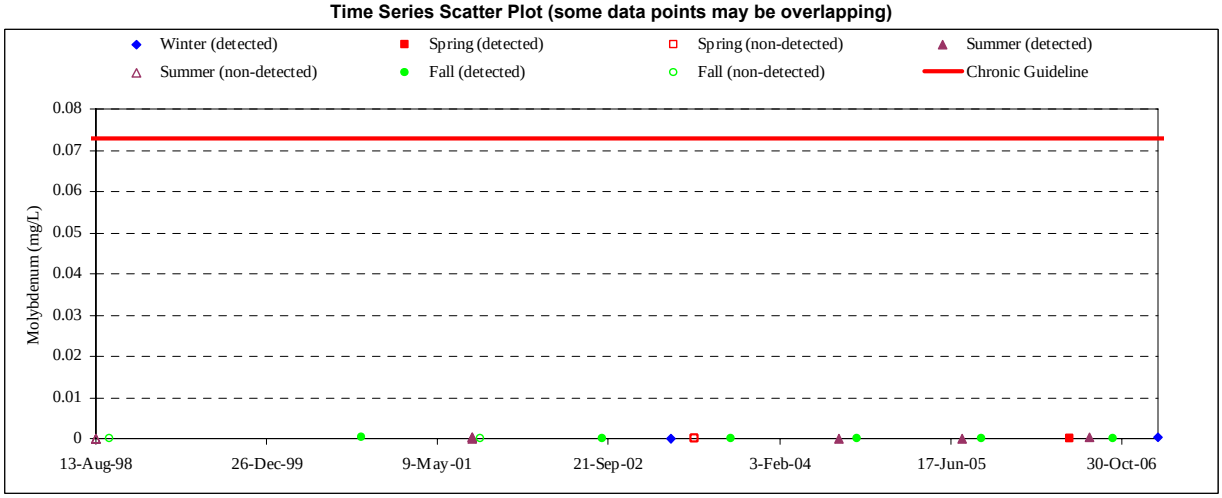
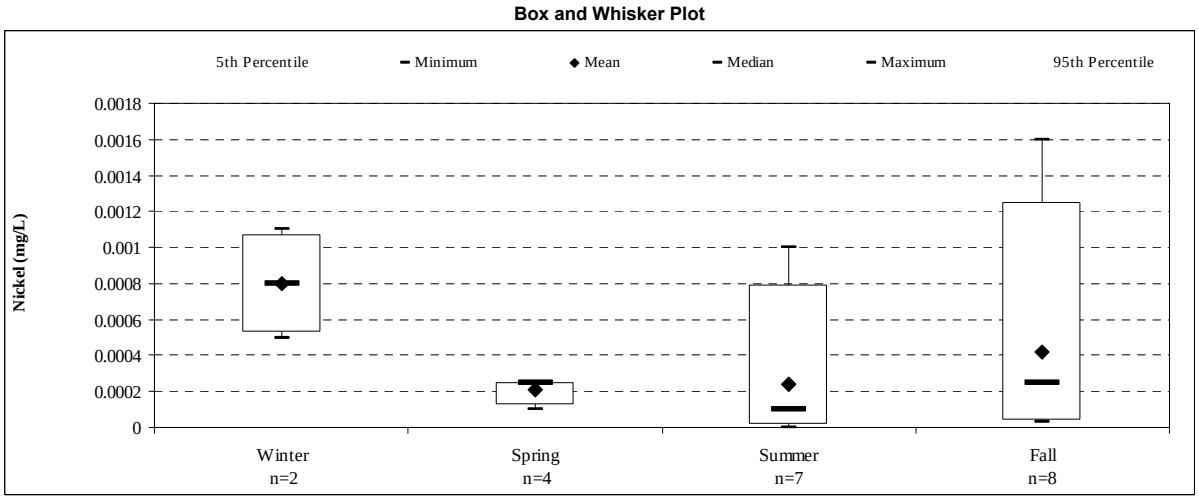


Figure G-2-8-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Kearl Lake



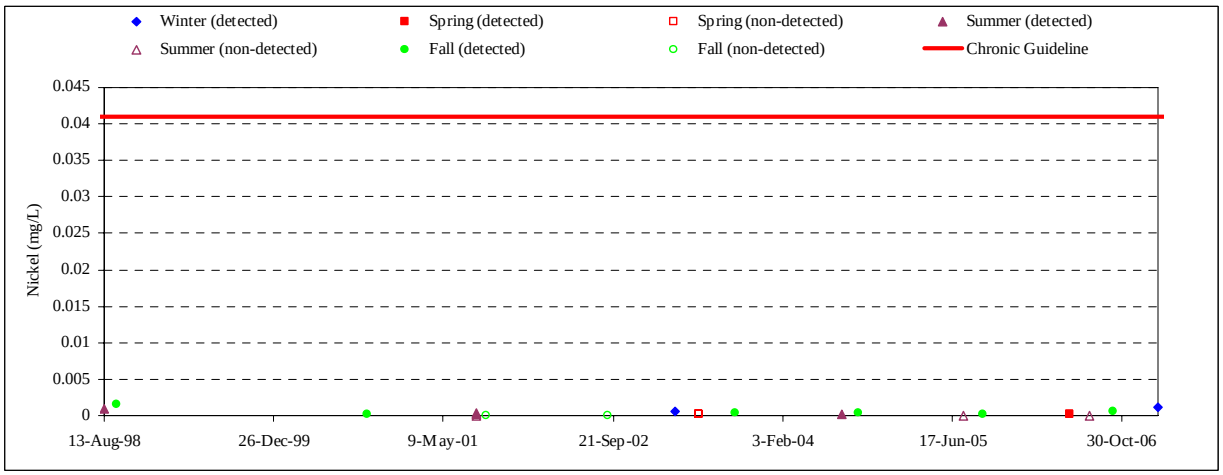
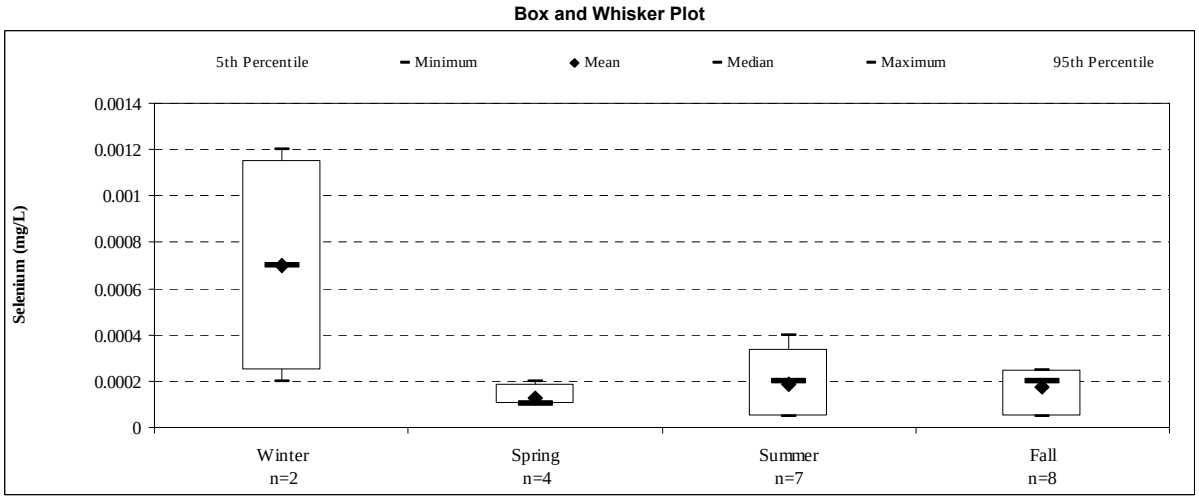


Figure G-2-8-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Kearl Lake



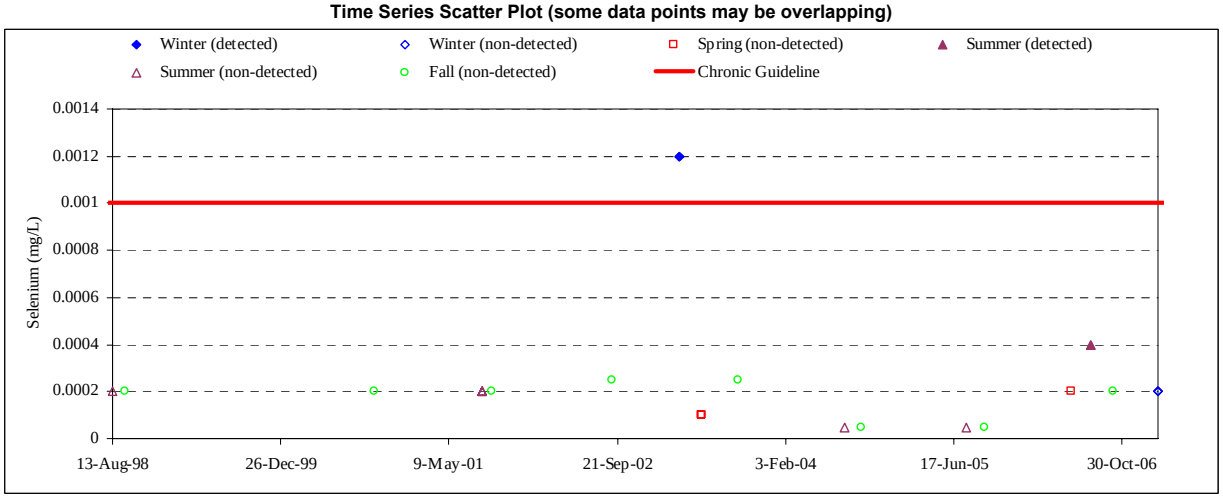
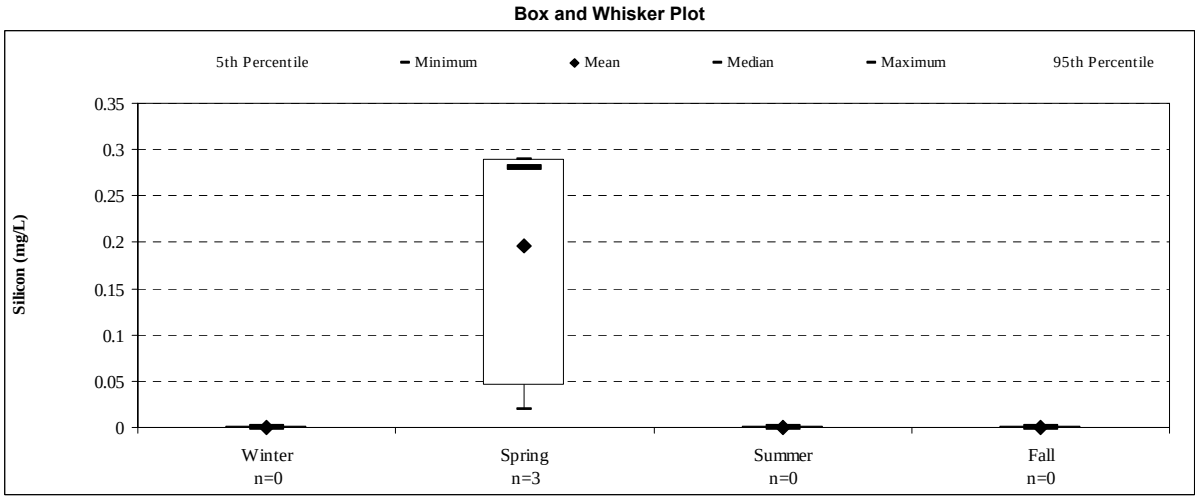


Figure G-2-8-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Kearl Lake



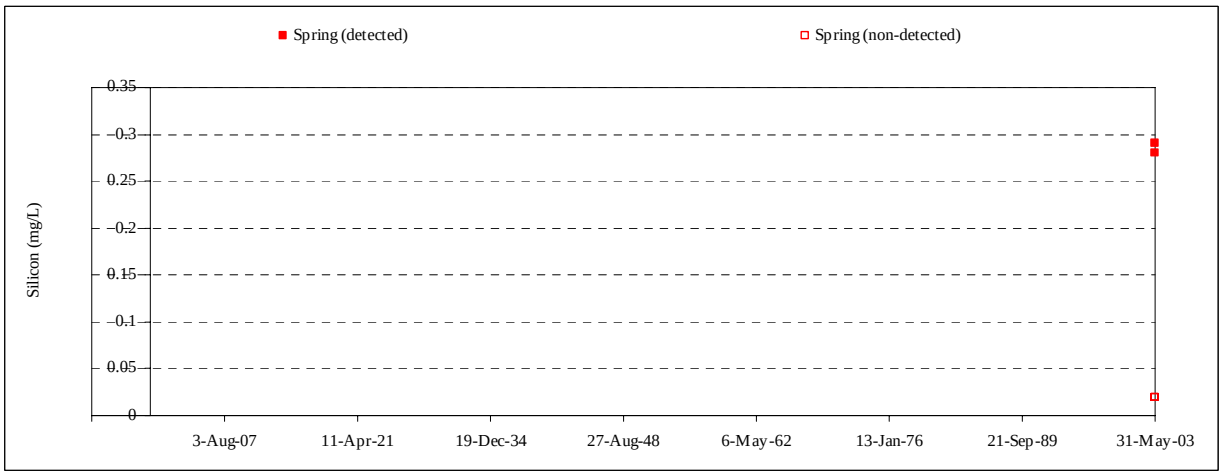
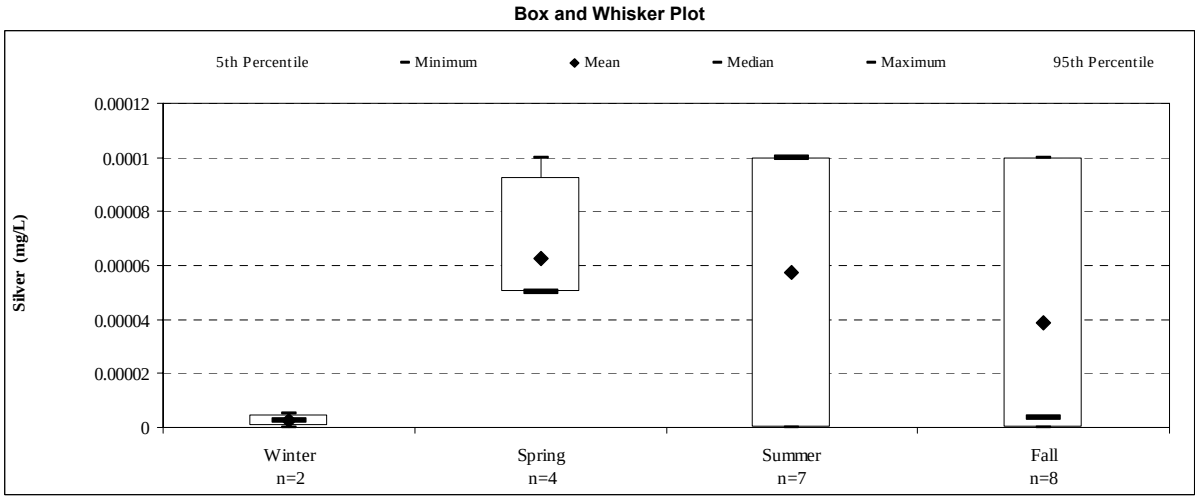


Figure G-2-8-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Kearl Lake



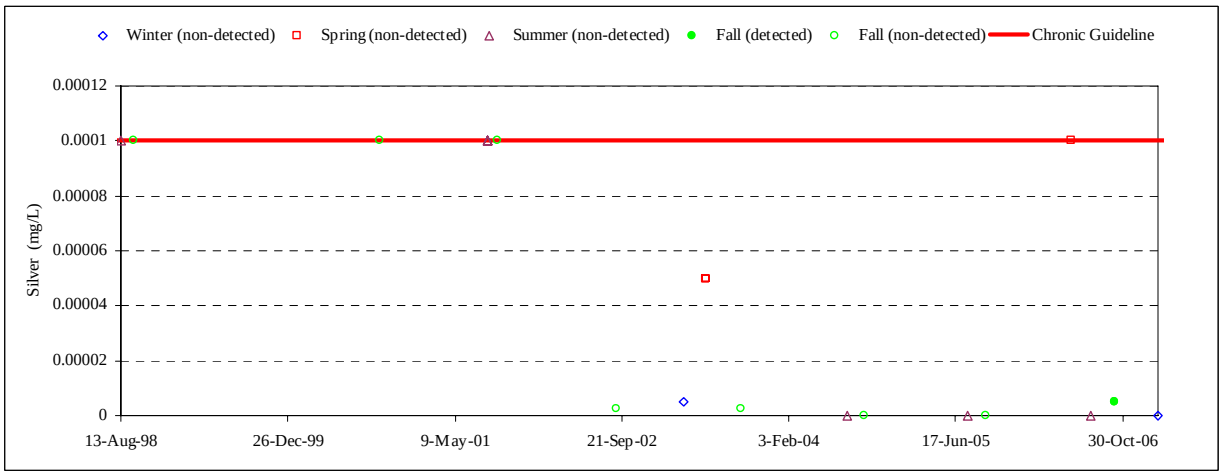
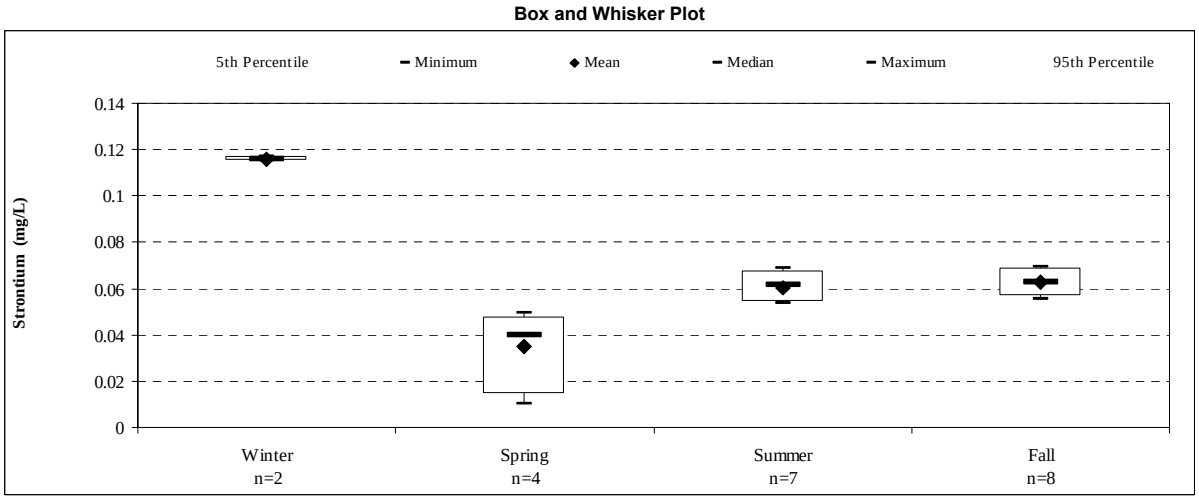


Figure G-2-8-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Kearl Lake



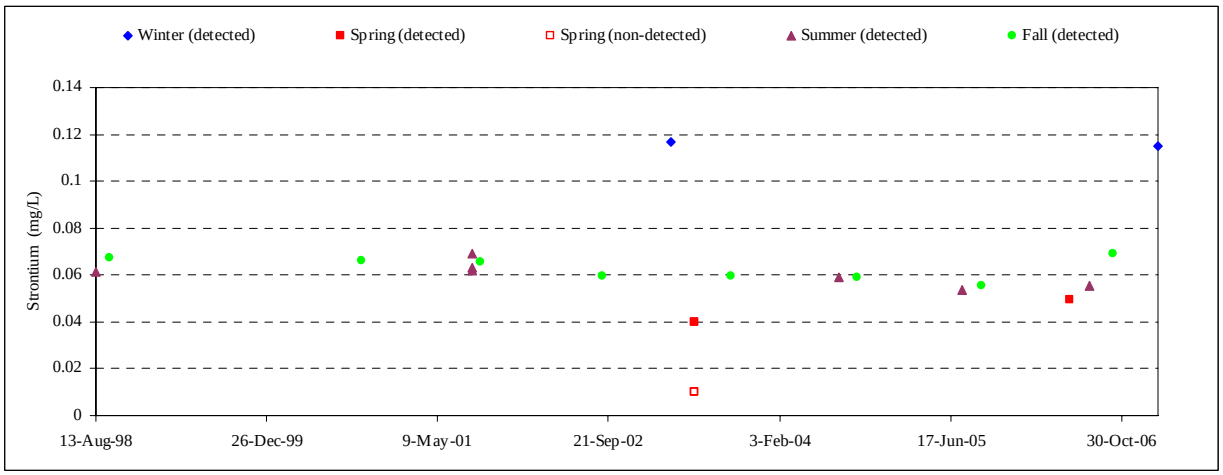
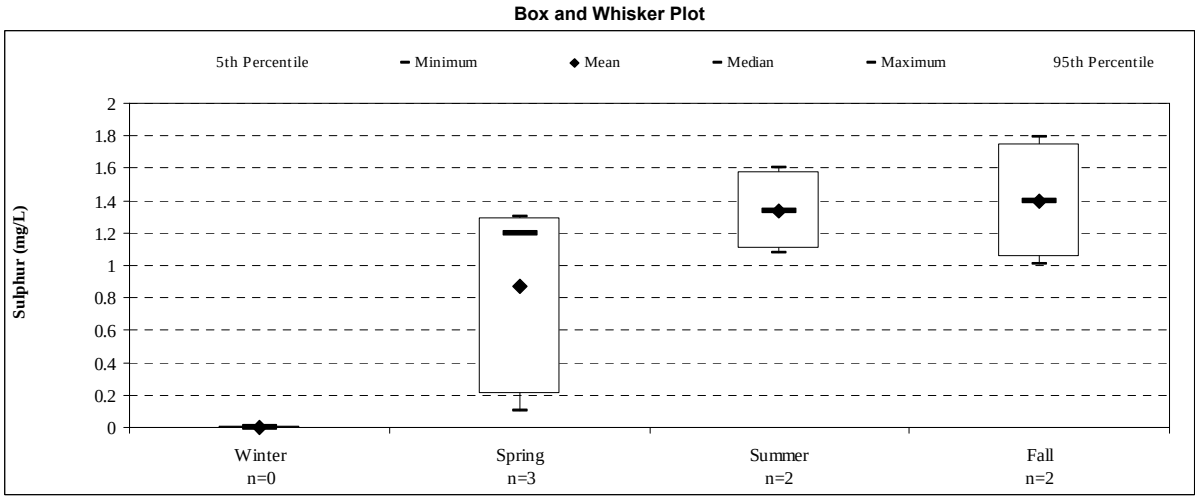


Figure G-2-8-113 Box Whisker and Time Series Scatter Plots of Observed Sulphur (Dissolved) Concentration in Kearl Lake



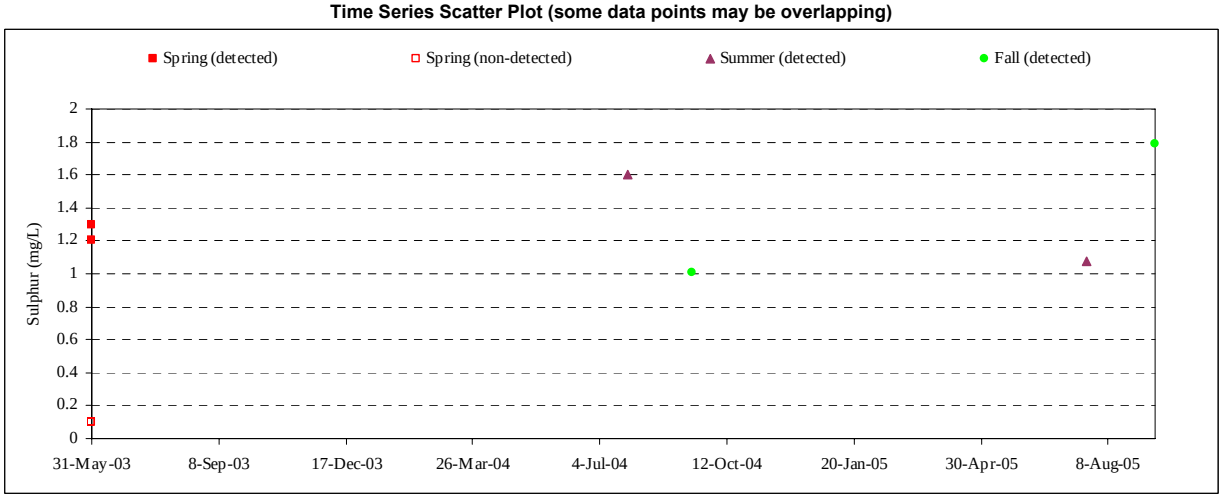
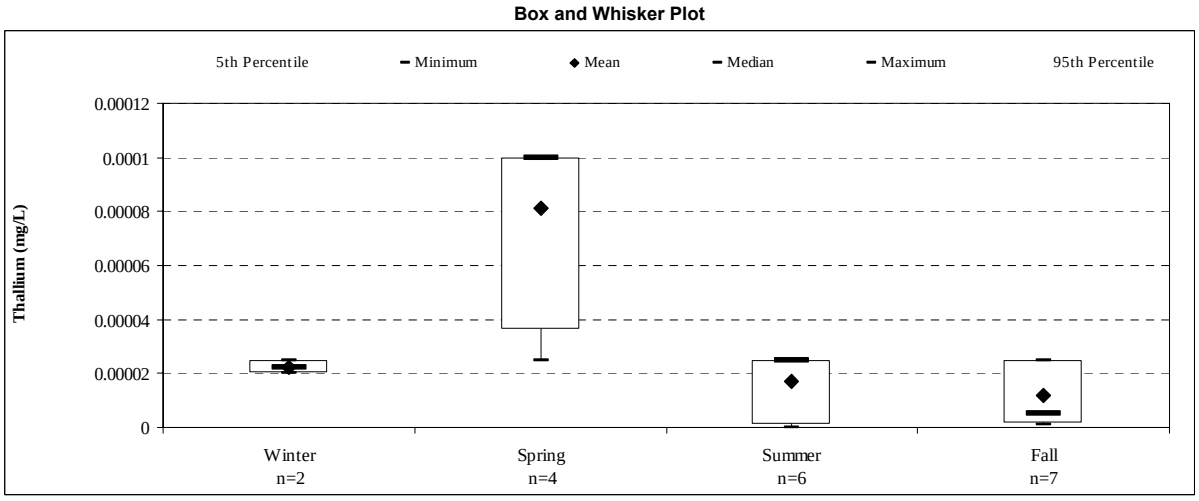


Figure G-2-8-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Kearl Lake



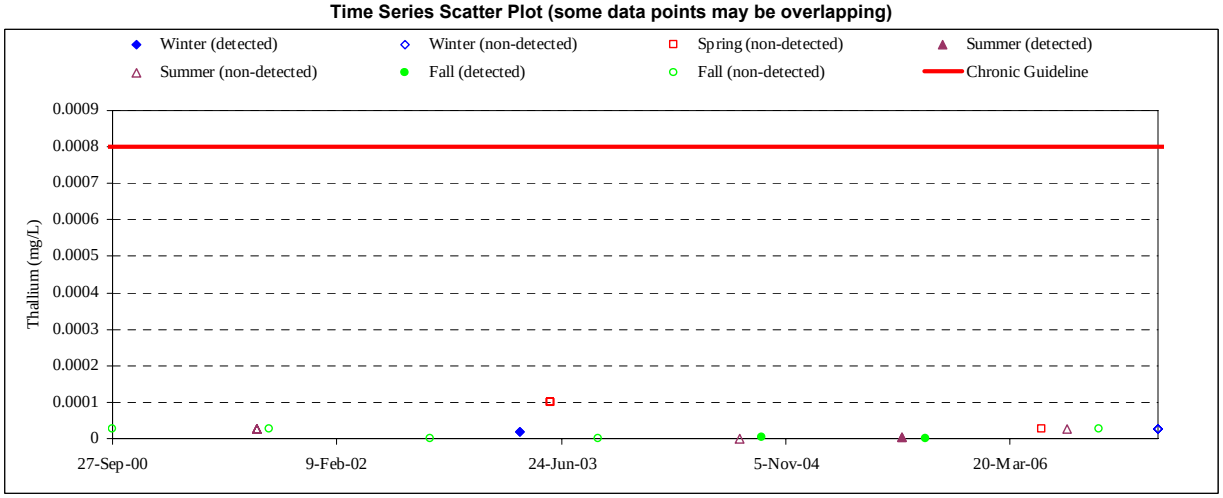
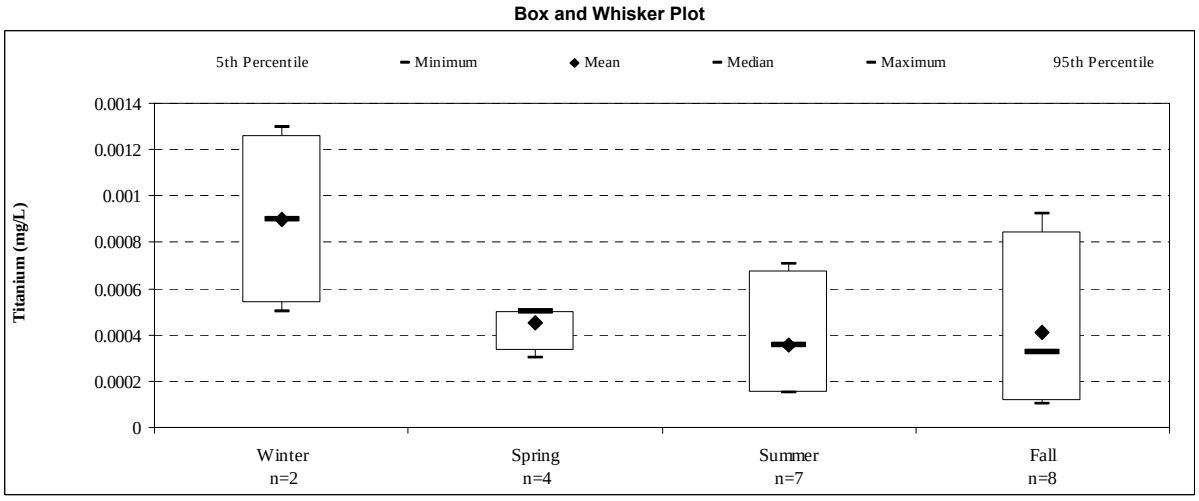


Figure G-2-8-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Kearl Lake



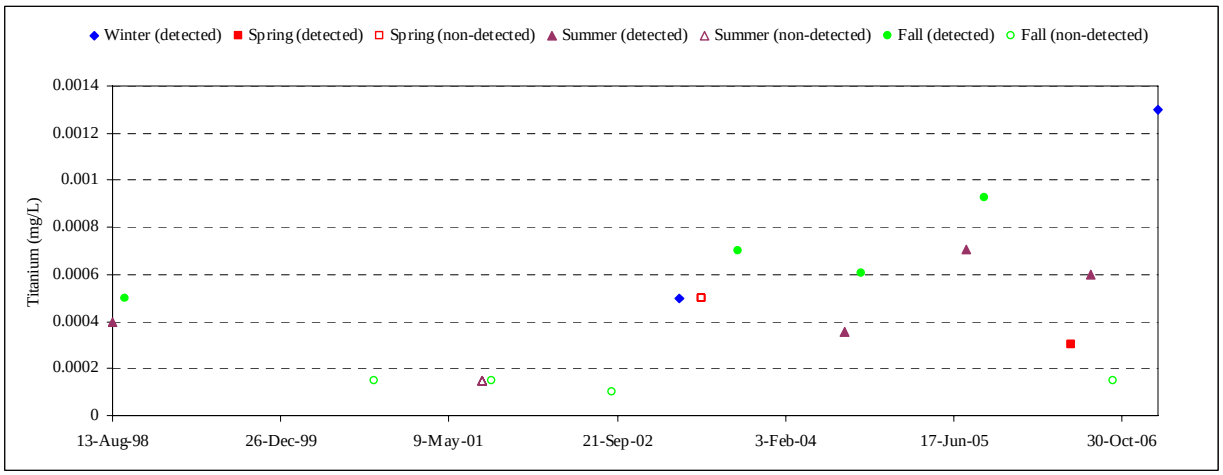
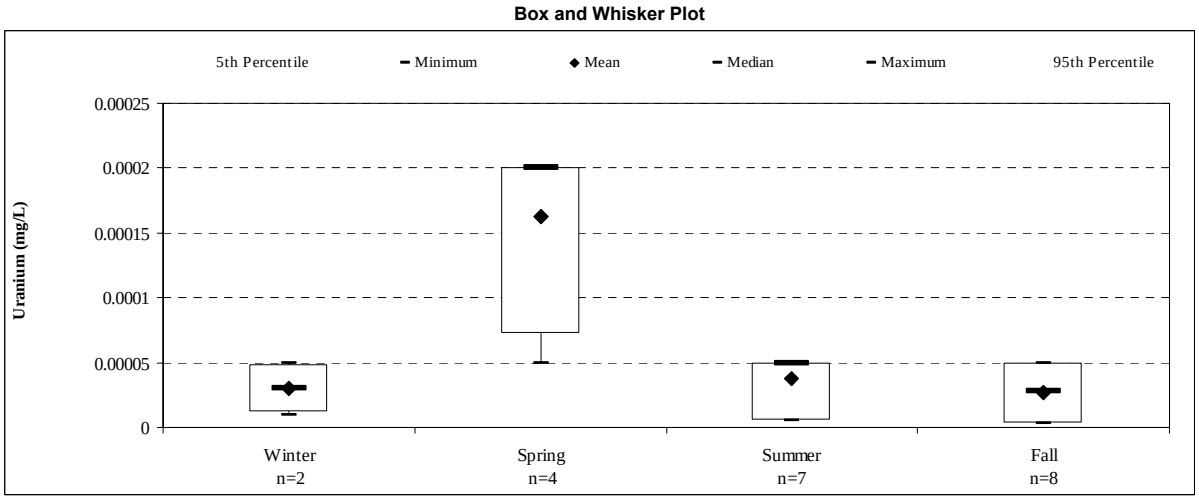


Figure G-2-8-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Kearl Lake



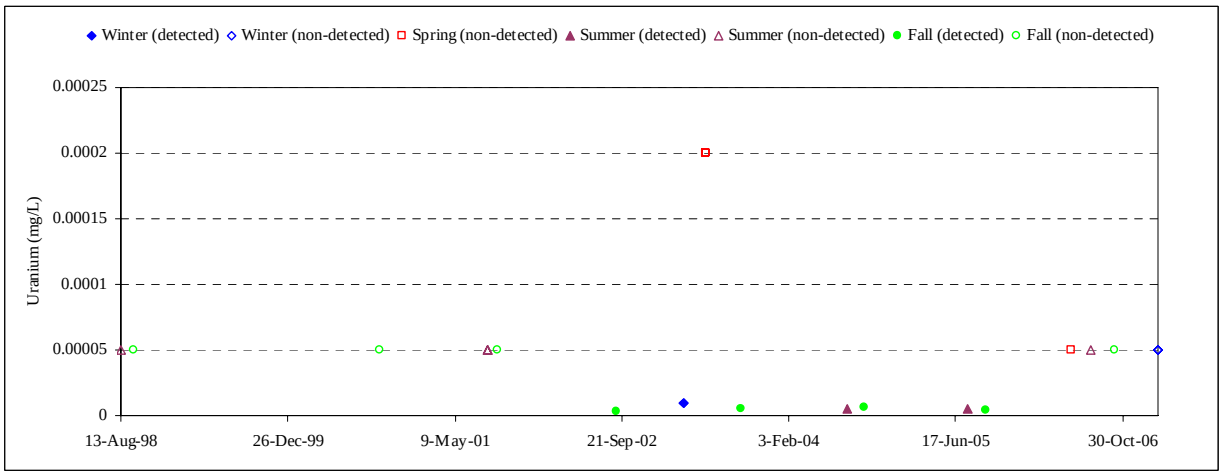
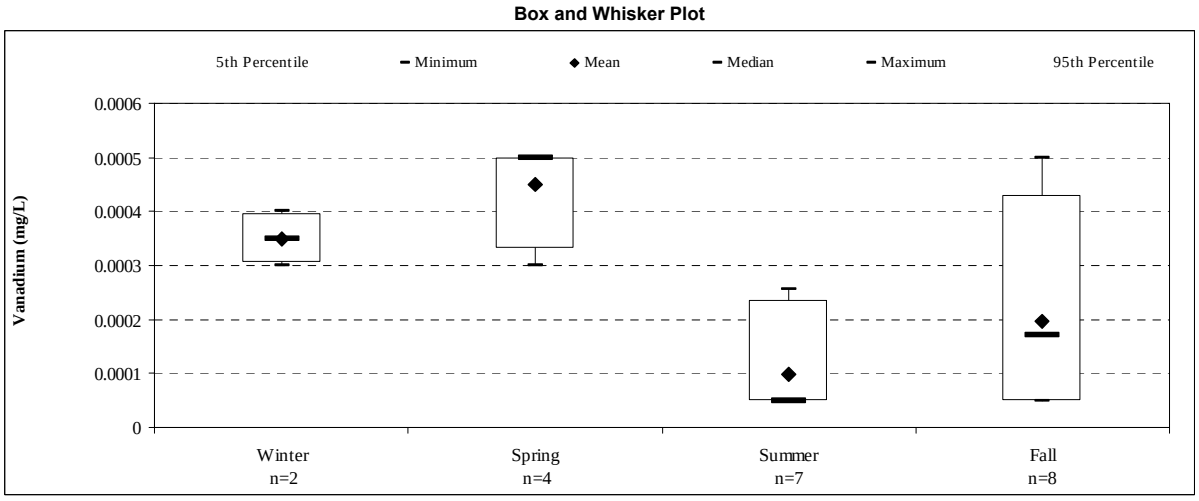


Figure G-2-8-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Kearl Lake



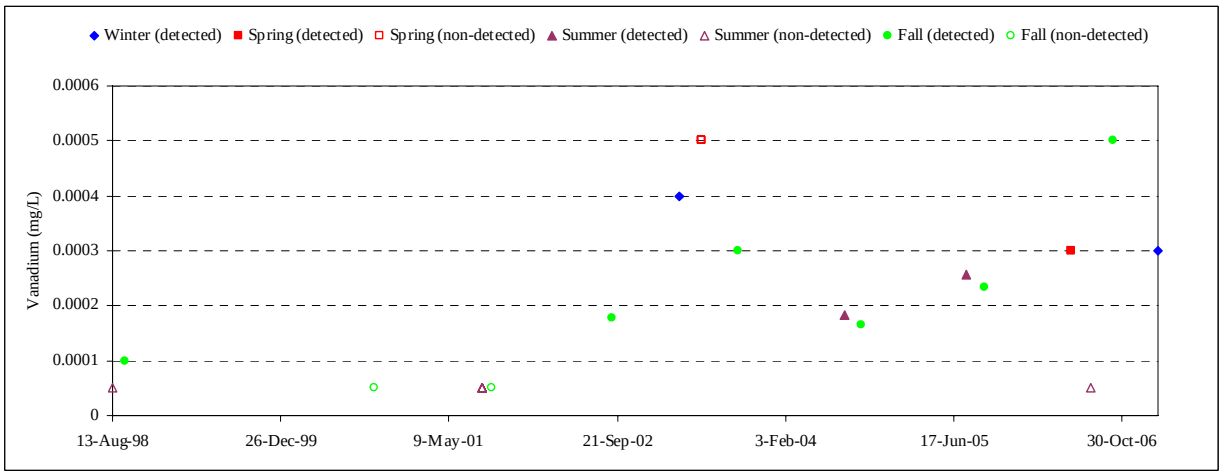
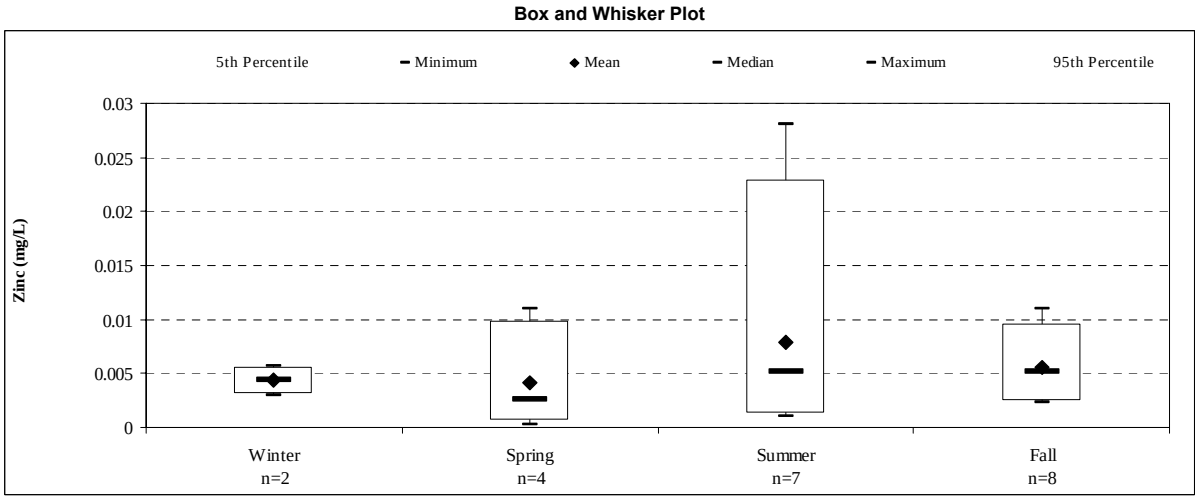


Figure G-2-8-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Kearl Lake



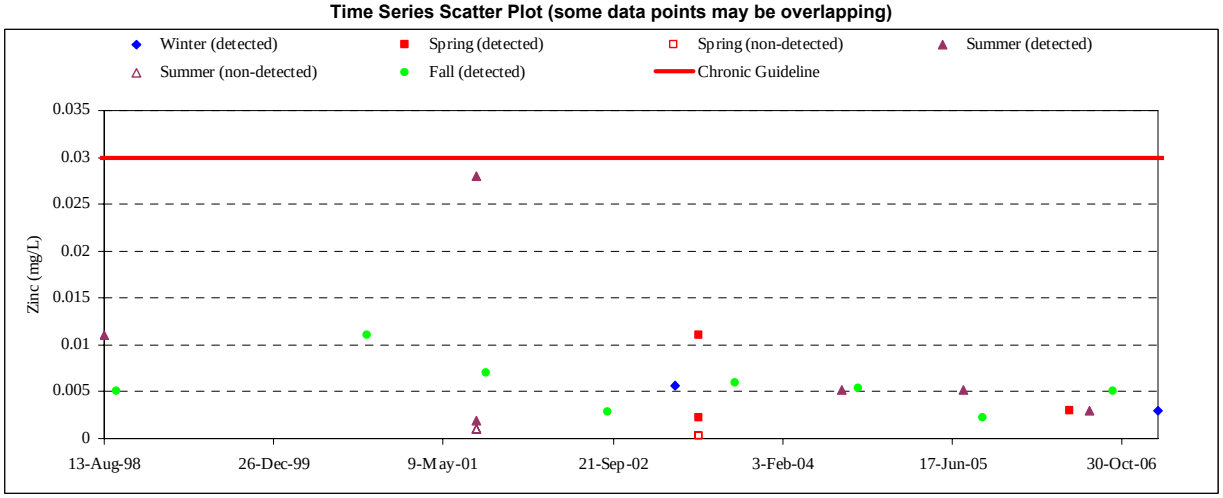
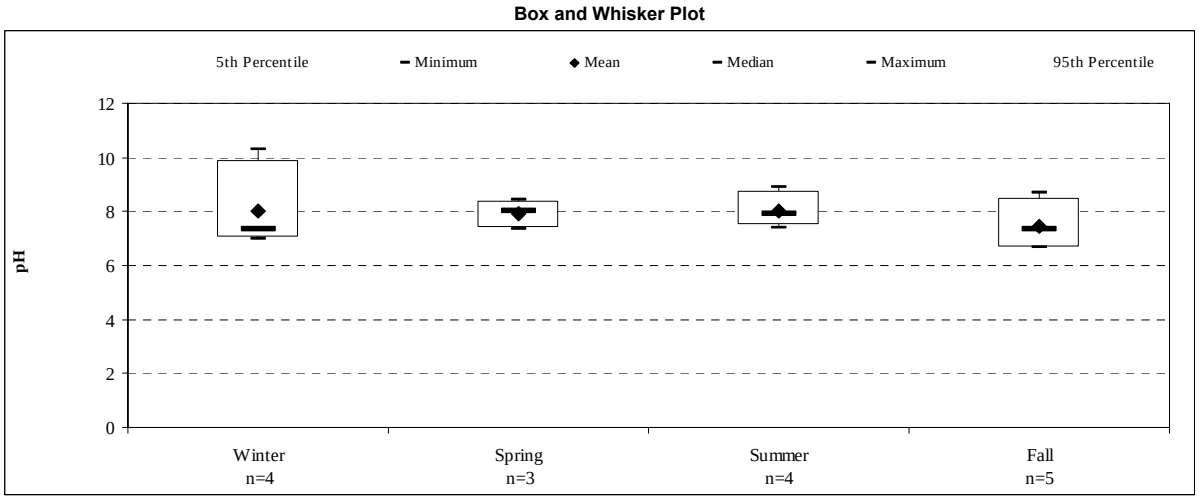


Figure G-2-9-1 Box Whisker and Time Series Scatter Plots of Observed pH in Unnamed Lakes within JEMA



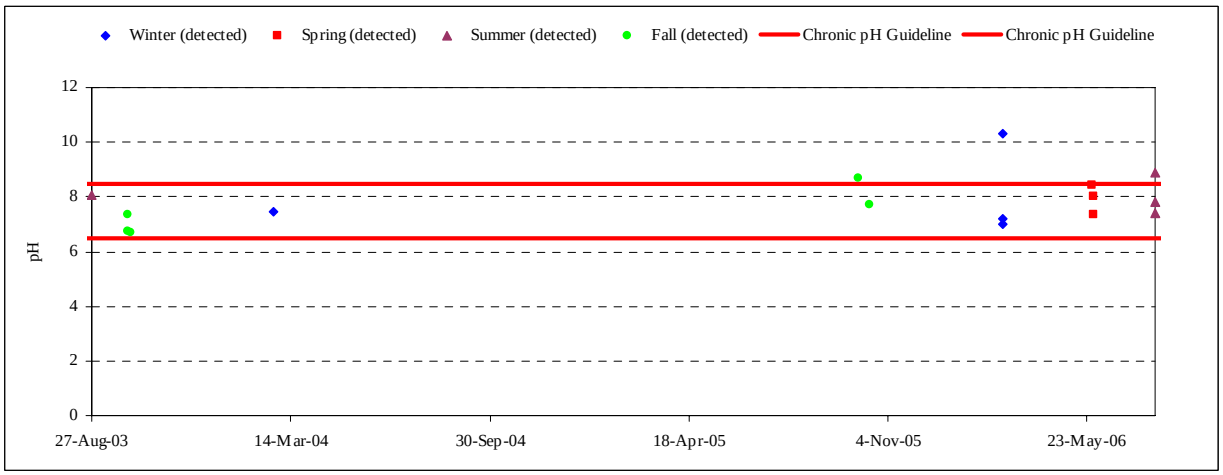
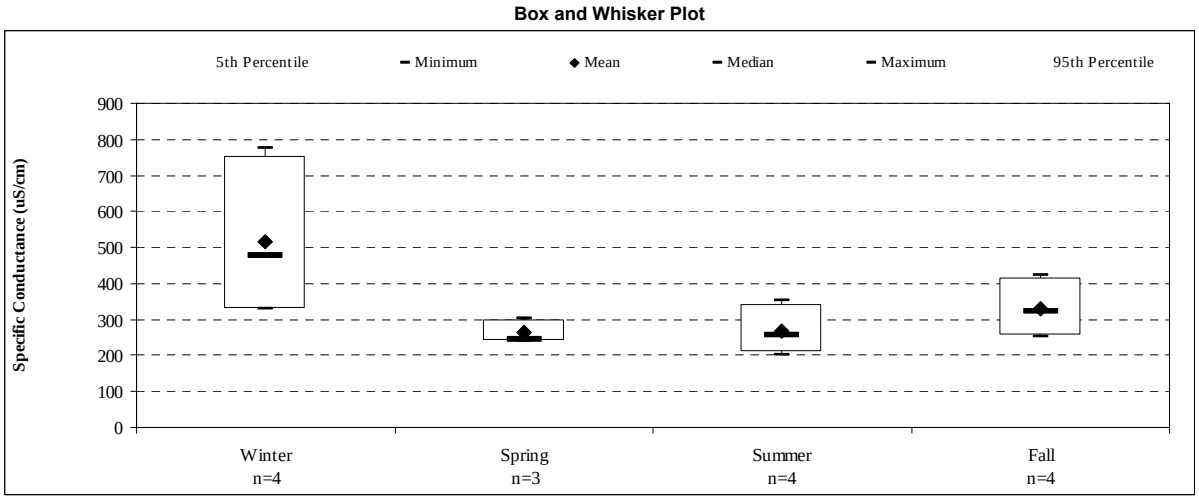


Figure G-2-9-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Unnamed Lakes within JEMA



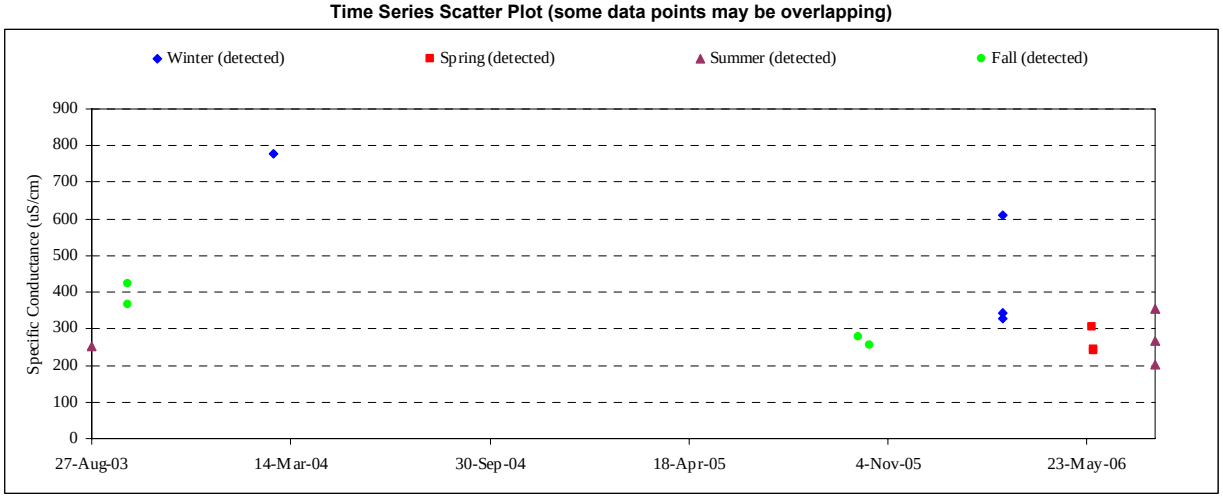
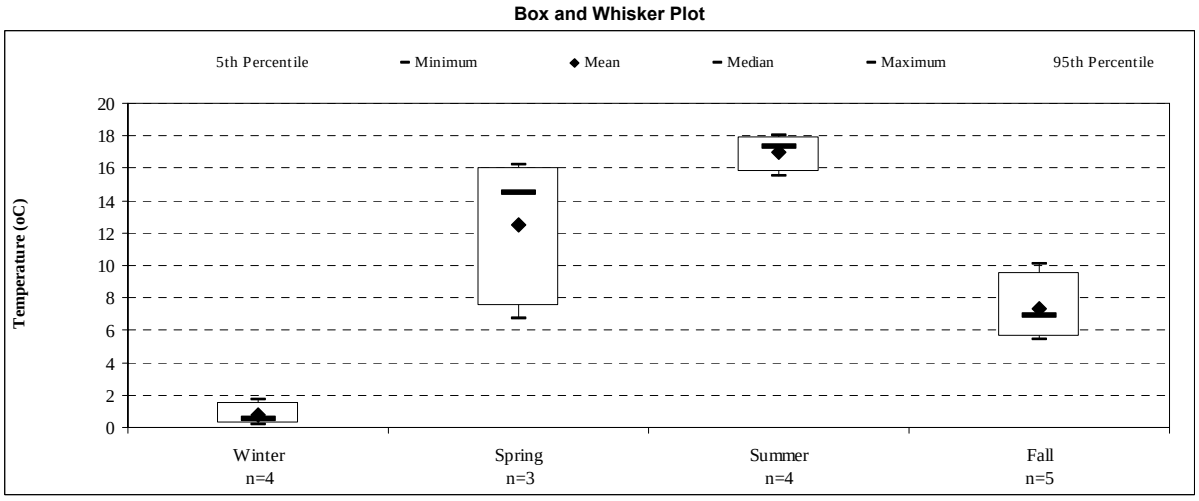


Figure G-2-9-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Unnamed Lakes within JEMA



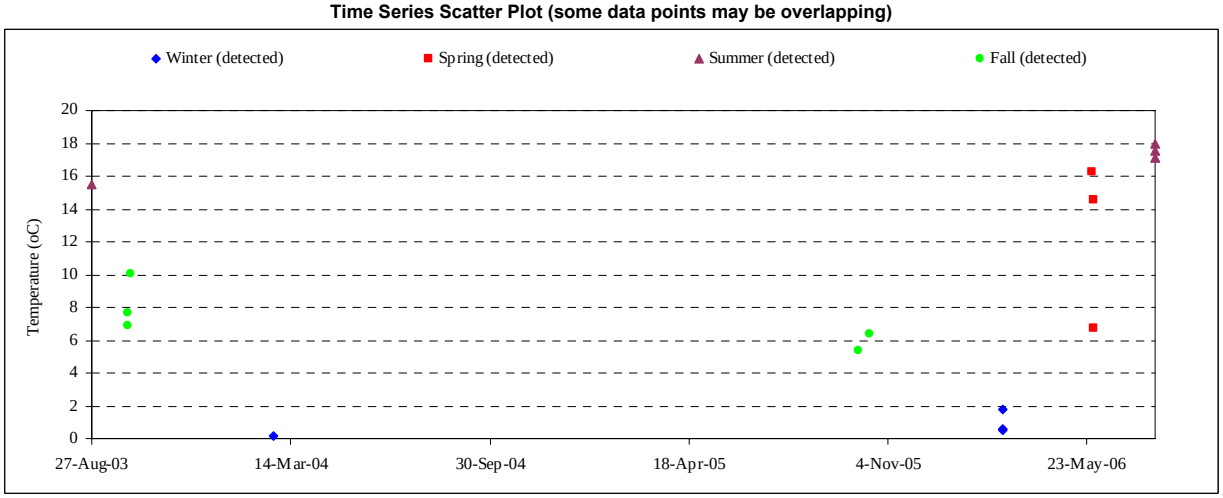
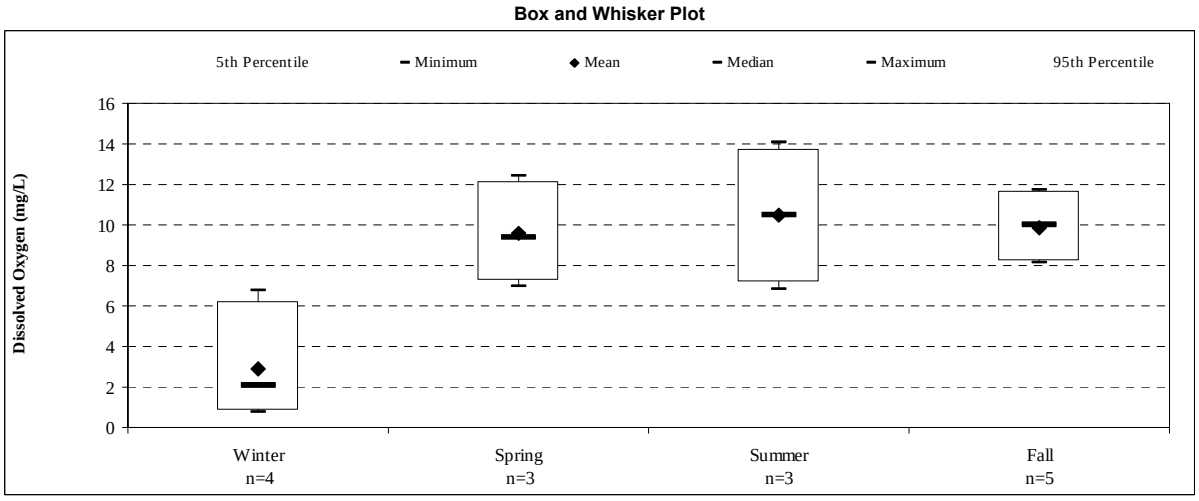


Figure G-2-9-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Unnamed Lakes within JEMA



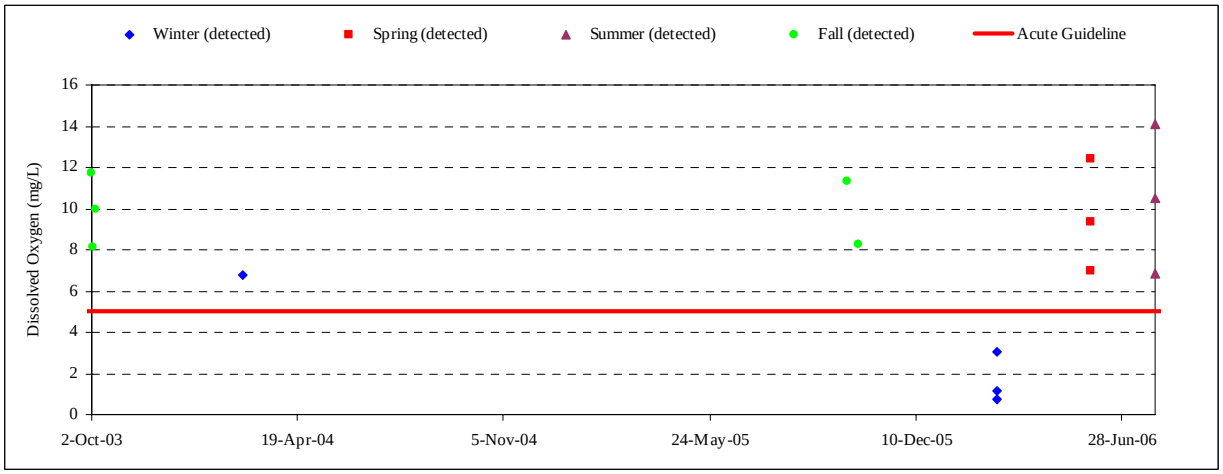
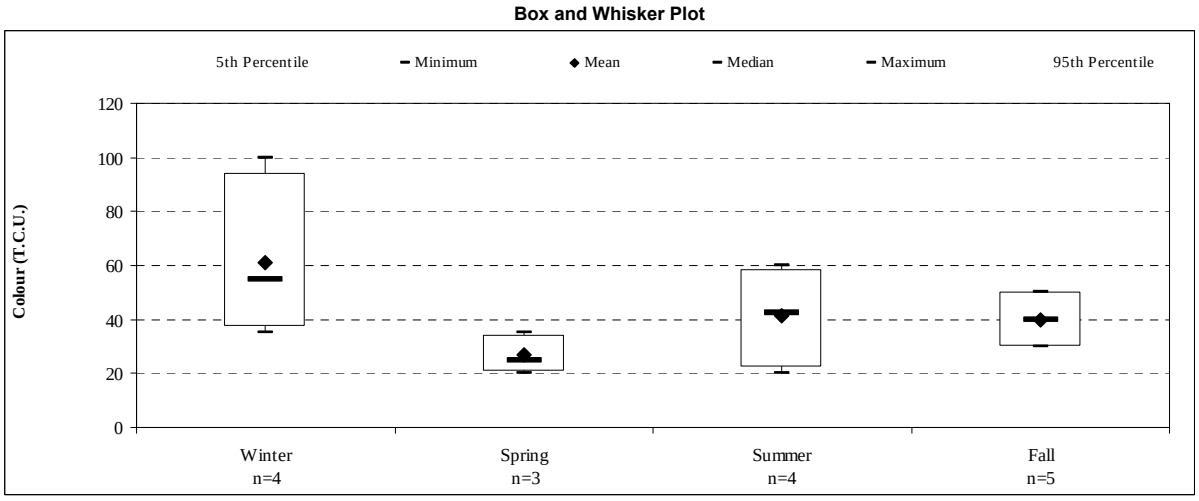


Figure G-2-9-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Unnamed Lakes within JEMA



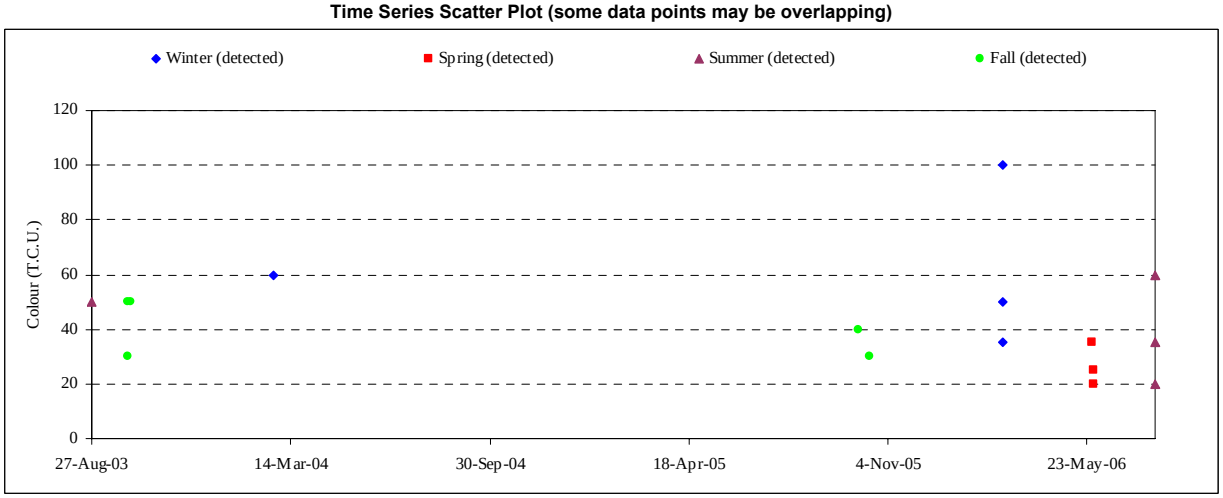
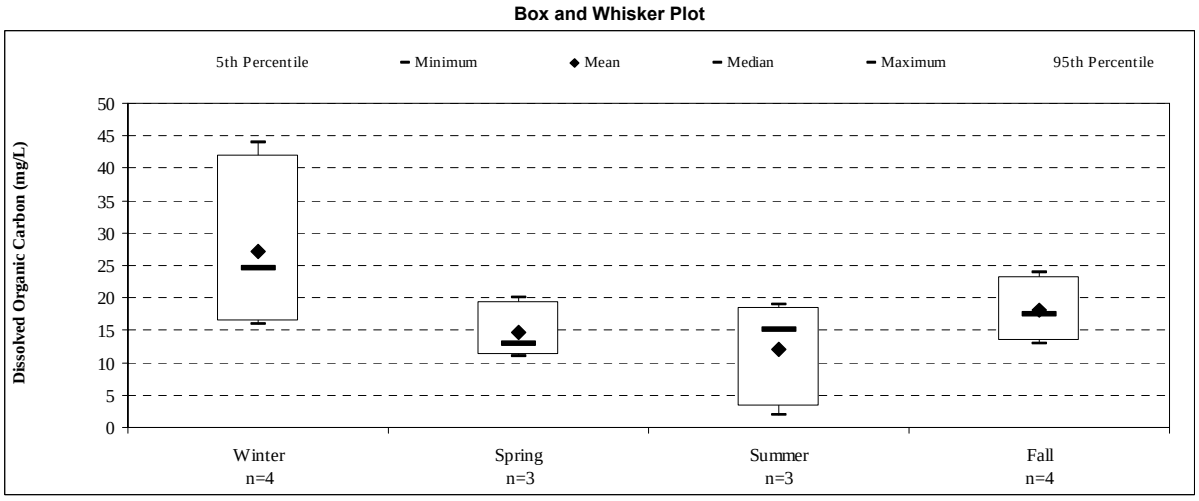


Figure G-2-9-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Unnamed Lakes within JEMA



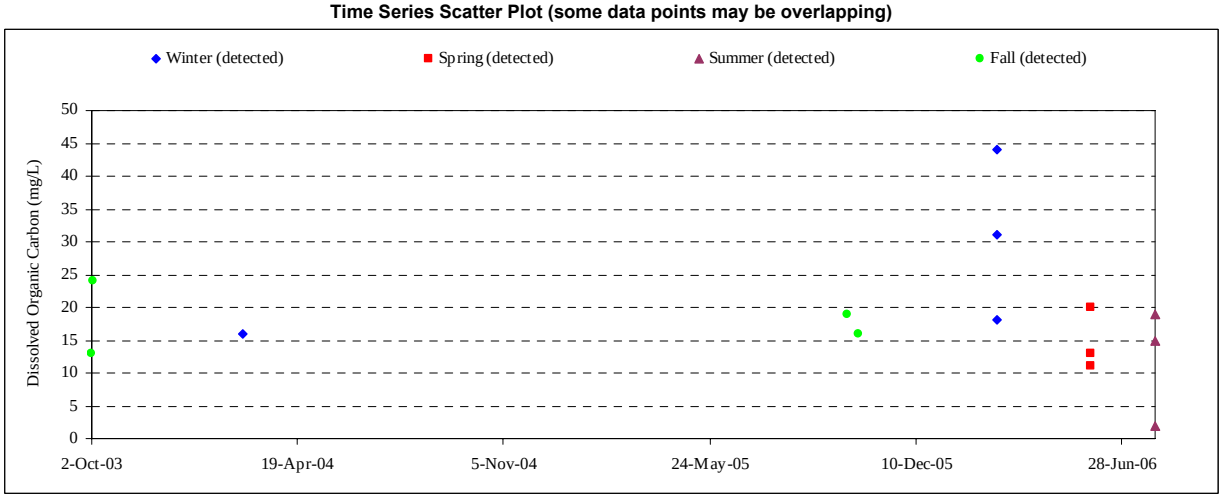
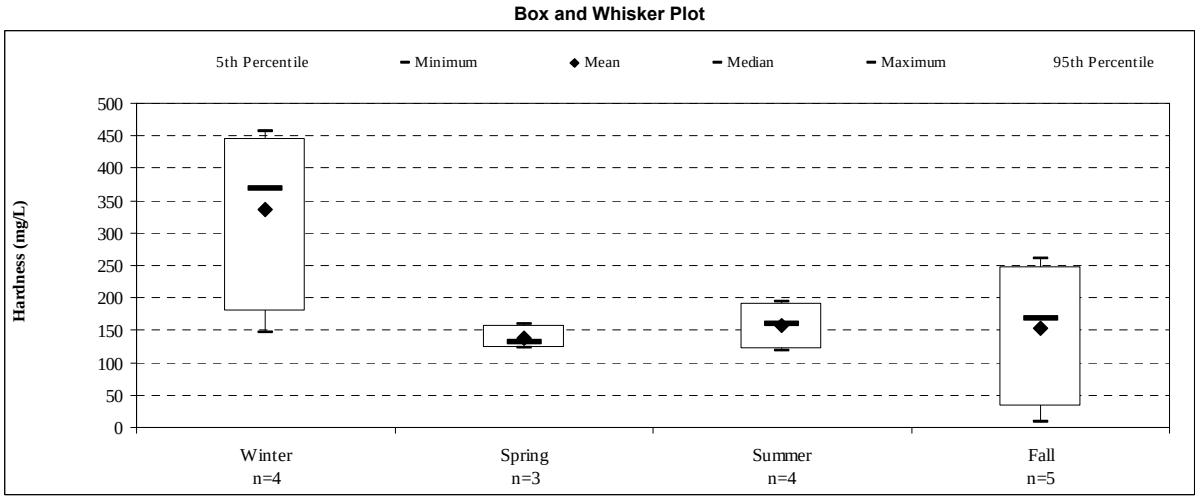


Figure G-2-9-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Unnamed Lakes within JEMA



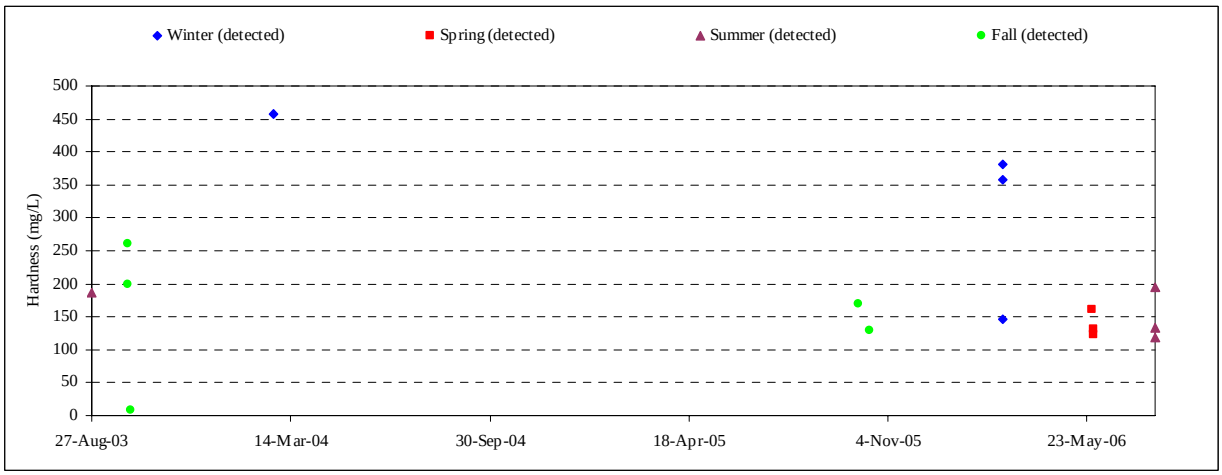
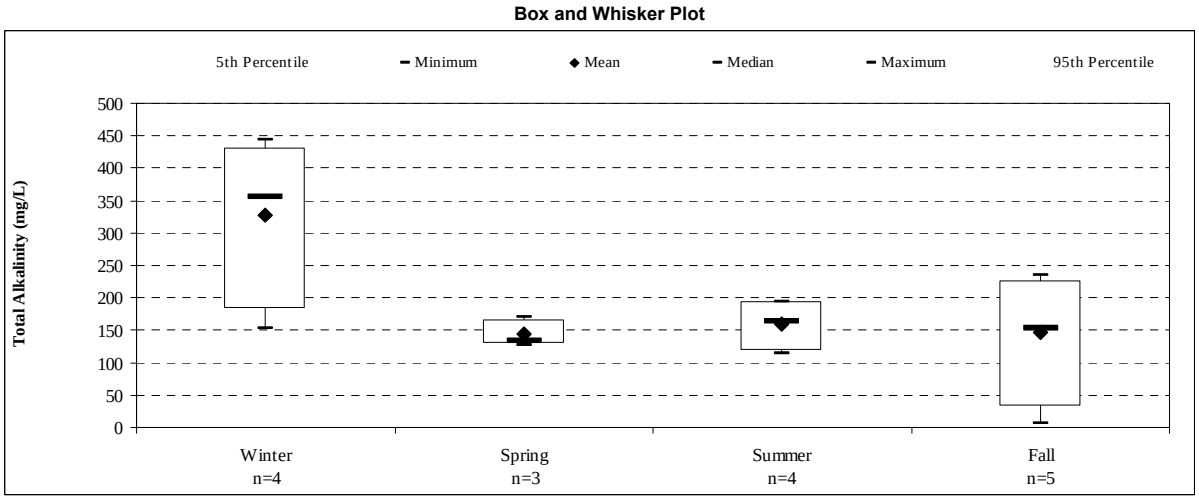


Figure G-2-9-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Unnamed Lakes within JEMA



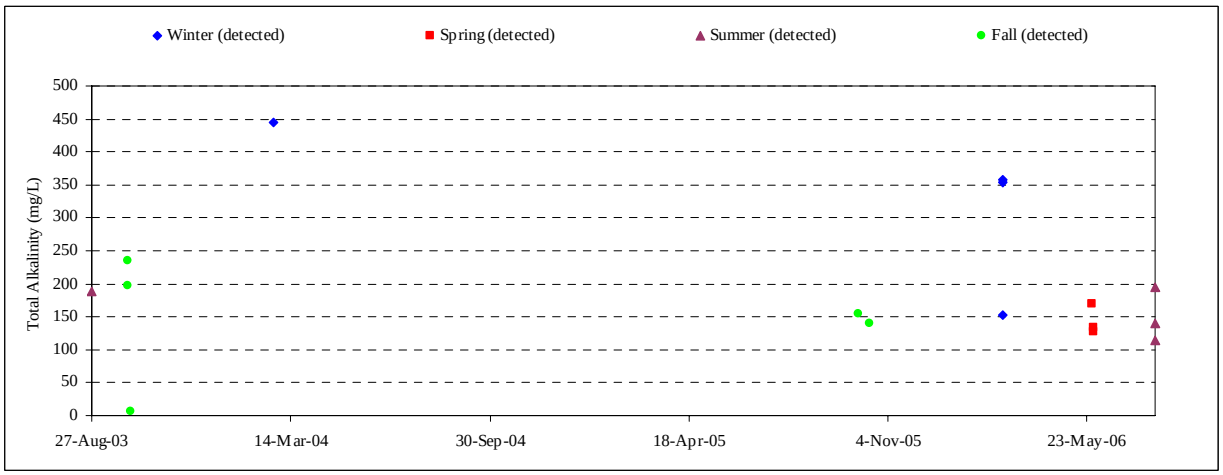
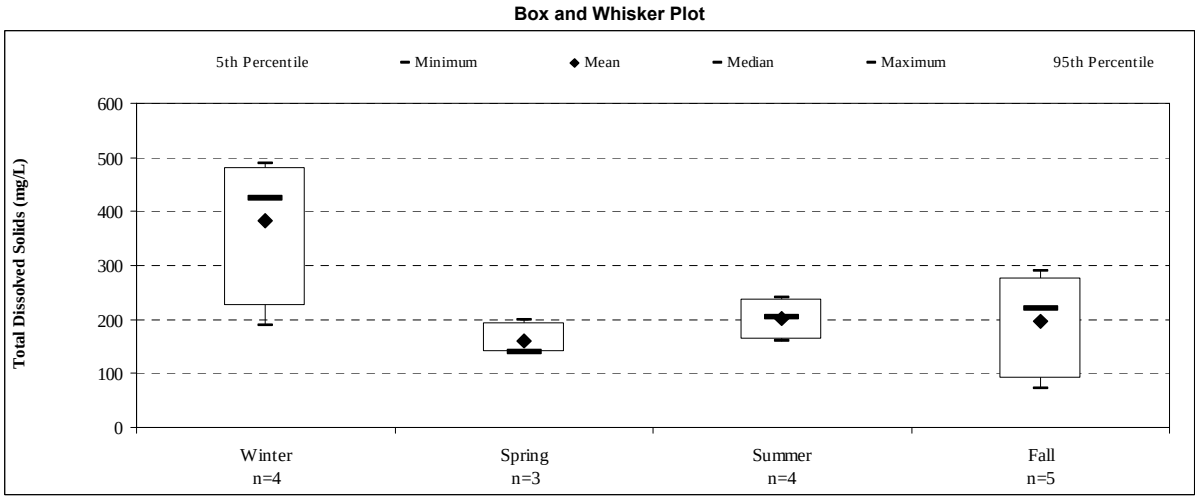


Figure G-2-9-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Unnamed Lakes within JEMA



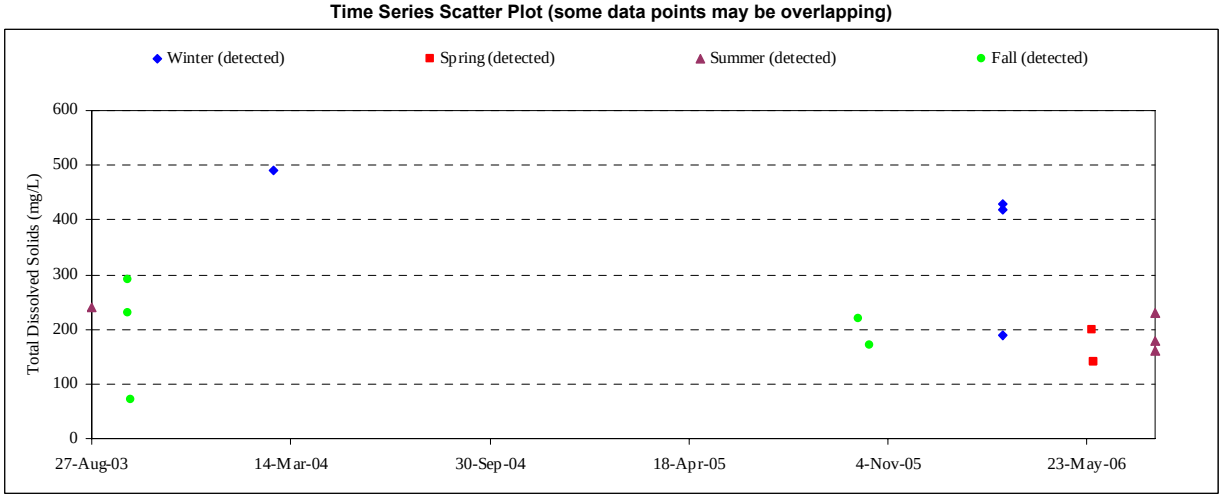
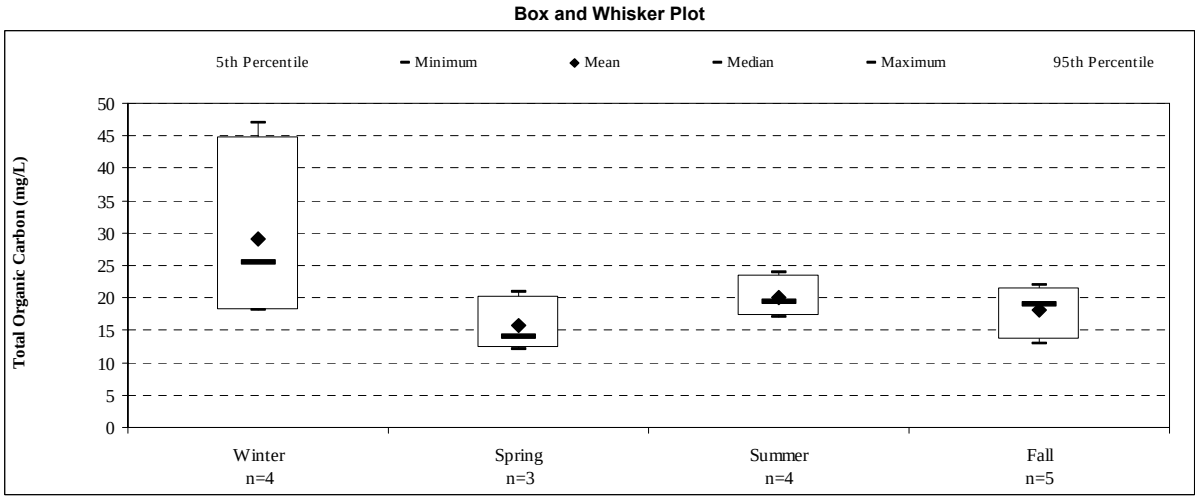


Figure G-2-9-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Unnamed Lakes within JEMA



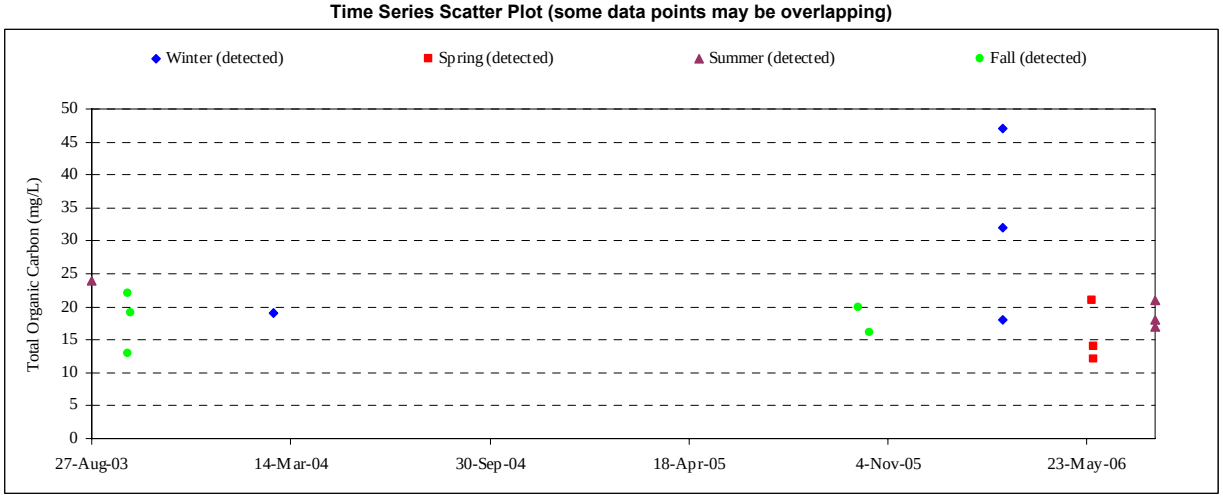
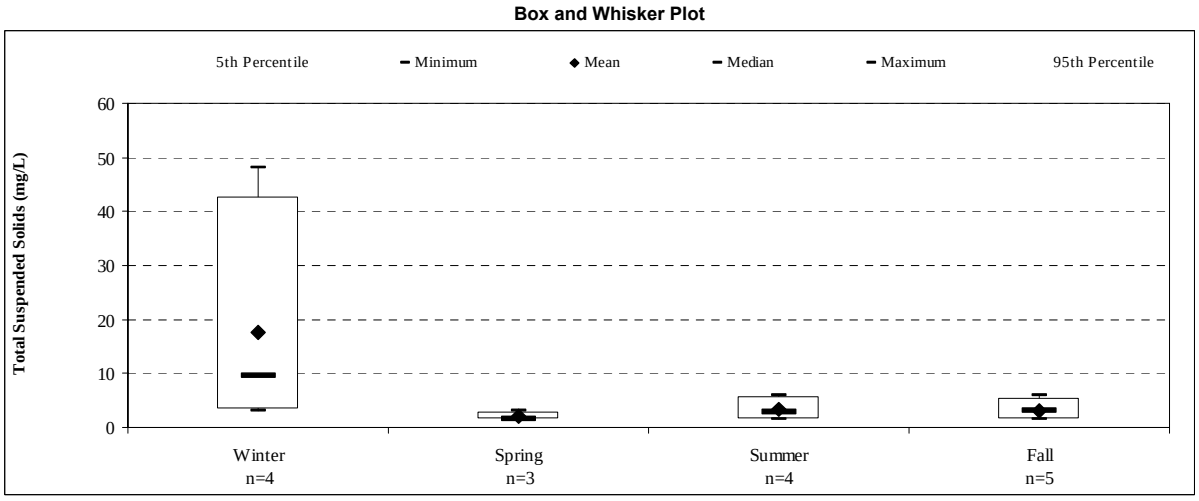


Figure G-2-9-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Unnamed Lakes within JEMA



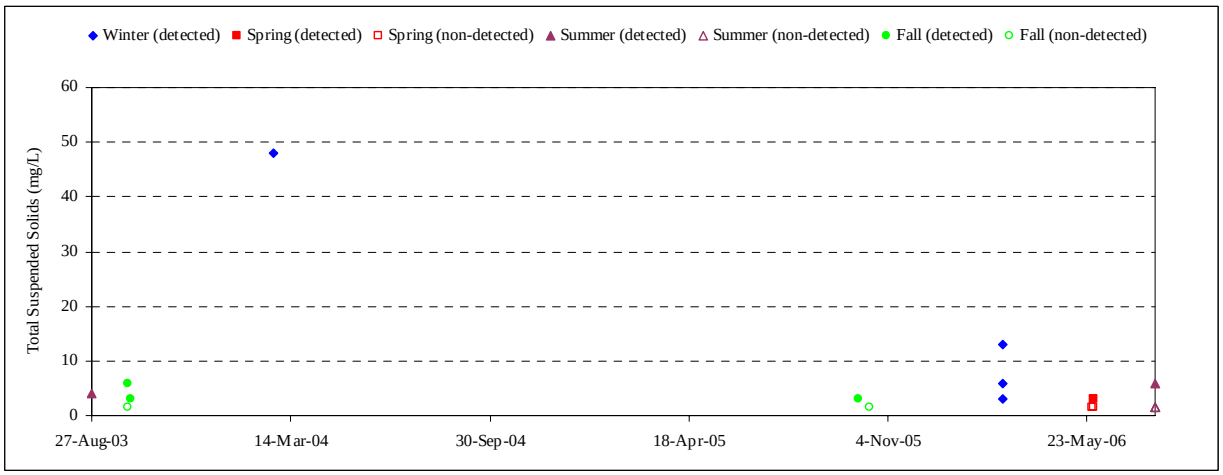
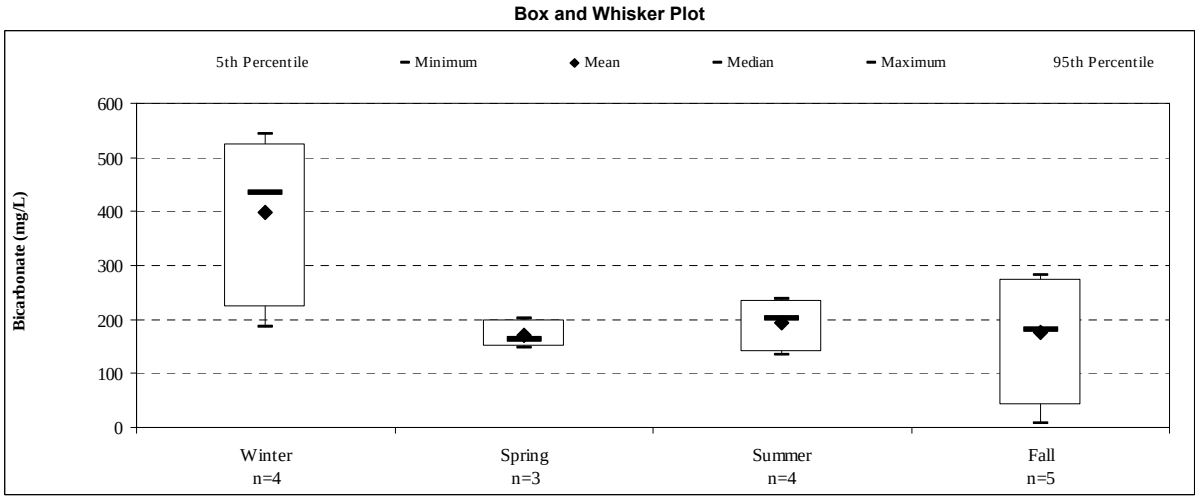


Figure G-2-9-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Unnamed Lakes within JEMA



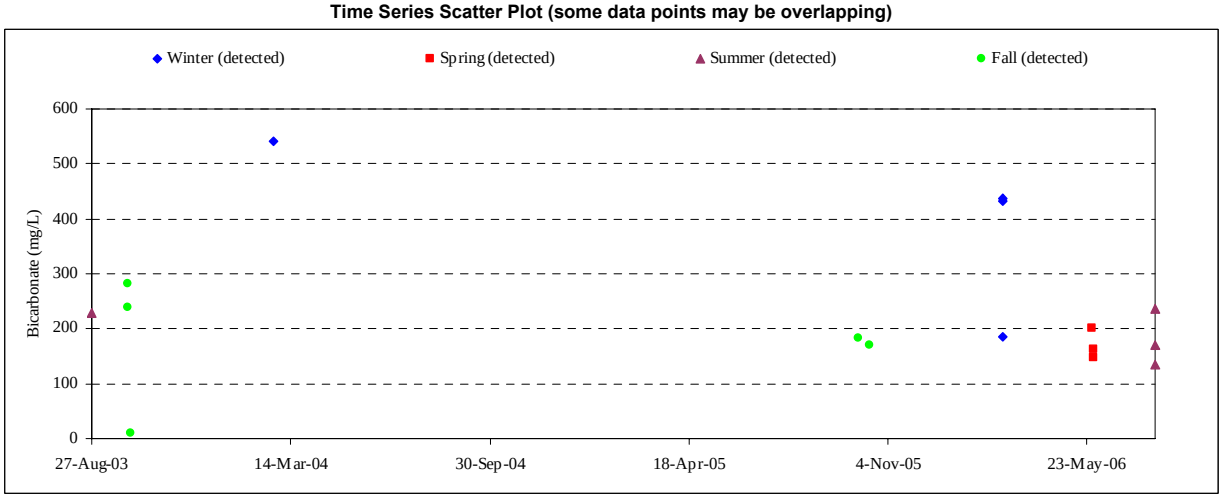
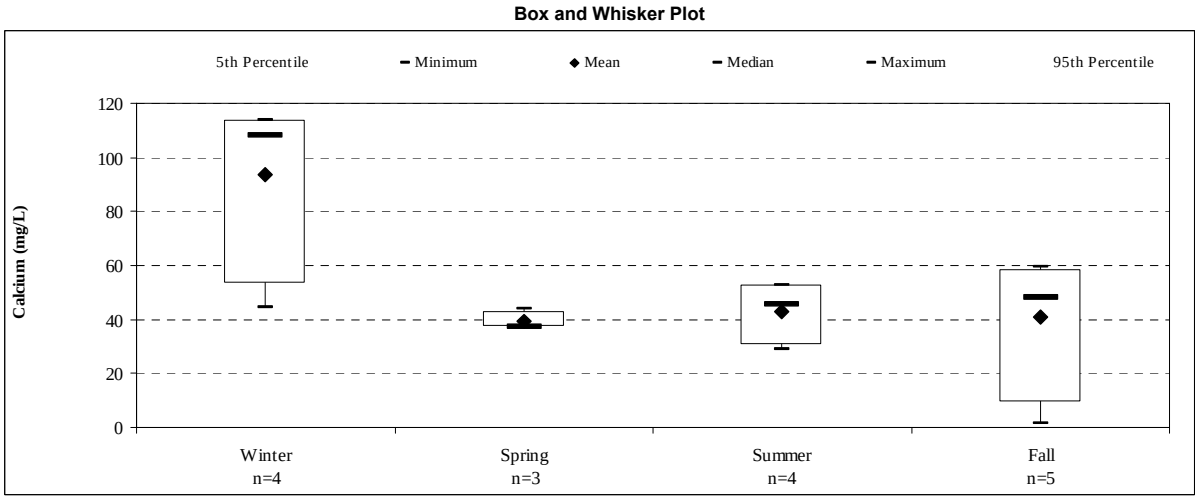


Figure G-2-9-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Unnamed Lakes within JEMA



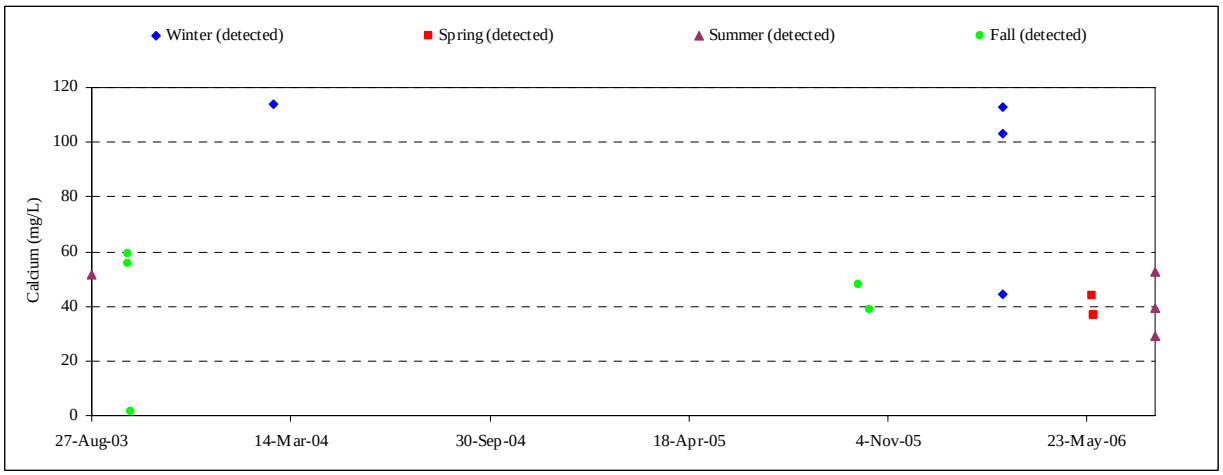
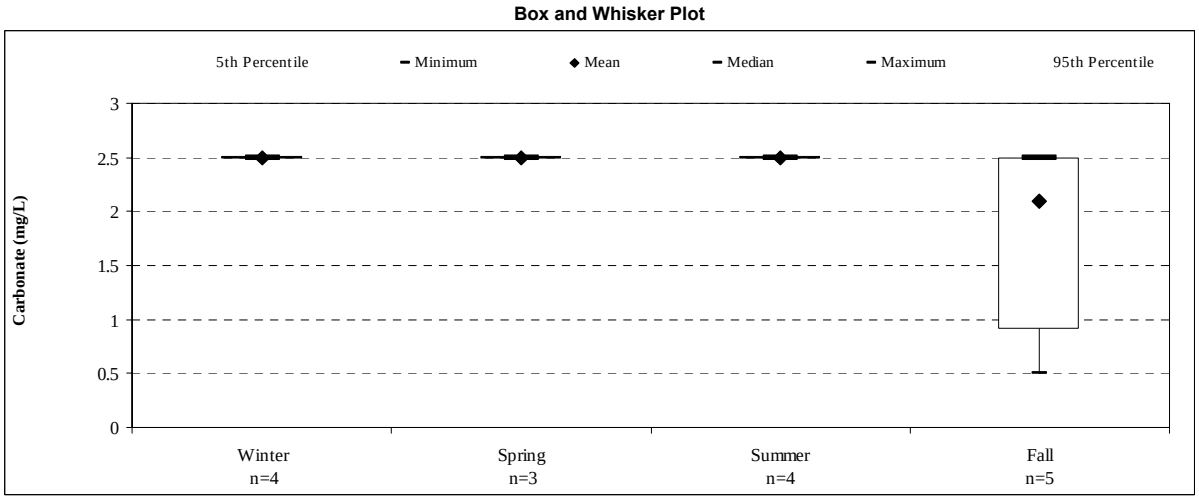


Figure G-2-9-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Unnamed Lakes within JEMA



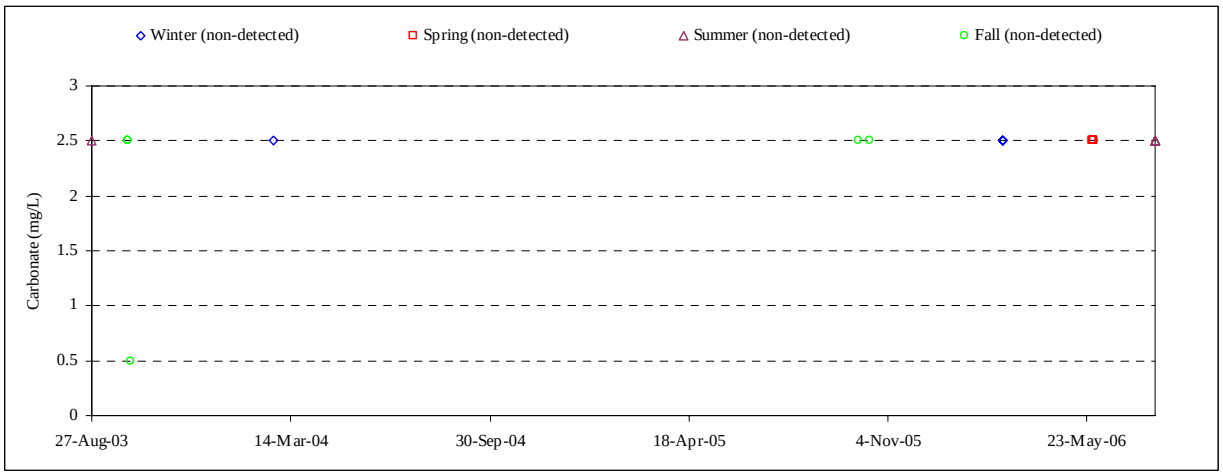
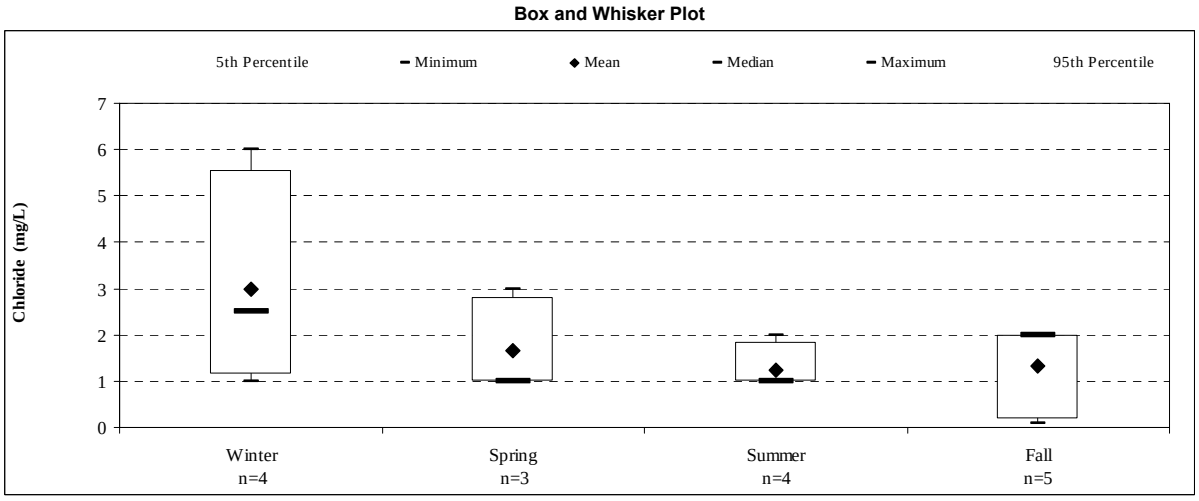


Figure G-2-9-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Unnamed Lakes within JEMA



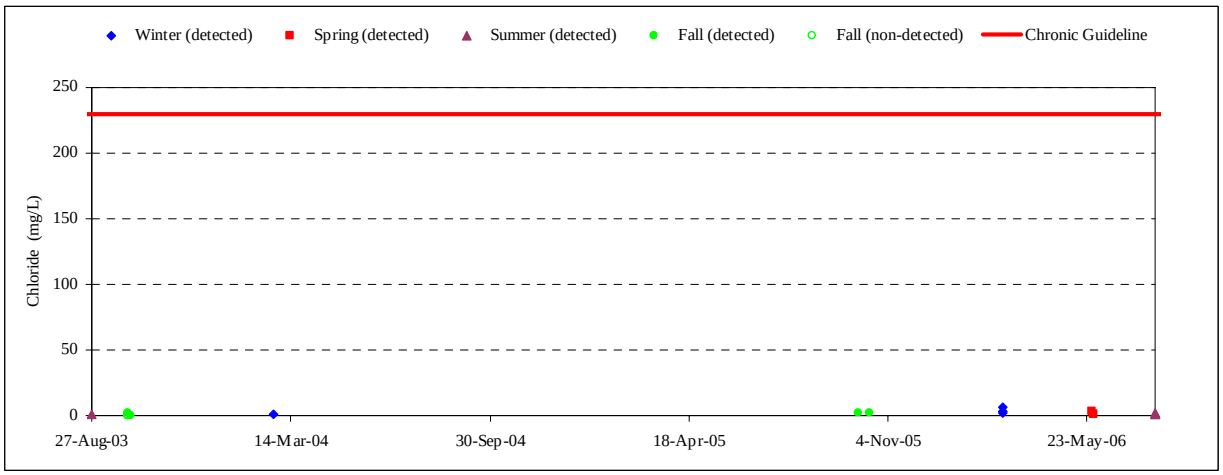
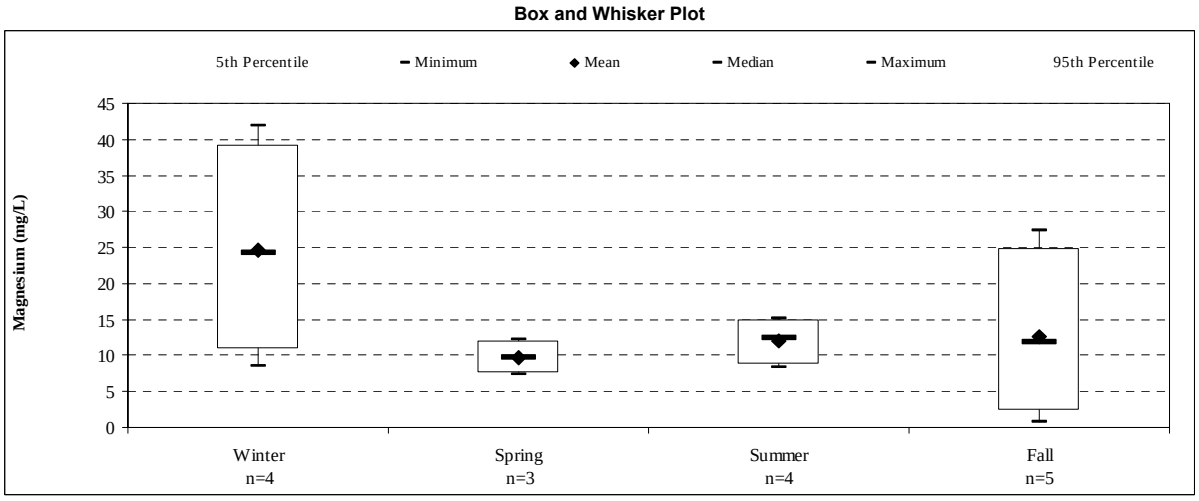


Figure G-2-9-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Unnamed Lakes within JEMA



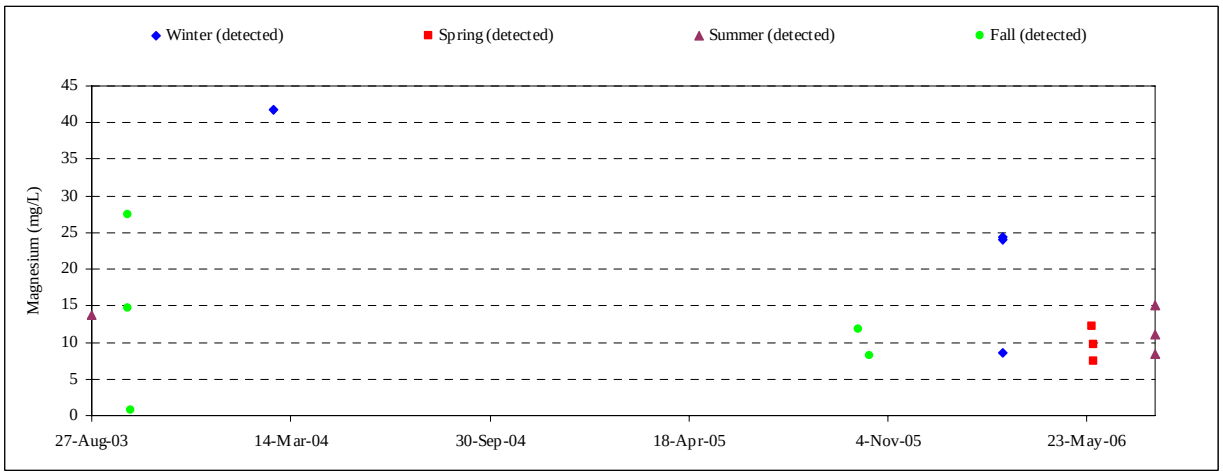
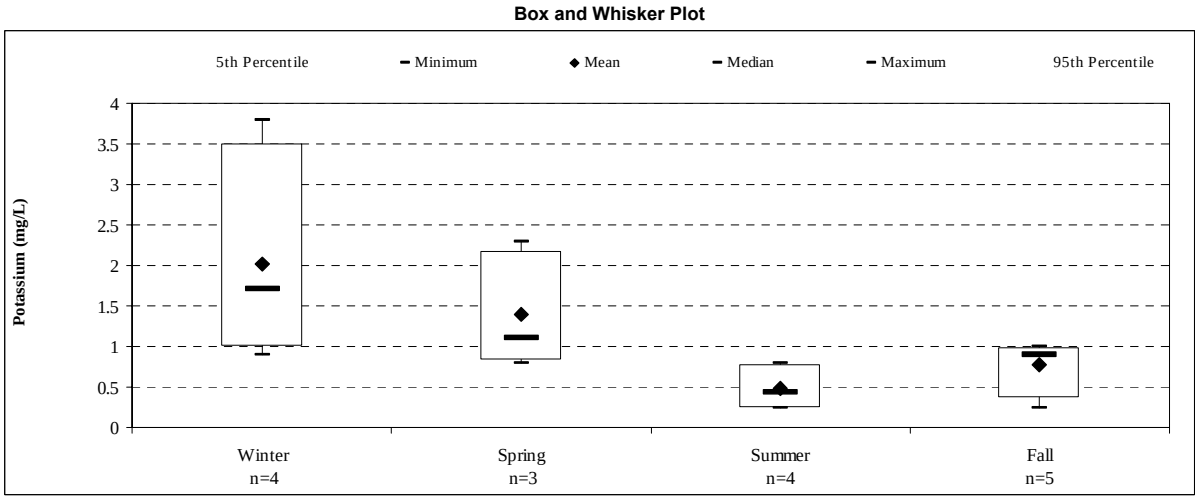


Figure G-2-9-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Unnamed Lakes within JEMA



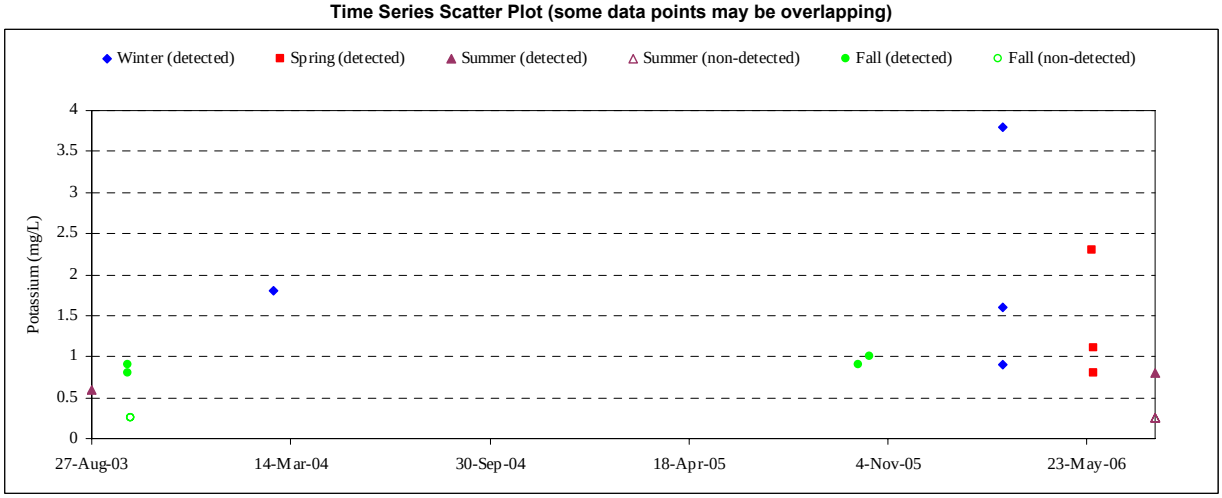
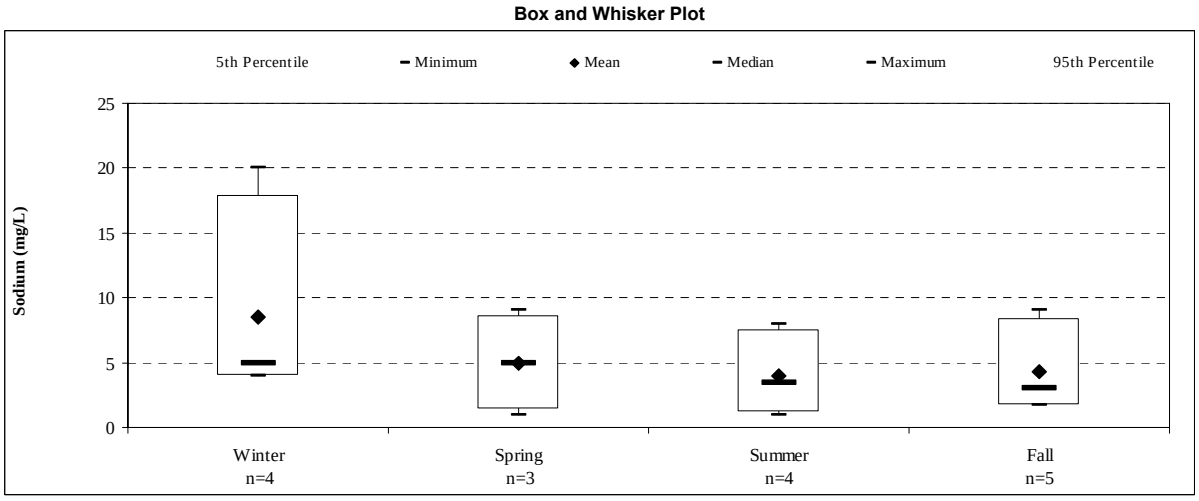


Figure G-2-9-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Unnamed Lakes within JEMA



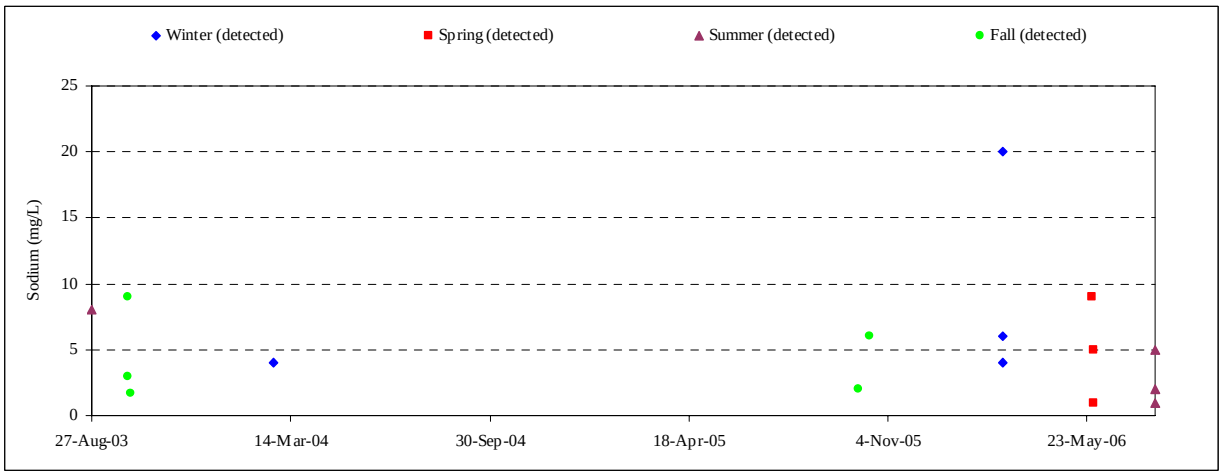
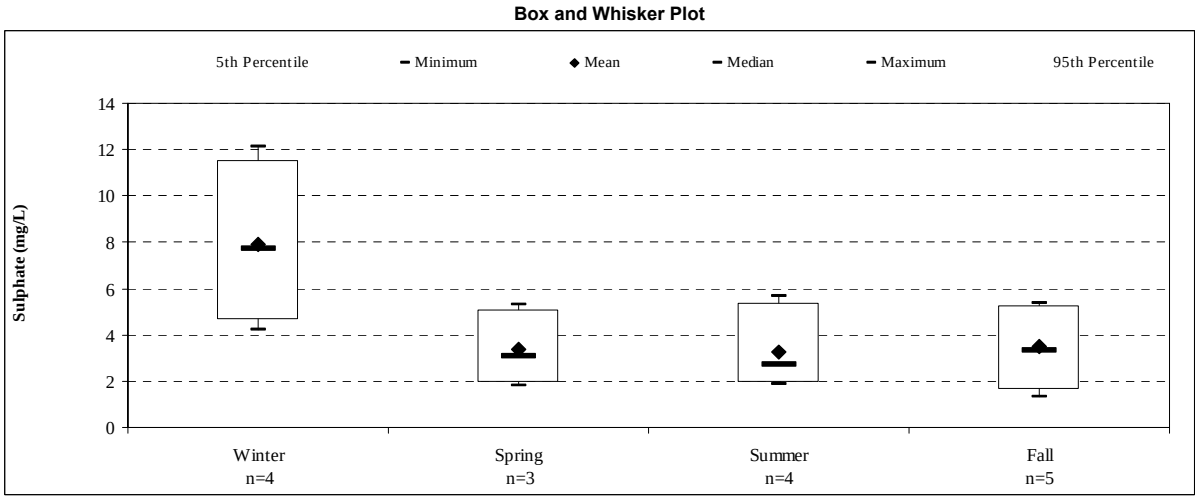


Figure G-2-9-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Unnamed Lakes within JEMA



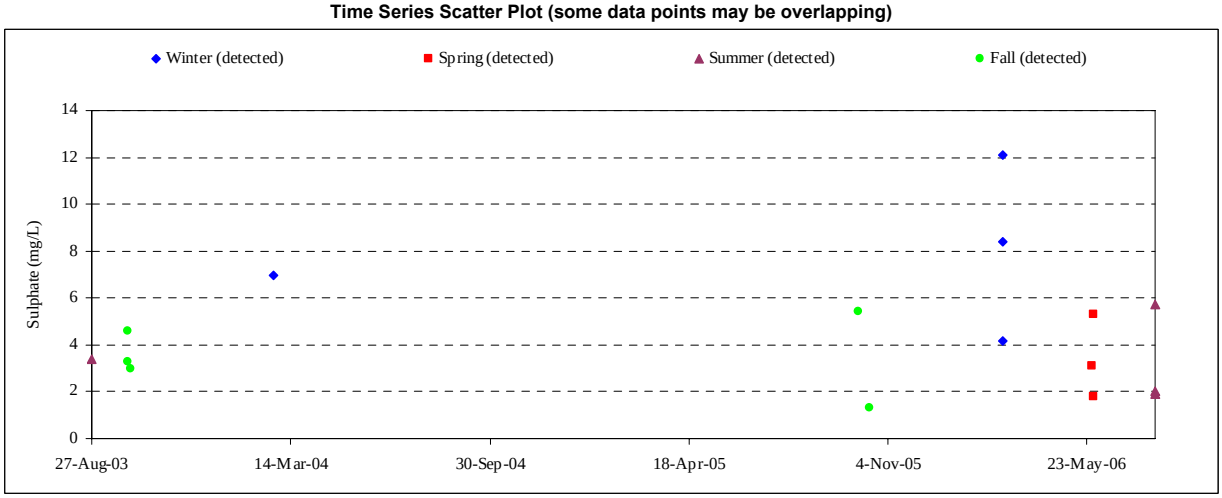
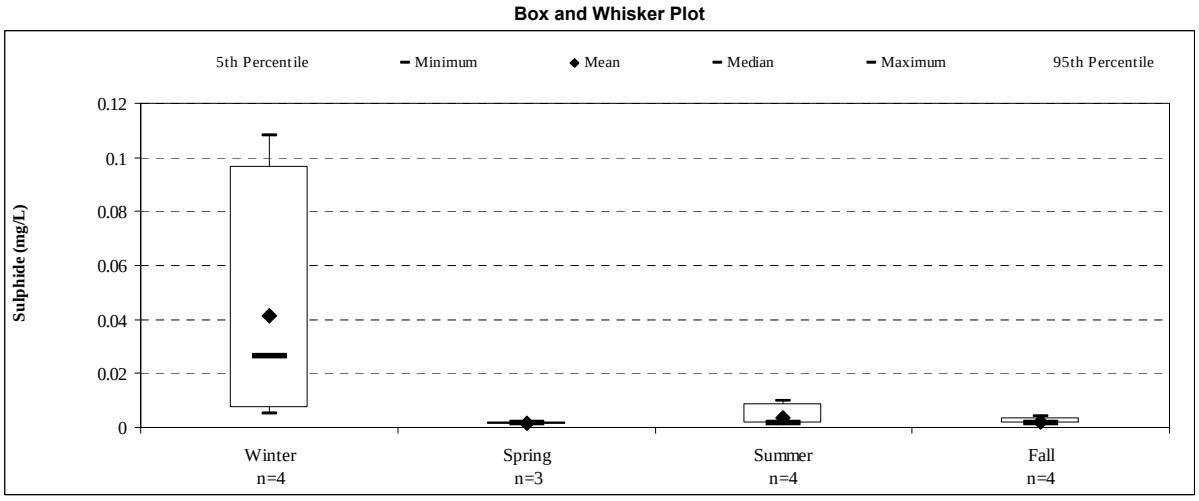


Figure G-2-9-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Unnamed Lakes within JEMA



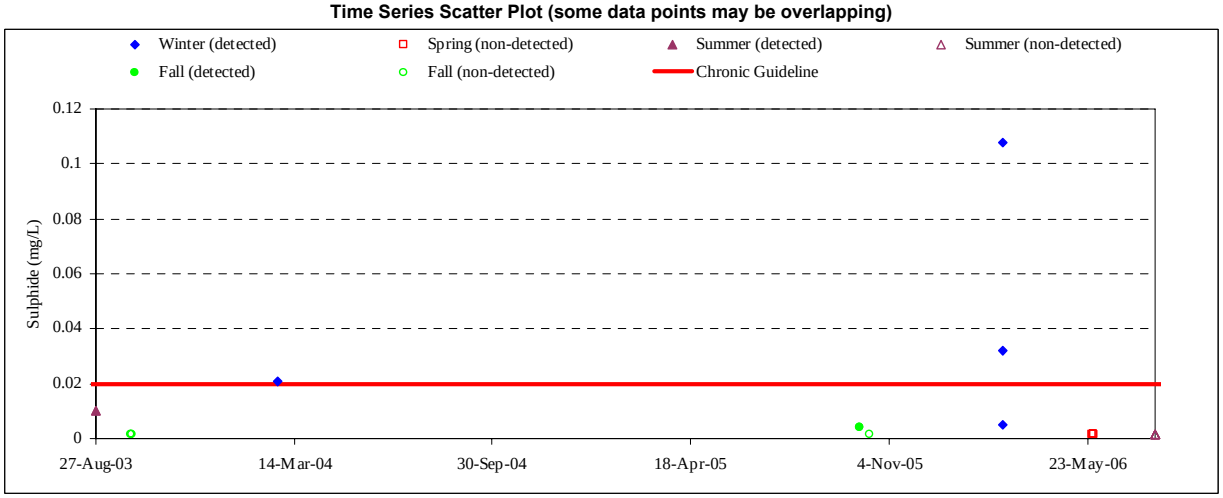
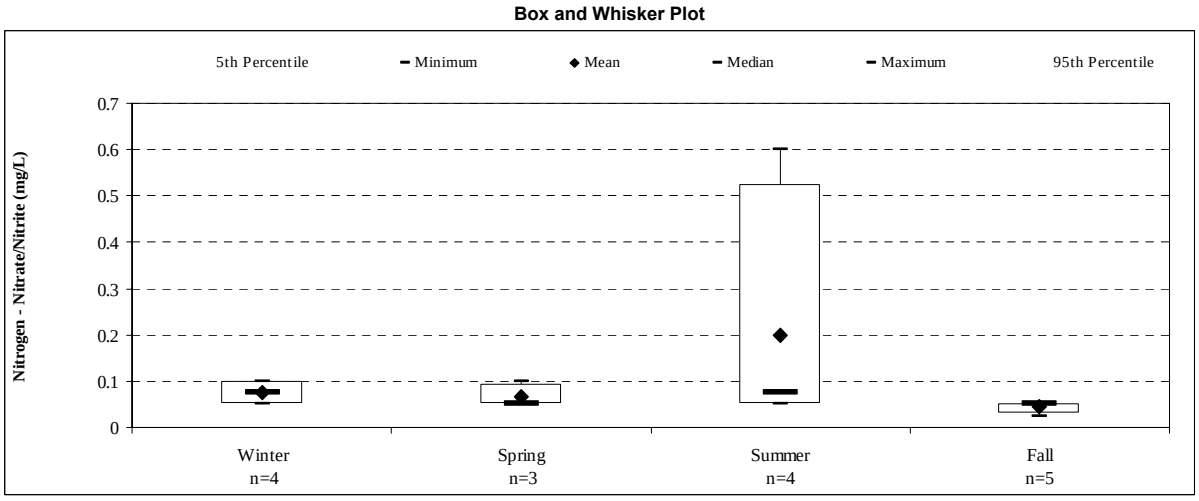


Figure G-2-9-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Unnamed Lakes within JEMA



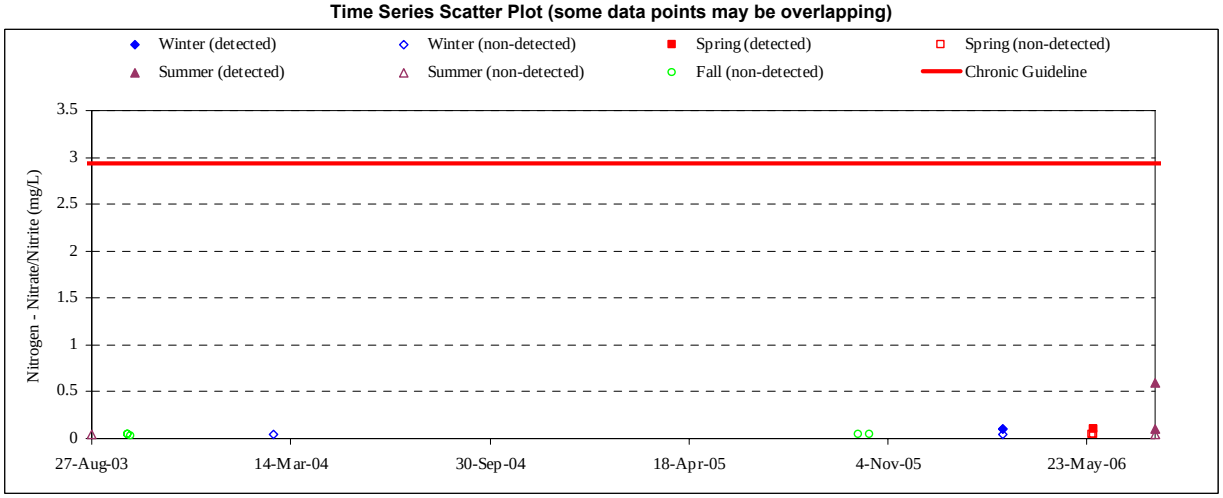
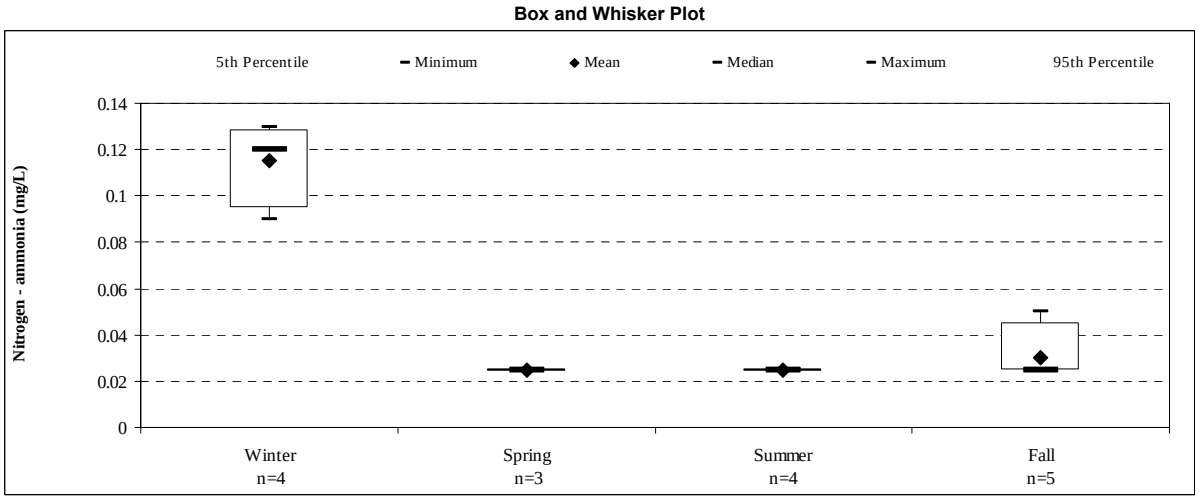


Figure G-2-9-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Unnamed Lakes within JEMA



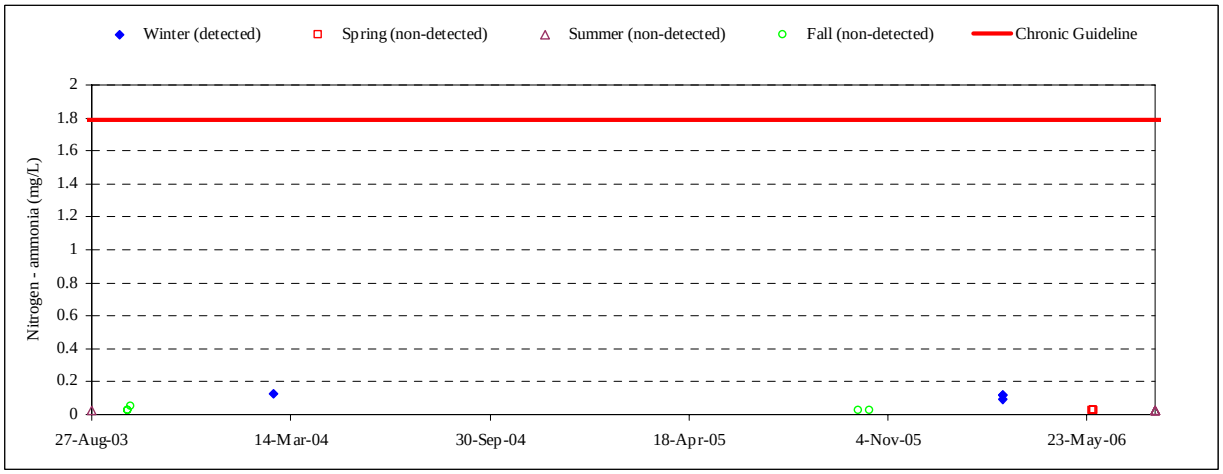
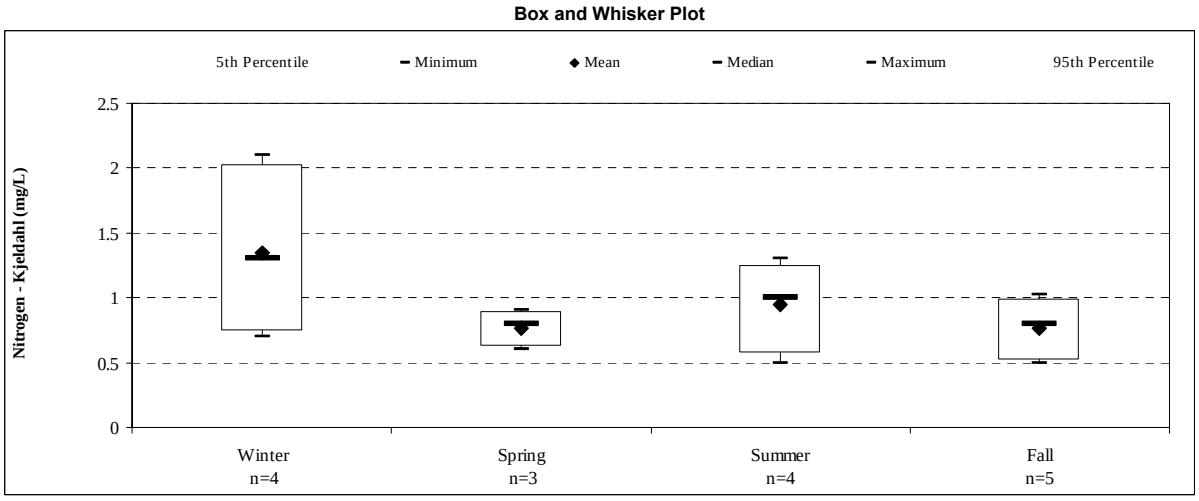


Figure G-2-9-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Unnamed Lakes within JEMA



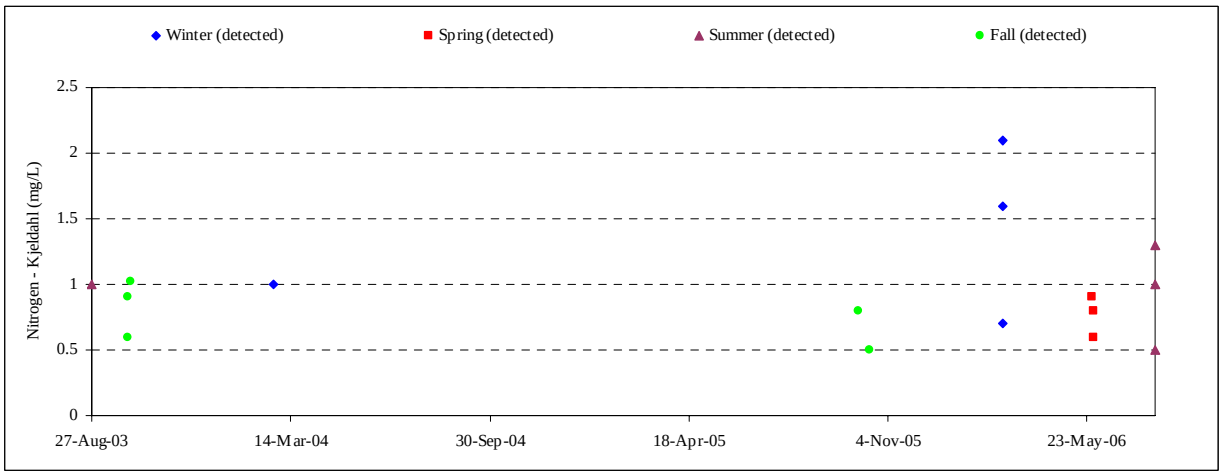
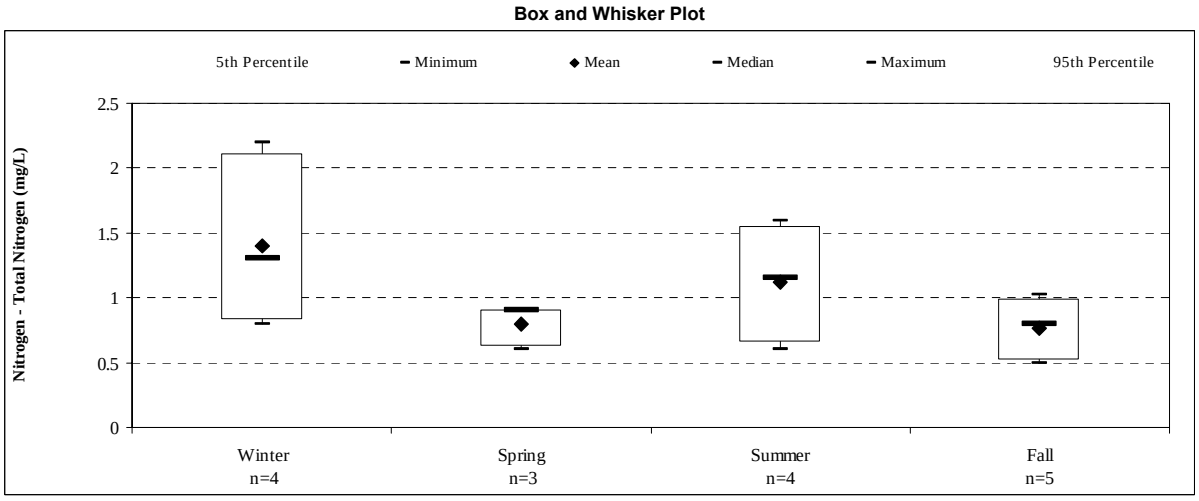


Figure G-2-9-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Unnamed Lakes within JEMA



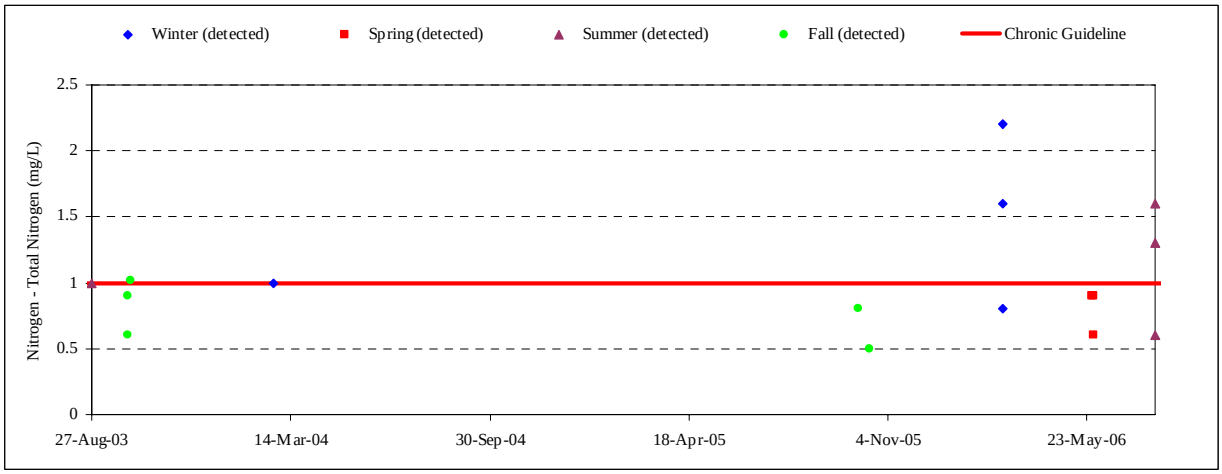
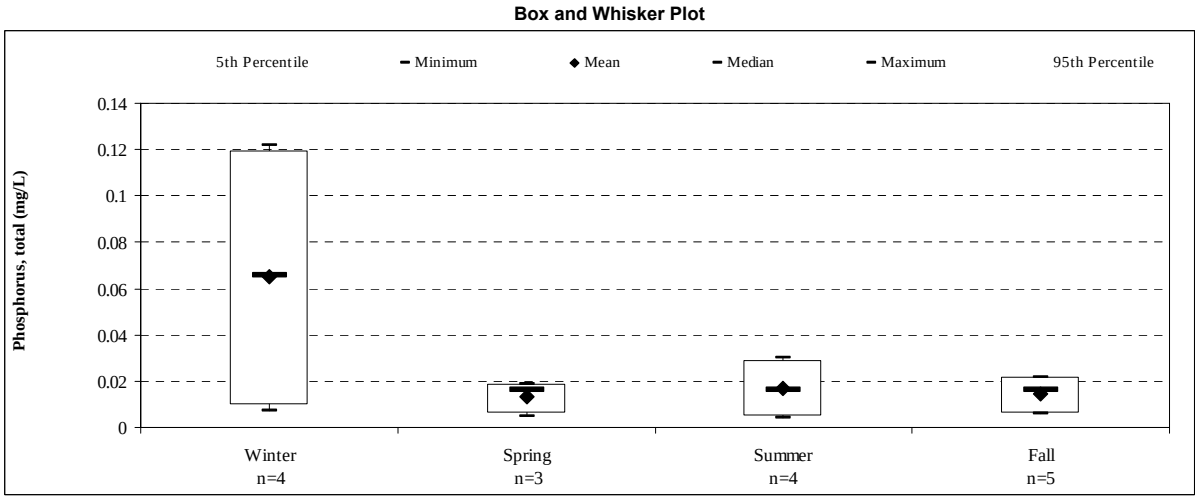


Figure G-2-9-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Unnamed Lakes within JEMA



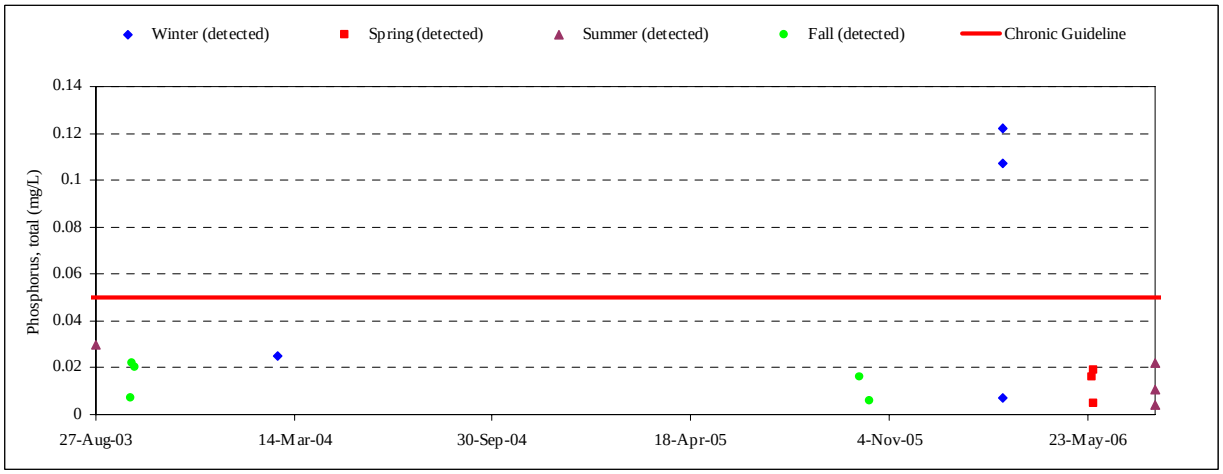


Figure G-2-9-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Unnamed Lakes within JEMA

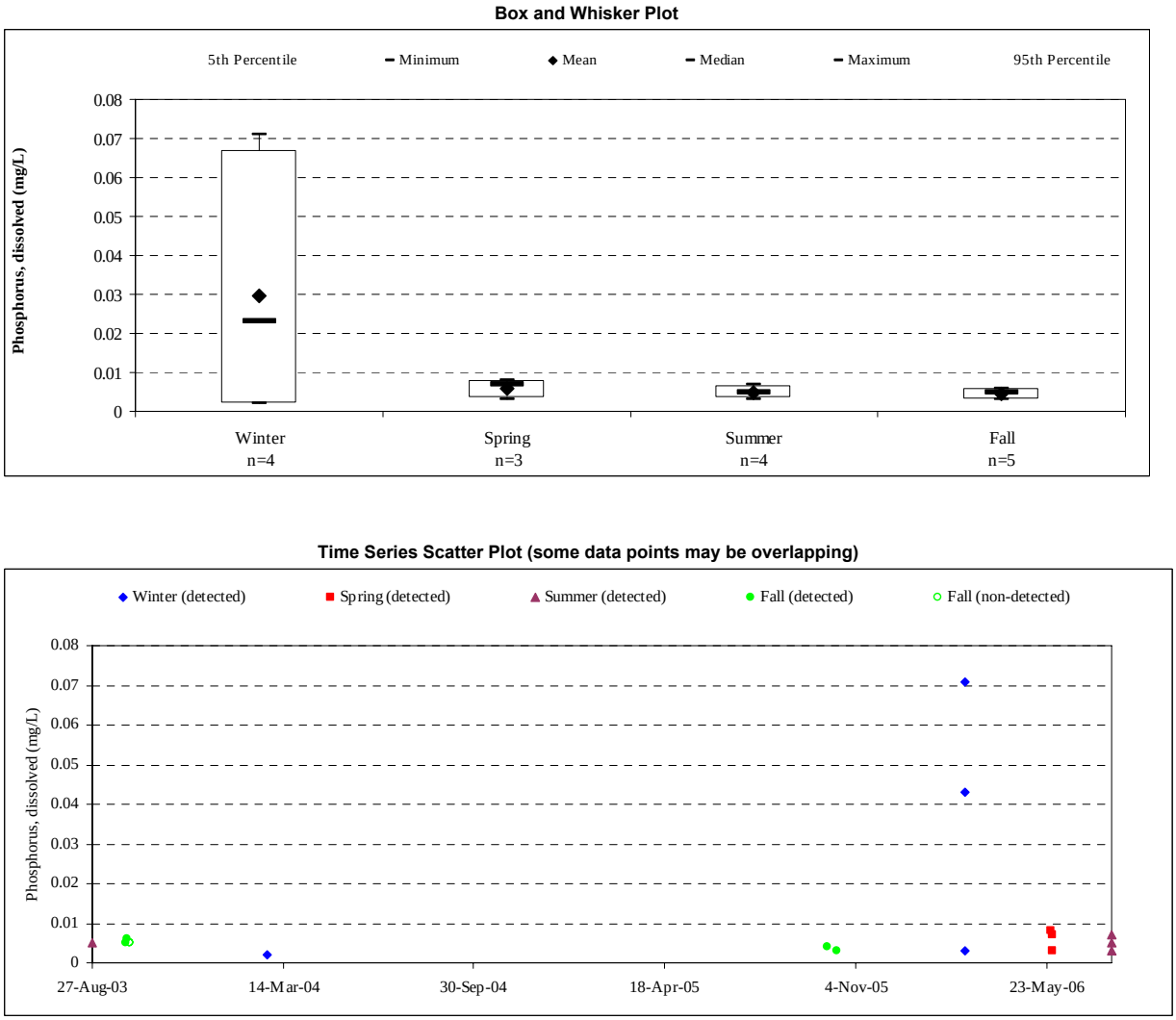
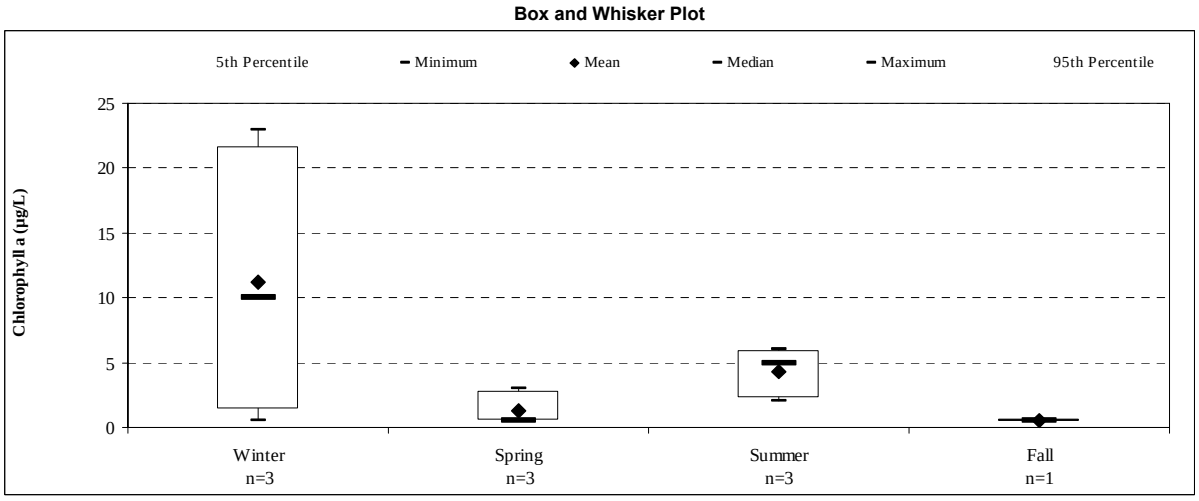


Figure G-2-9-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Unnamed Lakes within JEMA



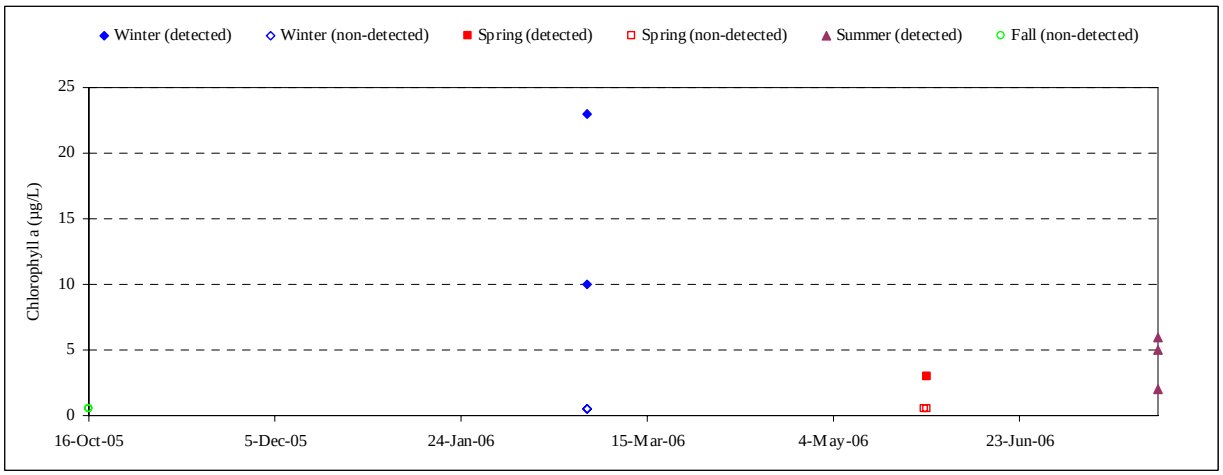
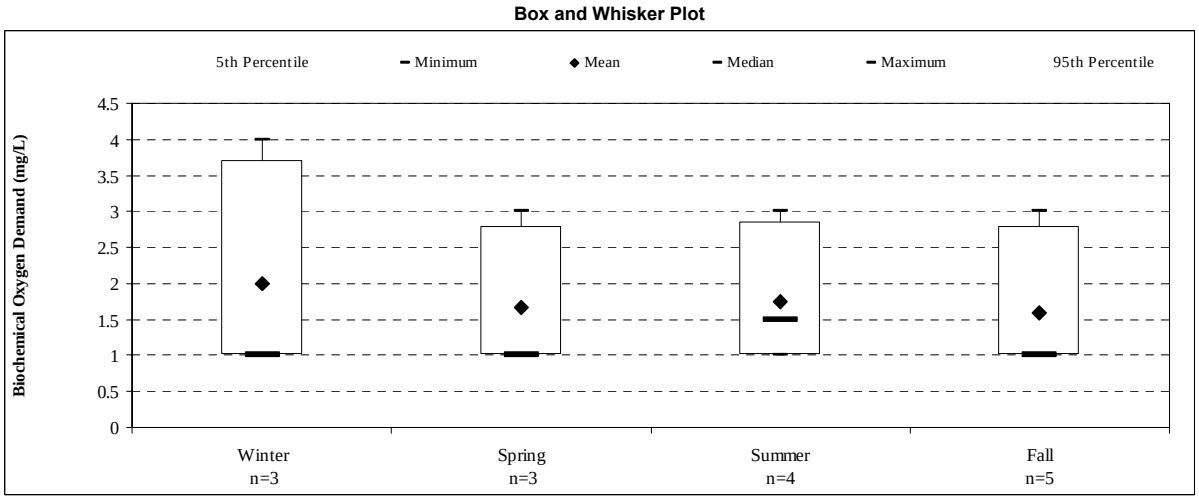


Figure G-2-9-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Unnamed Lakes within JEMA



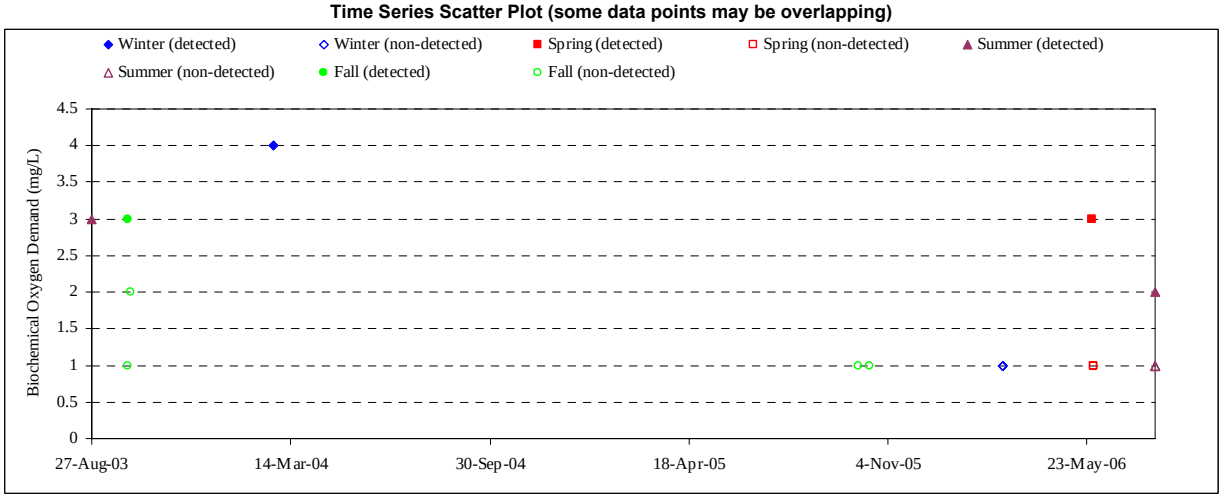
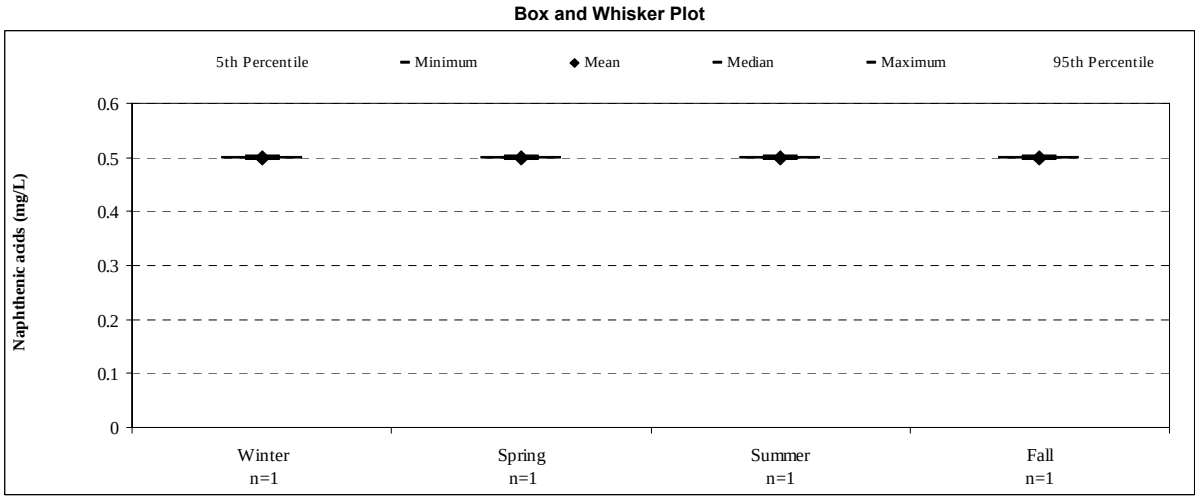


Figure G-2-9-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Unnamed Lakes within JEMA



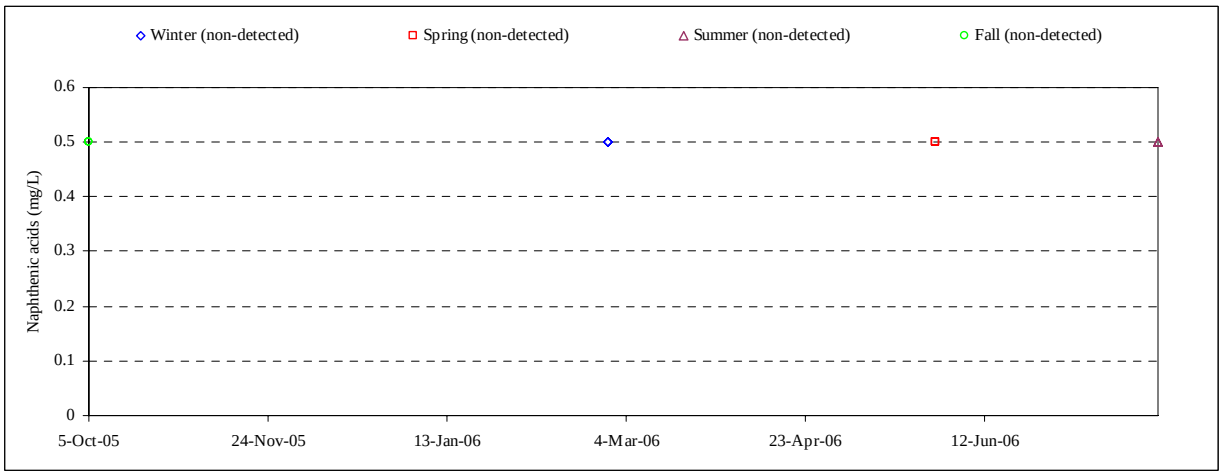
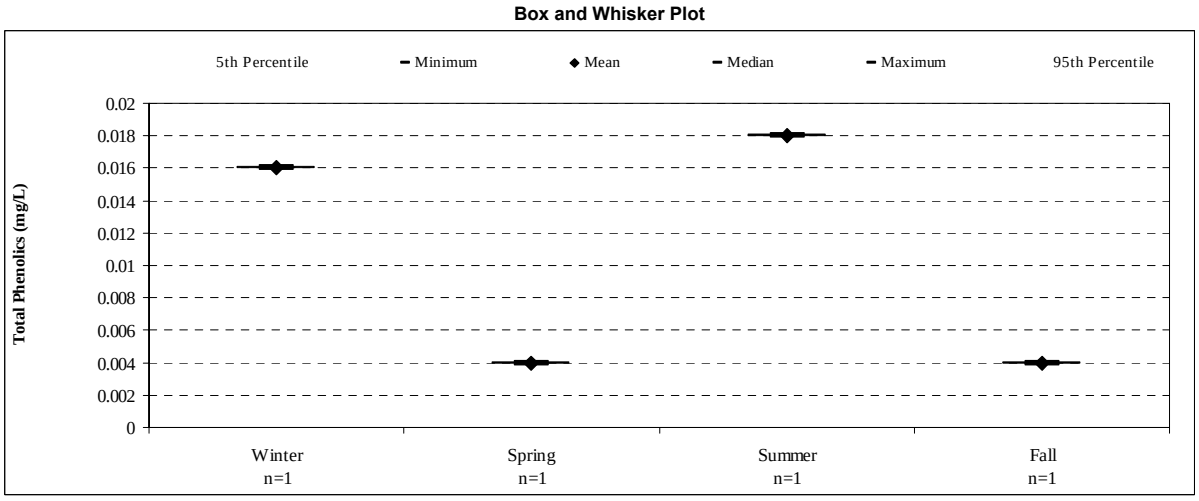


Figure G-2-9-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Unnamed Lakes within JEMA



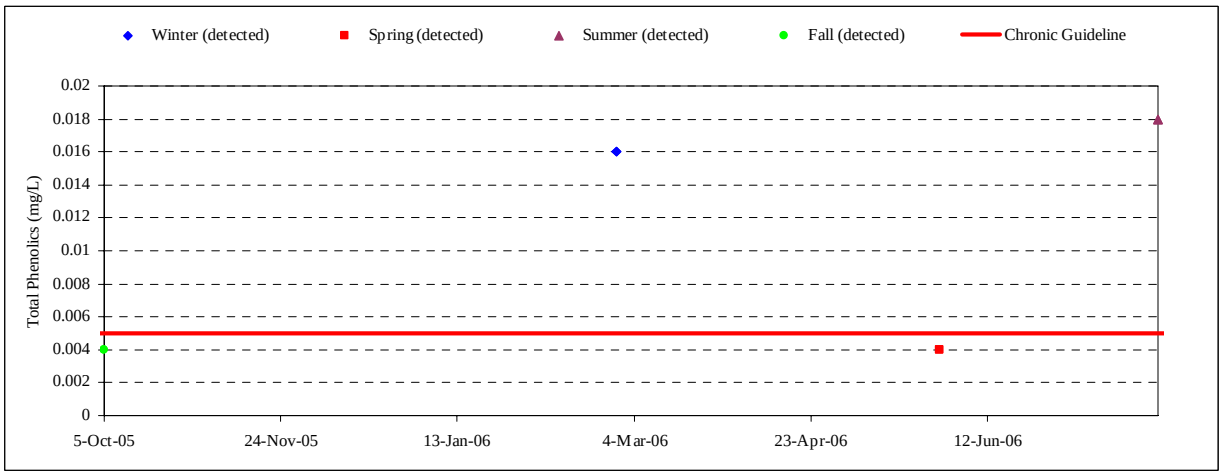
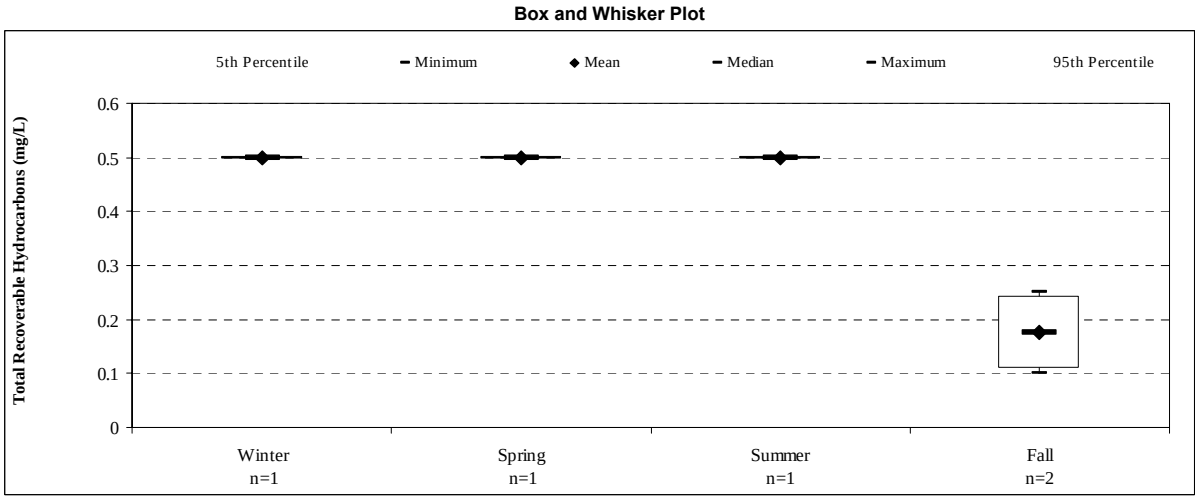


Figure G-2-9-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Unnamed Lakes within JEMA



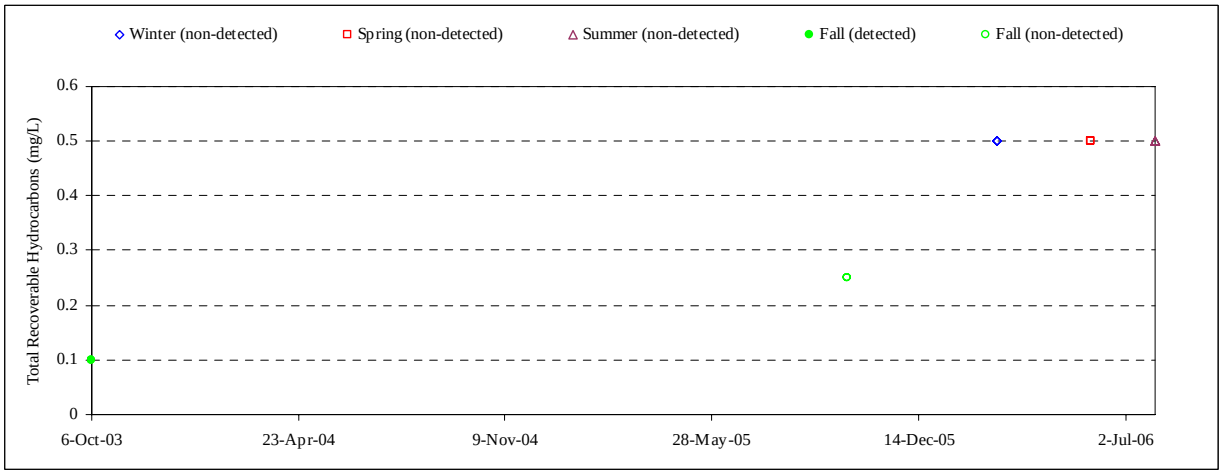
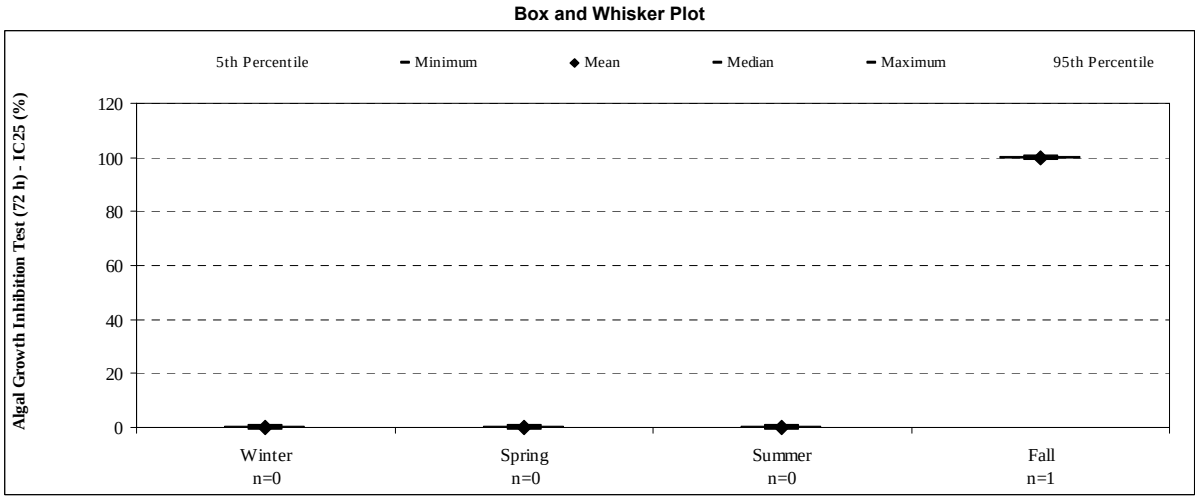


Figure G-2-9-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Unnamed Lakes within JEMA



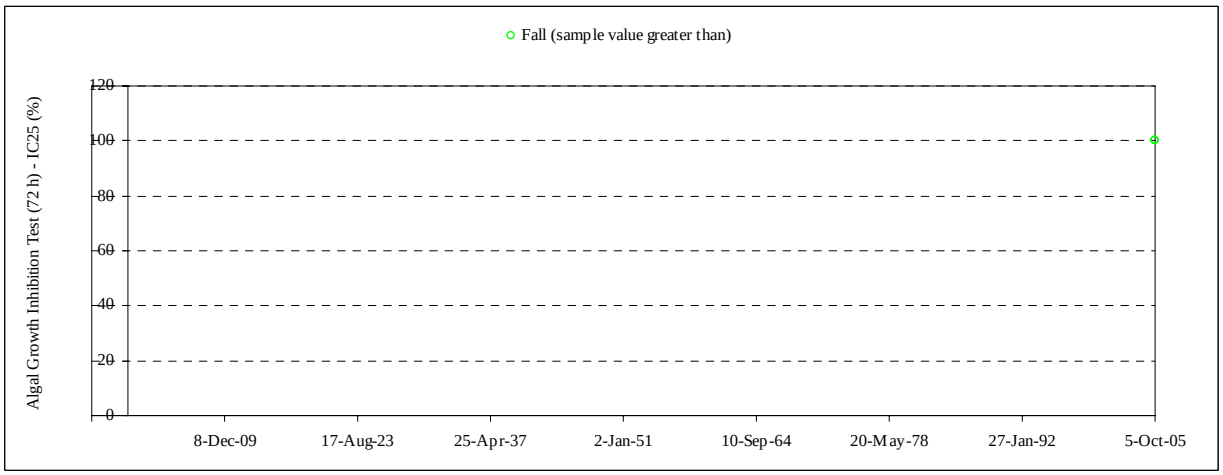
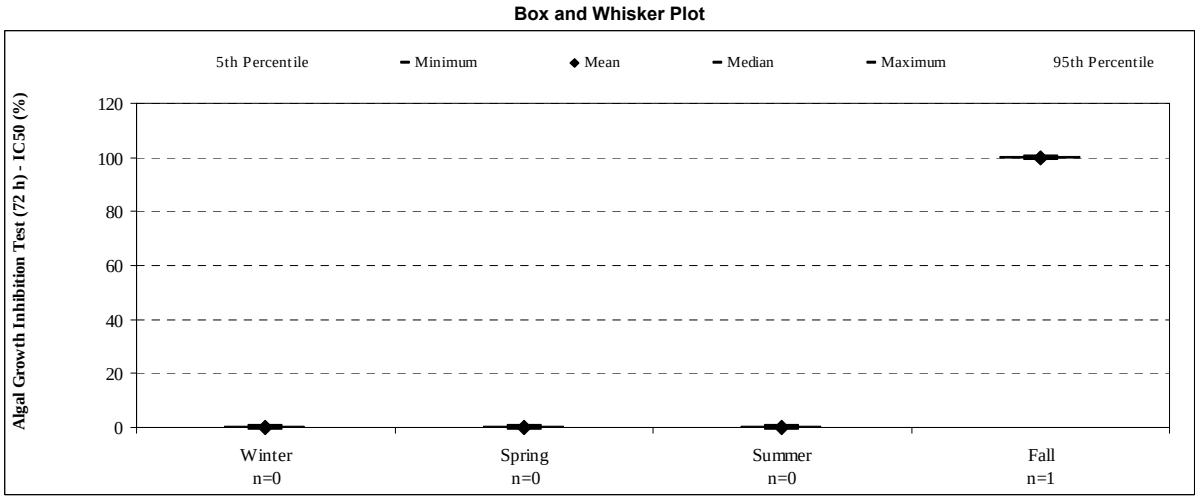


Figure G-2-9-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Unnamed Lakes within JEMA



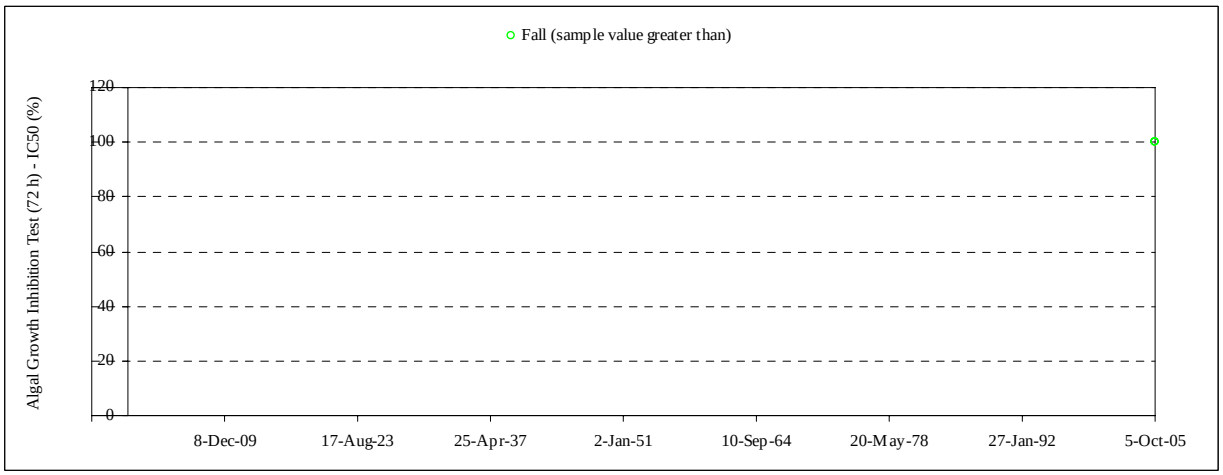
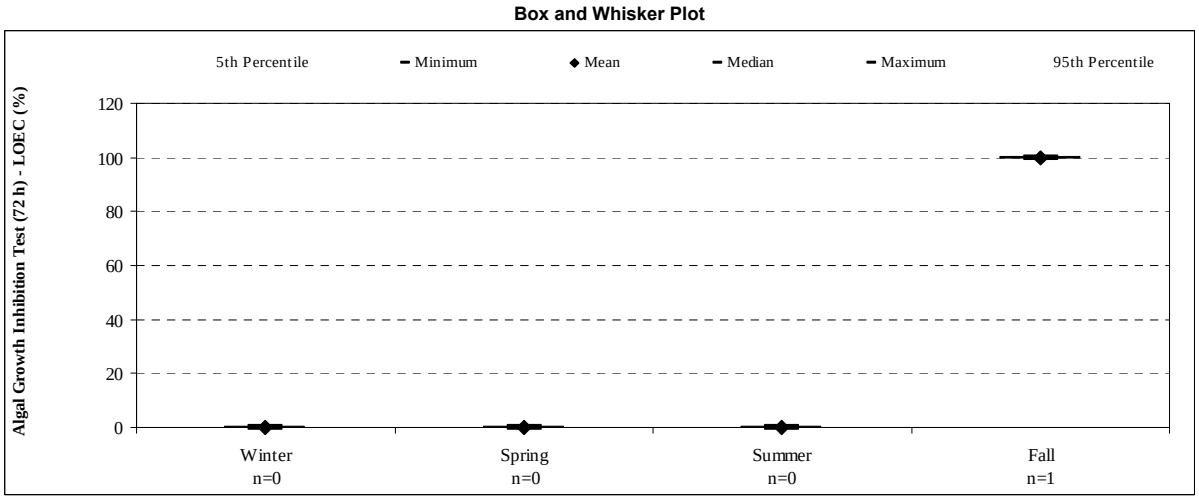


Figure G-2-9-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Unnamed Lakes within JEMA



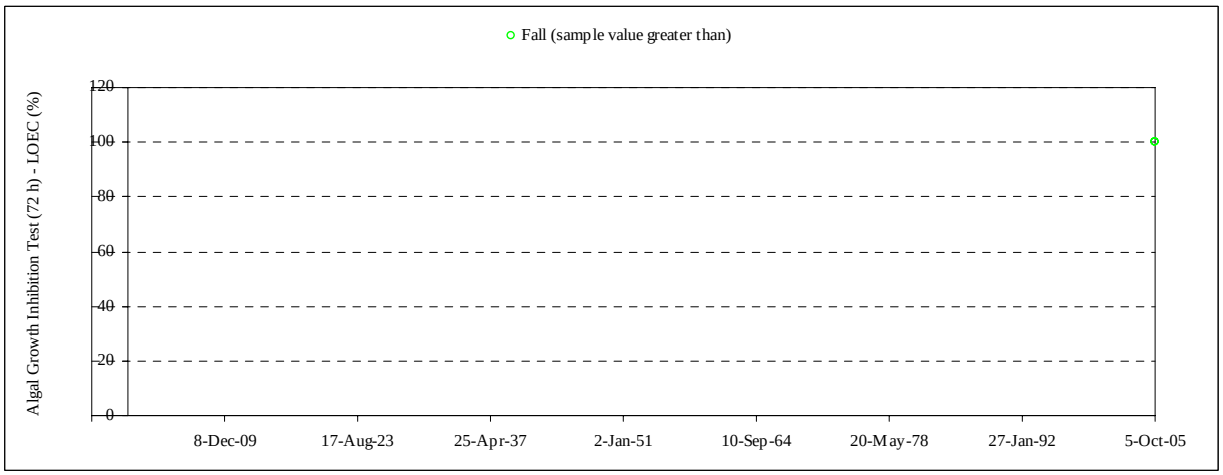
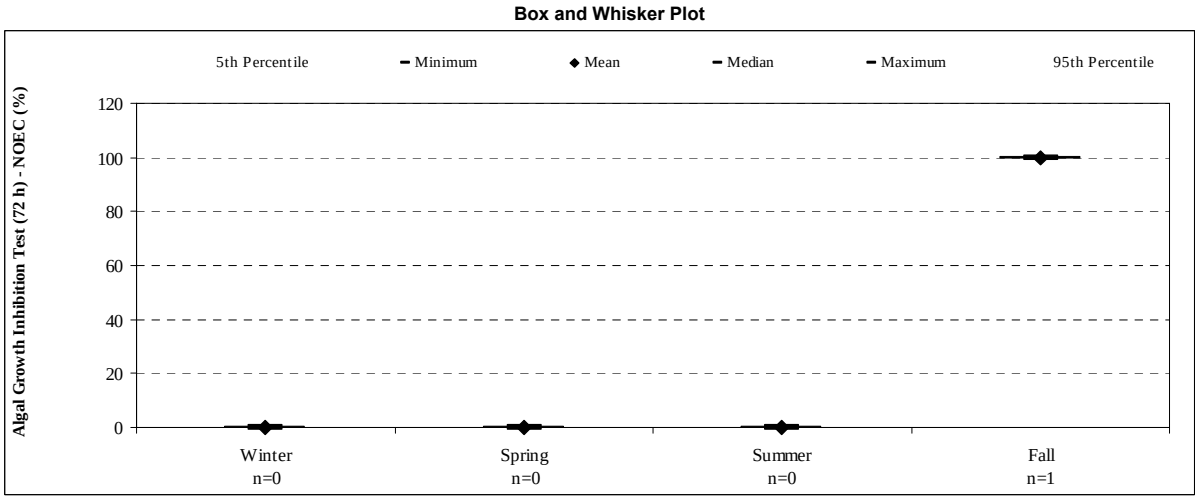


Figure G-2-9-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Unnamed Lakes within JEMA



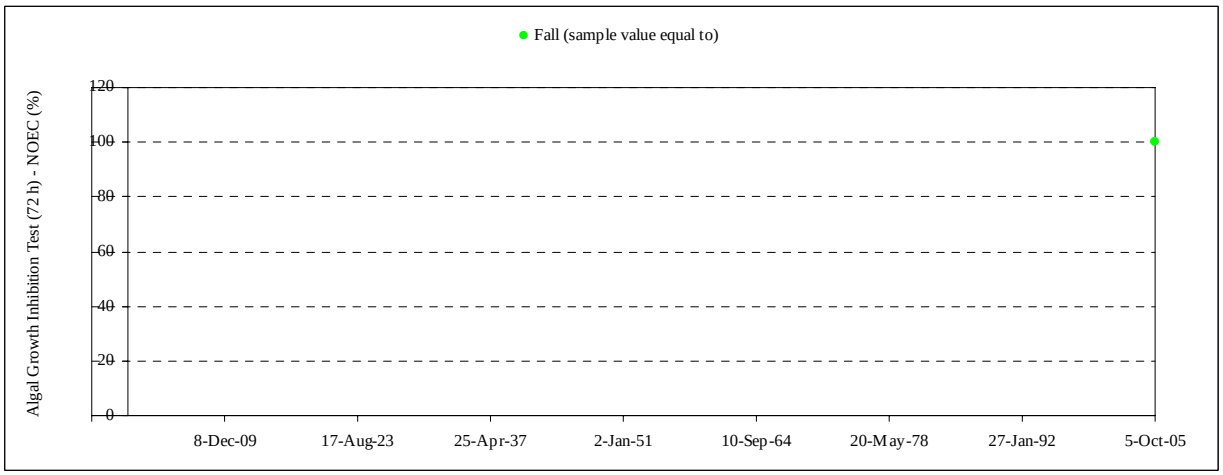
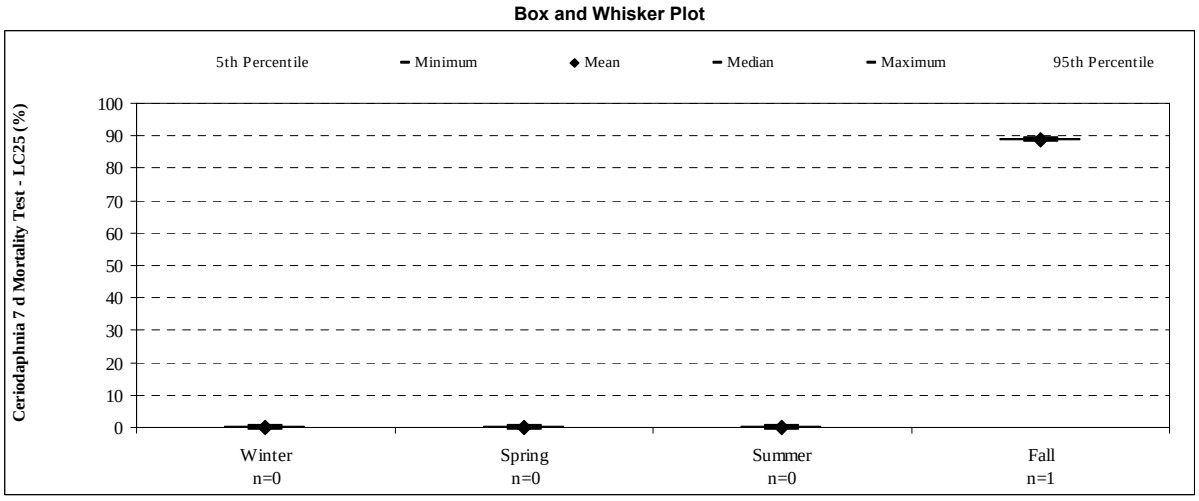


Figure G-2-9-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Unnamed Lakes within JEMA



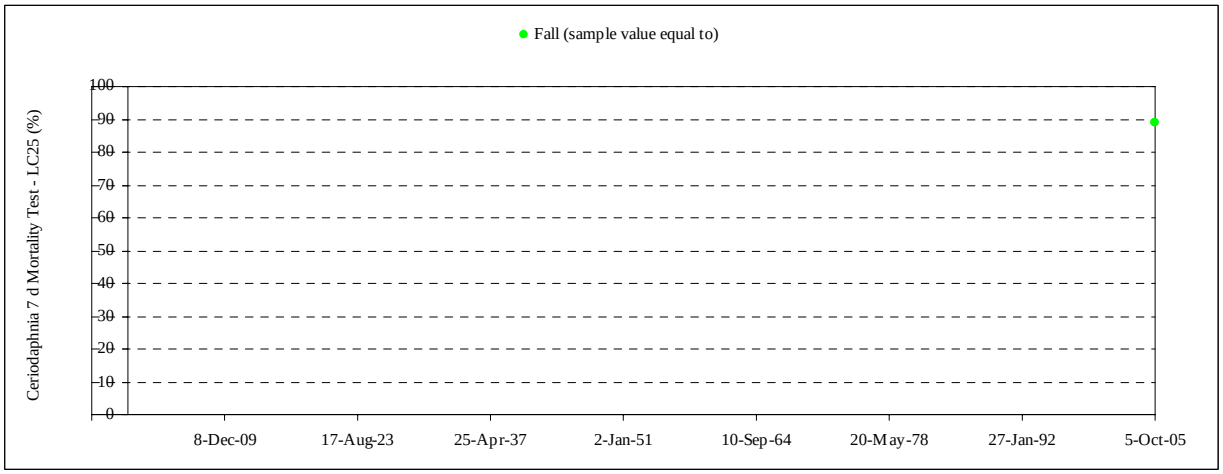
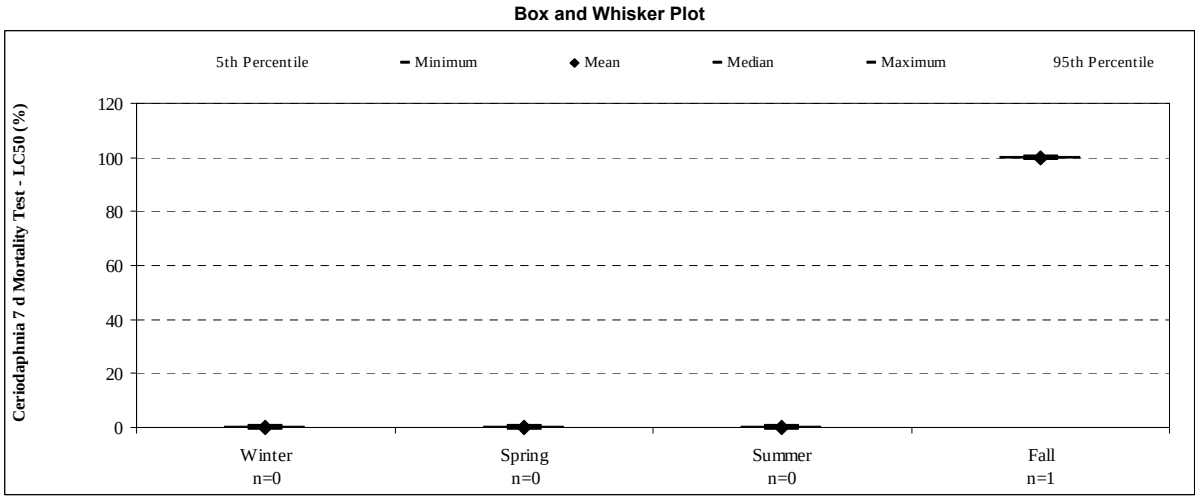


Figure G-2-9-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Unnamed Lakes within JEMA



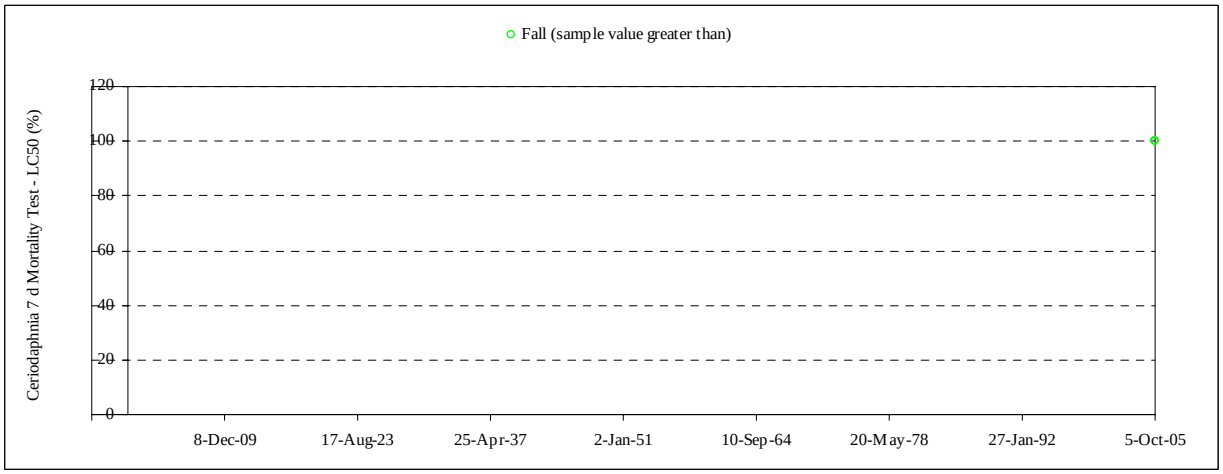


Figure G-2-9-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Unnamed Lakes withir JEMA

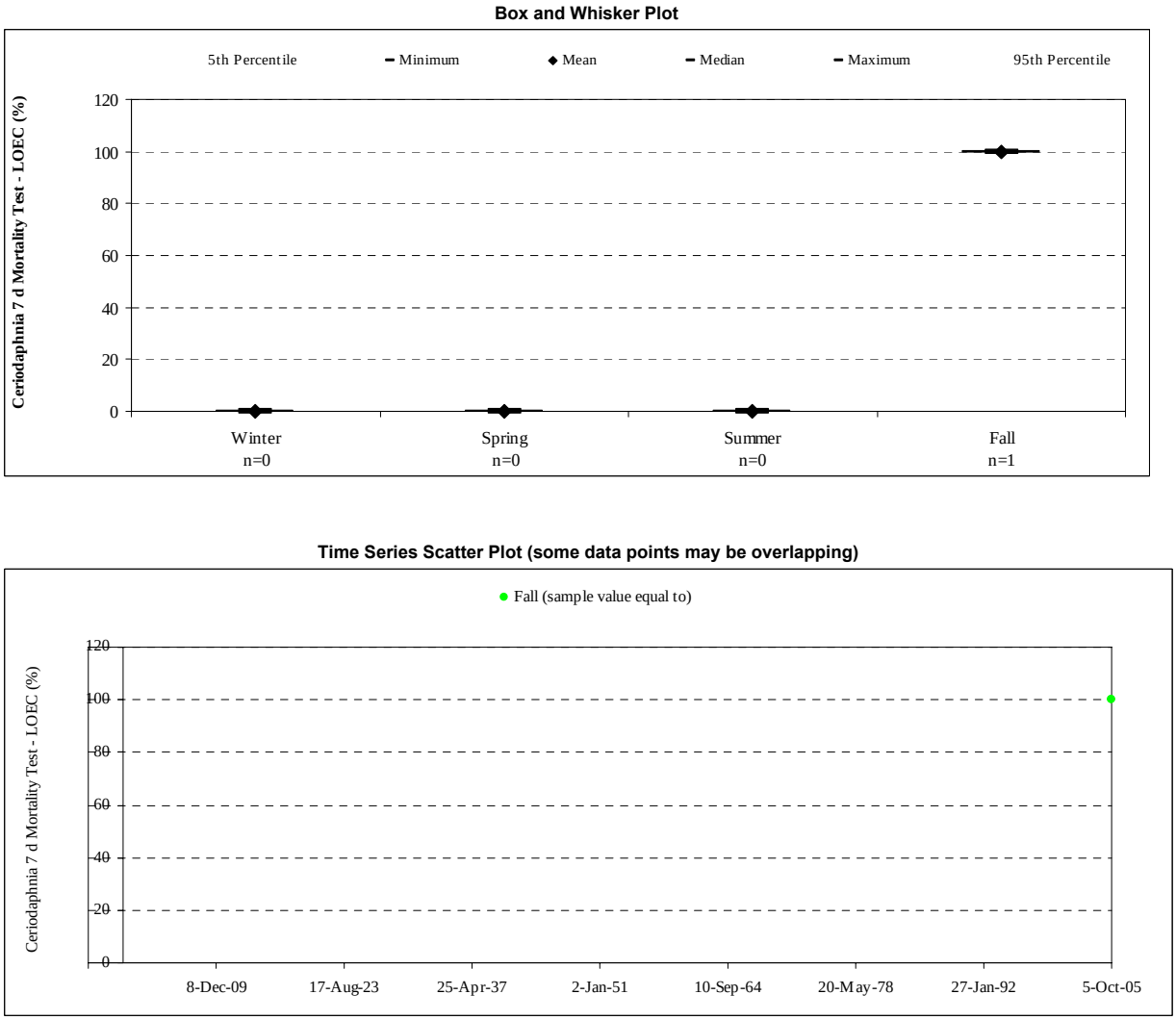
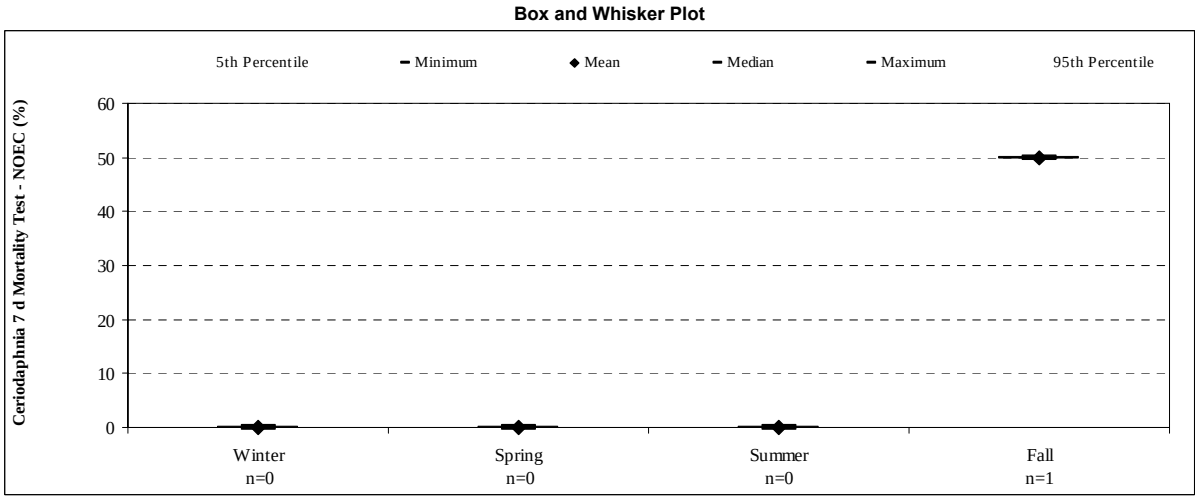


Figure G-2-9-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Unnamed Lakes within JEMA



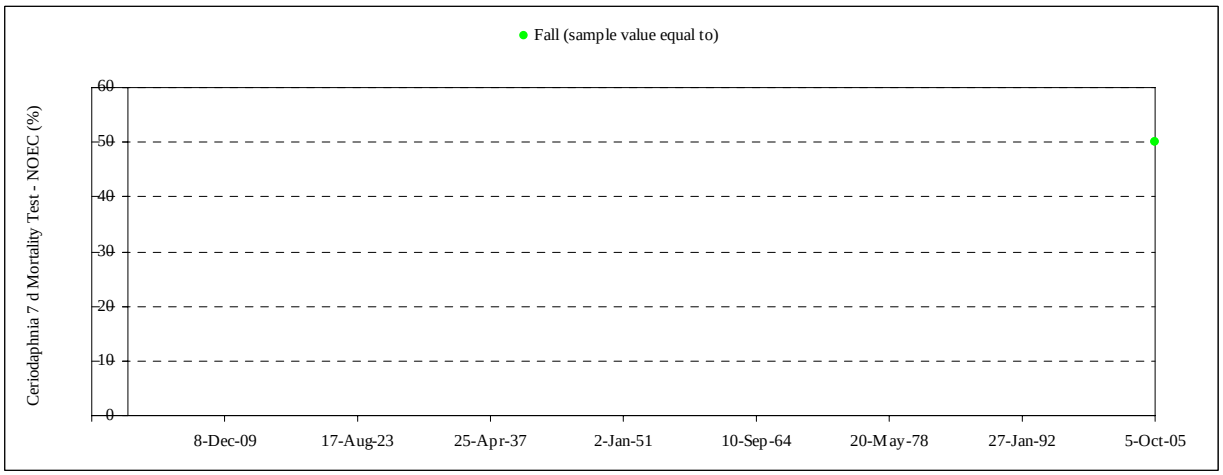
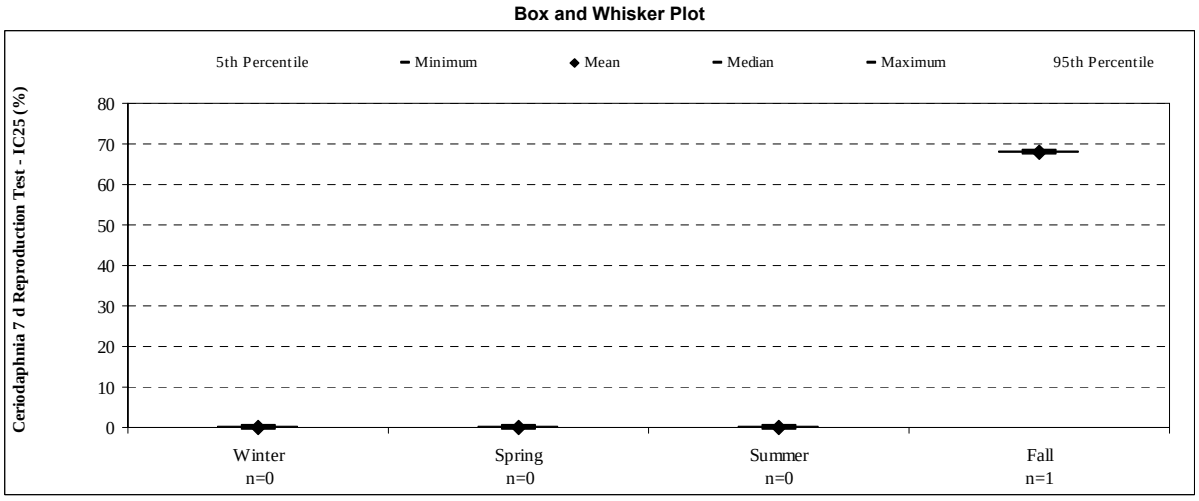


Figure G-2-9-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Unnamed Lakes within JEMA



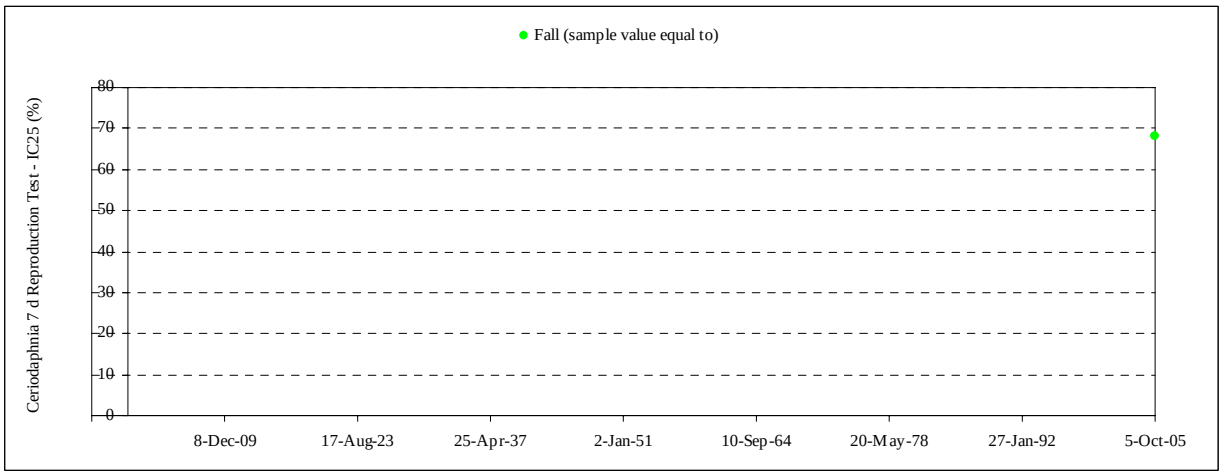
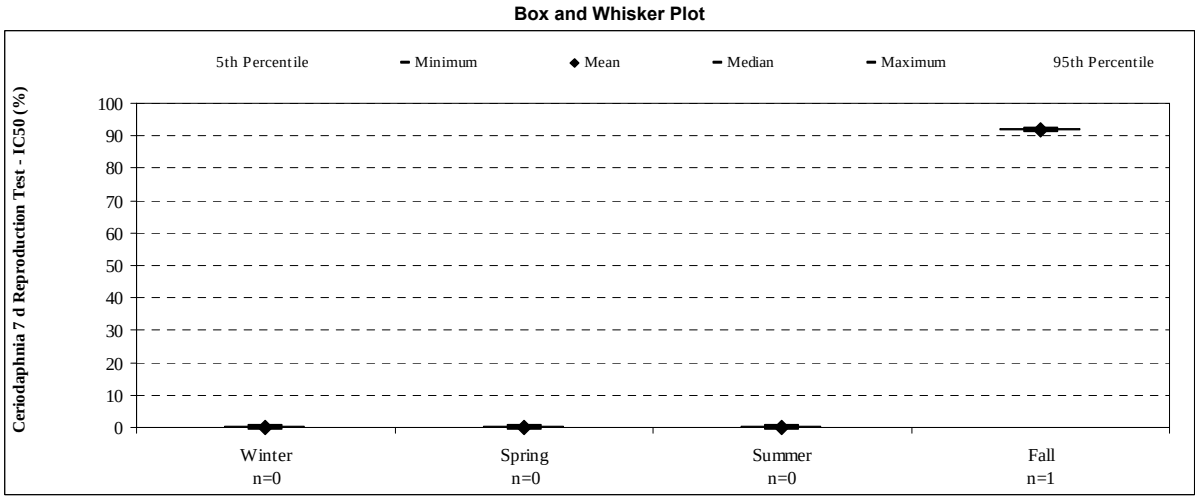


Figure G-2-9-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Unnamed Lakes within JEMA



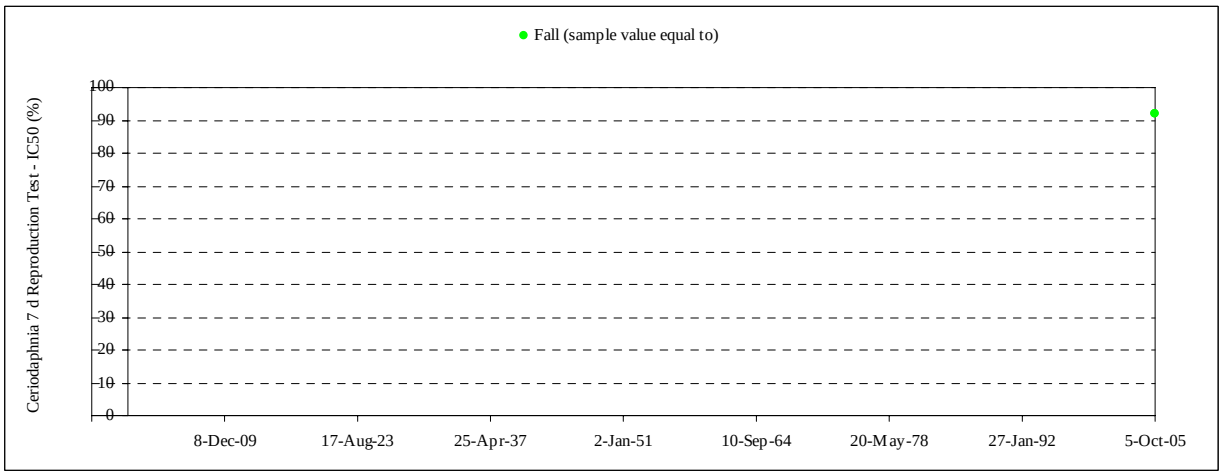
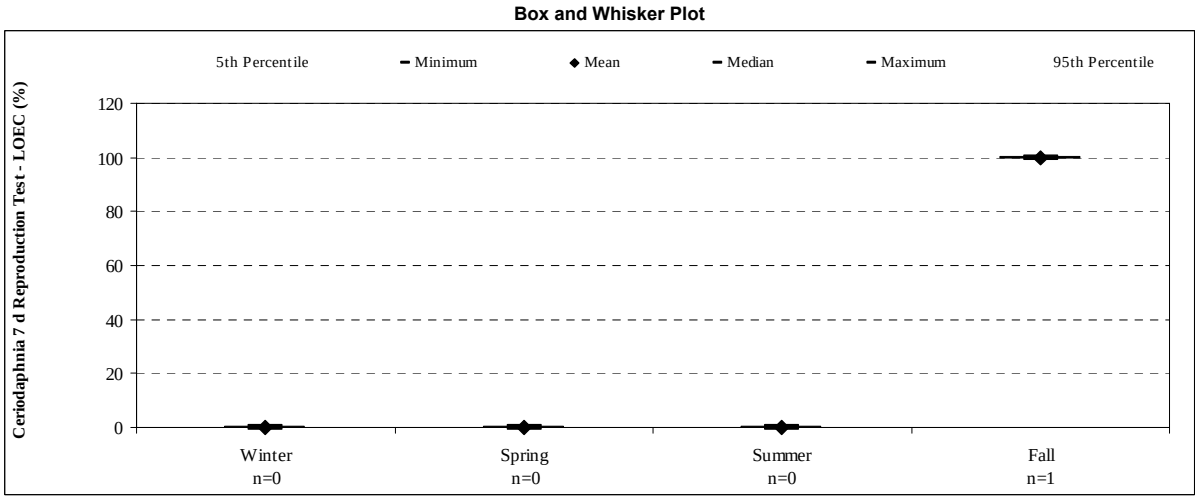


Figure G-2-9-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Unnamed Lakes within JEMA



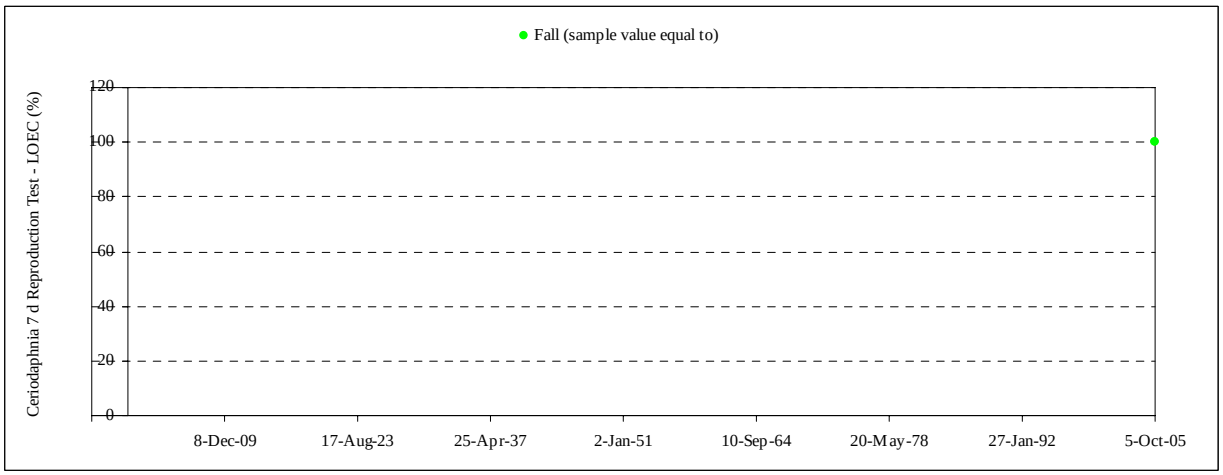
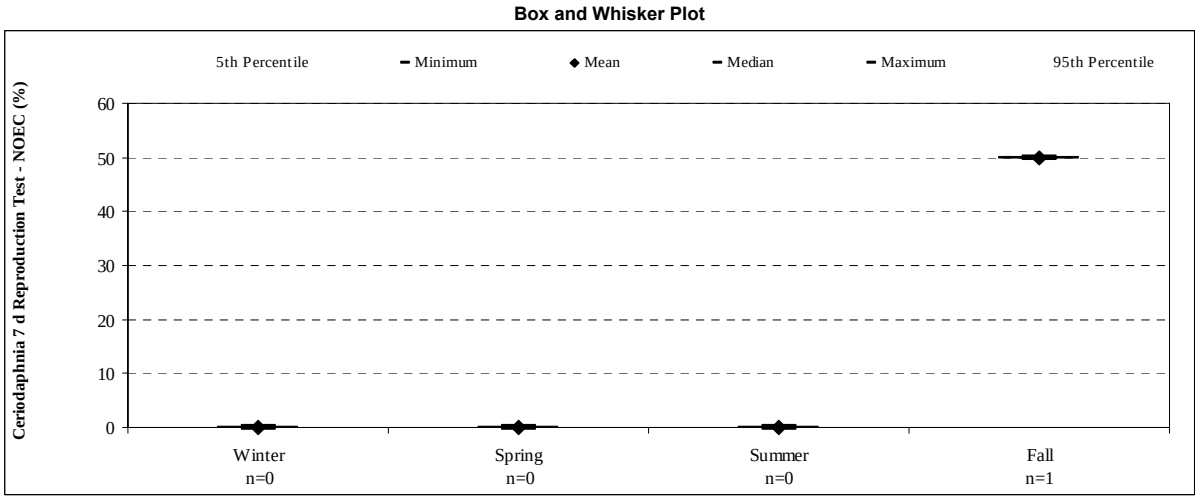


Figure G-2-9-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Unnamed Lakes within JEMA



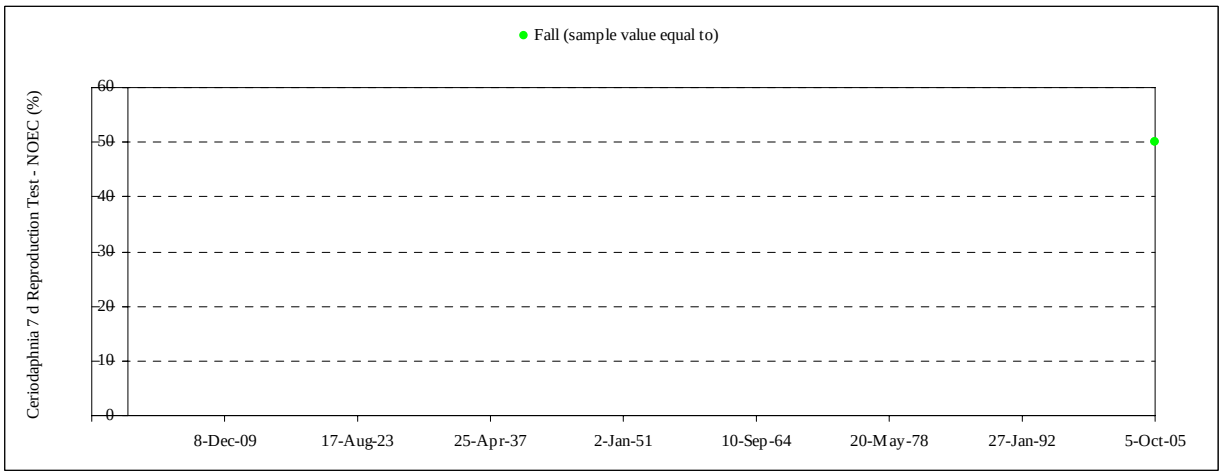


Figure G-2-9-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Unnamed Lakes within JEMA

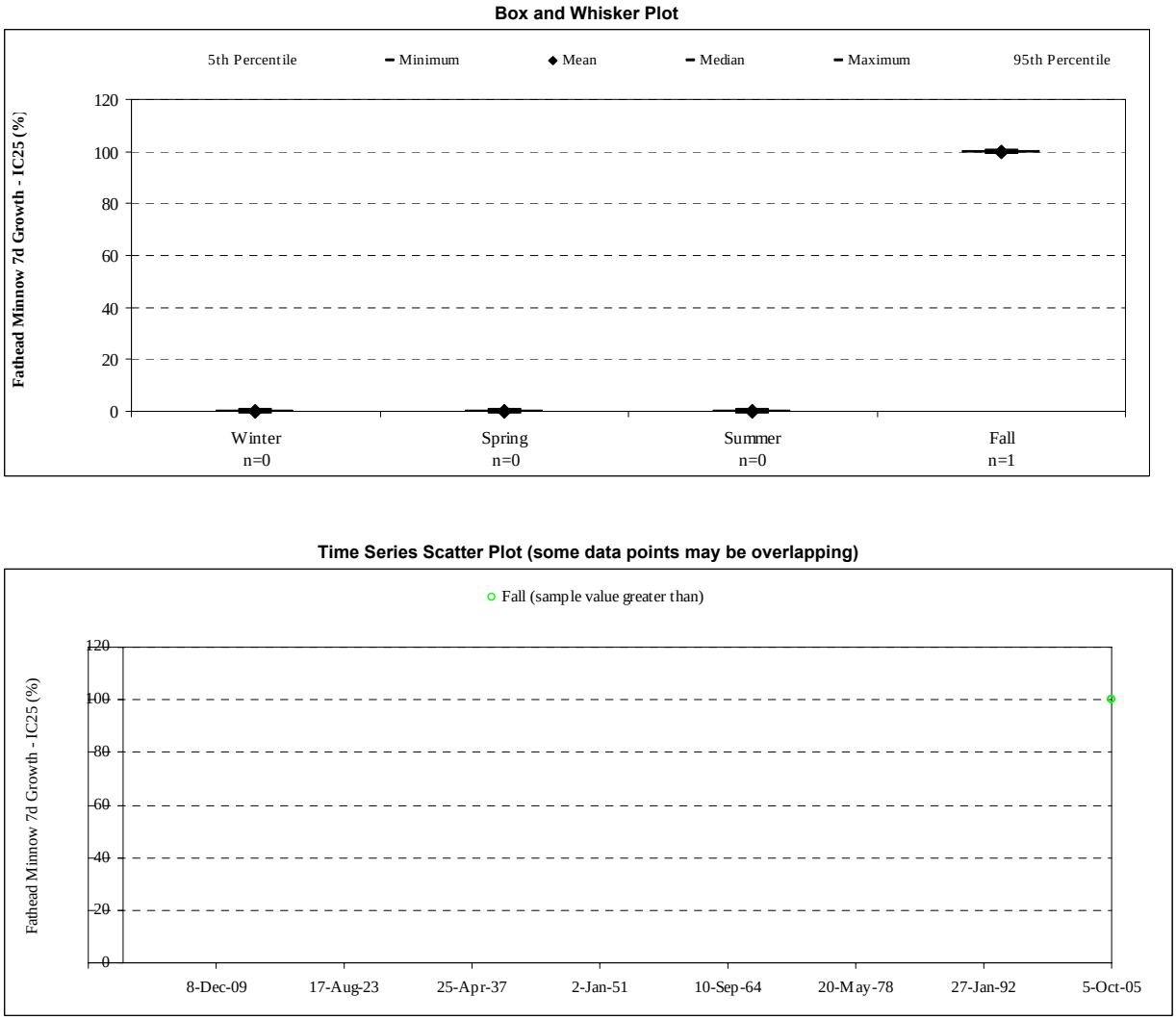
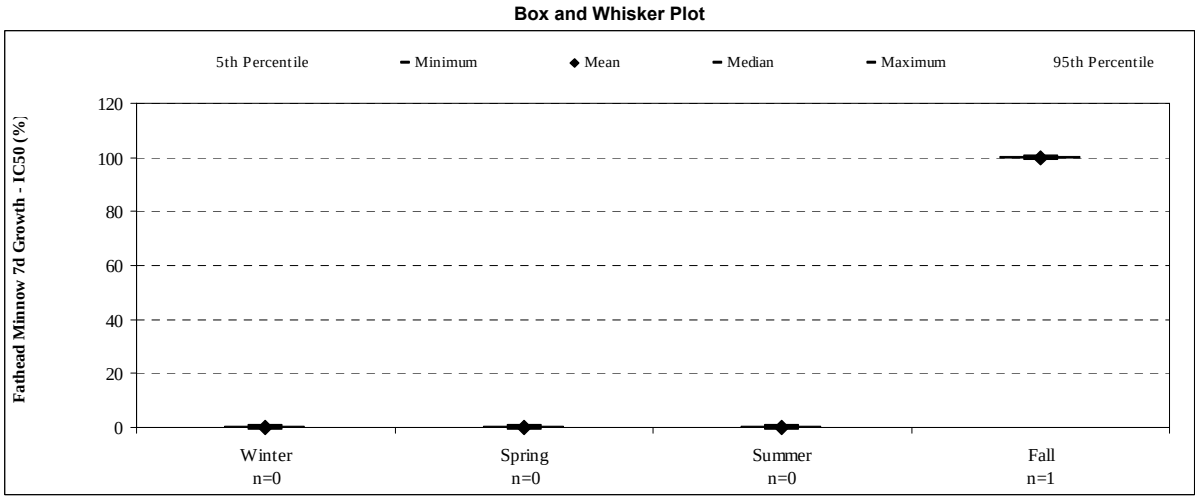


Figure G-2-9-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Unnamed Lakes within JEMA



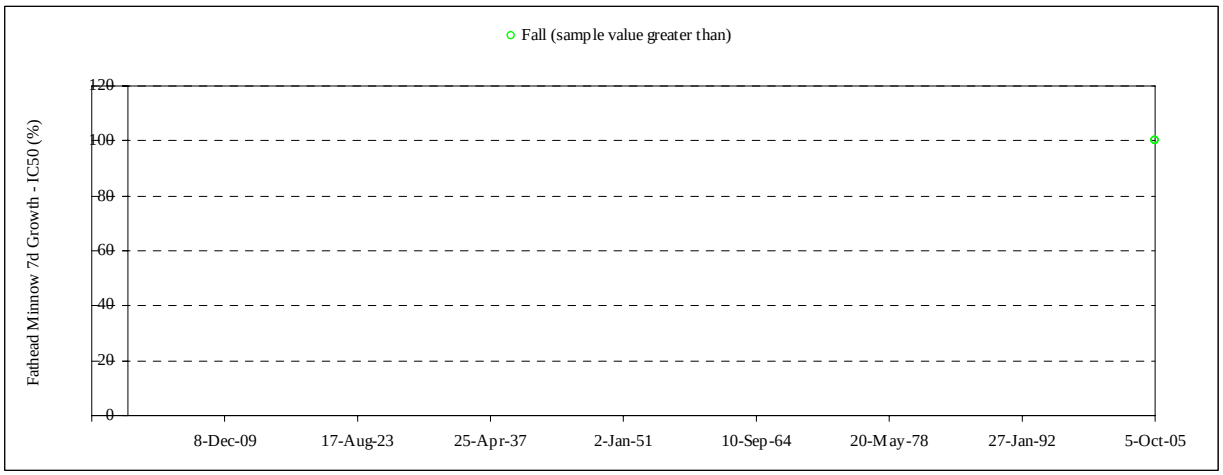
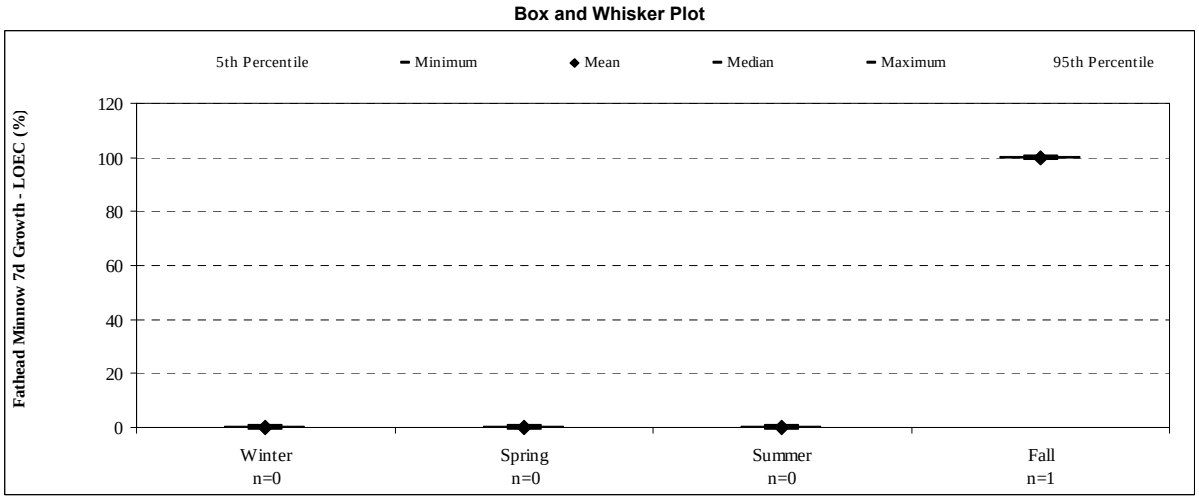


Figure G-2-9-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Unnamed Lakes within JEMA



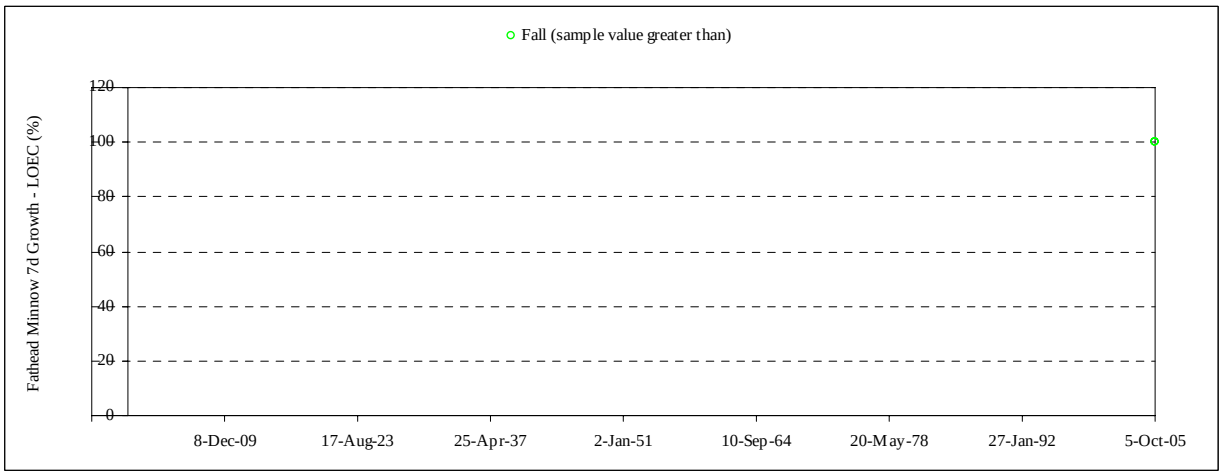
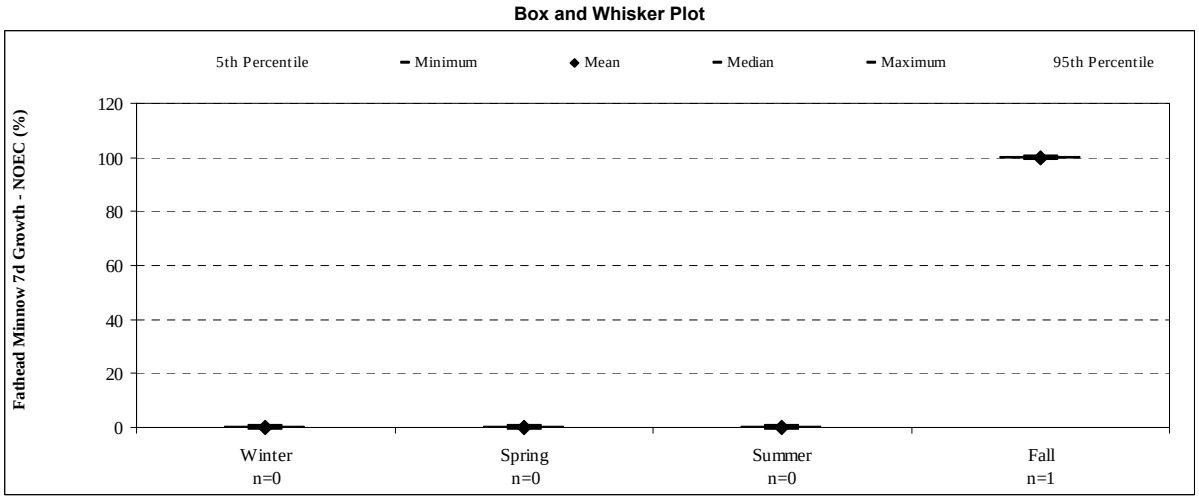


Figure G-2-9-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Unnamed Lakes within JEMA



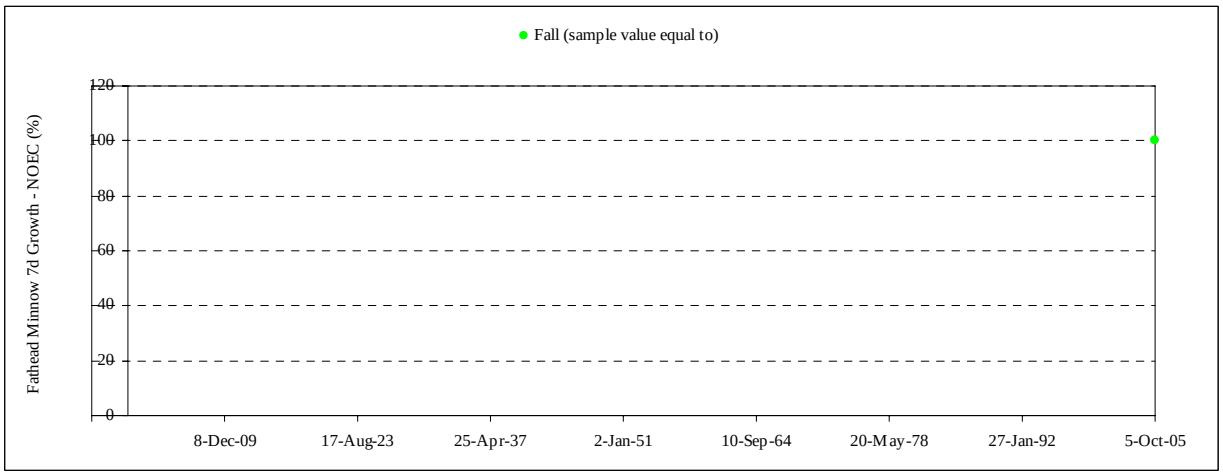


Figure G-2-9-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Unnamed Lakes within JEMA

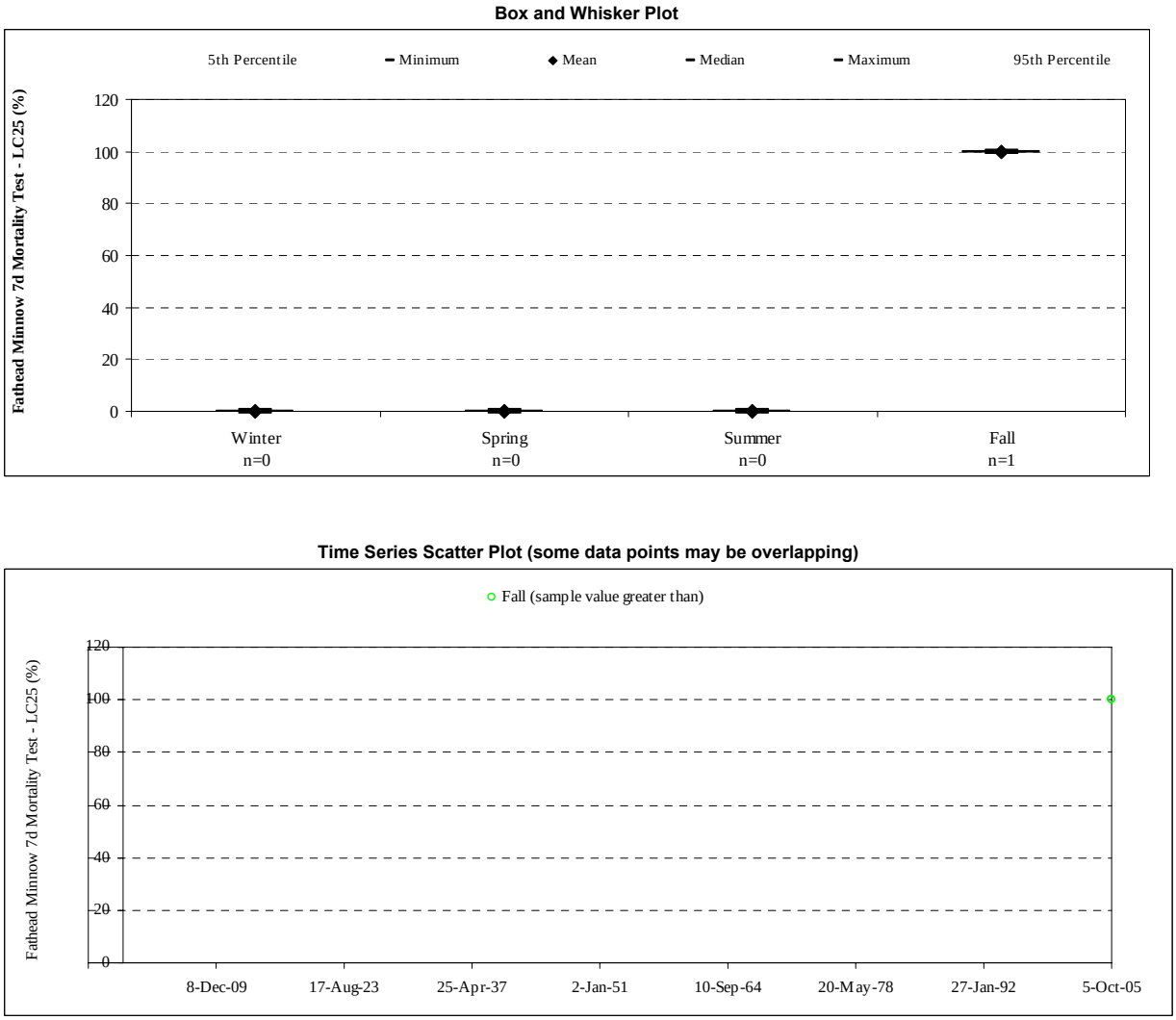


Figure G-2-9-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Unnamed Lakes within JEMA

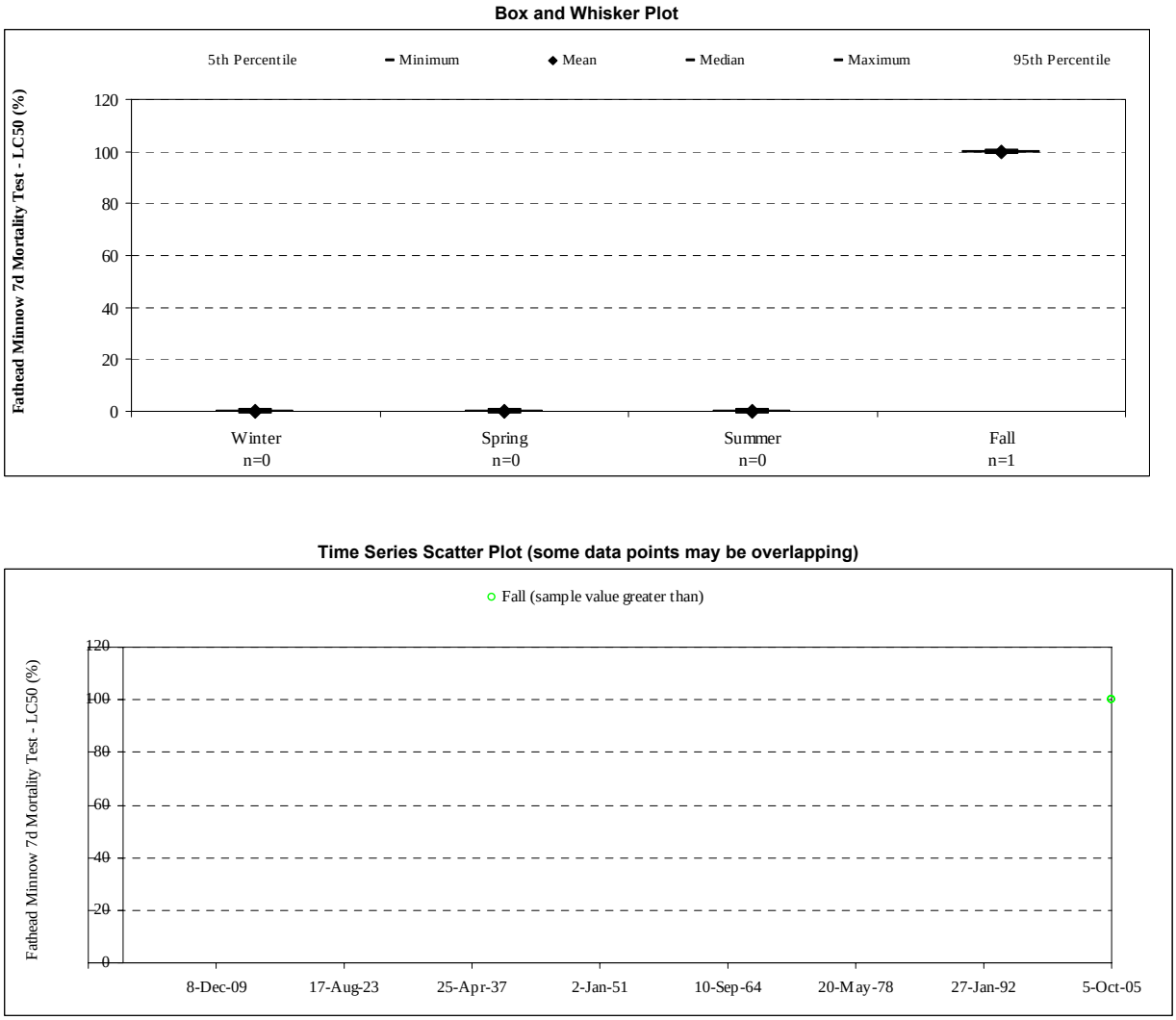
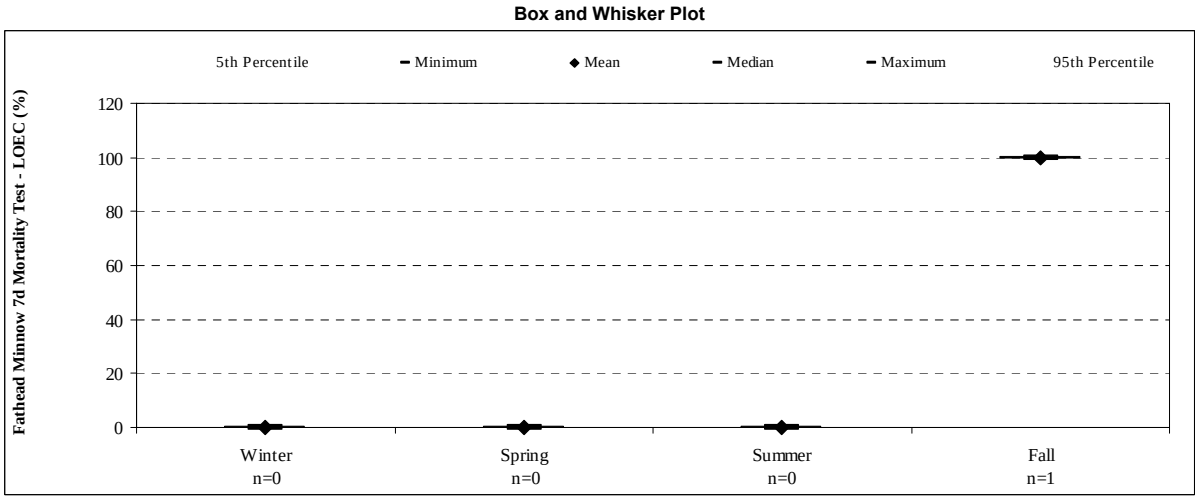


Figure G-2-9-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Unnamed Lakes within JEMA



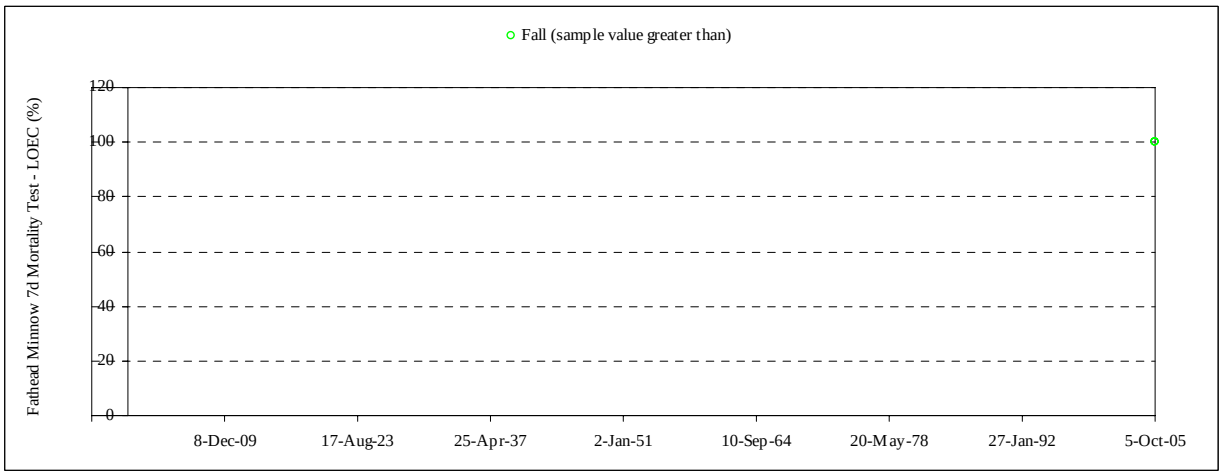


Figure G-2-9-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Unnamed Lakes within JEMA

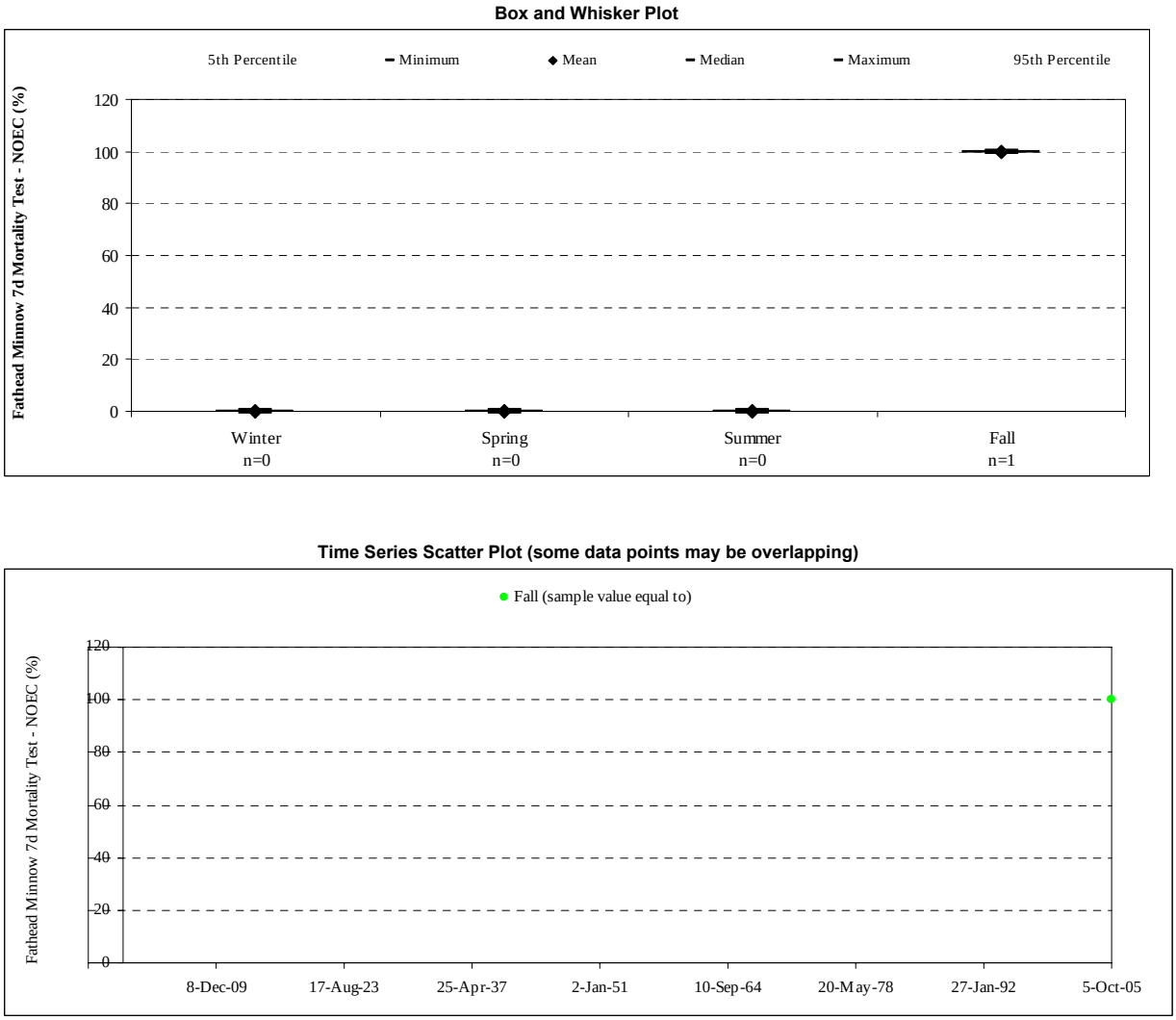
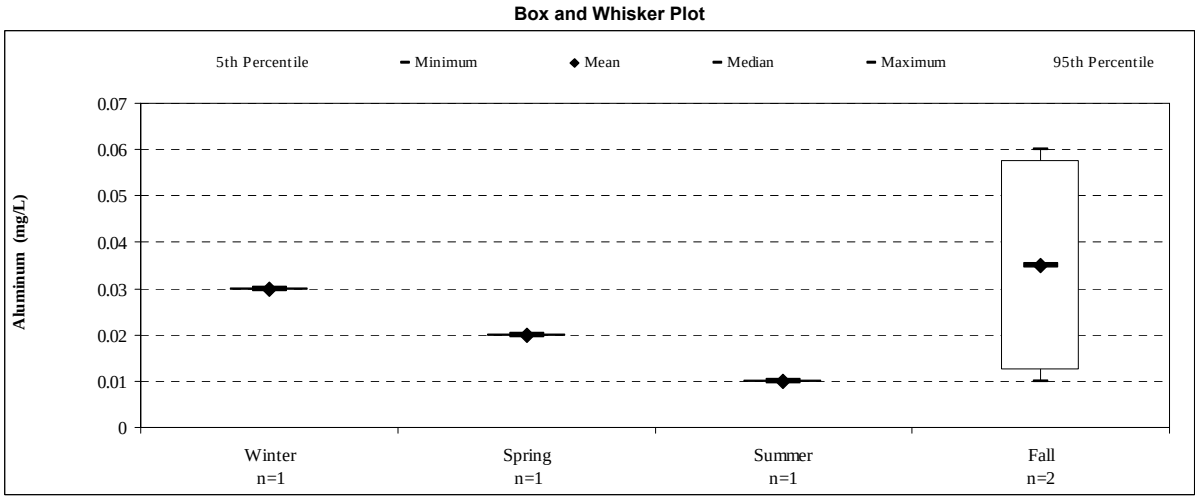


Figure G-2-9-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Unnamed Lakes within JEMA



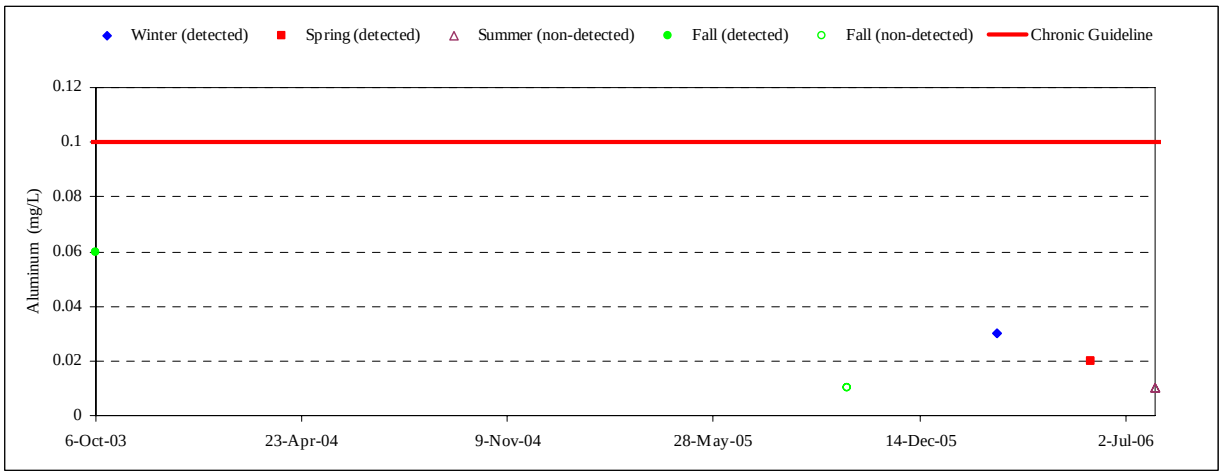
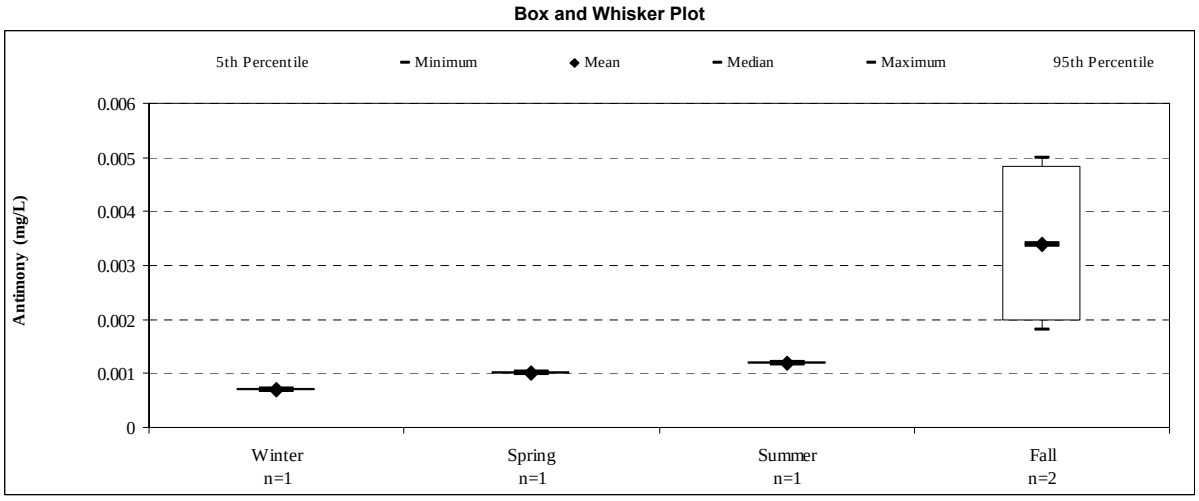


Figure G-2-9-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Unnamed Lakes within JEMA



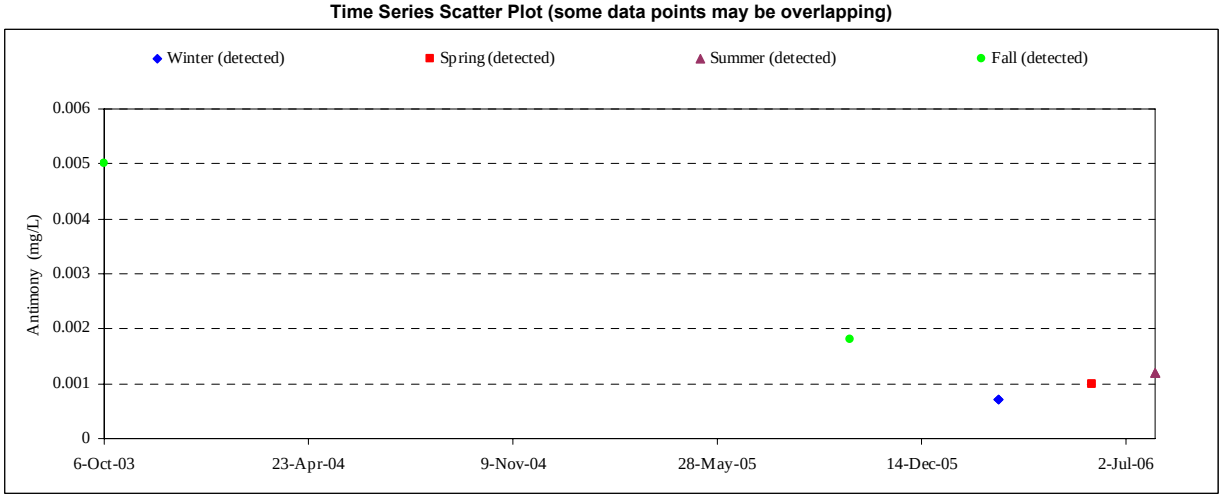
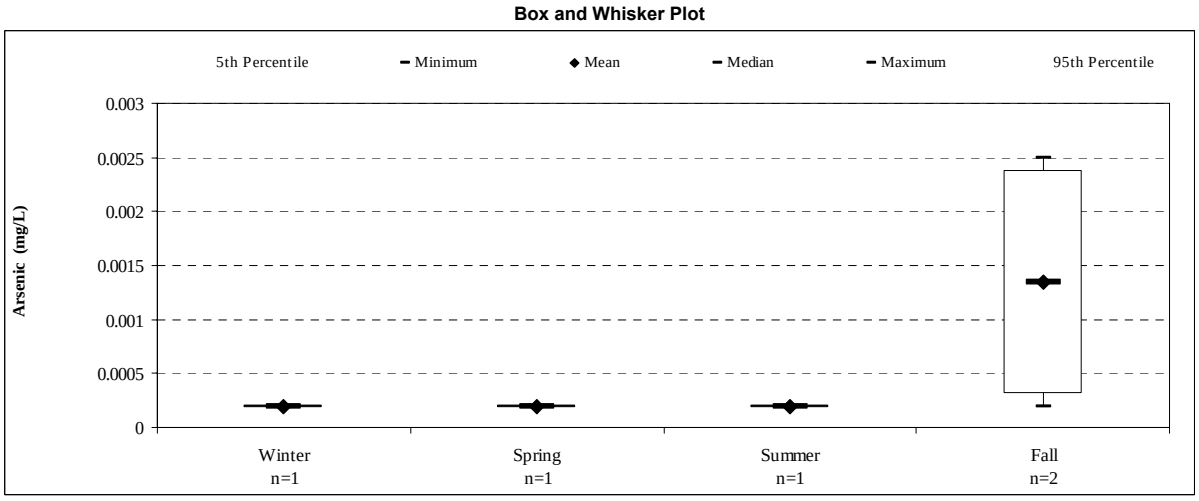


Figure G-2-9-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Unnamed Lakes within JEMA



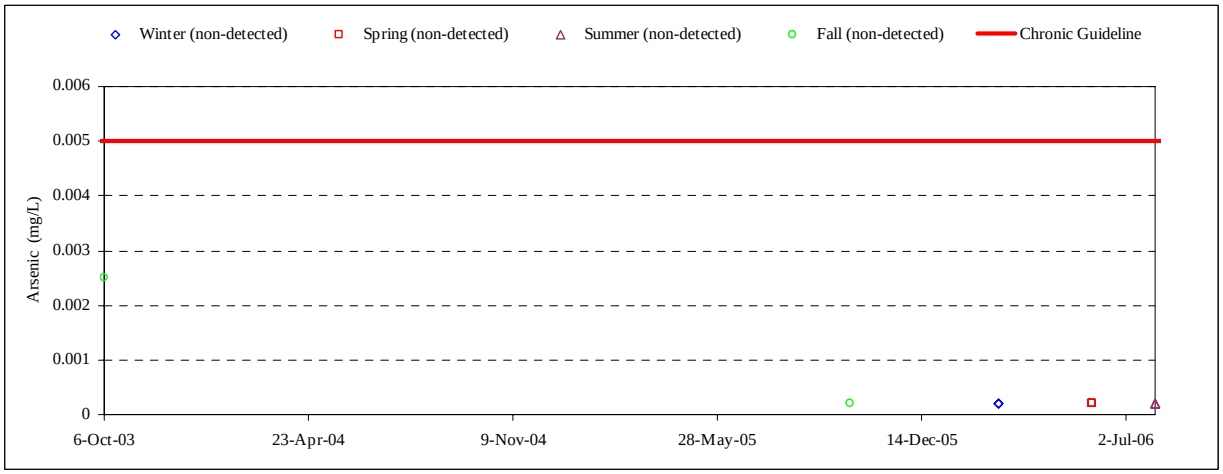
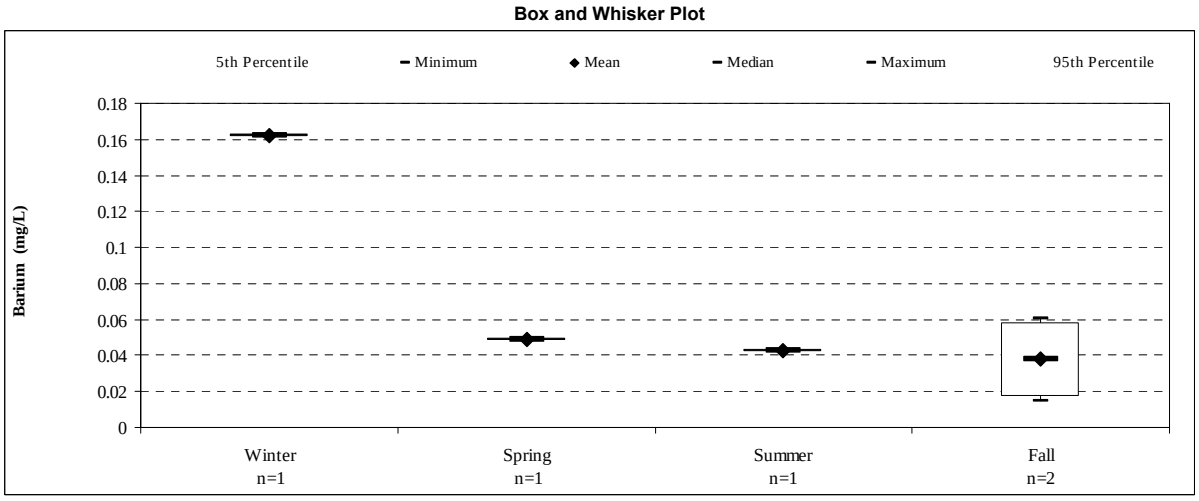


Figure G-2-9-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Unnamed Lakes within JEMA



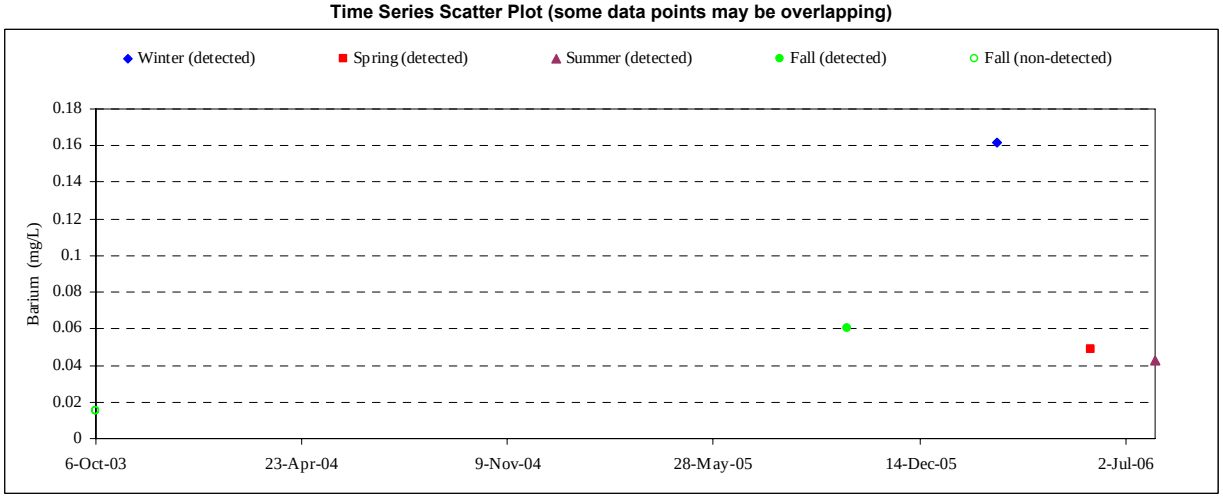
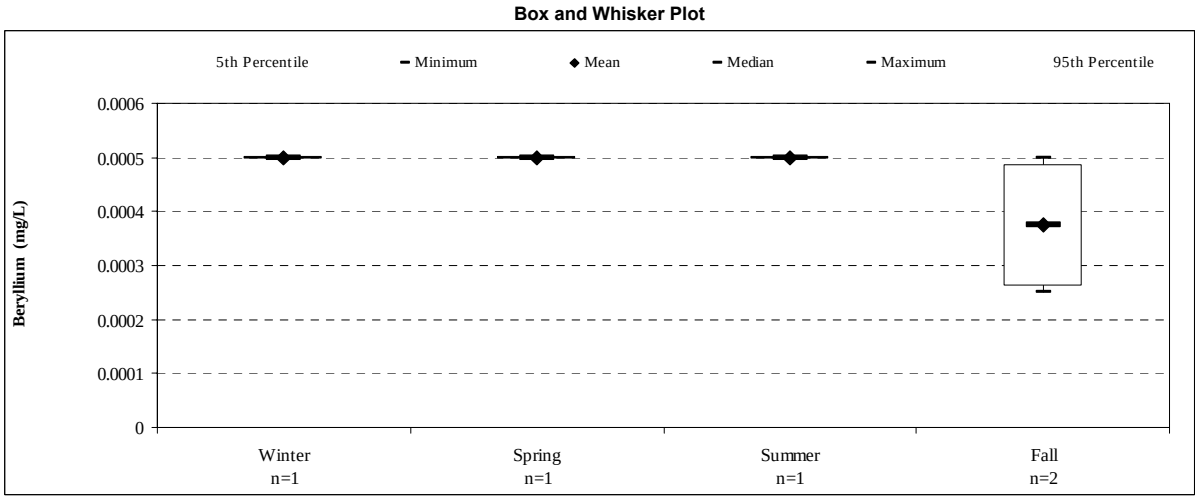


Figure G-2-9-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Unnamed Lakes within JEMA



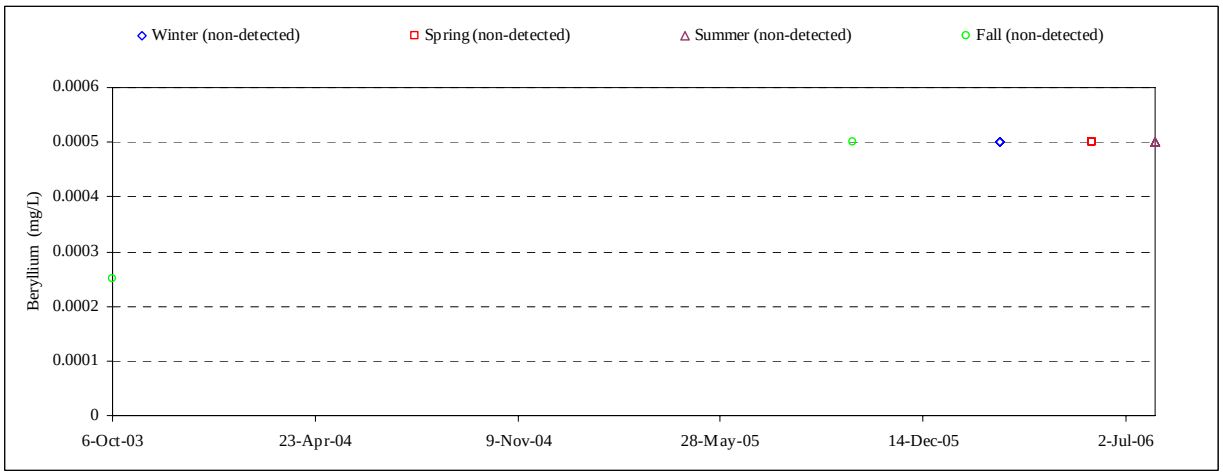
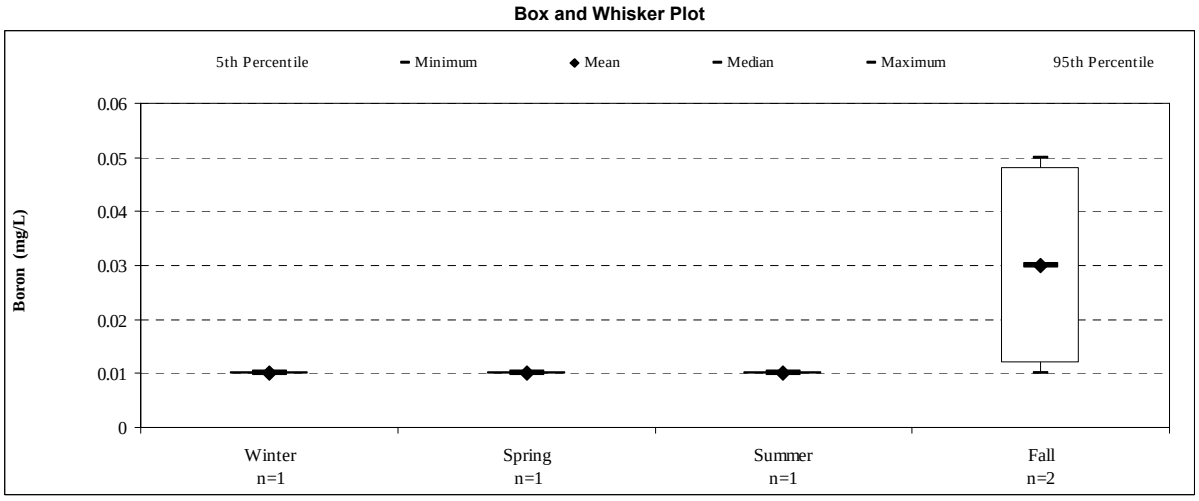


Figure G-2-9-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Unnamed Lakes within JEMA



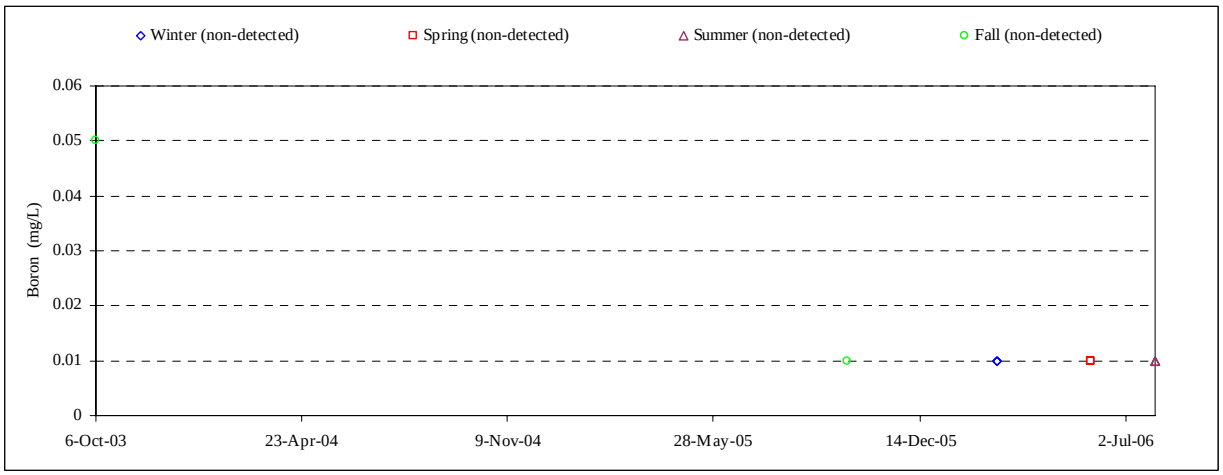
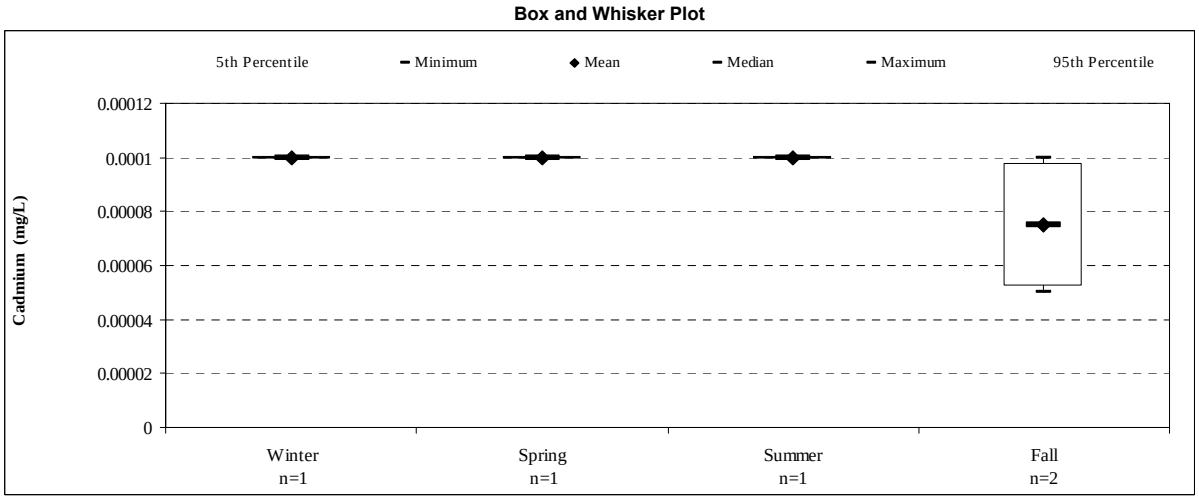


Figure G-2-9-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Unnamed Lakes within JEMA



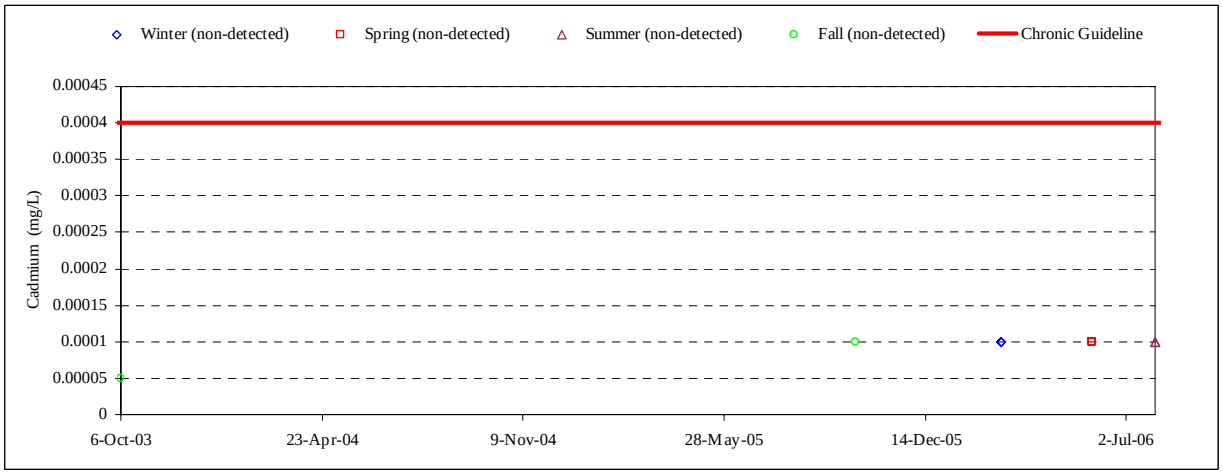
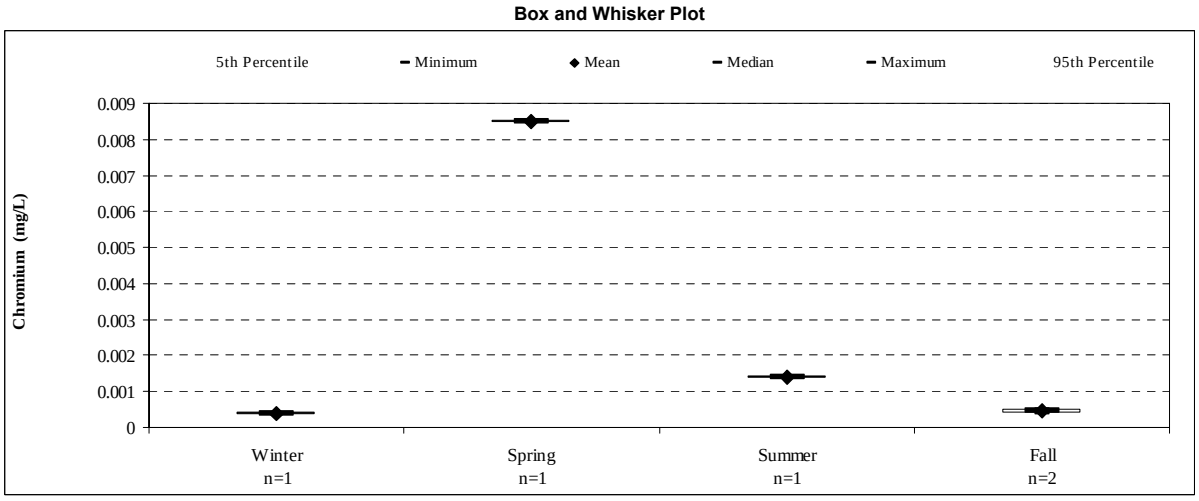


Figure G-2-9-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Unnamed Lakes within JEMA



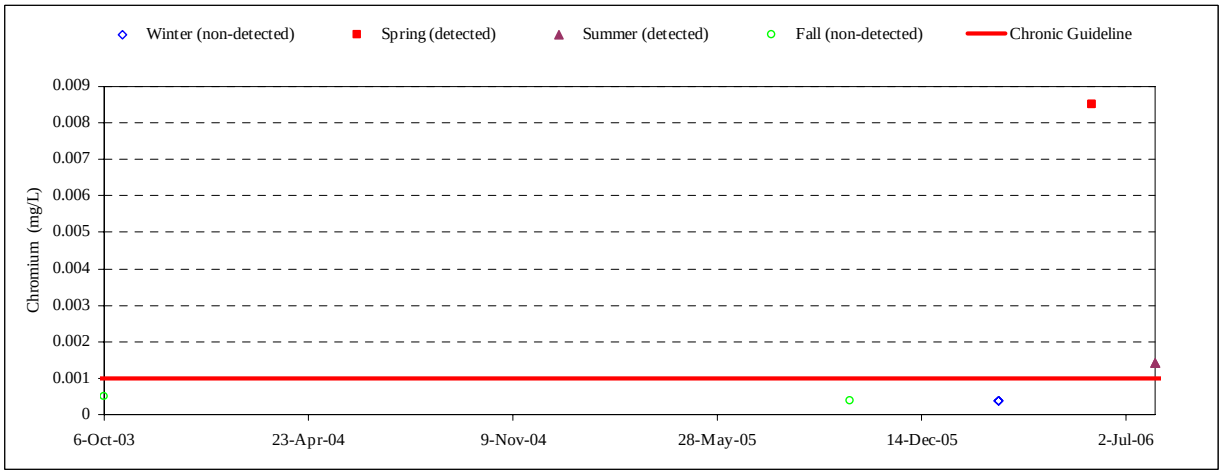
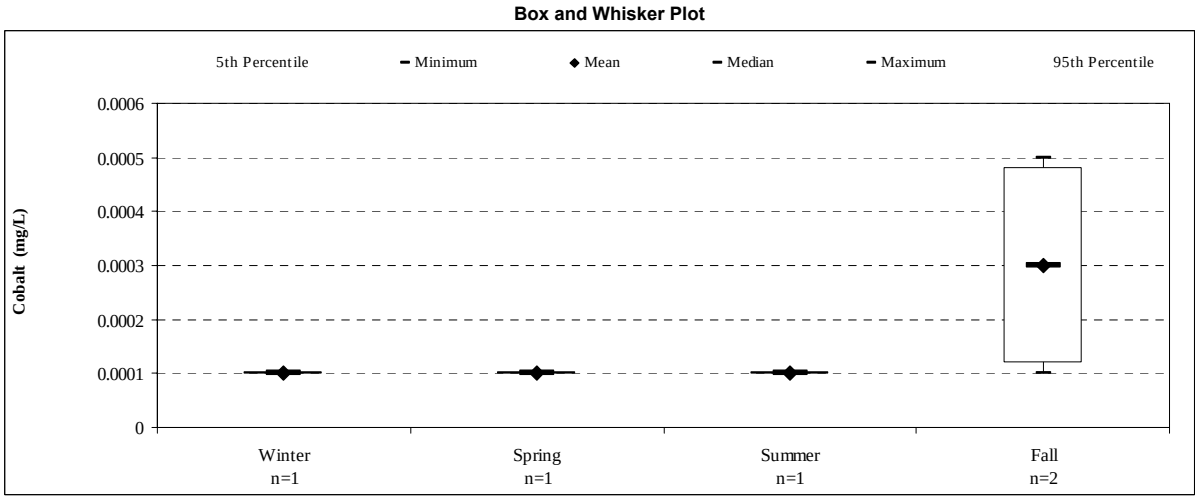


Figure G-2-9-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Unnamed Lakes within JEMA



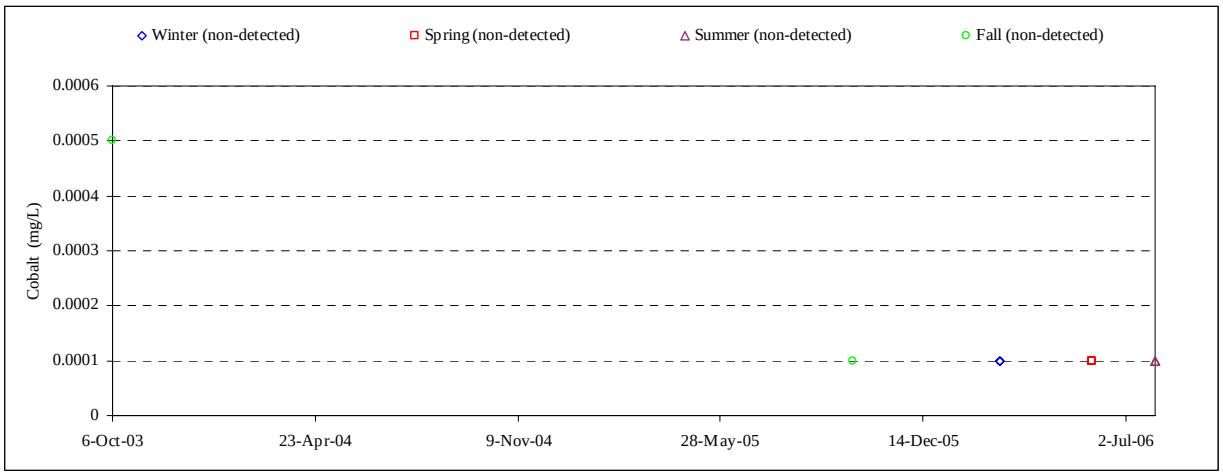
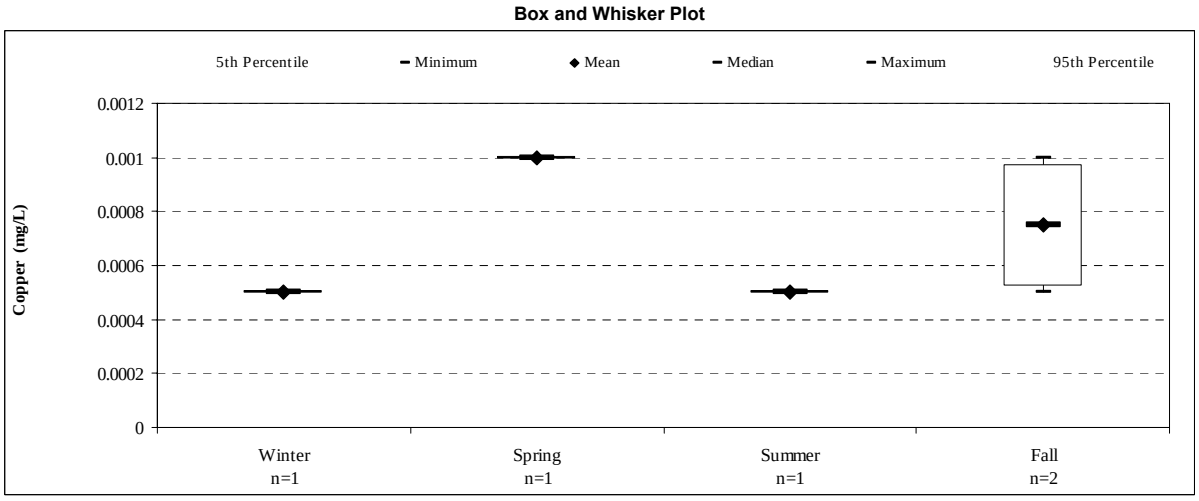


Figure G-2-9-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Unnamed Lakes within JEMA



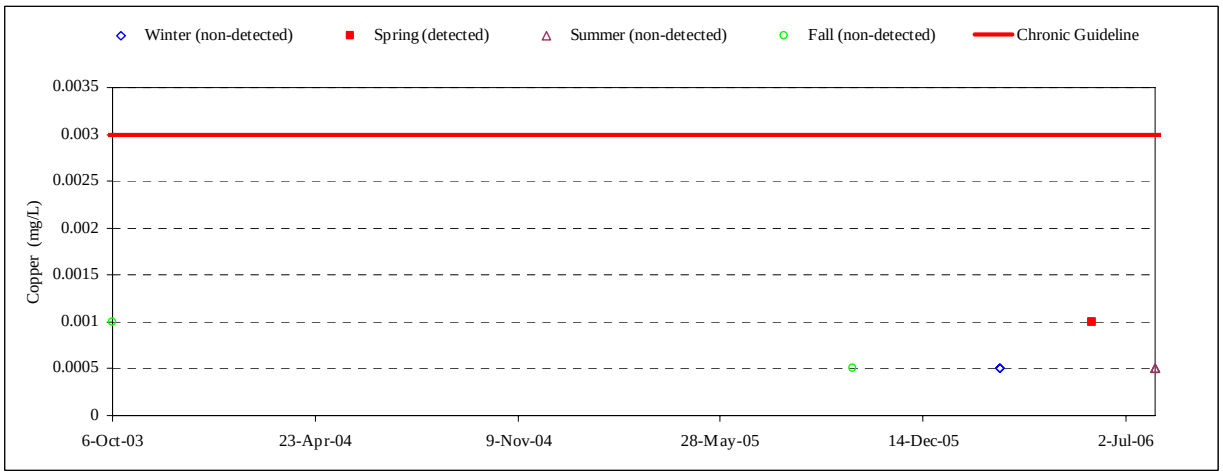
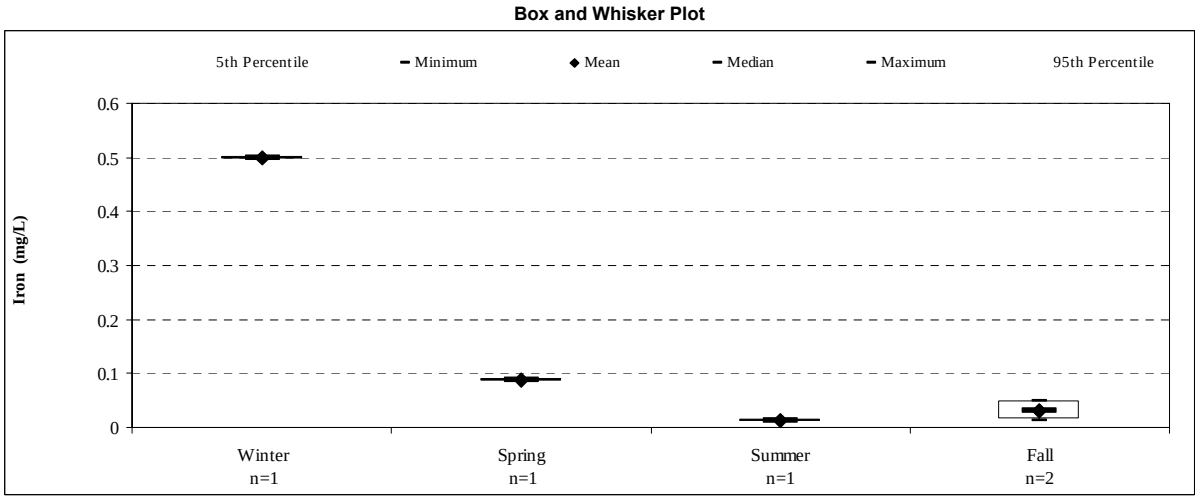


Figure G-2-9-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Unnamed Lakes within JEMA



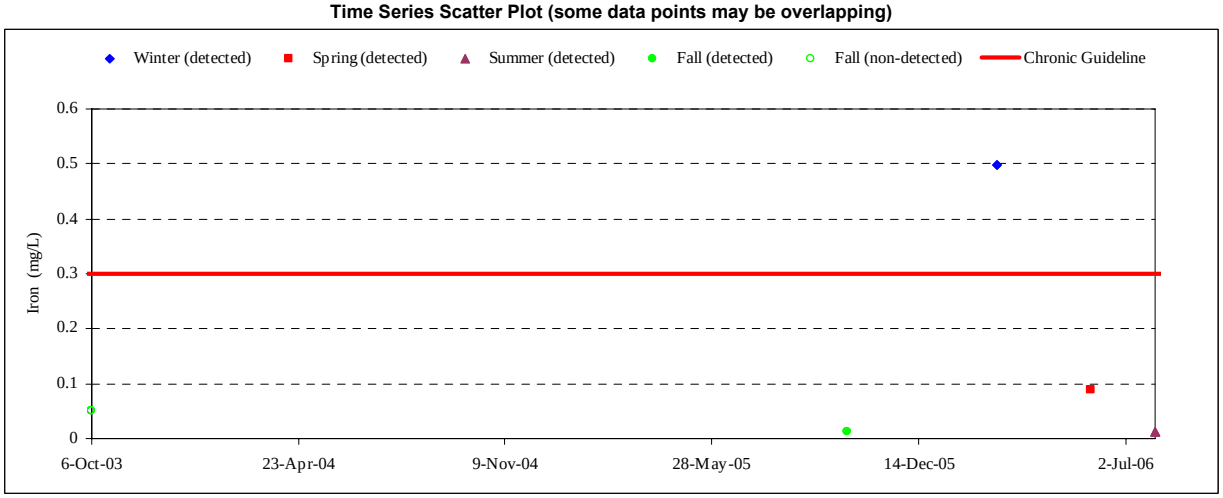
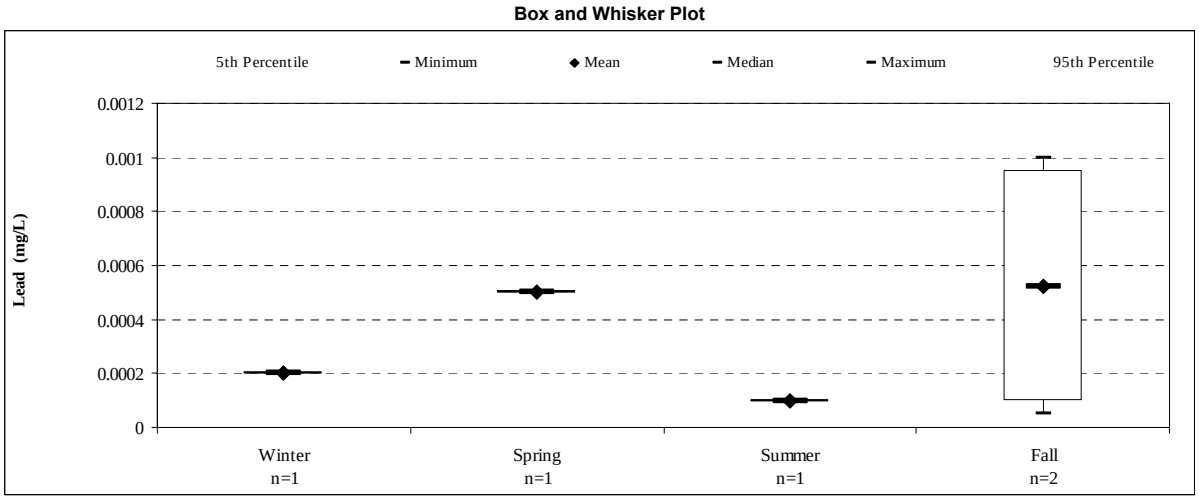


Figure G-2-9-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Unnamed Lakes within JEMA



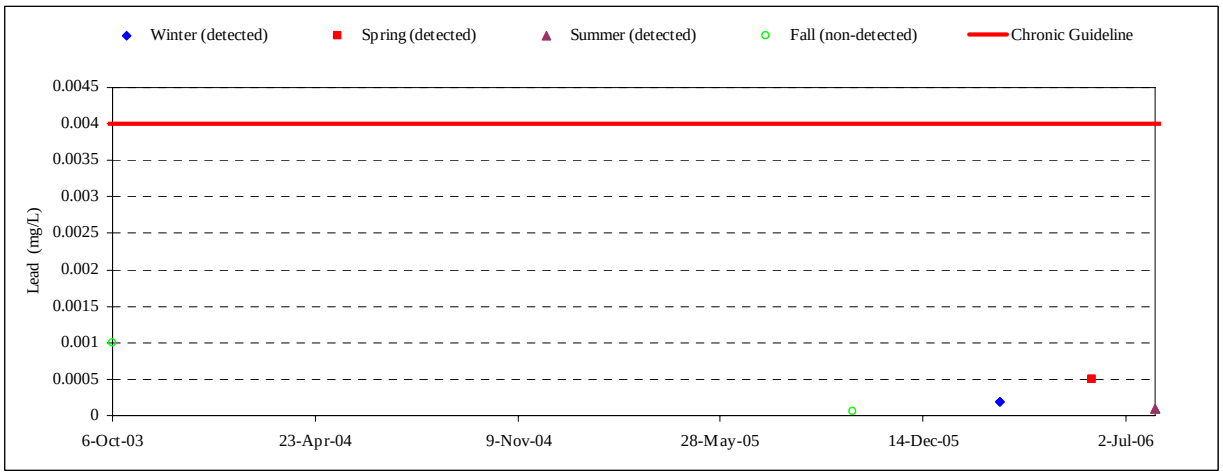
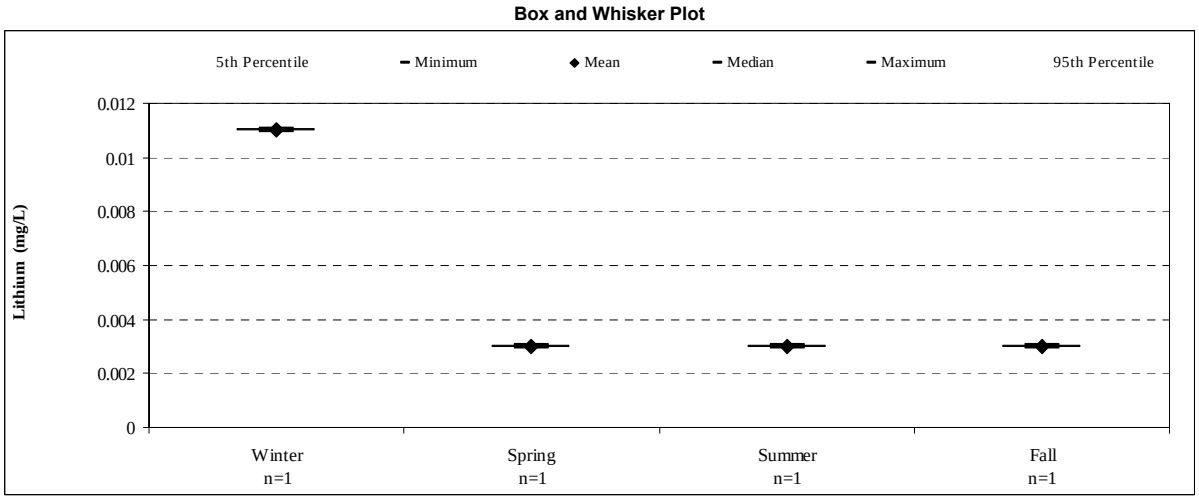


Figure G-2-9-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Unnamed Lakes within JEMA



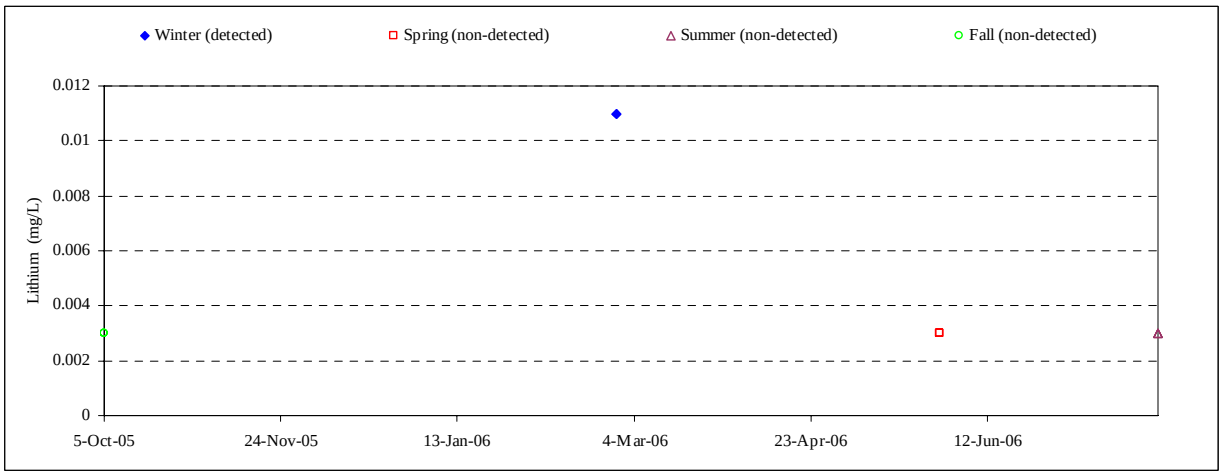
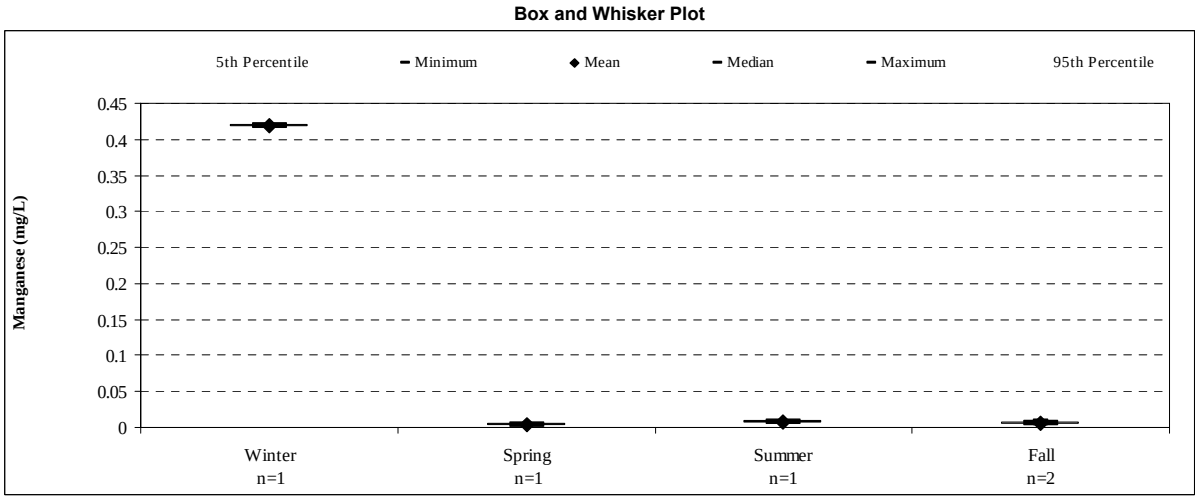


Figure G-2-9-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Unnamed Lakes within JEMA



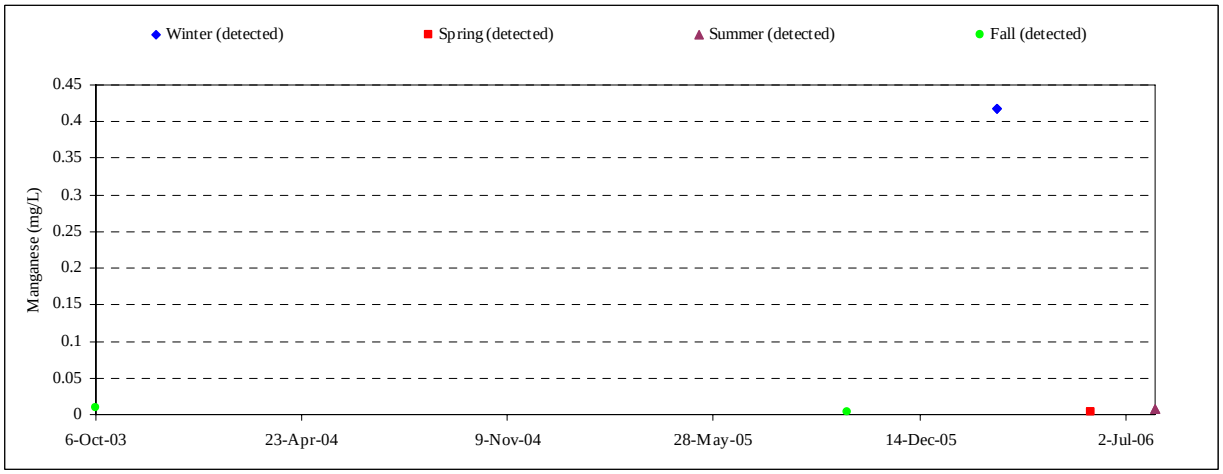
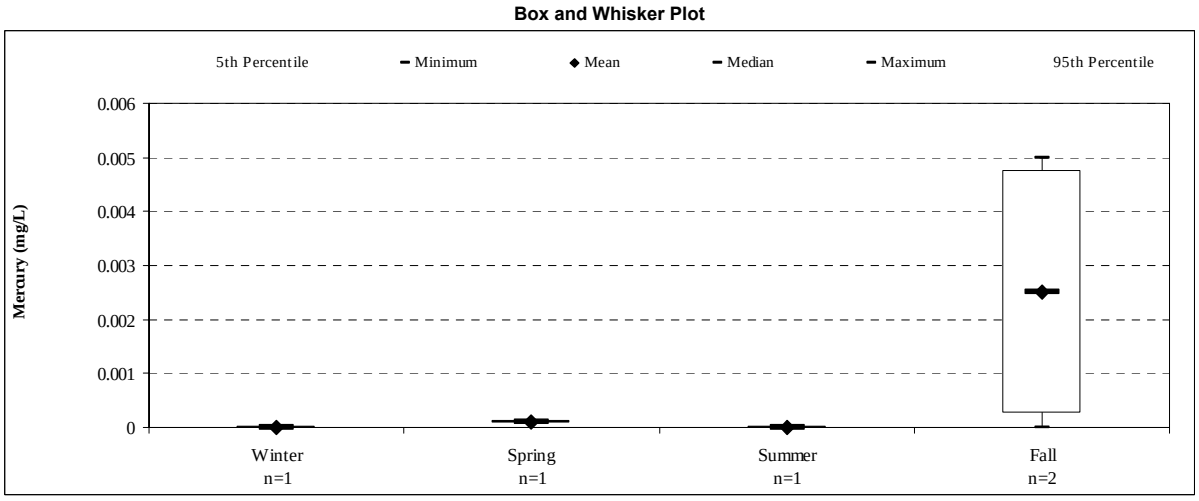


Figure G-2-9-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Unnamed Lakes within JEMA



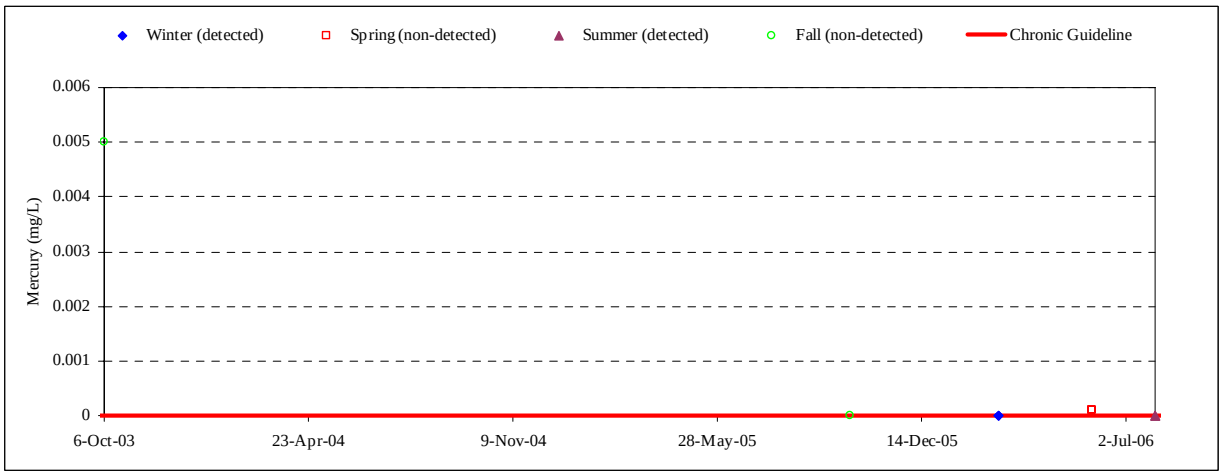
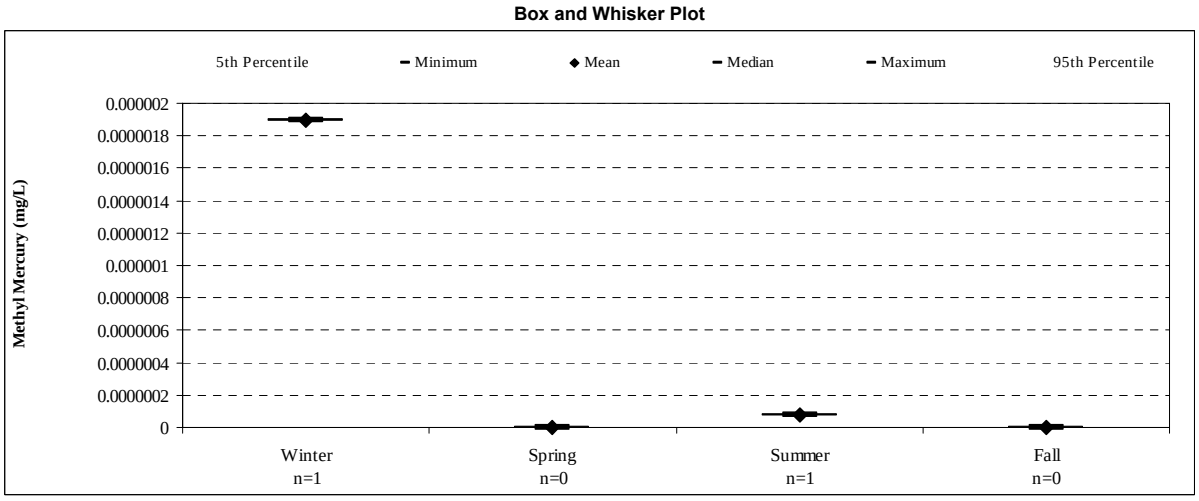


Figure G-2-9-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Unnamed Lakes within JEMA



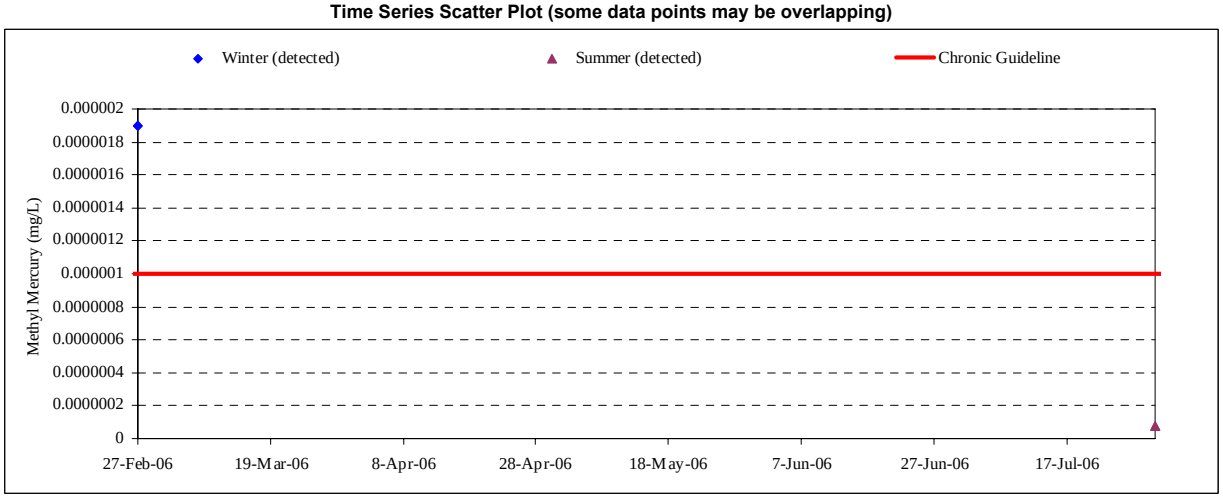
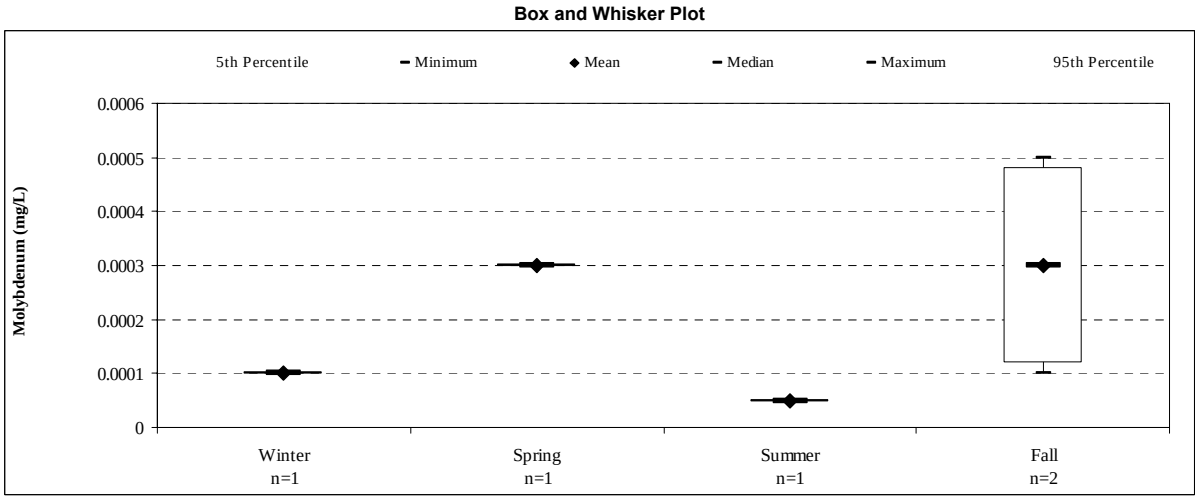


Figure G-2-9-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Unnamed Lakes within JEMA



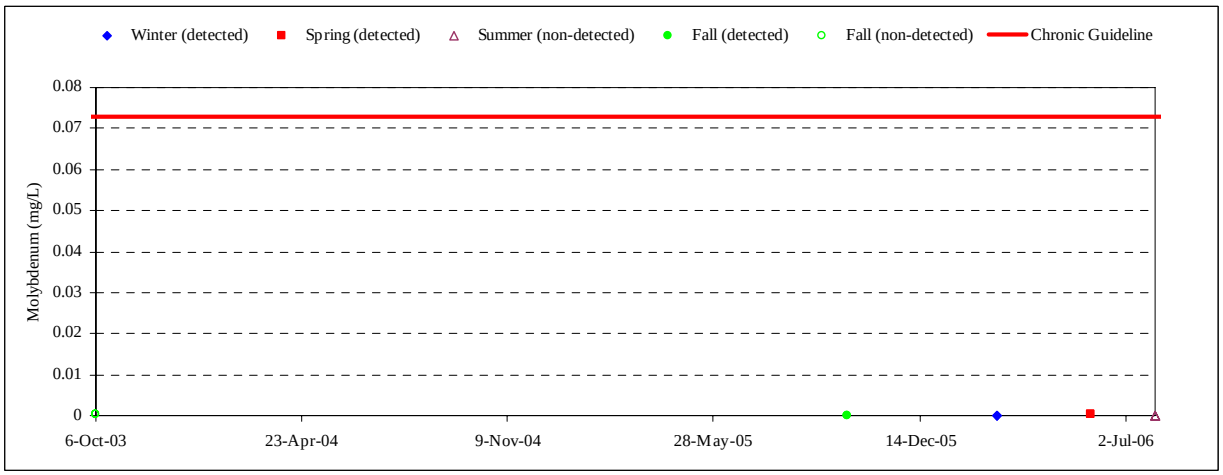
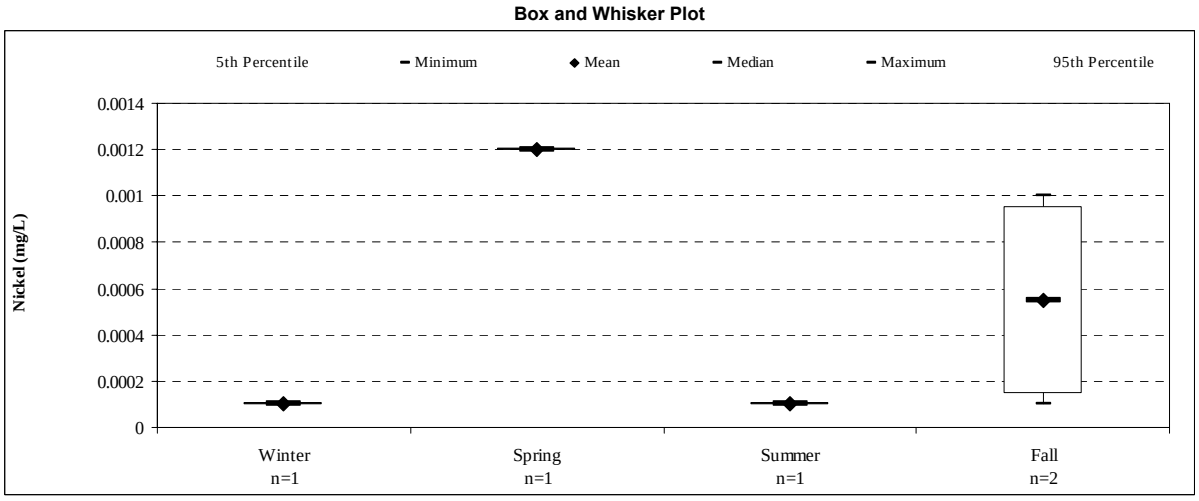


Figure G-2-9-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Unnamed Lakes within JEMA



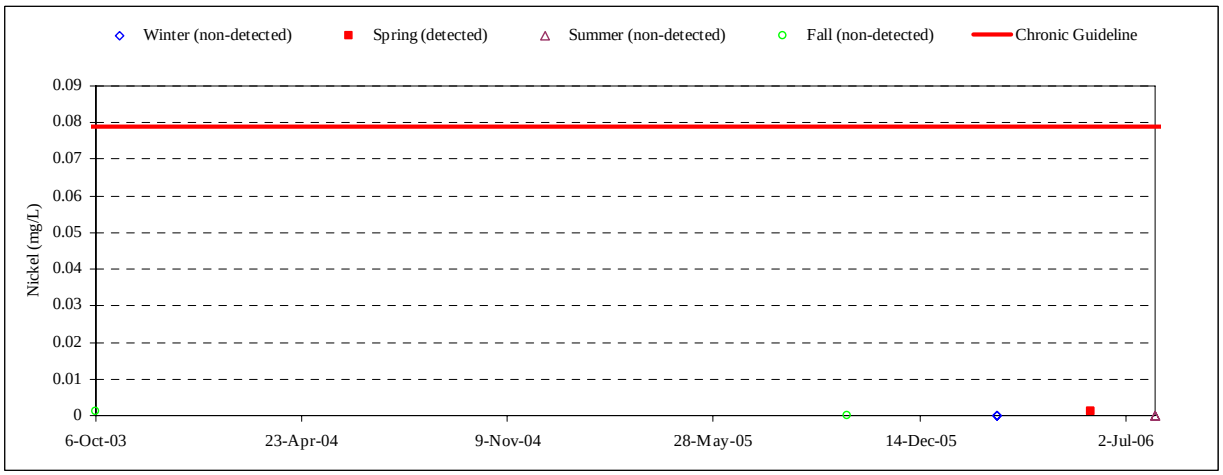
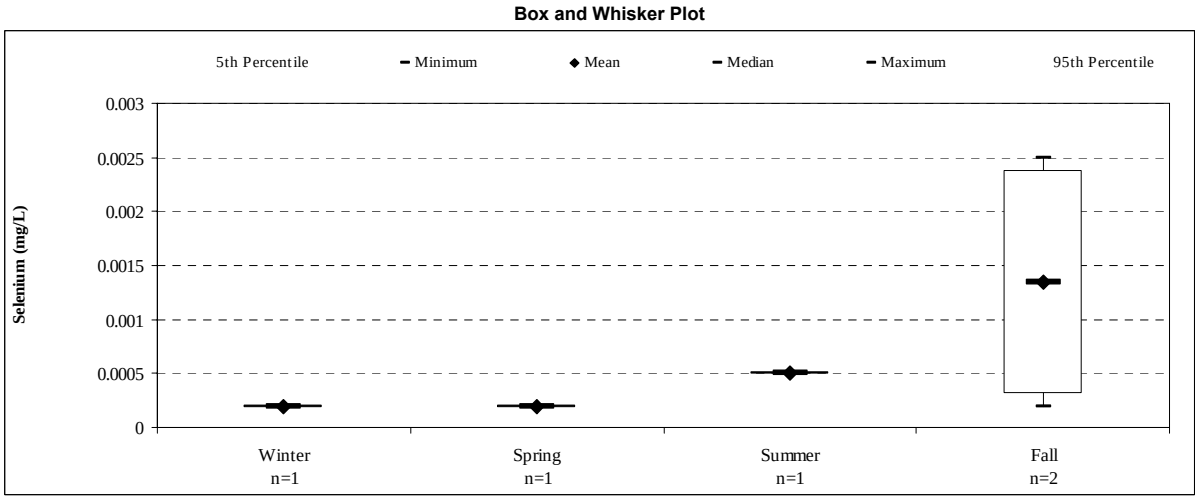


Figure G-2-9-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Unnamed Lakes within JEMA



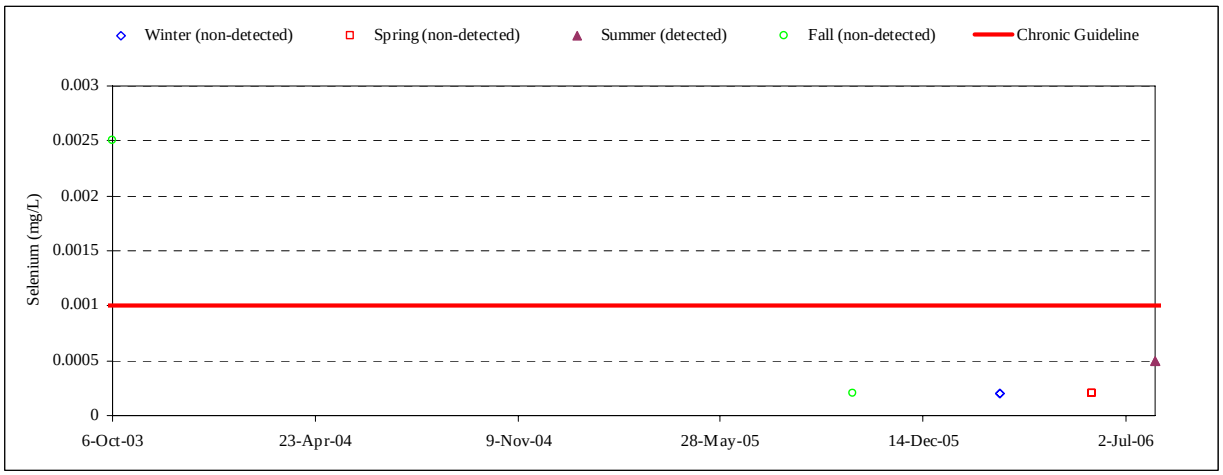
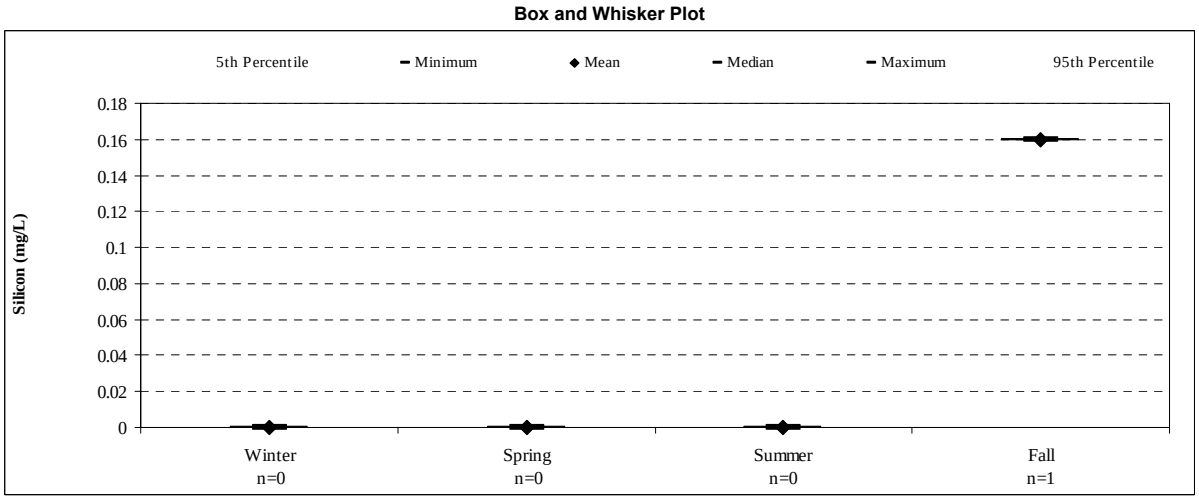


Figure G-2-9-82 Box Whisker and Time Series Scatter Plots of Observed Silicon (Total) Concentration in Unnamed Lakes within JEMA



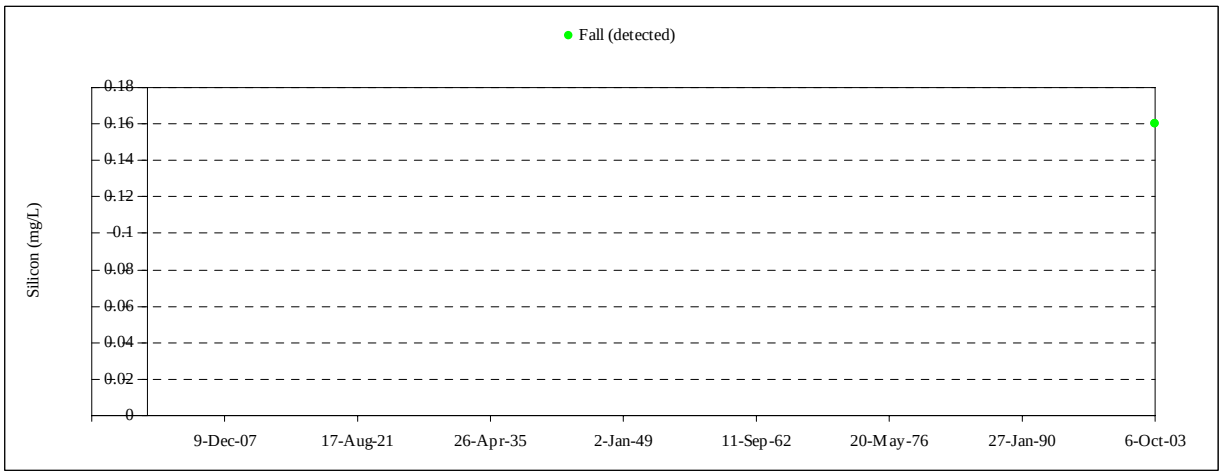
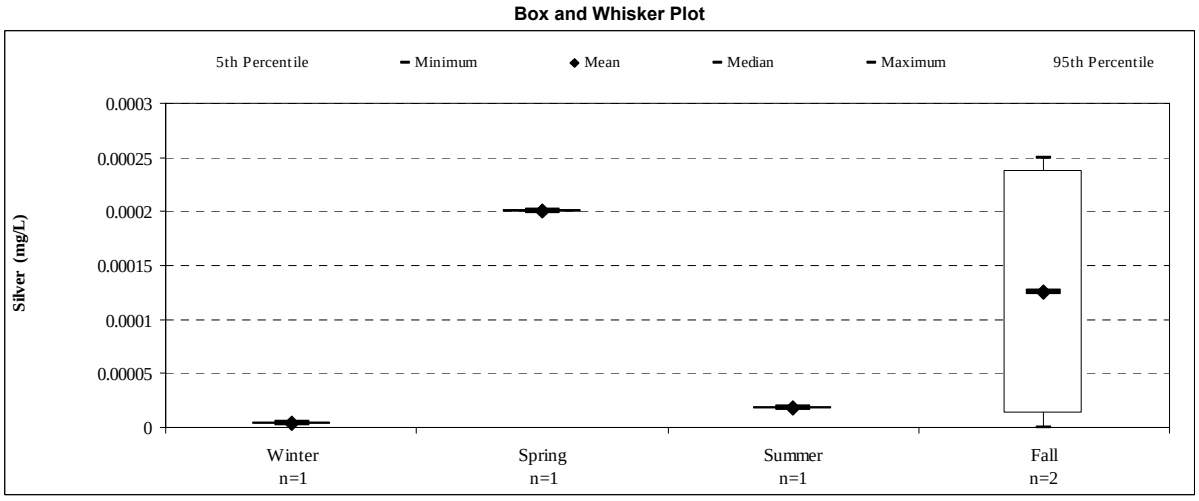


Figure G-2-9-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Unnamed Lakes within JEMA



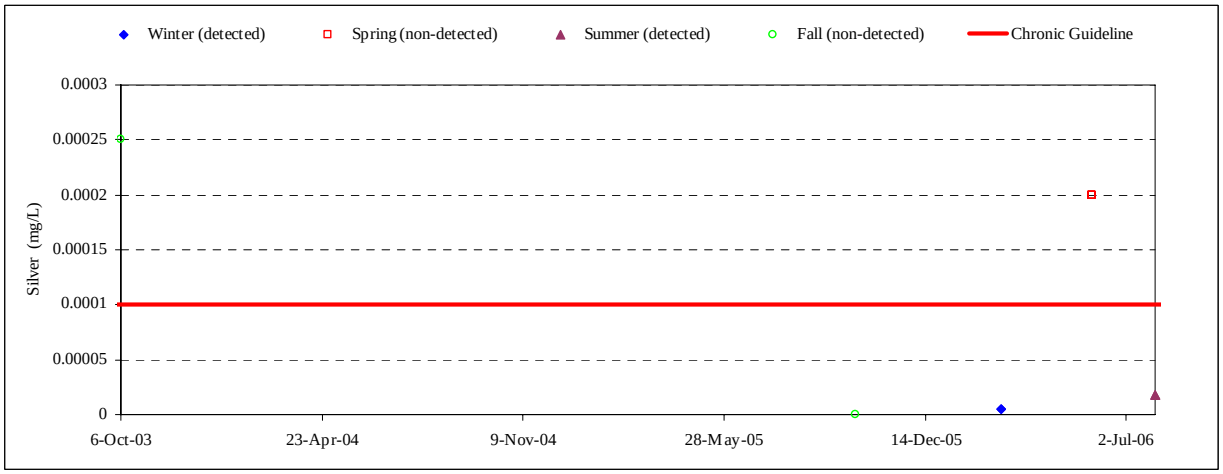
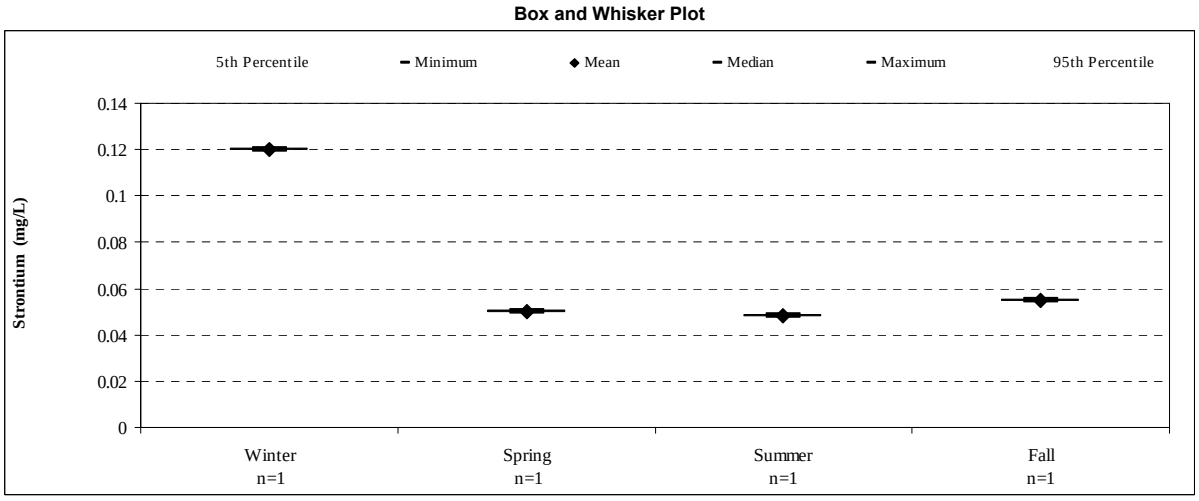


Figure G-2-9-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Unnamed Lakes within JEMA



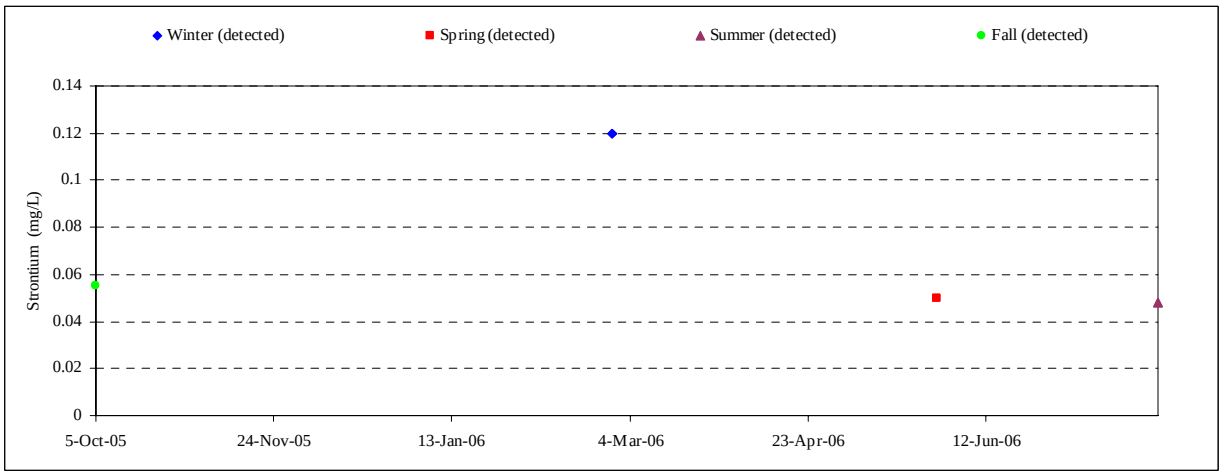
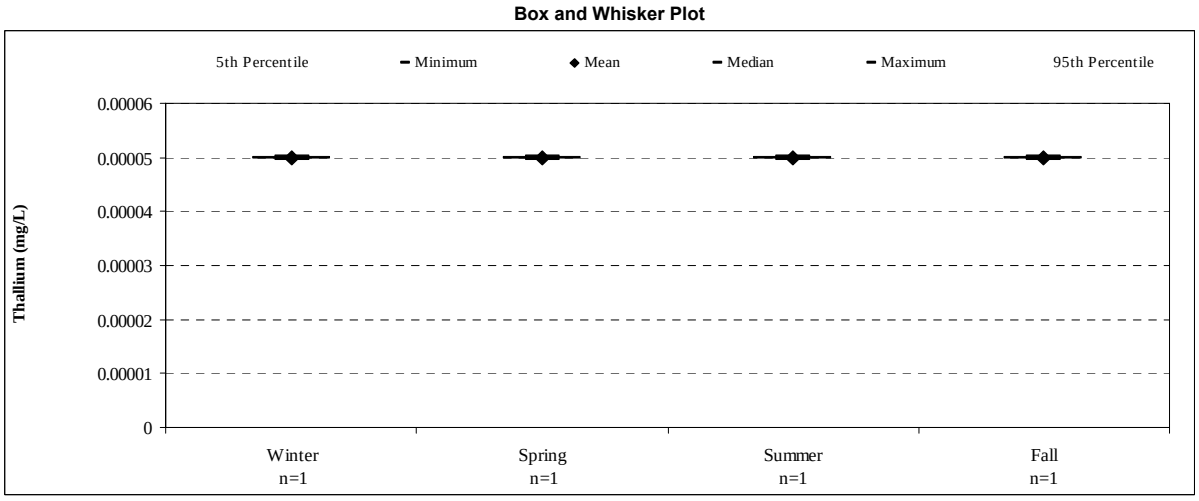


Figure G-2-9-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Unnamed Lakes within JEMA



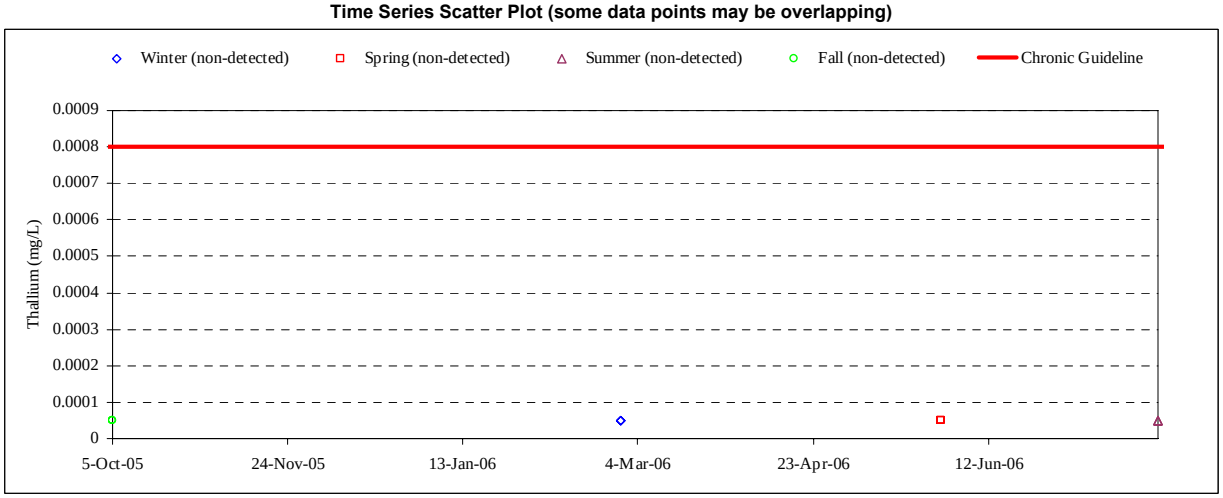
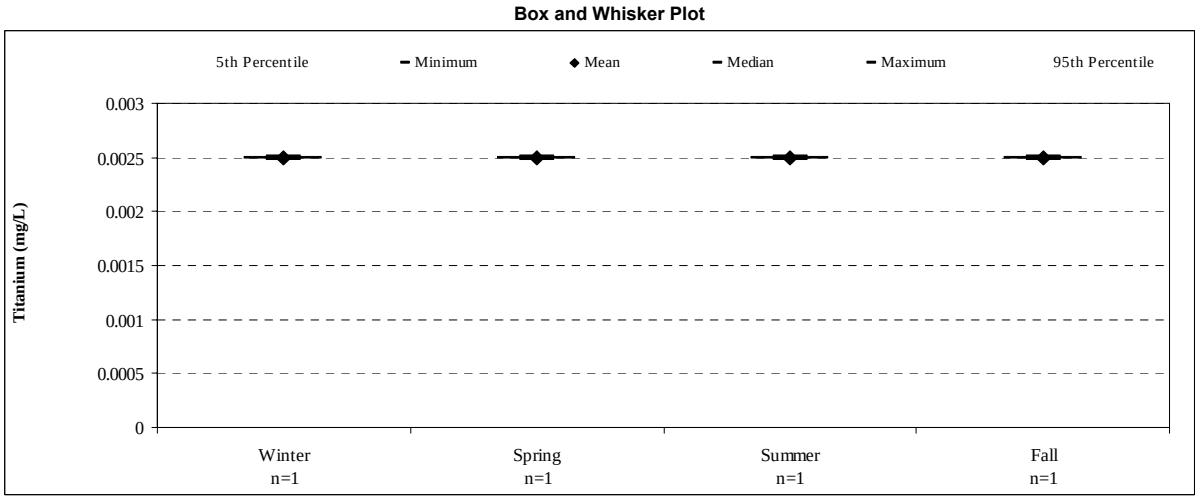


Figure G-2-9-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Unnamed Lakes within JEMA



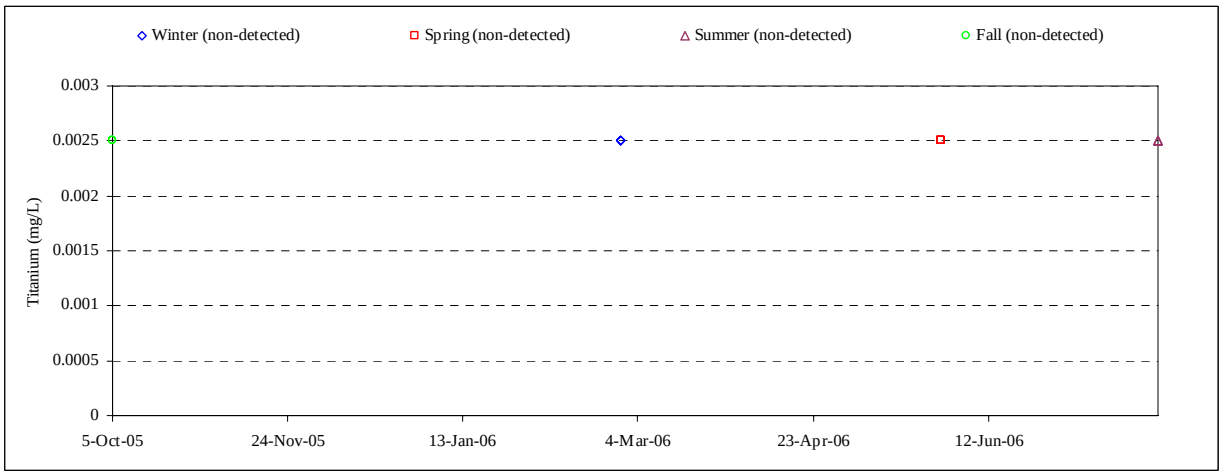
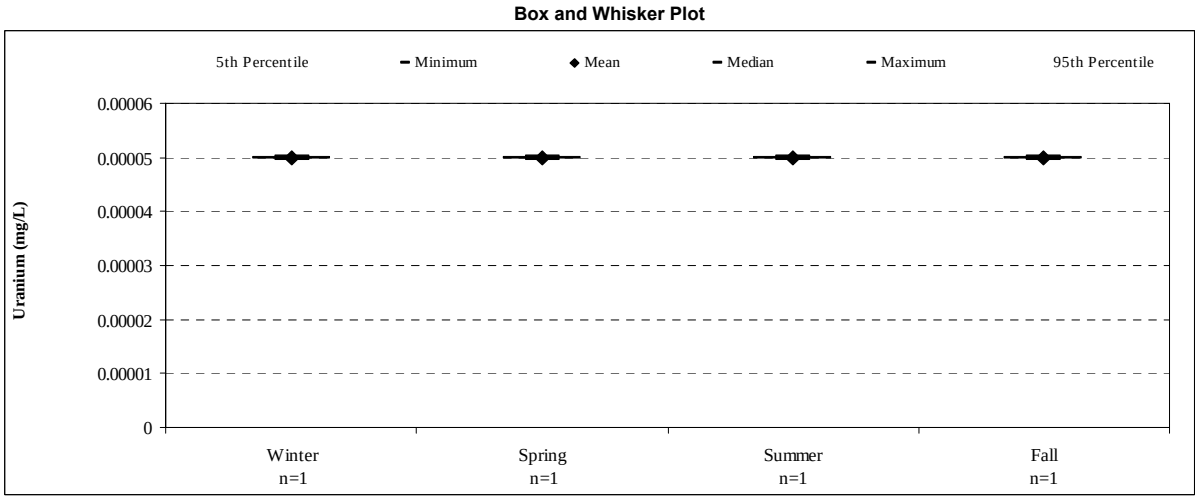


Figure G-2-9-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Unnamed Lakes within JEMA



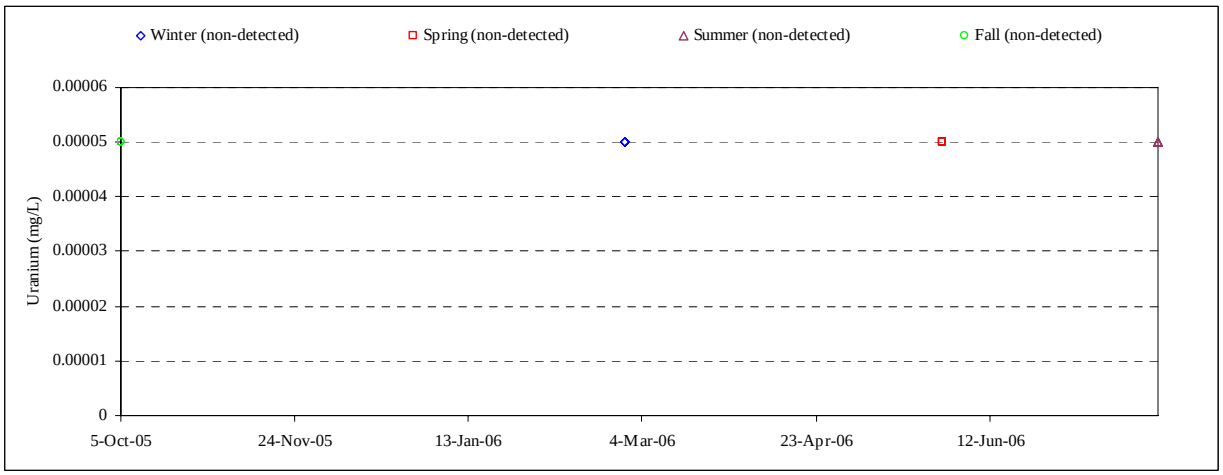
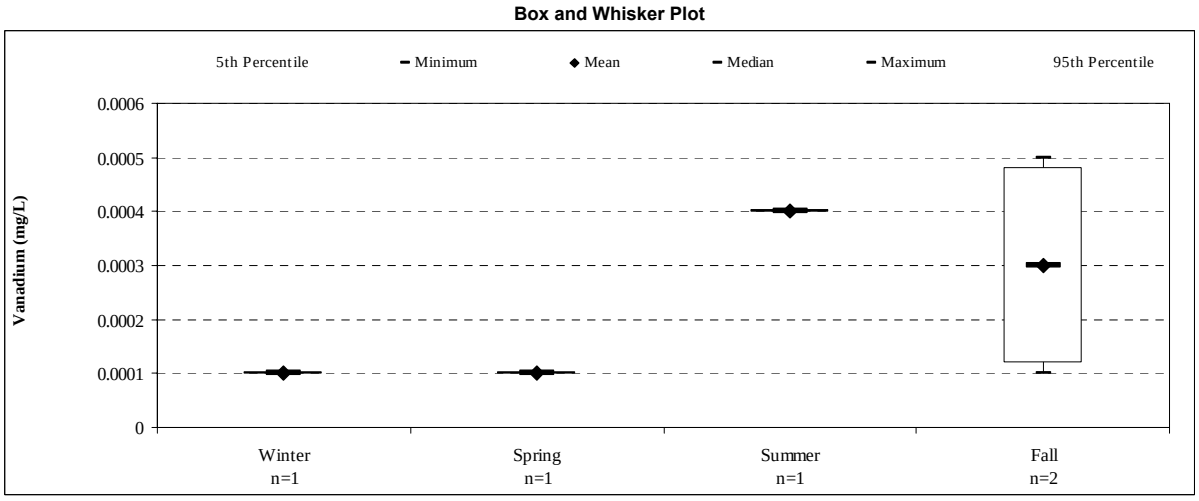


Figure G-2-9-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Unnamed Lakes within JEMA



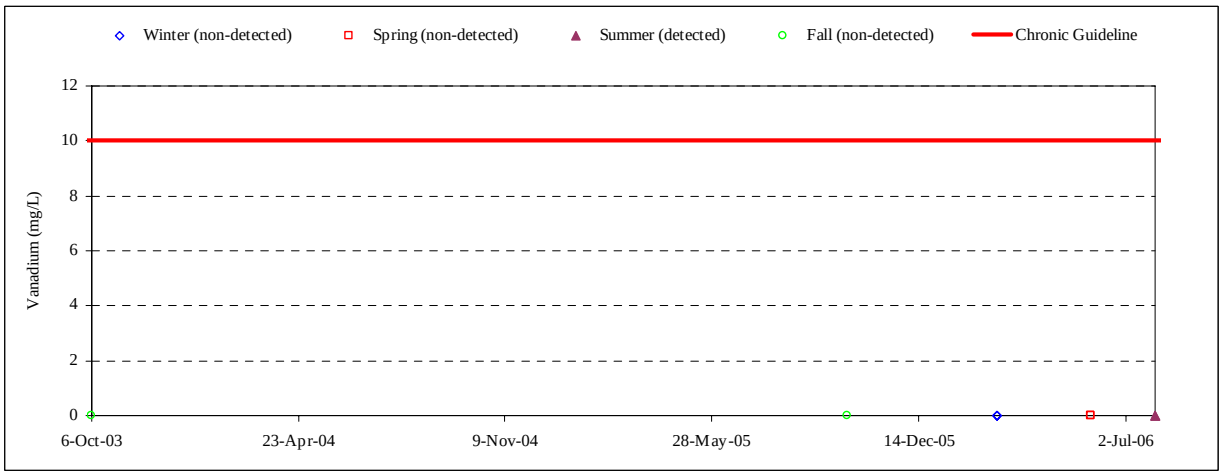
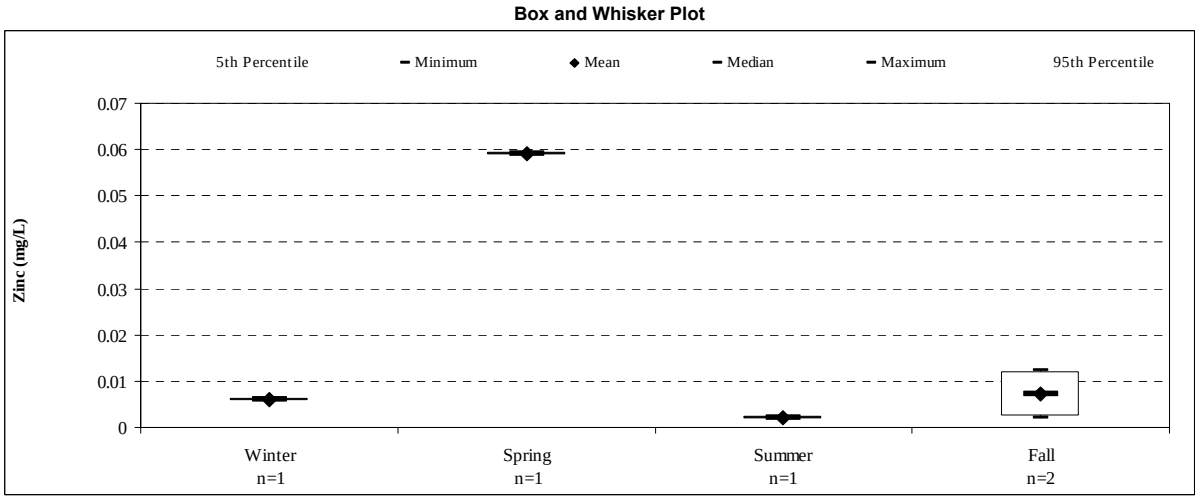


Figure G-2-9-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Unnamed Lakes within JEMA



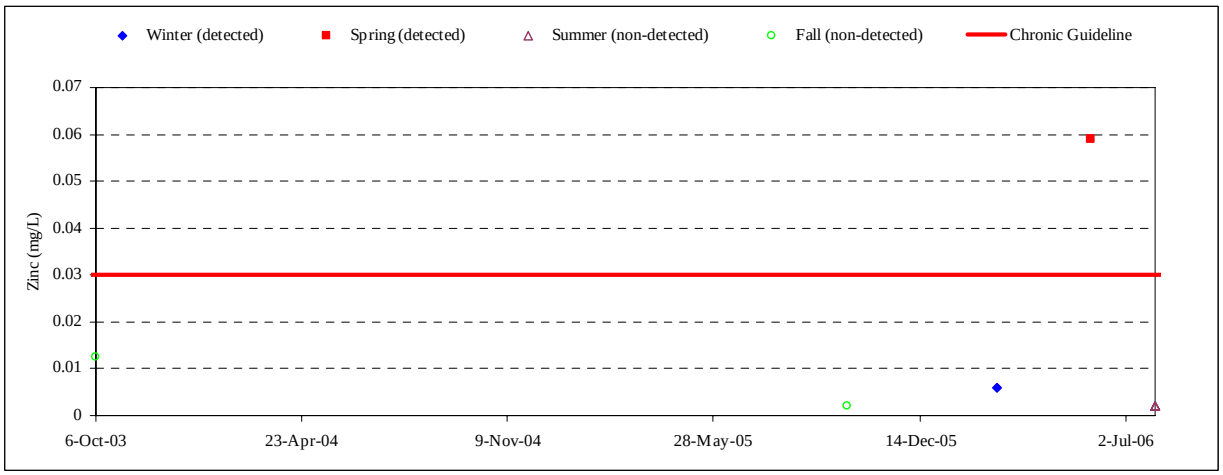
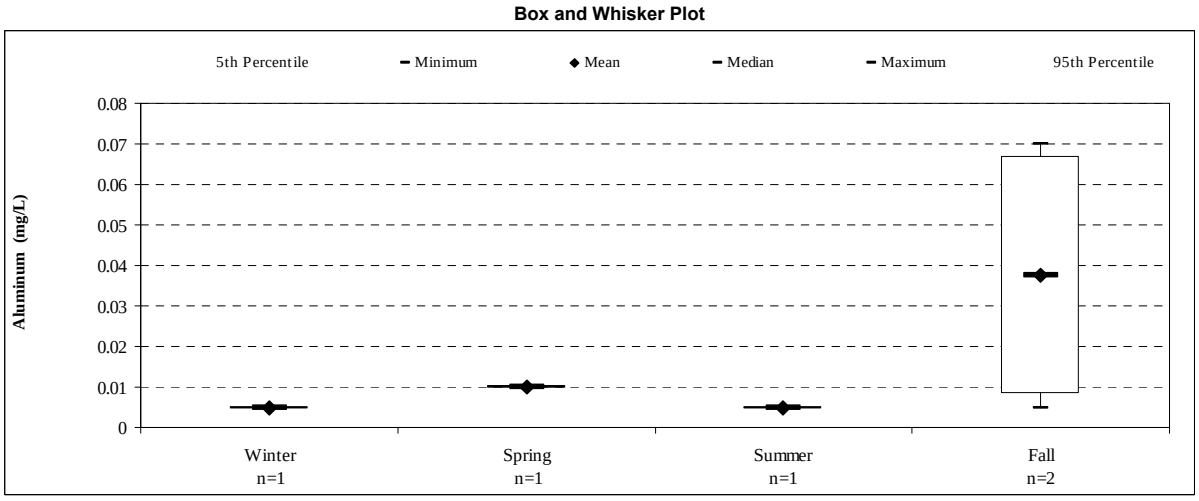


Figure G-2-9-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Unnamed Lakes within JEMA



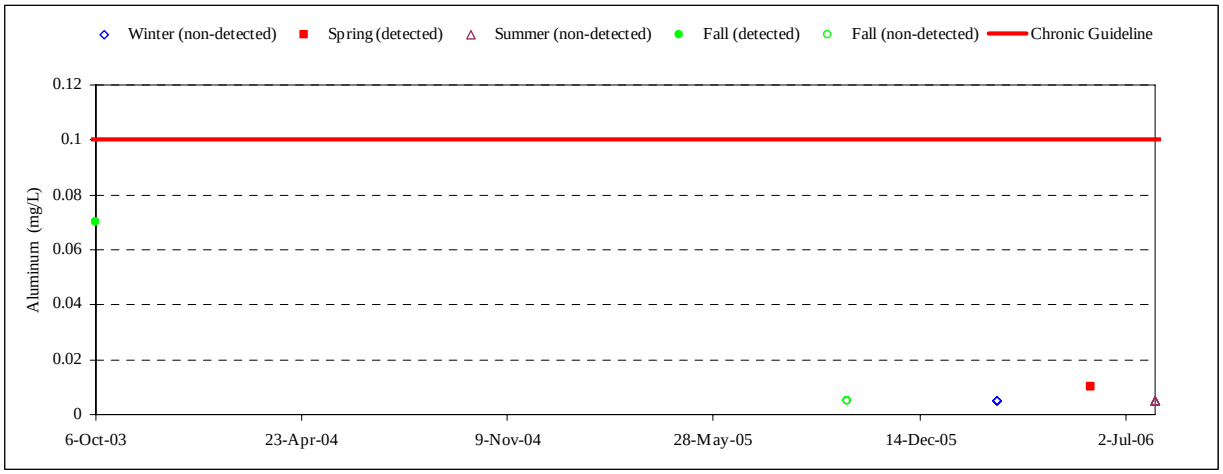
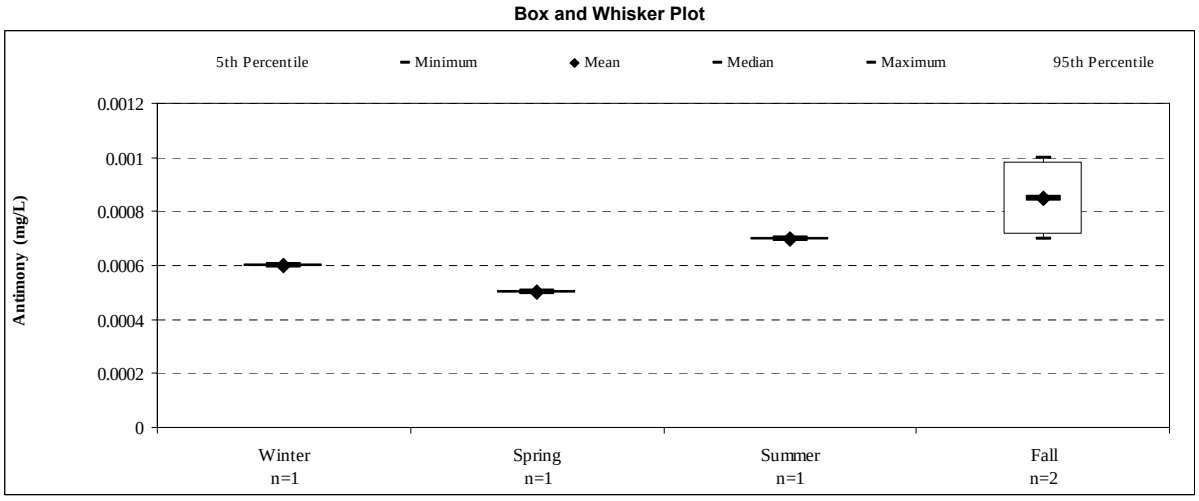


Figure G-2-9-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Unnamed Lakes within JEMA



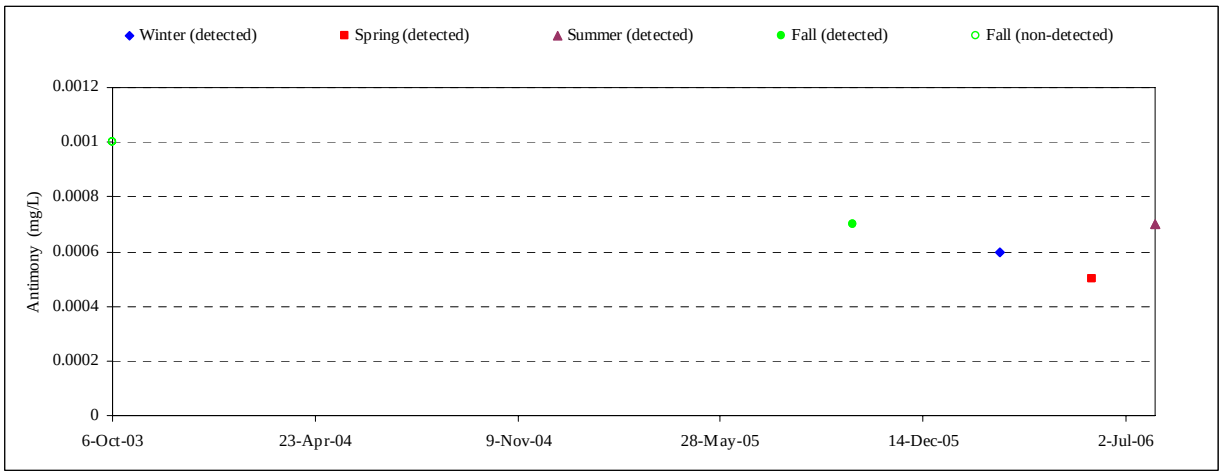
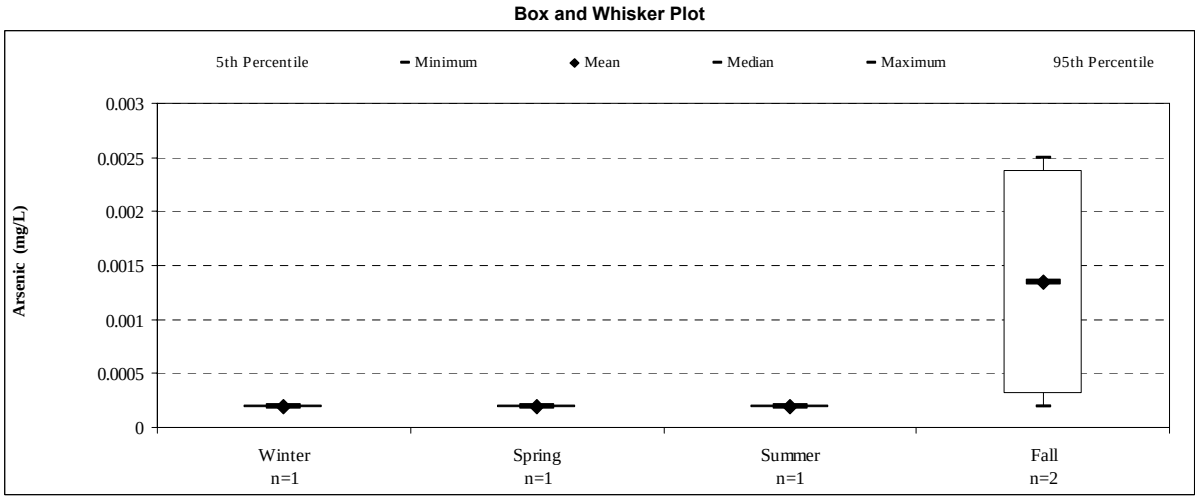


Figure G-2-9-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Unnamed Lakes within JEMA



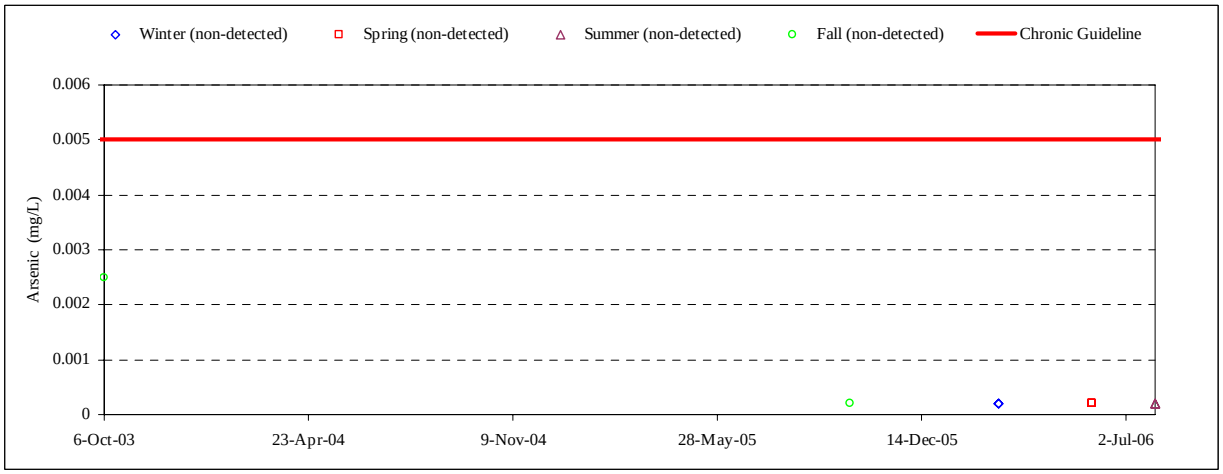
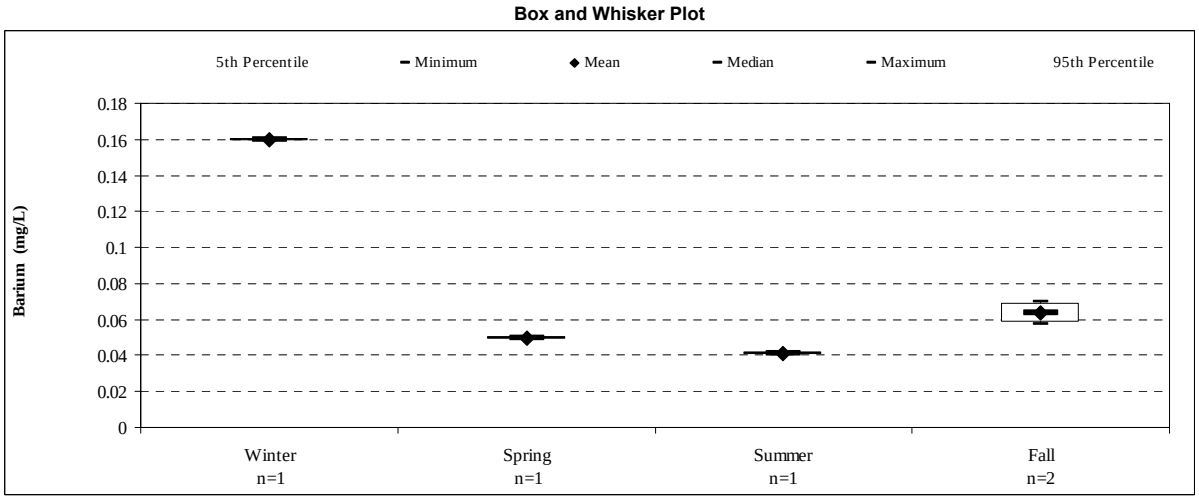


Figure G-2-9-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Unnamed Lakes within JEMA



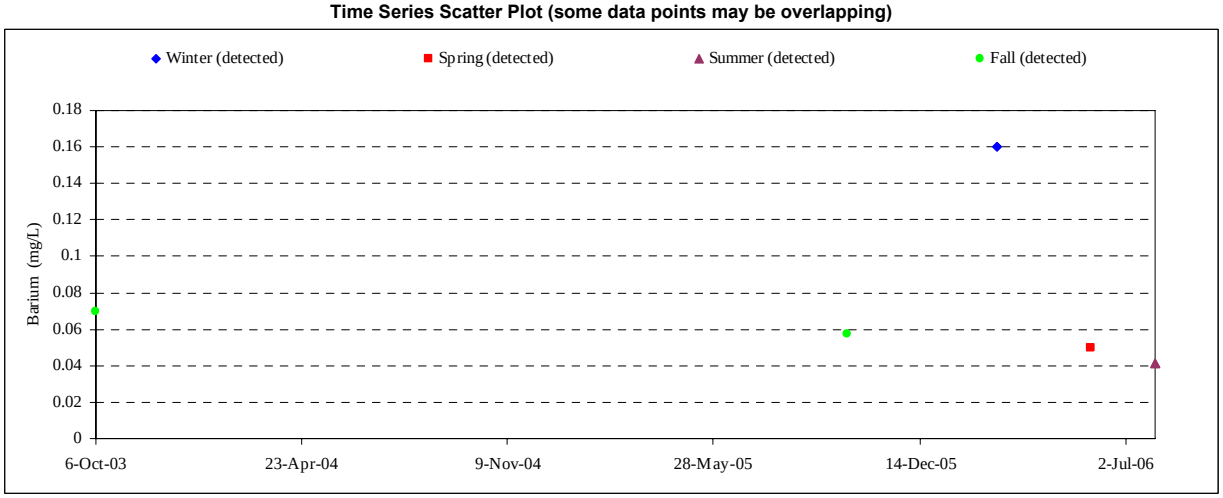
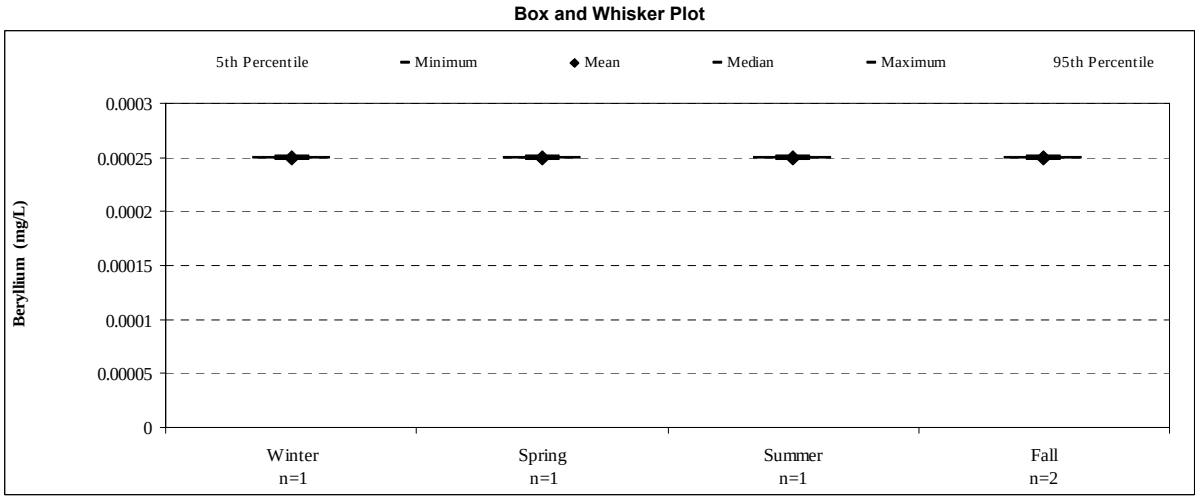


Figure G-2-9-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Unnamed Lakes within JEMA



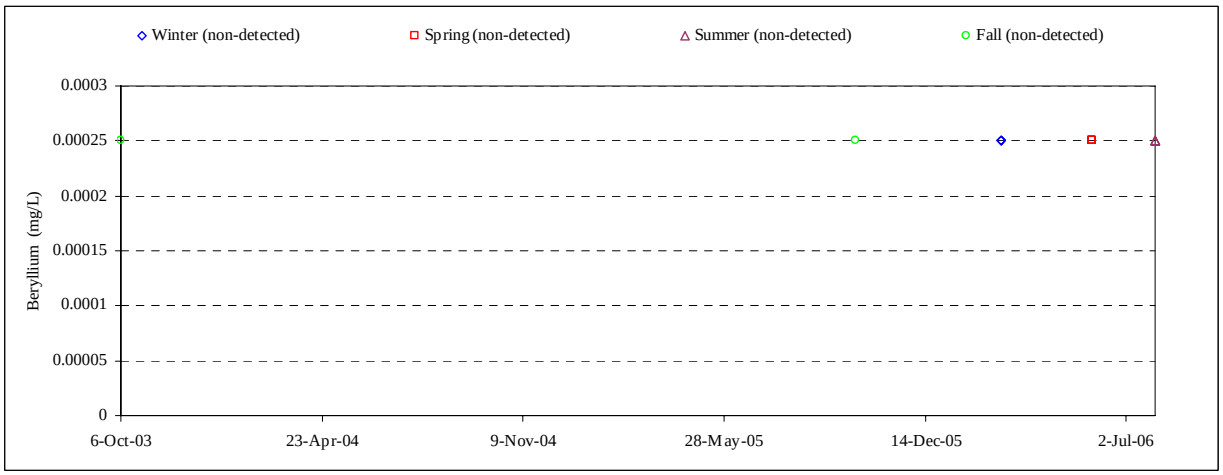
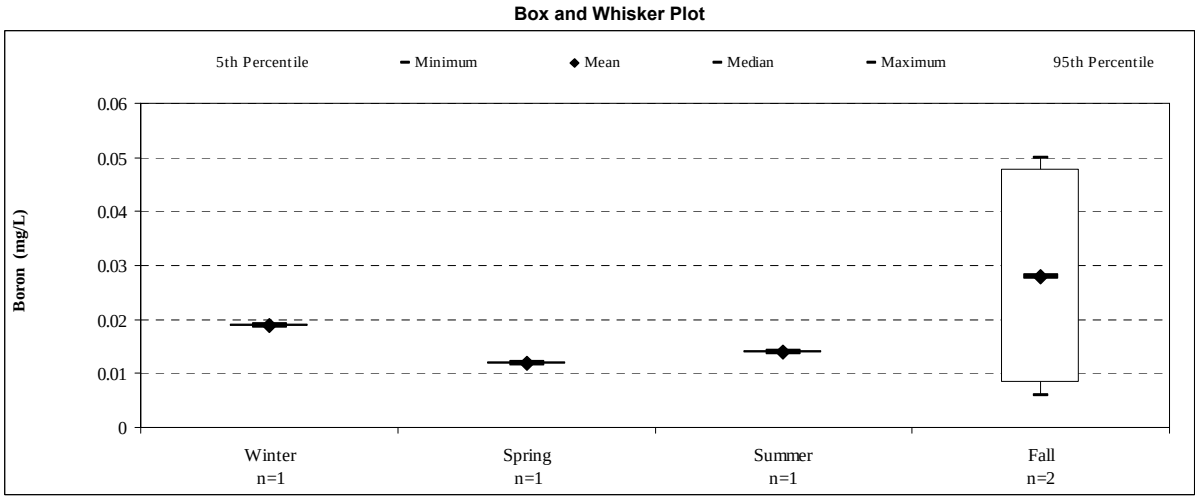


Figure G-2-9-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Unnamed Lakes within JEMA



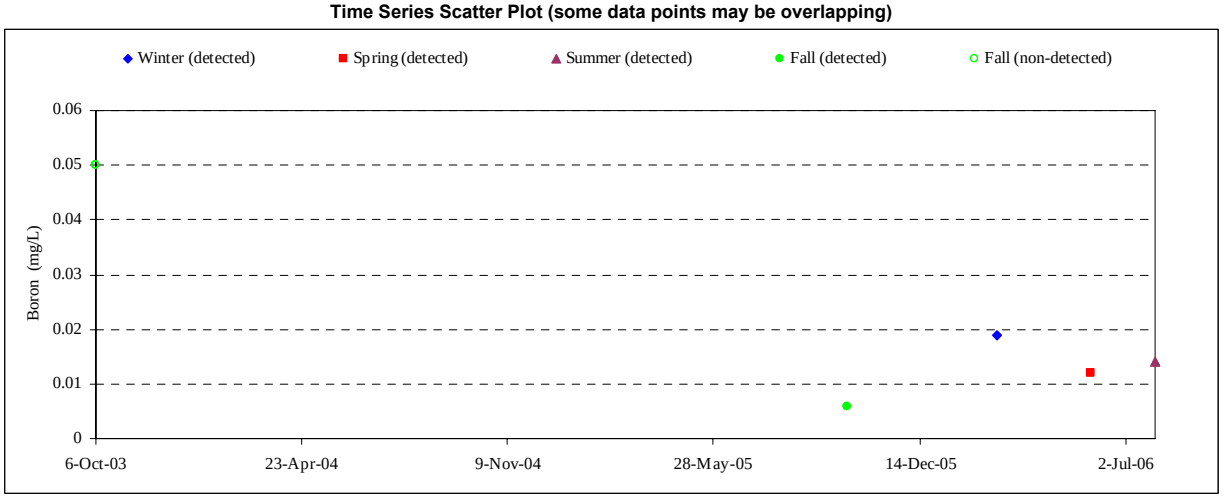
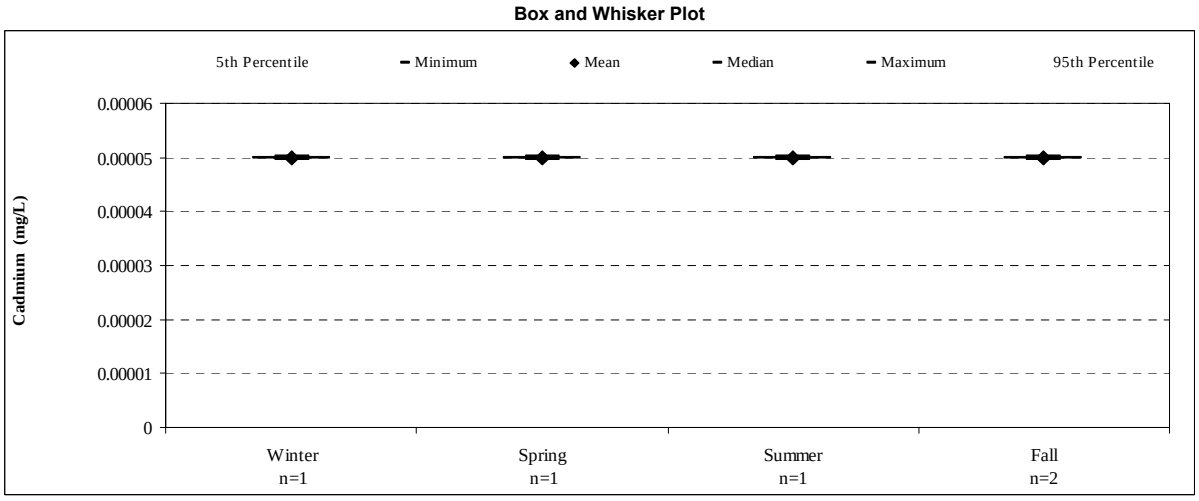


Figure G-2-9-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Unnamed Lakes within JEMA



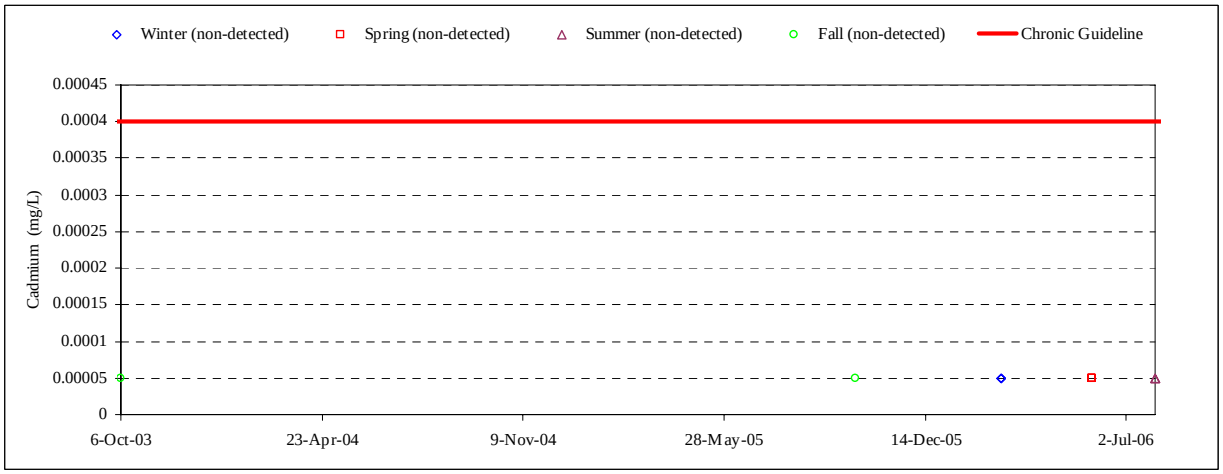
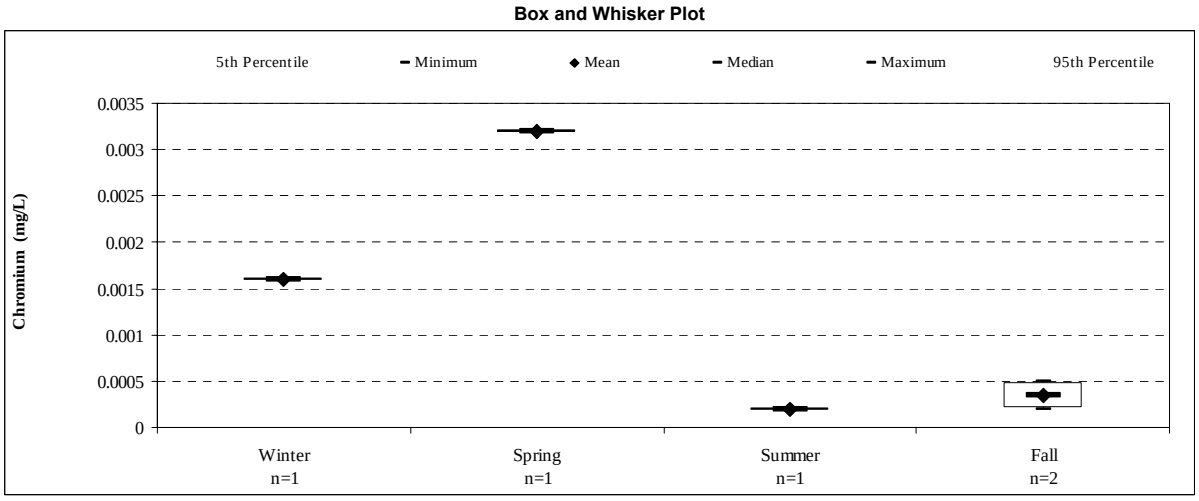


Figure G-2-9-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Unnamed Lakes withir JEMA



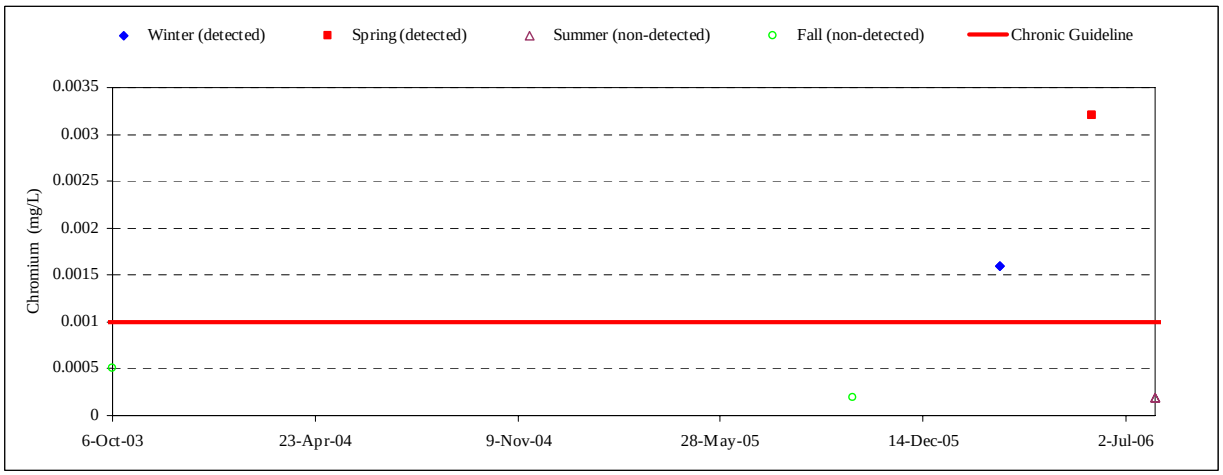
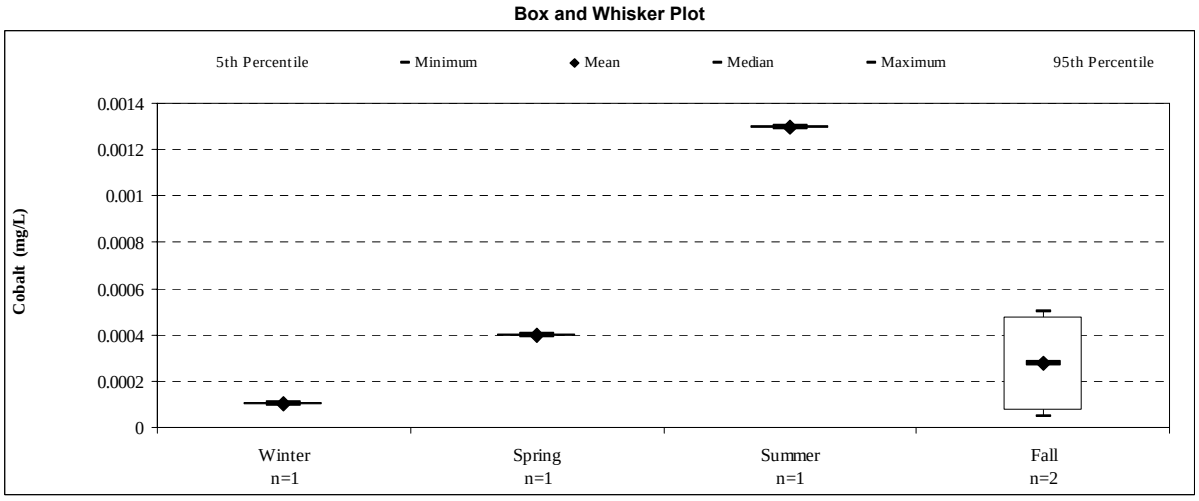


Figure G-2-9-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Unnamed Lakes within JEMA



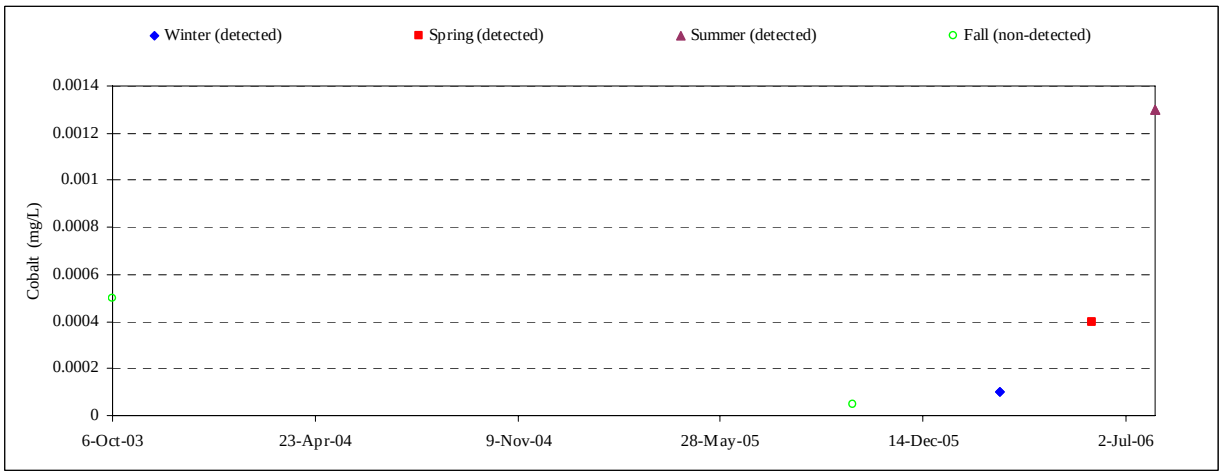
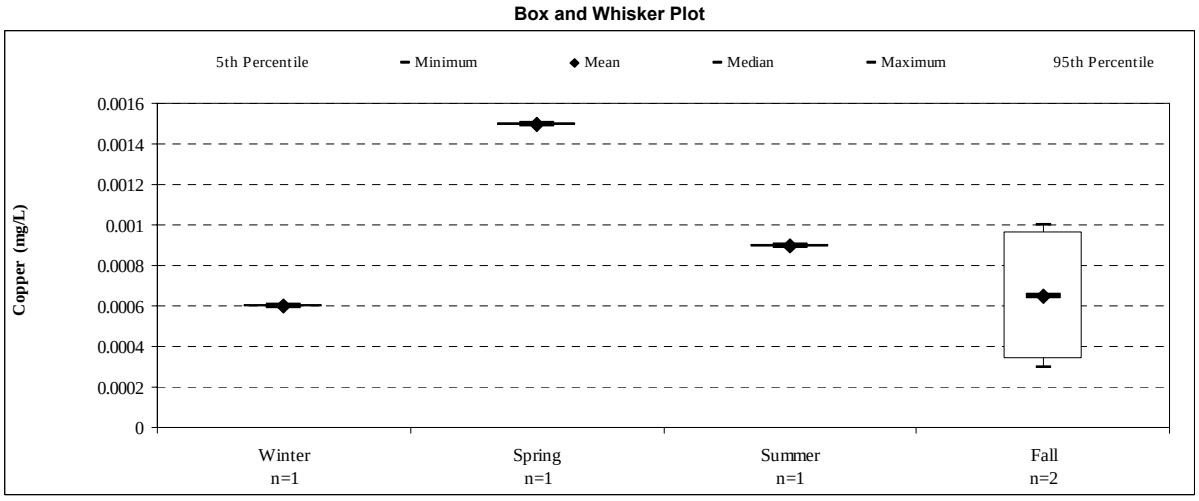


Figure G-2-9-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Unnamed Lakes within JEMA



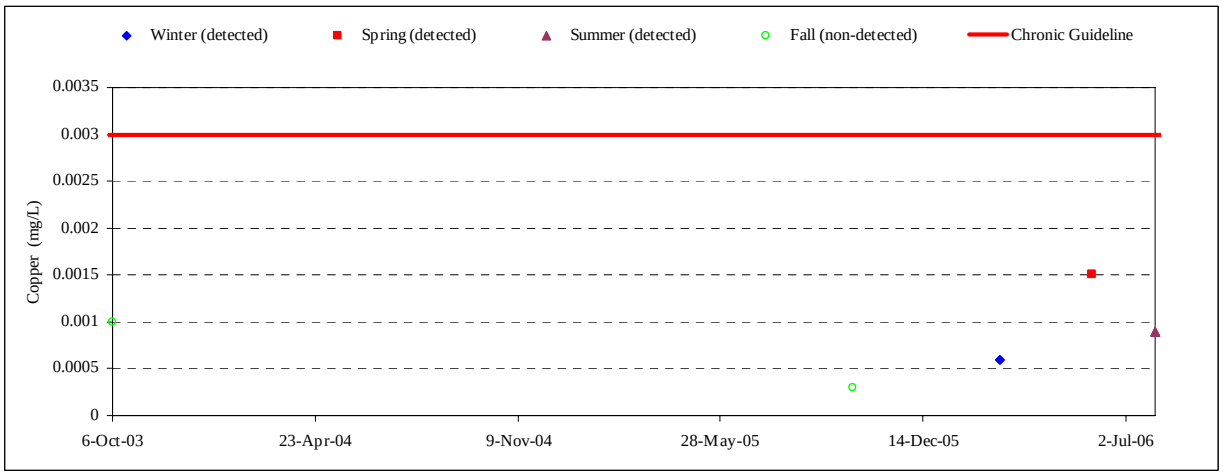
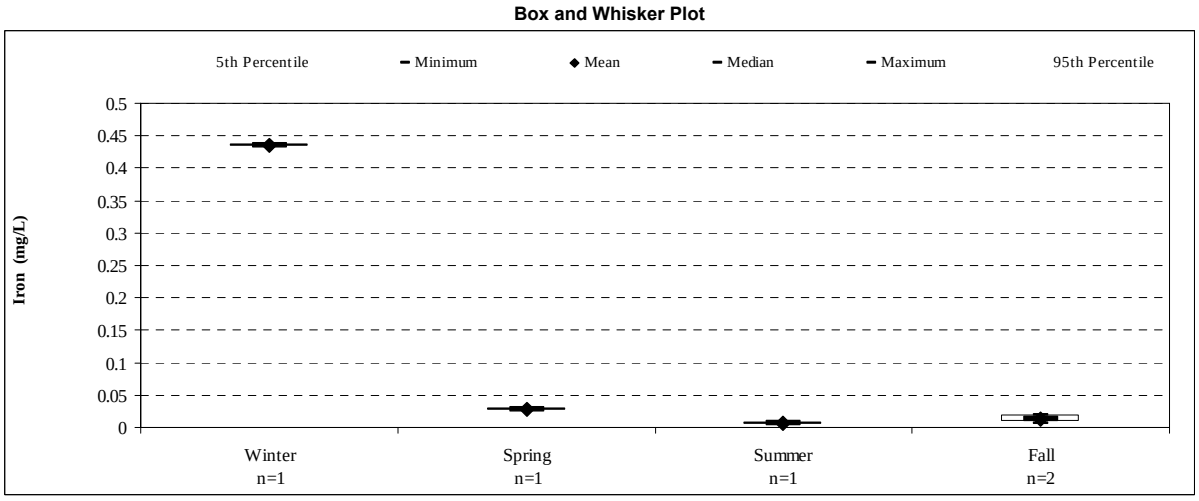


Figure G-2-9-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Unnamed Lakes within JEMA



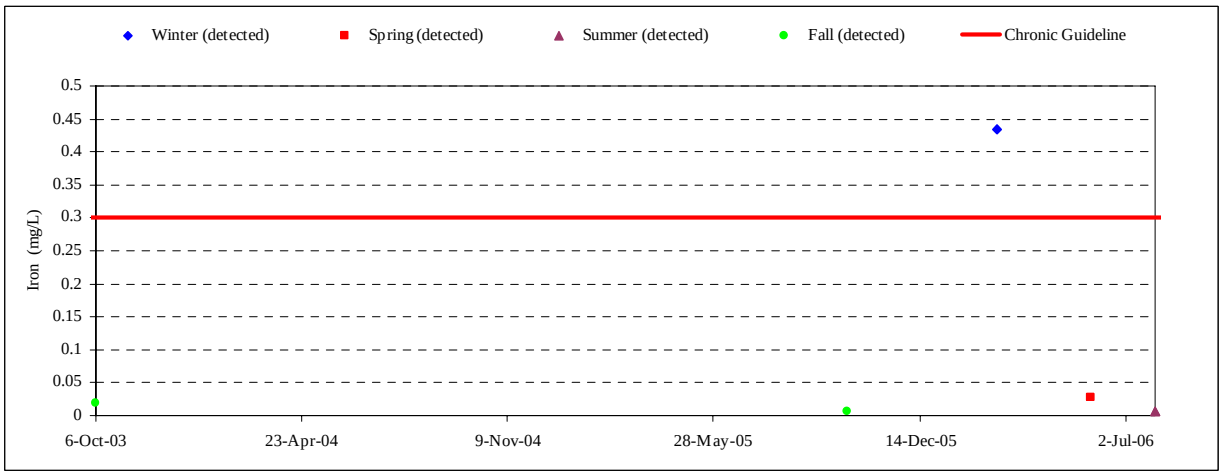
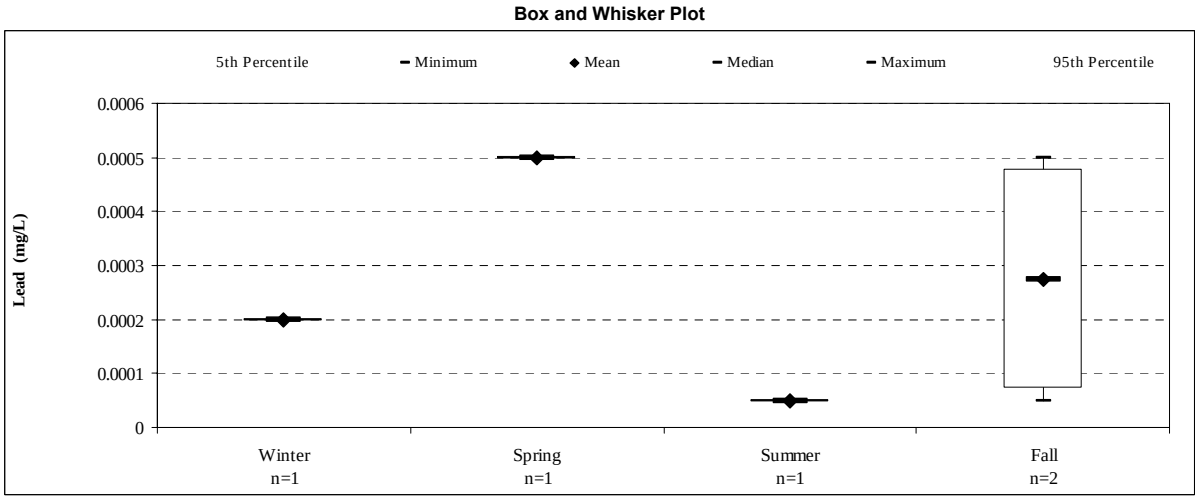


Figure G-2-9-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Unnamed Lakes within JEMA



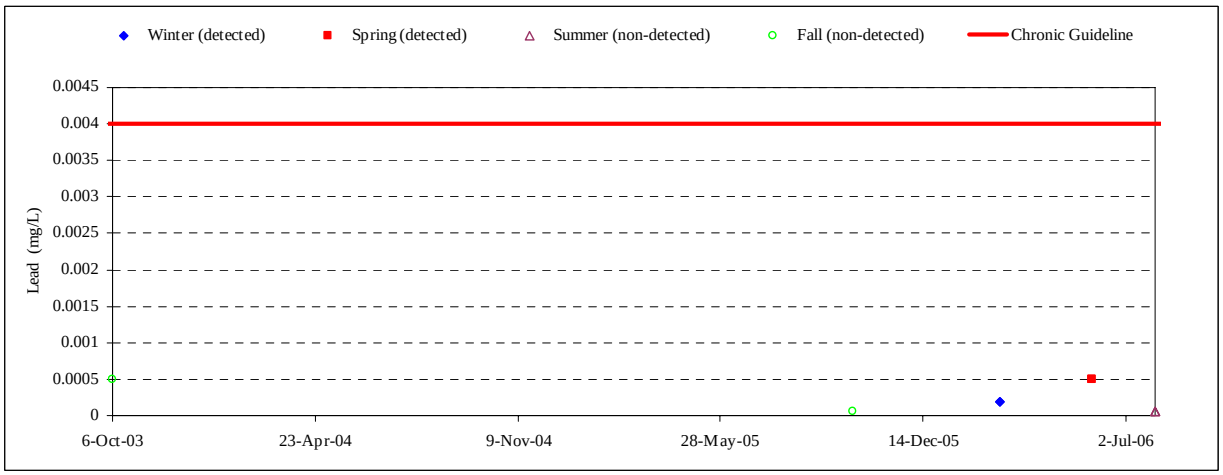
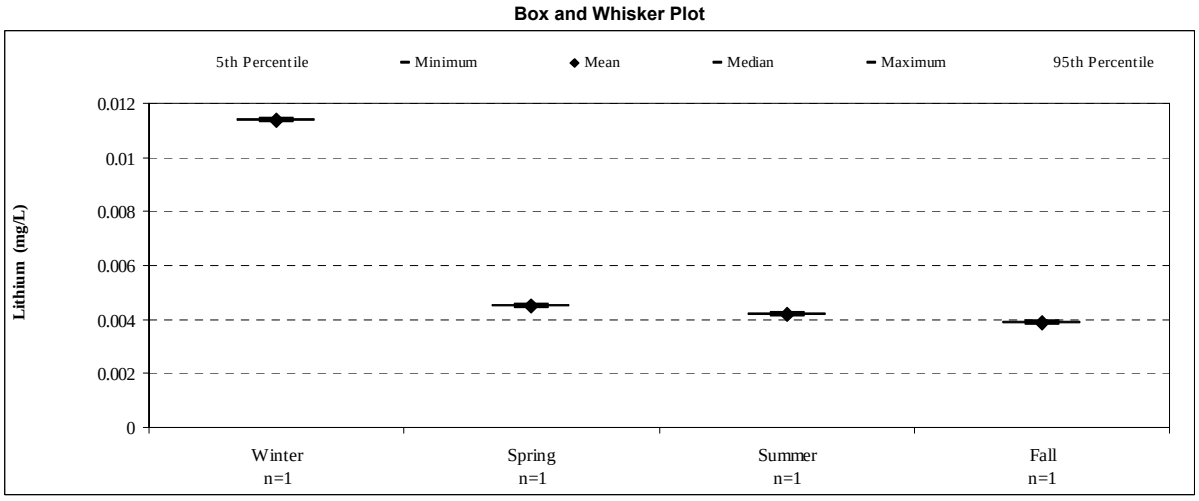


Figure G-2-9-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Unnamed Lakes within JEMA



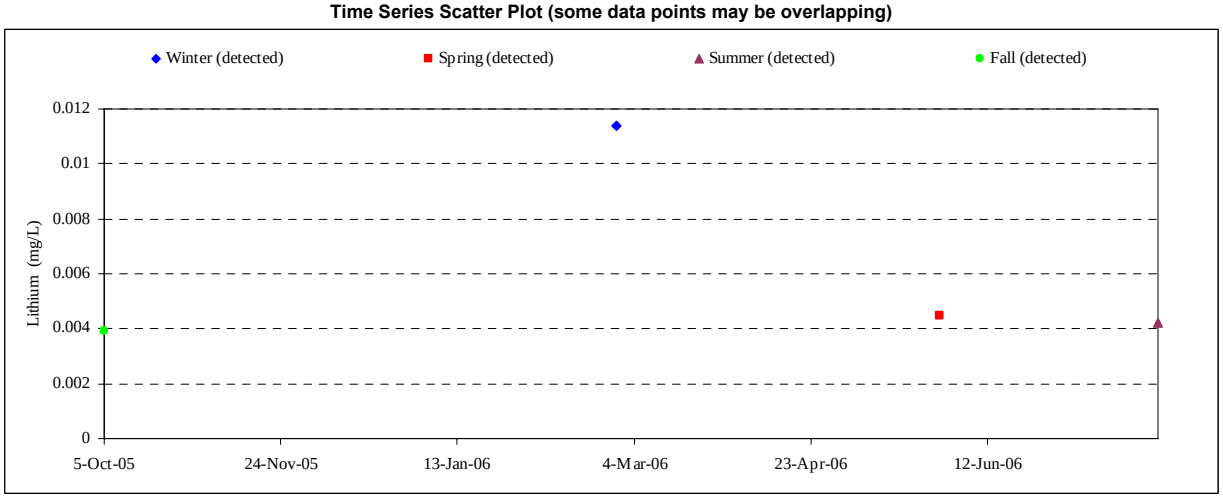
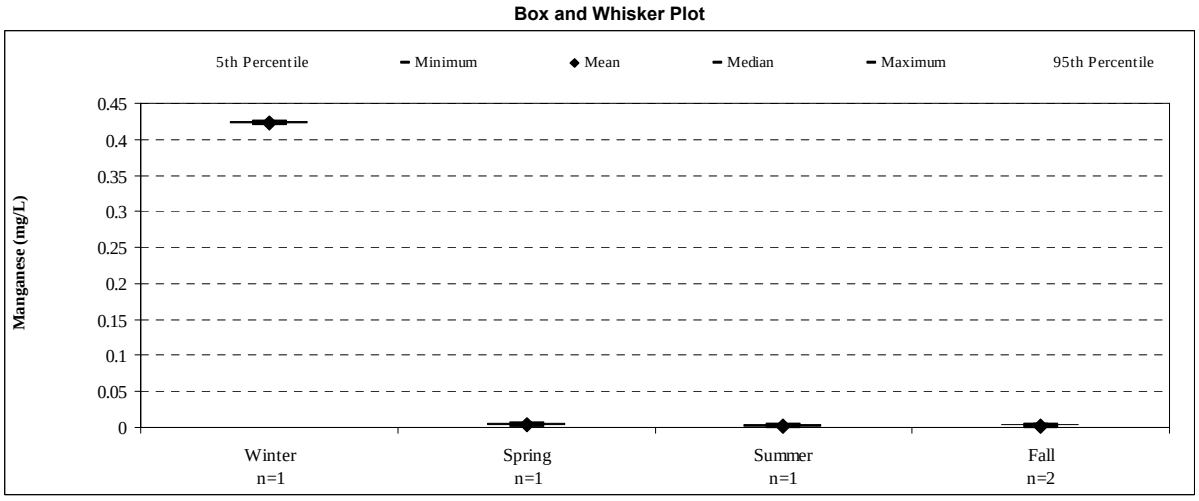


Figure G-2-9-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Unnamed Lakes within JEMA



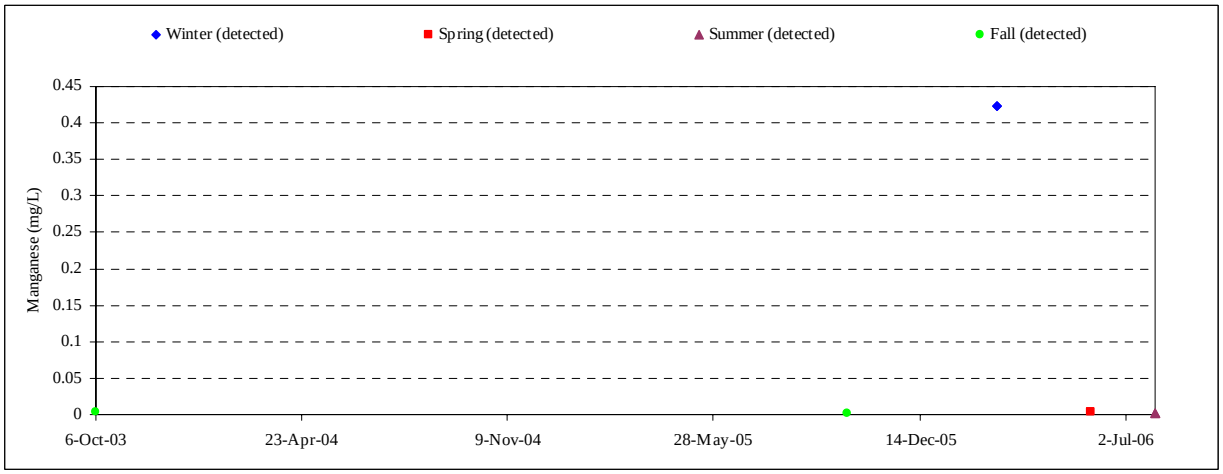
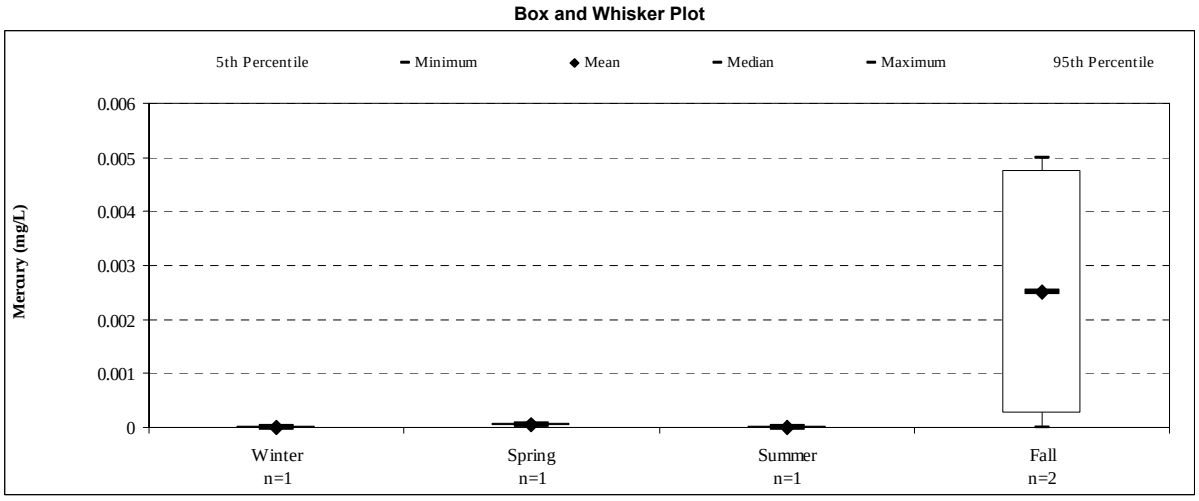


Figure G-2-9-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Unnamed Lakes within JEMA



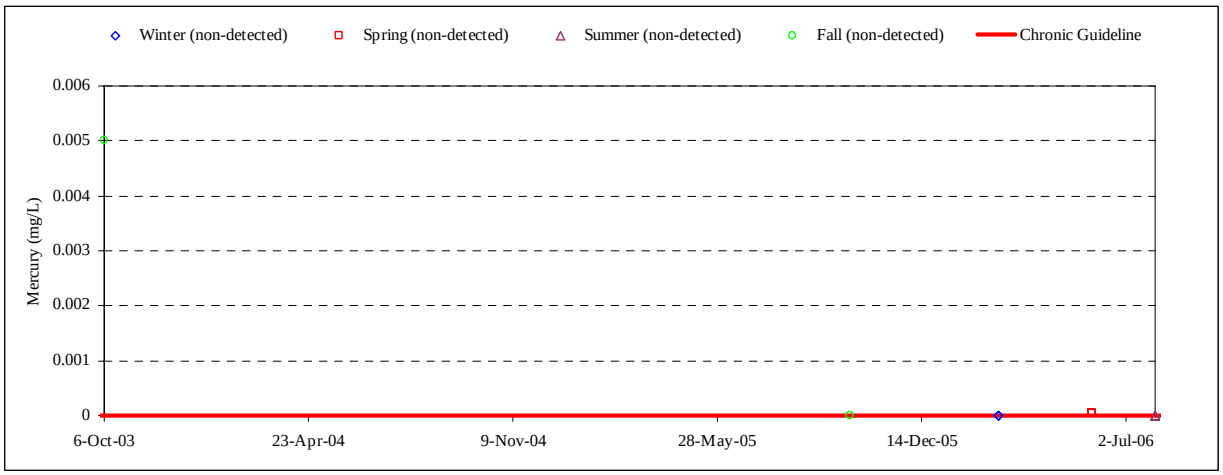
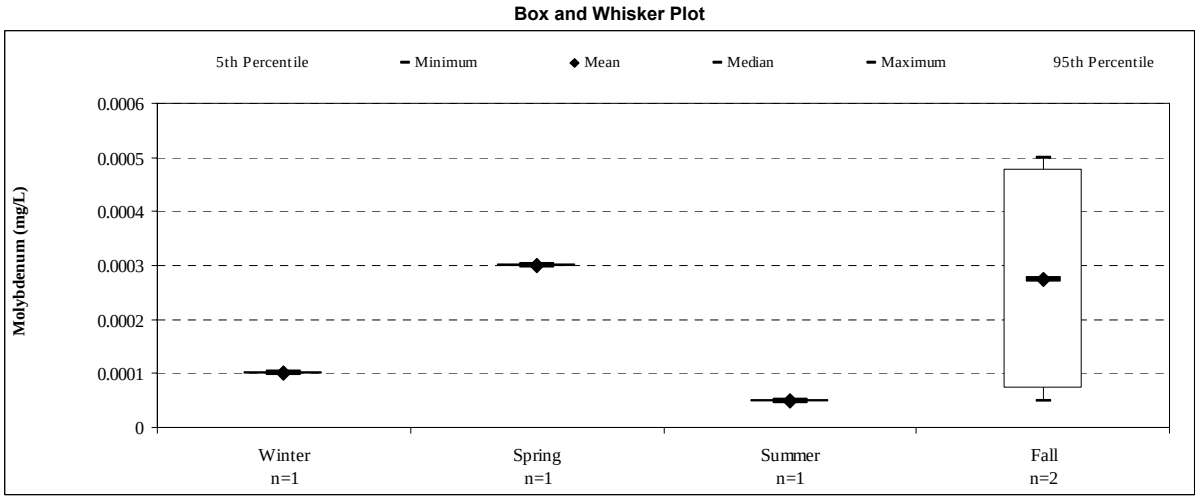


Figure G-2-9-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Unnamed Lakes within JEMA



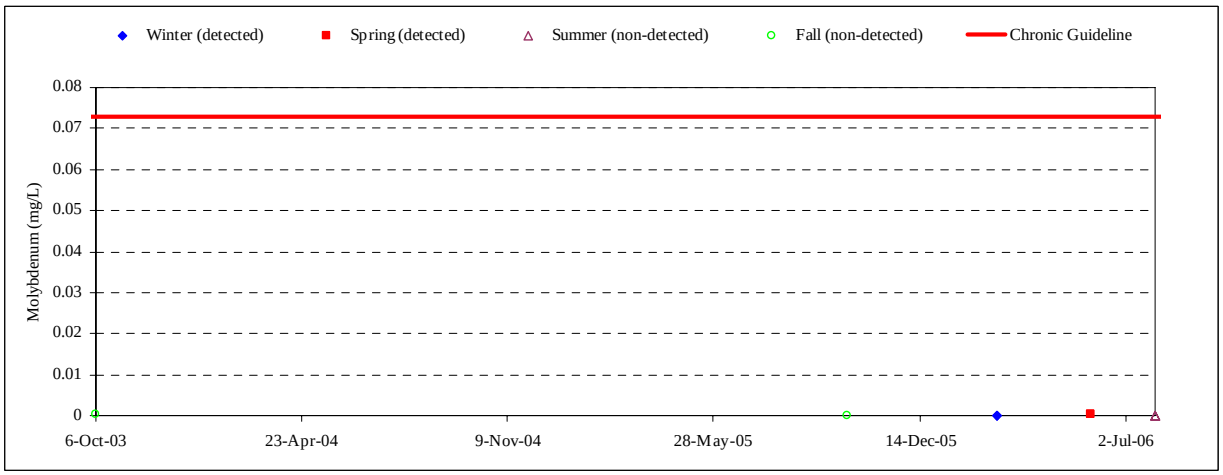
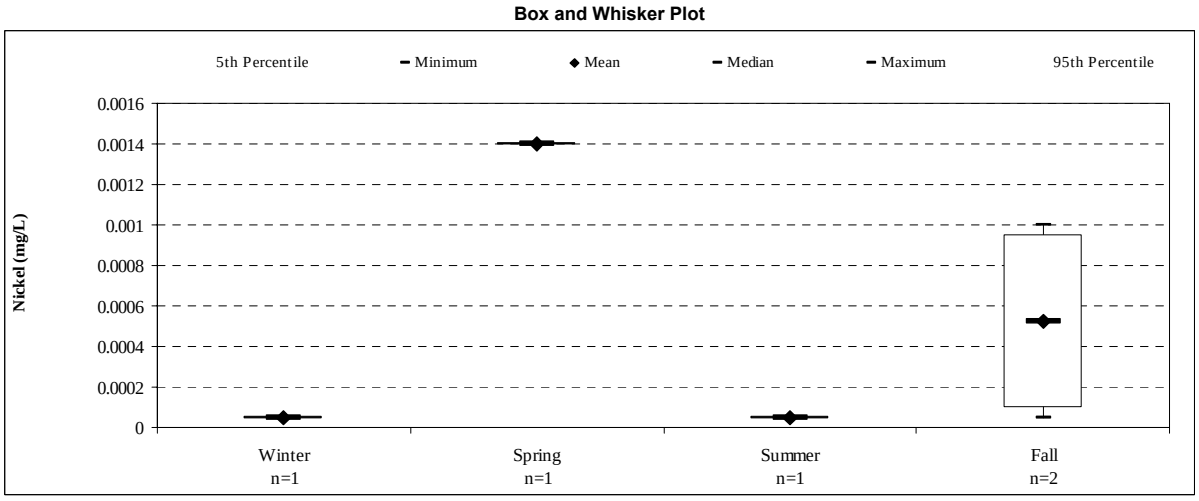


Figure G-2-9-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Unnamed Lakes within JEMA



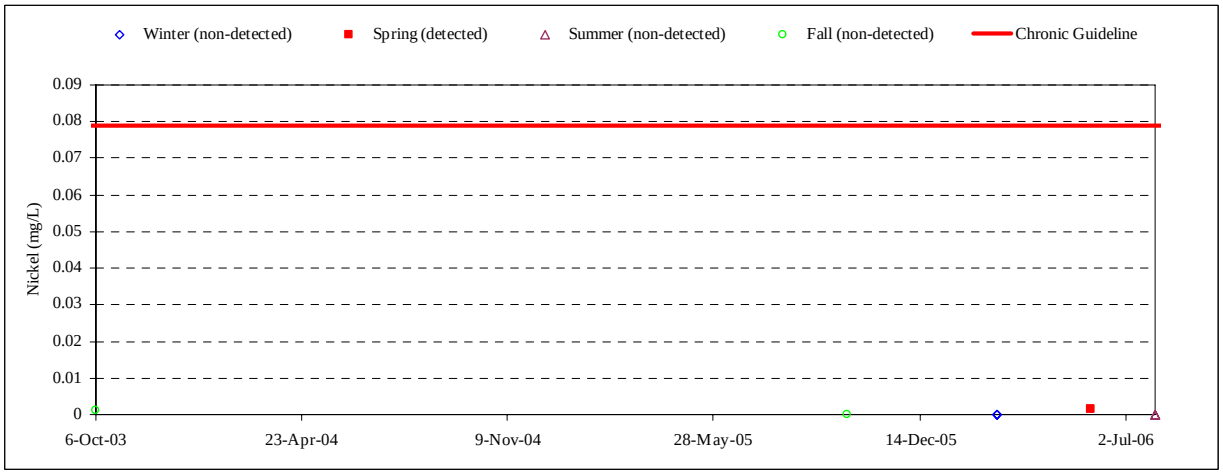
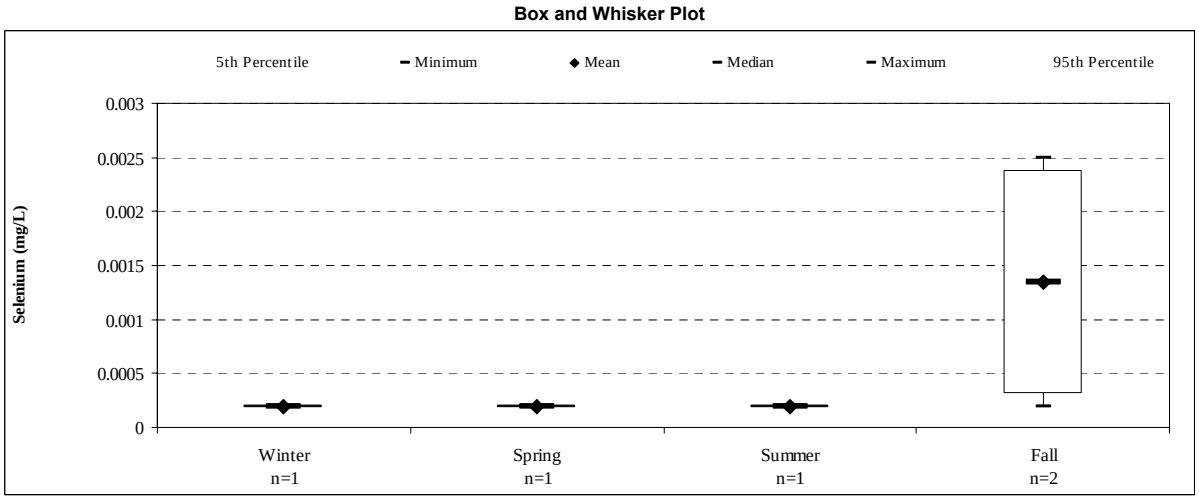


Figure G-2-9-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Unnamed Lakes within JEMA



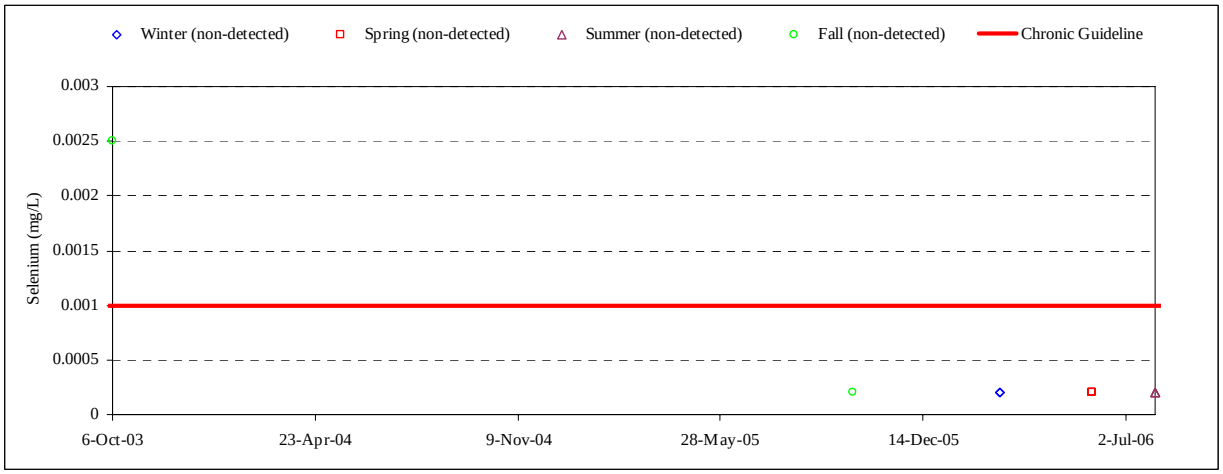
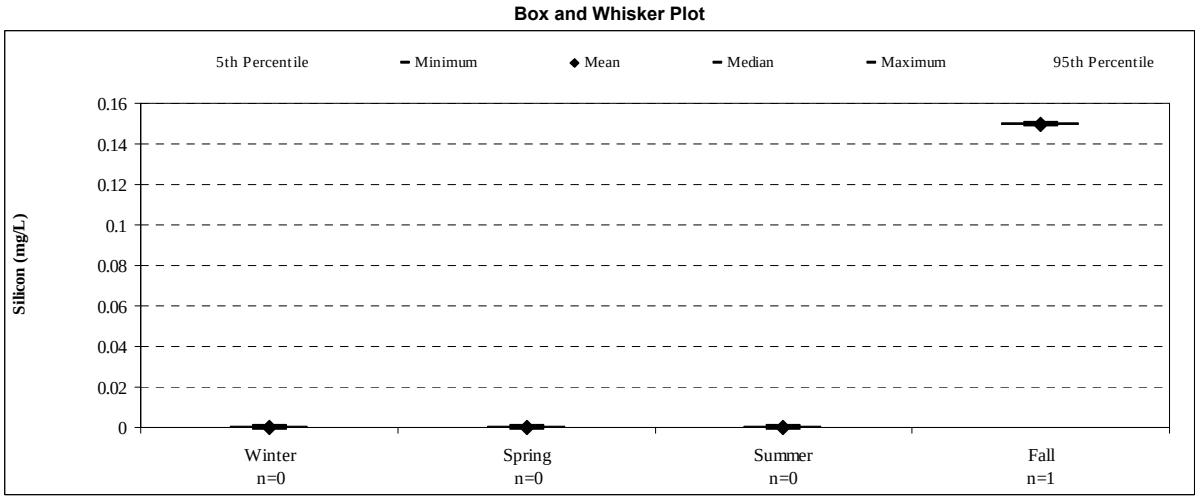


Figure G-2-9-110 Box Whisker and Time Series Scatter Plots of Observed Silicon (Dissolved) Concentration in Unnamed Lakes within JEMA



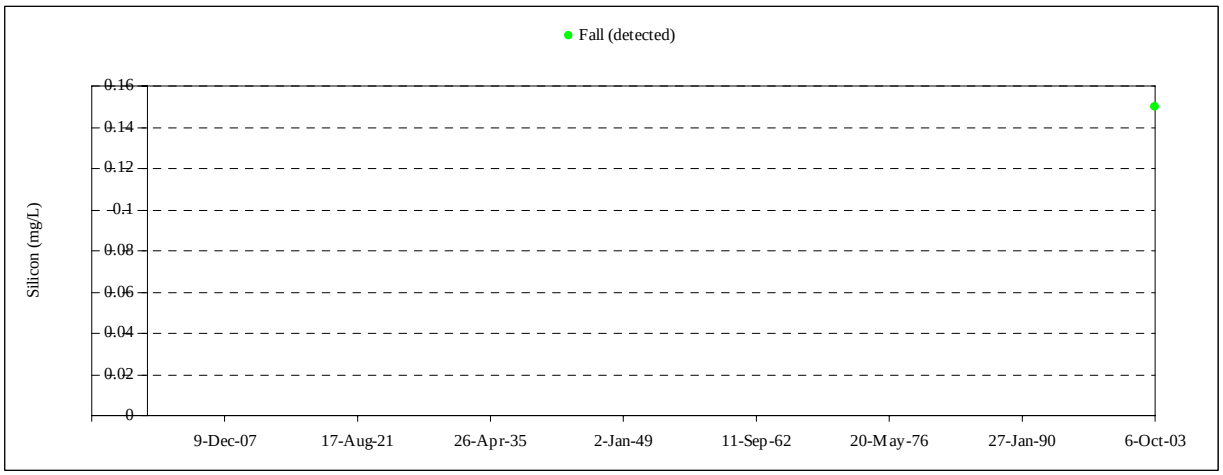
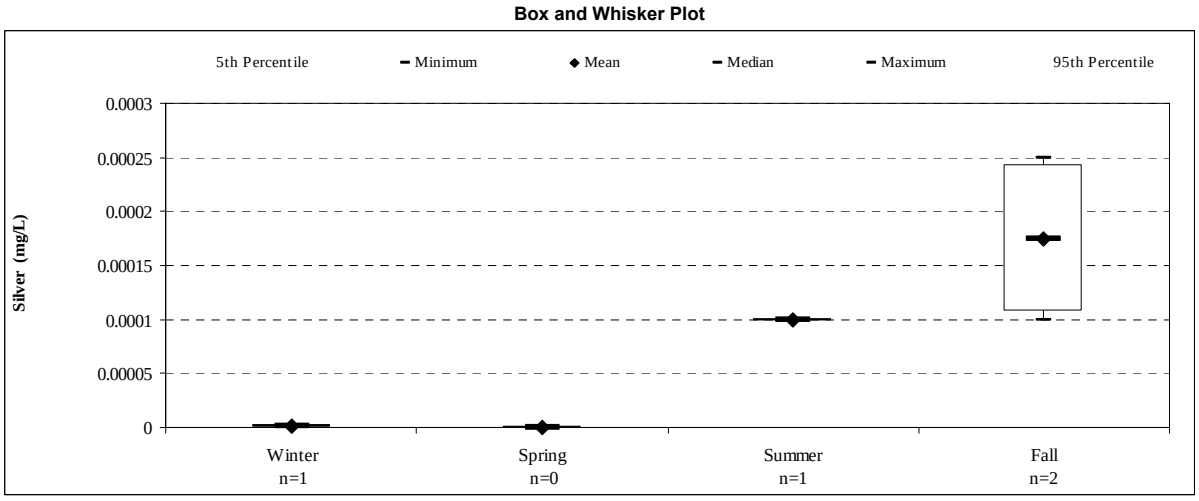


Figure G-2-9-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Unnamed Lakes within JEMA



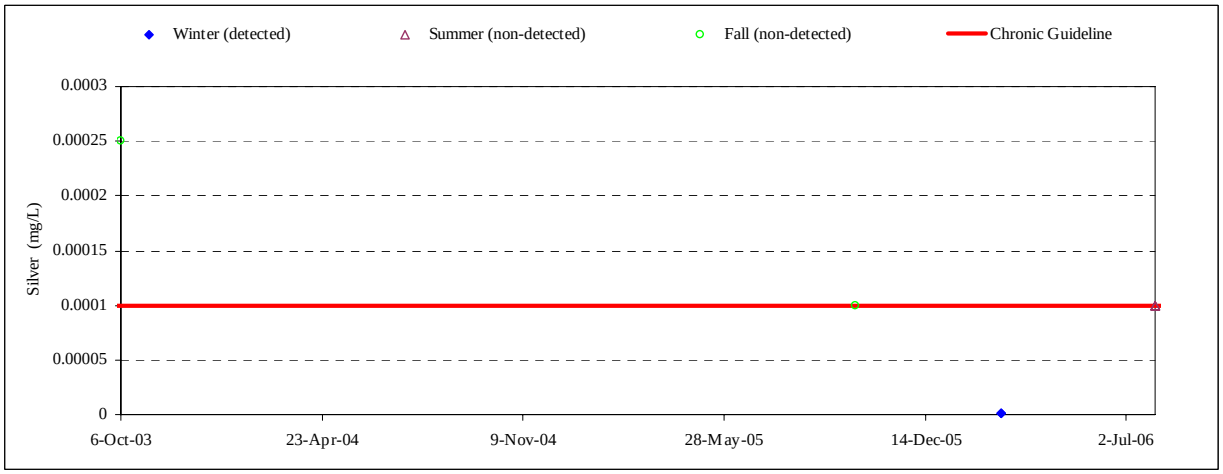
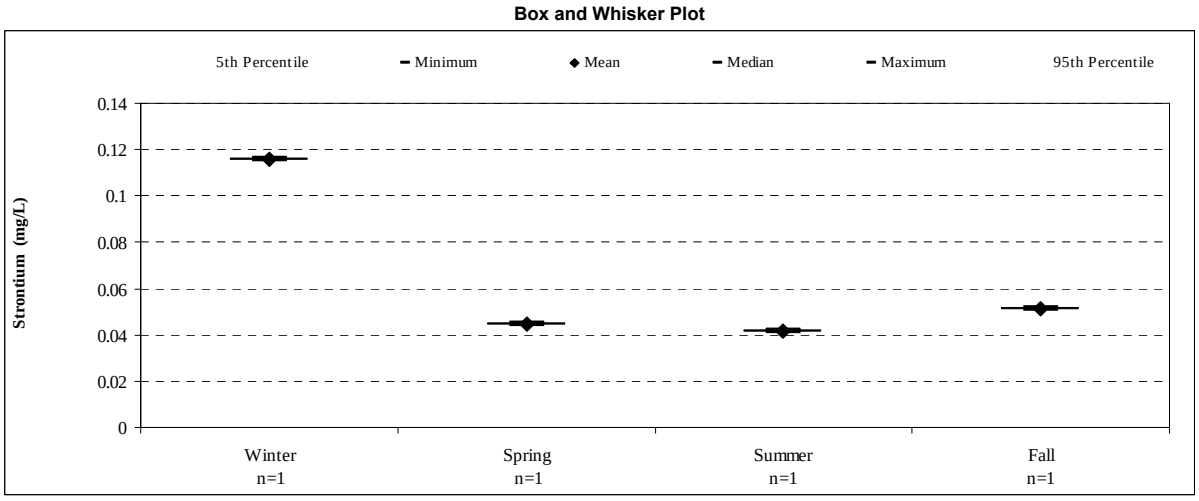


Figure G-2-9-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Unnamed Lakes within JEMA



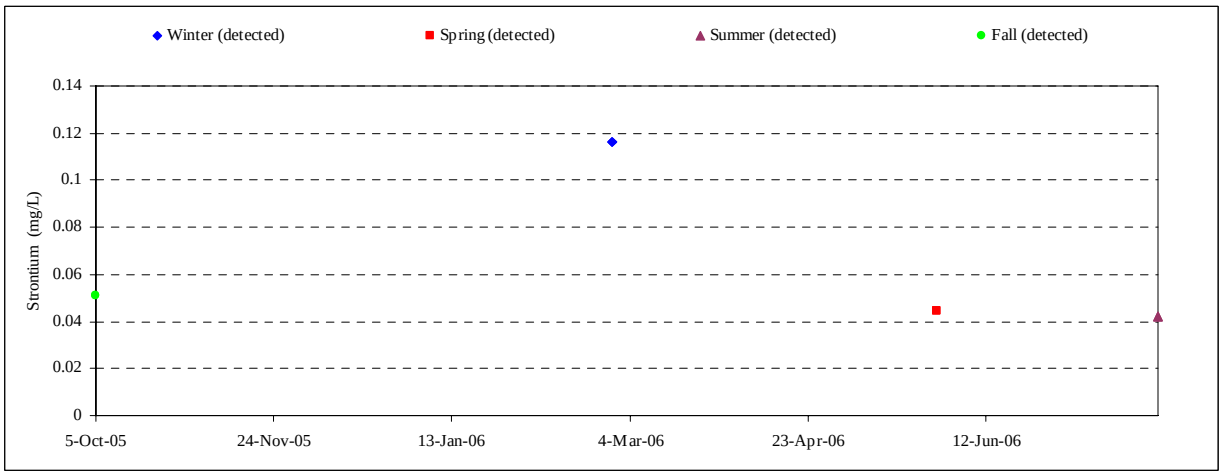


Figure G-2-9-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Unnamed Lakes within JEMA

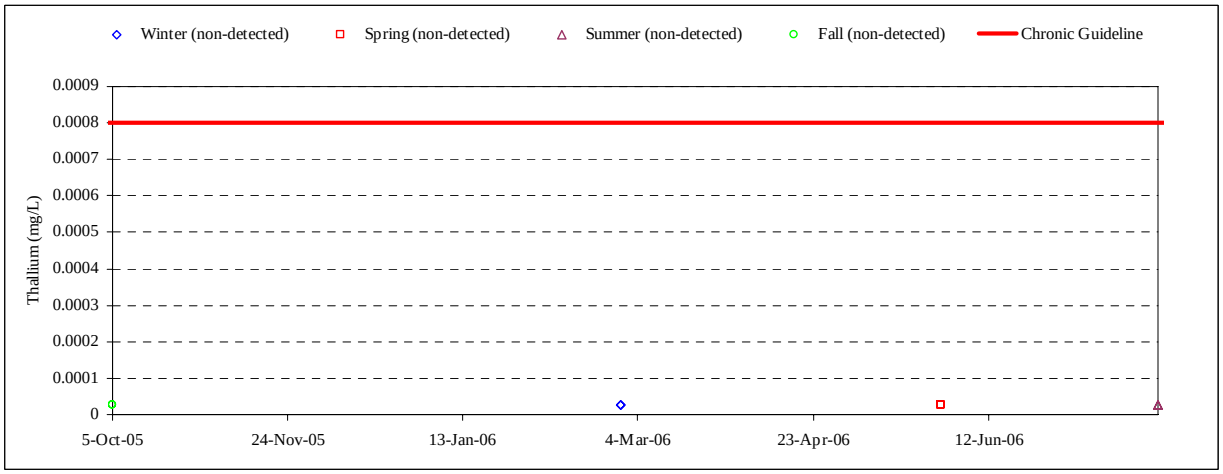
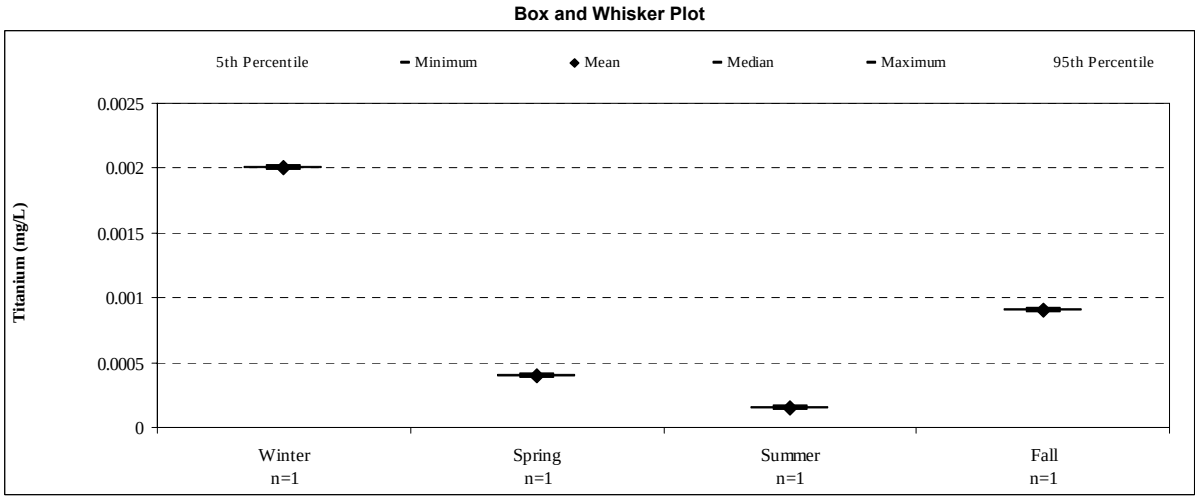


Figure G-2-9-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Unnamed Lakes within JEMA



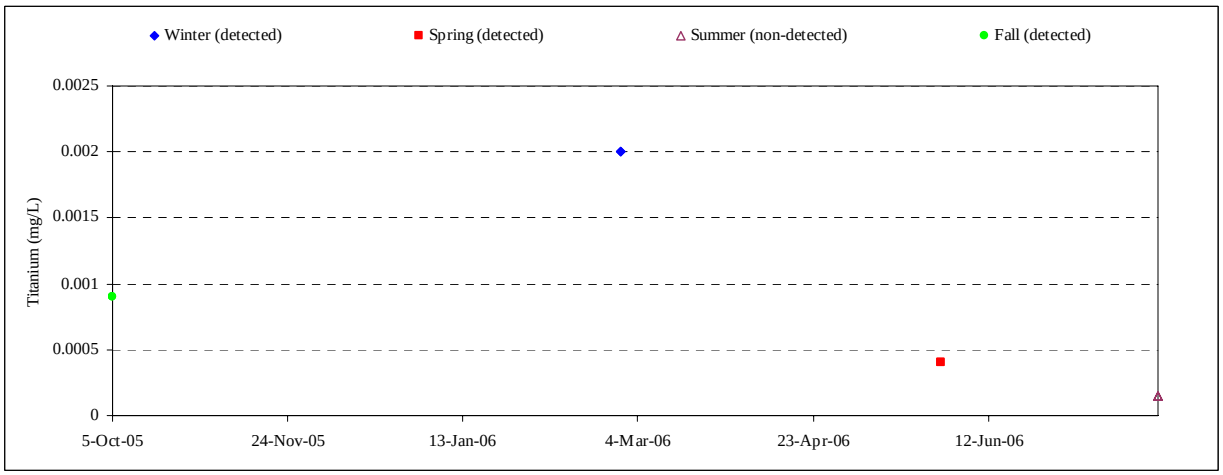
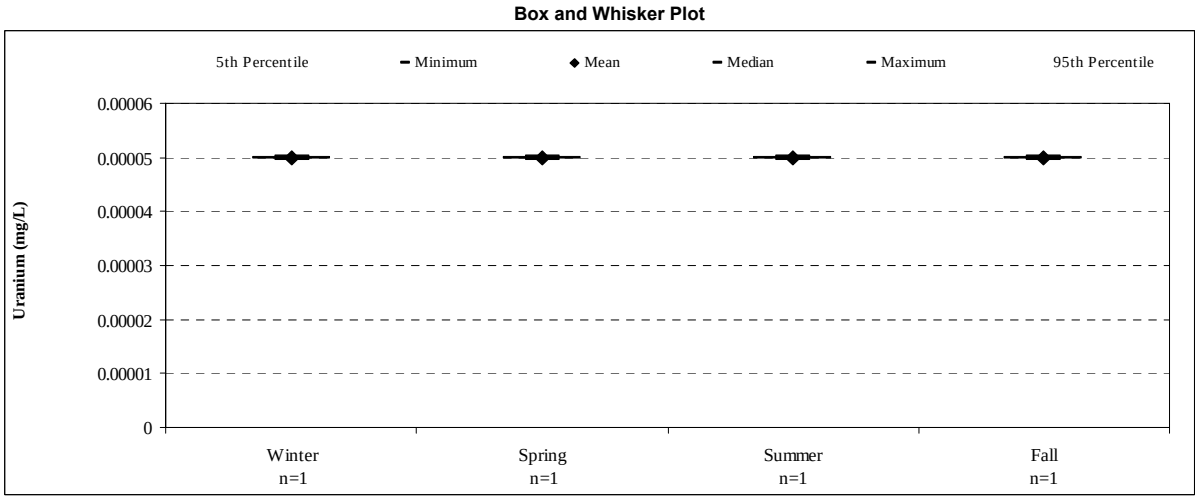


Figure G-2-9-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Unnamed Lakes within JEMA



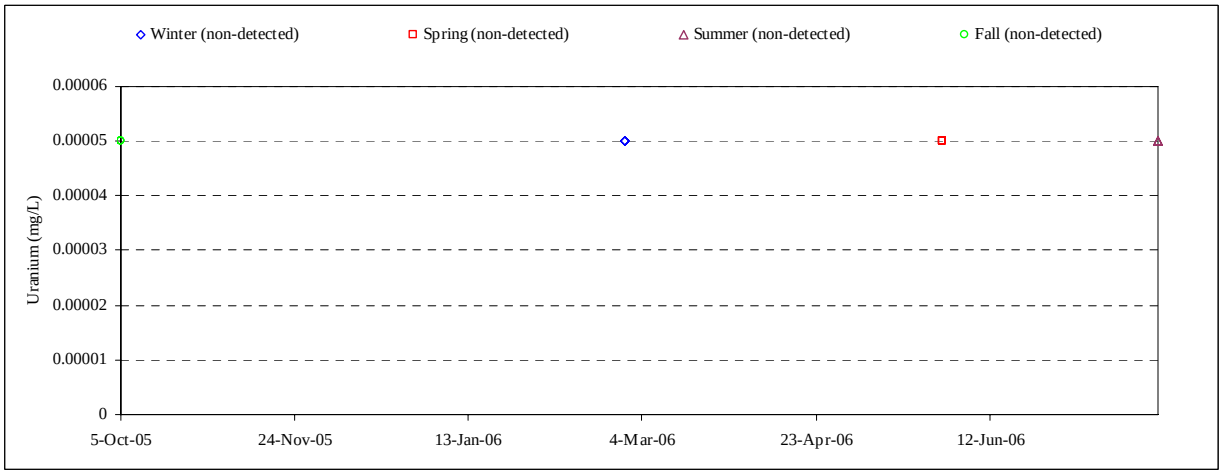
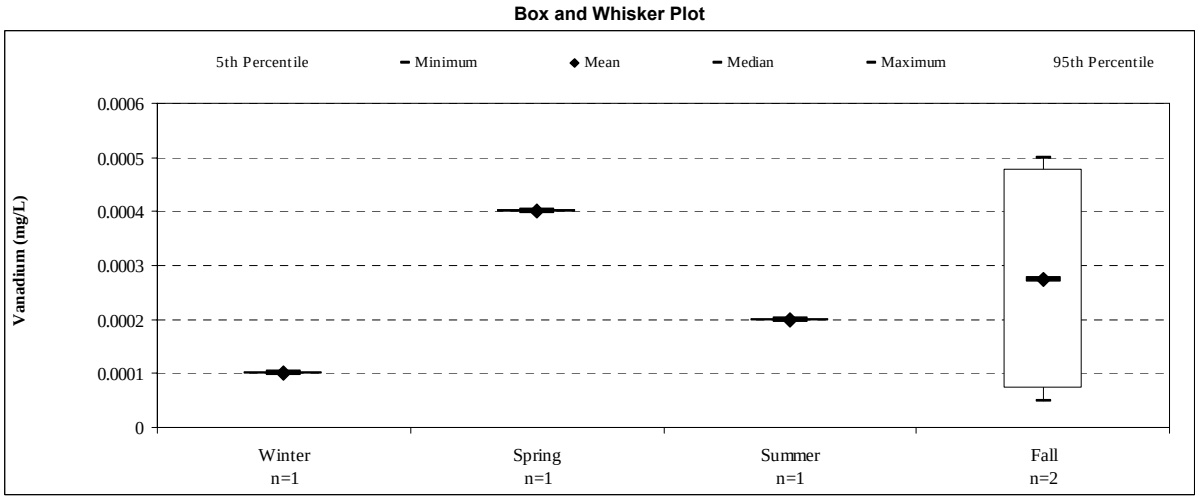


Figure G-2-9-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Unnamed Lakes within JEMA



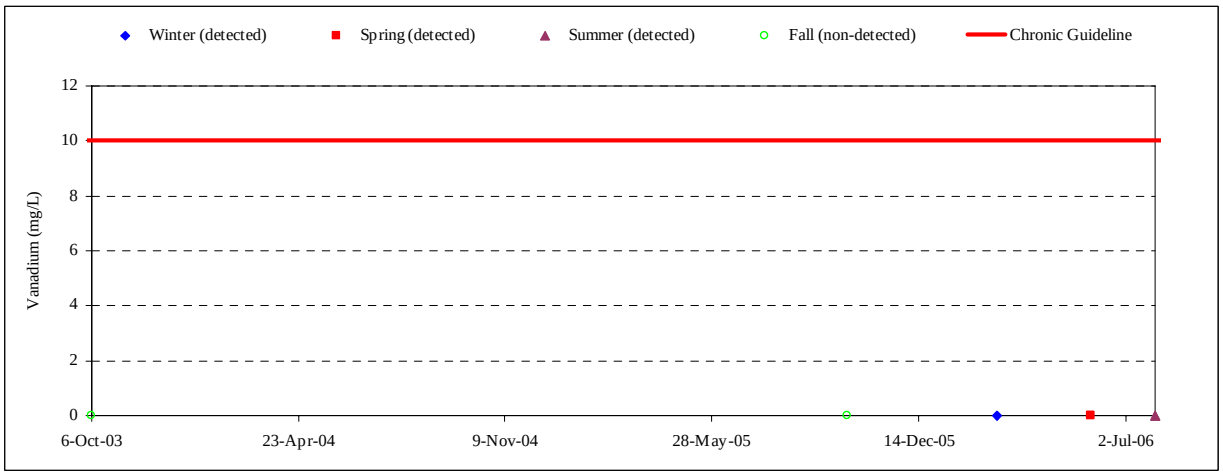
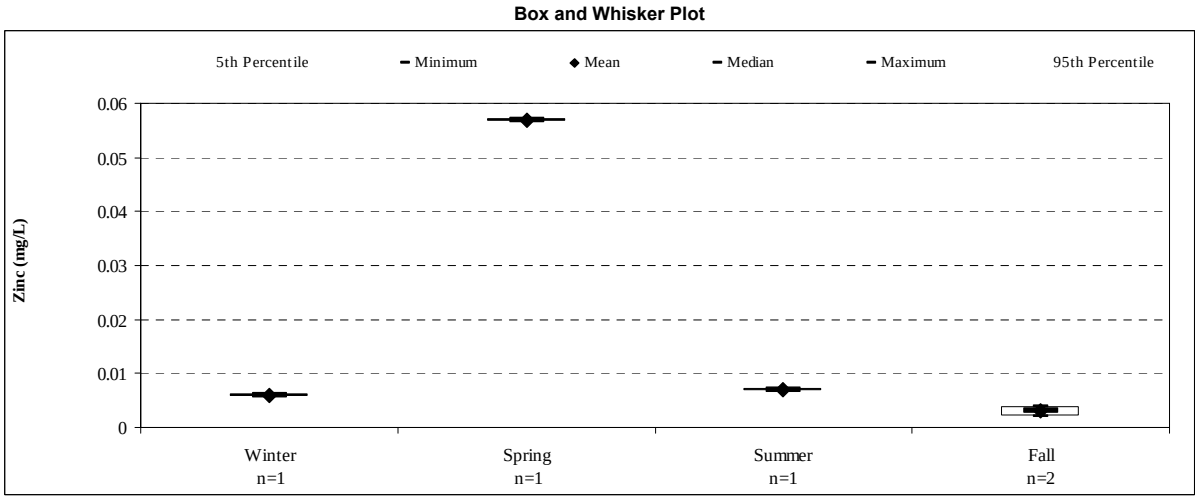


Figure G-2-9-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Unnamed Lakes within JEMA



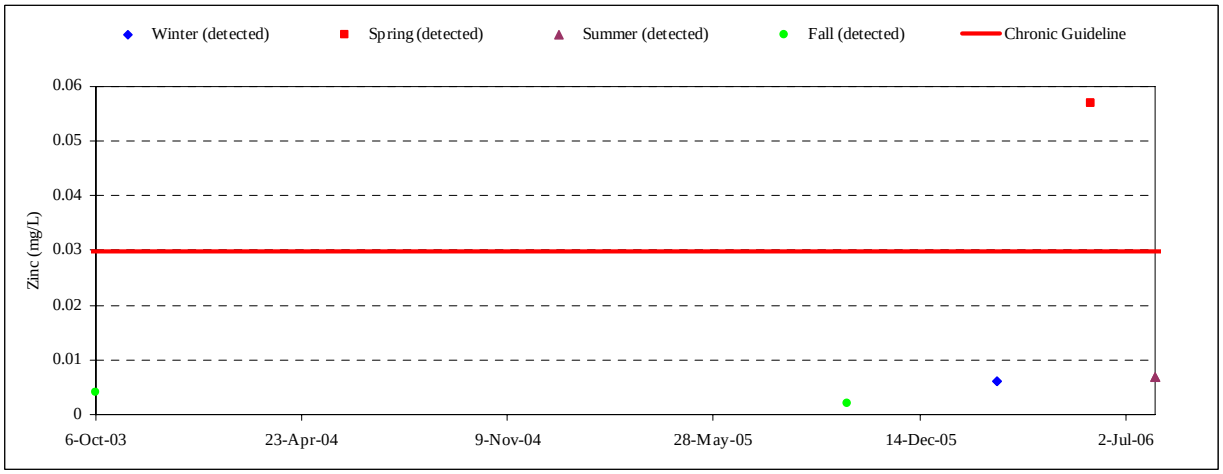


Table G-3. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Pierre River Mine Area

Water Quality Parameters	Pierre River	Eymundson Creek	Big Creek	Redclay Creek	Unnamed Lakes
	Pierre River and its tributaries	Eymundson Creek and its tributaries	Big Creek and its tributaries	Redclay Creek and its tributaries	unnamed waterbodies in the Pierre River, Eymundson Creek, Big Creek and Redclay Creek watersheds
pH	G-3-1-1	G-3-2-1	G-3-3-1	G-3-4-1	G-3-5-1
Specific Conductance	G-3-1-2	G-3-2-2	G-3-3-2	G-3-4-2	G-3-5-2
Temperature	G-3-1-3	G-3-2-3	G-3-3-3	G-3-4-3	G-3-5-3
Dissolved Oxygen	G-3-1-4	G-3-2-4	G-3-3-4	G-3-4-4	G-3-5-4
Colour	G-3-1-5	G-3-2-5	G-3-3-5	G-3-4-5	G-3-5-5
Dissolved Organic Carbon	G-3-1-6	G-3-2-6	G-3-3-6	G-3-4-6	G-3-5-6
Hardness	G-3-1-7	G-3-2-7	G-3-3-7	G-3-4-7	G-3-5-7
Total Alkalinity	G-3-1-8	G-3-2-8	G-3-3-8	G-3-4-8	G-3-5-8
Total Dissolved Solids	G-3-1-9	G-3-2-9	G-3-3-9	G-3-4-9	G-3-5-9
Total Organic Carbon	G-3-1-10	G-3-2-10	G-3-3-10	G-3-4-10	G-3-5-10
Total Suspended Solids	G-3-1-11	G-3-2-11	G-3-3-11	G-3-4-11	G-3-5-11
Bicarbonate	G-3-1-12	G-3-2-12	G-3-3-12	G-3-4-12	G-3-5-12
Calcium	G-3-1-13	G-3-2-13	G-3-3-13	G-3-4-13	G-3-5-13
Carbonate	G-3-1-14	G-3-2-14	G-3-3-14	G-3-4-14	G-3-5-14
Chloride	G-3-1-15	G-3-2-15	G-3-3-15	G-3-4-15	G-3-5-15
Magnesium	G-3-1-16	G-3-2-16	G-3-3-16	G-3-4-16	G-3-5-16
Potassium	G-3-1-17	G-3-2-17	G-3-3-17	G-3-4-17	G-3-5-17
Sodium	G-3-1-18	G-3-2-18	G-3-3-18	G-3-4-18	G-3-5-18
Sulphate	G-3-1-19	G-3-2-19	G-3-3-19	G-3-4-19	G-3-5-19
Sulphide	G-3-1-20	G-3-2-20	G-3-3-20	G-3-4-20	G-3-5-20
Nitrate/Nitrite	G-3-1-21	G-3-2-21	G-3-3-21	G-3-4-21	G-3-5-21
Ammonia	G-3-1-22	G-3-2-22	G-3-3-22	G-3-4-22	G-3-5-22
Kjeldahl Nitrogen	G-3-1-23	G-3-2-23	G-3-3-23	G-3-4-23	G-3-5-23
Total Nitrogen	G-3-1-24	G-3-2-24	G-3-3-24	G-3-4-24	G-3-5-24
Total Phosphorus	G-3-1-25	G-3-2-25	G-3-3-25	G-3-4-25	G-3-5-25
Dissolved Phosphorus	G-3-1-26	G-3-2-26	G-3-3-26	G-3-4-26	G-3-5-26
Chlorophyll *a*	G-3-1-27	G-3-2-27	G-3-3-27	G-3-4-27	G-3-5-27
Biochemical Oxygen Demand	G-3-1-28	G-3-2-28	G-3-3-28	G-3-4-28	G-3-5-28
Naphthenic acids	G-3-1-29	G-3-2-29	G-3-3-29	G-3-4-29	G-3-5-29
Total Phenolics	G-3-1-30	G-3-2-30	G-3-3-30	G-3-4-30	G-3-5-30
Total Recoverable Hydrocarbons	G-3-1-31	G-3-2-31	G-3-3-31	G-3-4-31	G-3-5-31
Microtox IC50 @ 15 min	G-3-1-32	G-3-2-32	G-3-3-32	G-3-4-32	G-3-5-32
Microtox IC25 @ 15 min	G-3-1-33	G-3-2-33	G-3-3-33	G-3-4-33	G-3-5-33
Algal Growth Inhibition Test (72 h) - IC25	G-3-1-34	G-3-2-34	G-3-3-34	G-3-4-34	G-3-5-34
Algal Growth Inhibition Test (72 h) - IC50	G-3-1-35	G-3-2-35	G-3-3-35	G-3-4-35	G-3-5-35
Algal Growth Inhibition Test (72 h) - LOEC	G-3-1-36	G-3-2-36	G-3-3-36	G-3-4-36	G-3-5-36
Algal Growth Inhibition Test (72 h) - NOEC	G-3-1-37	G-3-2-37	G-3-3-37	G-3-4-37	G-3-5-37
Ceriodaphnia 7 d Mortality Test - LC25	G-3-1-38	G-3-2-38	G-3-3-38	G-3-4-38	G-3-5-38
Ceriodaphnia 7 d Mortality Test - LC50	G-3-1-39	G-3-2-39	G-3-3-39	G-3-4-39	G-3-5-39
Ceriodaphnia 7 d Mortality Test - LOEC	G-3-1-40	G-3-2-40	G-3-3-40	G-3-4-40	G-3-5-40

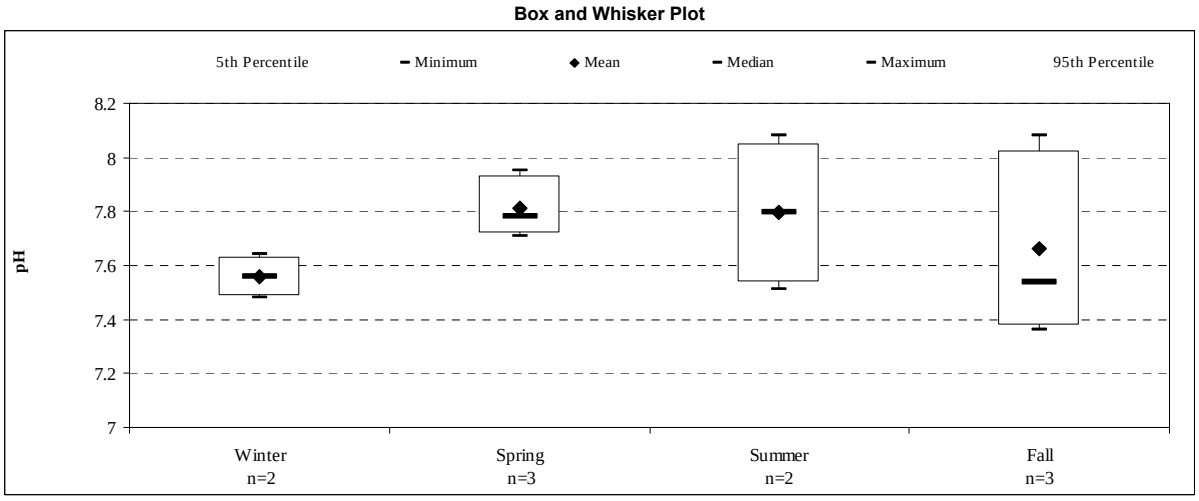
Table G-3. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Pierre River Mine Area

Water Quality Parameters	Pierre River	Eymundson Creek	Big Creek	Redclay Creek	Unnamed Lakes
Ceriodaphnia 7 d Mortality Test - NOEC	G-3-1-41	G-3-2-41	G-3-3-41	G-3-4-41	G-3-5-41
Ceriodaphnia 7 d Reproduction Test - IC25	G-3-1-42	G-3-2-42	G-3-3-42	G-3-4-42	G-3-5-42
Ceriodaphnia 7 d Reproduction Test - IC50	G-3-1-43	G-3-2-43	G-3-3-43	G-3-4-43	G-3-5-43
Ceriodaphnia 7 d Reproduction Test - LOEC	G-3-1-44	G-3-2-44	G-3-3-44	G-3-4-44	G-3-5-44
Ceriodaphnia 7 d Reproduction Test - NOEC	G-3-1-45	G-3-2-45	G-3-3-45	G-3-4-45	G-3-5-45
Daphnia 48 h Static Acute Test - LC25	G-3-1-46	G-3-2-46	G-3-3-46	G-3-4-46	G-3-5-46
Daphnia 48 h Static Acute Test - LC50	G-3-1-47	G-3-2-47	G-3-3-47	G-3-4-47	G-3-5-47
Daphnia 48 h Static Acute Test - LOEC	G-3-1-48	G-3-2-48	G-3-3-48	G-3-4-48	G-3-5-48
Daphnia 48 h Static Acute Test - NOEC	G-3-1-49	G-3-2-49	G-3-3-49	G-3-4-49	G-3-5-49
Fathead Minnow 7d Growth - IC25	G-3-1-50	G-3-2-50	G-3-3-50	G-3-4-50	G-3-5-50
Fathead Minnow 7d Growth - IC50	G-3-1-51	G-3-2-51	G-3-3-51	G-3-4-51	G-3-5-51
Fathead Minnow 7d Growth - LOEC	G-3-1-52	G-3-2-52	G-3-3-52	G-3-4-52	G-3-5-52
Fathead Minnow 7d Growth - NOEC	G-3-1-53	G-3-2-53	G-3-3-53	G-3-4-53	G-3-5-53
Fathead Minnow 7d Mortality Test - LC25	G-3-1-54	G-3-2-54	G-3-3-54	G-3-4-54	G-3-5-54
Fathead Minnow 7d Mortality Test - LC50	G-3-1-55	G-3-2-55	G-3-3-55	G-3-4-55	G-3-5-55
Fathead Minnow 7d Mortality Test - LOEC	G-3-1-56	G-3-2-56	G-3-3-56	G-3-4-56	G-3-5-56
Fathead Minnow 7d Mortality Test - NOEC	G-3-1-57	G-3-2-57	G-3-3-57	G-3-4-57	G-3-5-57
Trout 96 h Static Acute Test - LC25	G-3-1-58	G-3-2-58	G-3-3-58	G-3-4-58	G-3-5-58
Trout 96 h Static Acute Test - LC50	G-3-1-59	G-3-2-59	G-3-3-59	G-3-4-59	G-3-5-59
Trout 96 h Static Acute Test - LOEC	G-3-1-60	G-3-2-60	G-3-3-60	G-3-4-60	G-3-5-60
Trout 96 h Static Acute Test - NOEC	G-3-1-61	G-3-2-61	G-3-3-61	G-3-4-61	G-3-5-61
Aluminum	G-3-1-62	G-3-2-62	G-3-3-62	G-3-4-62	G-3-5-62
Antimony	G-3-1-63	G-3-2-63	G-3-3-63	G-3-4-63	G-3-5-63
Arsenic	G-3-1-64	G-3-2-64	G-3-3-64	G-3-4-64	G-3-5-64
Barium	G-3-1-65	G-3-2-65	G-3-3-65	G-3-4-65	G-3-5-65
Beryllium	G-3-1-66	G-3-2-66	G-3-3-66	G-3-4-66	G-3-5-66
Boron	G-3-1-67	G-3-2-67	G-3-3-67	G-3-4-67	G-3-5-67
Cadmium	G-3-1-68	G-3-2-68	G-3-3-68	G-3-4-68	G-3-5-68
Chromium	G-3-1-69	G-3-2-69	G-3-3-69	G-3-4-69	G-3-5-69
Chromium - hexavalent	G-3-1-70	G-3-2-70	G-3-3-70	G-3-4-70	G-3-5-70
Cobalt	G-3-1-71	G-3-2-71	G-3-3-71	G-3-4-71	G-3-5-71
Copper	G-3-1-72	G-3-2-72	G-3-3-72	G-3-4-72	G-3-5-72
Iron	G-3-1-73	G-3-2-73	G-3-3-73	G-3-4-73	G-3-5-73
Lead	G-3-1-74	G-3-2-74	G-3-3-74	G-3-4-74	G-3-5-74
Lithium	G-3-1-75	G-3-2-75	G-3-3-75	G-3-4-75	G-3-5-75

Table G-3. List of Box/Whisker and Scatter Plots of Observed Water Quality Data for Pierre River Mine Area

Water Quality Parameters	Pierre River	Eymundson Creek	Big Creek	Redclay Creek	Unnamed Lakes
Manganese	G-3-1-76	G-3-2-76	G-3-3-76	G-3-4-76	G-3-5-76
Mercury	G-3-1-77	G-3-2-77	G-3-3-77	G-3-4-77	G-3-5-77
Methyl Mercury	G-3-1-78	G-3-2-78	G-3-3-78	G-3-4-78	G-3-5-78
Molybdenum	G-3-1-79	G-3-2-79	G-3-3-79	G-3-4-79	G-3-5-79
Nickel	G-3-1-80	G-3-2-80	G-3-3-80	G-3-4-80	G-3-5-80
Selenium	G-3-1-81	G-3-2-81	G-3-3-81	G-3-4-81	G-3-5-81
Silicon	G-3-1-82	G-3-2-82	G-3-3-82	G-3-4-82	G-3-5-82
Silver	G-3-1-83	G-3-2-83	G-3-3-83	G-3-4-83	G-3-5-83
Strontium	G-3-1-84	G-3-2-84	G-3-3-84	G-3-4-84	G-3-5-84
Sulphur	G-3-1-85	G-3-2-85	G-3-3-85	G-3-4-85	G-3-5-85
Thallium	G-3-1-86	G-3-2-86	G-3-3-86	G-3-4-86	G-3-5-86
Titanium	G-3-1-87	G-3-2-87	G-3-3-87	G-3-4-87	G-3-5-87
Uranium	G-3-1-88	G-3-2-88	G-3-3-88	G-3-4-88	G-3-5-88
Vanadium	G-3-1-89	G-3-2-89	G-3-3-89	G-3-4-89	G-3-5-89
Zinc	G-3-1-90	G-3-2-90	G-3-3-90	G-3-4-90	G-3-5-90
Aluminum	G-3-1-91	G-3-2-91	G-3-3-91	G-3-4-91	G-3-5-91
Antimony	G-3-1-92	G-3-2-92	G-3-3-92	G-3-4-92	G-3-5-92
Arsenic	G-3-1-93	G-3-2-93	G-3-3-93	G-3-4-93	G-3-5-93
Barium	G-3-1-94	G-3-2-94	G-3-3-94	G-3-4-94	G-3-5-94
Beryllium	G-3-1-95	G-3-2-95	G-3-3-95	G-3-4-95	G-3-5-95
Boron	G-3-1-96	G-3-2-96	G-3-3-96	G-3-4-96	G-3-5-96
Cadmium	G-3-1-97	G-3-2-97	G-3-3-97	G-3-4-97	G-3-5-97
Chromium	G-3-1-98	G-3-2-98	G-3-3-98	G-3-4-98	G-3-5-98
Chromium - hexavalent	G-3-1-99	G-3-2-99	G-3-3-99	G-3-4-99	G-3-5-99
Cobalt	G-3-1-100	G-3-2-100	G-3-3-100	G-3-4-100	G-3-5-100
Copper	G-3-1-101	G-3-2-101	G-3-3-101	G-3-4-101	G-3-5-101
Iron	G-3-1-102	G-3-2-102	G-3-3-102	G-3-4-102	G-3-5-102
Lead	G-3-1-103	G-3-2-103	G-3-3-103	G-3-4-103	G-3-5-103
Lithium	G-3-1-104	G-3-2-104	G-3-3-104	G-3-4-104	G-3-5-104
Manganese	G-3-1-105	G-3-2-105	G-3-3-105	G-3-4-105	G-3-5-105
Mercury	G-3-1-106	G-3-2-106	G-3-3-106	G-3-4-106	G-3-5-106
Molybdenum	G-3-1-107	G-3-2-107	G-3-3-107	G-3-4-107	G-3-5-107
Nickel	G-3-1-108	G-3-2-108	G-3-3-108	G-3-4-108	G-3-5-108
Selenium	G-3-1-109	G-3-2-109	G-3-3-109	G-3-4-109	G-3-5-109
Silicon	G-3-1-110	G-3-2-110	G-3-3-110	G-3-4-110	G-3-5-110
Silver	G-3-1-111	G-3-2-111	G-3-3-111	G-3-4-111	G-3-5-111
Strontium	G-3-1-112	G-3-2-112	G-3-3-112	G-3-4-112	G-3-5-112
Sulphur	G-3-1-113	G-3-2-113	G-3-3-113	G-3-4-113	G-3-5-113
Thallium	G-3-1-114	G-3-2-114	G-3-3-114	G-3-4-114	G-3-5-114
Titanium	G-3-1-115	G-3-2-115	G-3-3-115	G-3-4-115	G-3-5-115
Uranium	G-3-1-116	G-3-2-116	G-3-3-116	G-3-4-116	G-3-5-116
Vanadium	G-3-1-117	G-3-2-117	G-3-3-117	G-3-4-117	G-3-5-117
Zinc	G-3-1-118	G-3-2-118	G-3-3-118	G-3-4-118	G-3-5-118

Figure G-3-1-1 Box Whisker and Time Series Scatter Plots of Observed pH in Pierre River



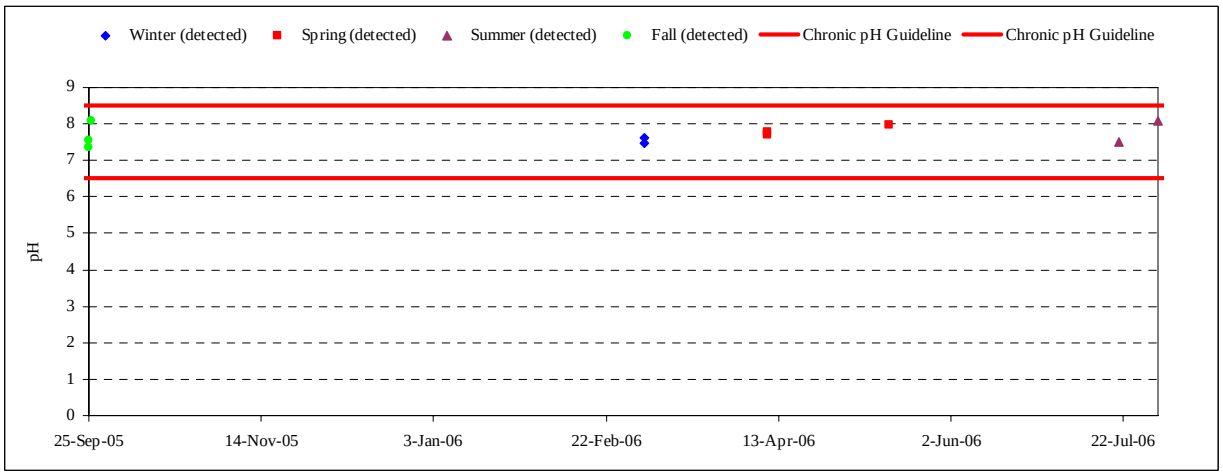
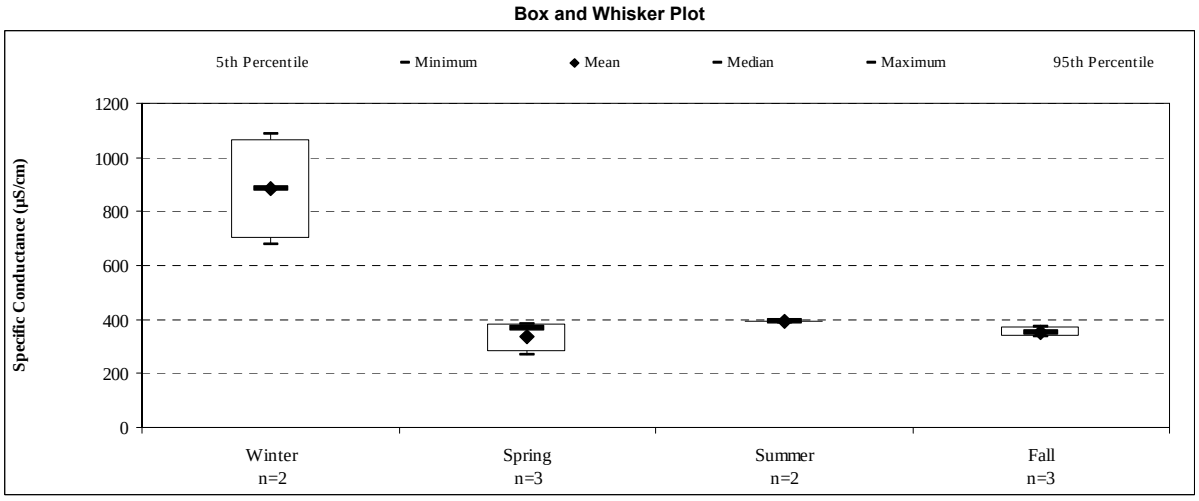


Figure G-3-1-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Pierre River



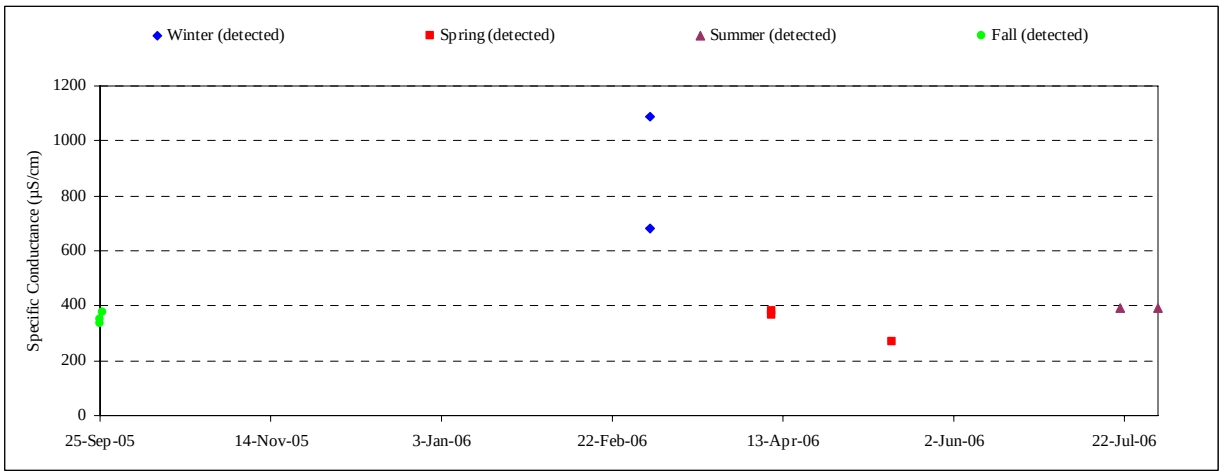
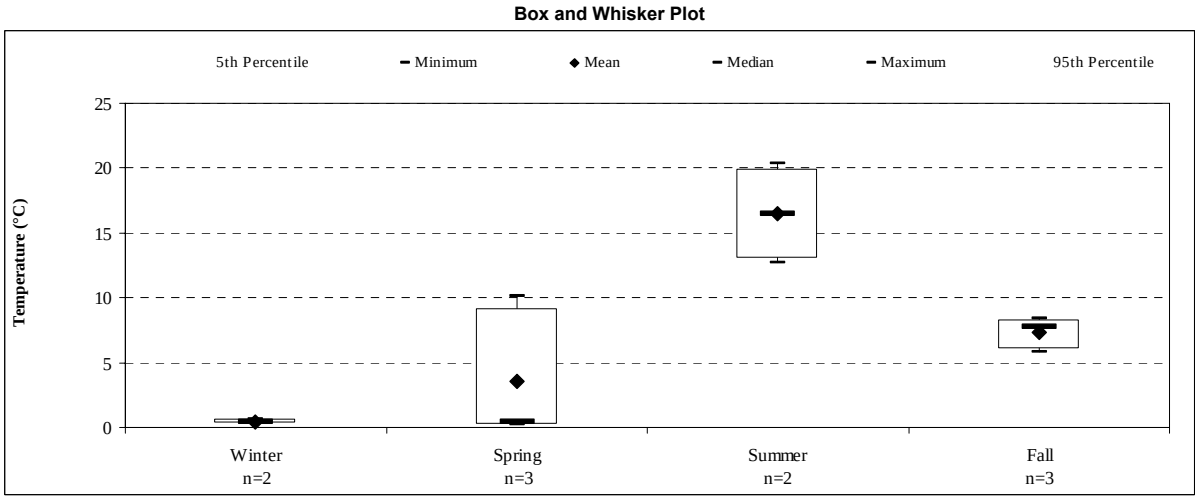


Figure G-3-1-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Pierre River



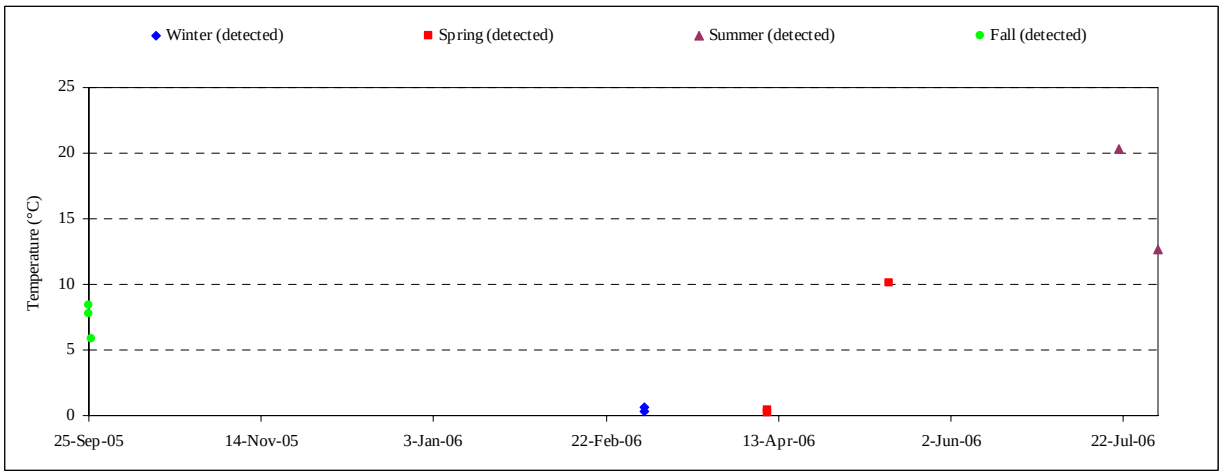
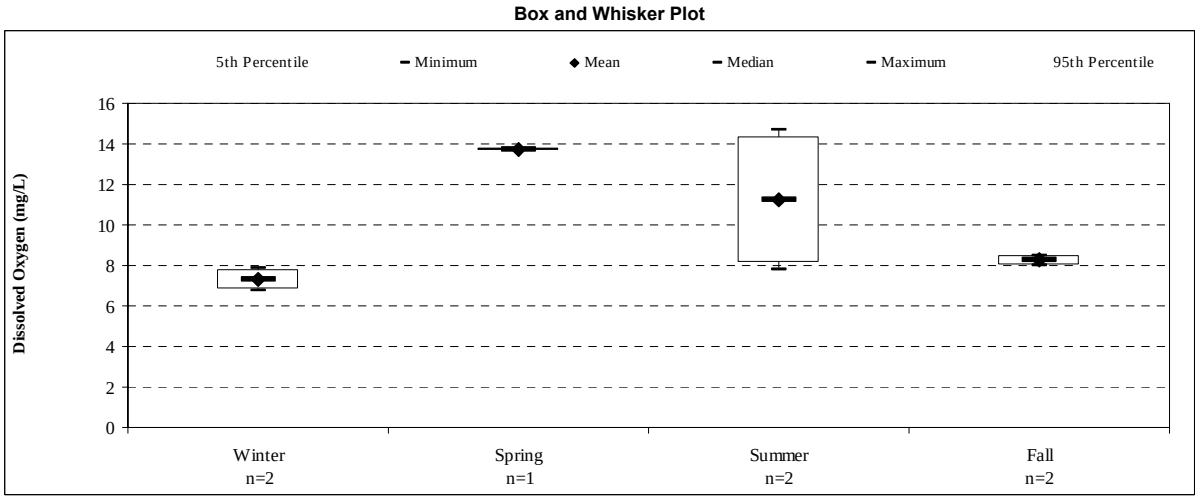


Figure G-3-1-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Pierre River



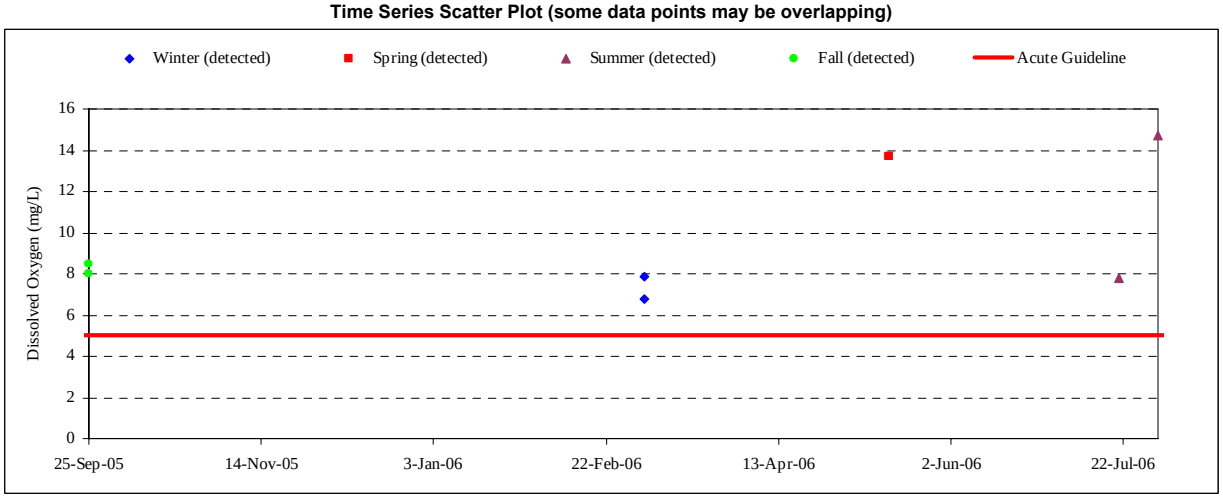
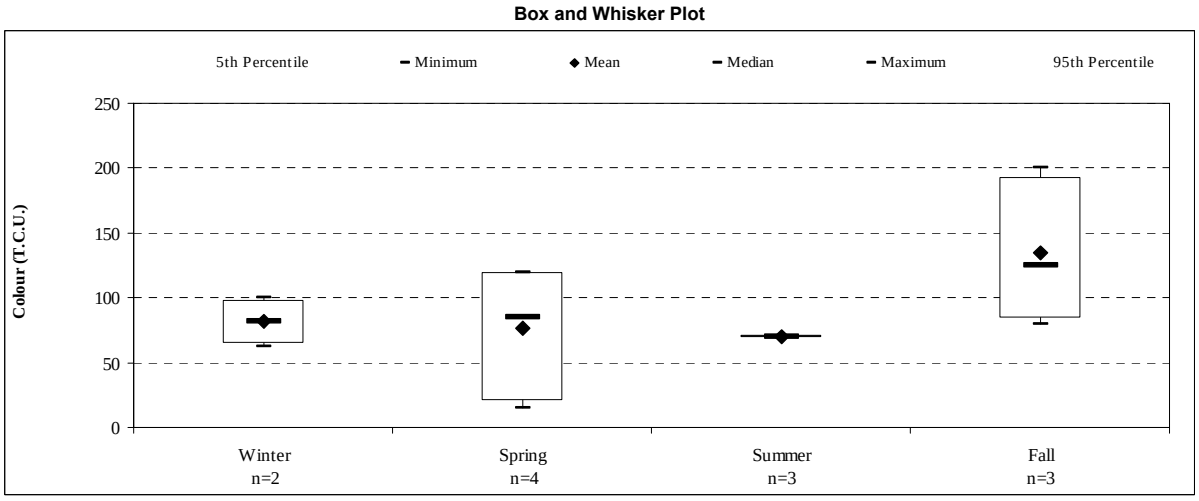


Figure G-3-1-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Pierre River



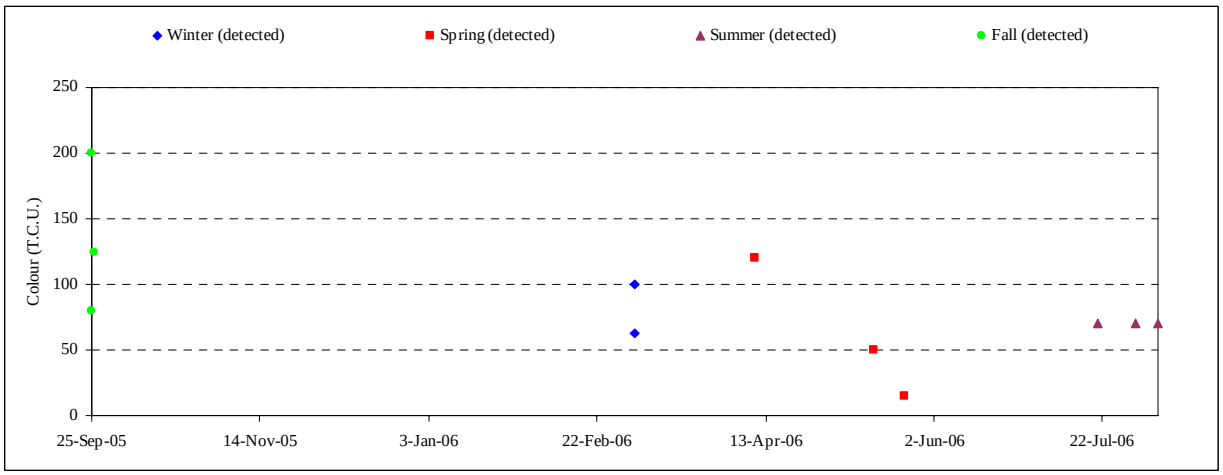
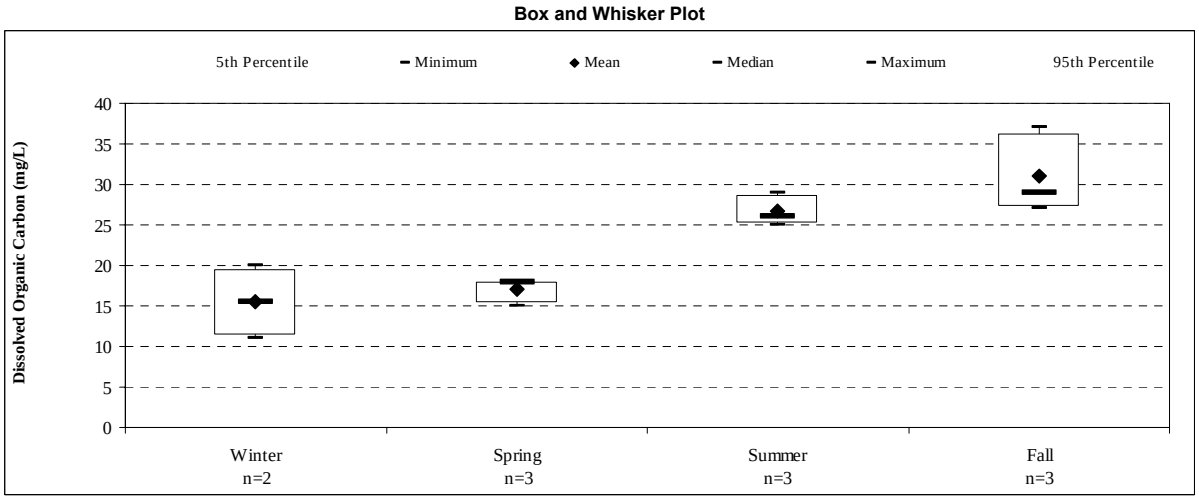


Figure G-3-1-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Pierre River



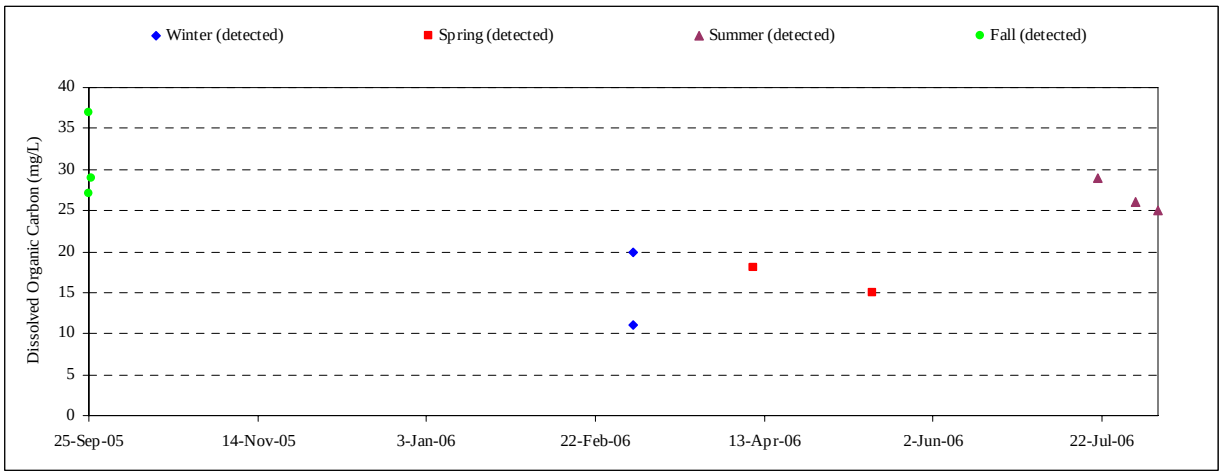
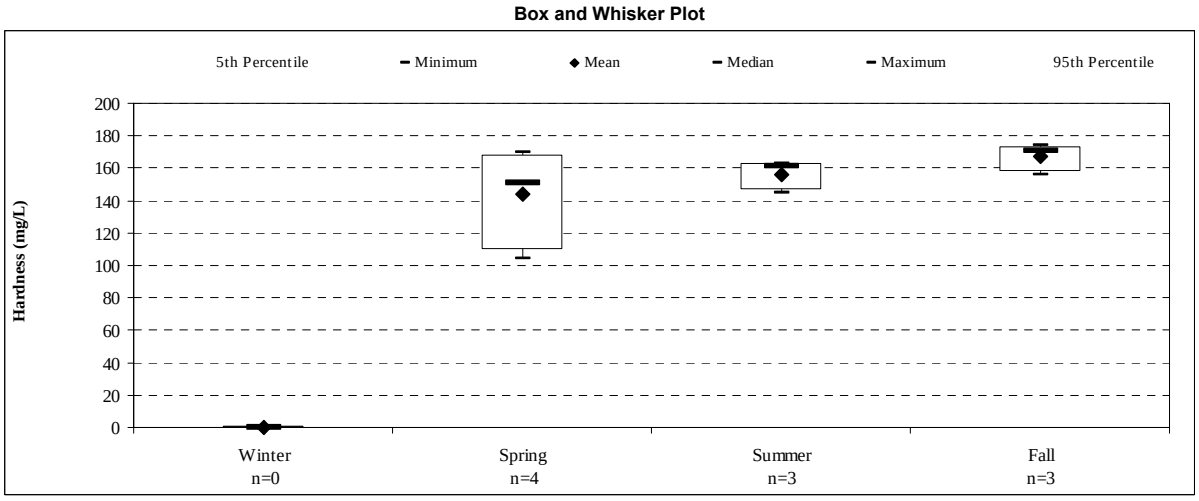


Figure G-3-1-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Pierre River



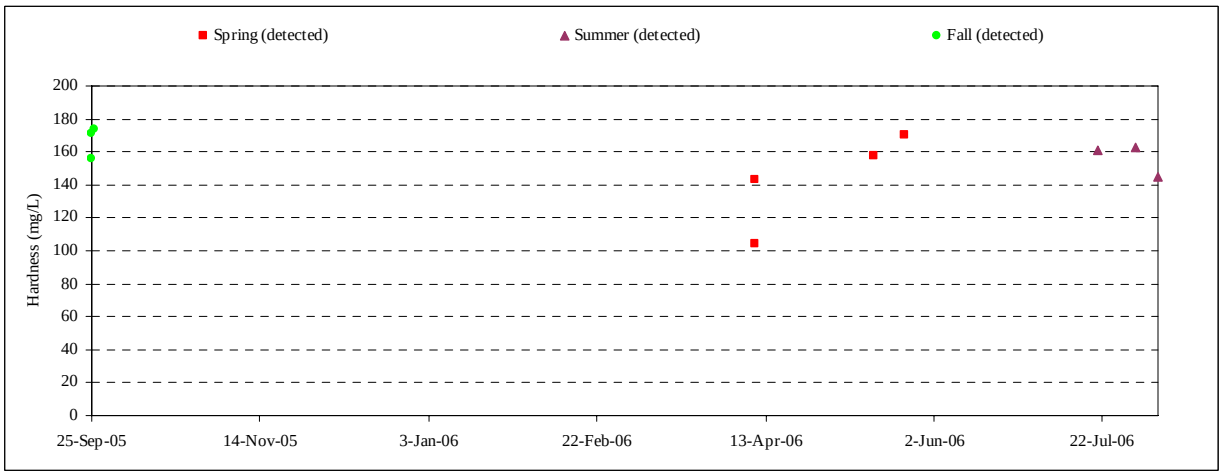
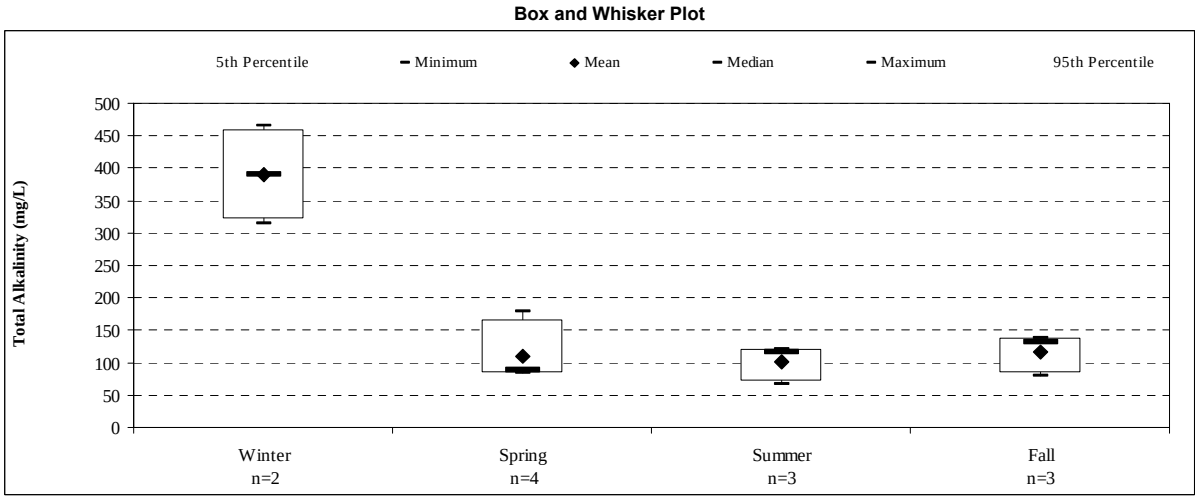


Figure G-3-1-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Pierre River



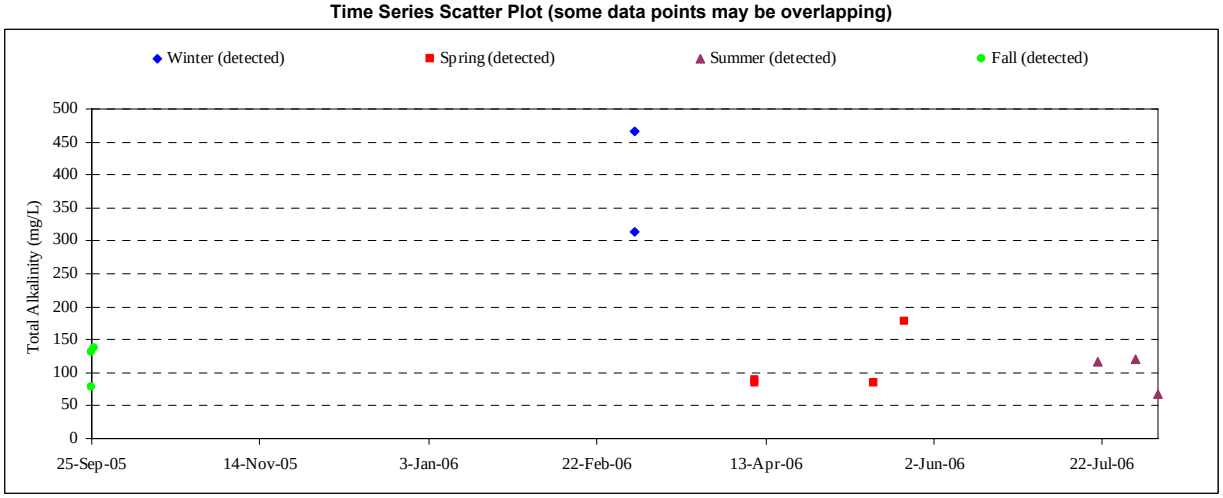
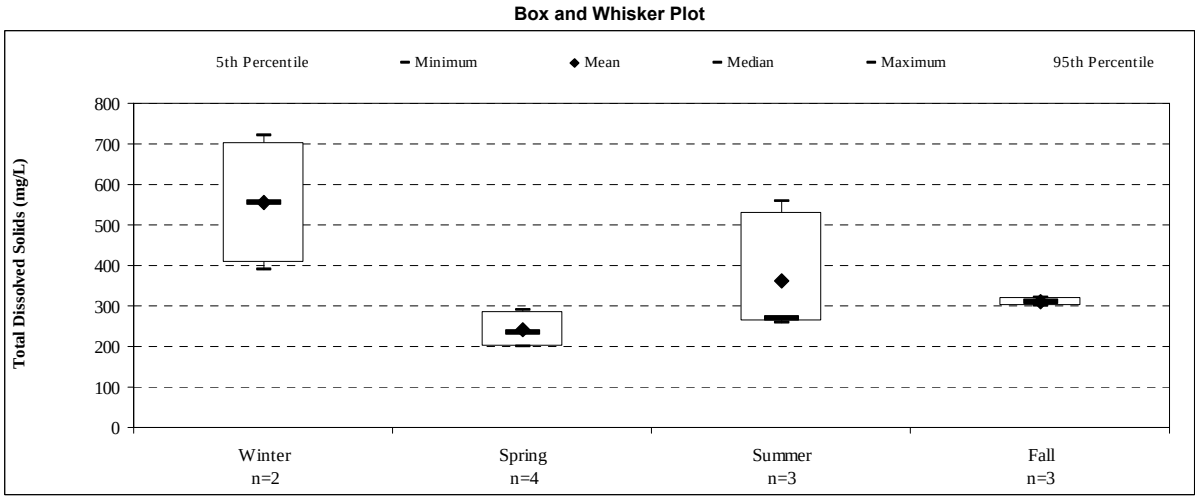


Figure G-3-1-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Pierre River



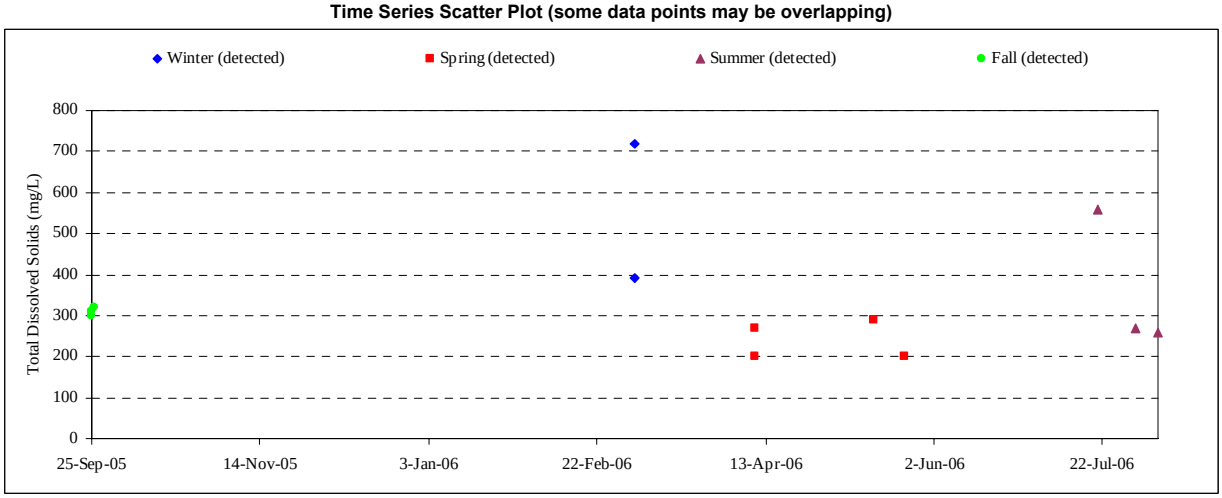
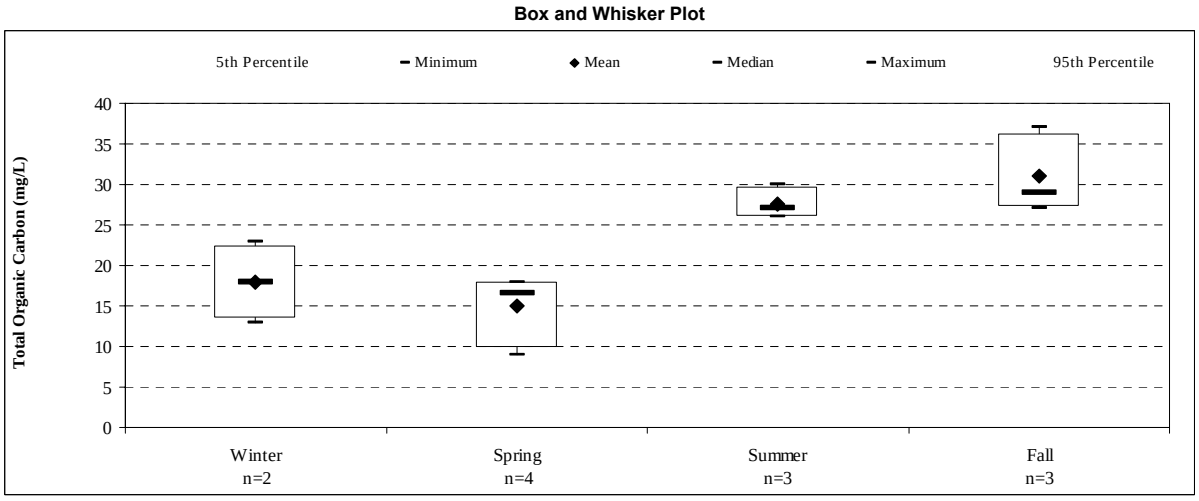


Figure G-3-1-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Pierre River



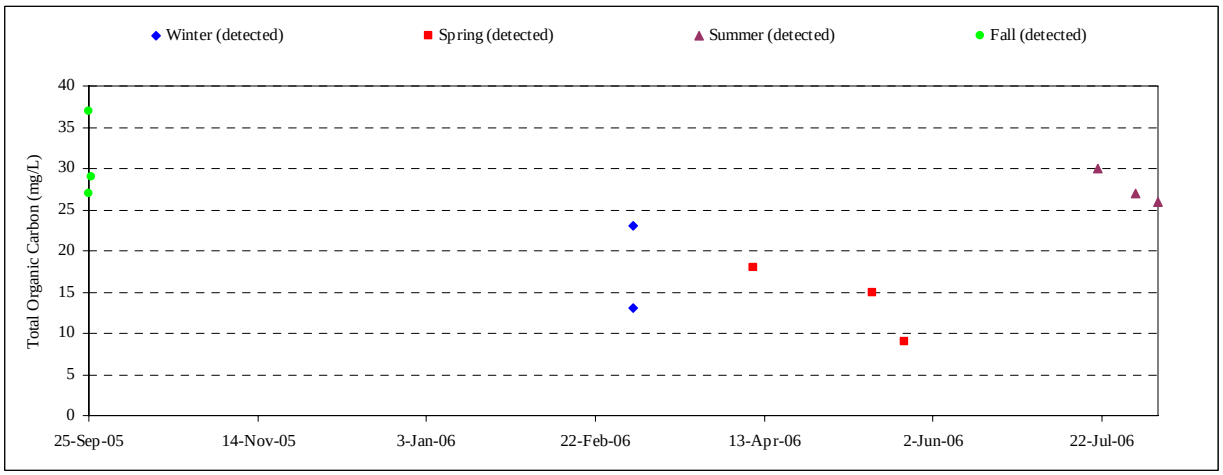
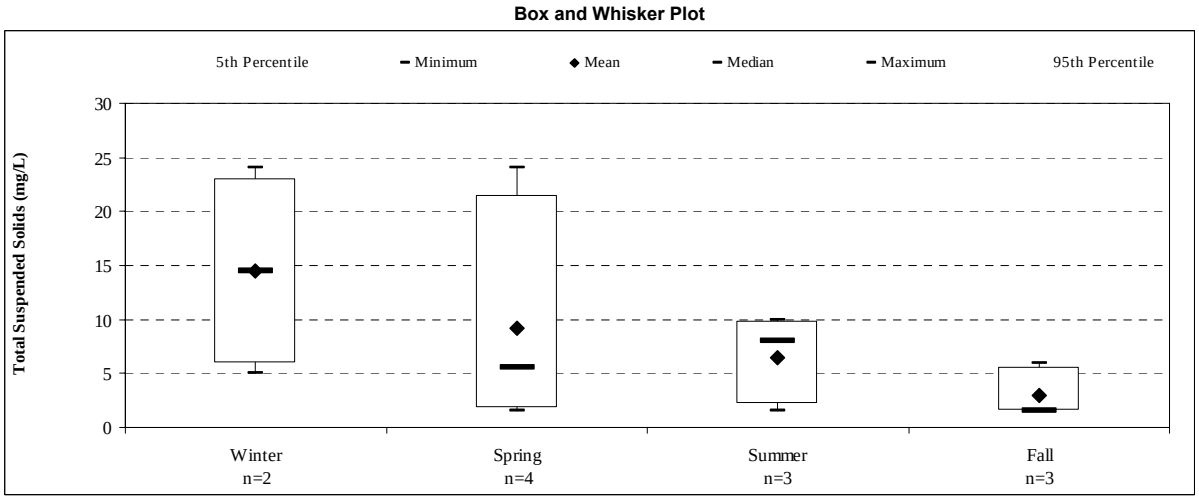


Figure G-3-1-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Pierre River



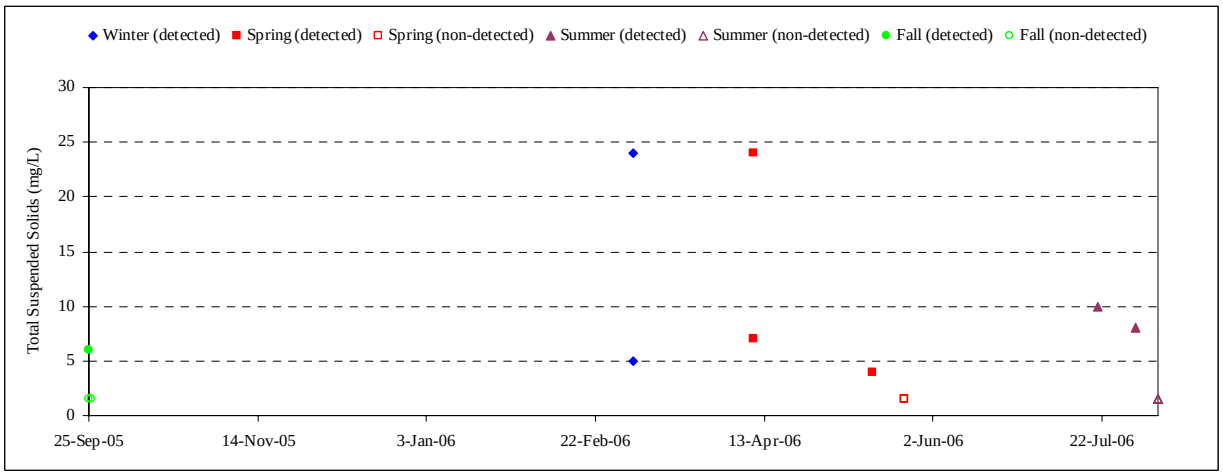
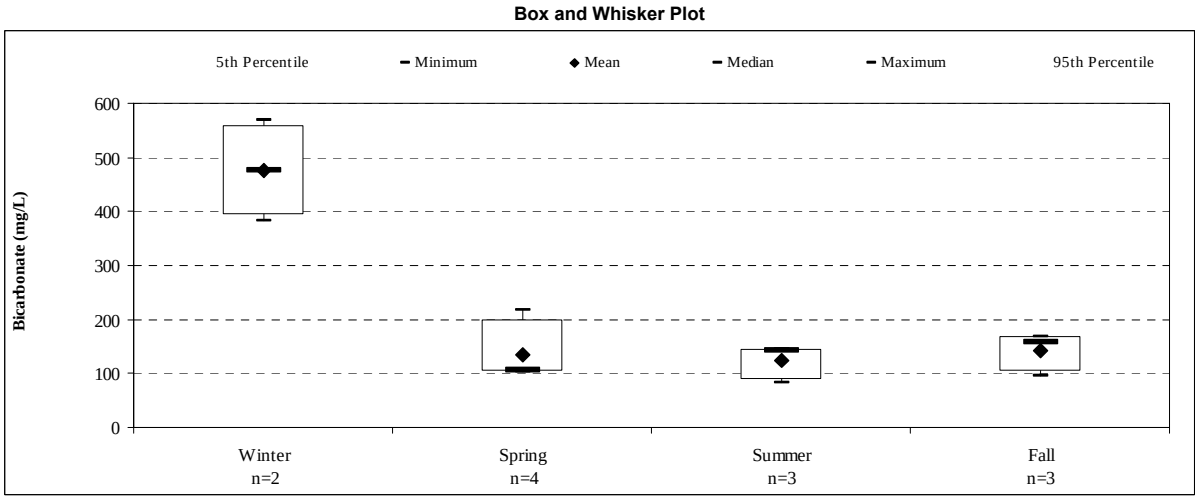


Figure G-3-1-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Pierre River



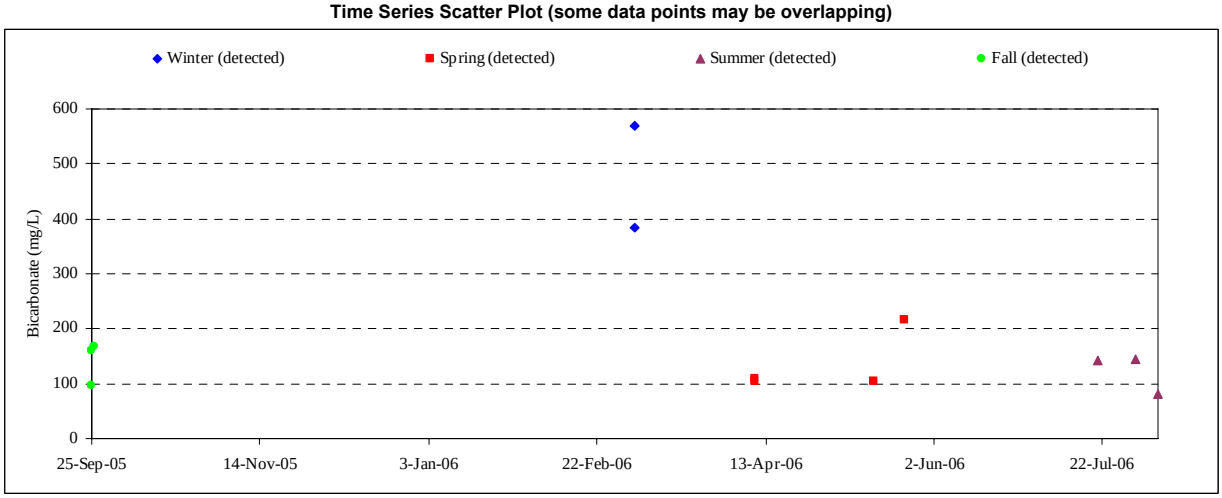
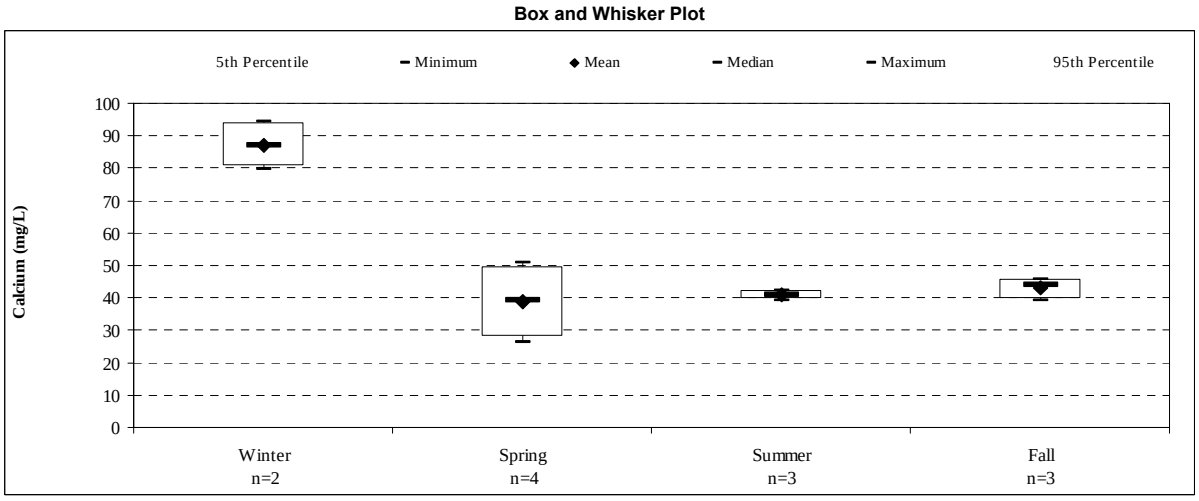


Figure G-3-1-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Pierre River



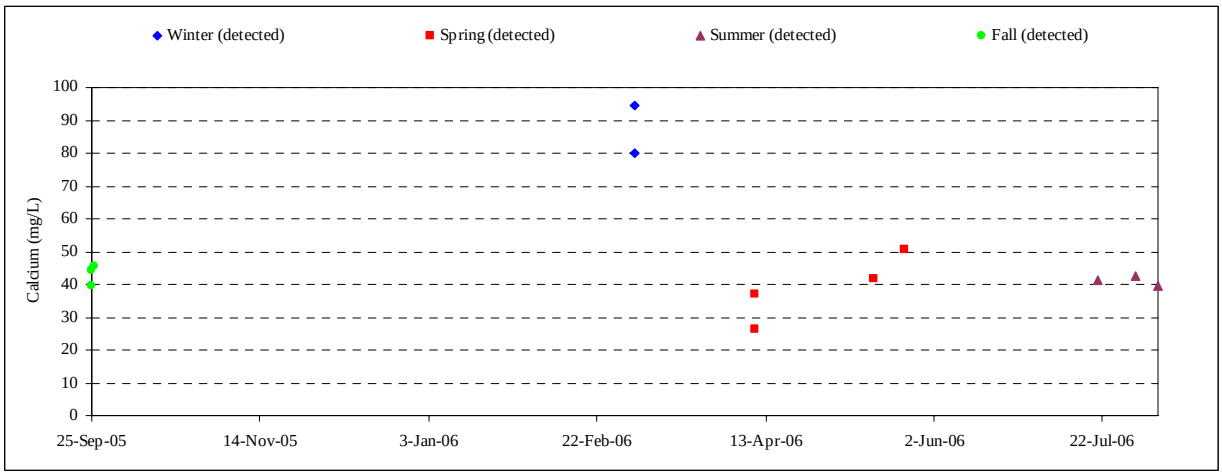
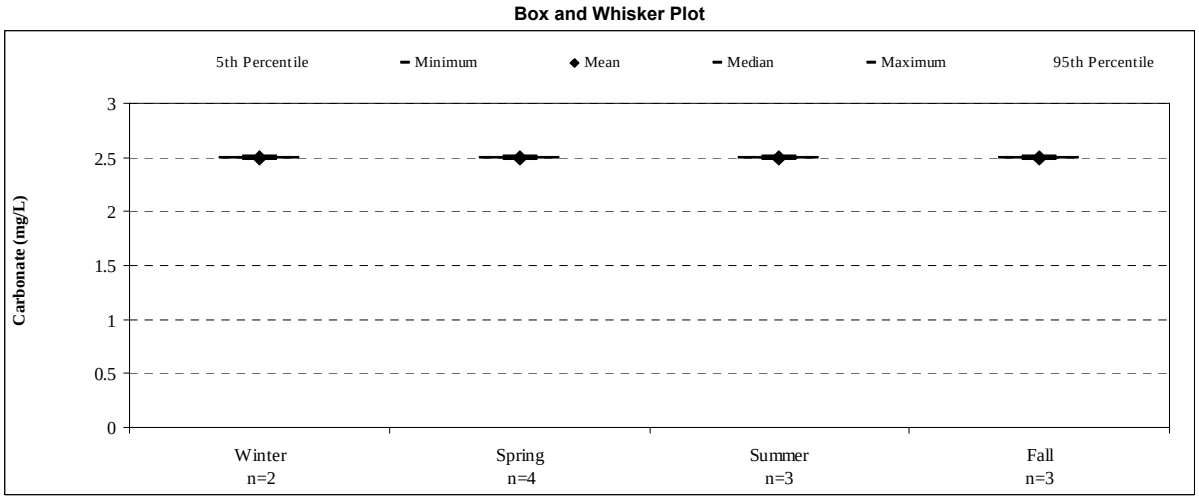


Figure G-3-1-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Pierre River



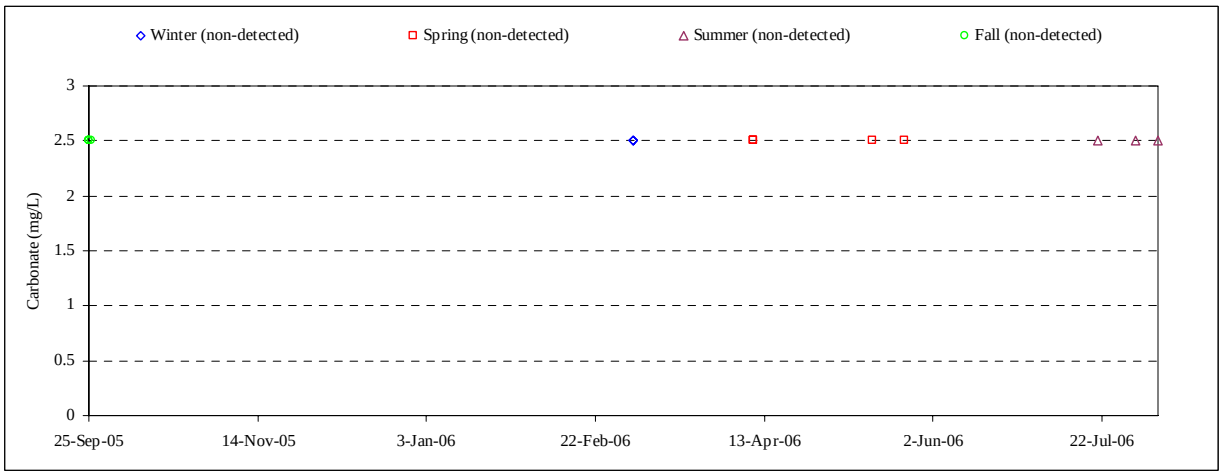


Figure G-3-1-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Pierre River

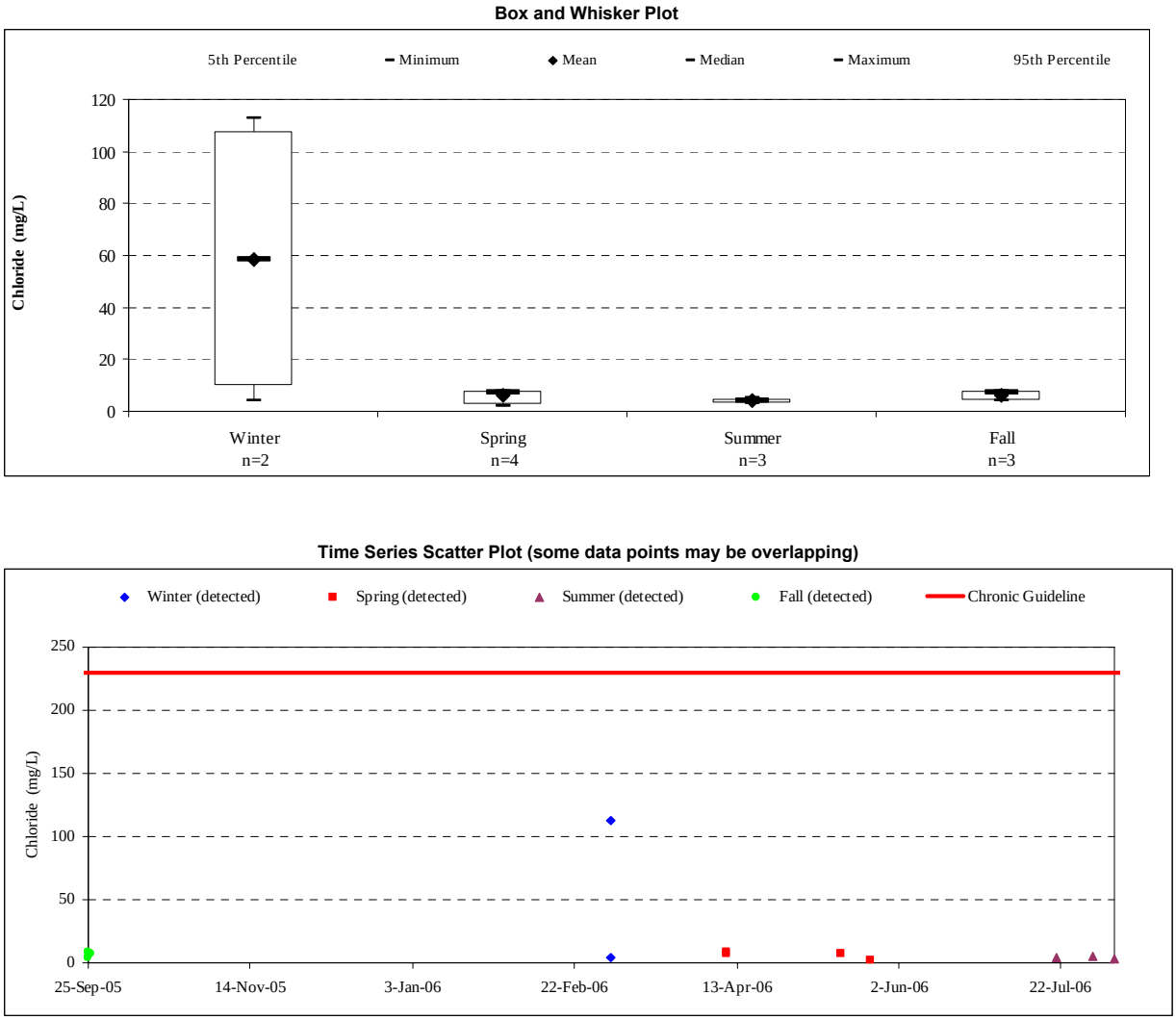
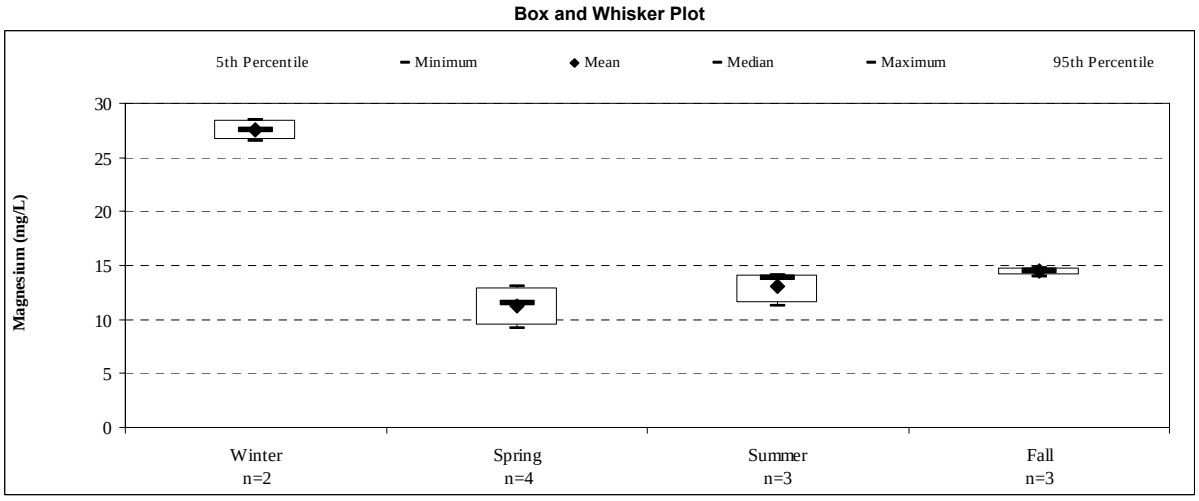


Figure G-3-1-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Pierre River



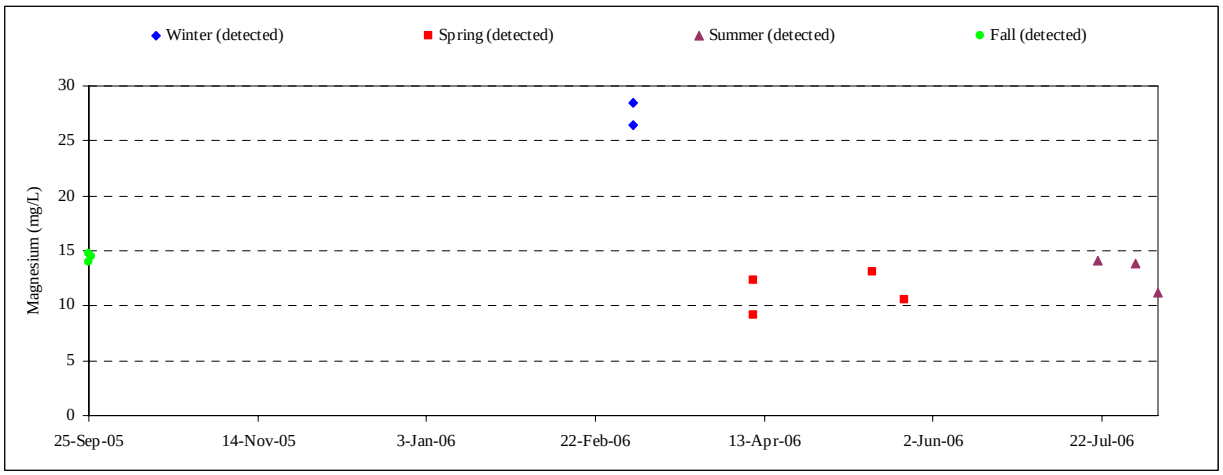
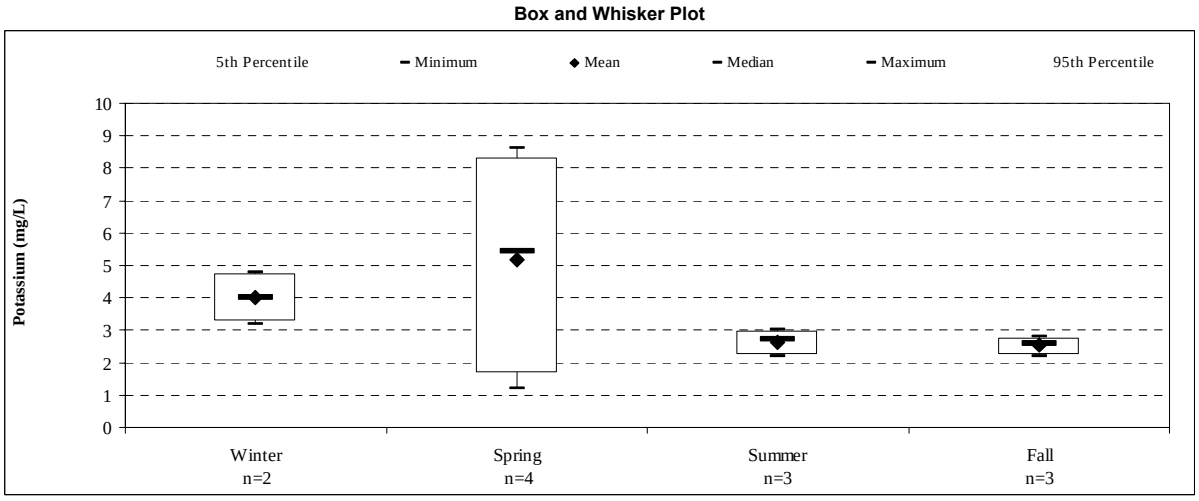


Figure G-3-1-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Pierre River



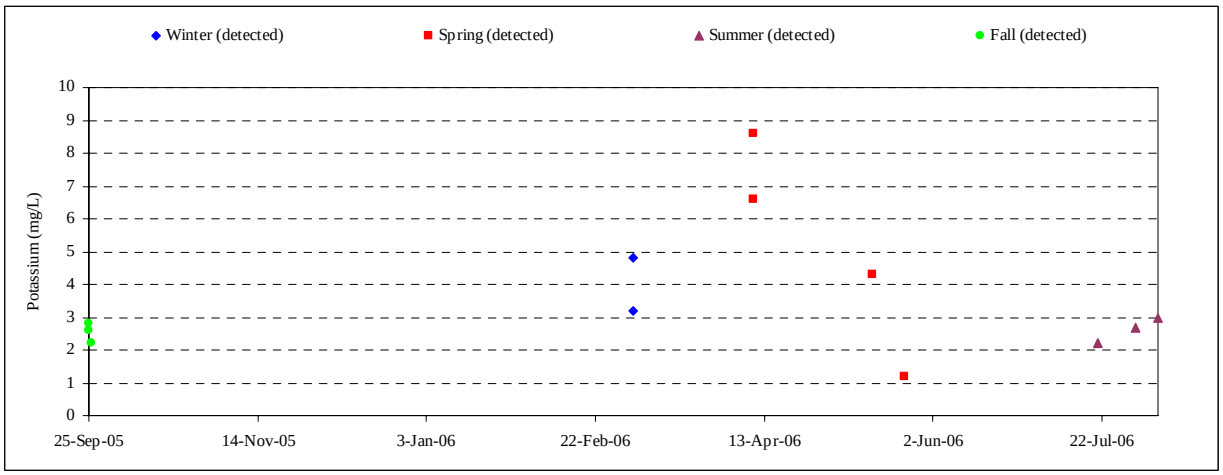
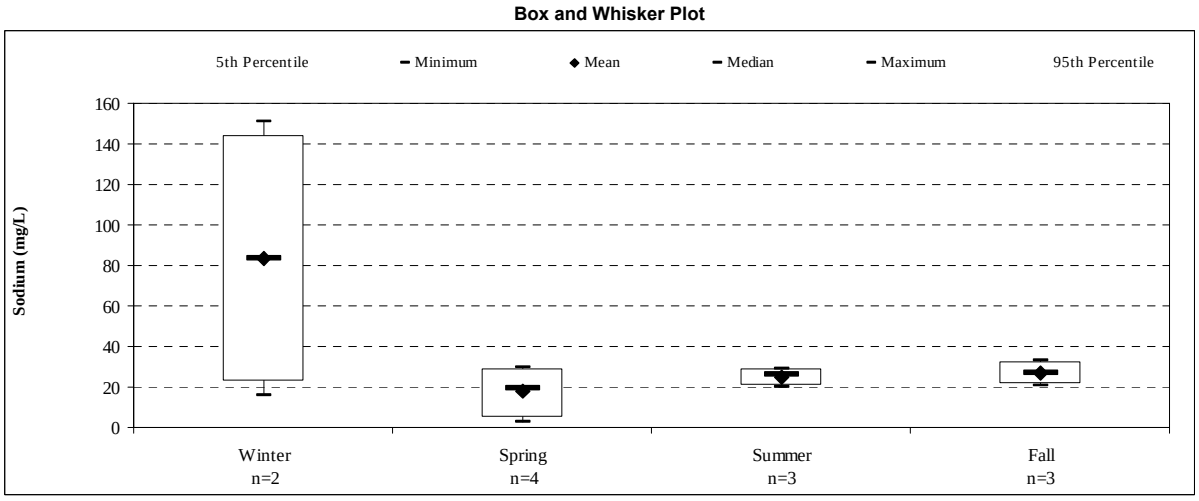


Figure G-3-1-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Pierre River



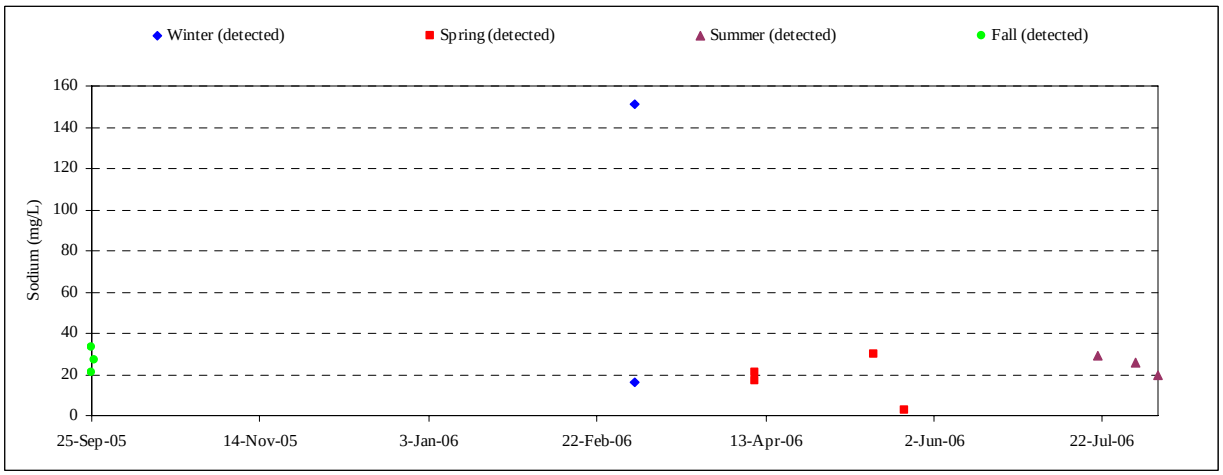
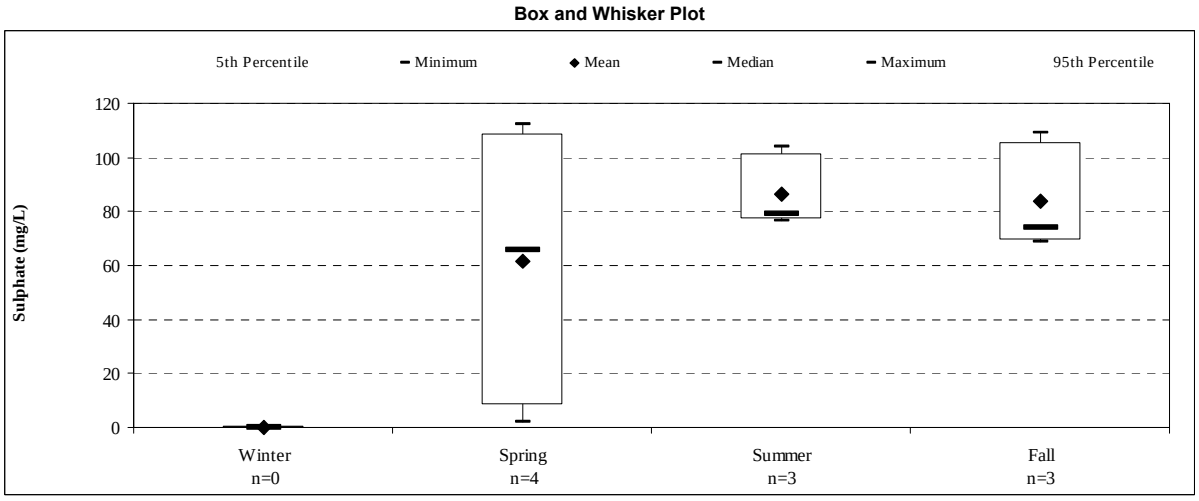


Figure G-3-1-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Pierre River



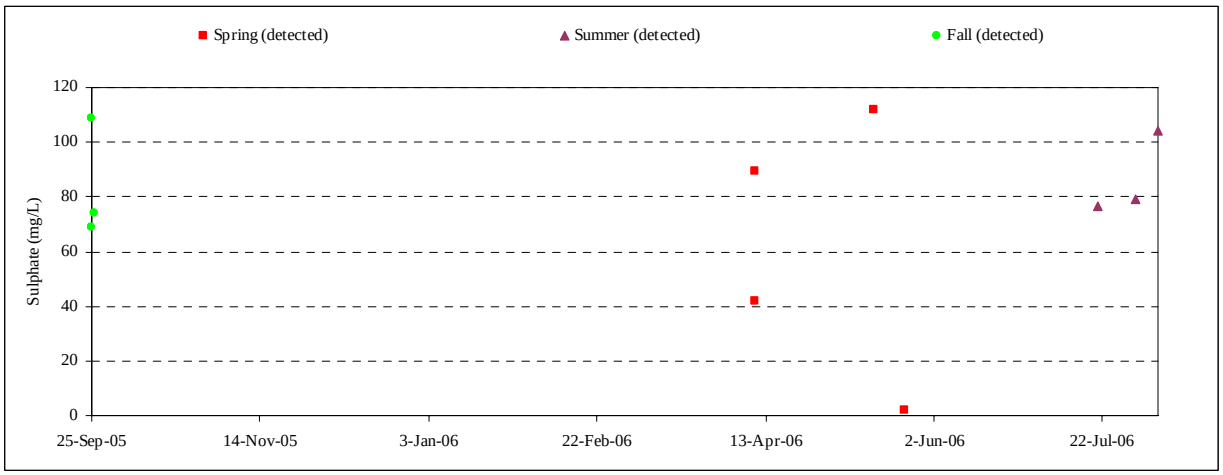
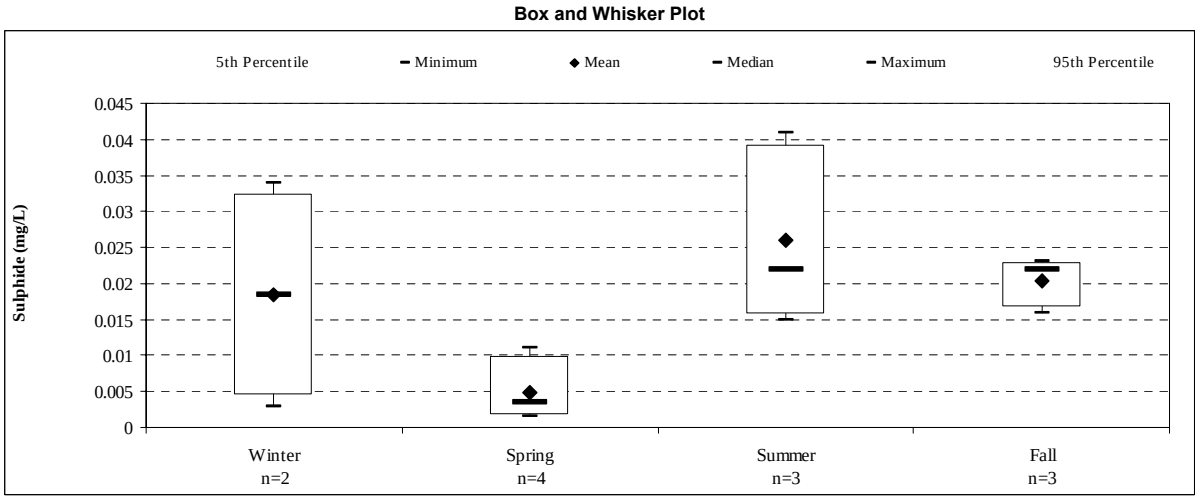


Figure G-3-1-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Pierre River



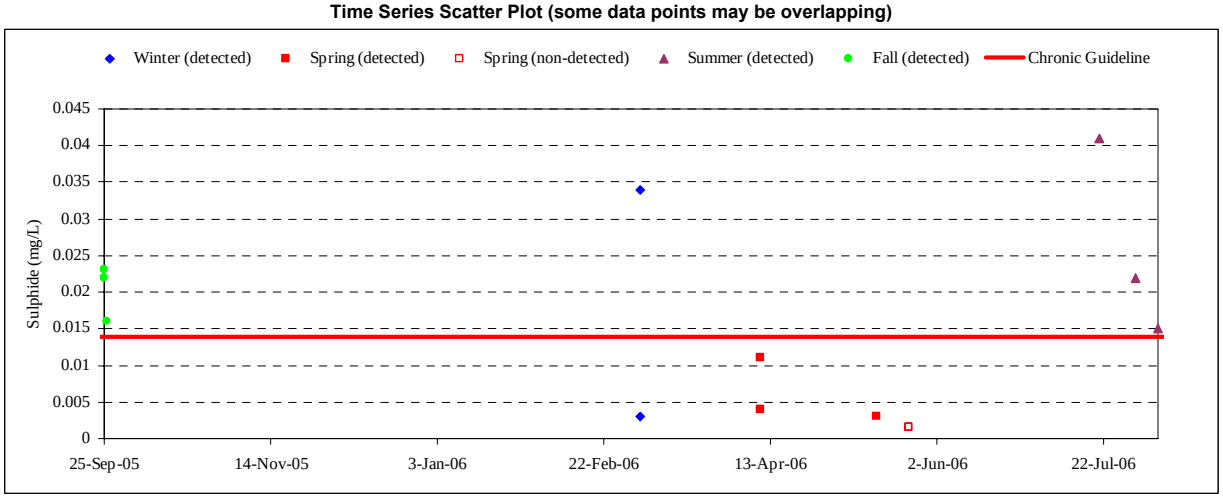
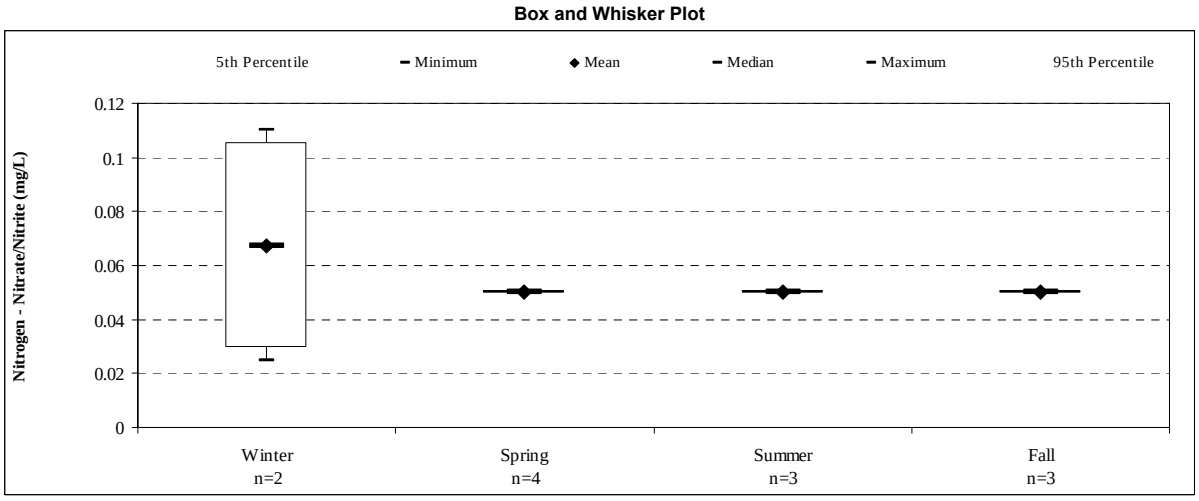


Figure G-3-1-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Pierre River



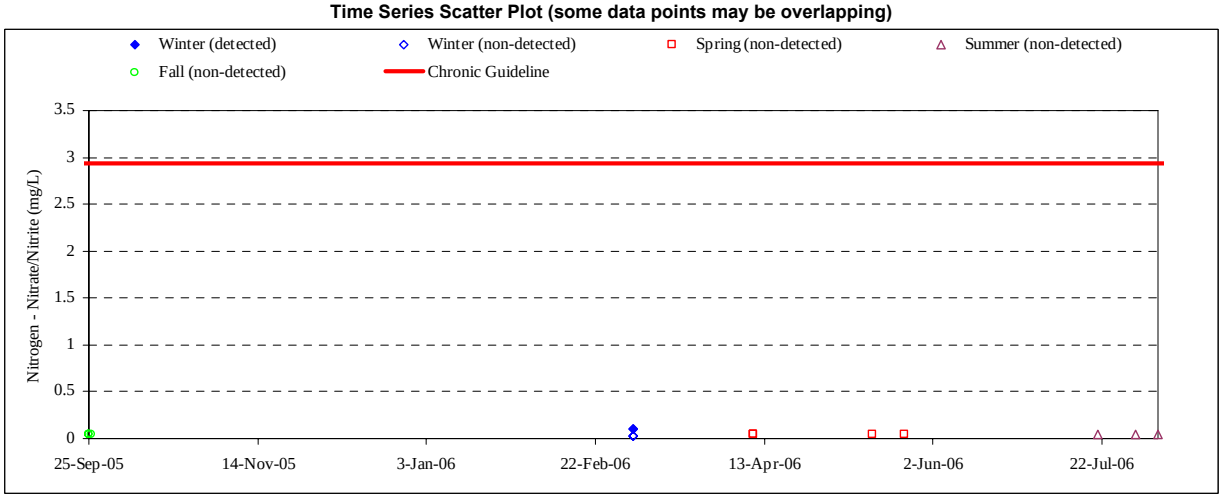
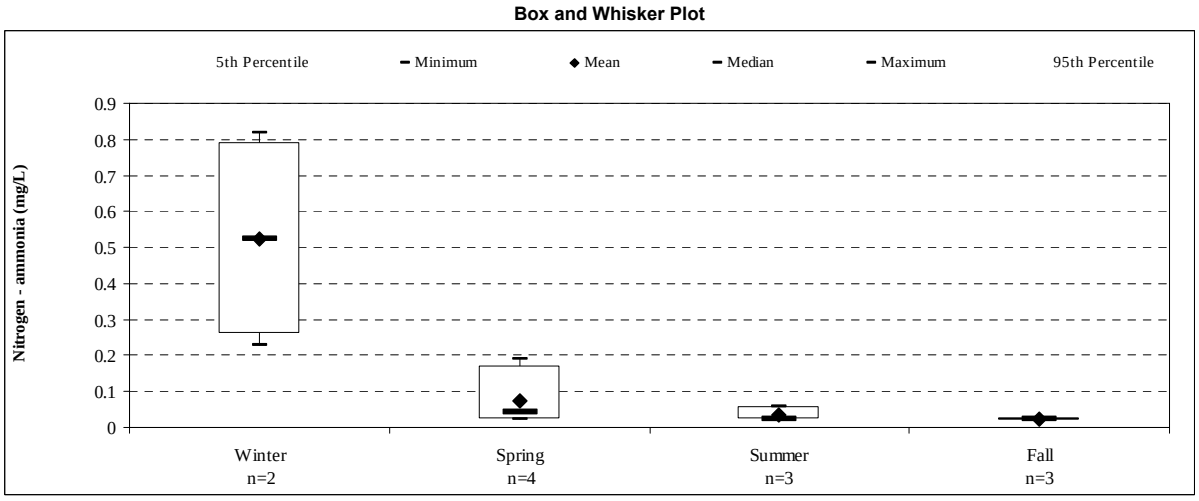


Figure G-3-1-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Pierre River



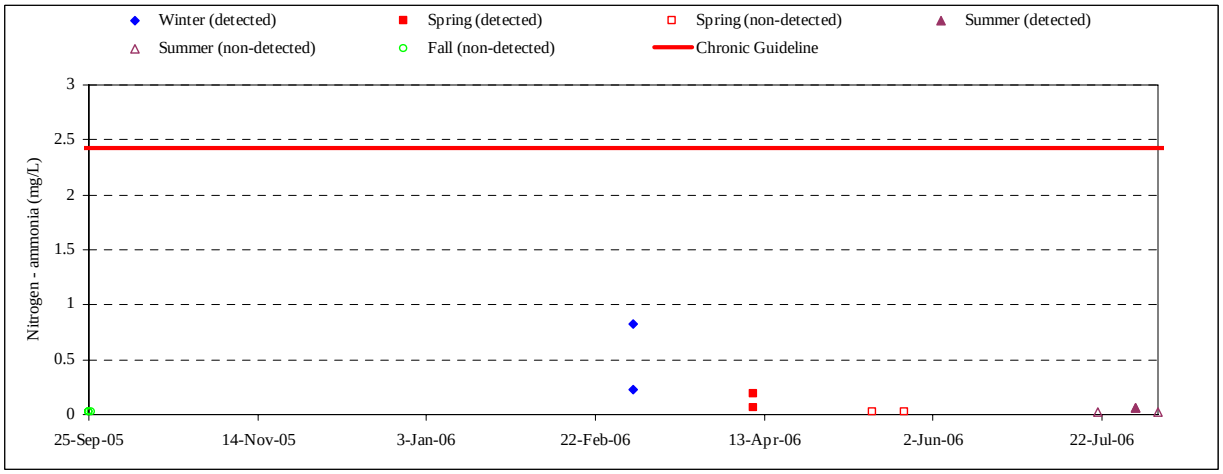
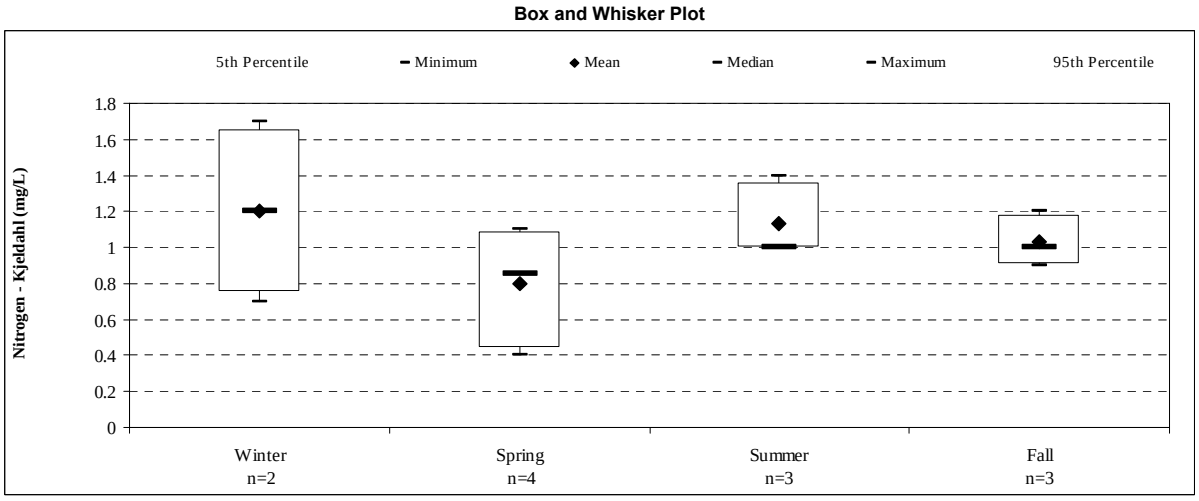


Figure G-3-1-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Pierre River



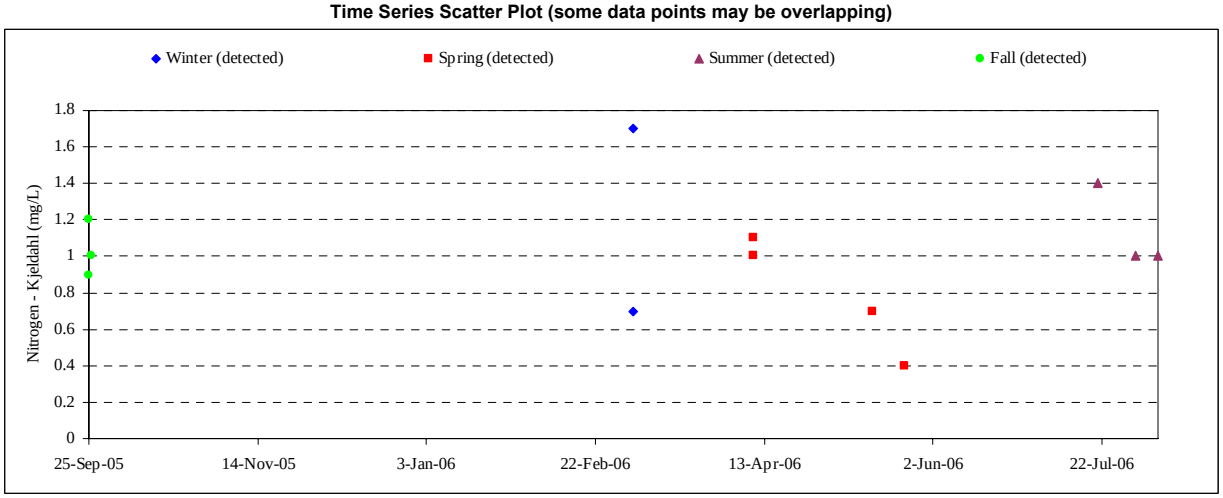
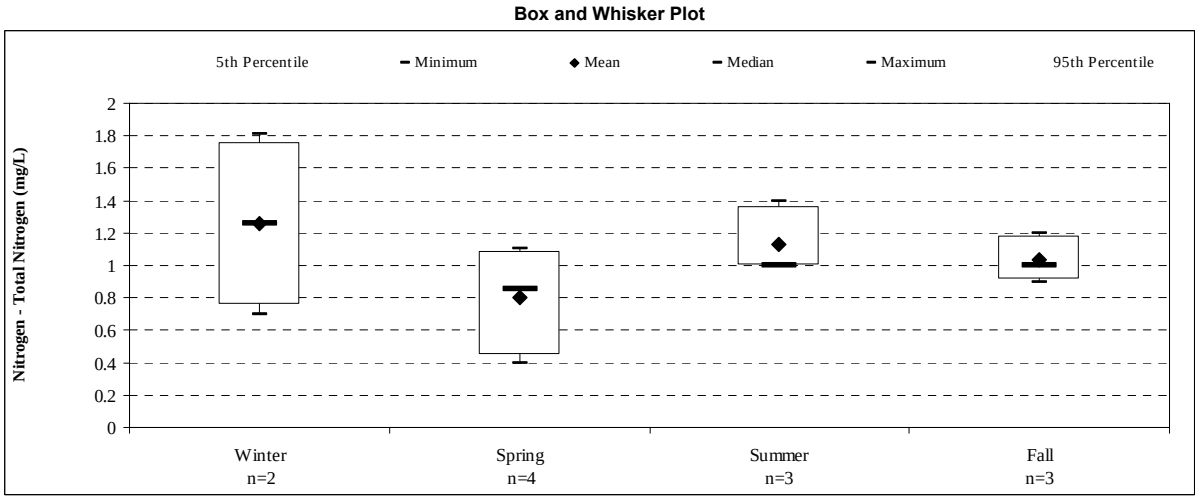


Figure G-3-1-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Pierre River



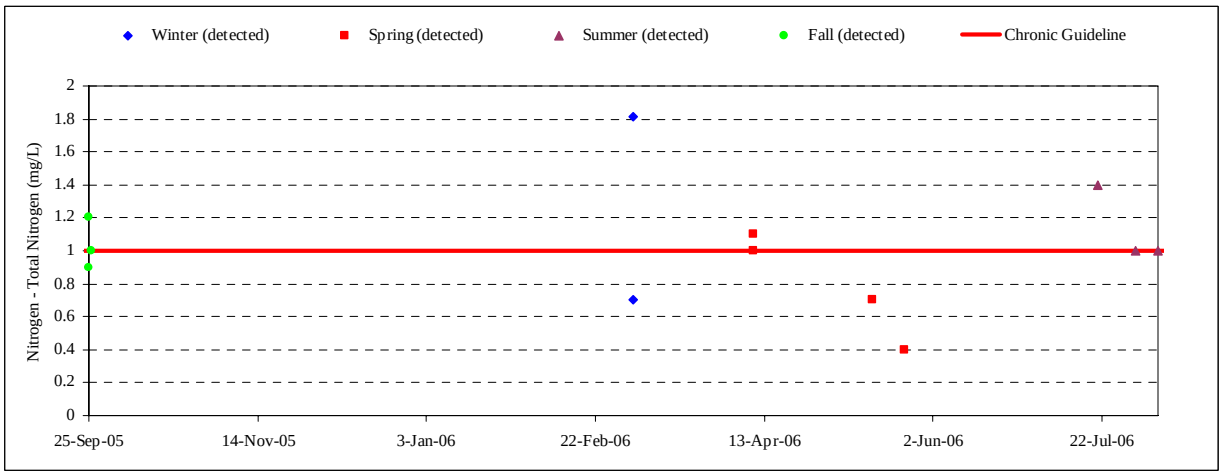
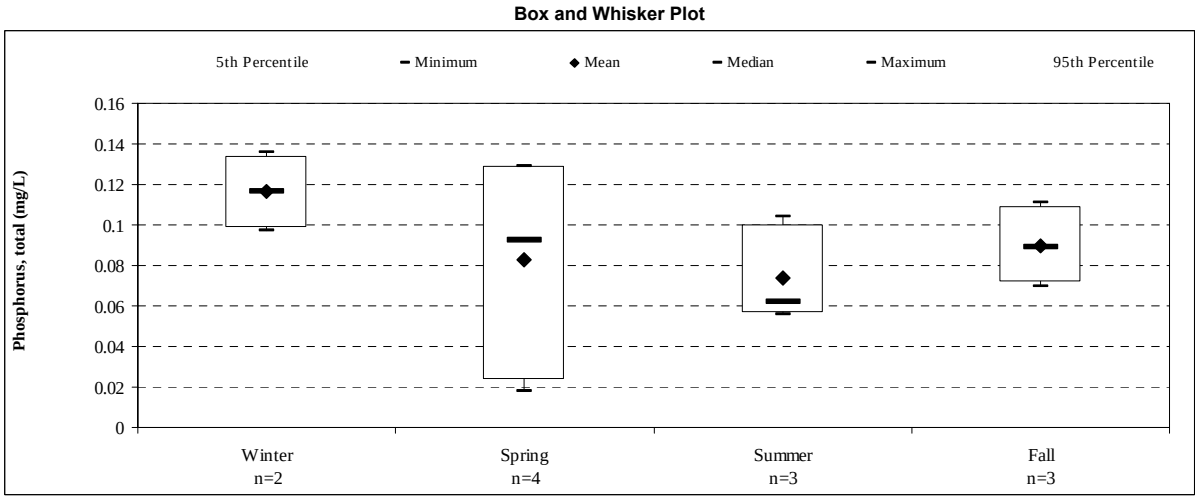


Figure G-3-1-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Pierre River



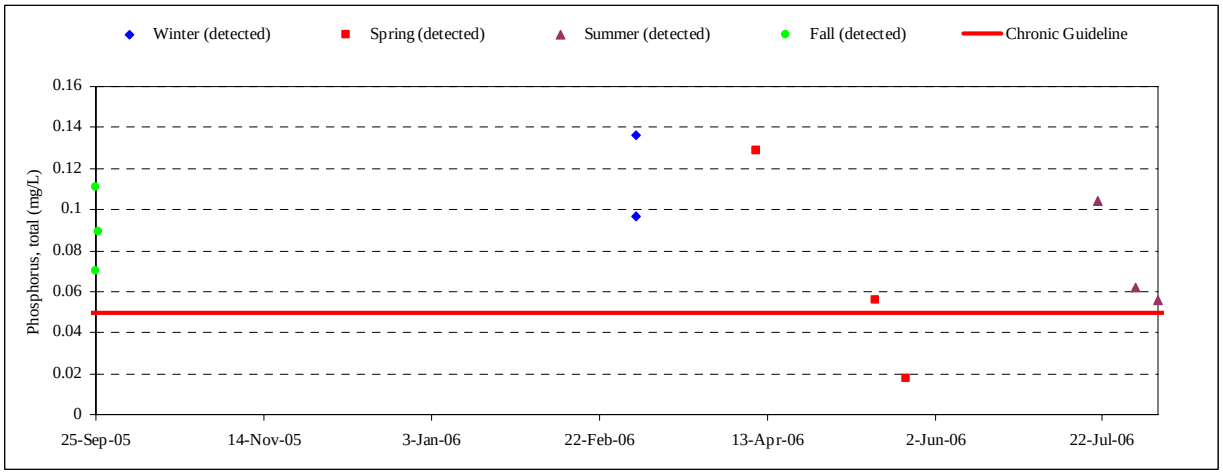
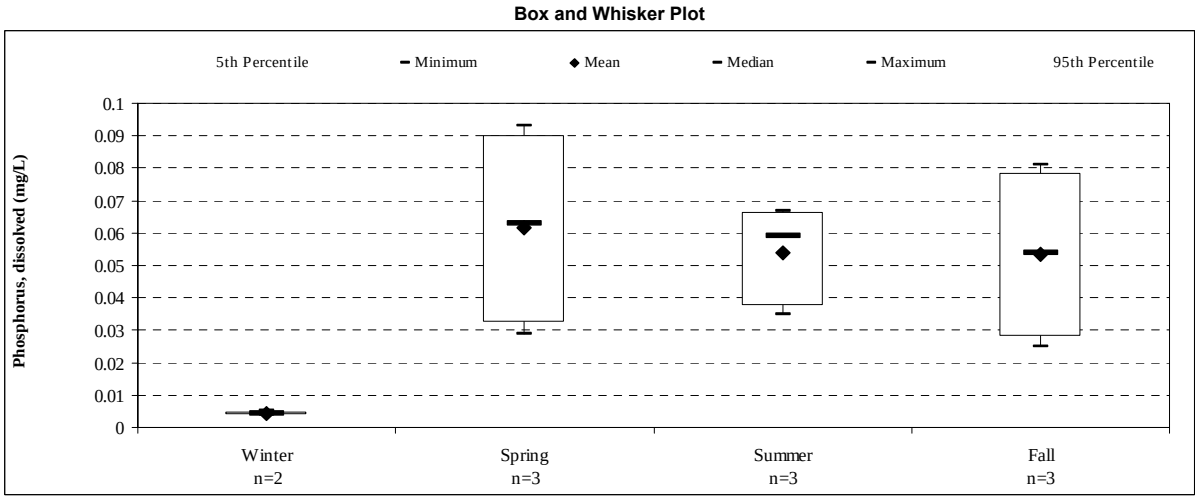


Figure G-3-1-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Pierre River



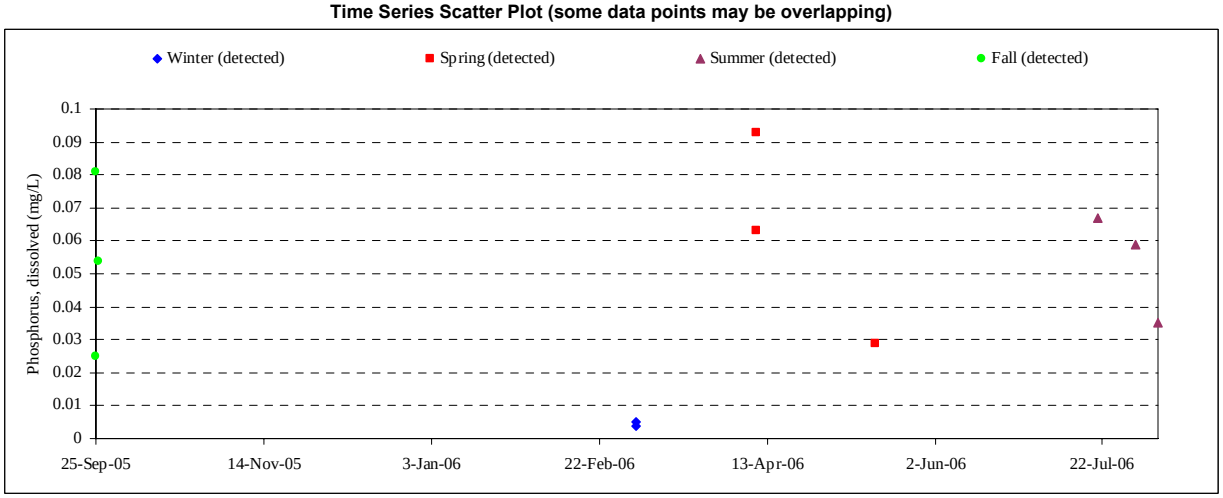
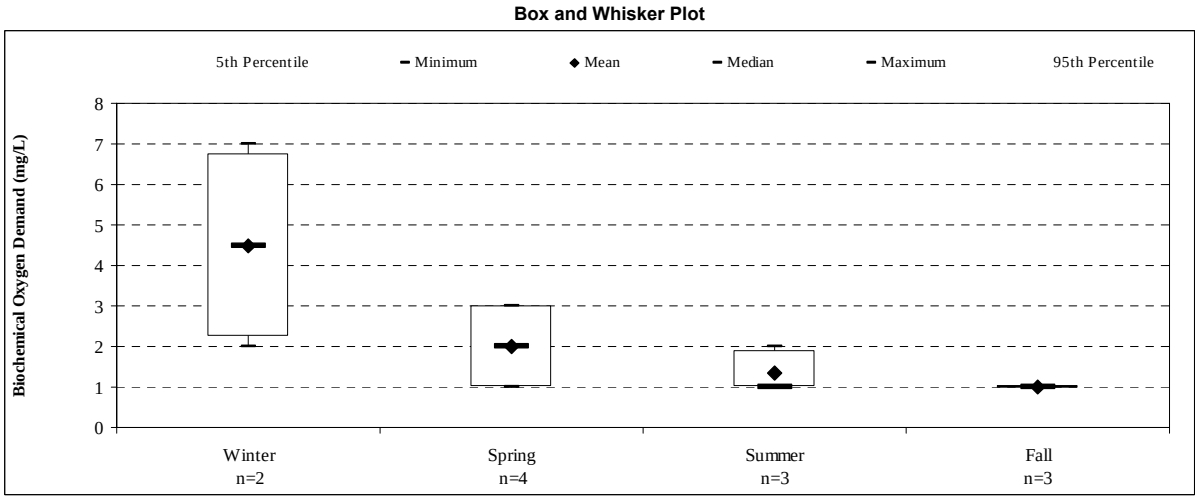


Figure G-3-1-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Pierre River



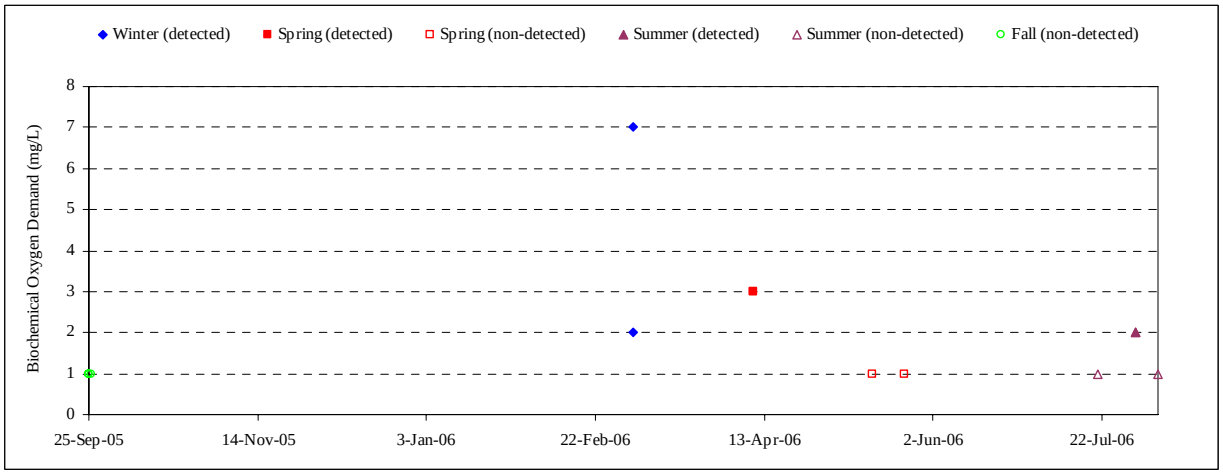
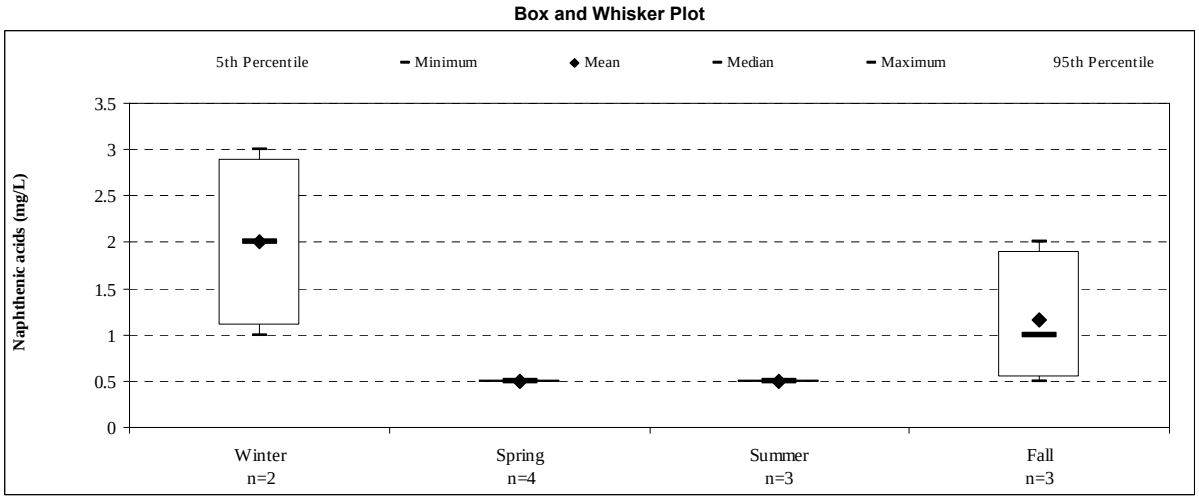


Figure G-3-1-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Pierre River



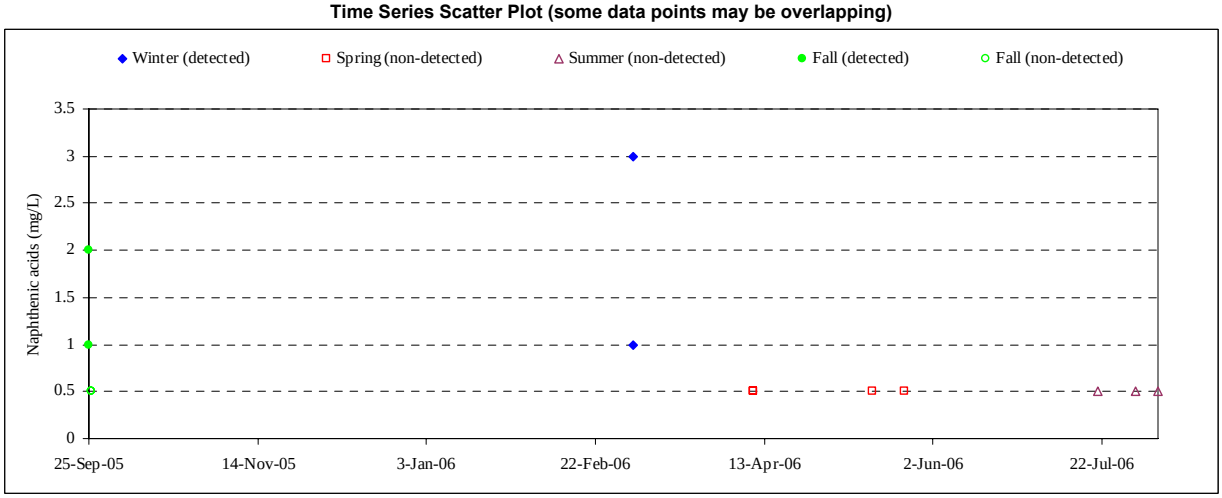
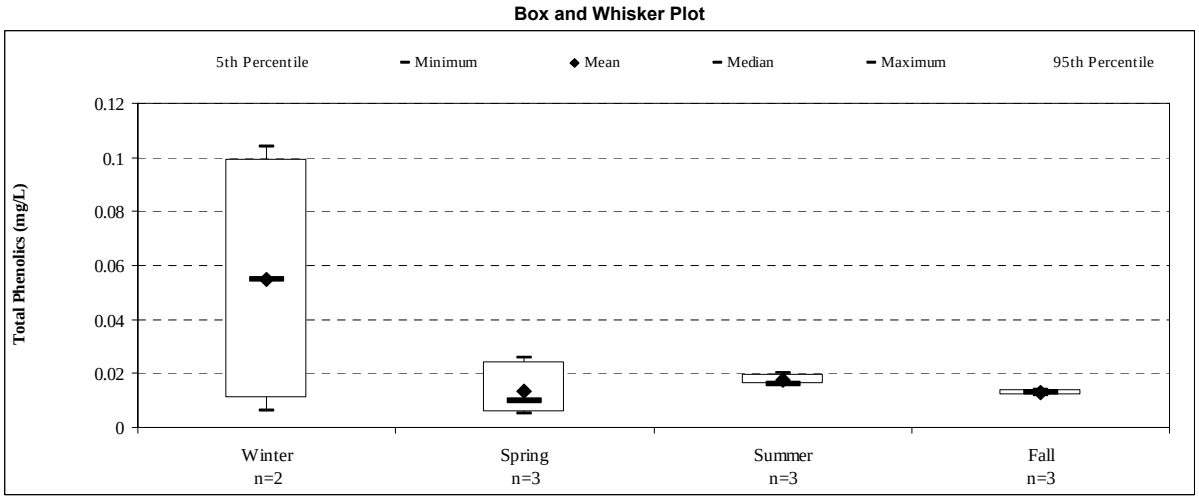


Figure G-3-1-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Pierre River



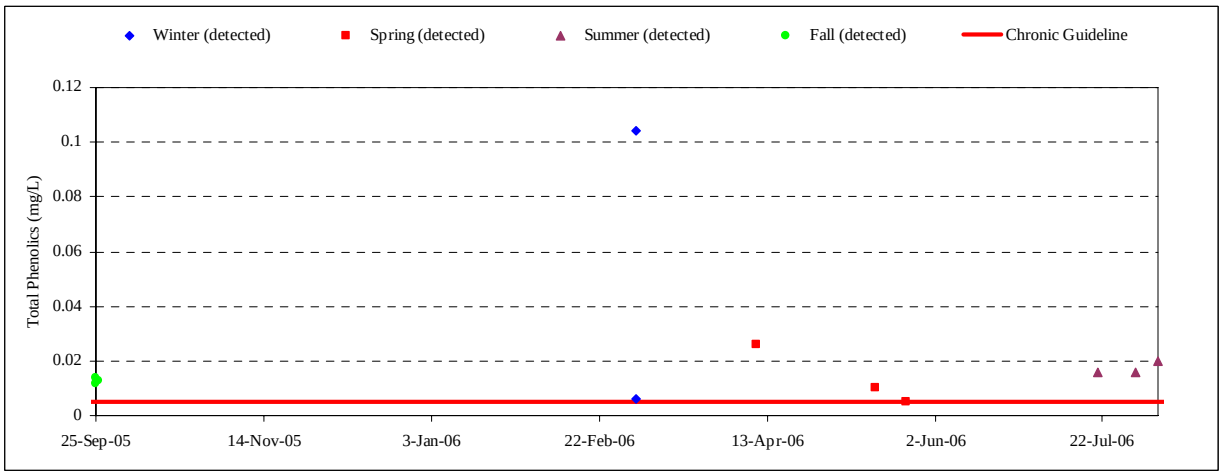
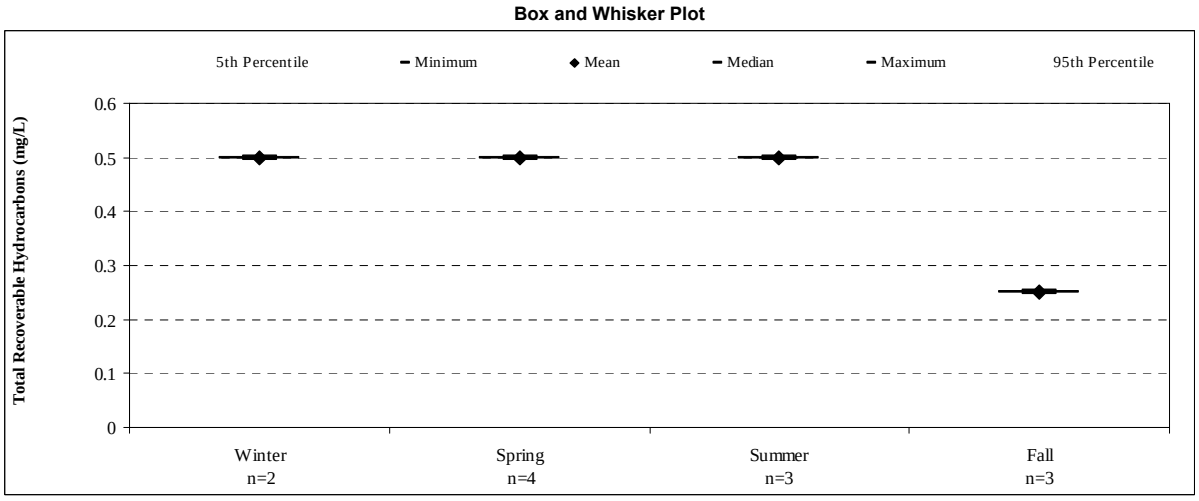


Figure G-3-1-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Pierre River



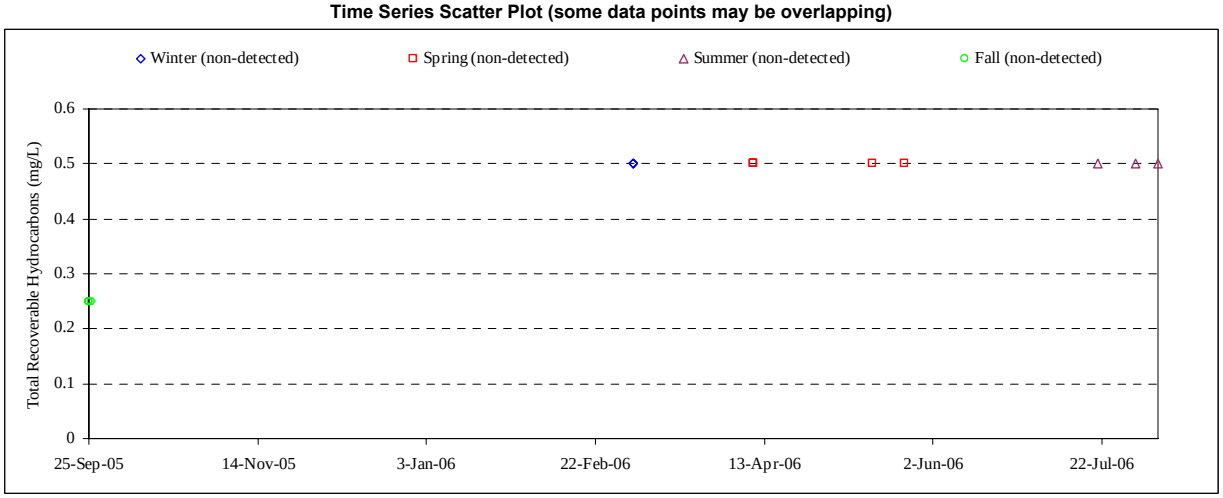
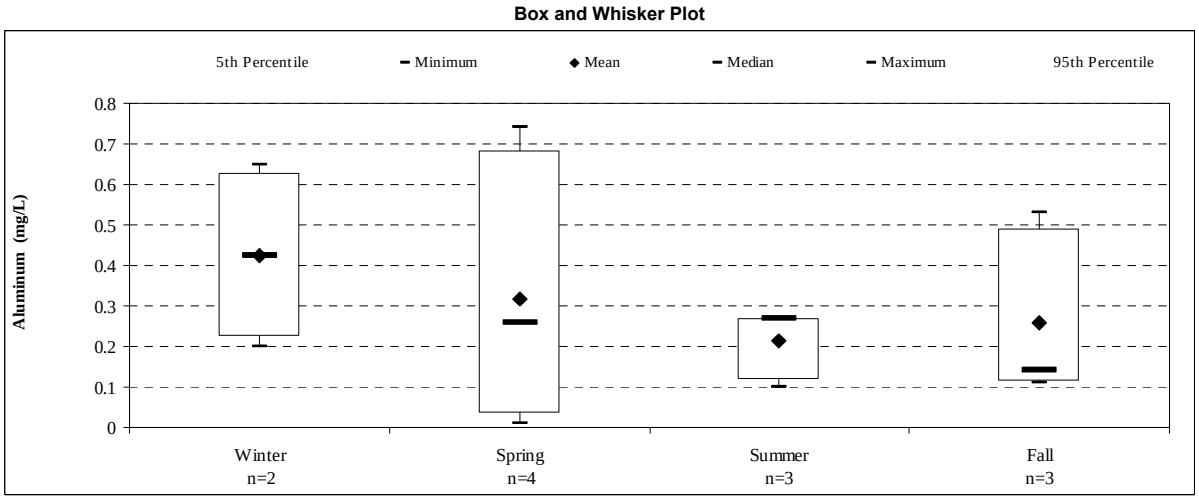


Figure G-3-1-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Pierre River



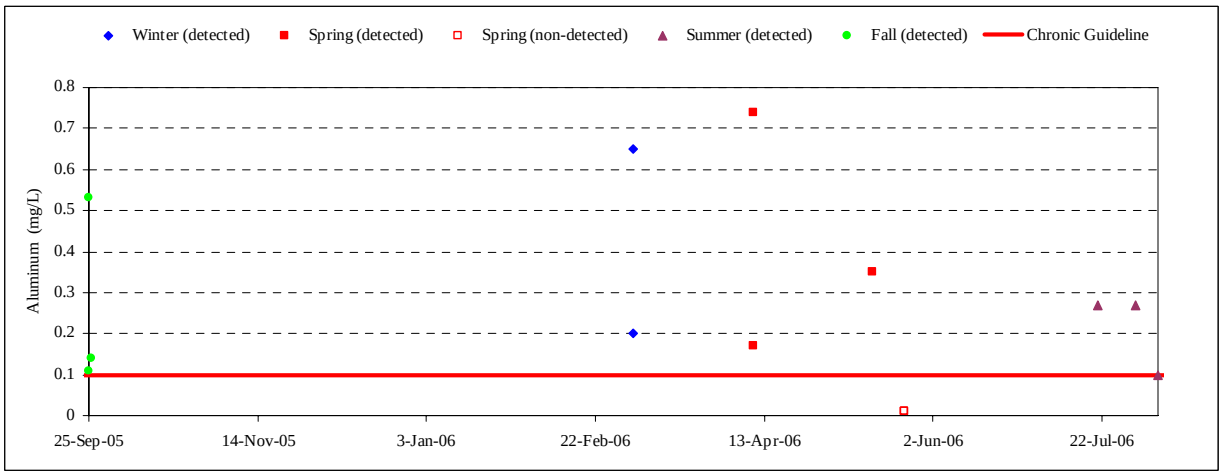
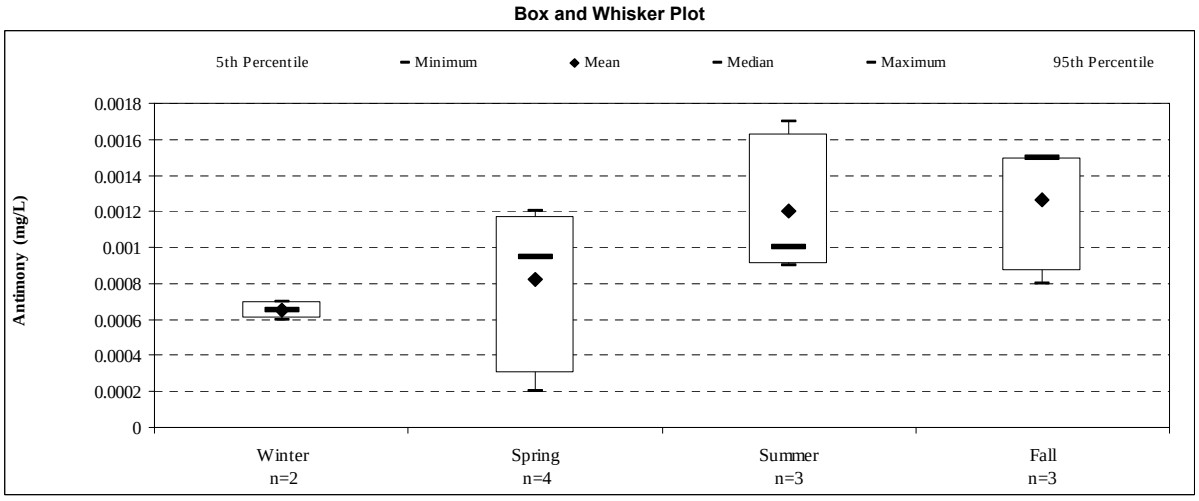


Figure G-3-1-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Pierre River



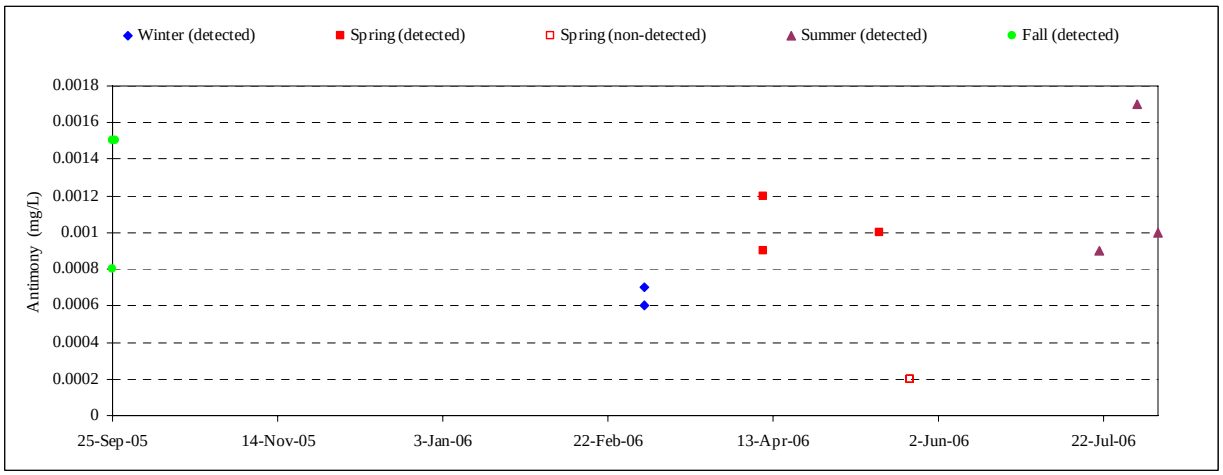
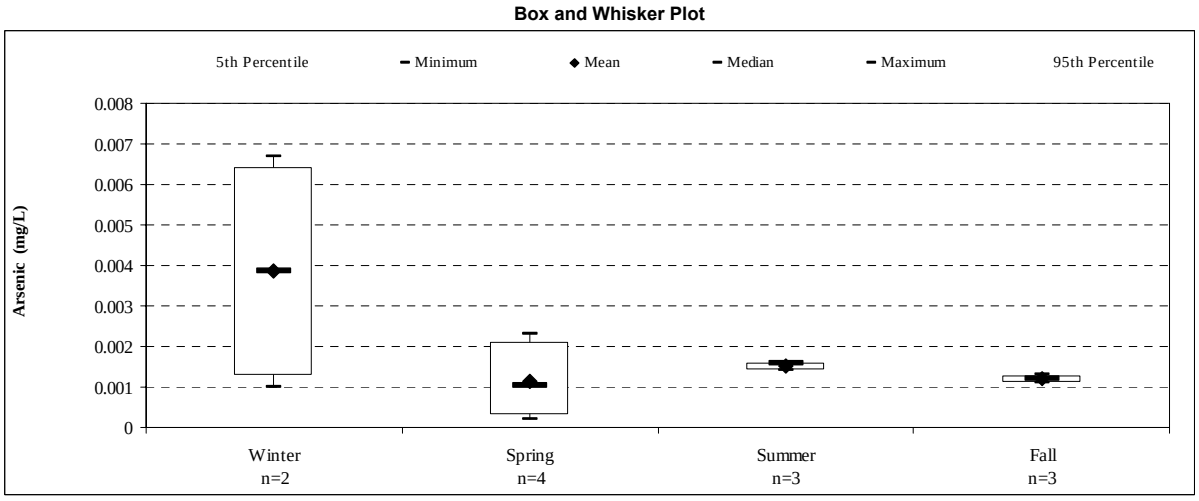


Figure G-3-1-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Pierre River



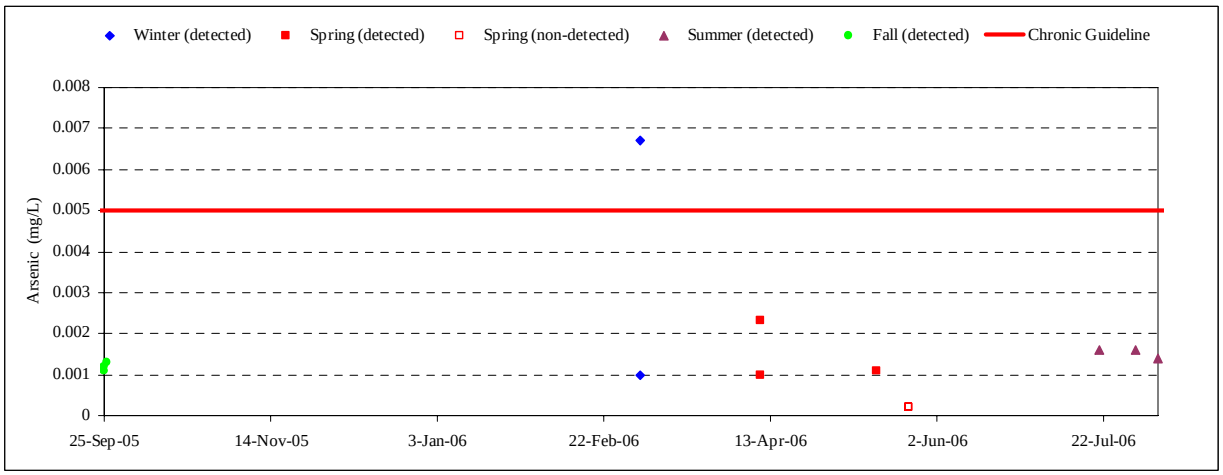
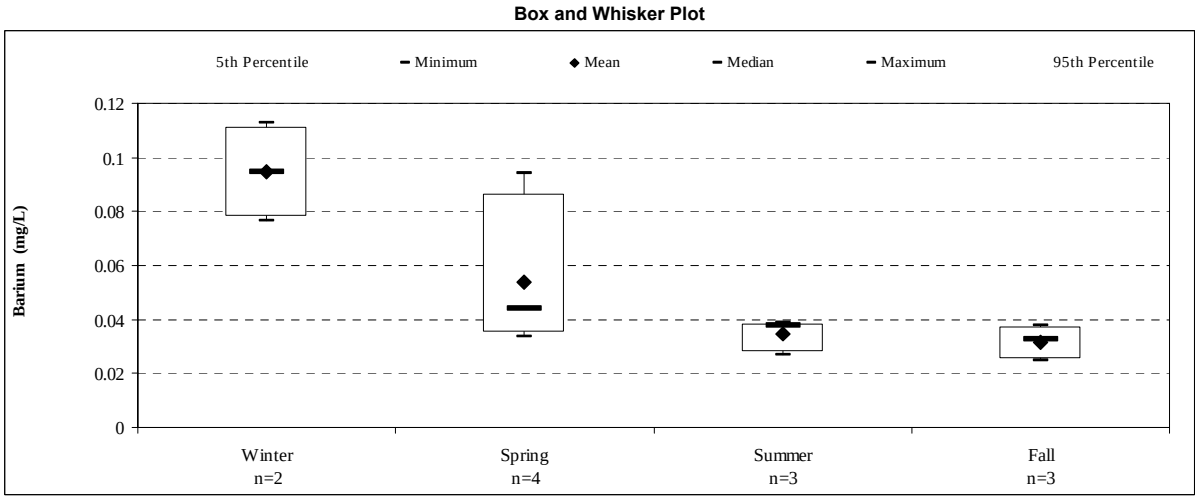


Figure G-3-1-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Pierre River



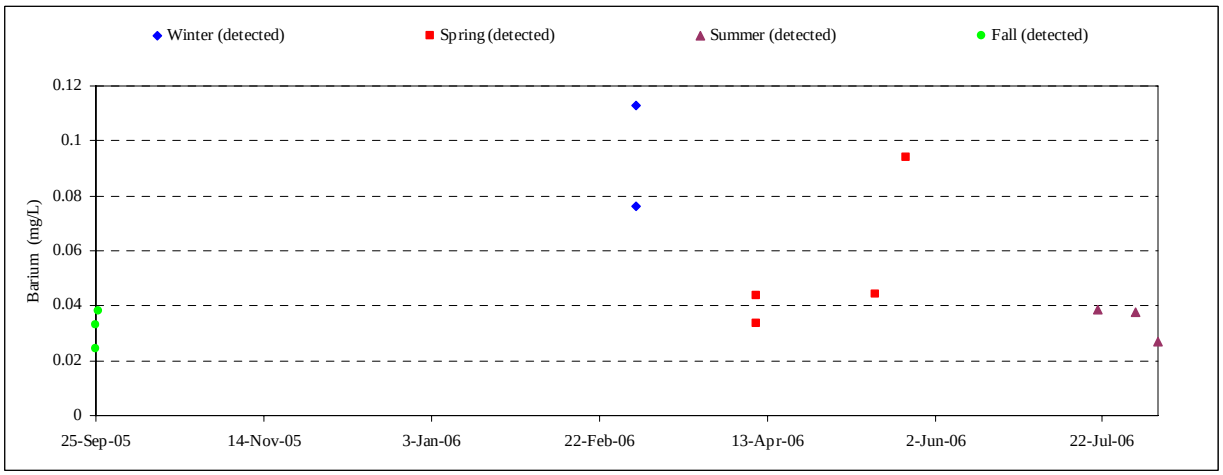
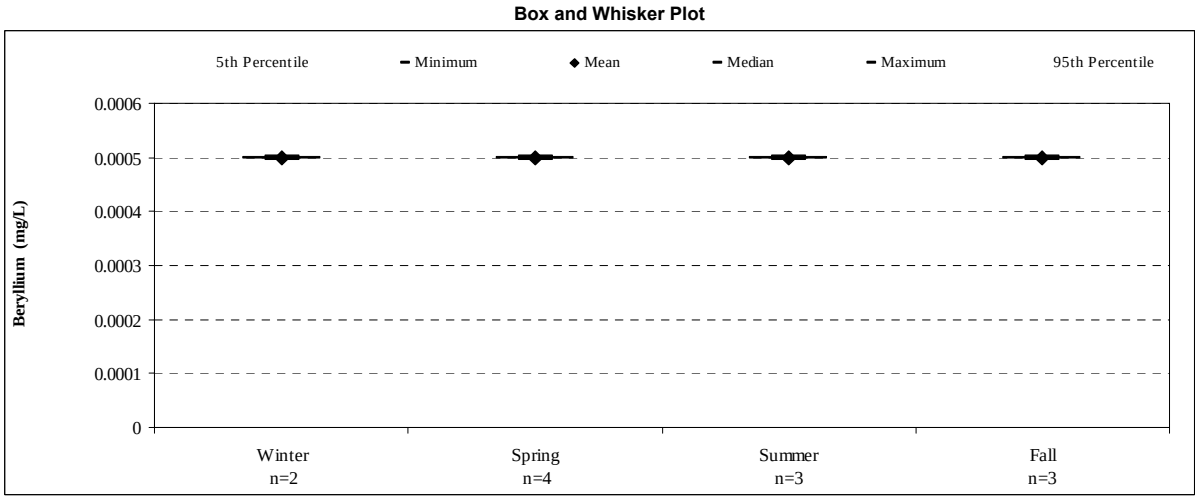


Figure G-3-1-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Pierre River



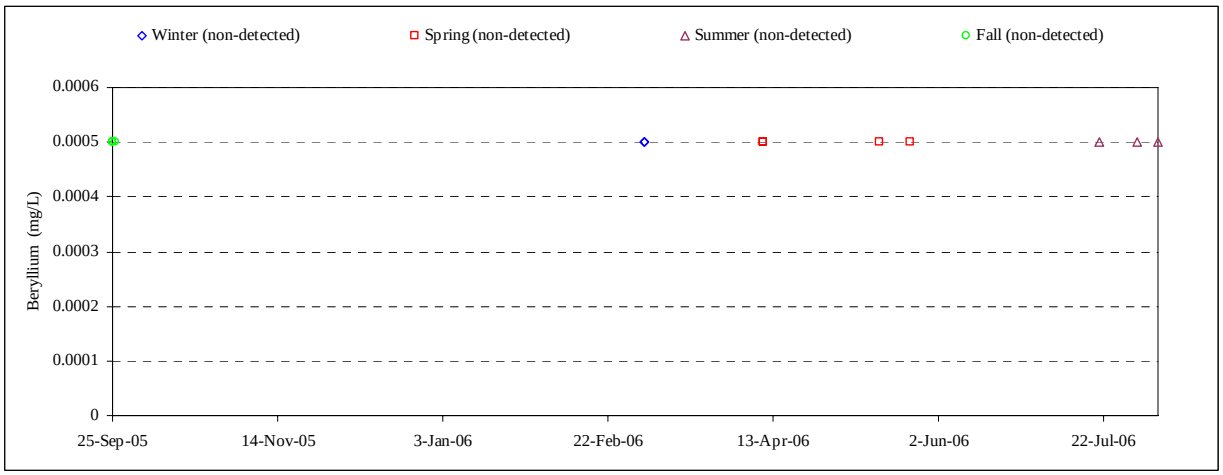
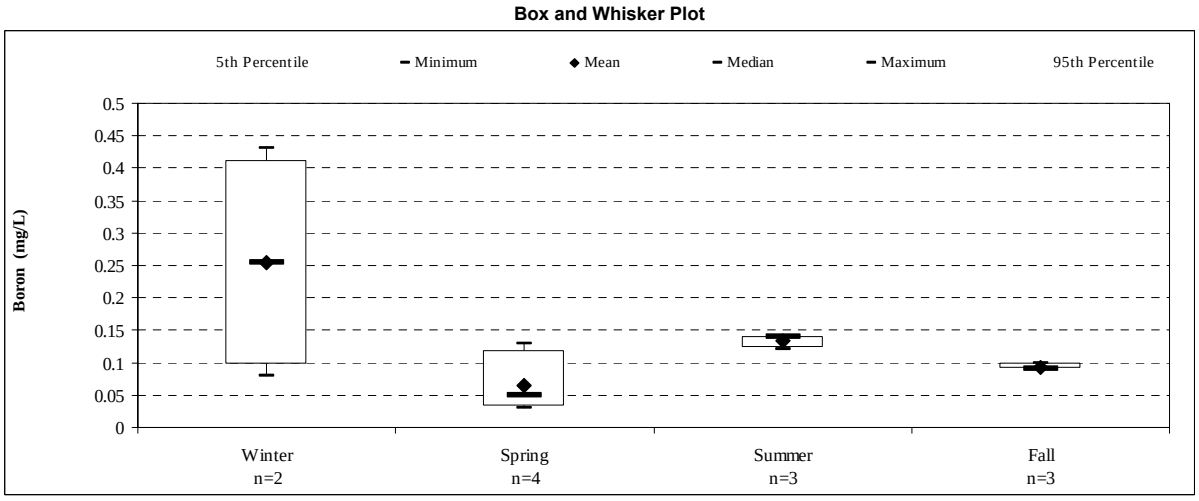


Figure G-3-1-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Pierre River



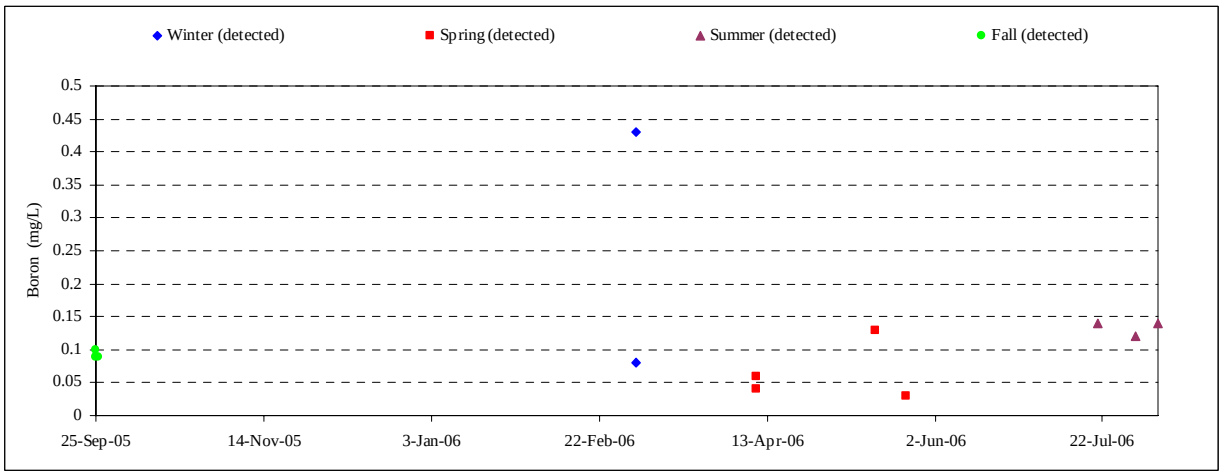
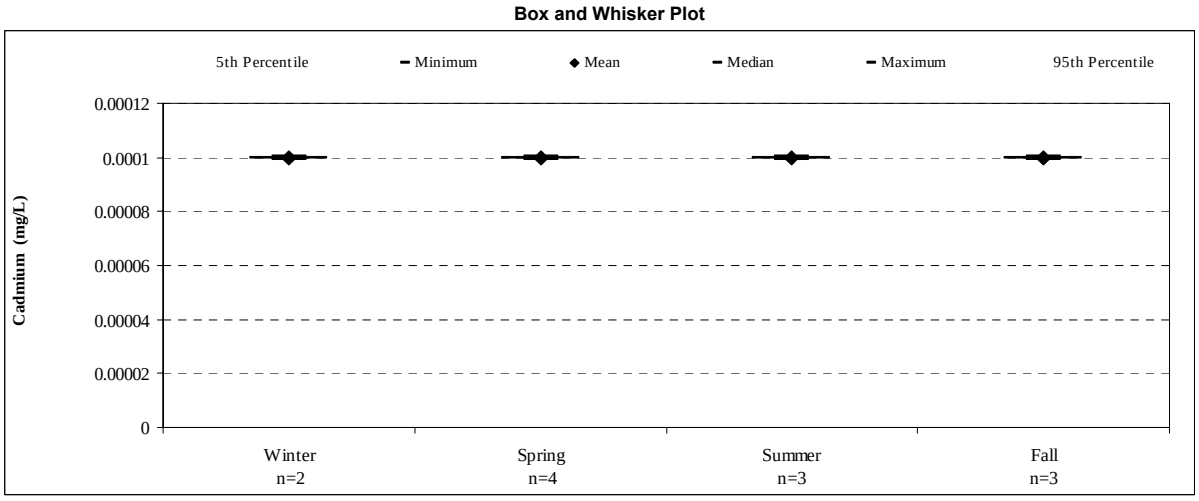


Figure G-3-1-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Pierre River



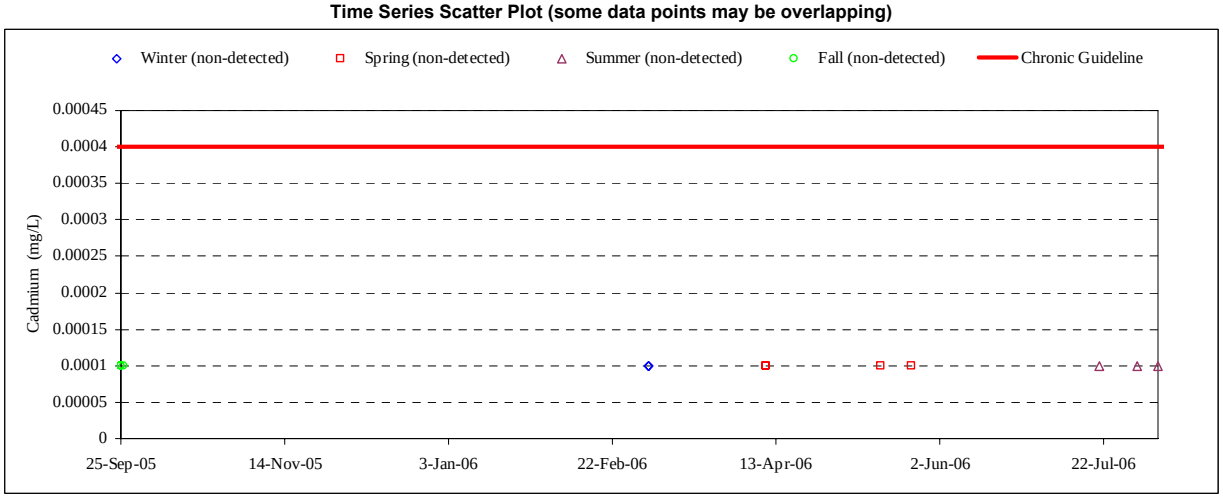
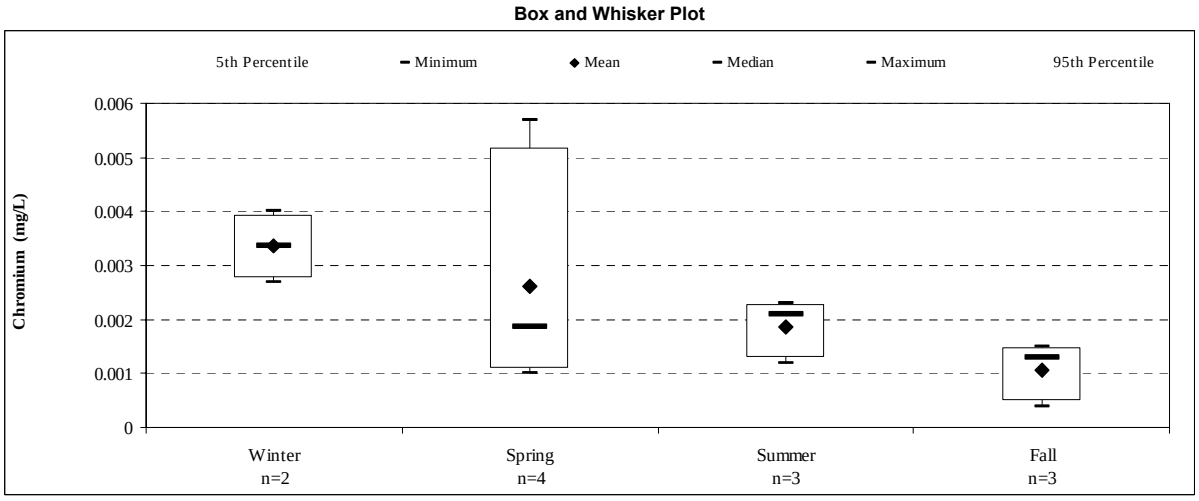


Figure G-3-1-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Pierre River



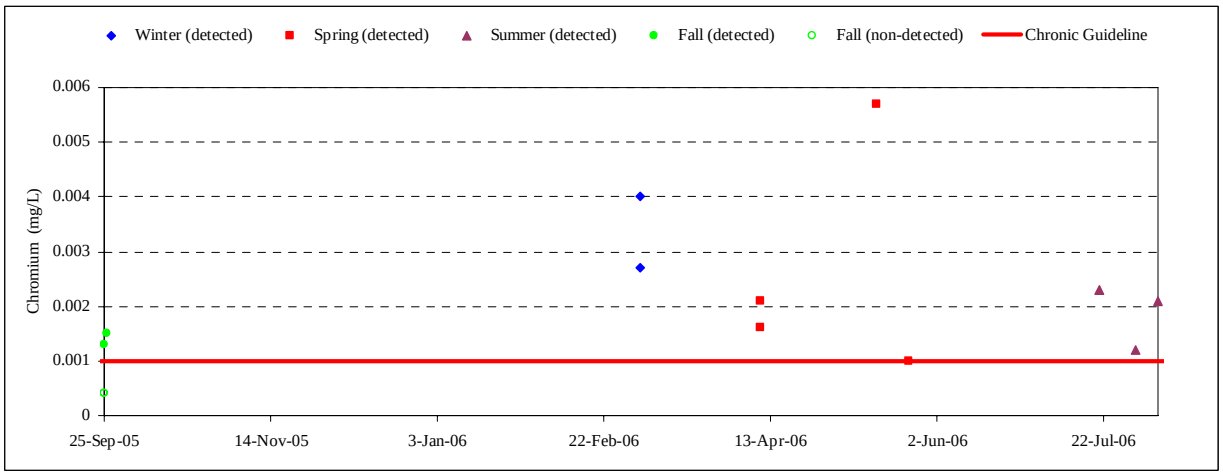
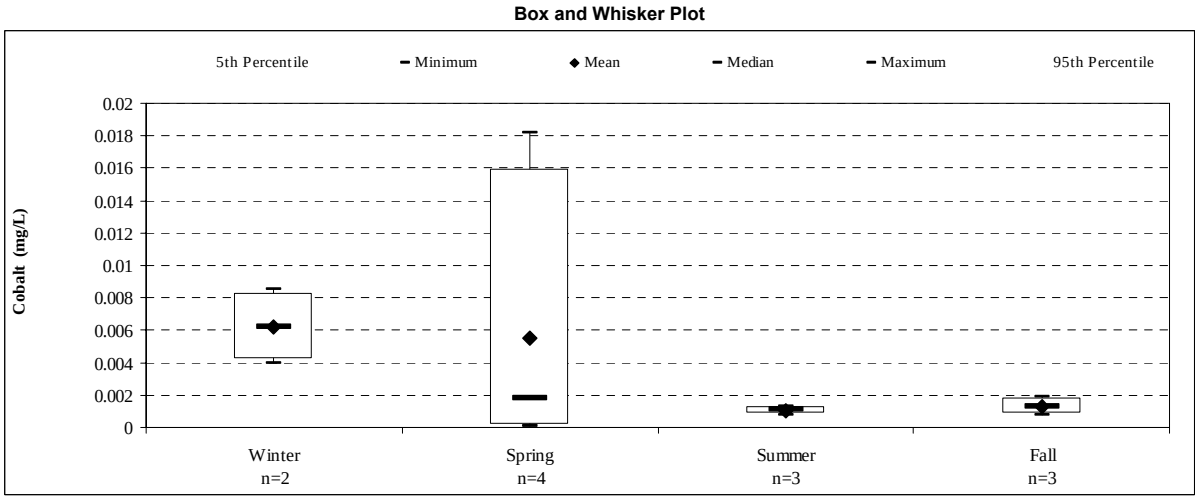


Figure G-3-1-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Pierre River



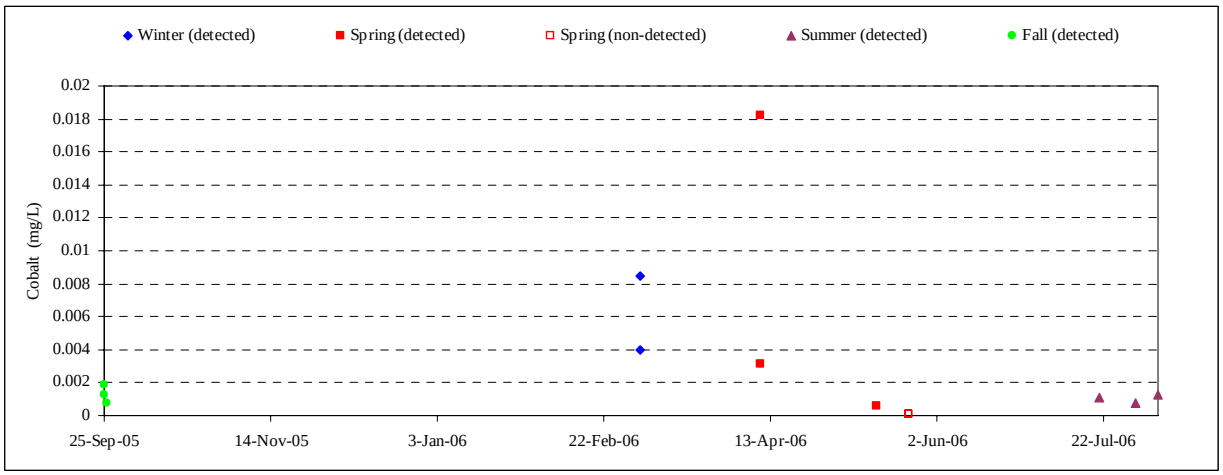
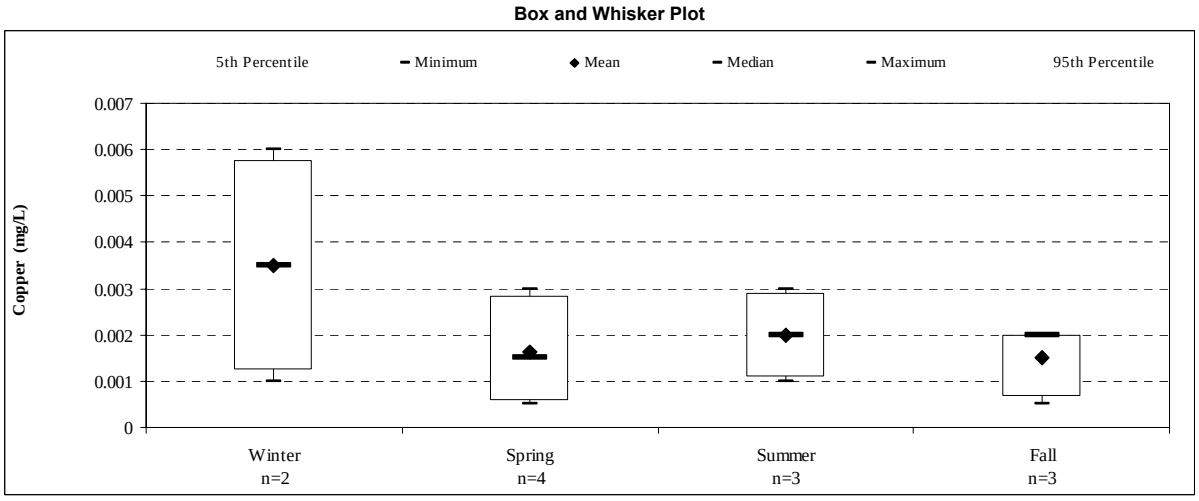


Figure G-3-1-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Pierre River



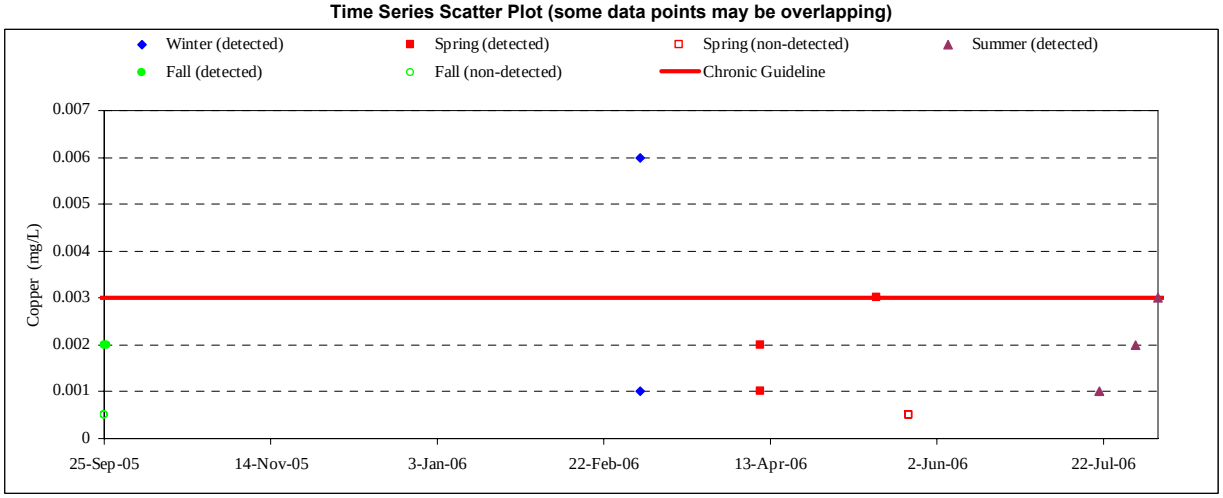
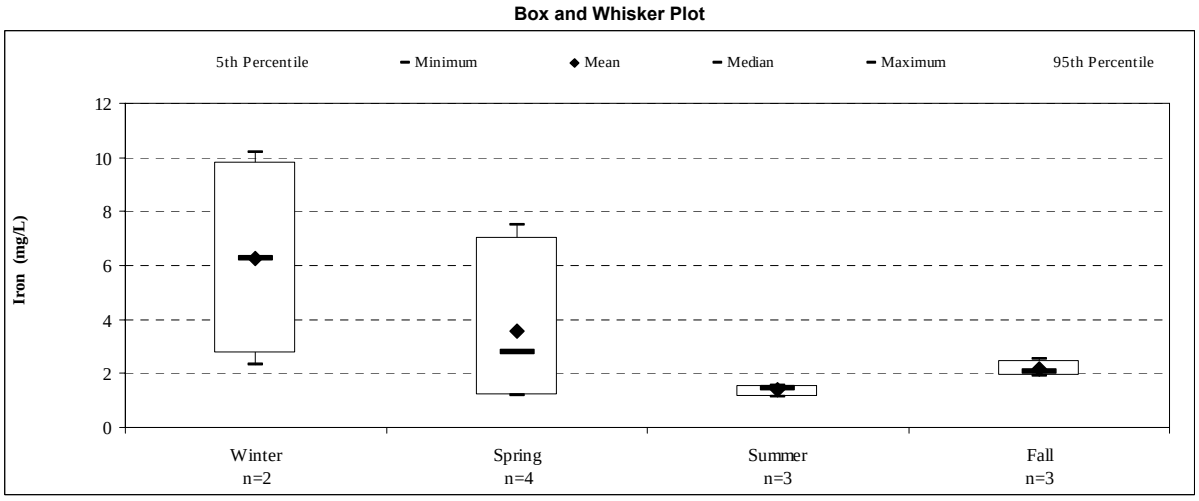


Figure G-3-1-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Pierre River



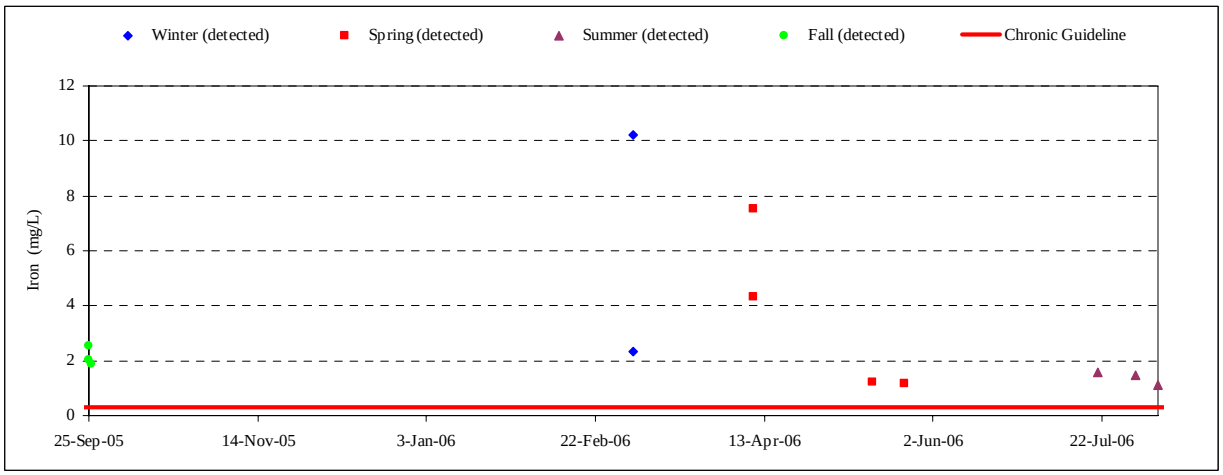
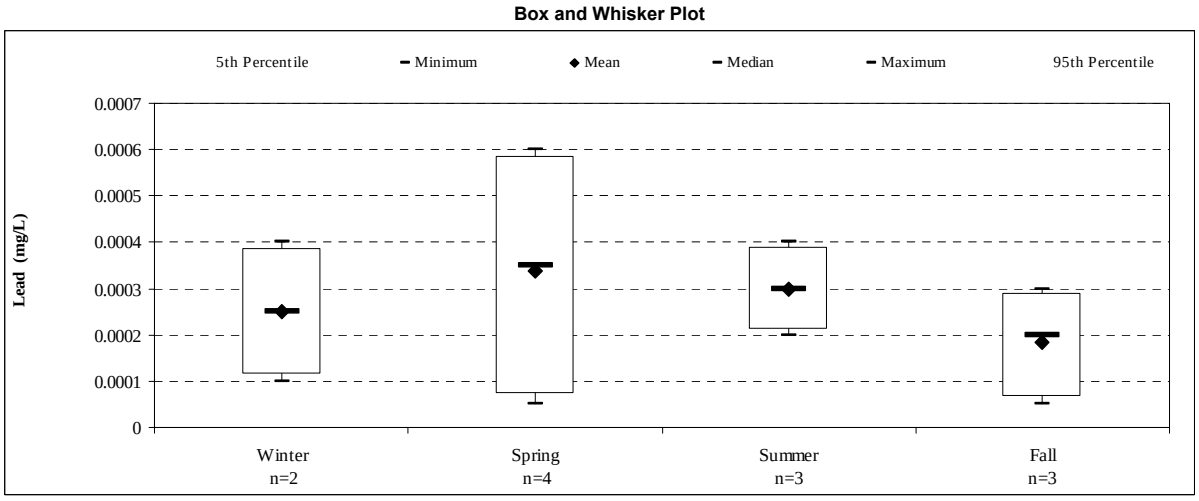


Figure G-3-1-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Pierre River



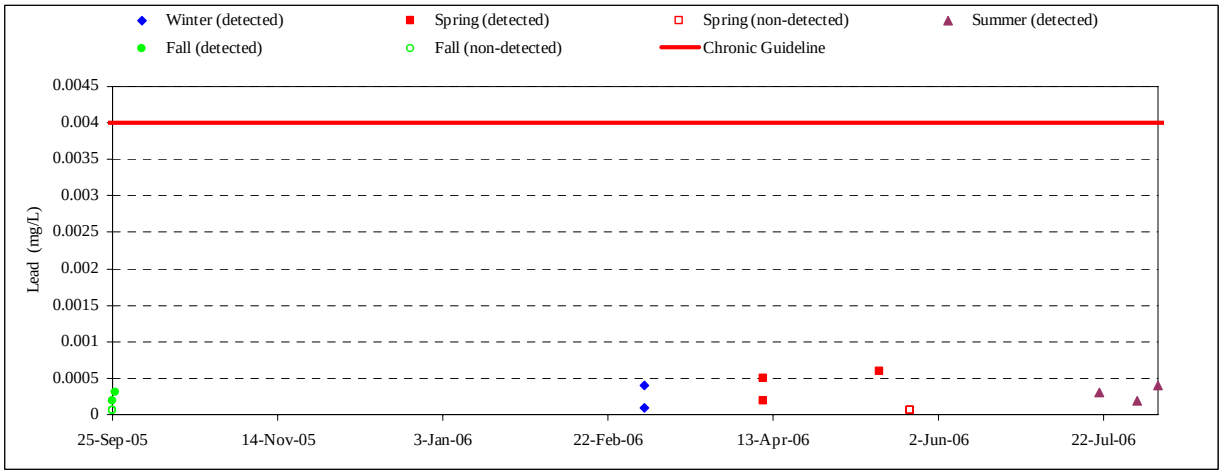
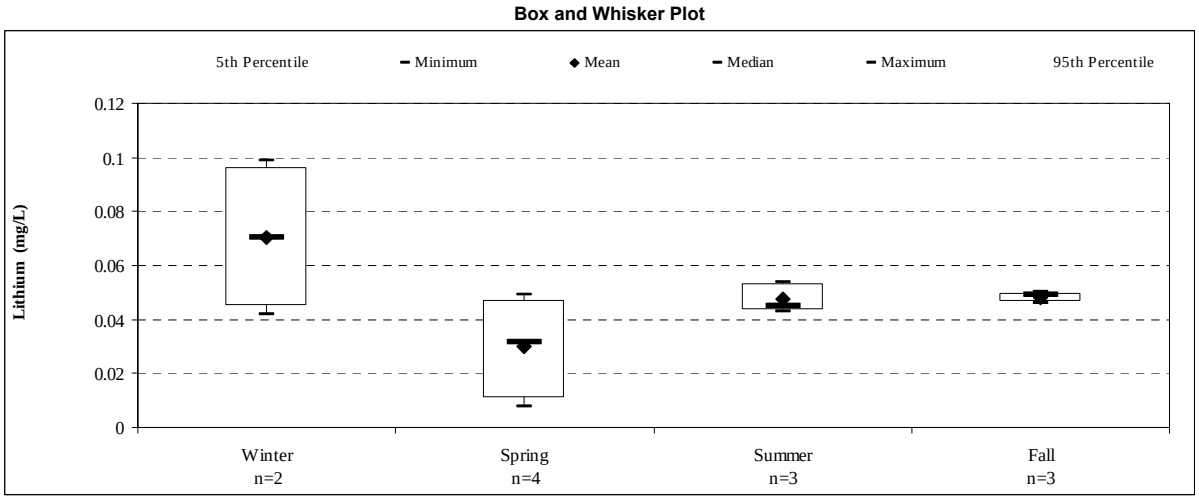


Figure G-3-1-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Pierre River



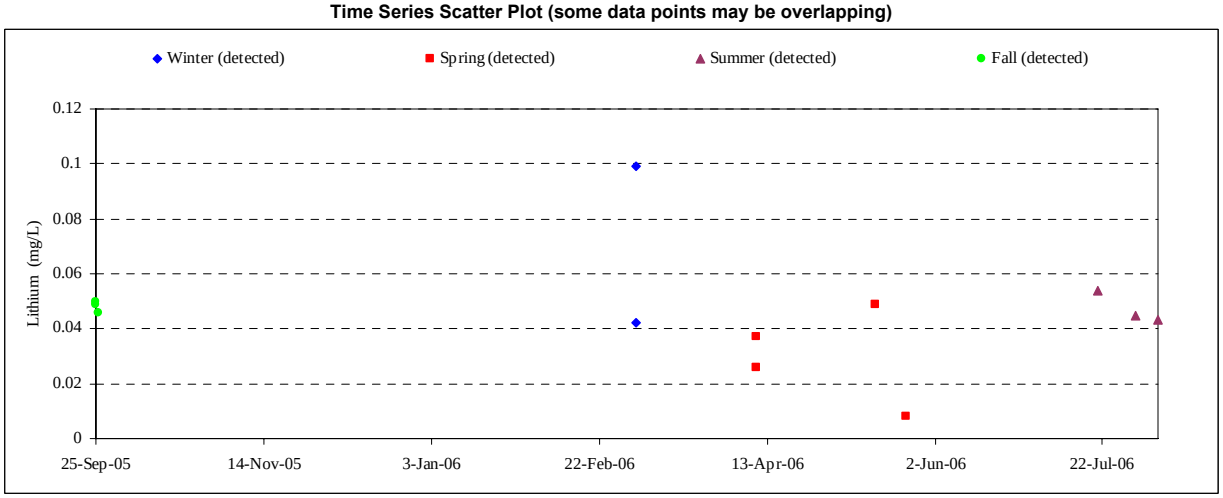
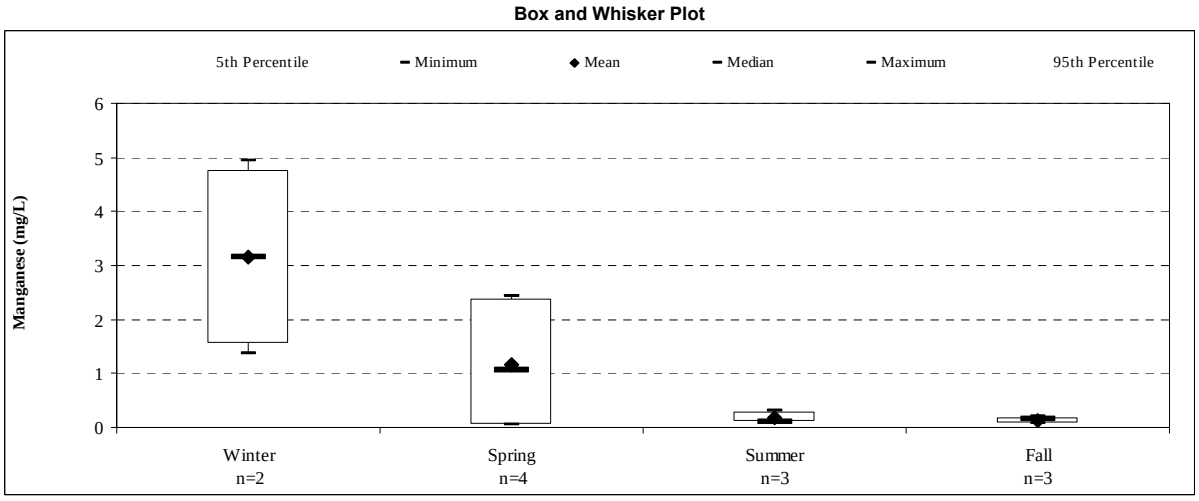


Figure G-3-1-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Pierre River



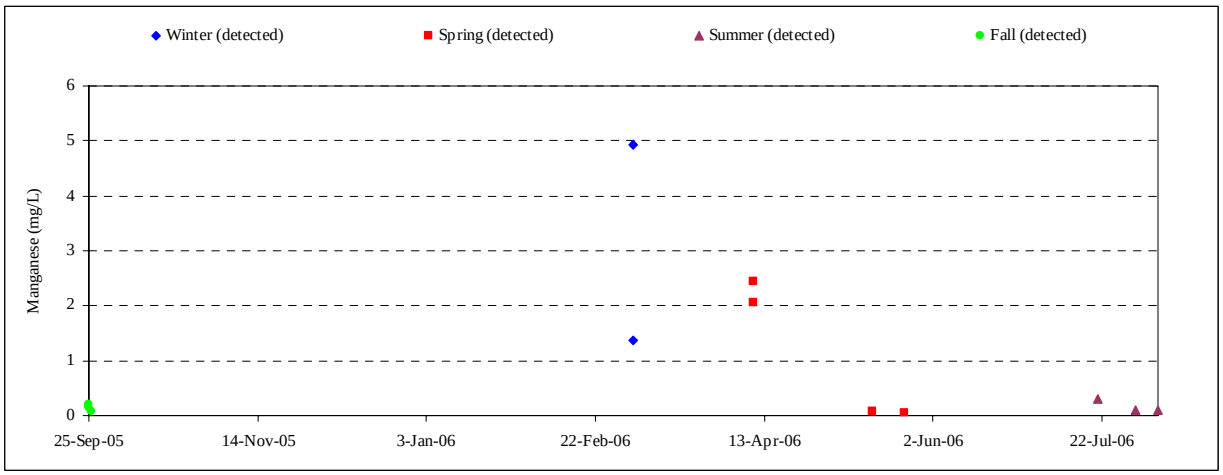
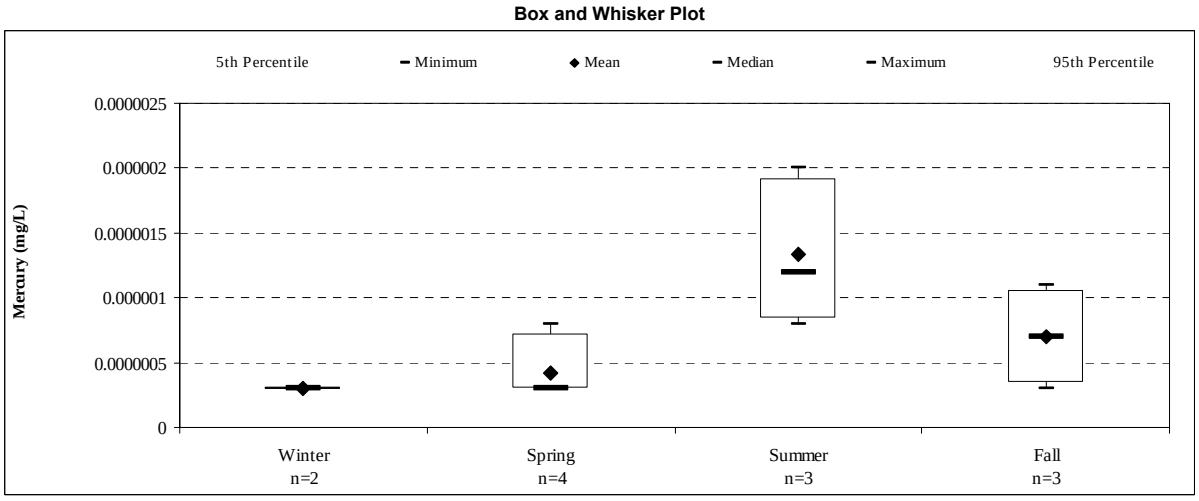


Figure G-3-1-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Pierre River



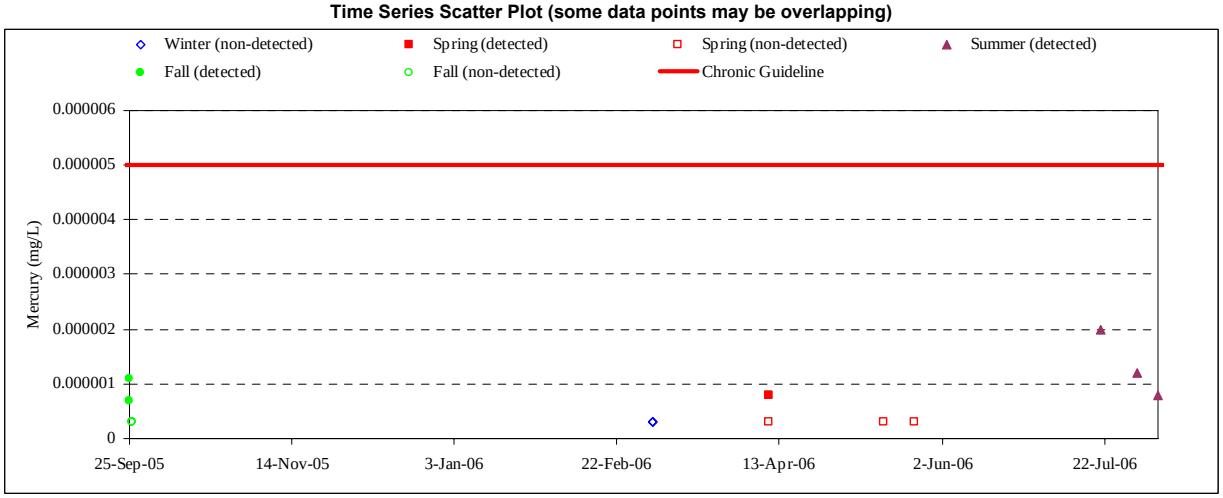
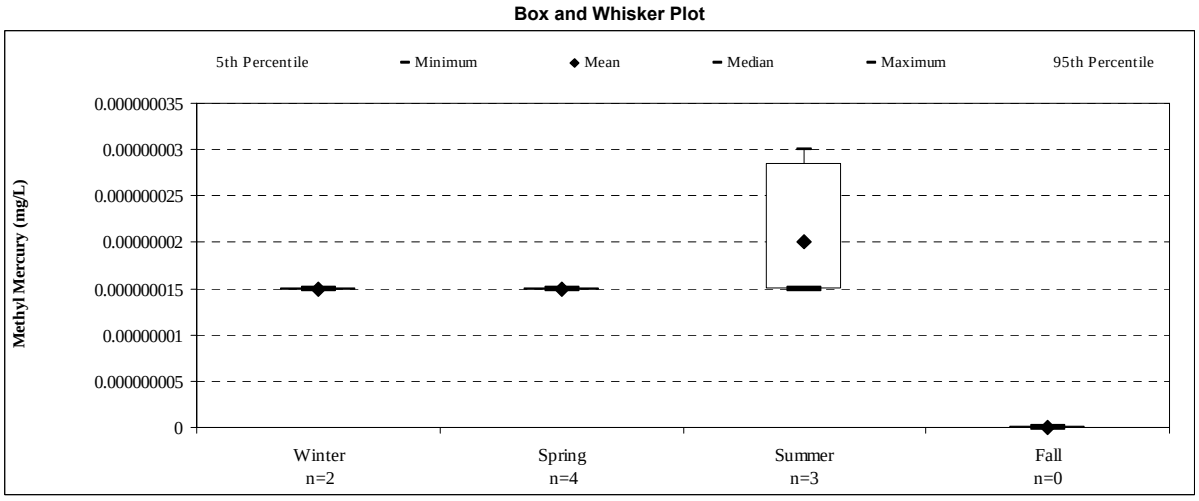


Figure G-3-1-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Pierre River



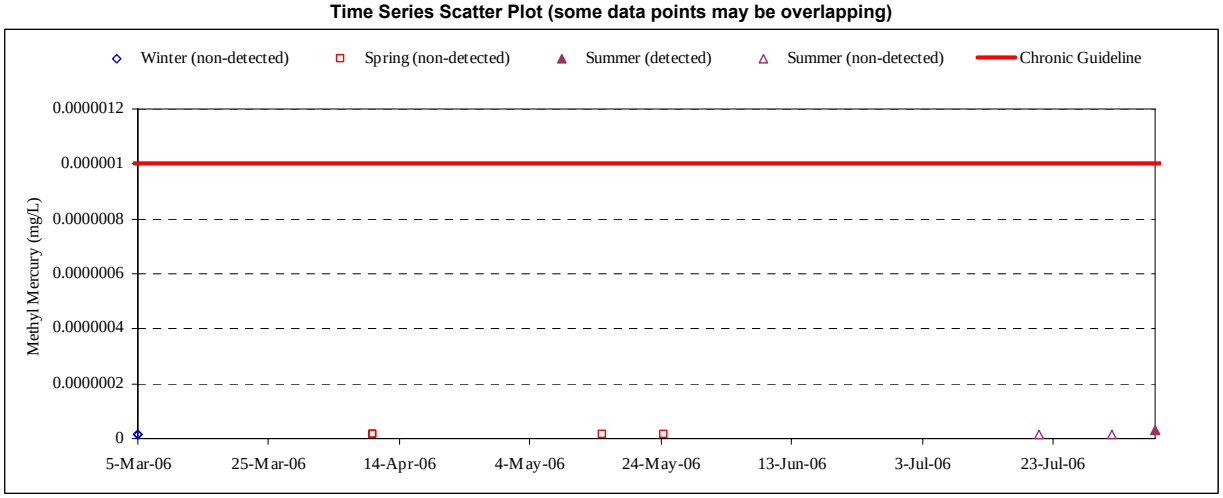
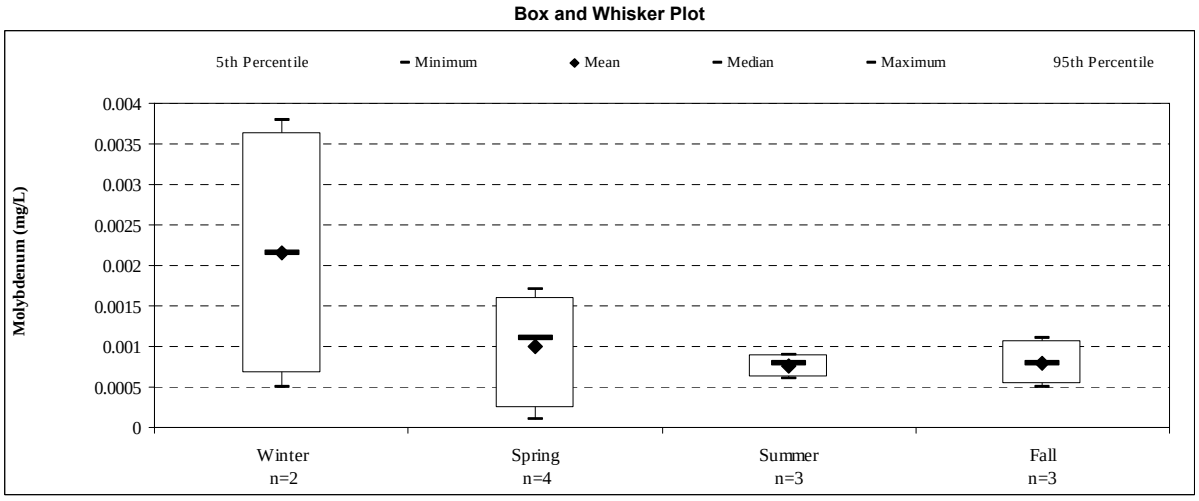


Figure G-3-1-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Pierre River



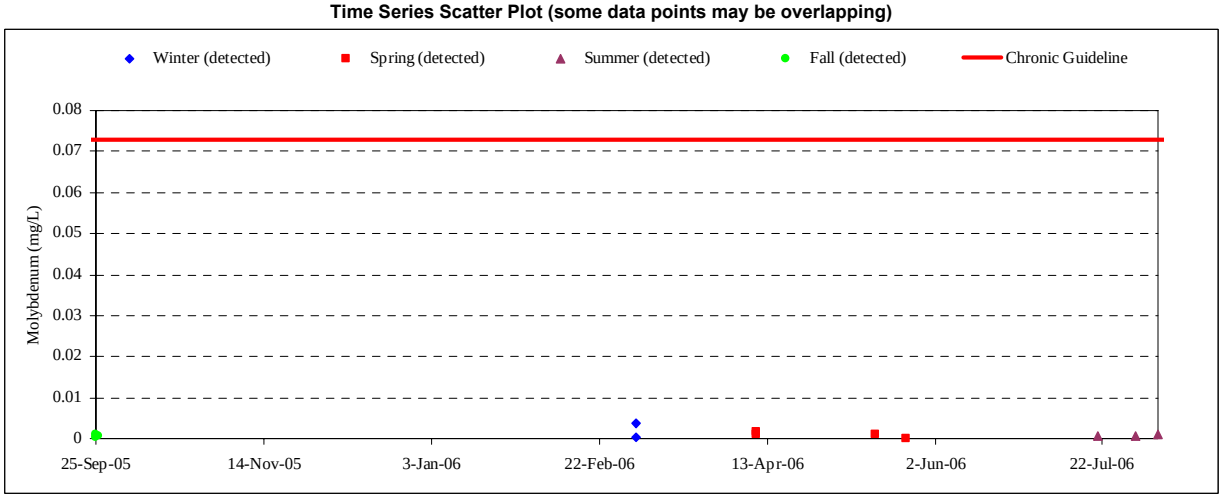
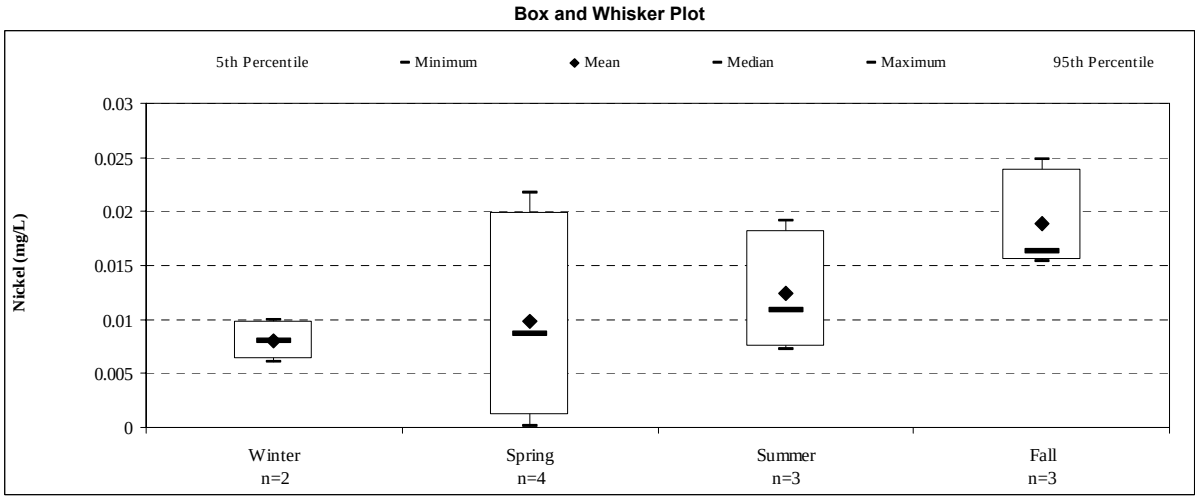


Figure G-3-1-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Pierre River



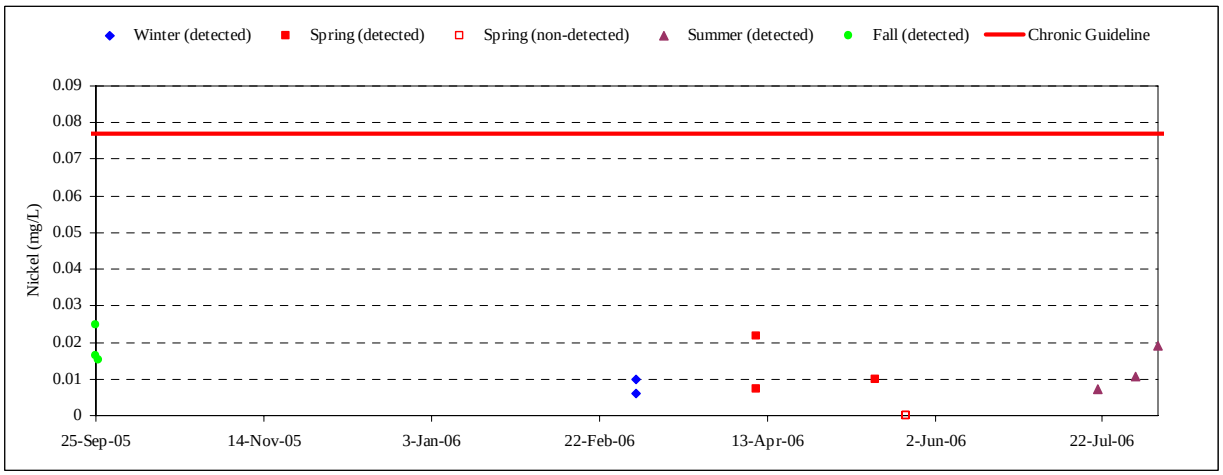
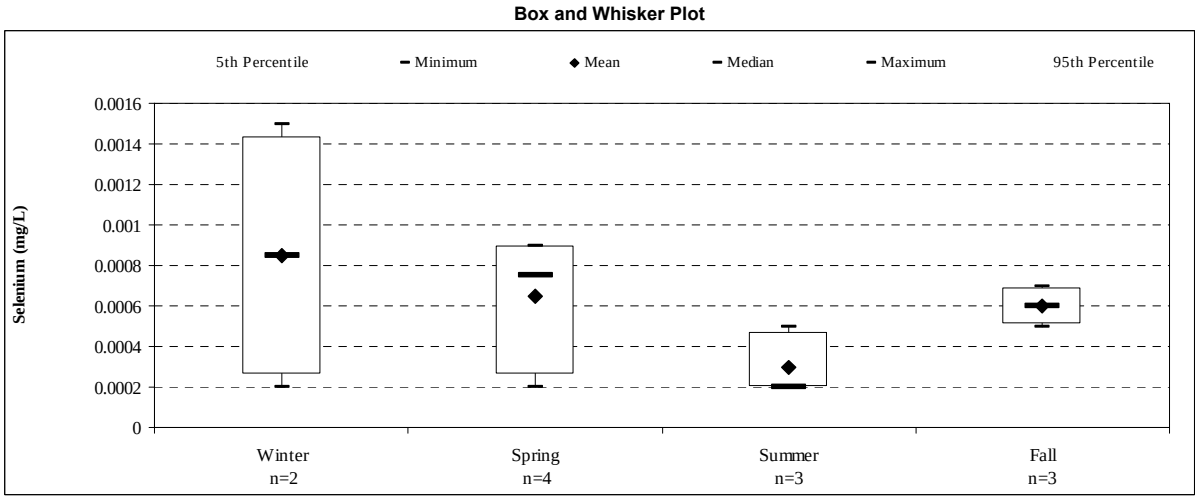


Figure G-3-1-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Pierre River



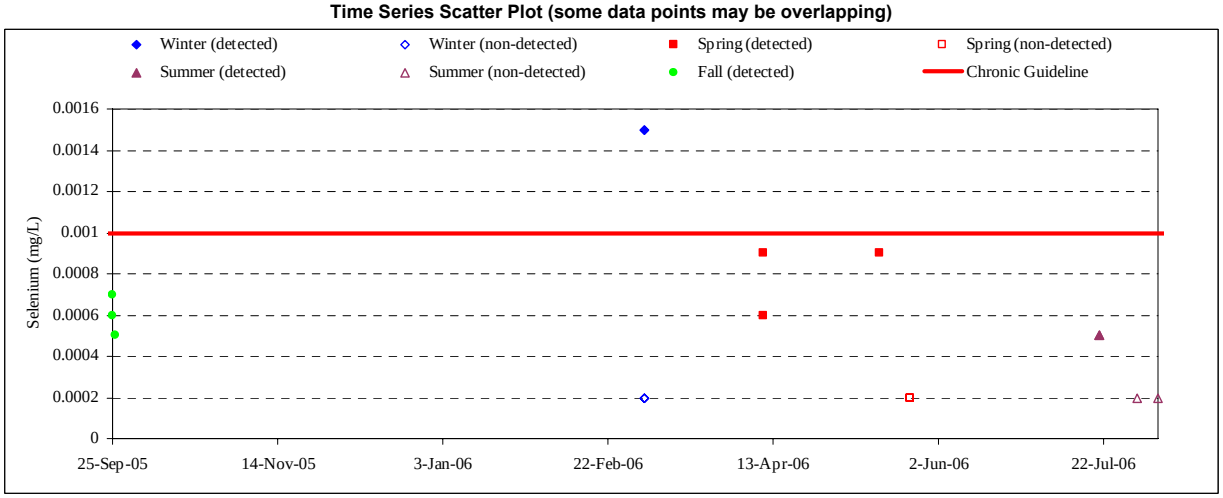
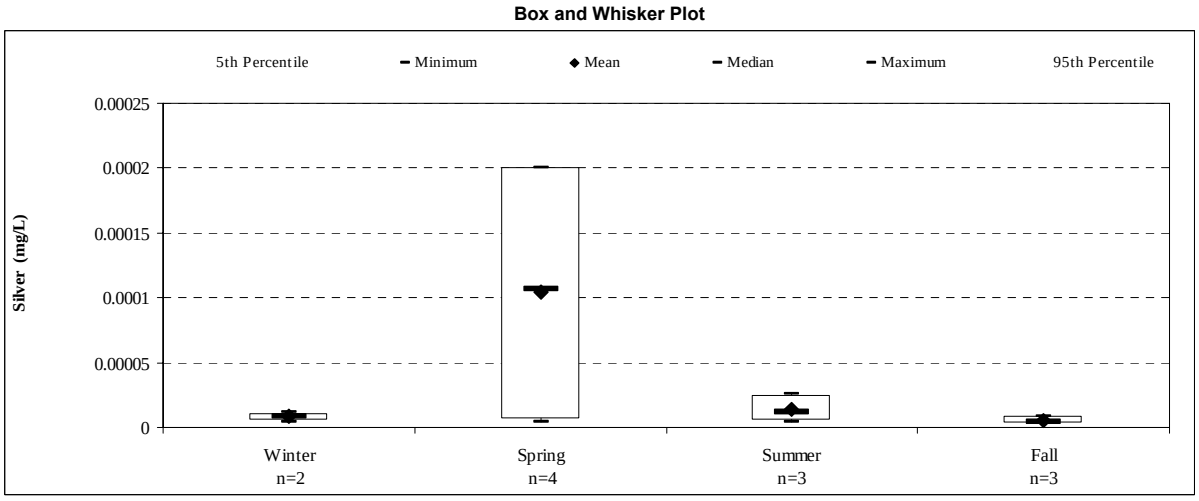


Figure G-3-1-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Pierre River



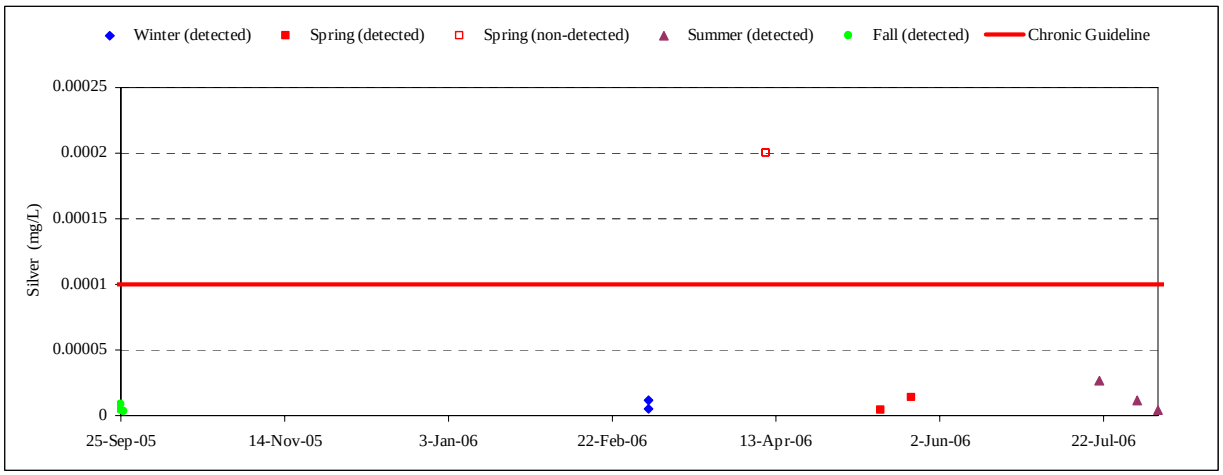
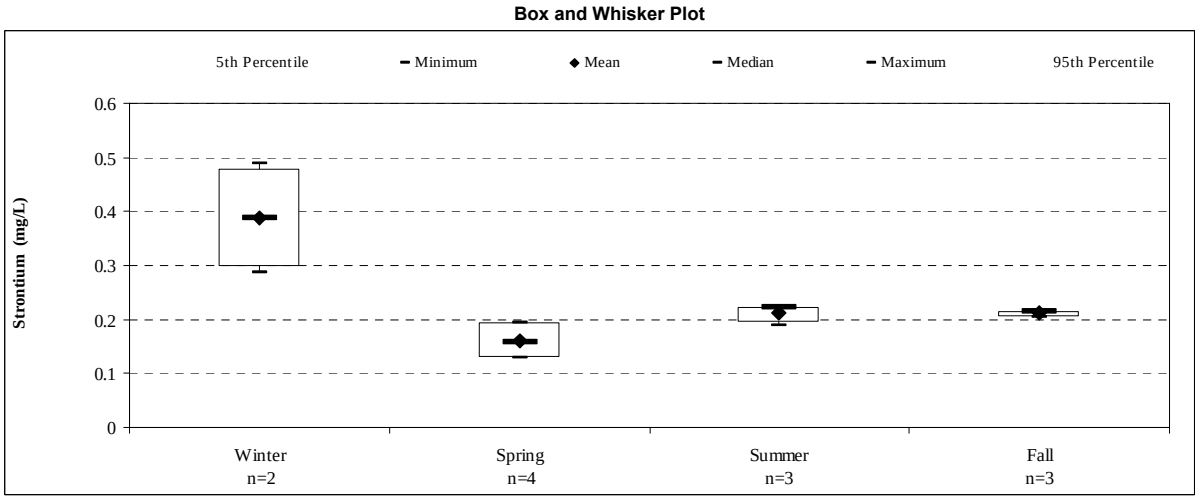


Figure G-3-1-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Pierre River



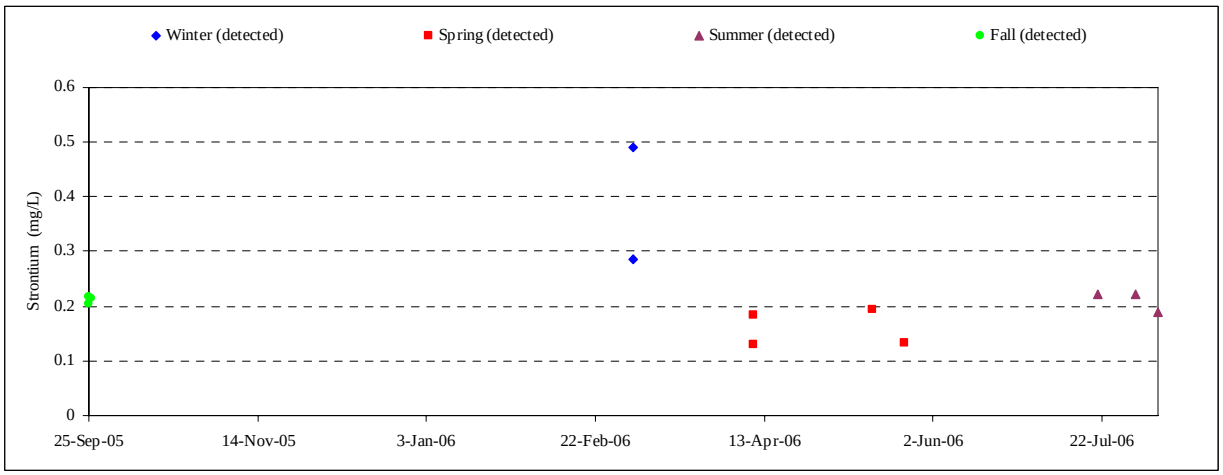
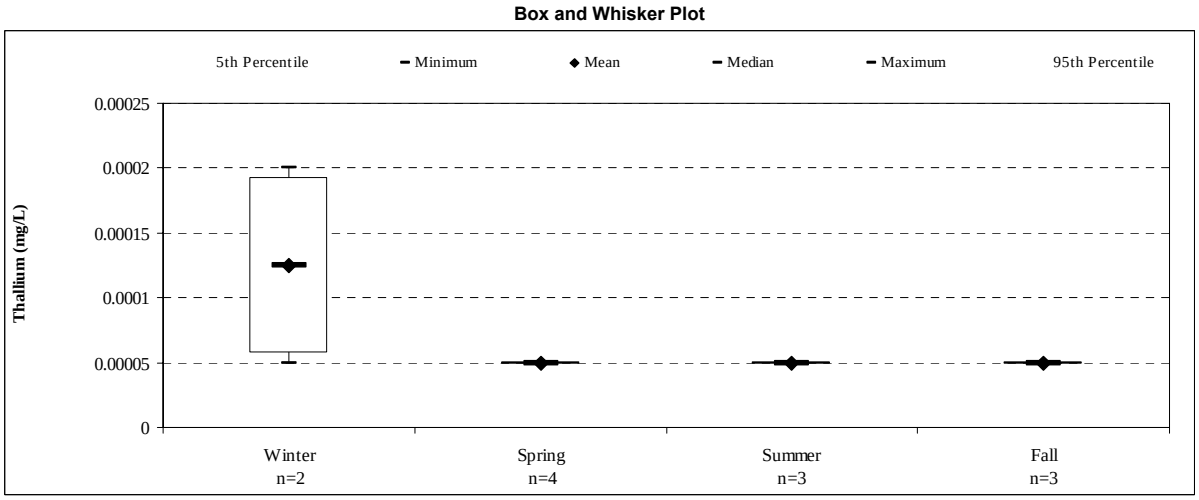


Figure G-3-1-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Pierre River



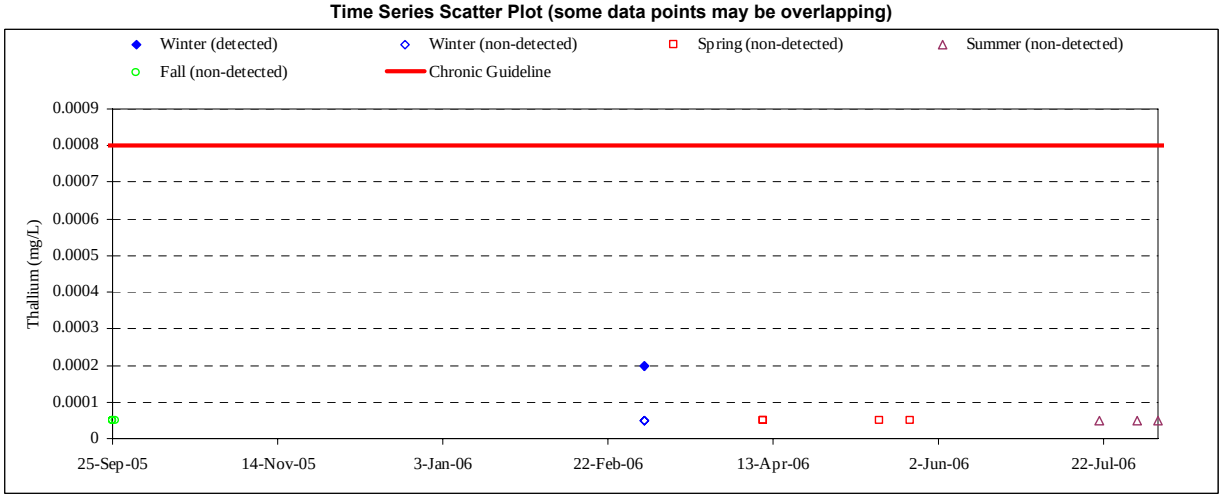
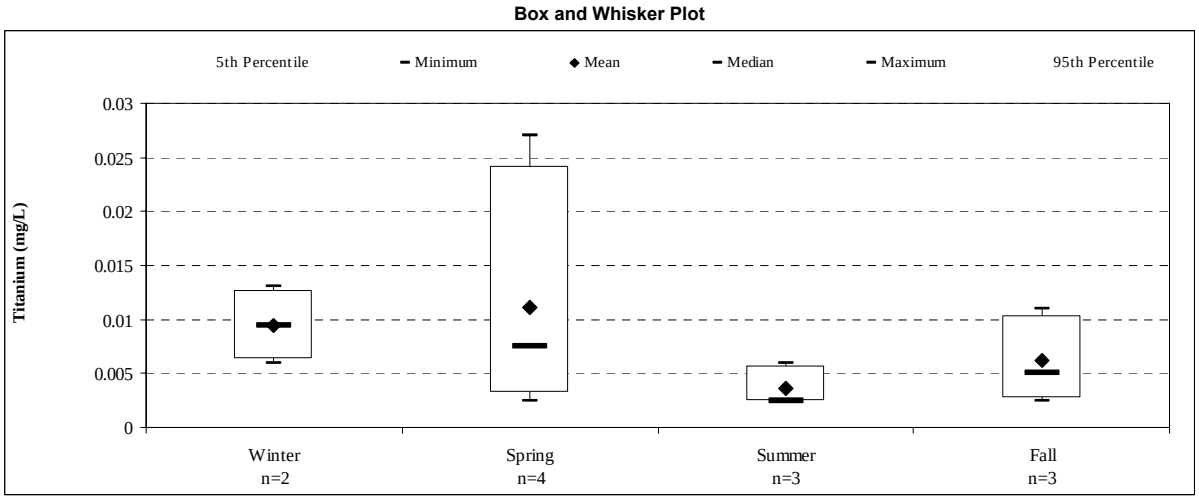


Figure G-3-1-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Pierre River



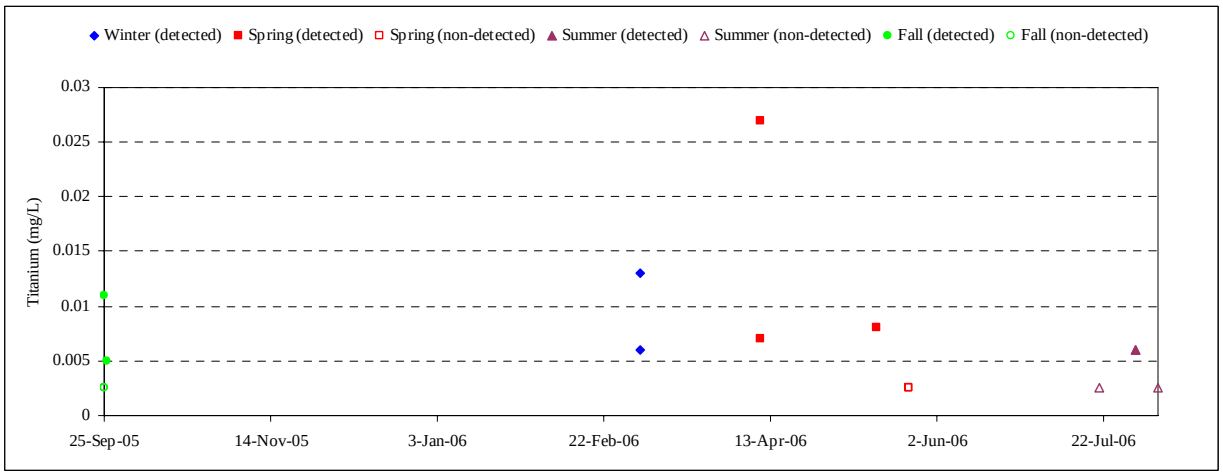
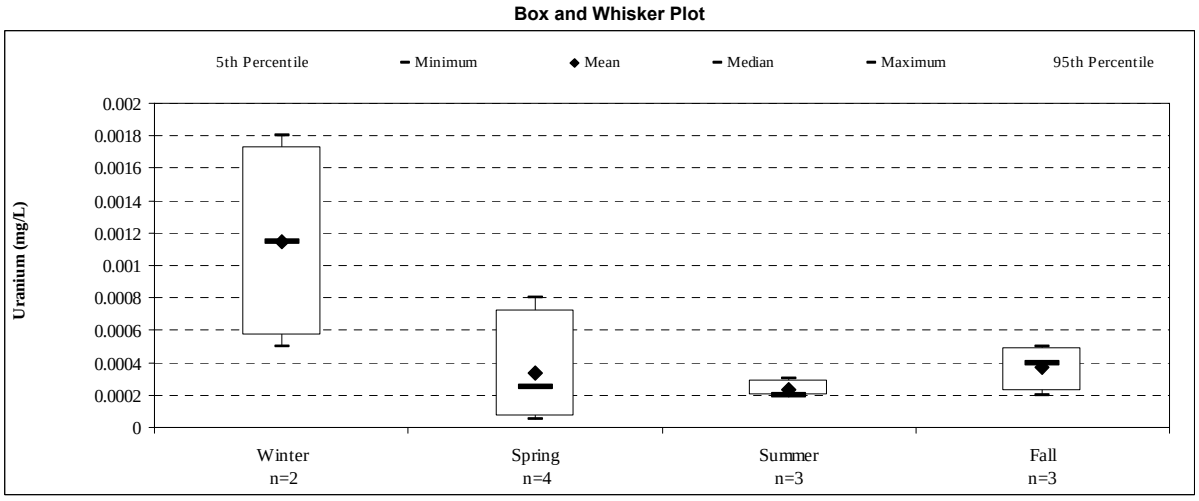


Figure G-3-1-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Pierre River



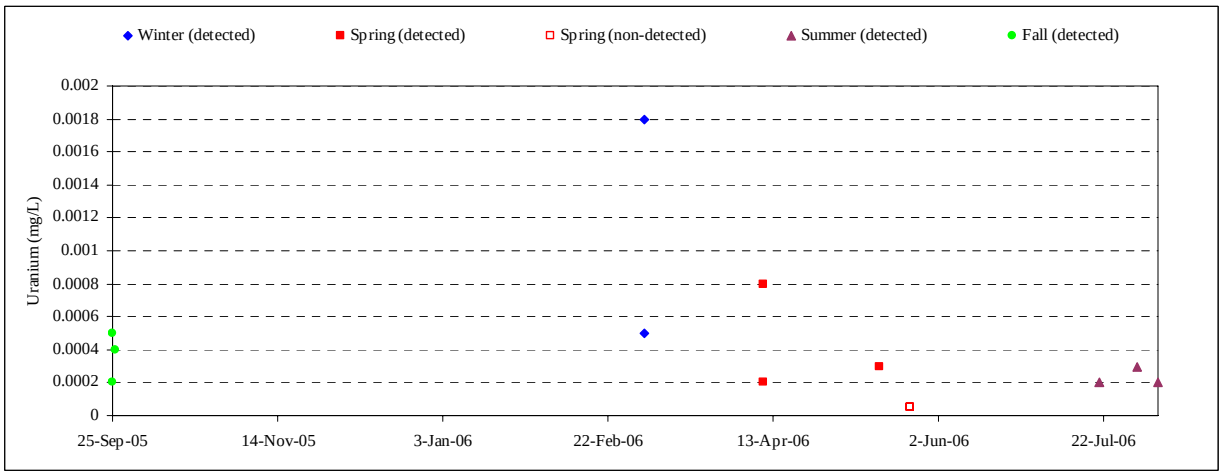
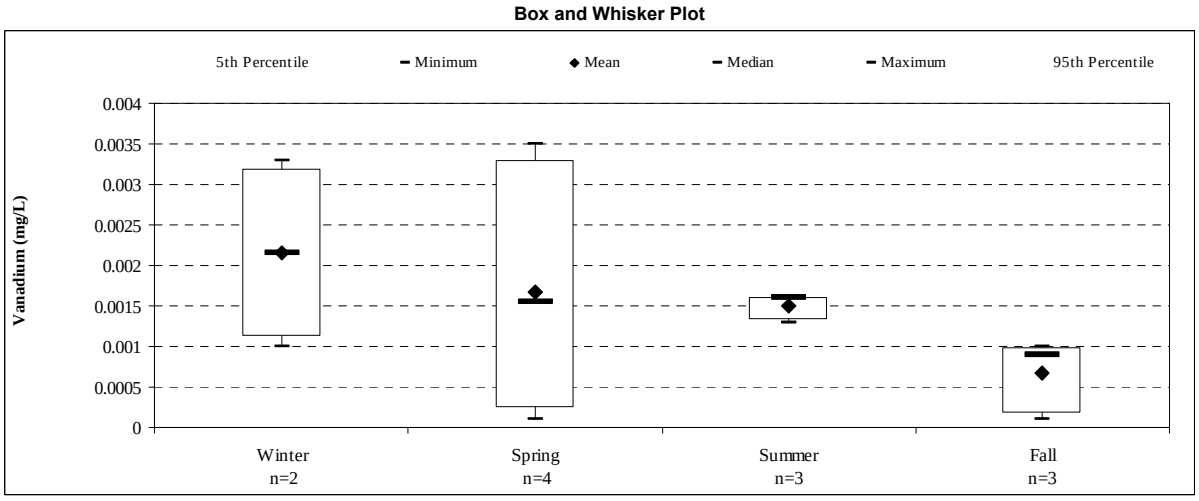


Figure G-3-1-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Pierre River



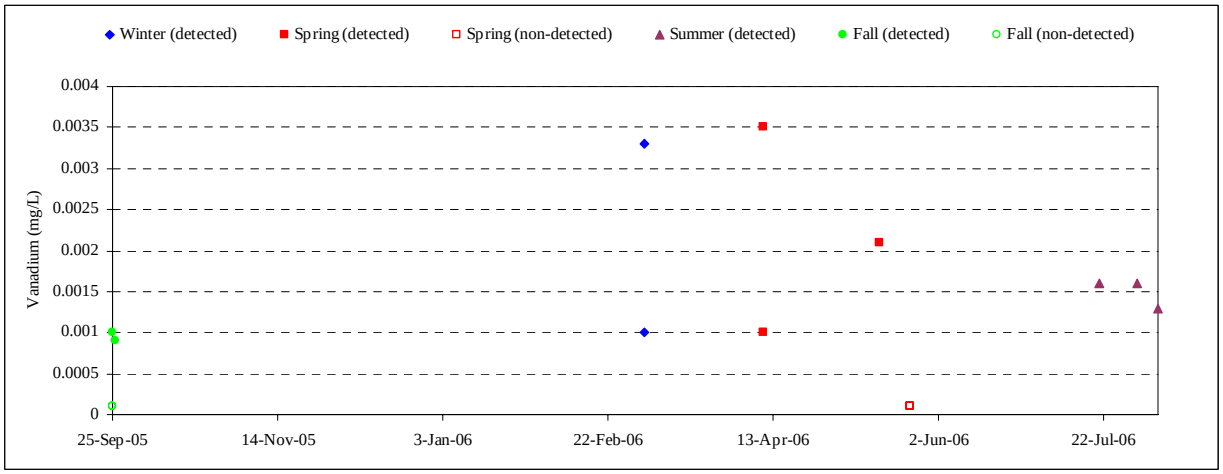
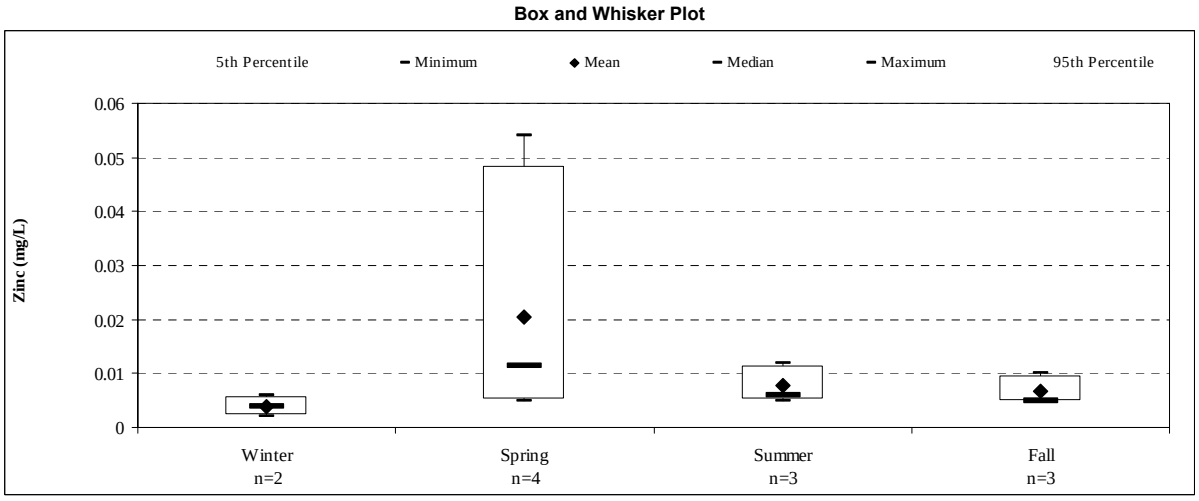


Figure G-3-1-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Pierre River



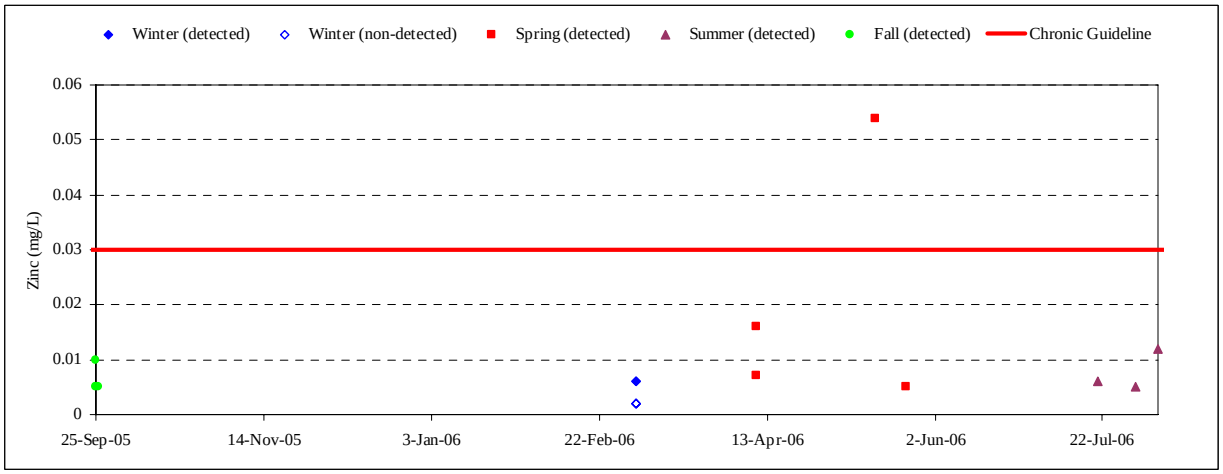
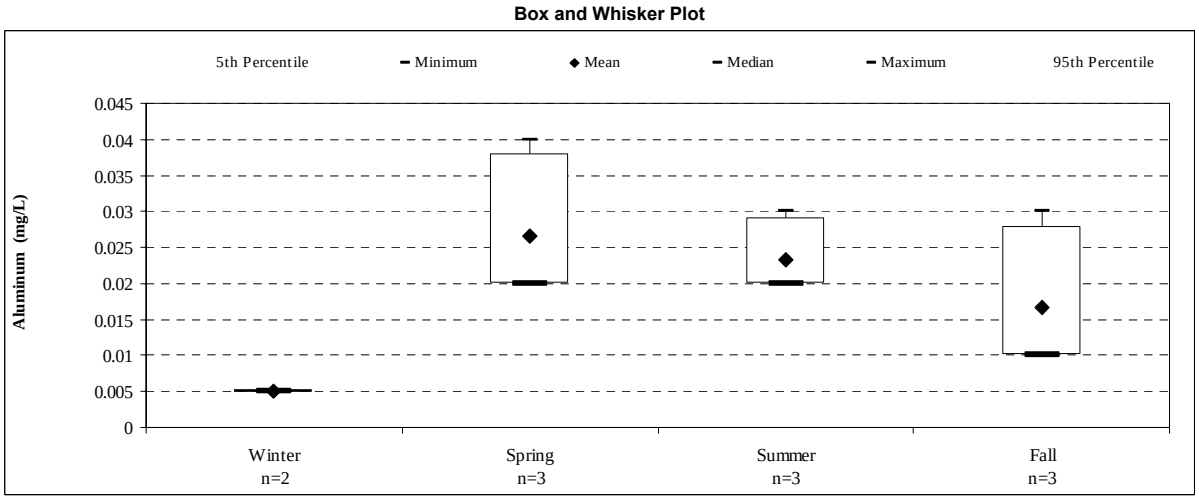


Figure G-3-1-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Pierre River



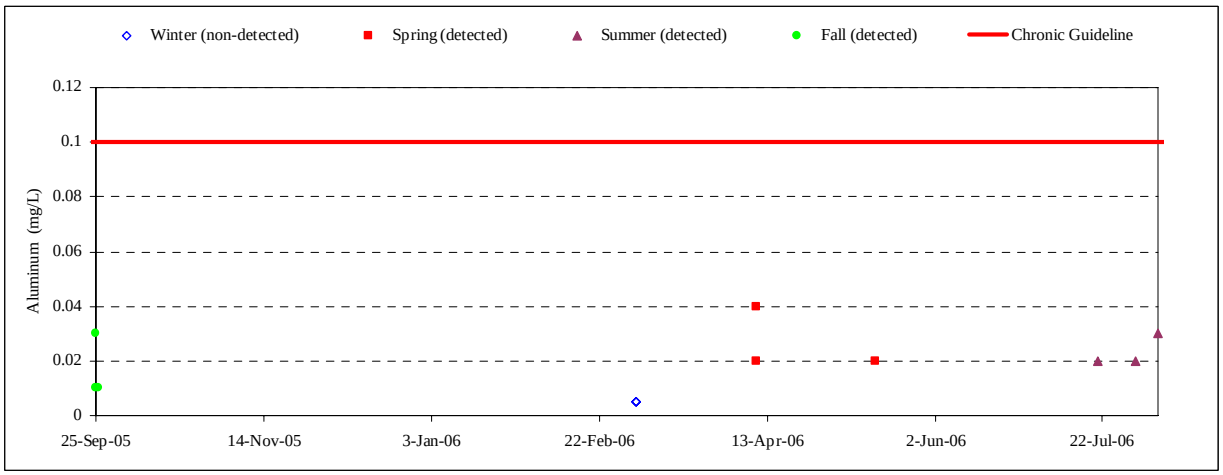
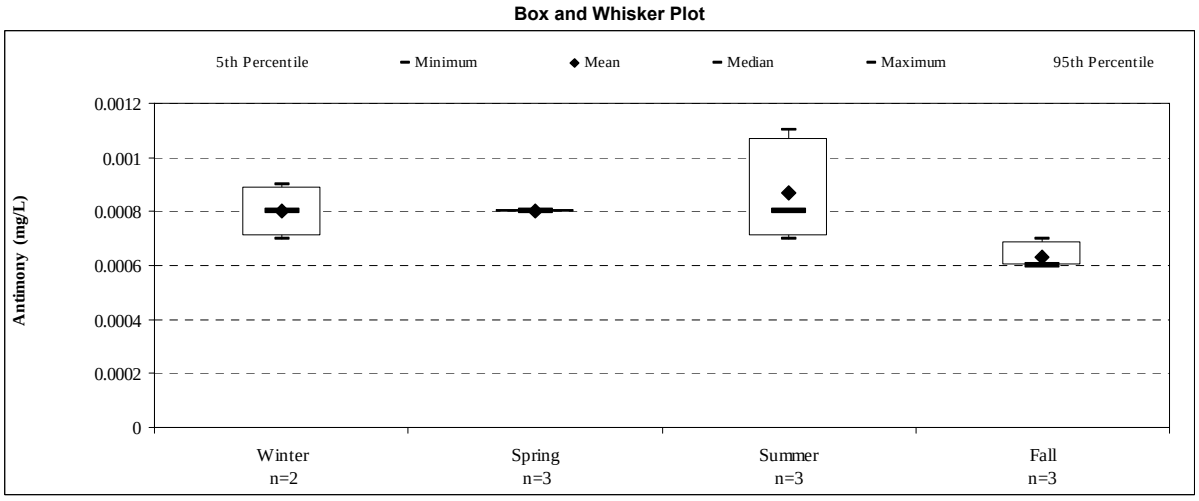


Figure G-3-1-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Pierre River



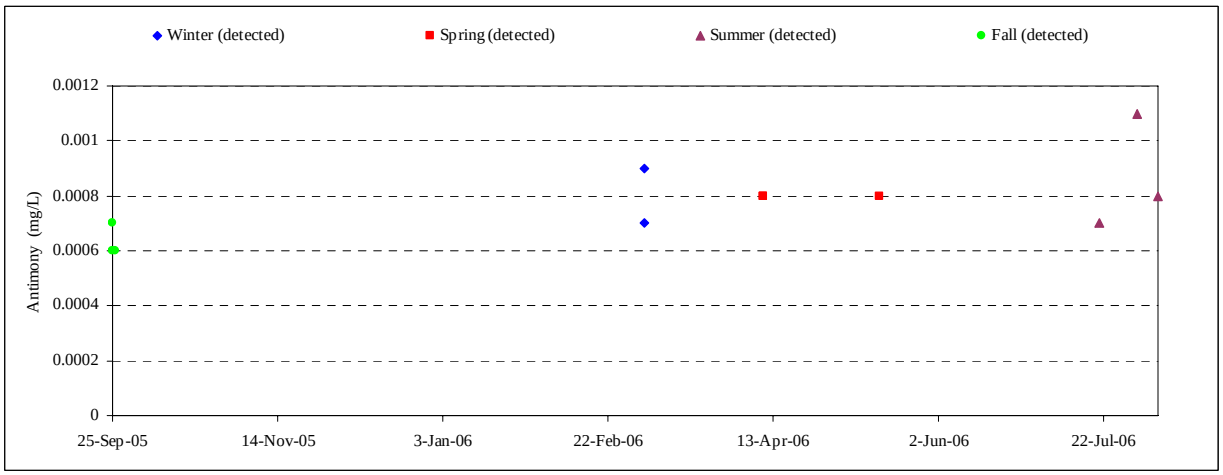
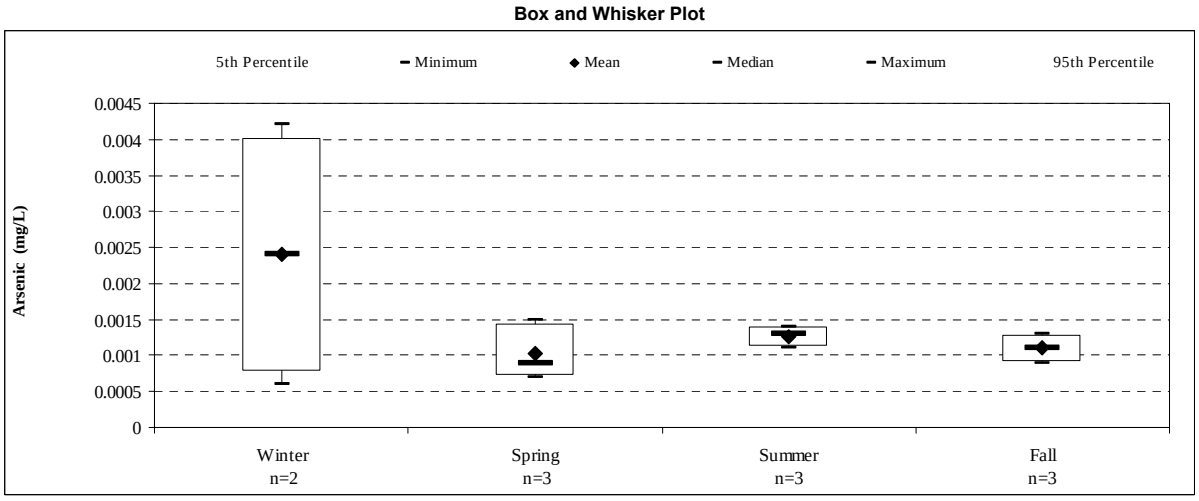


Figure G-3-1-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Pierre River



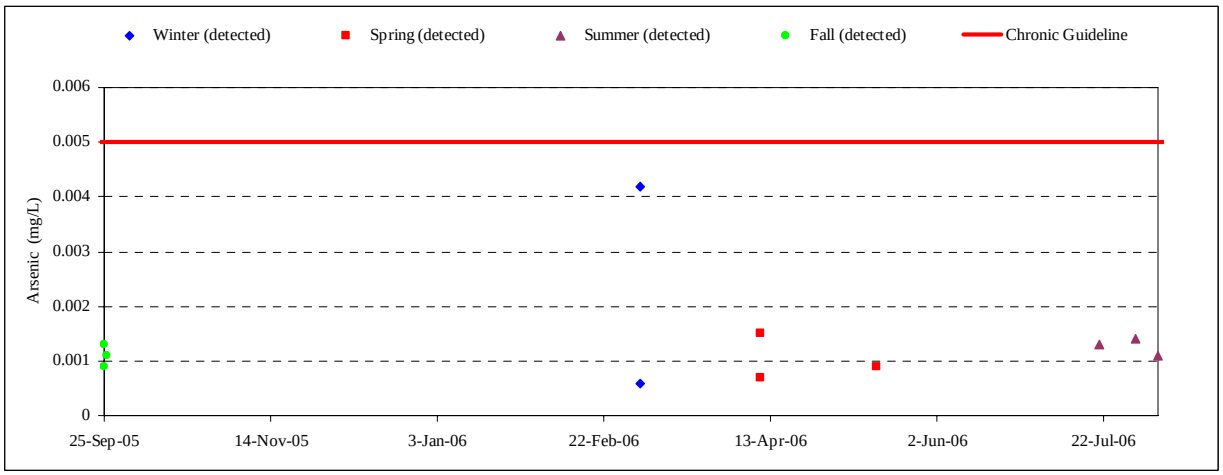
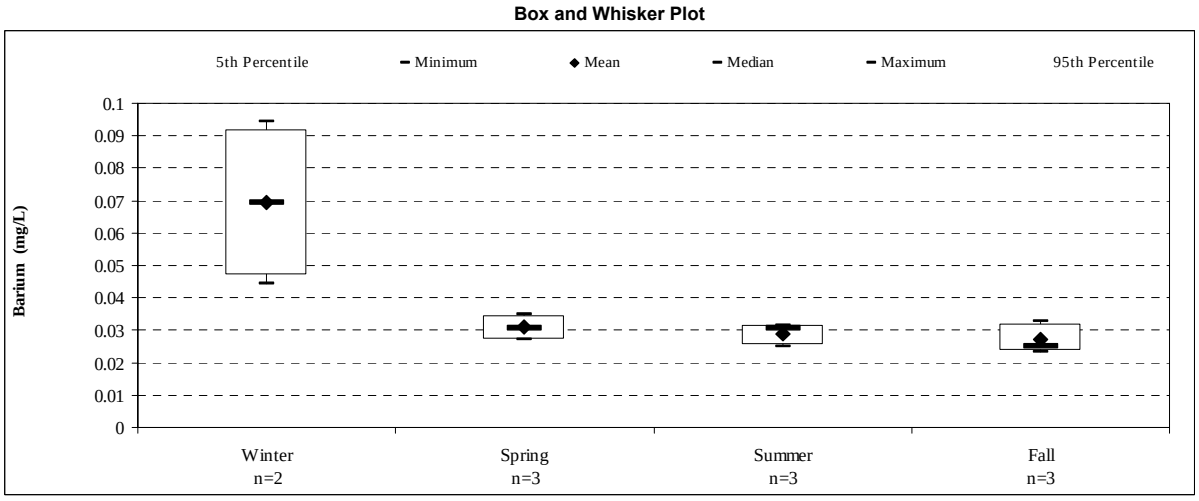


Figure G-3-1-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Pierre River



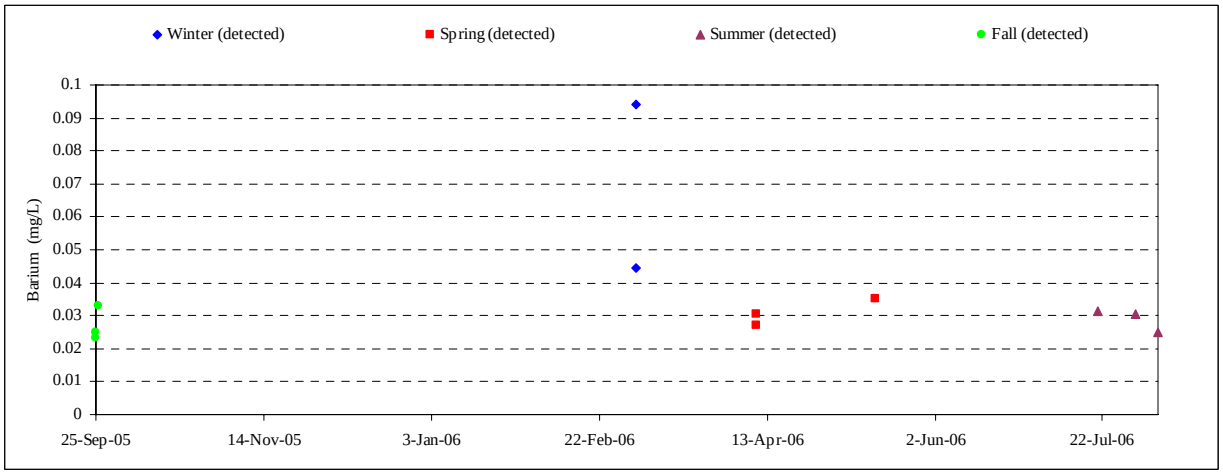
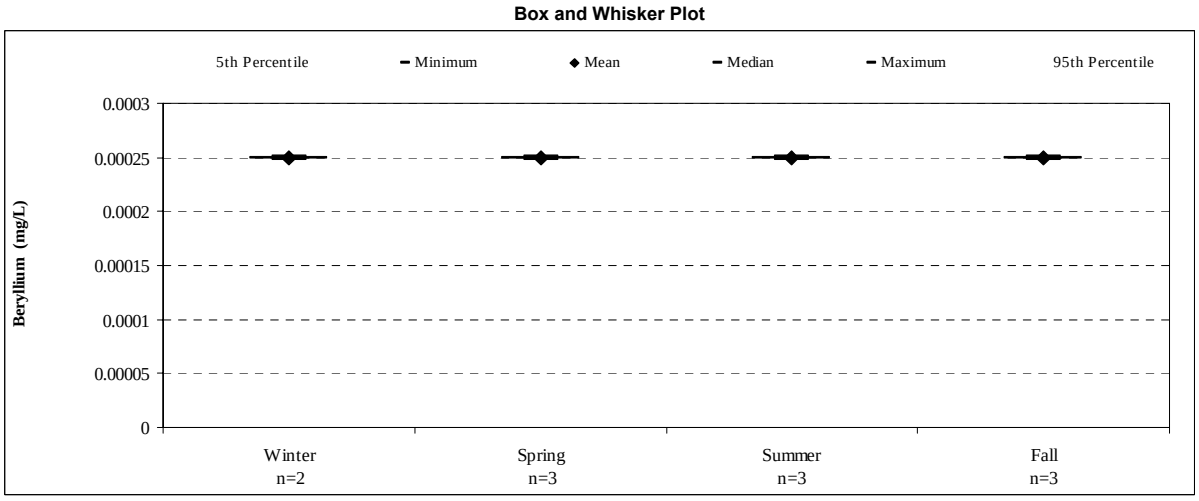


Figure G-3-1-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Pierre River



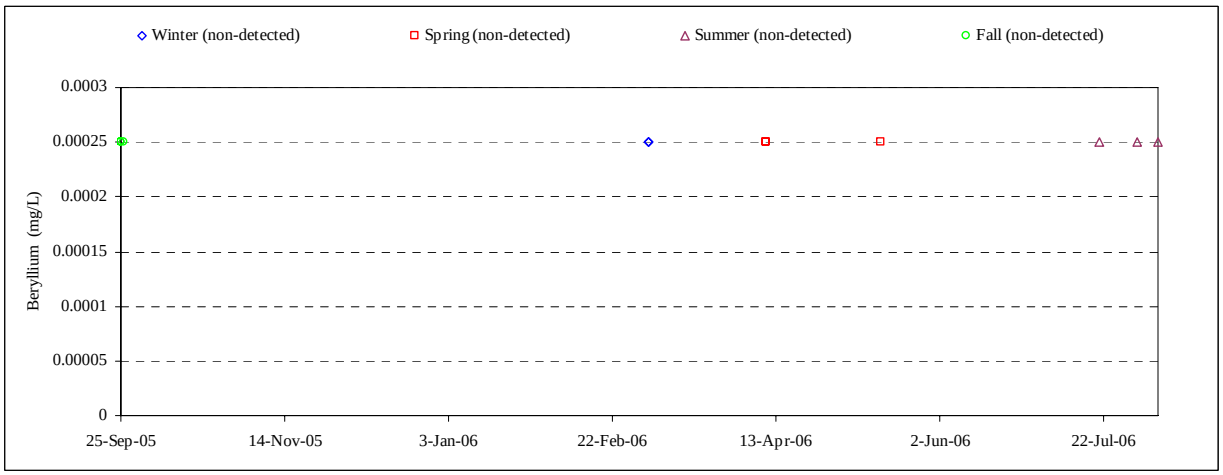
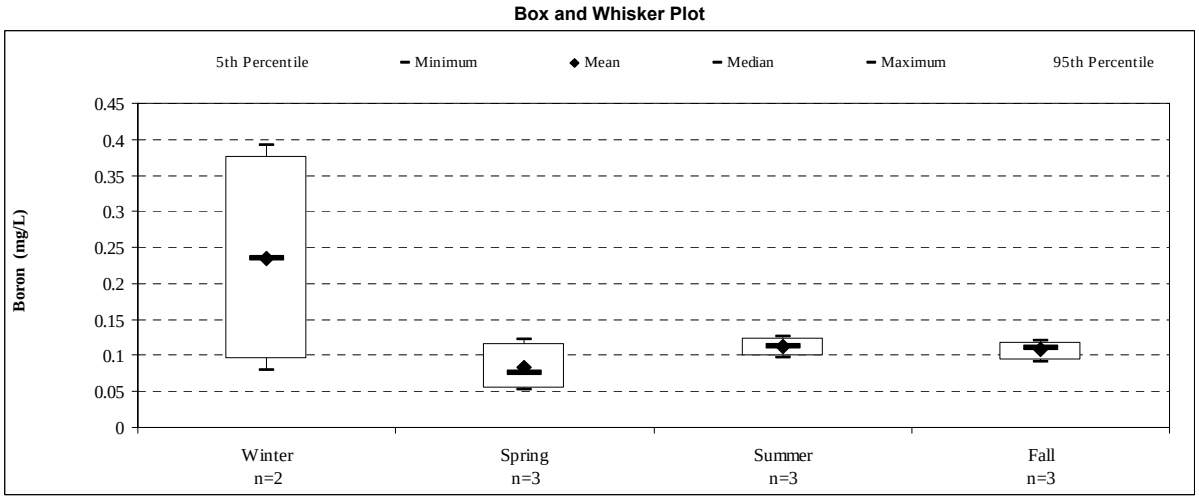


Figure G-3-1-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Pierre River



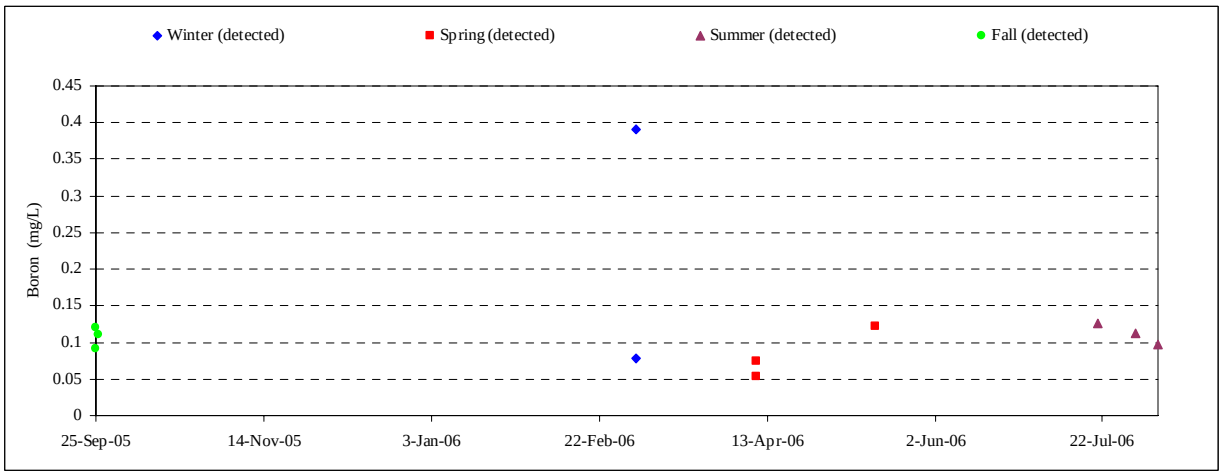
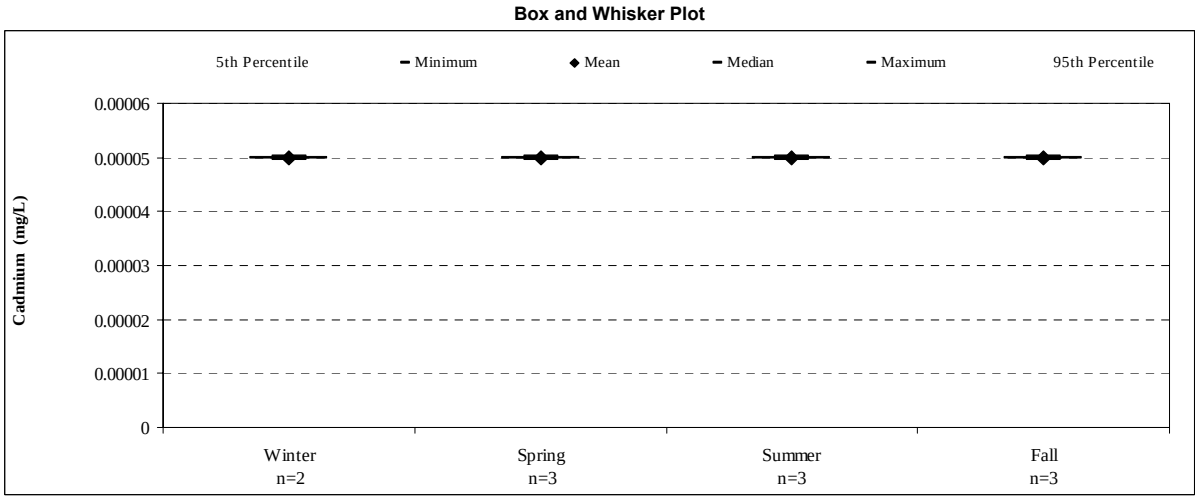


Figure G-3-1-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Pierre River



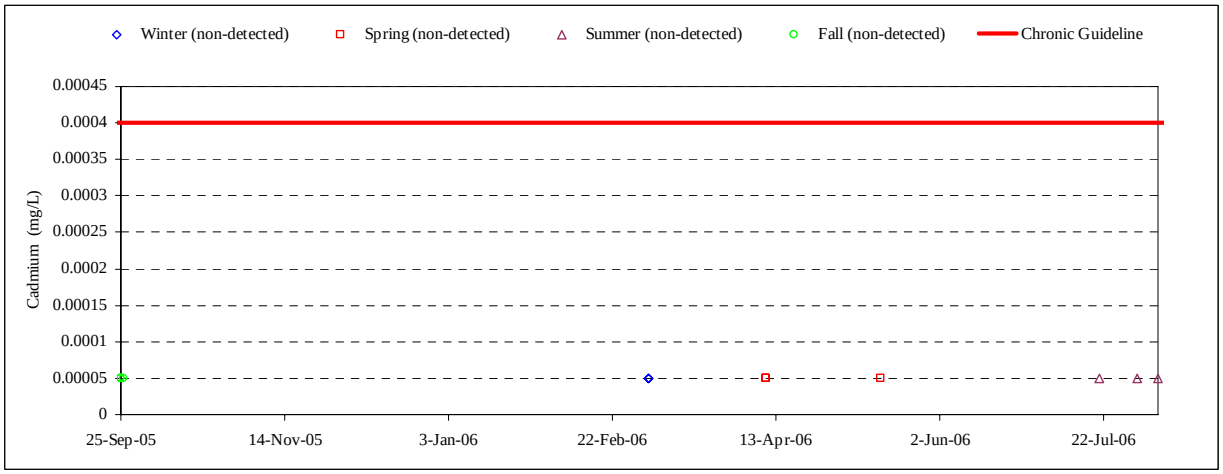
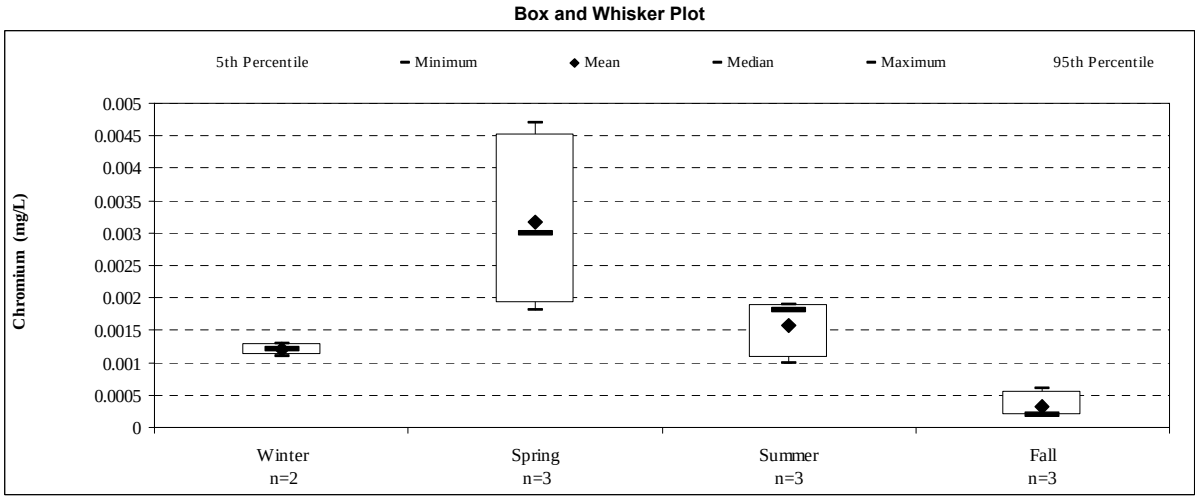


Figure G-3-1-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Pierre River



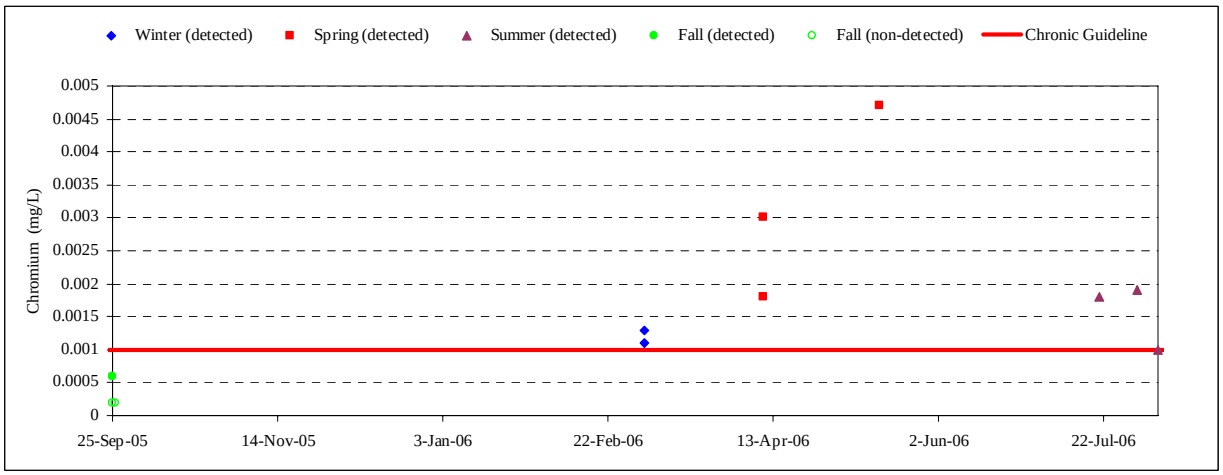
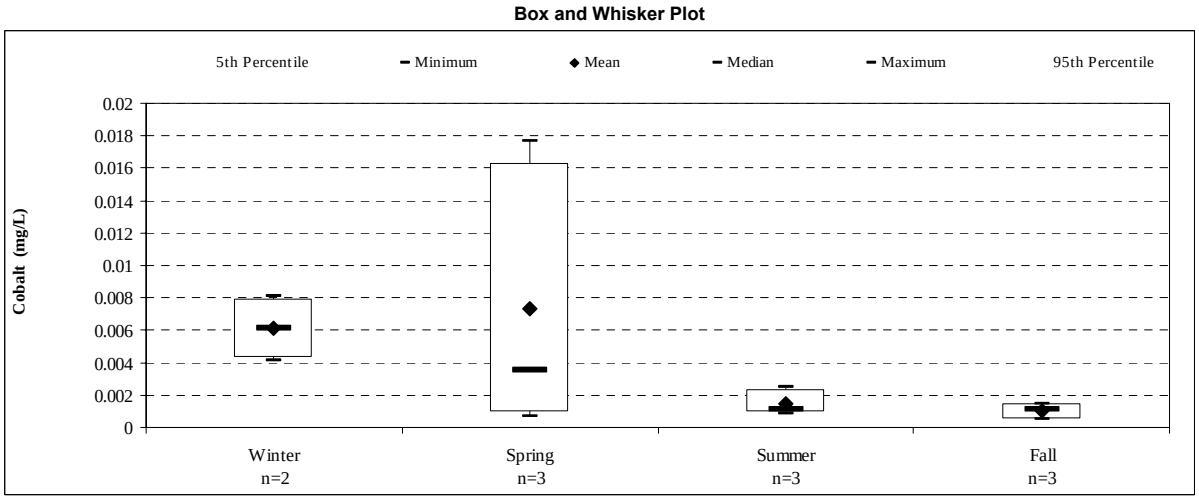


Figure G-3-1-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Pierre River



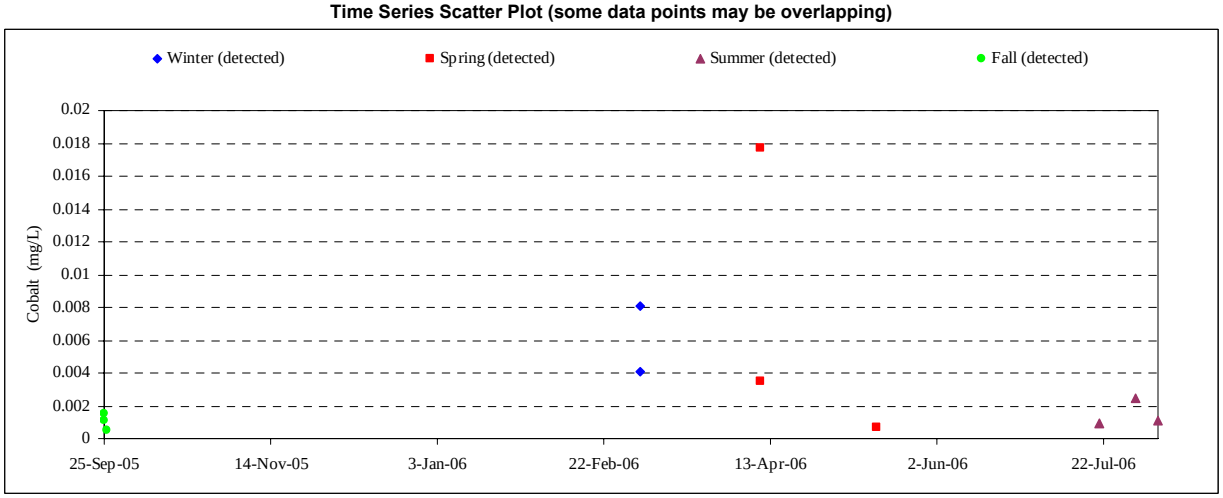
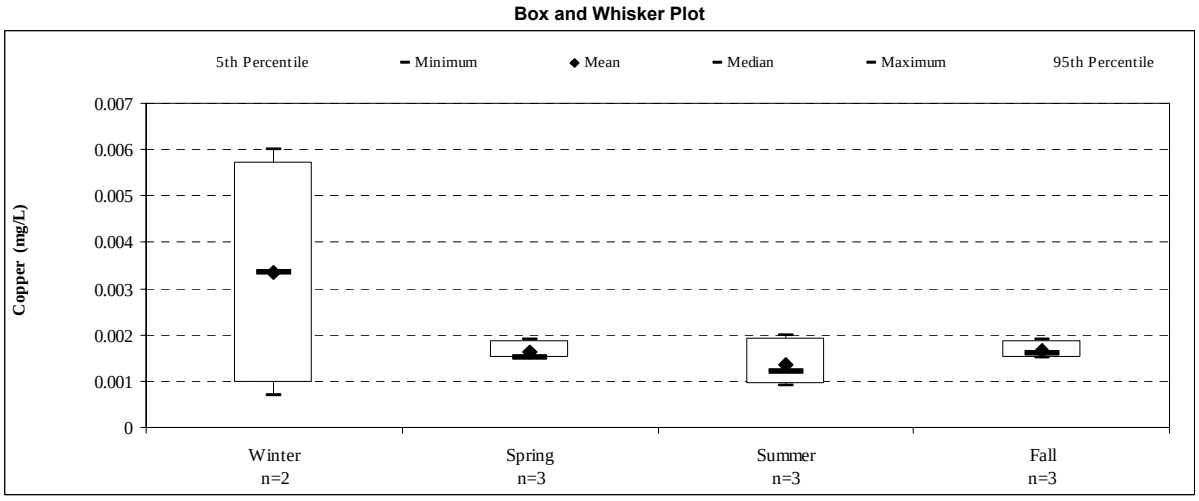


Figure G-3-1-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Pierre River



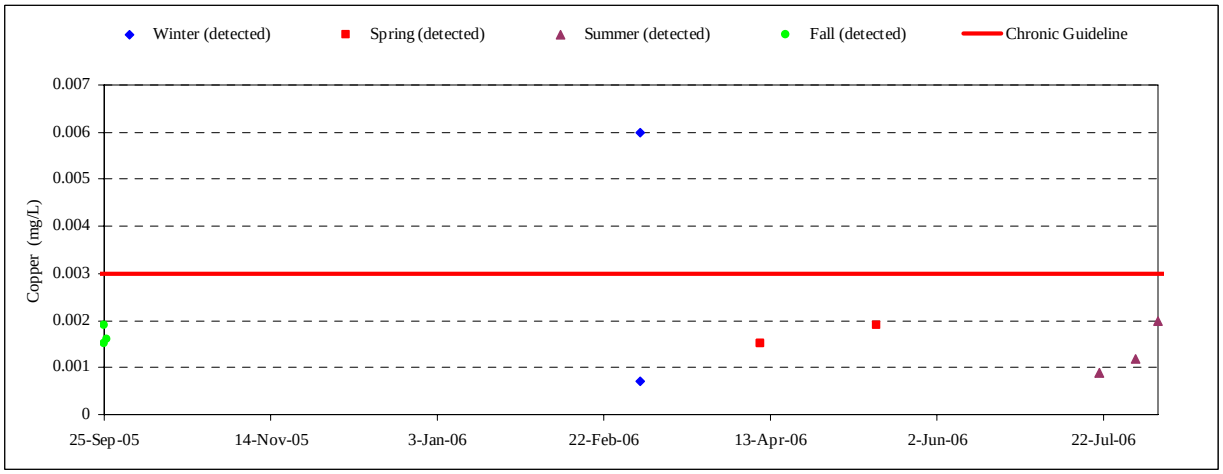
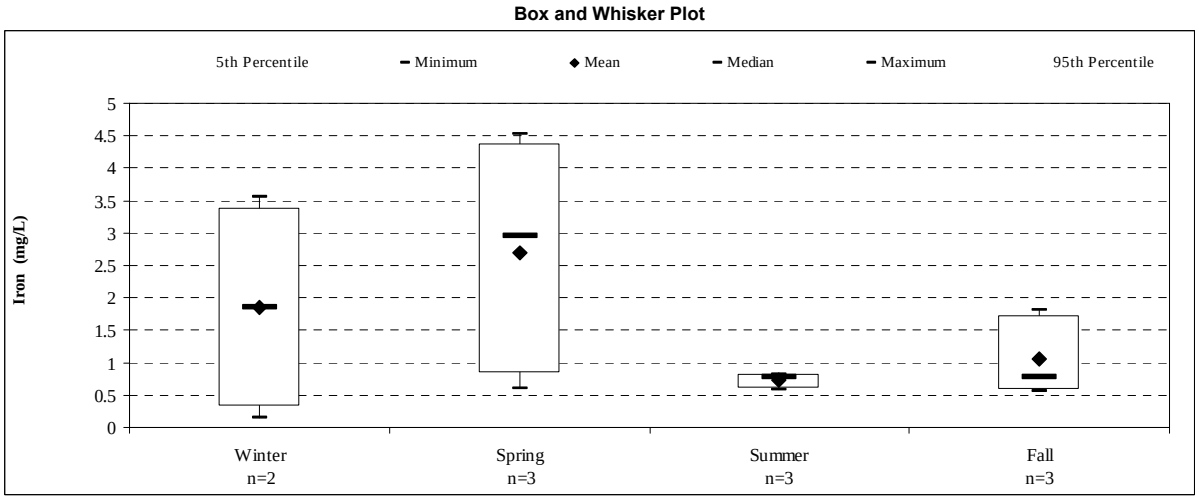


Figure G-3-1-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Pierre River



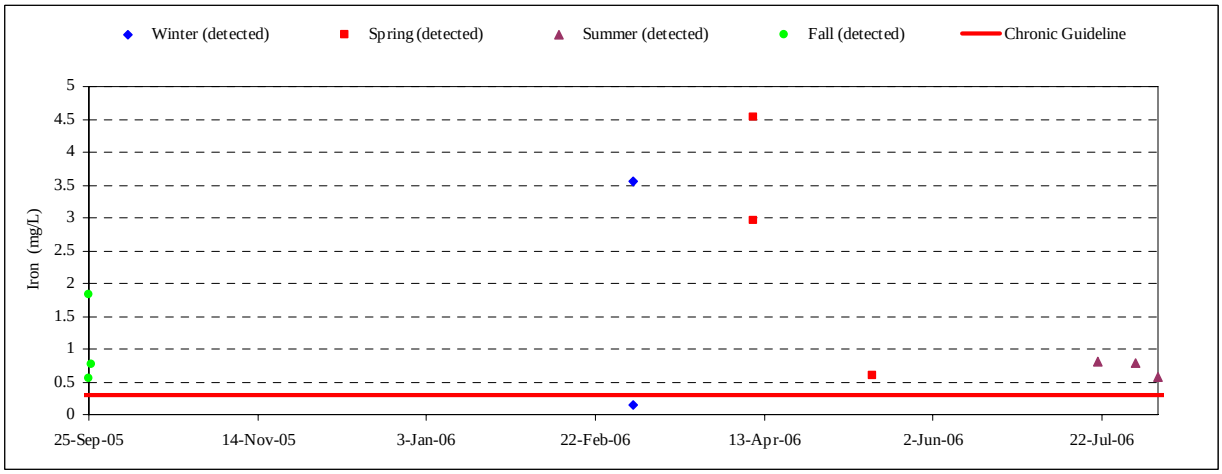
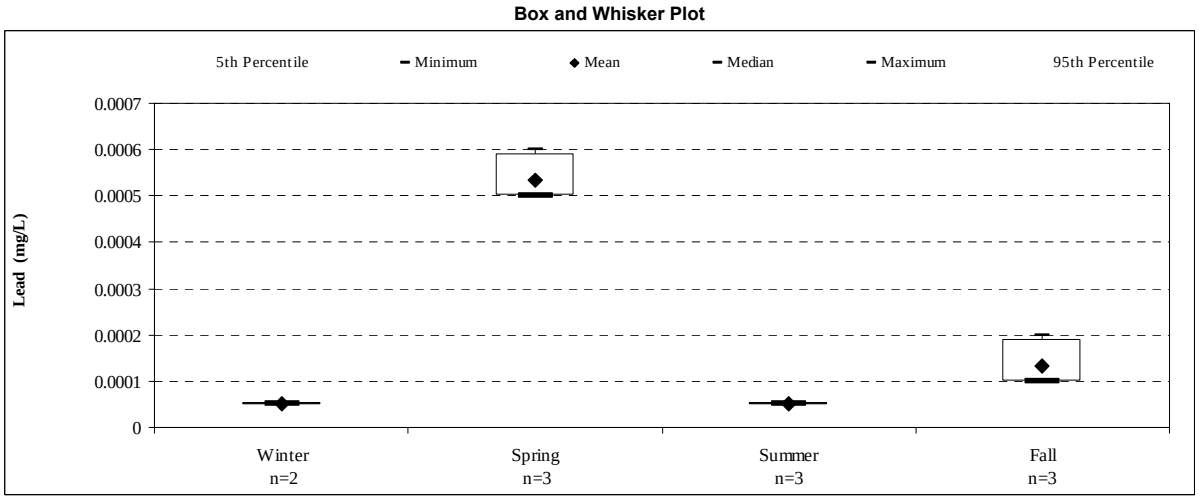


Figure G-3-1-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Pierre River



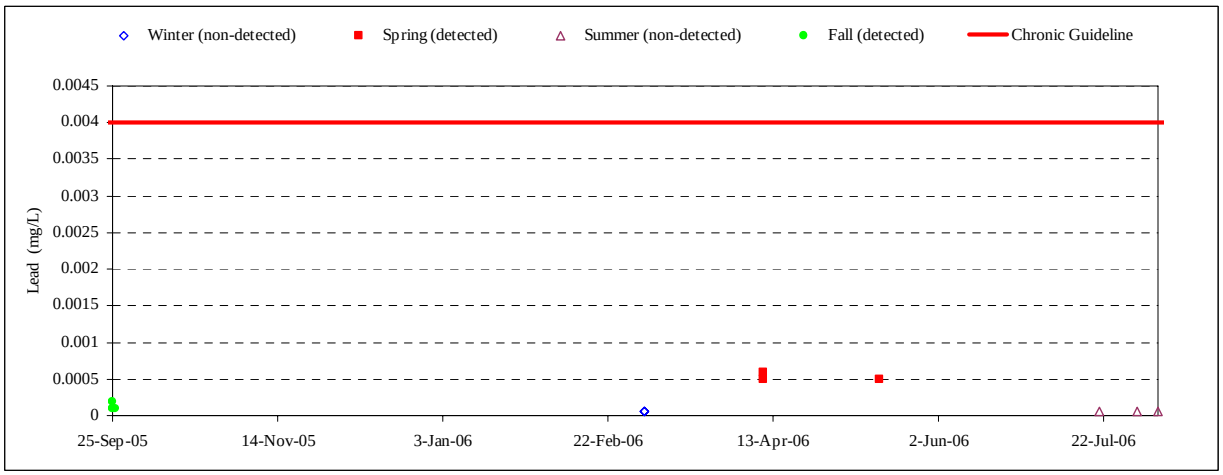
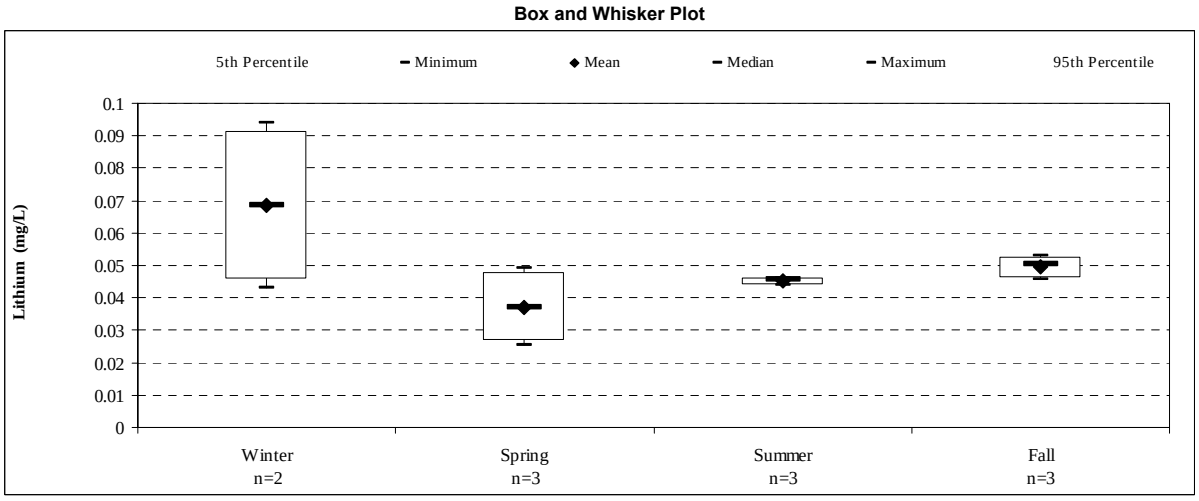


Figure G-3-1-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Pierre River



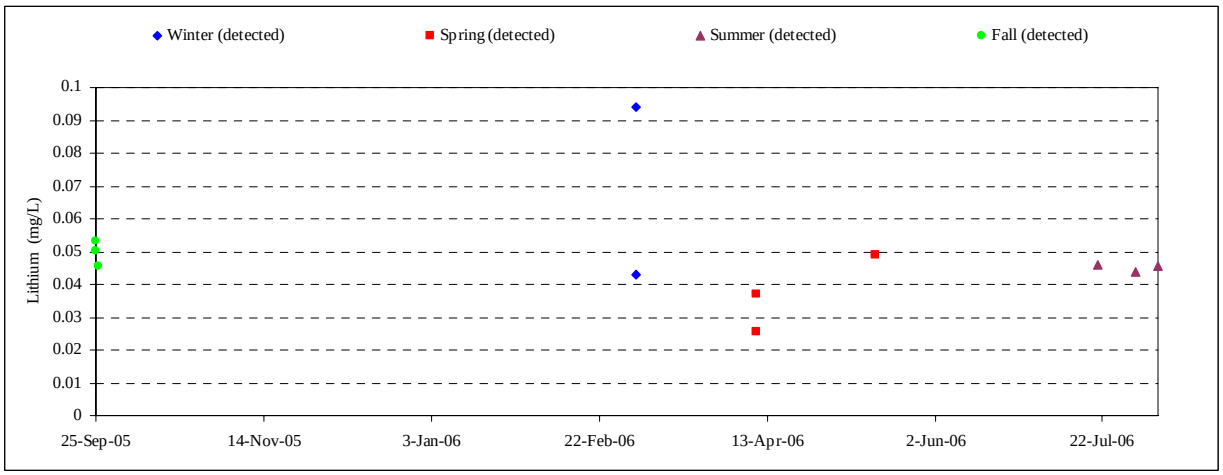
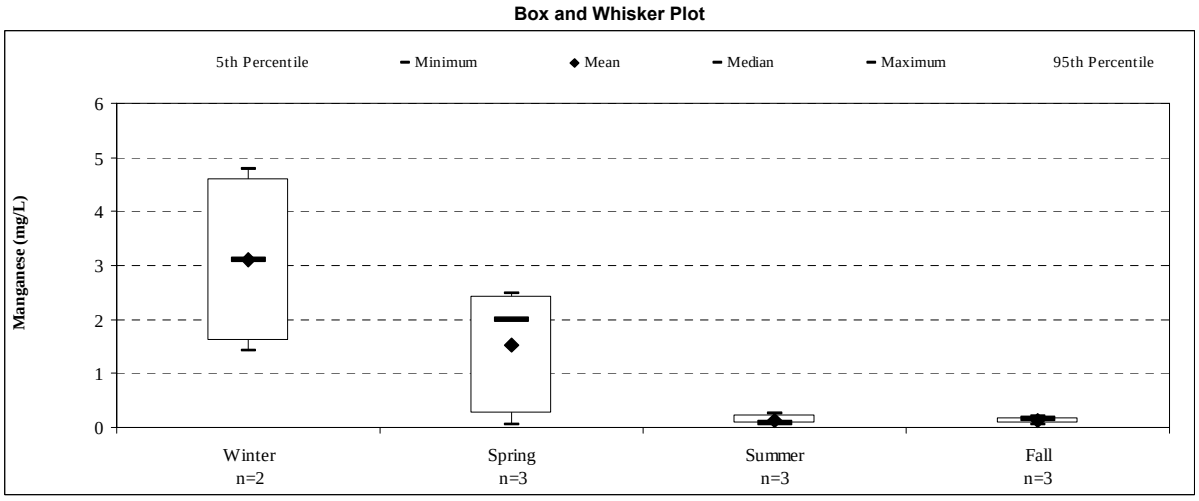


Figure G-3-1-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Pierre River



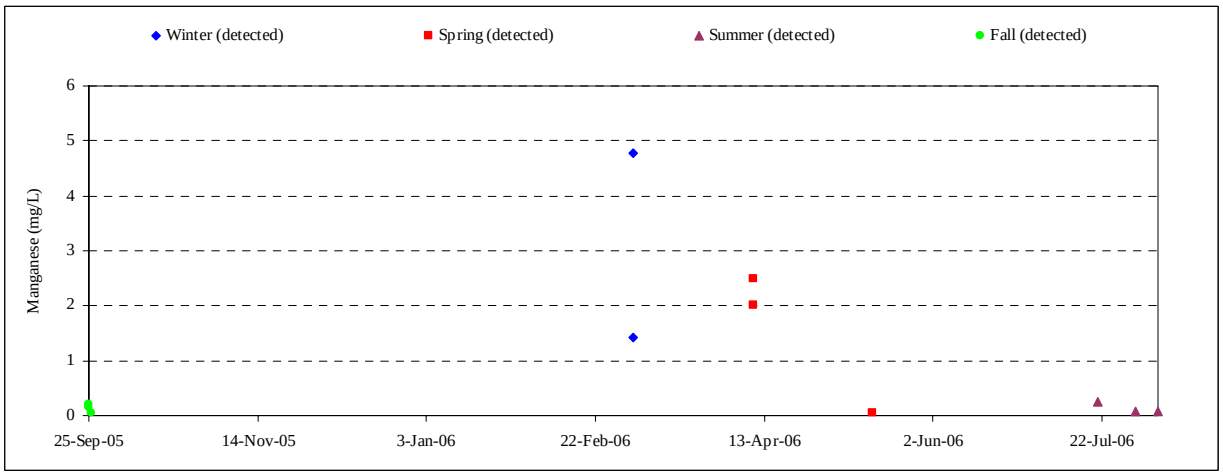
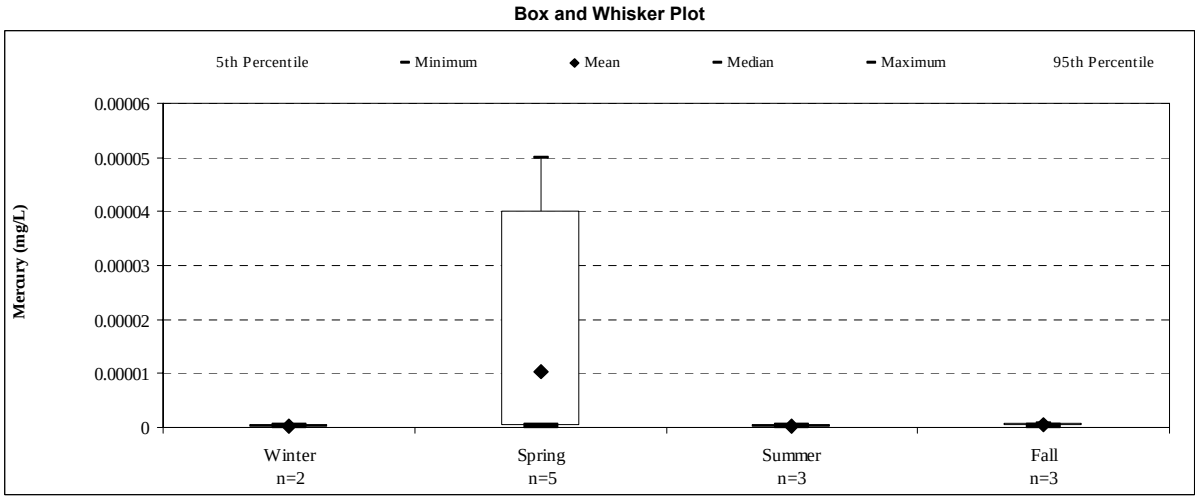


Figure G-3-1-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Pierre River



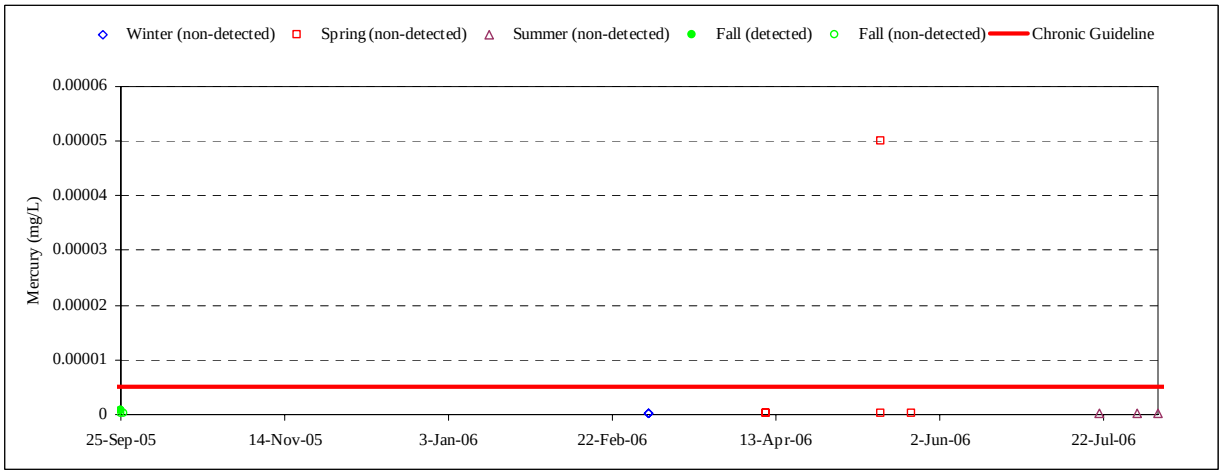
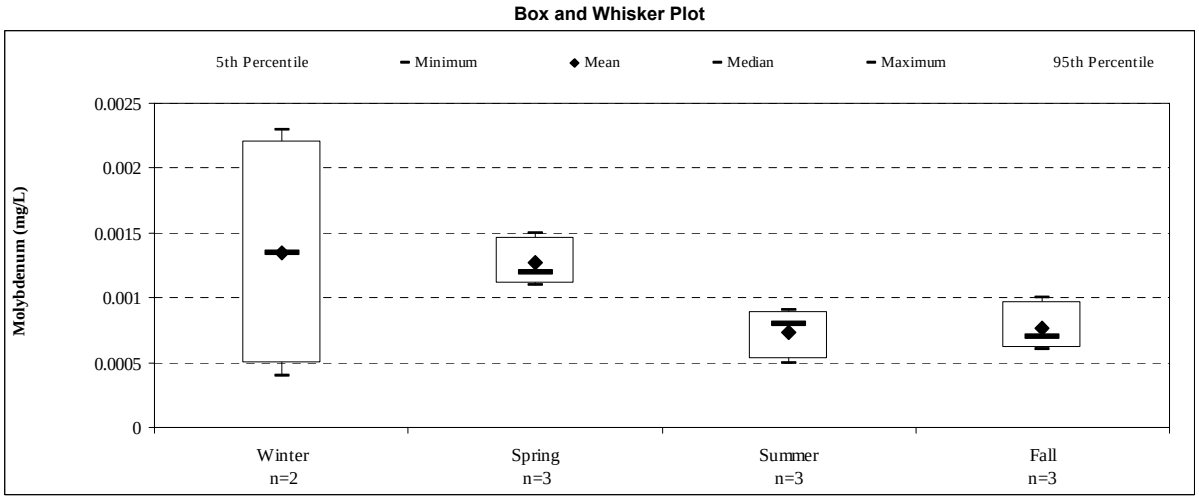


Figure G-3-1-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Pierre River



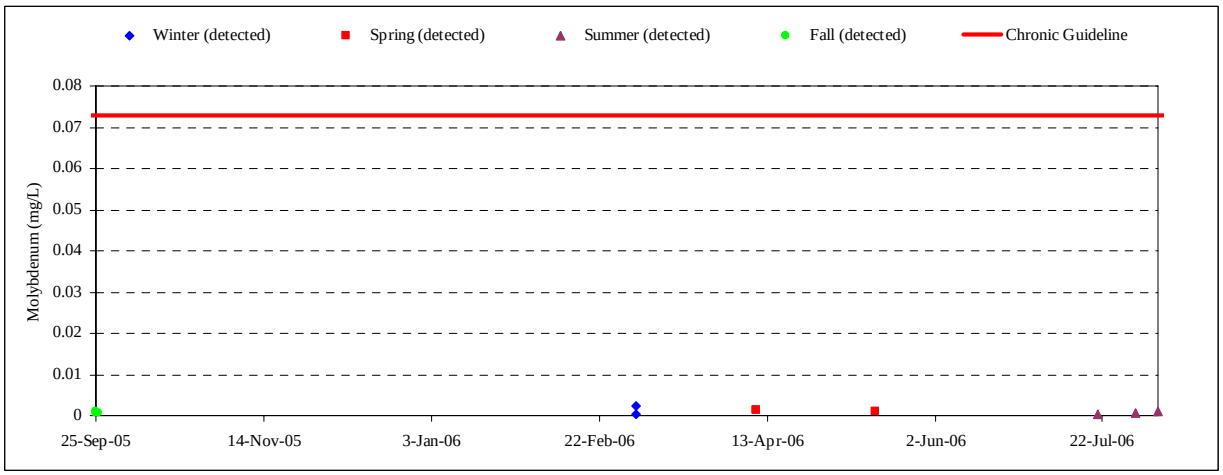
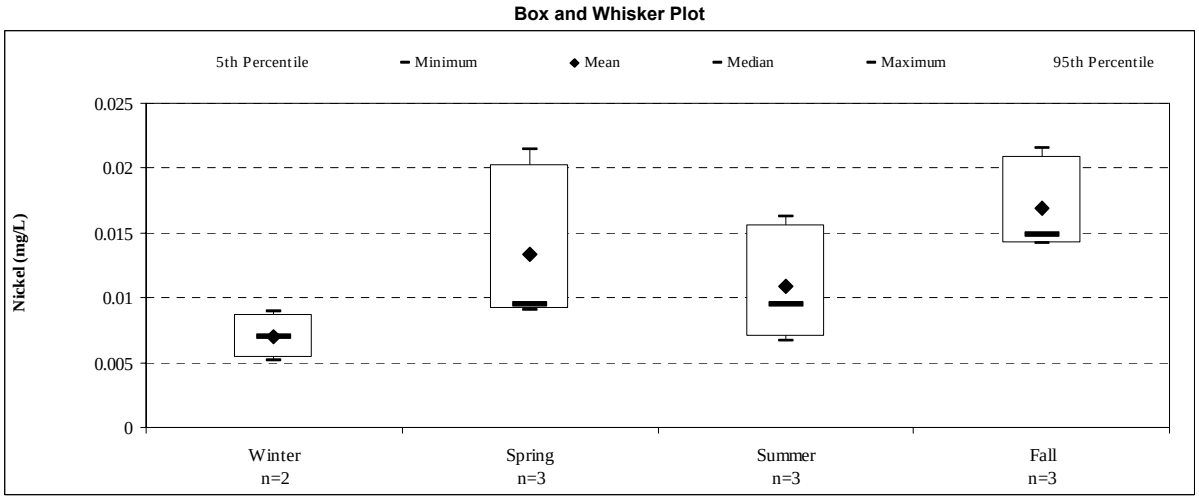


Figure G-3-1-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Pierre River



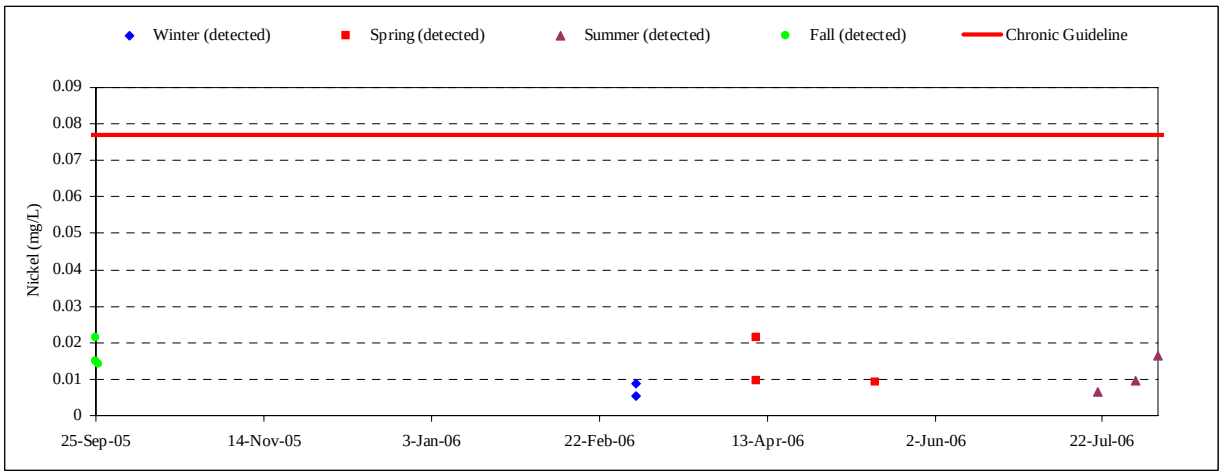
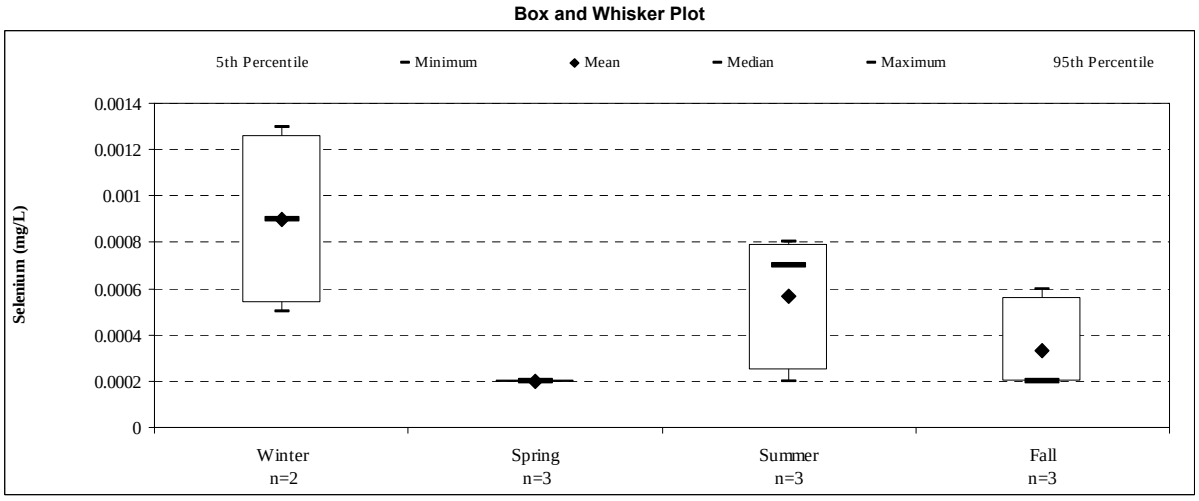


Figure G-3-1-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Pierre River



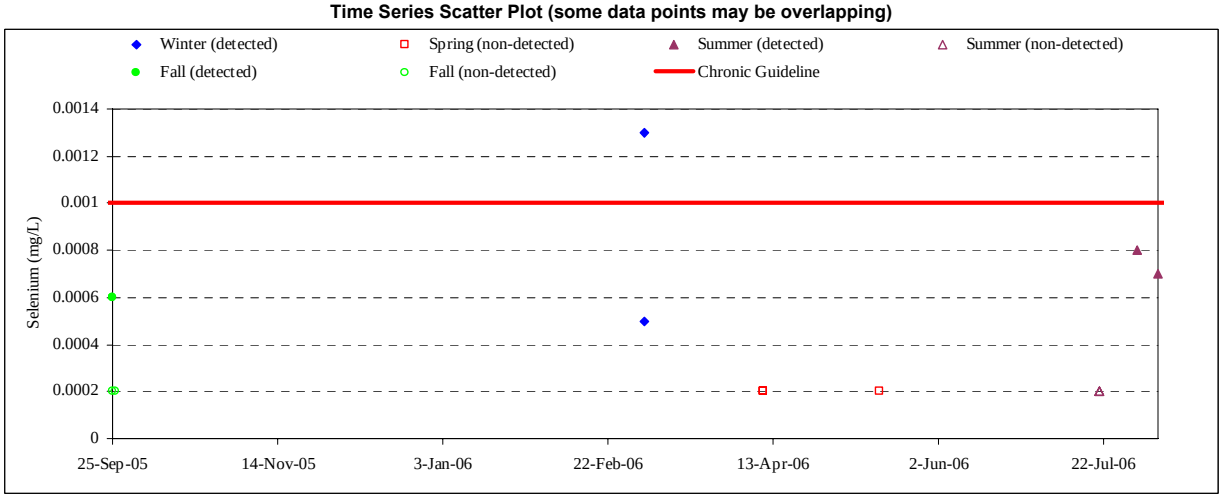
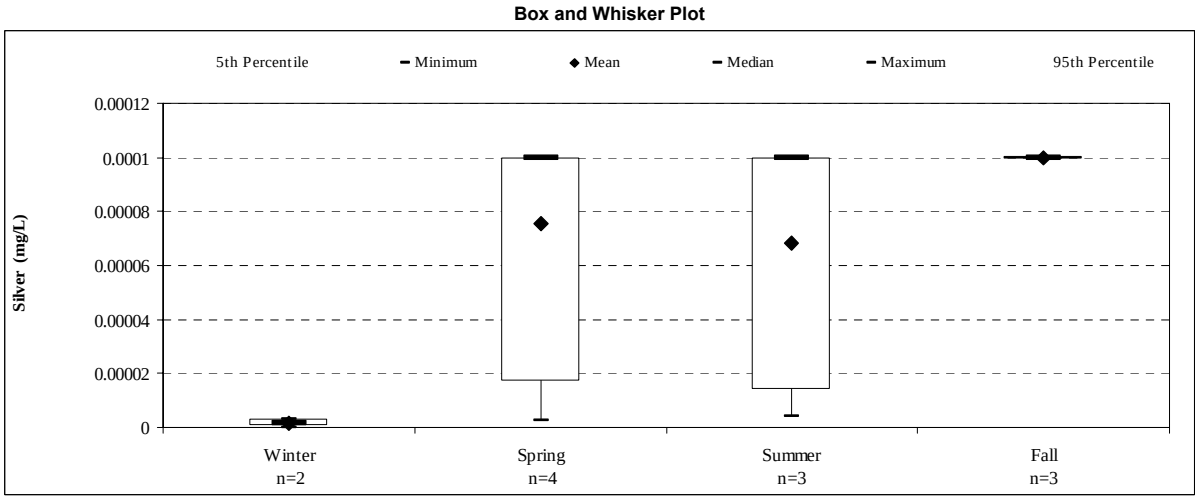


Figure G-3-1-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Pierre River



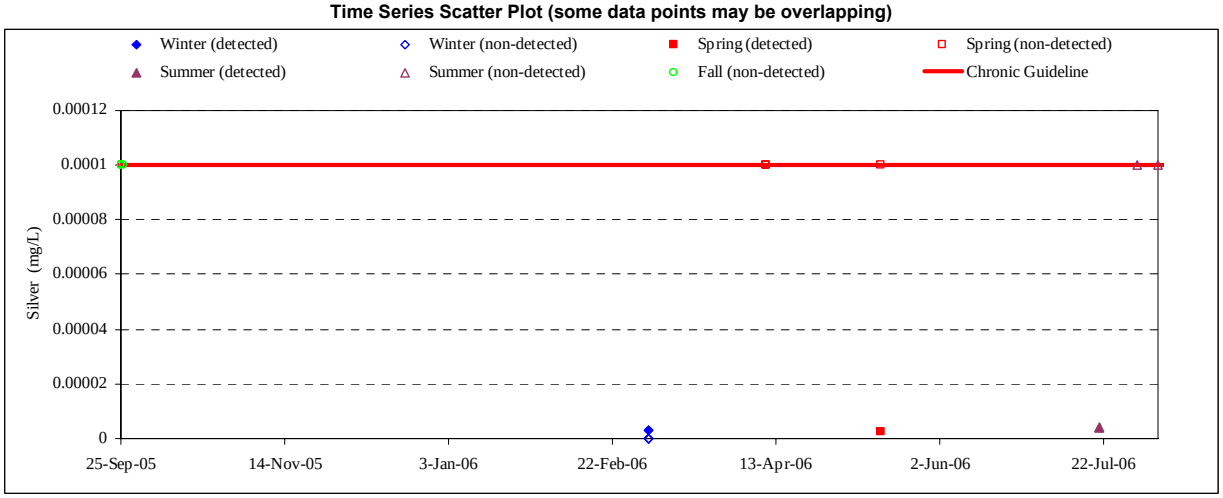
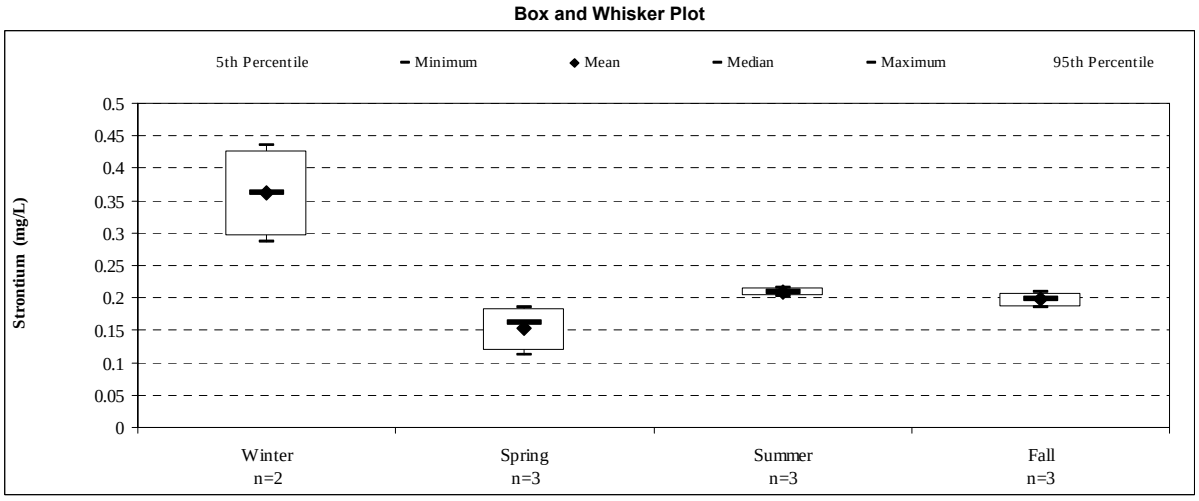


Figure G-3-1-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Pierre River



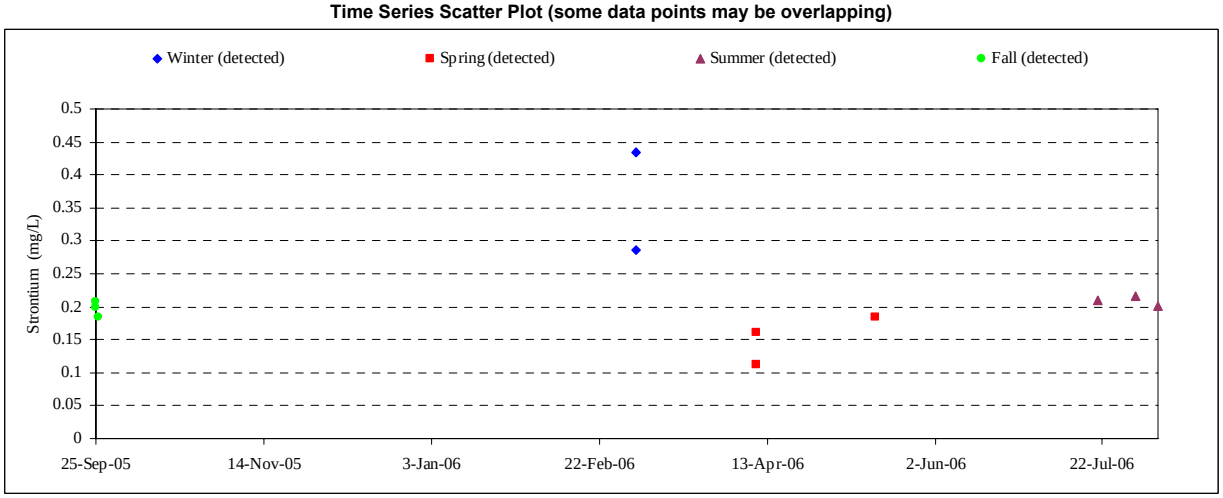
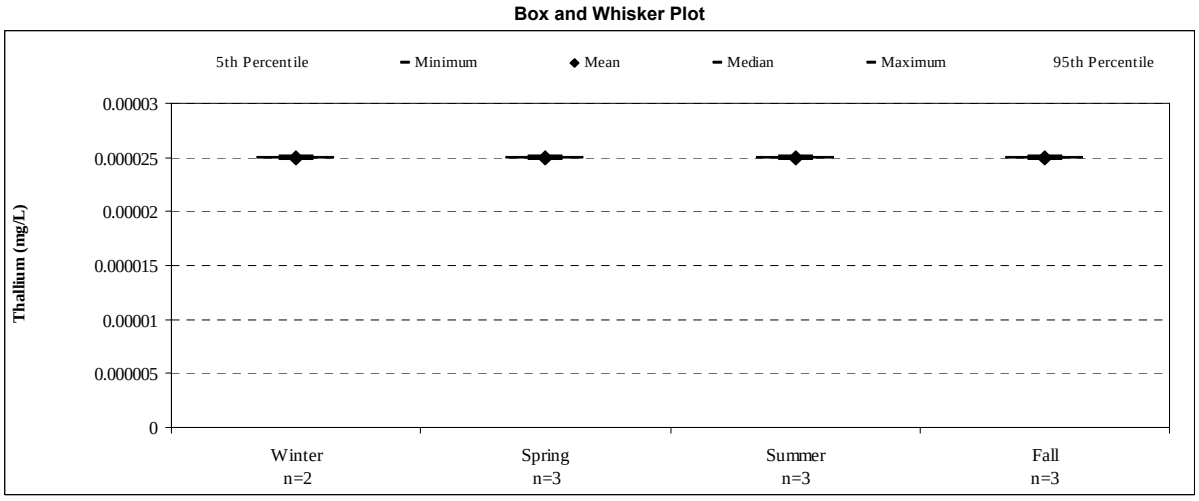


Figure G-3-1-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Pierre River



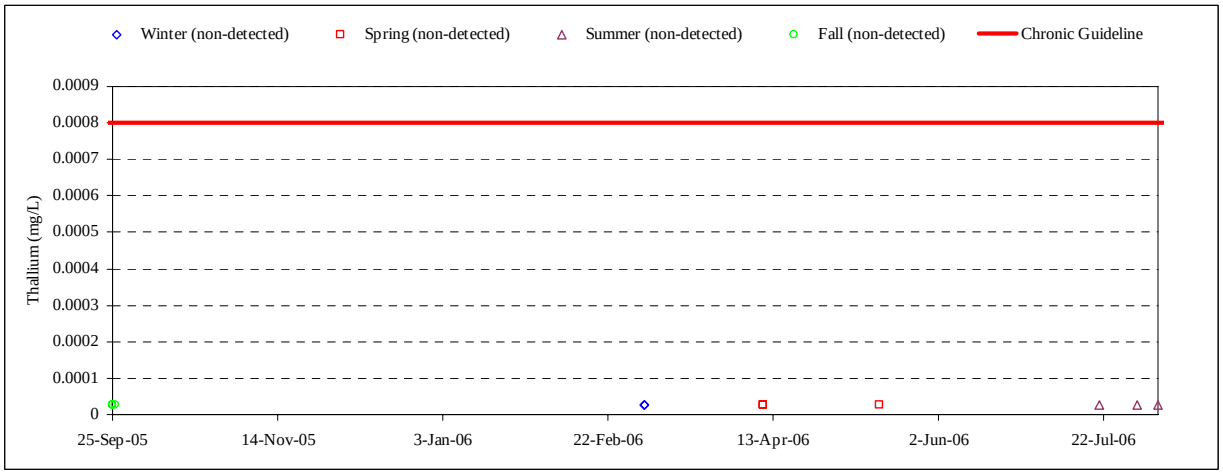
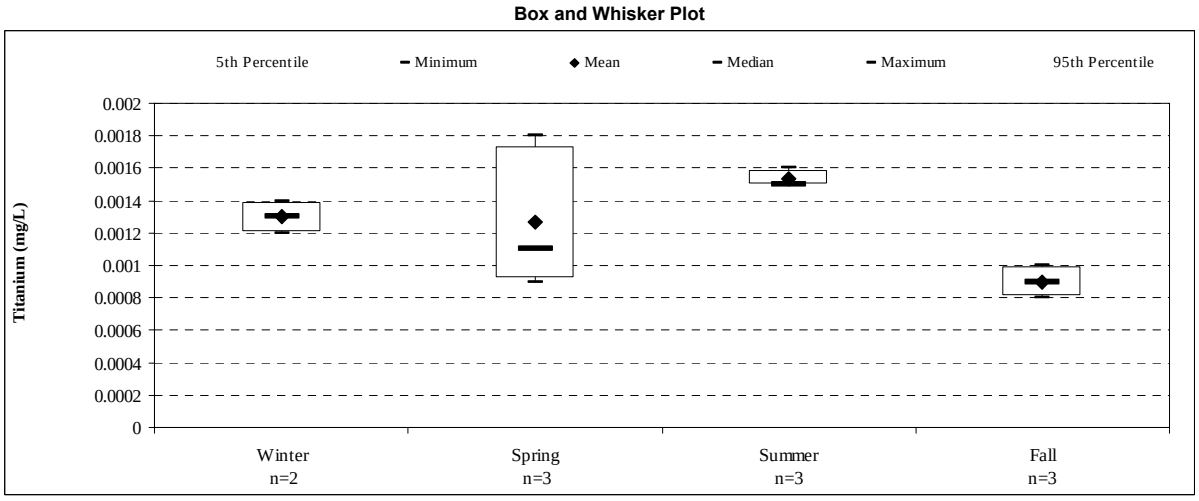


Figure G-3-1-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Pierre River



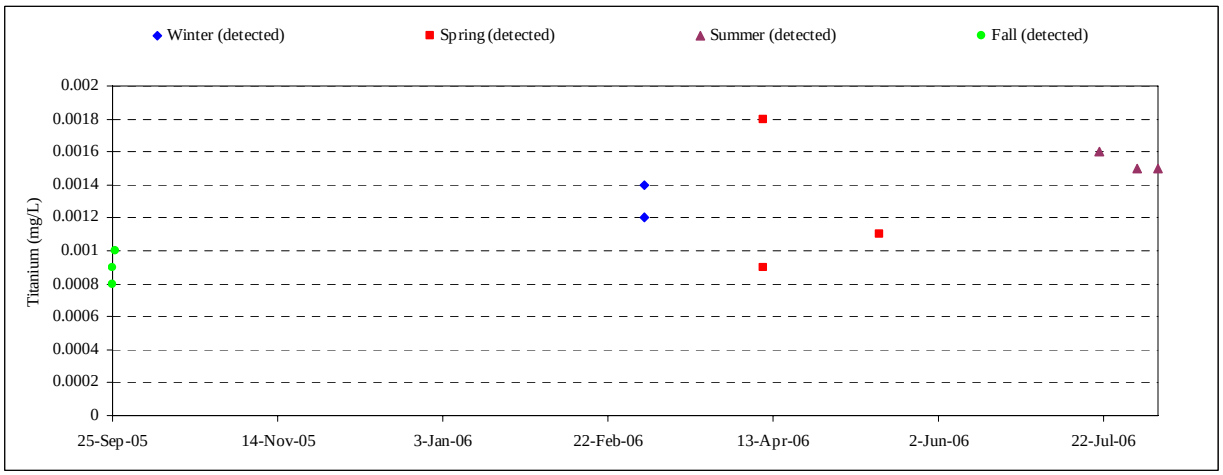
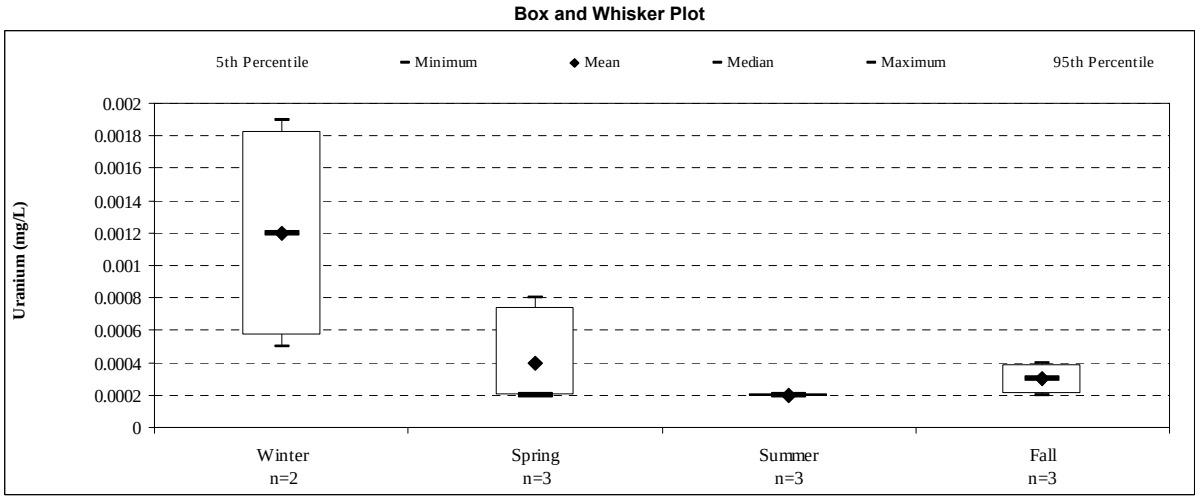


Figure G-3-1-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Pierre River



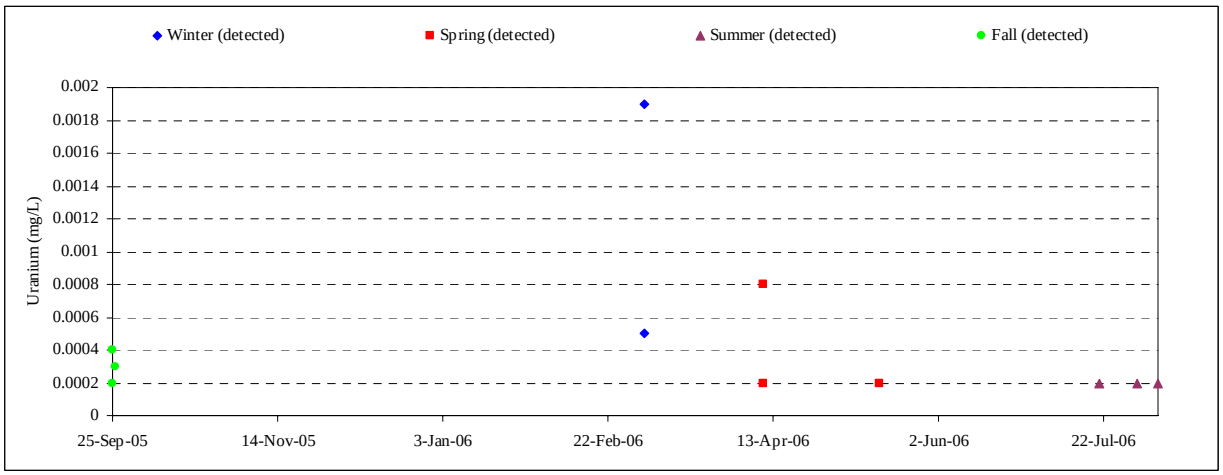
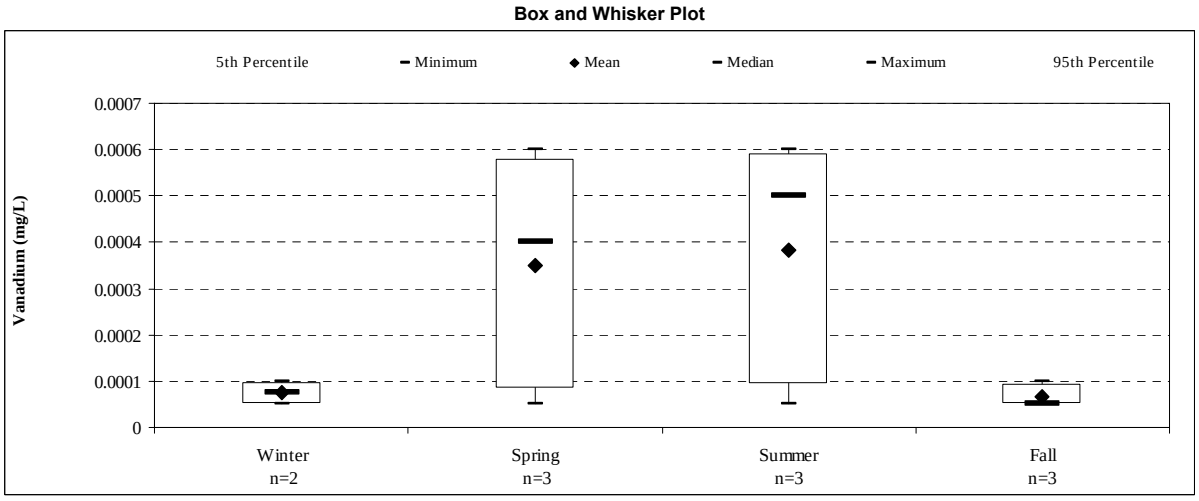


Figure G-3-1-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Pierre River



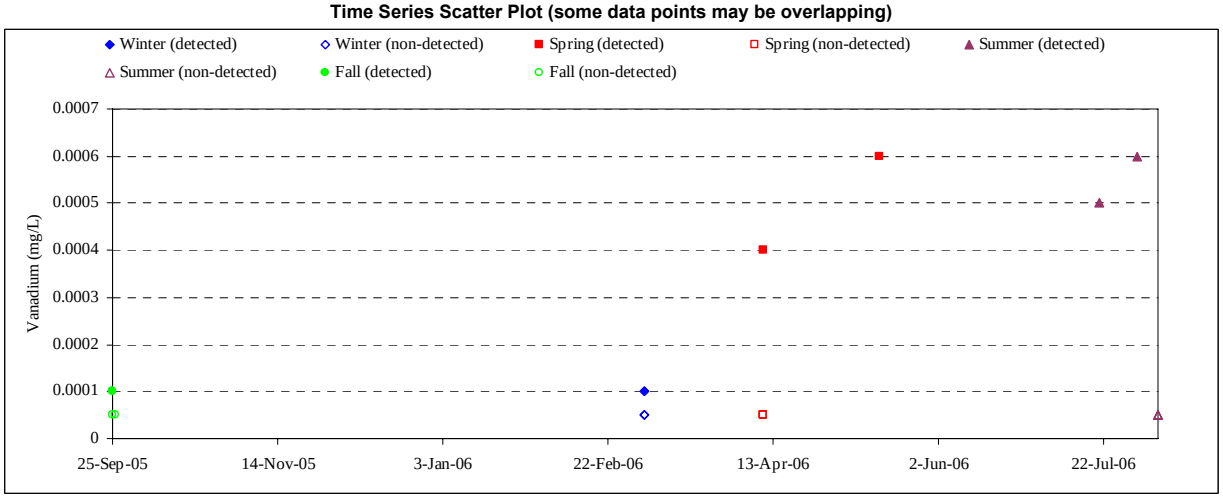
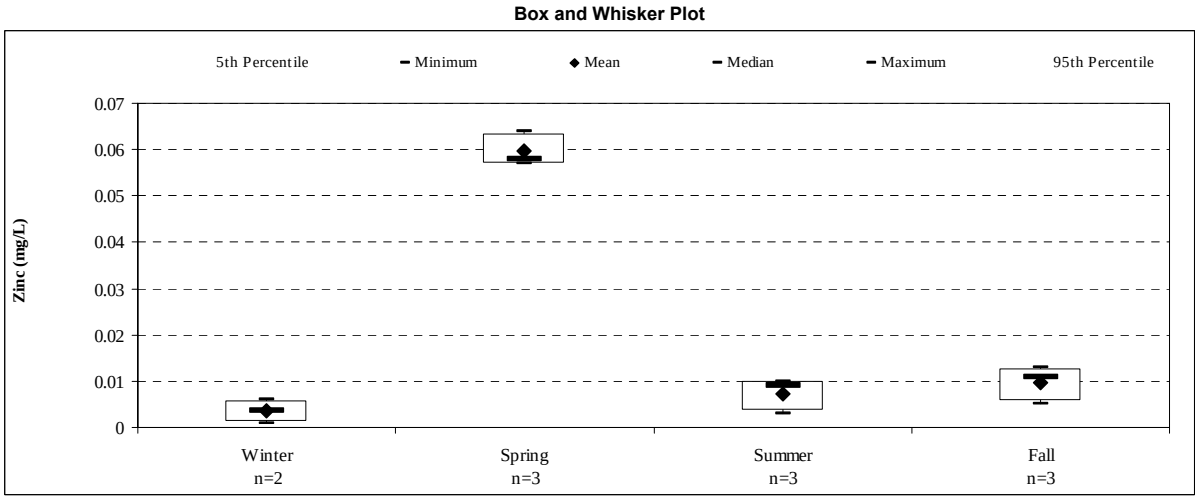


Figure G-3-1-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Pierre River



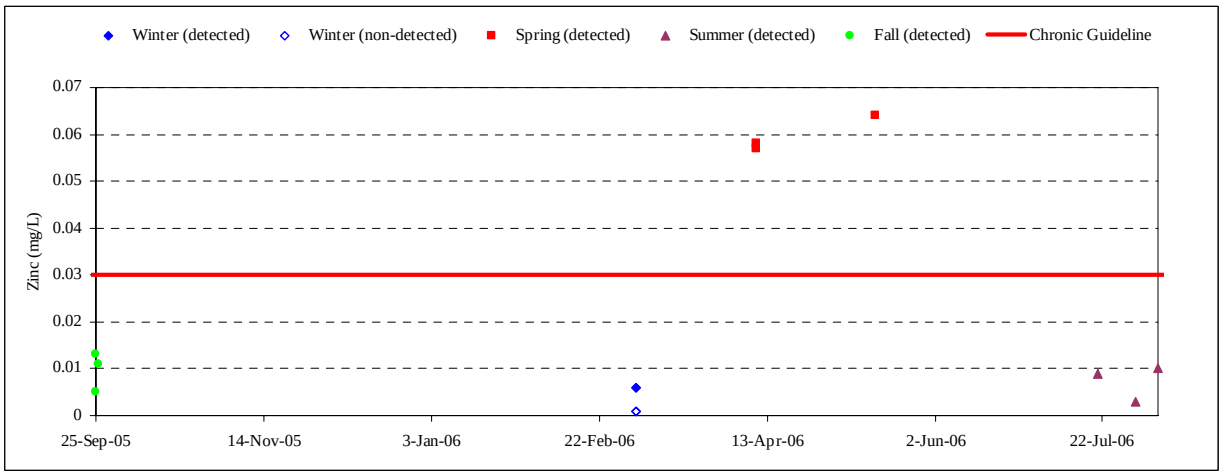
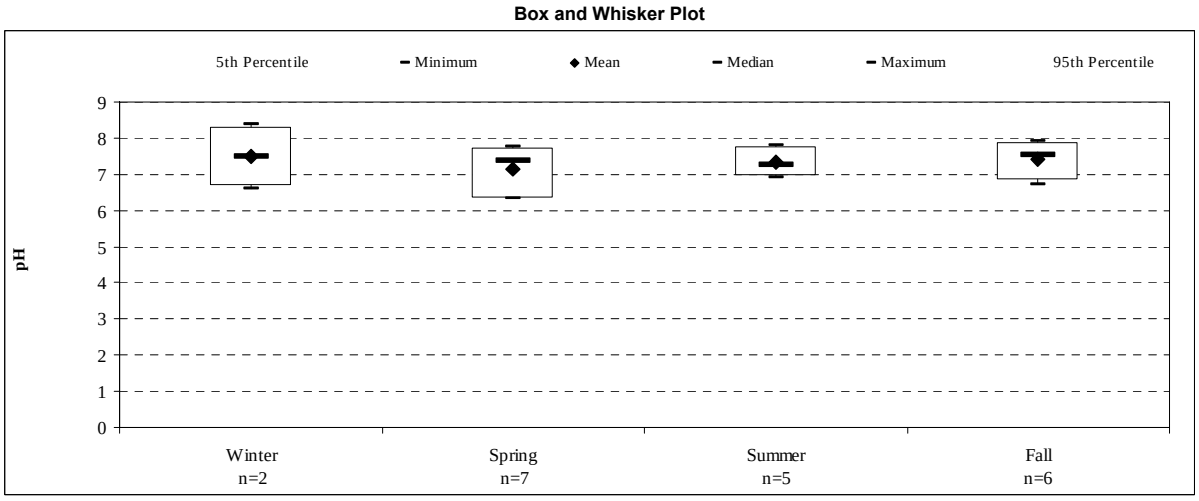


Figure G-3-2-1 Box Whisker and Time Series Scatter Plots of Observed pH in Eymundson Creek



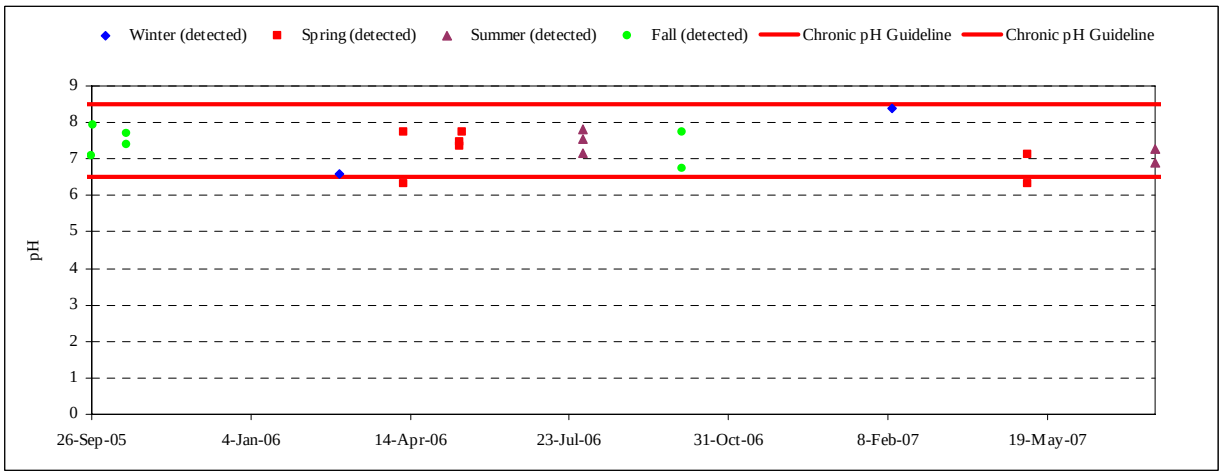
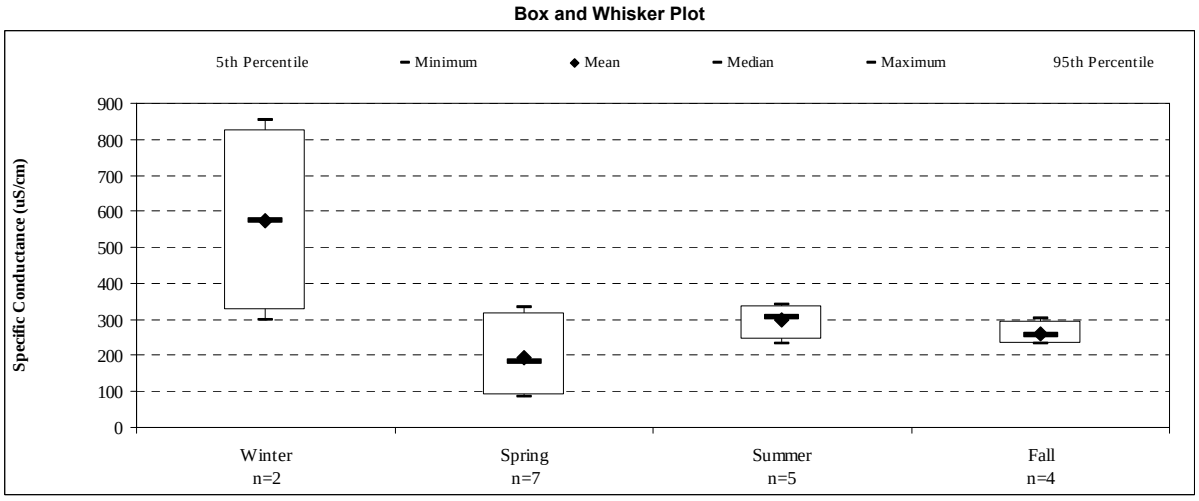


Figure G-3-2-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Eymundson Creek



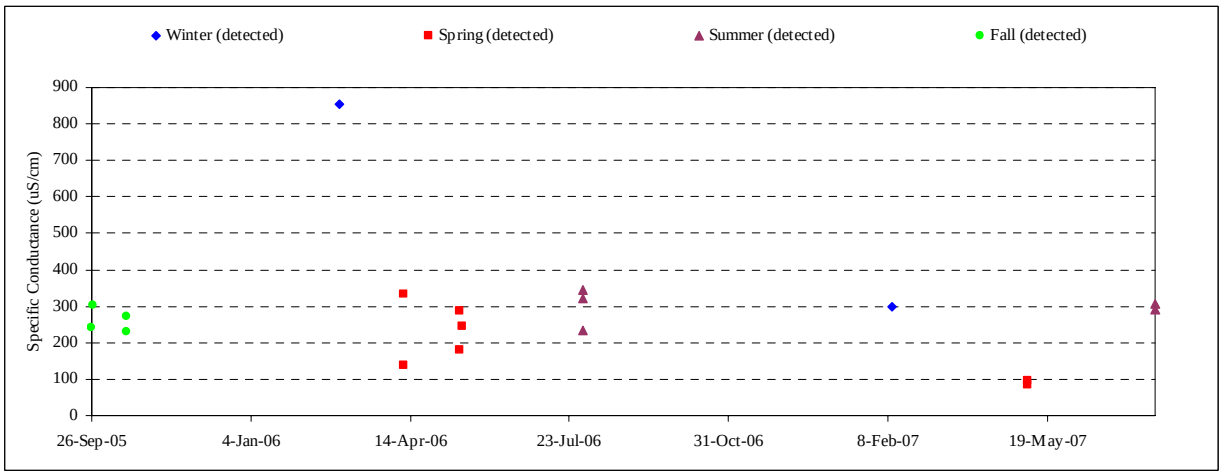
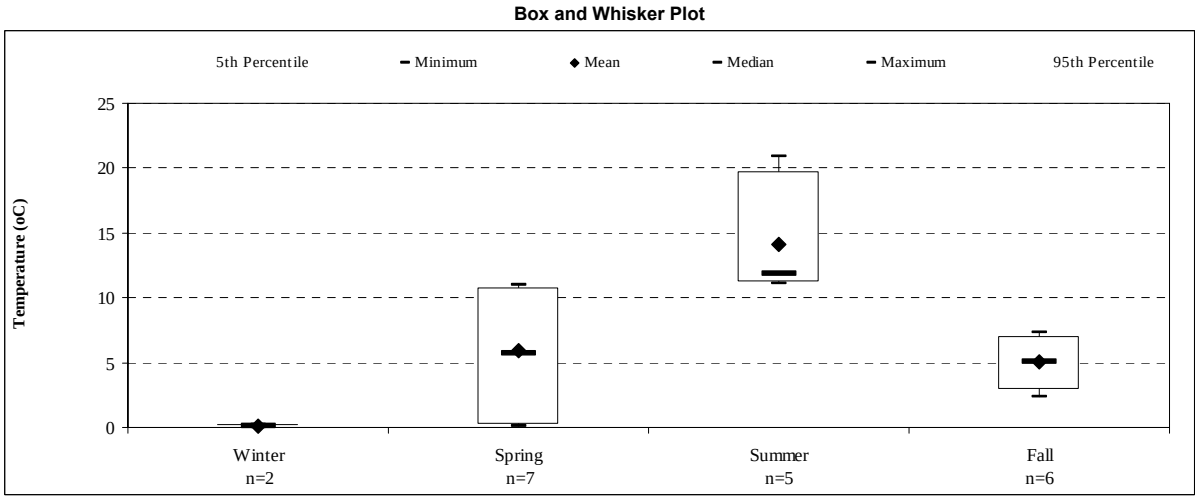


Figure G-3-2-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Eymundson Creek



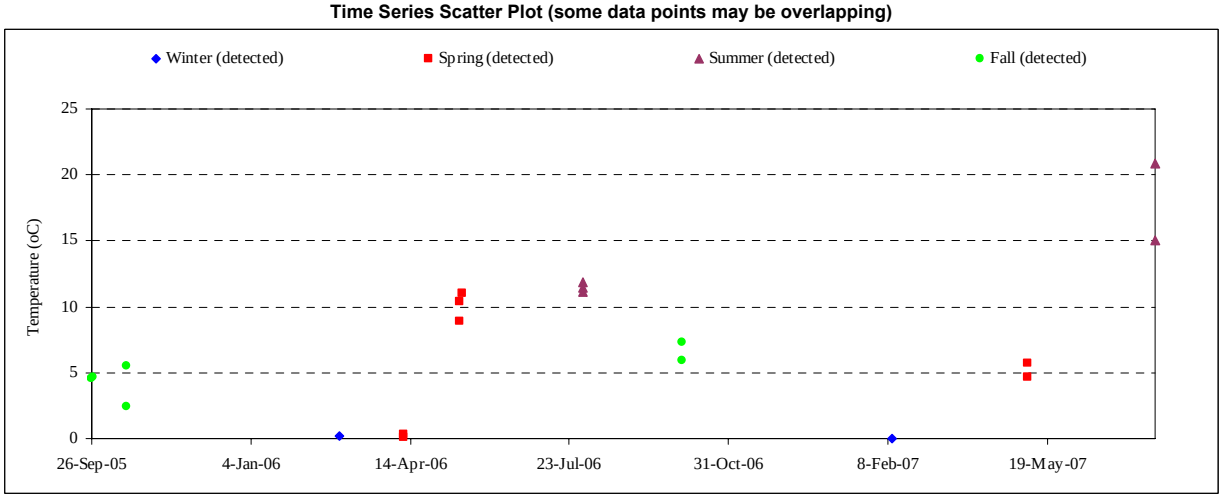
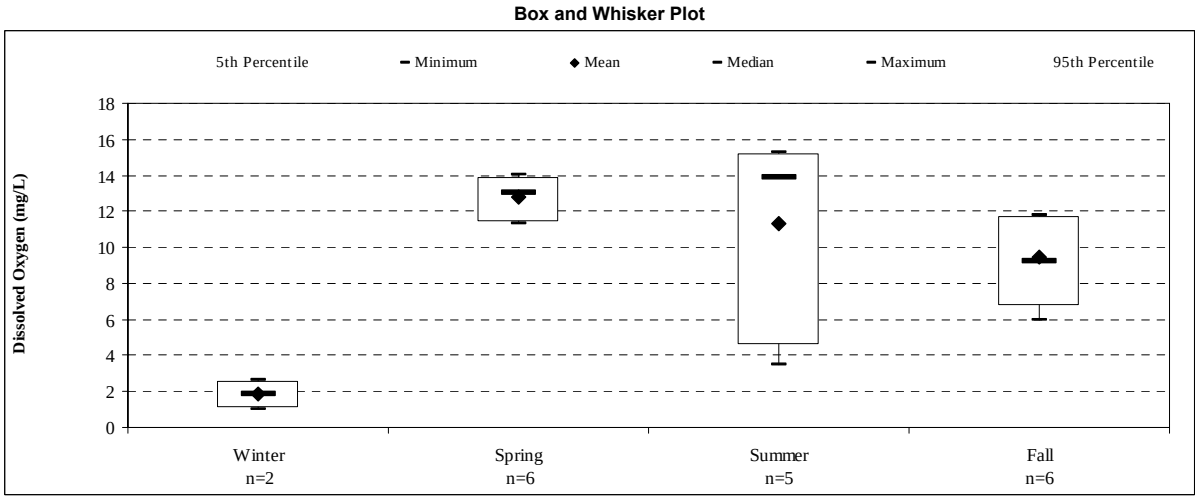


Figure G-3-2-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Eymundson Creek



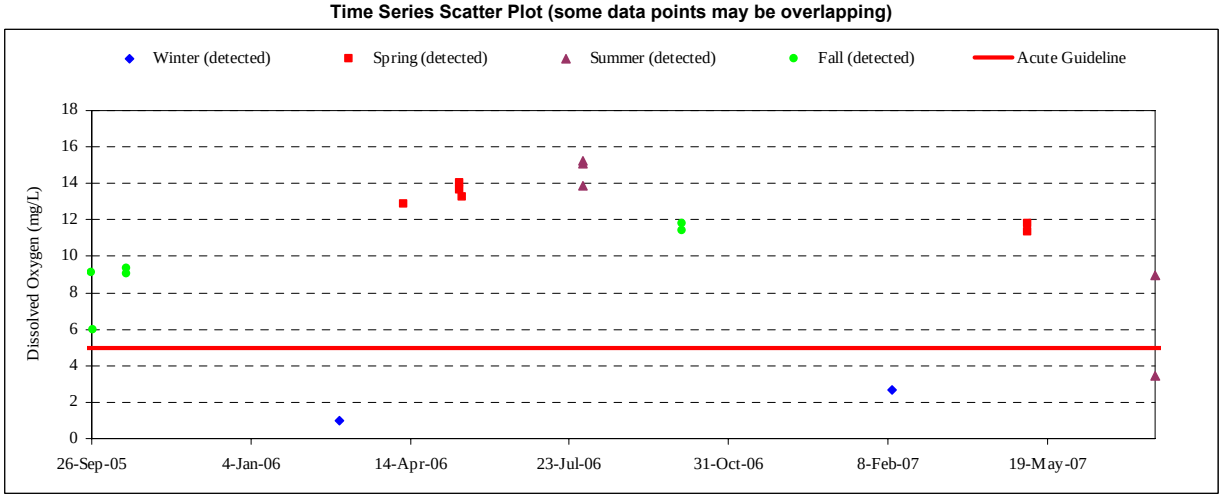
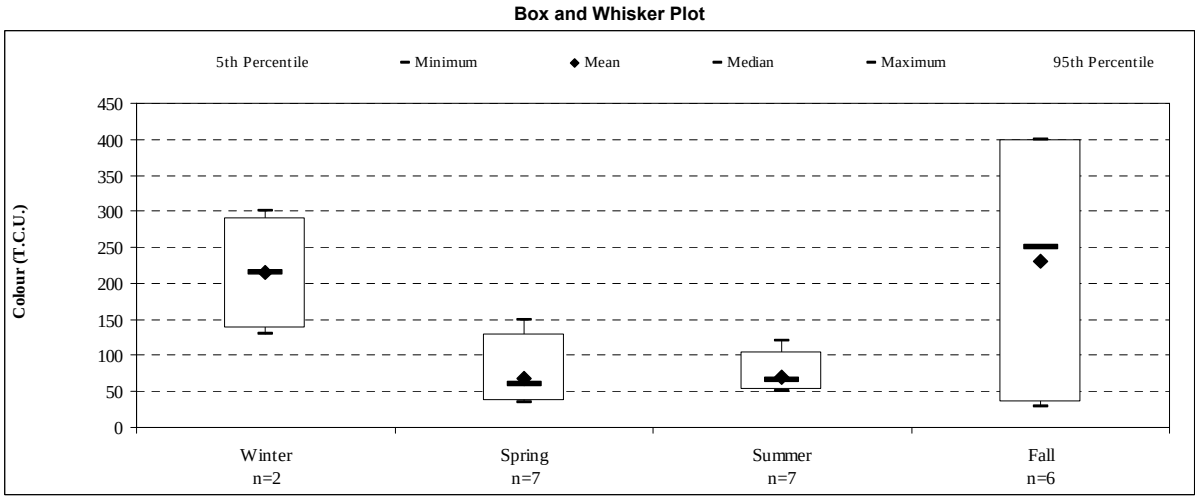


Figure G-3-2-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Eymundson Creek



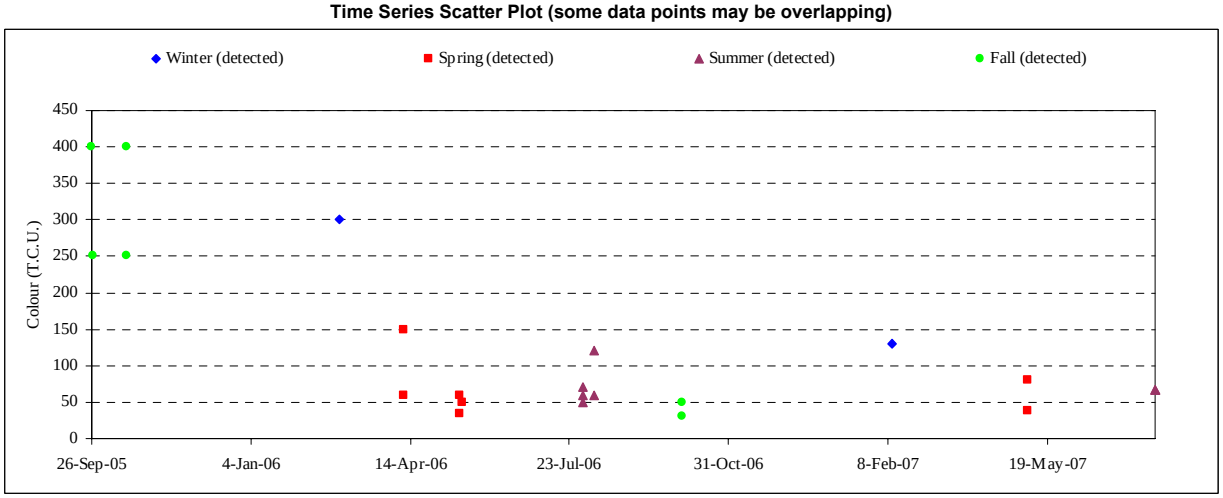
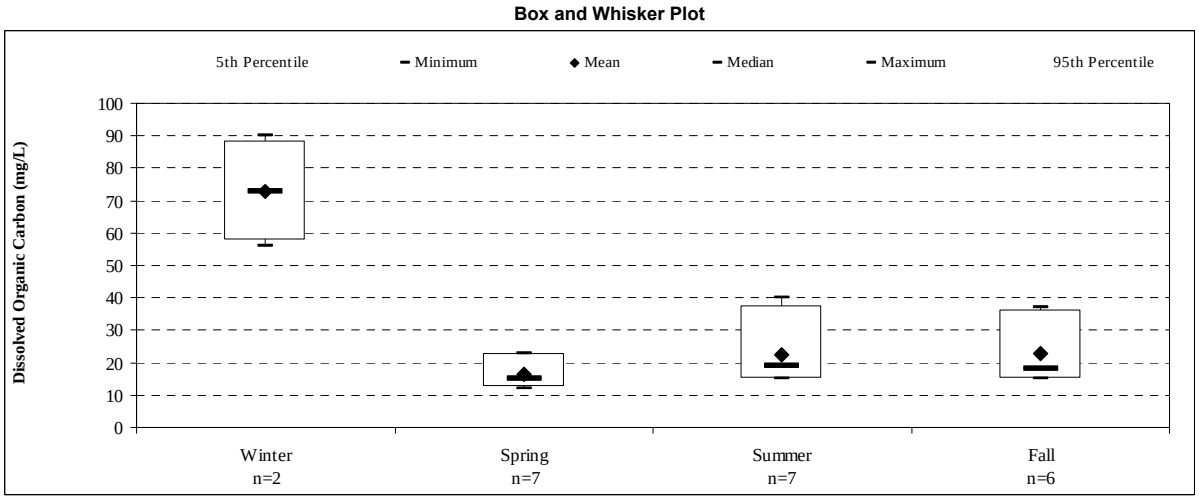


Figure G-3-2-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Eymundson Creek



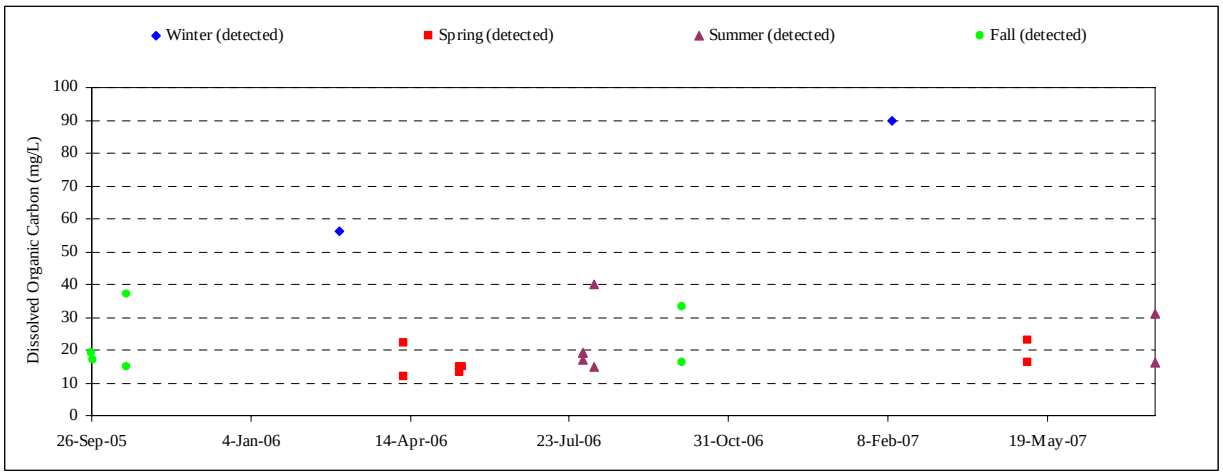
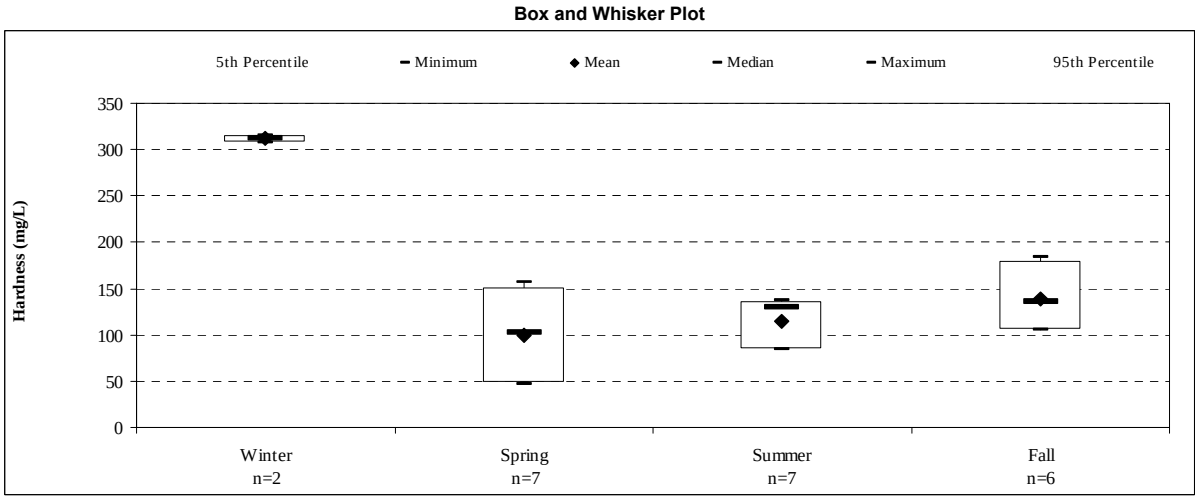


Figure G-3-2-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Eymundson Creek



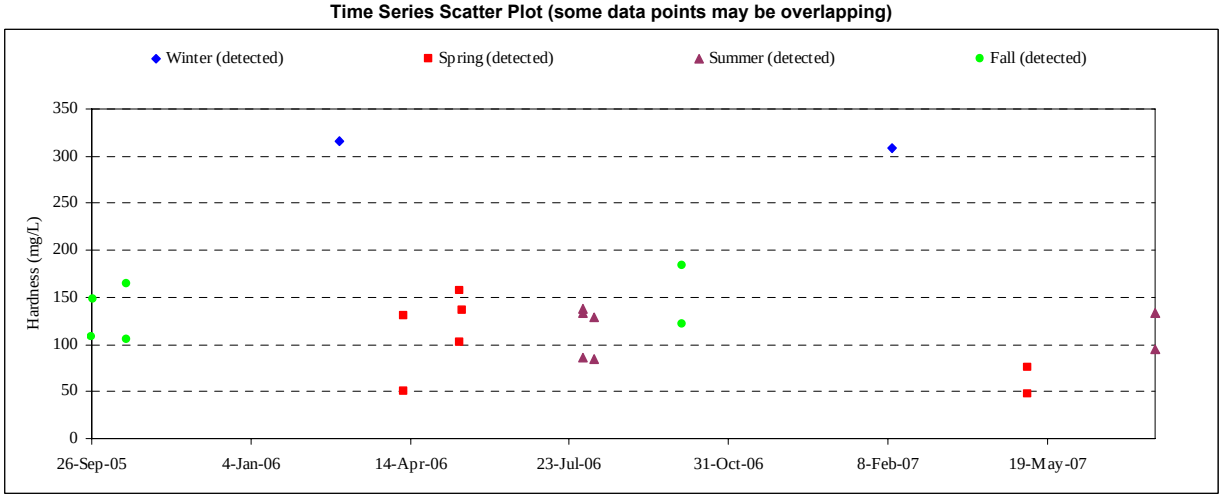


Figure G-3-2-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Eymundson Creek

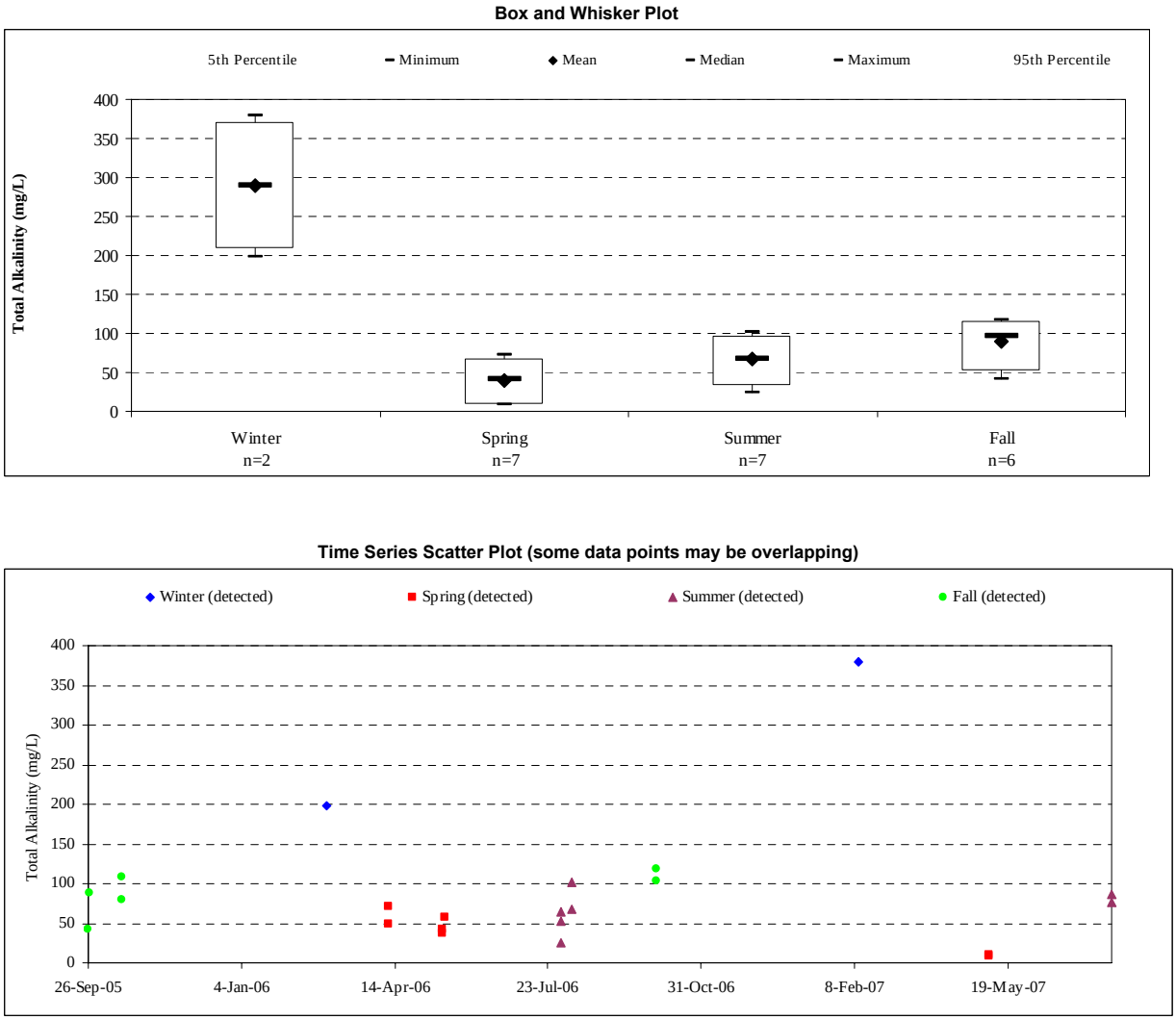
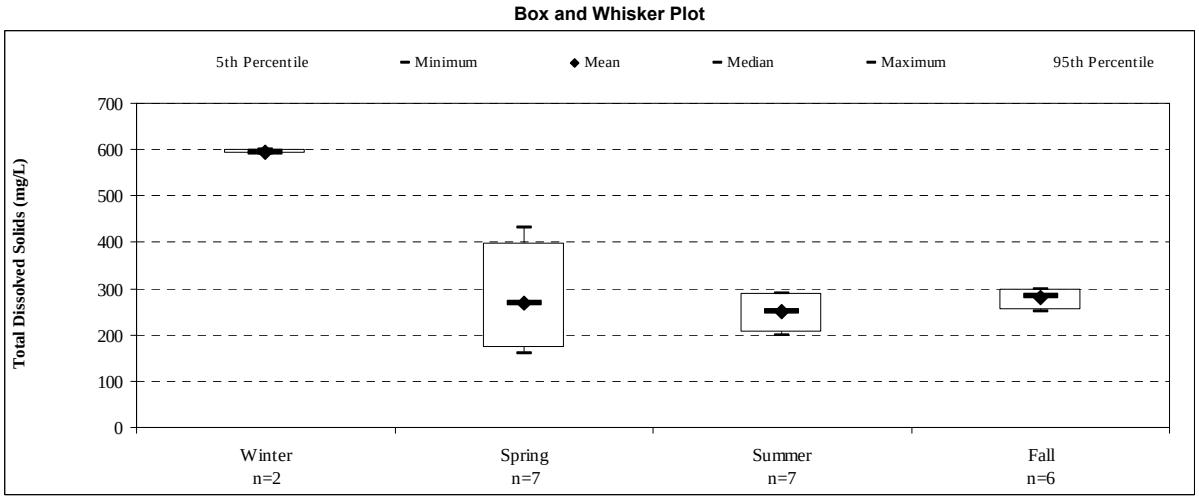


Figure G-3-2-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Eymundson Creek



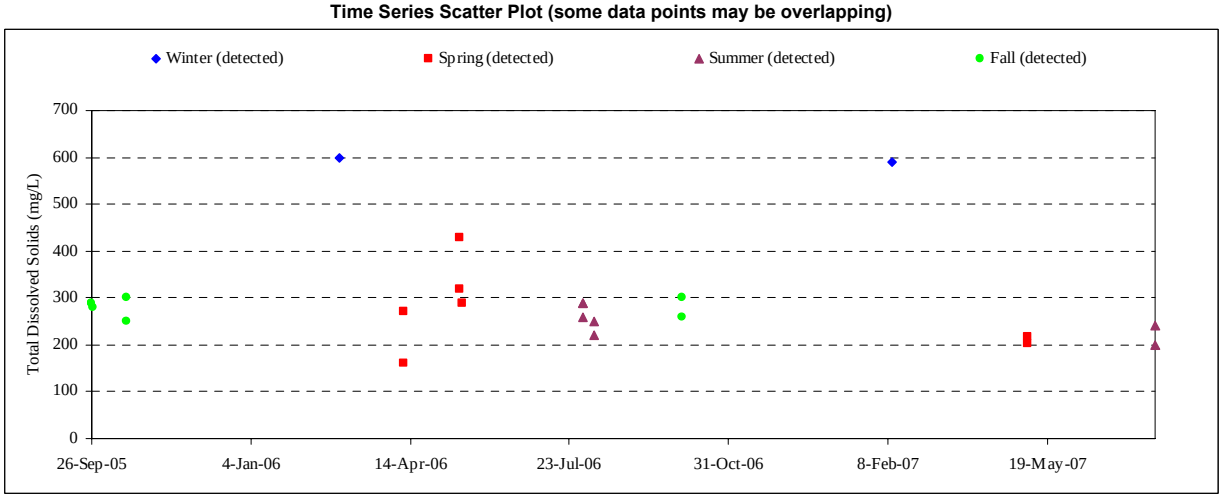
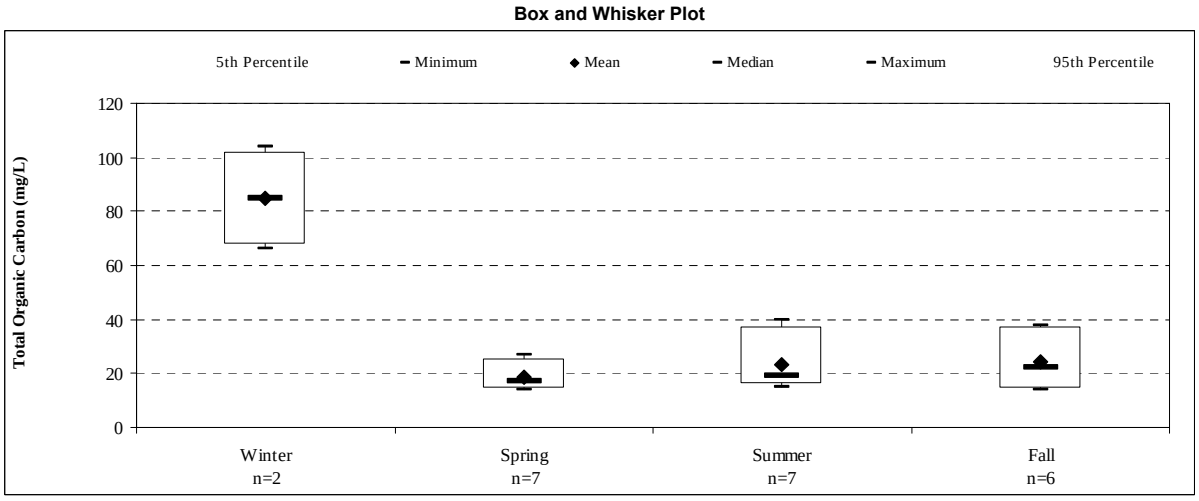


Figure G-3-2-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Eymundson Creek



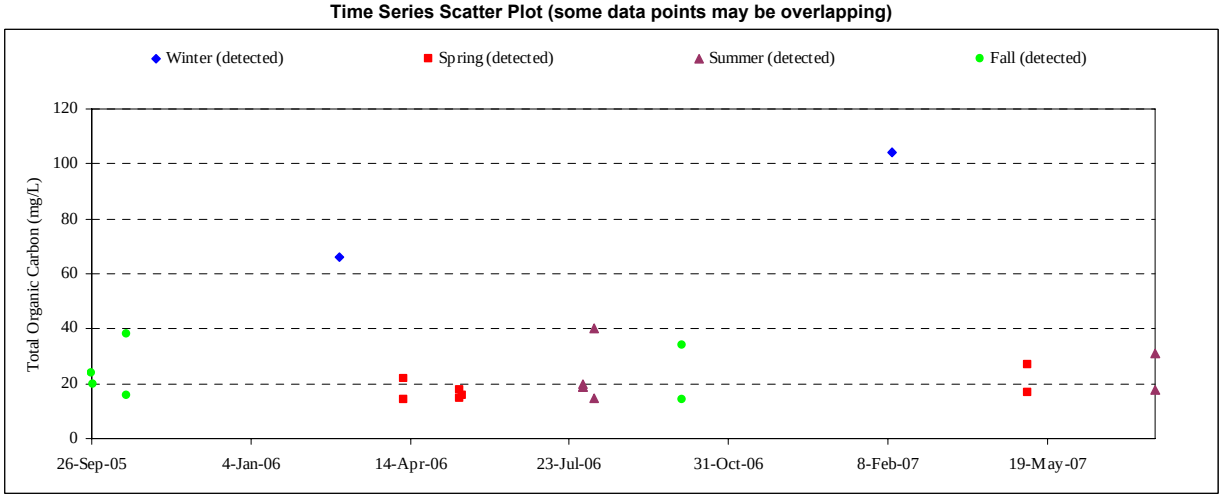
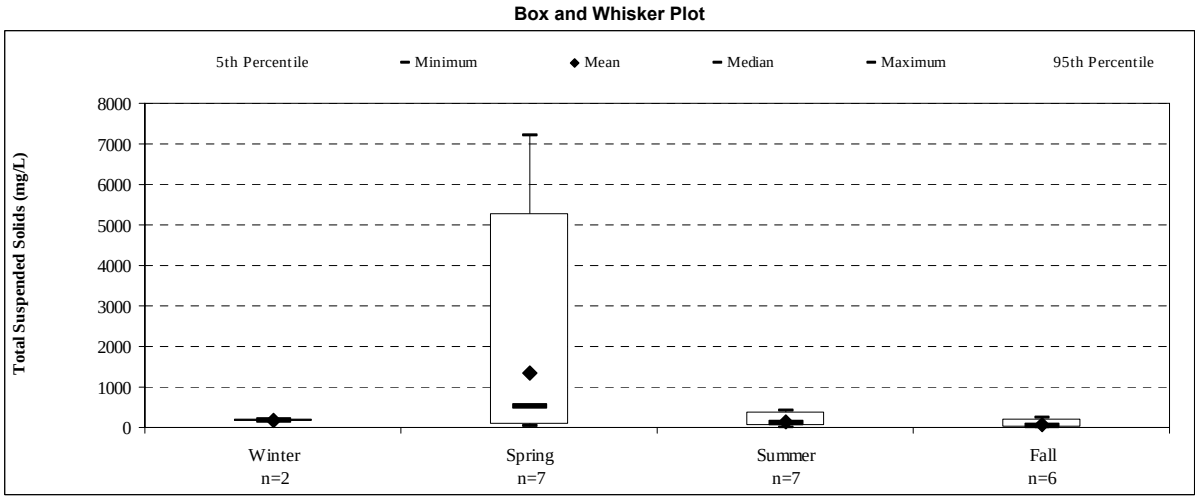


Figure G-3-2-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Eymundson Creek



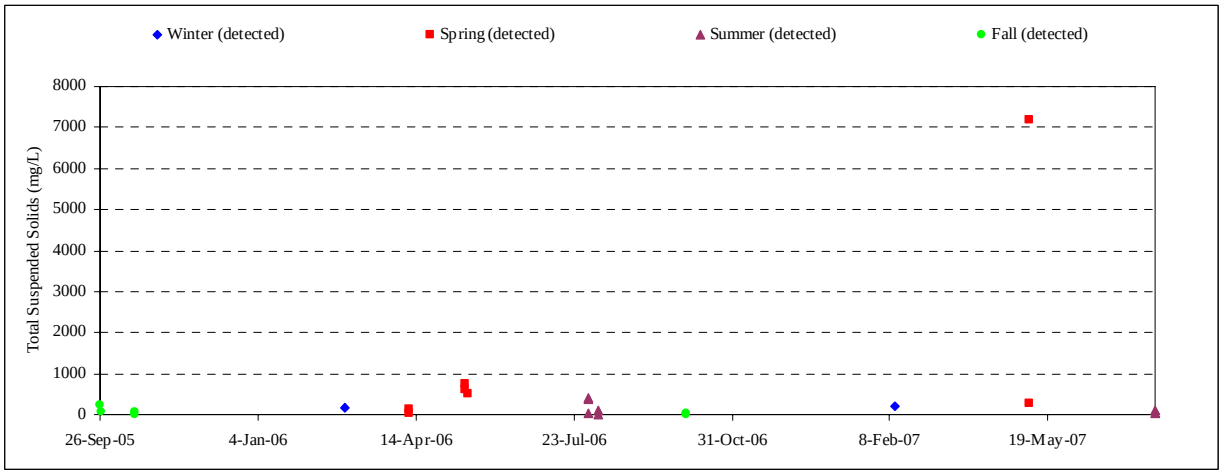
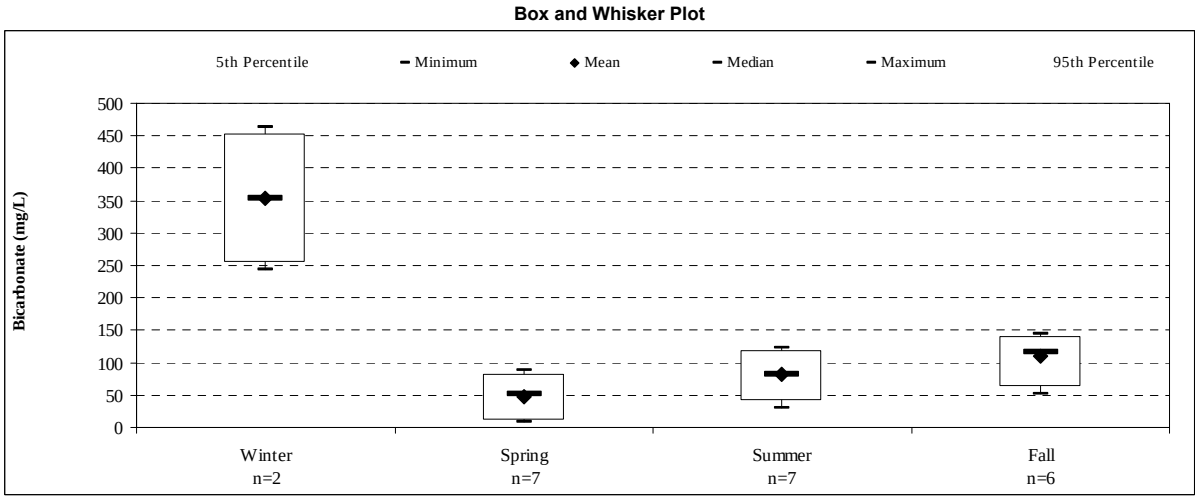


Figure G-3-2-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Eymundson Creek



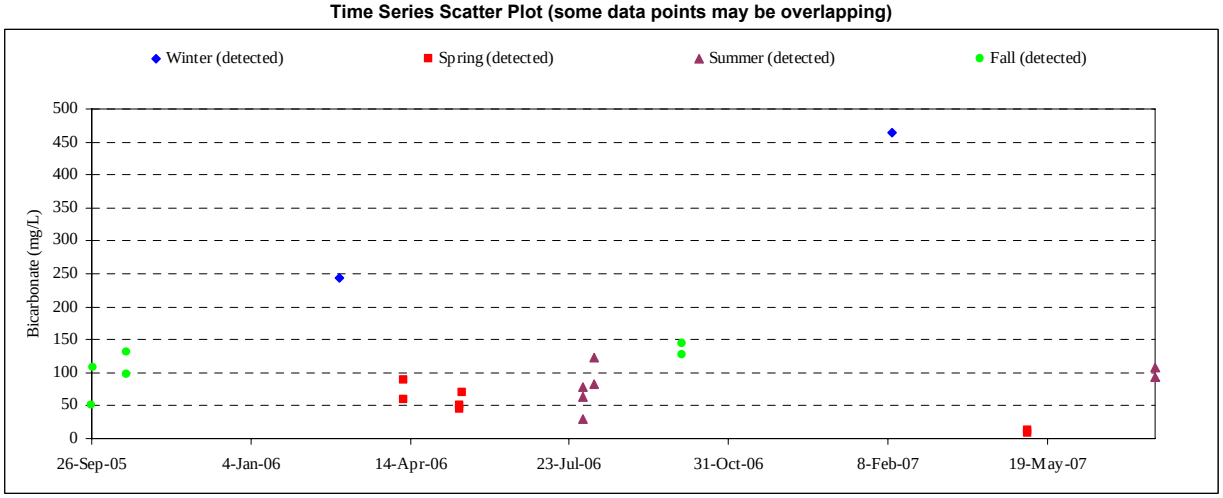


Figure G-3-2-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Eymundson Creek

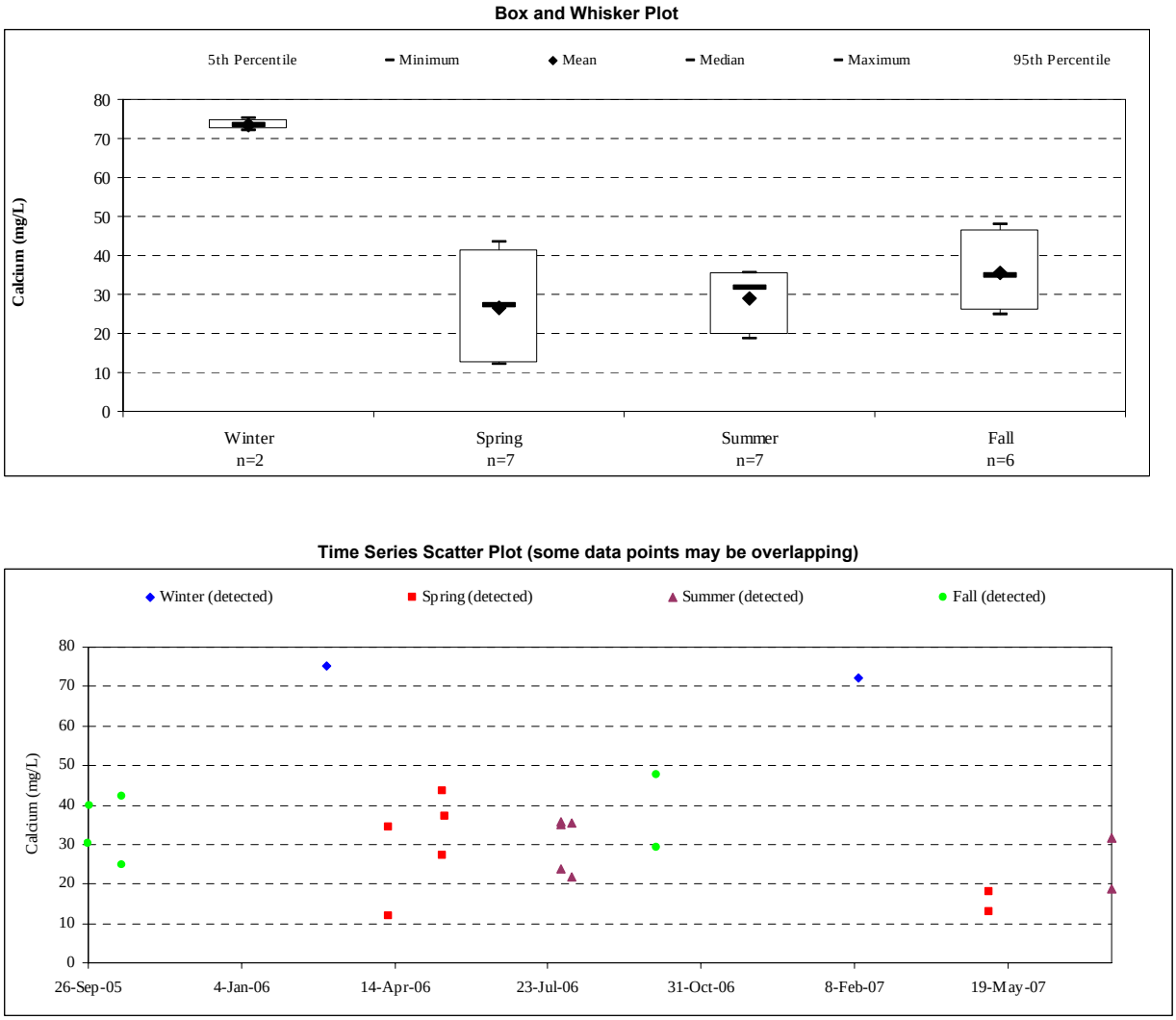
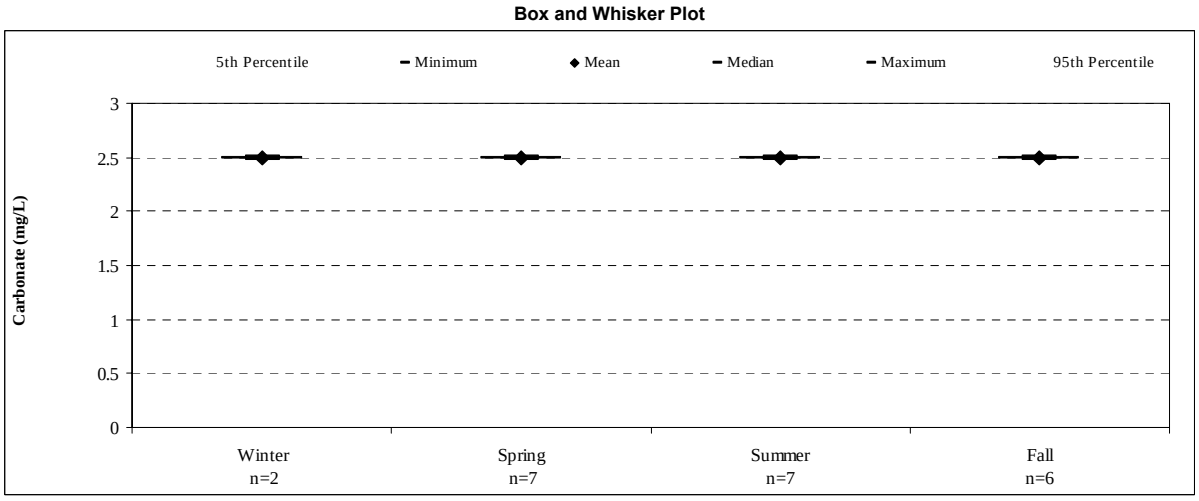


Figure G-3-2-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Eymundson Creek



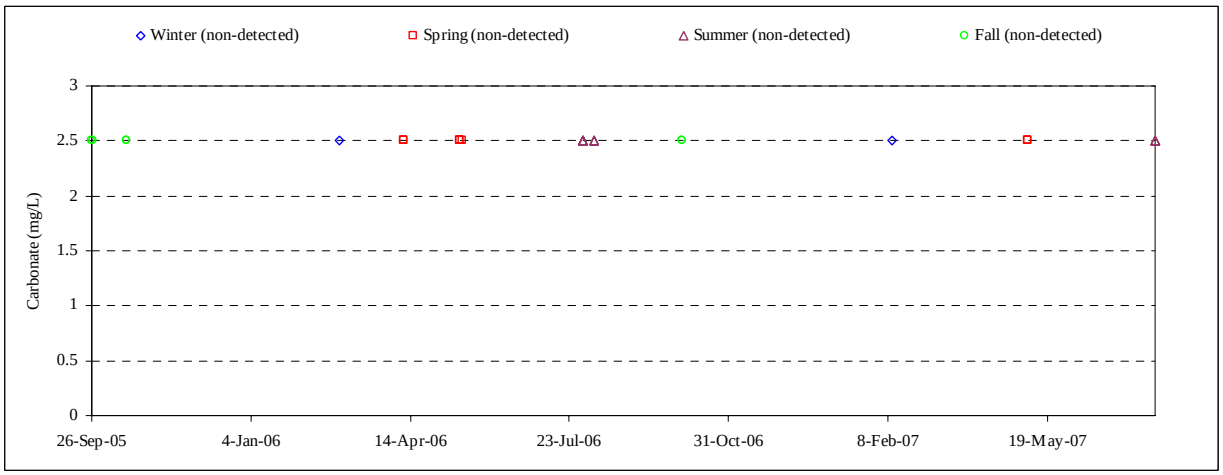
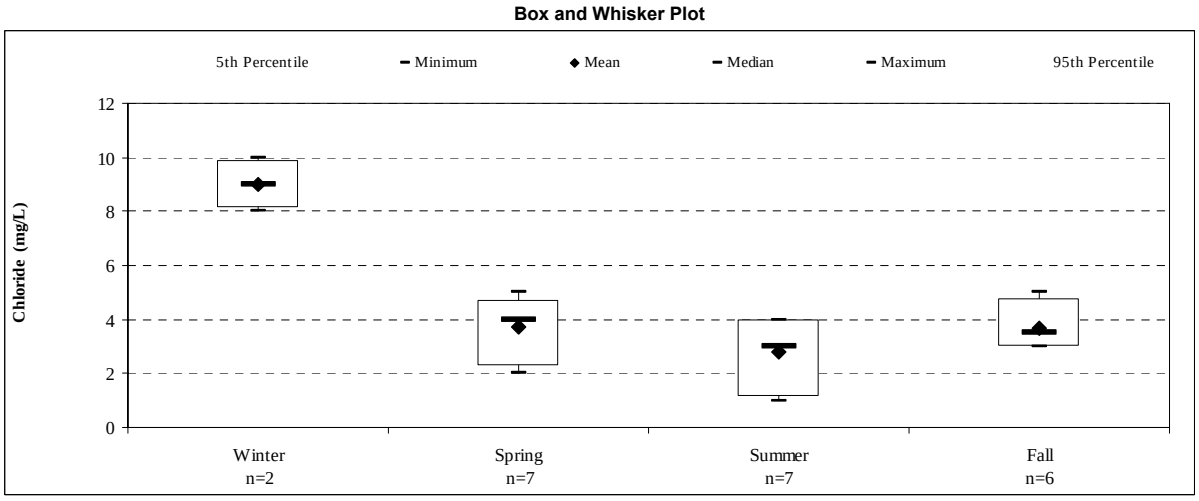


Figure G-3-2-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Eymundson Creek



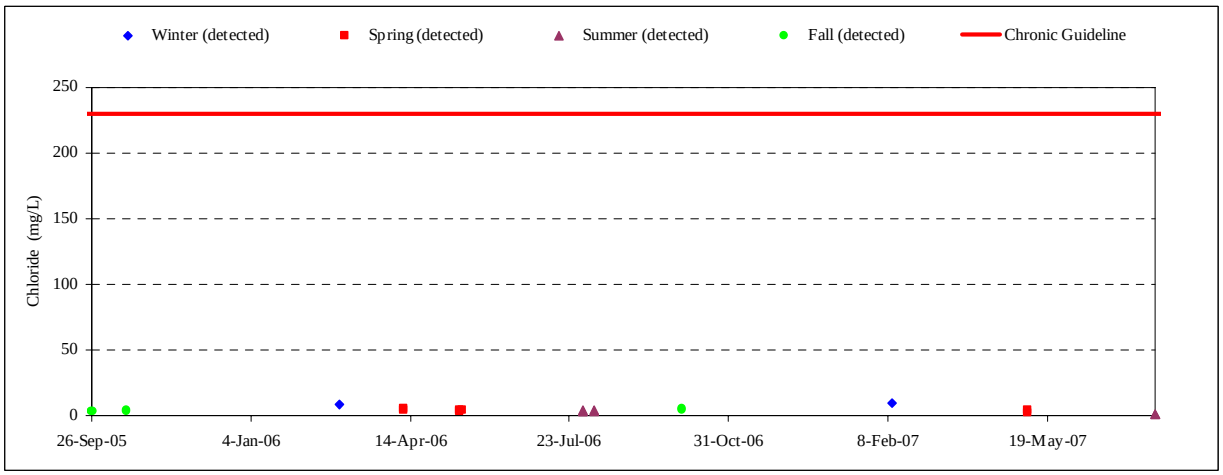
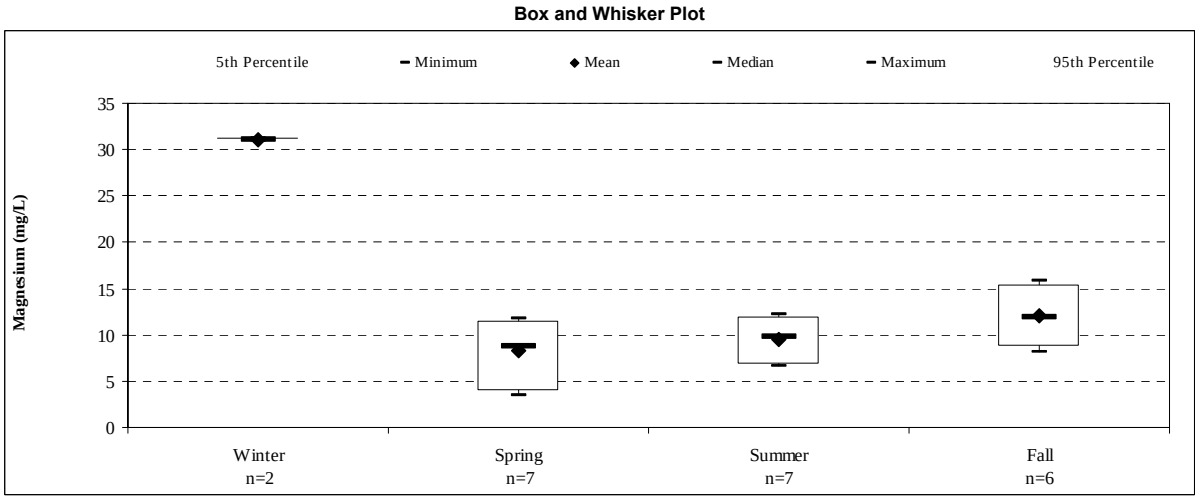


Figure G-3-2-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Eymundson Creek



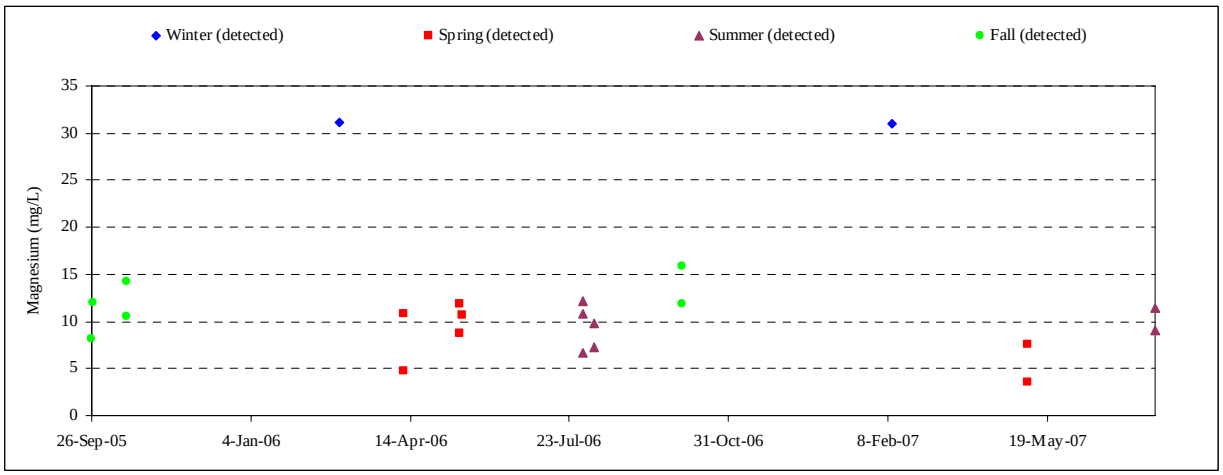


Figure G-3-2-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Eymundson Creek

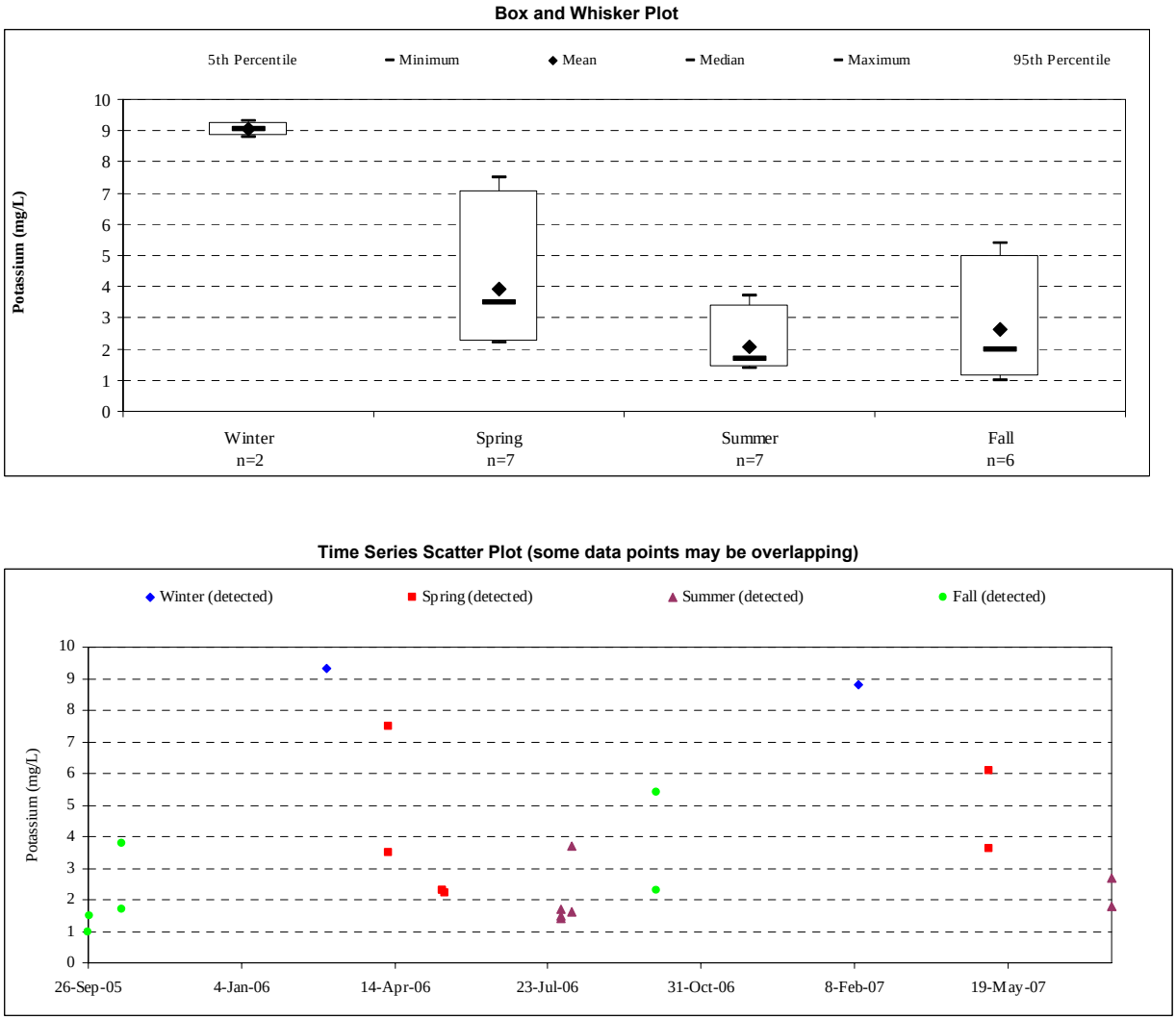
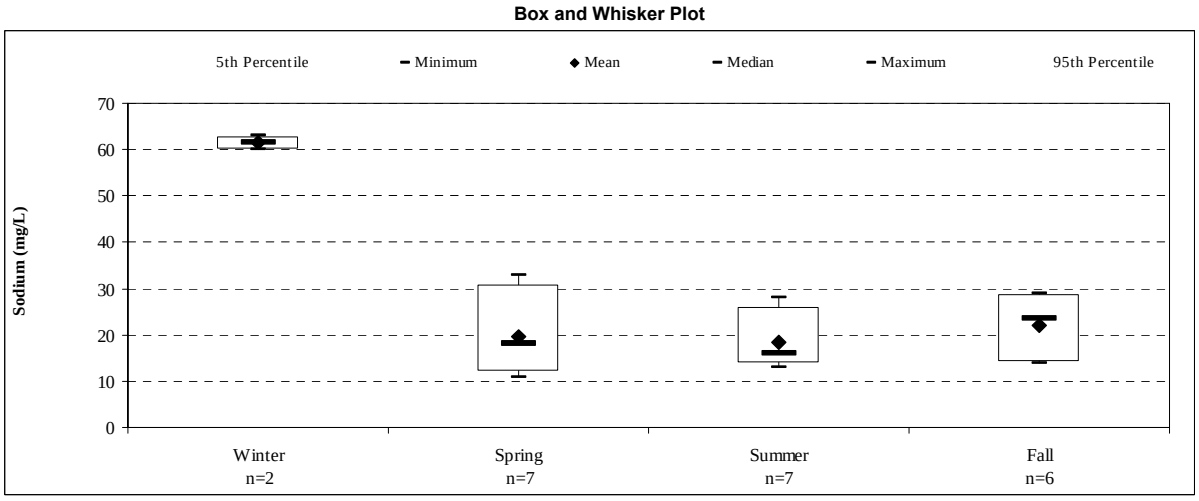


Figure G-3-2-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Eymundson Creek



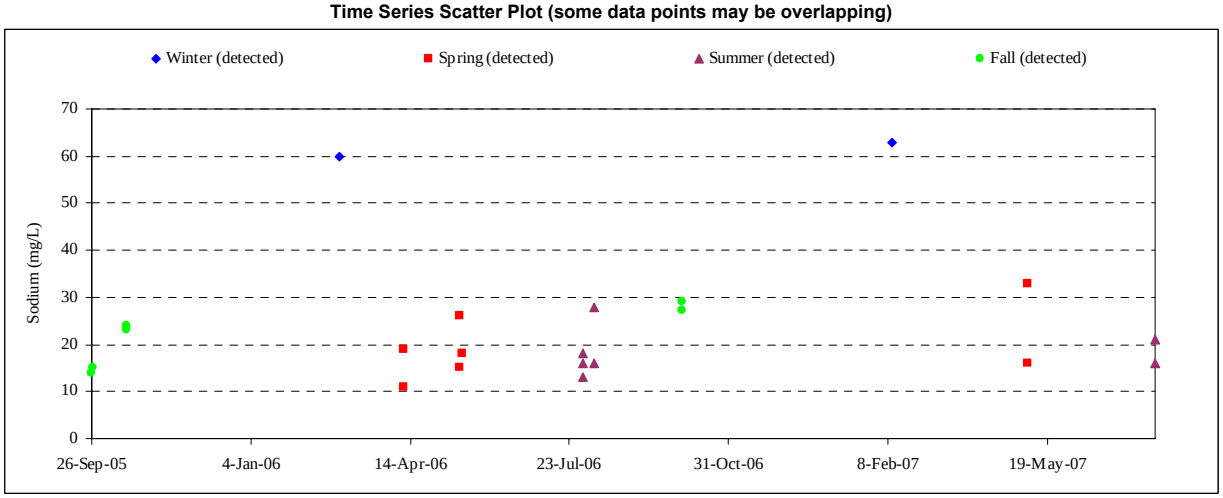
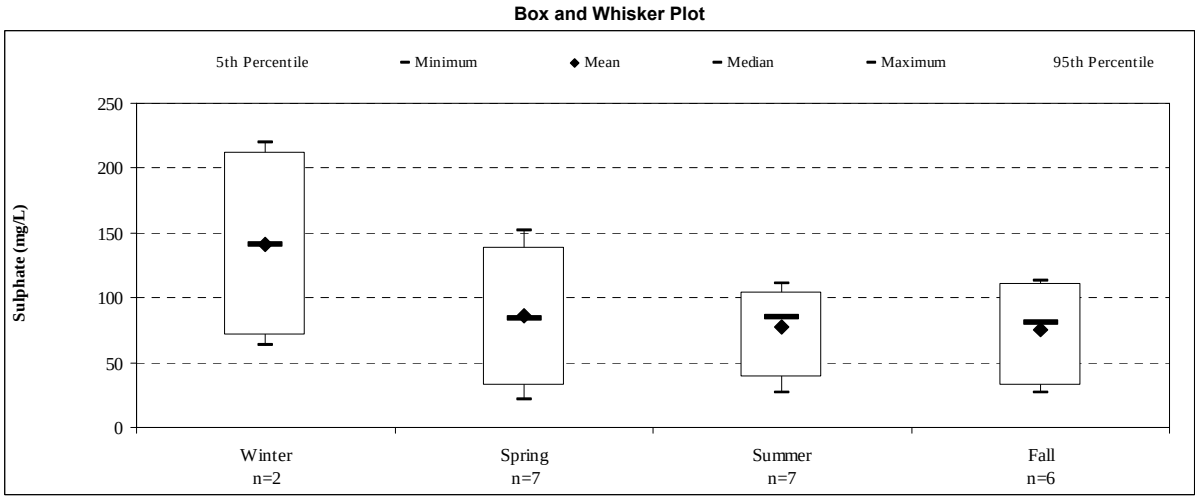


Figure G-3-2-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Eymundson Creek



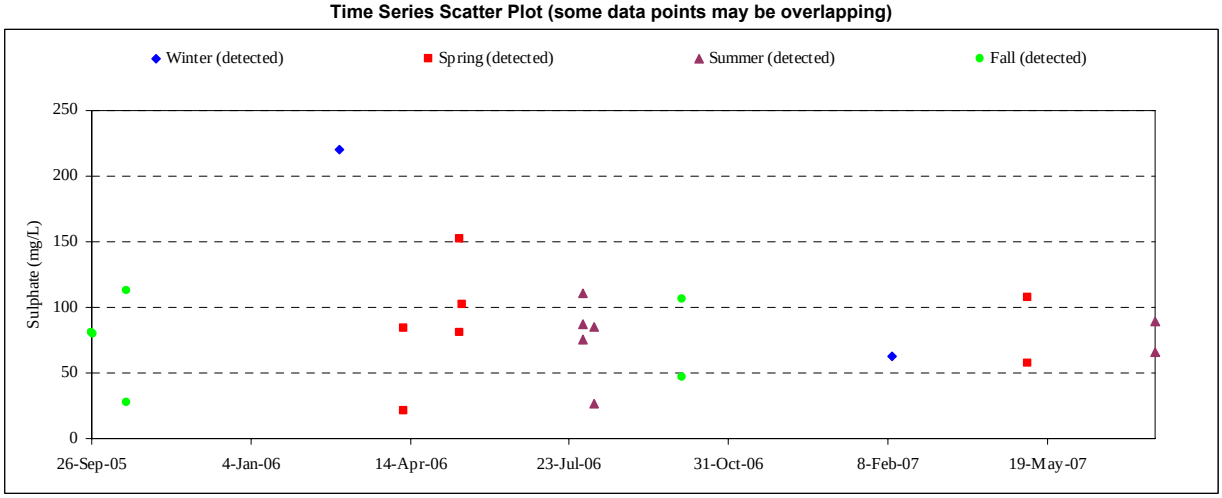
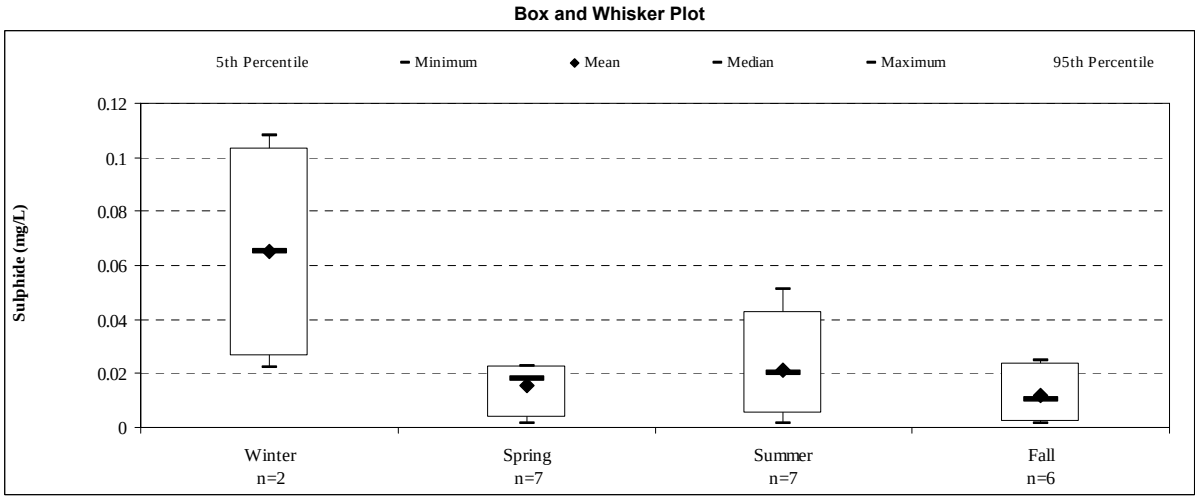


Figure G-3-2-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Eymundson Creek



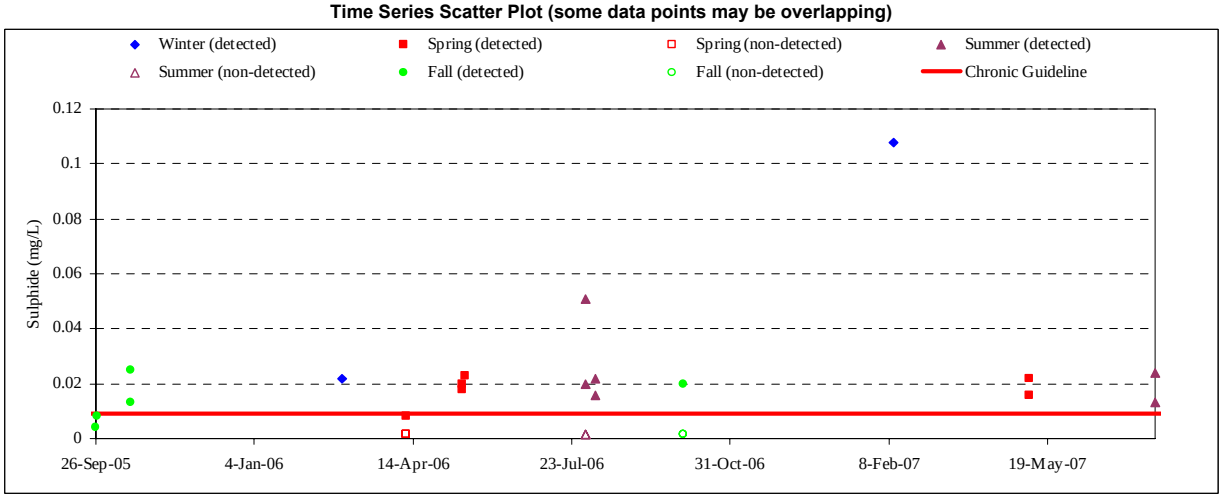
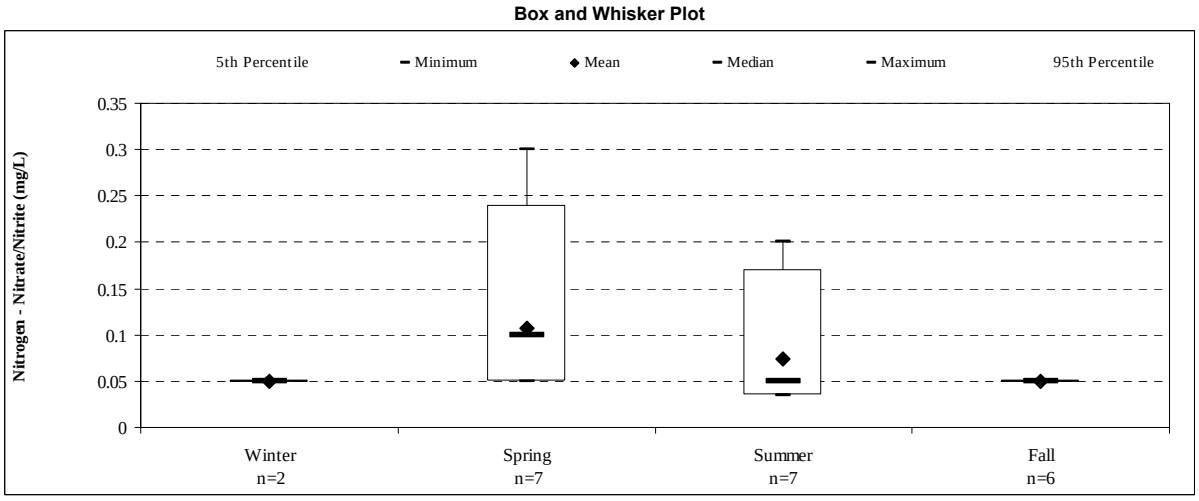


Figure G-3-2-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Eymundson Creek



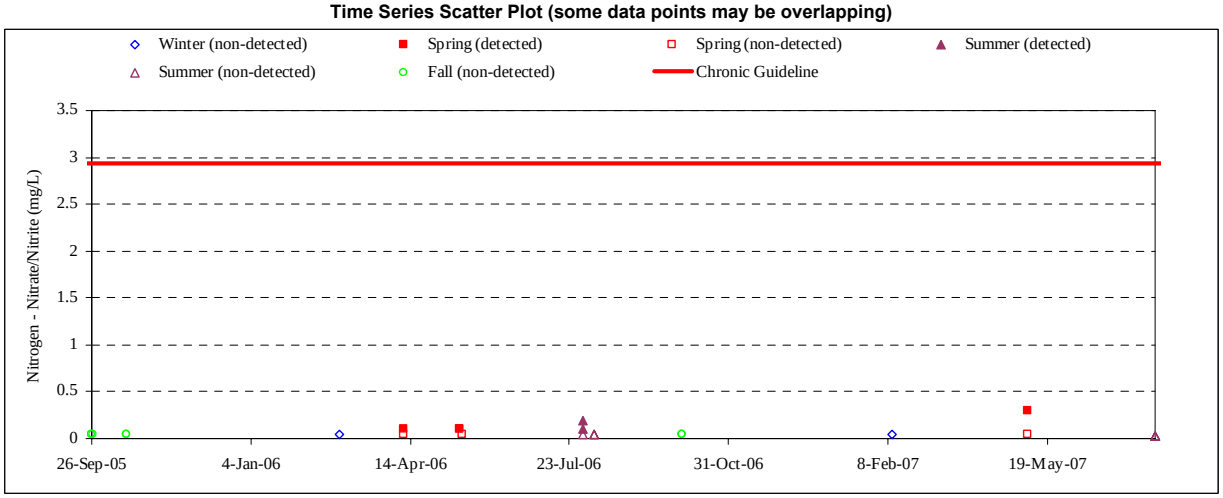
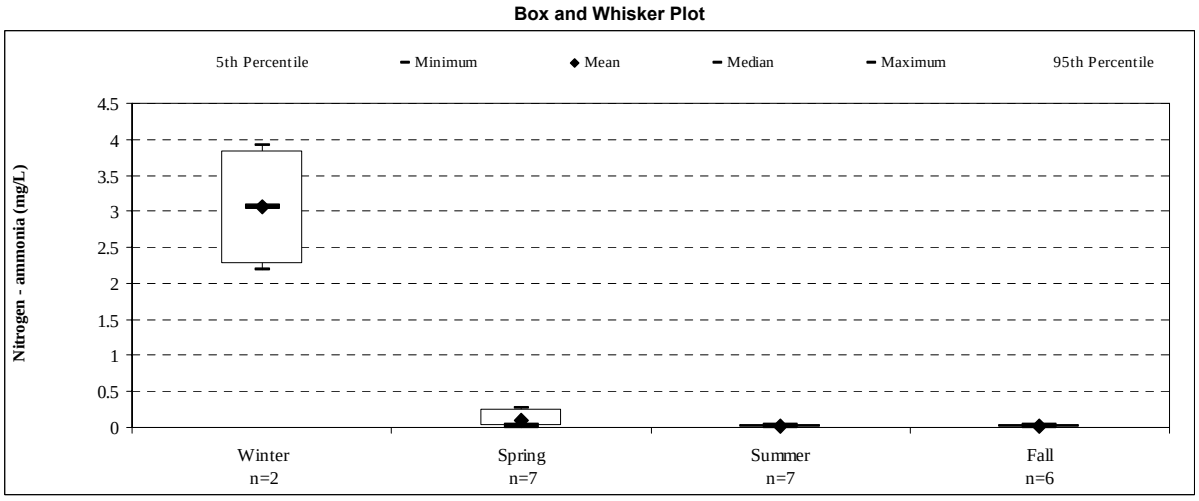


Figure G-3-2-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Eymundson Creek



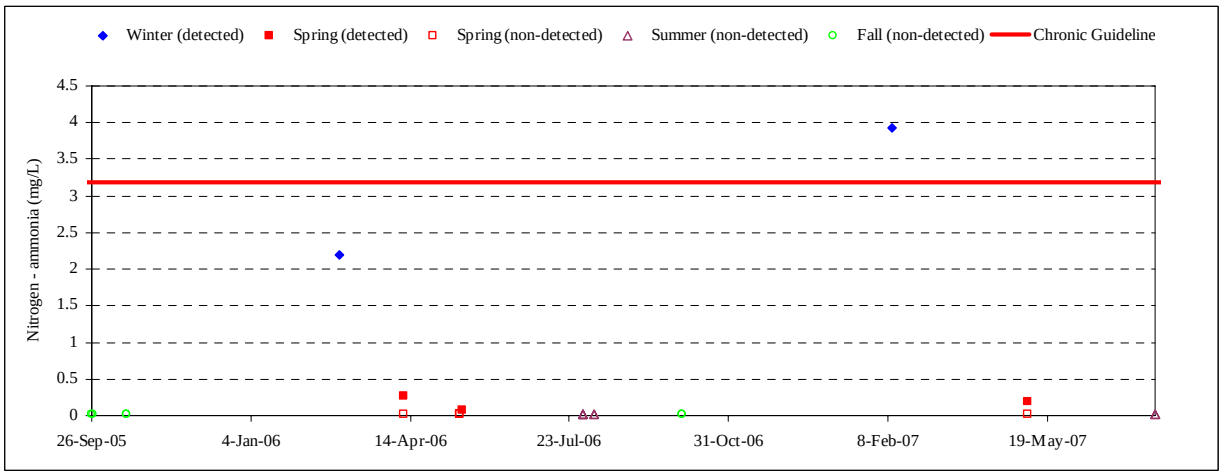
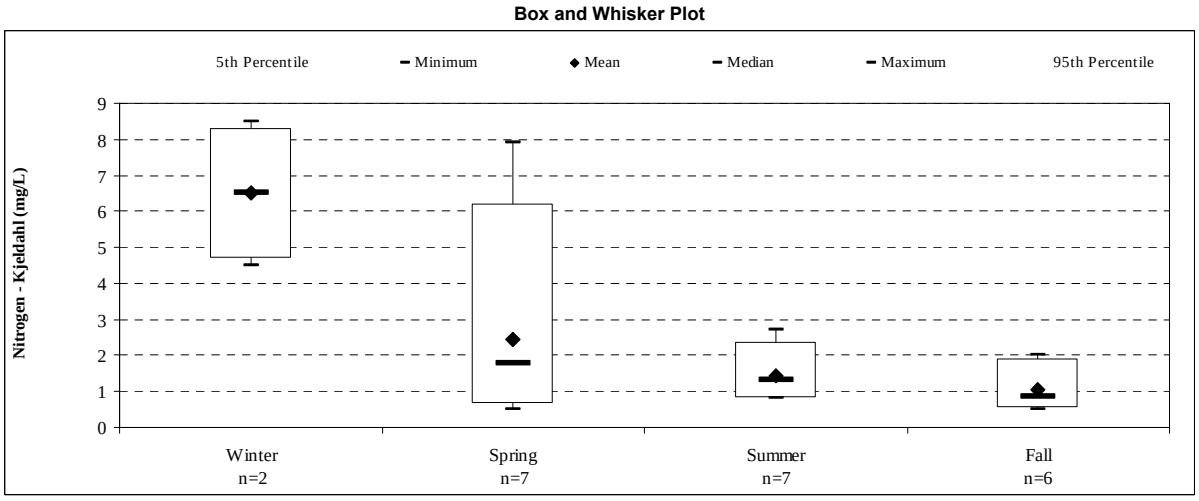


Figure G-3-2-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Eymundson Creek



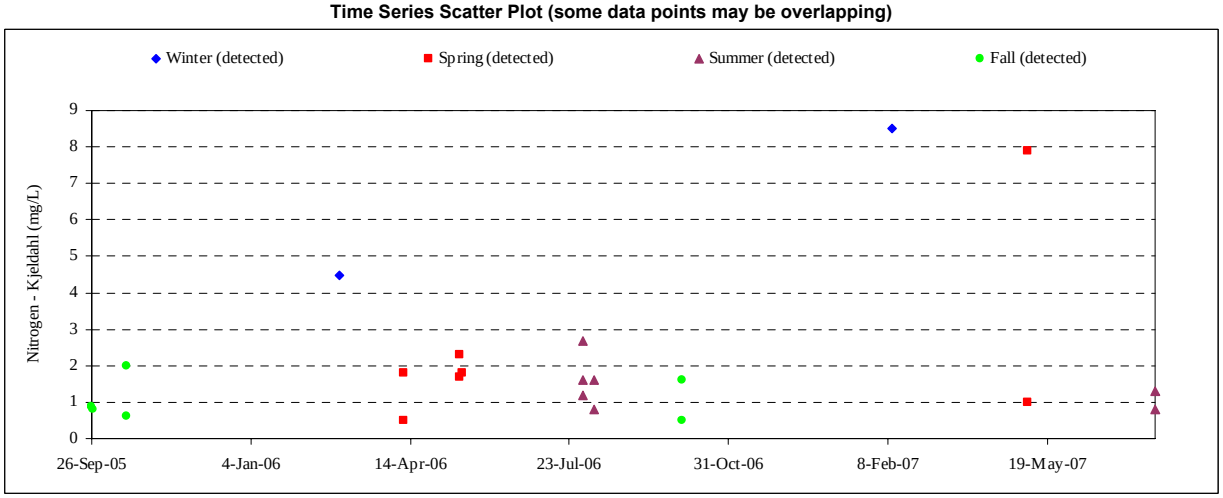
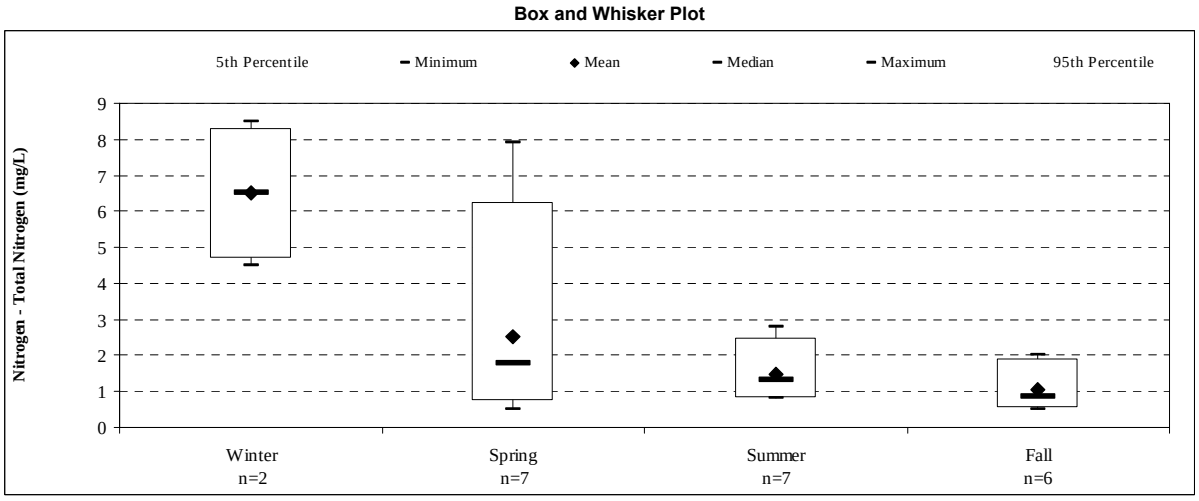


Figure G-3-2-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Eymundson Creek



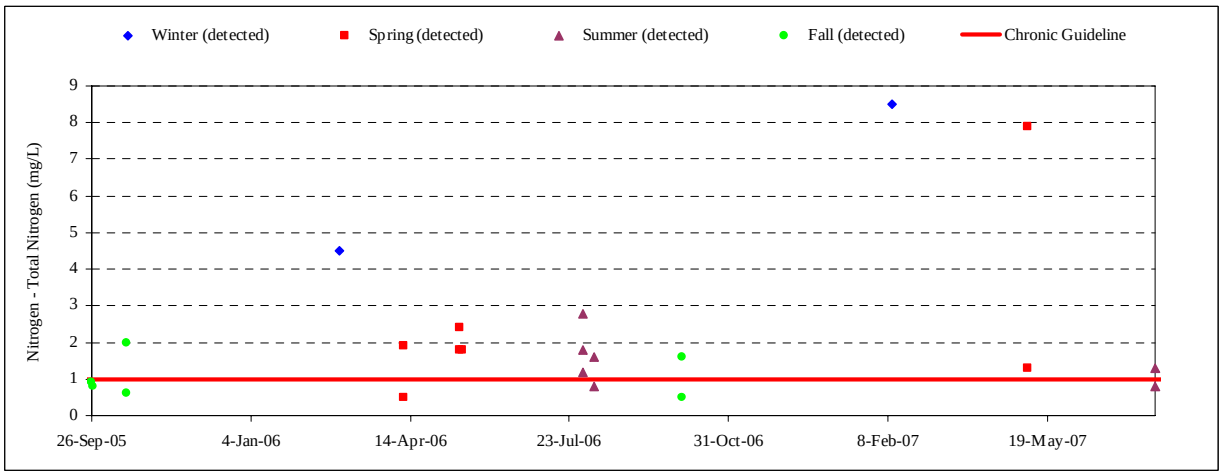
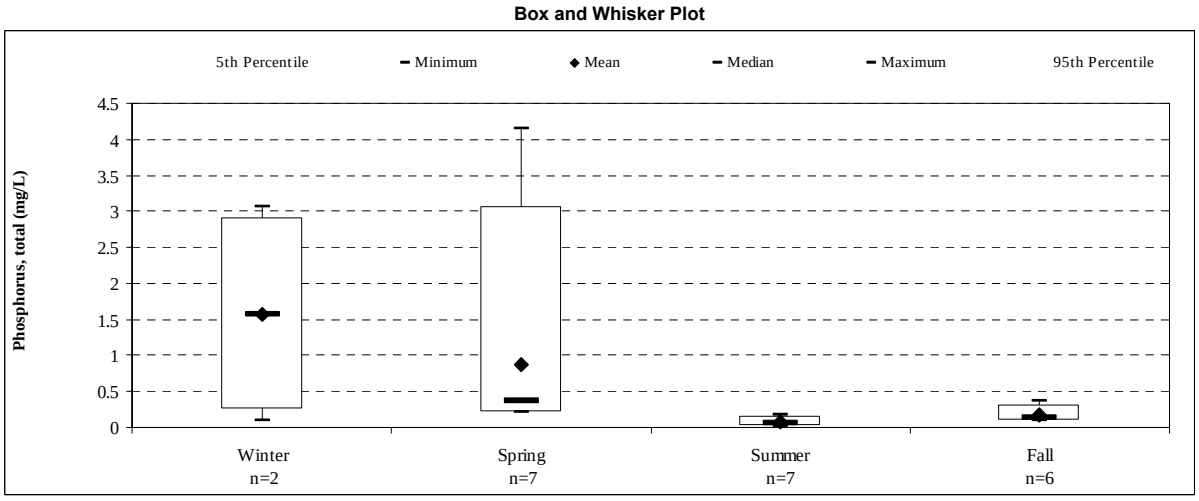


Figure G-3-2-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Eymundson Creek



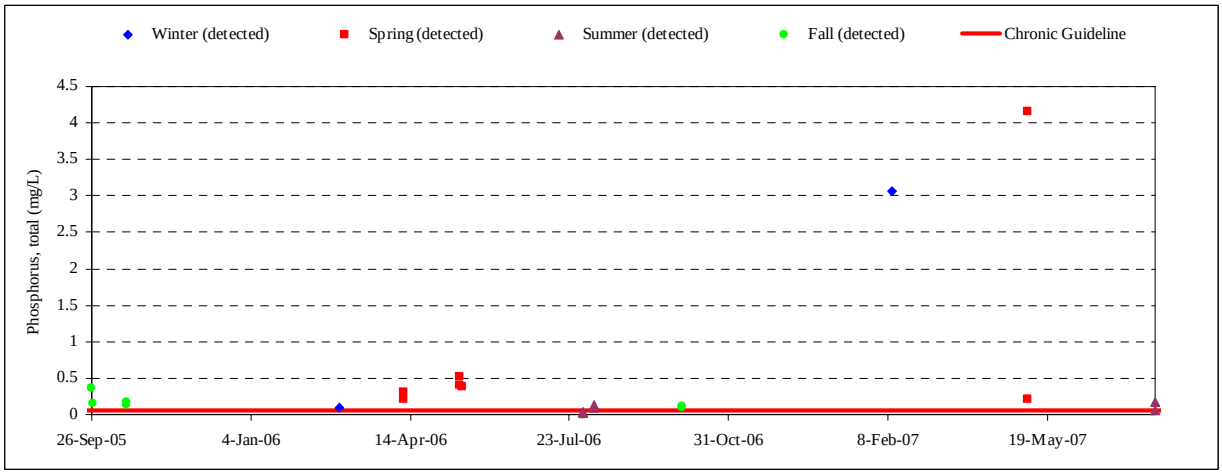
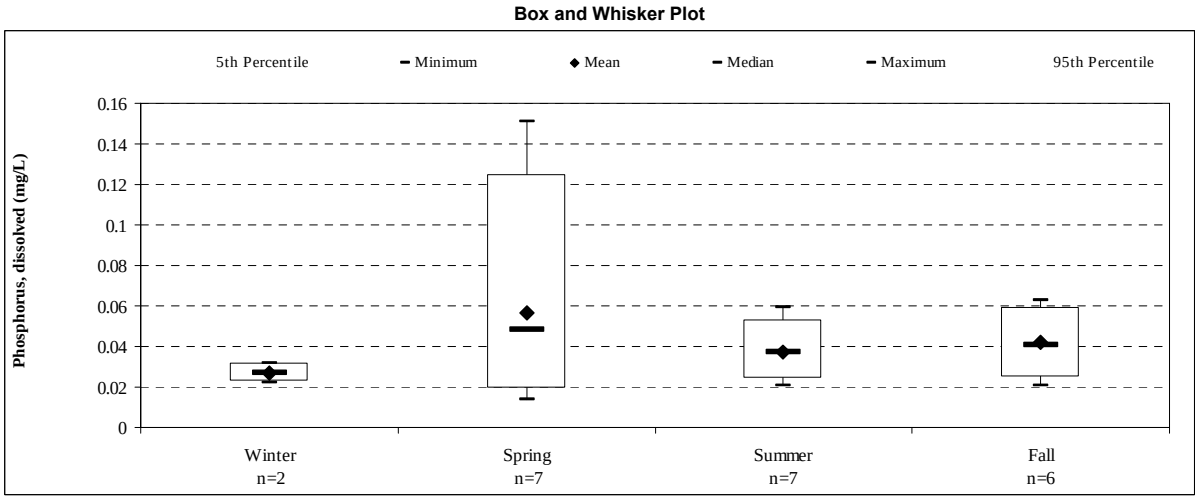


Figure G-3-2-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Eymundson Creek



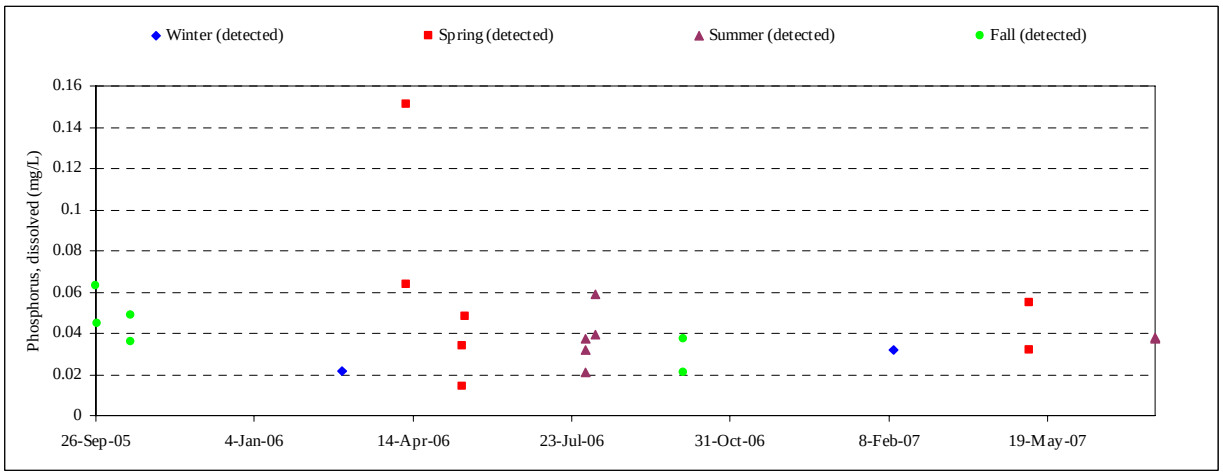
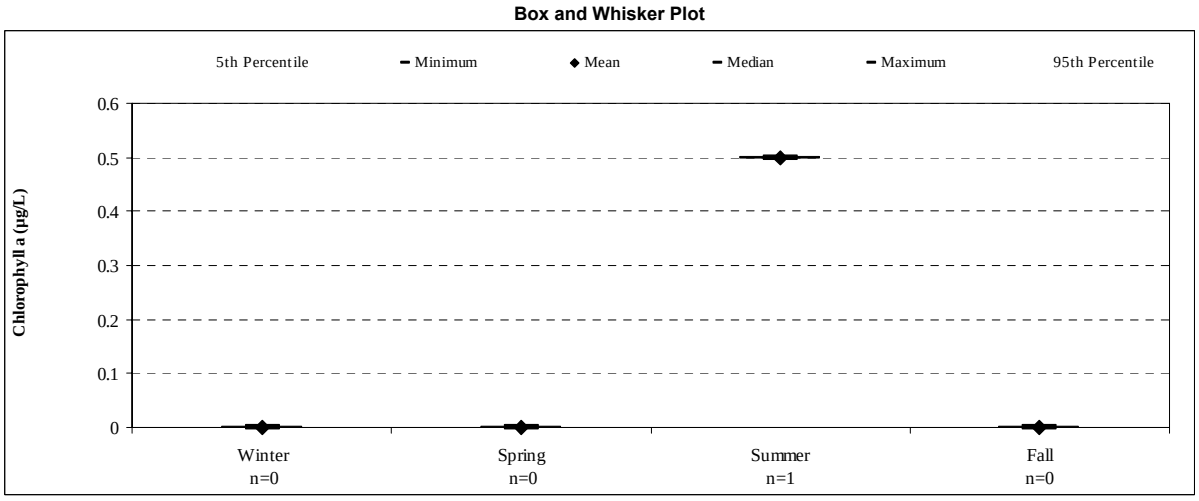


Figure G-3-2-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Eymundson Creek



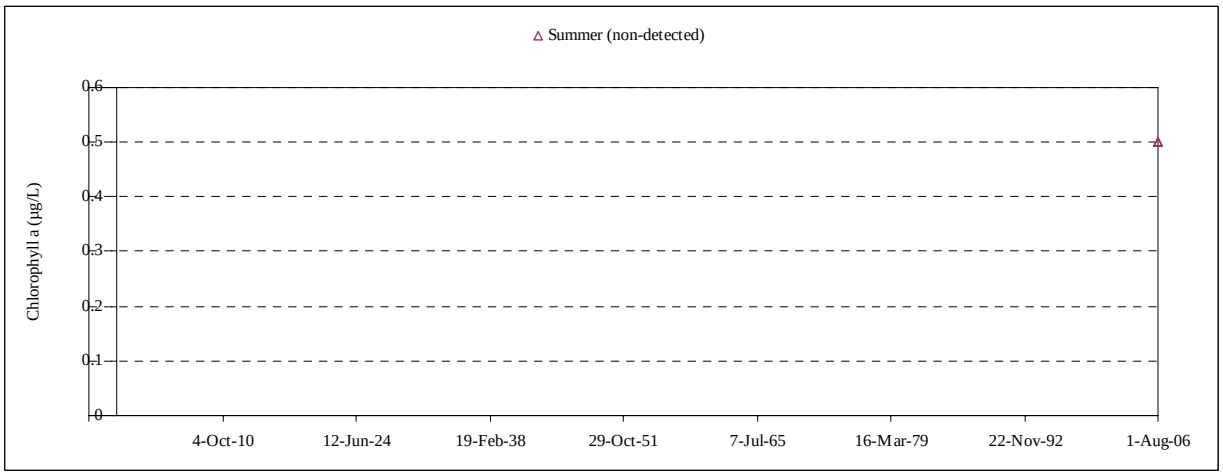
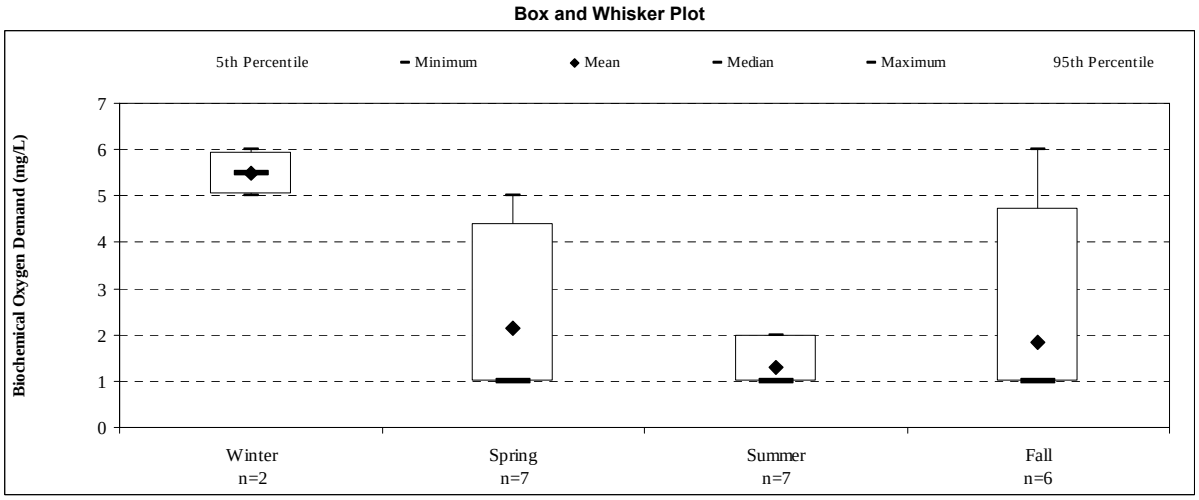


Figure G-3-2-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Eymundson Creek



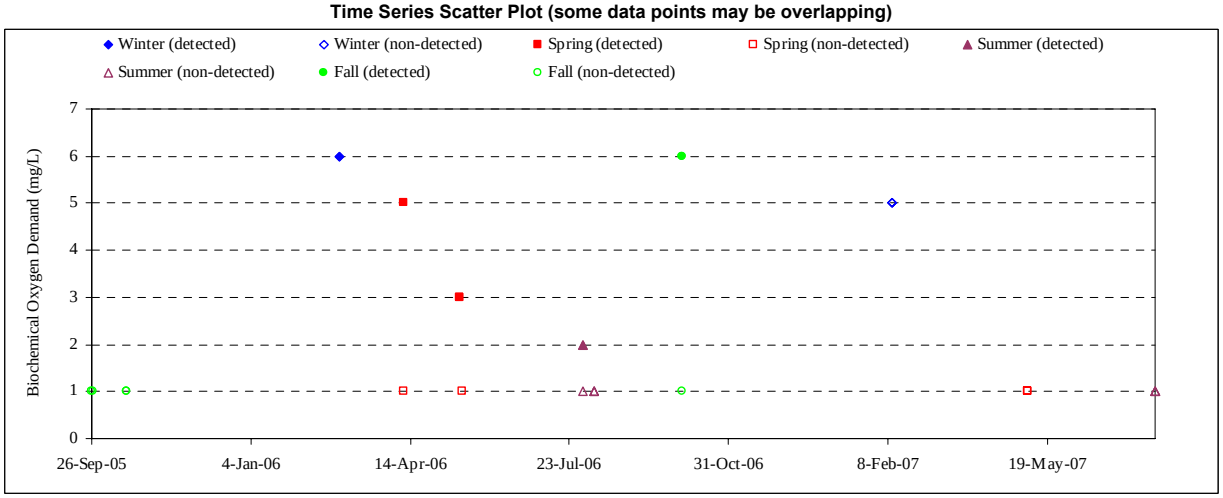
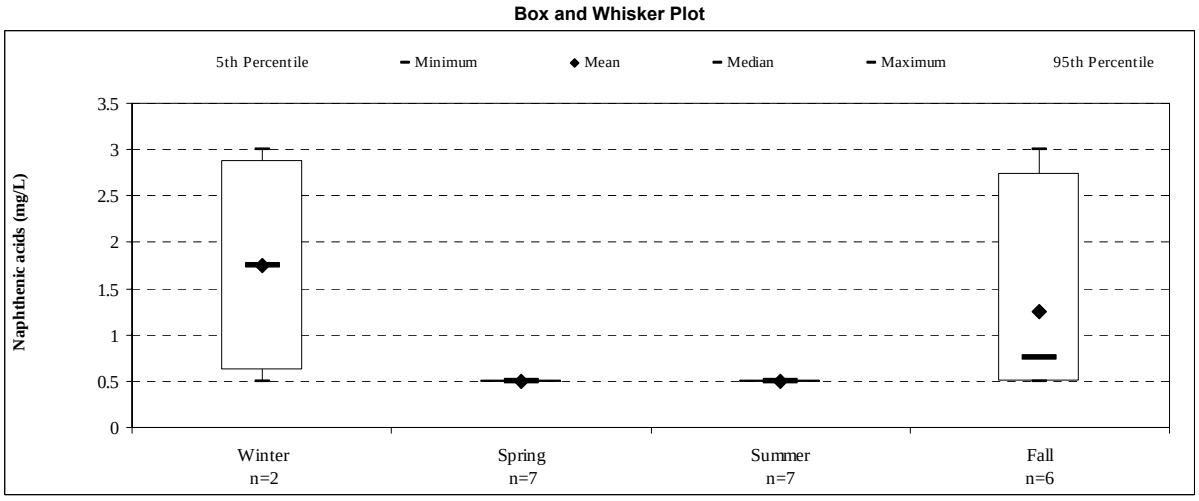


Figure G-3-2-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Eymundson Creek



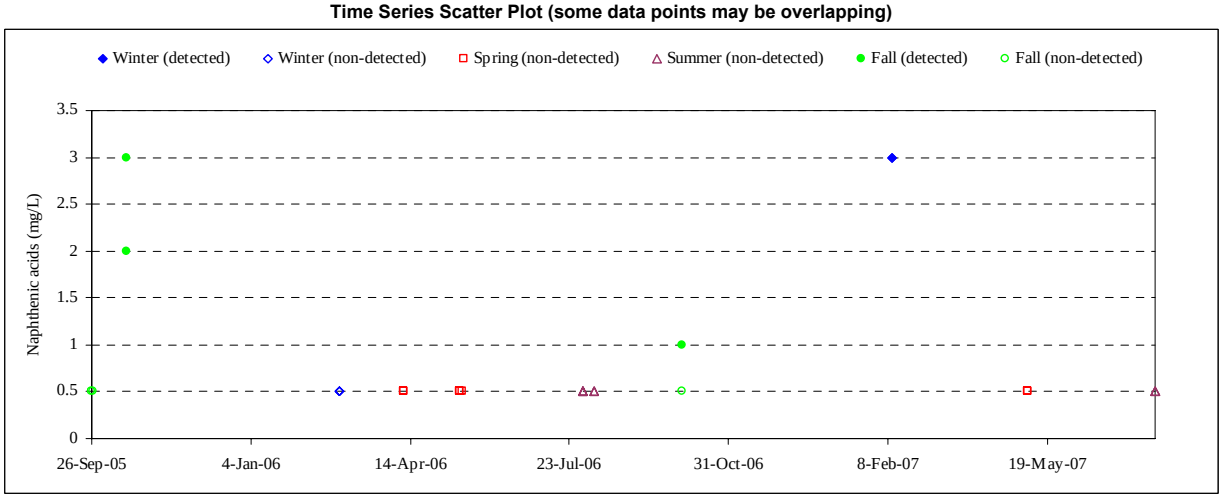
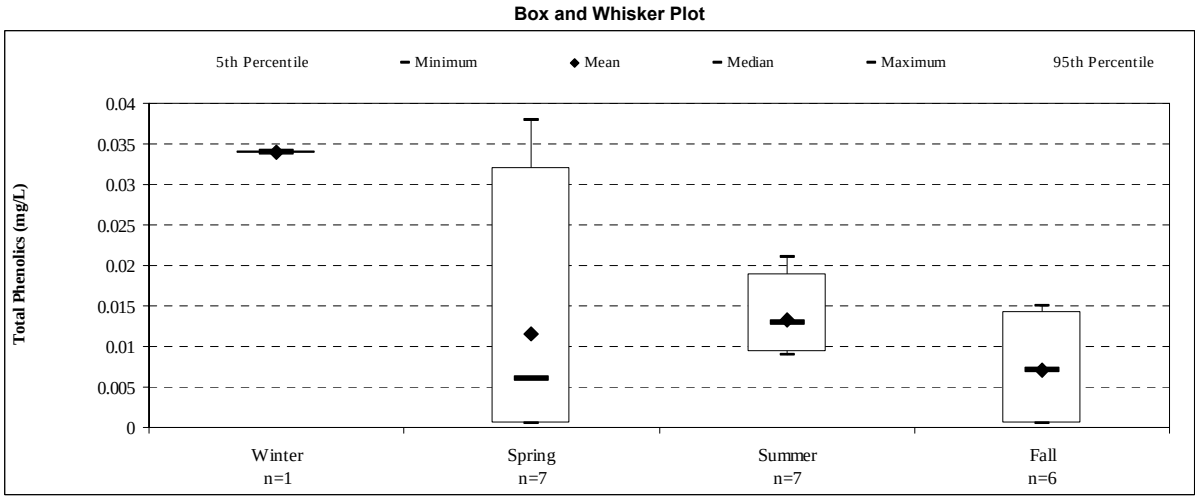


Figure G-3-2-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Eymundson Creek



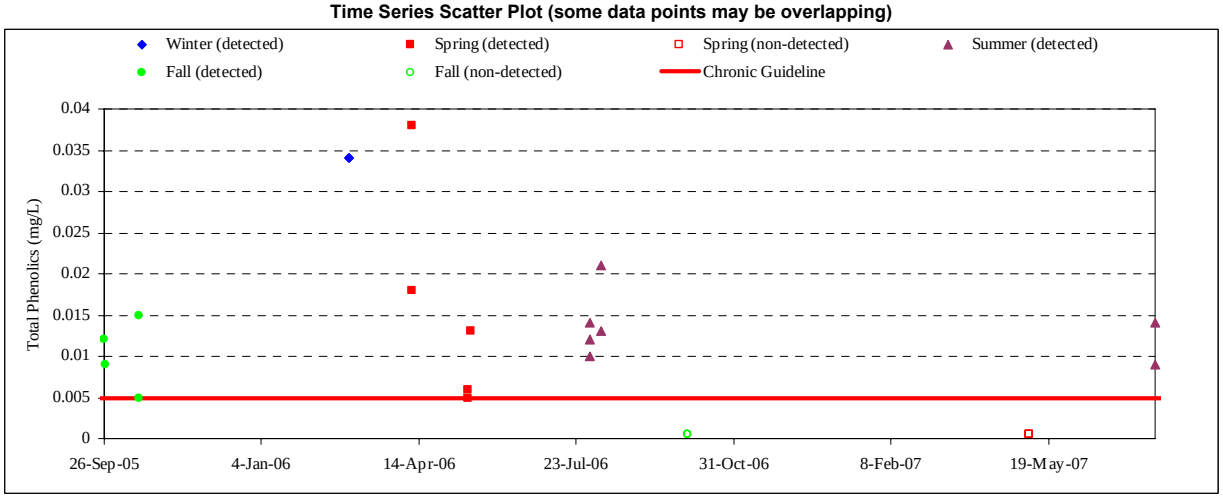
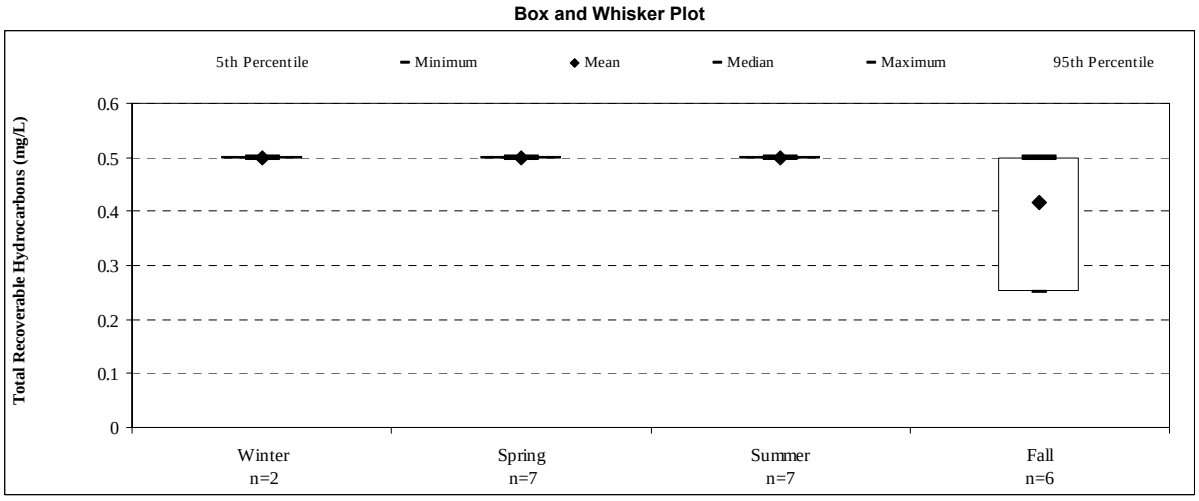


Figure G-3-2-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Eymundson Creek



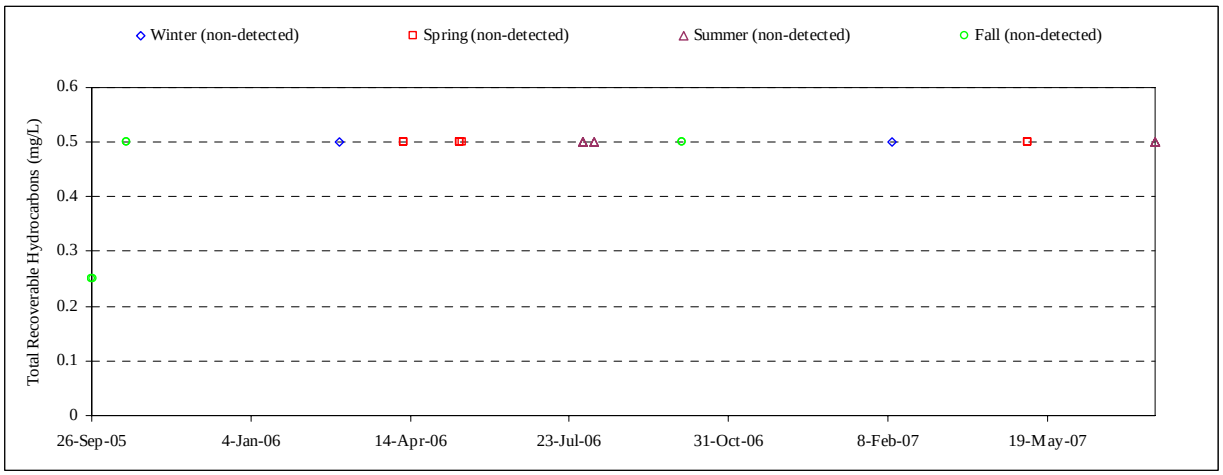
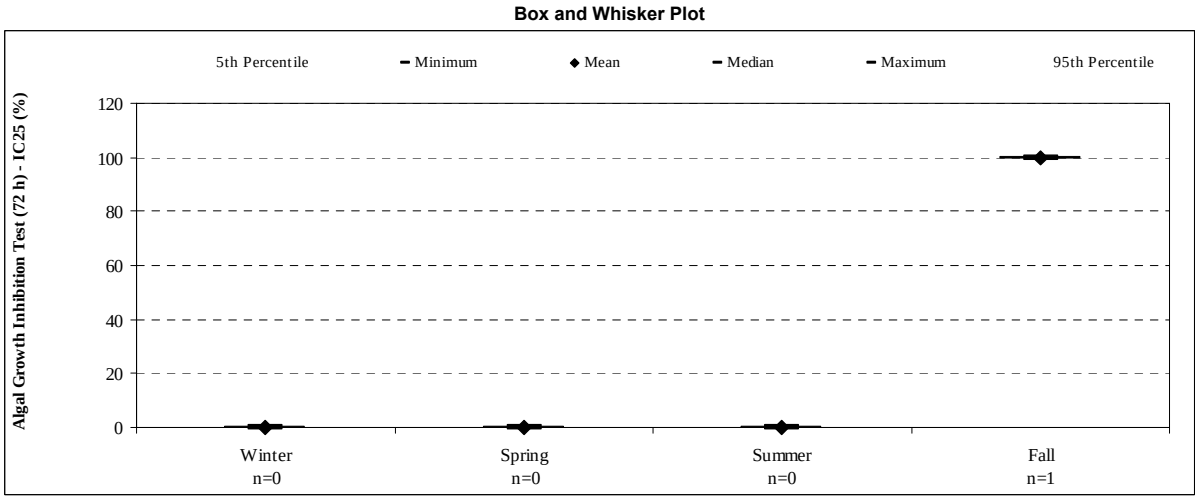


Figure G-3-2-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Eymundson Creek



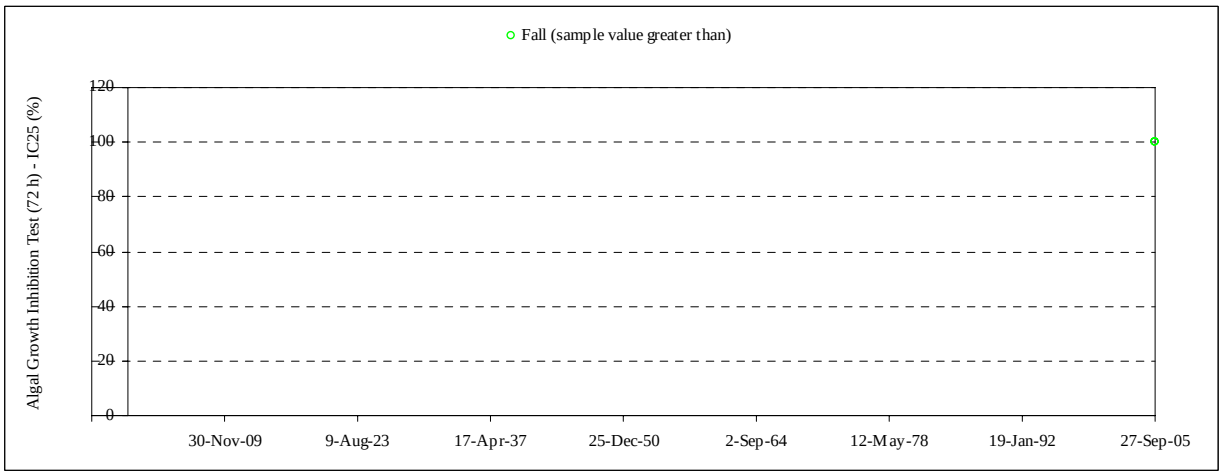
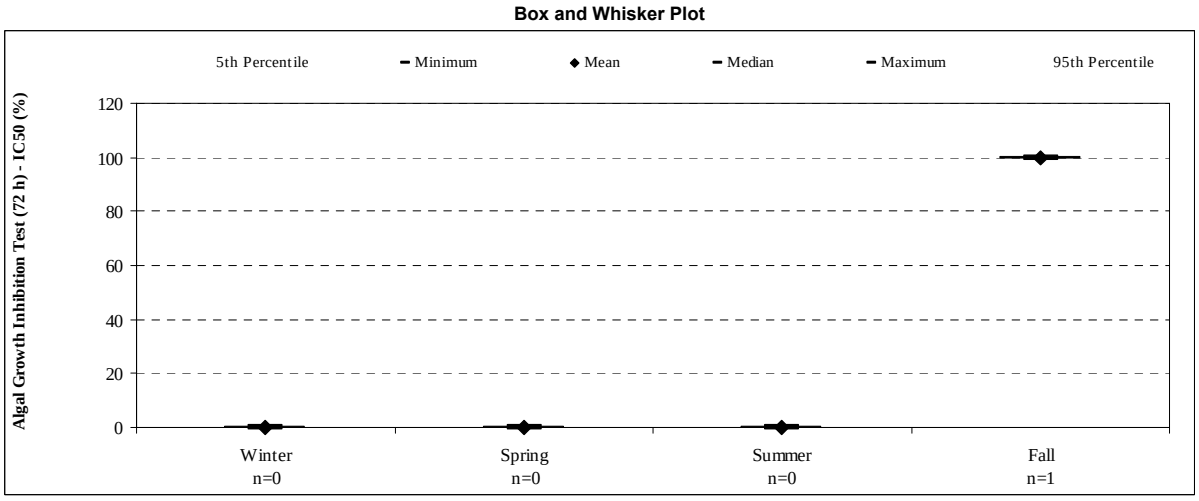


Figure G-3-2-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Eymundson Creek



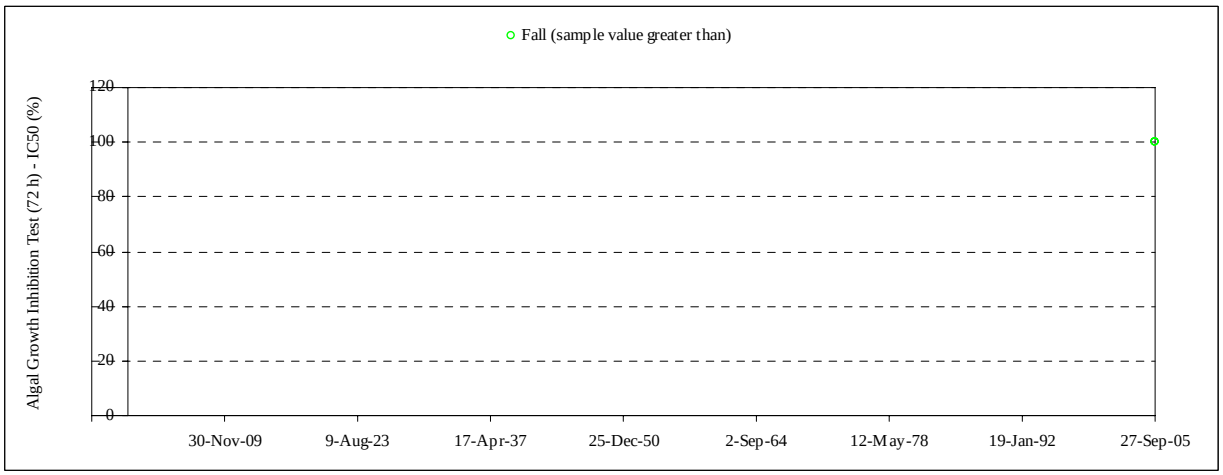
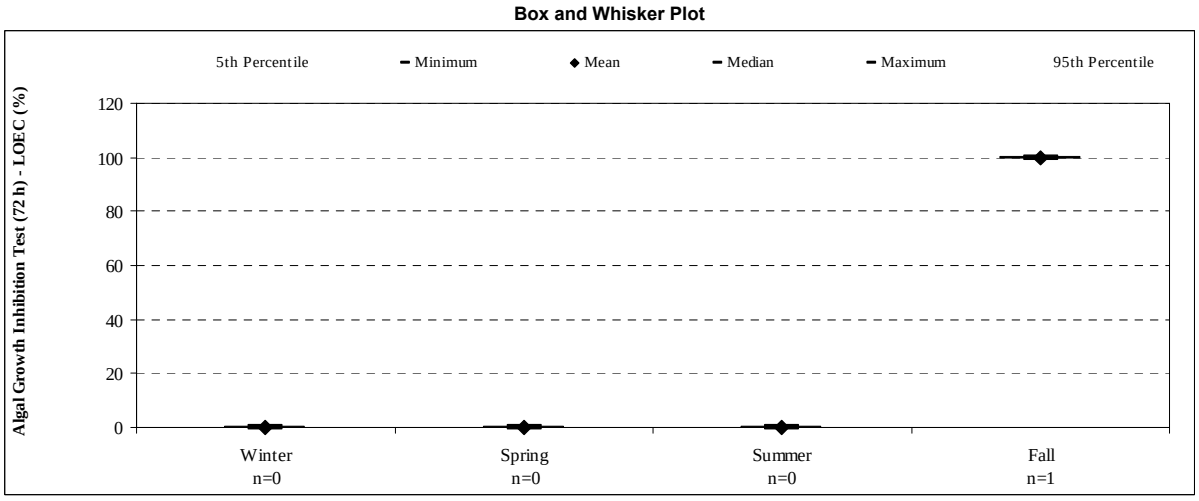


Figure G-3-2-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Eymundson Creek



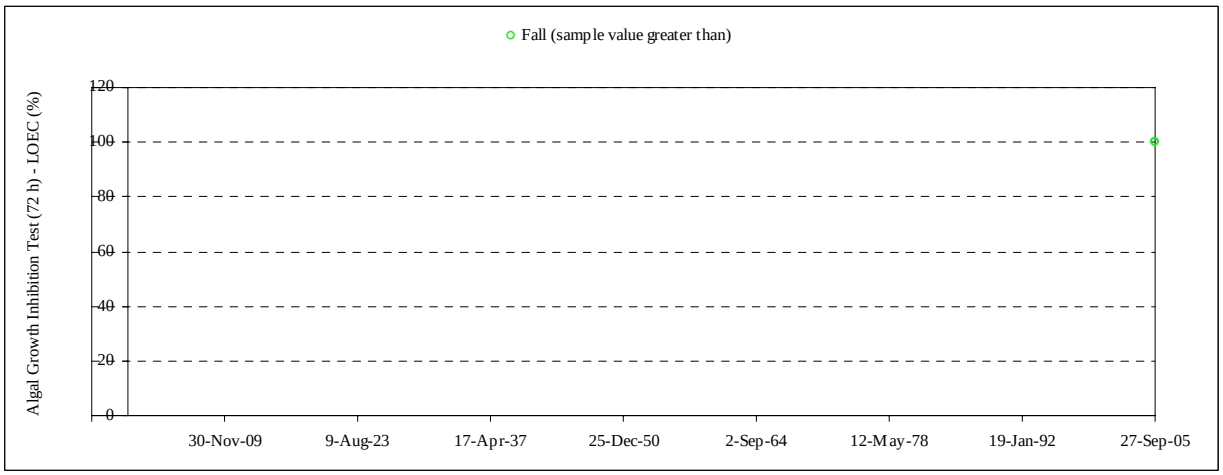
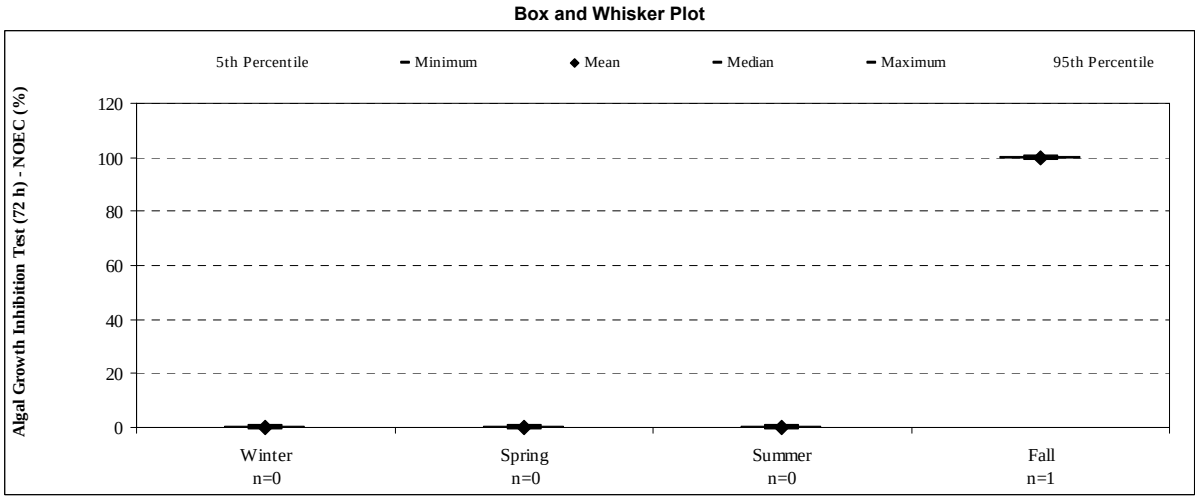


Figure G-3-2-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Eymundson Creek



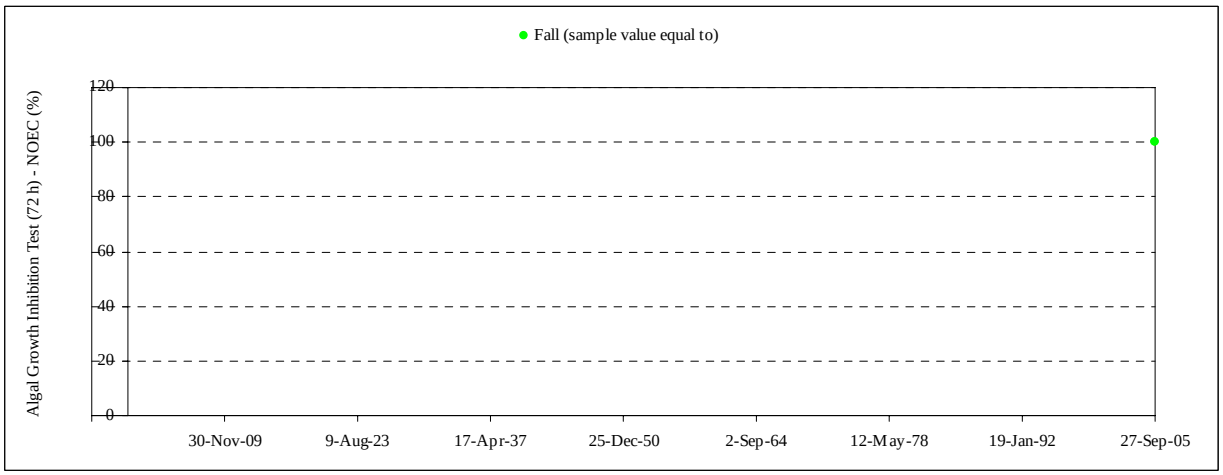
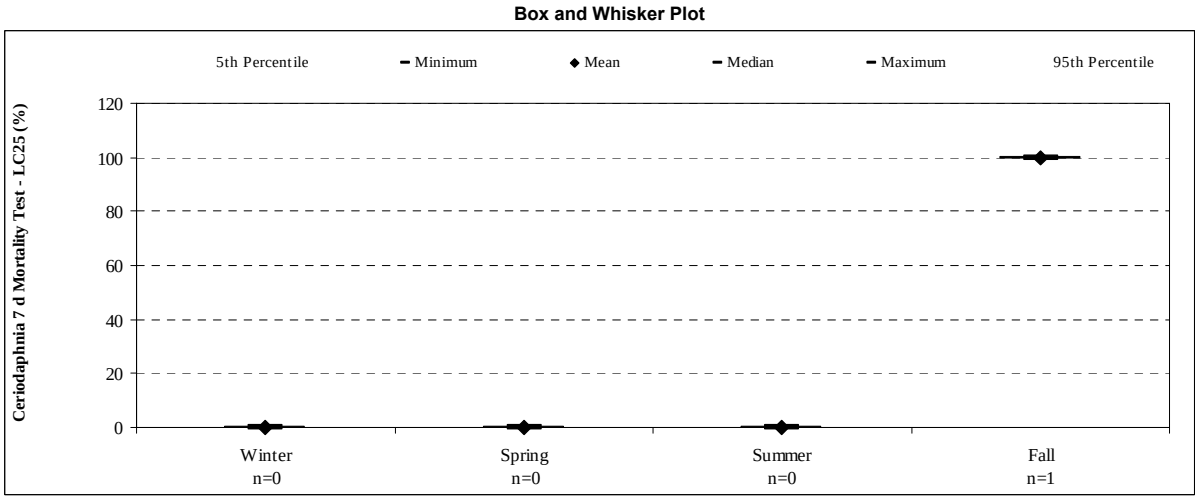


Figure G-3-2-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Eymundson Creek



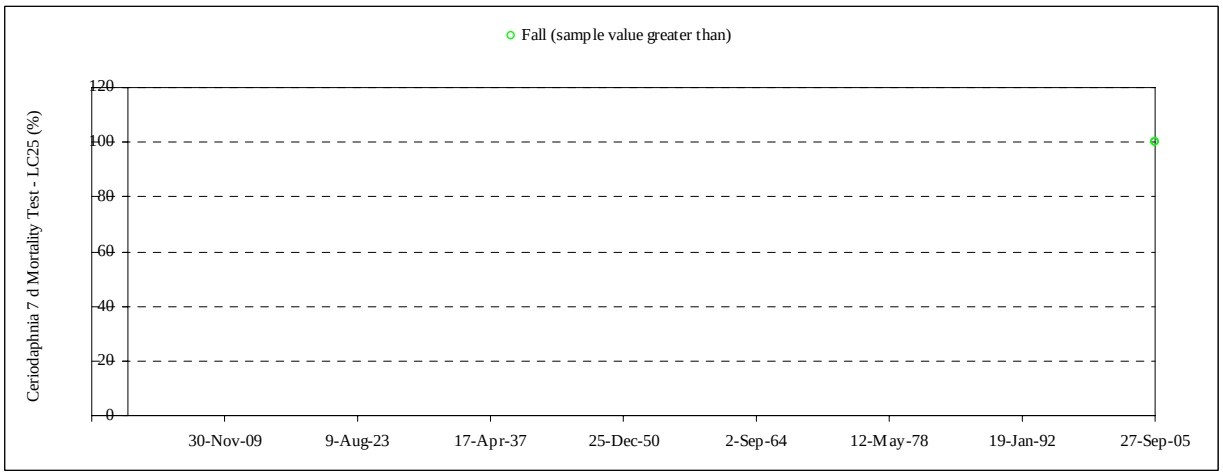
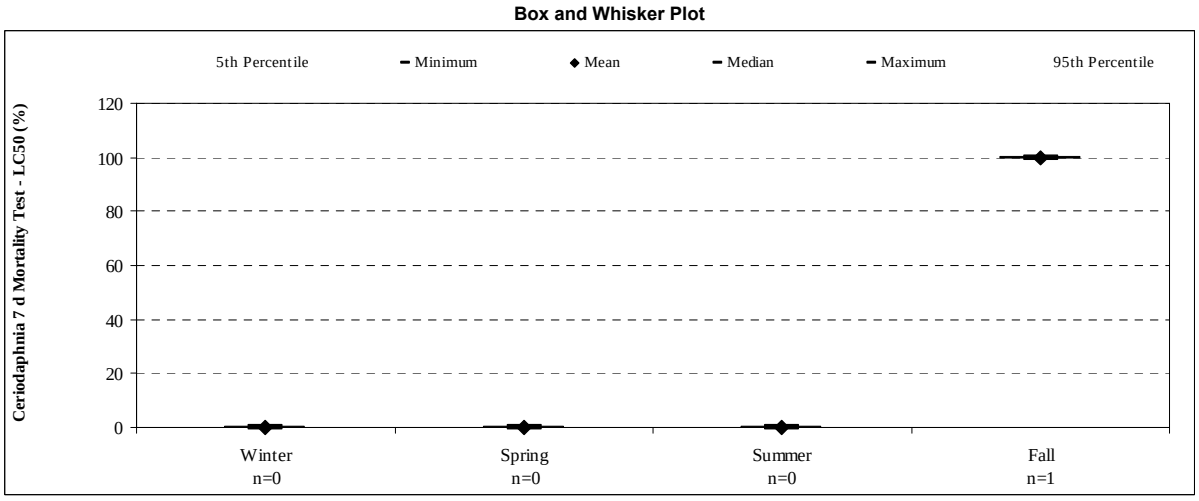


Figure G-3-2-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Eymundson Creek



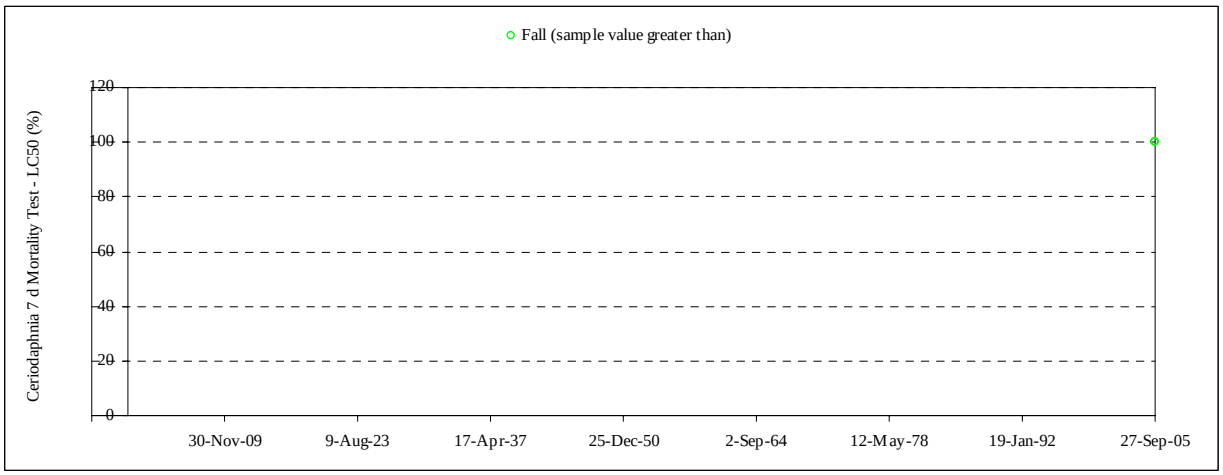
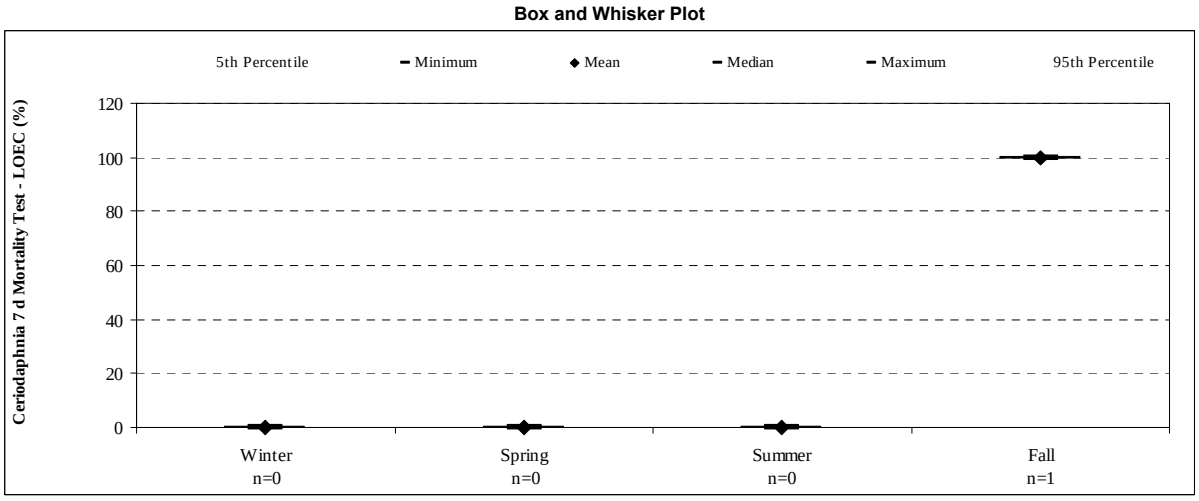


Figure G-3-2-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Eymundson Creek



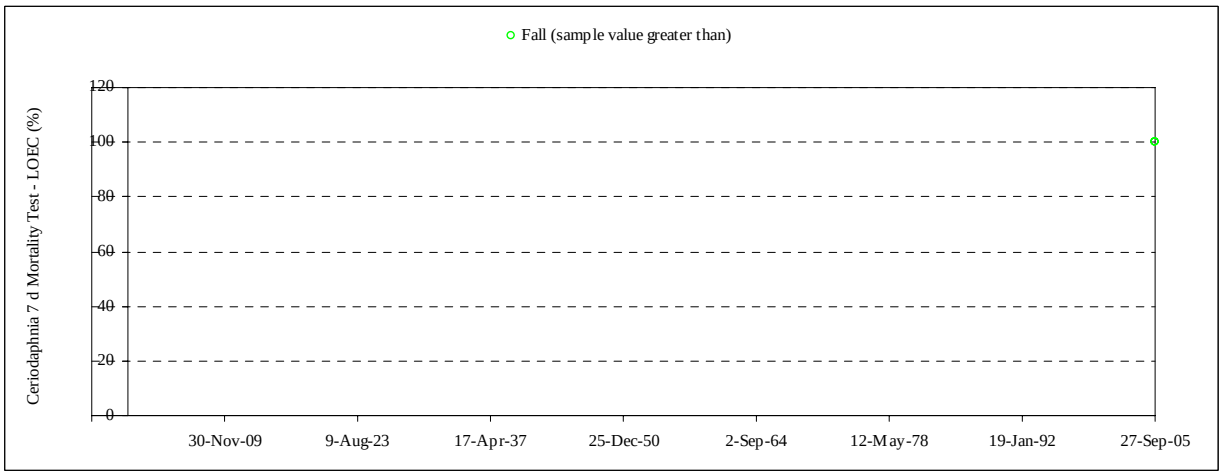
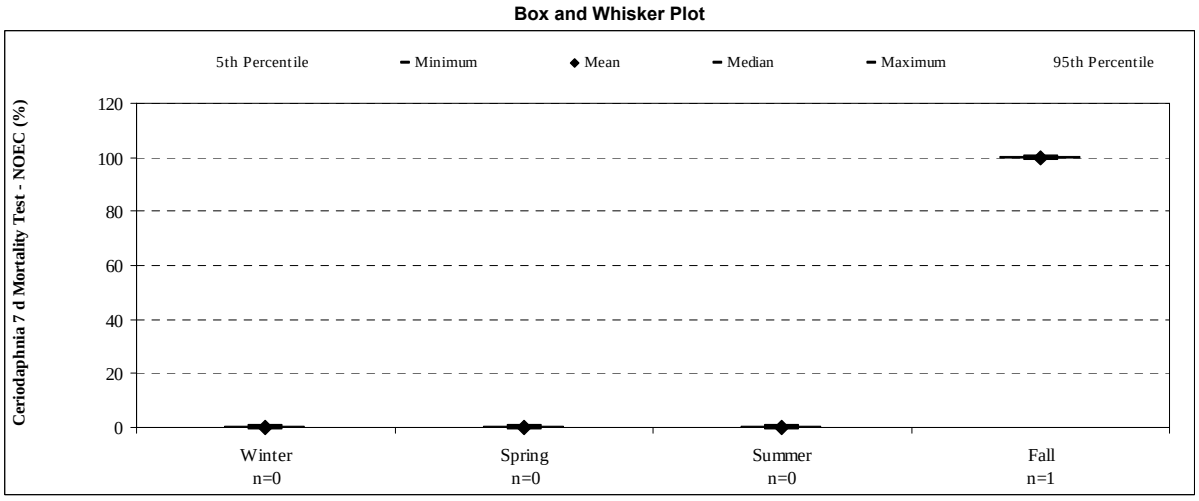


Figure G-3-2-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Eymundson Creek



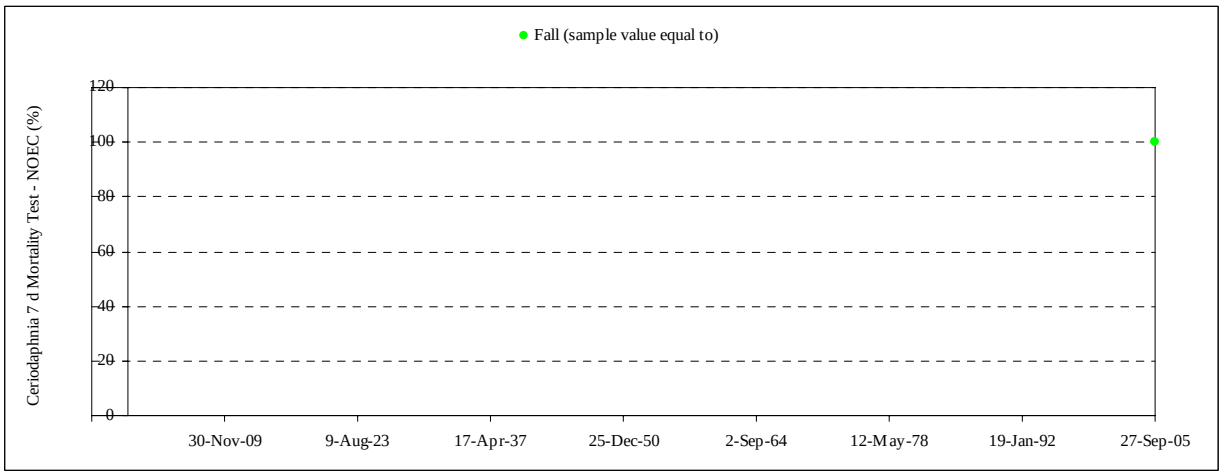
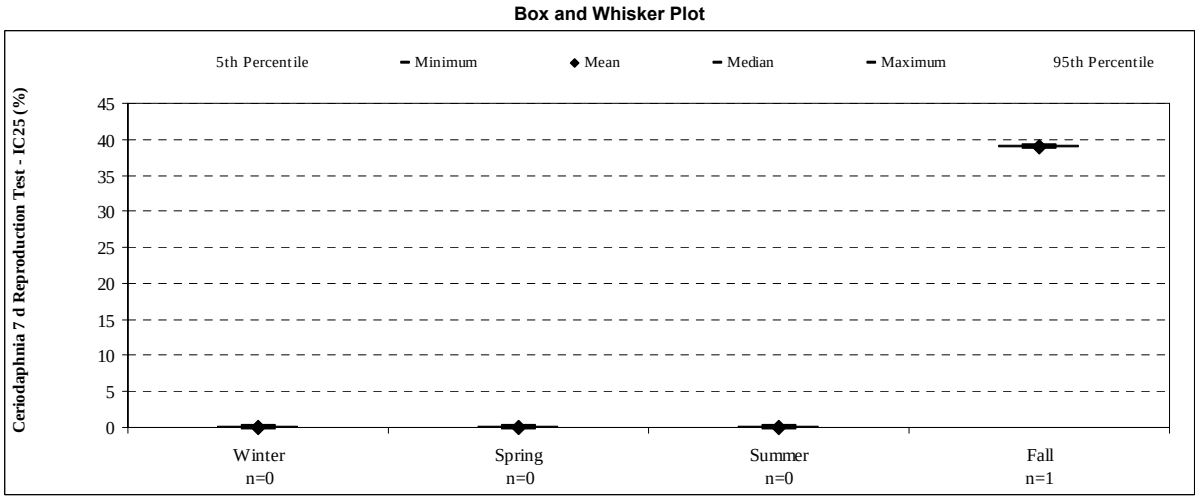


Figure G-3-2-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Eymundson Creek



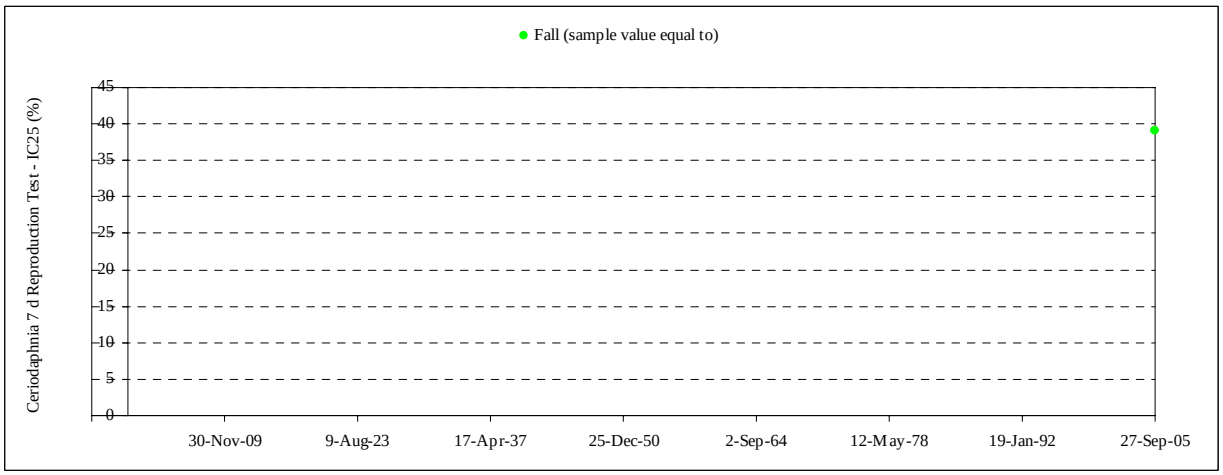
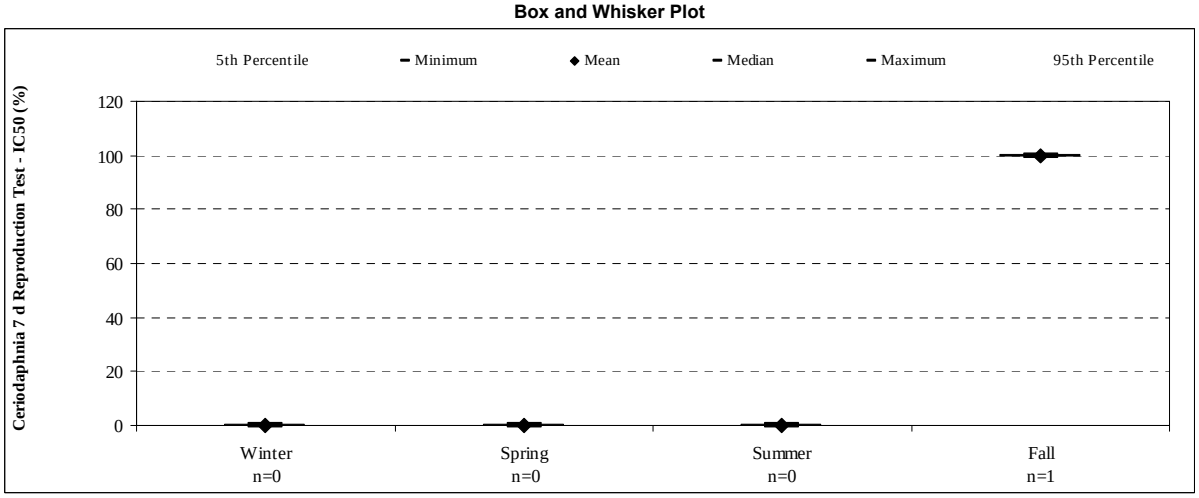


Figure G-3-2-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Eymundson Creek



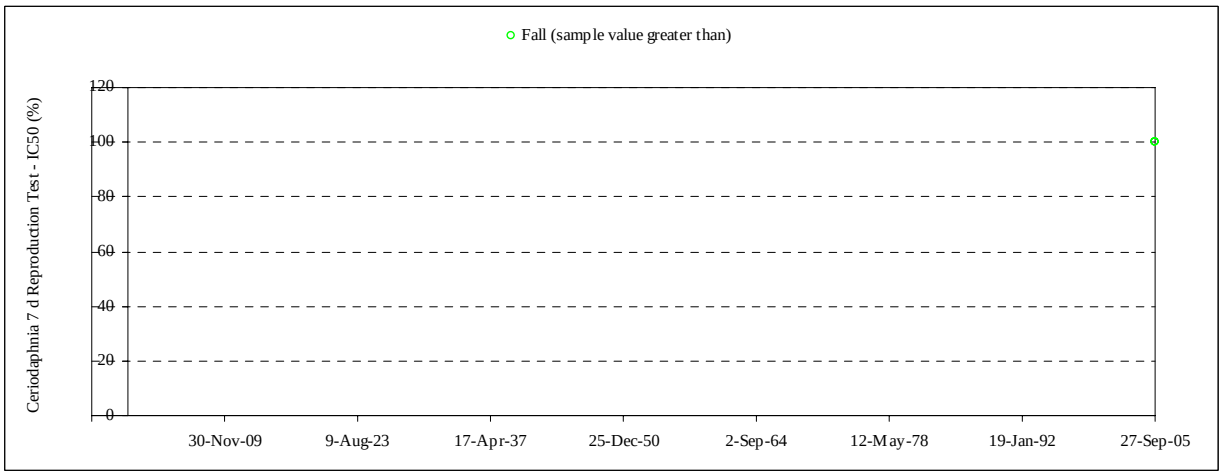
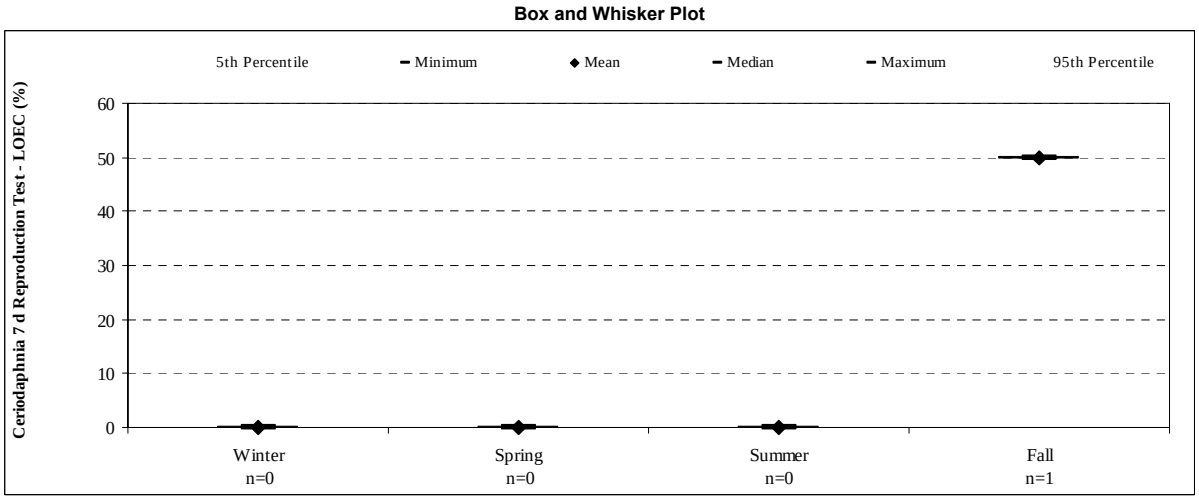


Figure G-3-2-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Eymundson Creek



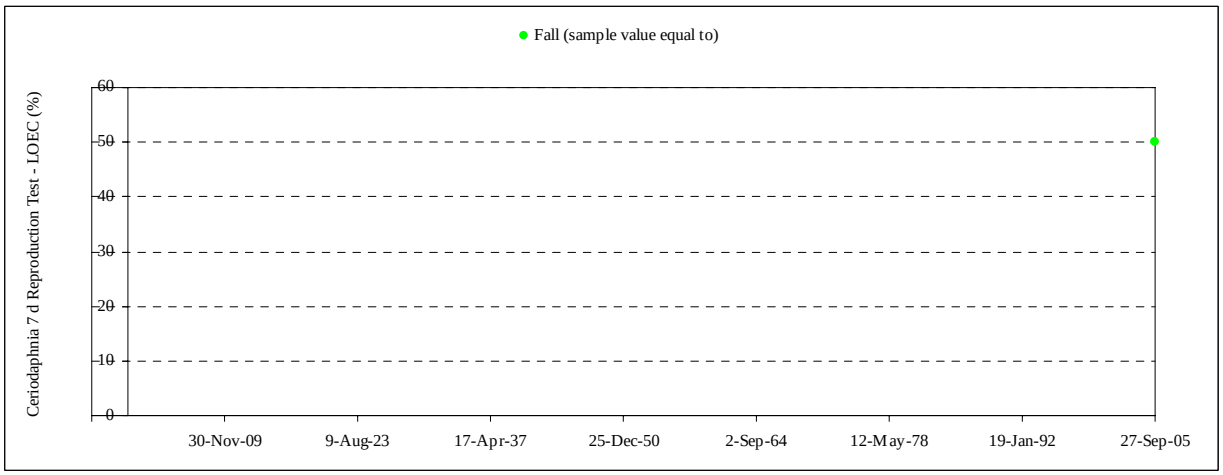
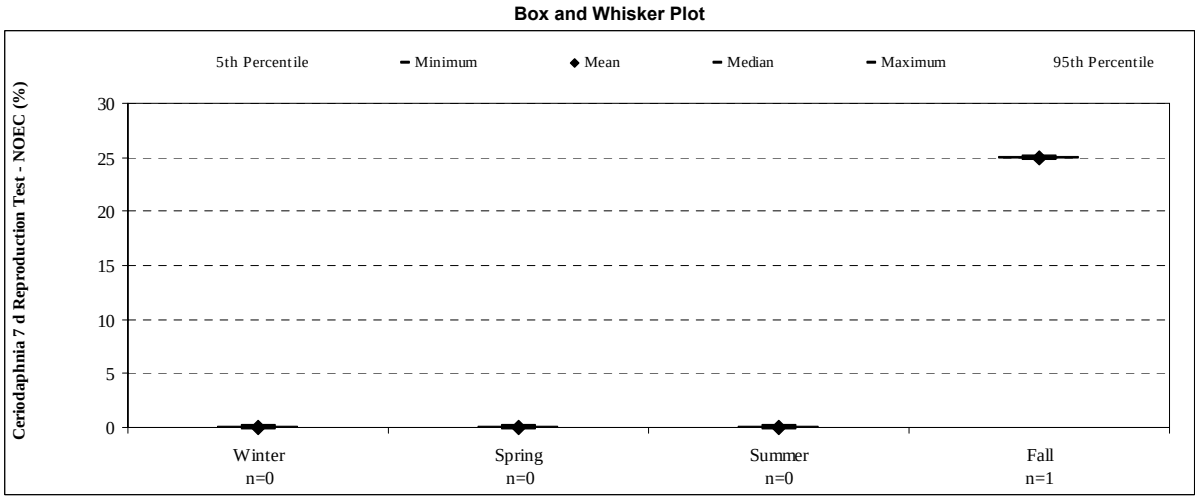


Figure G-3-2-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Eymundson Creek



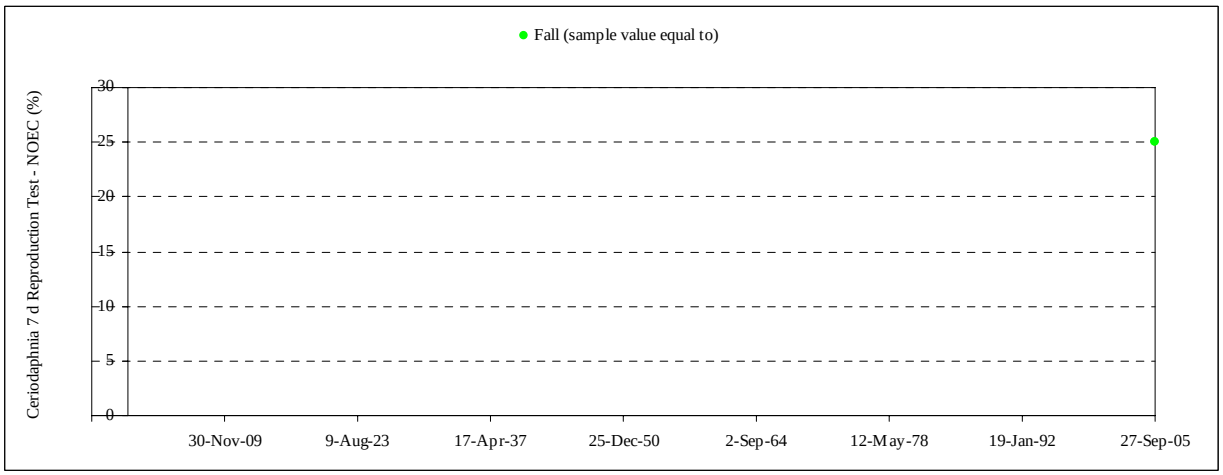
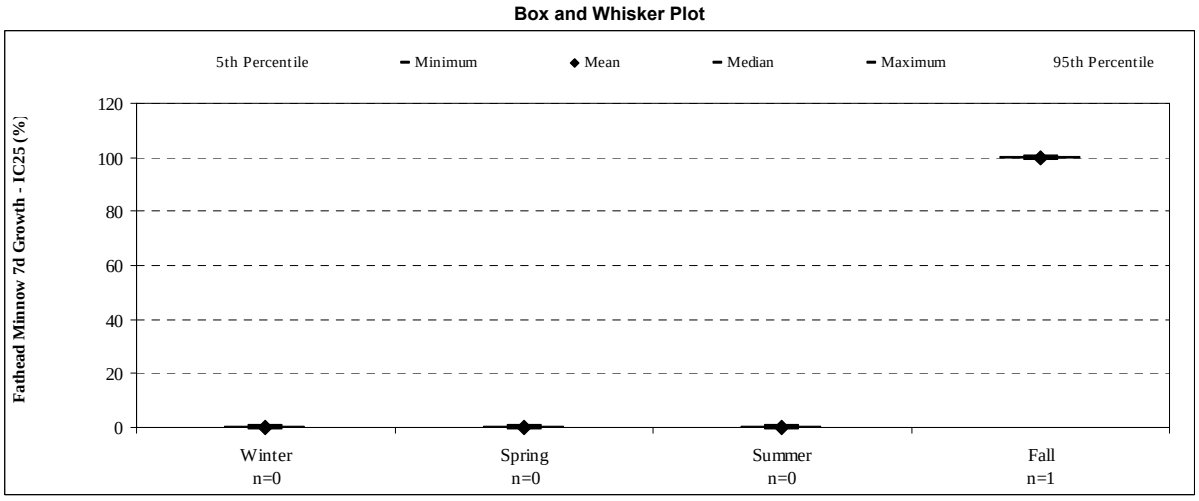


Figure G-3-2-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Eymundson Creek



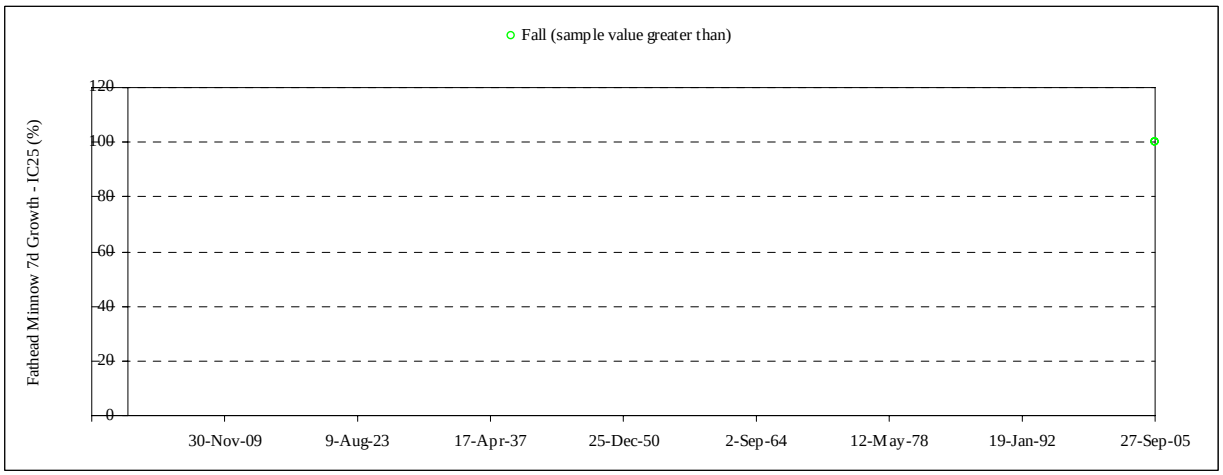
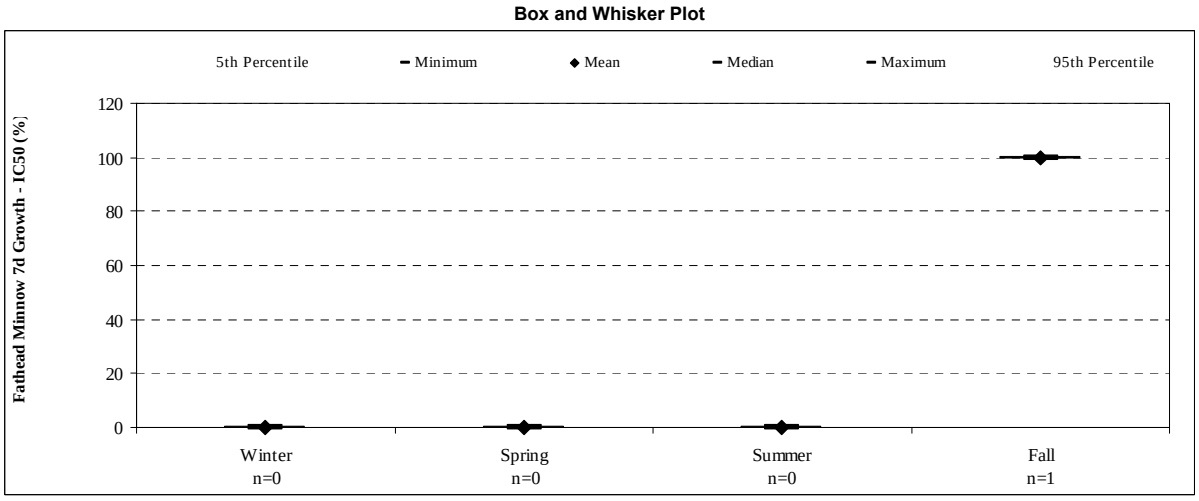


Figure G-3-2-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Eymundson Creek



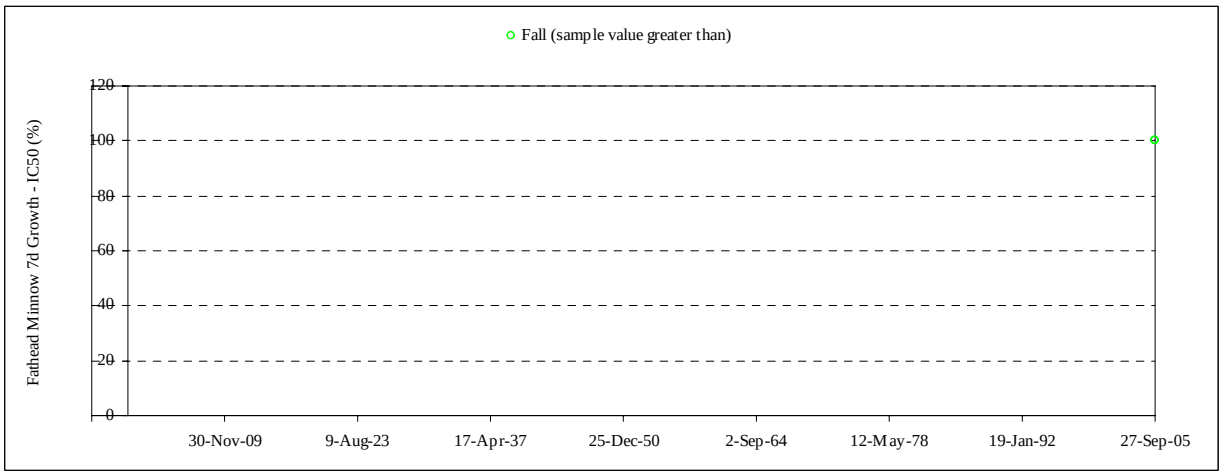
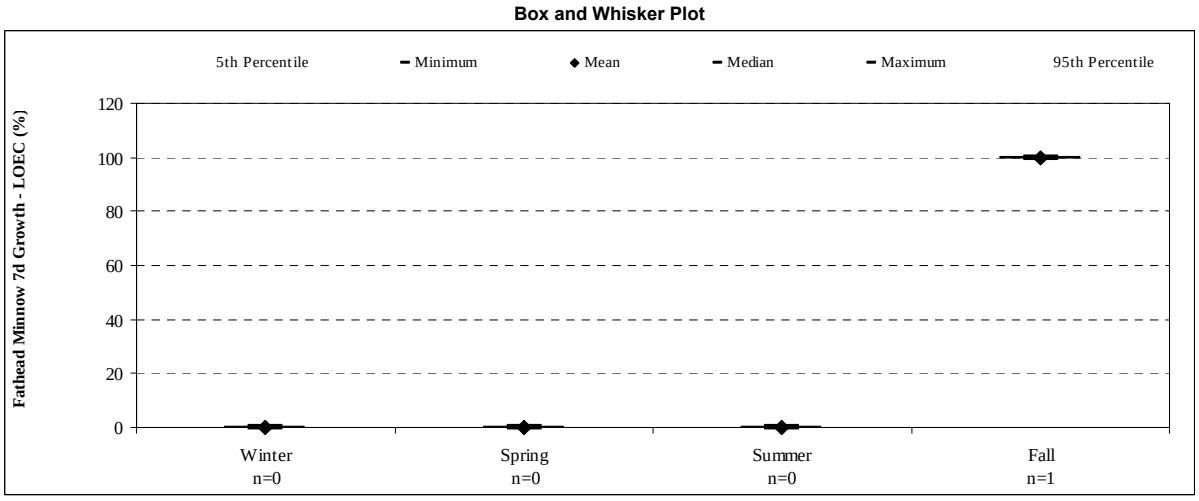


Figure G-3-2-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Eymundson Creek



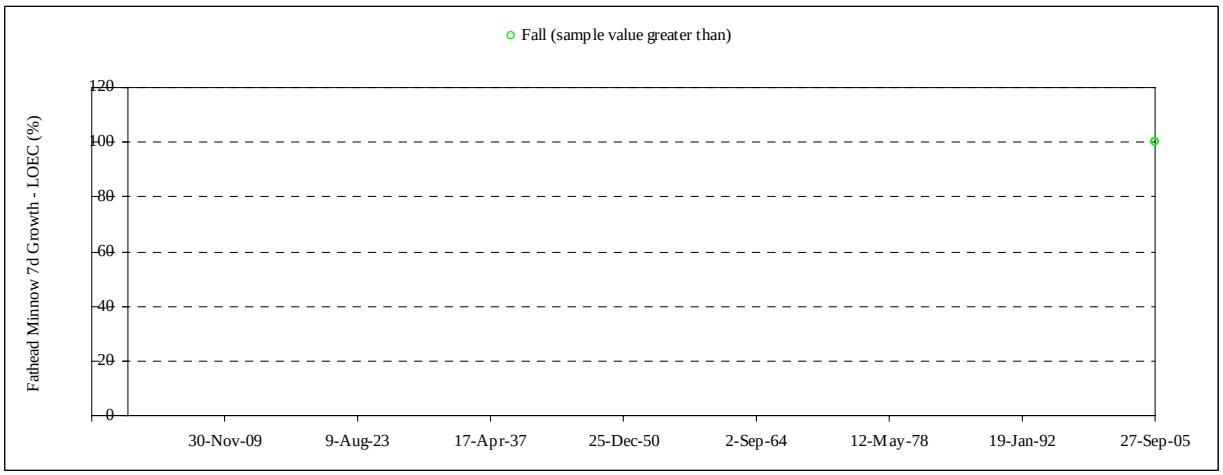
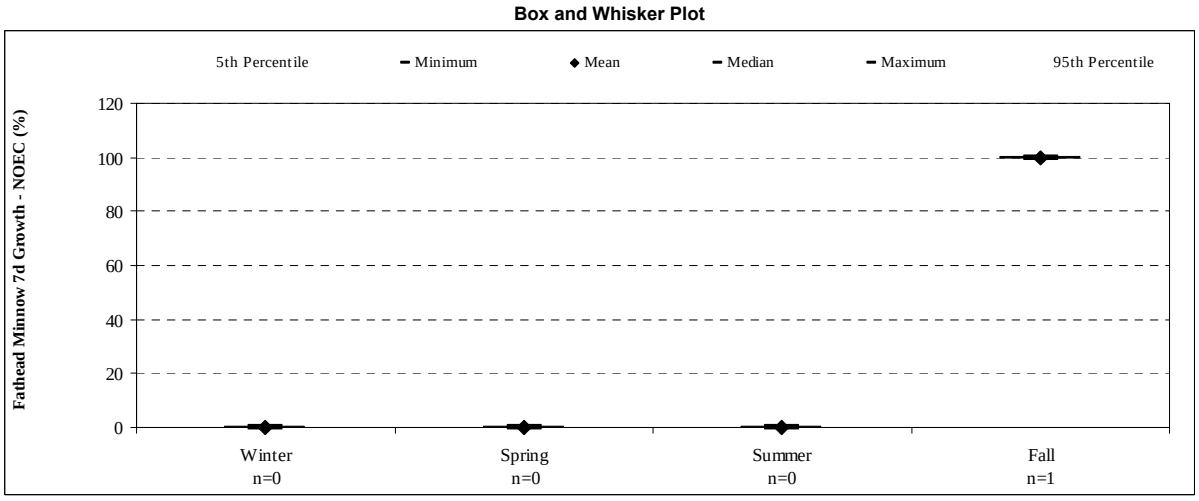


Figure G-3-2-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Eymundson Creek



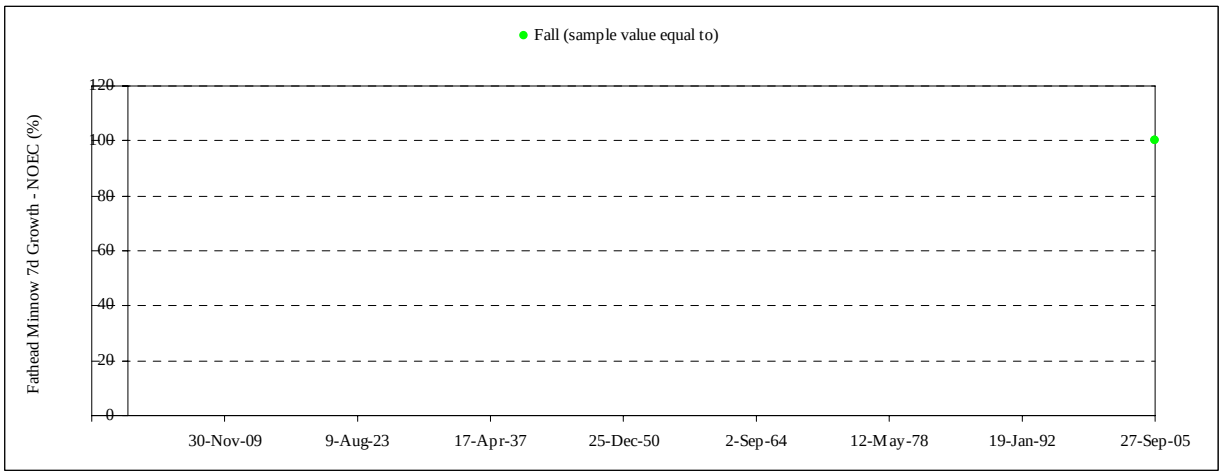
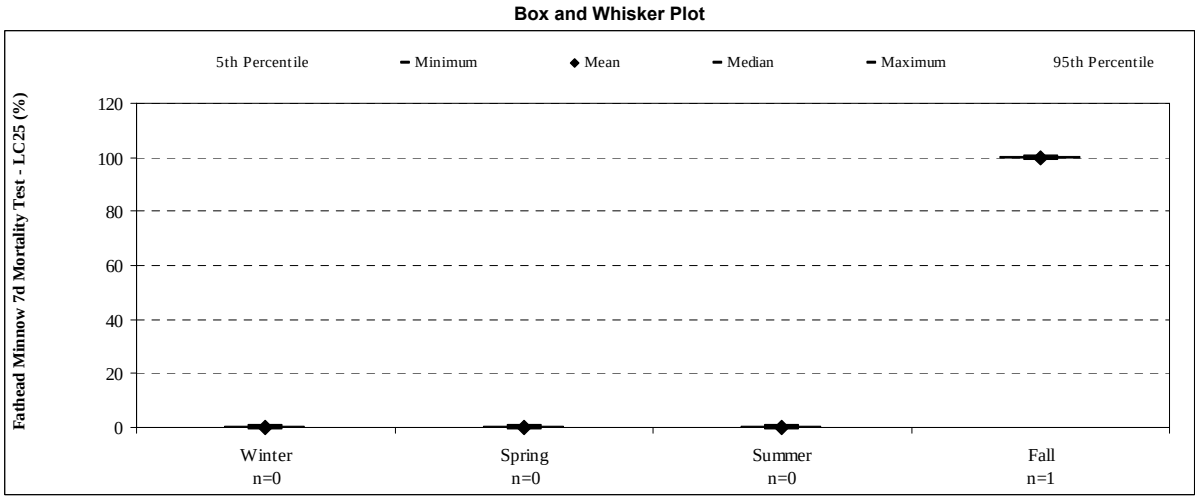


Figure G-3-2-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Eymundson Creek



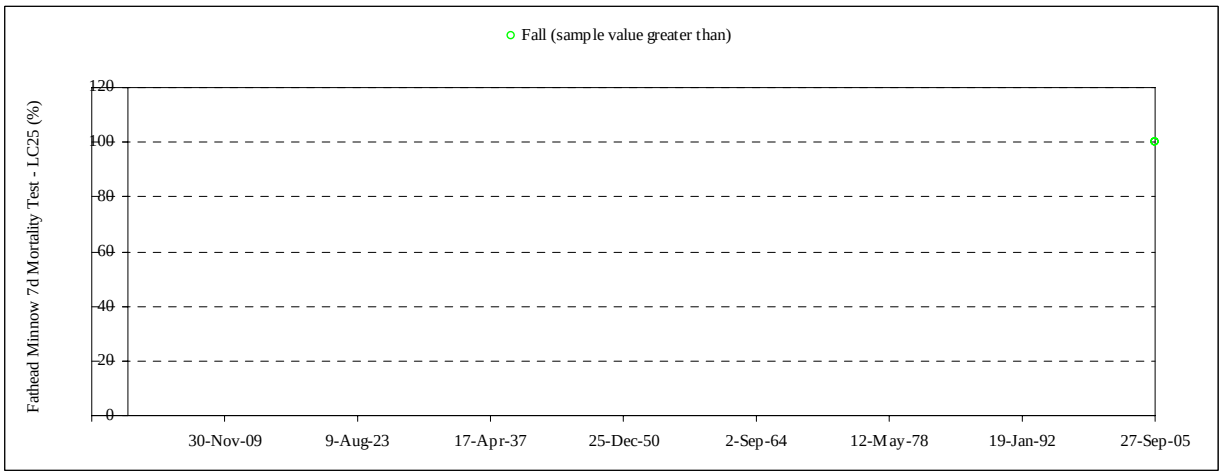
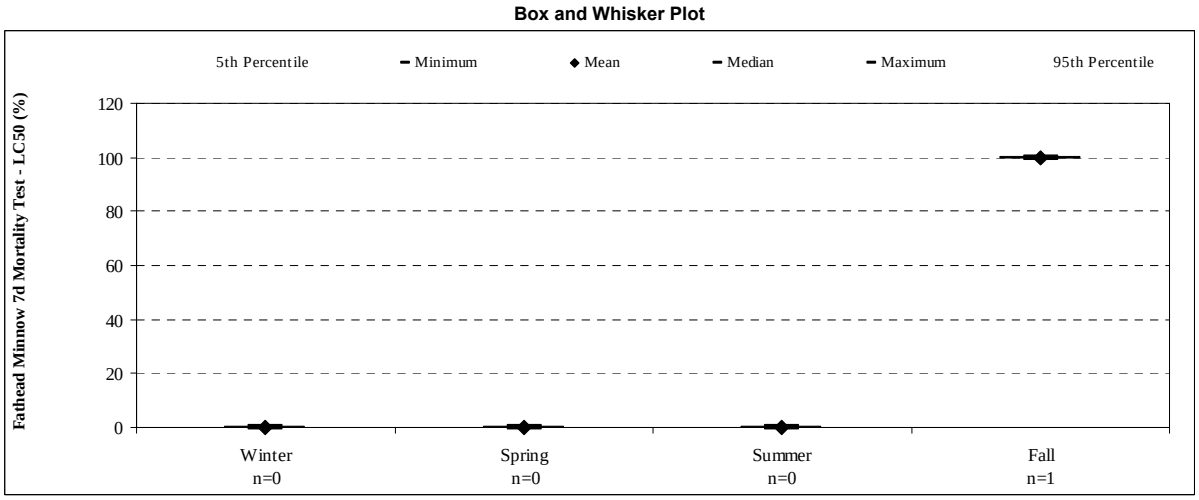


Figure G-3-2-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Eymundson Creek



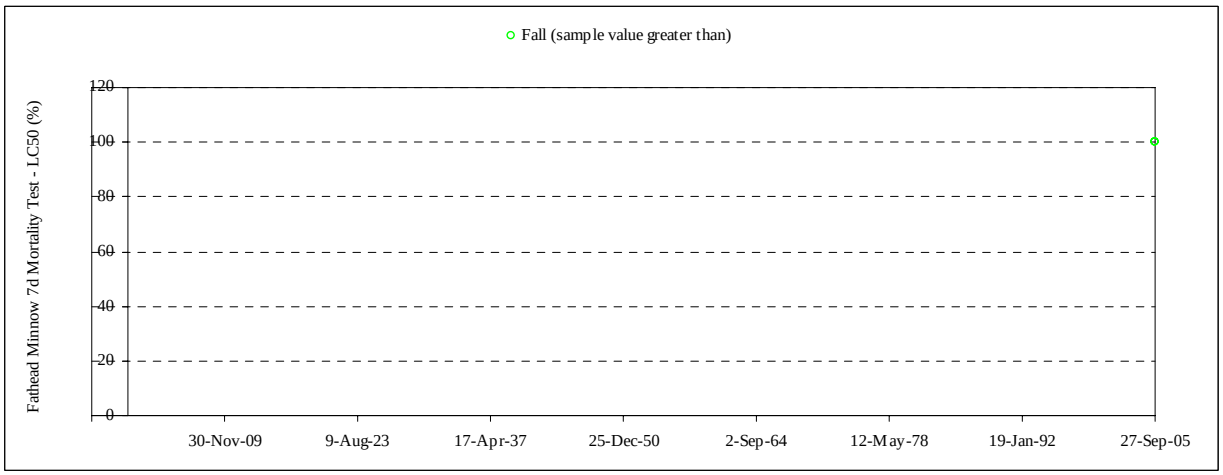
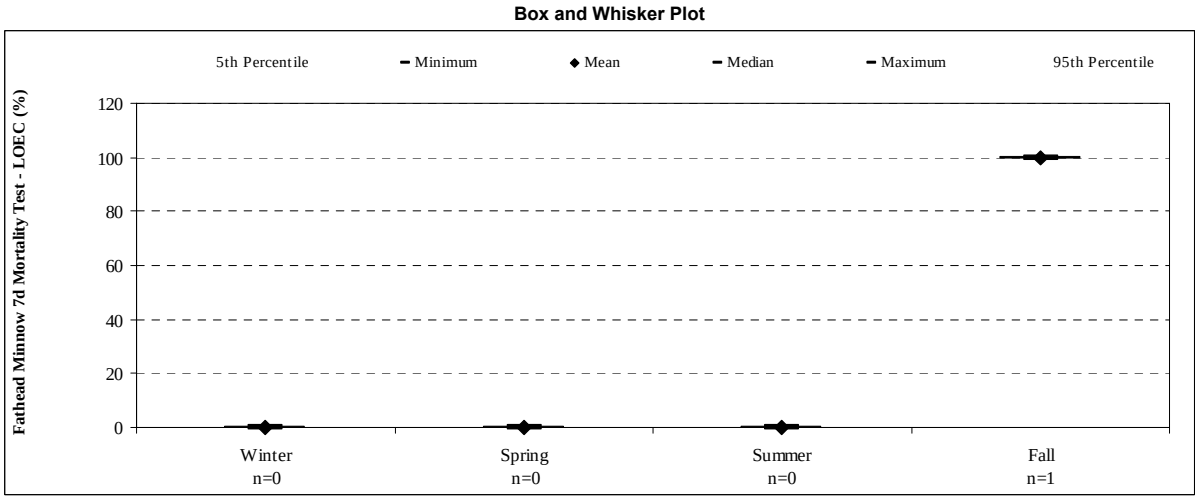


Figure G-3-2-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Eymundson Creek



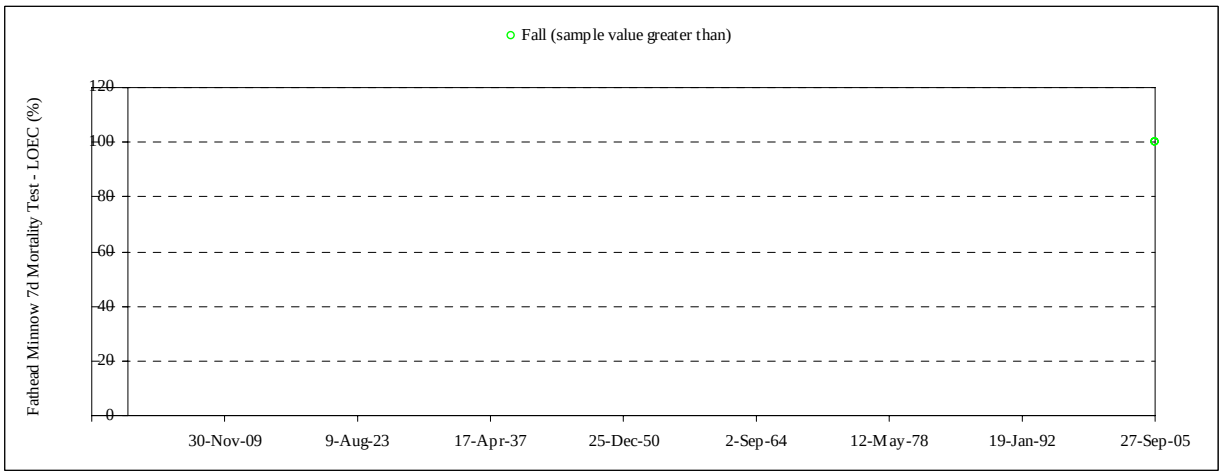
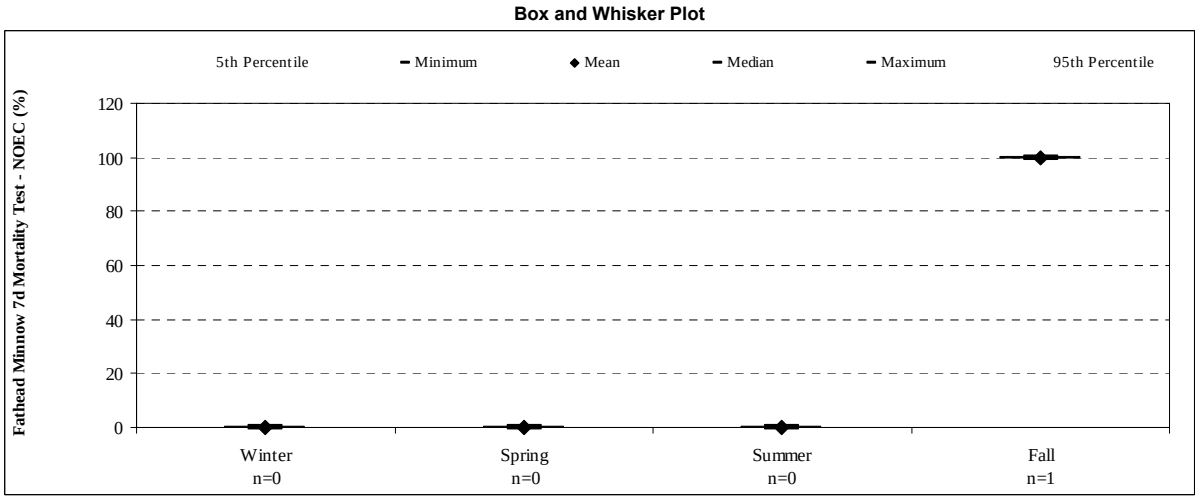


Figure G-3-2-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Eymundson Creek



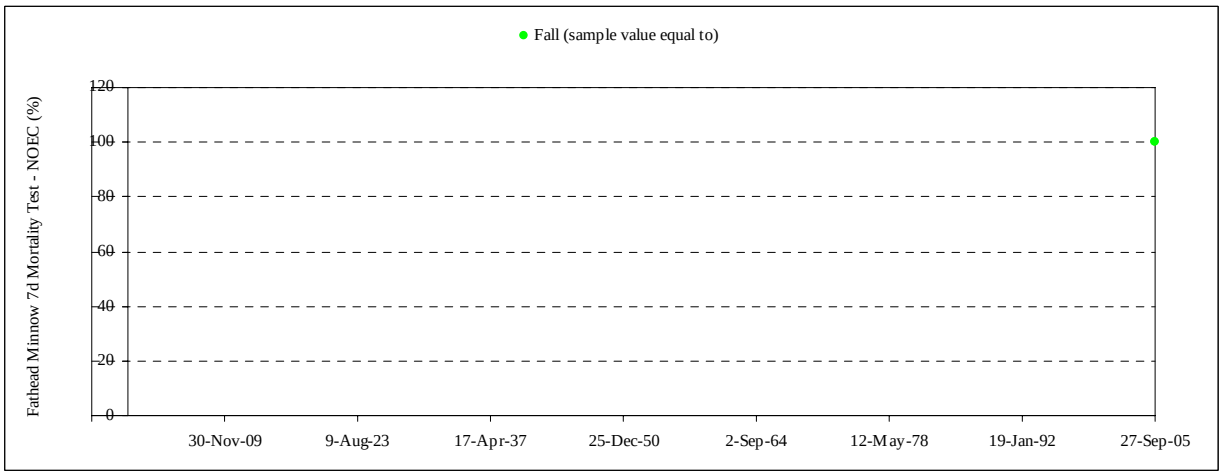
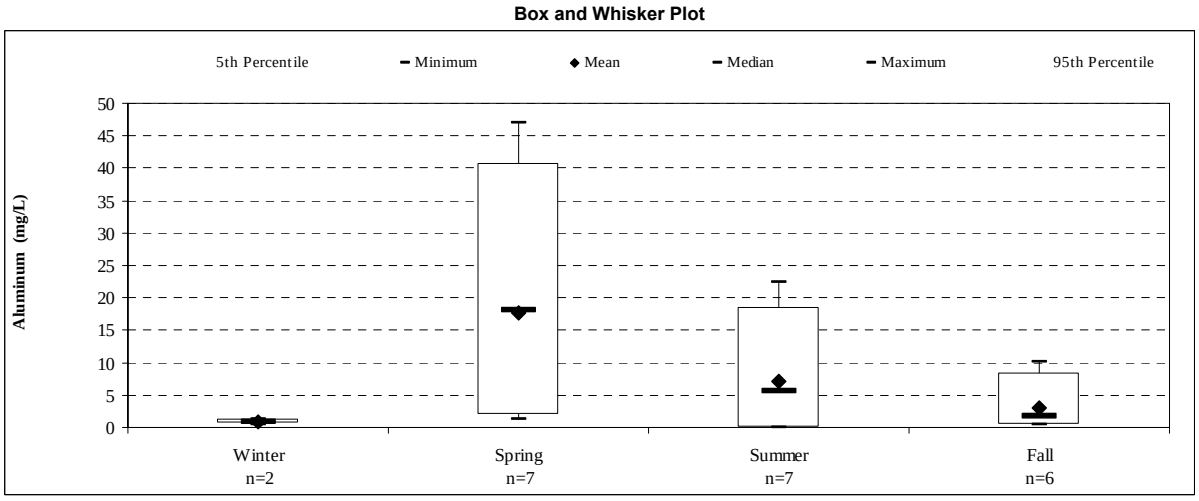


Figure G-3-2-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Eymundson Creek



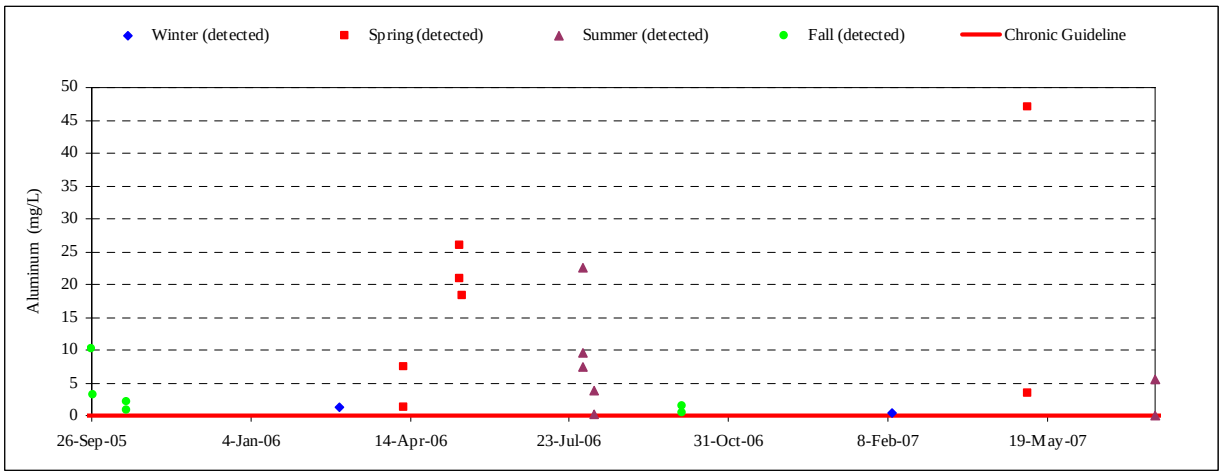
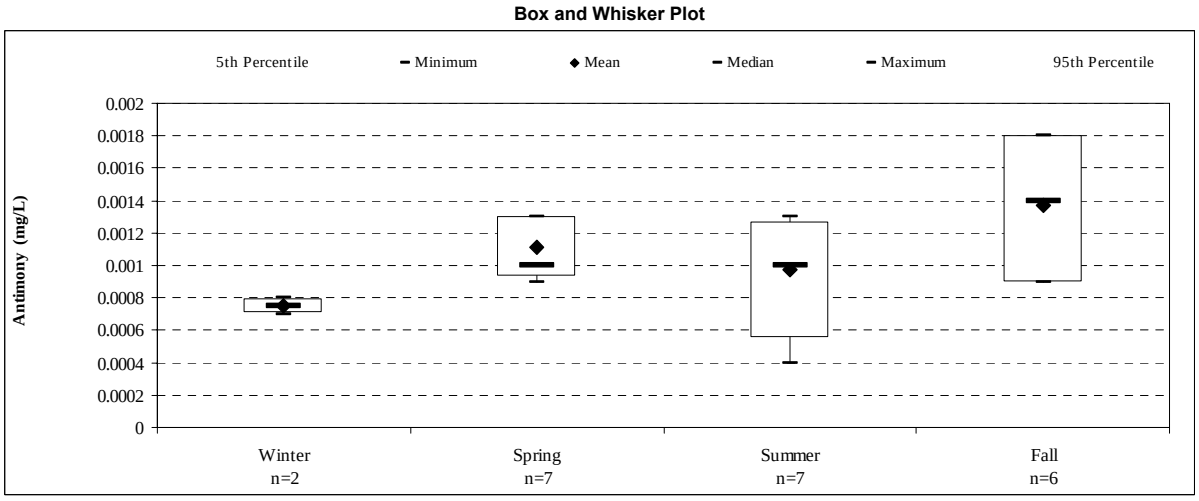


Figure G-3-2-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Eymundson Creek



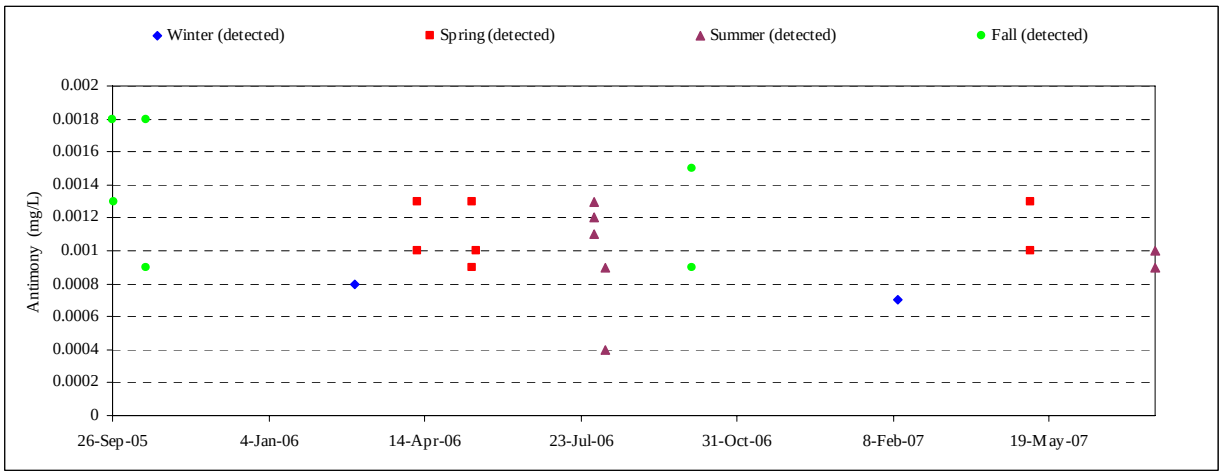
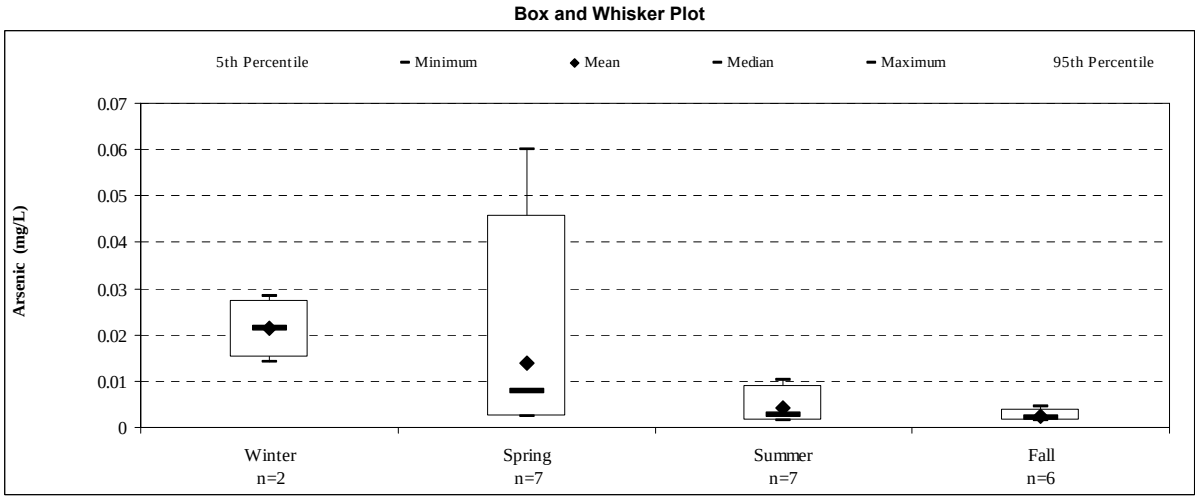


Figure G-3-2-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Eymundson Creek



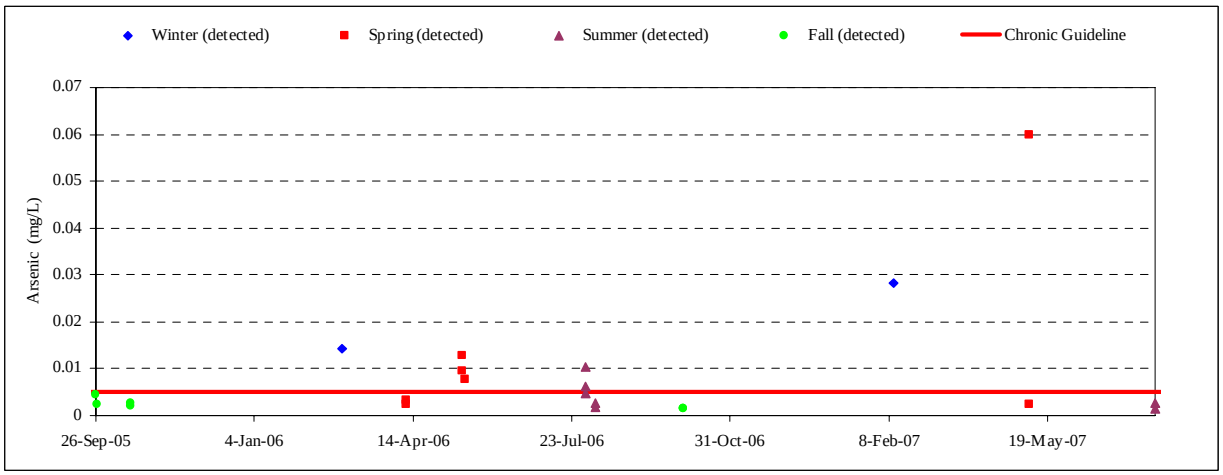
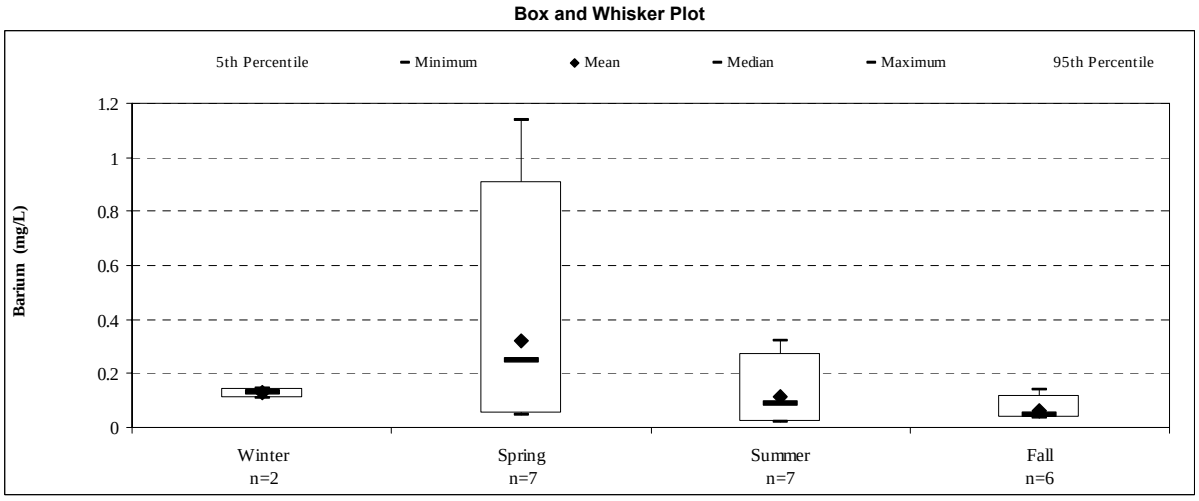


Figure G-3-2-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Eymundson Creek



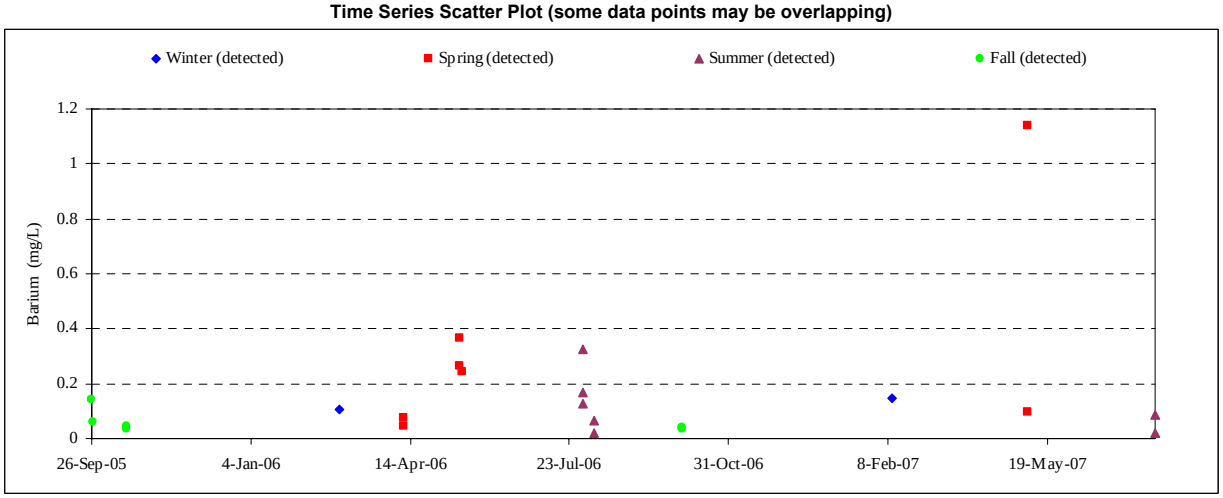
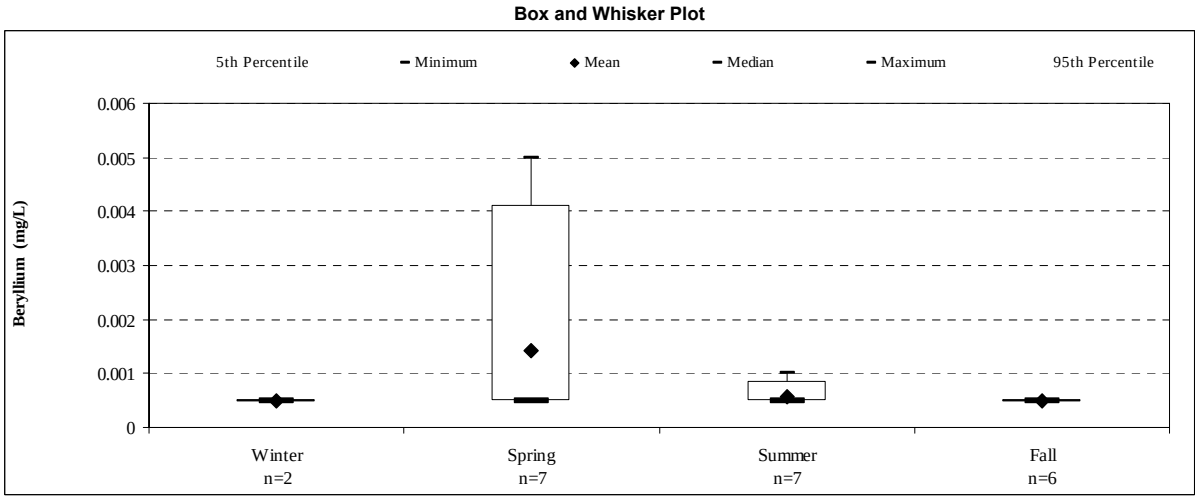


Figure G-3-2-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Eymundson Creek



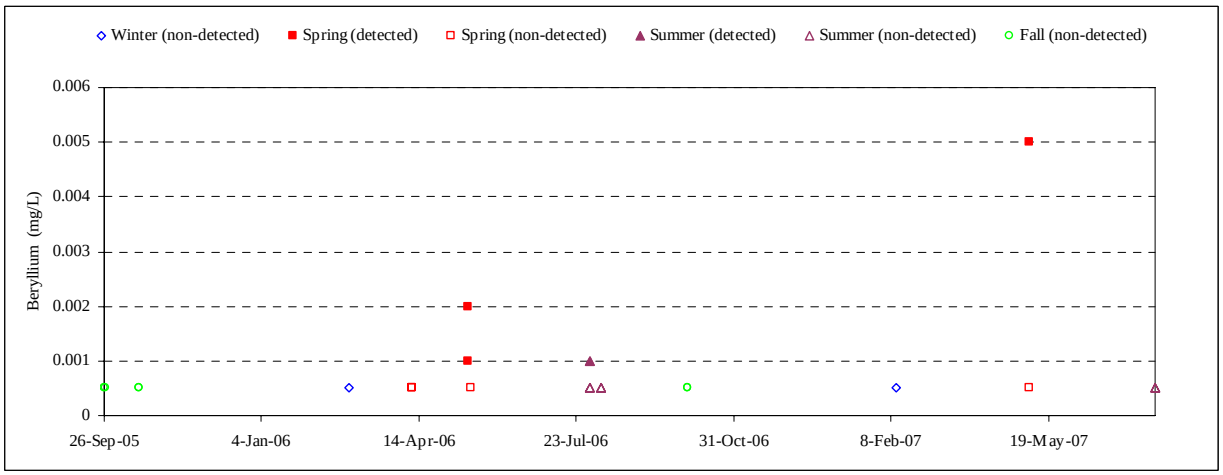
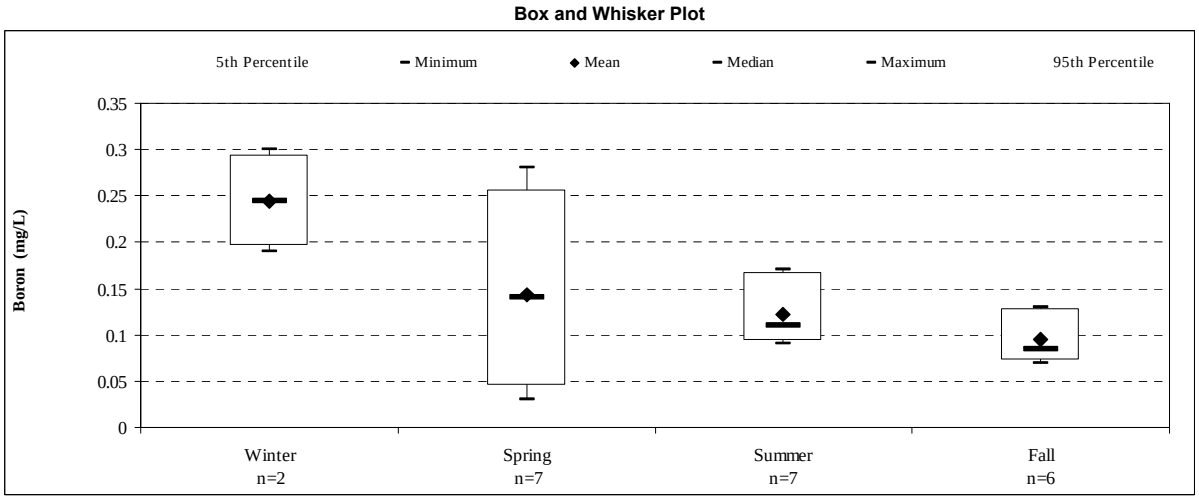


Figure G-3-2-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Eymundson Creek



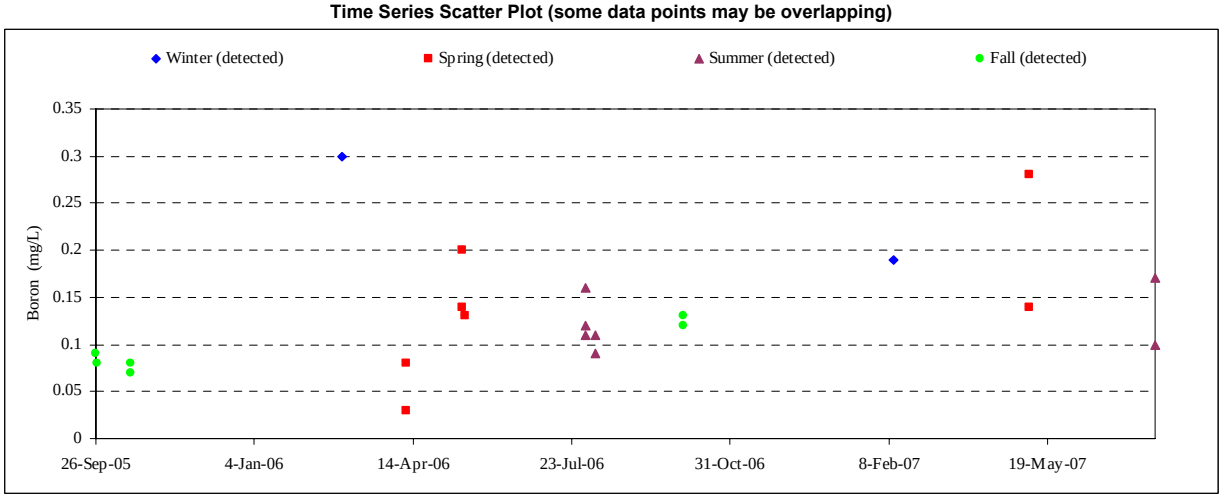
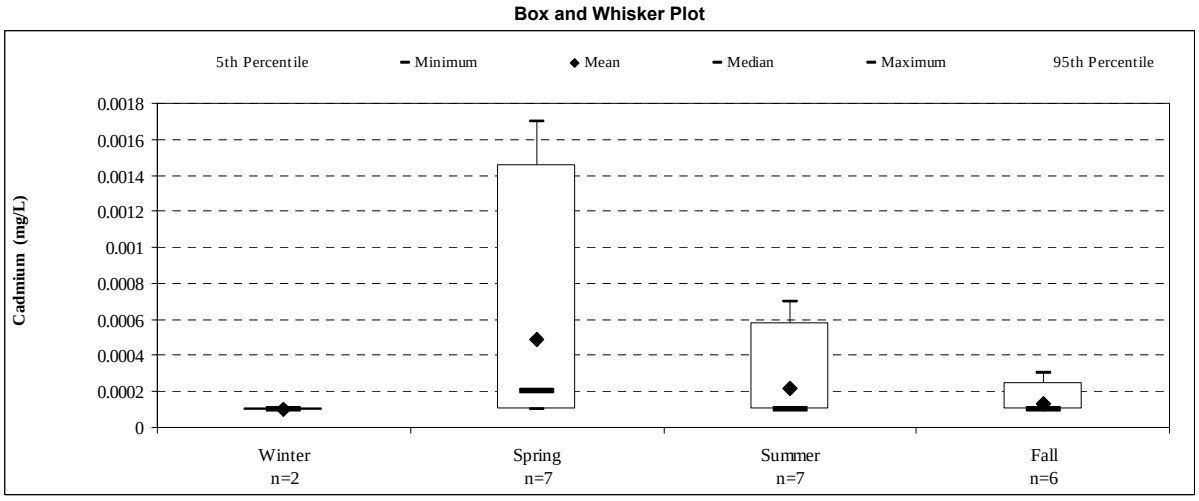


Figure G-3-2-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Eymundson Creek



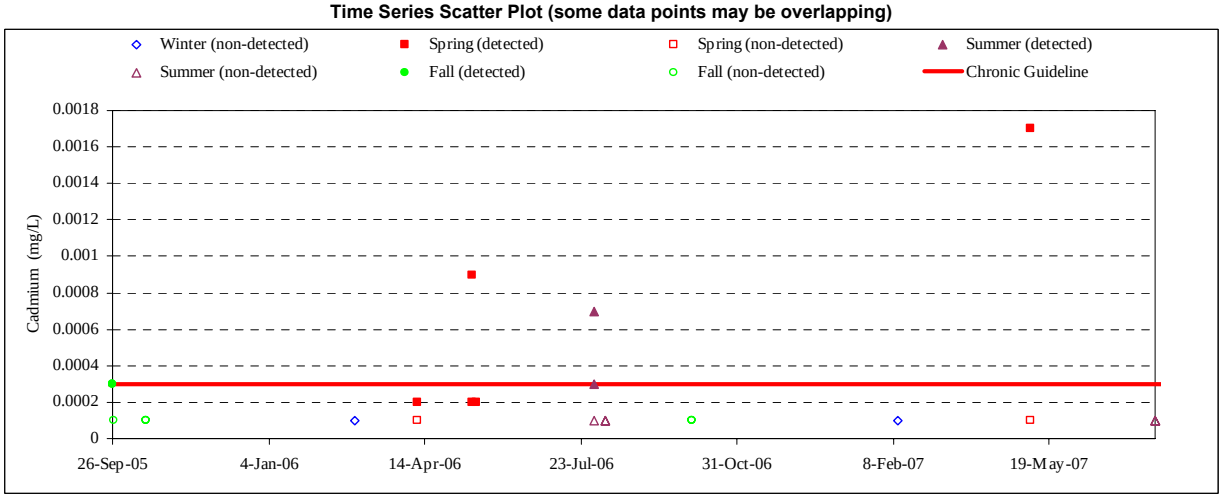
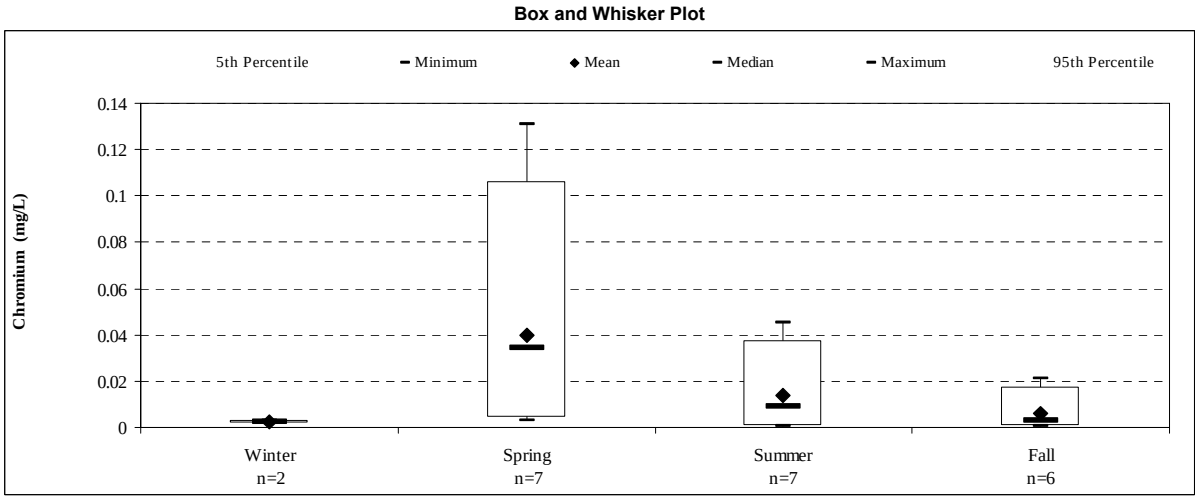


Figure G-3-2-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Eymundson Creek



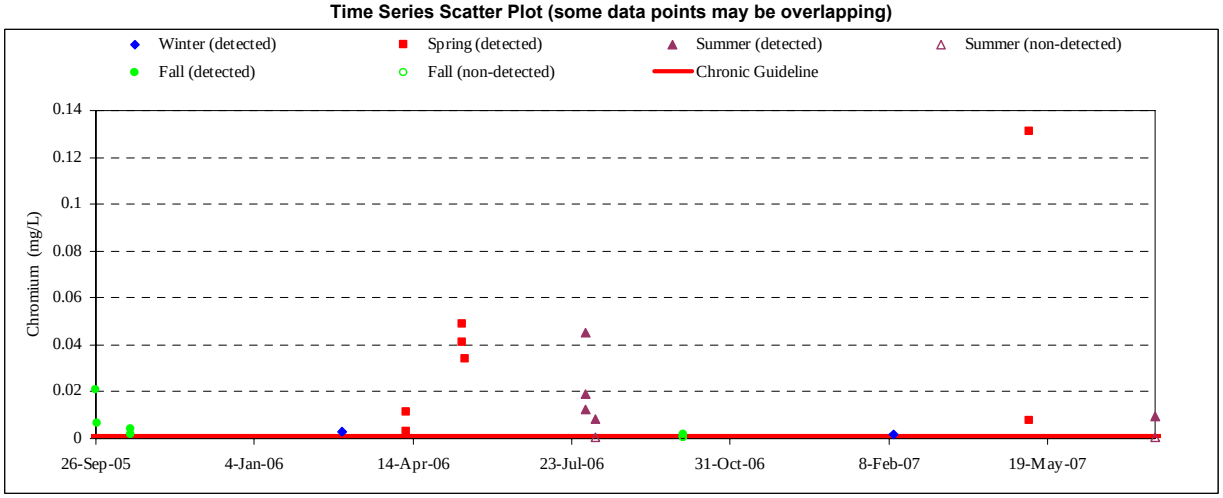
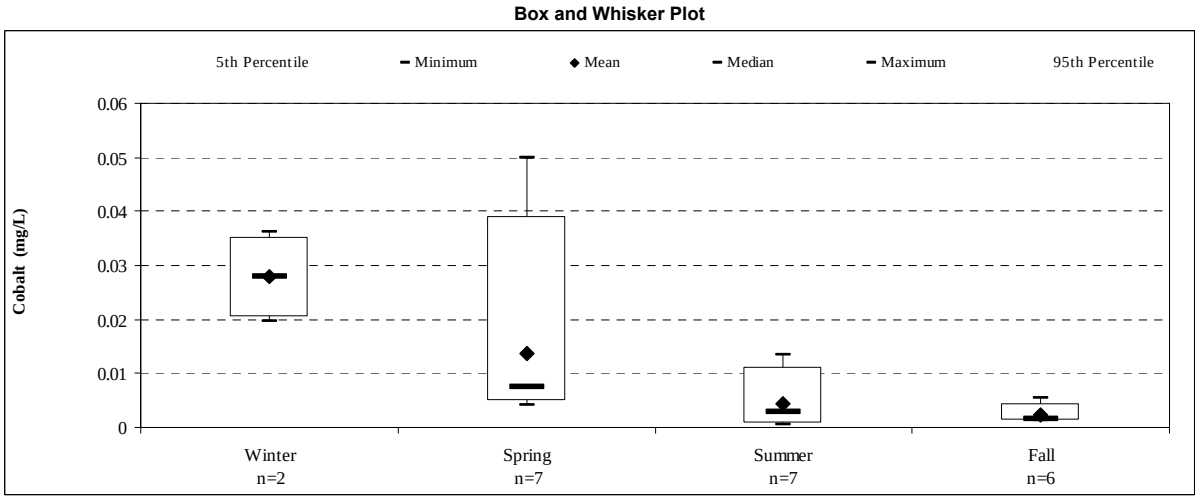


Figure G-3-2-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Eymundson Creek



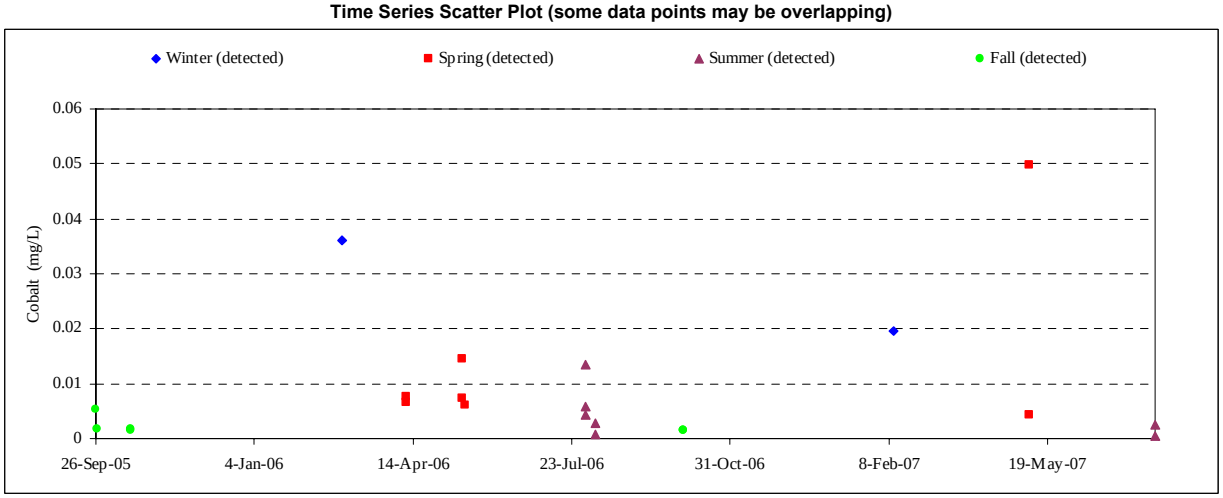
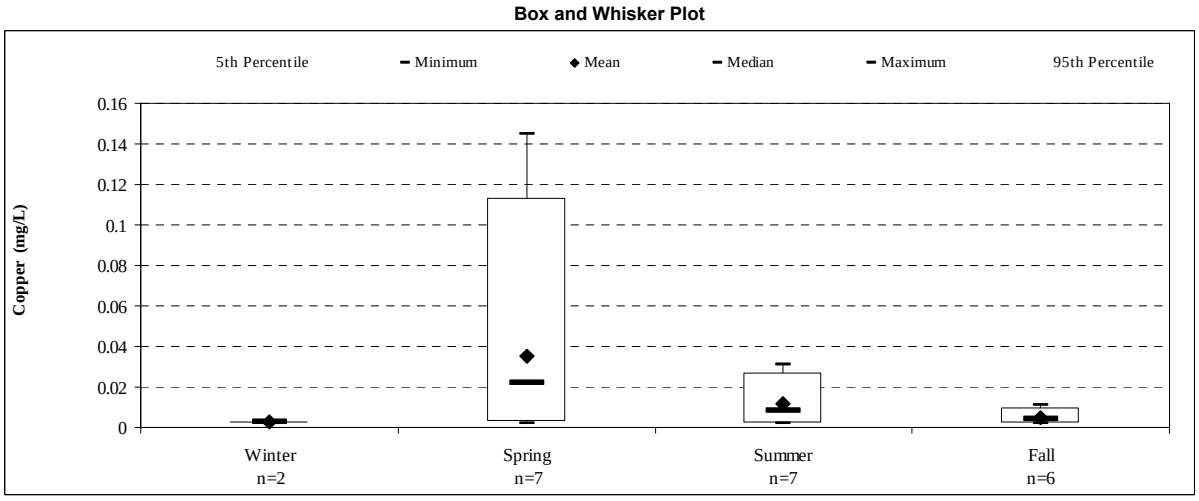


Figure G-3-2-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Eymundson Creek



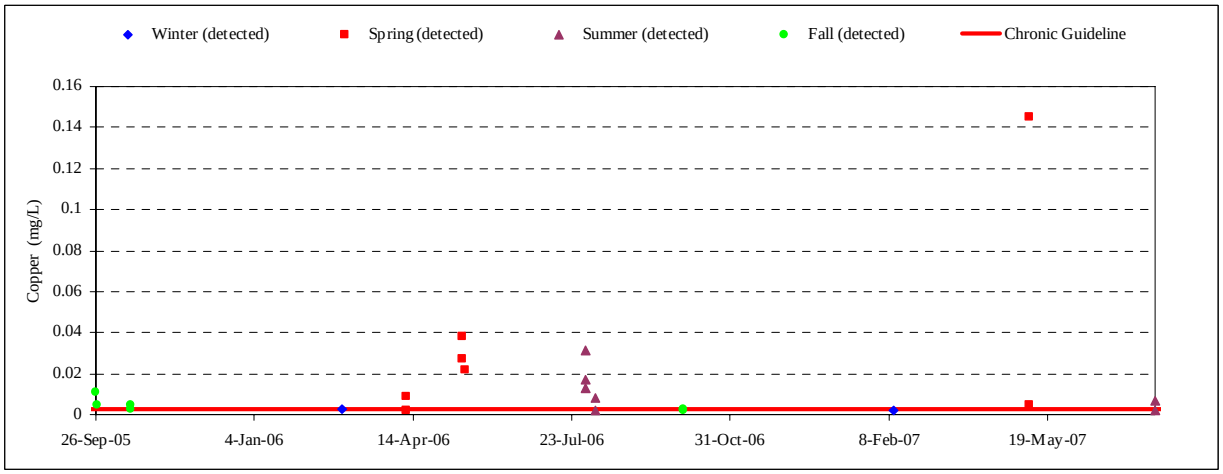
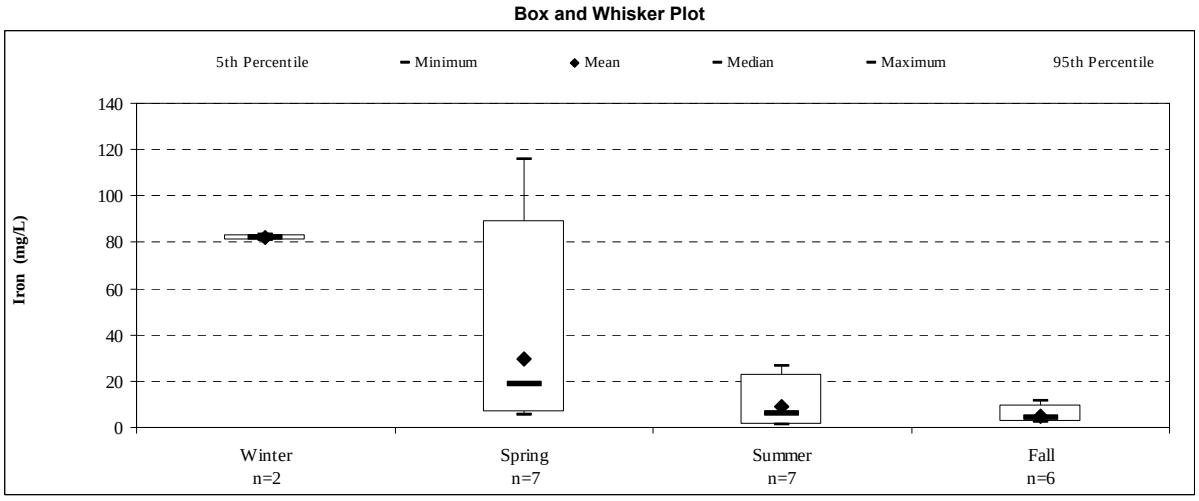


Figure G-3-2-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Eymundson Creek



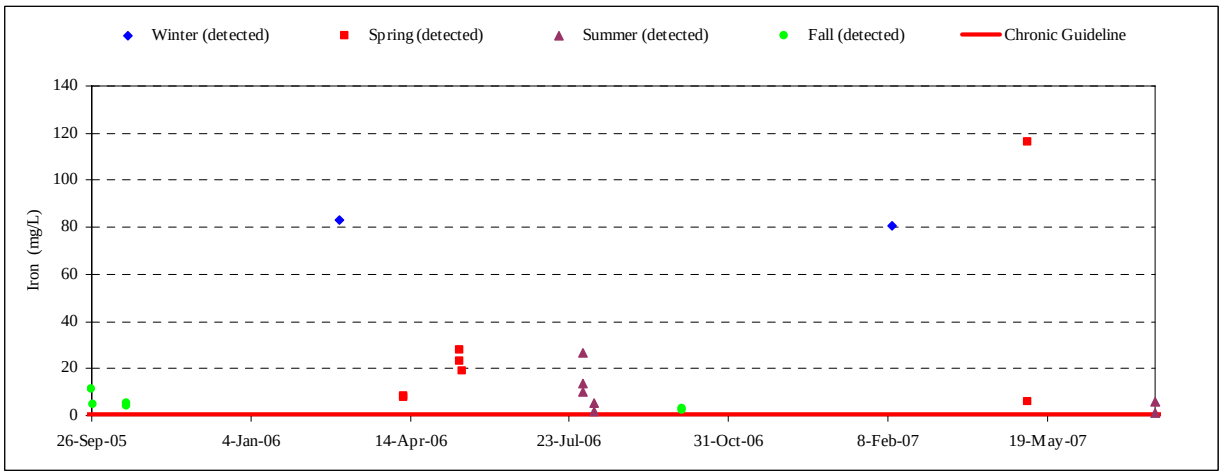
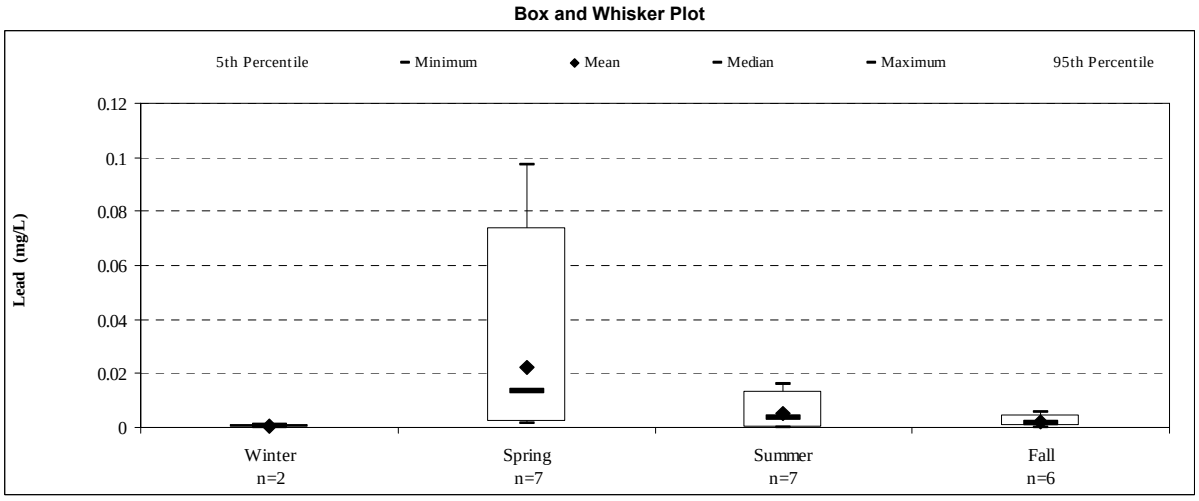


Figure G-3-2-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Eymundson Creek



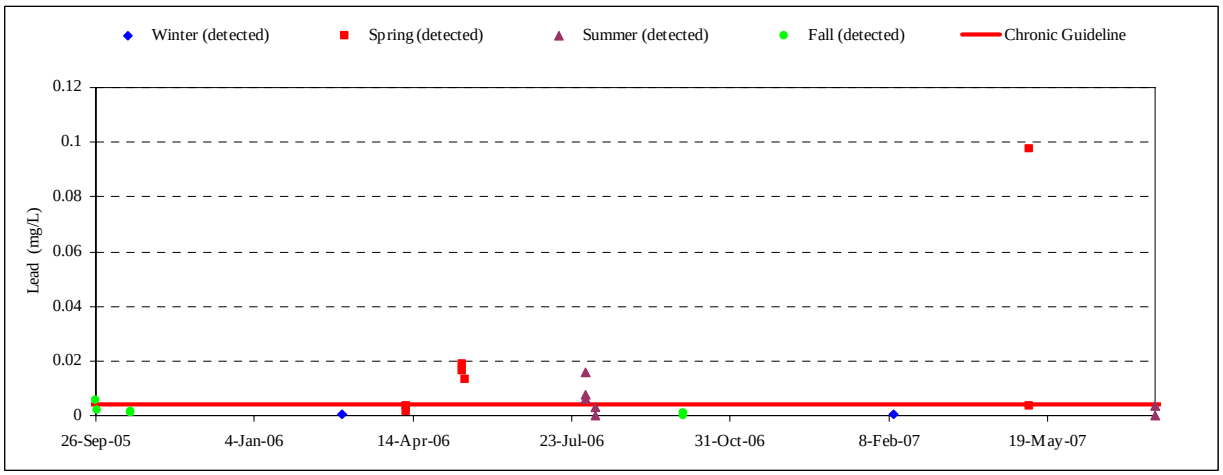
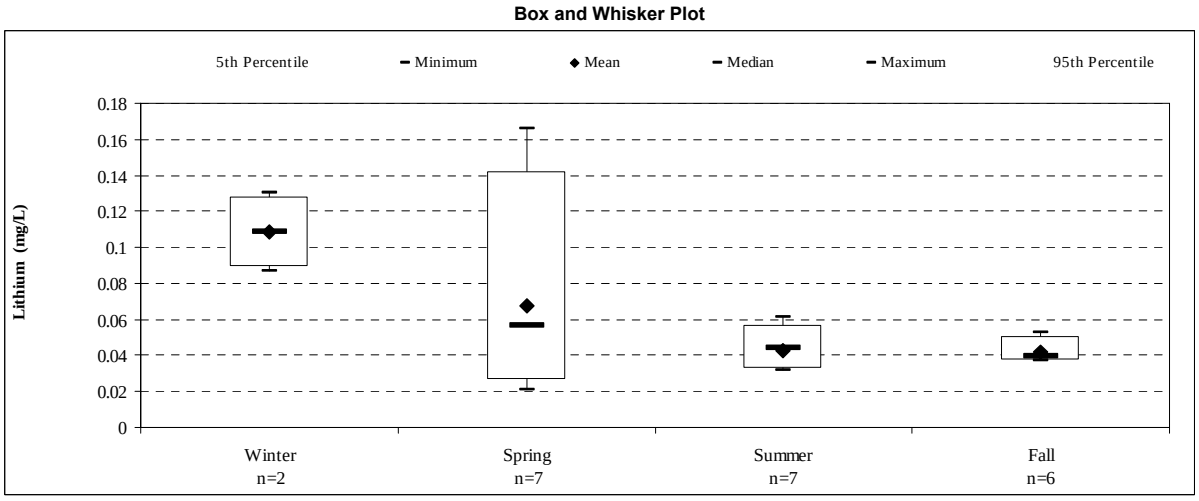


Figure G-3-2-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Eymundson Creek



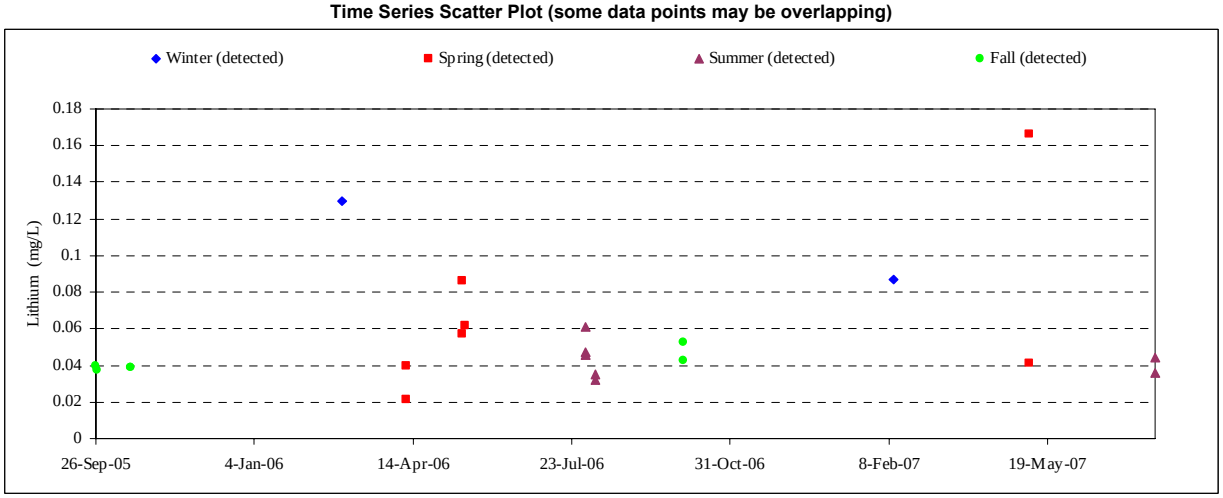
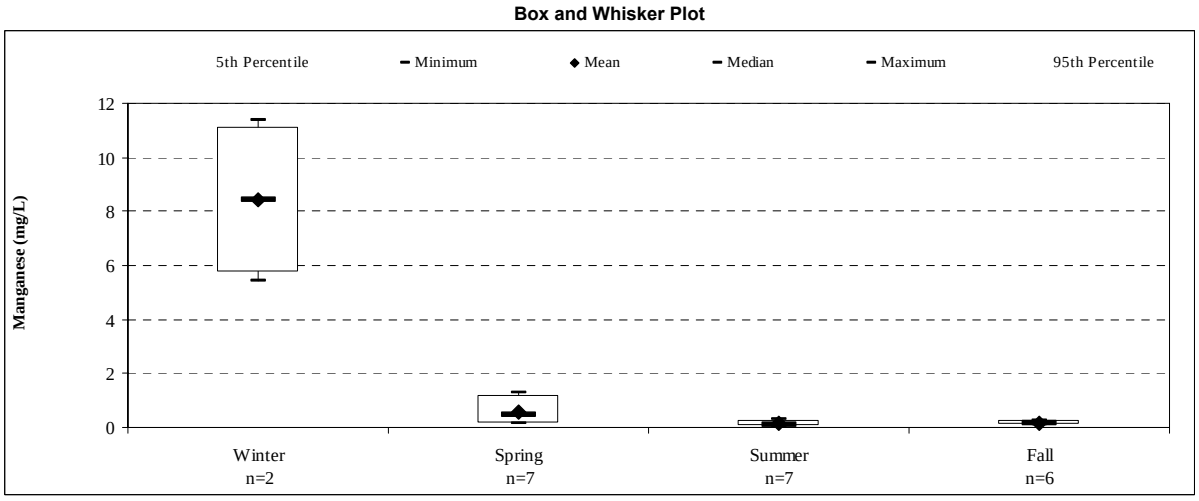


Figure G-3-2-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Eymundson Creek



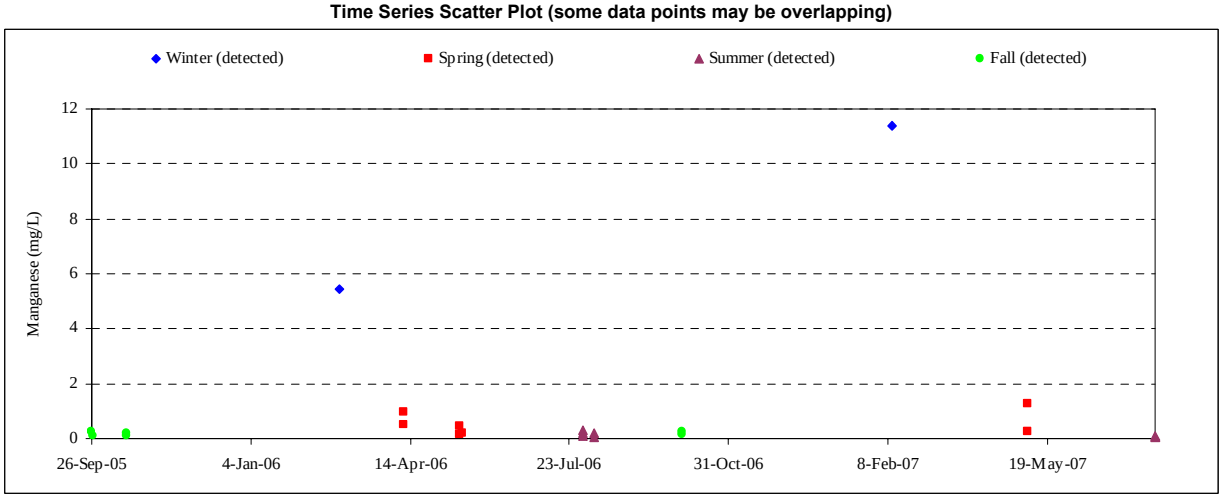
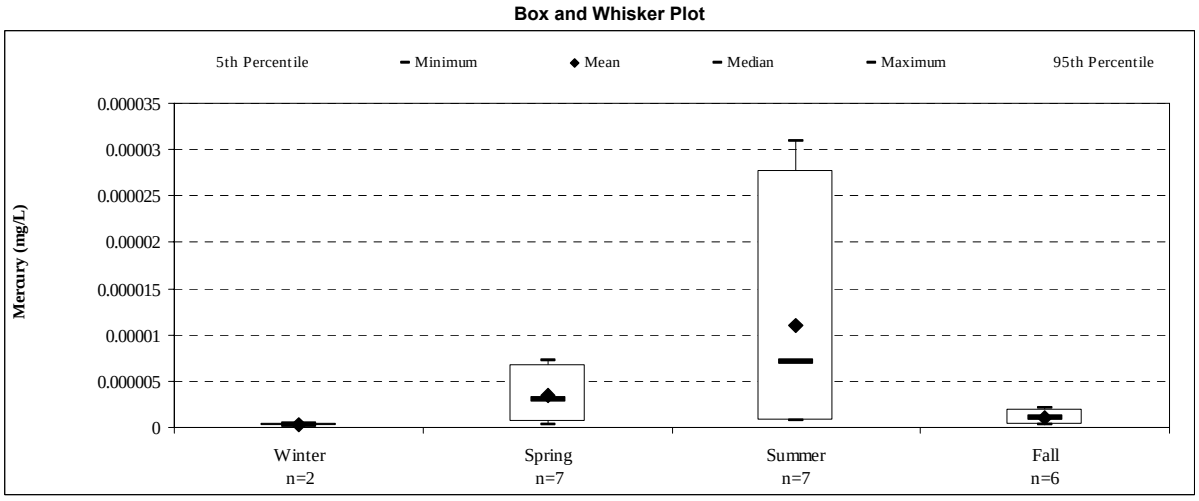


Figure G-3-2-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Eymundson Creek



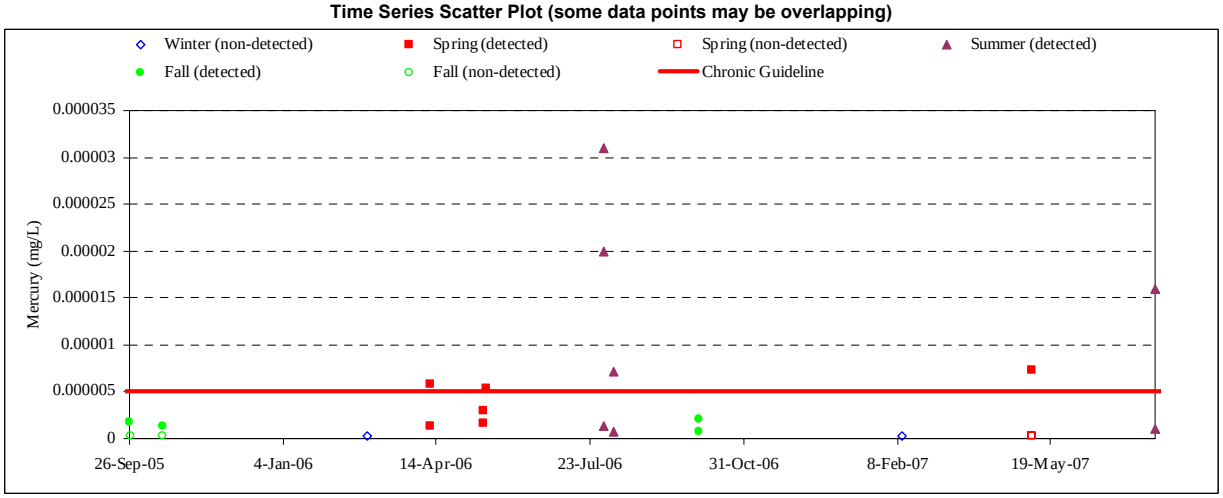
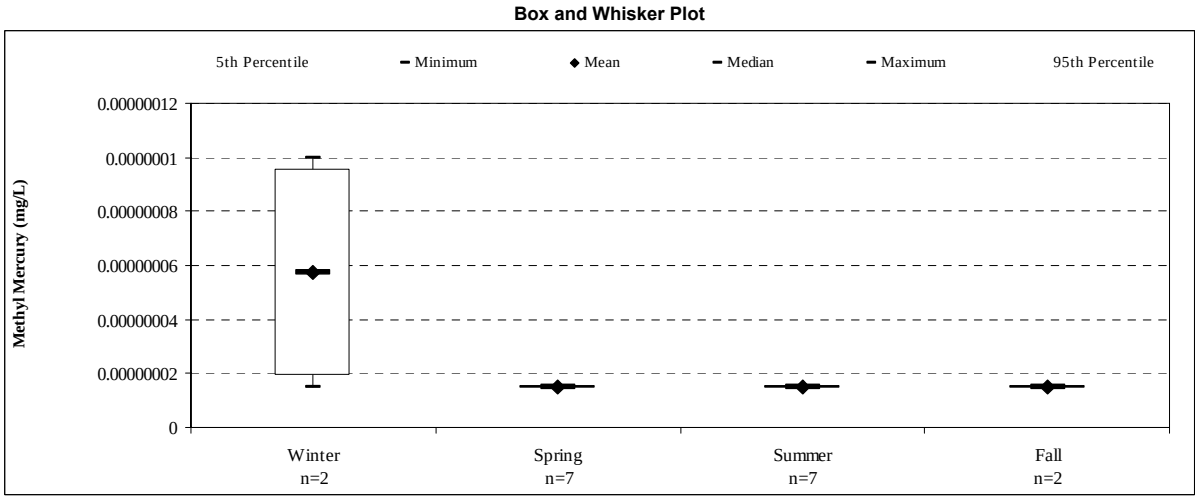


Figure G-3-2-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Eymundson Creek



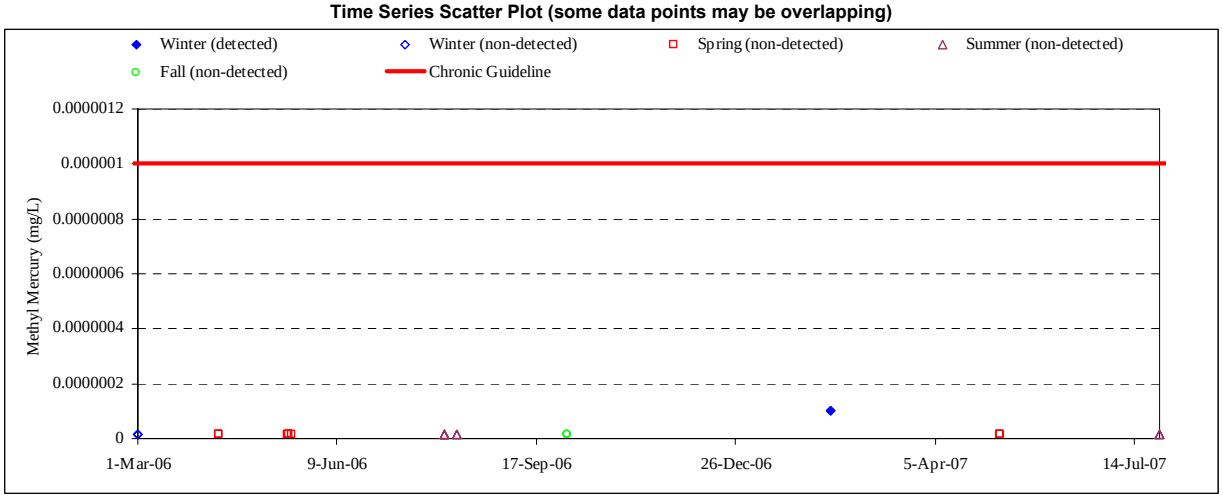
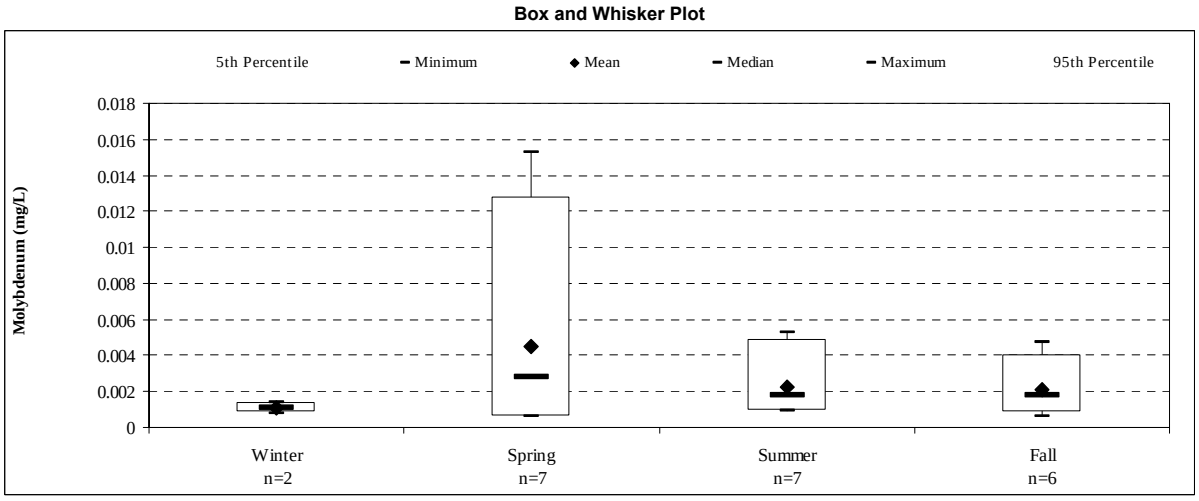


Figure G-3-2-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Eymundson Creek



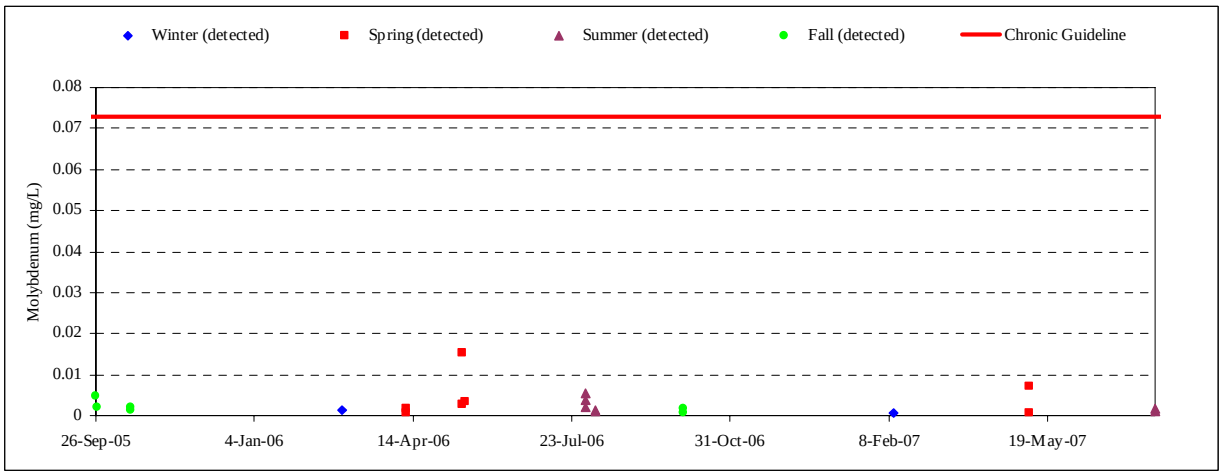
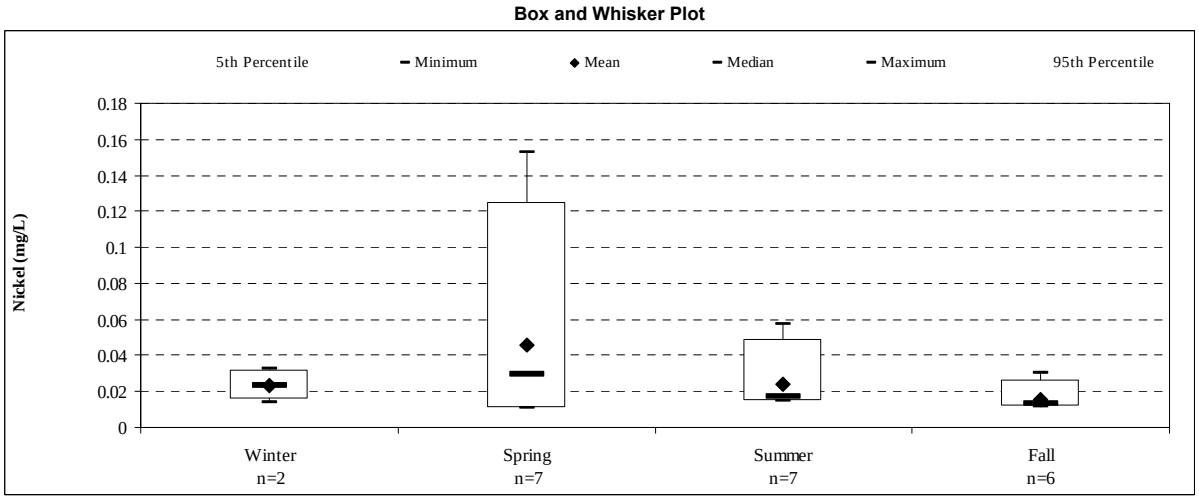


Figure G-3-2-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Eymundson Creek



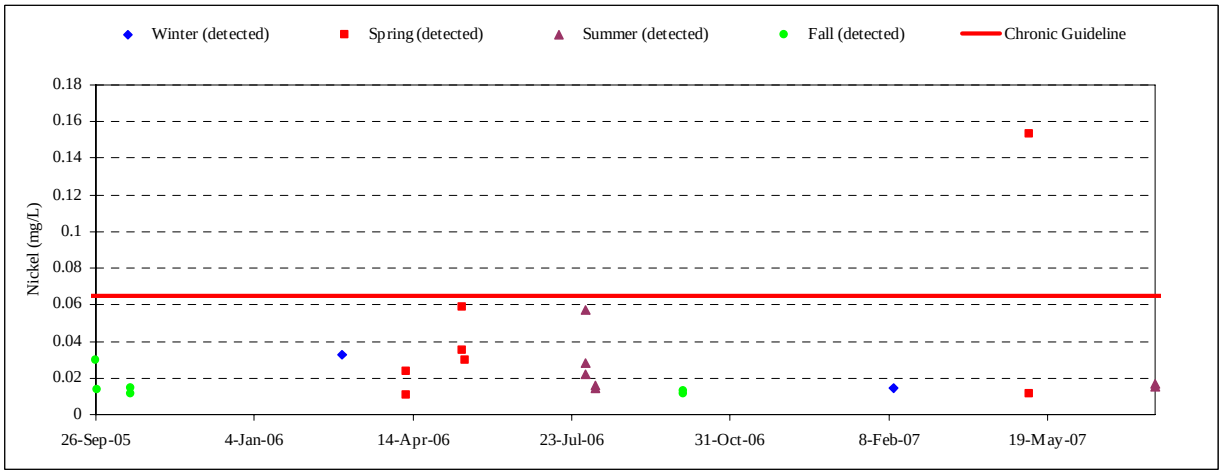
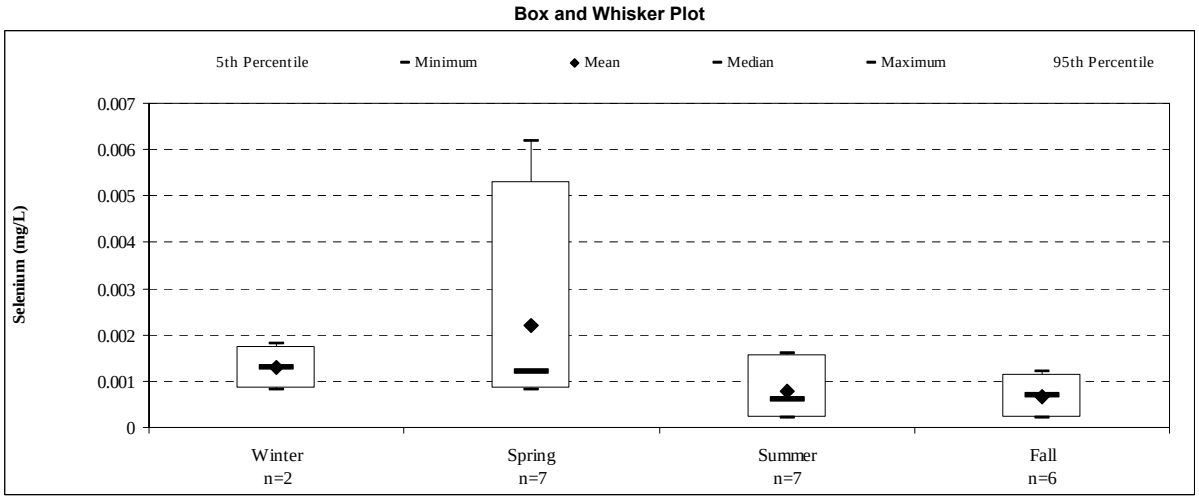


Figure G-3-2-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Eymundson Creek



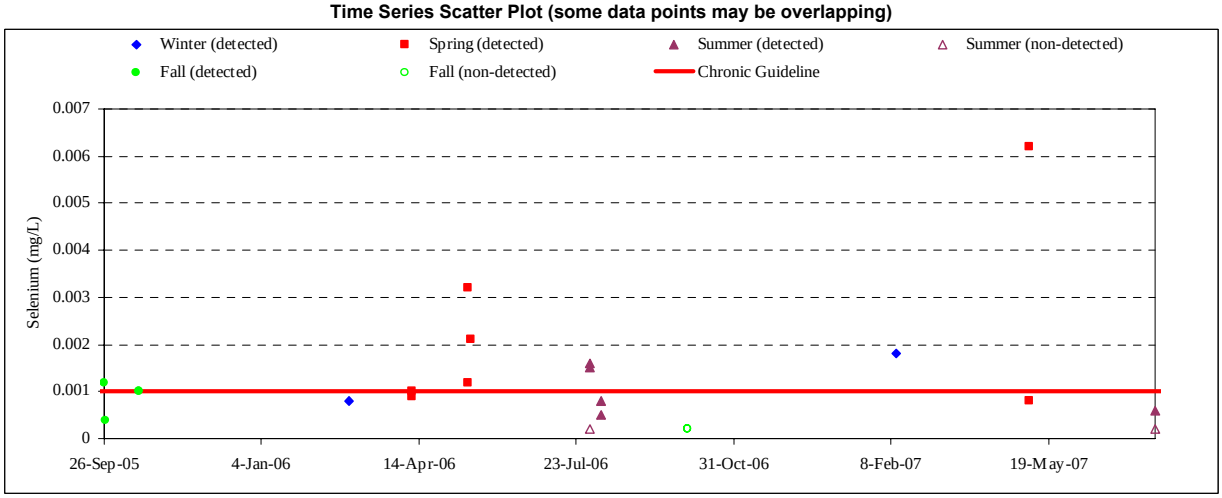
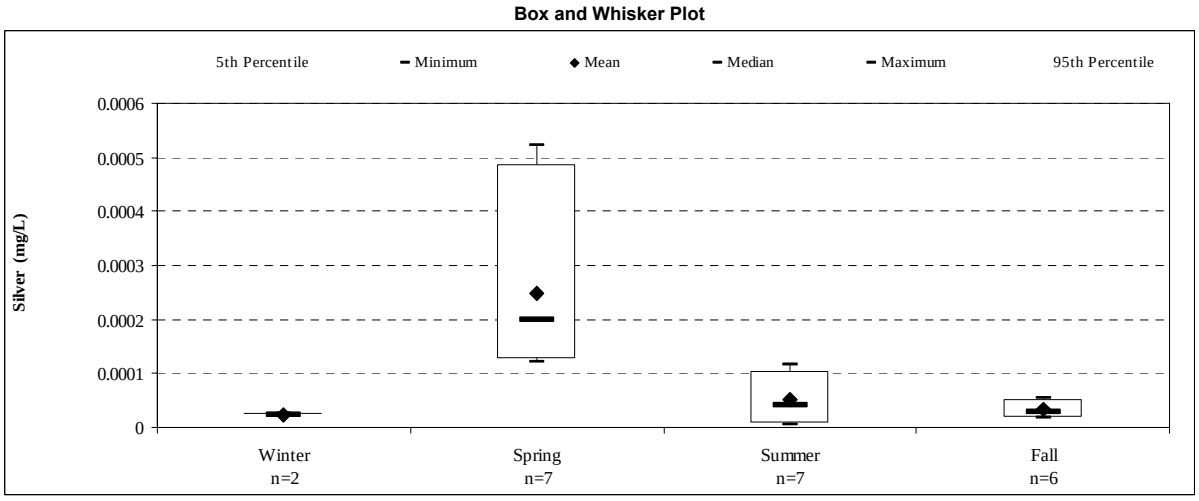


Figure G-3-2-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Eymundson Creek



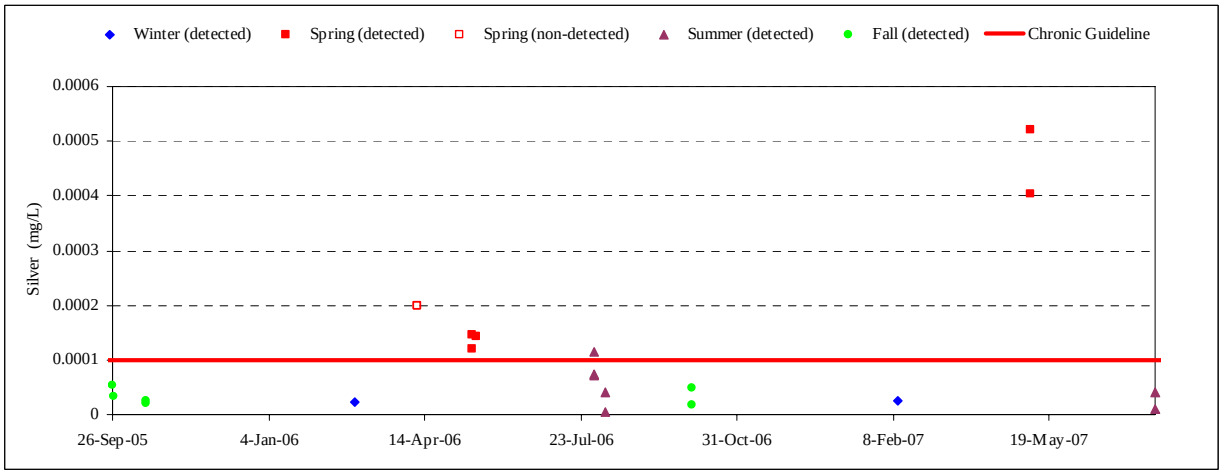
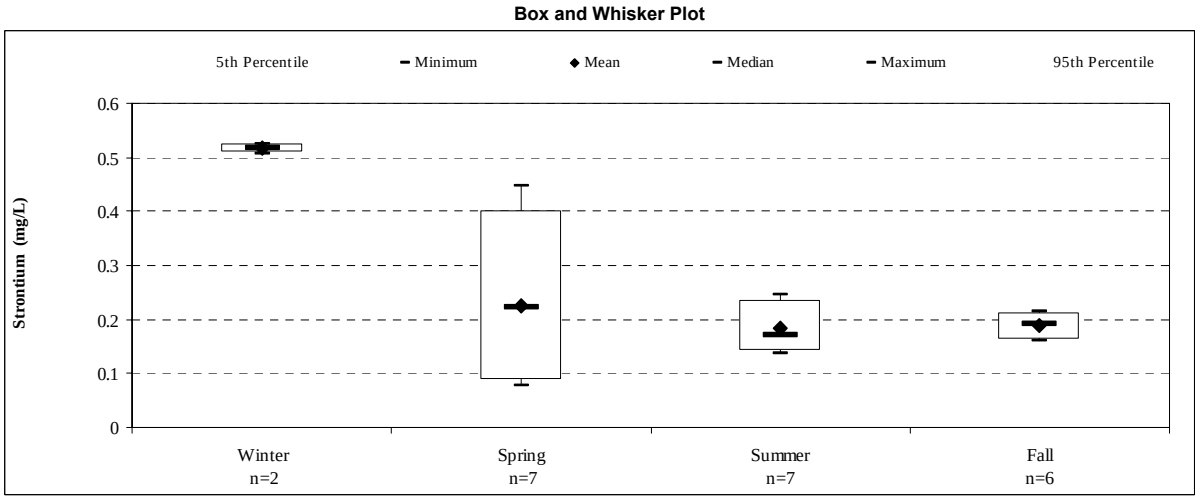


Figure G-3-2-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Eymundson Creek



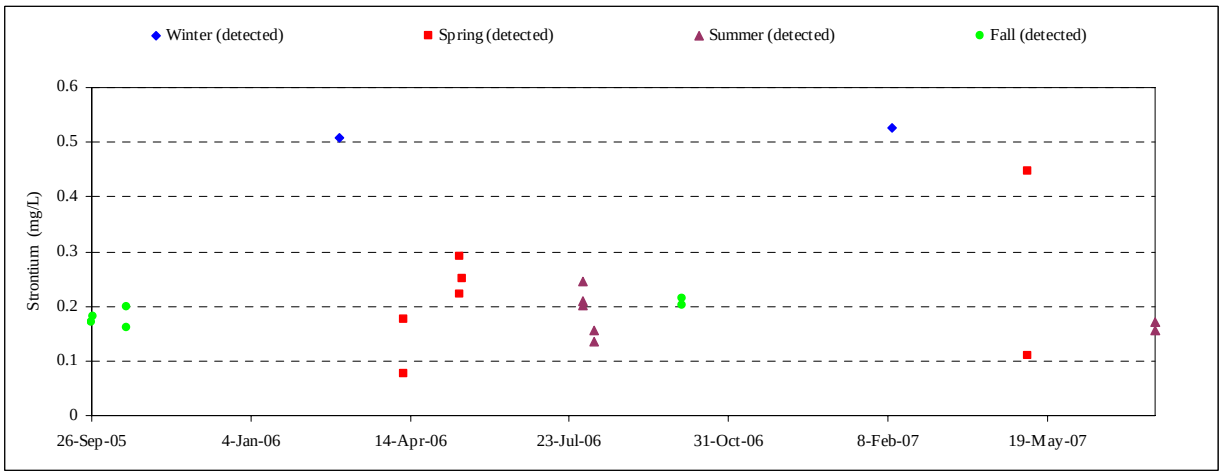
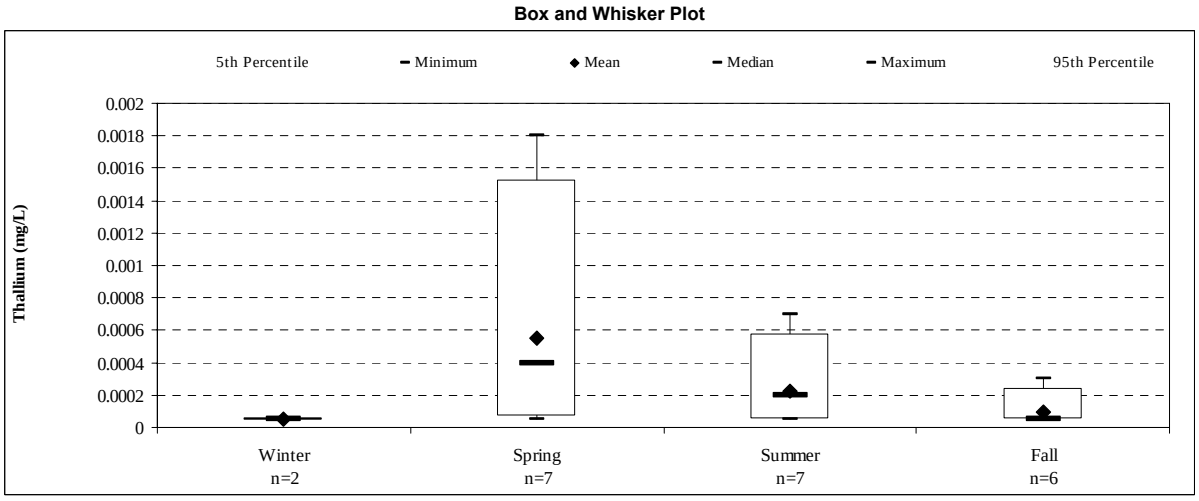


Figure G-3-2-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Eymundson Creek



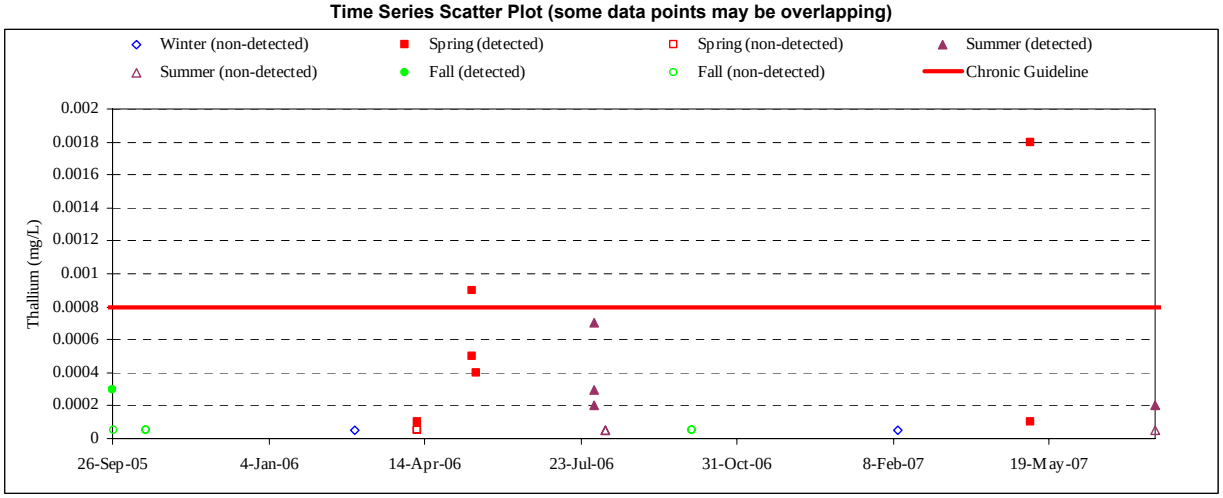
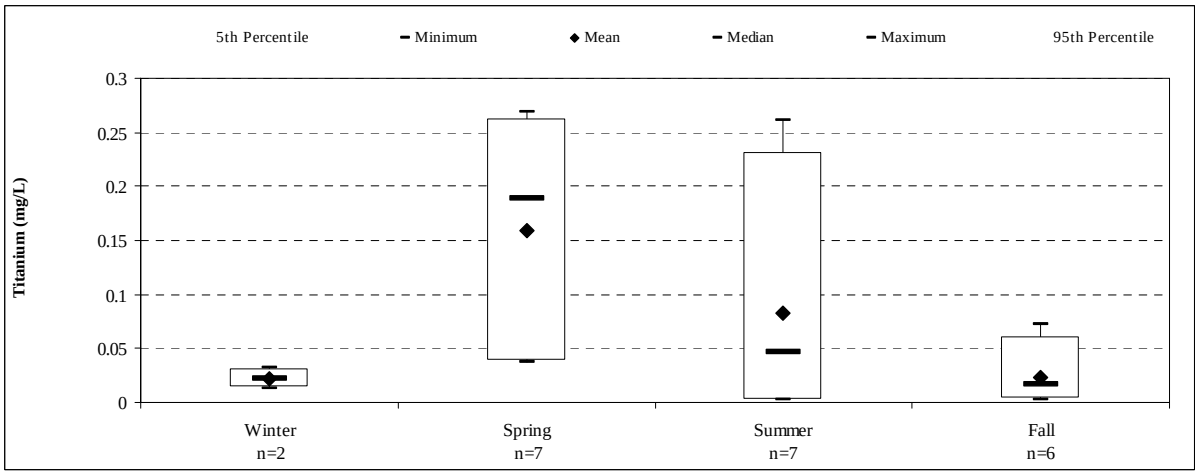


Figure G-3-2-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Eymundson Creek

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

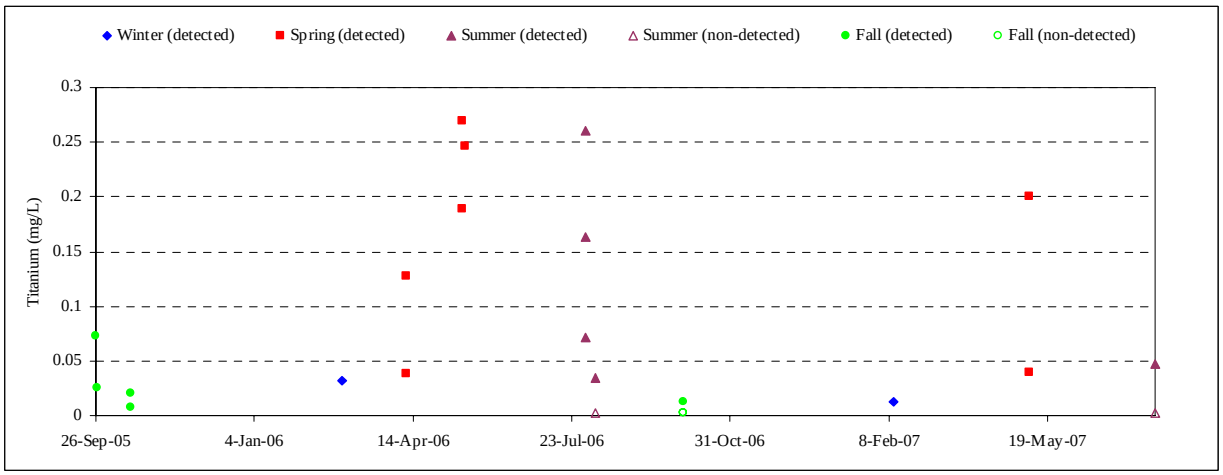
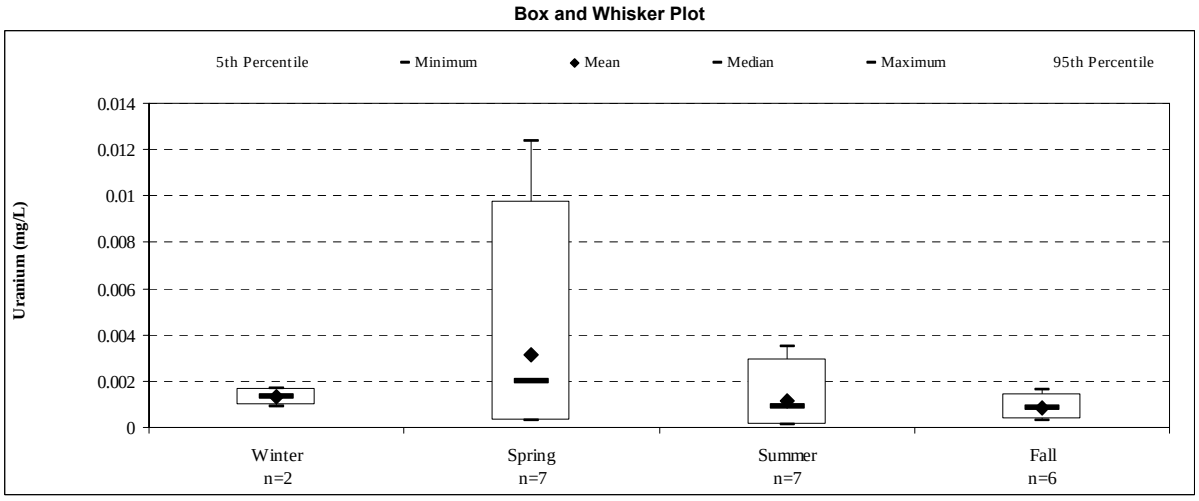


Figure G-3-2-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Eymundson Creek



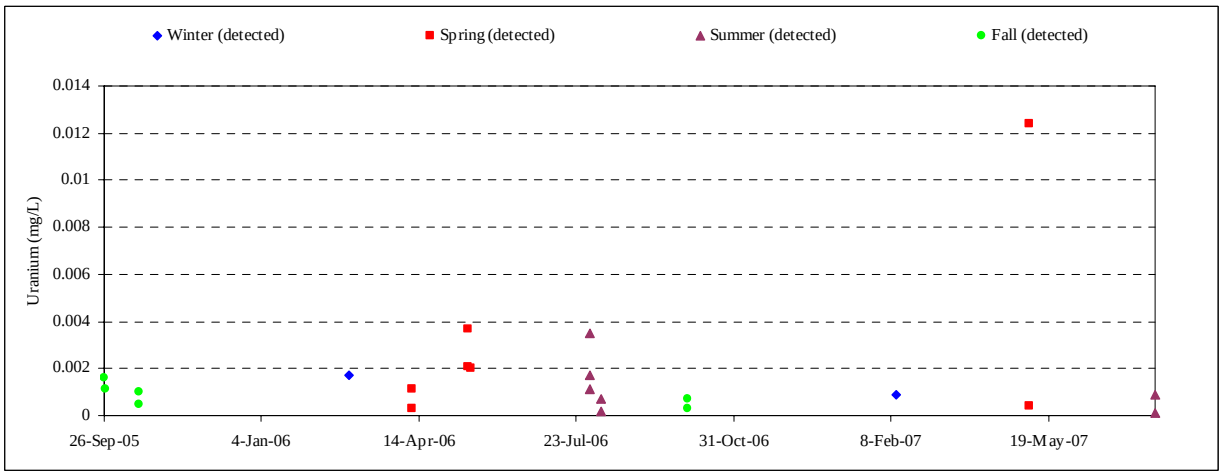
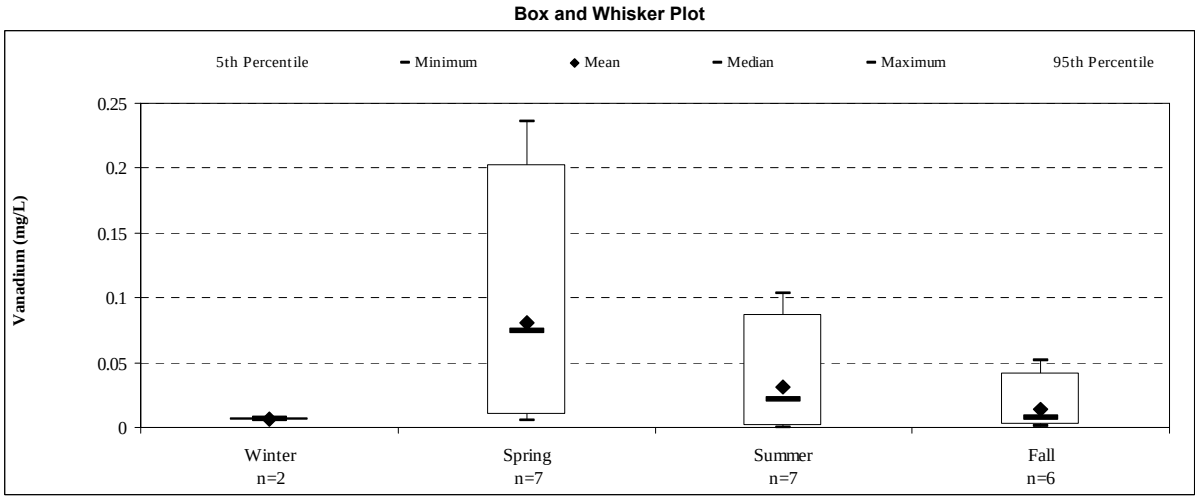


Figure G-3-2-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Eymundson Creek



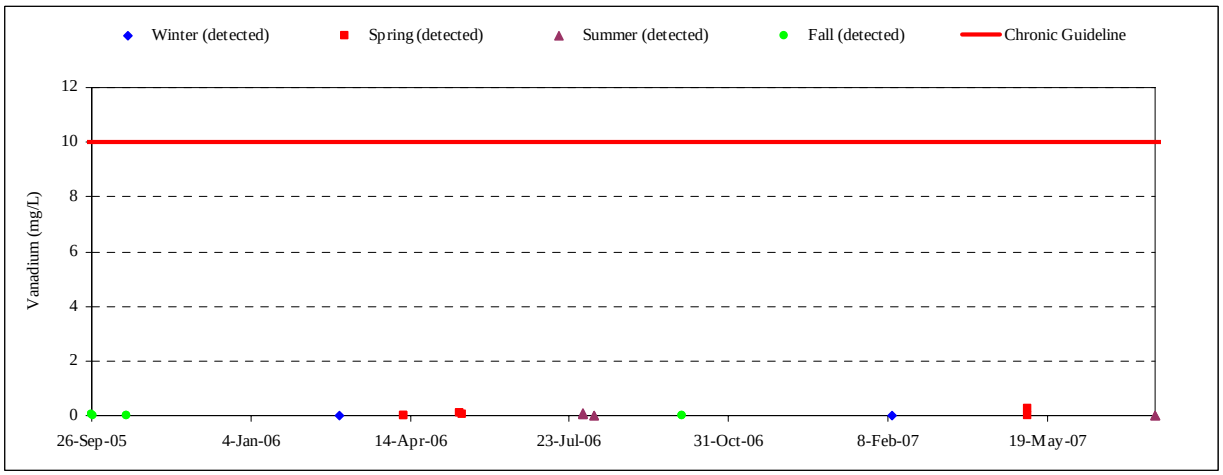
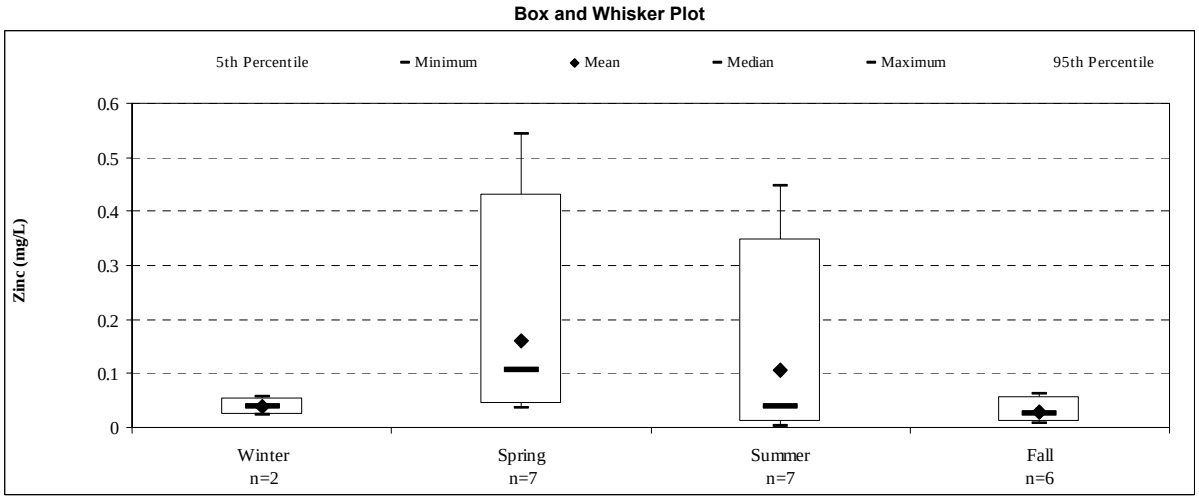


Figure G-3-2-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Eymundson Creek



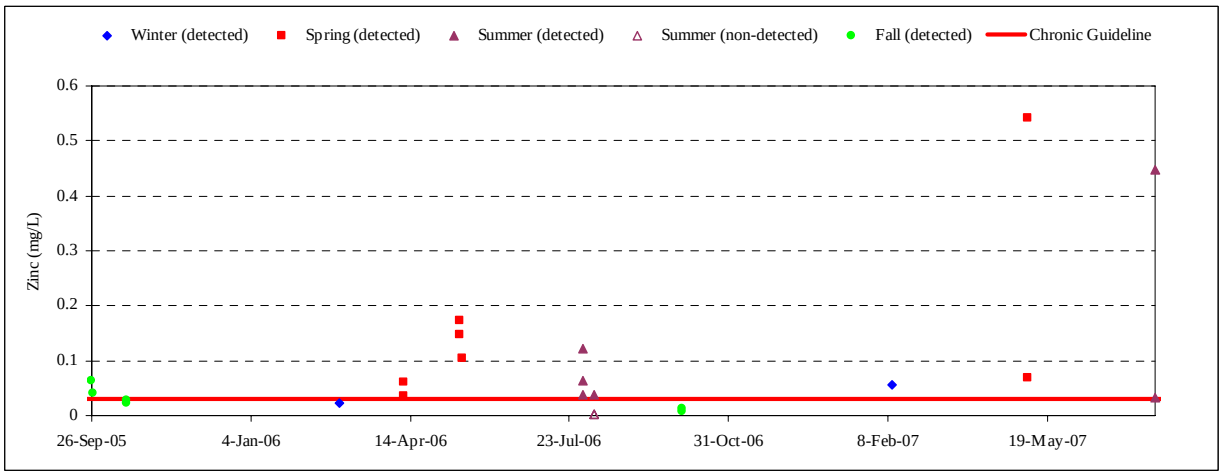
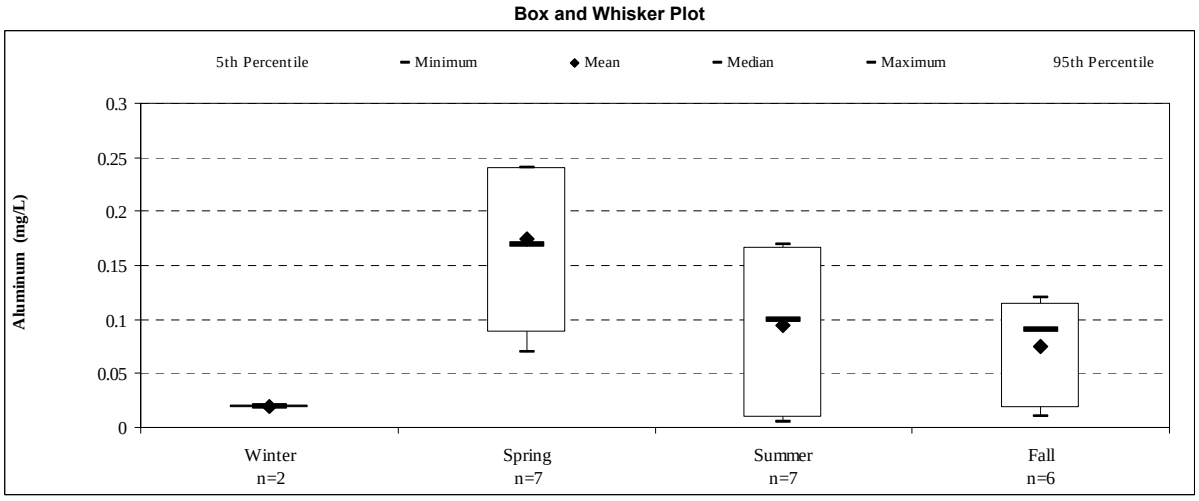


Figure G-3-2-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Eymundson Creek



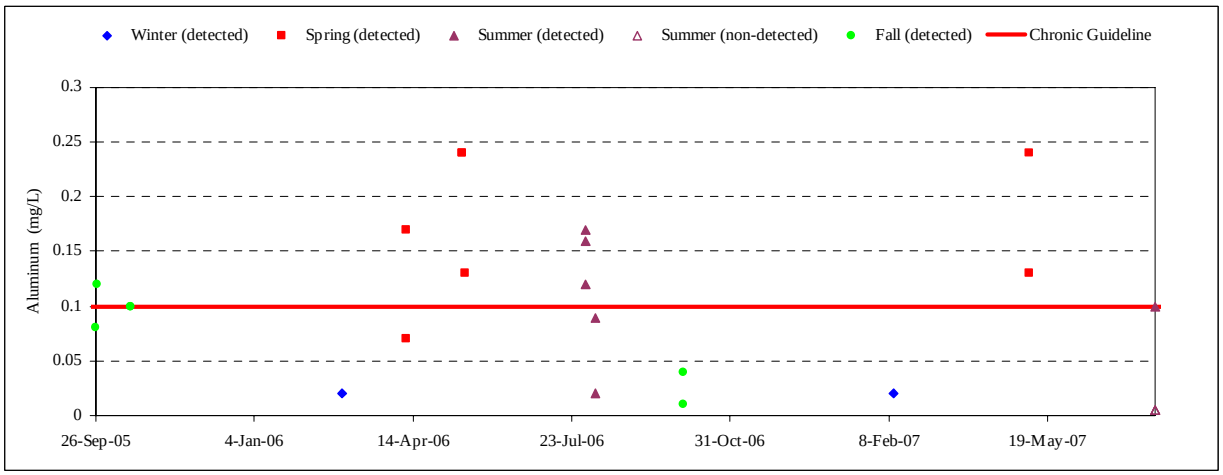
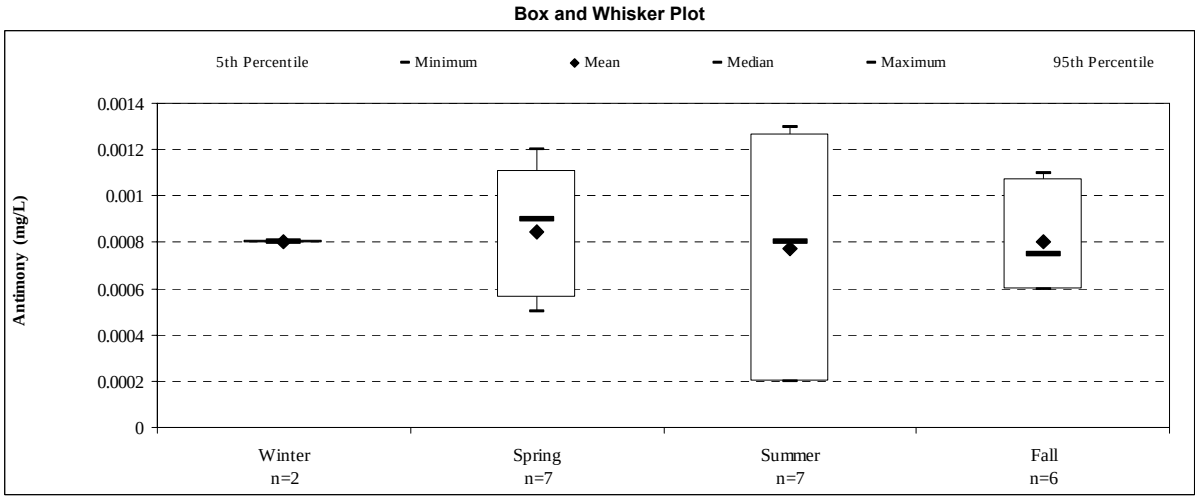


Figure G-3-2-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Eymundson Creek



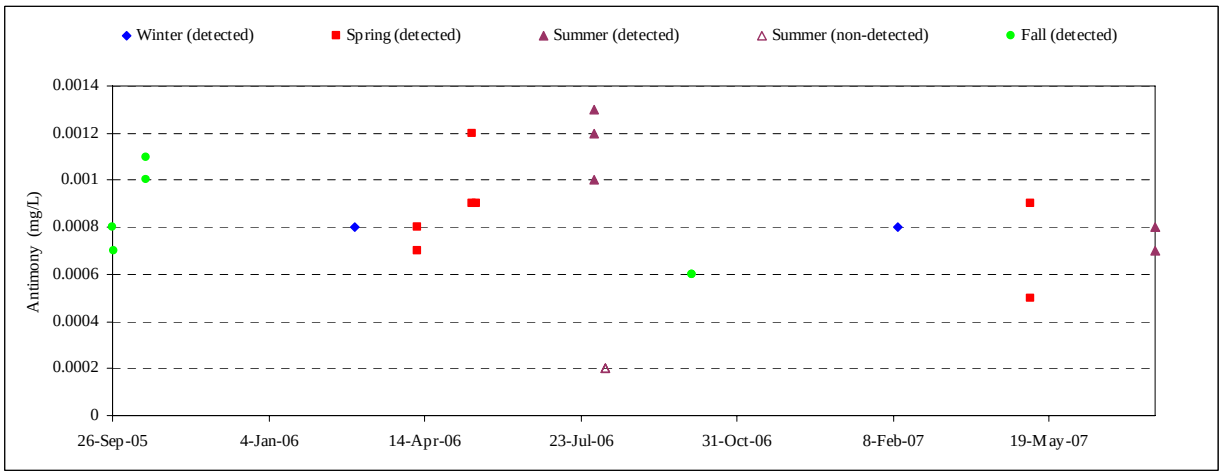
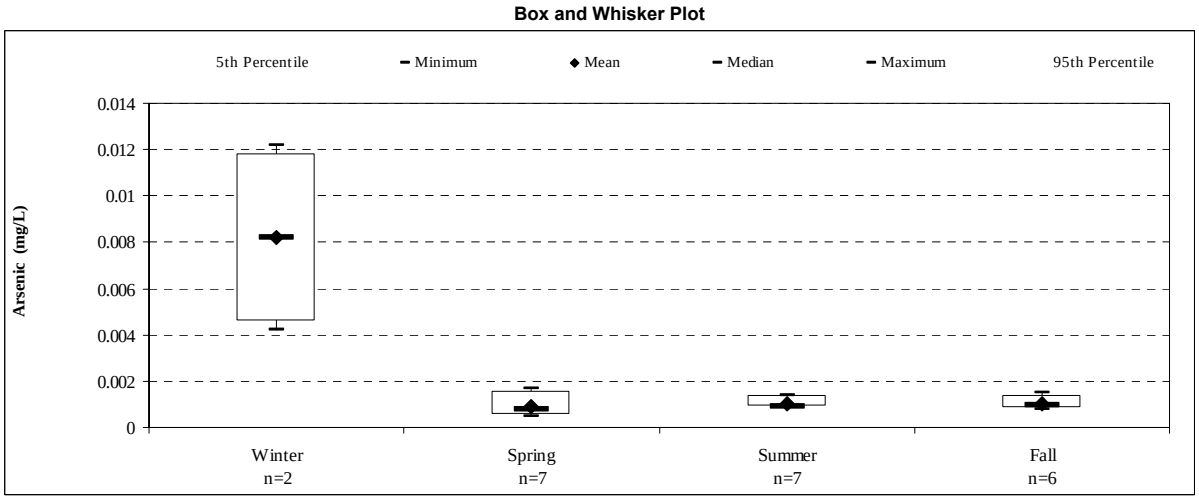


Figure G-3-2-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Eymundson Creek



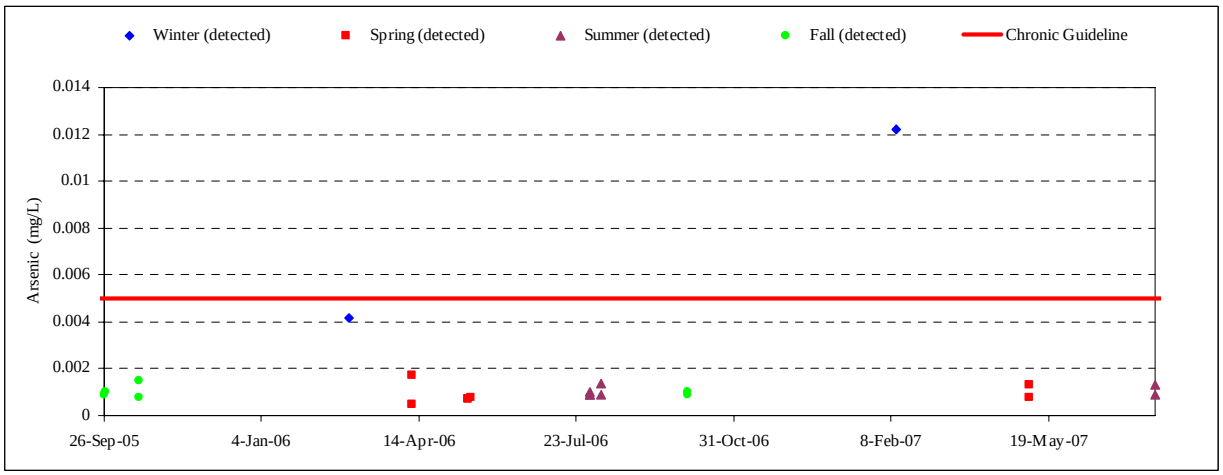
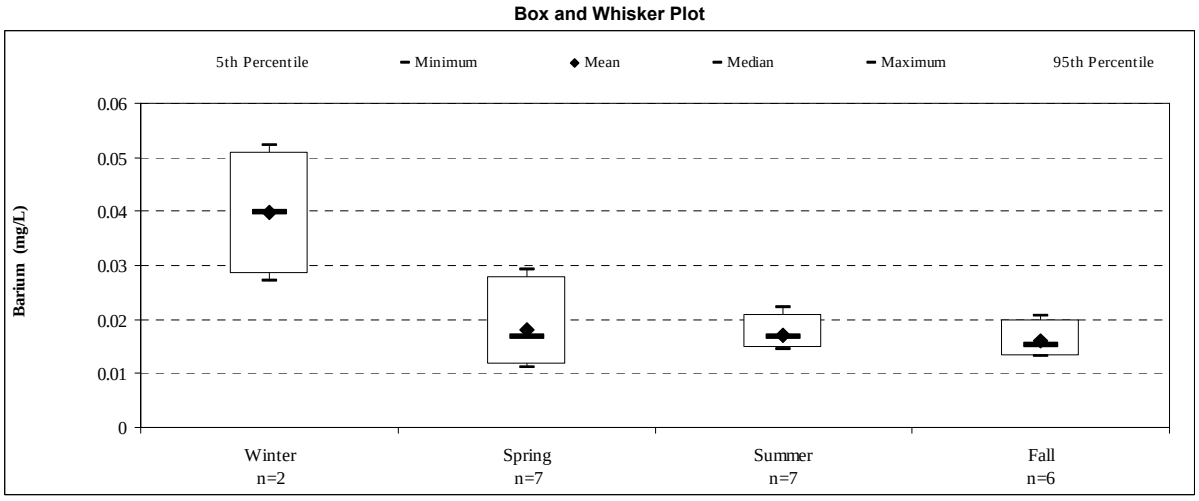


Figure G-3-2-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Eymundson Creek



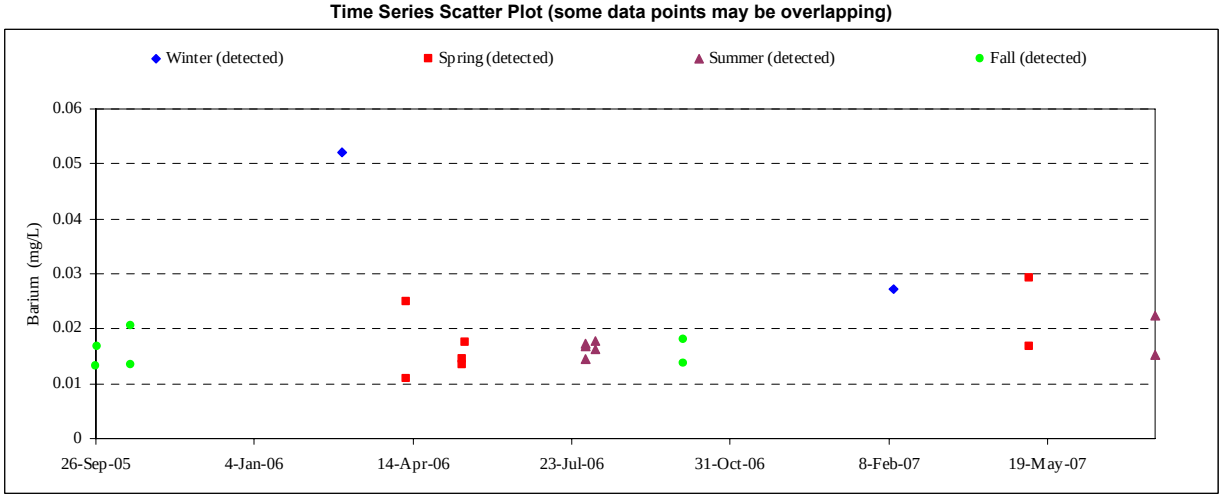
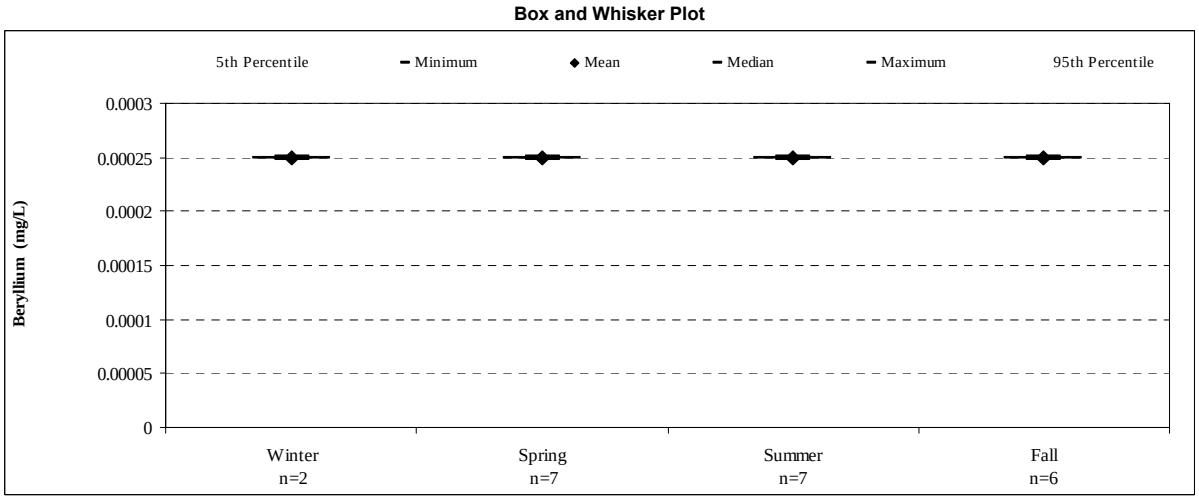


Figure G-3-2-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Eymundson Creek



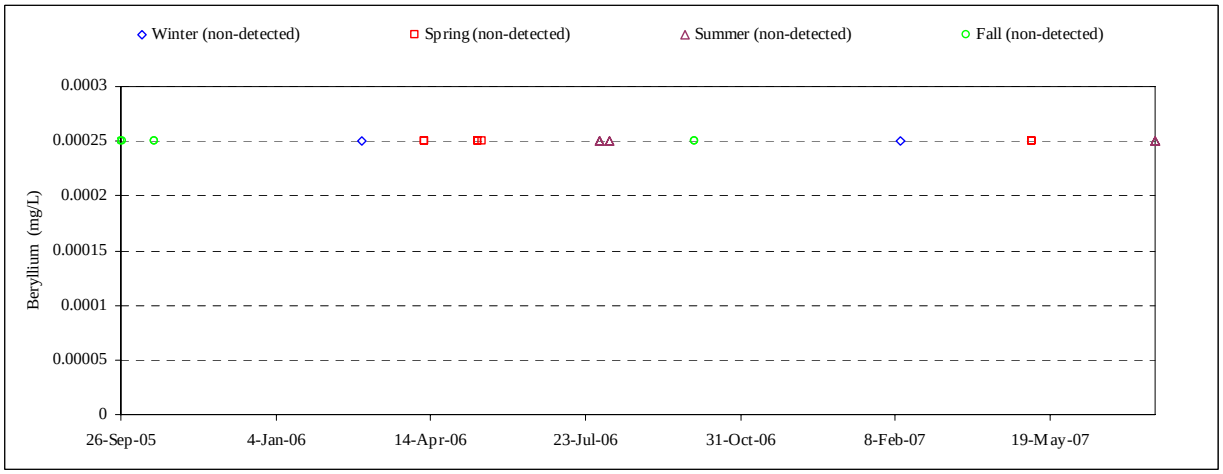
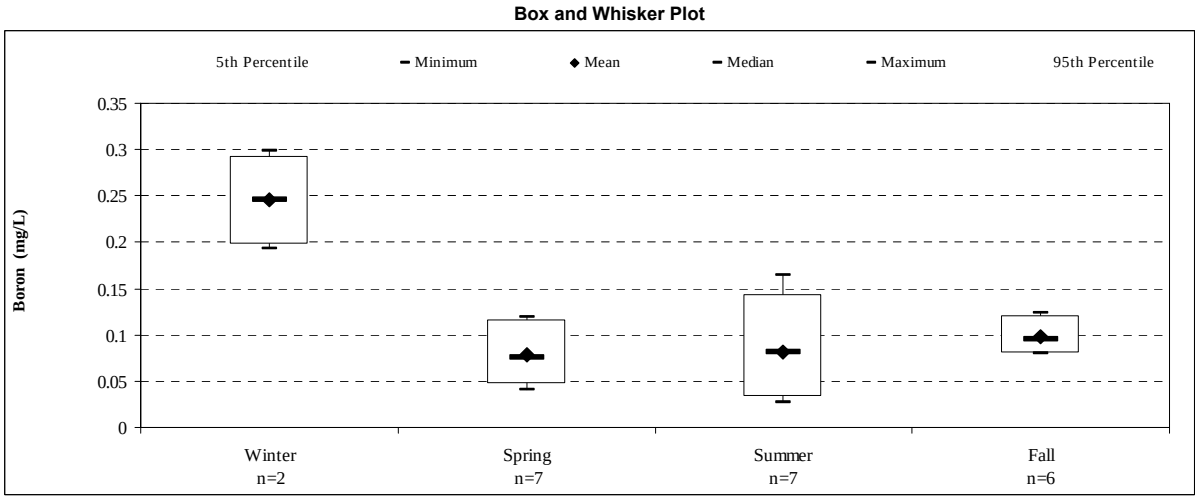


Figure G-3-2-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Eymundson Creek



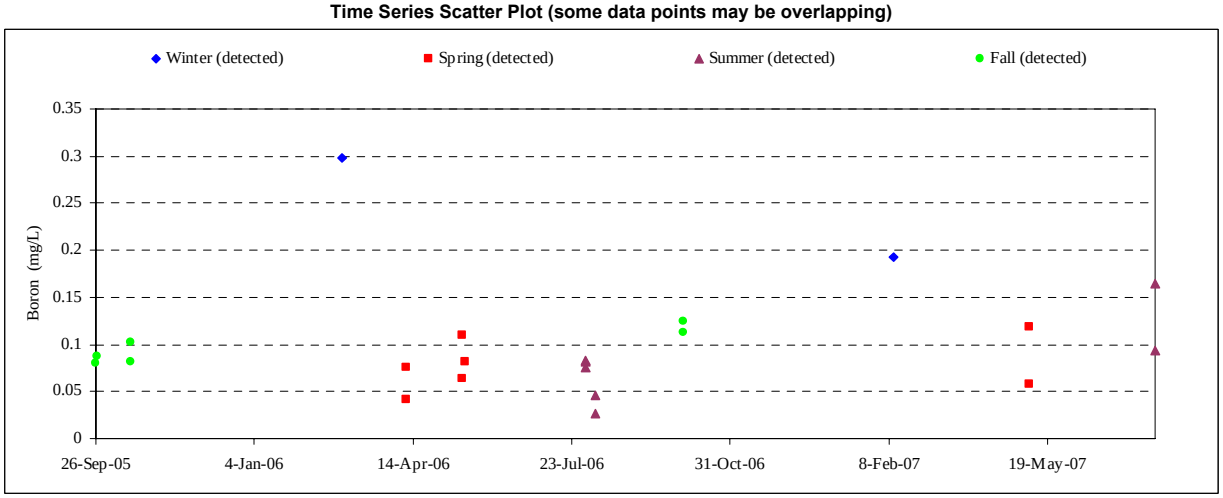
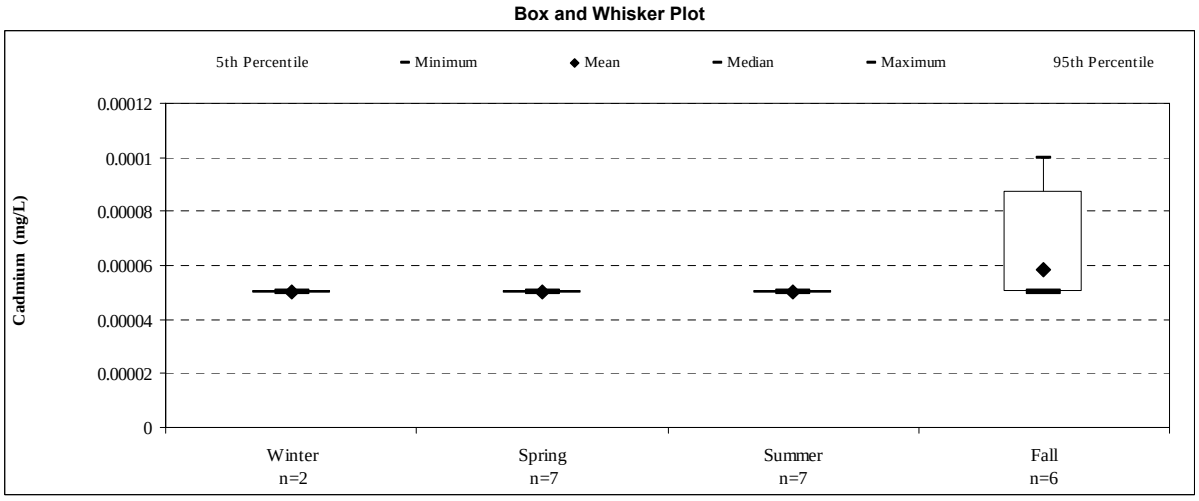


Figure G-3-2-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Eymundson Creek



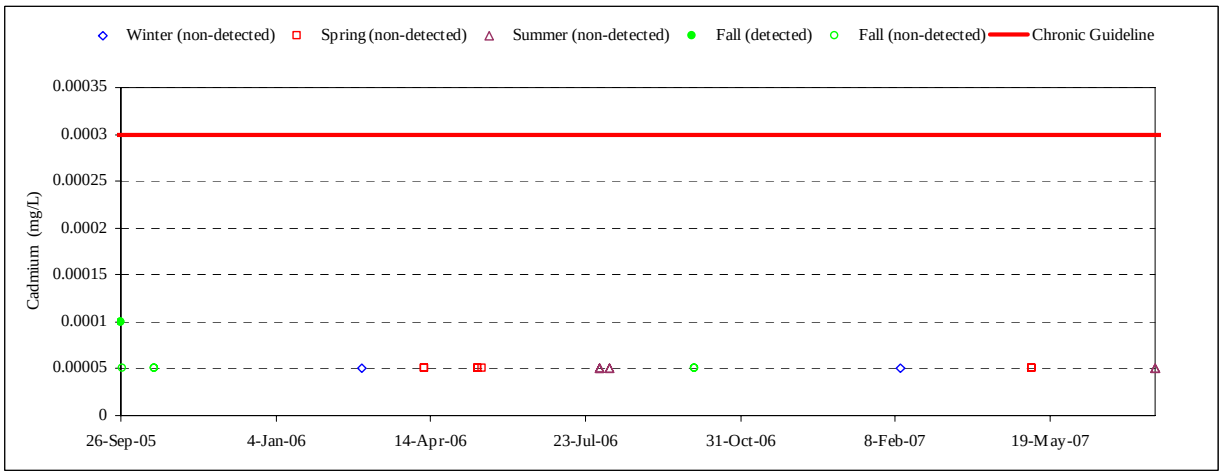
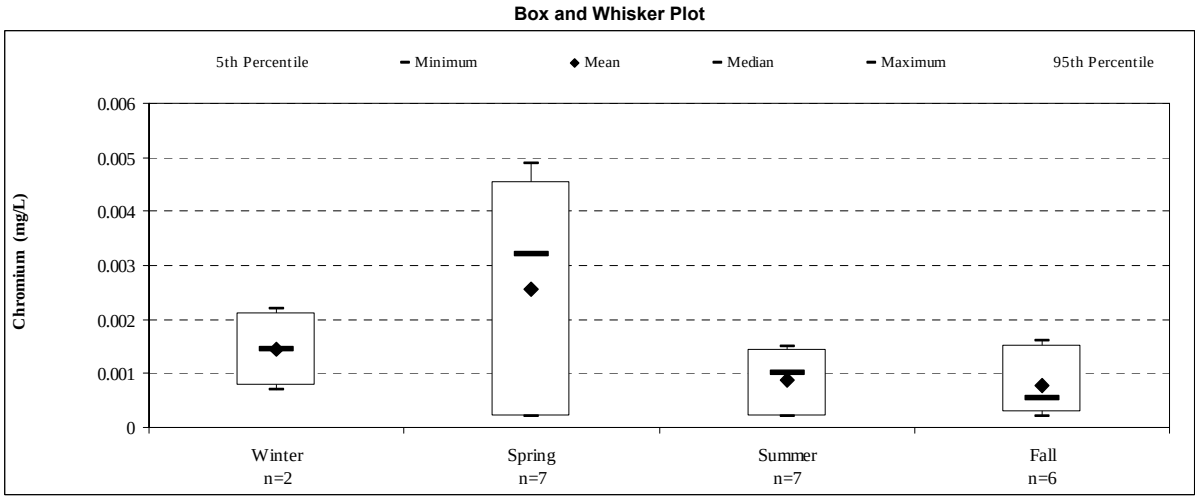


Figure G-3-2-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Eymundson Creek



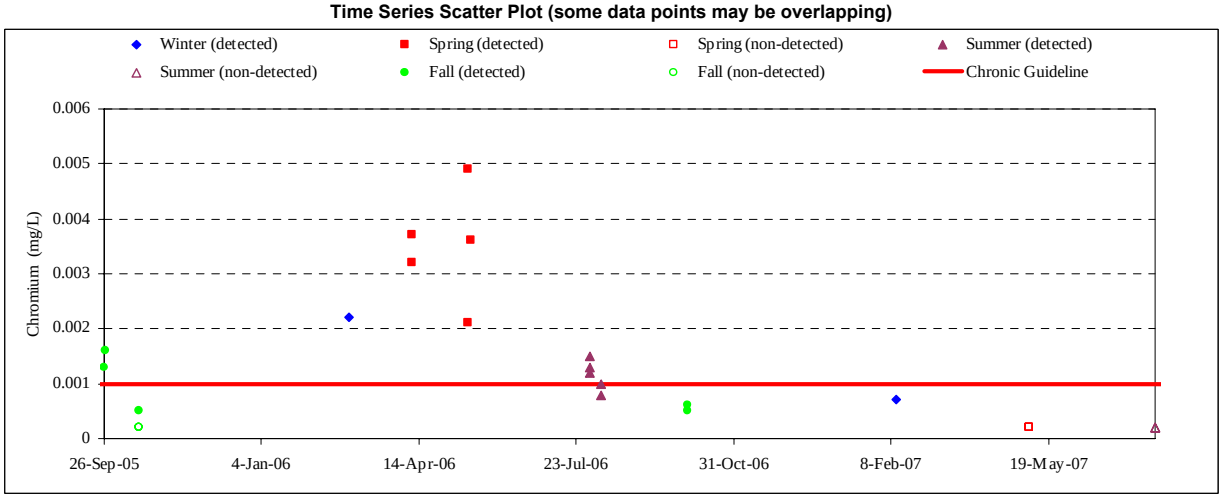
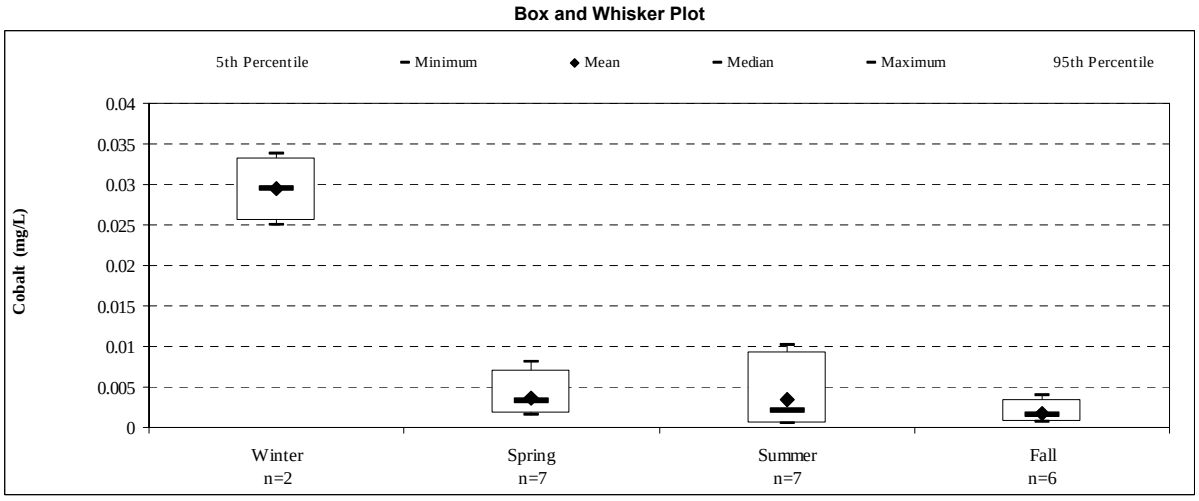


Figure G-3-2-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Eymundson Creek



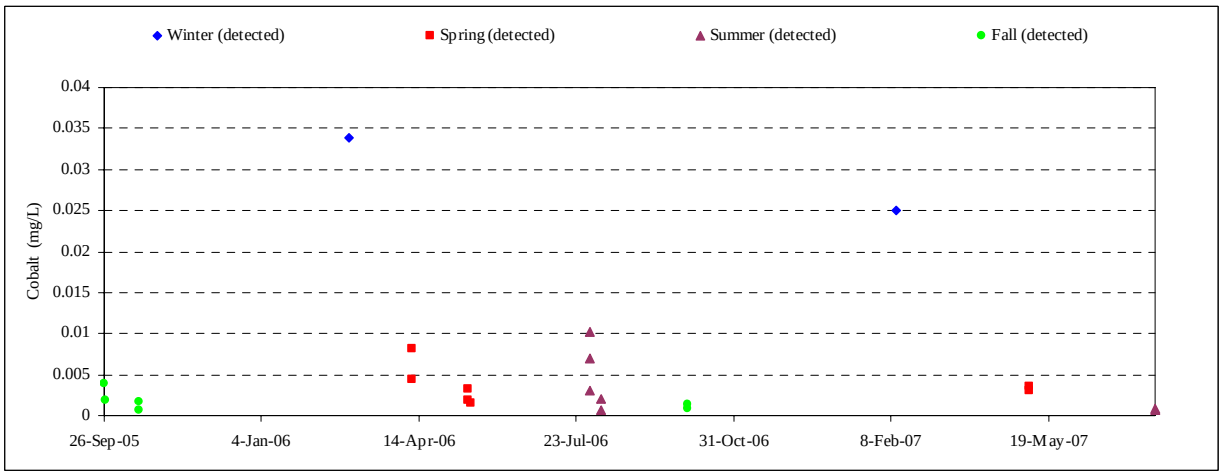
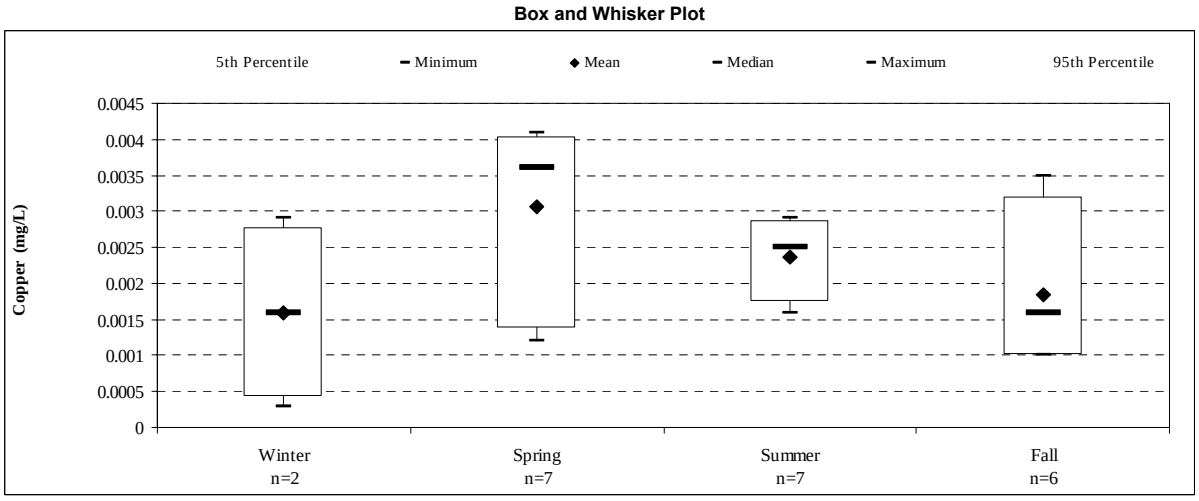


Figure G-3-2-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Eymundson Creek



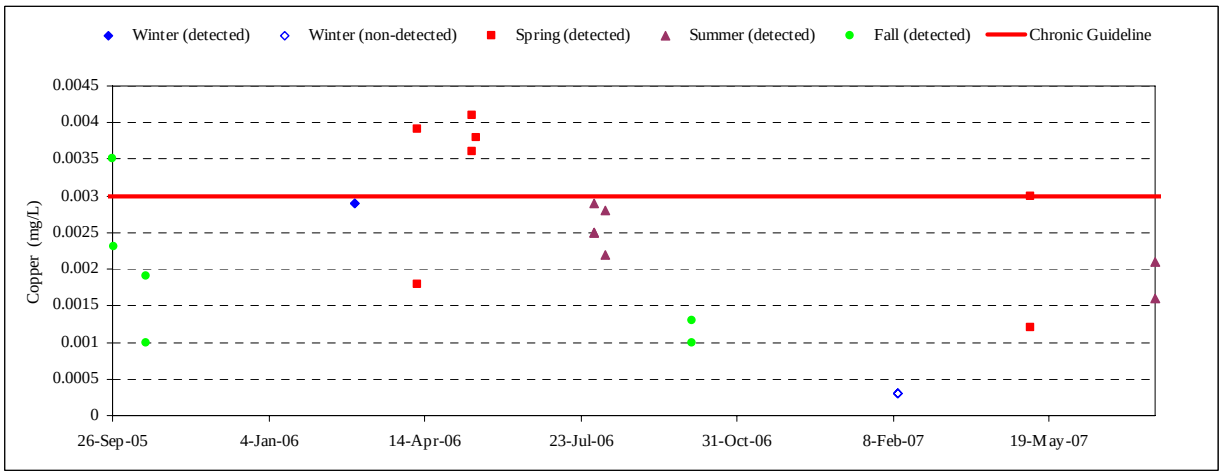
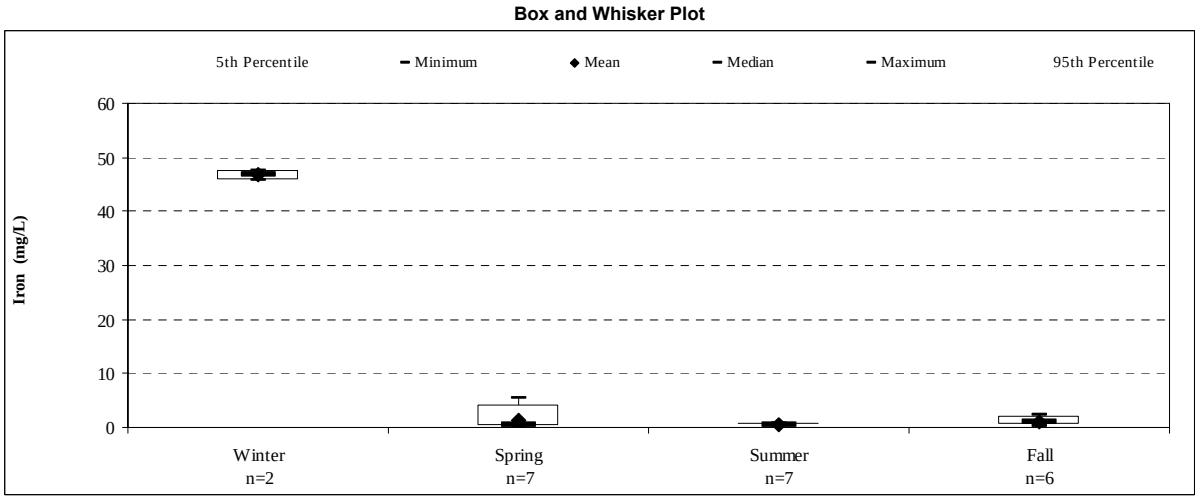


Figure G-3-2-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Eymundson Creek



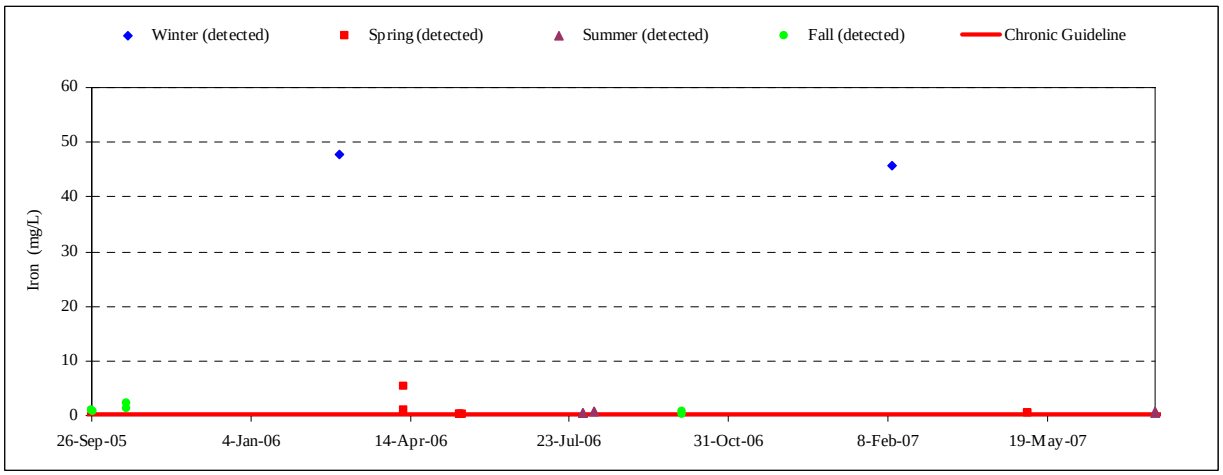
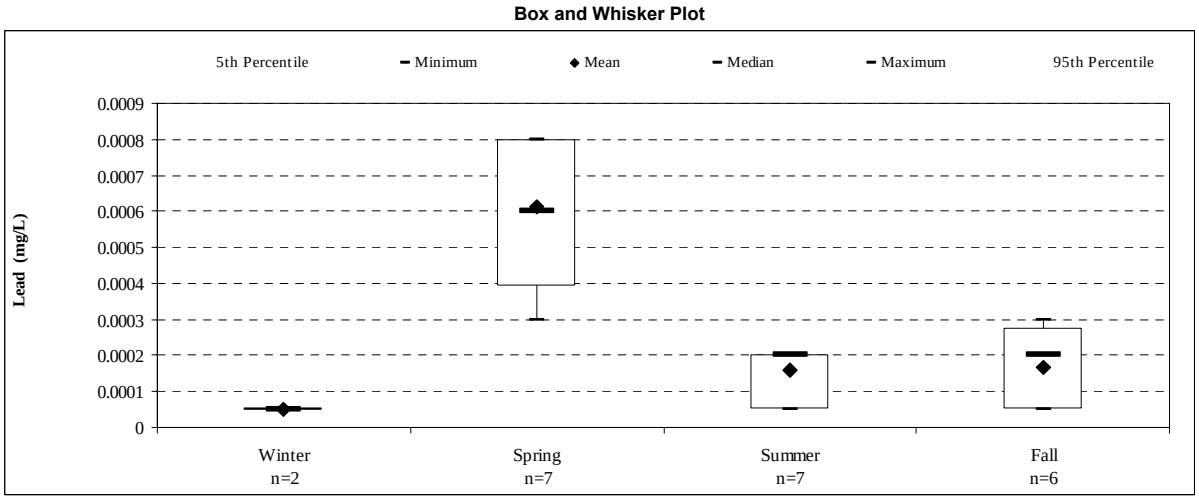


Figure G-3-2-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Eymundson Creek



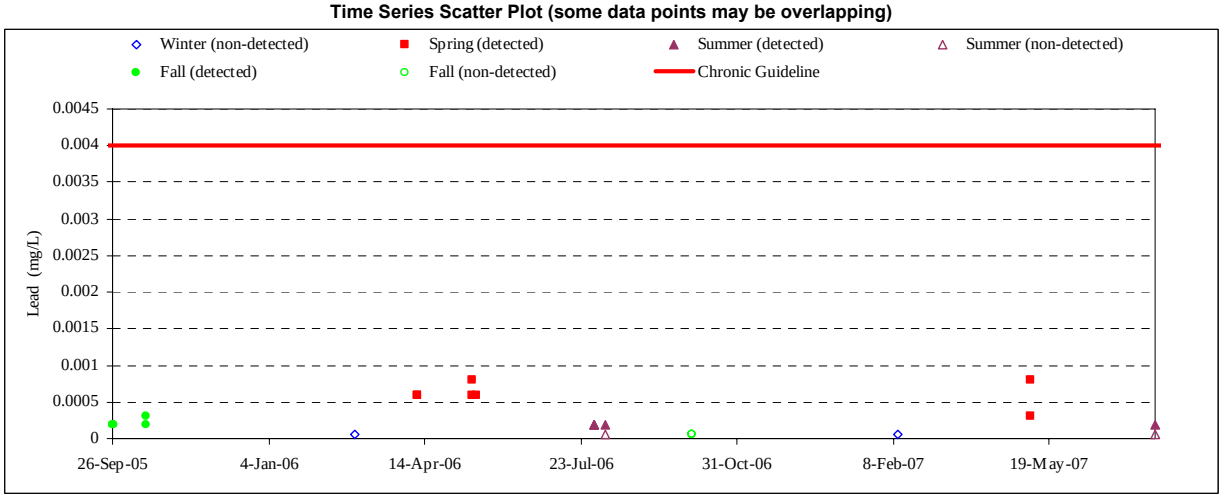
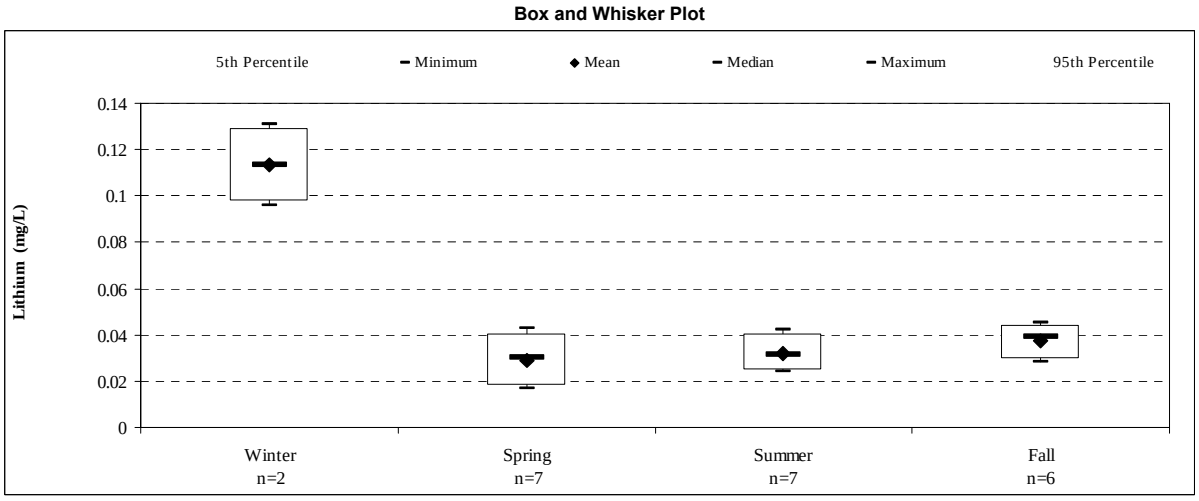


Figure G-3-2-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Eymundson Creek



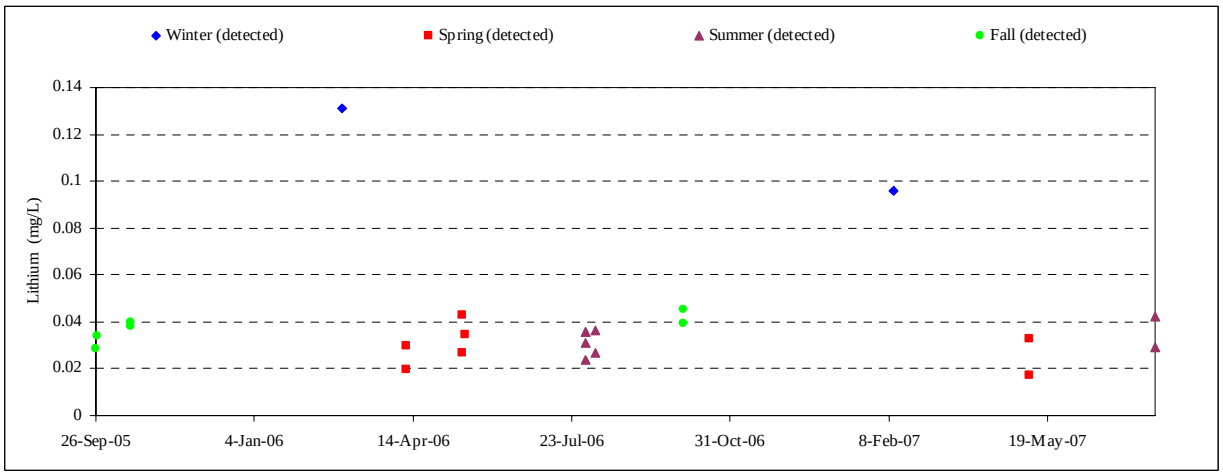
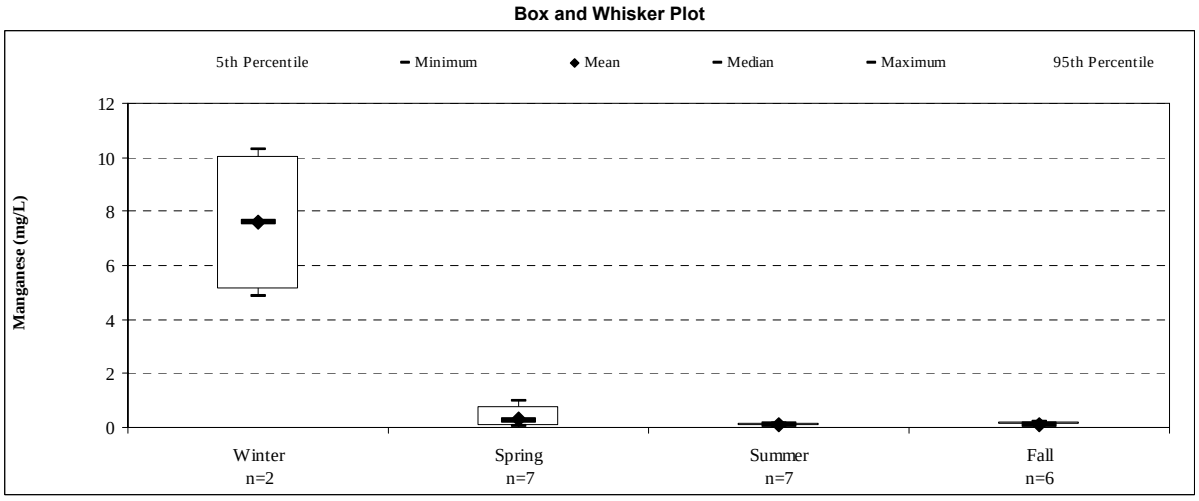


Figure G-3-2-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Eymundson Creek



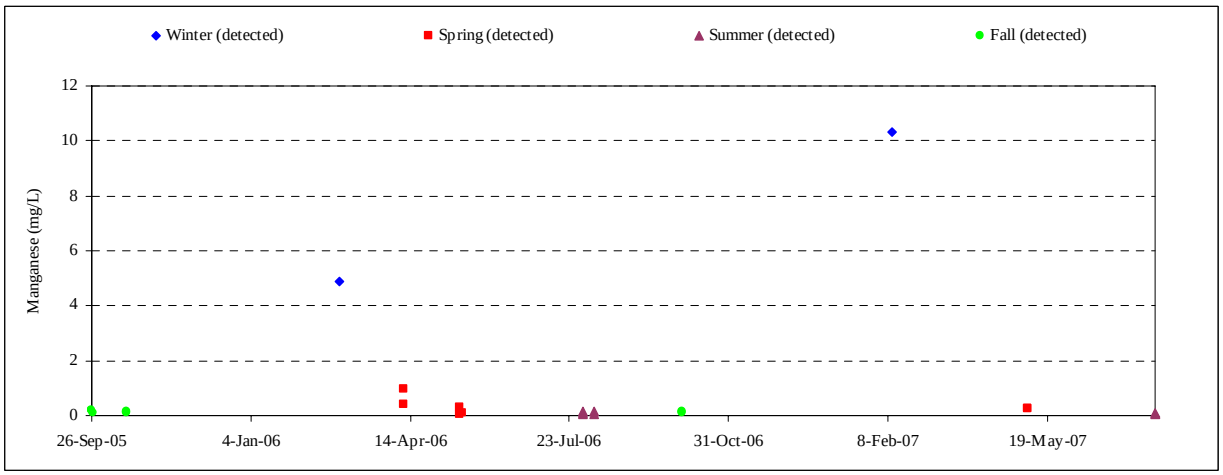
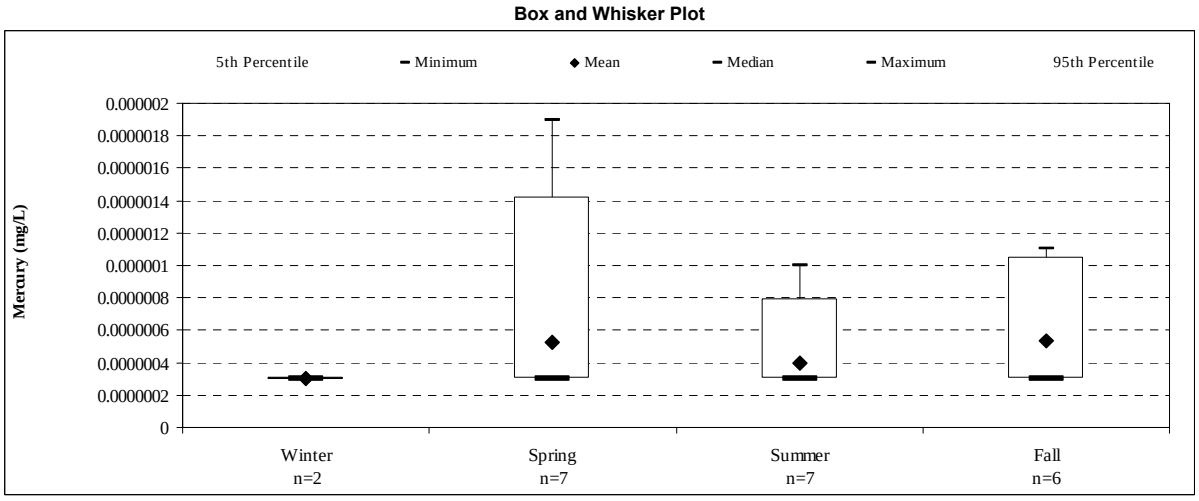


Figure G-3-2-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Eymundson Creek



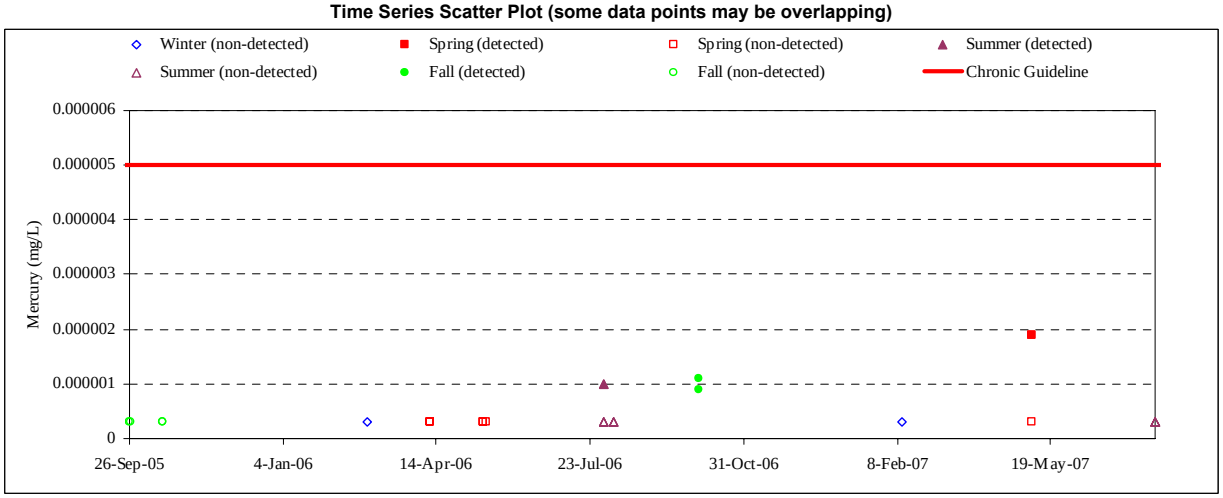
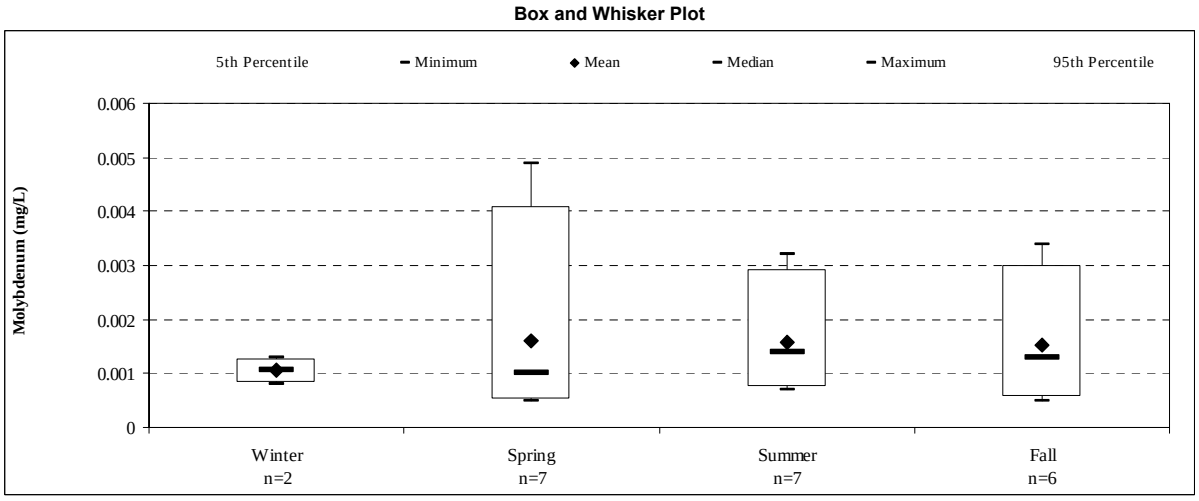


Figure G-3-2-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Eymundson Creek



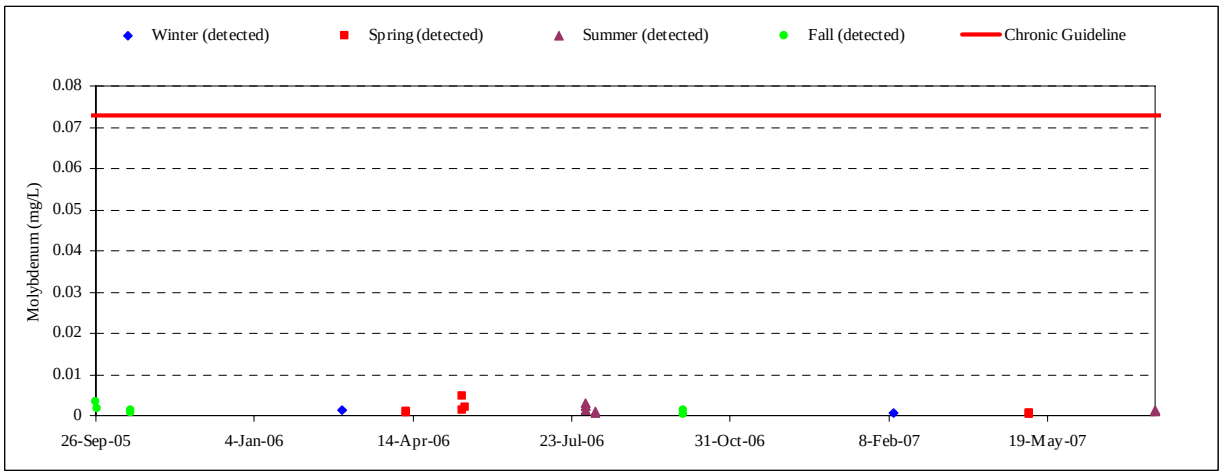
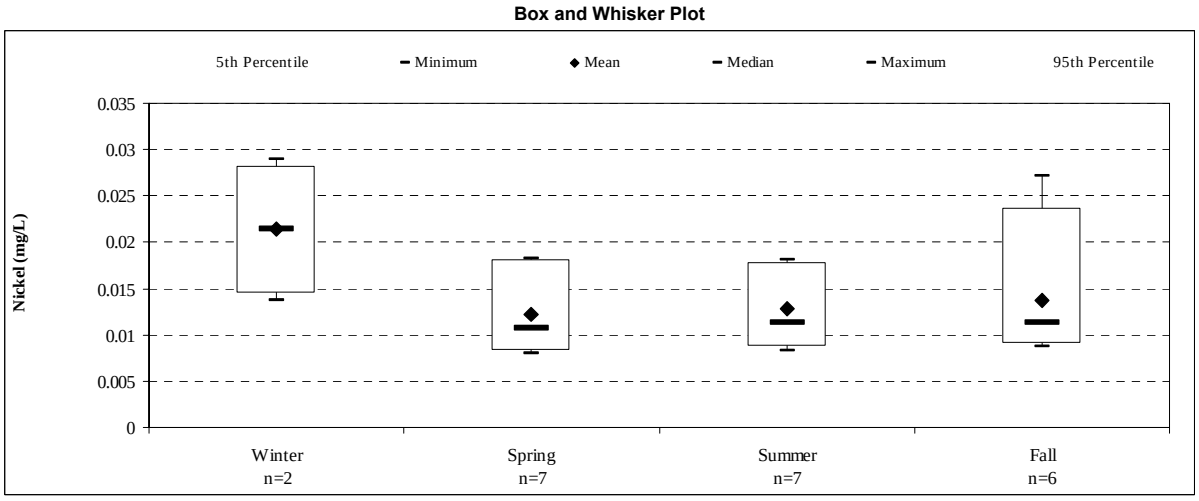


Figure G-3-2-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Eymundson Creek



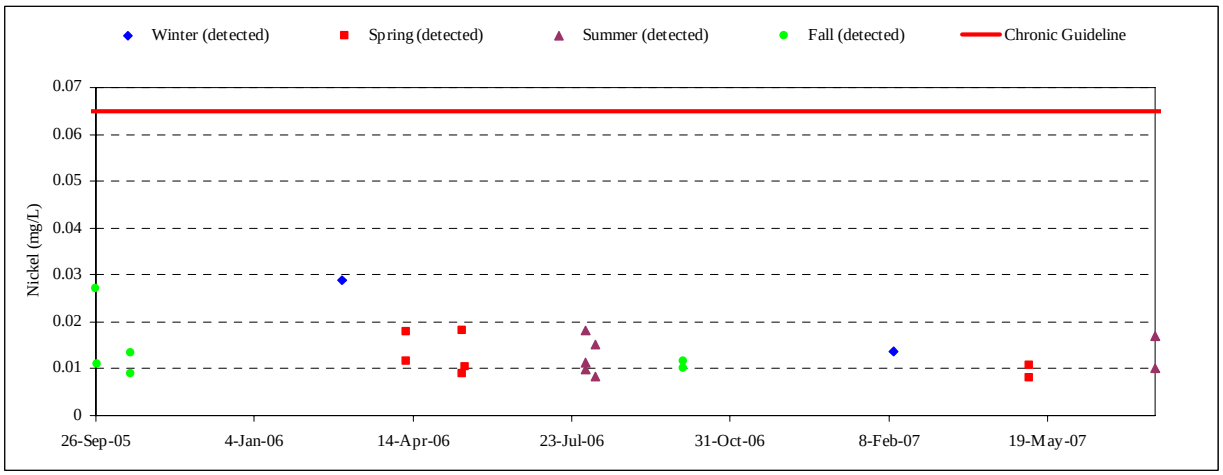
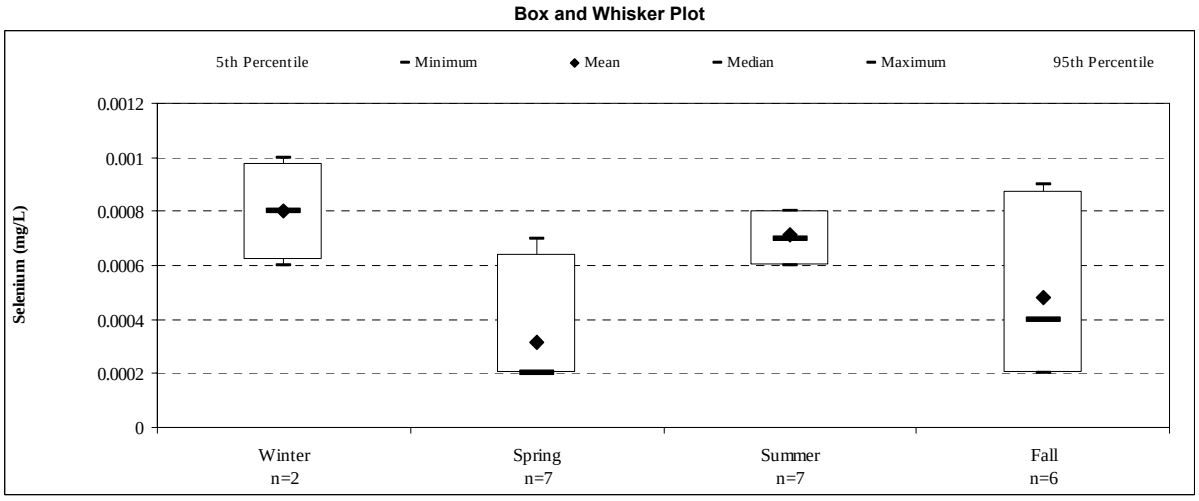


Figure G-3-2-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Eymundson Creek



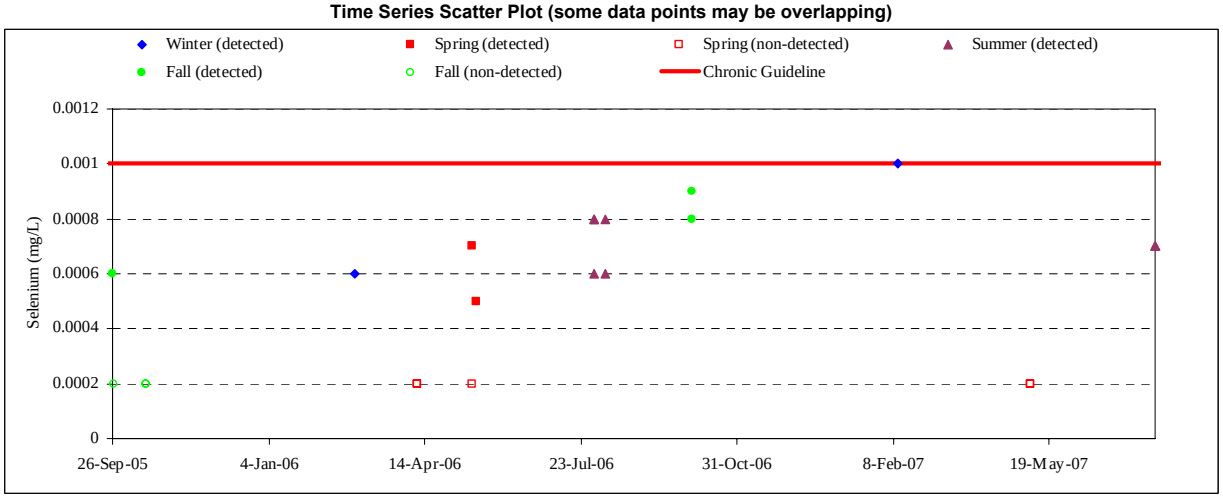
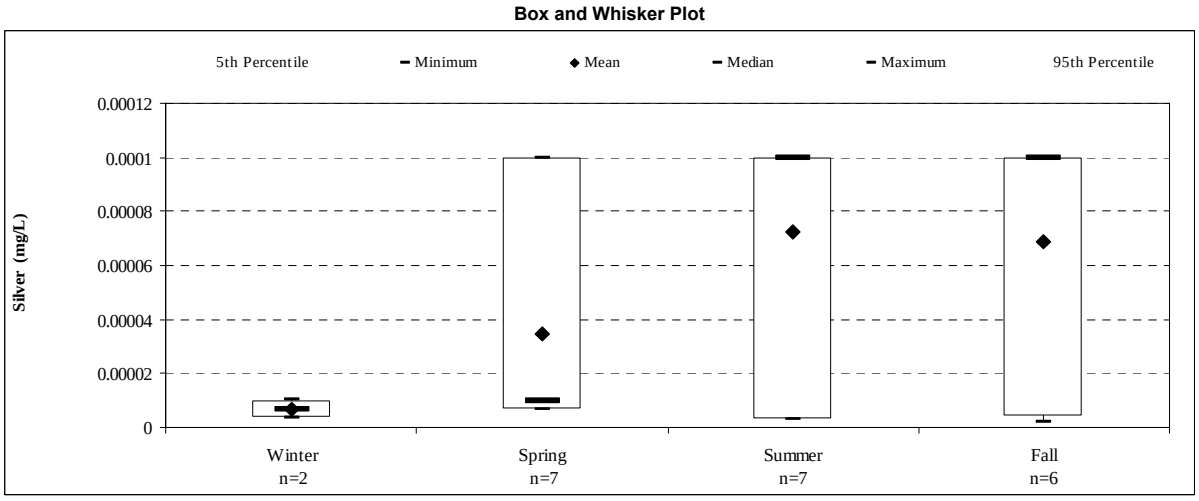


Figure G-3-2-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Eymundson Creek



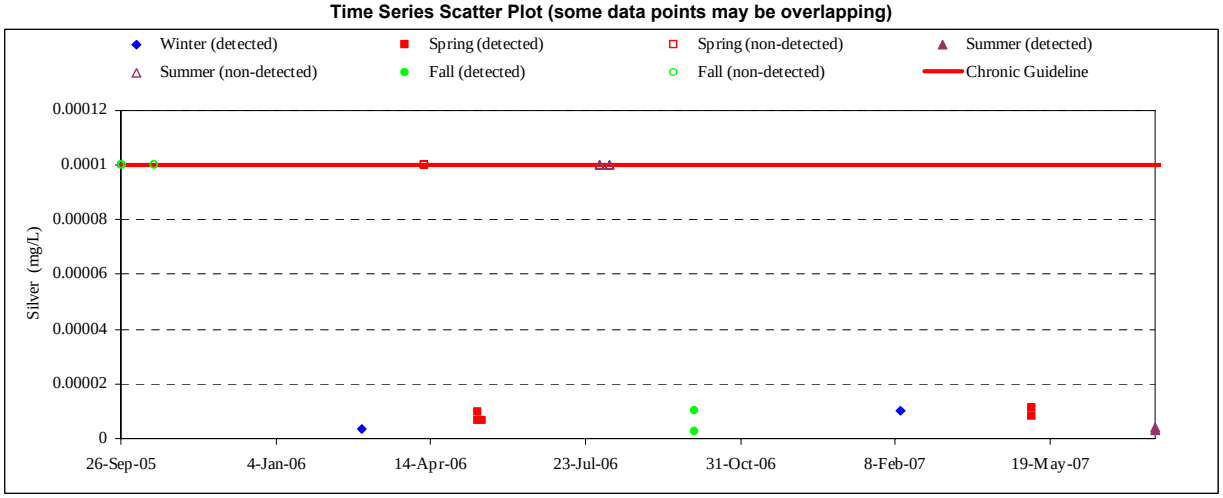
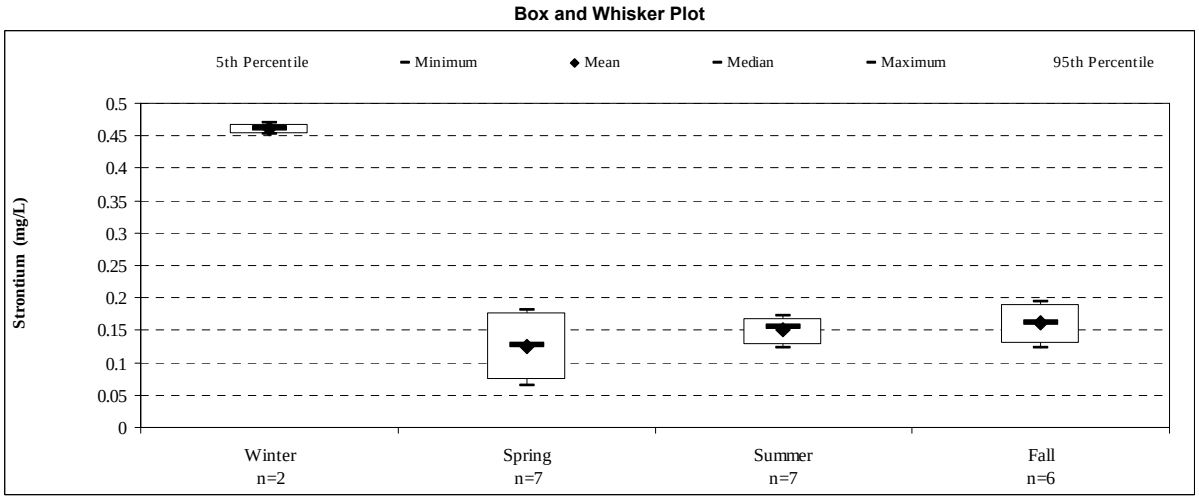


Figure G-3-2-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Eymundson Creek



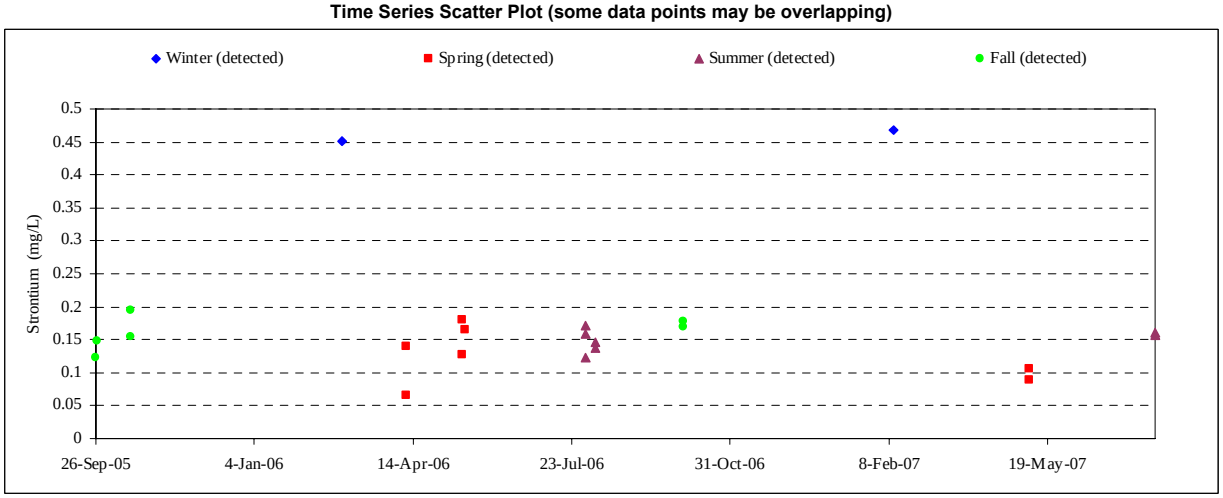
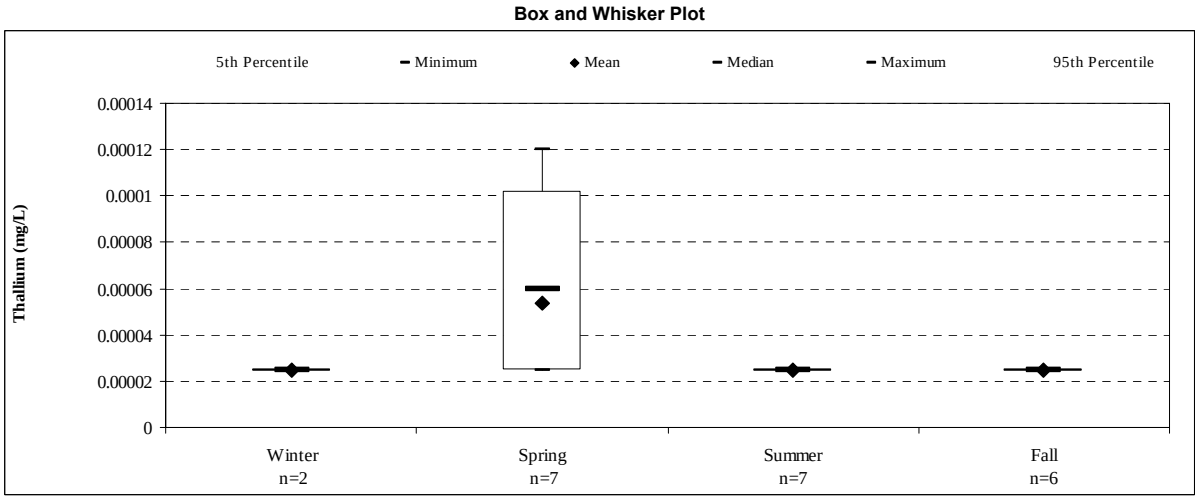


Figure G-3-2-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Eymundson Creek



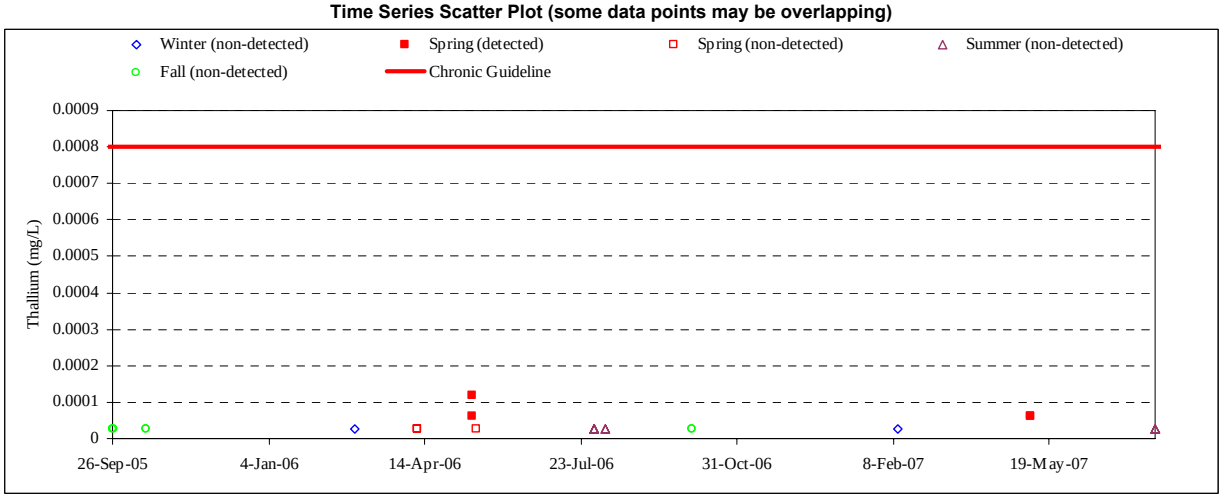
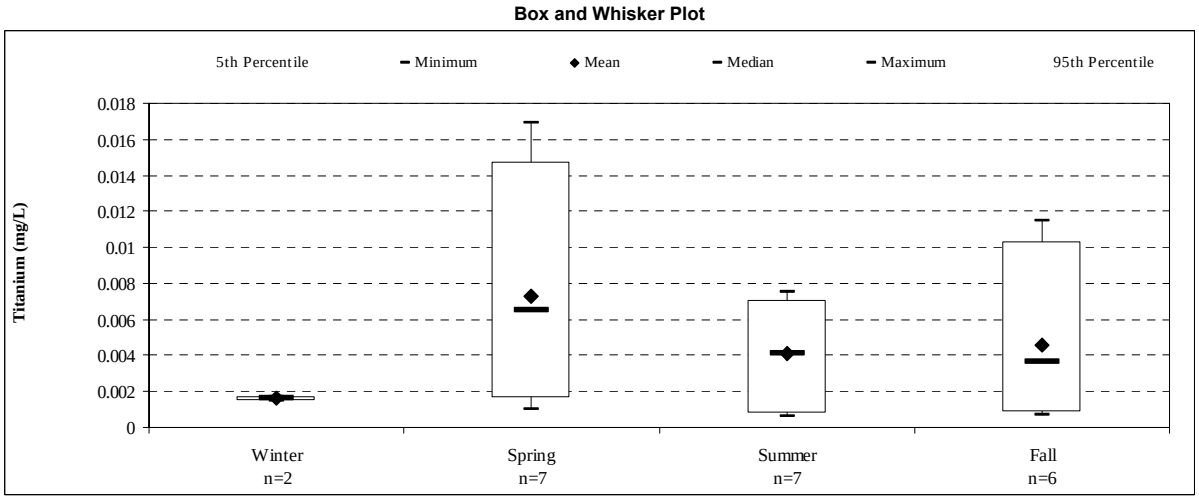


Figure G-3-2-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Eymundson Creek



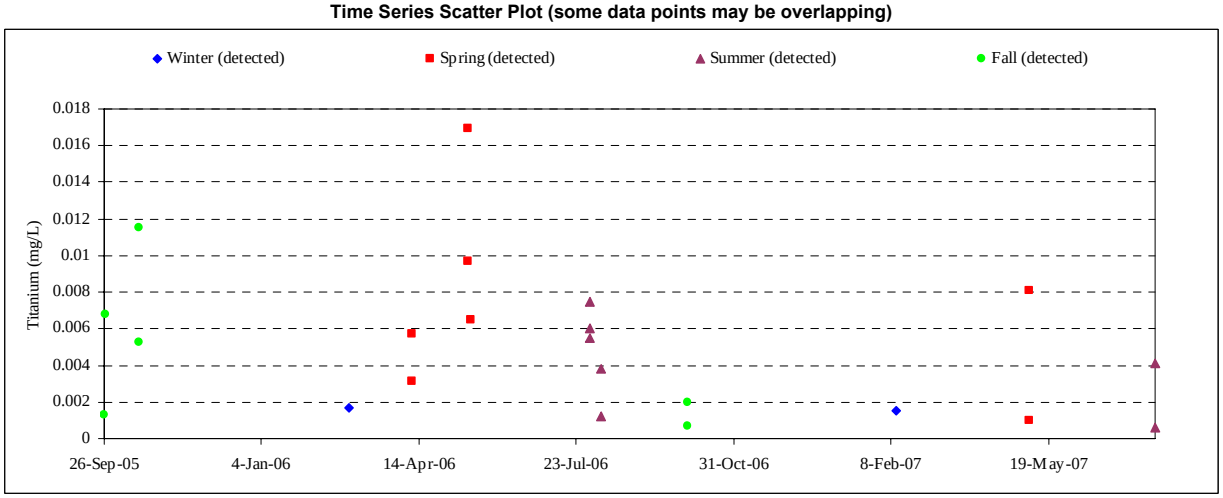
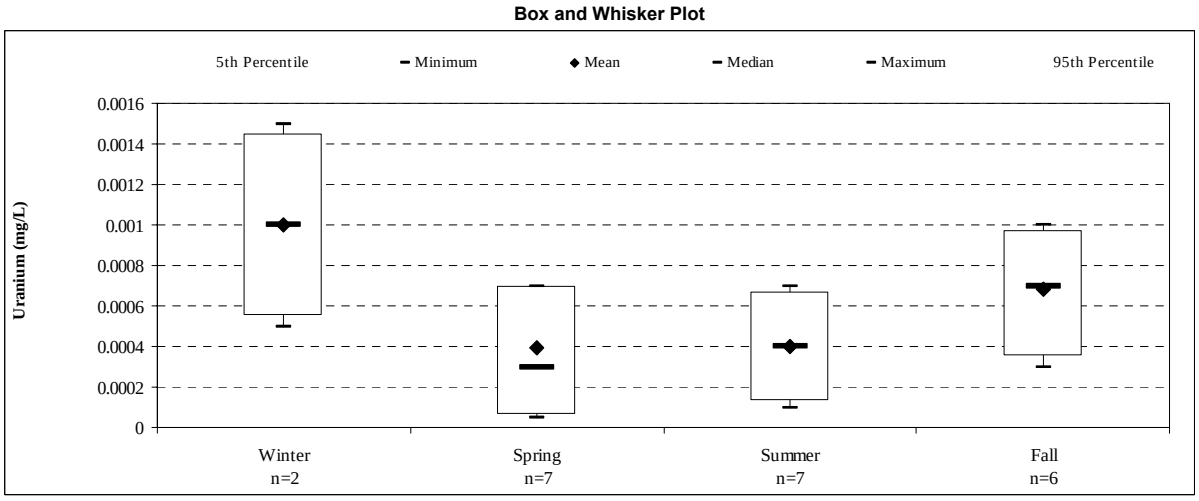


Figure G-3-2-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Eymundson Creek



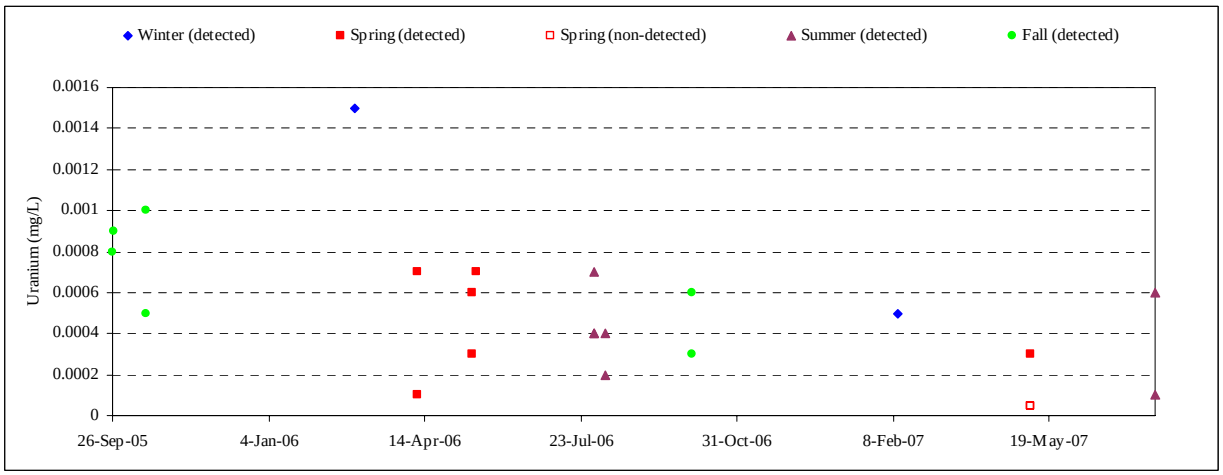
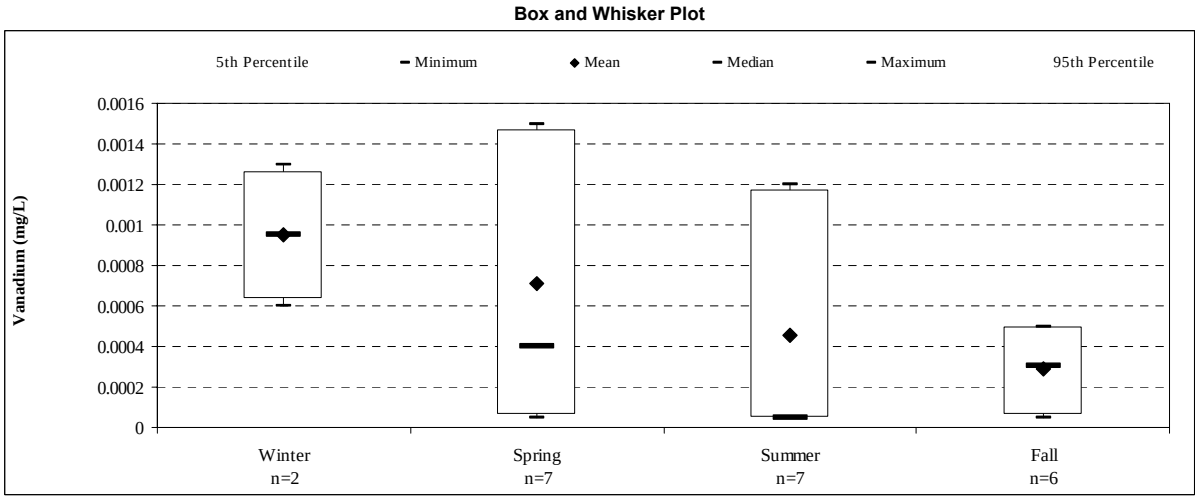


Figure G-3-2-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Eymundson Creek



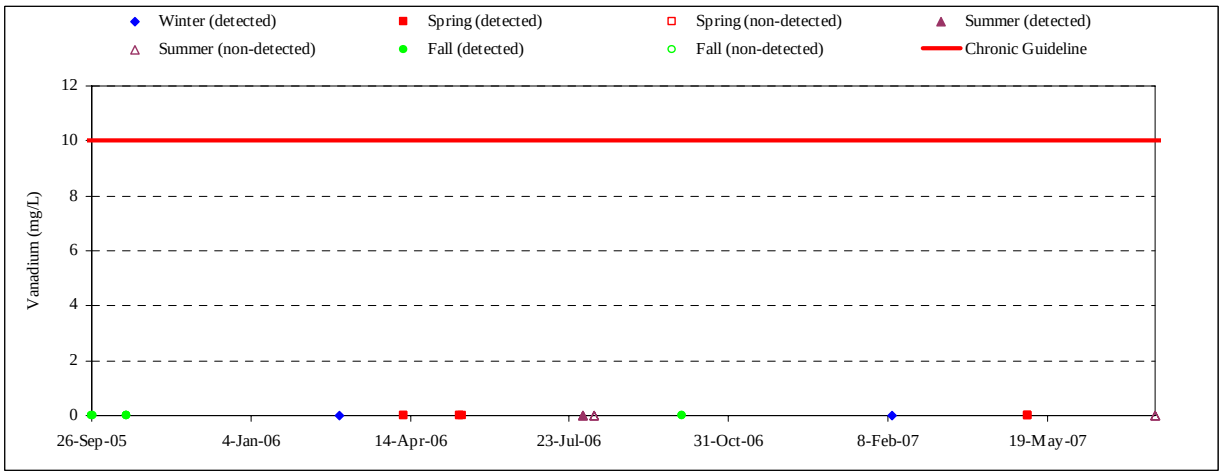
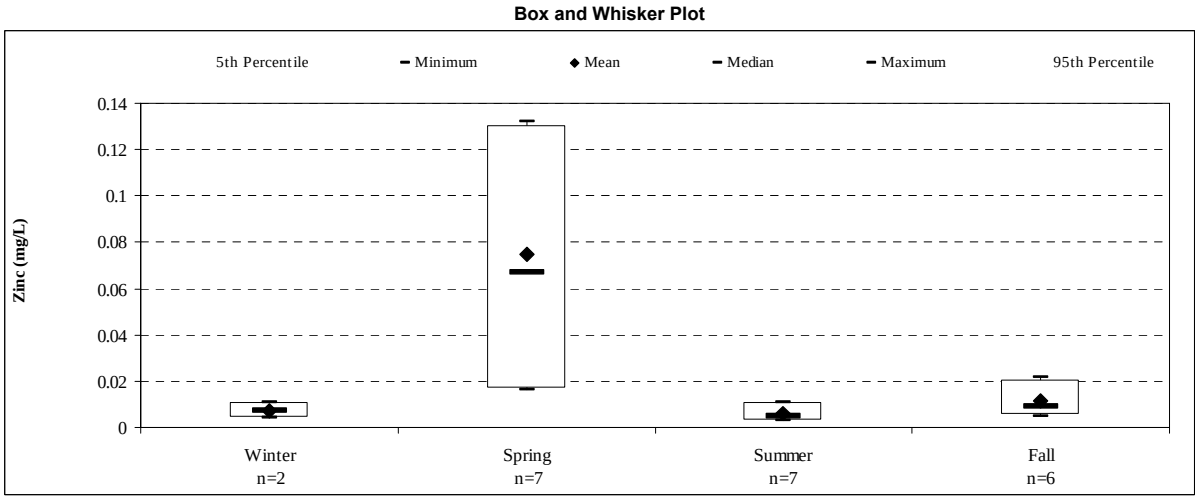


Figure G-3-2-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Eymundson Creek



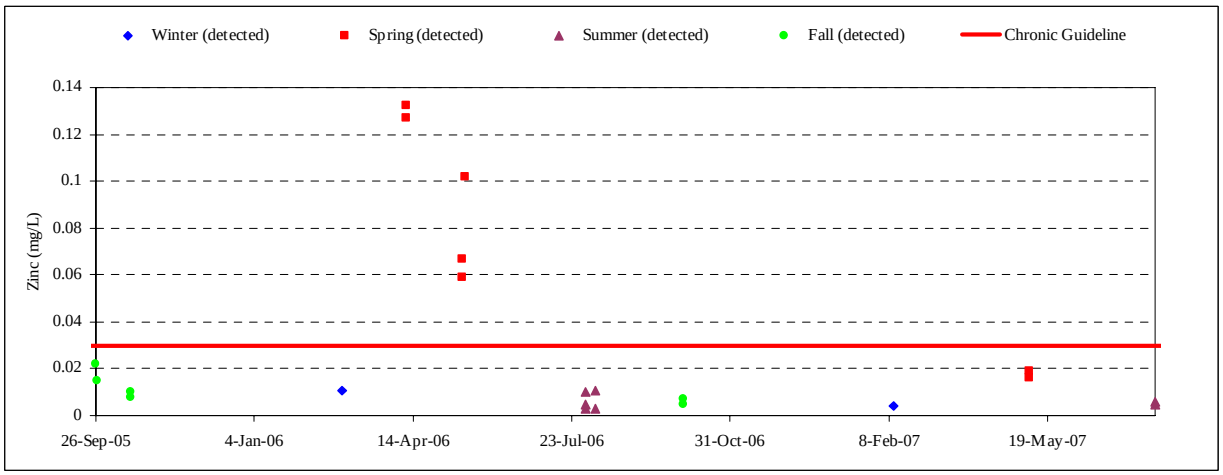
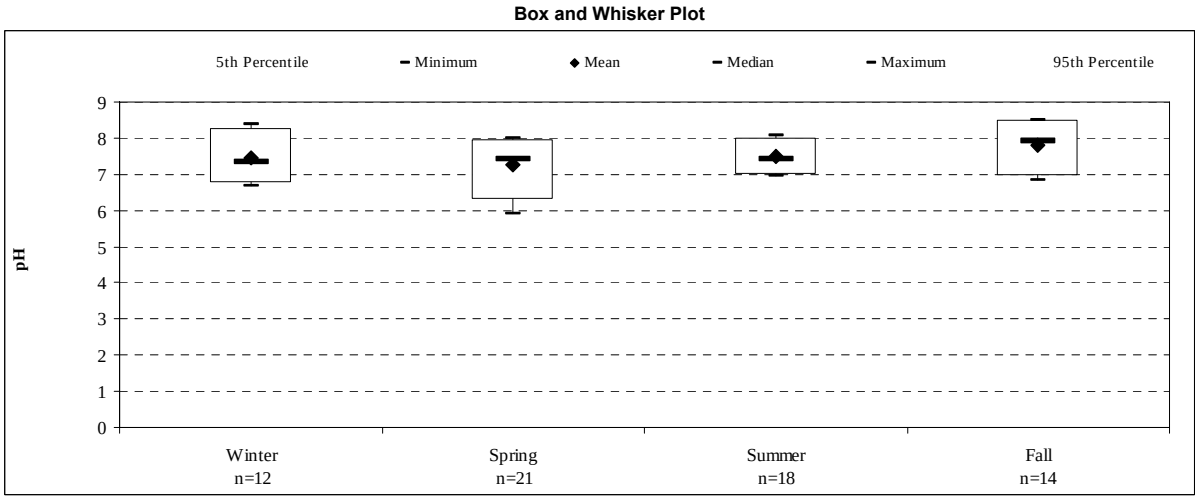


Figure G-3-3-1 Box Whisker and Time Series Scatter Plots of Observed pH in Big Creek



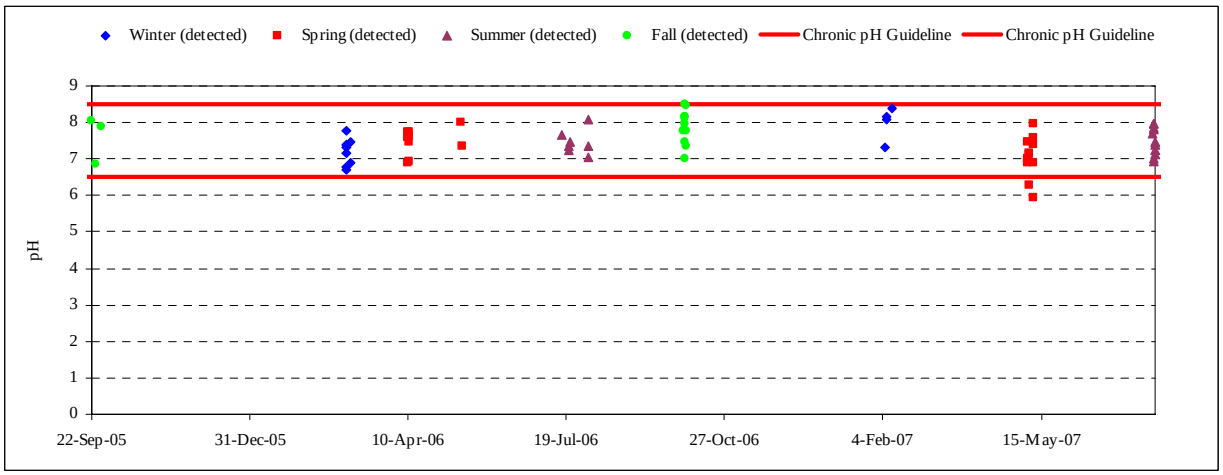
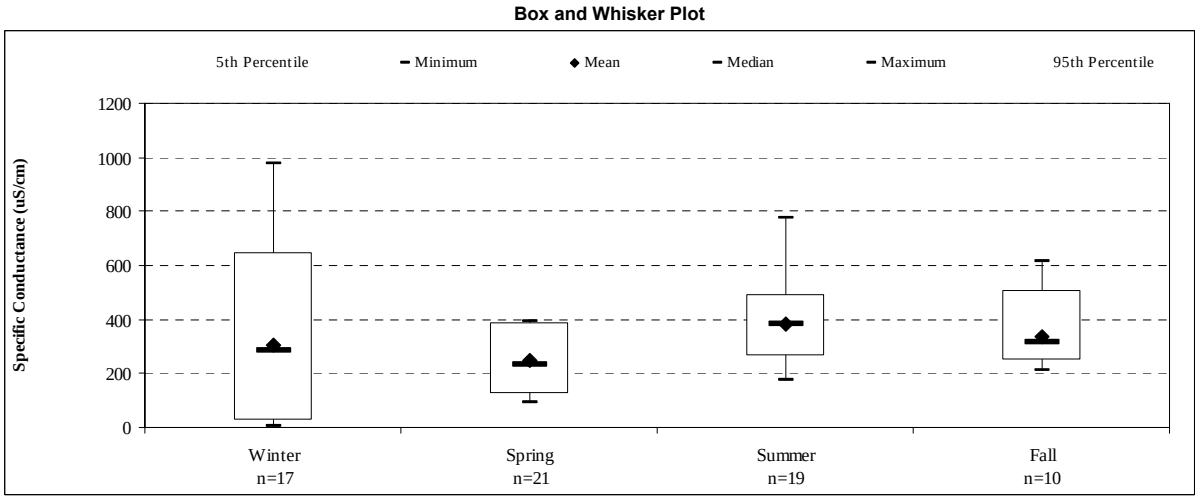


Figure G-3-3-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Big Creek



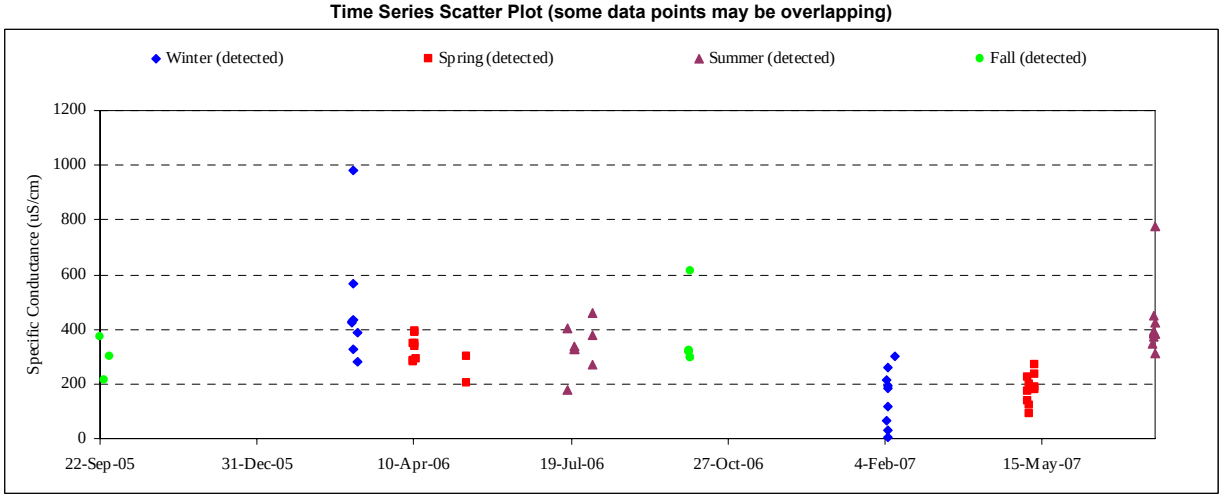
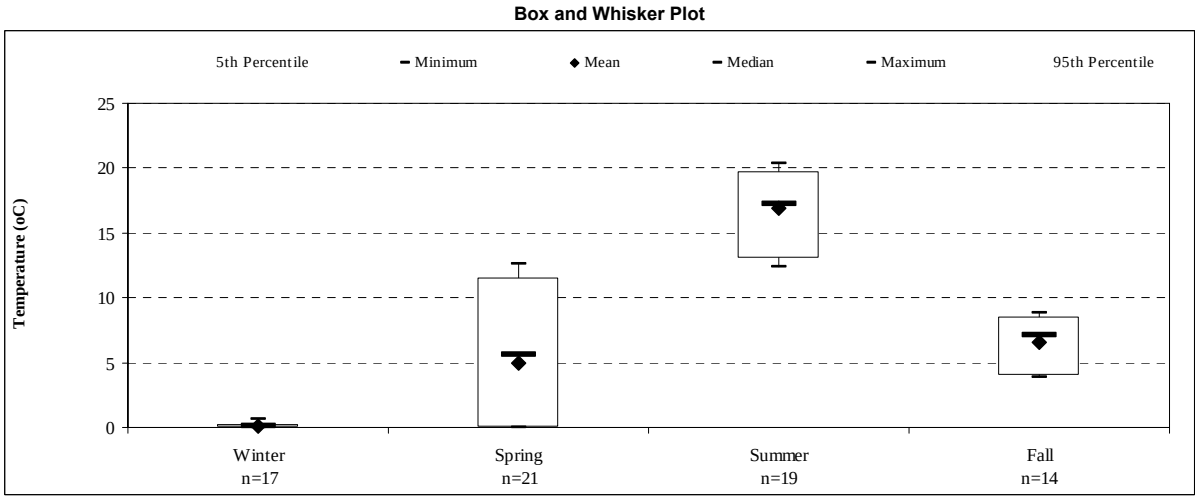


Figure G-3-3-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Big Creek



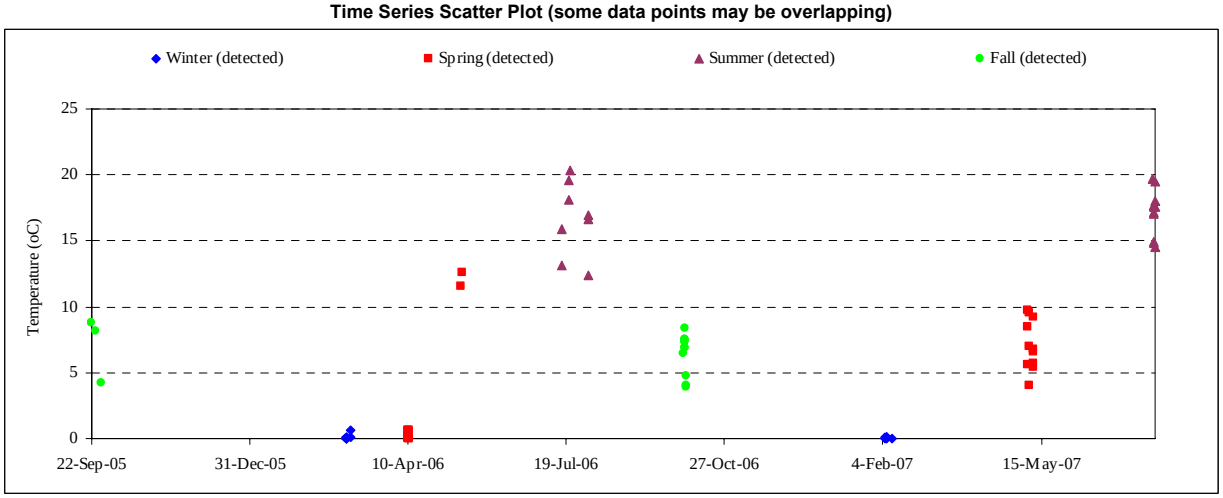
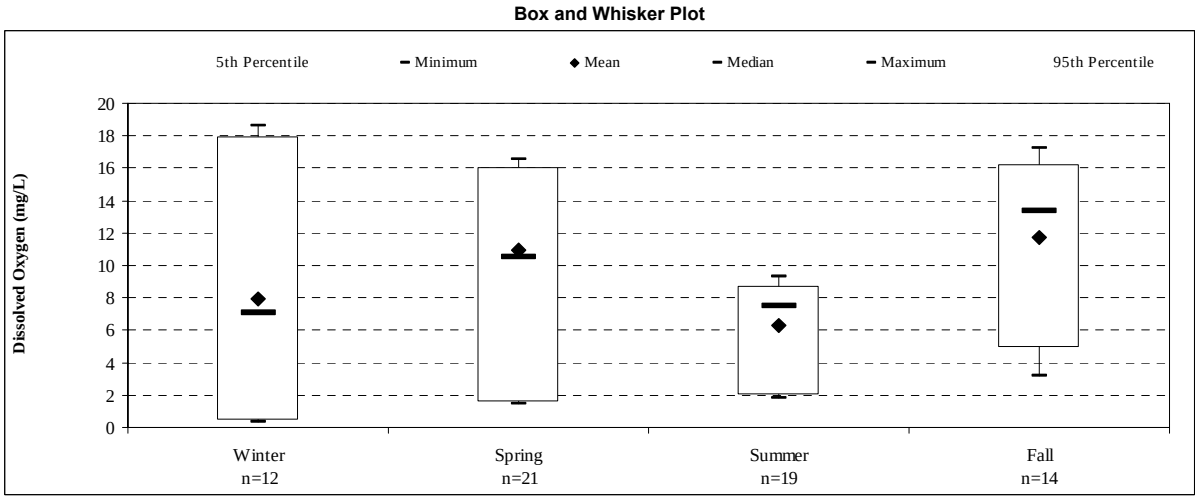


Figure G-3-3-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Big Creek



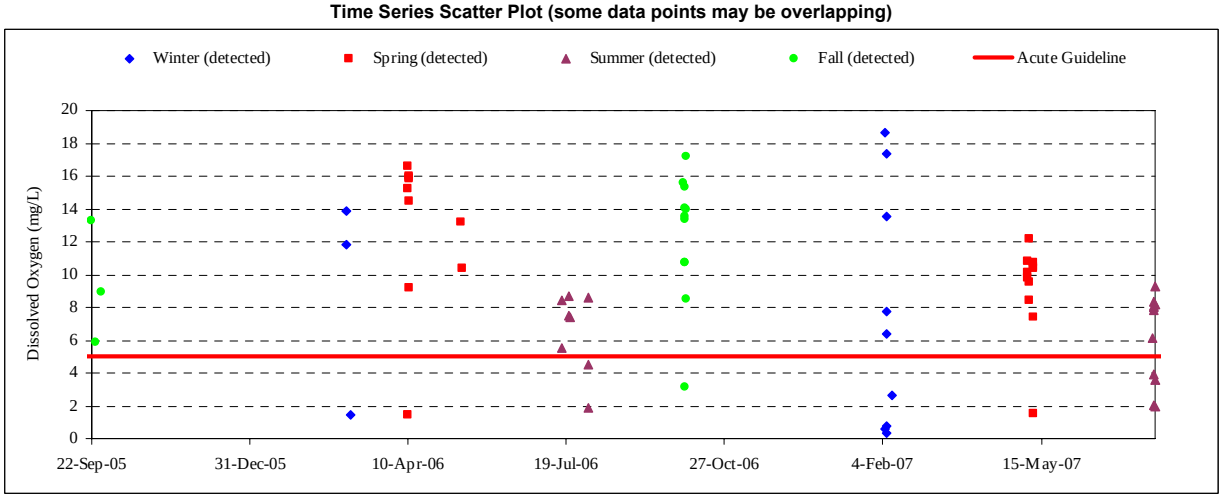
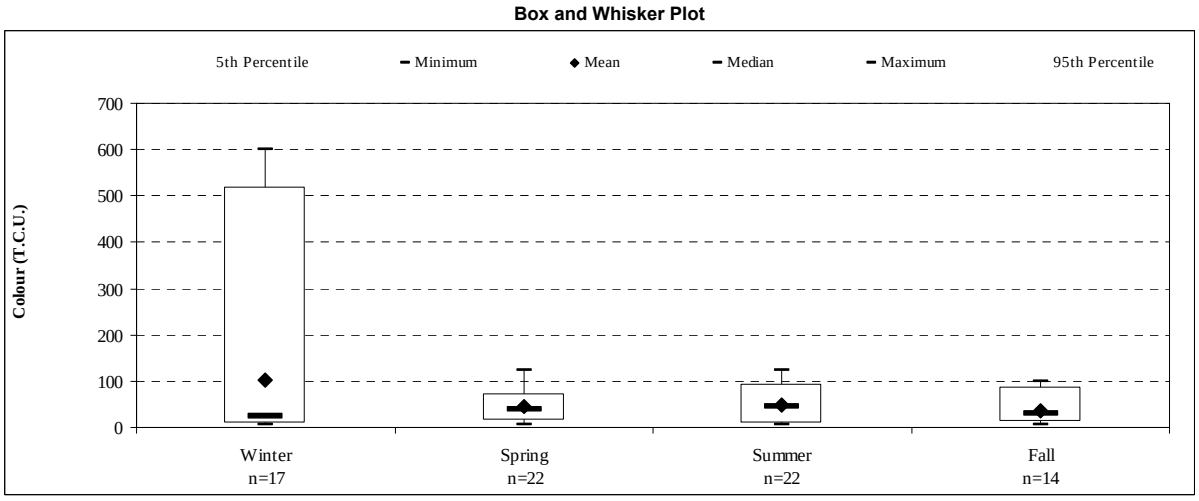


Figure G-3-3-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Big Creek



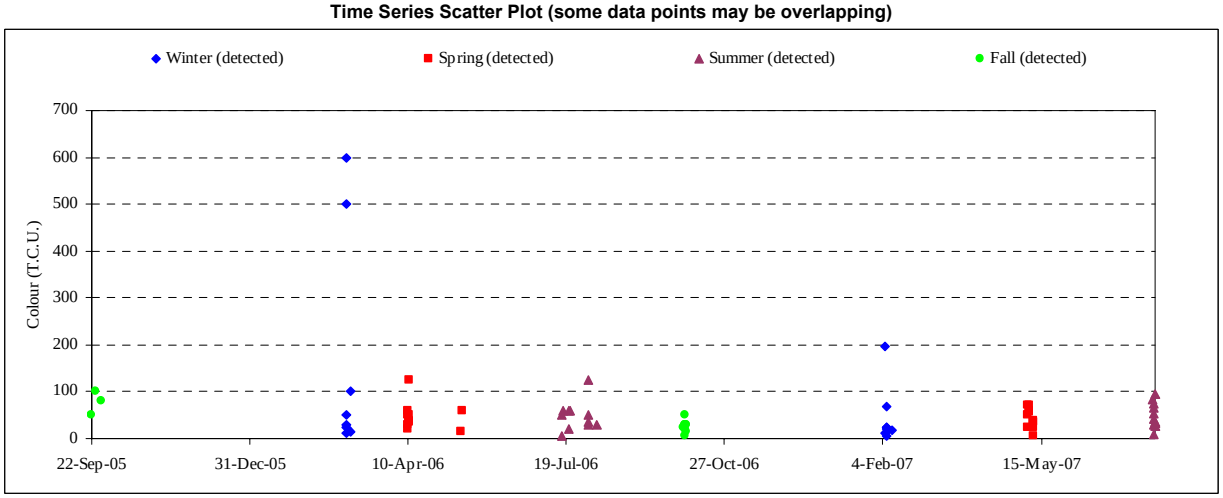
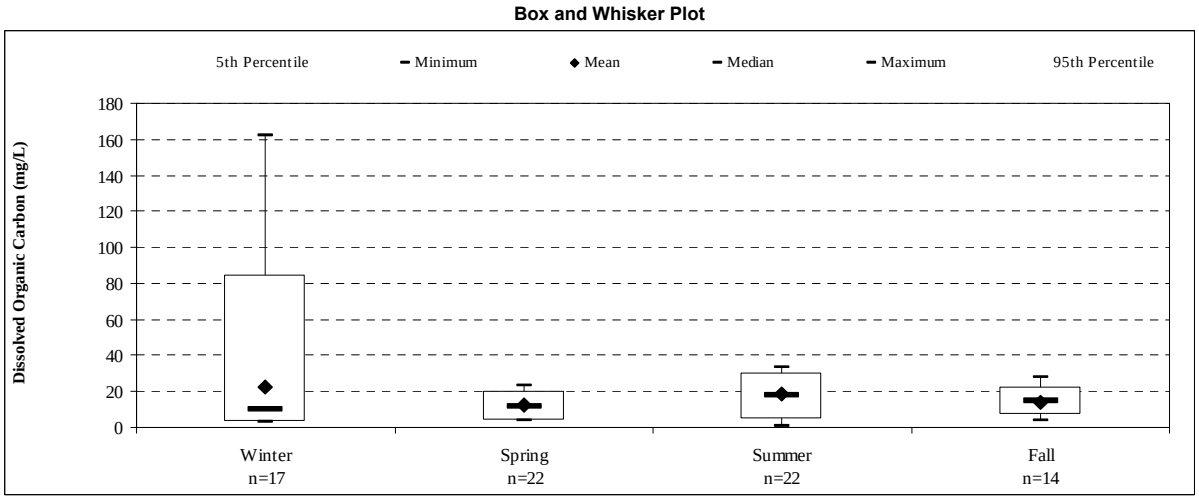


Figure G-3-3-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Big Creek



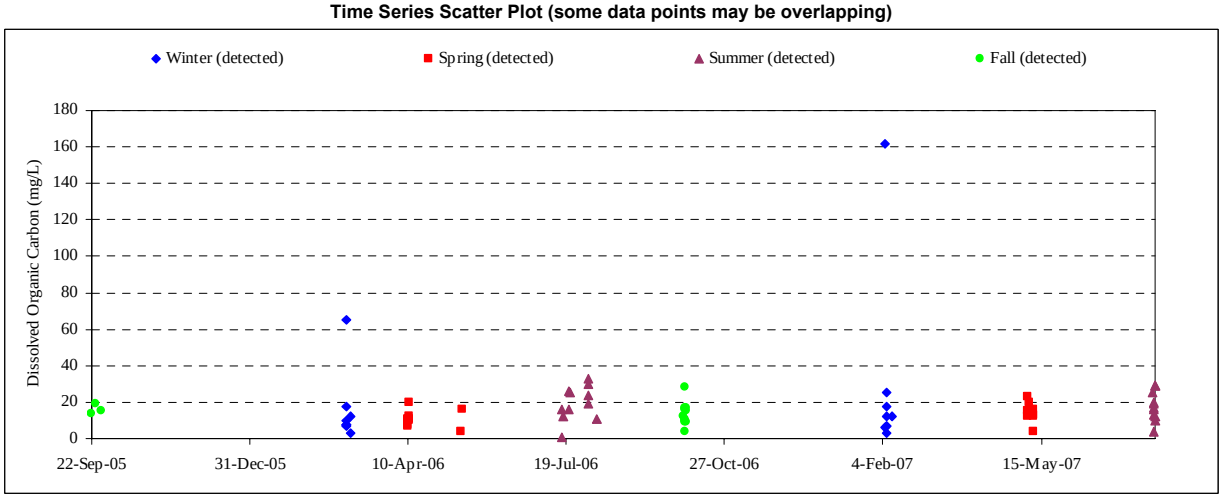
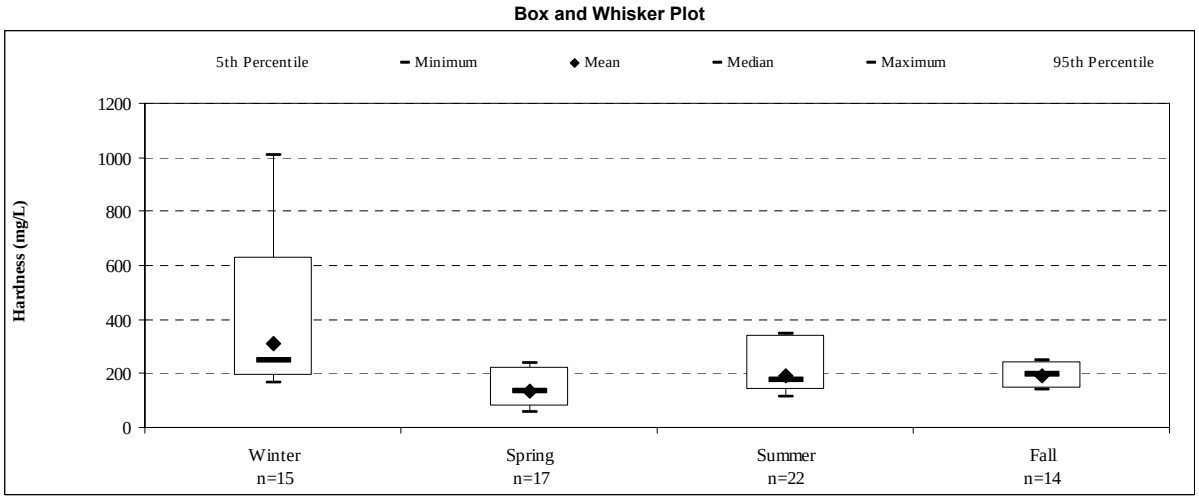


Figure G-3-3-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Big Creek



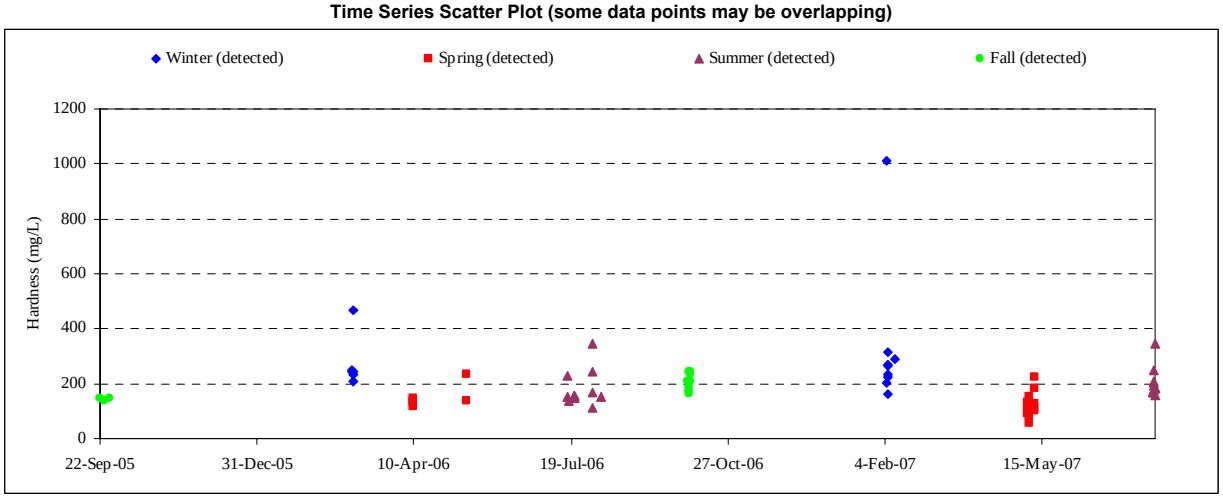


Figure G-3-3-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Big Creek

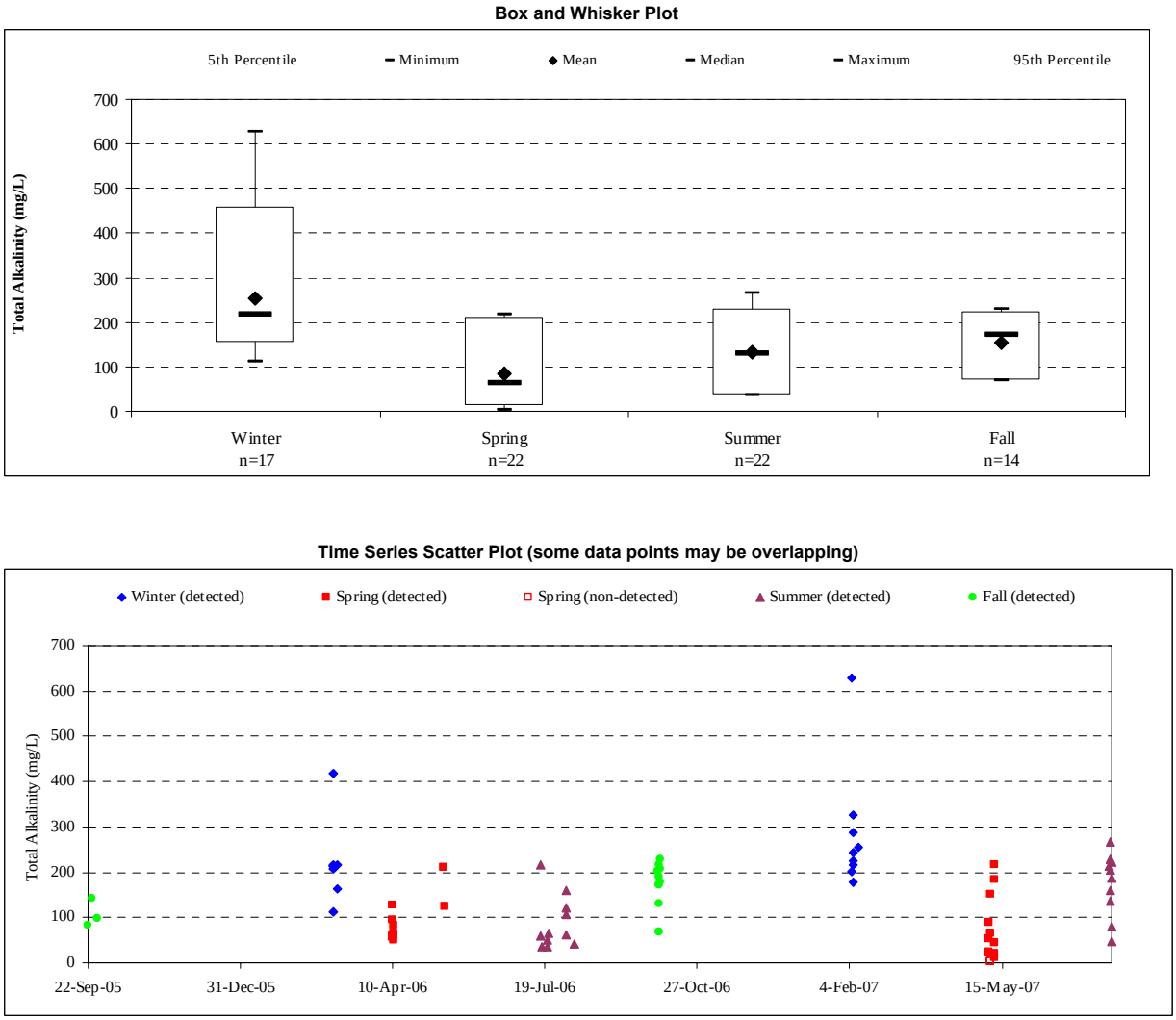


Figure G-3-3-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Big Creek

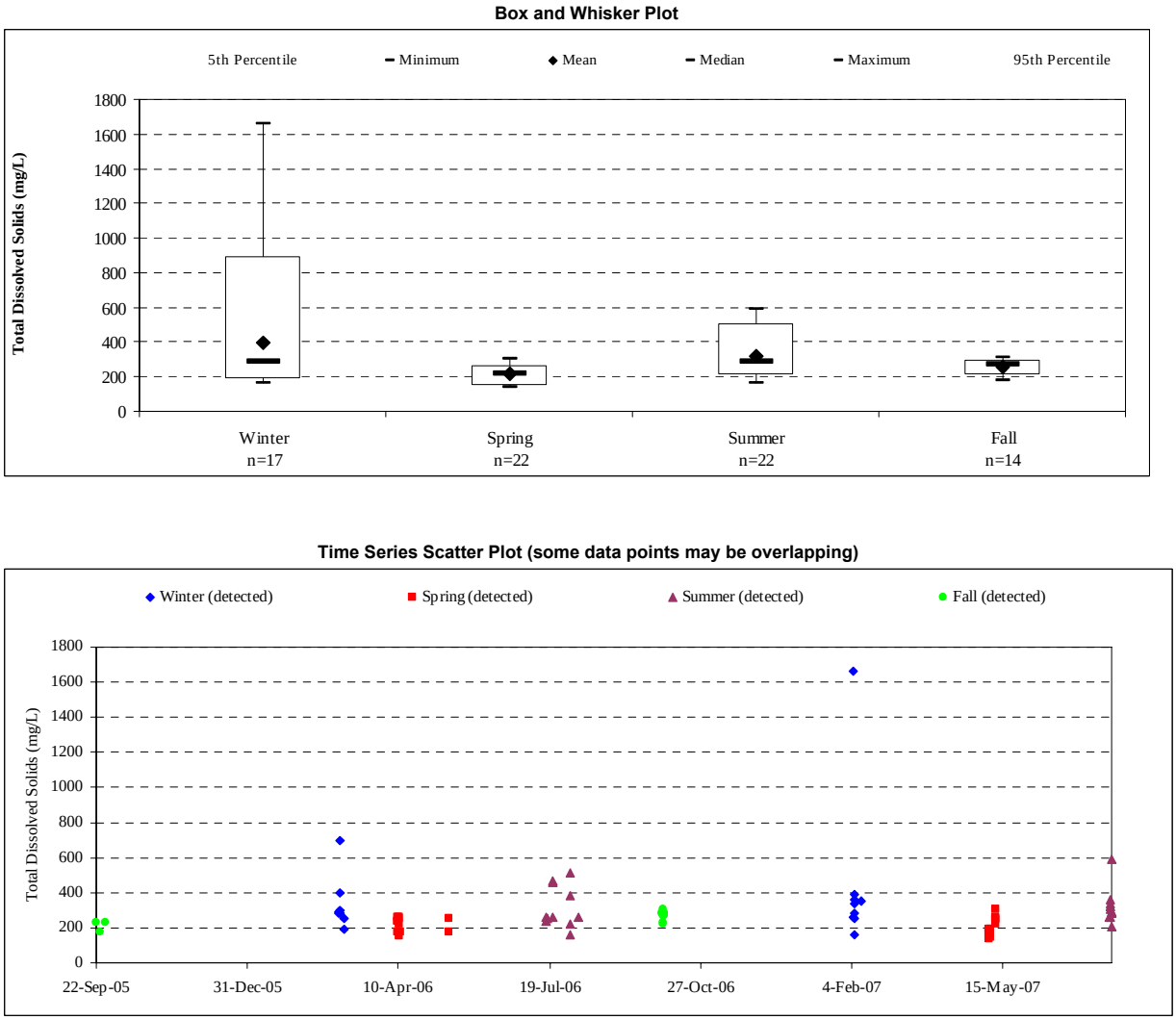
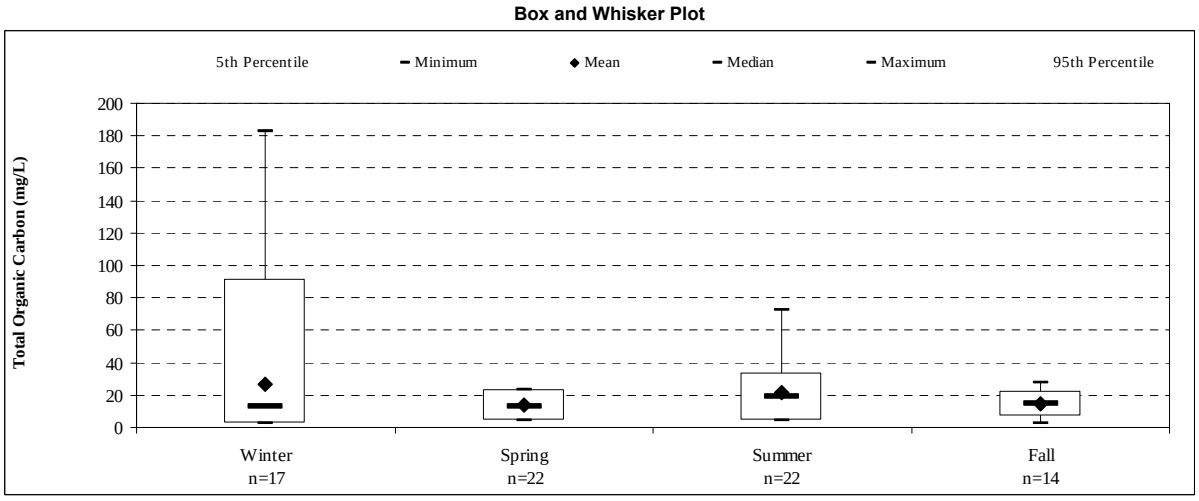


Figure G-3-3-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Big Creek



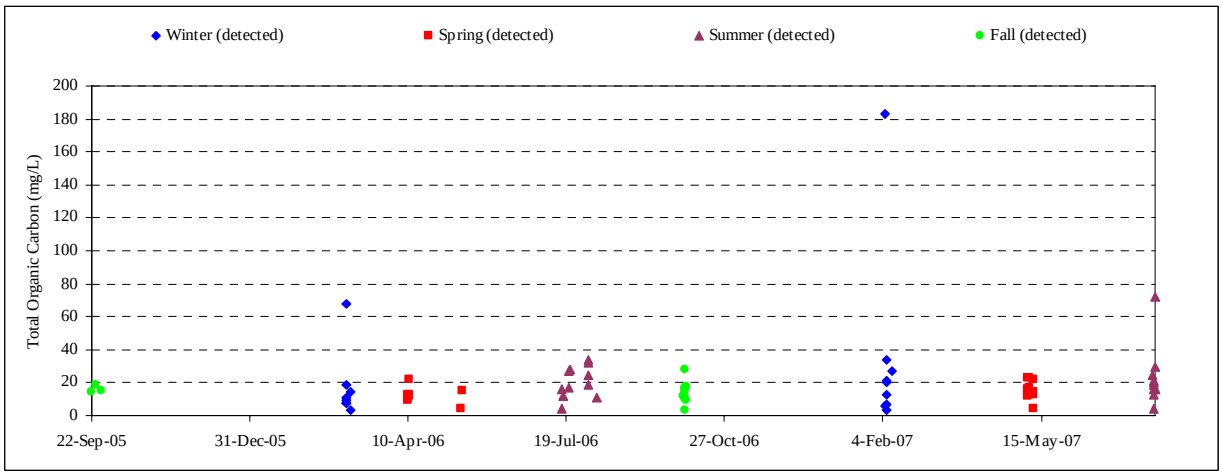
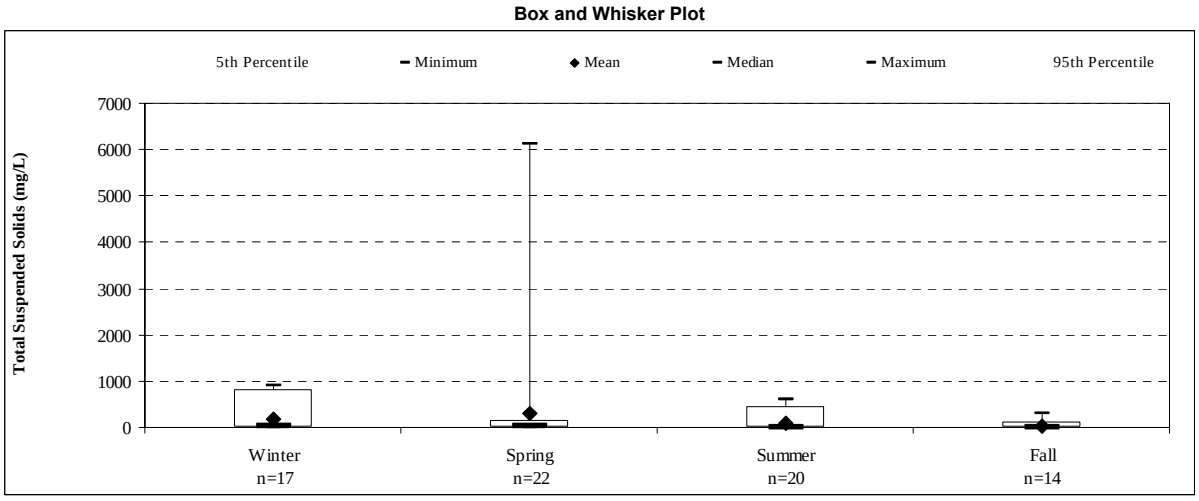


Figure G-3-3-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Big Creek



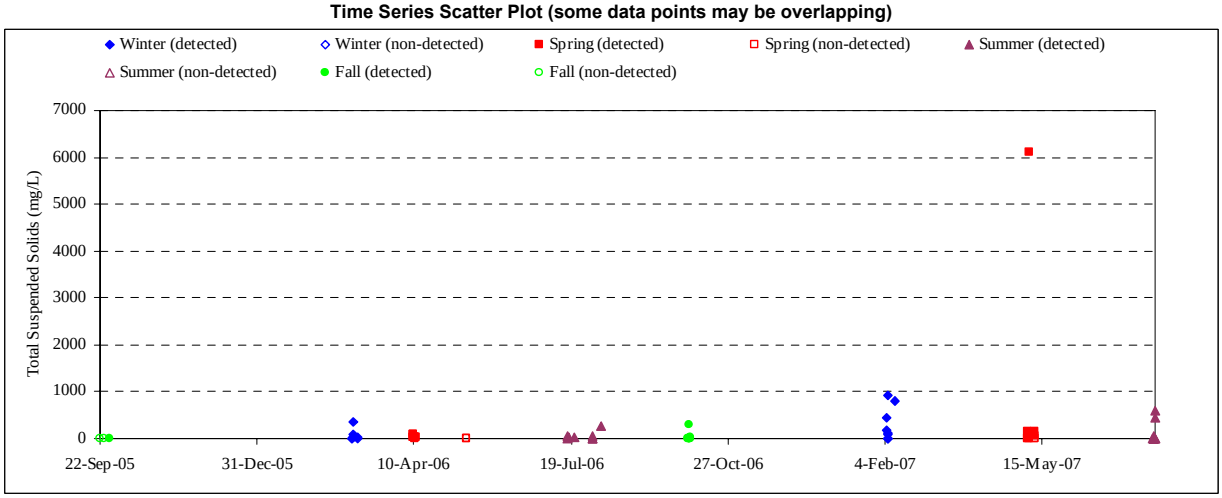
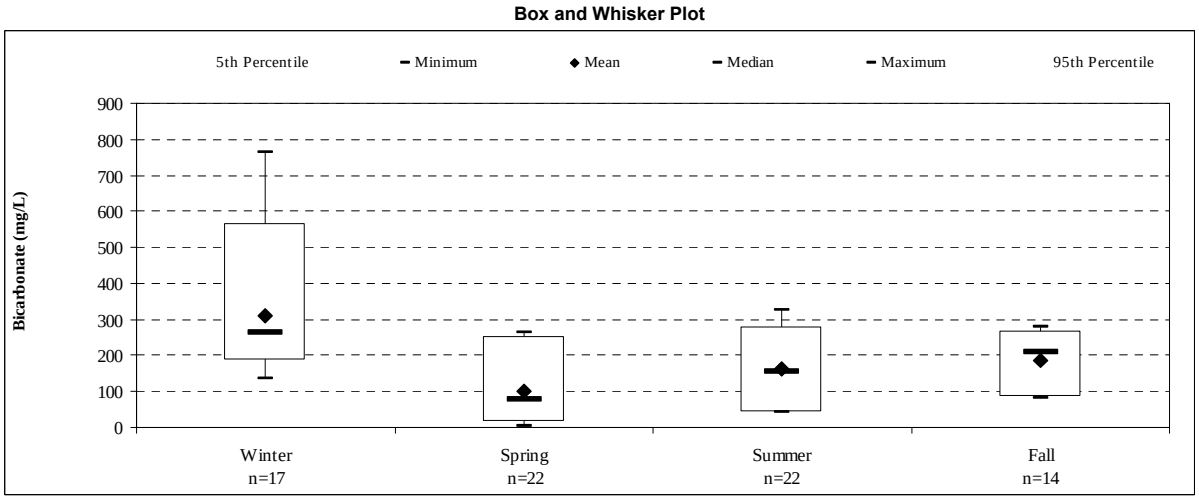


Figure G-3-3-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Big Creek



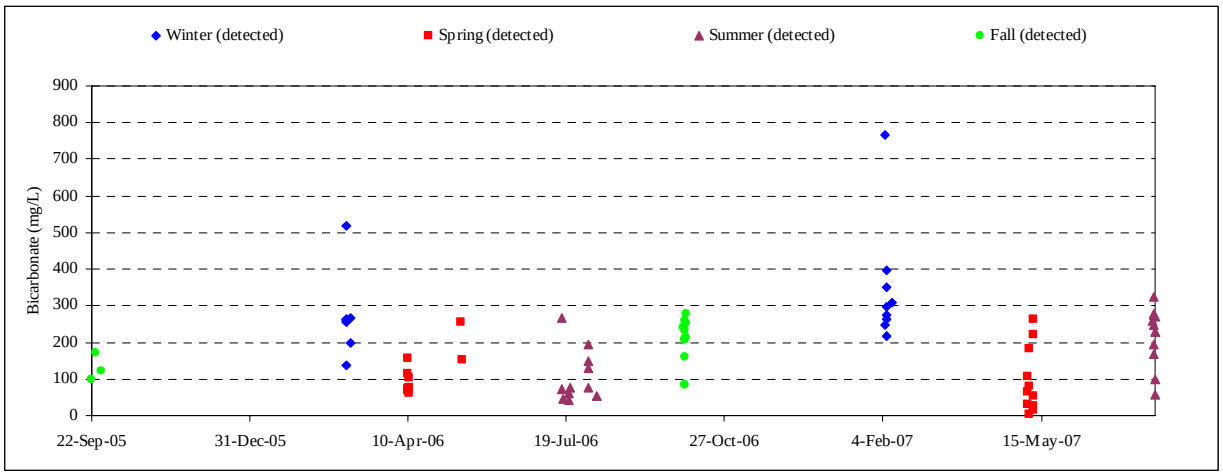
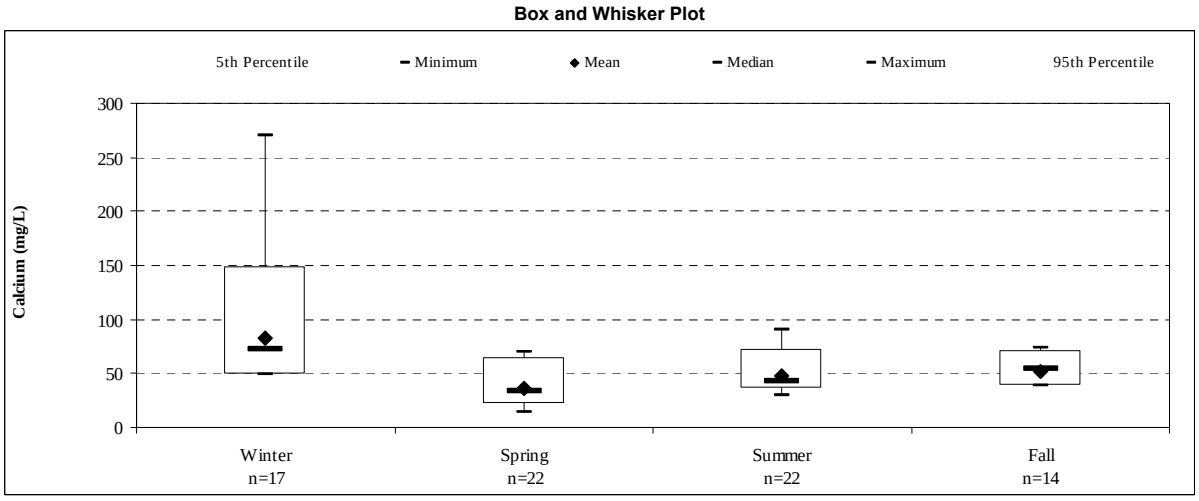


Figure G-3-3-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Big Creek



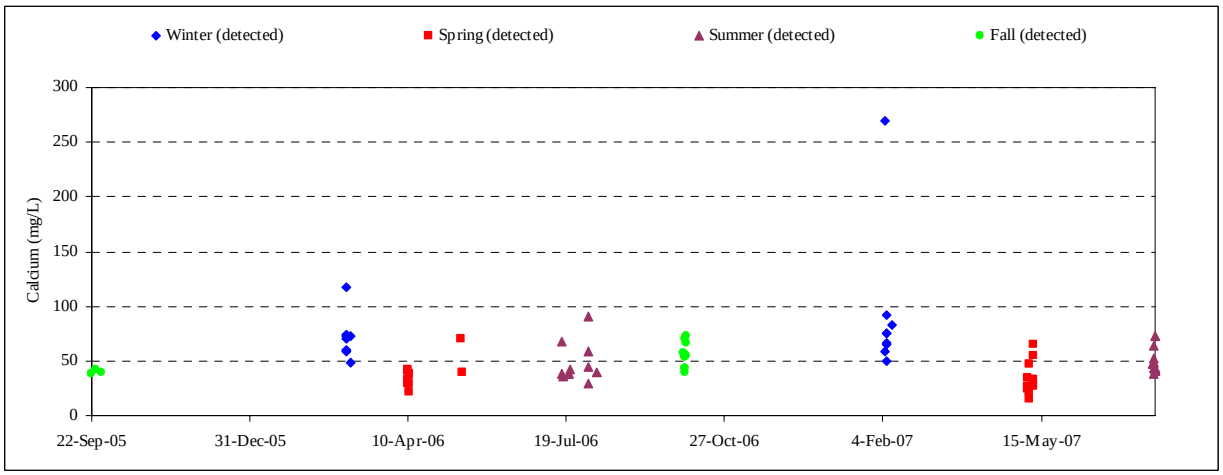
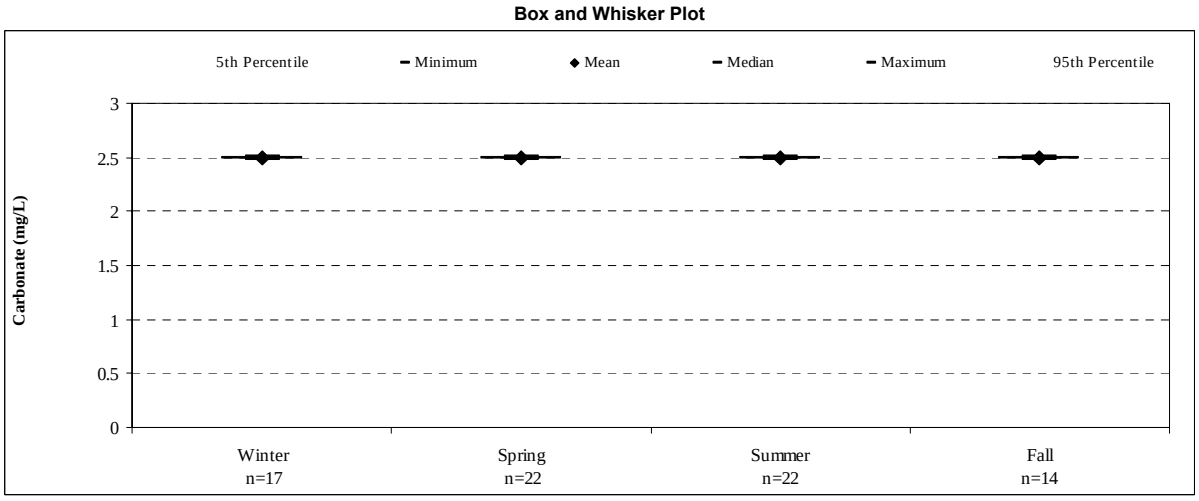


Figure G-3-3-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Big Creek



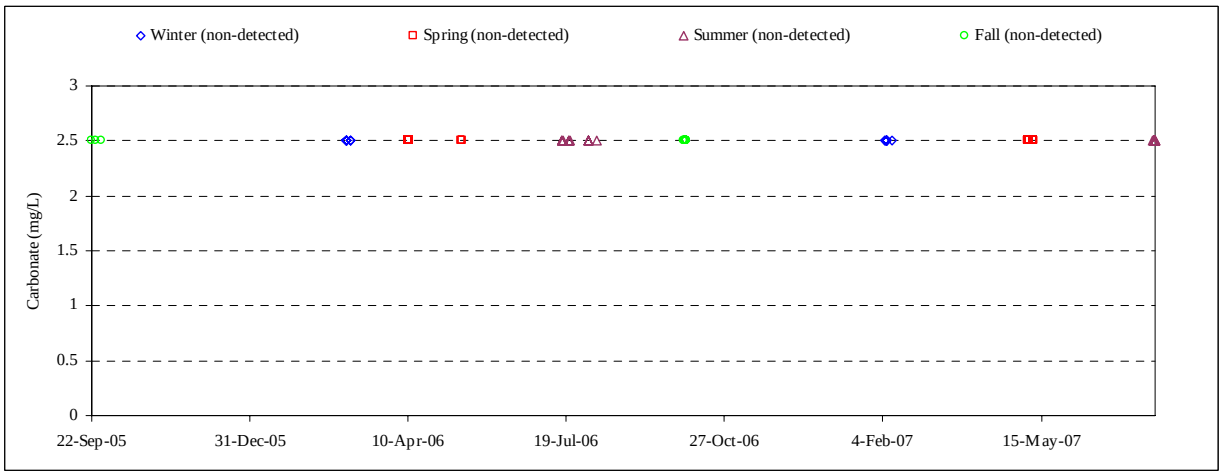
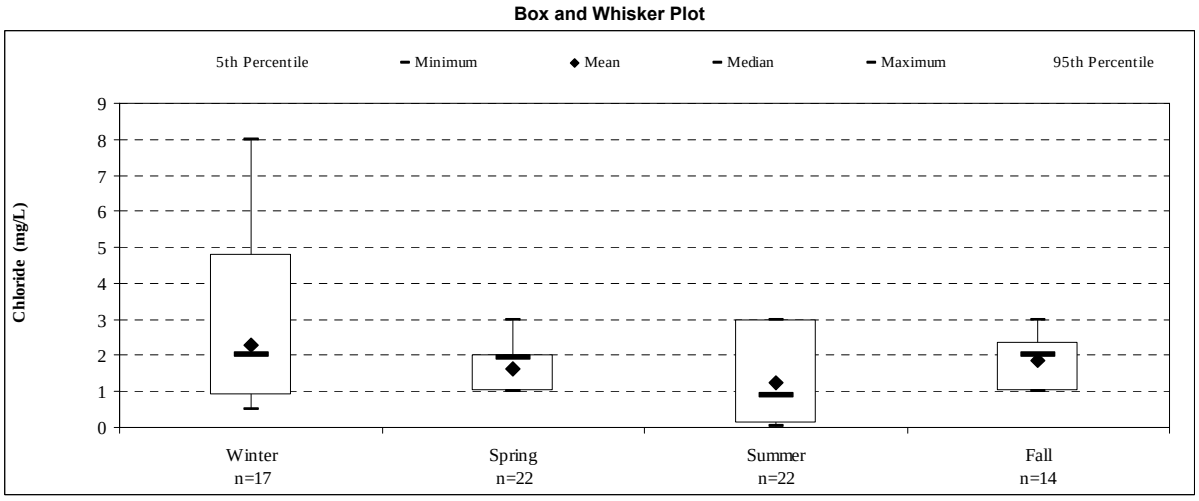


Figure G-3-3-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Big Creek



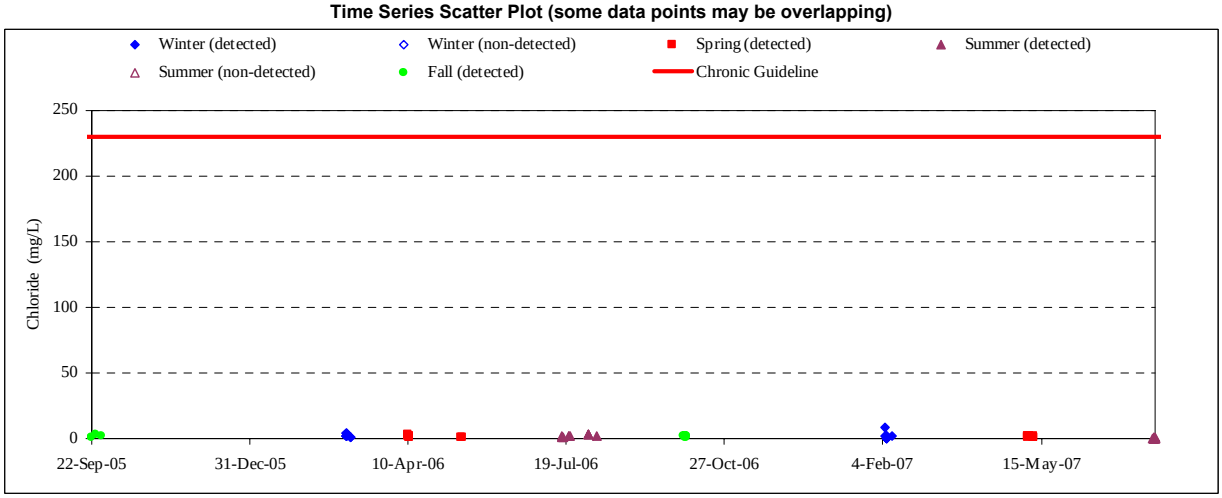
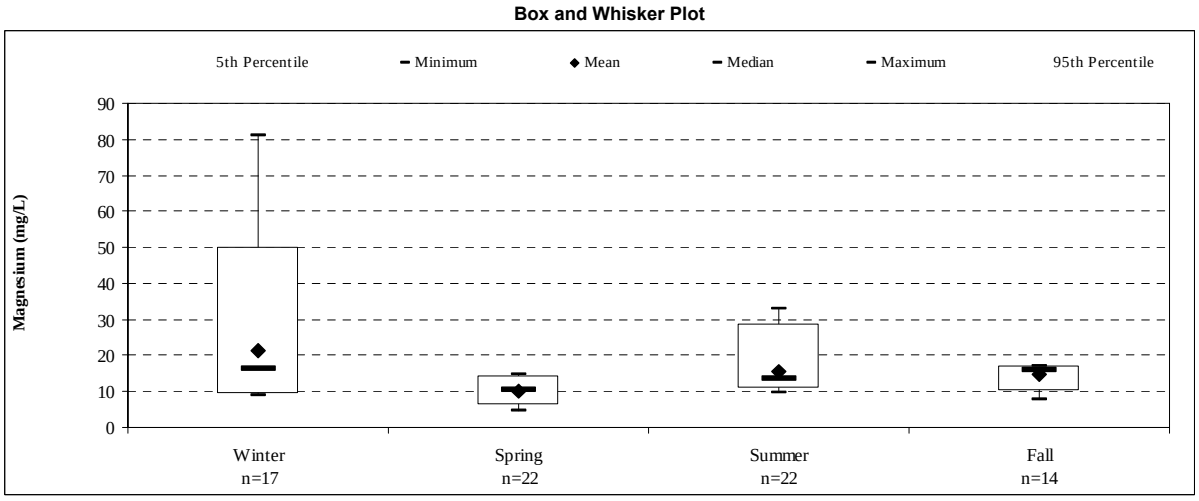


Figure G-3-3-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Big Creek



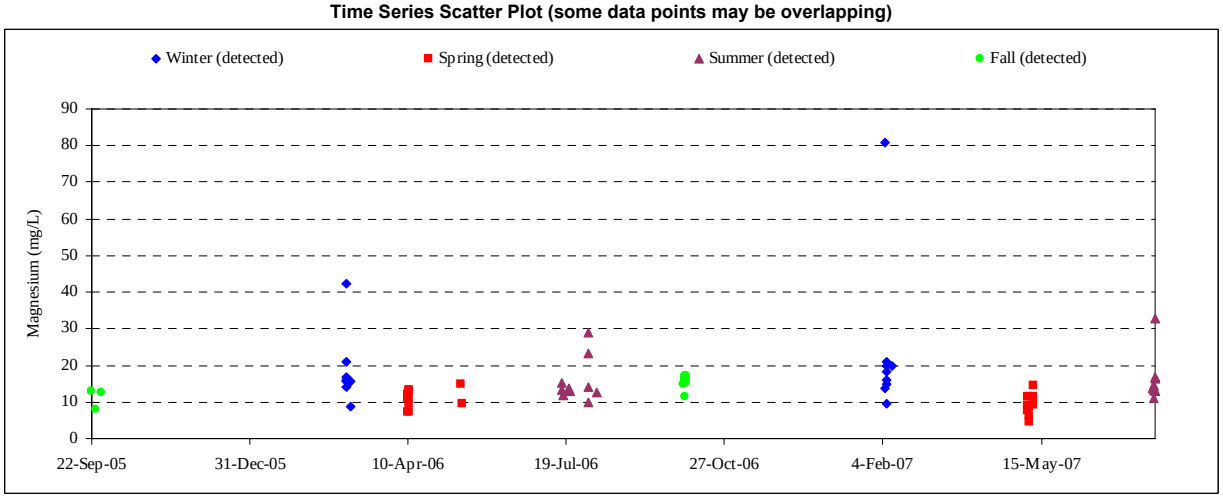
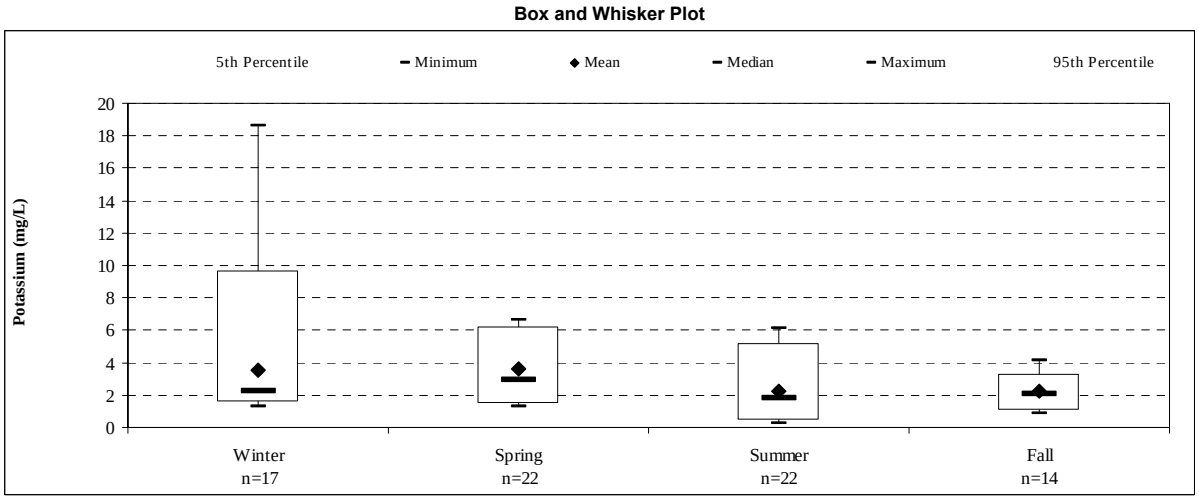


Figure G-3-3-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Big Creek



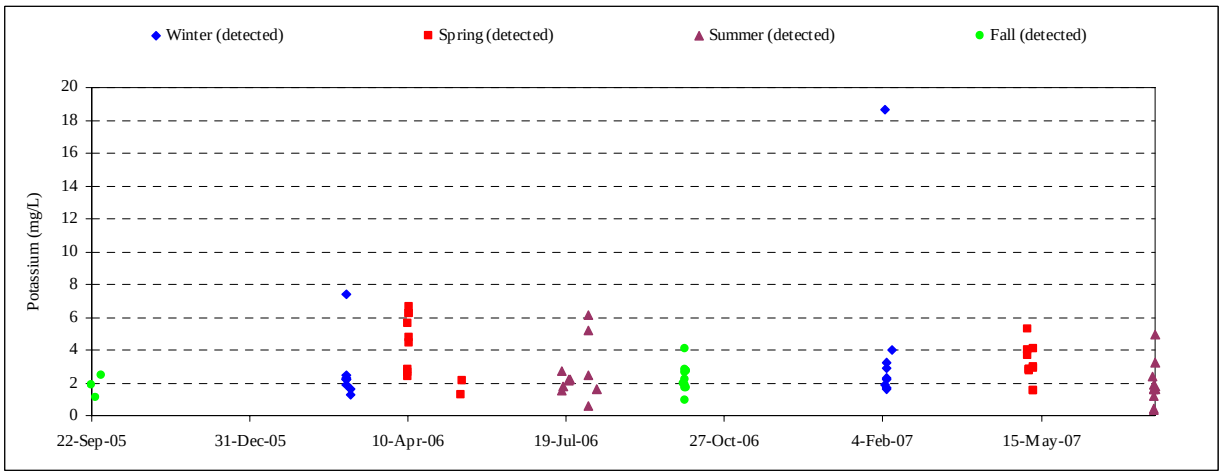
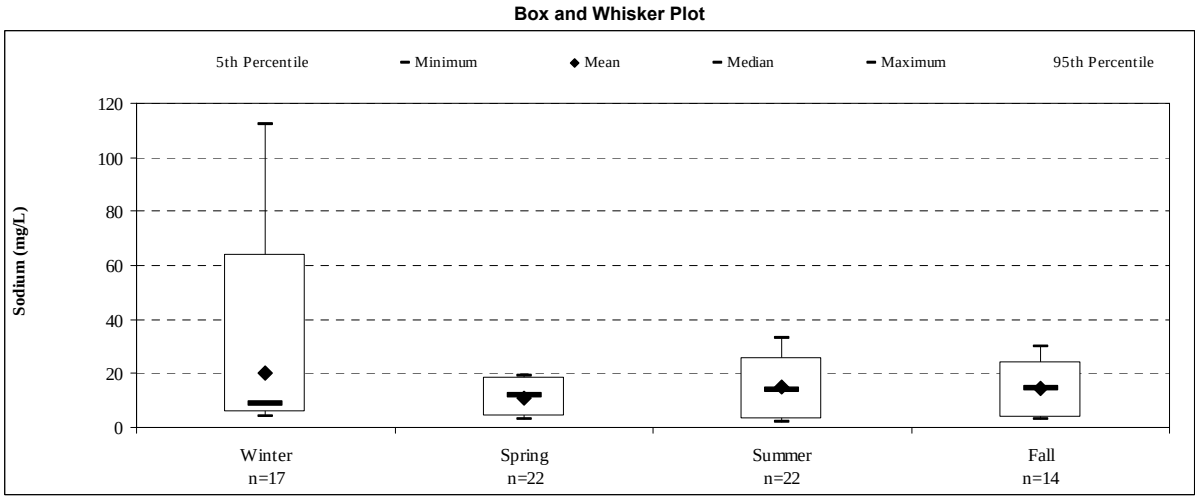


Figure G-3-3-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Big Creek



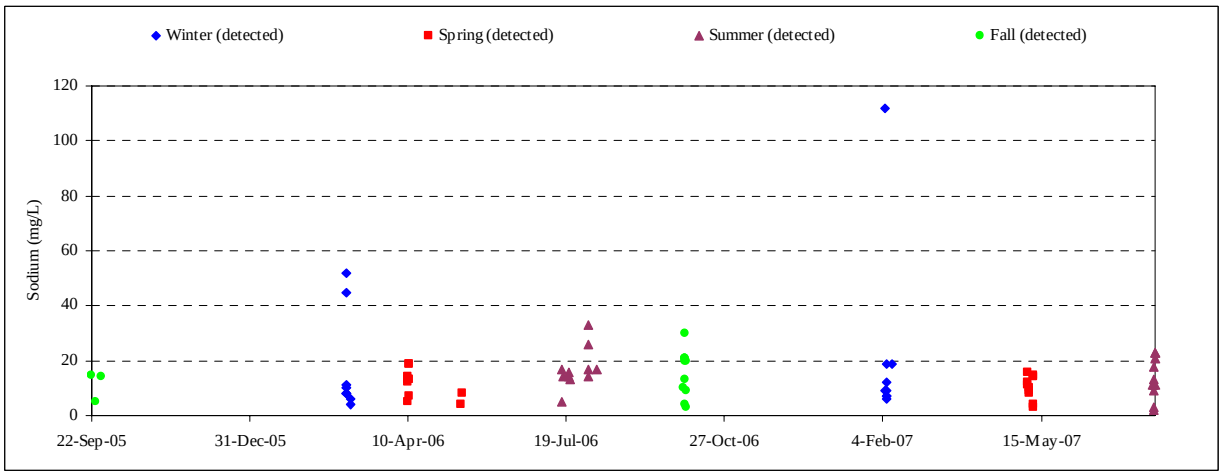
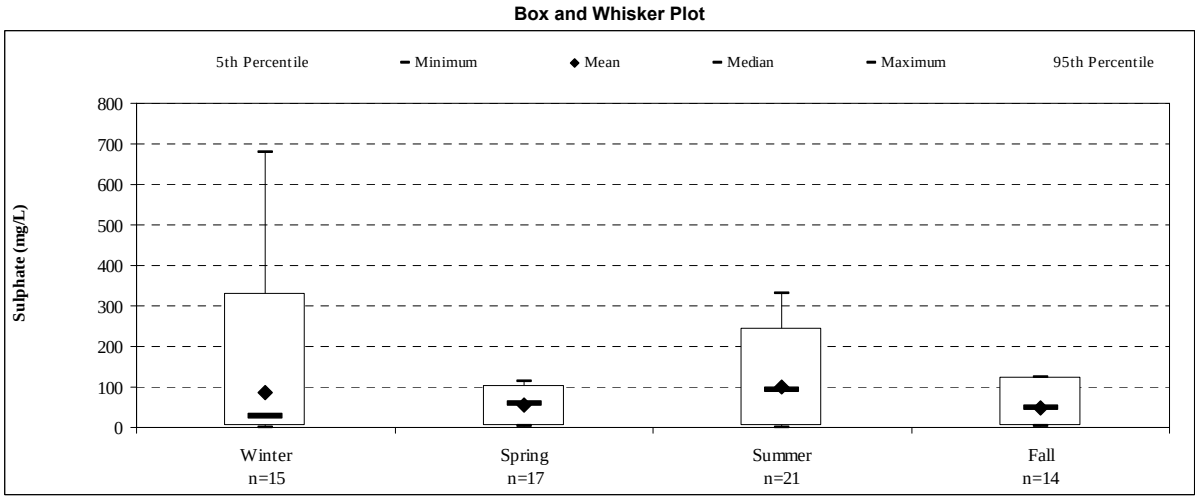


Figure G-3-3-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Big Creek



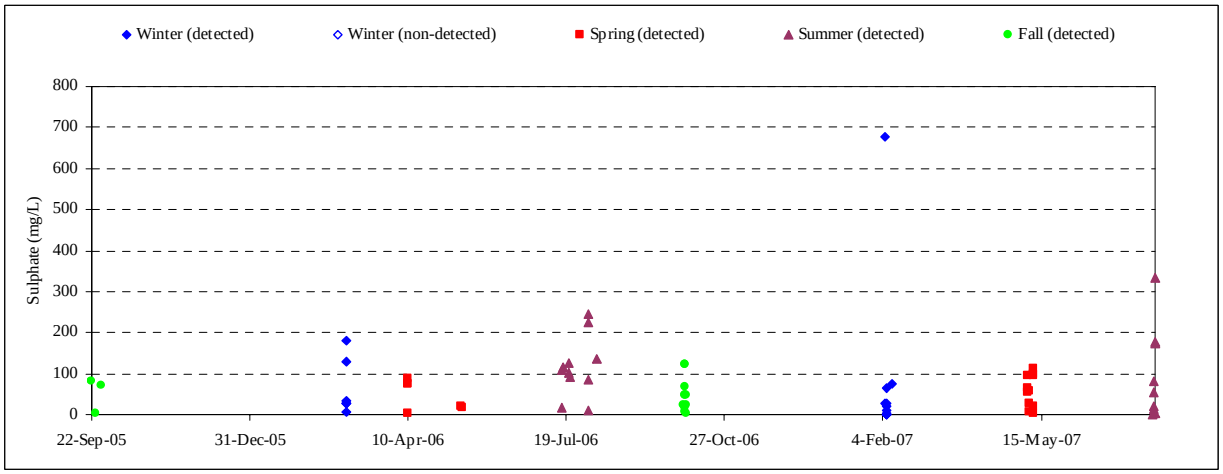


Figure G-3-3-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Big Creek

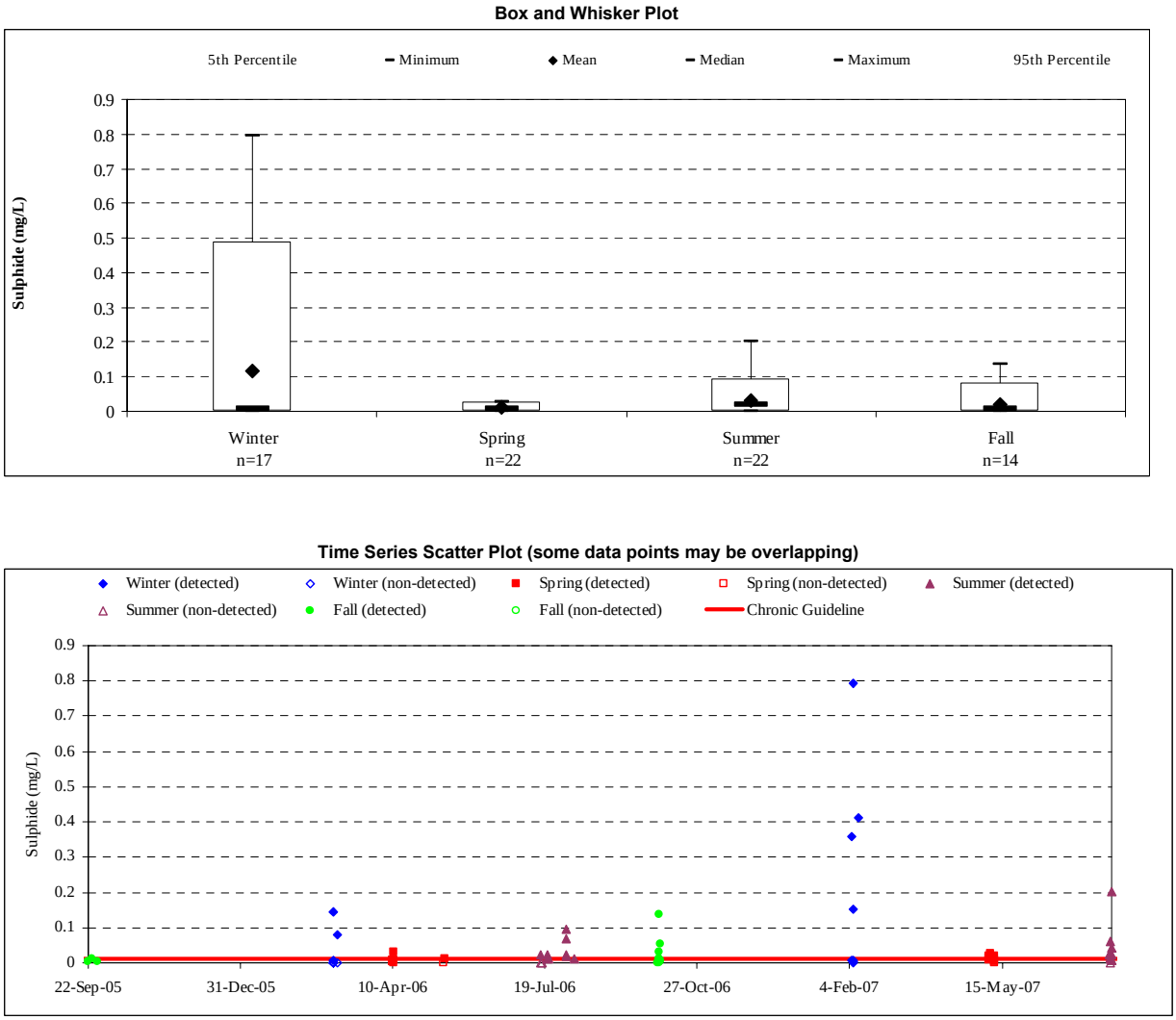


Figure G-3-3-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Big Creek

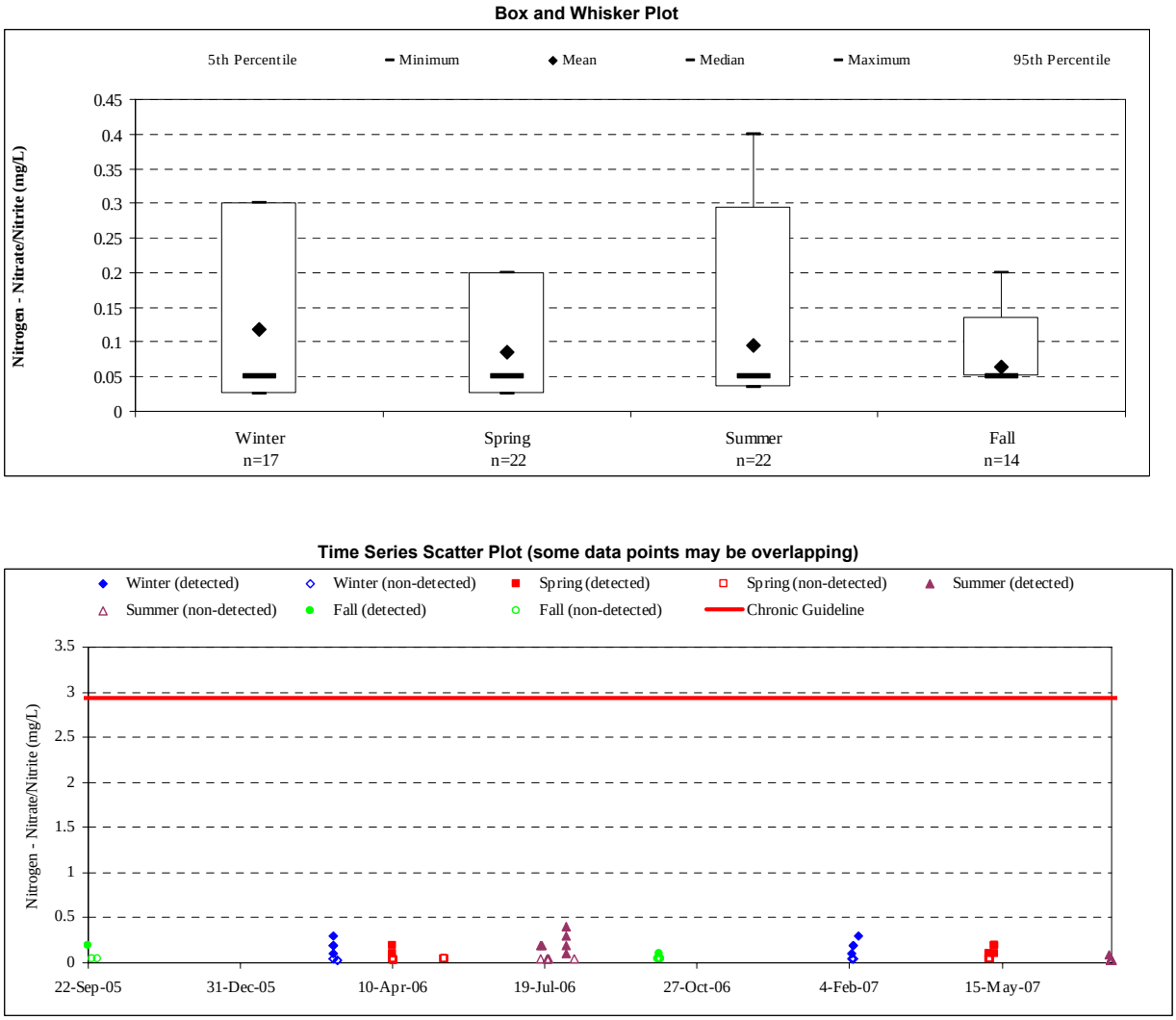
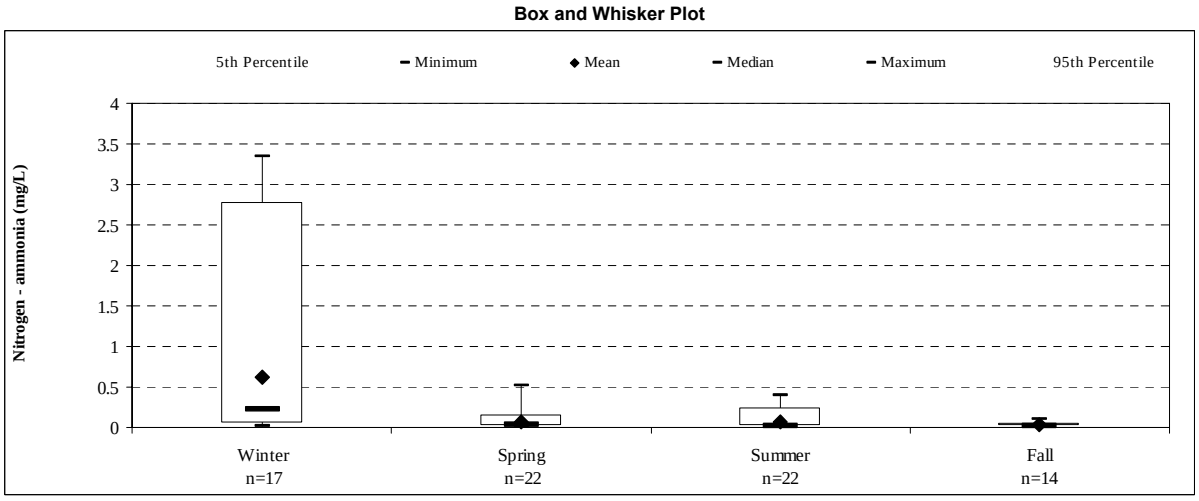


Figure G-3-3-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Big Creek



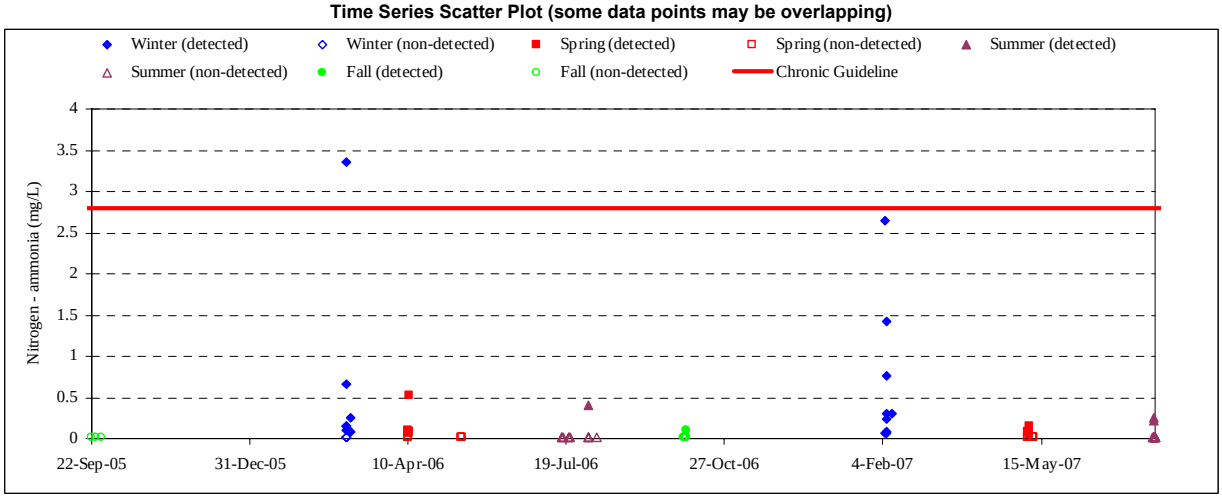
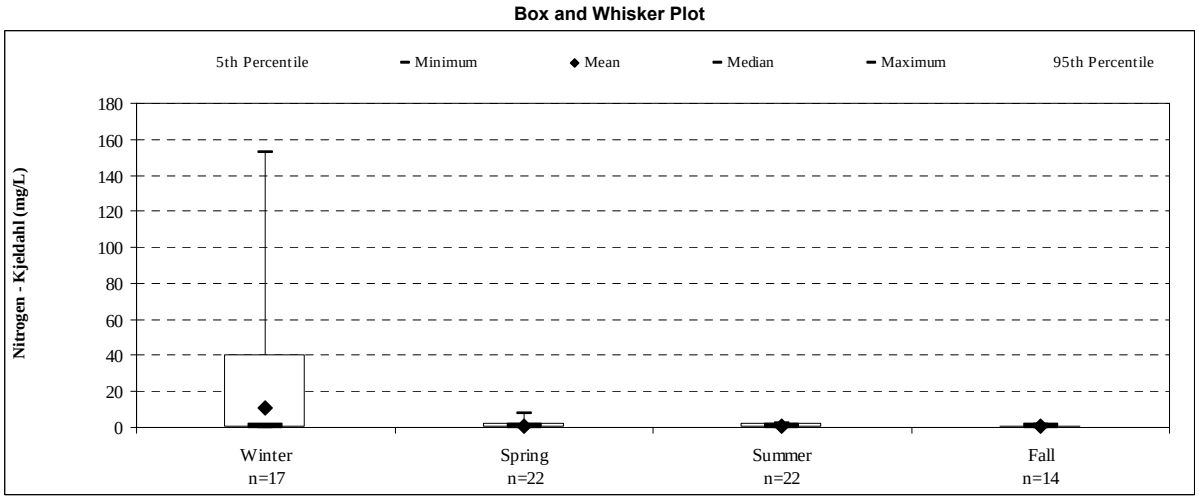


Figure G-3-3-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Big Creek



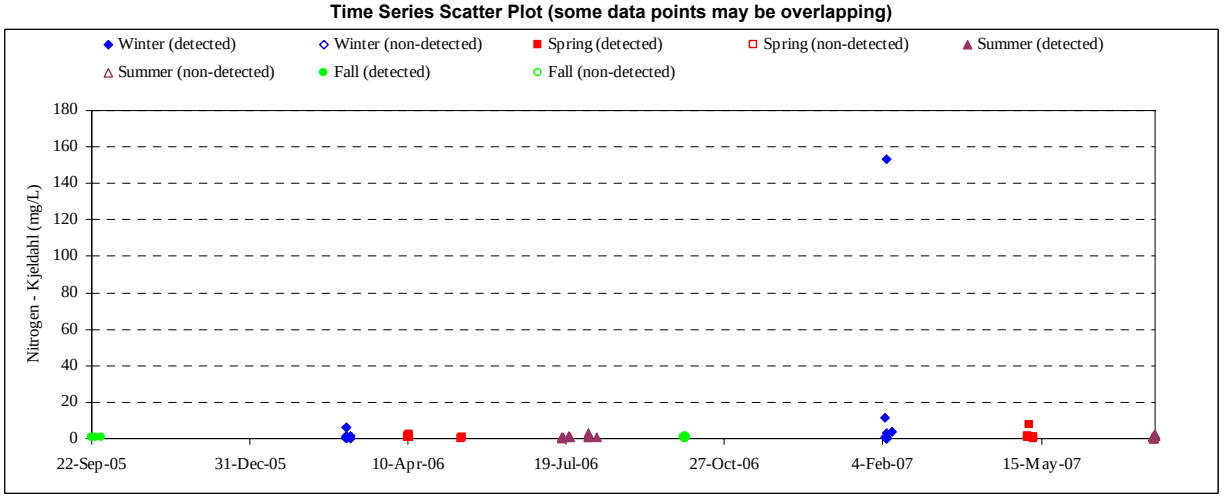
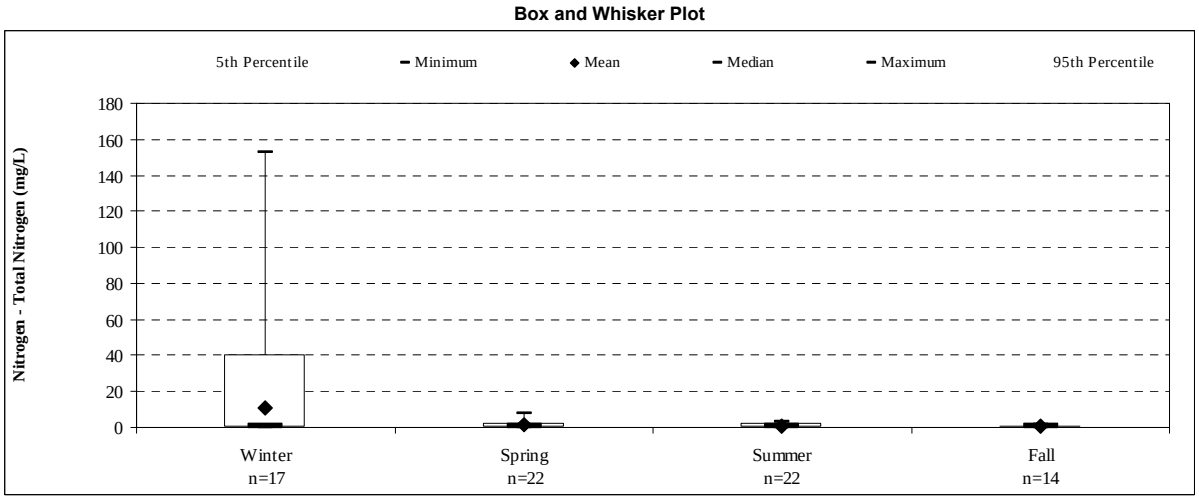


Figure G-3-3-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Big Creek



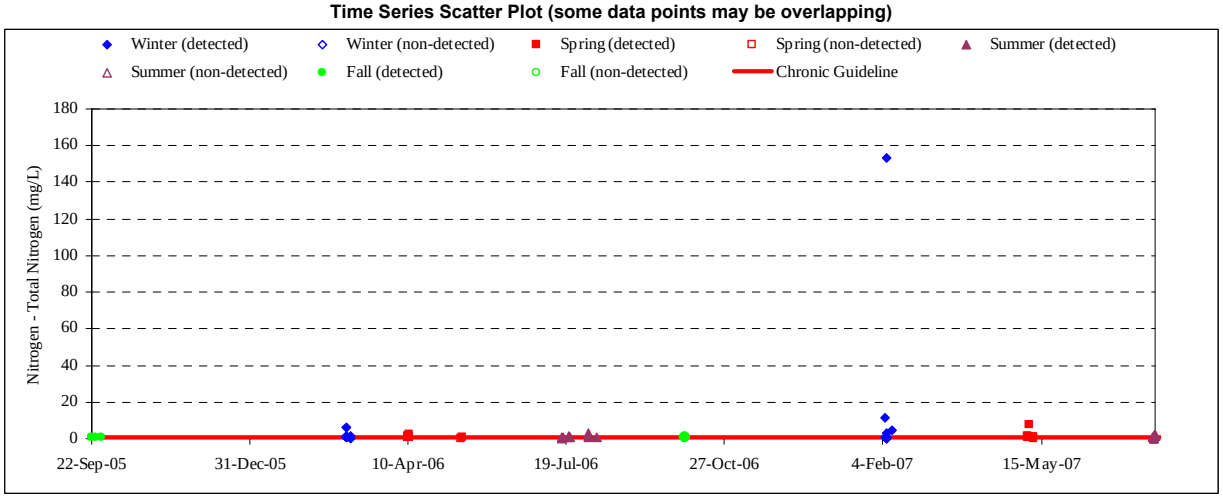
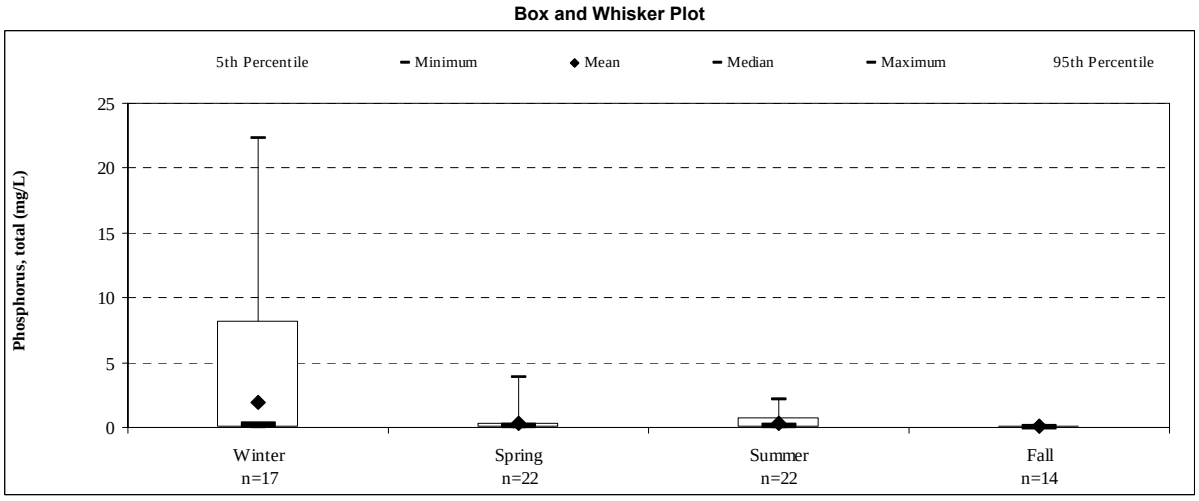


Figure G-3-3-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Big Creek



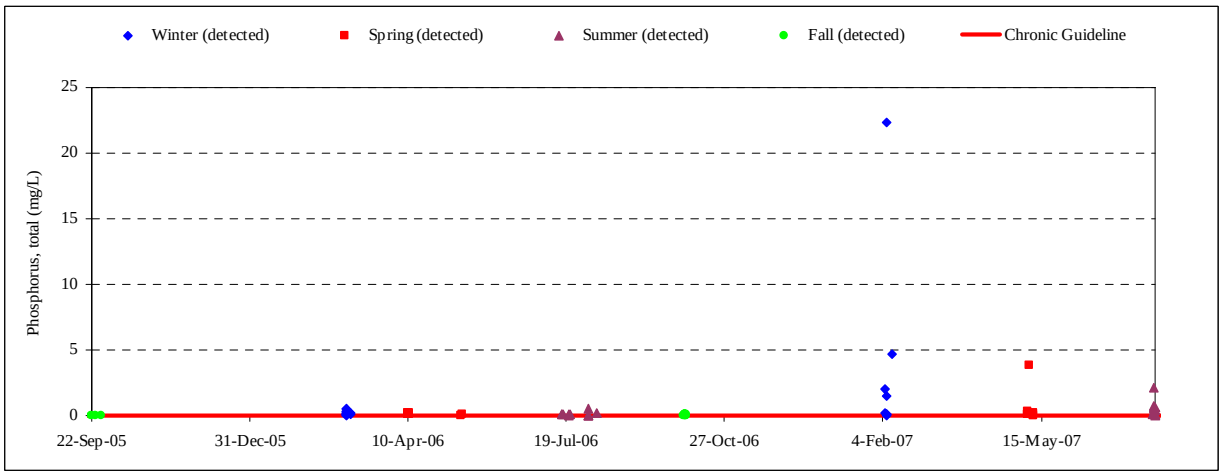
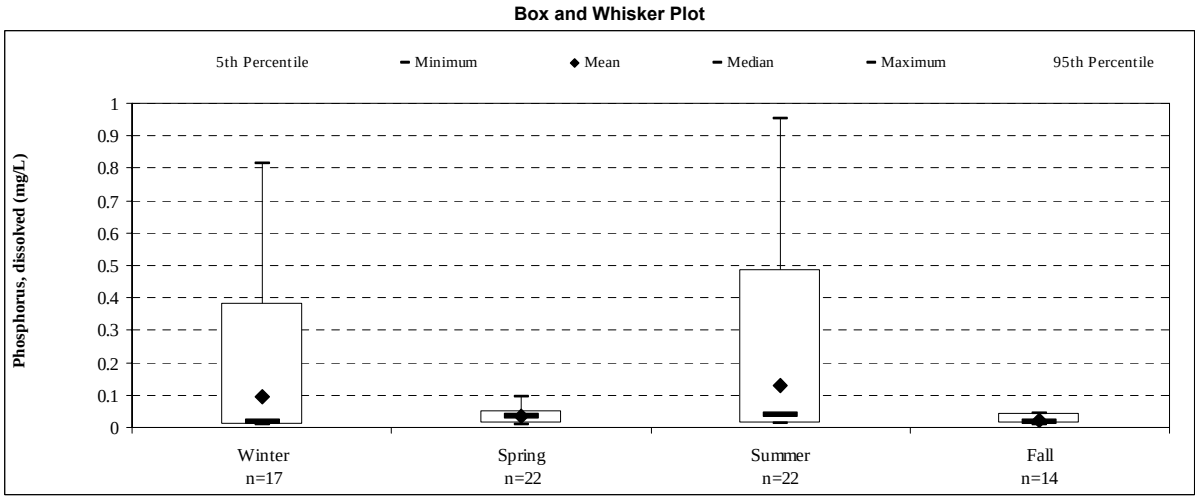


Figure G-3-3-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Big Creek



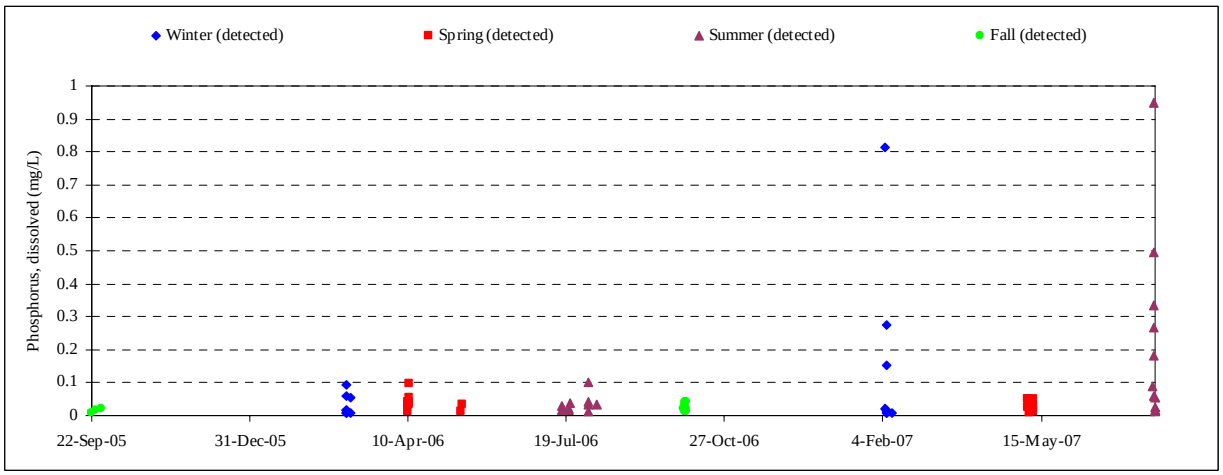
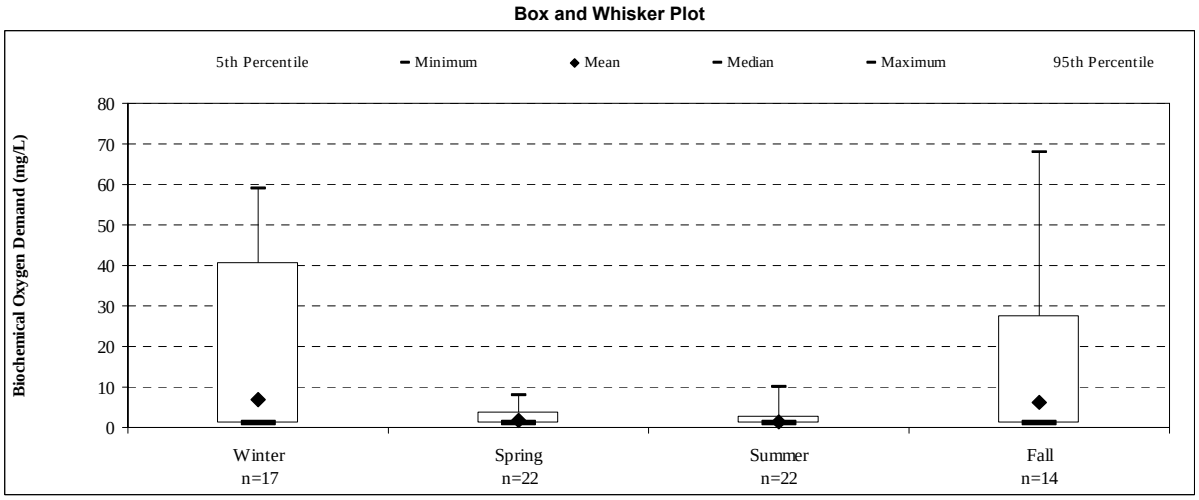


Figure G-3-3-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Big Creek



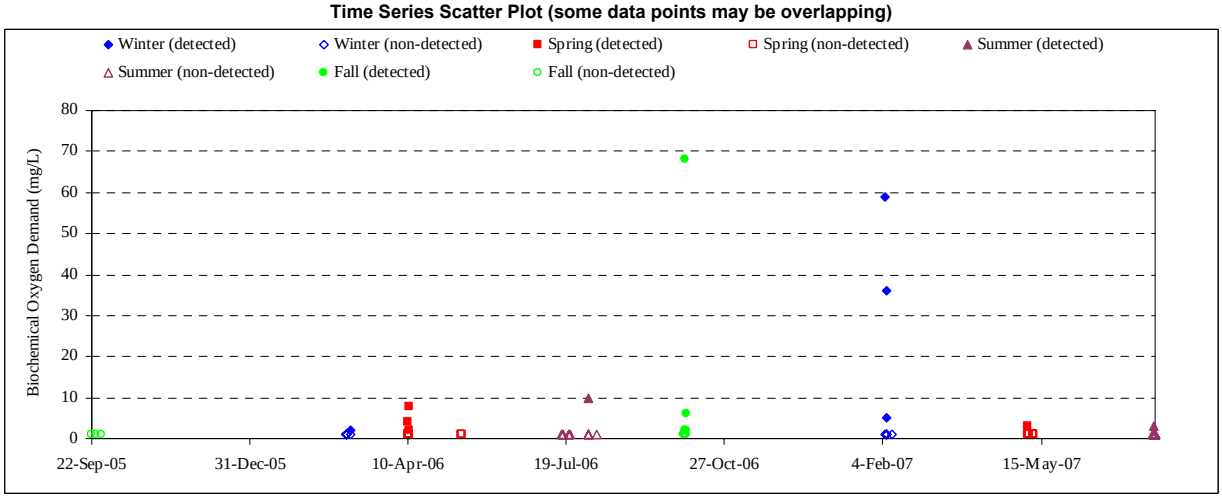
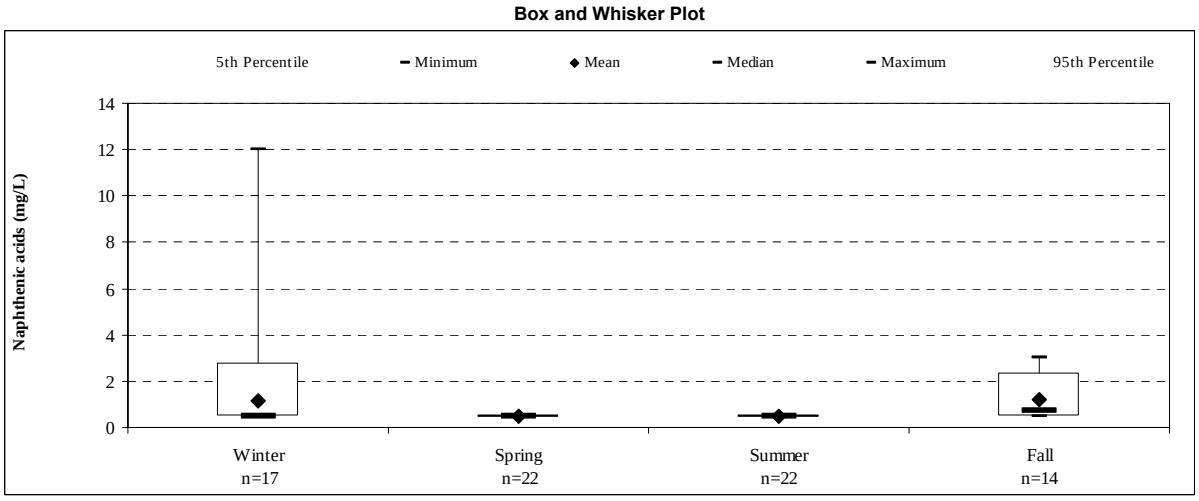


Figure G-3-3-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Big Creek



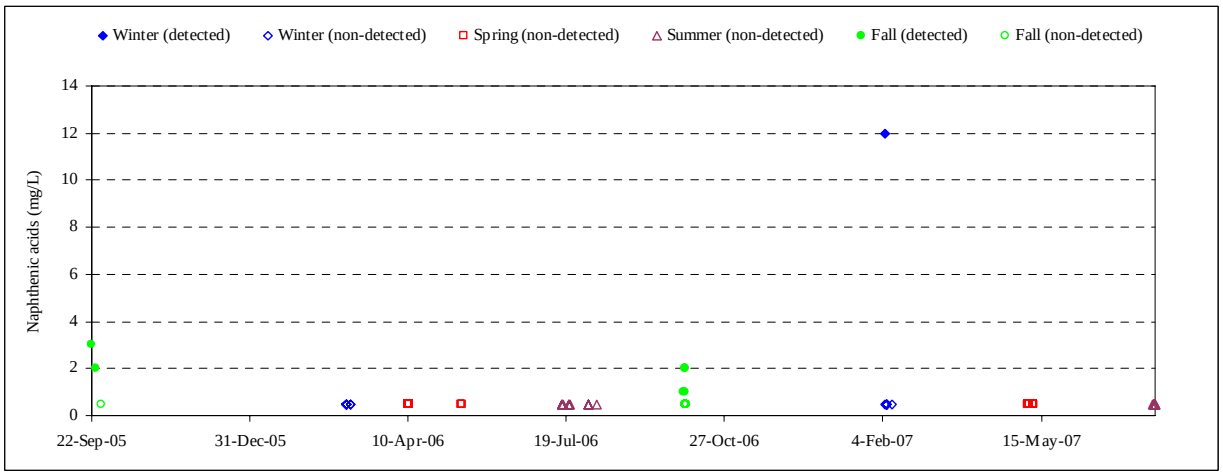
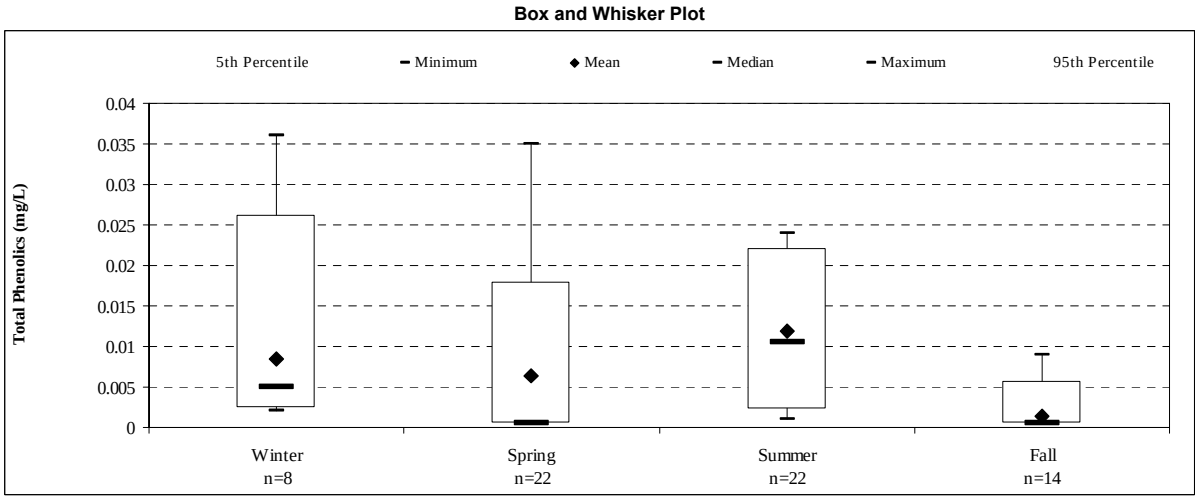


Figure G-3-3-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Big Creek



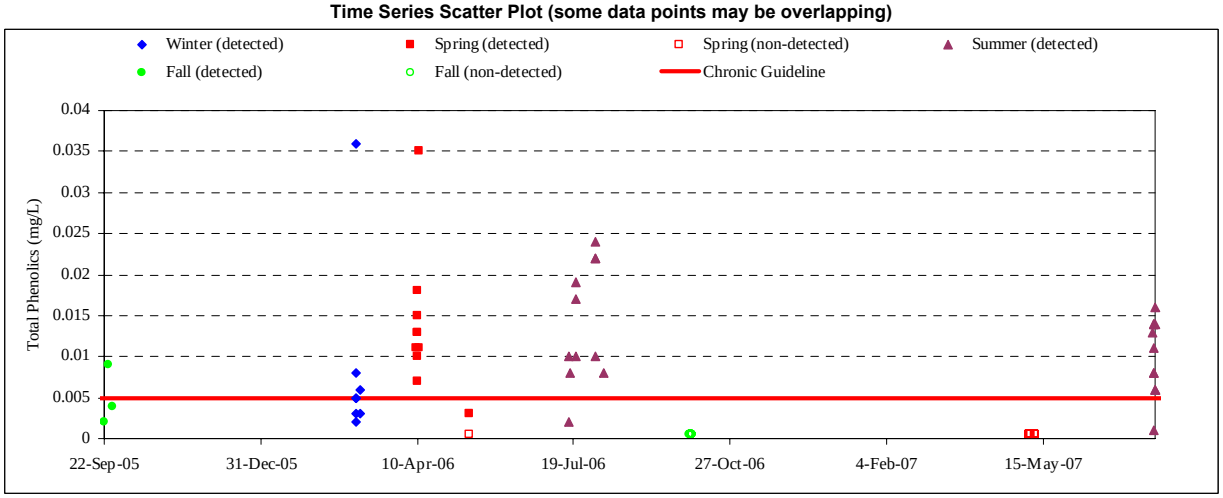
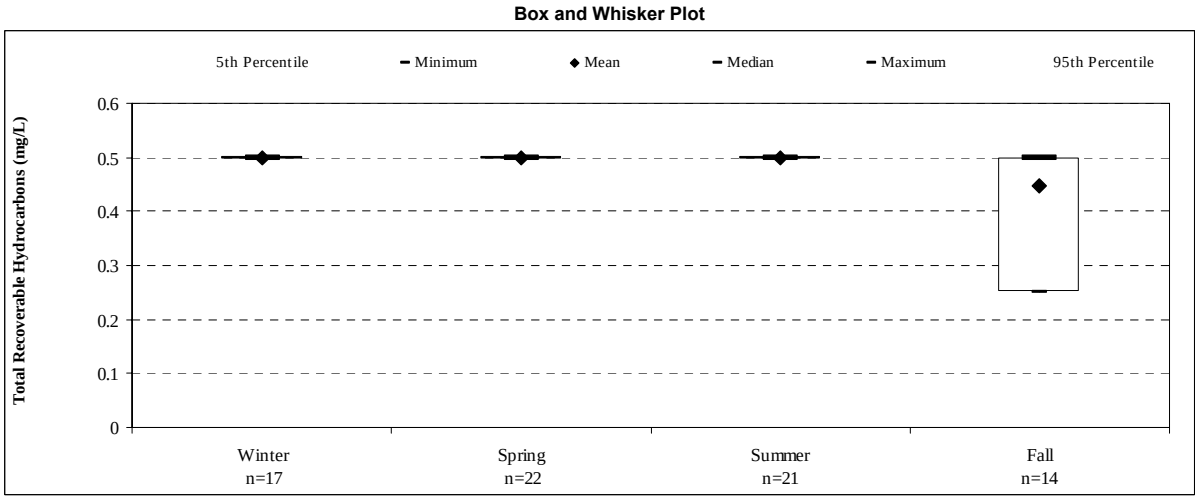


Figure G-3-3-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Big Creek



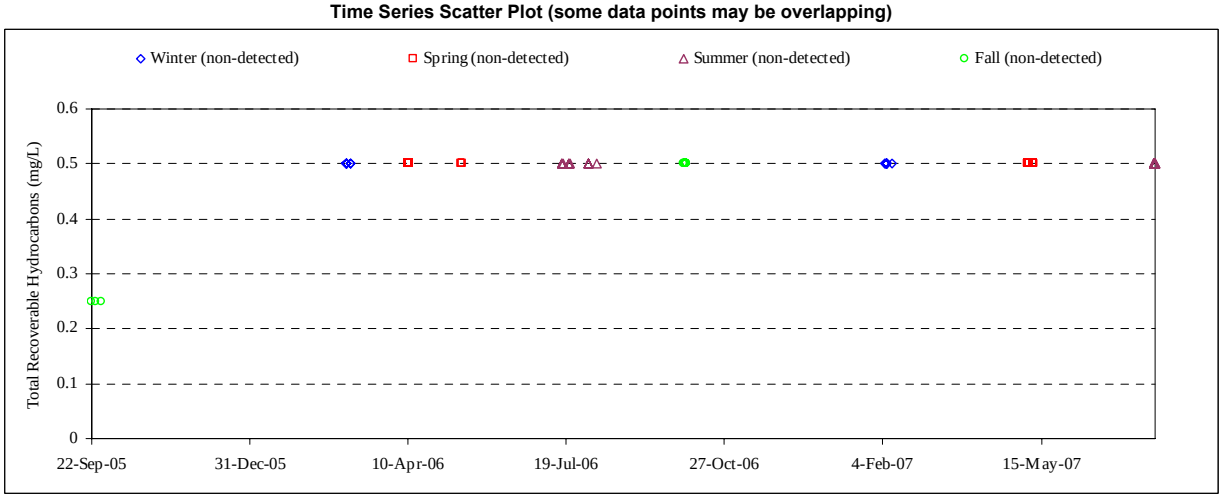
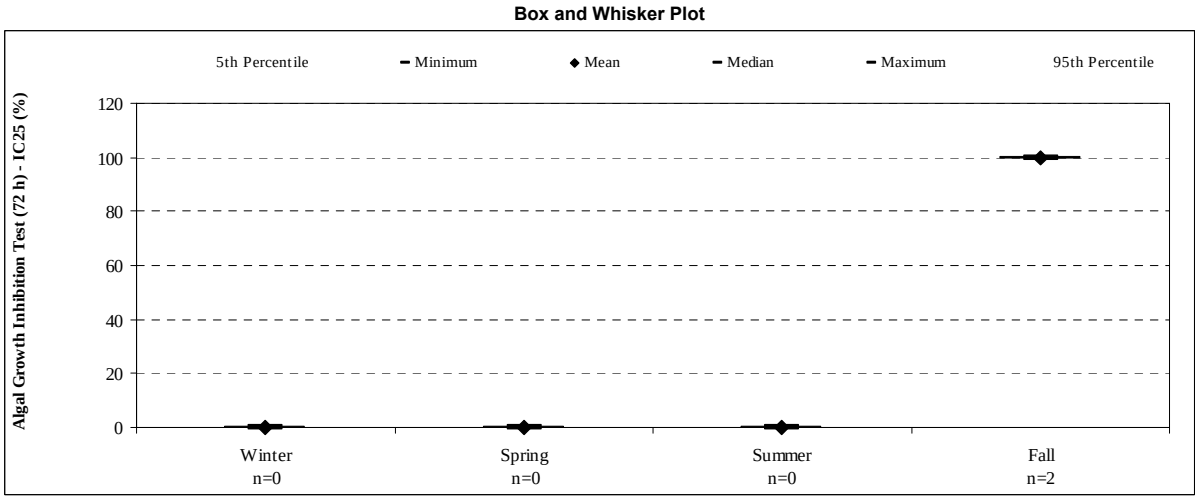


Figure G-3-3-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Big Creek



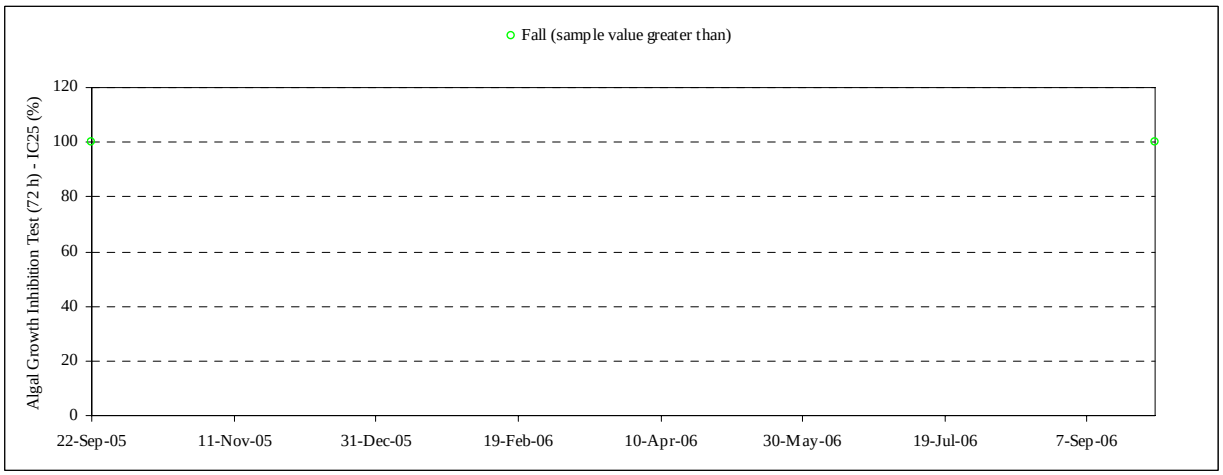
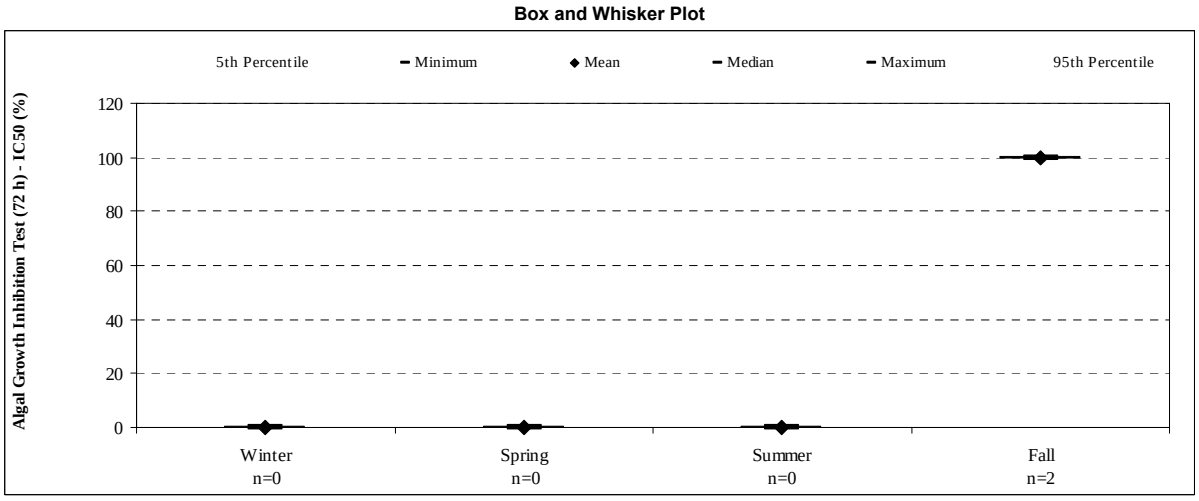


Figure G-3-3-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Big Creek



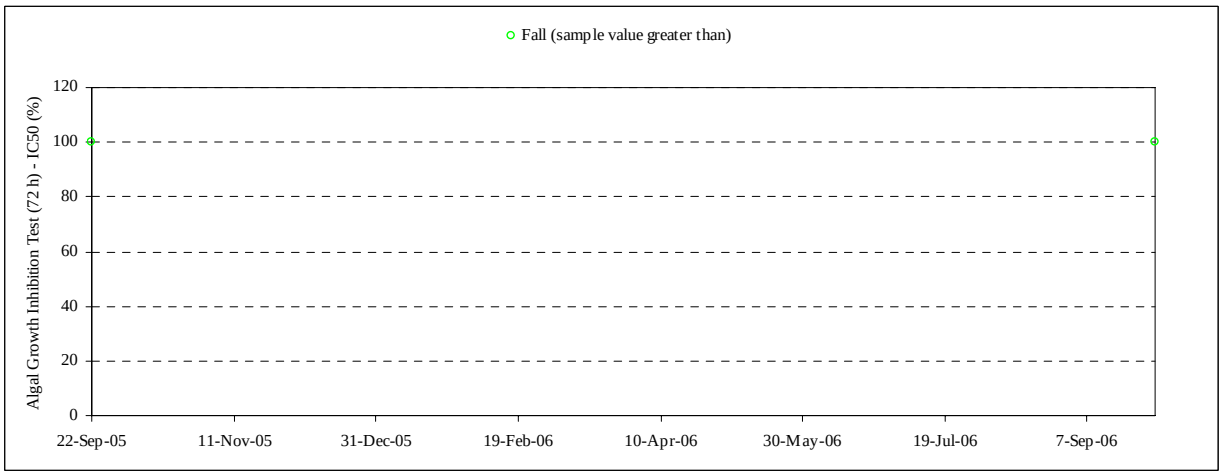


Figure G-3-3-36 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - LOEC in Big Creek

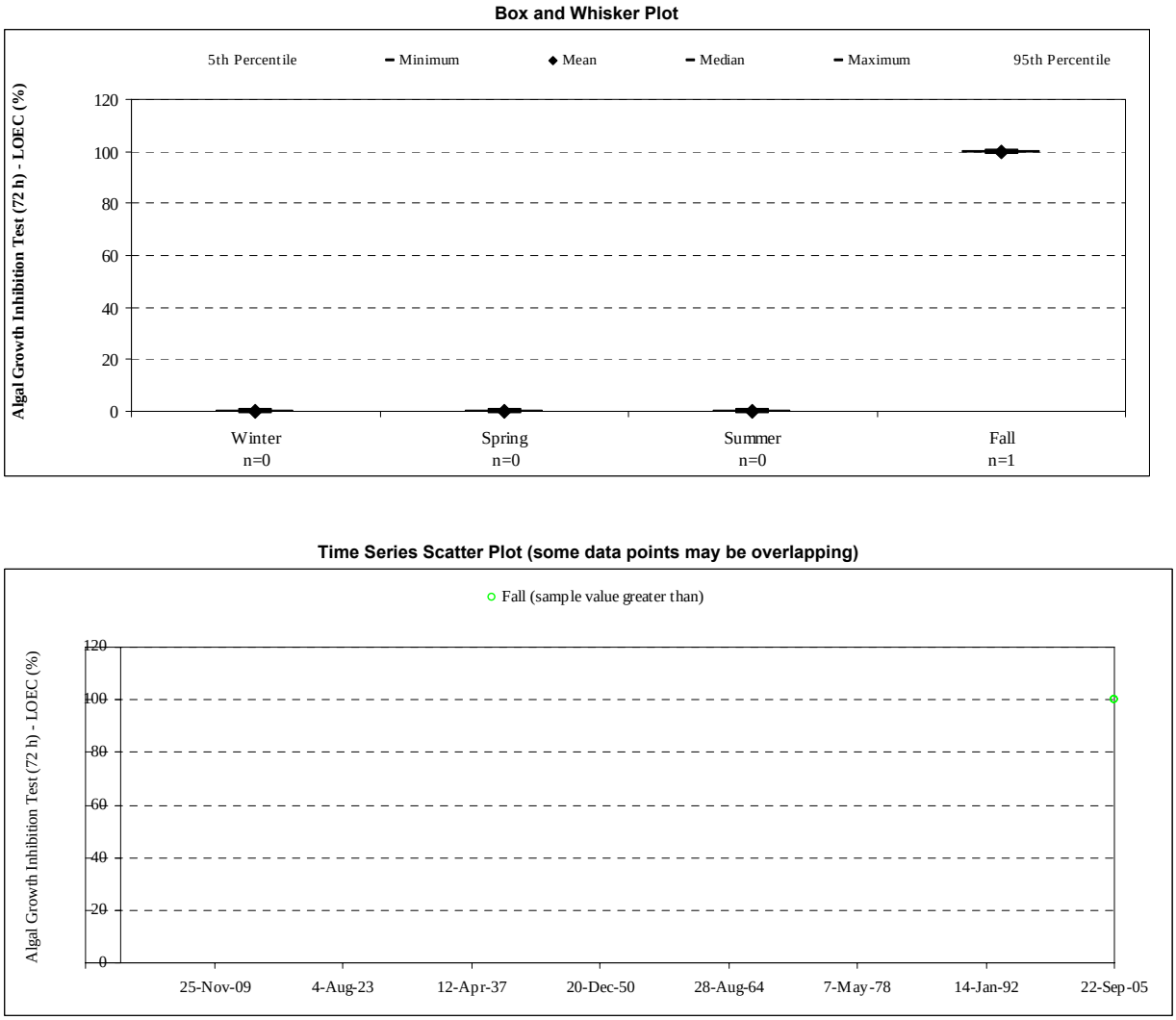
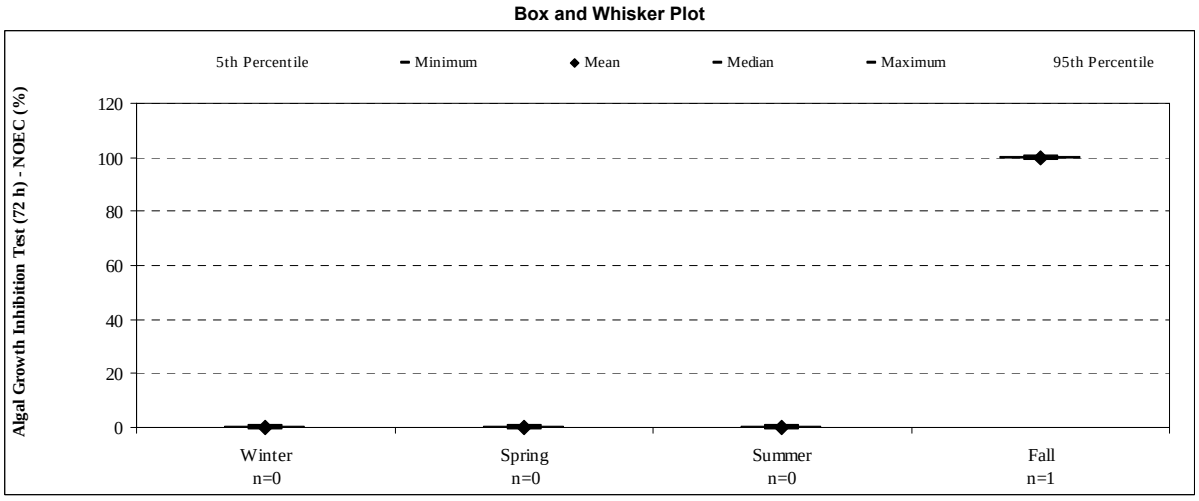


Figure G-3-3-37 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - NOEC in Big Creek



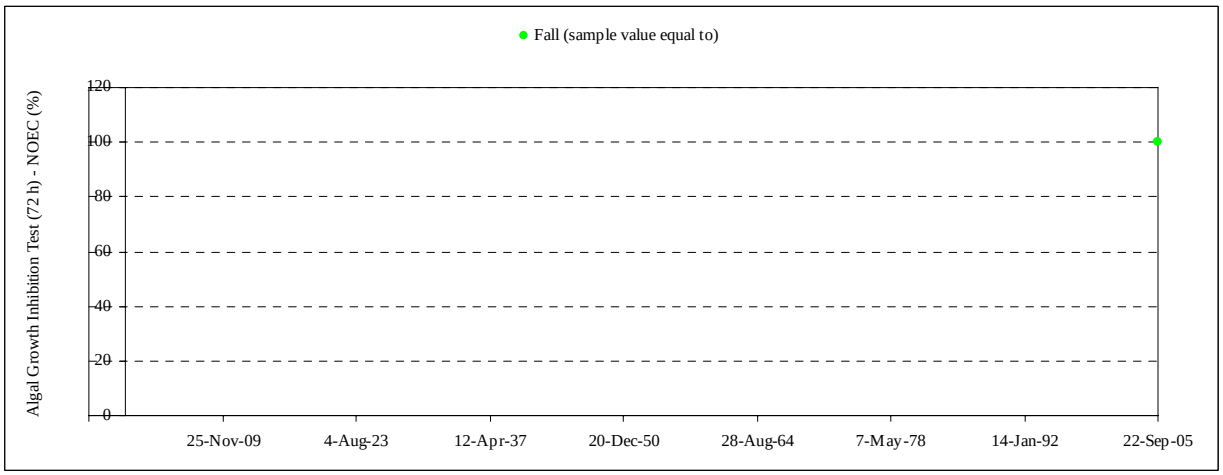
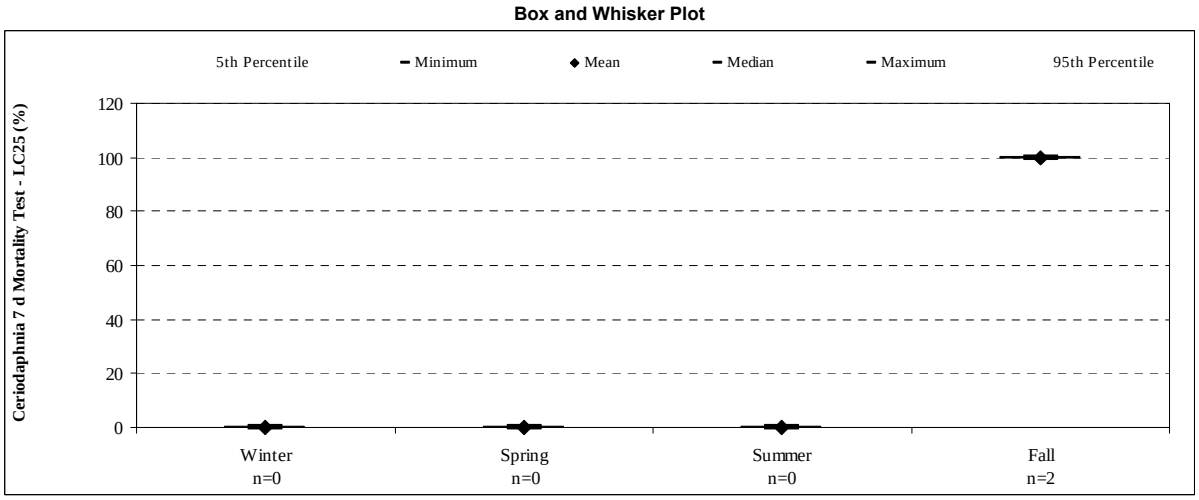


Figure G-3-3-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Big Creek



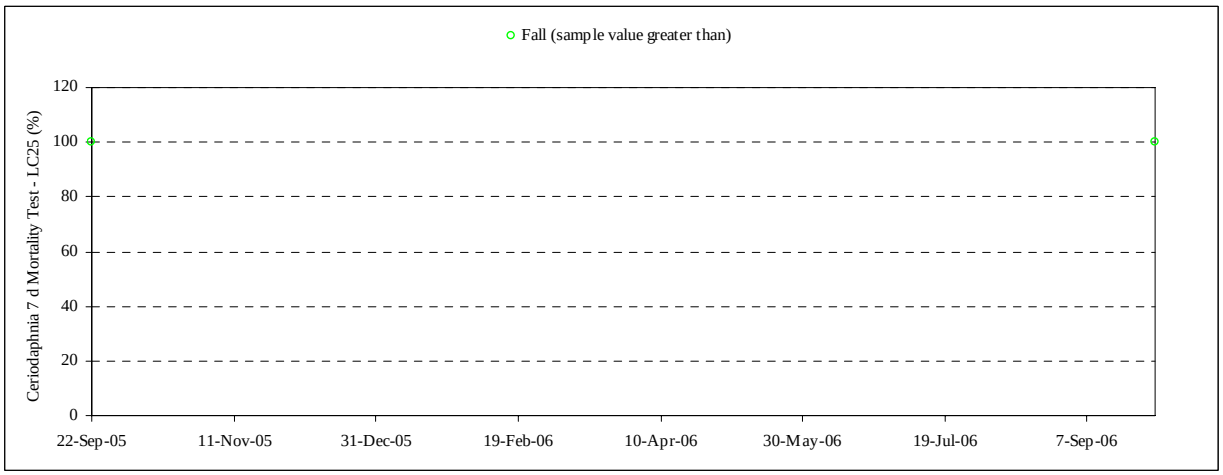
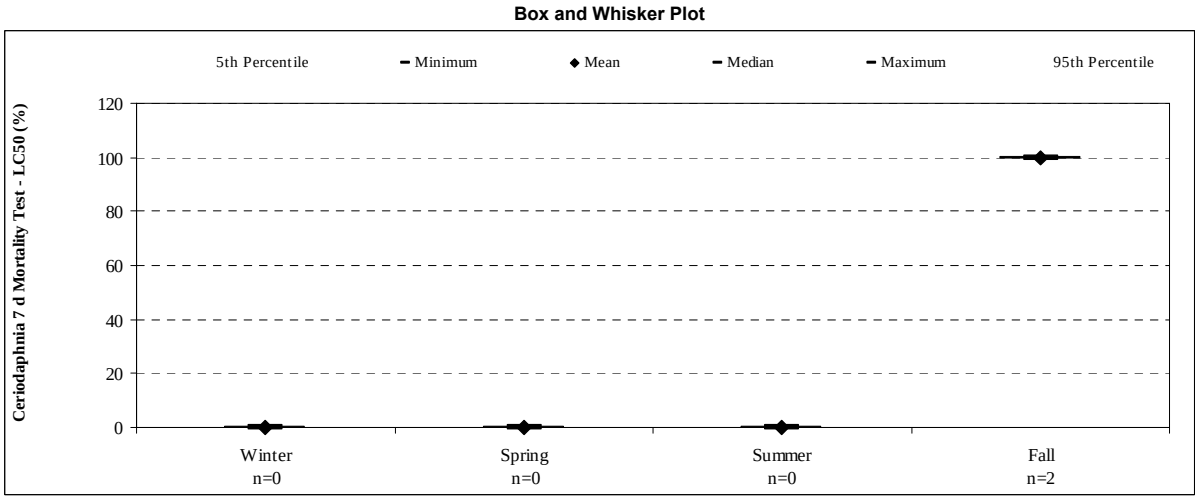


Figure G-3-3-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Big Creek



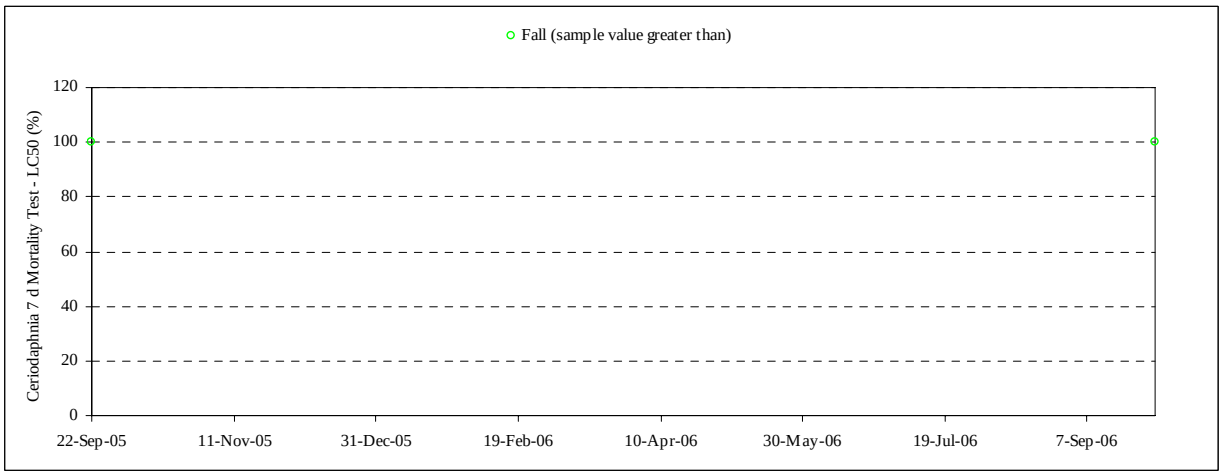
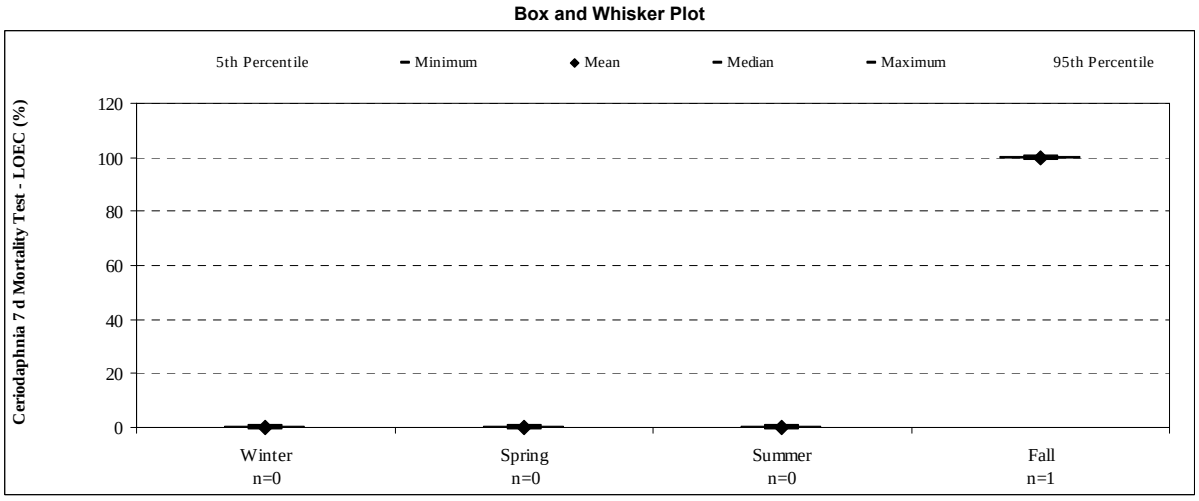


Figure G-3-3-40 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LOEC in Big Creek



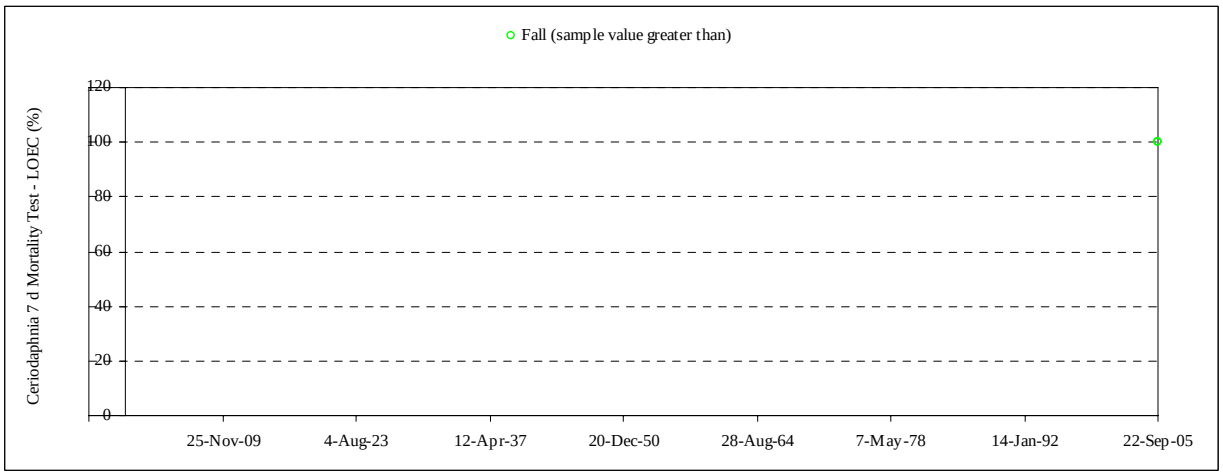
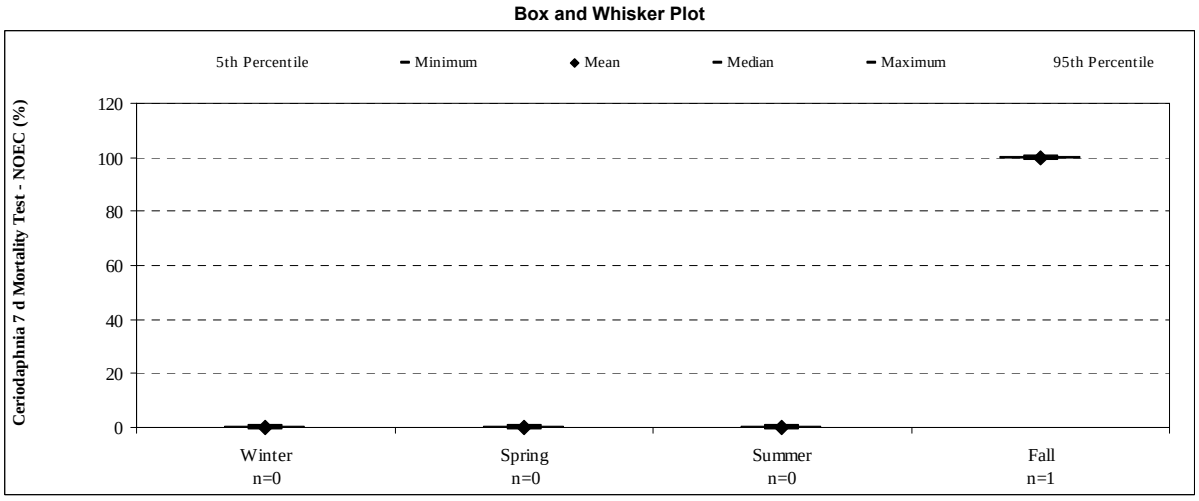


Figure G-3-3-41 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - NOEC in Big Creek



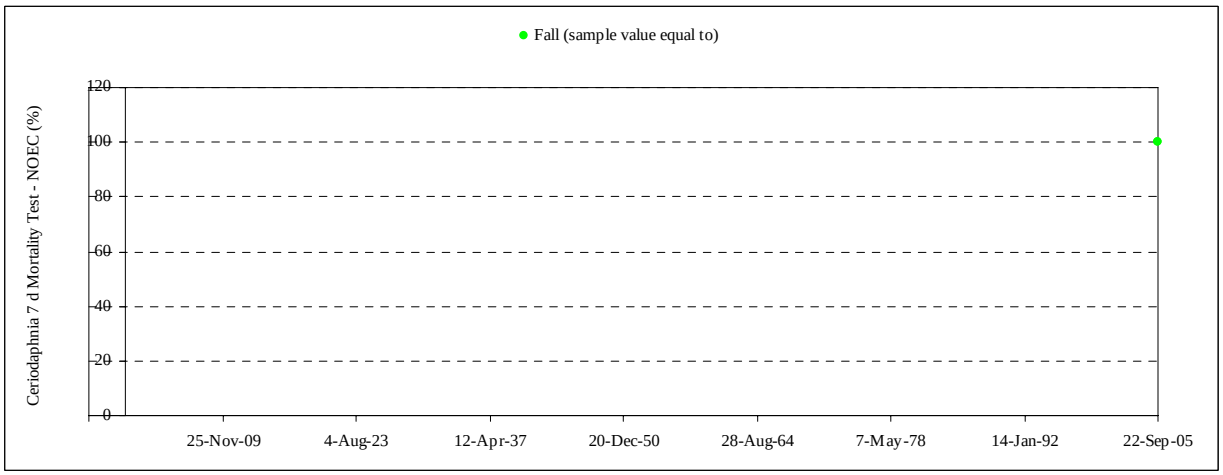
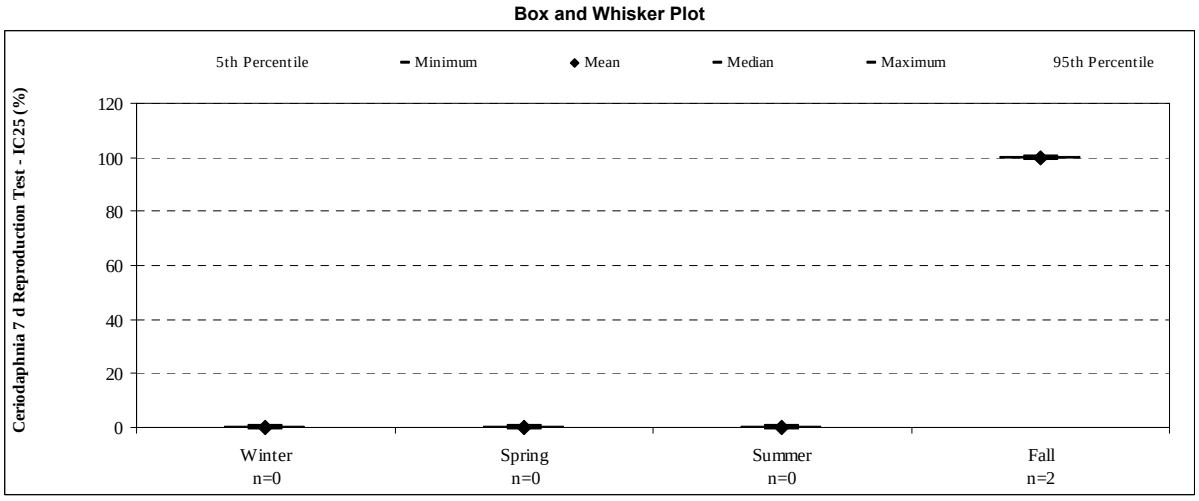


Figure G-3-3-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Big Creek



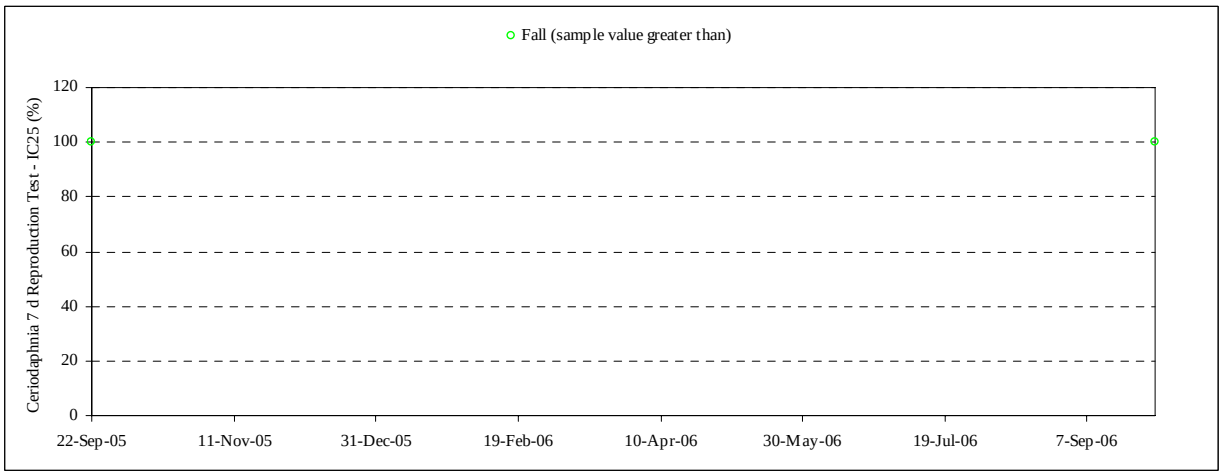
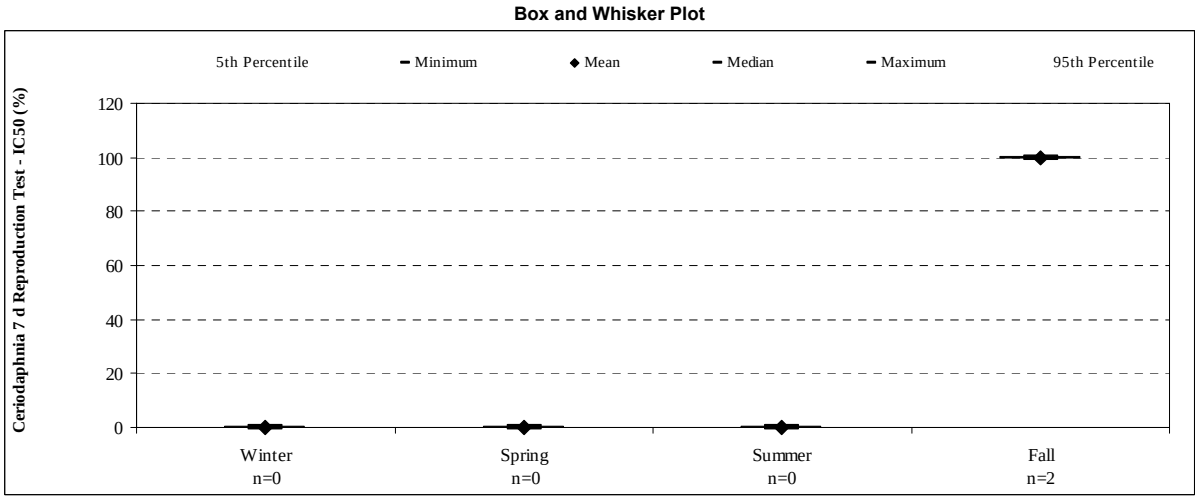


Figure G-3-3-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Big Creek



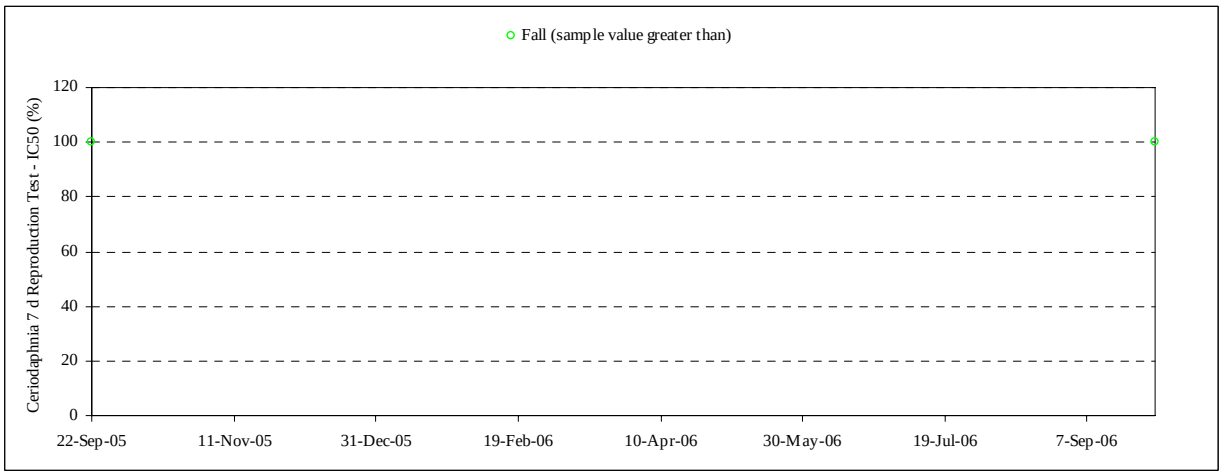
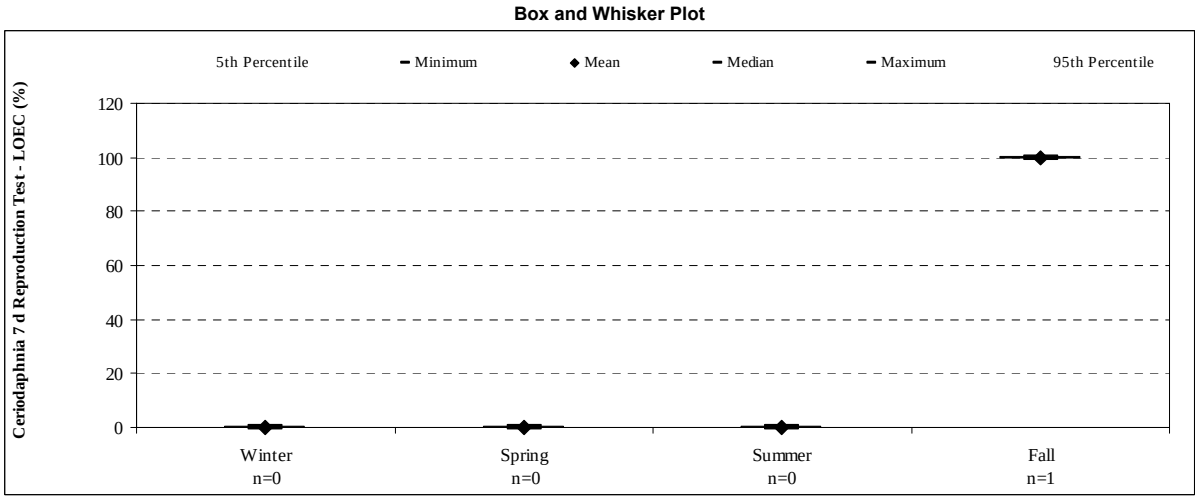


Figure G-3-3-44 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - LOEC in Big Creek



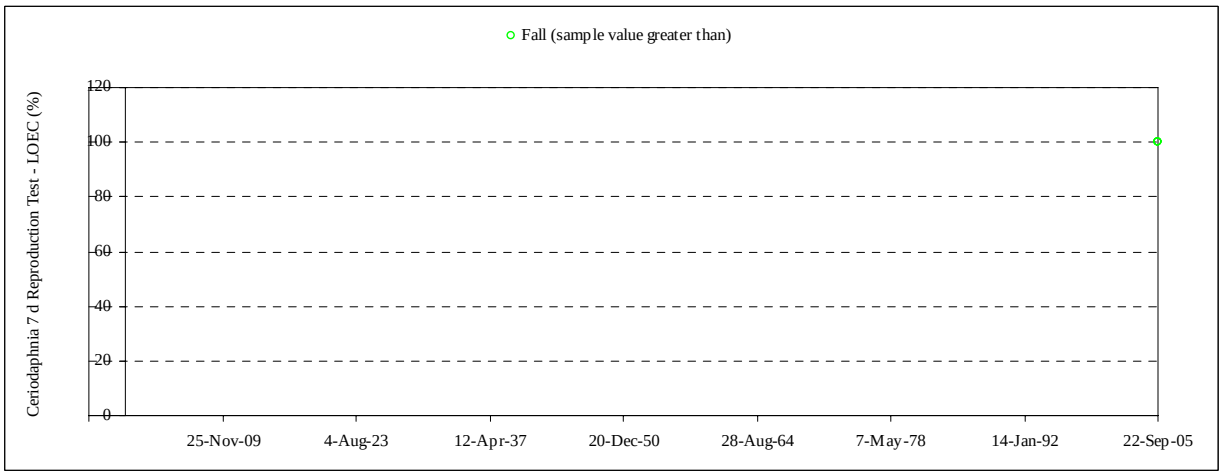


Figure G-3-3-45 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - NOEC in Big Creek

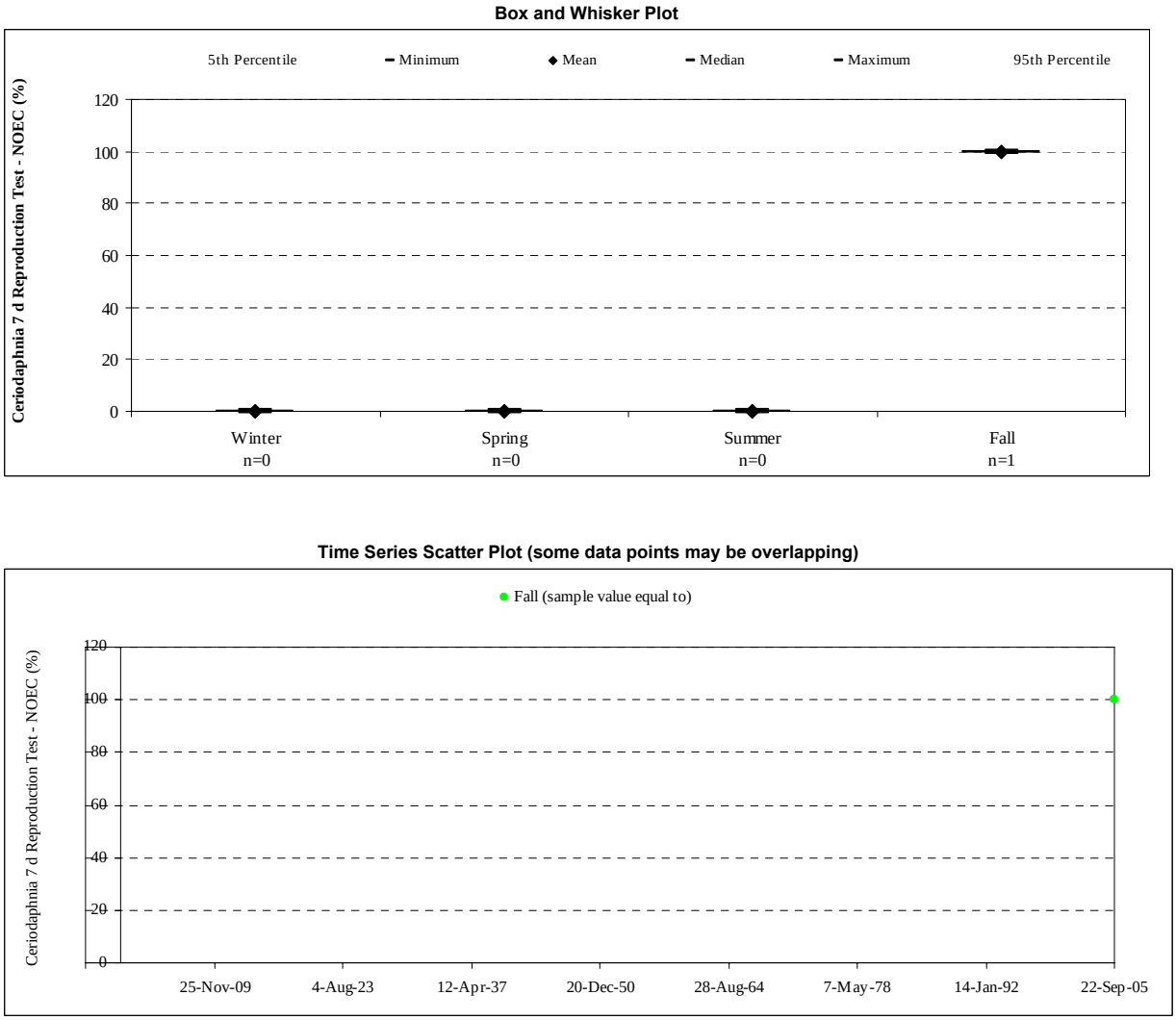
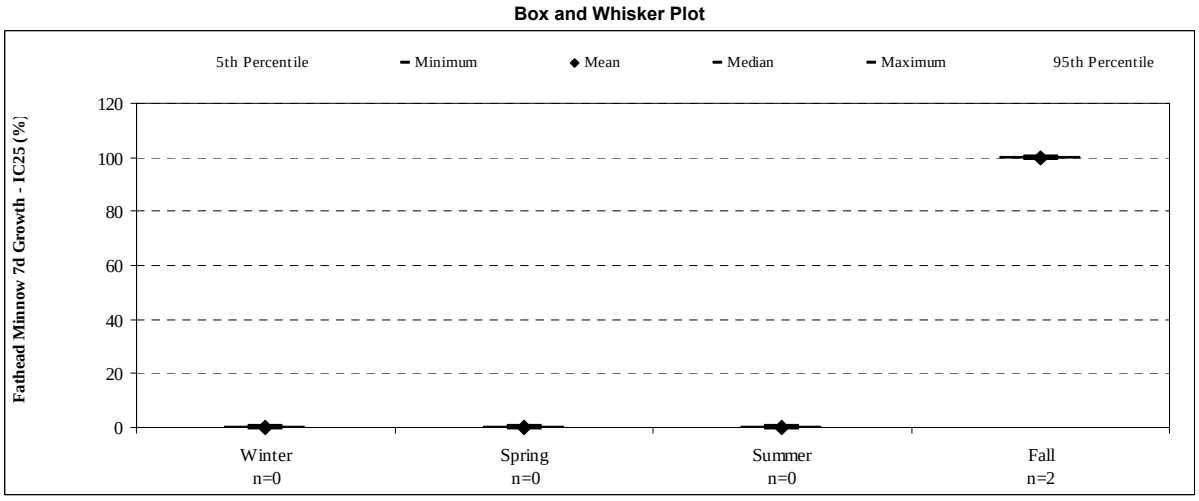


Figure G-3-3-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Big Creek



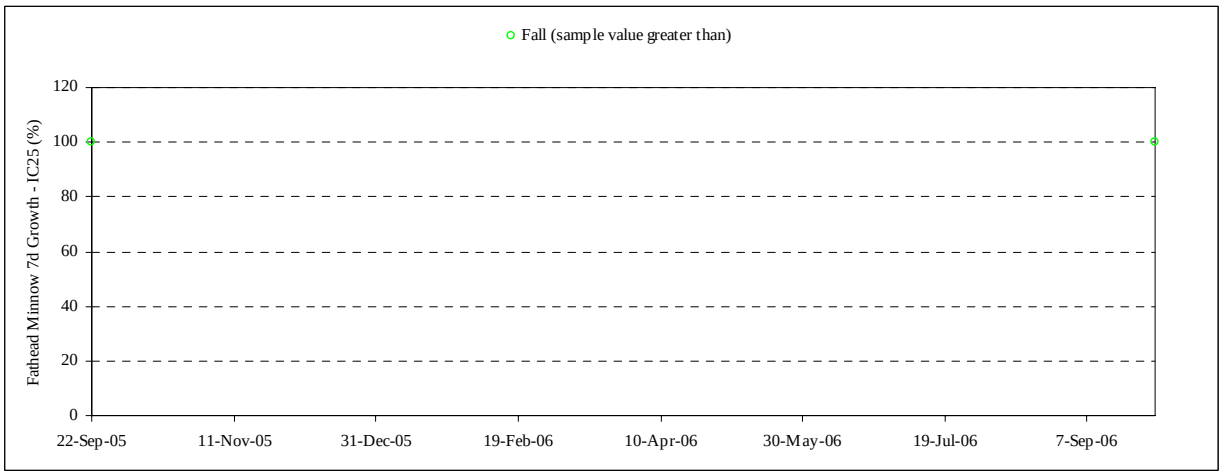
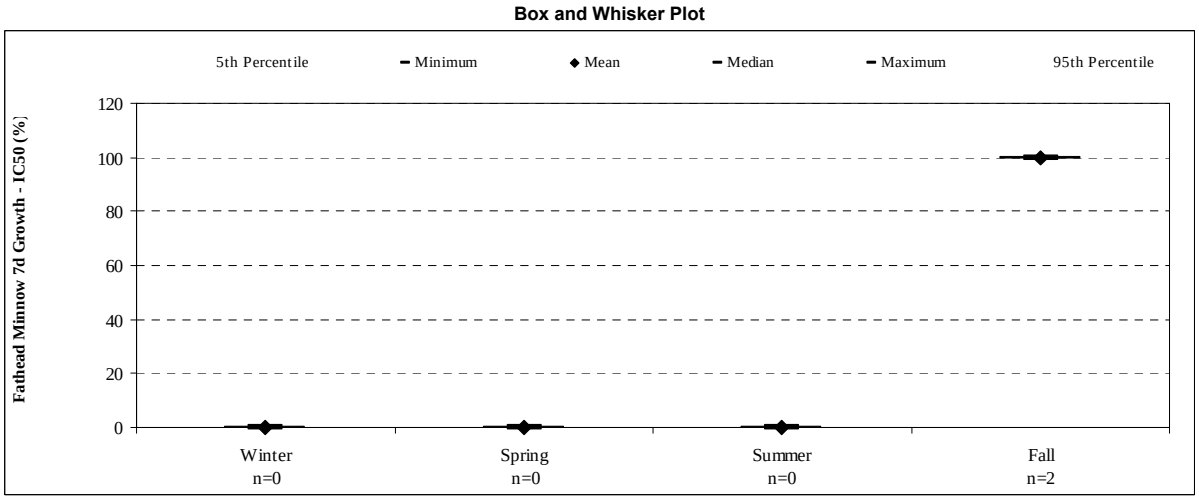


Figure G-3-3-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Big Creek



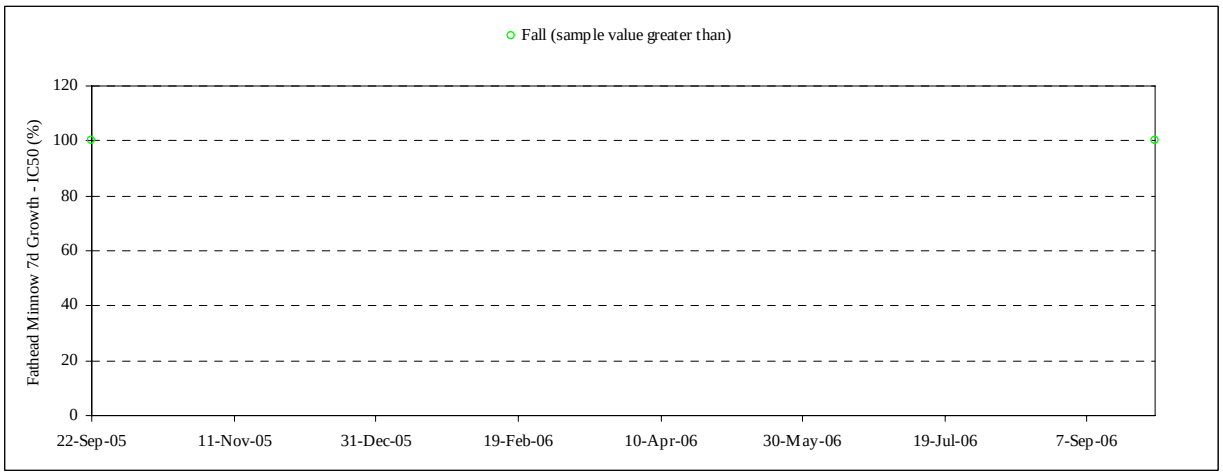


Figure G-3-3-52 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - LOEC in Big Creek

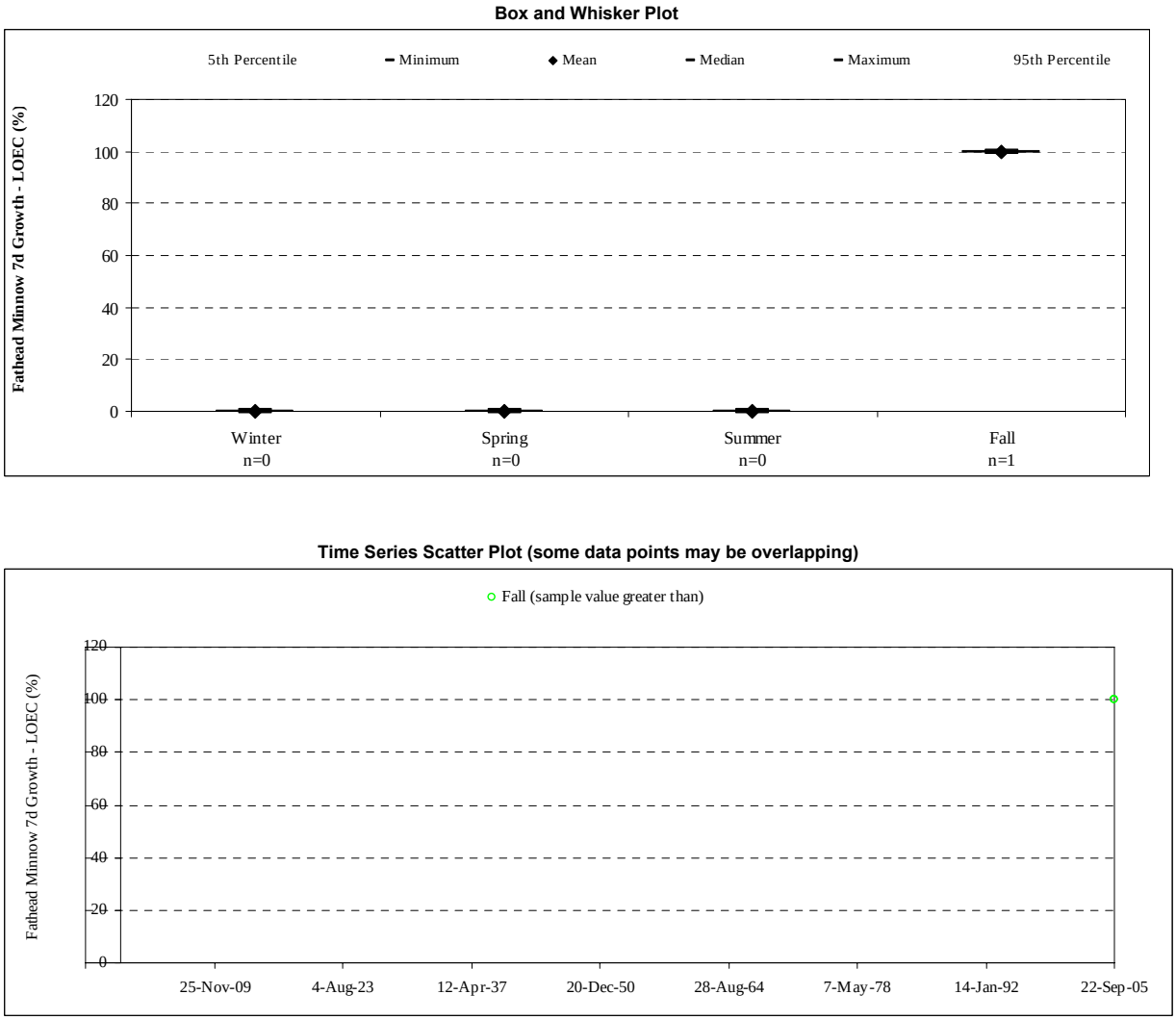


Figure G-3-3-53 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - NOEC in Big Creek

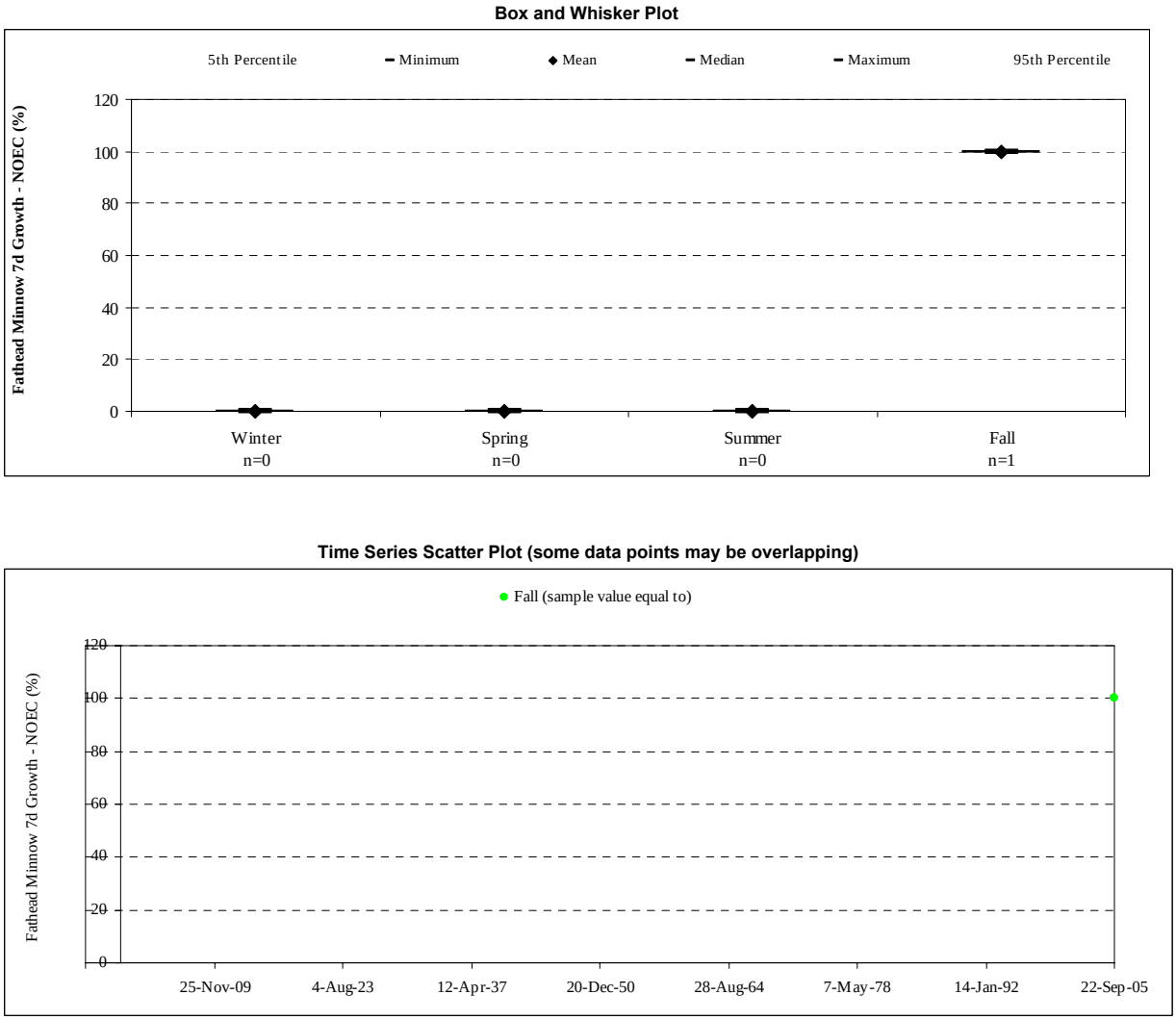
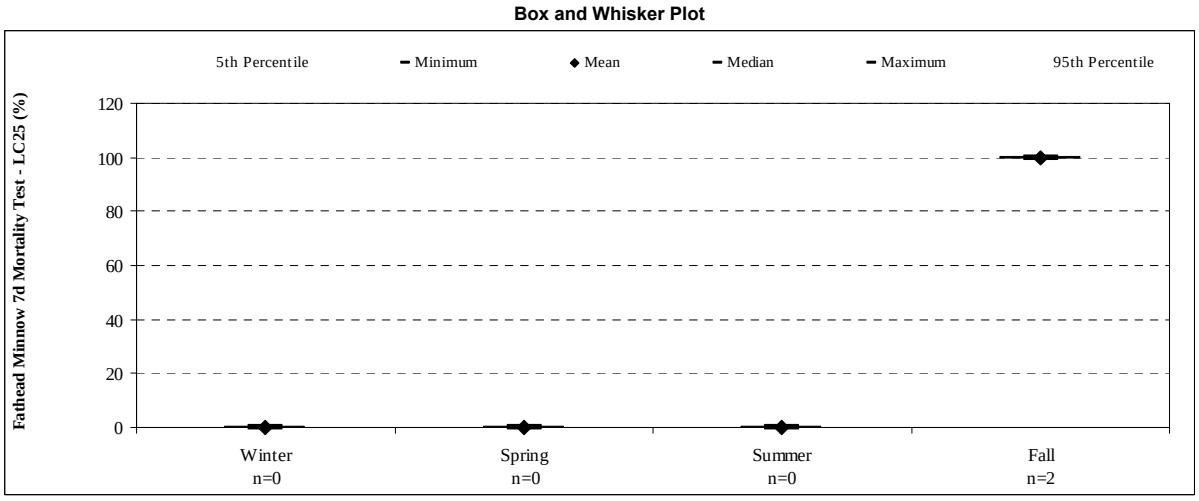


Figure G-3-3-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Big Creek



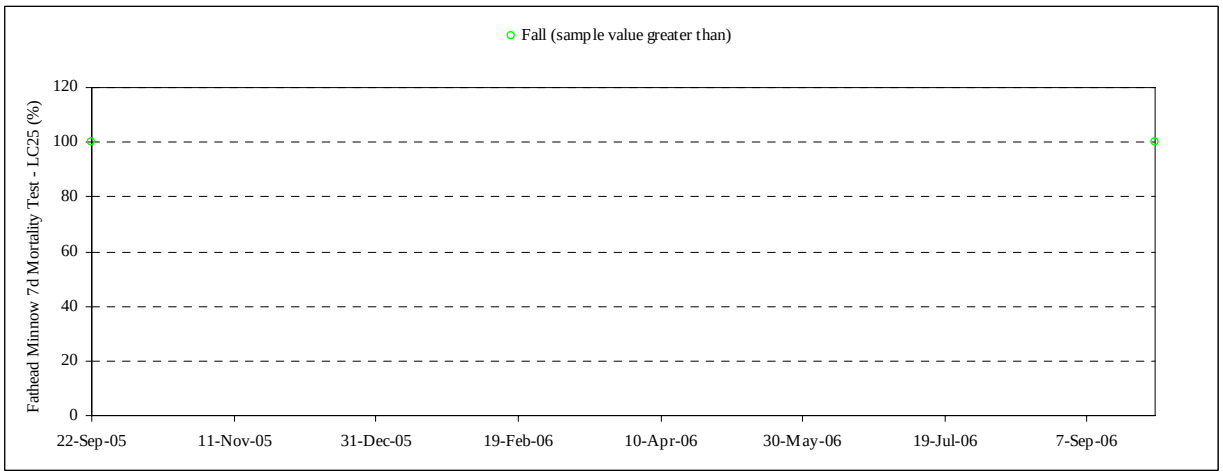
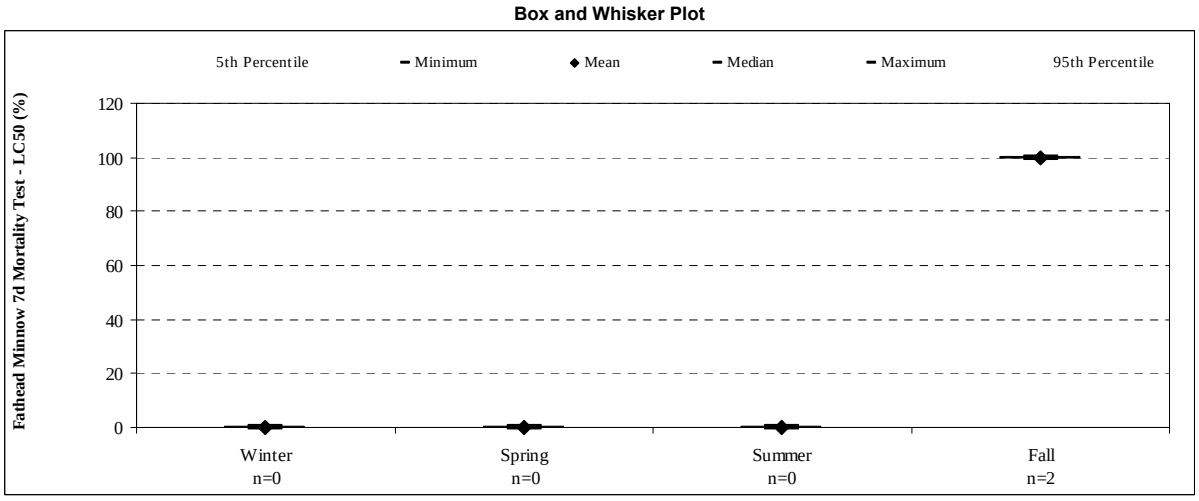


Figure G-3-3-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Big Creek



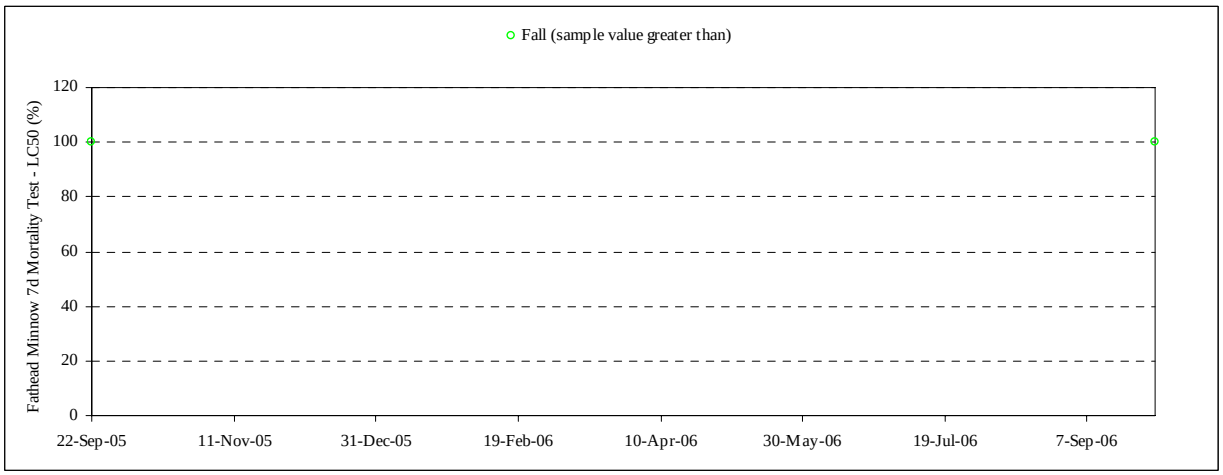
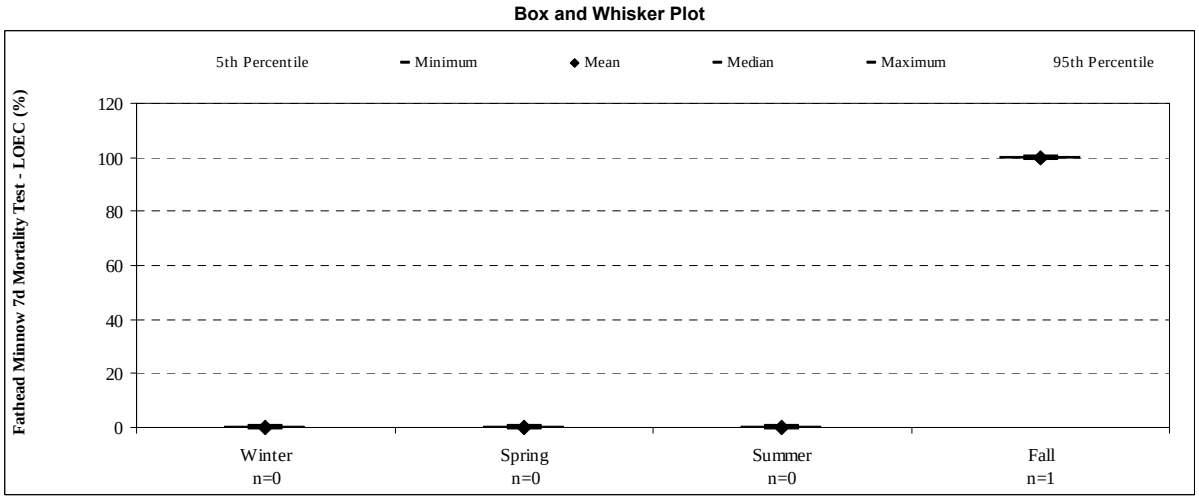


Figure G-3-3-56 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LOEC in Big Creek



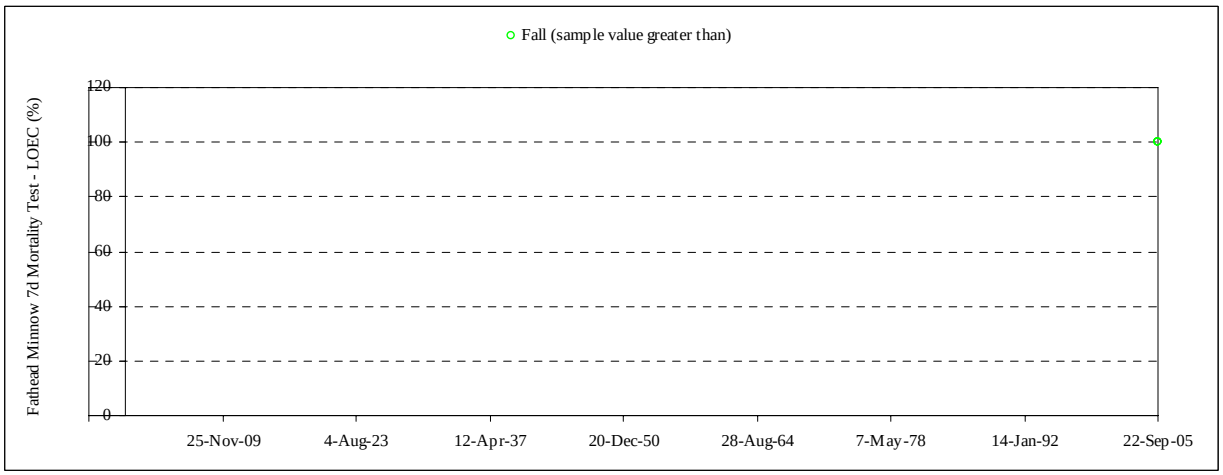
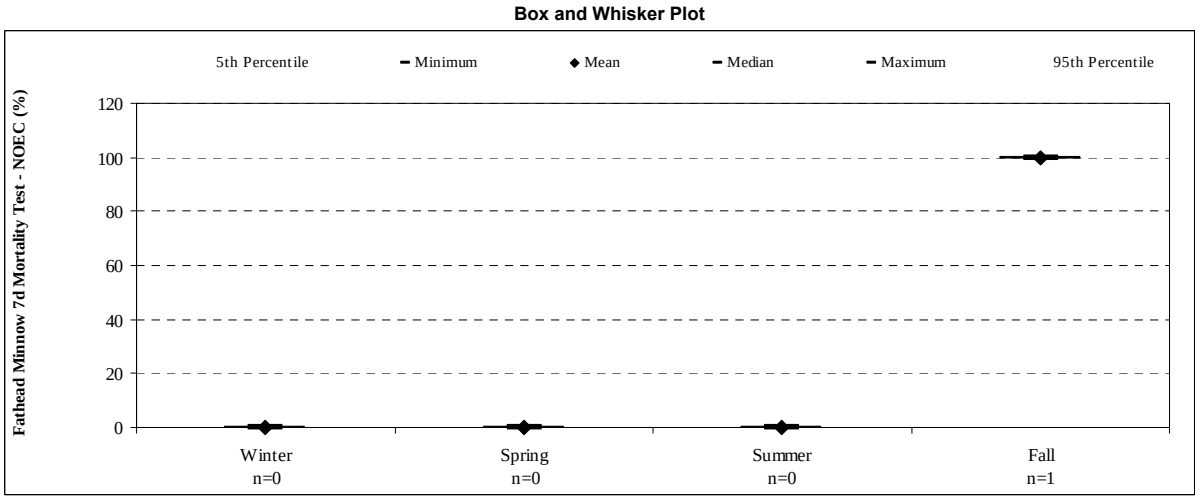


Figure G-3-3-57 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - NOEC in Big Creek



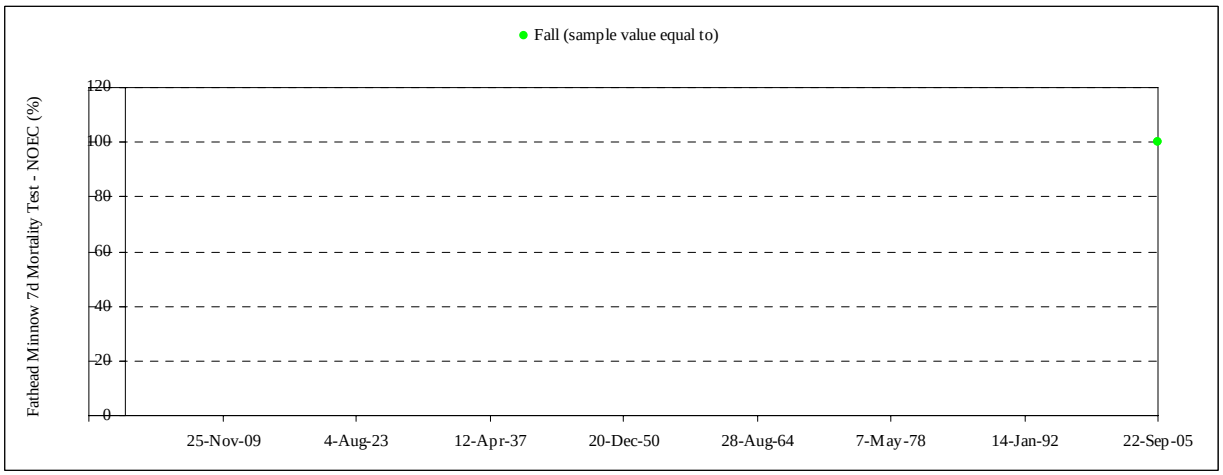
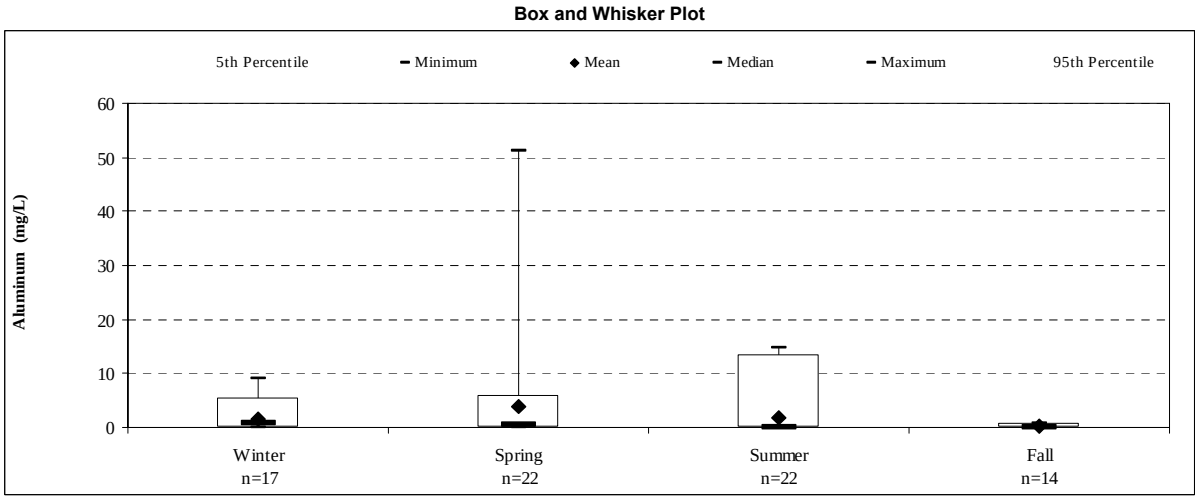


Figure G-3-3-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Big Creek



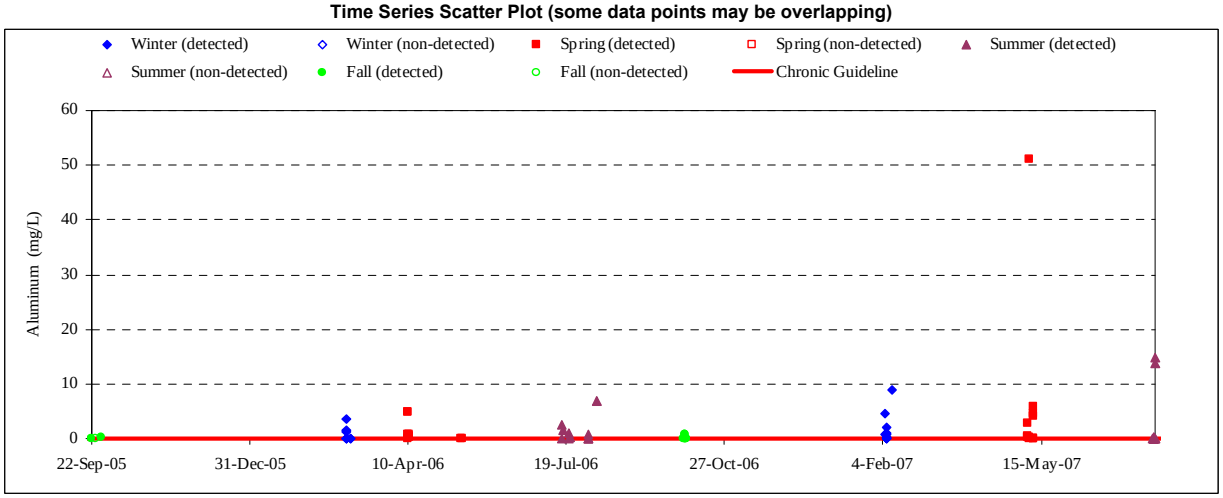
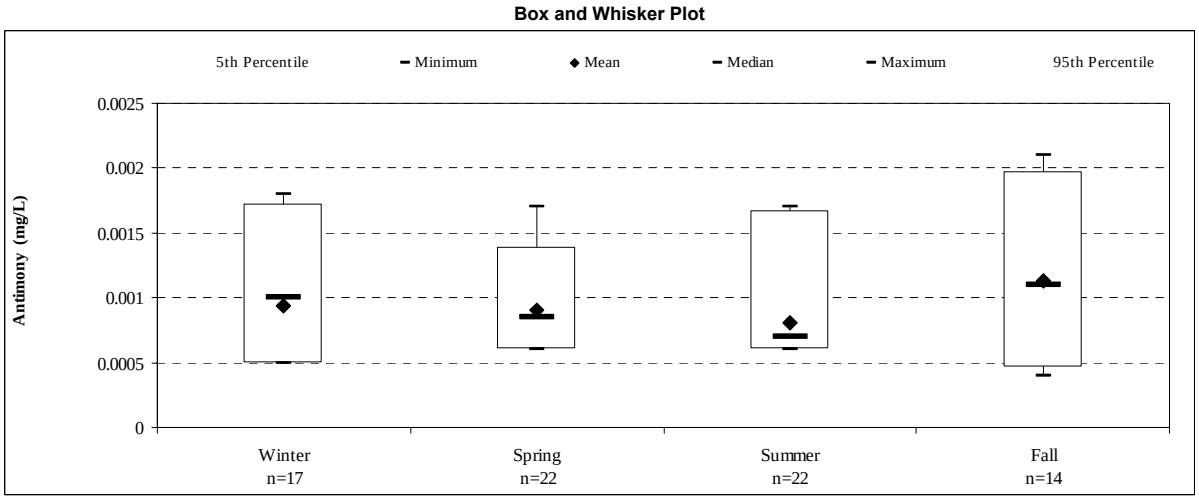


Figure G-3-3-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Big Creek



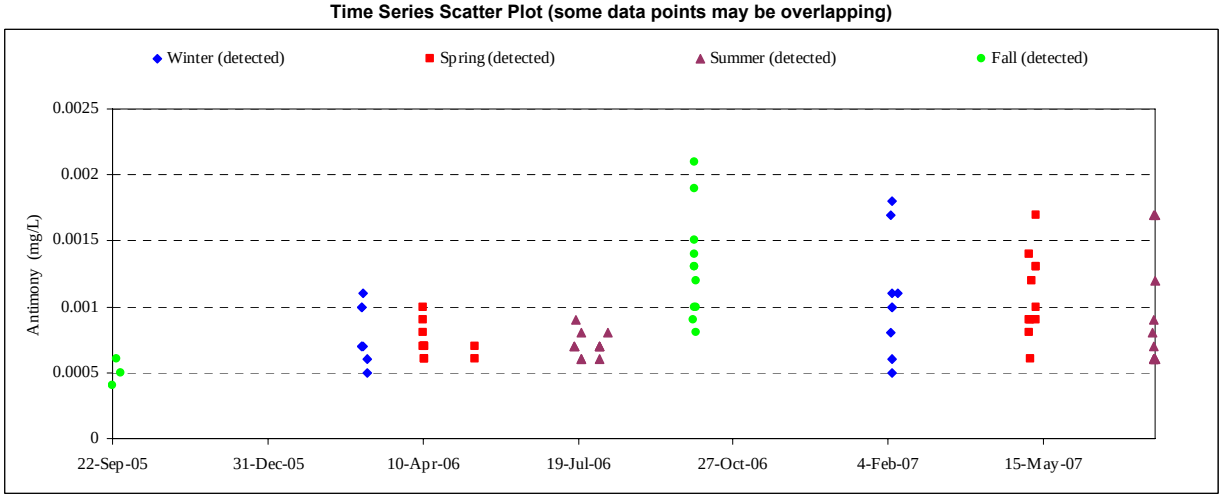
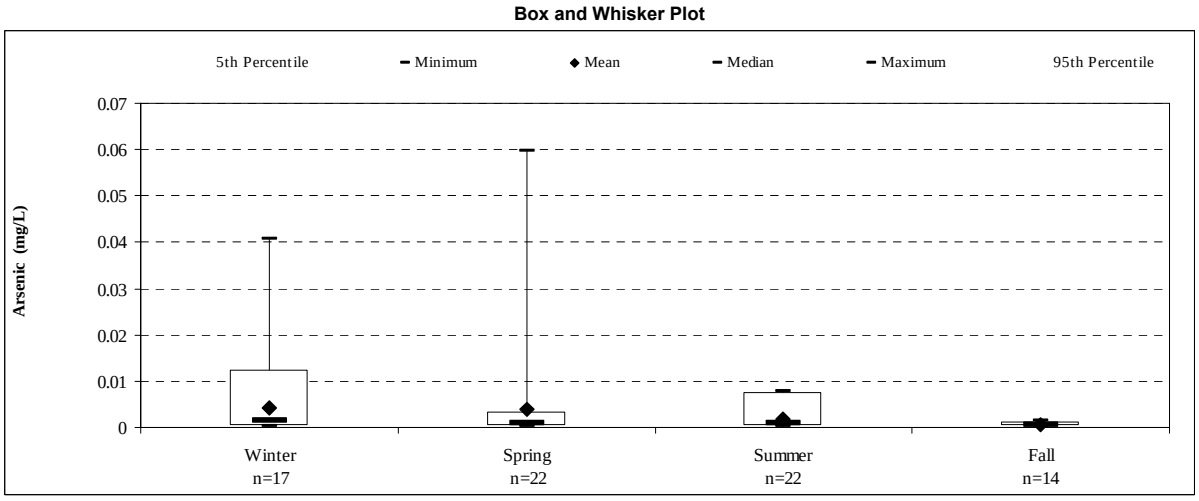


Figure G-3-3-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Big Creek



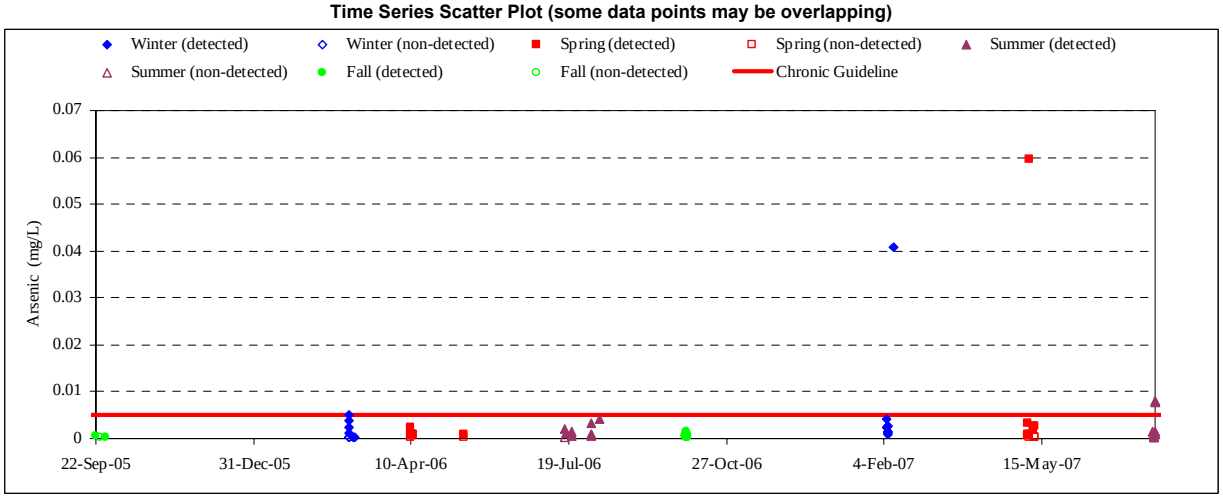
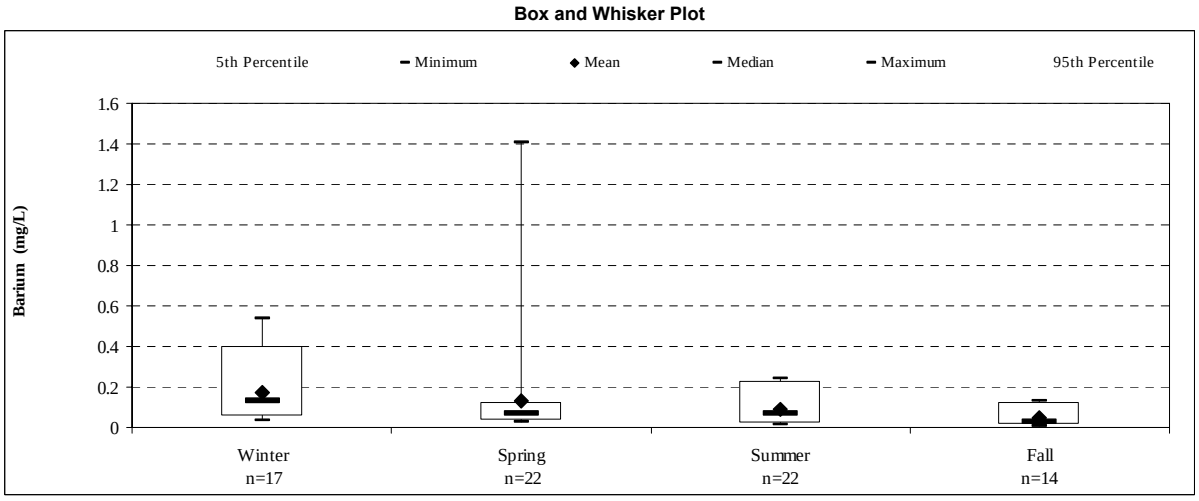


Figure G-3-3-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Big Creek



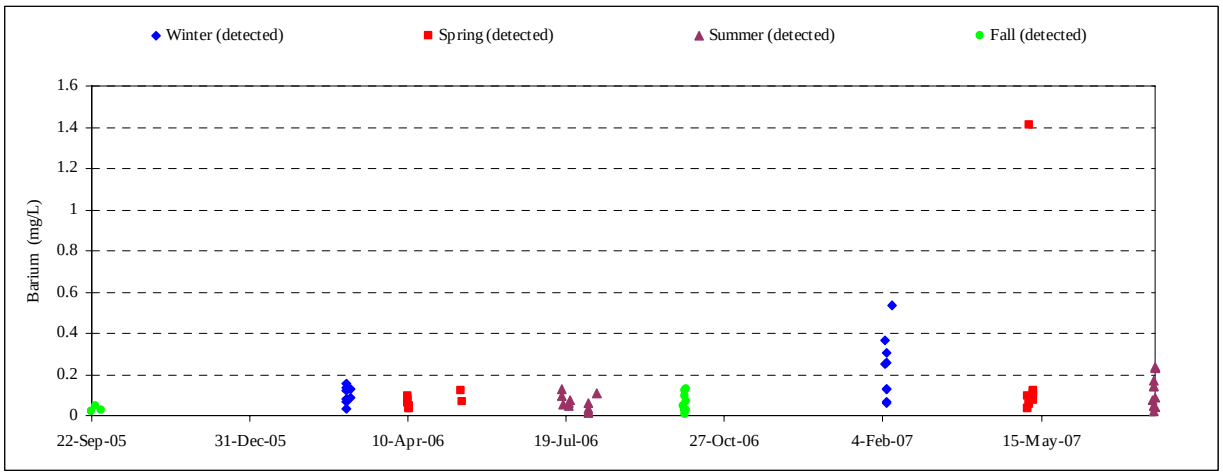
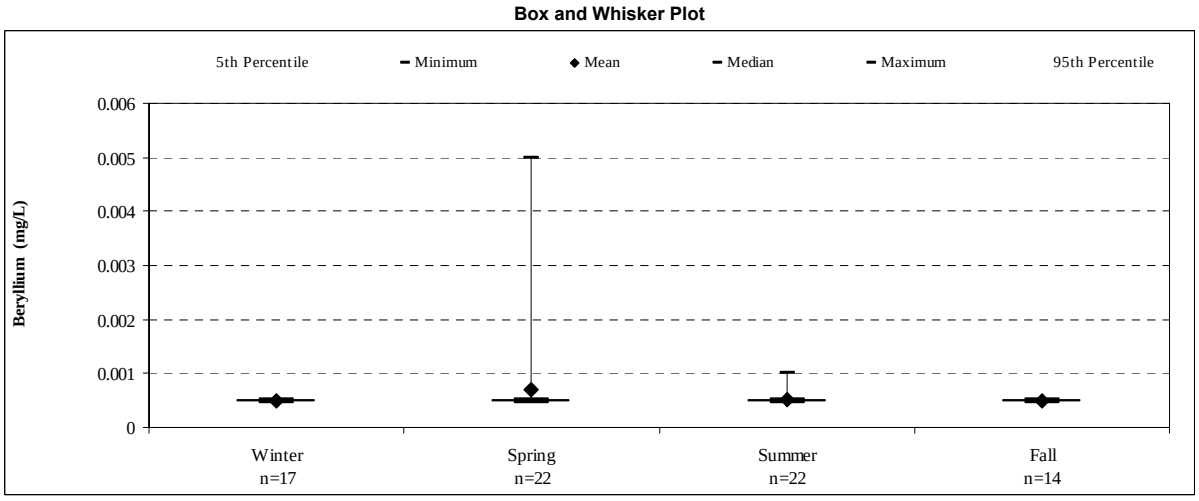


Figure G-3-3-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Big Creek



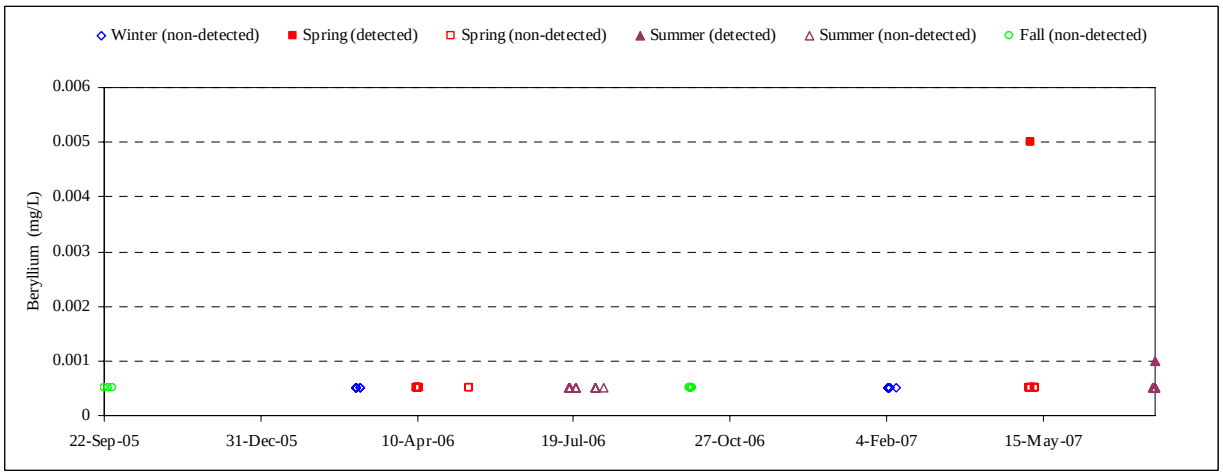
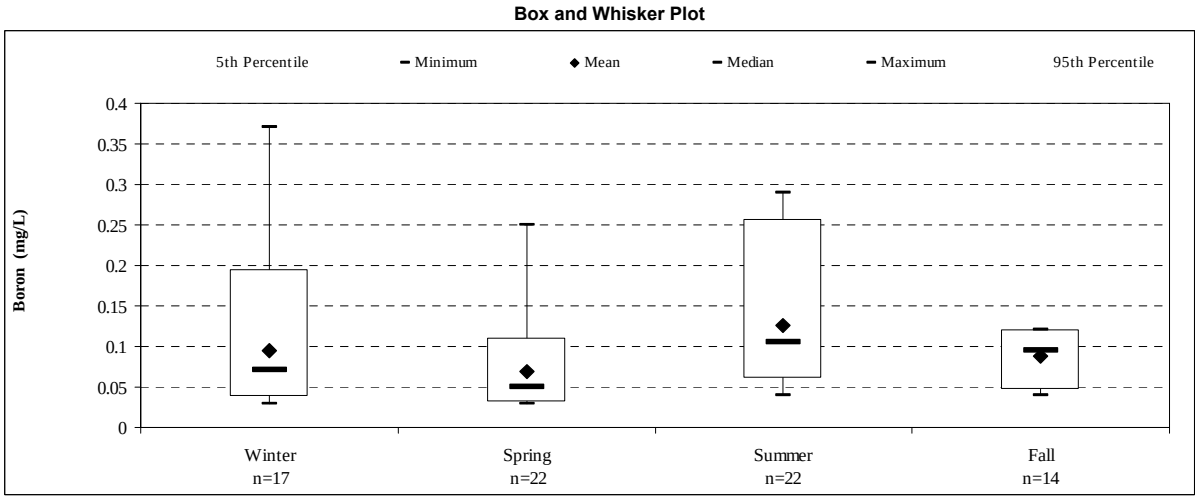


Figure G-3-3-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Big Creek



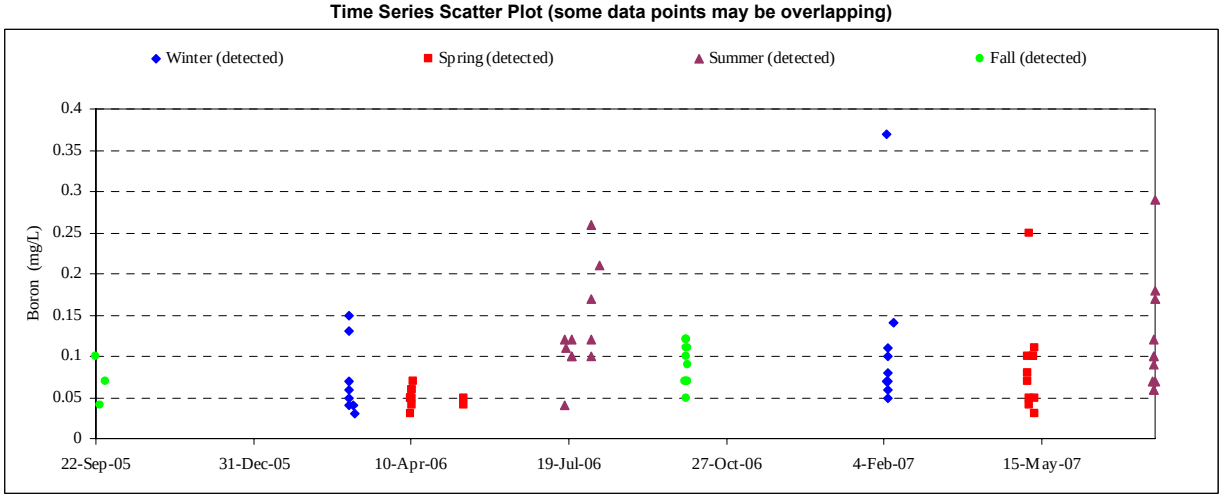
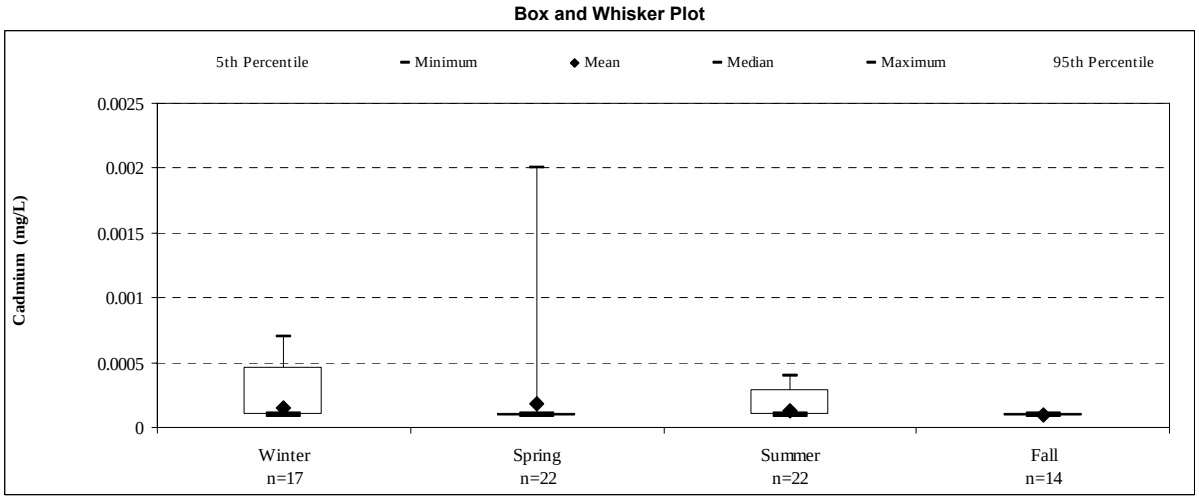


Figure G-3-3-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Big Creek



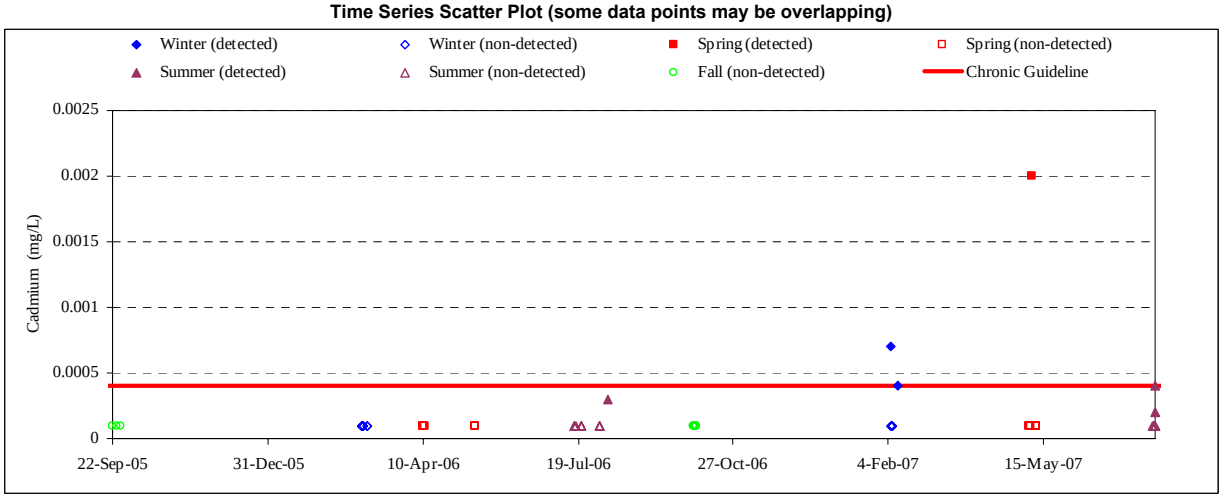


Figure G-3-3-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Big Creek

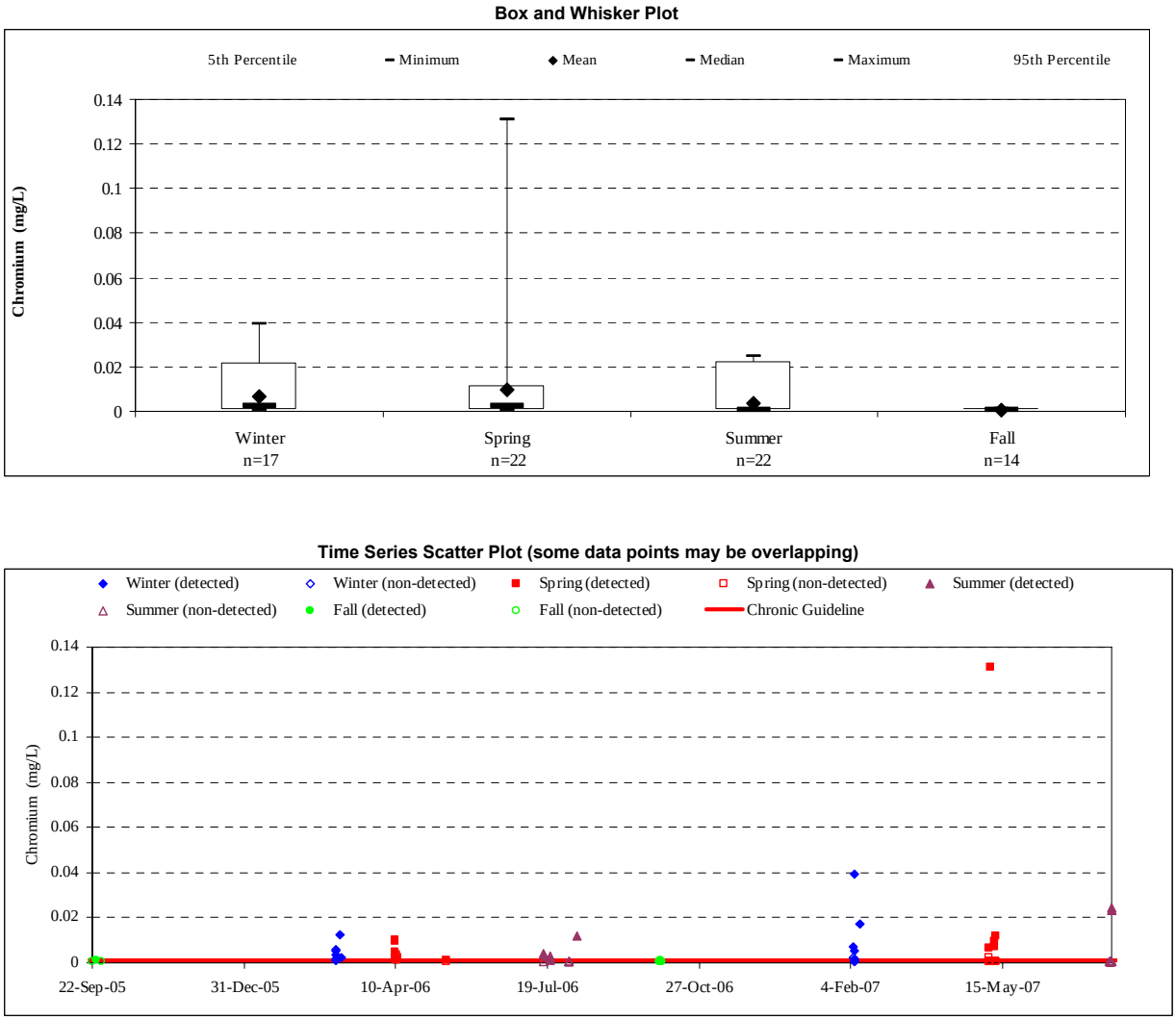
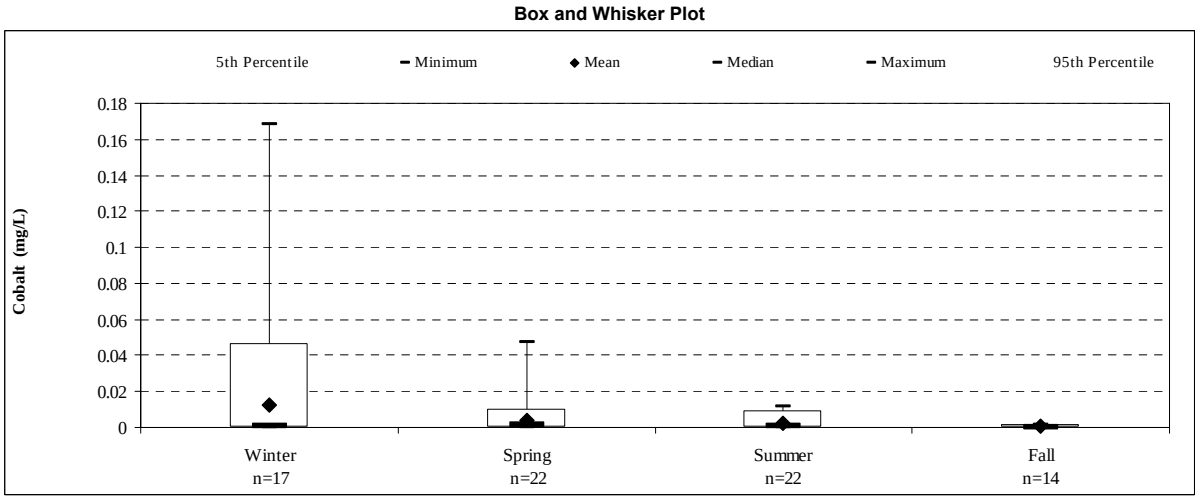


Figure G-3-3-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Big Creek



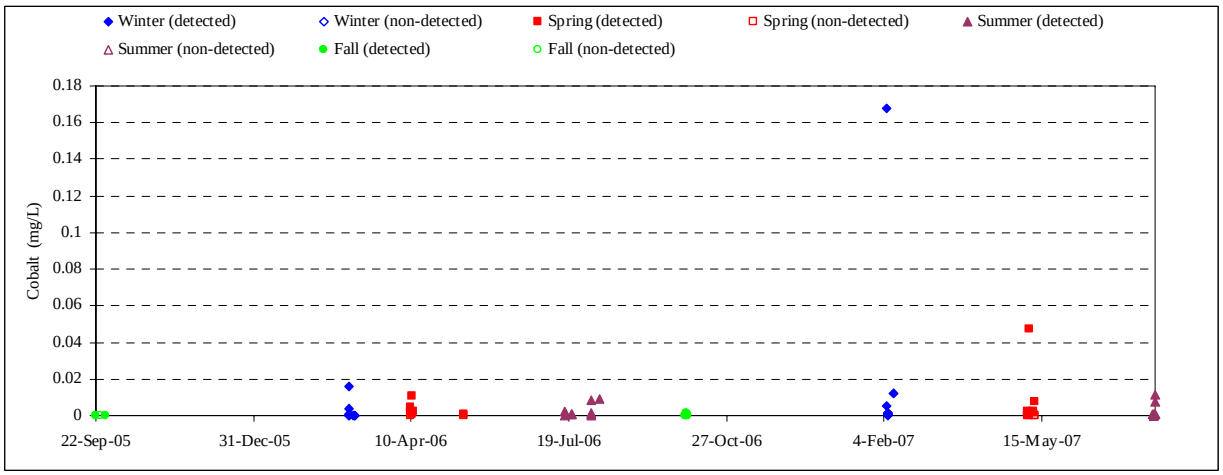
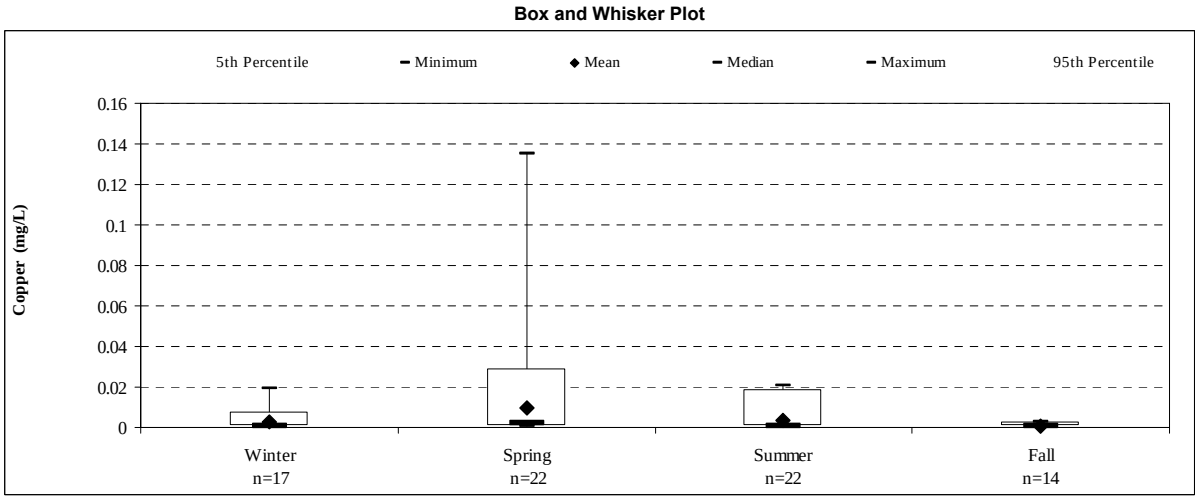


Figure G-3-3-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Big Creek



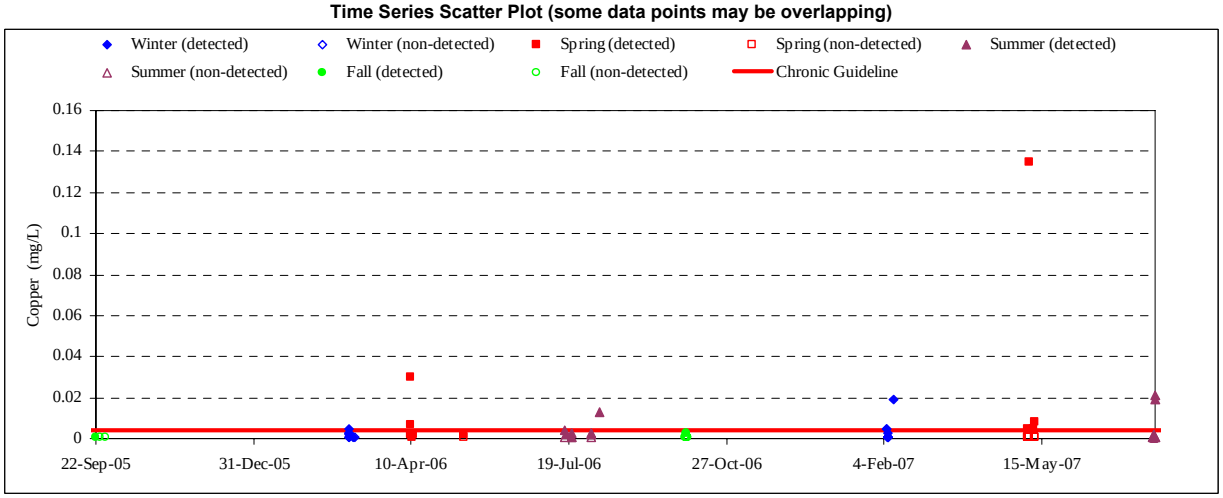
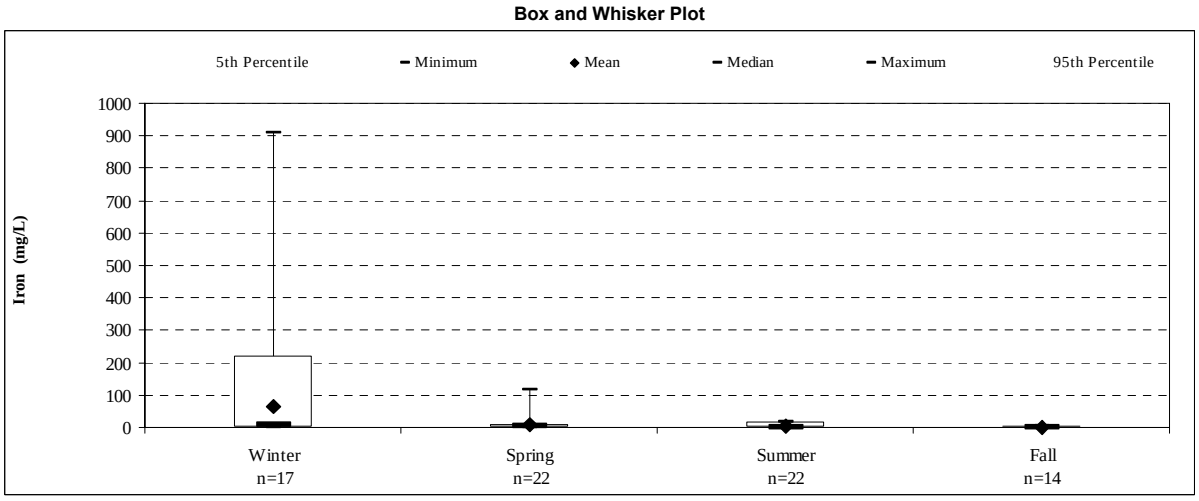


Figure G-3-3-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Big Creek



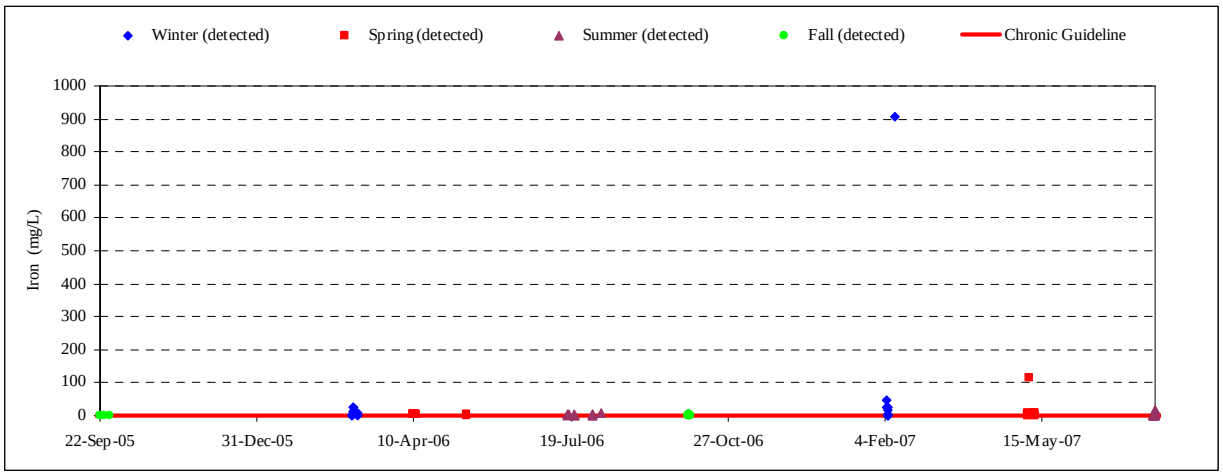
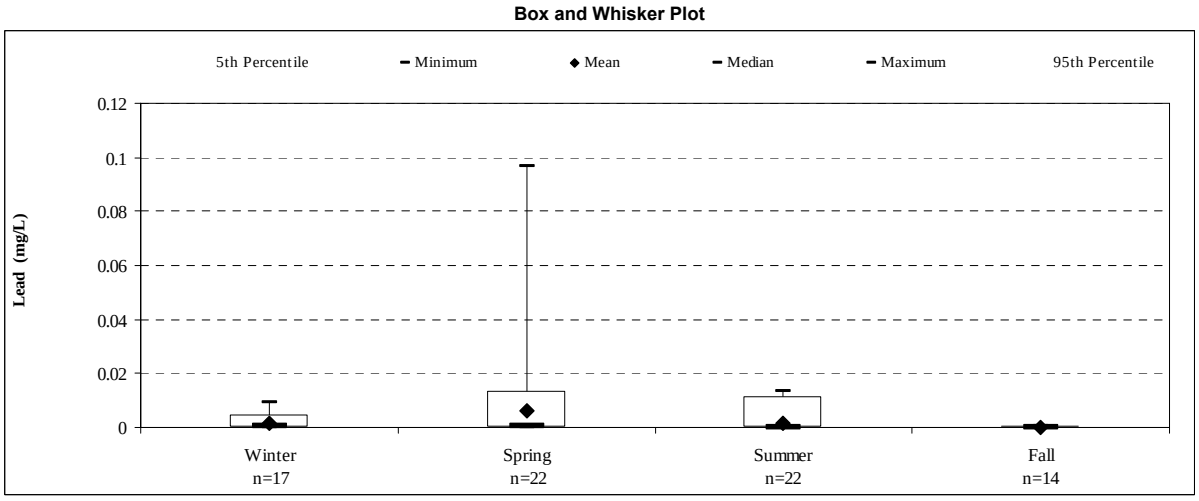


Figure G-3-3-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Big Creek



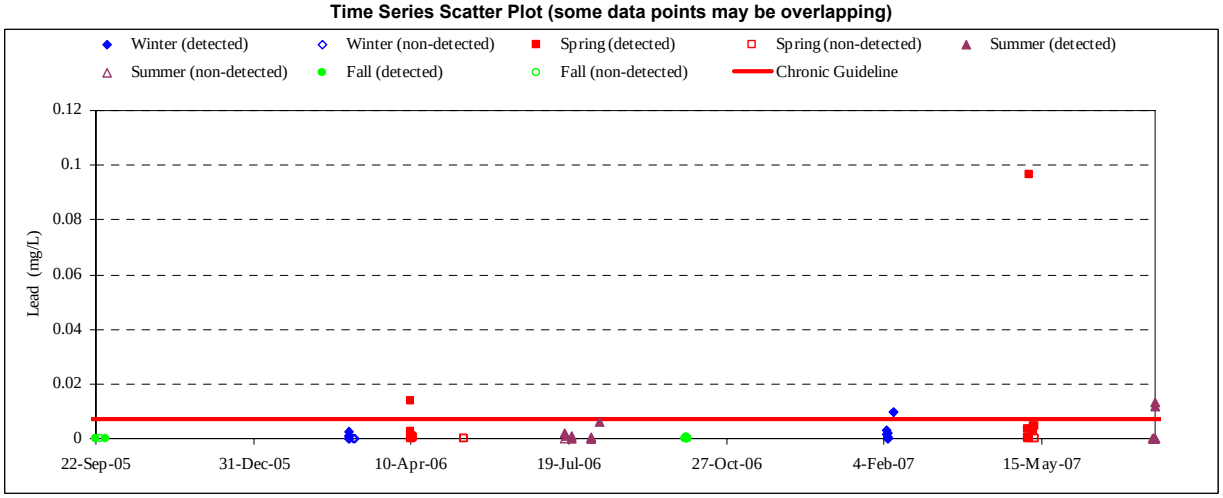
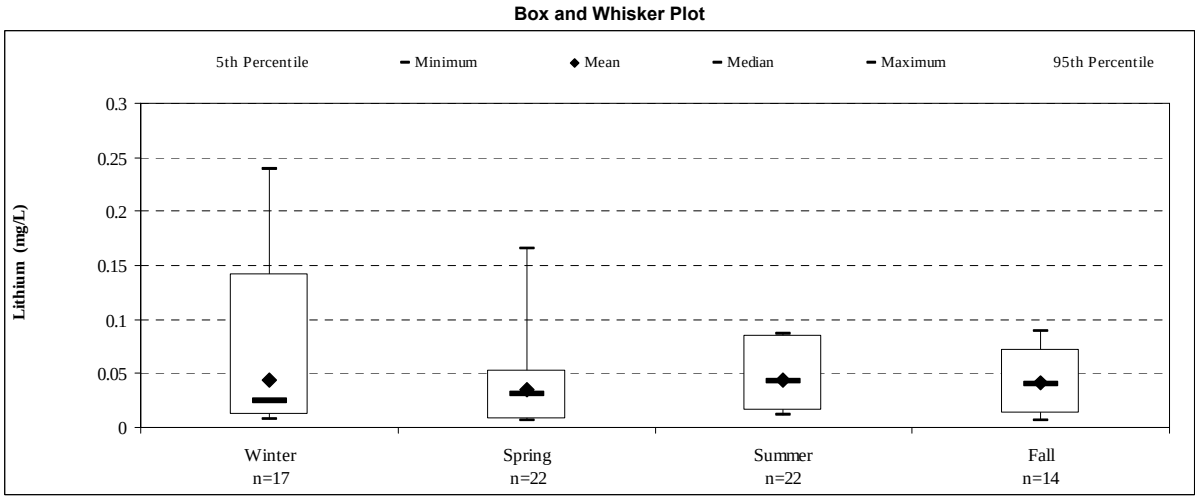


Figure G-3-3-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Big Creek



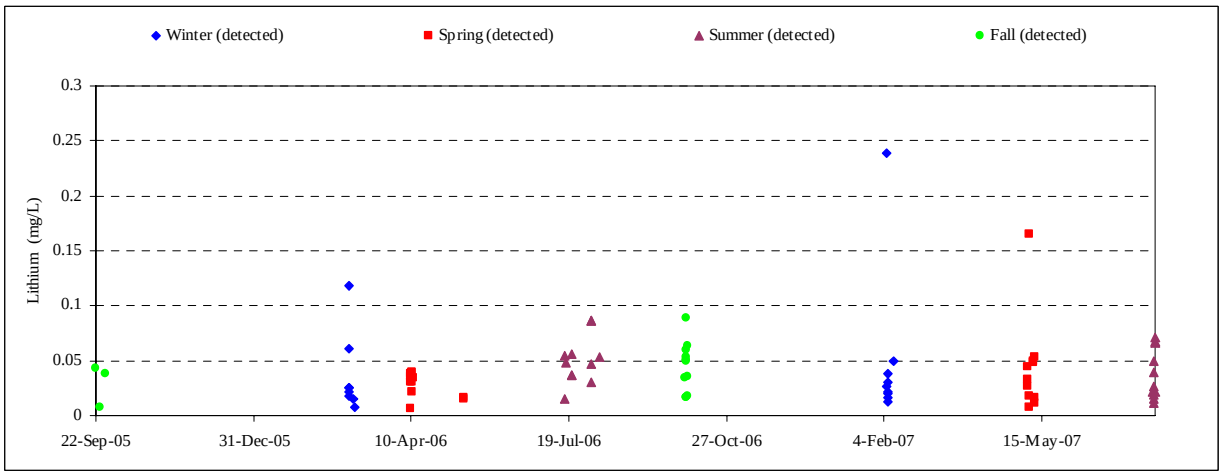
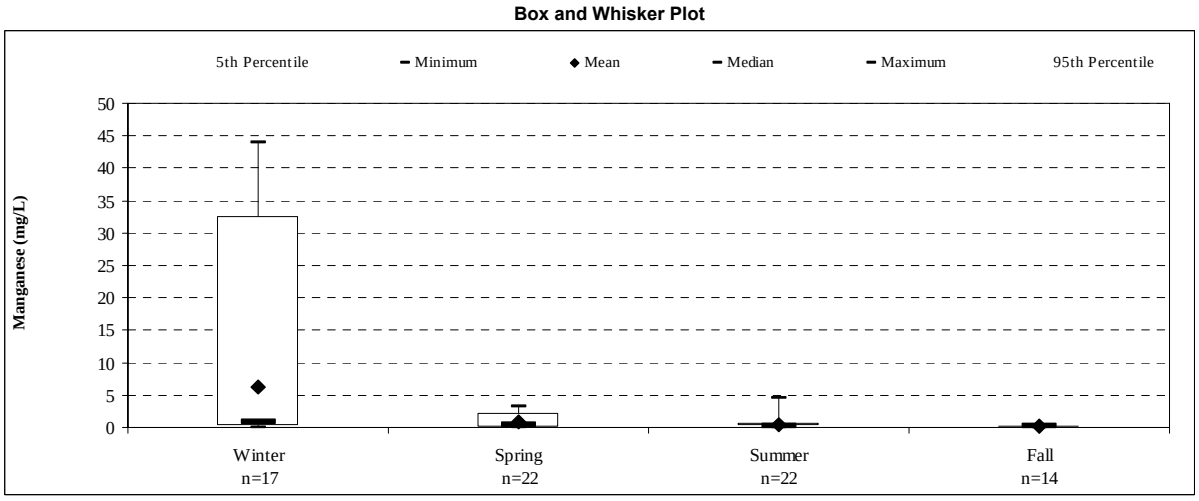


Figure G-3-3-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Big Creek



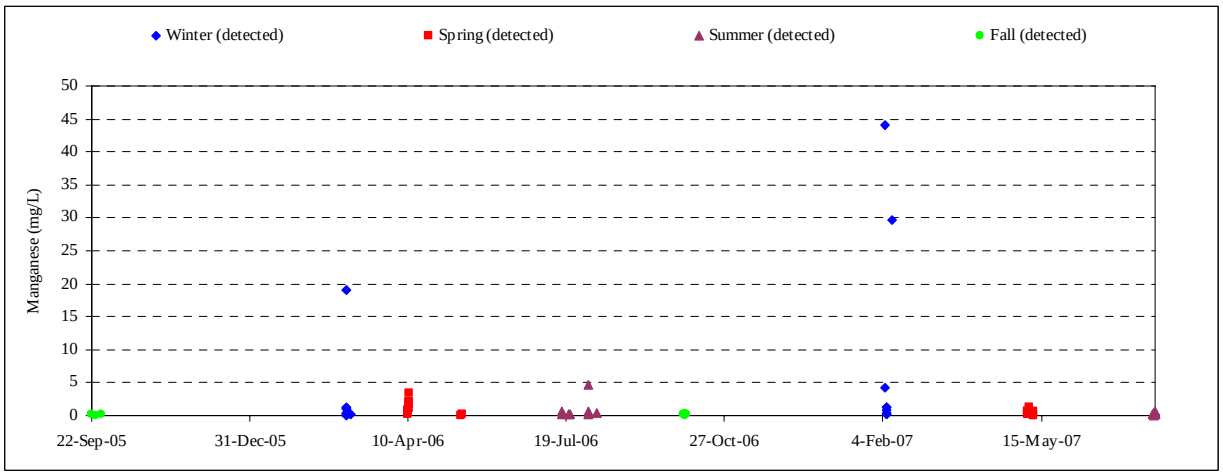
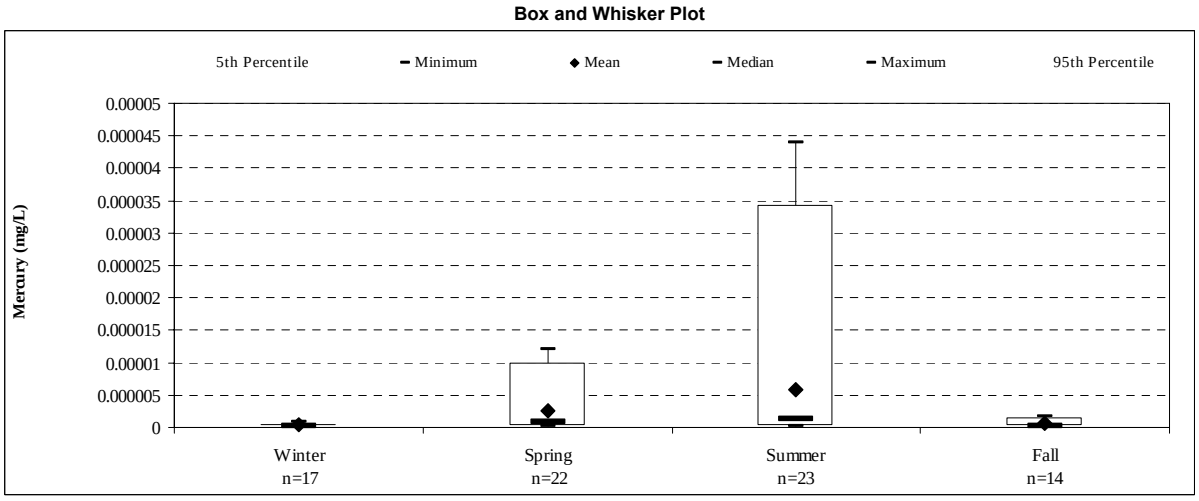


Figure G-3-3-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Big Creek



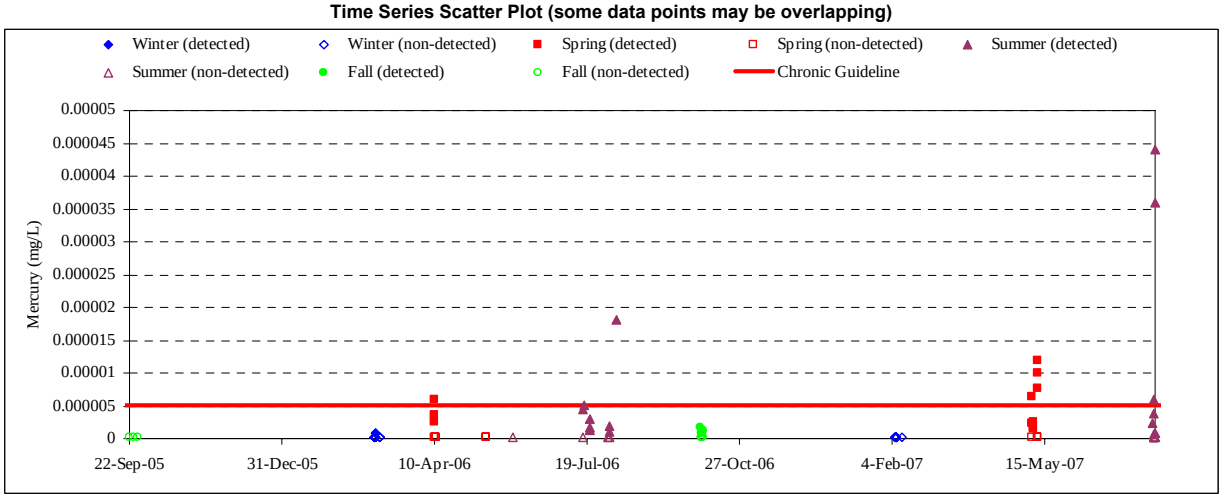
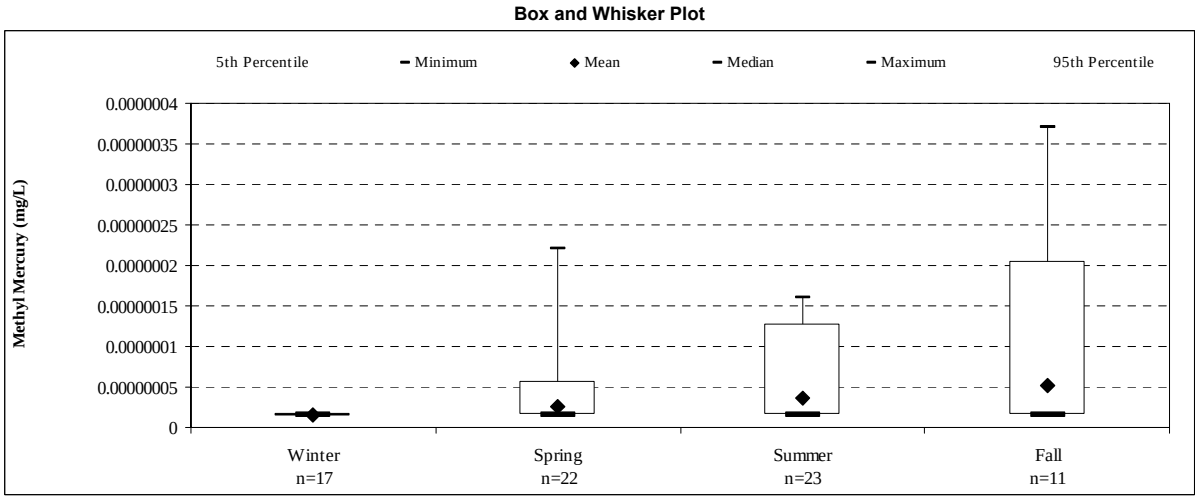


Figure G-3-3-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Big Creek



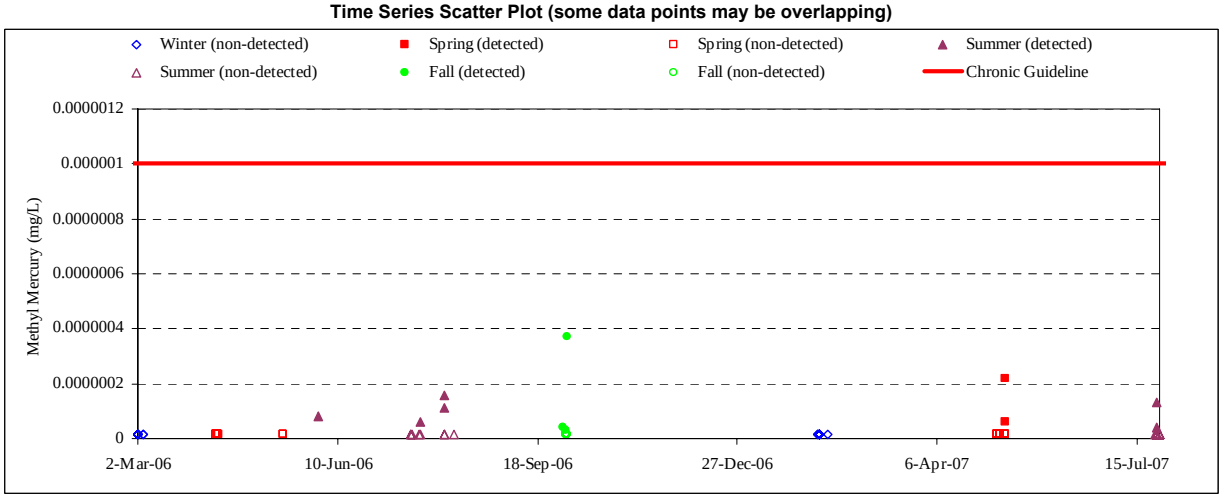
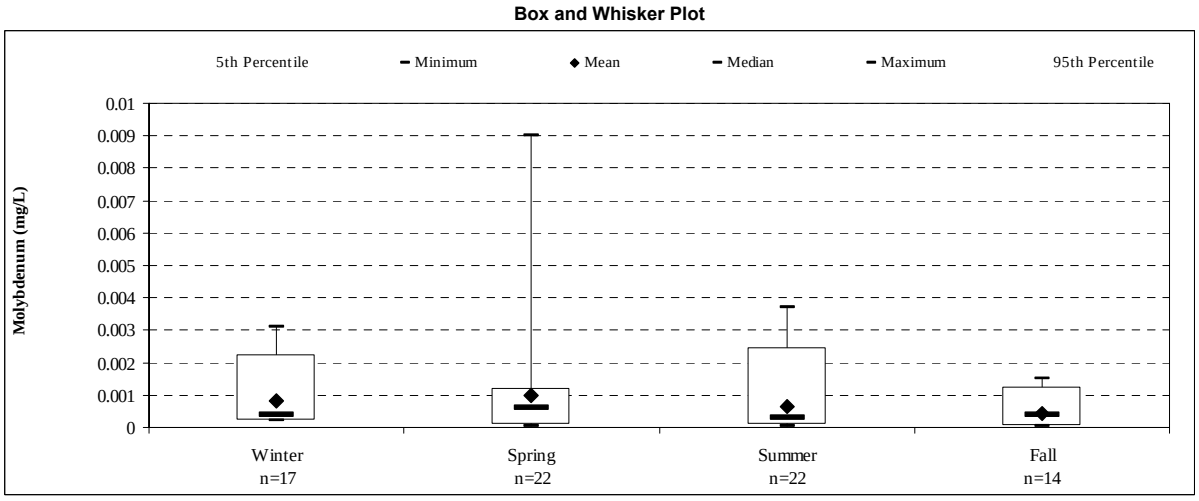


Figure G-3-3-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Big Creek



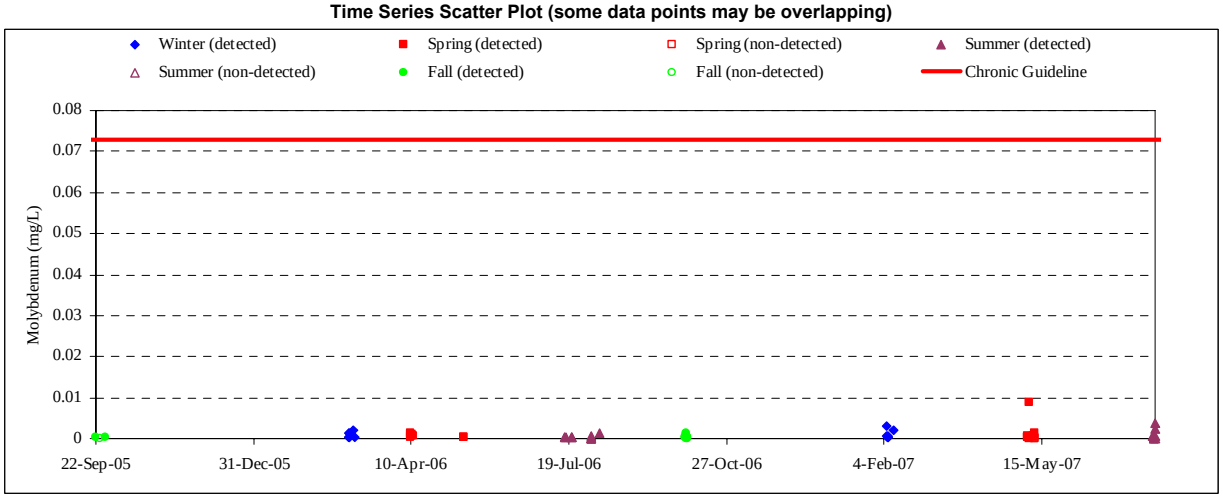


Figure G-3-3-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Big Creek

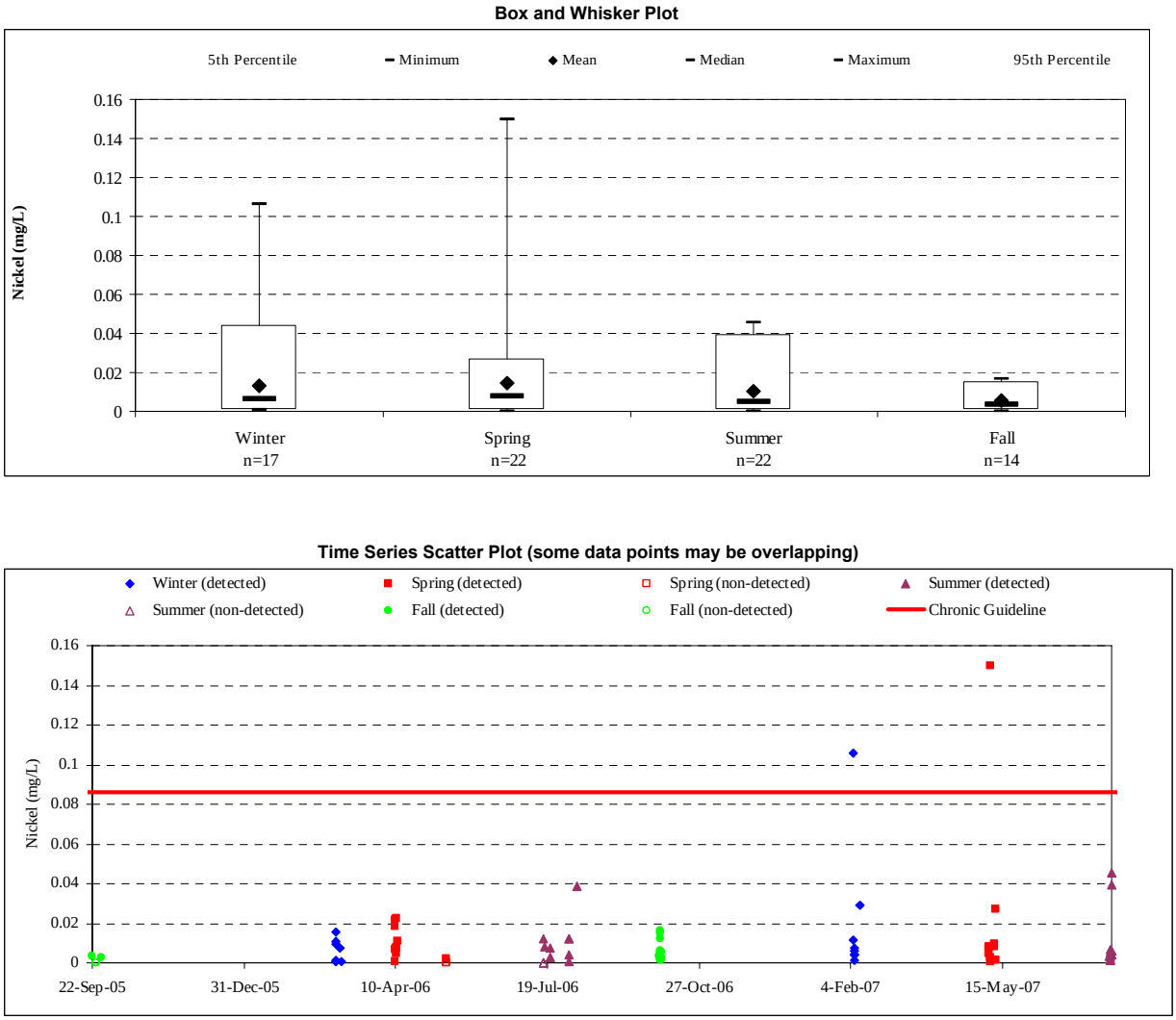
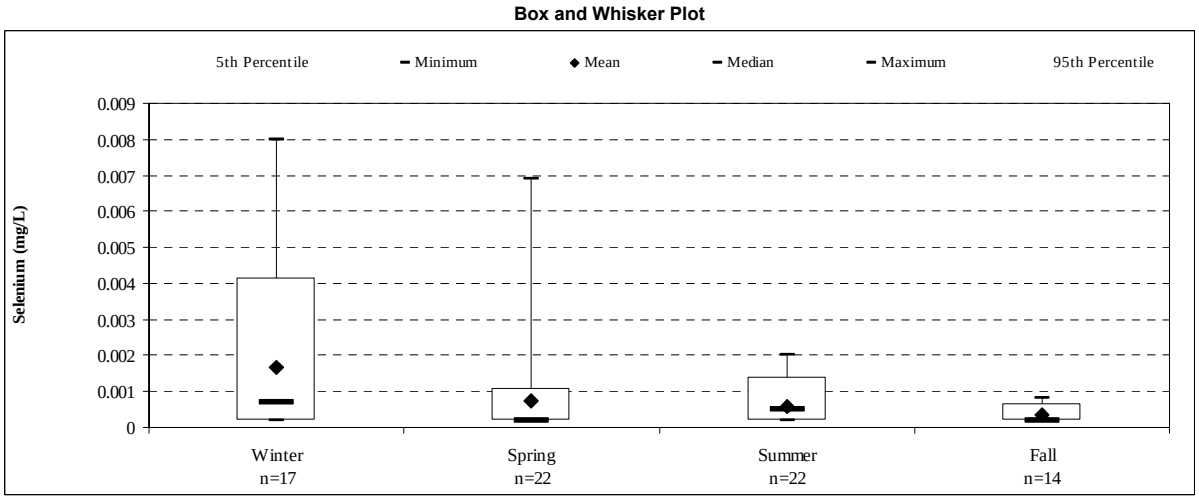


Figure G-3-3-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Big Creek



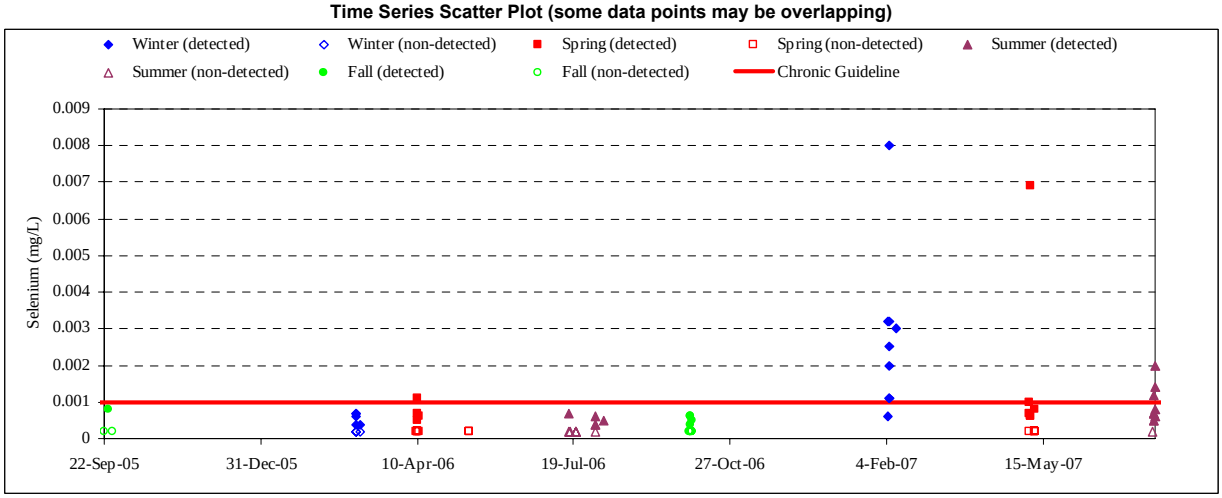
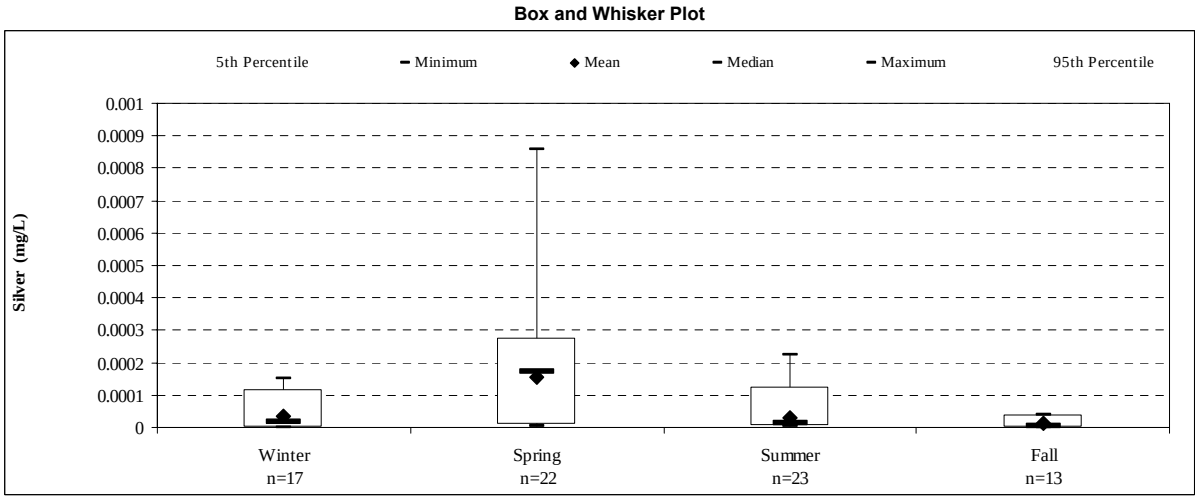


Figure G-3-3-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Big Creek



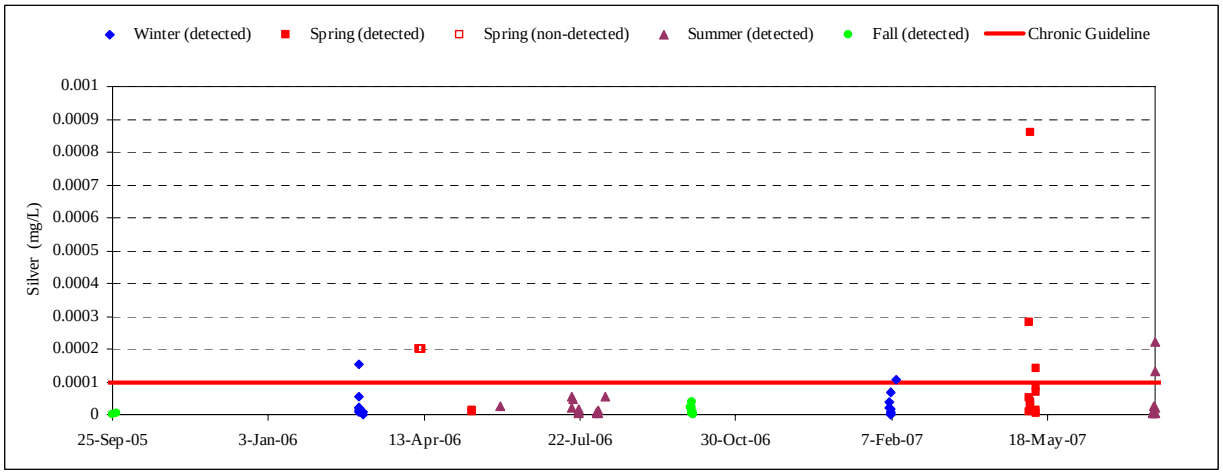
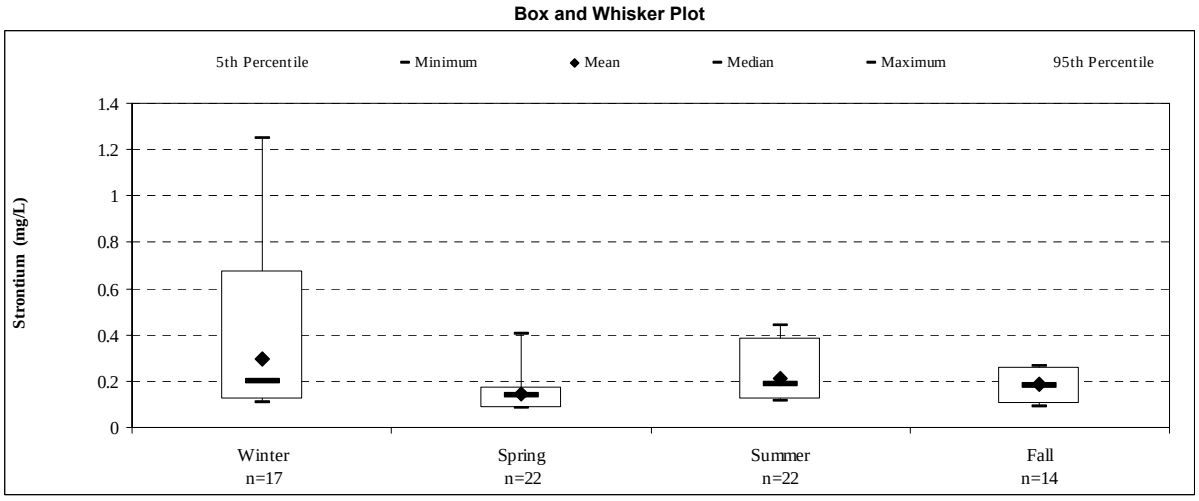


Figure G-3-3-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Big Creek



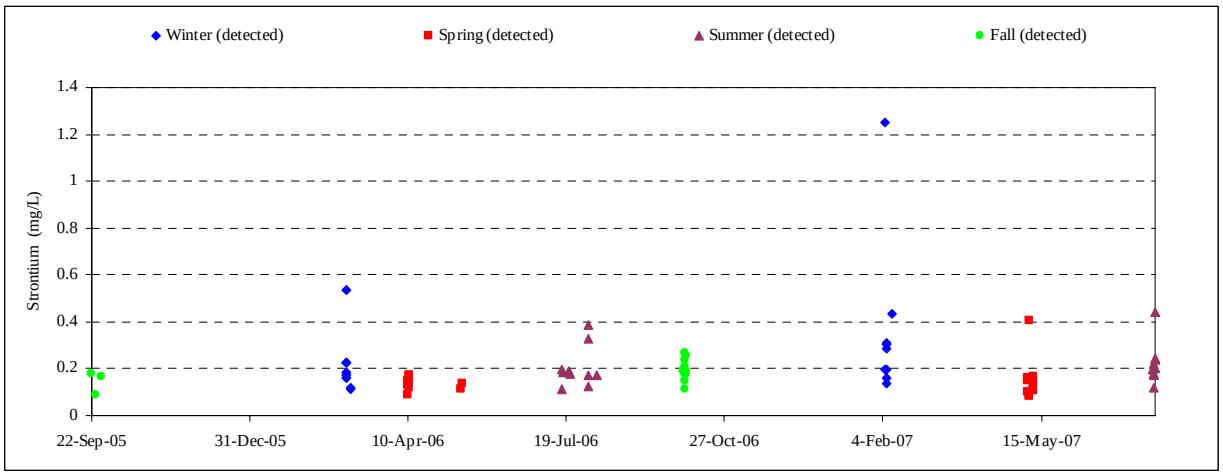
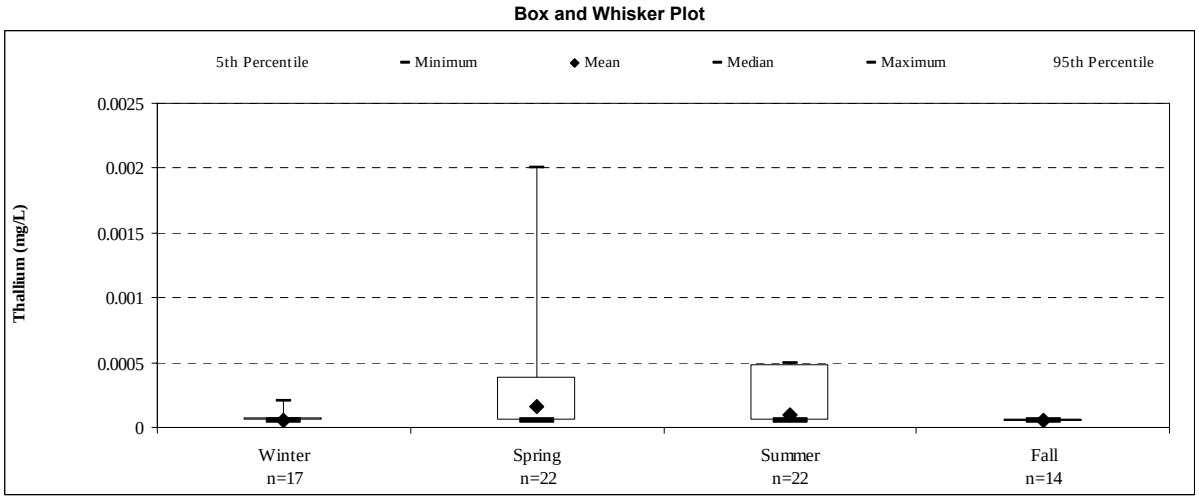


Figure G-3-3-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Big Creek



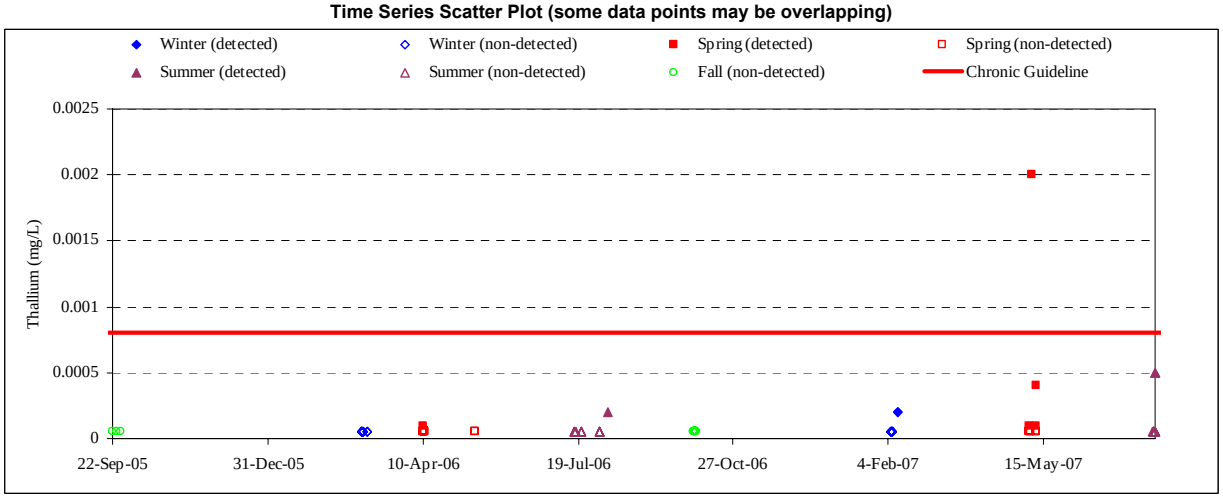
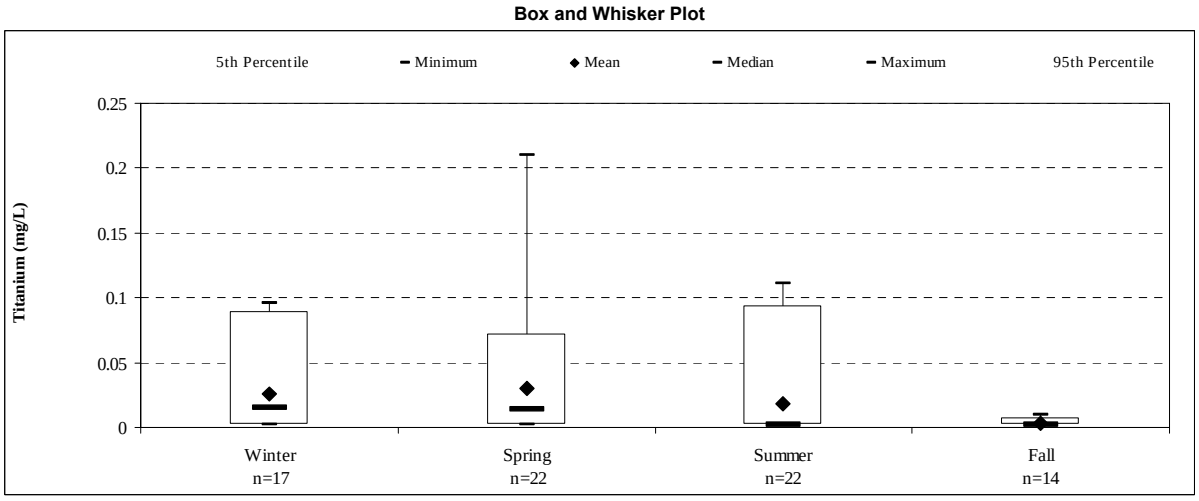


Figure G-3-3-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Big Creek



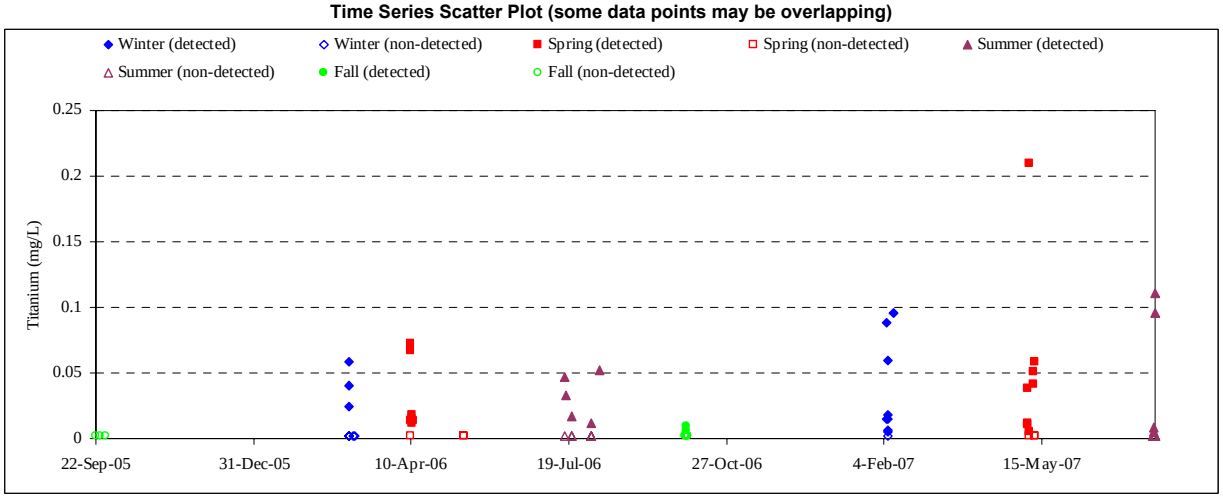
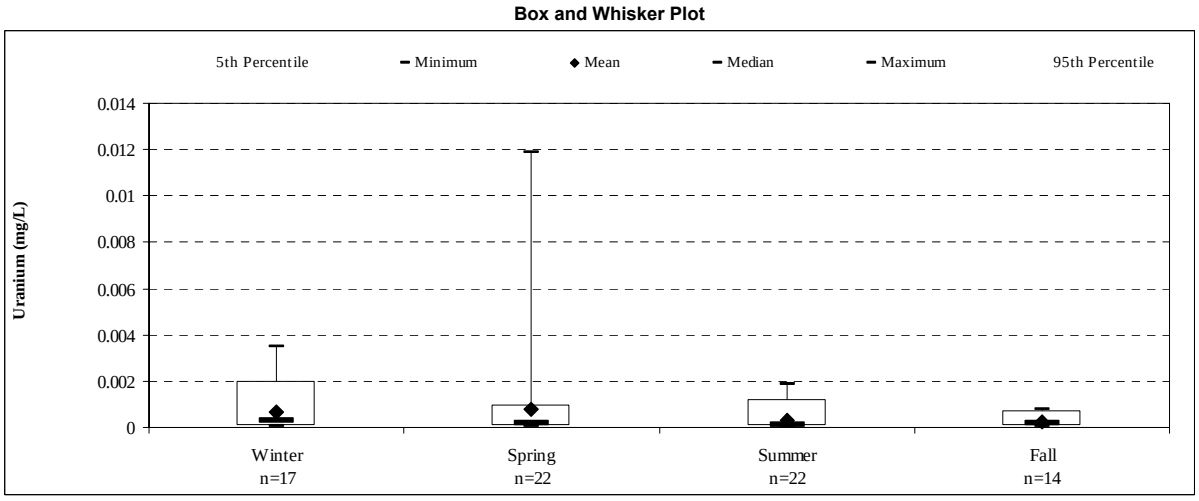


Figure G-3-3-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Big Creek



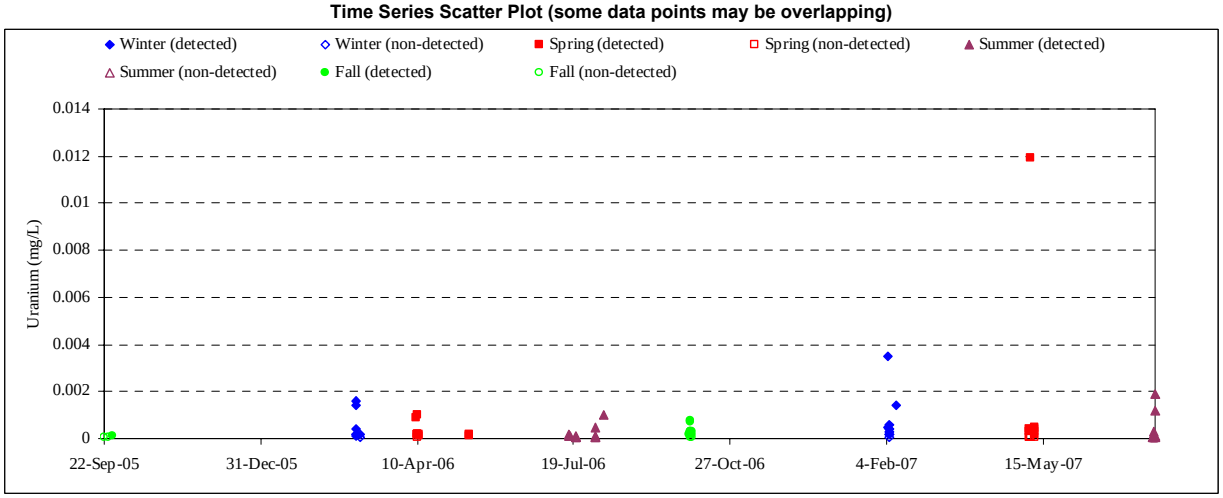
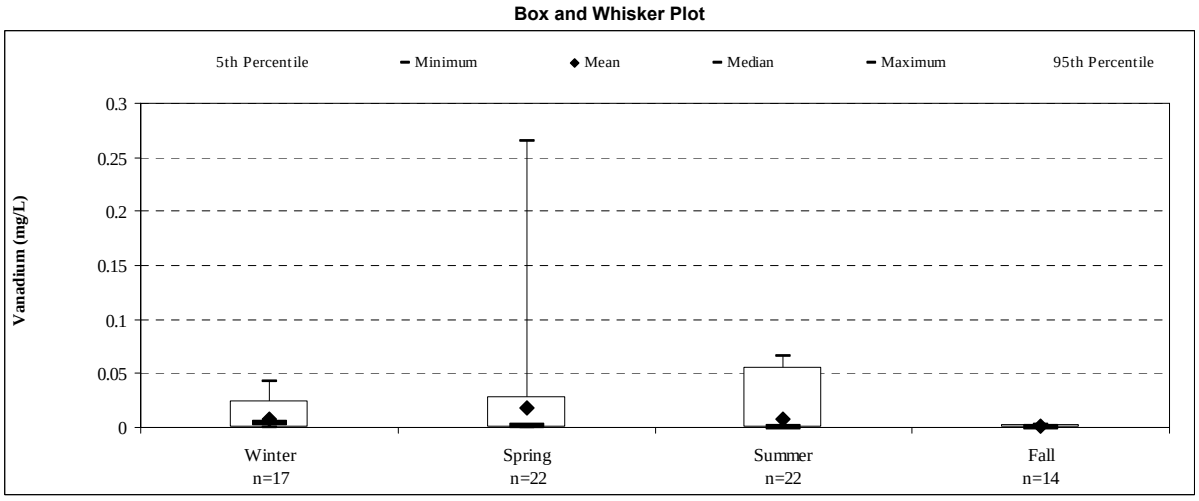


Figure G-3-3-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Big Creek



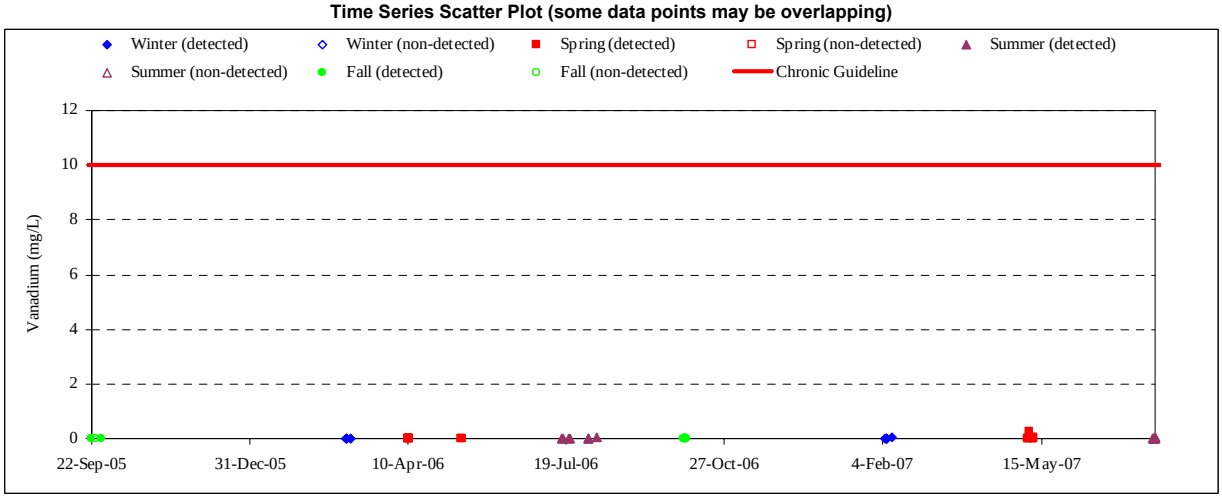
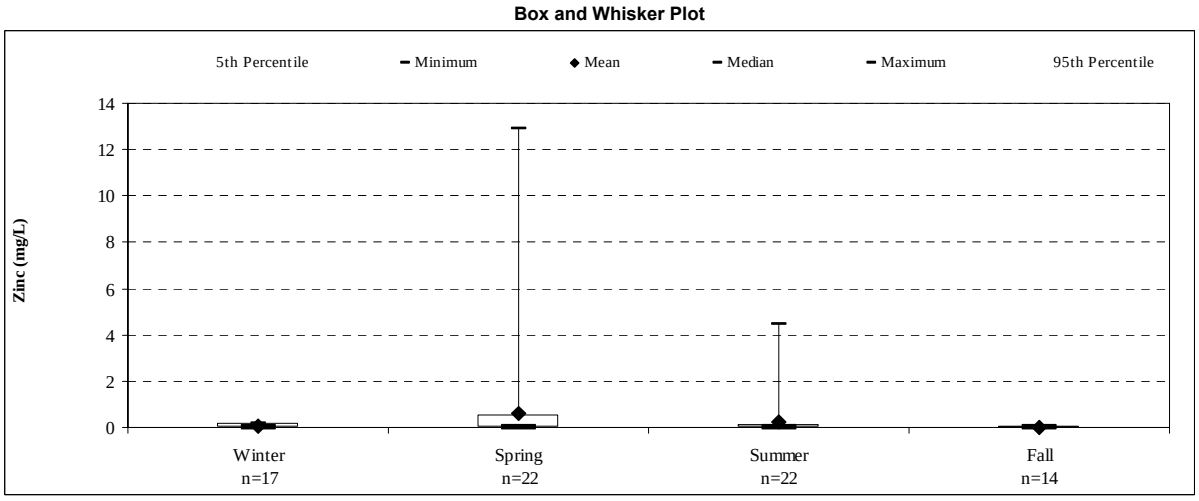


Figure G-3-3-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Big Creek



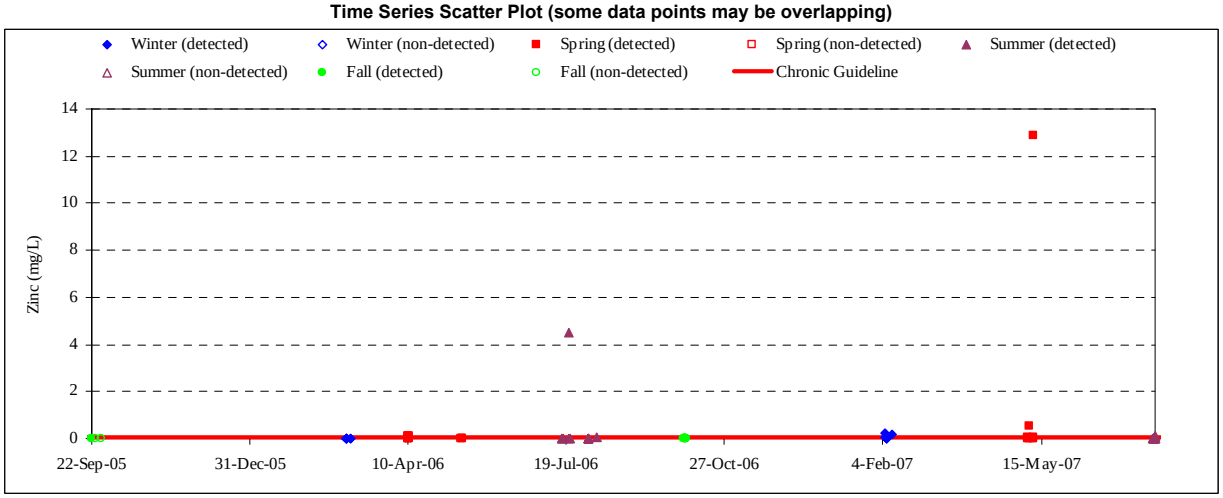
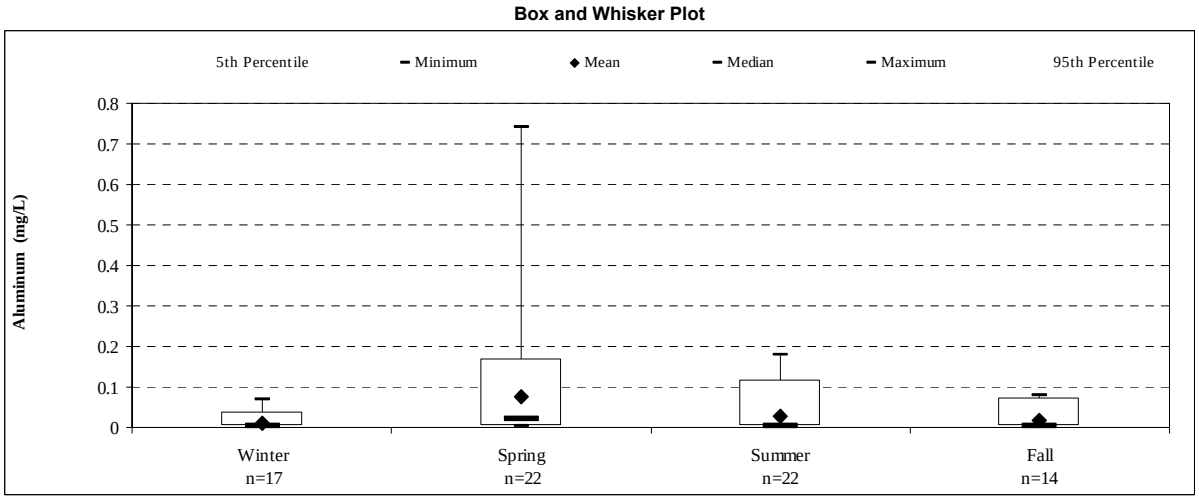


Figure G-3-3-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Big Creek



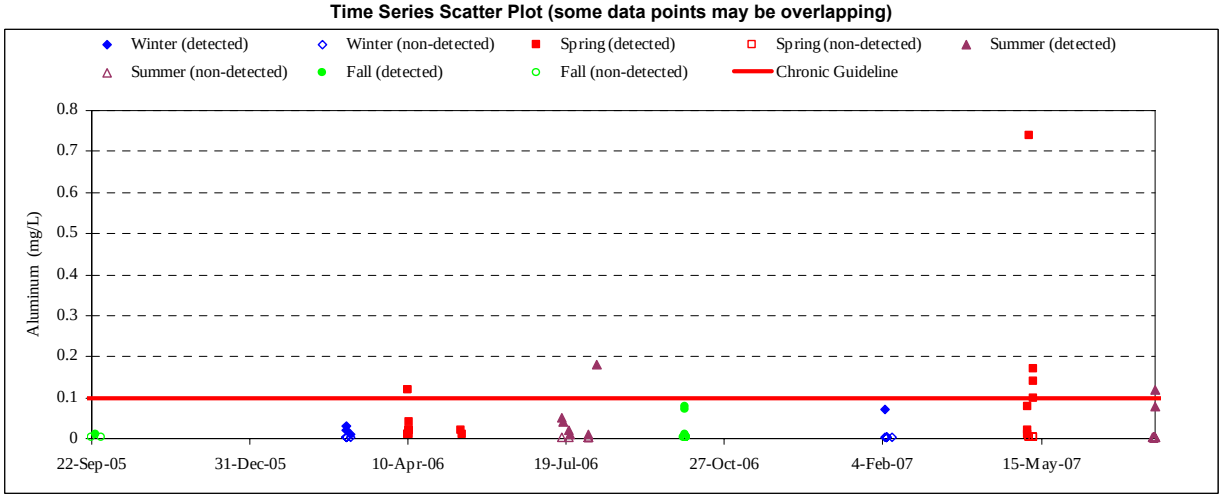
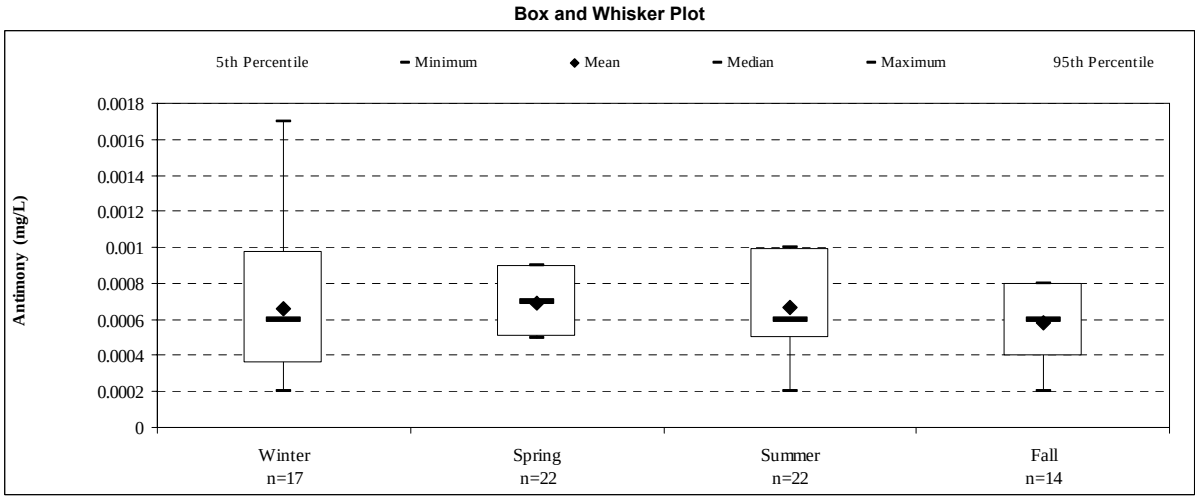


Figure G-3-3-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Big Creek



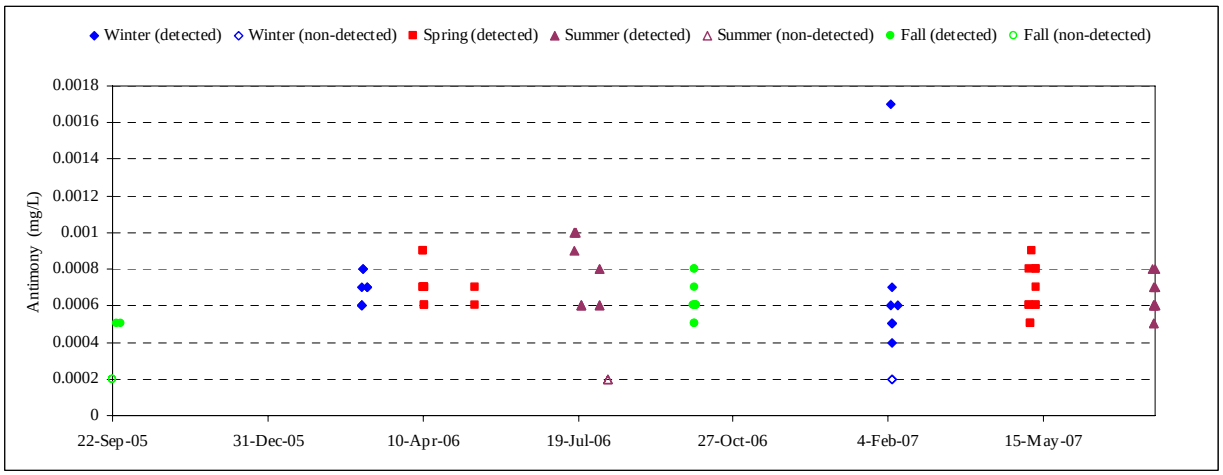
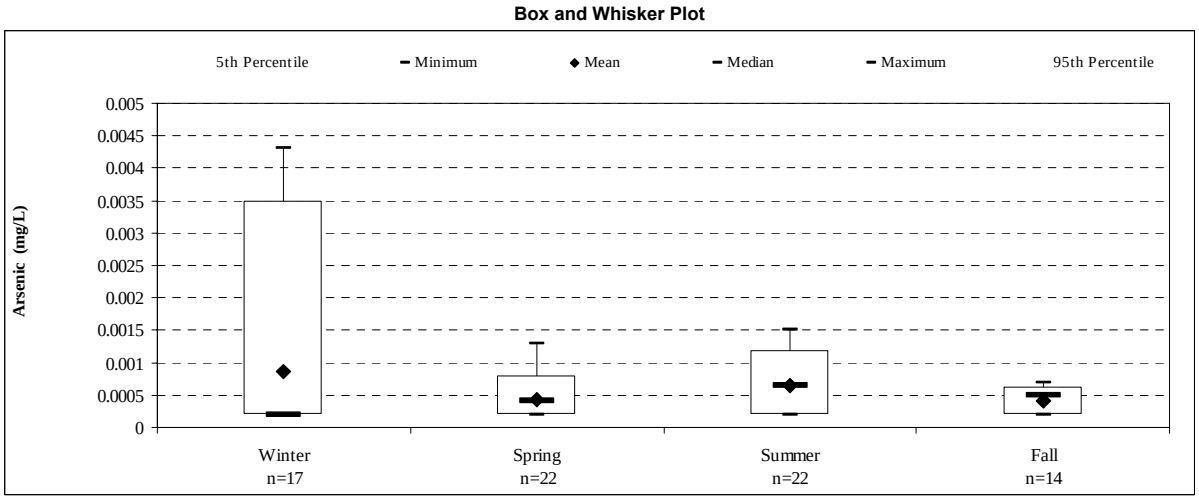


Figure G-3-3-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Big Creek



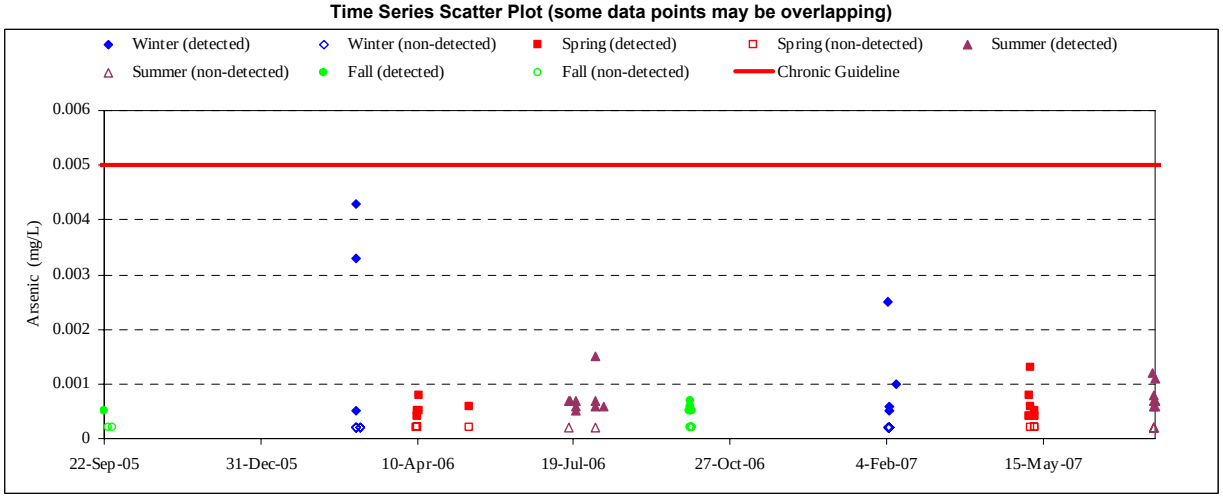
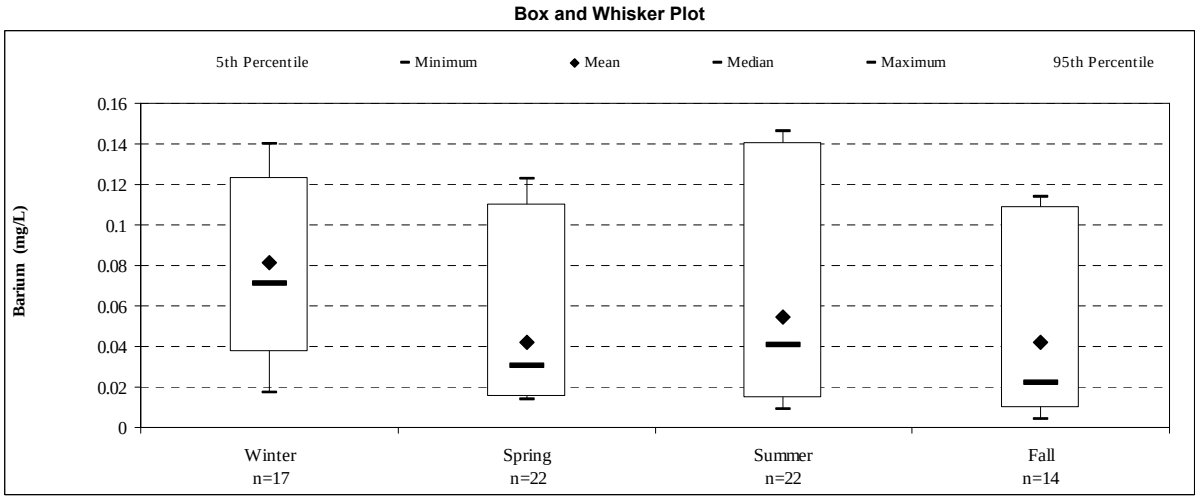


Figure G-3-3-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Big Creek



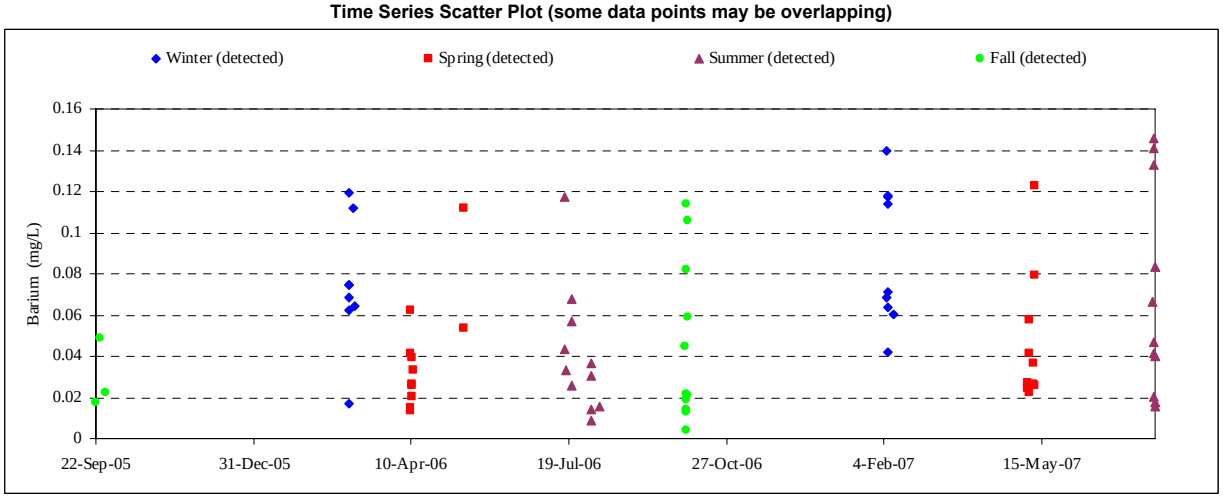
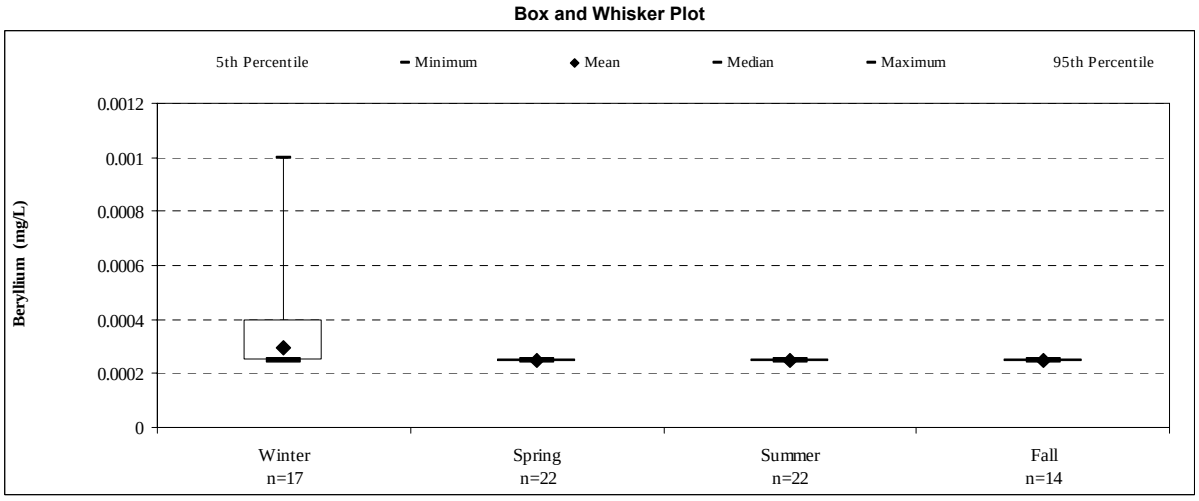


Figure G-3-3-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Big Creek



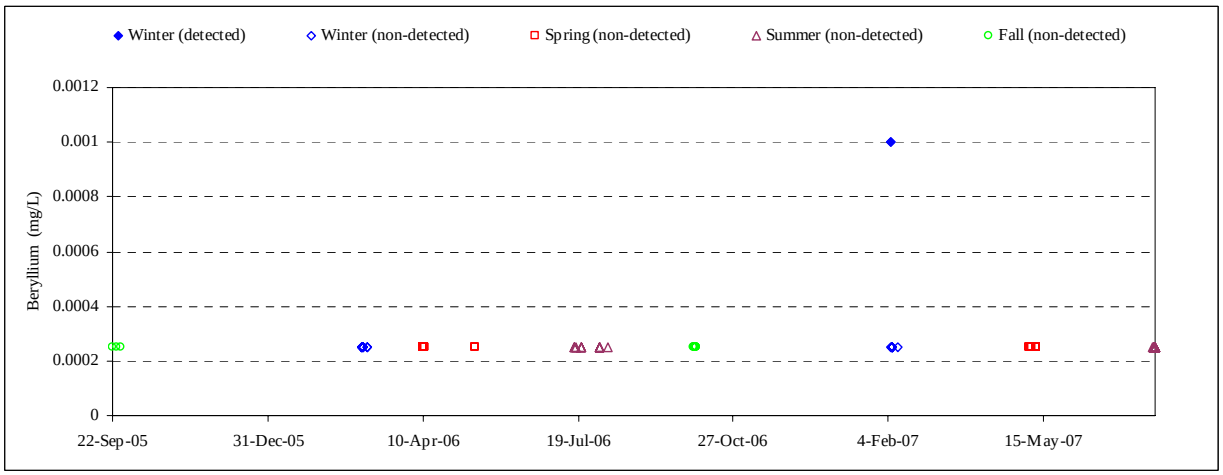
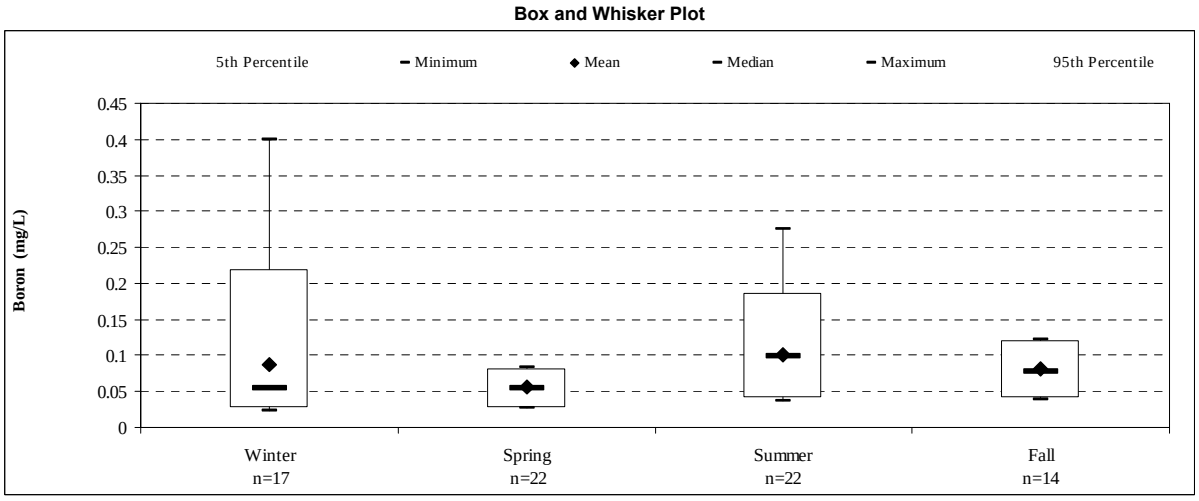


Figure G-3-3-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Big Creek



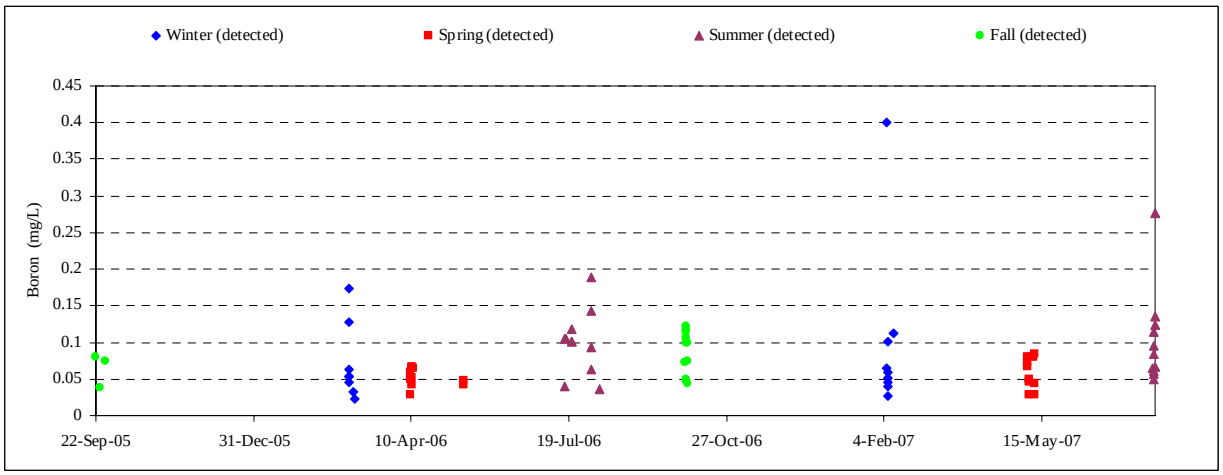
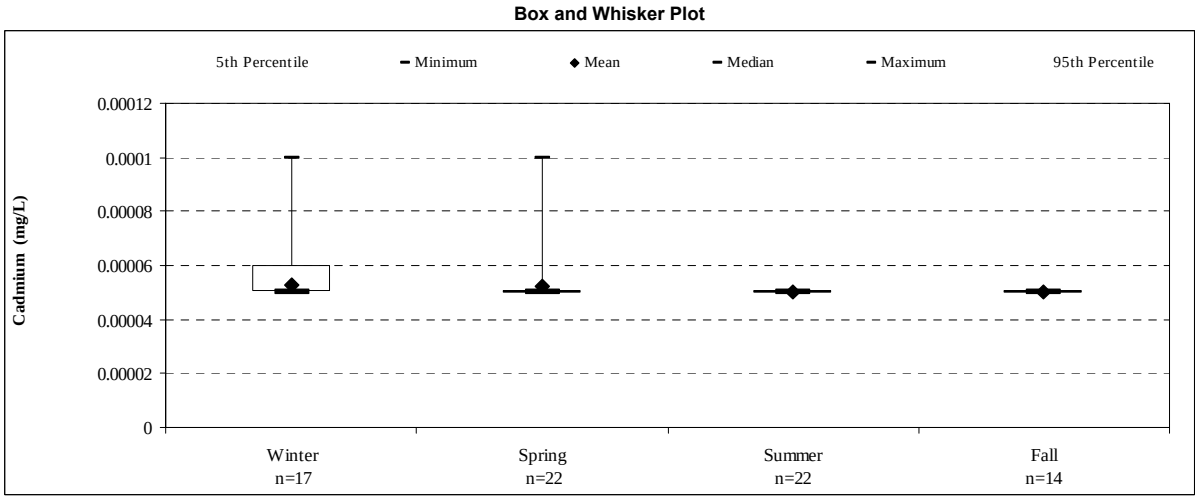


Figure G-3-3-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Big Creek



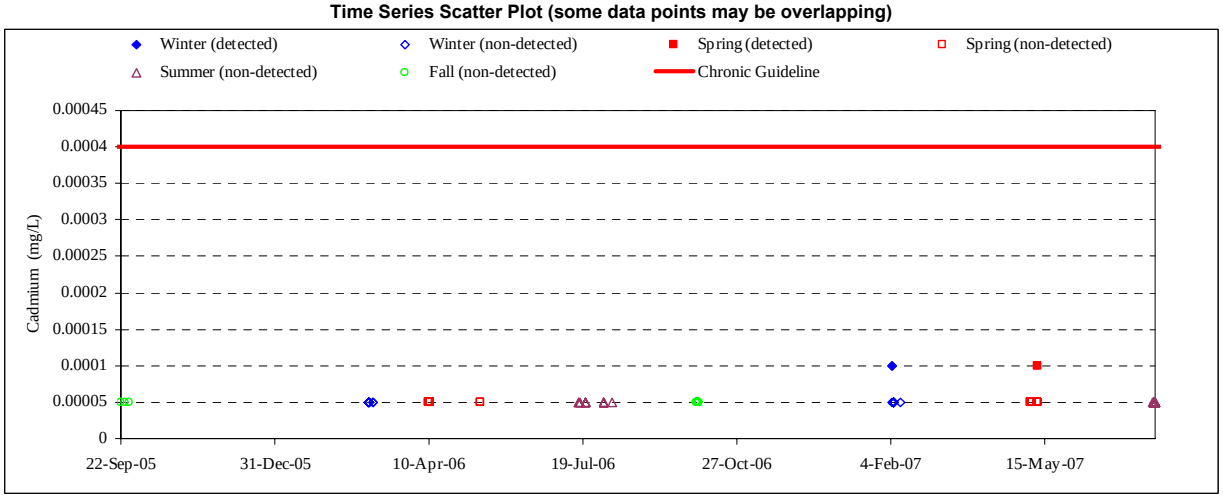
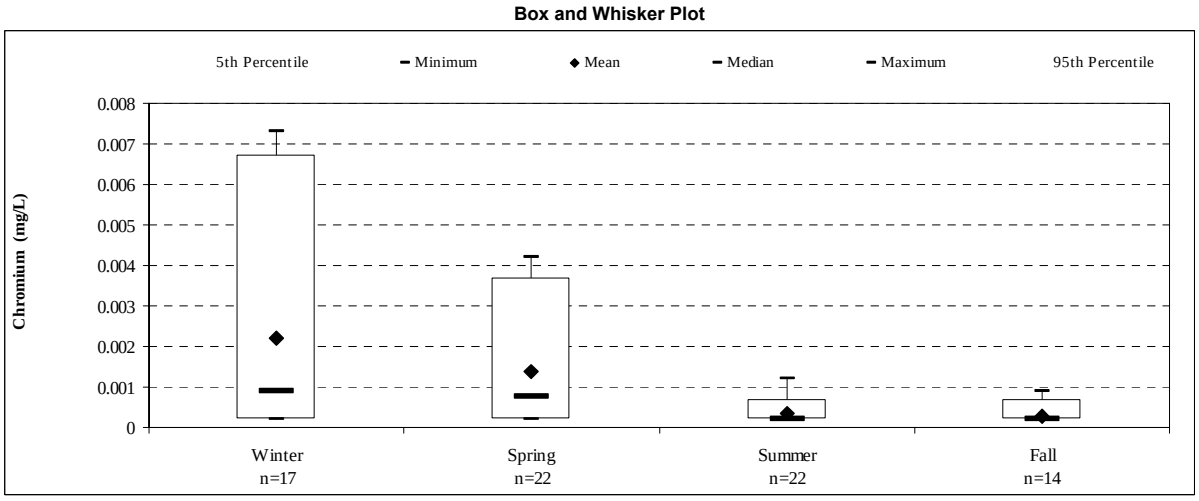


Figure G-3-3-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Big Creek



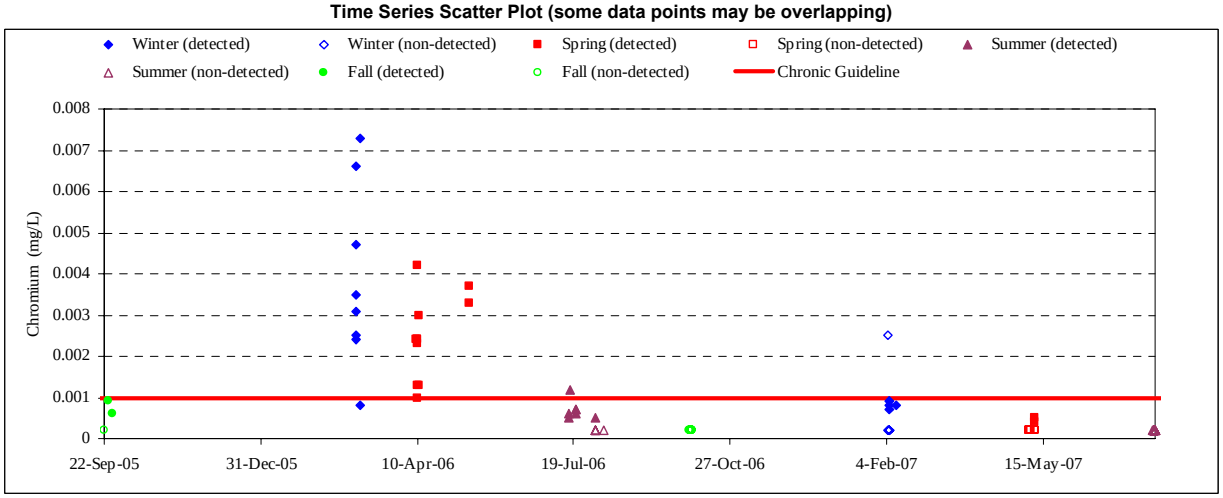
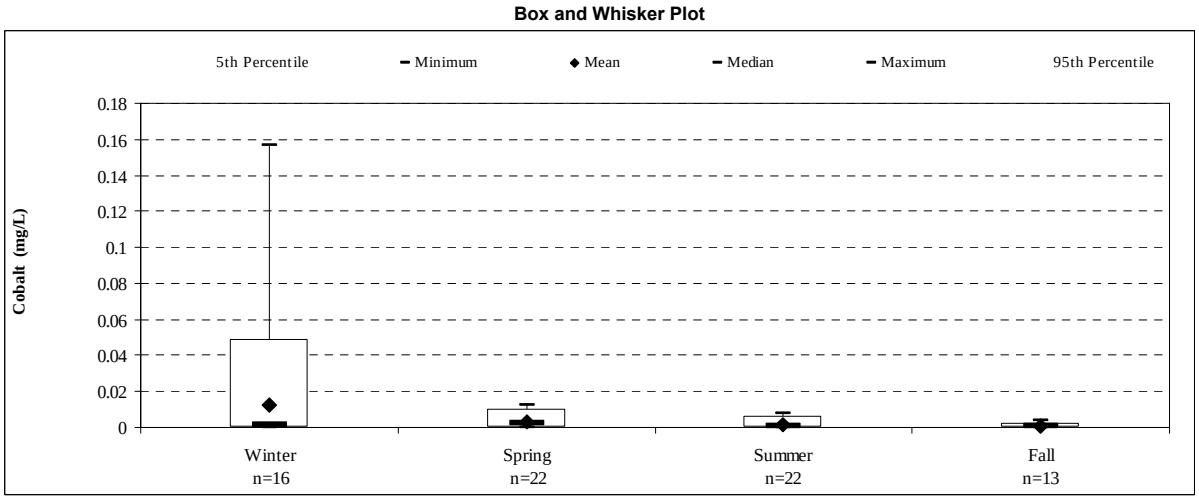


Figure G-3-3-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Big Creek



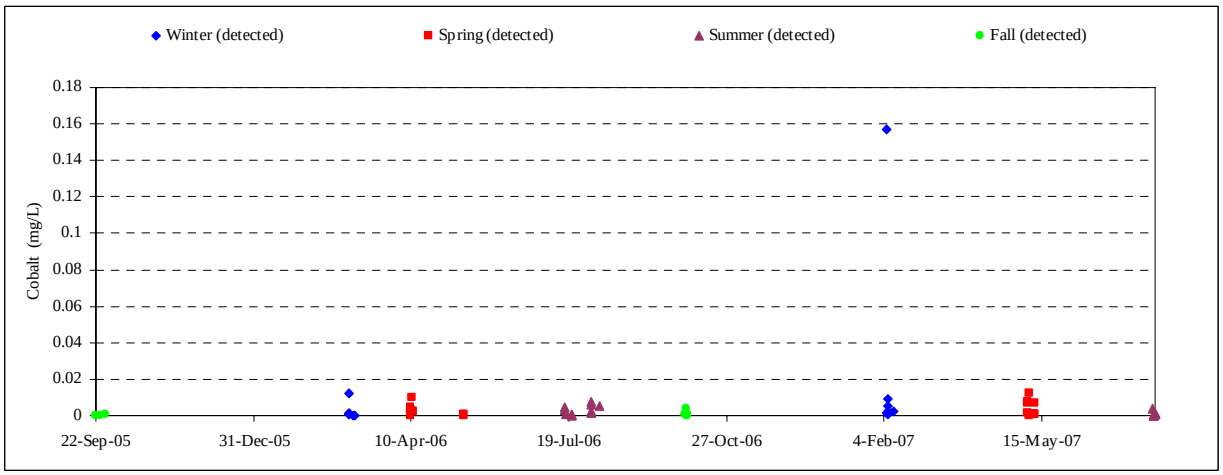
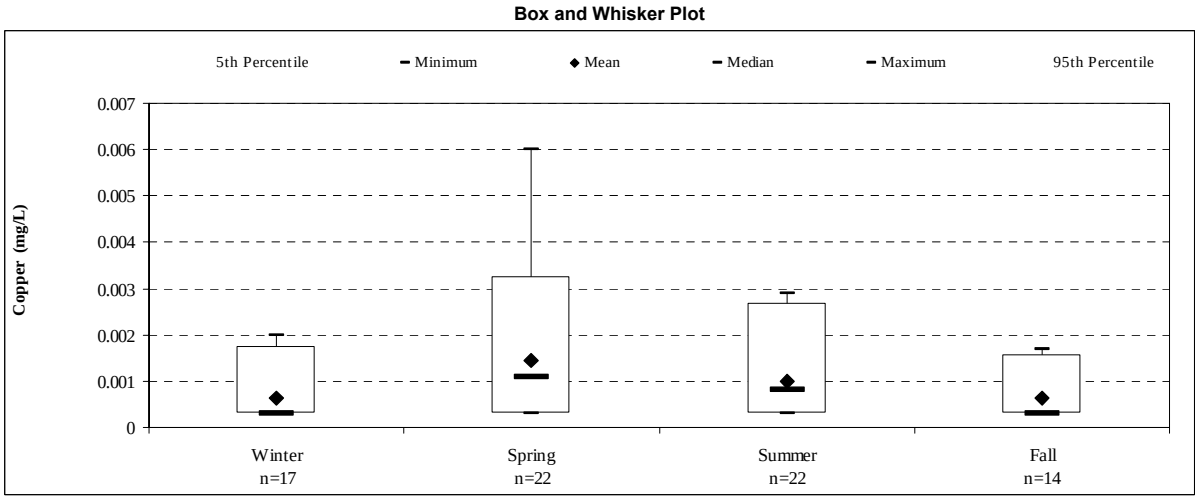


Figure G-3-3-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Big Creek



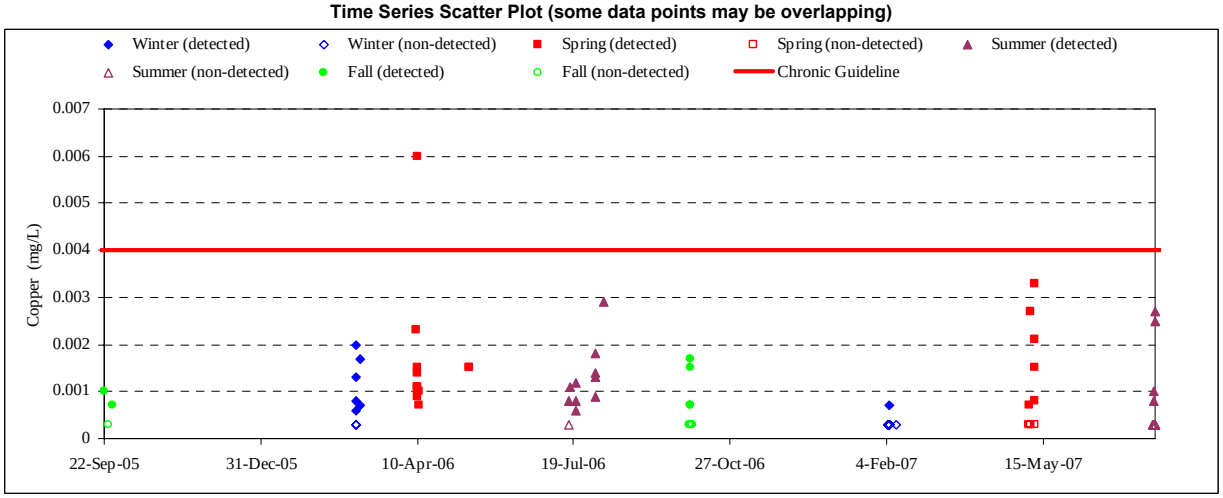
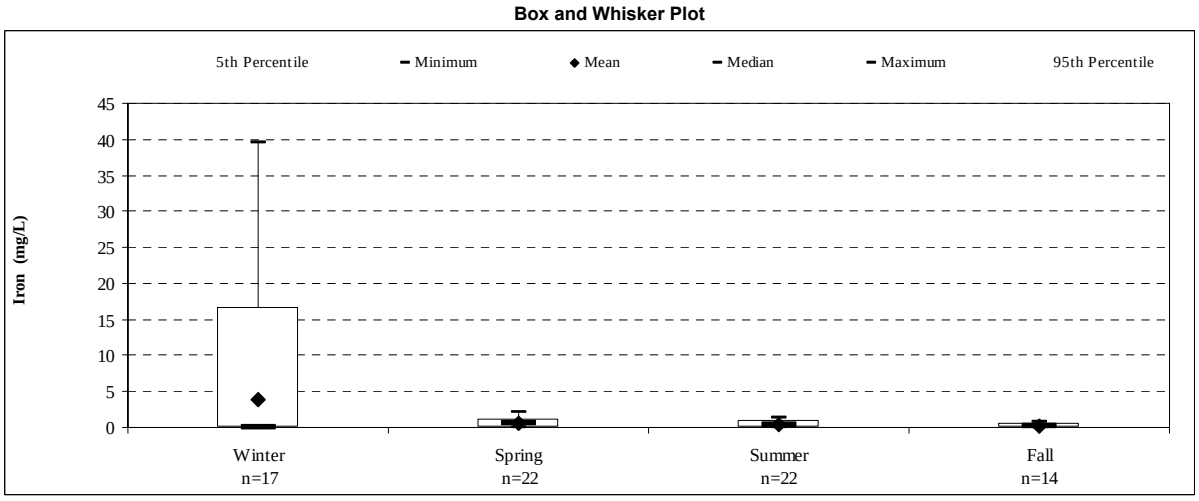


Figure G-3-3-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Big Creek



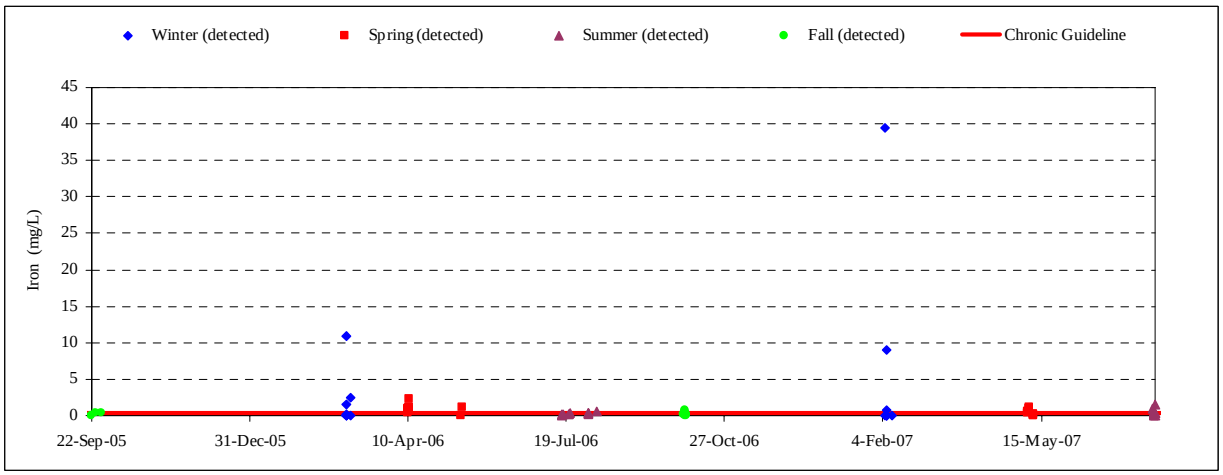
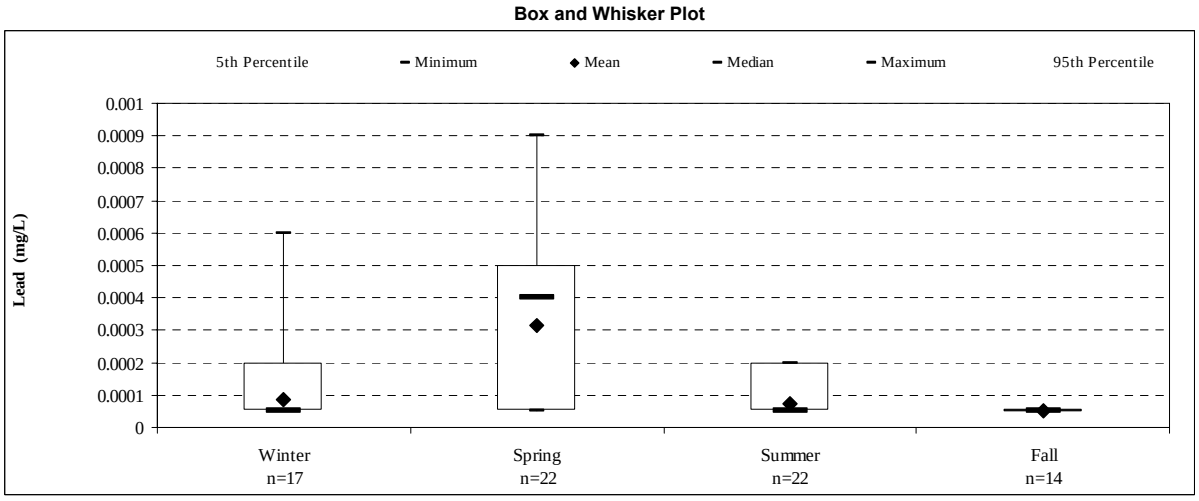


Figure G-3-3-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Big Creek



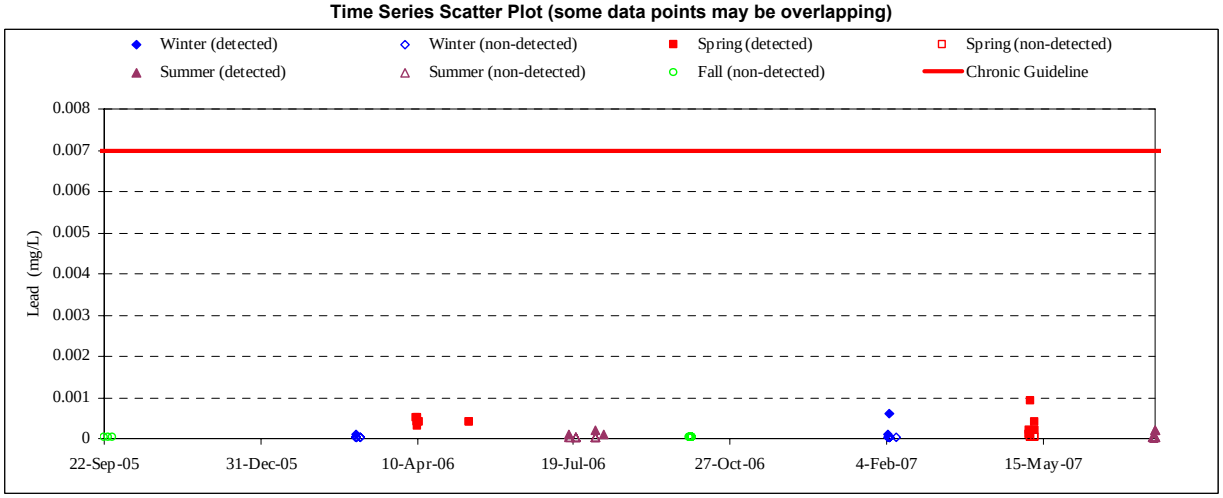
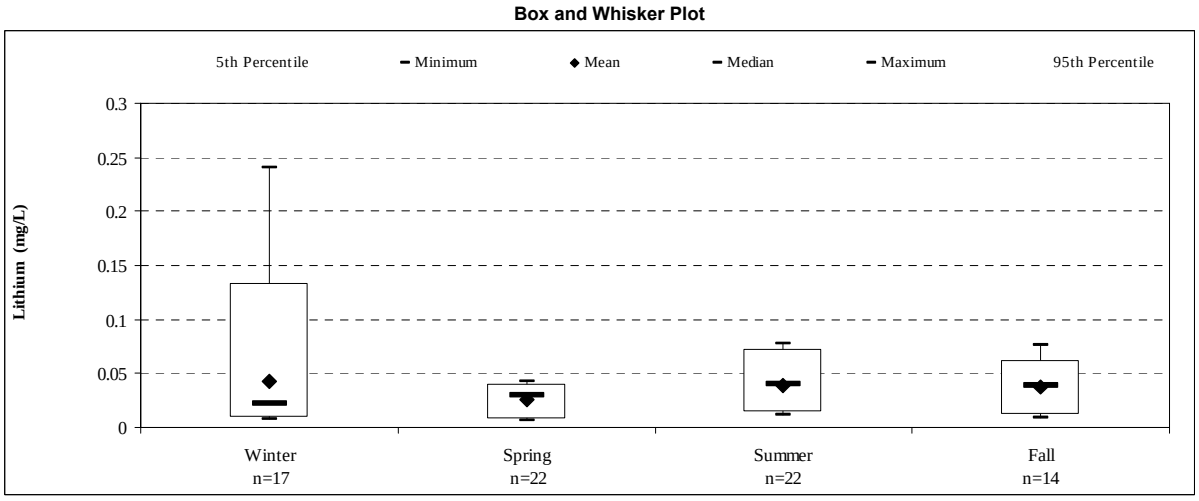


Figure G-3-3-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Big Creek



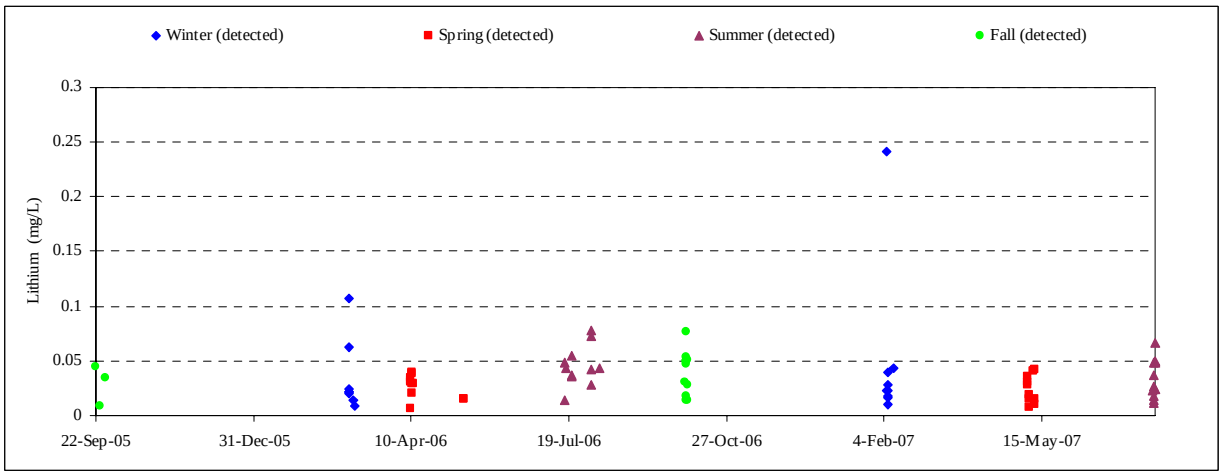
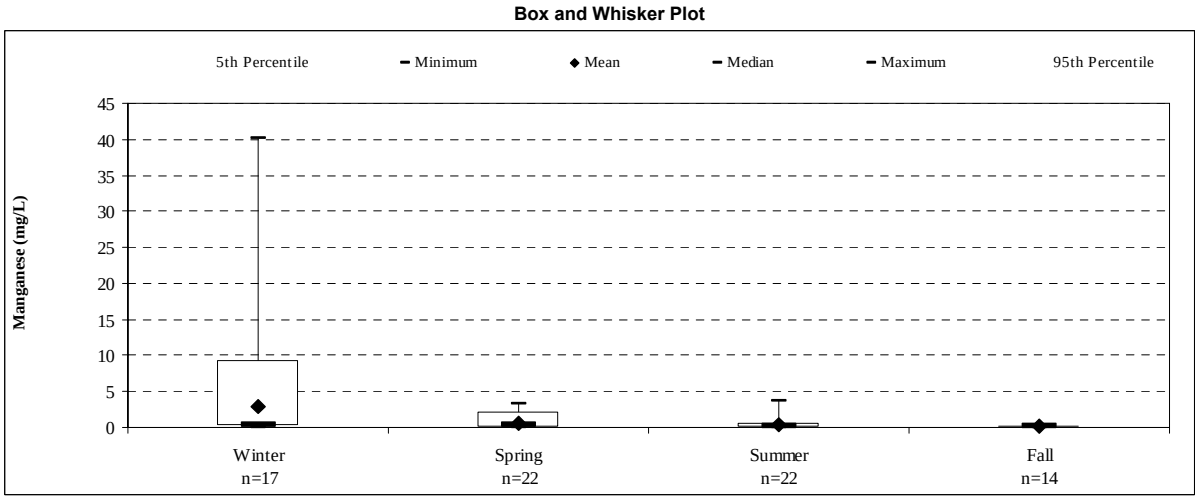


Figure G-3-3-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Big Creek



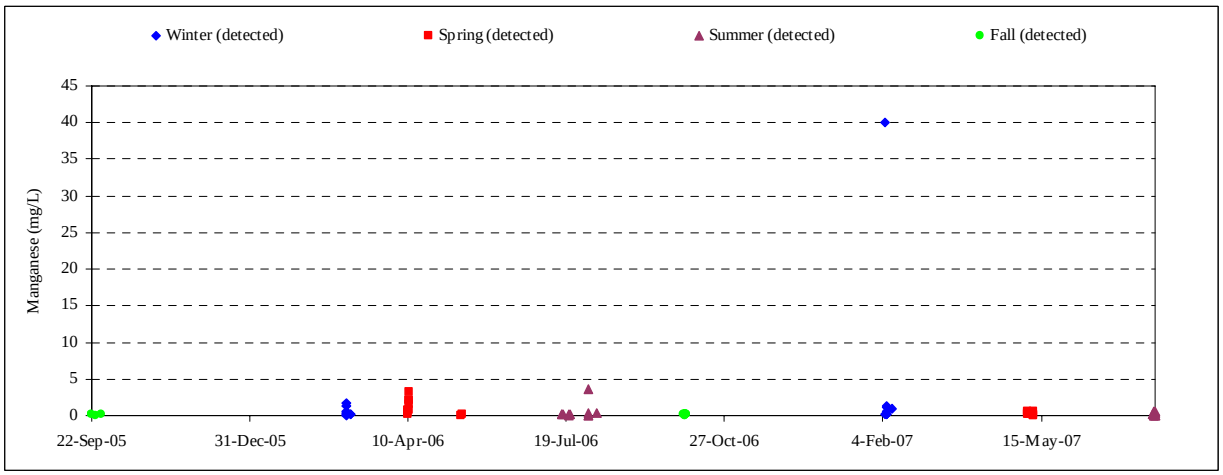
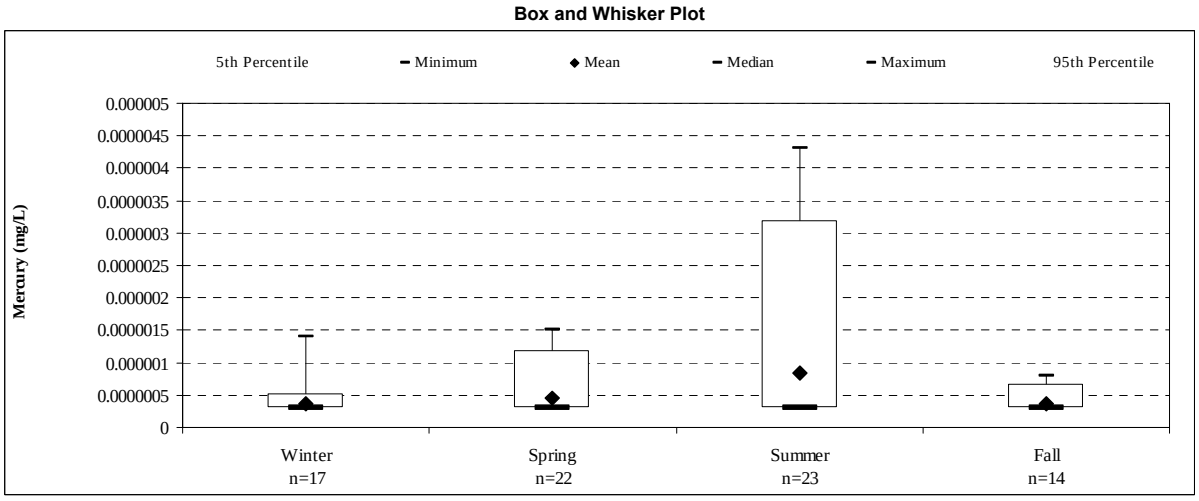


Figure G-3-3-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Big Creek



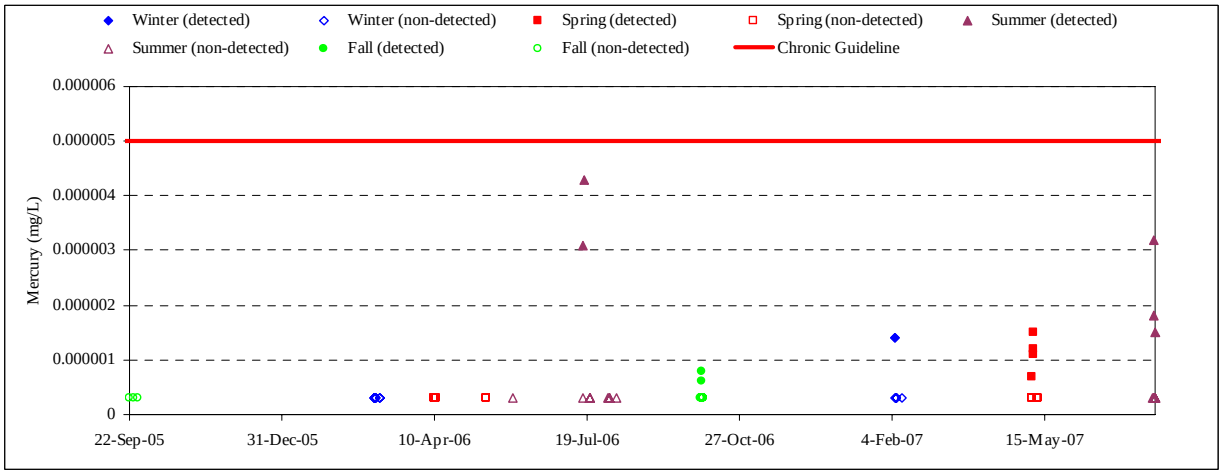
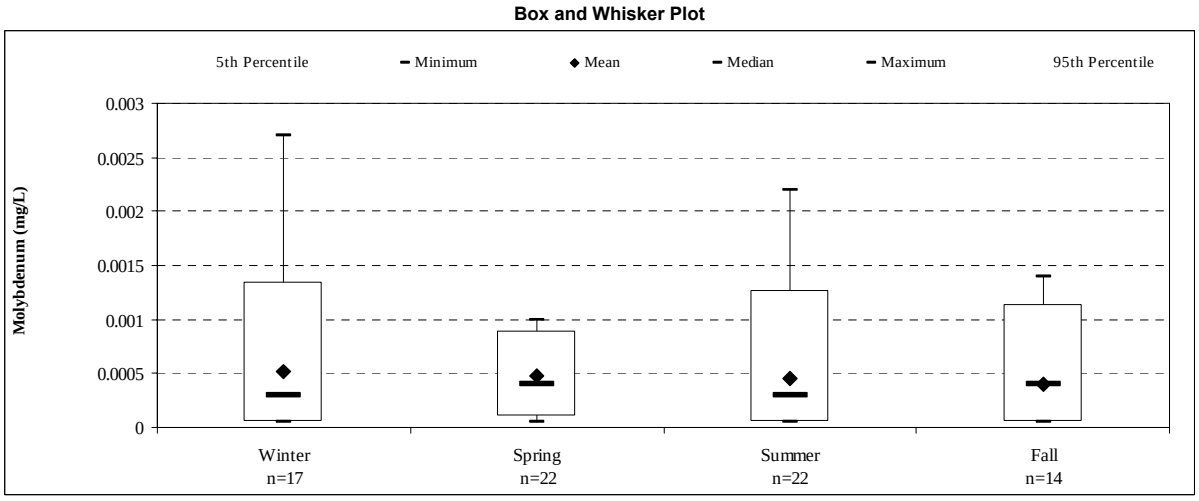


Figure G-3-3-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Big Creek



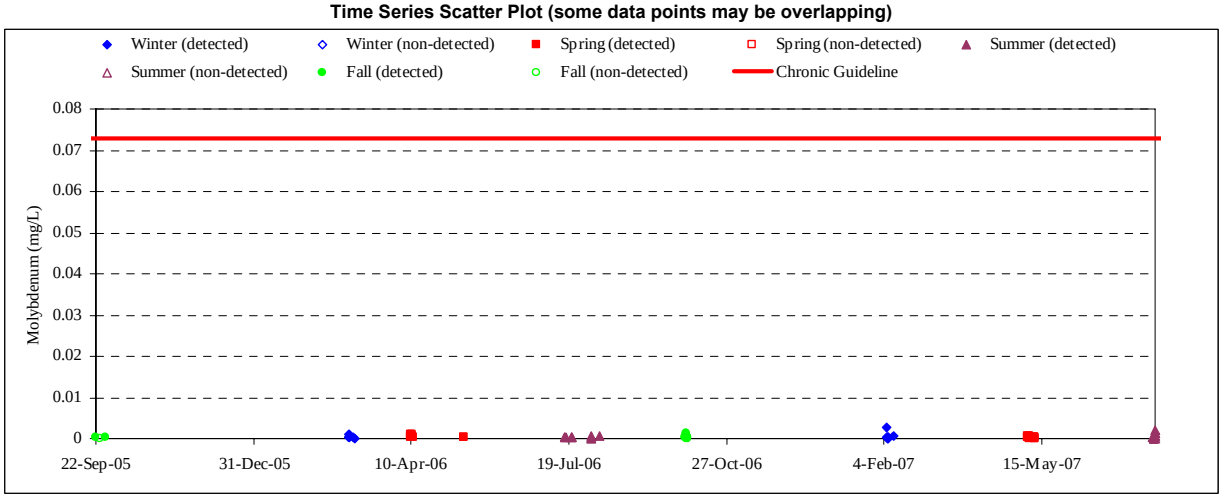
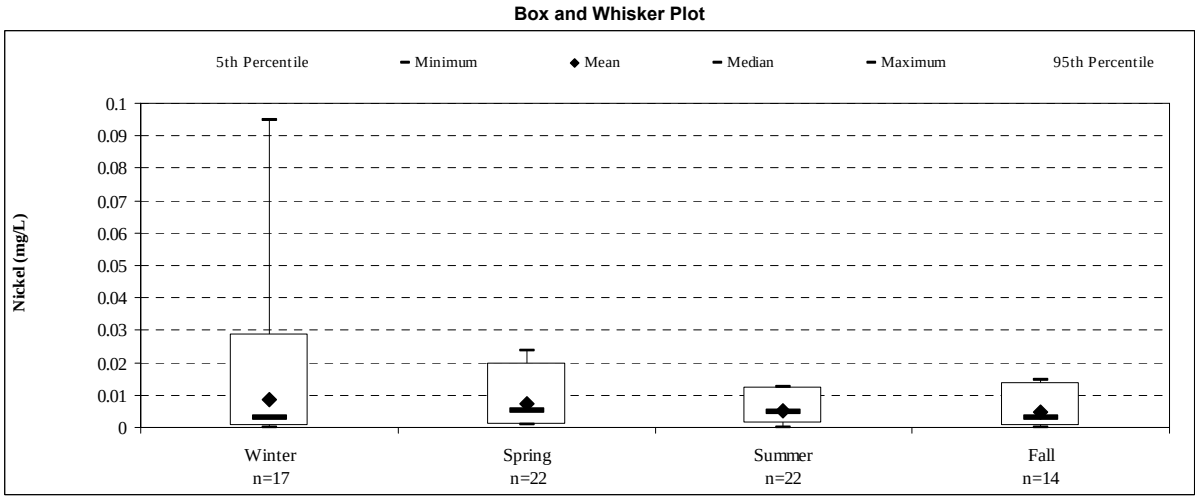


Figure G-3-3-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Big Creek



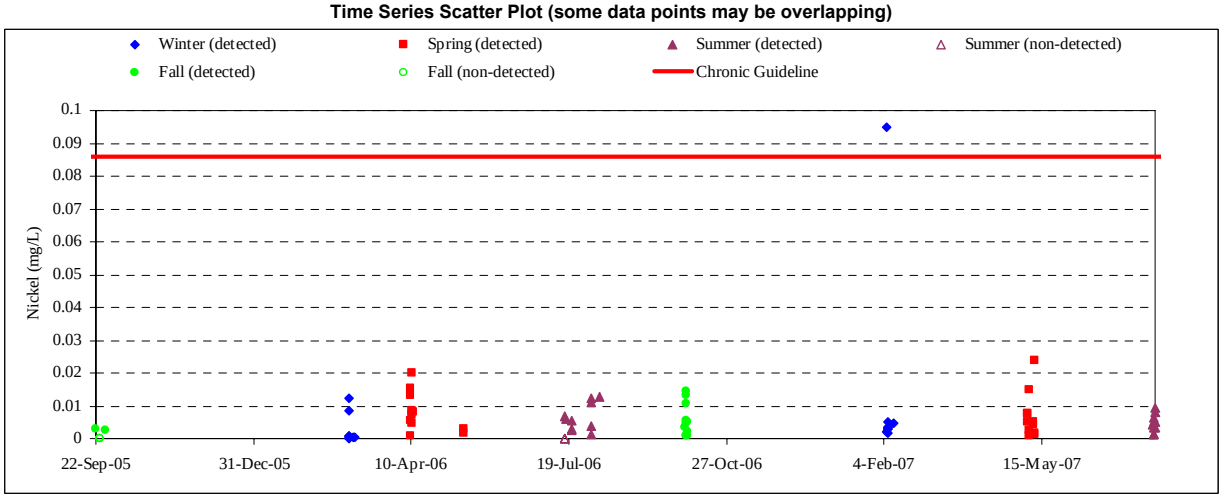
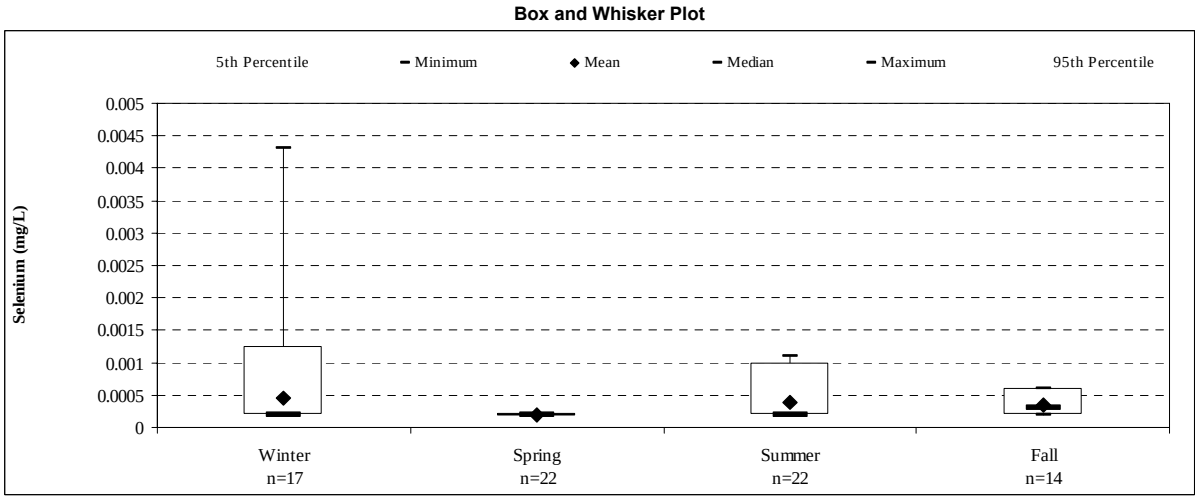


Figure G-3-3-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Big Creek



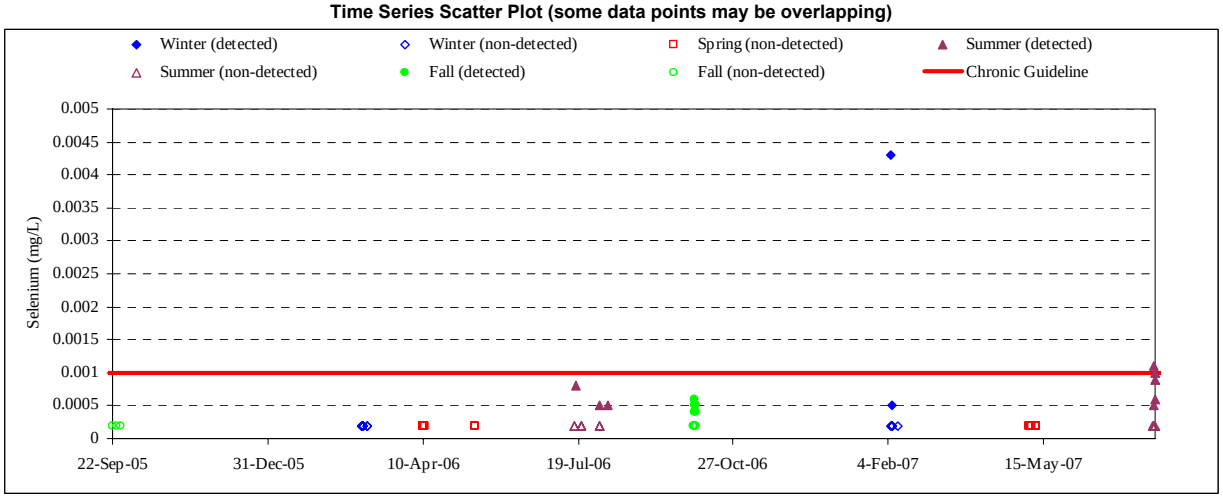
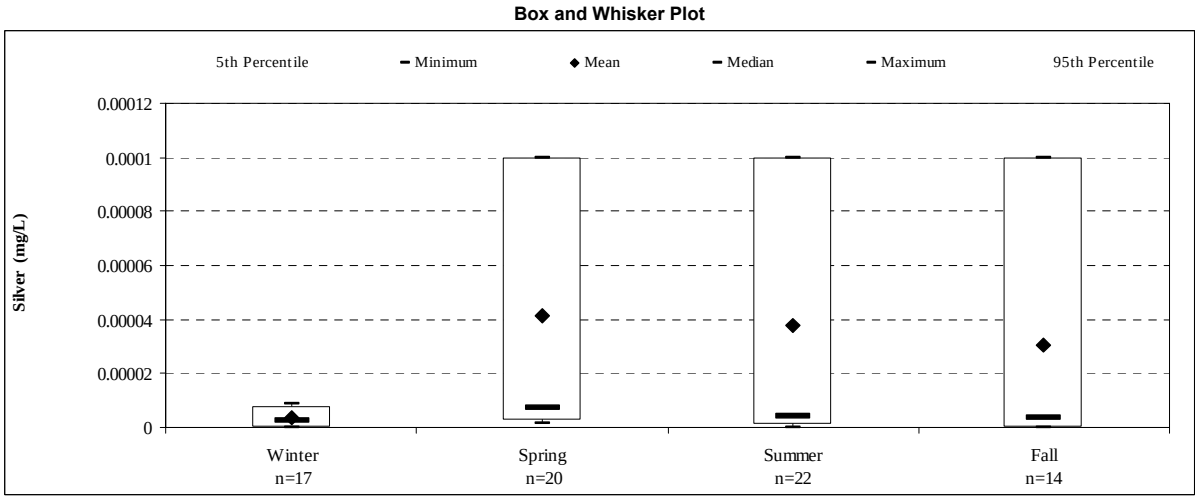


Figure G-3-3-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Big Creek



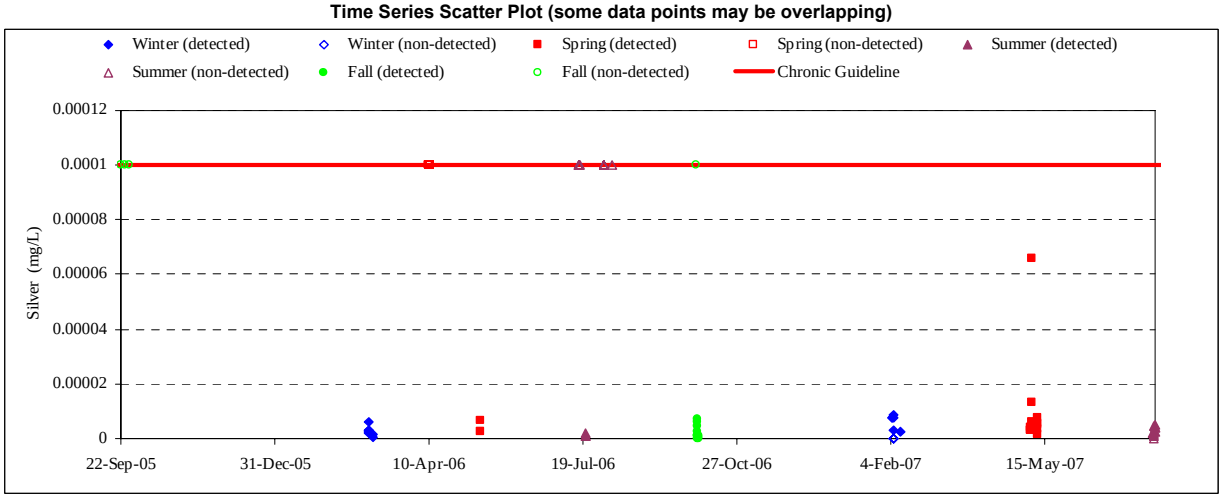
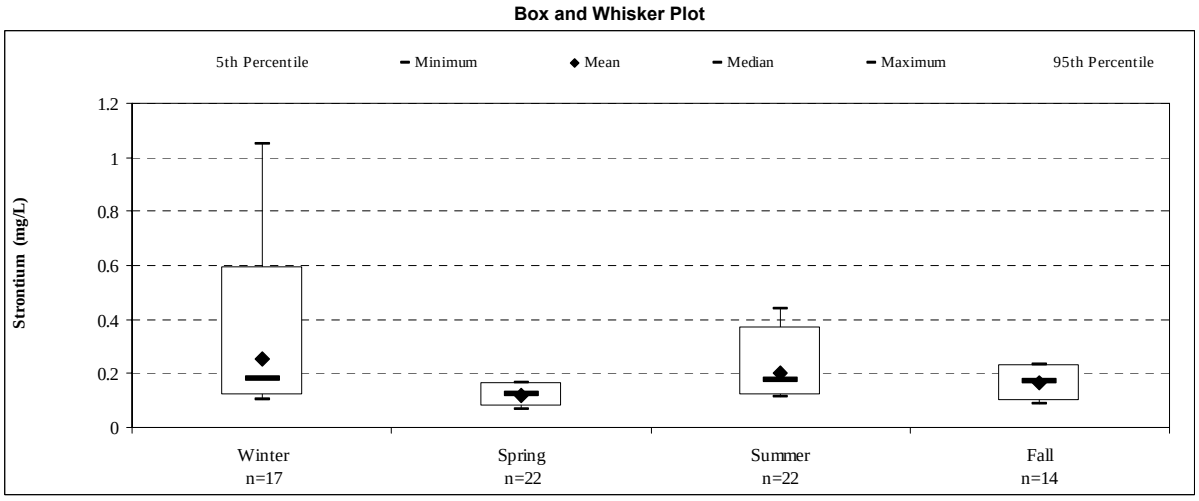


Figure G-3-3-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Big Creek



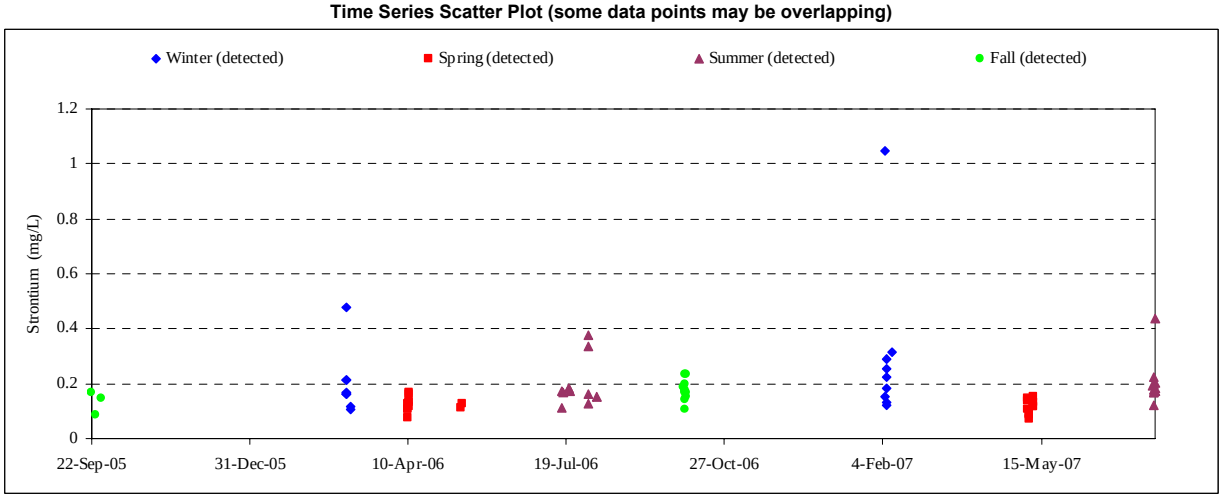
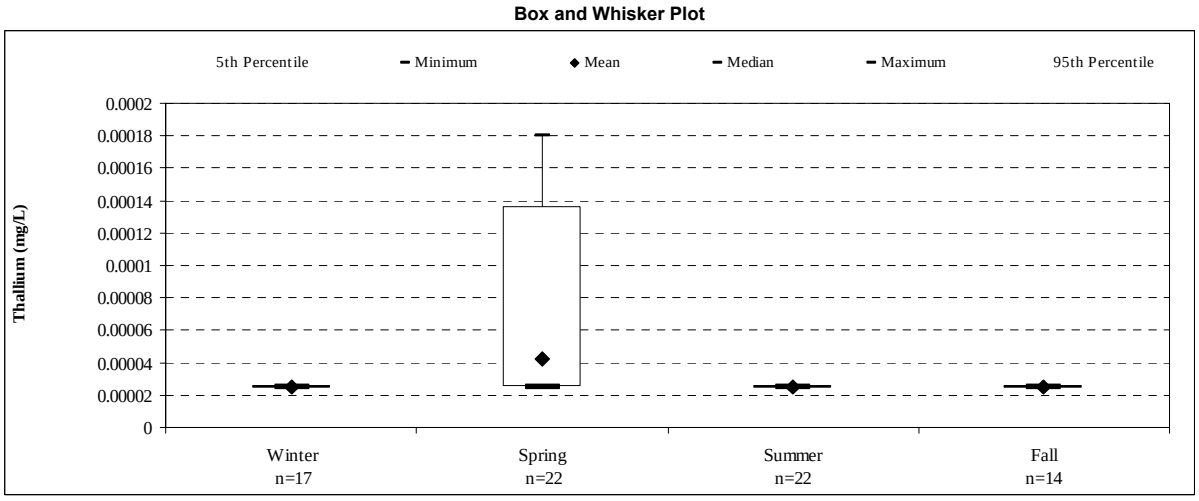


Figure G-3-3-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Big Creek



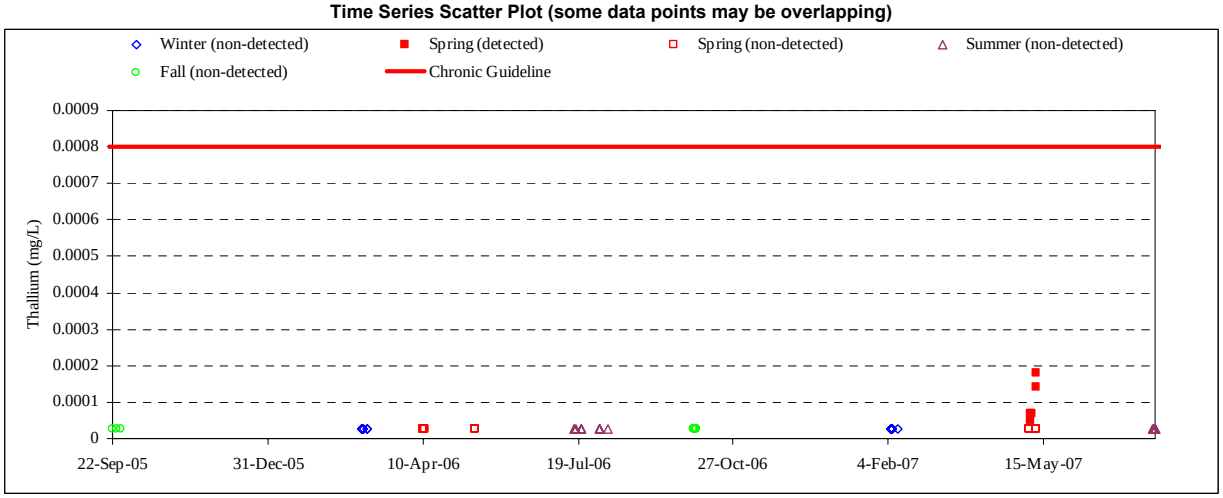
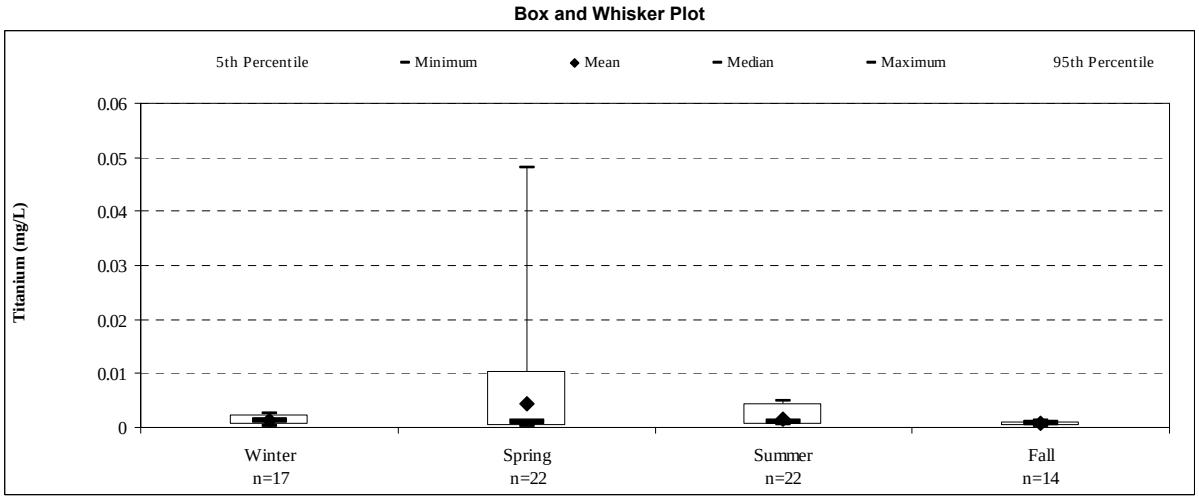


Figure G-3-3-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Big Creek



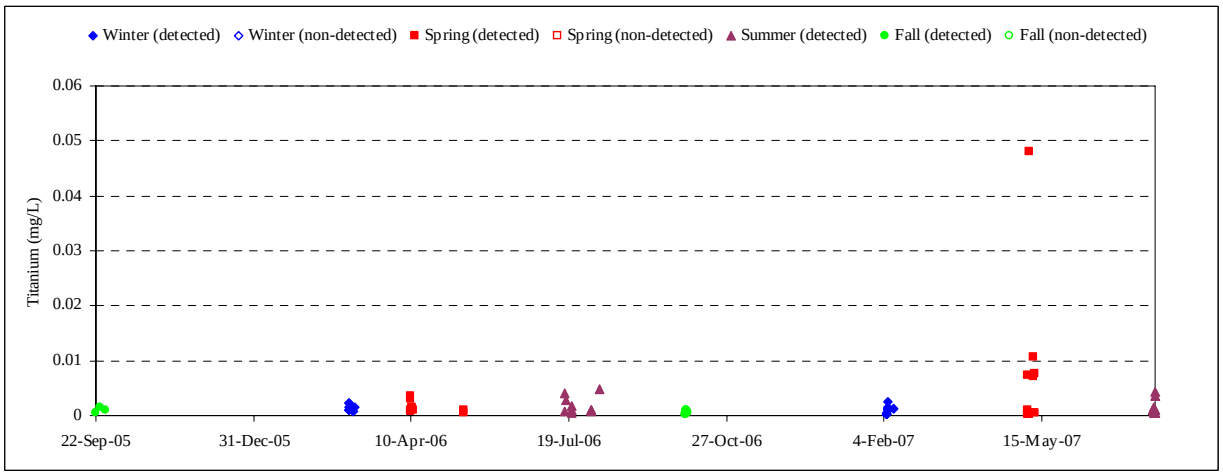
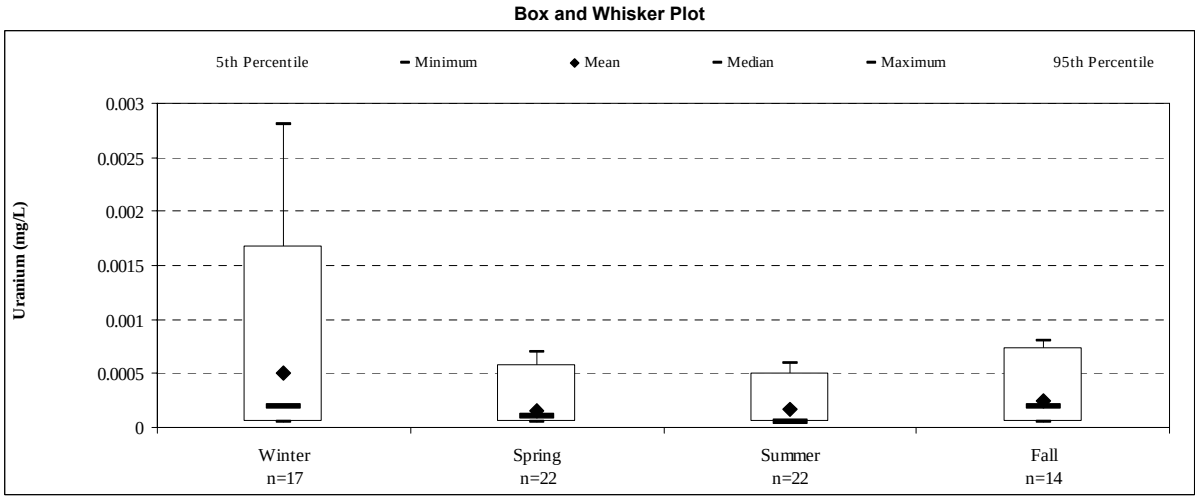


Figure G-3-3-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Big Creek



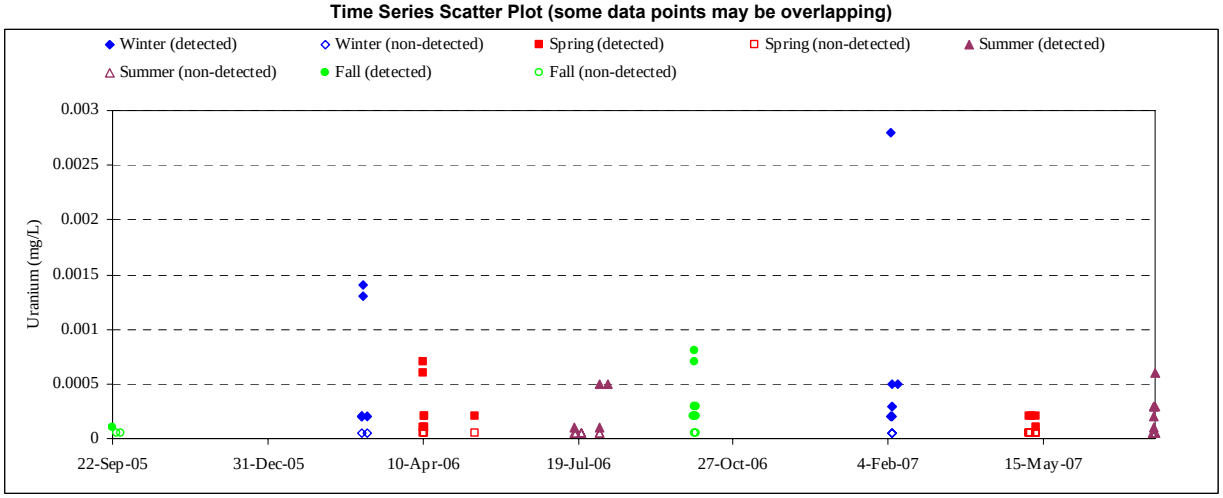
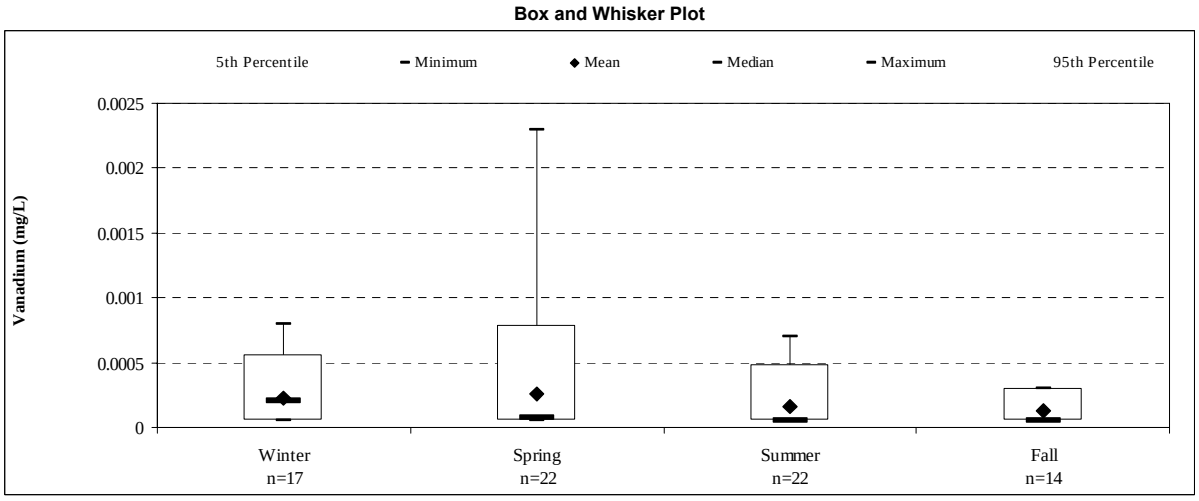


Figure G-3-3-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Big Creek



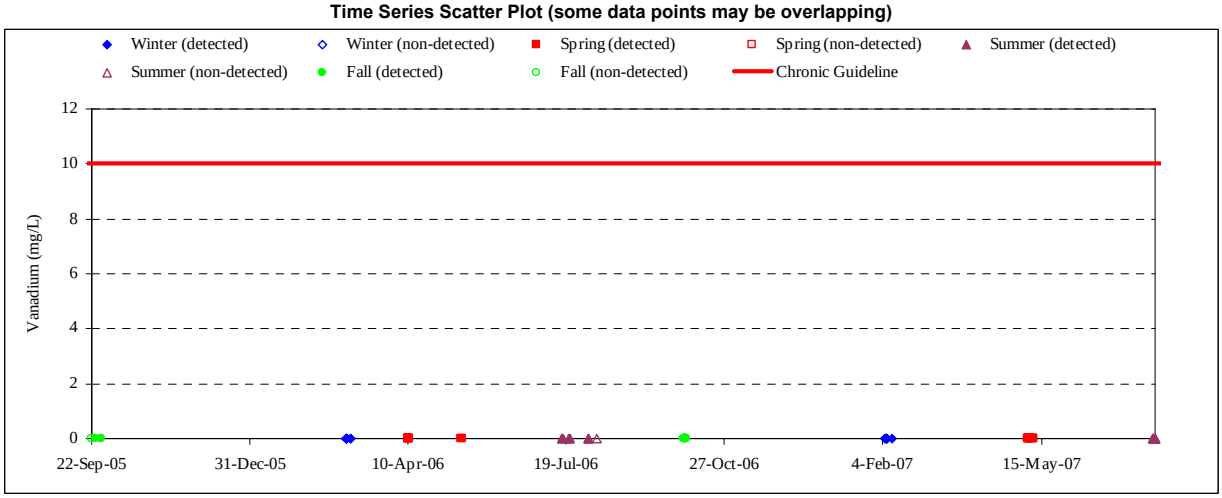
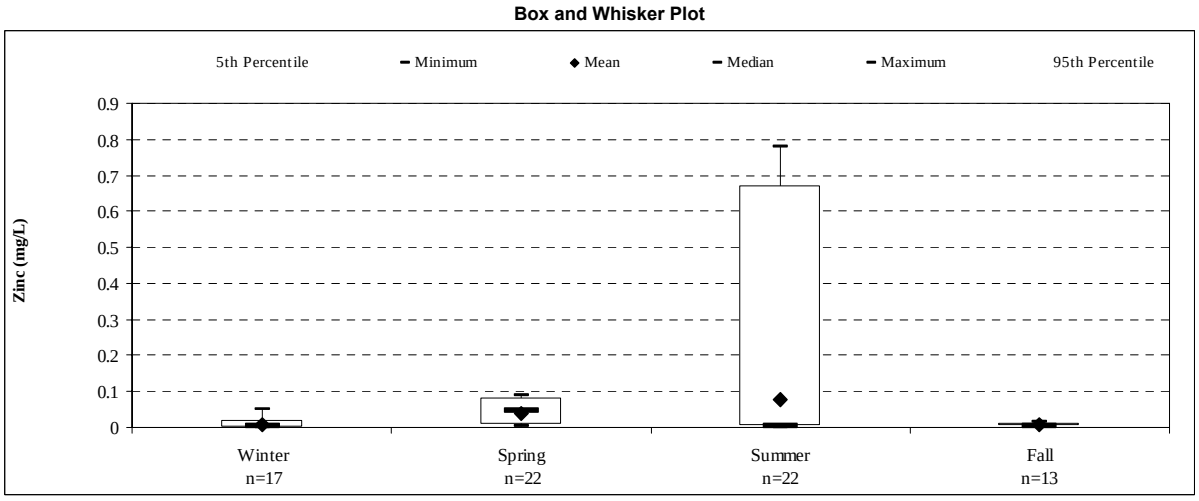


Figure G-3-3-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Big Creek



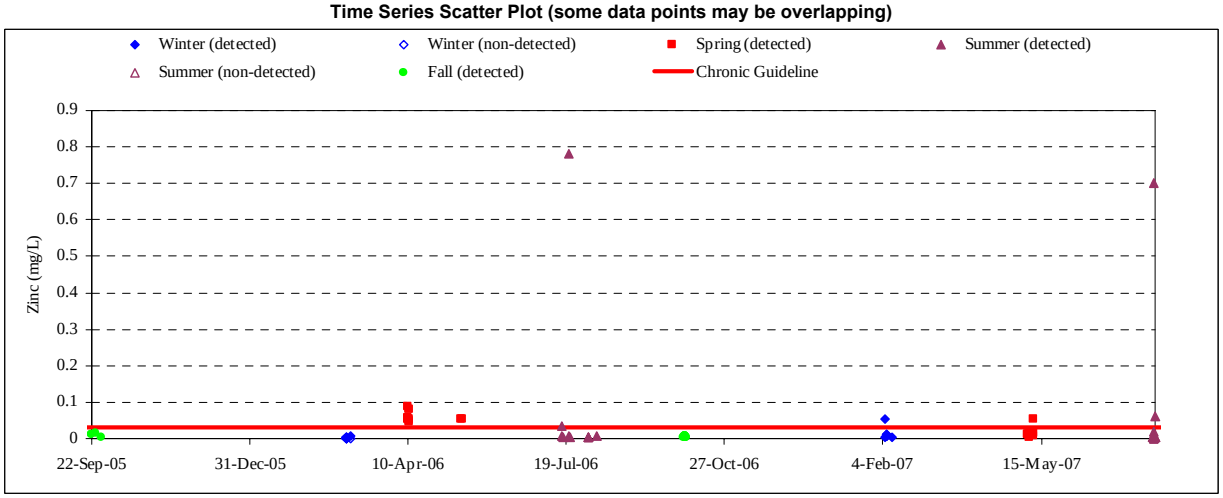
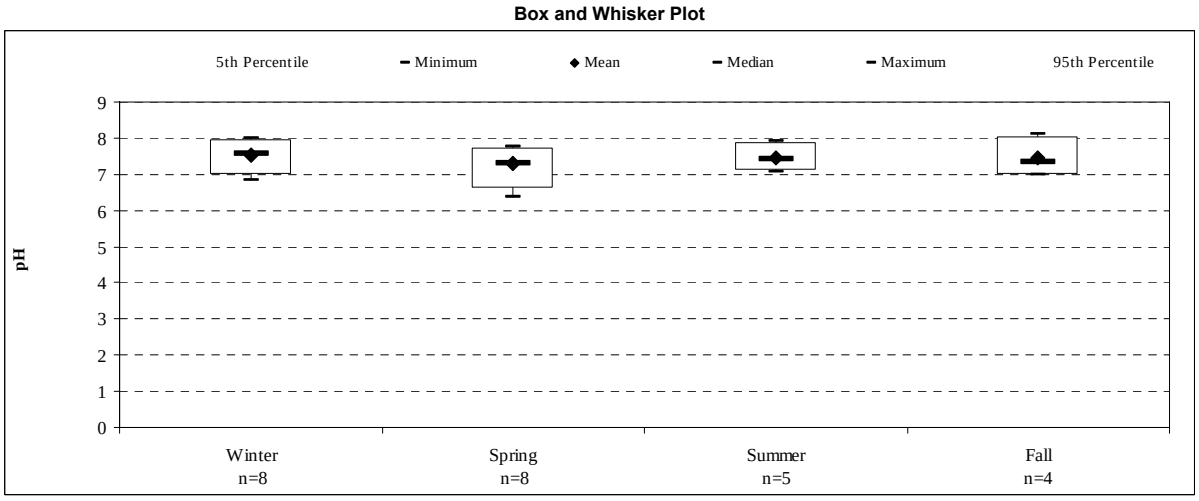


Figure G-3-4-1 Box Whisker and Time Series Scatter Plots of Observed pH in Redclay Creek



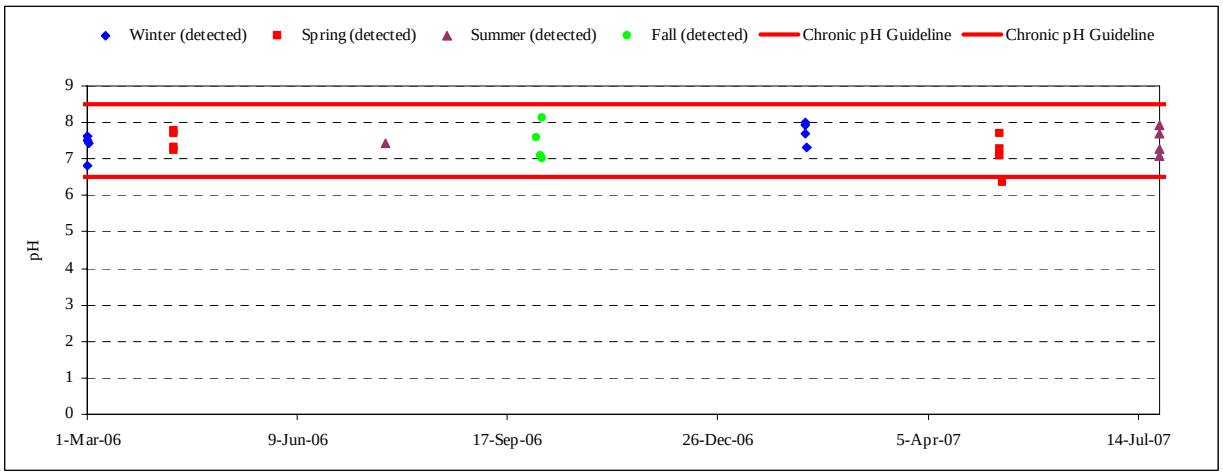
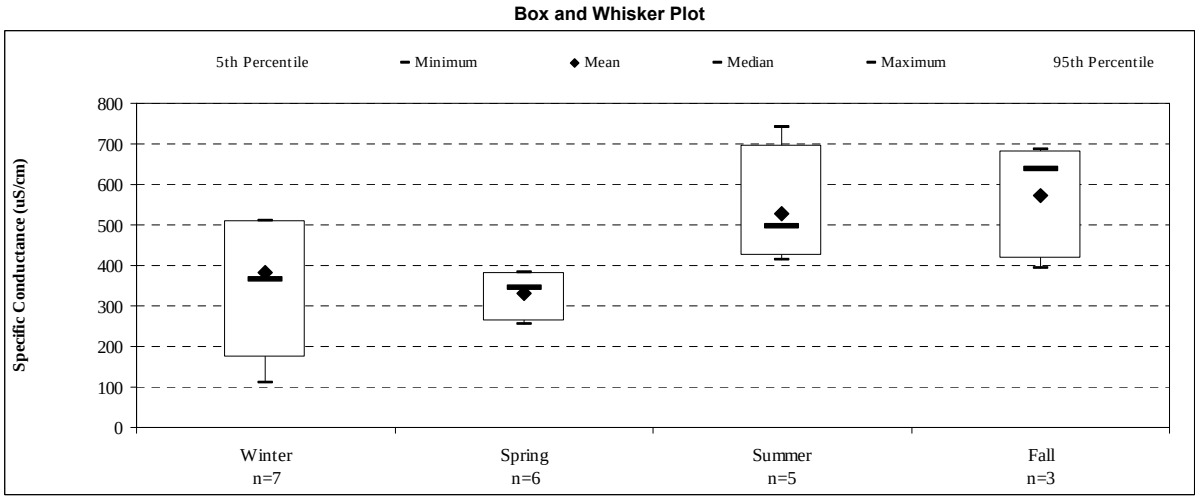


Figure G-3-4-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Redclay Creek



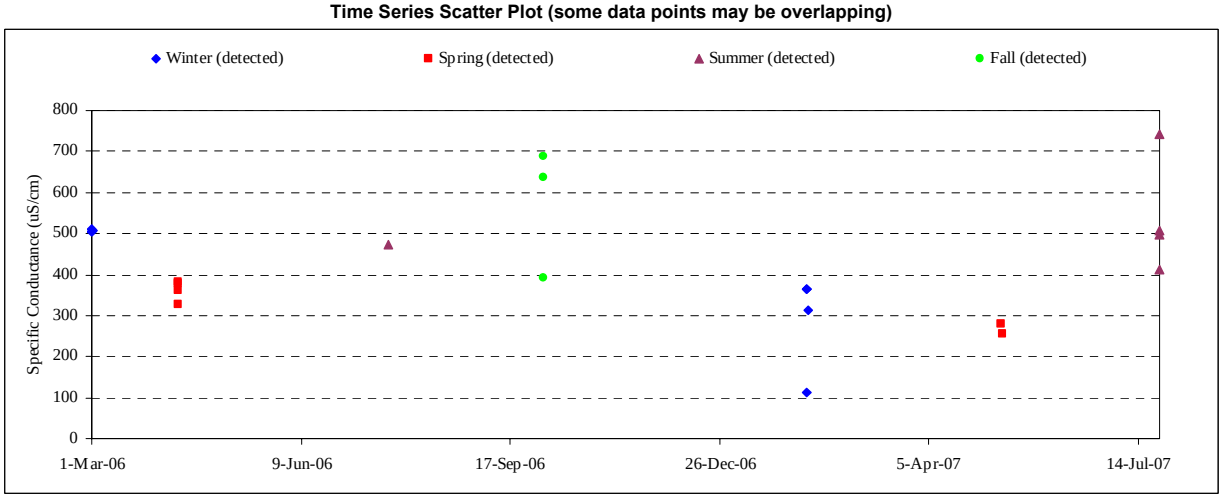
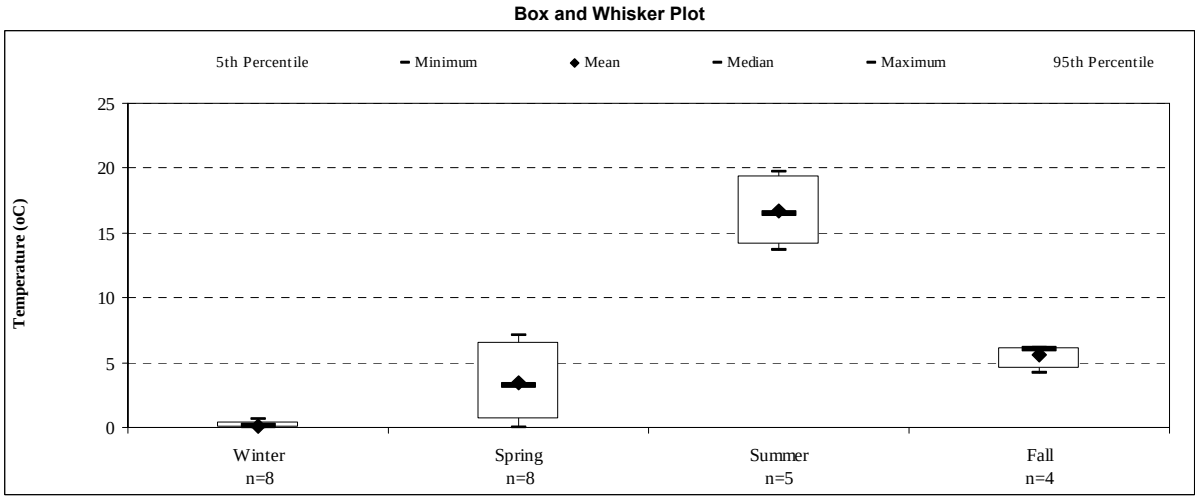


Figure G-3-4-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Redclay Creek



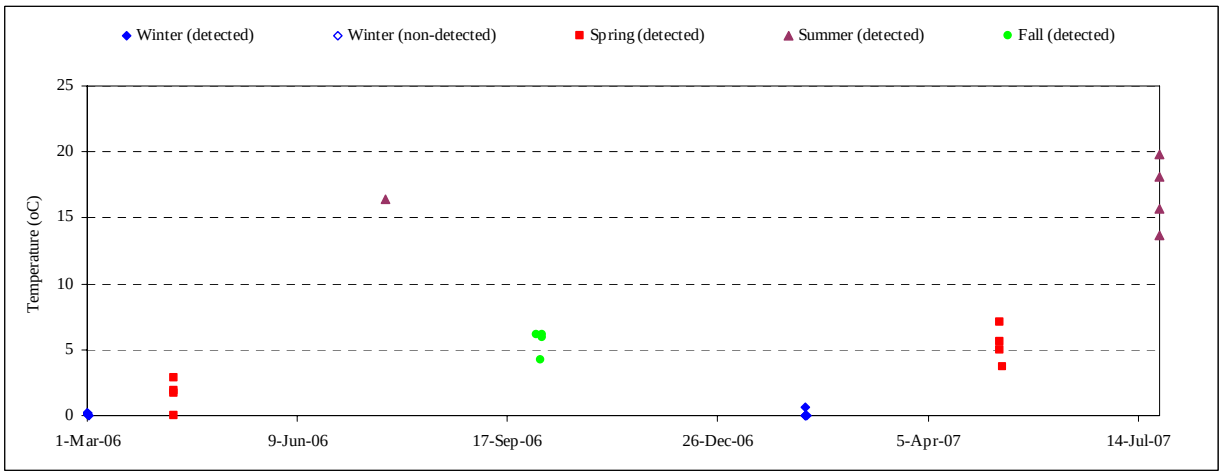
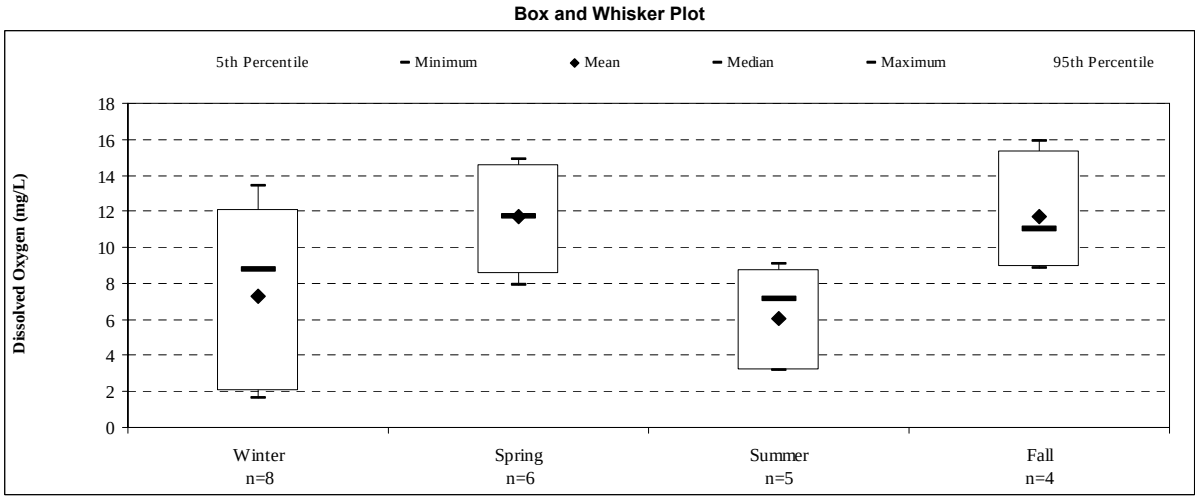


Figure G-3-4-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Redclay Creek



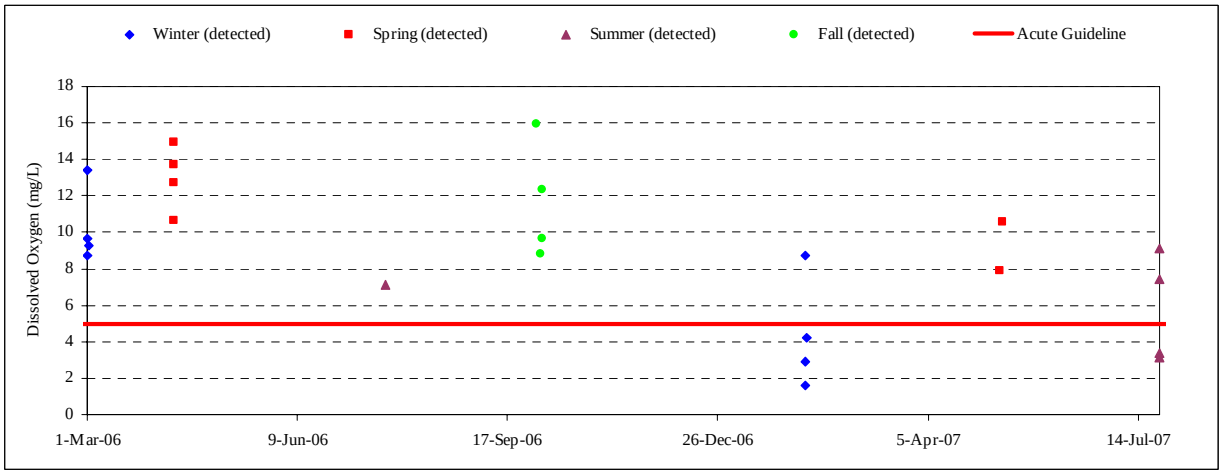
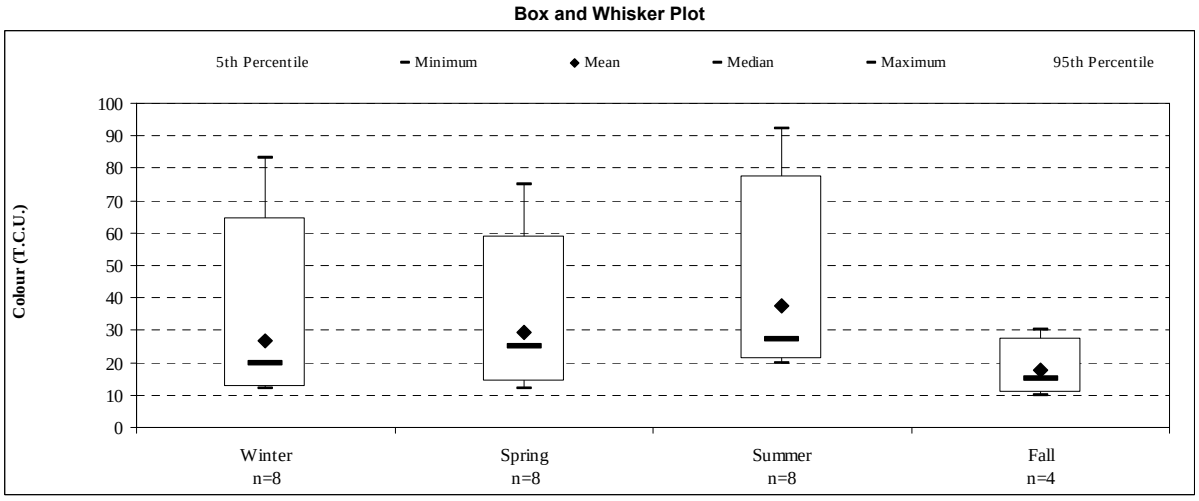


Figure G-3-4-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Redclay Creek



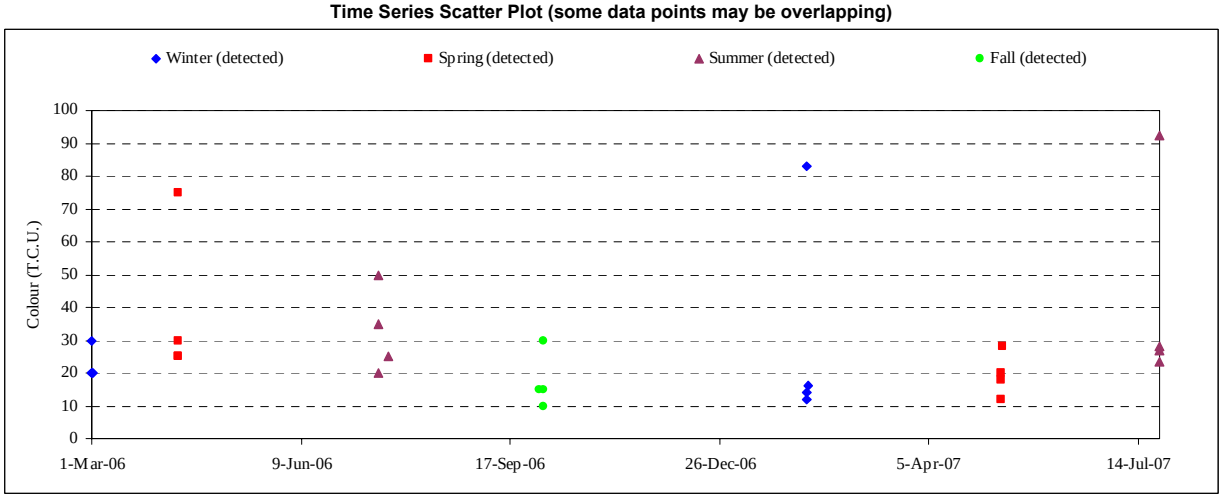
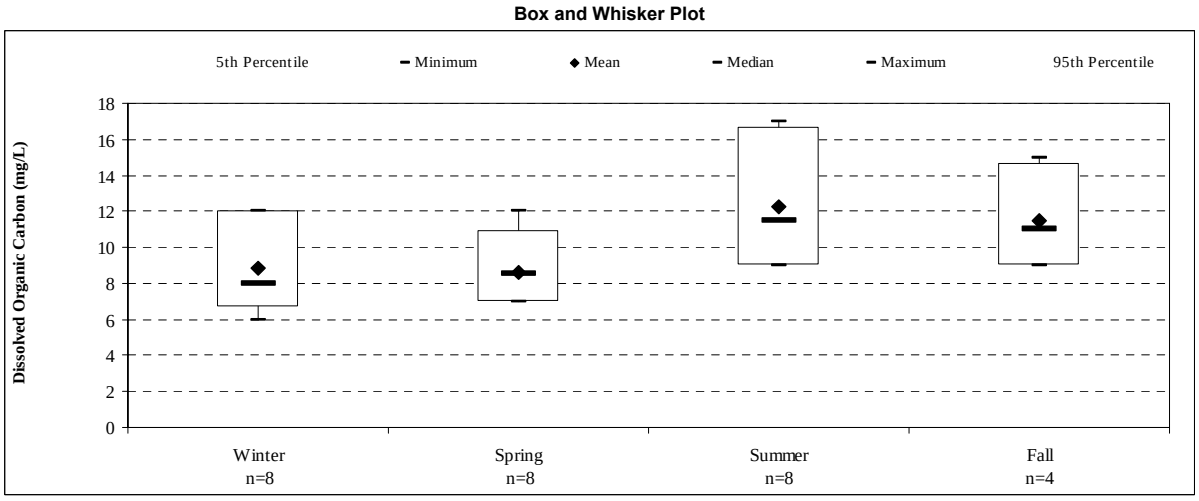


Figure G-3-4-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Redclay Creek



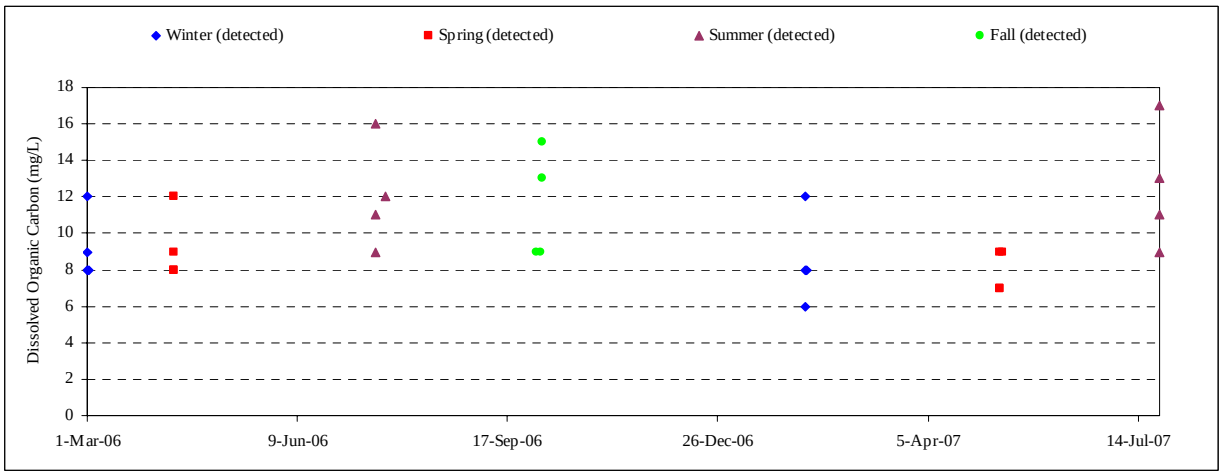
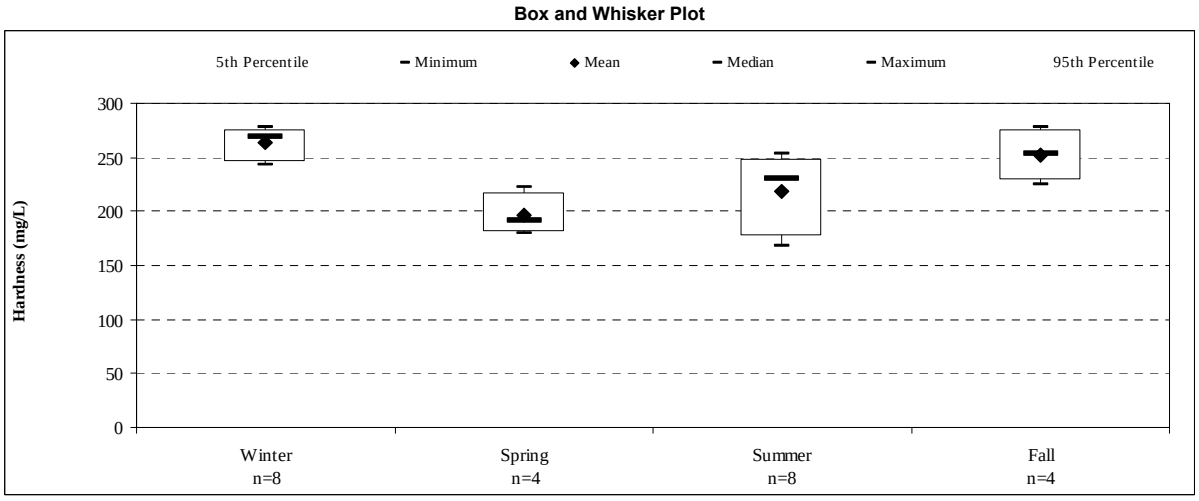


Figure G-3-4-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Redclay Creek



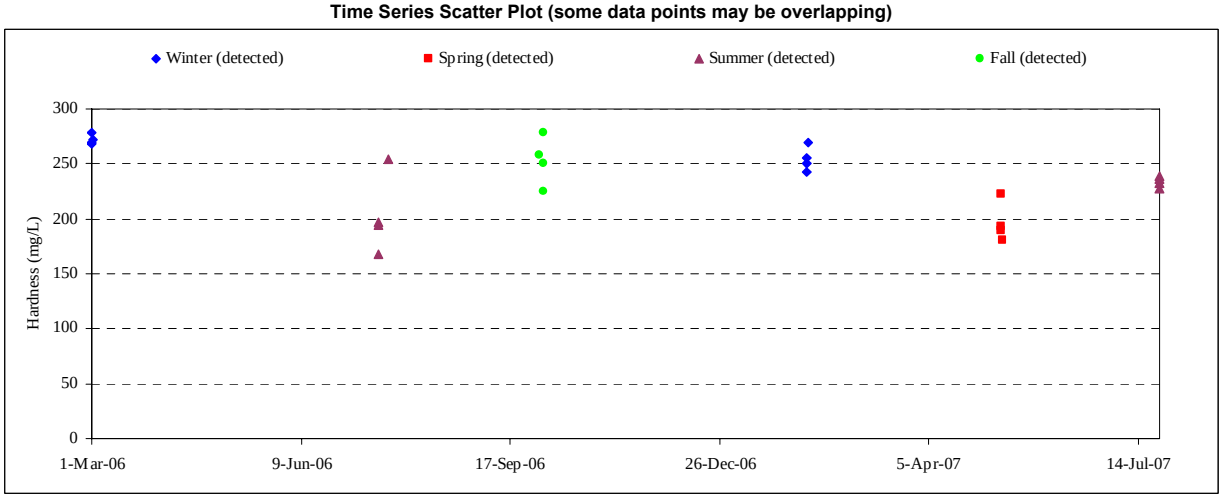
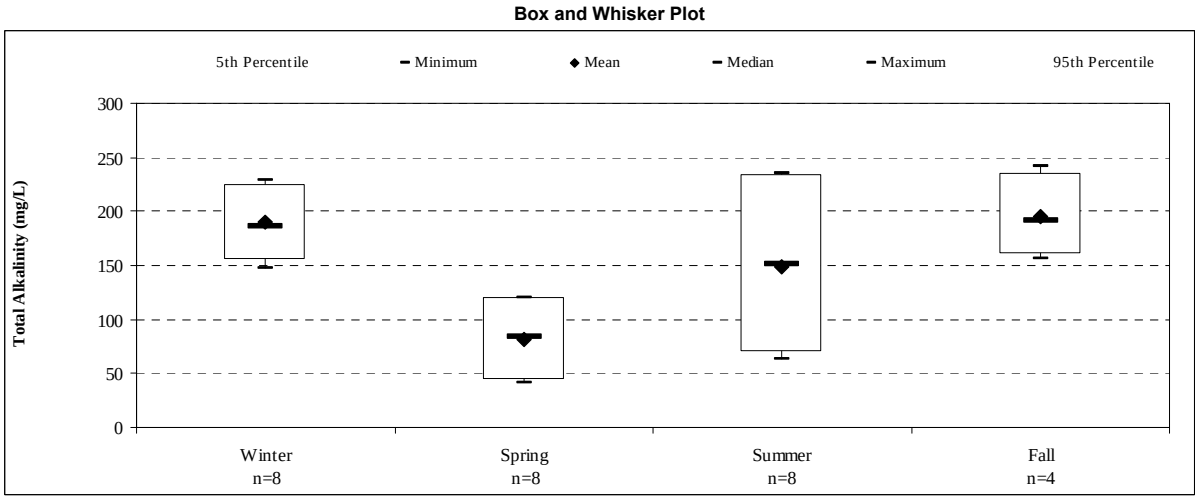


Figure G-3-4-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Redclay Creek



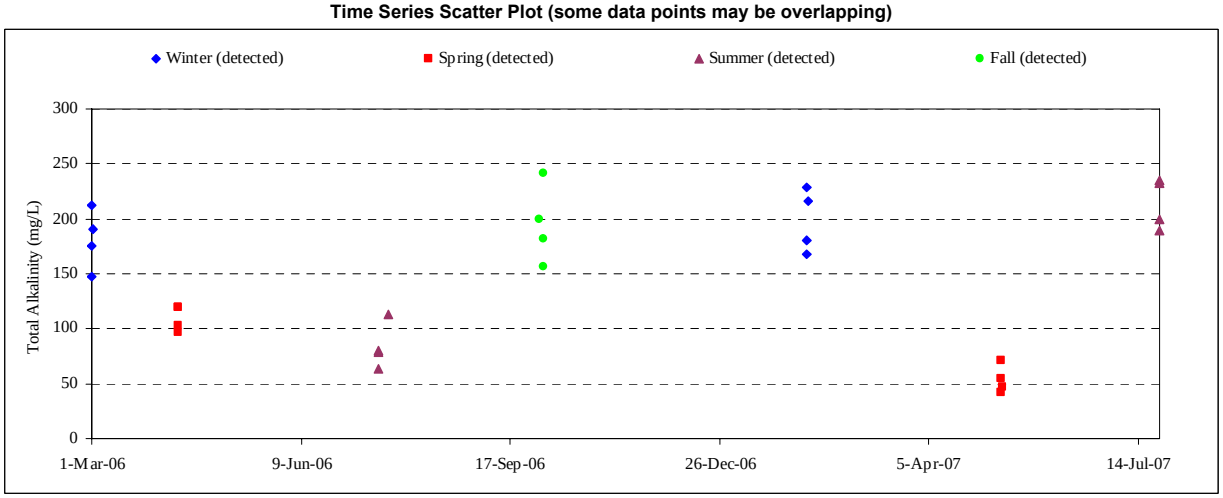
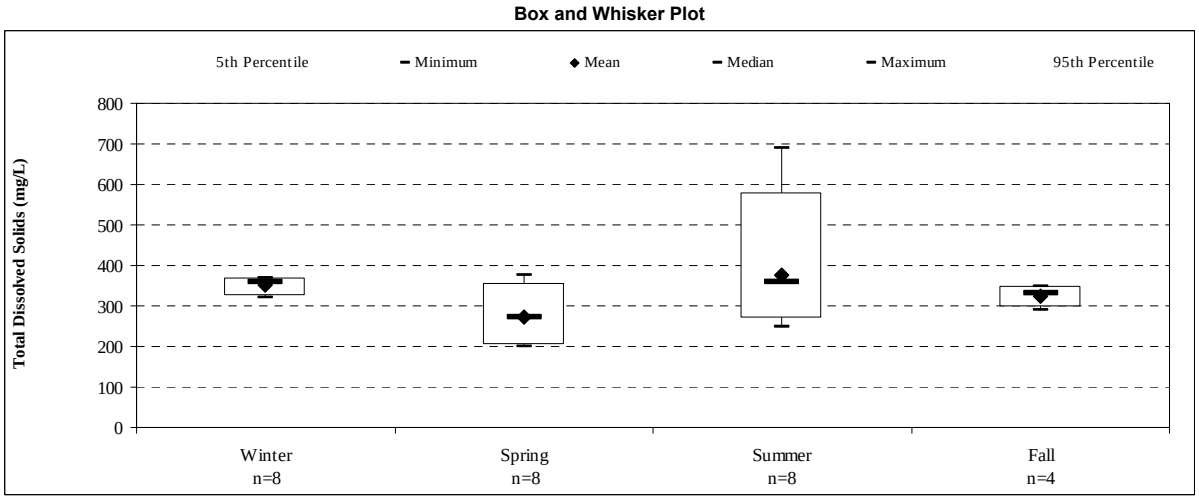


Figure G-3-4-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Redclay Creek



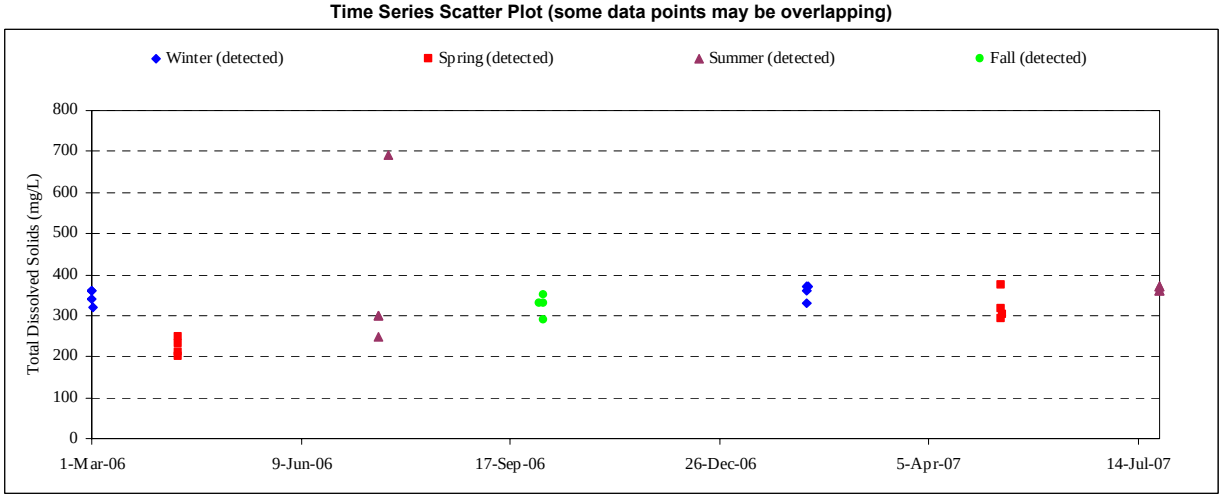
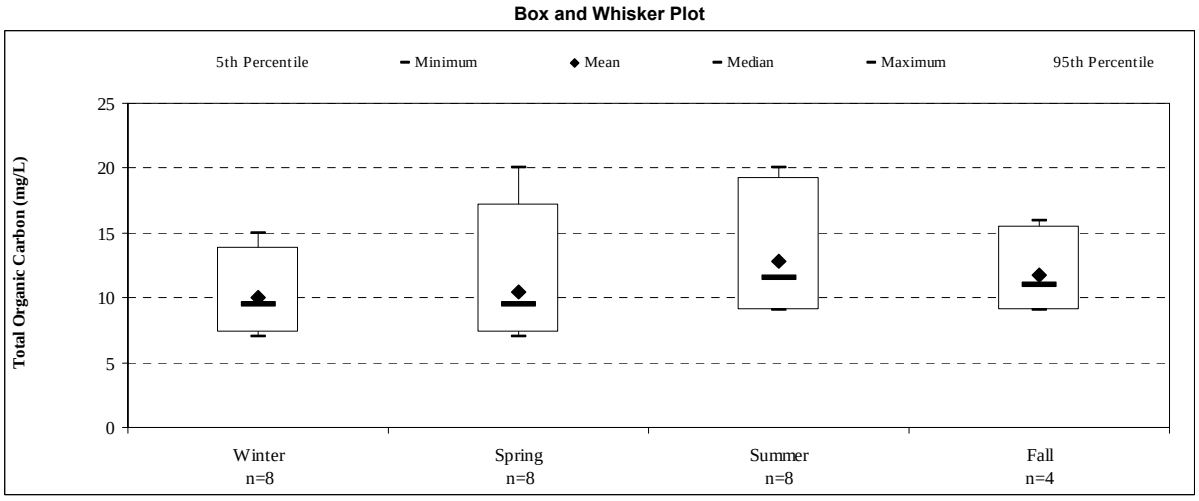


Figure G-3-4-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Redclay Creek



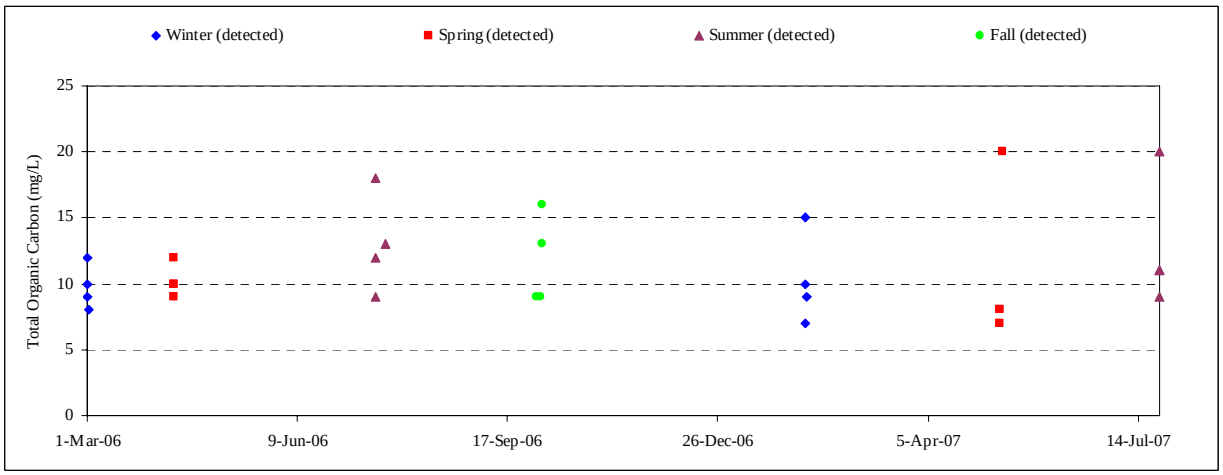
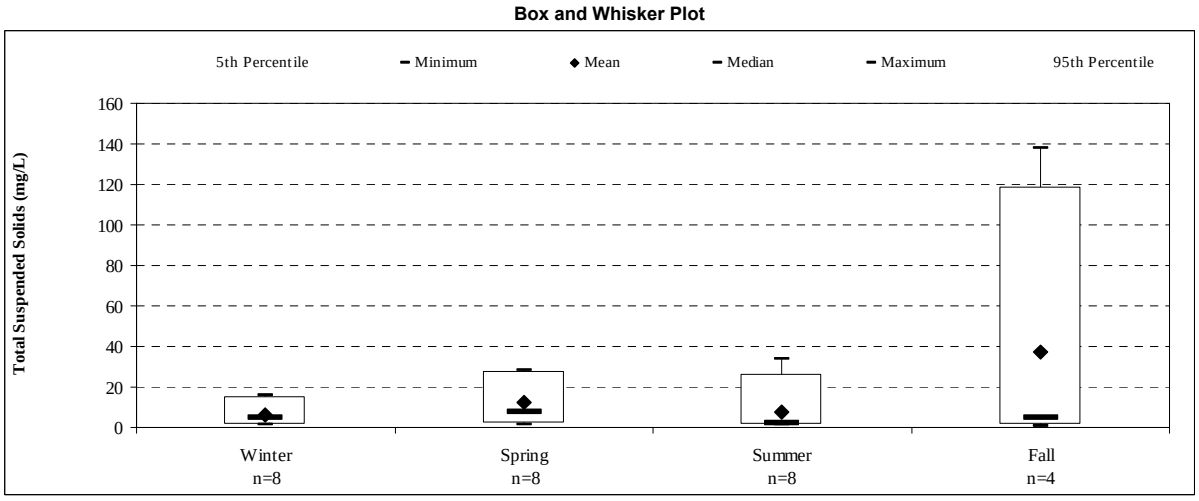


Figure G-3-4-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Redclay Creek



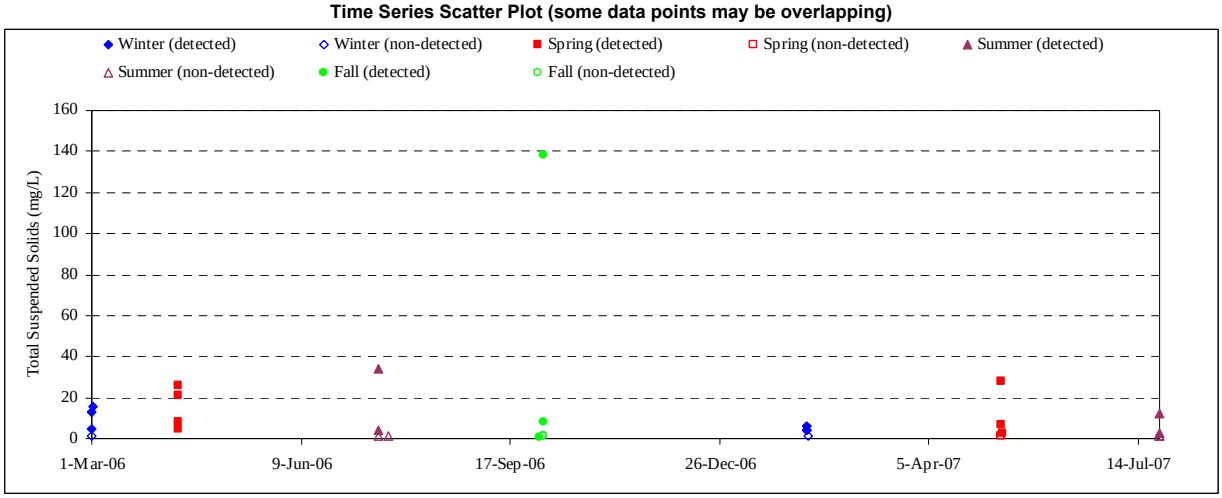
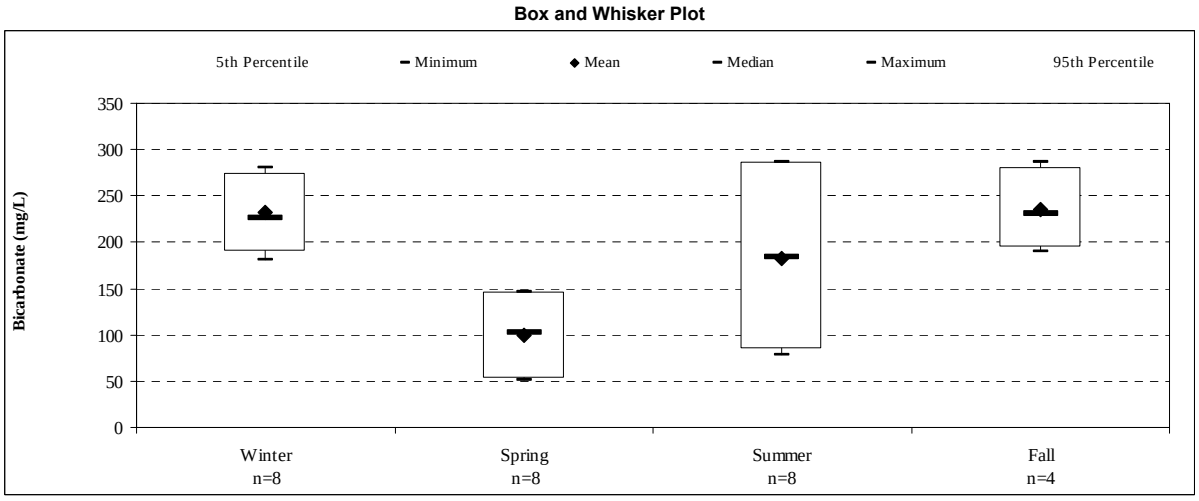


Figure G-3-4-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Redclay Creek



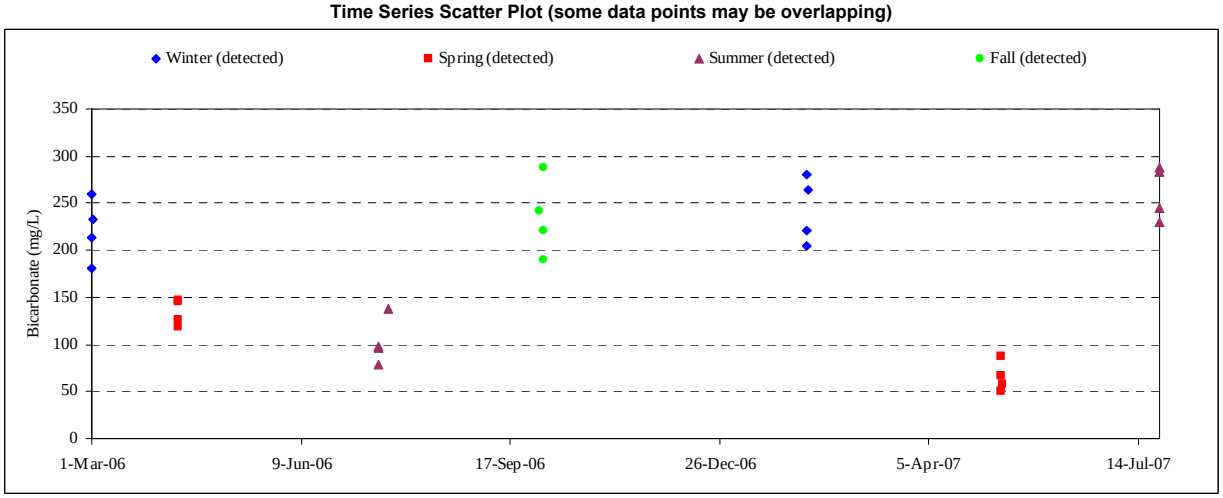
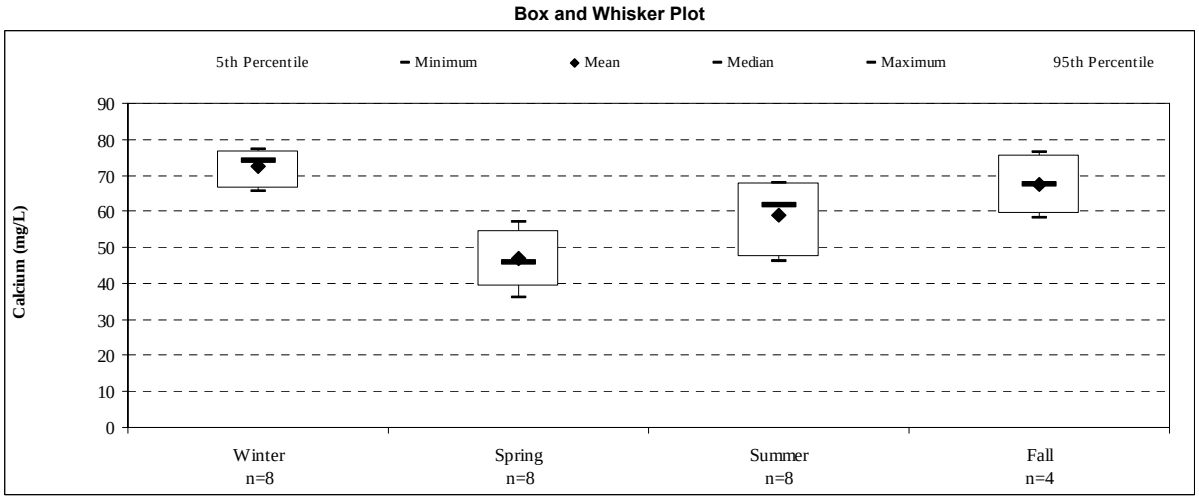


Figure G-3-4-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Redclay Creek



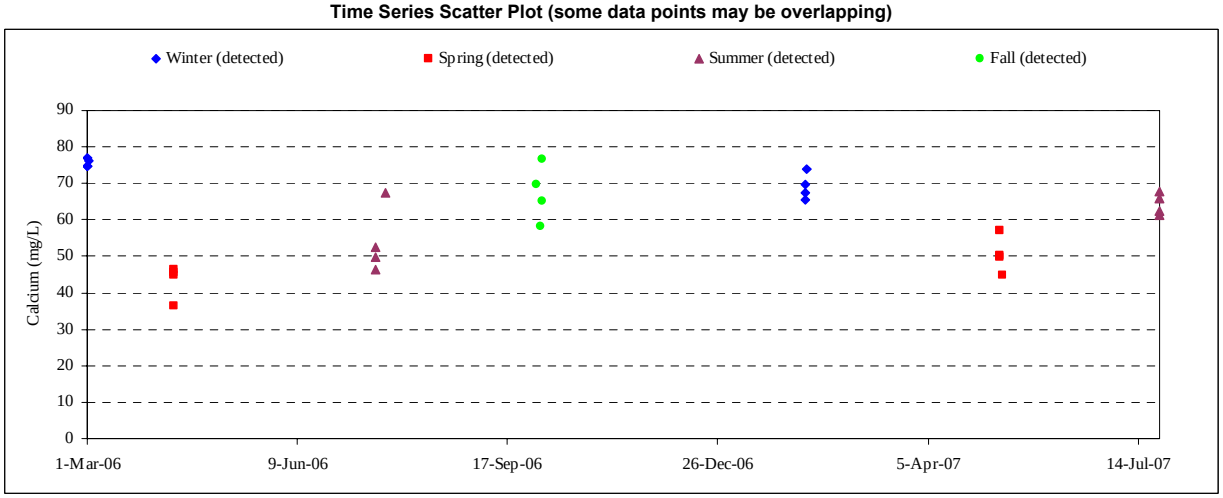
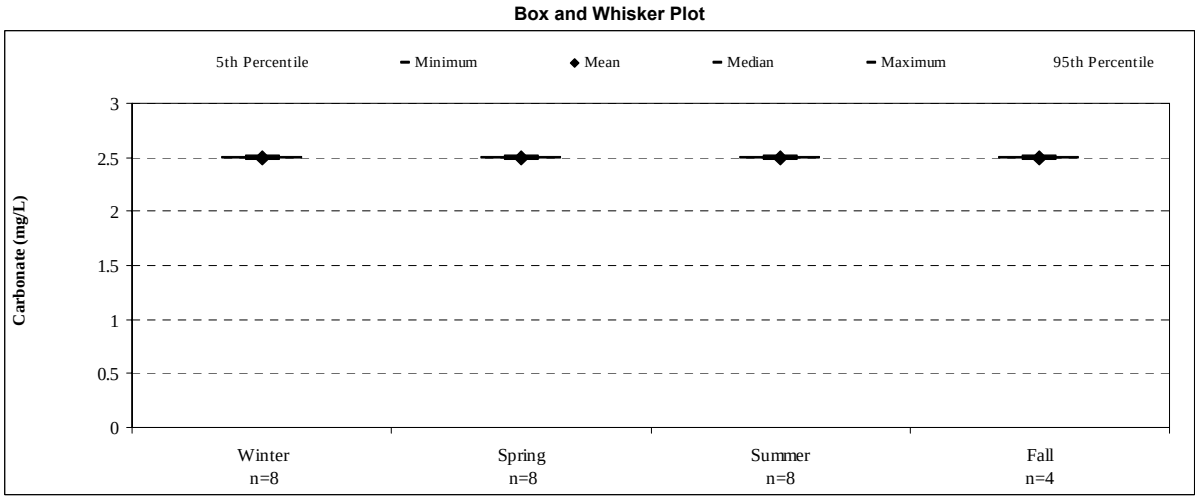


Figure G-3-4-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Redclay Creek



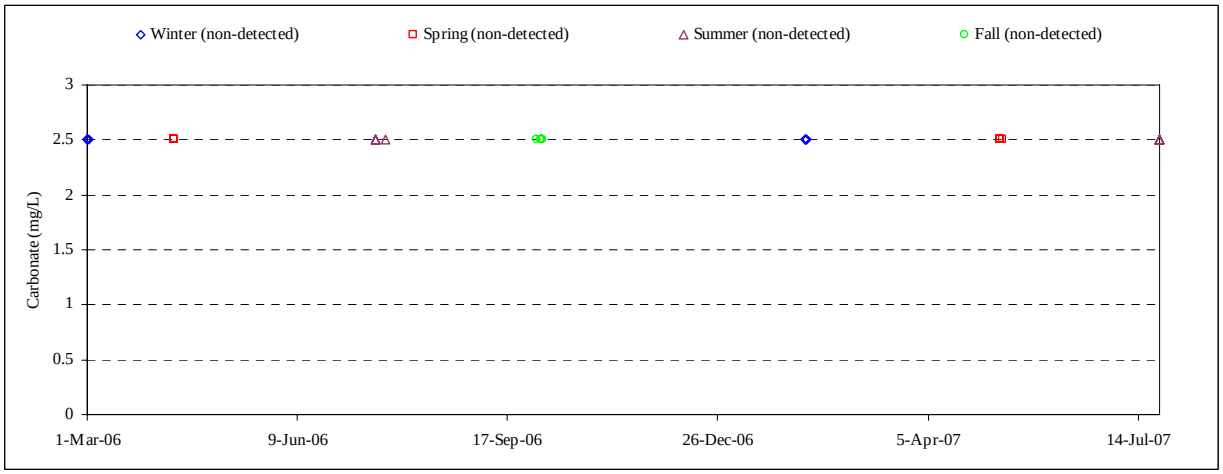
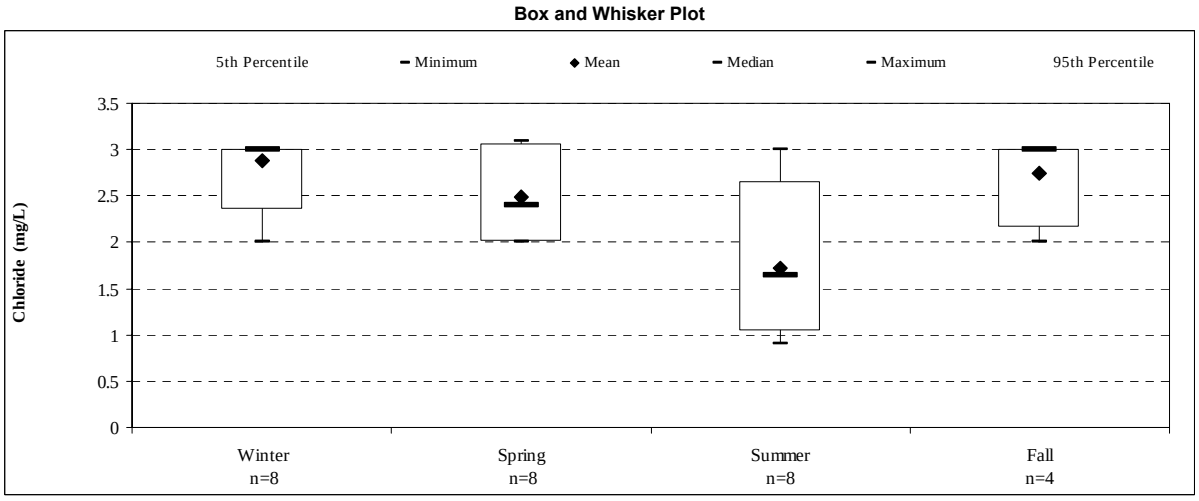


Figure G-3-4-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Redclay Creek



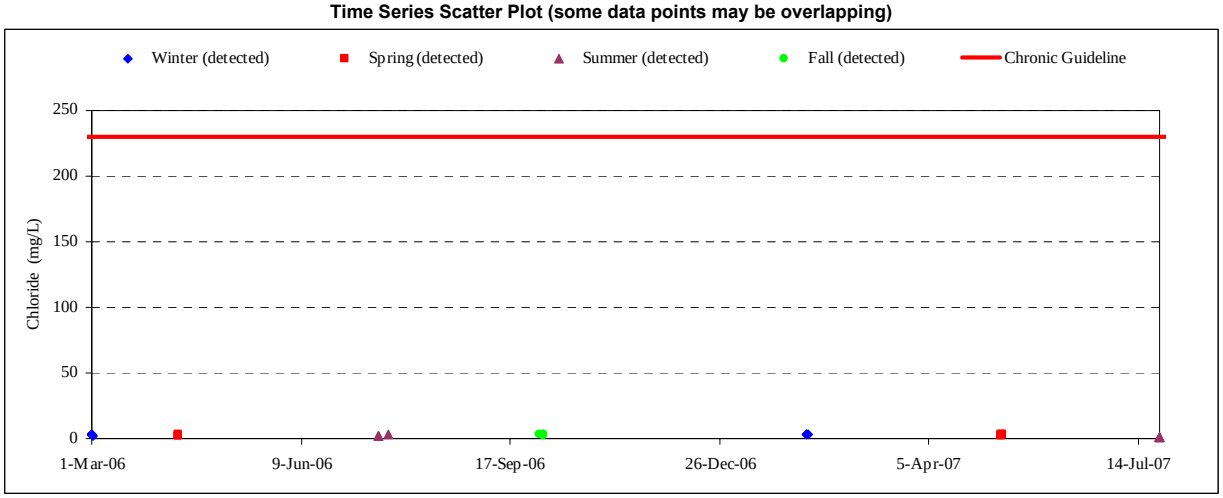
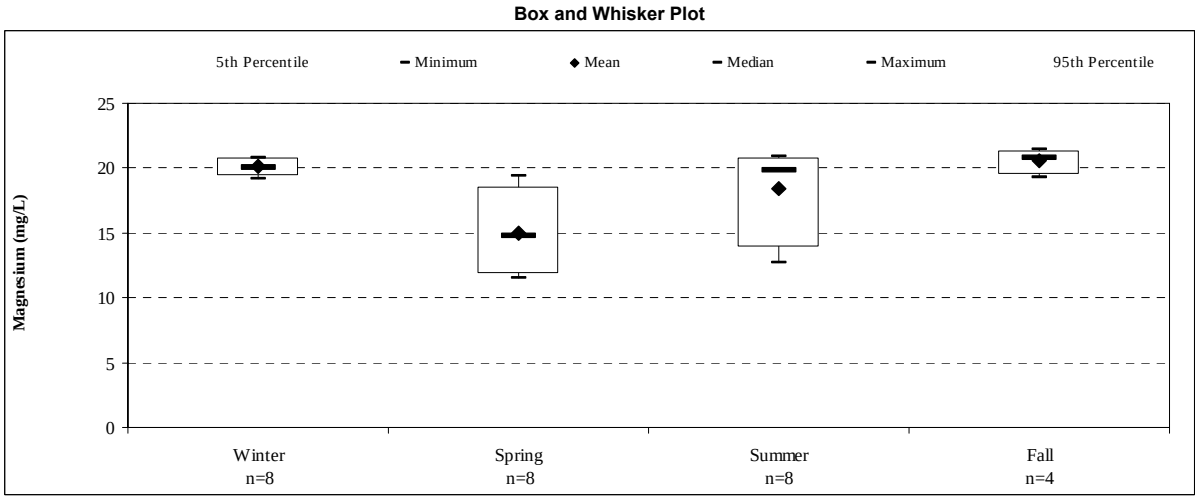


Figure G-3-4-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Redclay Creek



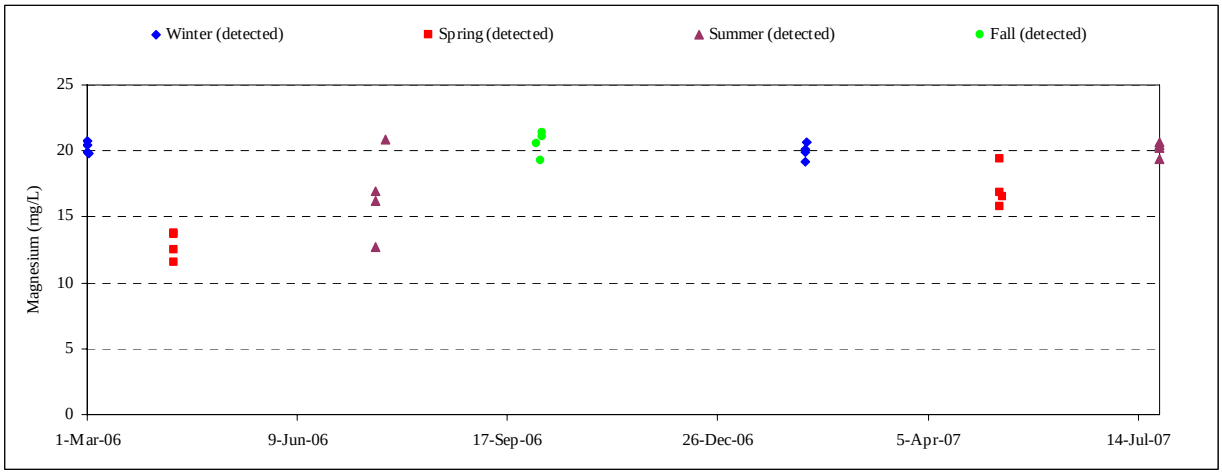
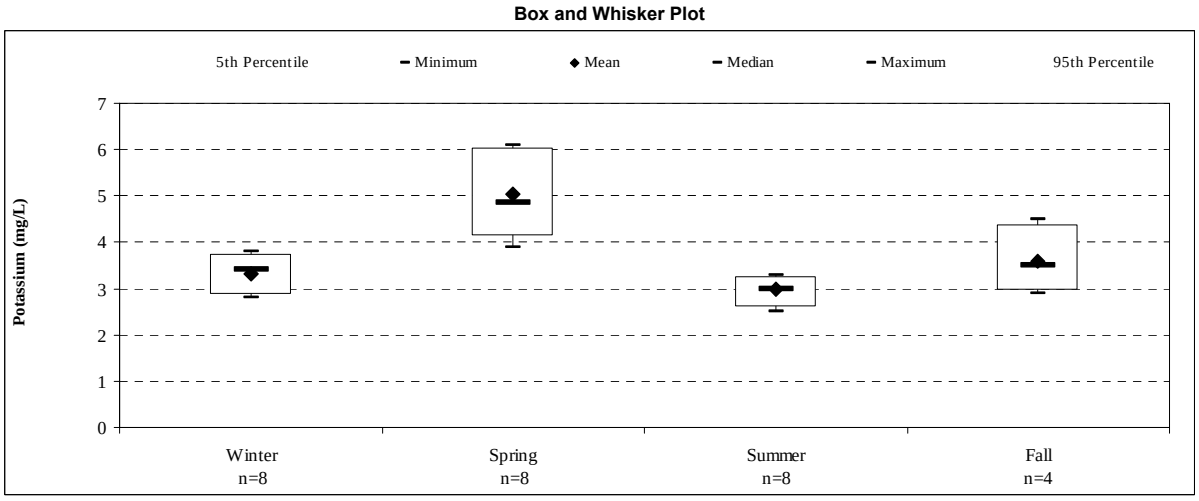


Figure G-3-4-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Redclay Creek



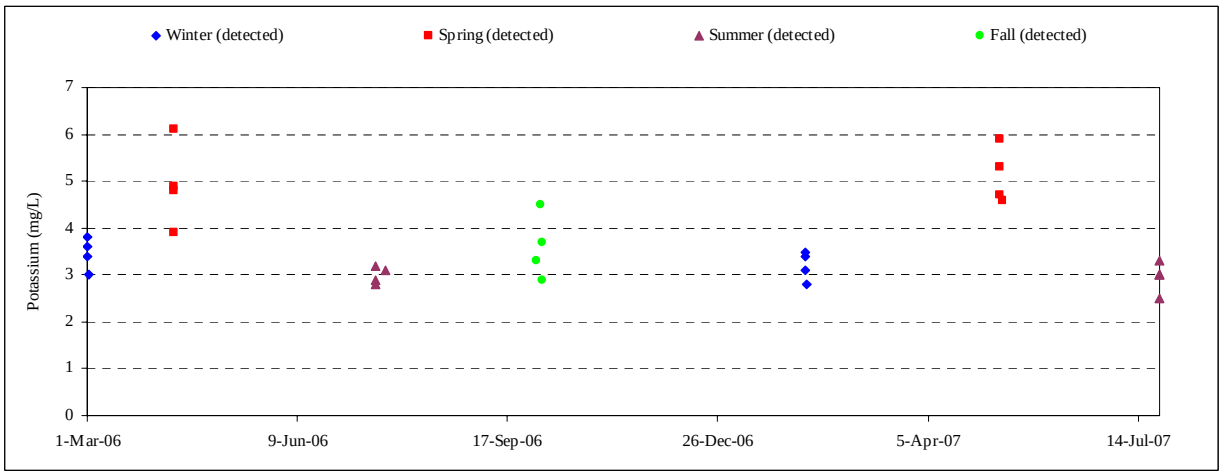
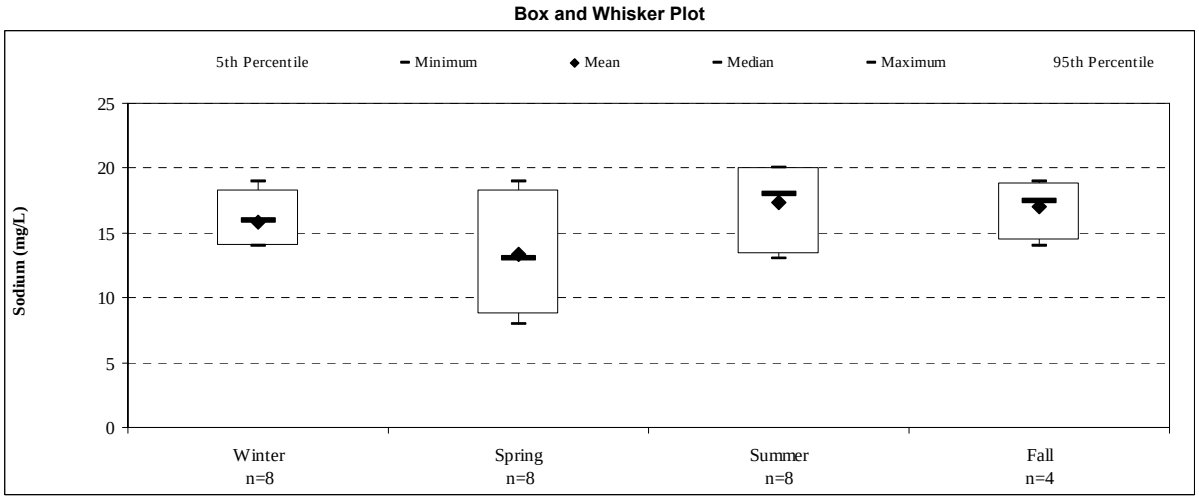


Figure G-3-4-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Redclay Creek



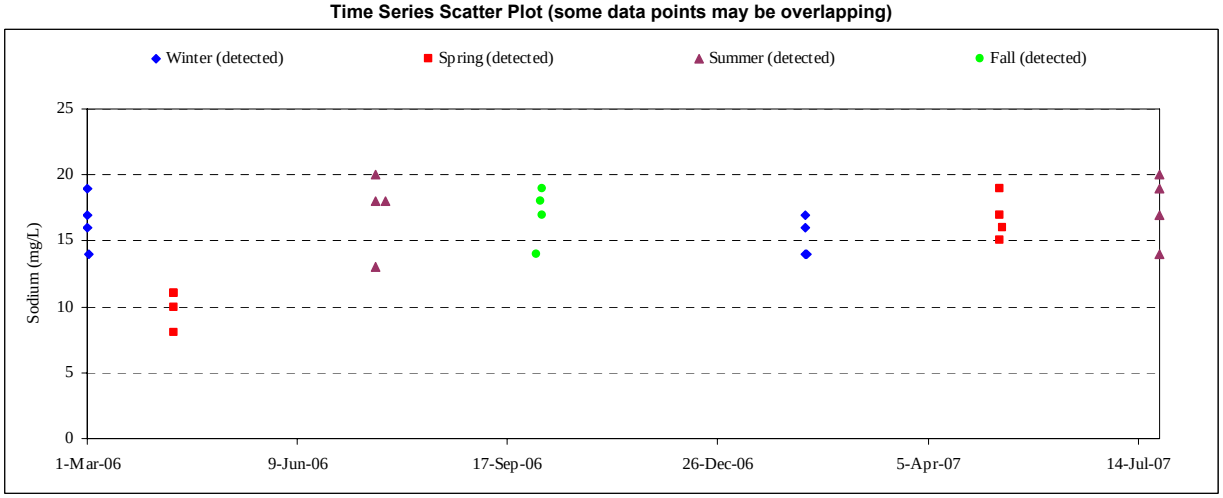
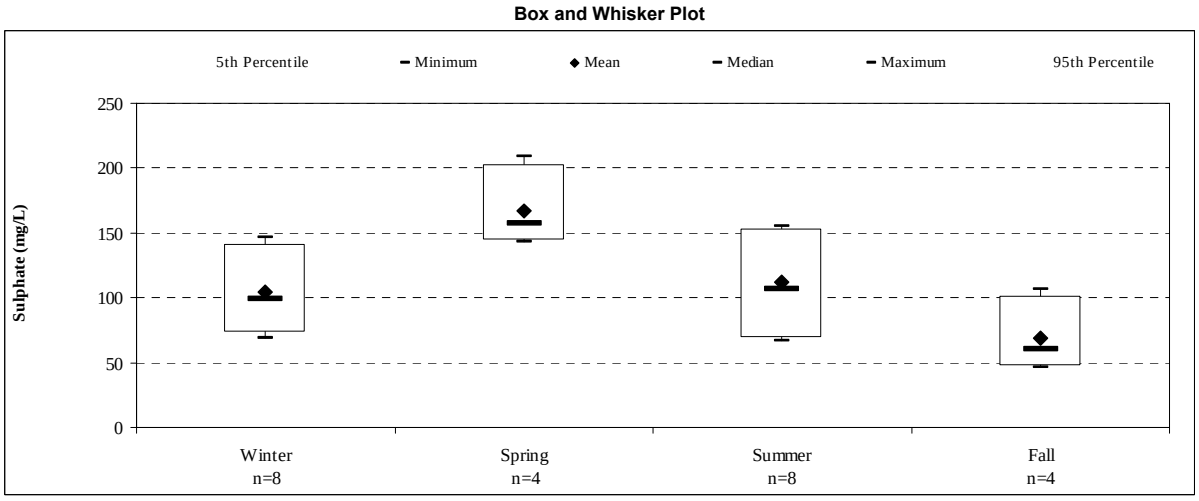


Figure G-3-4-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Redclay Creek



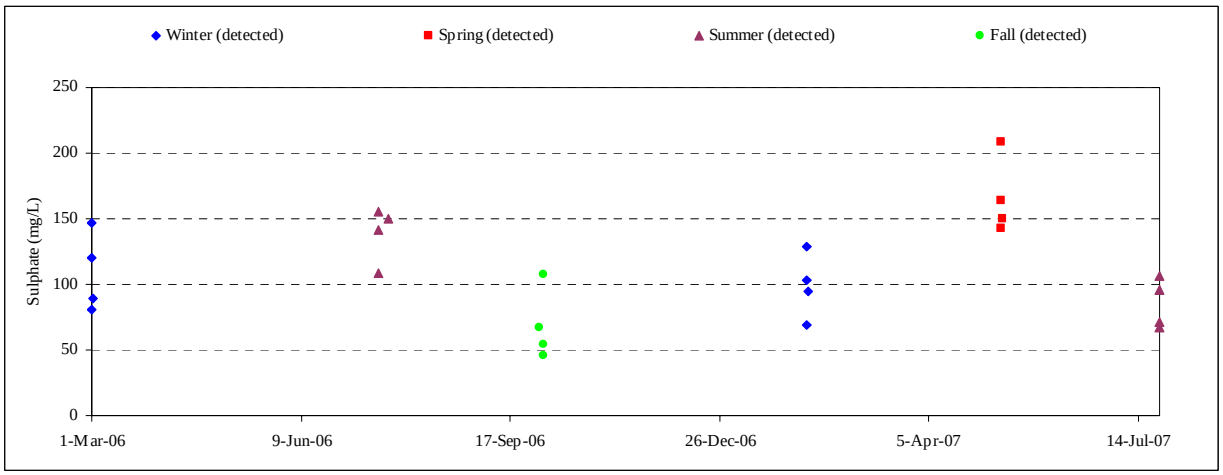


Figure G-3-4-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Redclay Creek

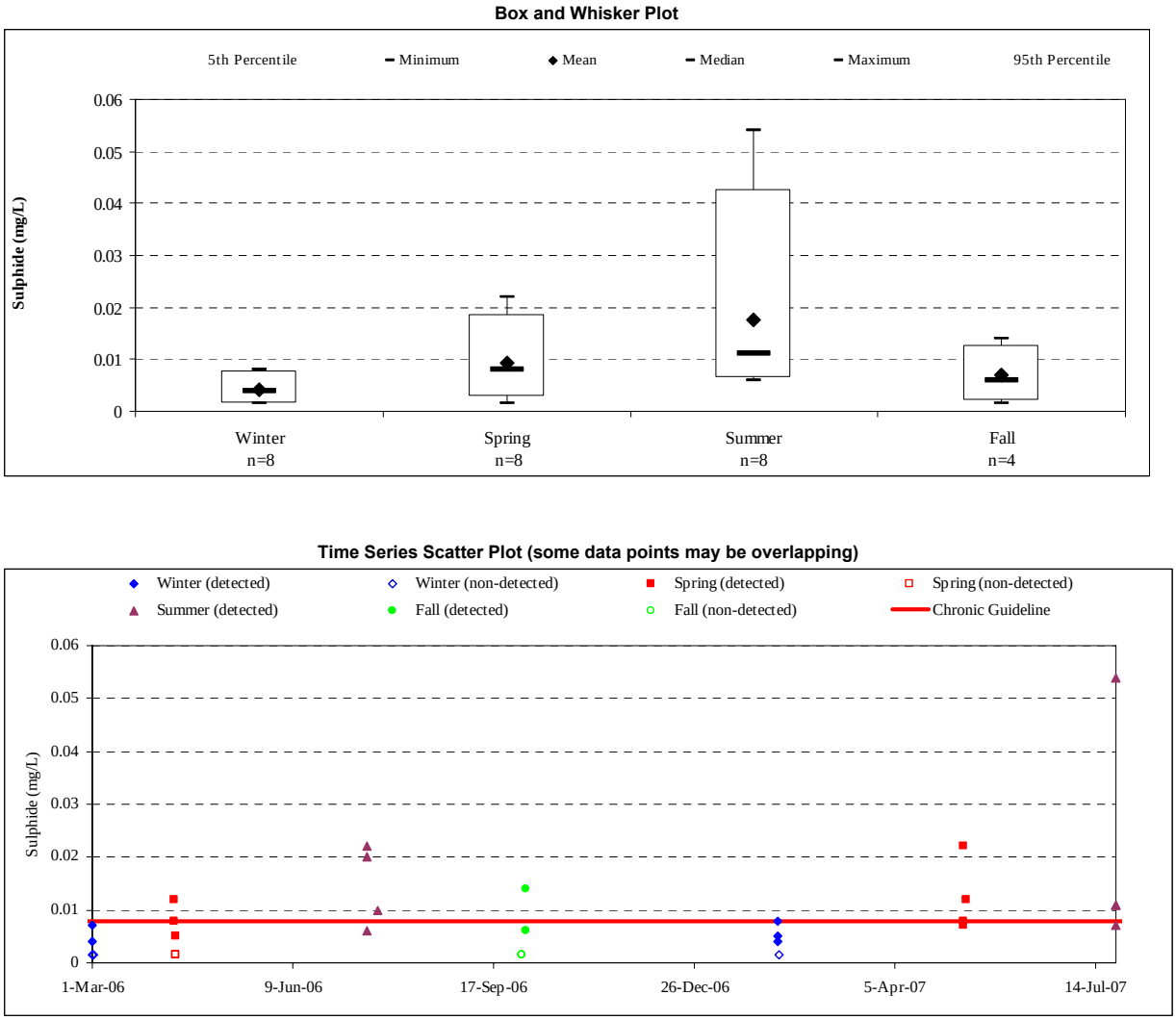
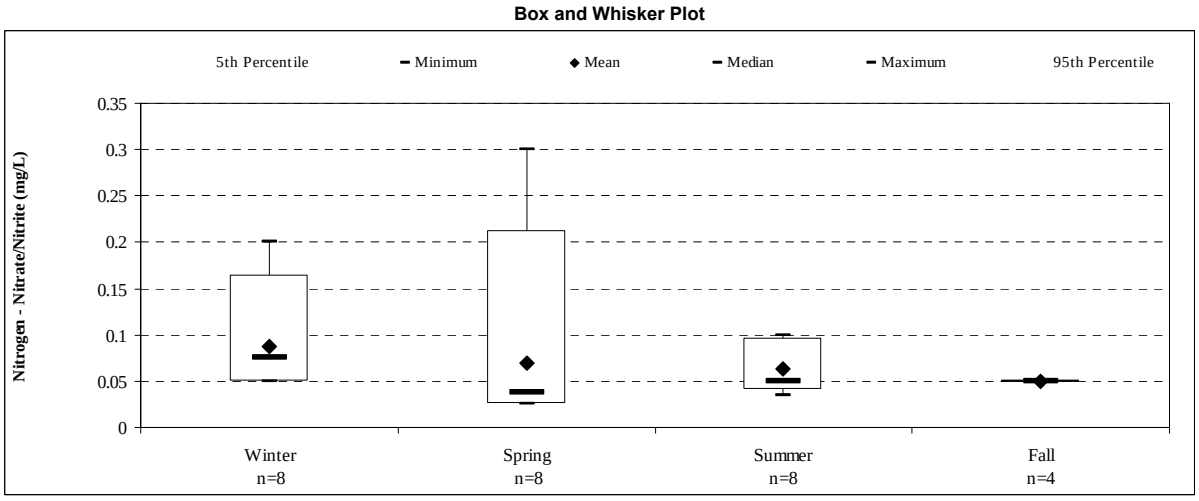


Figure G-3-4-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Redclay Creek



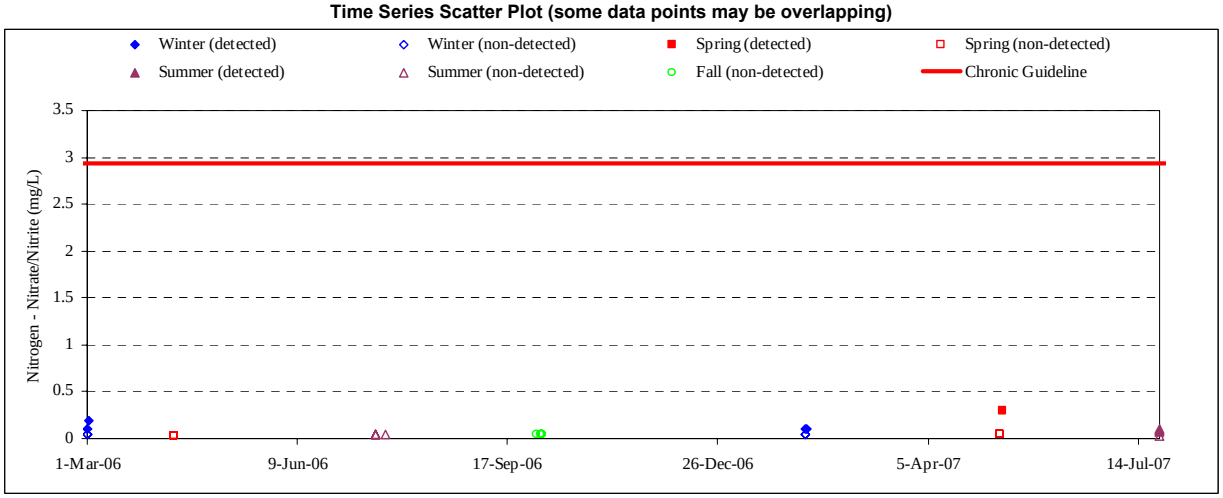
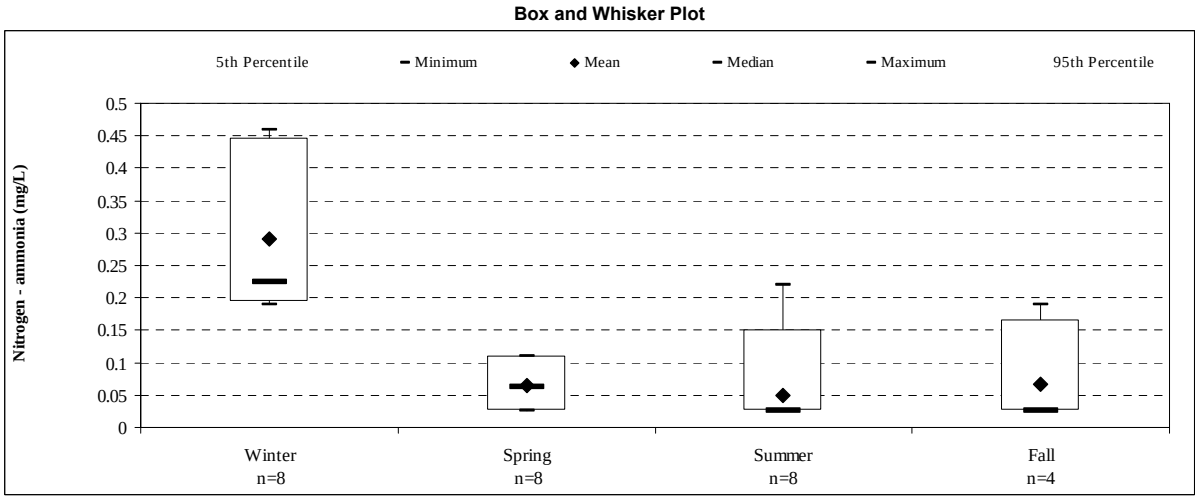


Figure G-3-4-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Redclay Creek



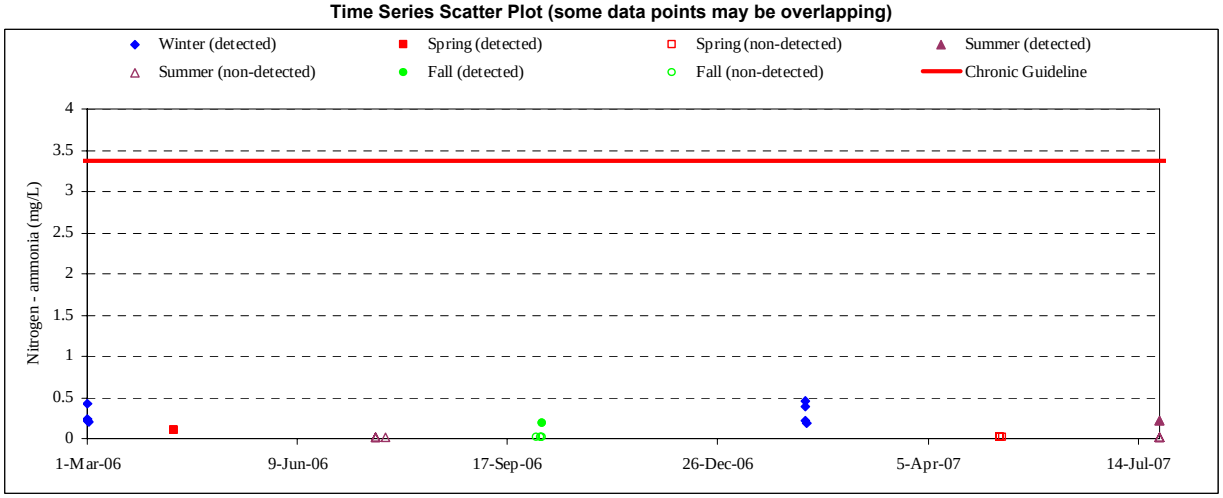
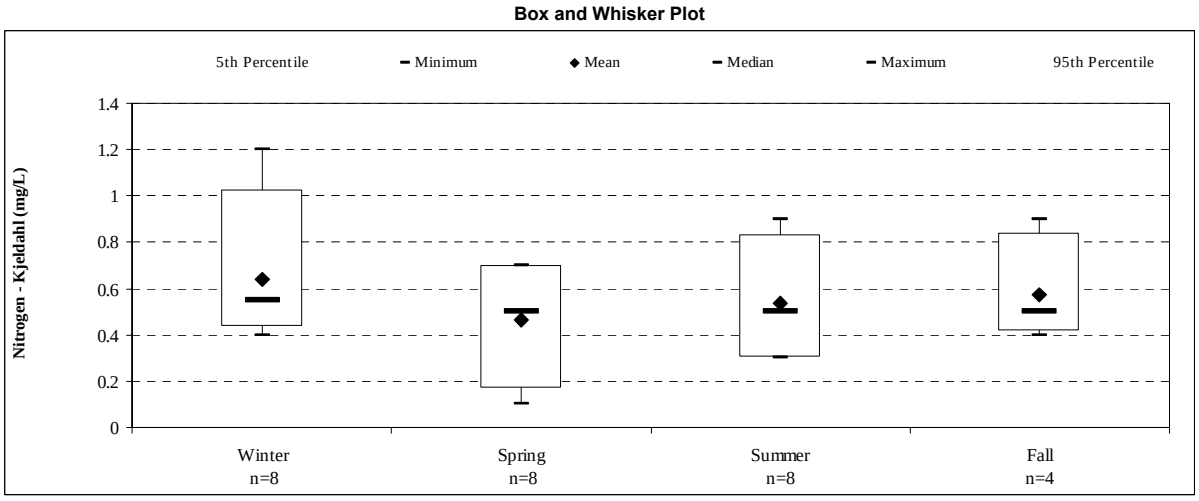


Figure G-3-4-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Redclay Creek



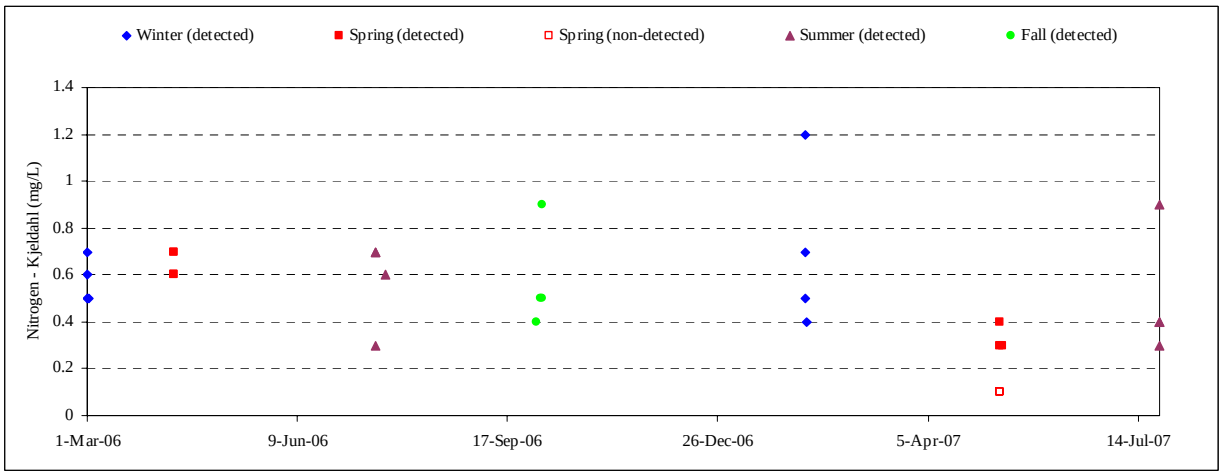
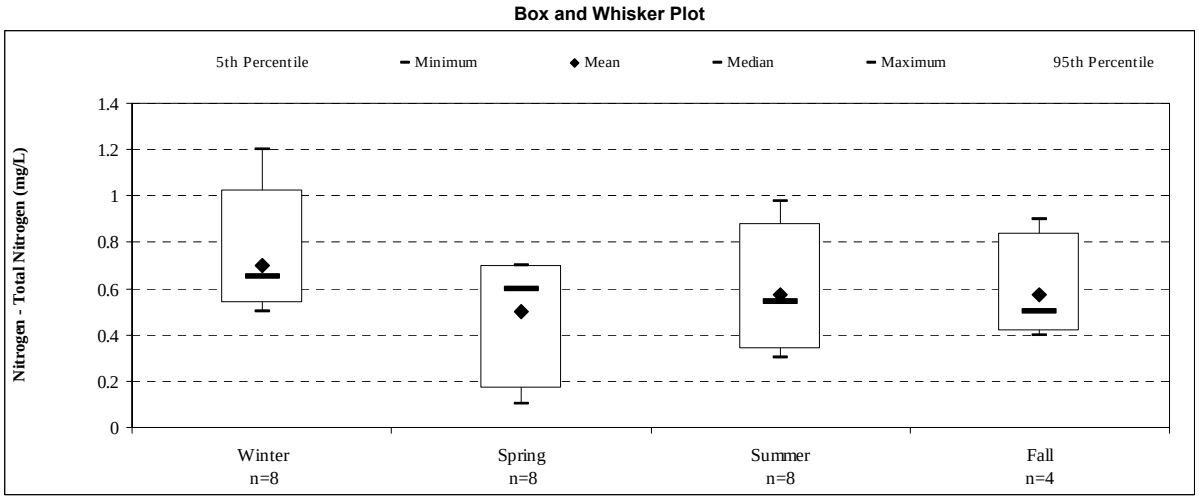


Figure G-3-4-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Redclay Creek



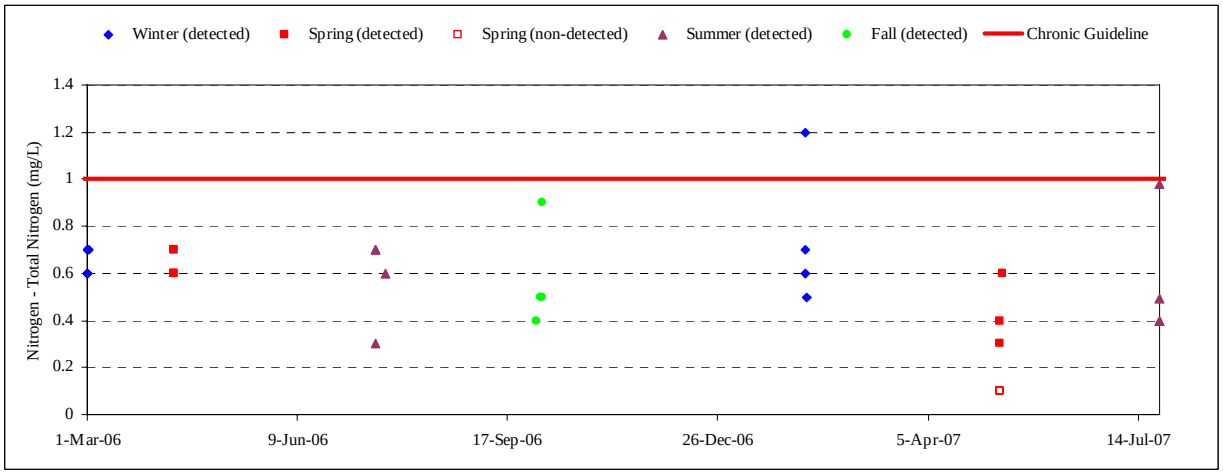
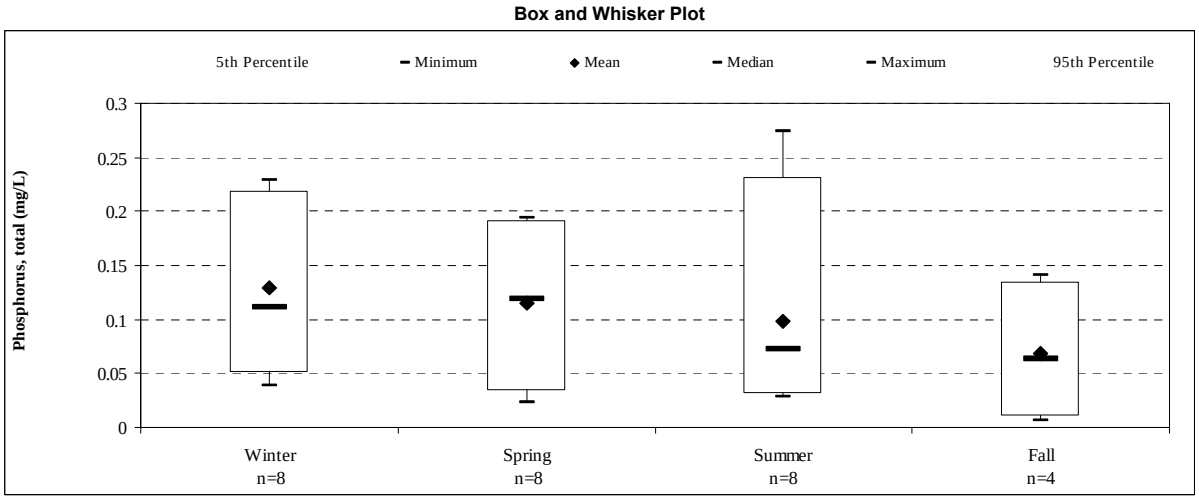


Figure G-3-4-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Redclay Creek



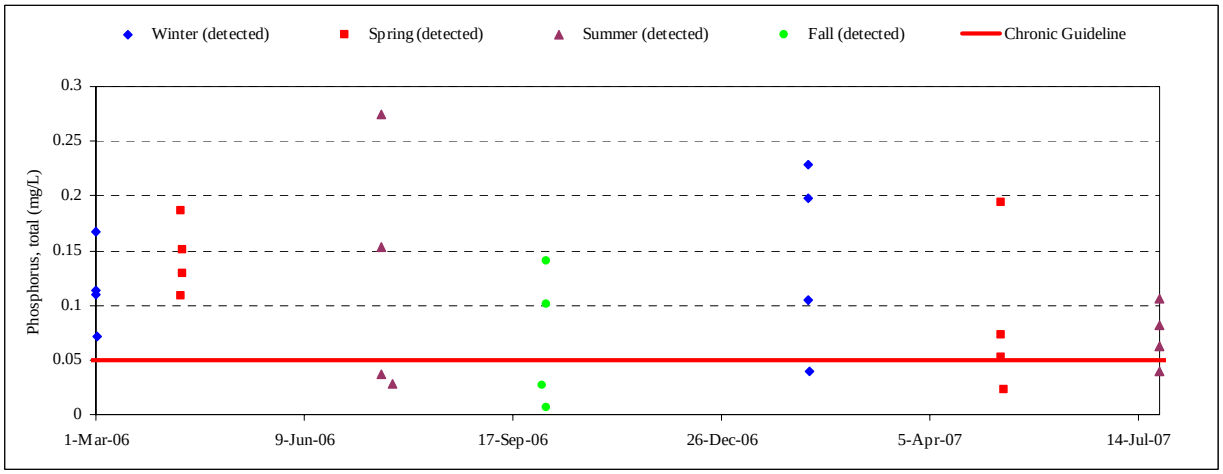
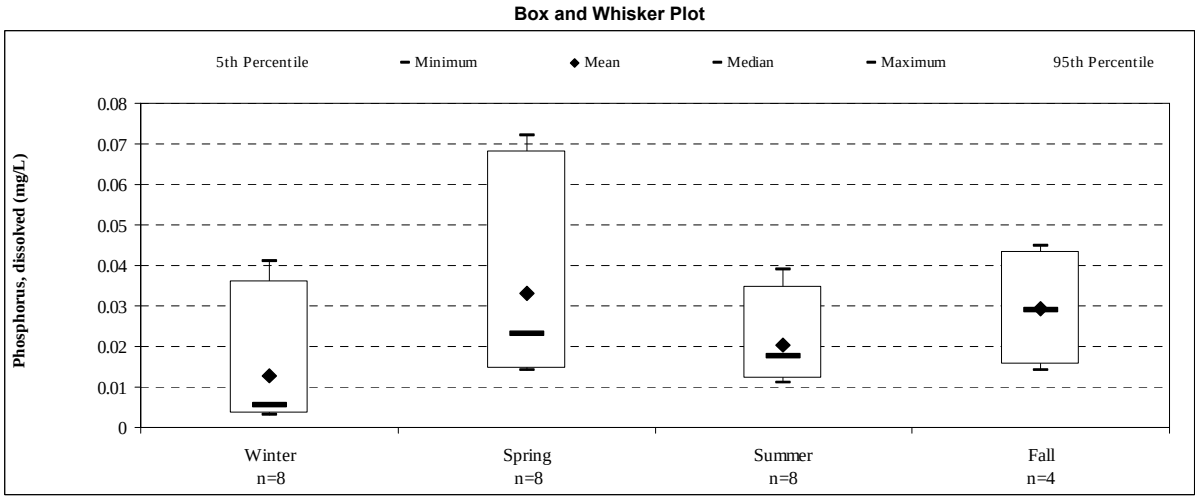


Figure G-3-4-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Redclay Creek



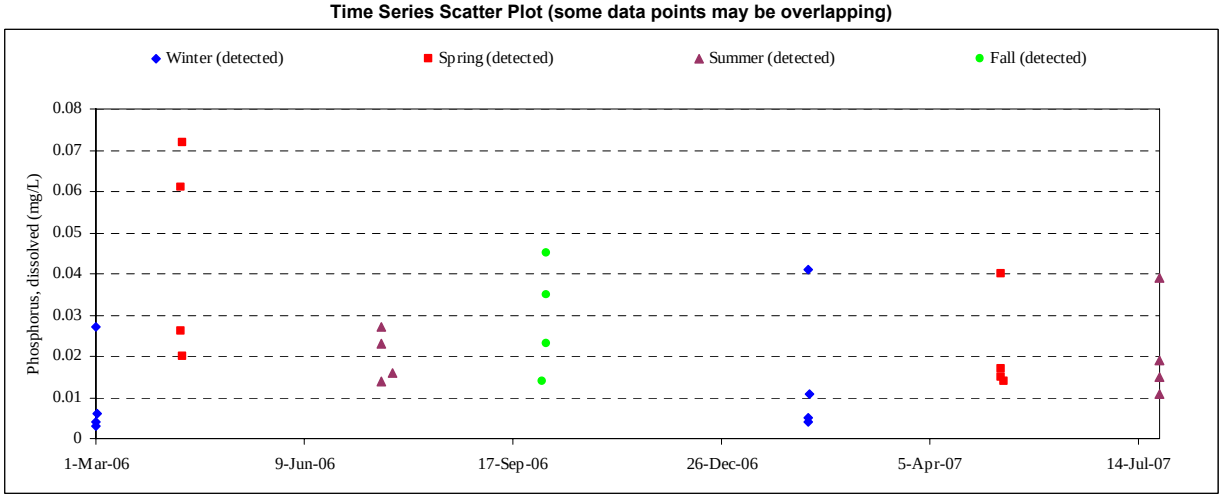
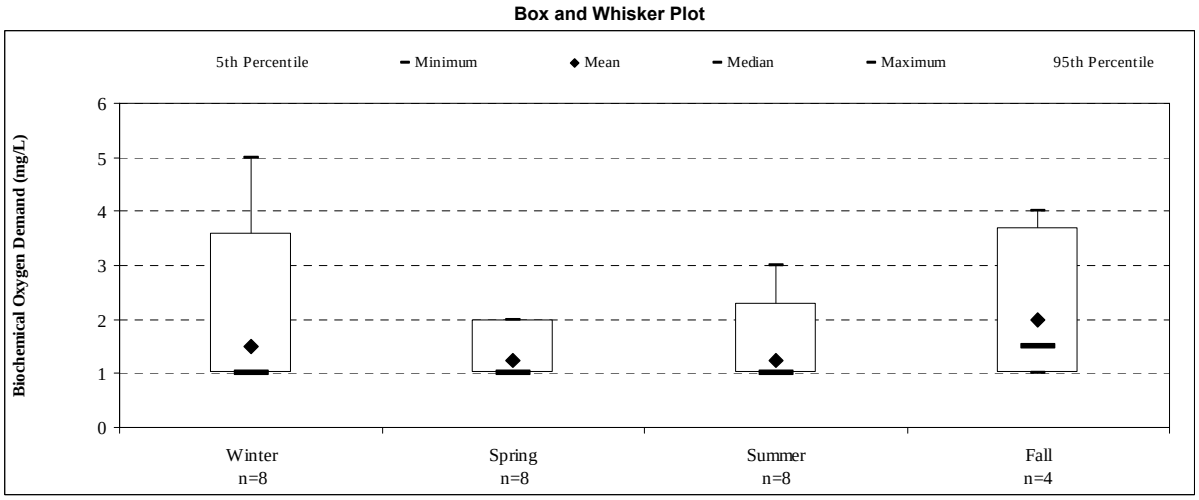


Figure G-3-4-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Redclay Creek



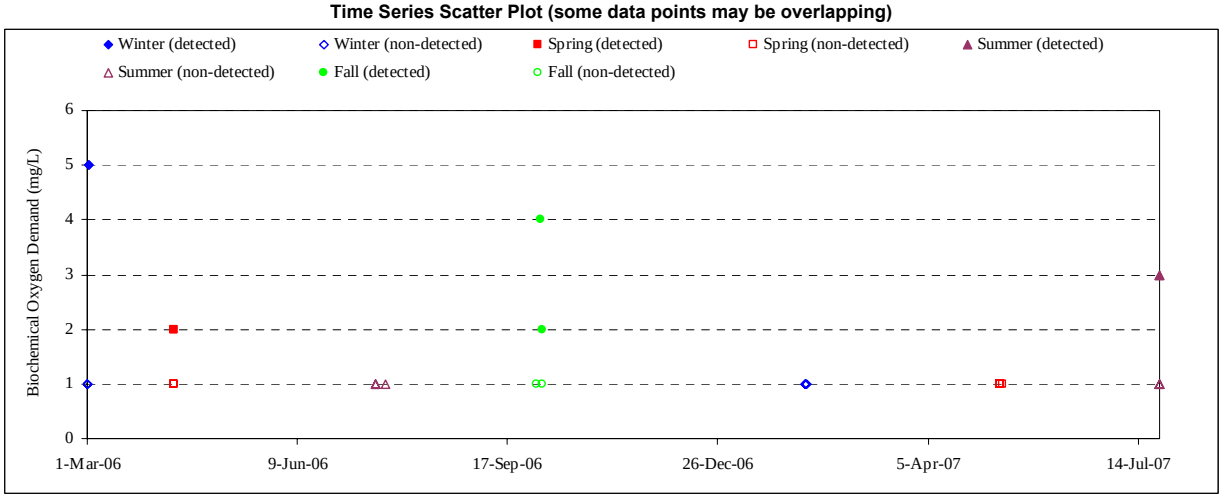
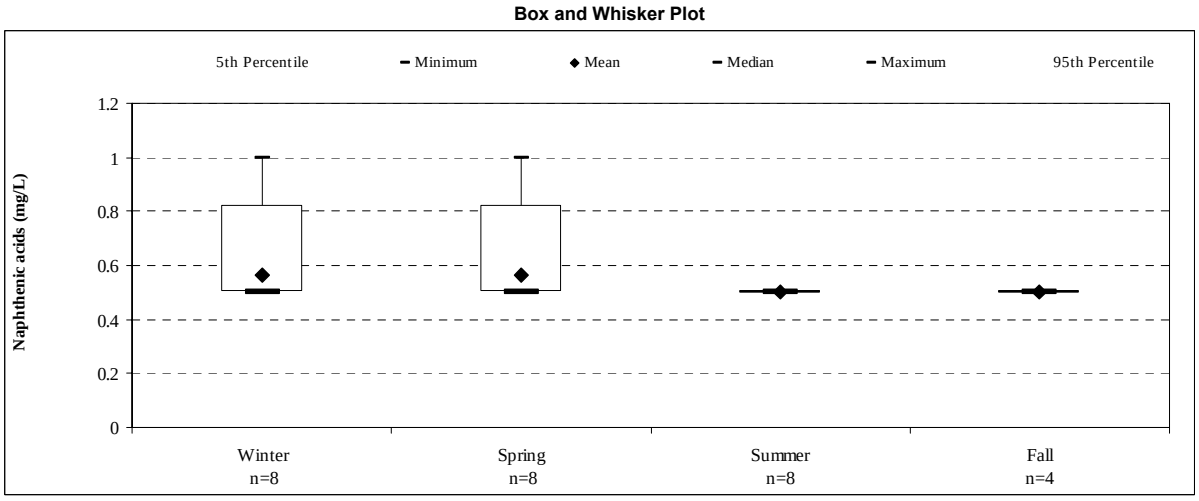


Figure G-3-4-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Redclay Creek



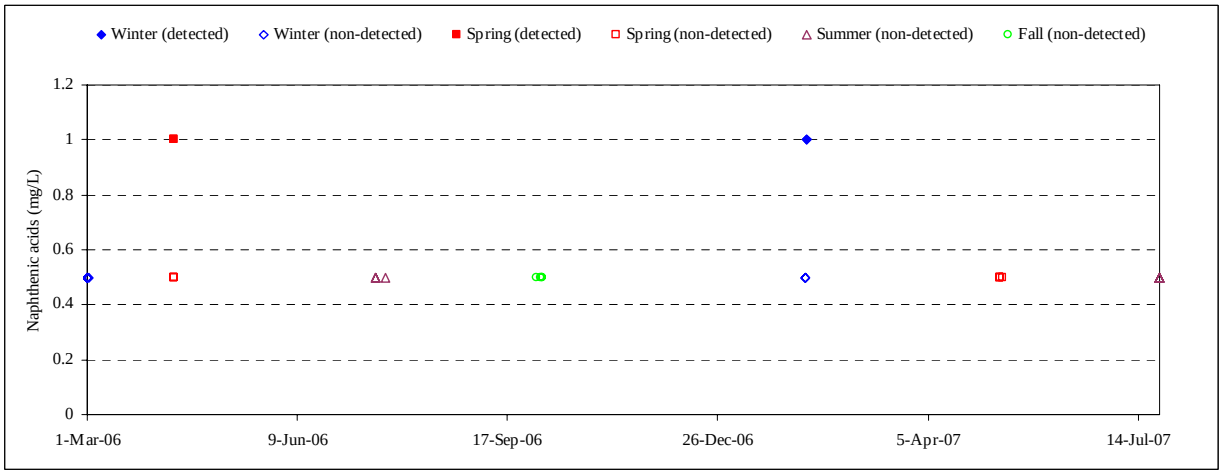
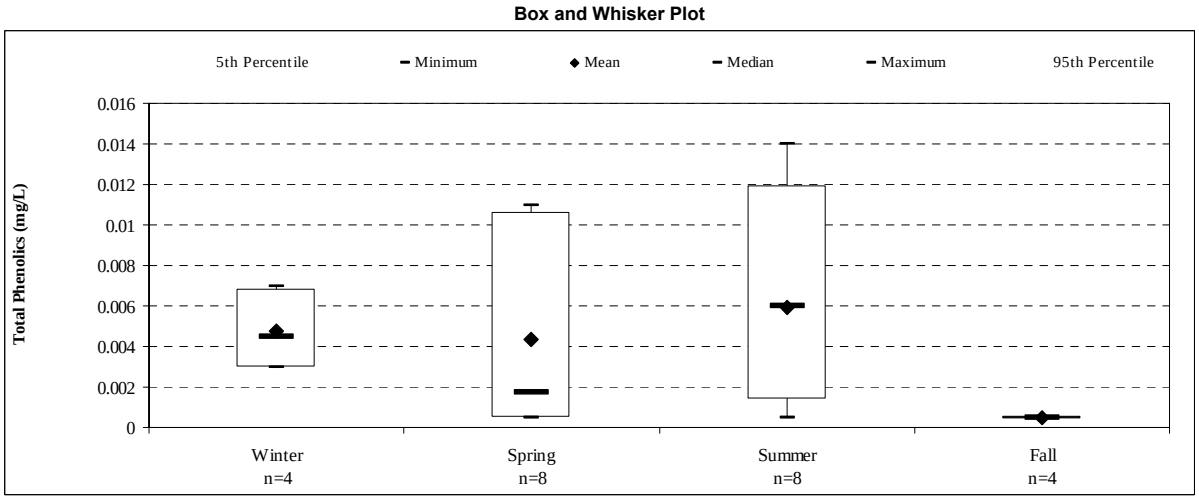


Figure G-3-4-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Redclay Creek



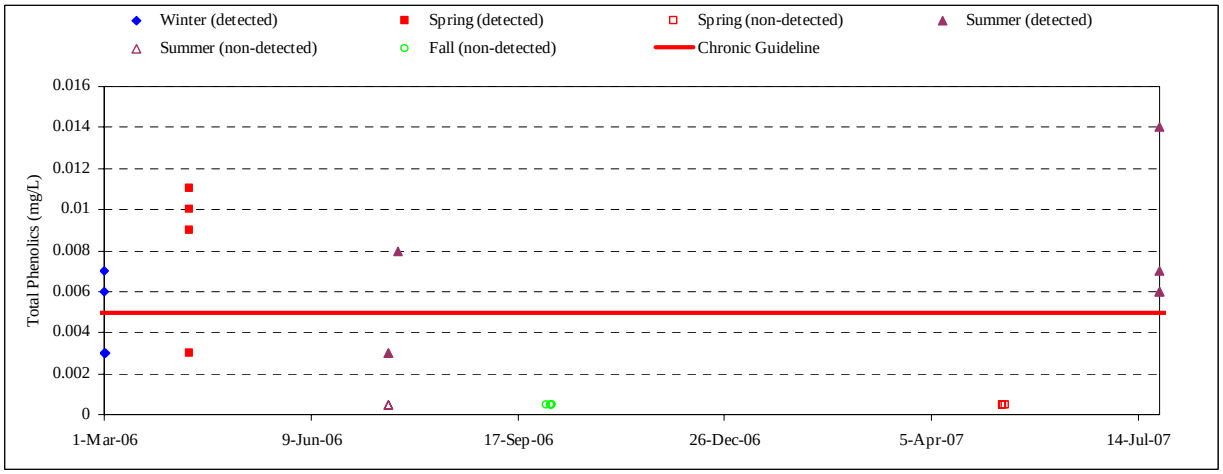
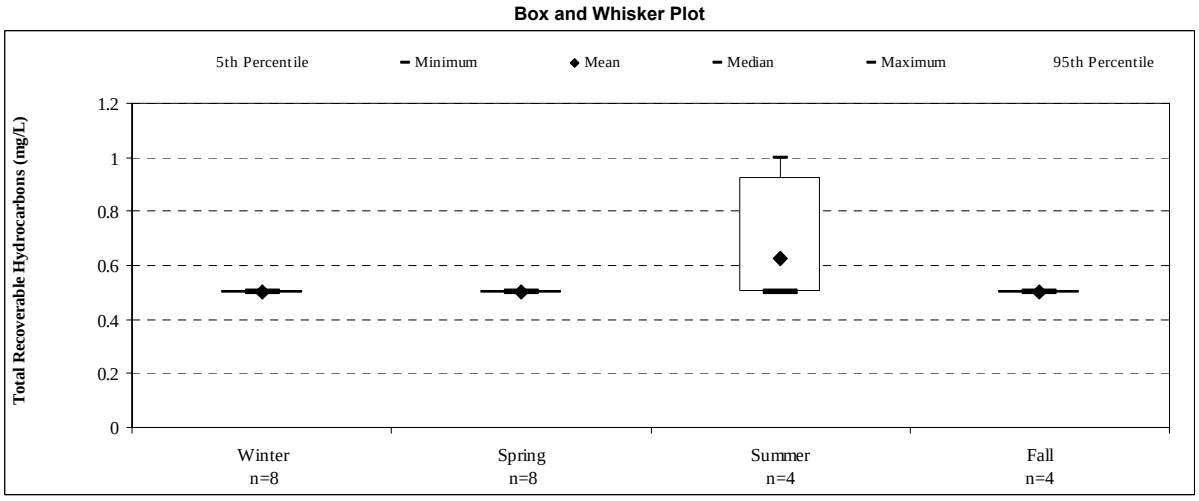


Figure G-3-4-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Redclay Creek



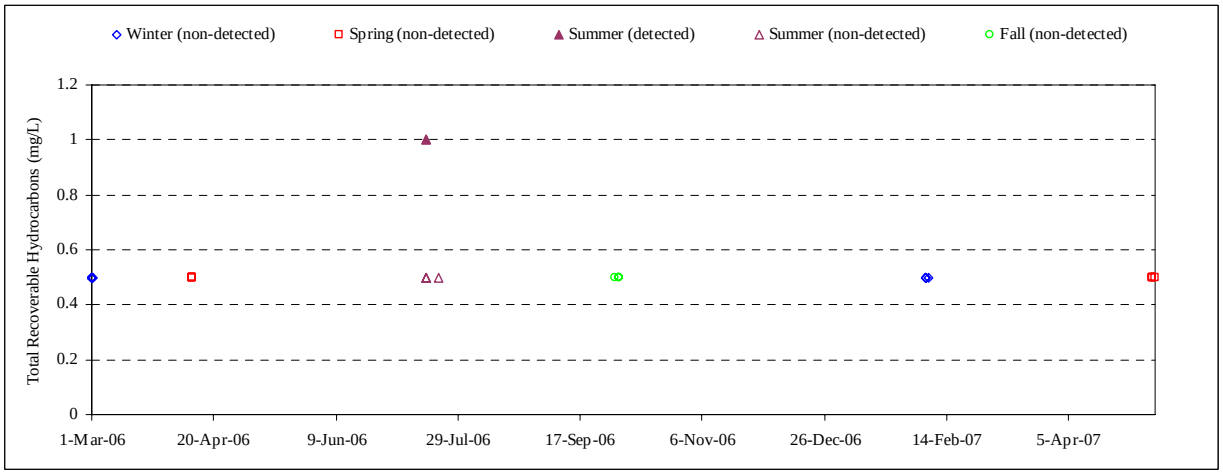
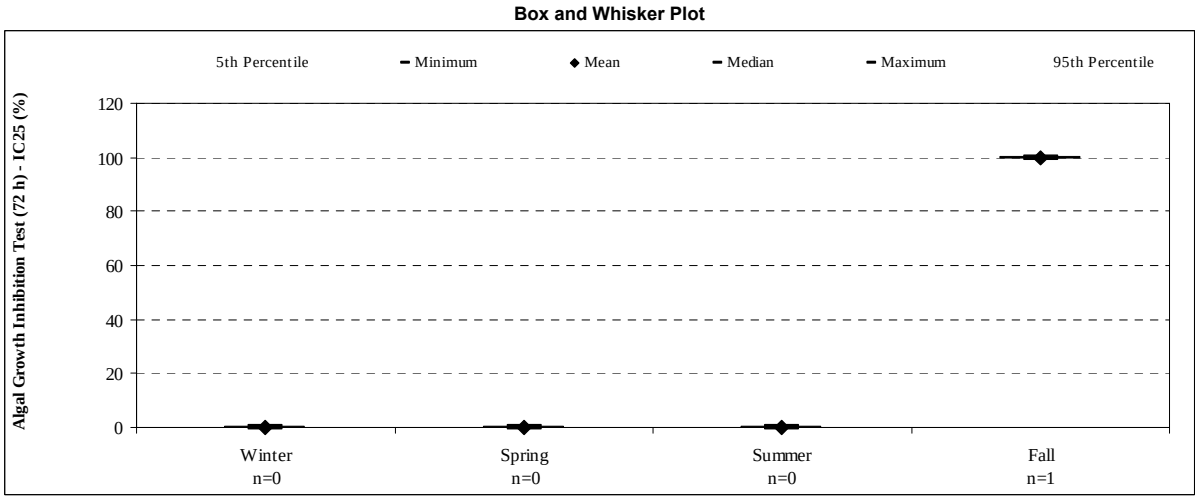


Figure G-3-4-34 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC25 in Redclay Creek



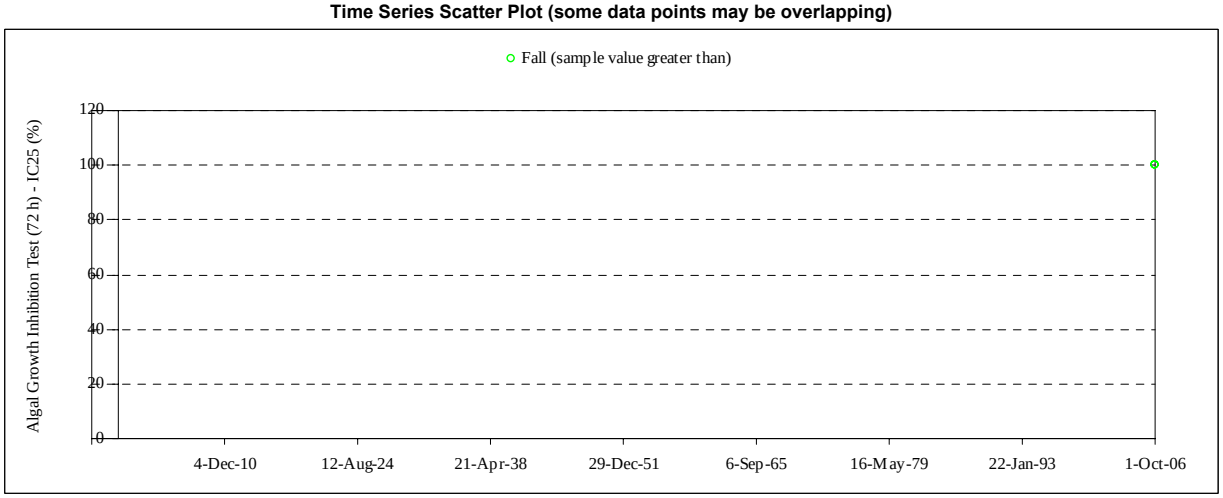
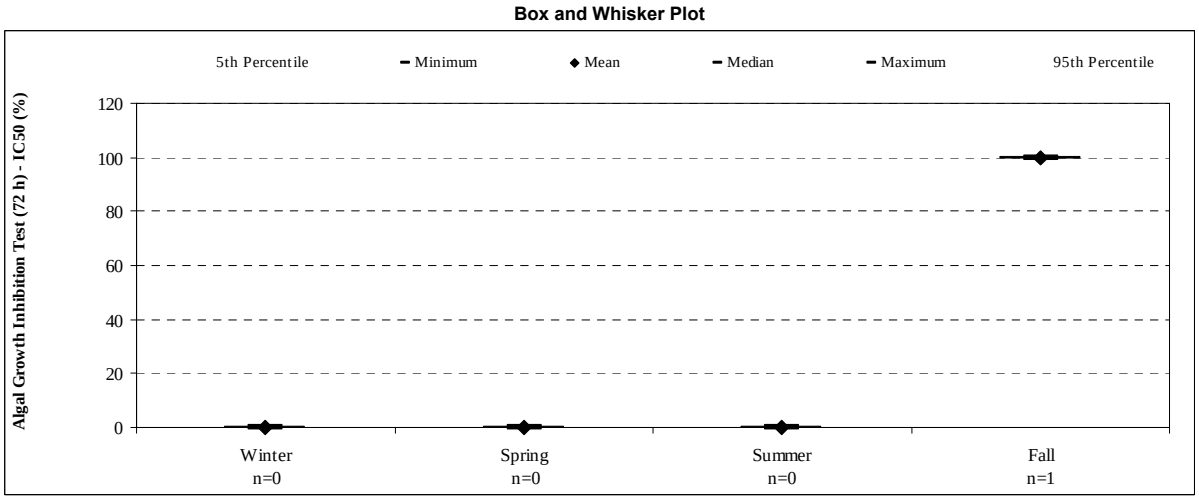


Figure G-3-4-35 Box Whisker and Time Series Scatter Plots of Observed Algal Growth Inhibition Test (72 h) - IC50 in Redclay Creek



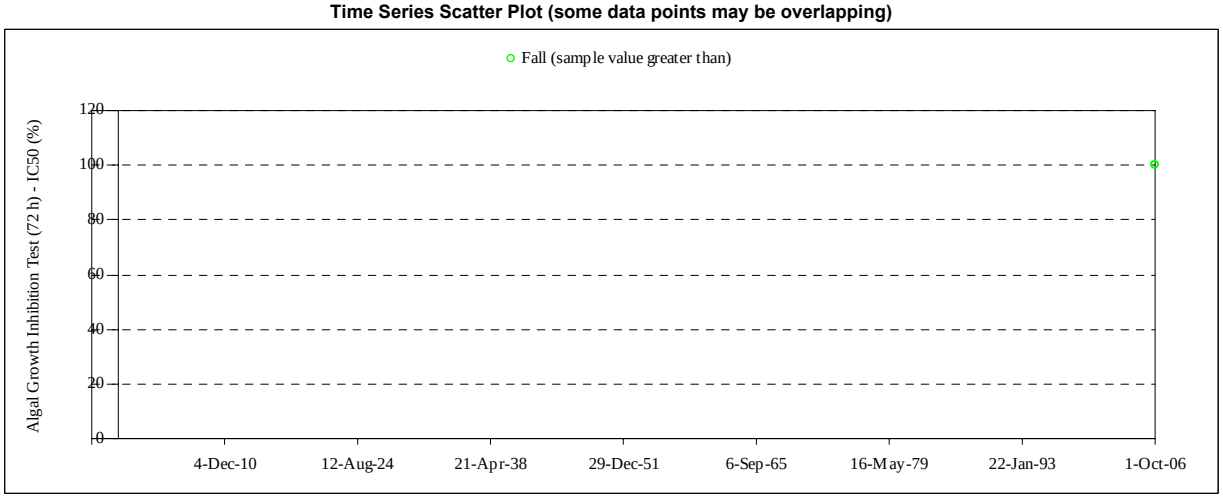
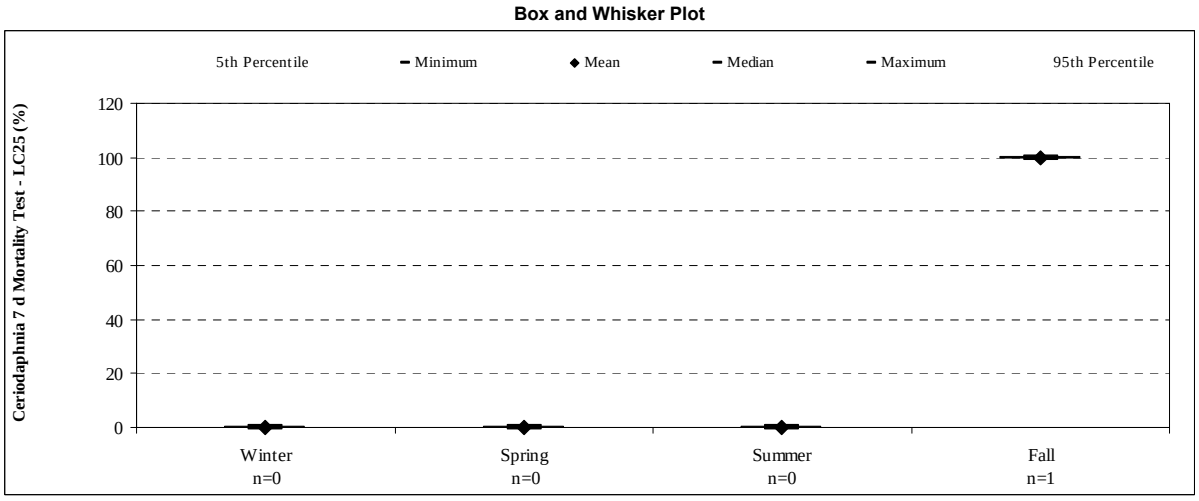


Figure G-3-4-38 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC25 in Redclay Creek



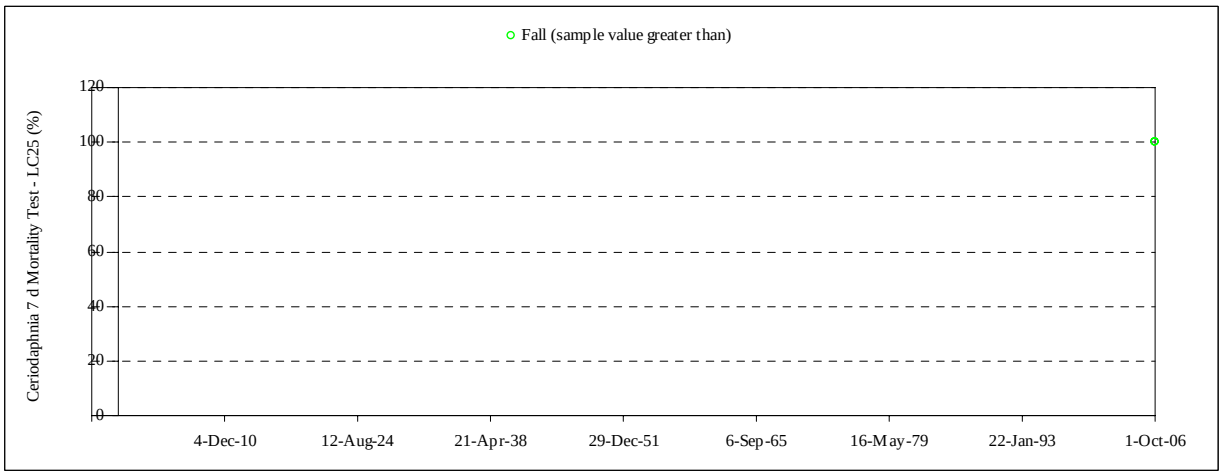
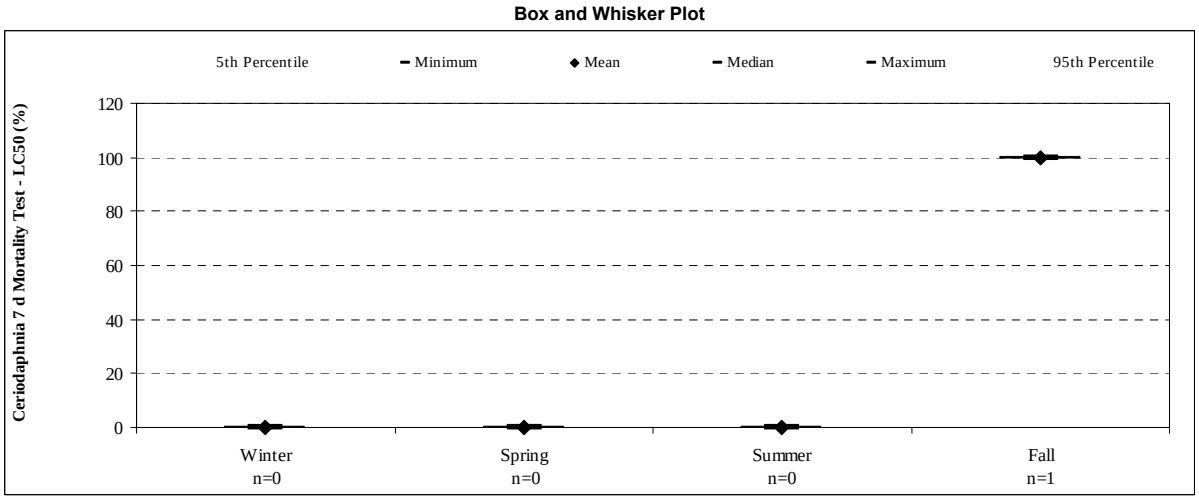


Figure G-3-4-39 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Mortality Test - LC50 in Redclay Creek



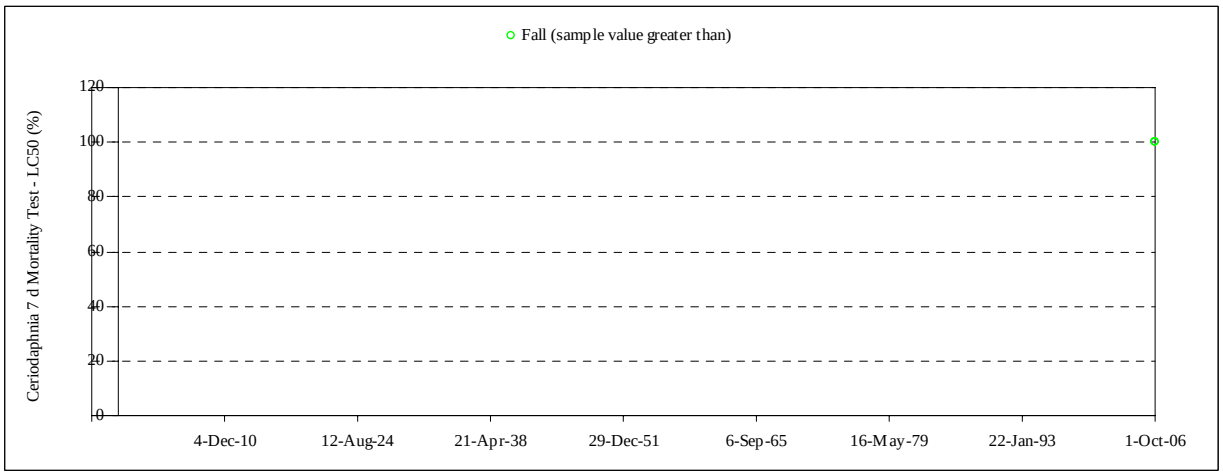
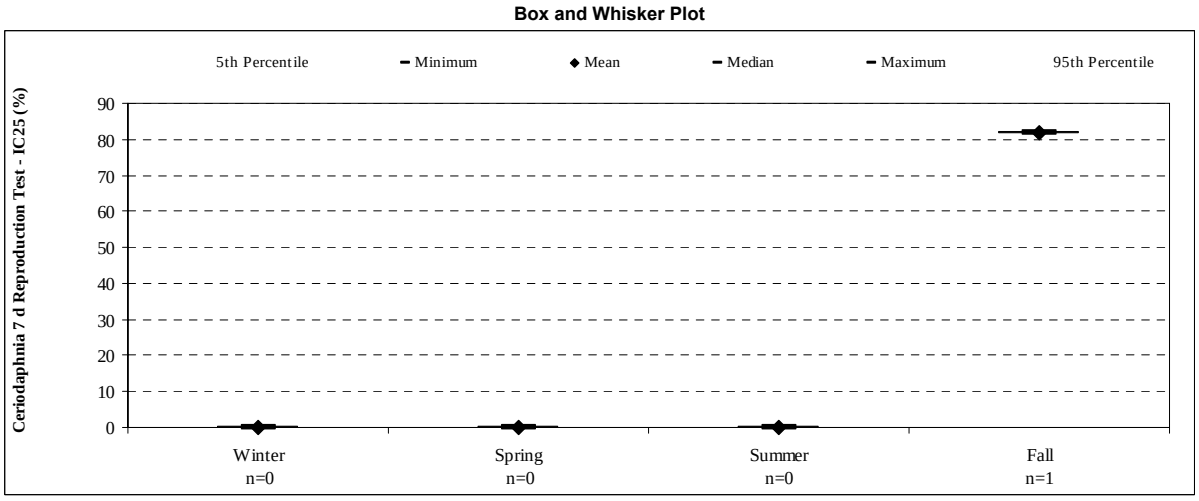


Figure G-3-4-42 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC25 in Redclay Creek



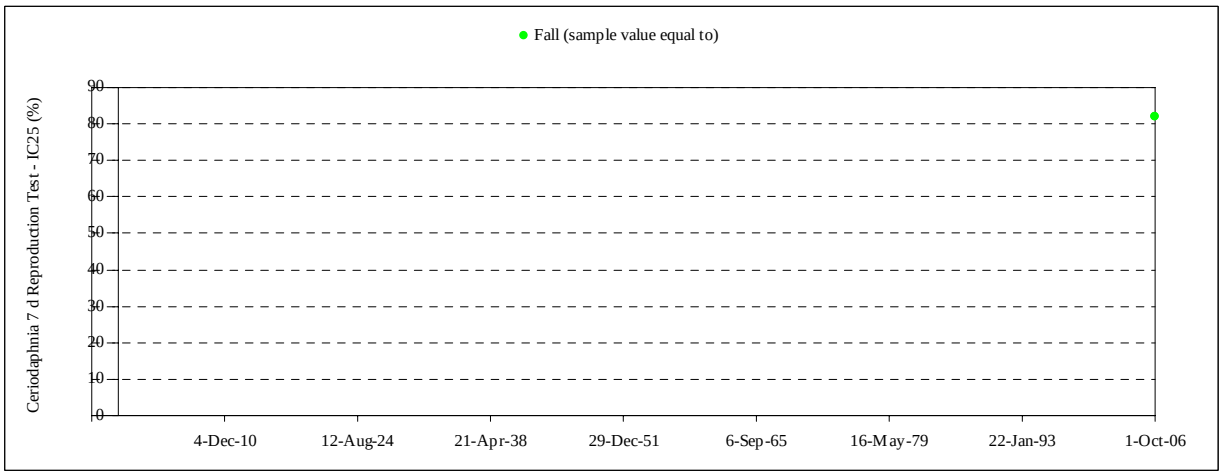
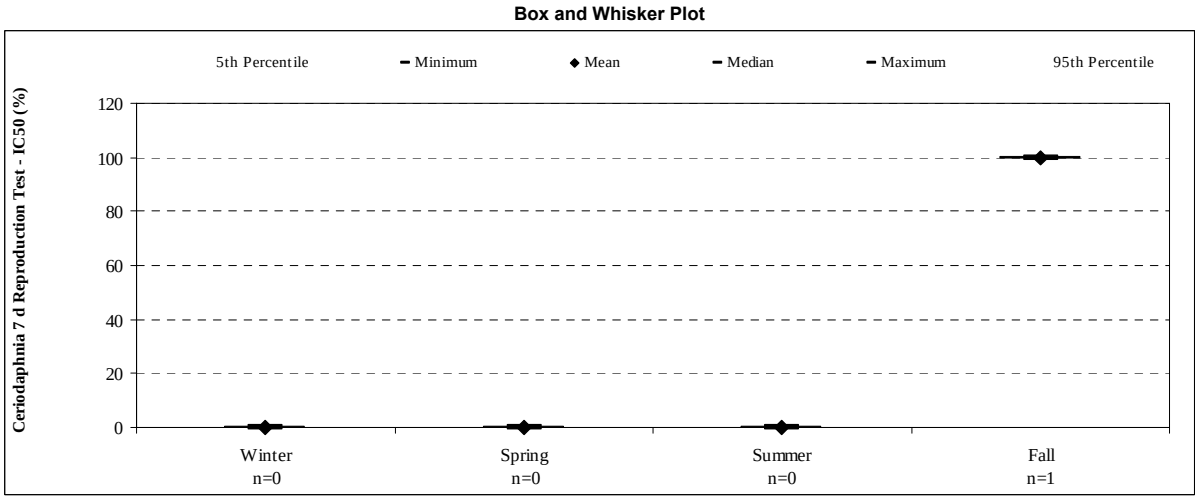


Figure G-3-4-43 Box Whisker and Time Series Scatter Plots of Observed Ceriodaphnia 7 d Reproduction Test - IC50 in Redclay Creek



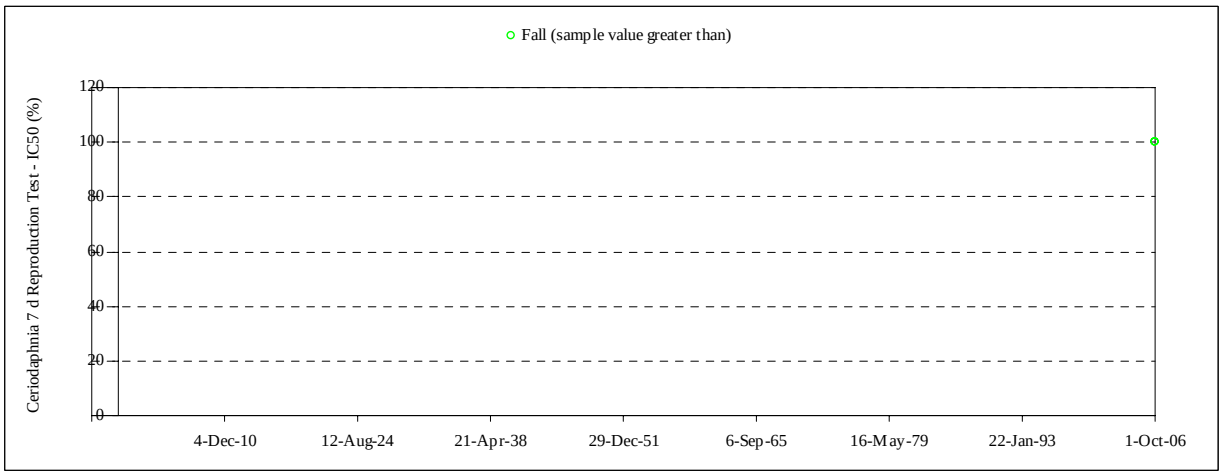
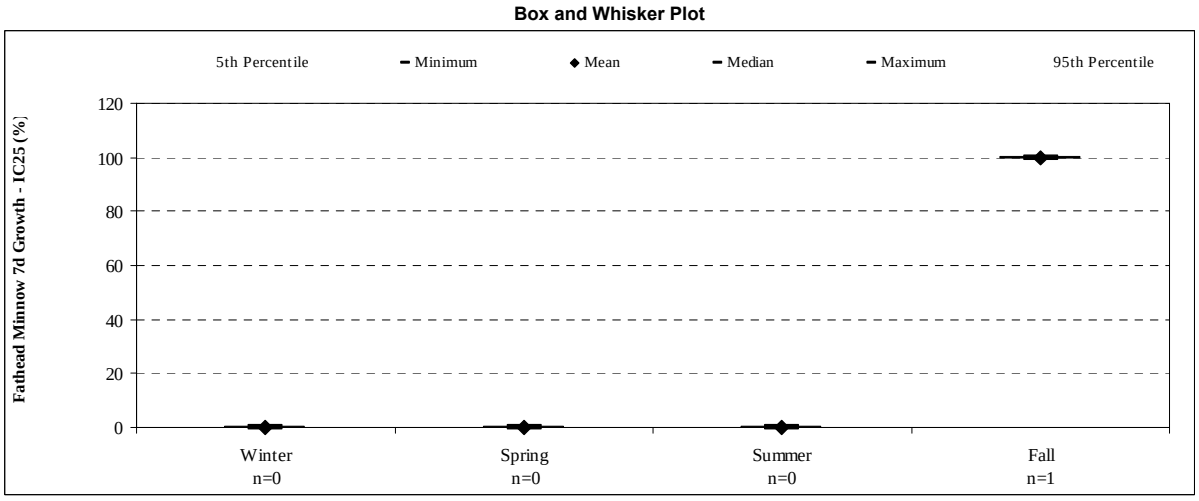


Figure G-3-4-50 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC25 in Redclay Creek



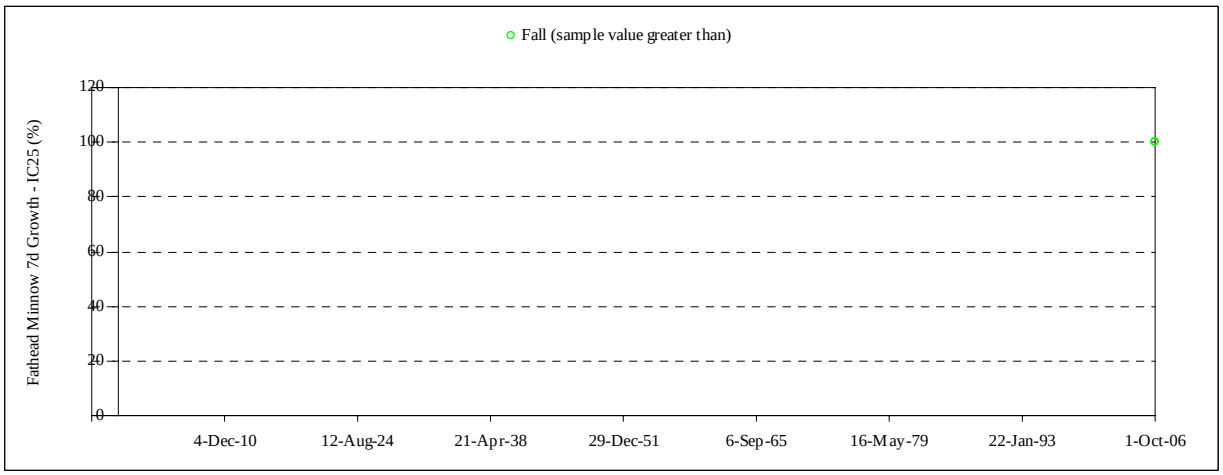


Figure G-3-4-51 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Growth - IC50 in Redclay Creek

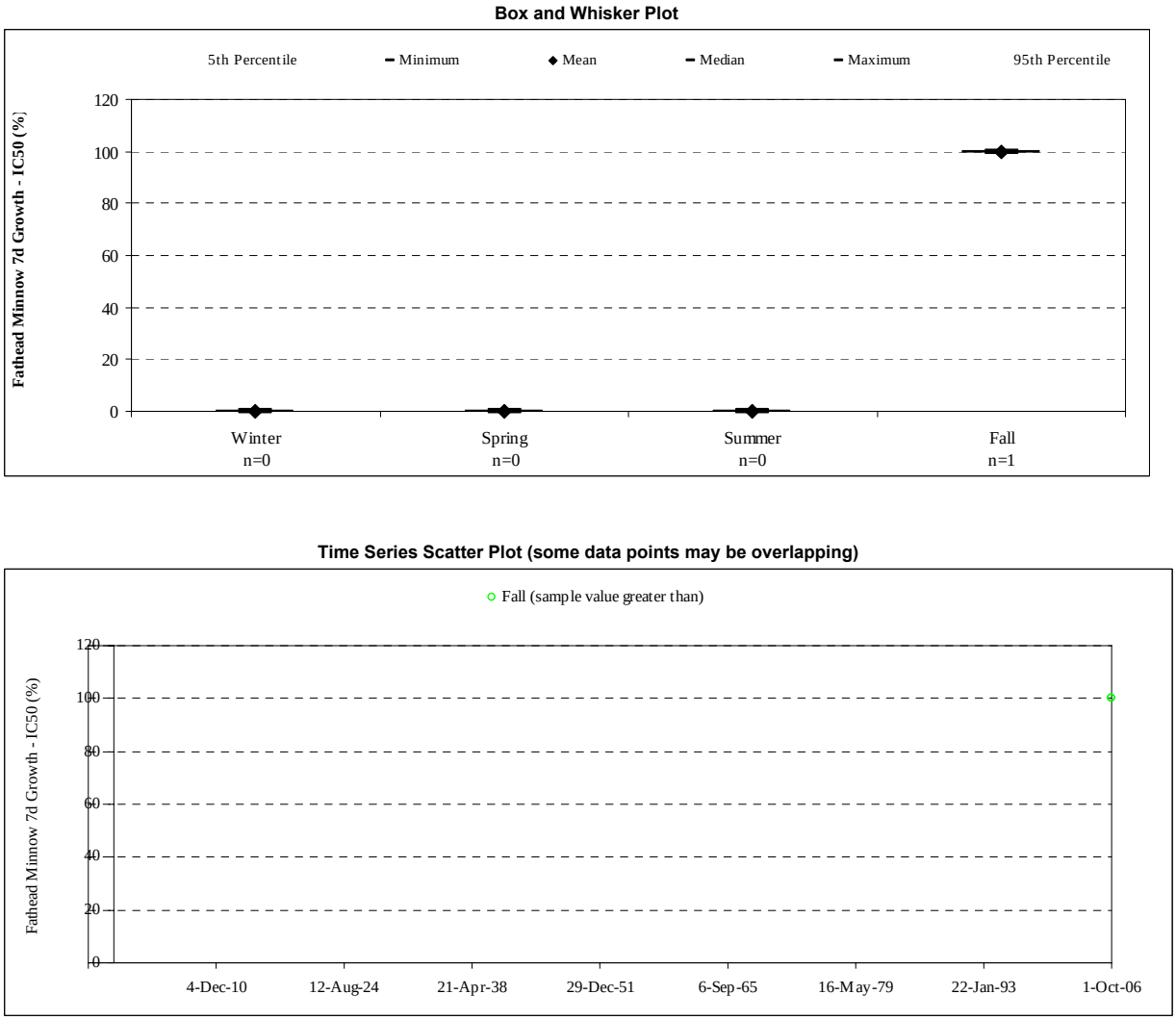
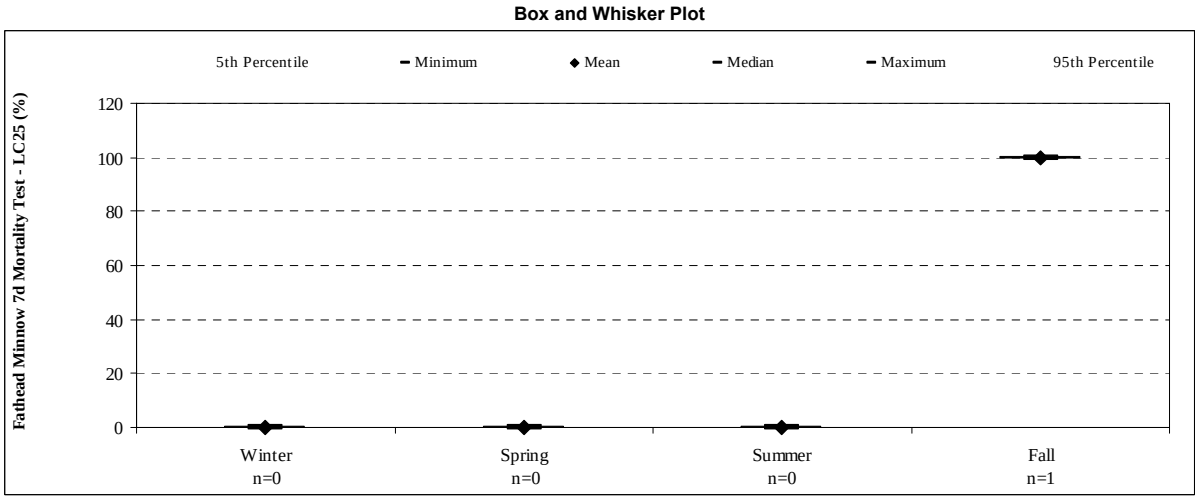


Figure G-3-4-54 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC25 in Redclay Creek



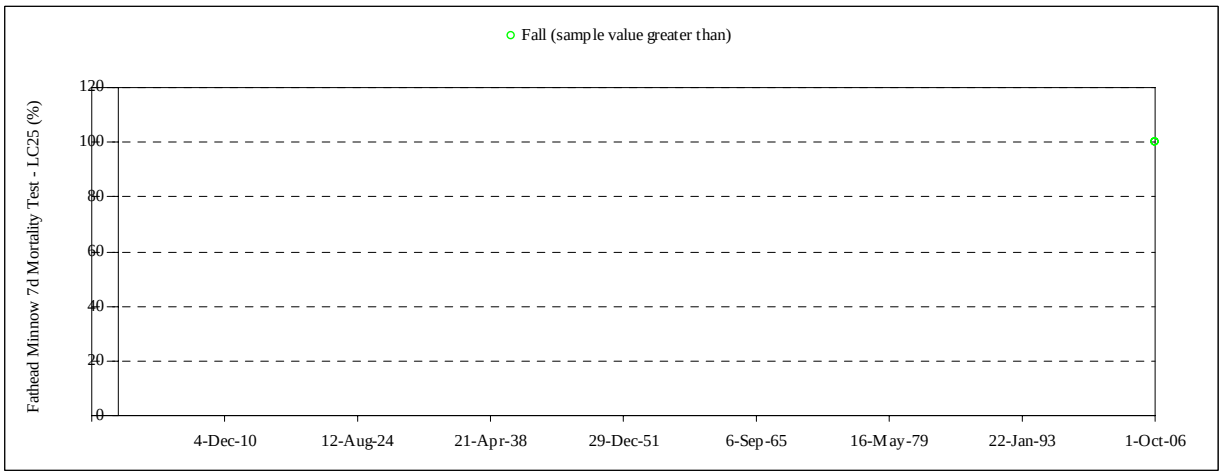
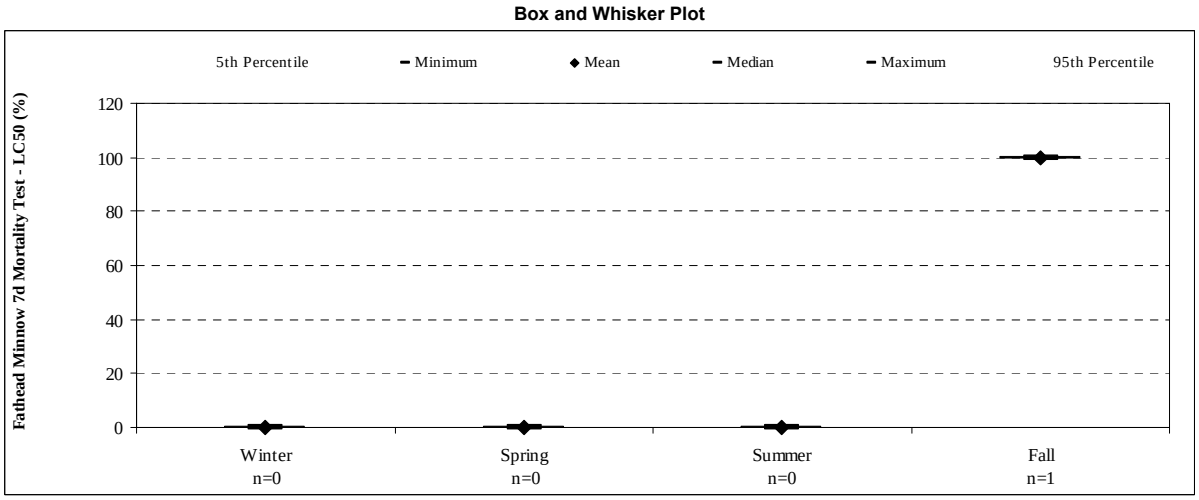


Figure G-3-4-55 Box Whisker and Time Series Scatter Plots of Observed Fathead Minnow 7d Mortality Test - LC50 in Redclay Creek



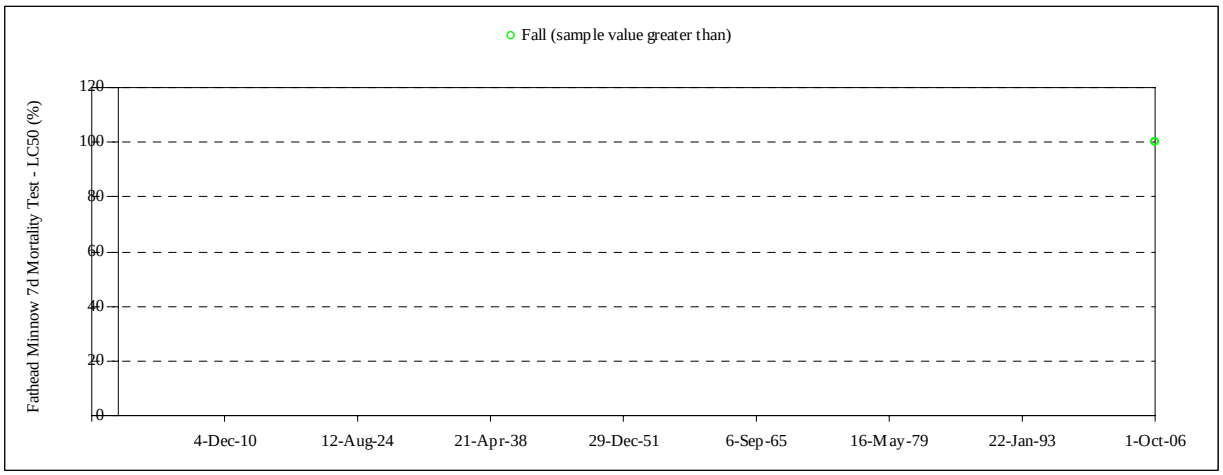


Figure G-3-4-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Redclay Creek

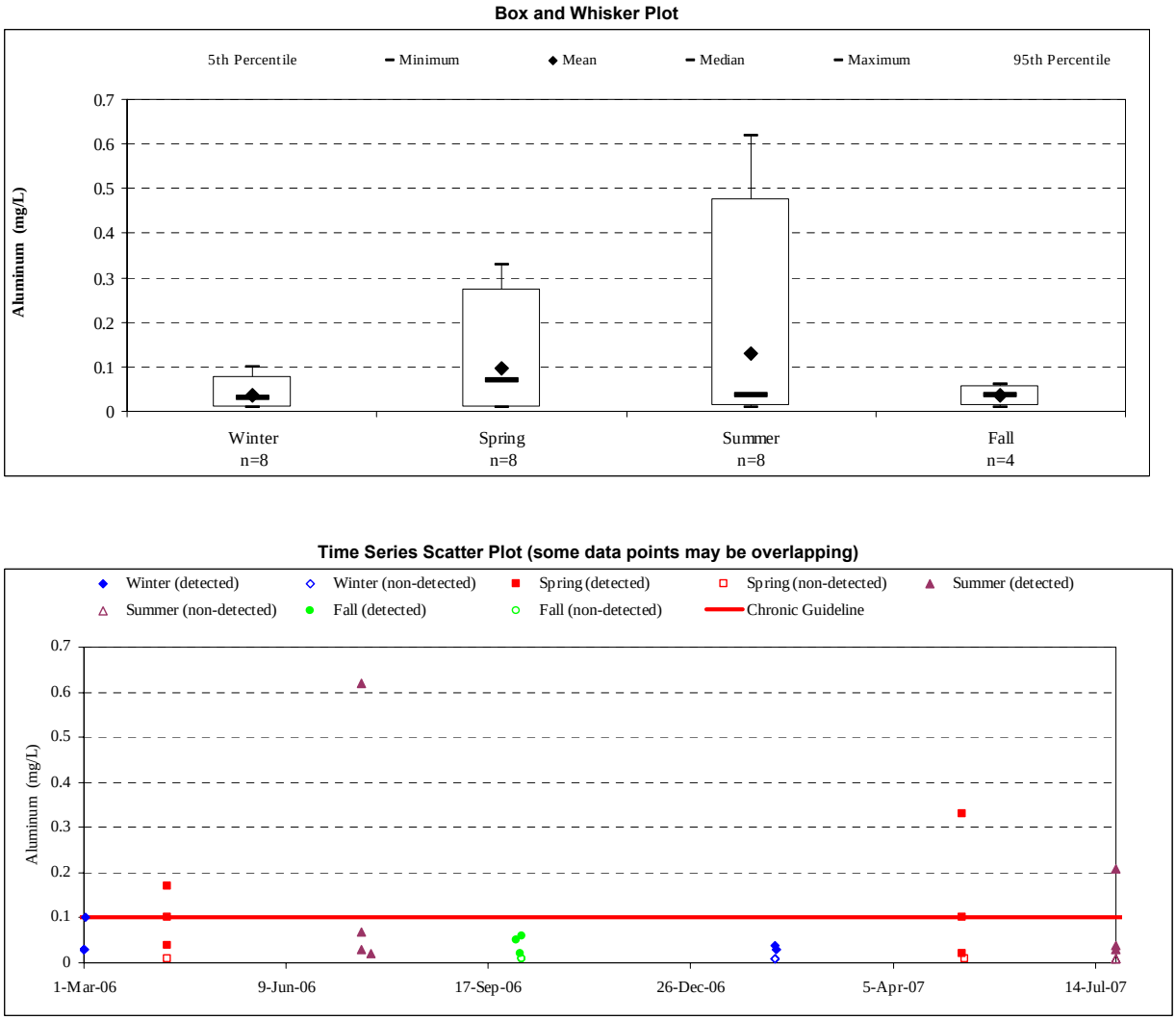
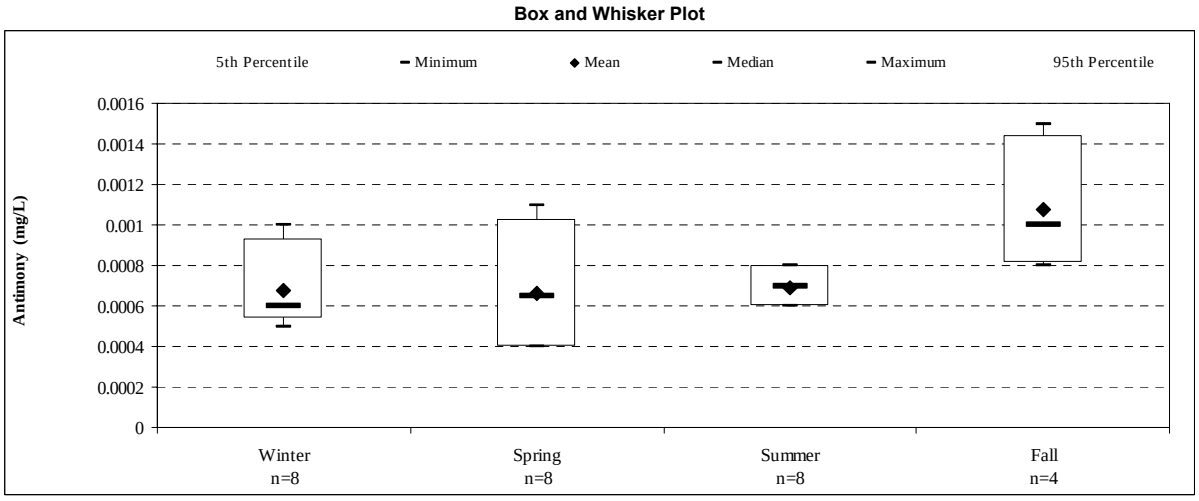


Figure G-3-4-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Redclay Creek



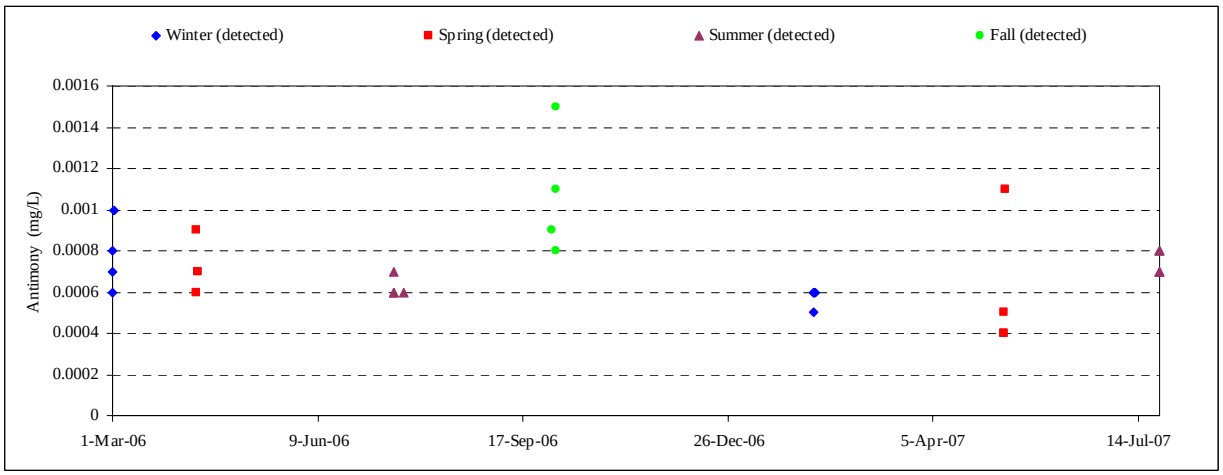
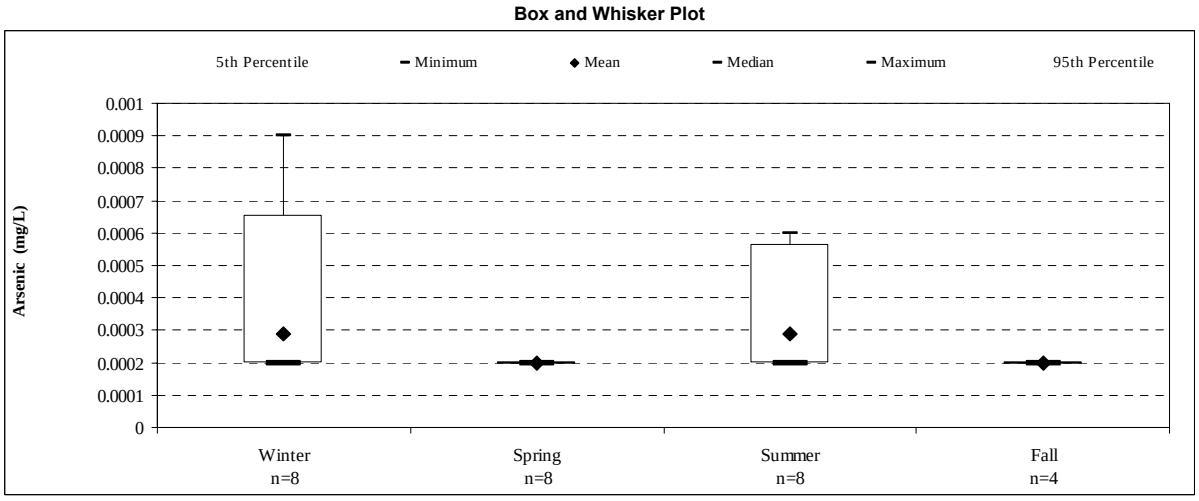


Figure G-3-4-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Redclay Creek



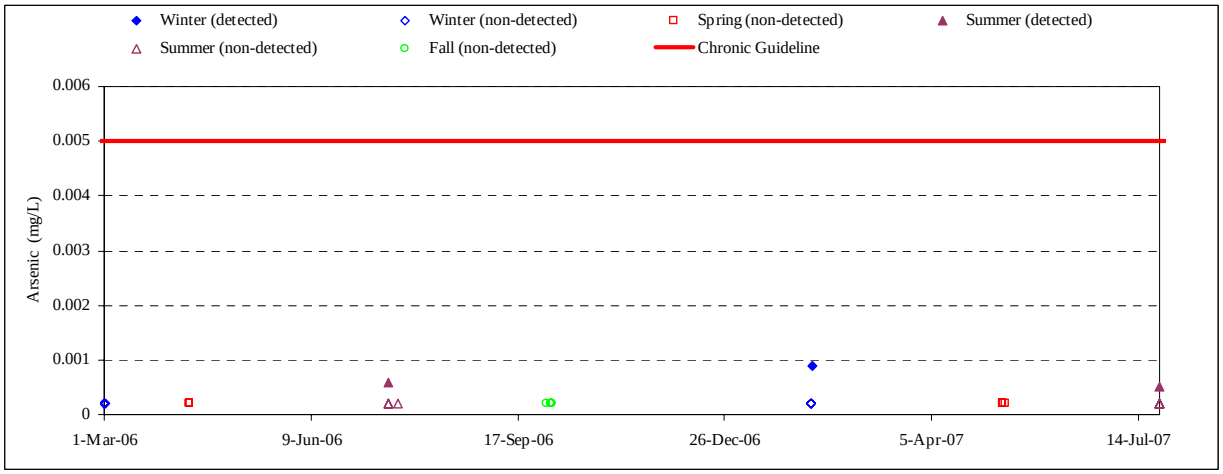
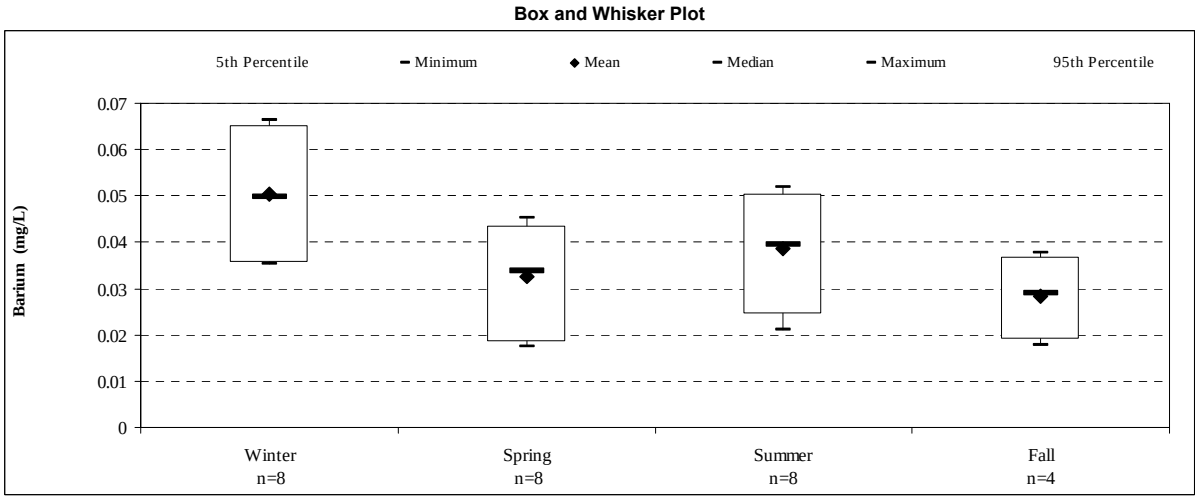


Figure G-3-4-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Redclay Creek



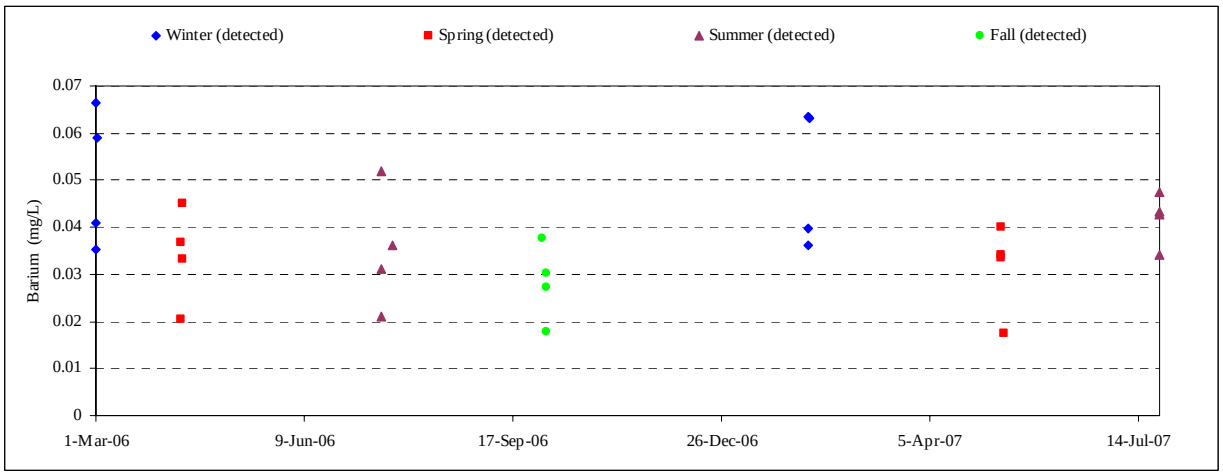
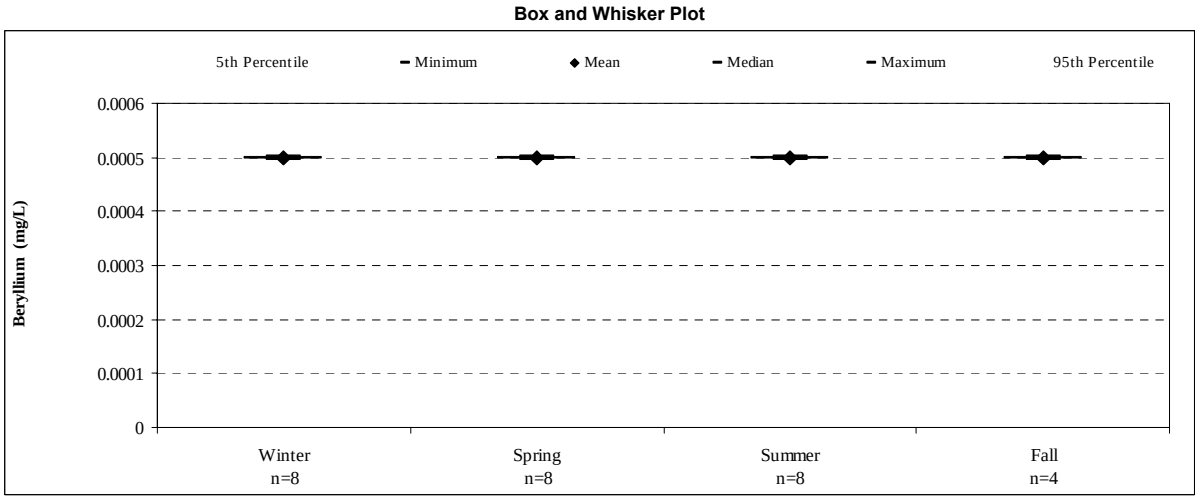


Figure G-3-4-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Redclay Creek



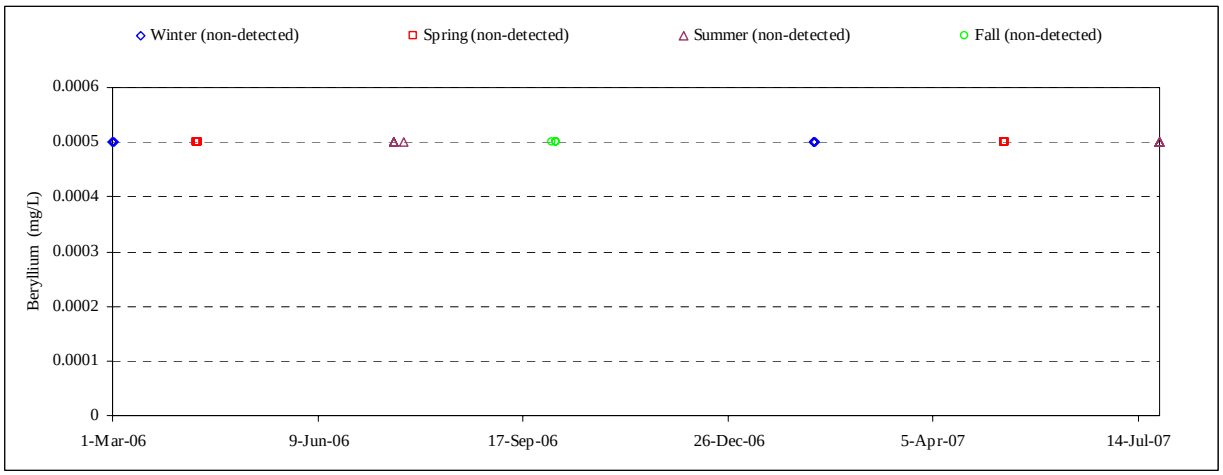
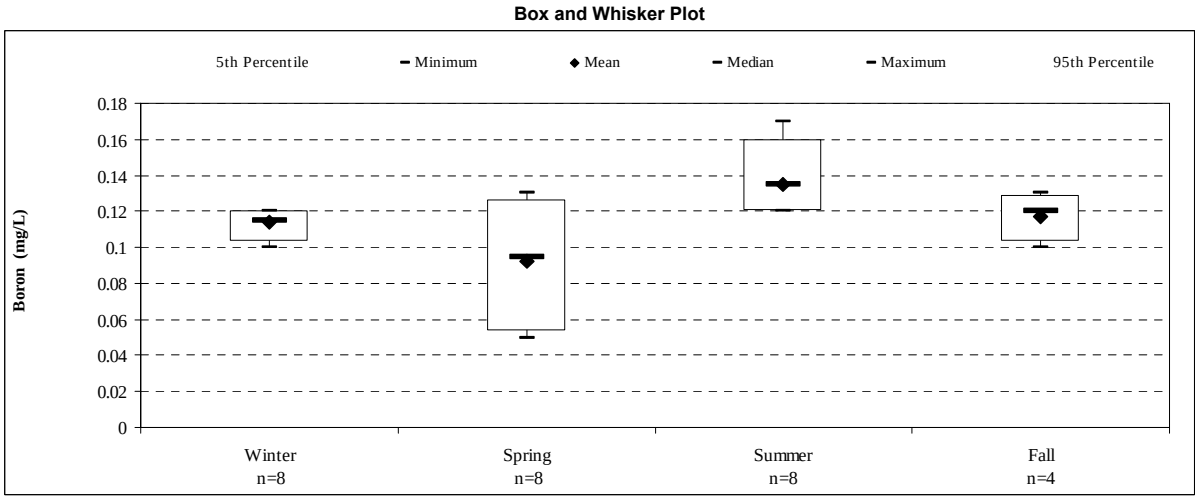


Figure G-3-4-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Redclay Creek



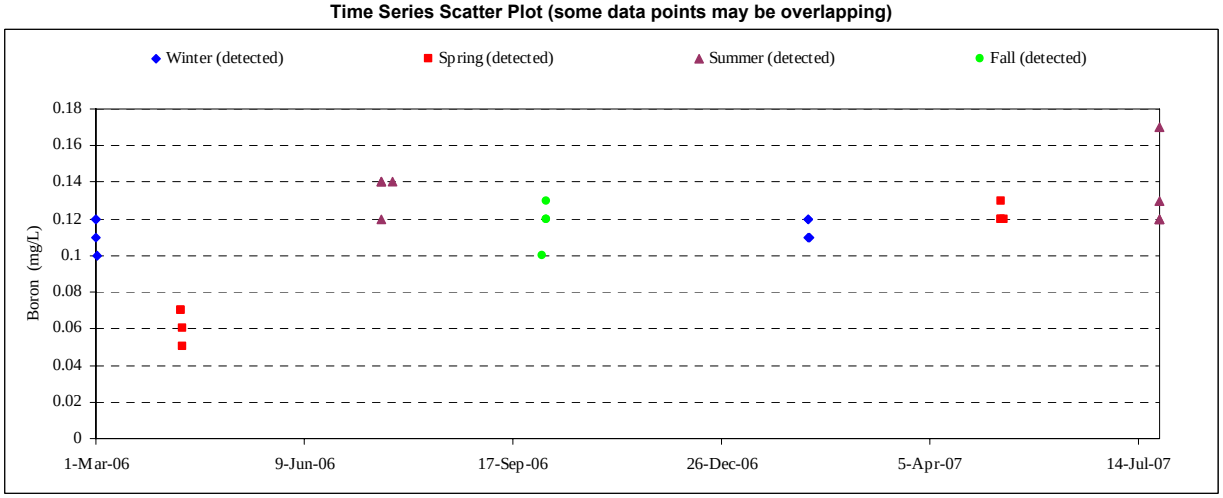
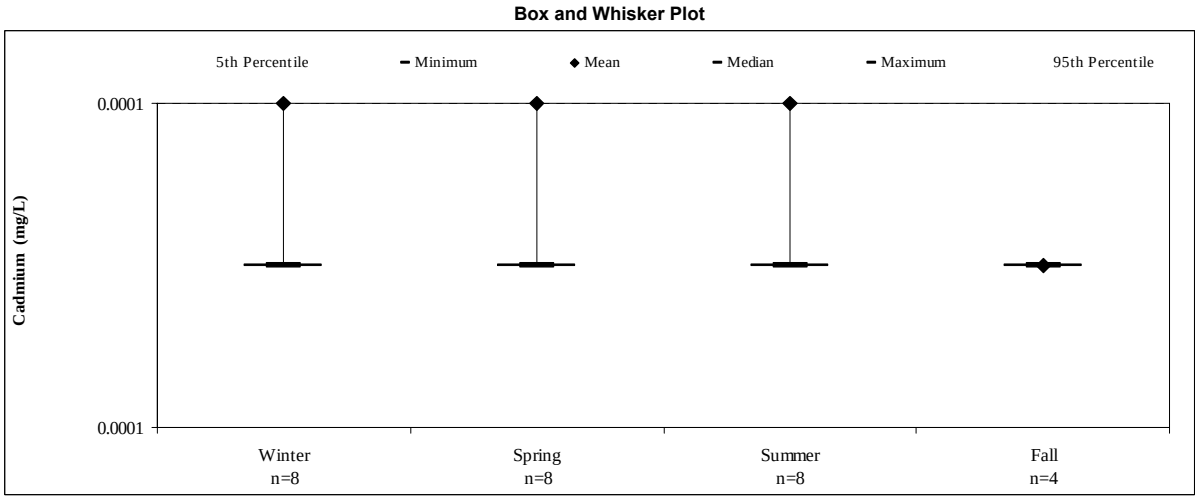


Figure G-3-4-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Redclay Creek



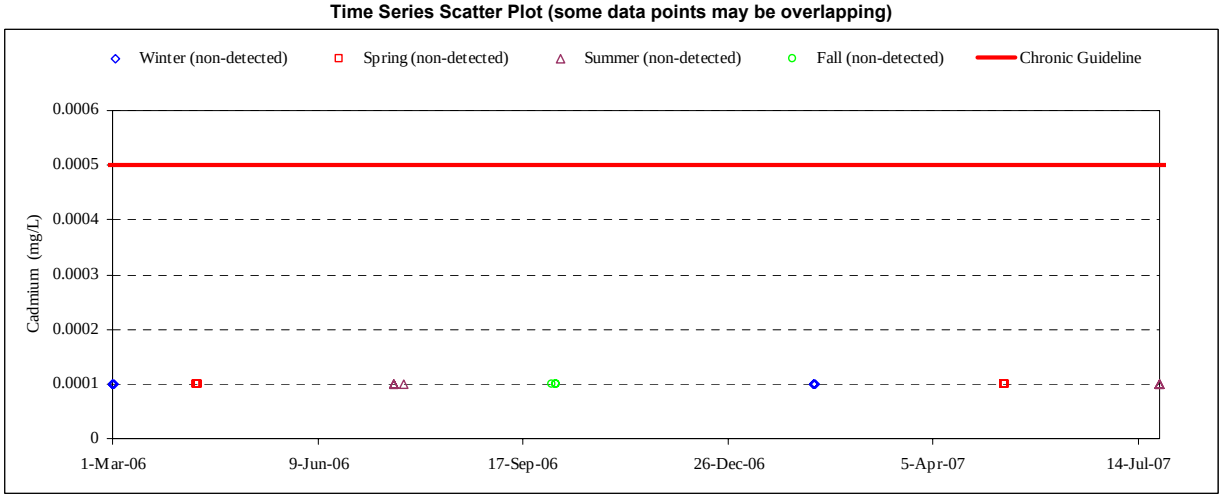
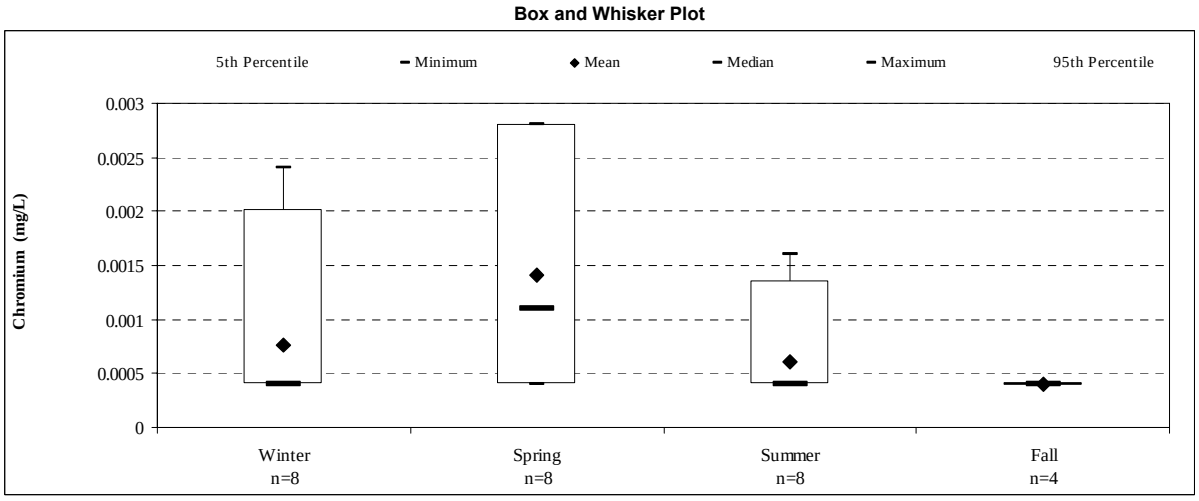


Figure G-3-4-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Redclay Creek



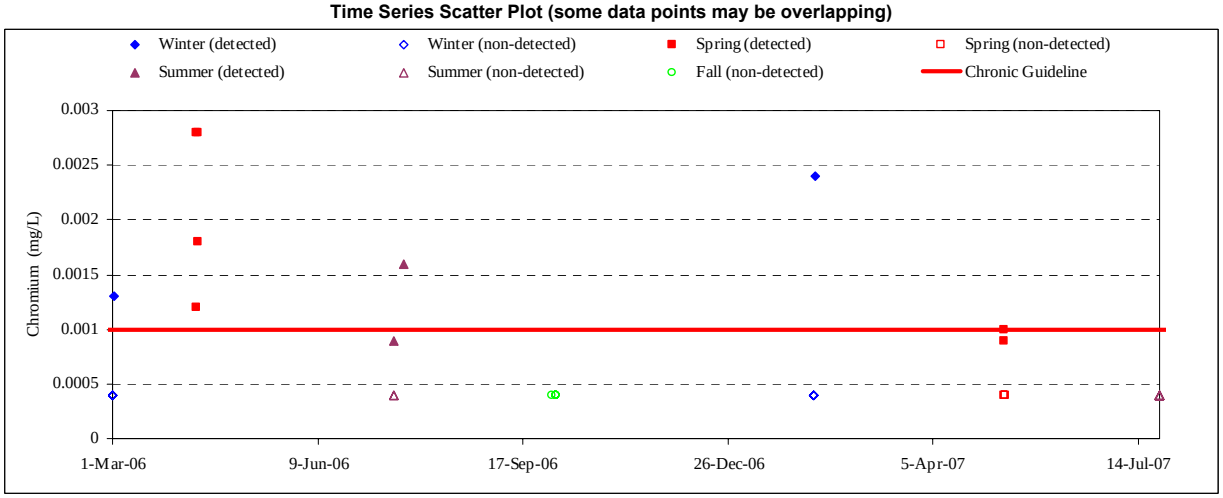
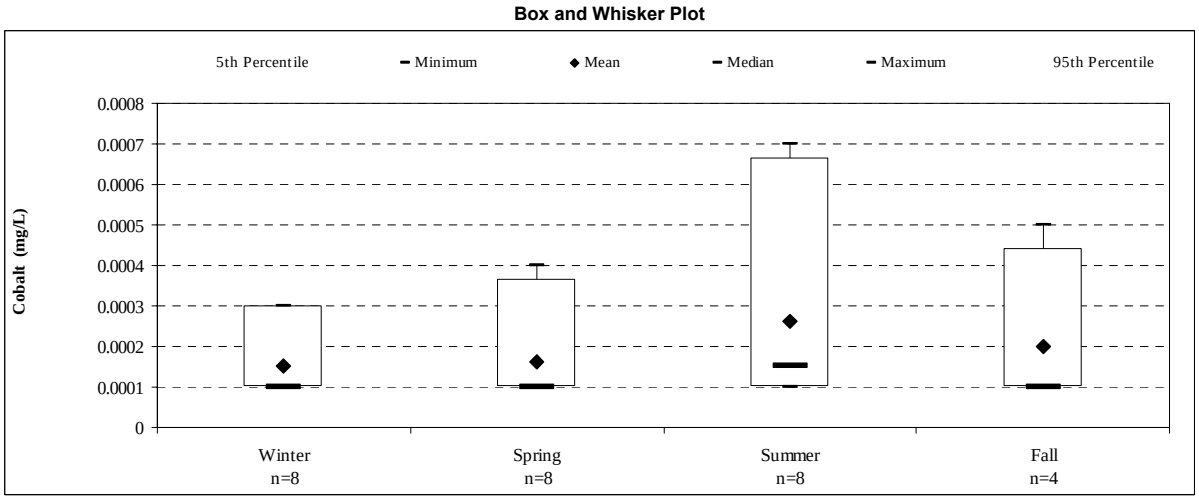


Figure G-3-4-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Redclay Creek



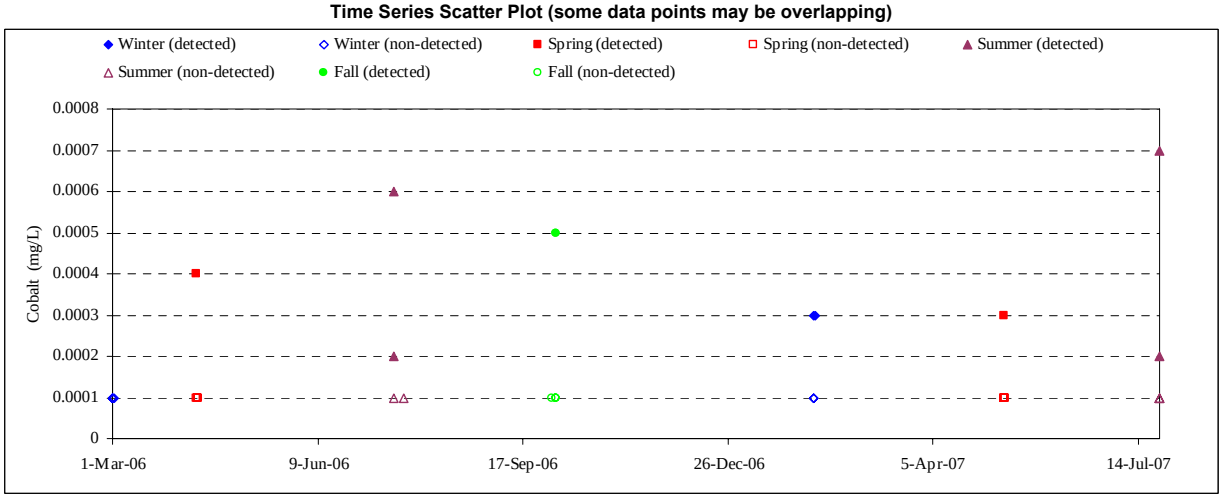
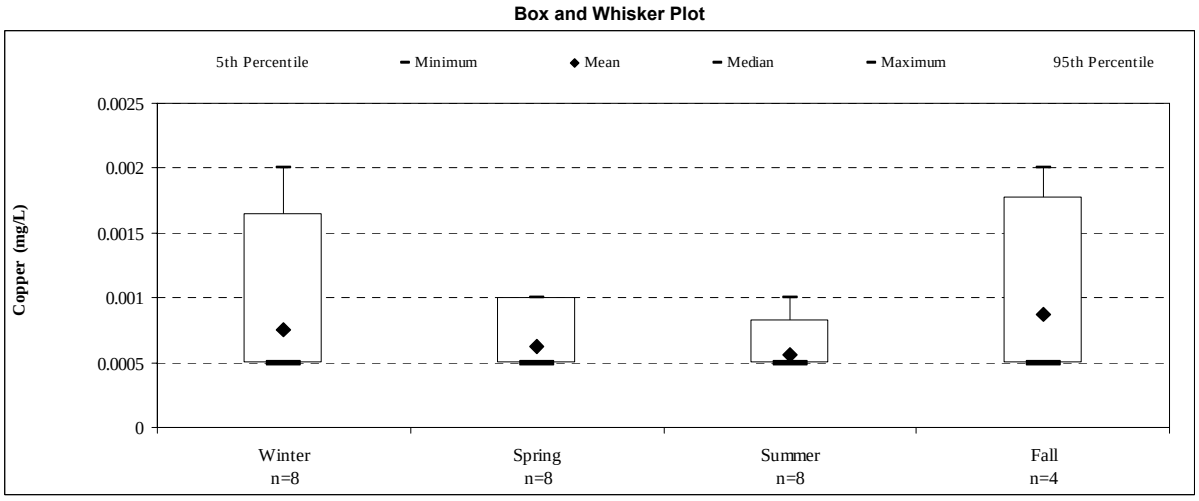


Figure G-3-4-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Redclay Creek



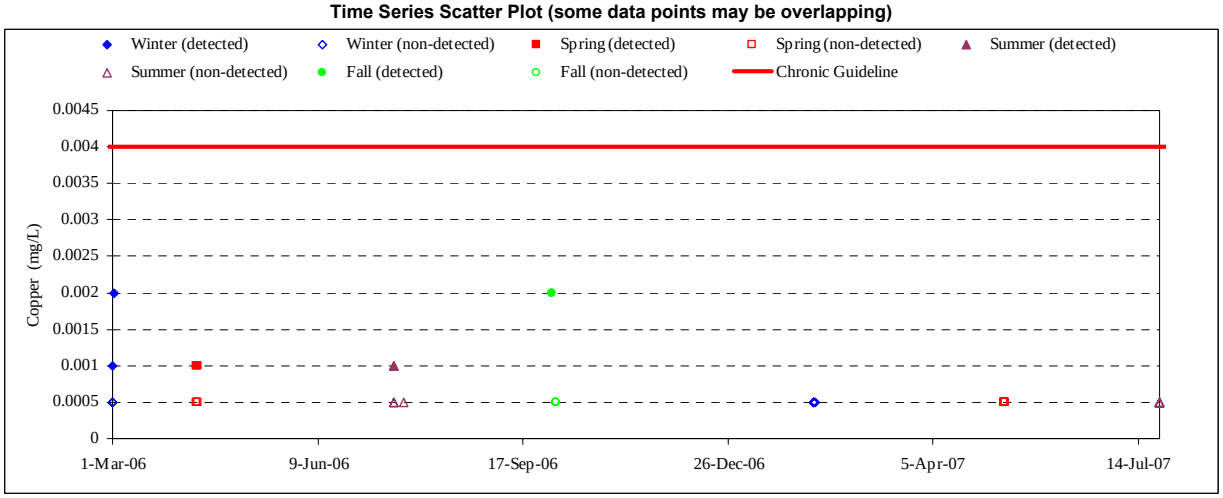
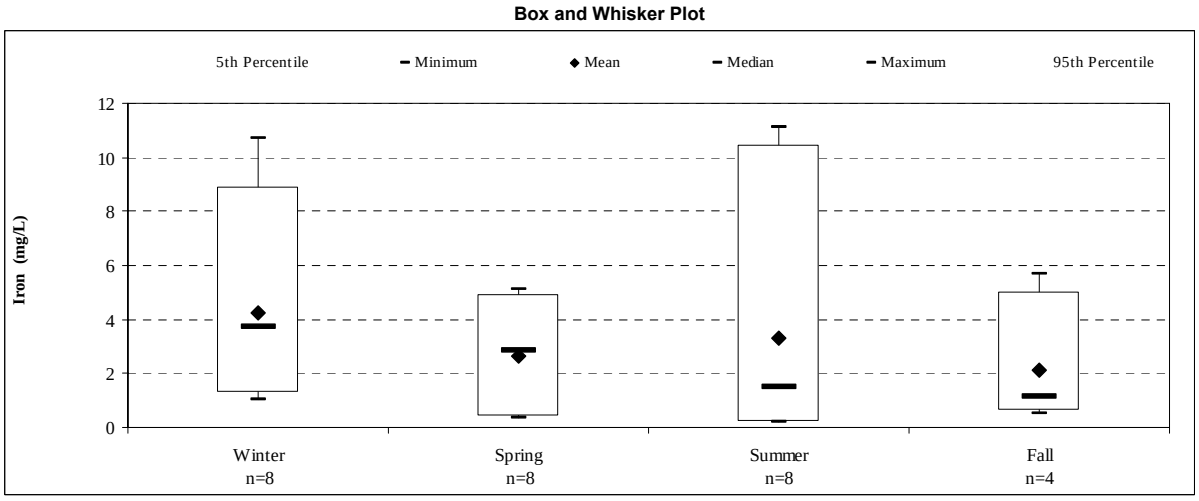


Figure G-3-4-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Redclay Creek



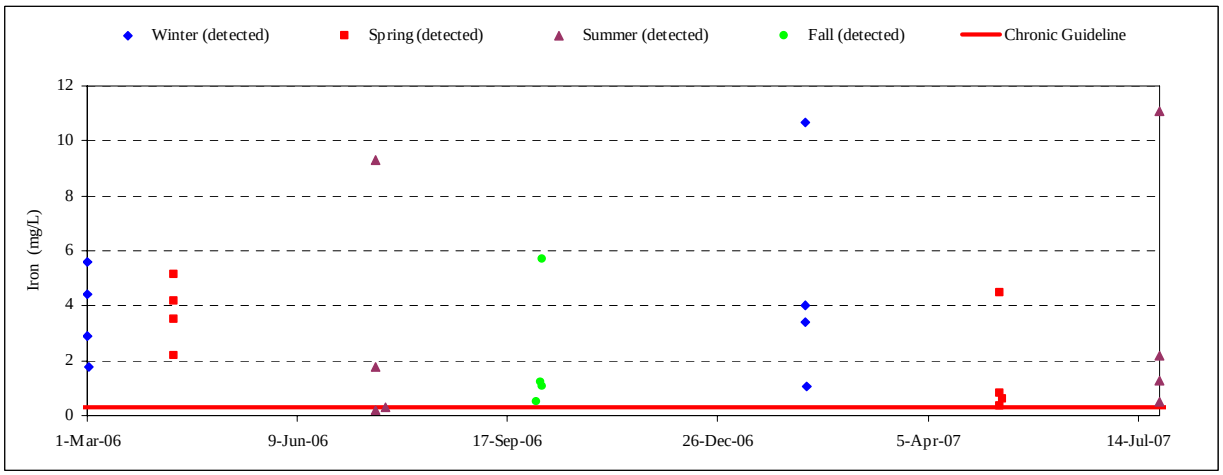
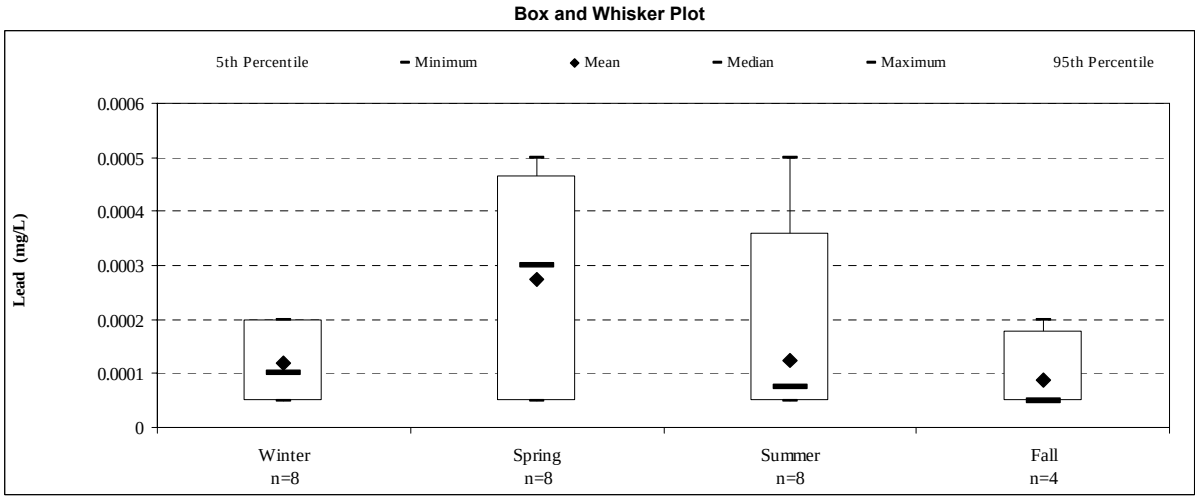


Figure G-3-4-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Redclay Creek



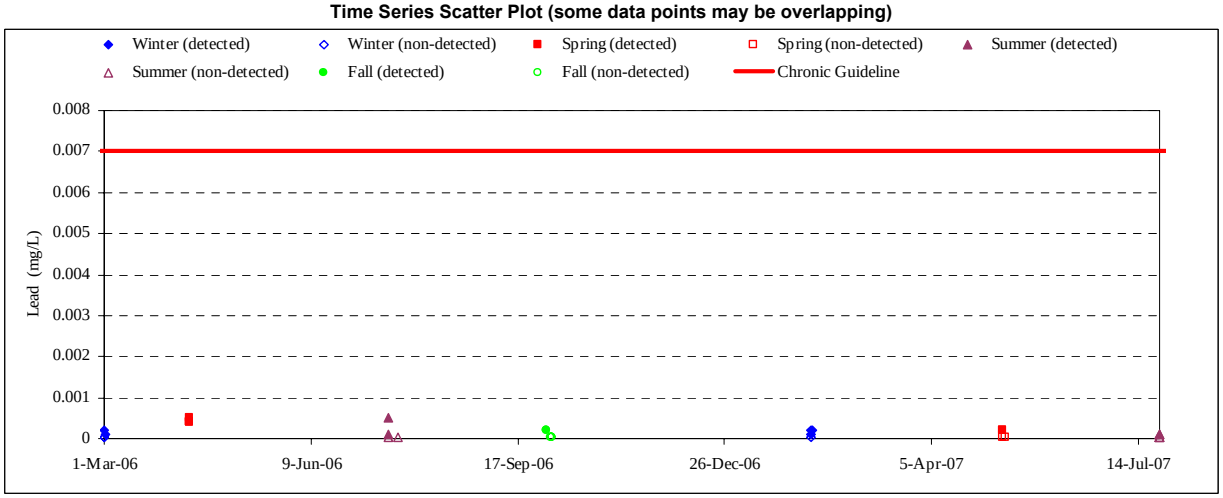
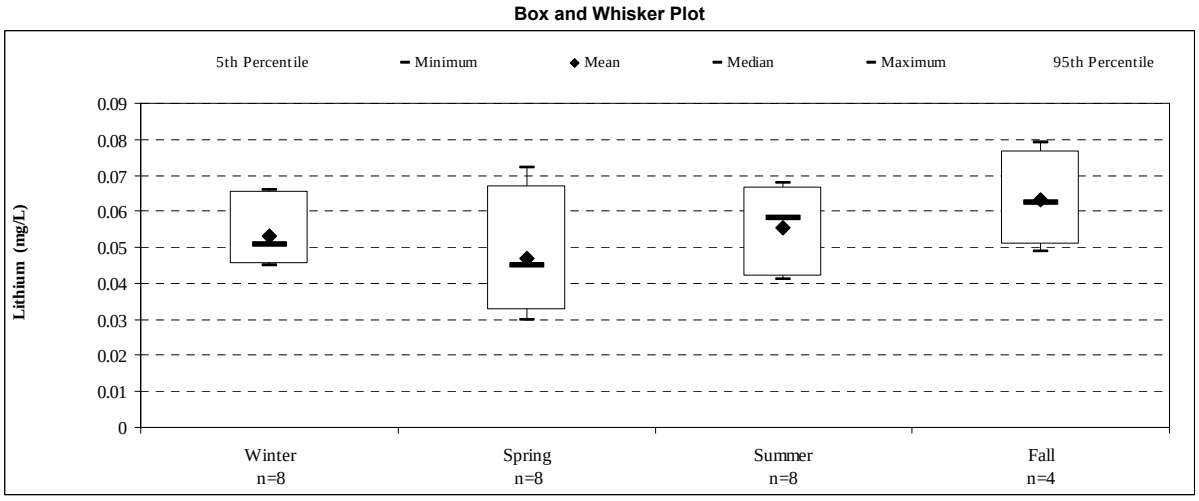


Figure G-3-4-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Redclay Creek



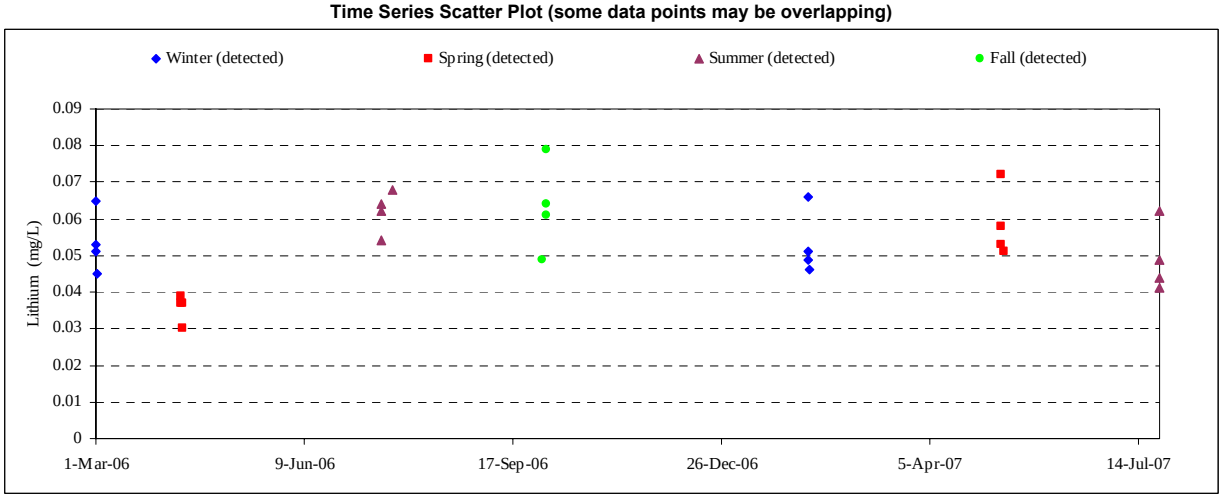
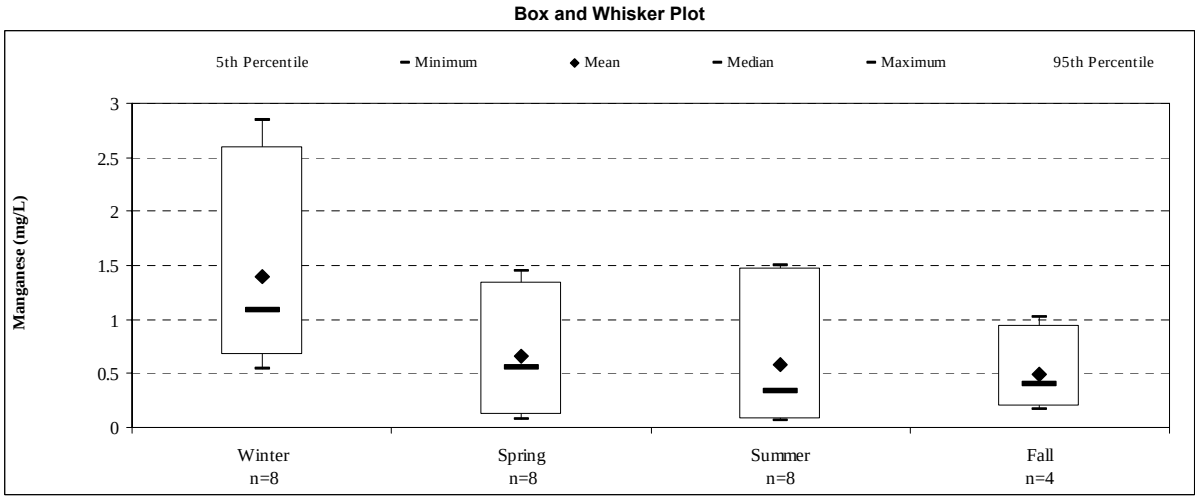


Figure G-3-4-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Redclay Creek



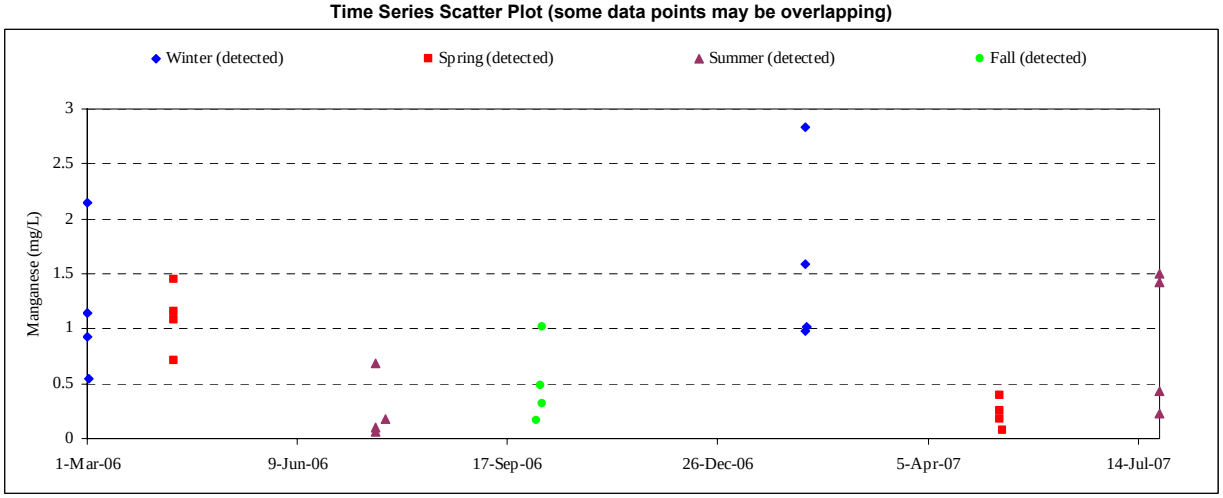
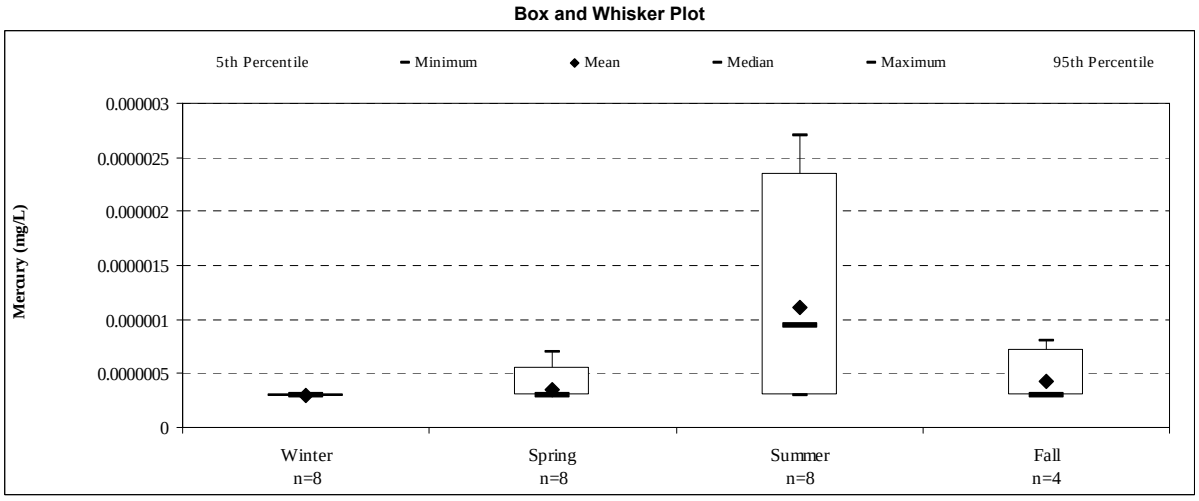


Figure G-3-4-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Redclay Creek



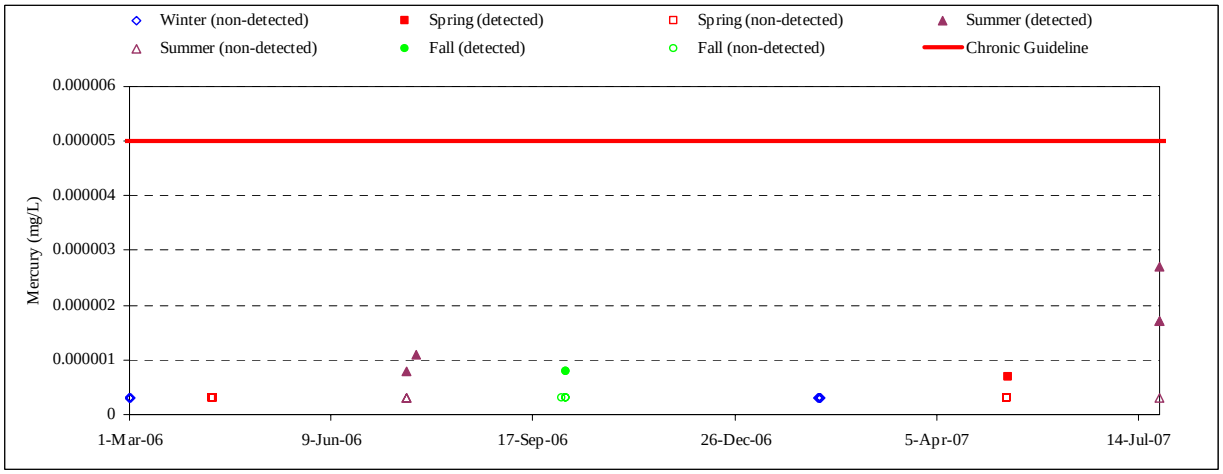
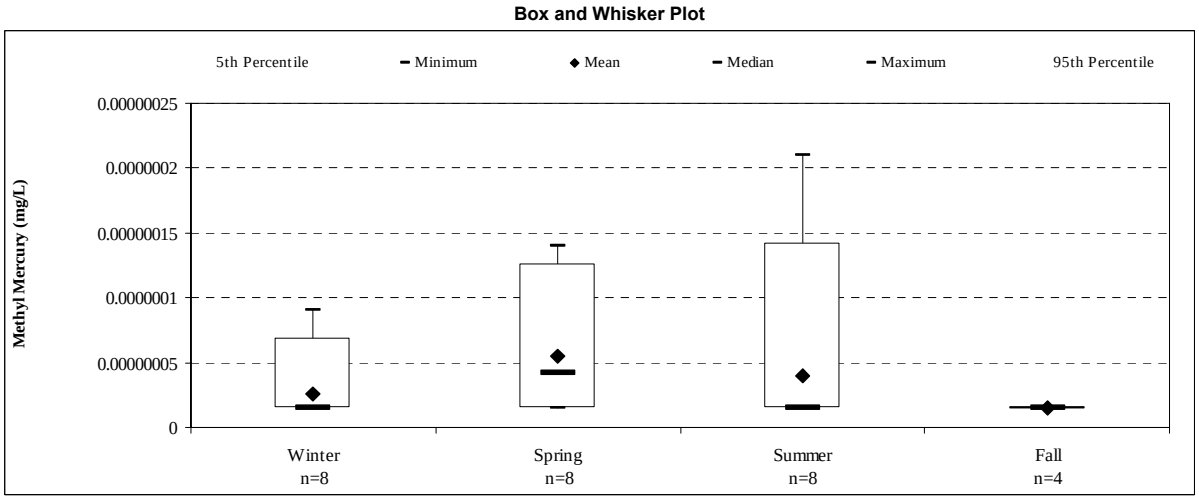


Figure G-3-4-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Redclay Creek



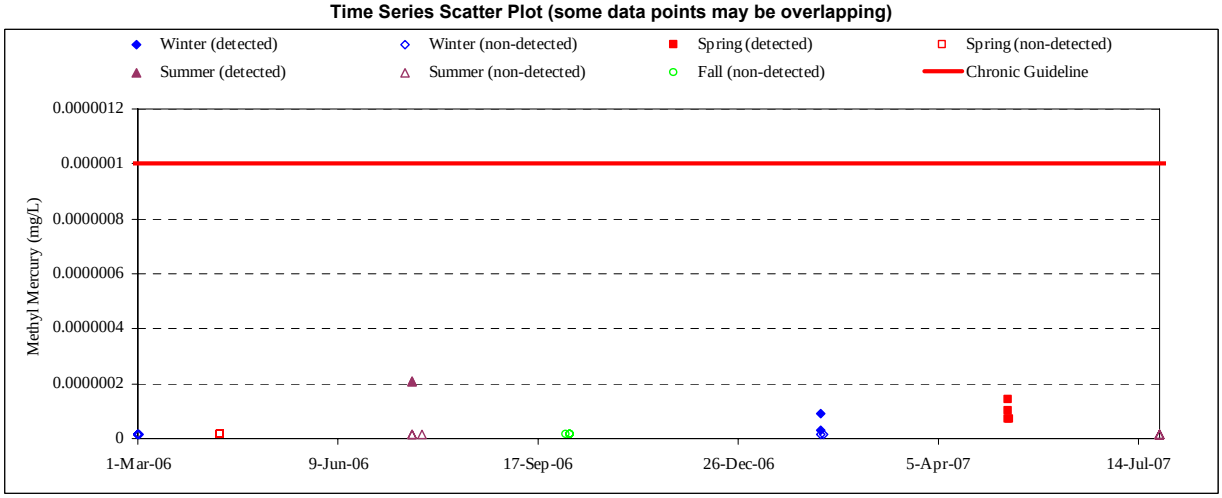
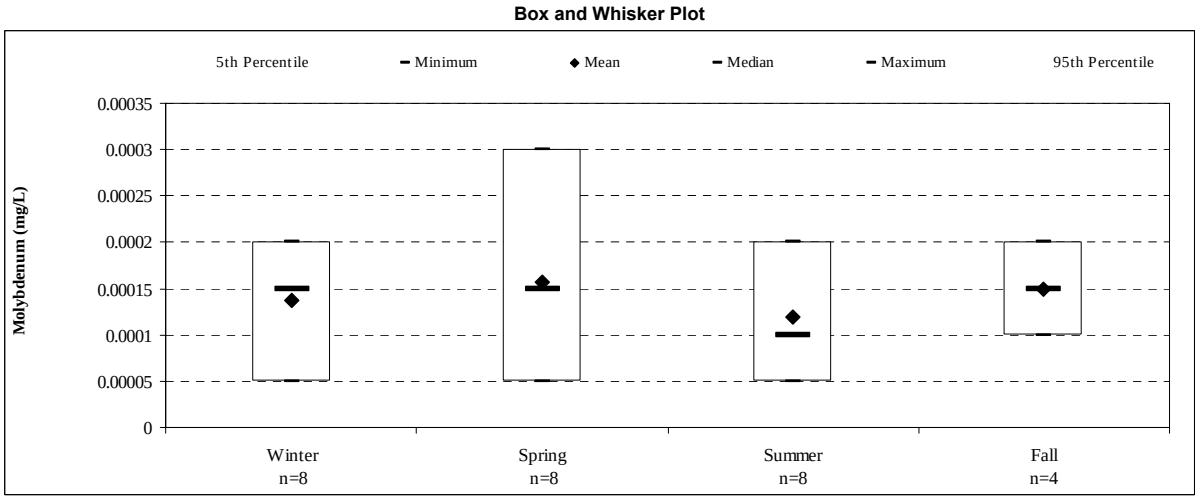


Figure G-3-4-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Redclay Creek



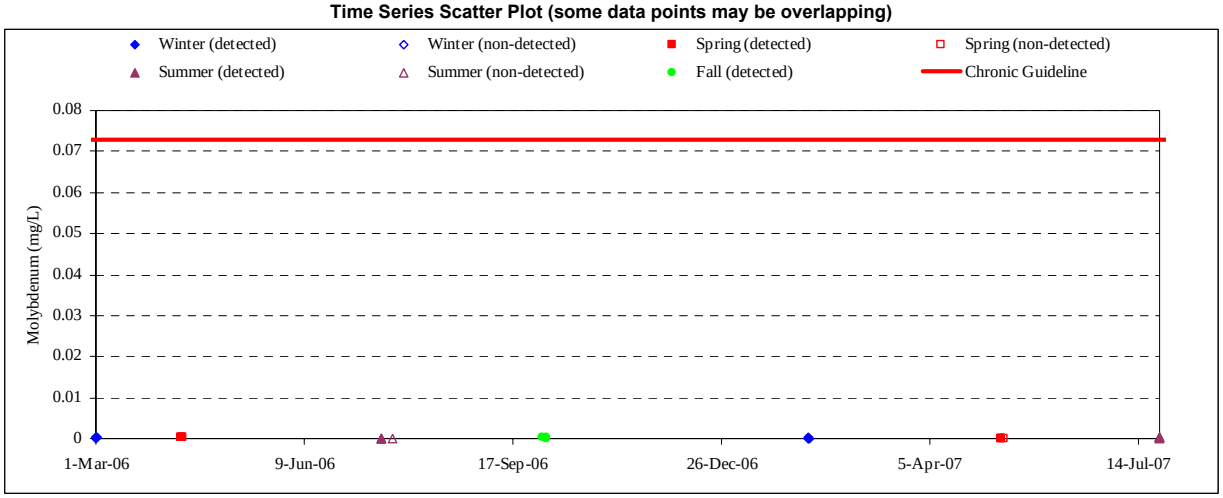
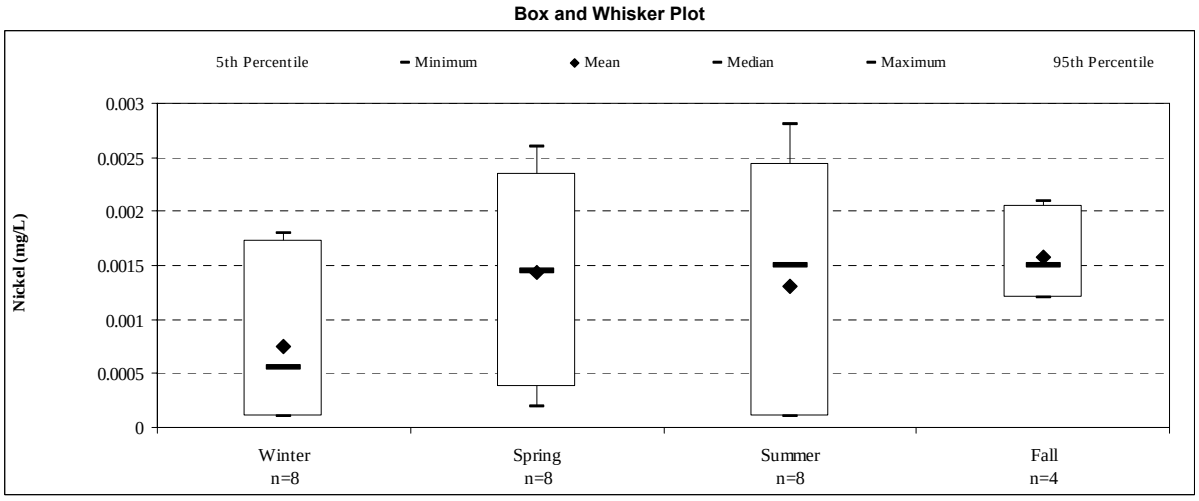


Figure G-3-4-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Redclay Creek



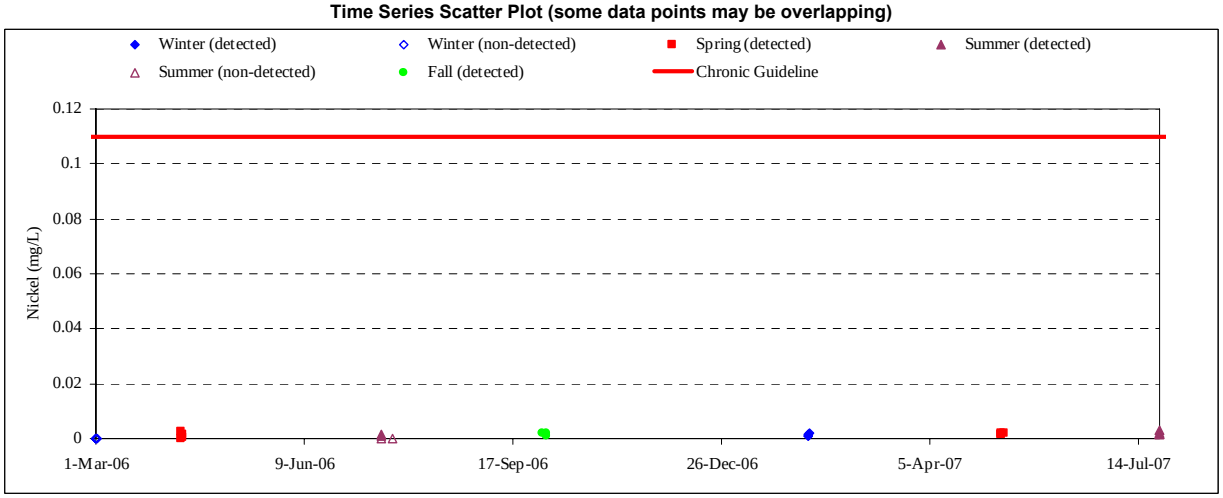
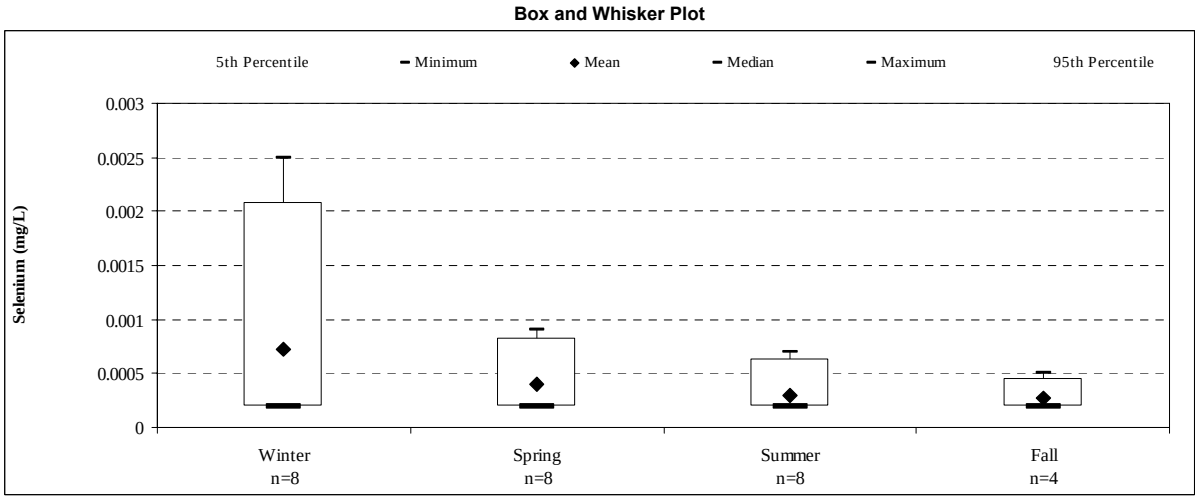


Figure G-3-4-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Redclay Creek



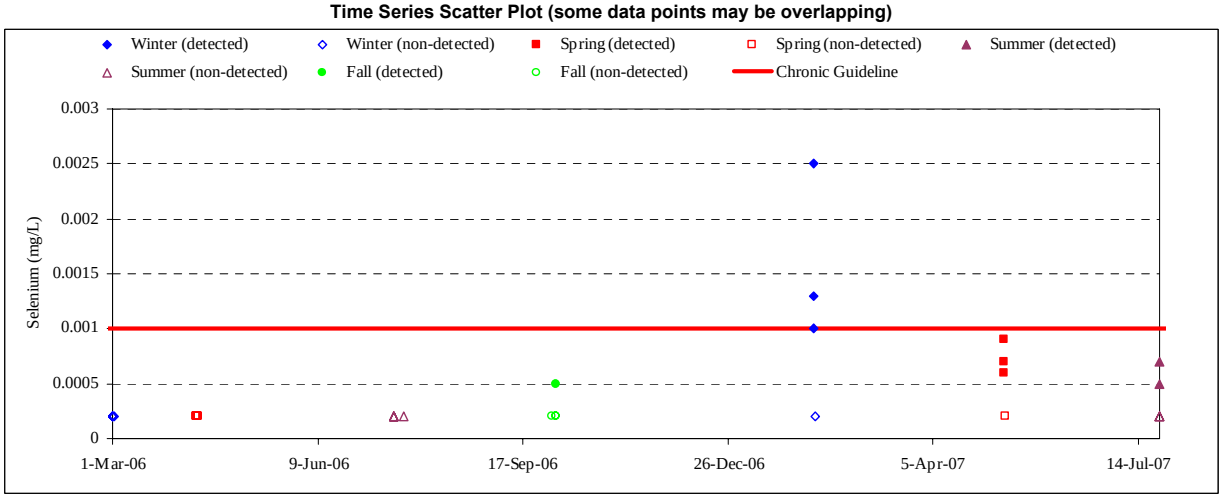
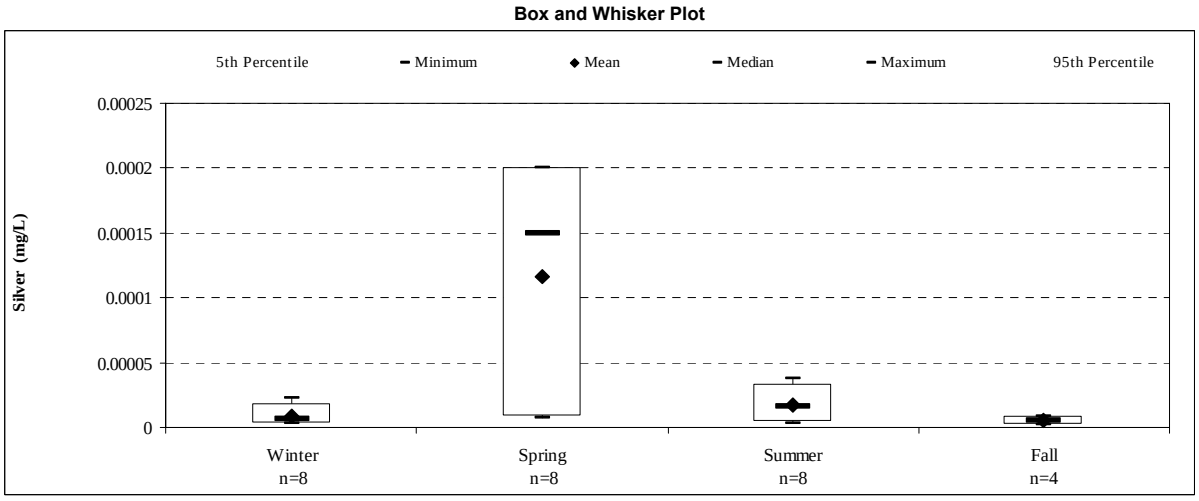


Figure G-3-4-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Redclay Creek



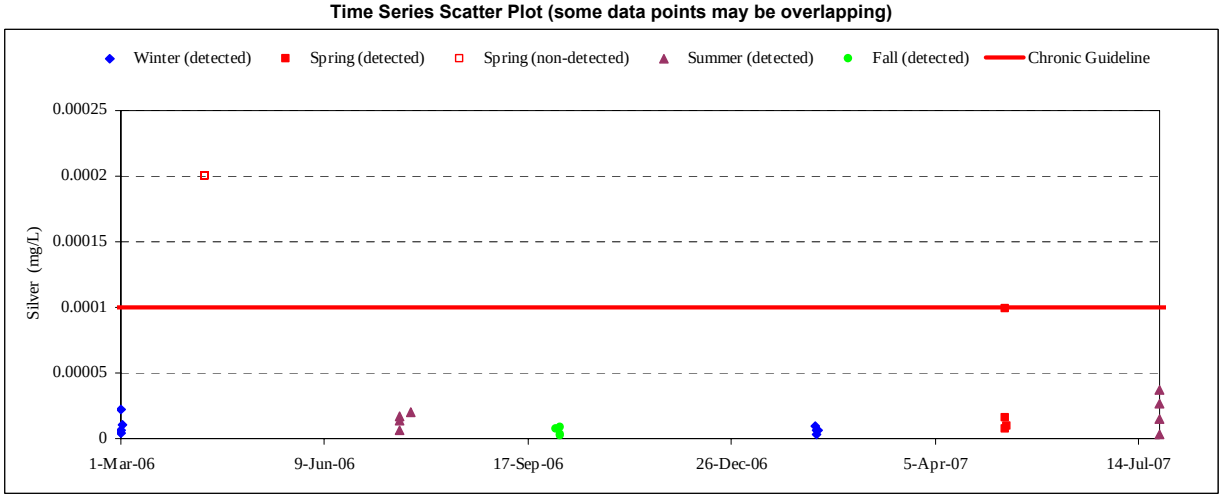
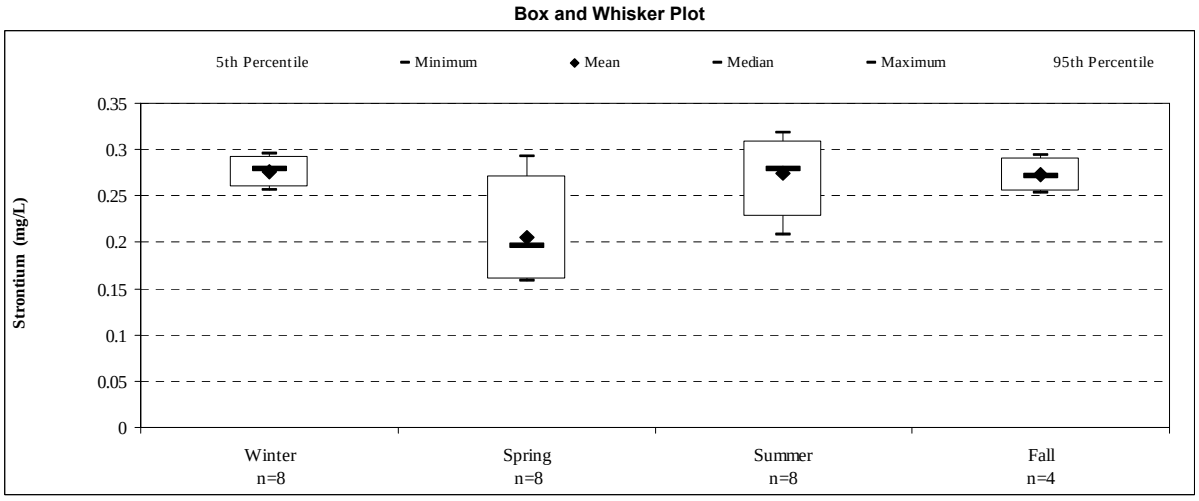


Figure G-3-4-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Redclay Creek



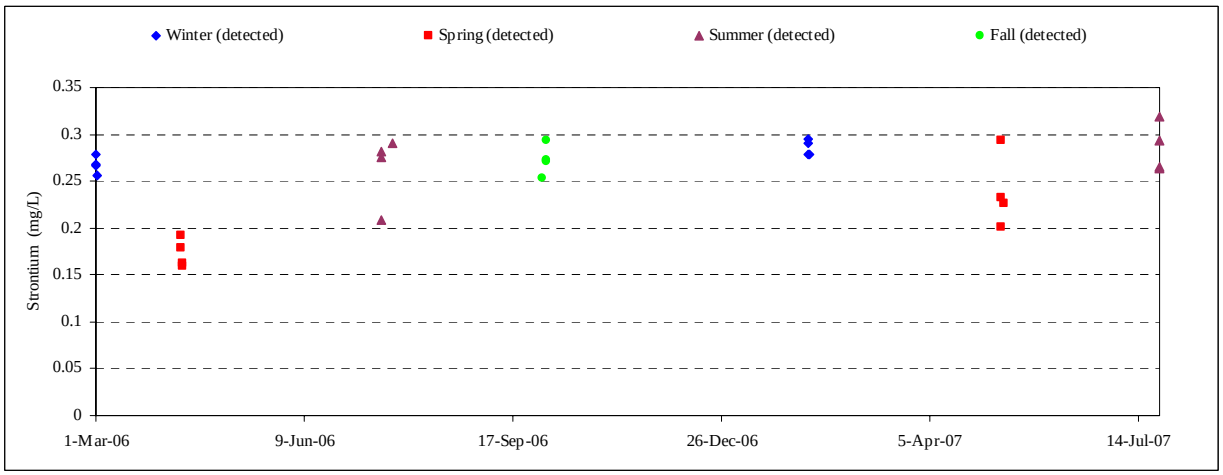
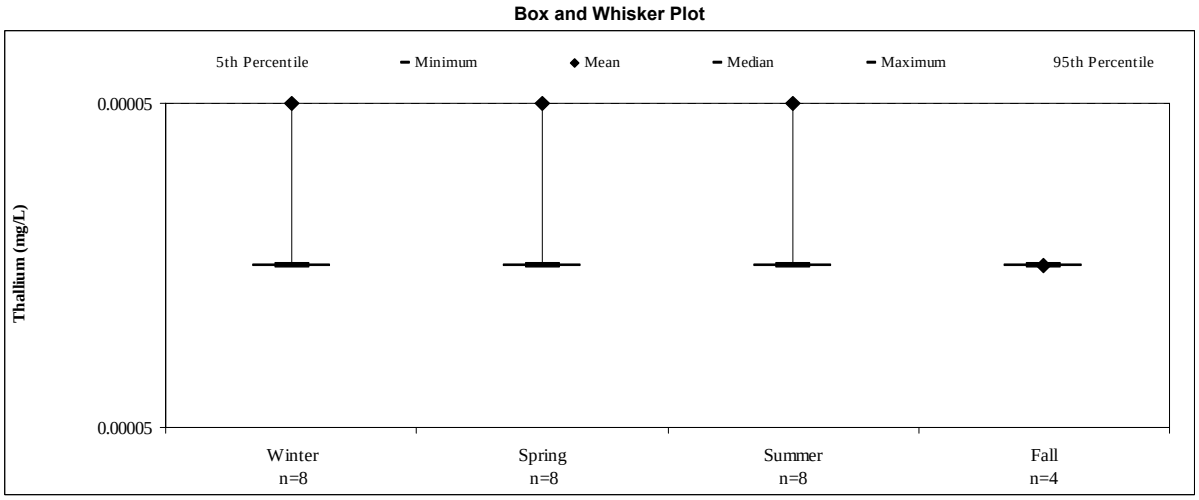


Figure G-3-4-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Redclay Creek



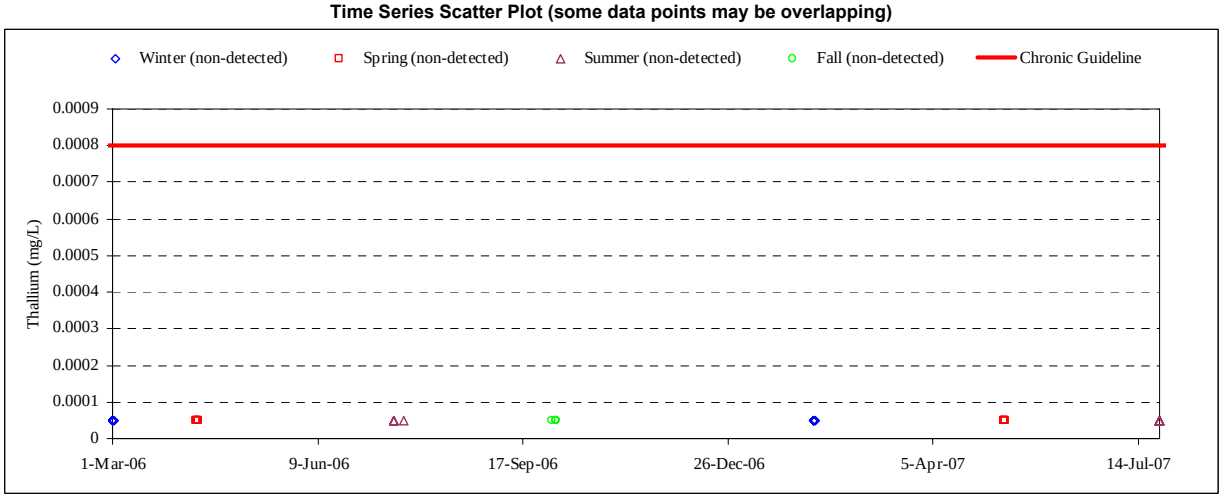
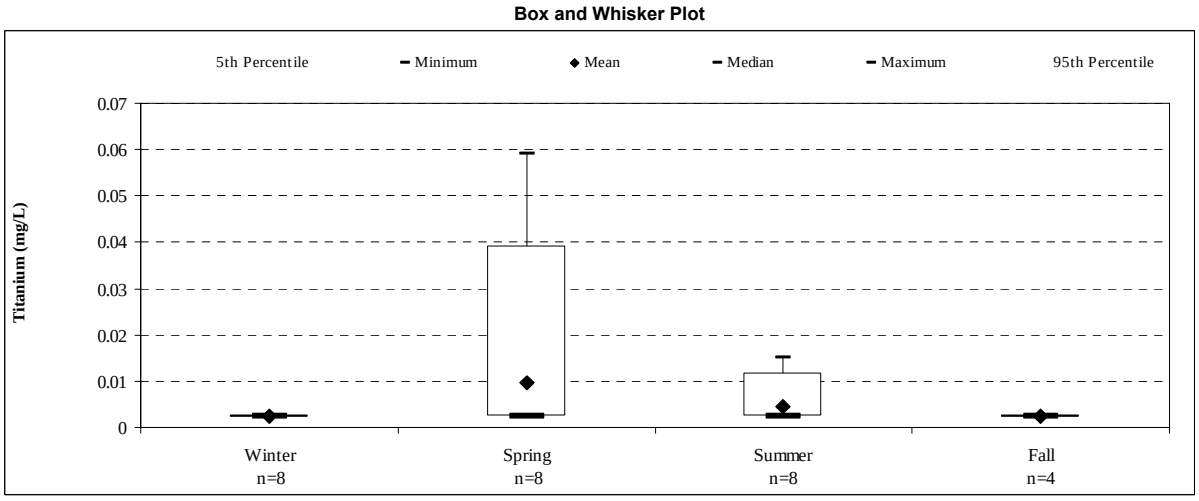


Figure G-3-4-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Redclay Creek



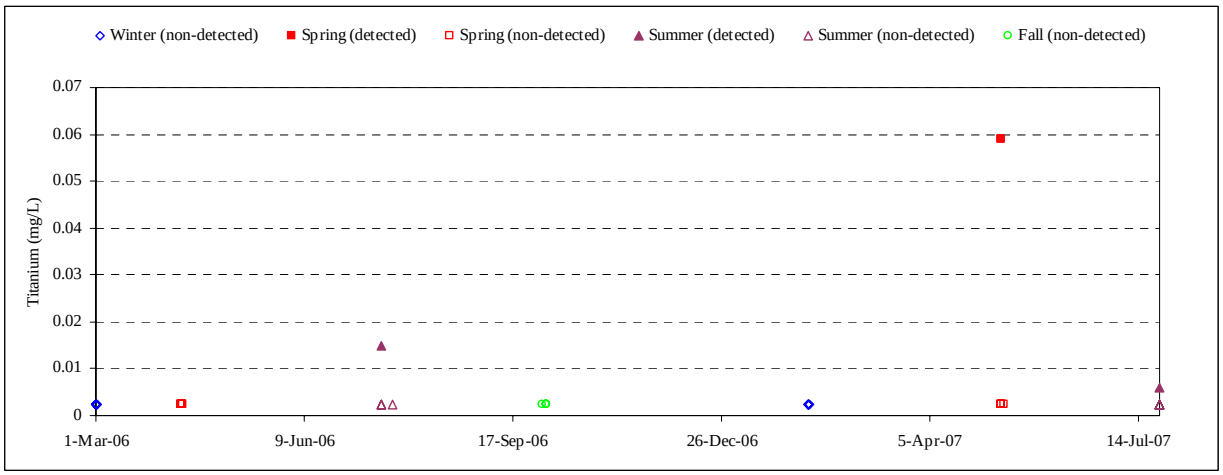
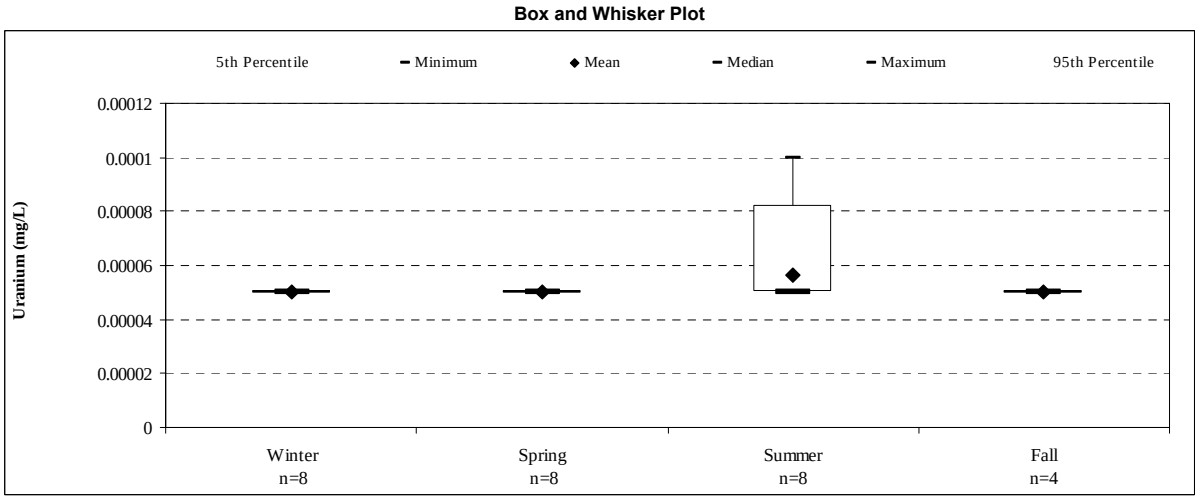


Figure G-3-4-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Redclay Creek



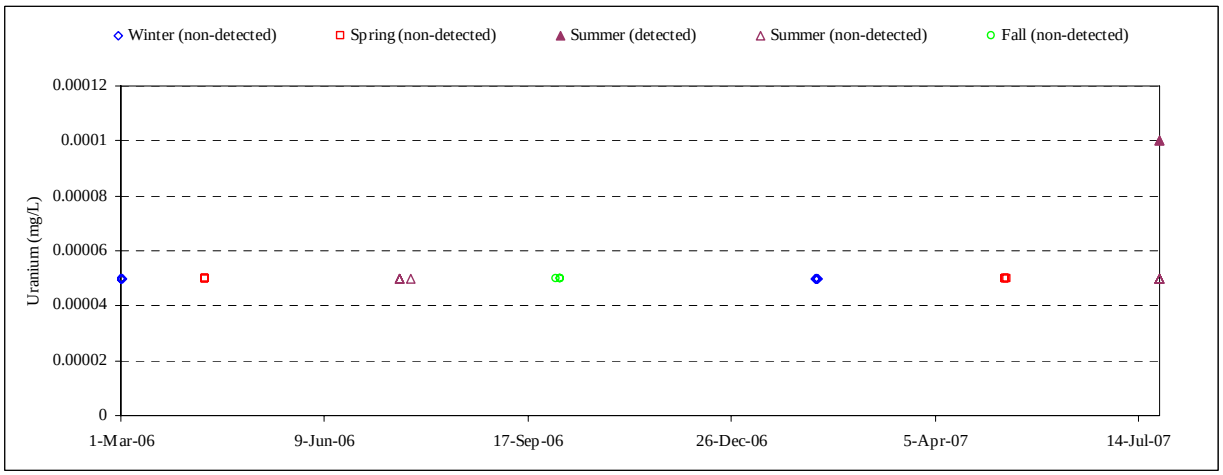
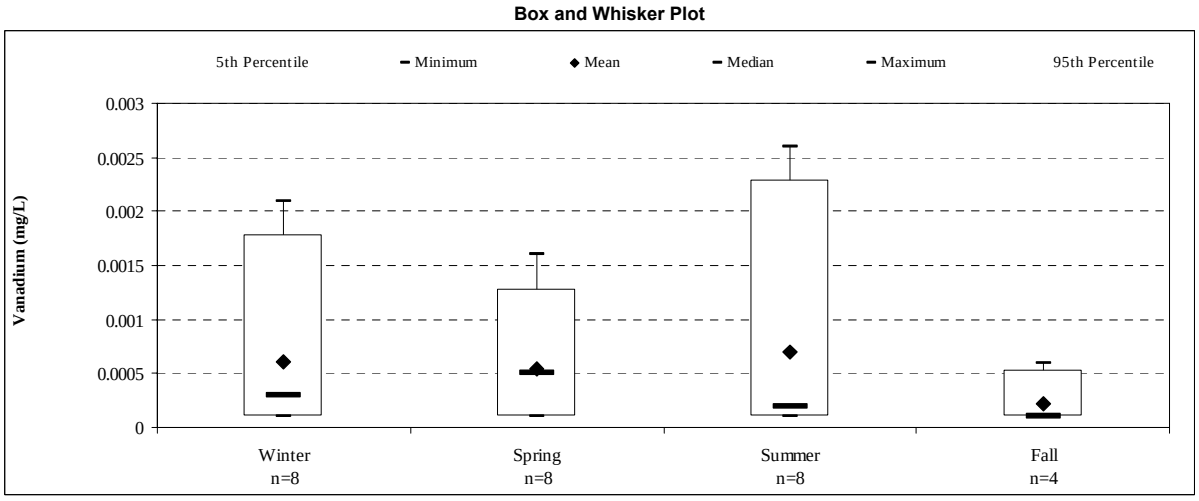


Figure G-3-4-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Redclay Creek



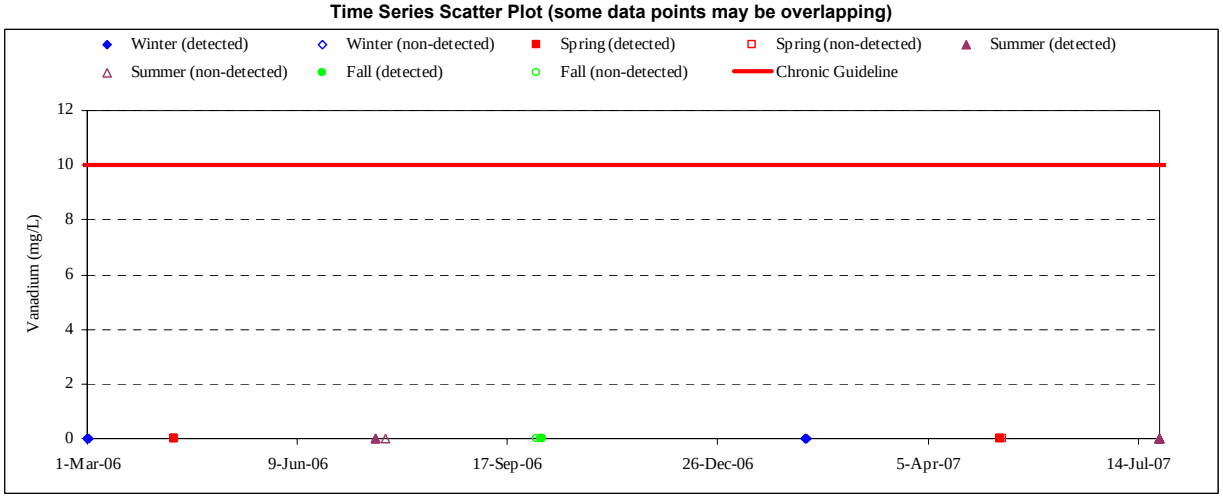
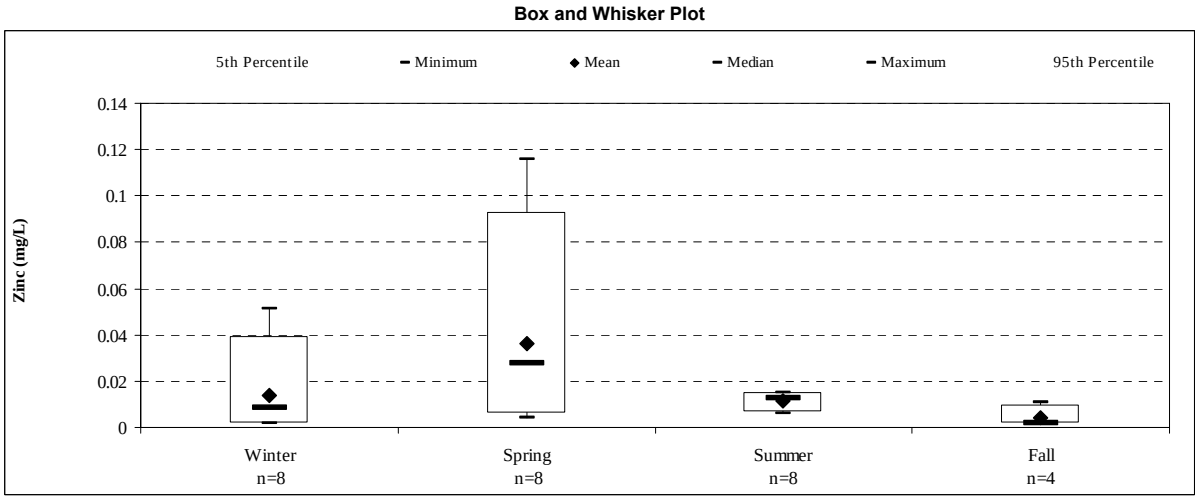


Figure G-3-4-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Redclay Creek



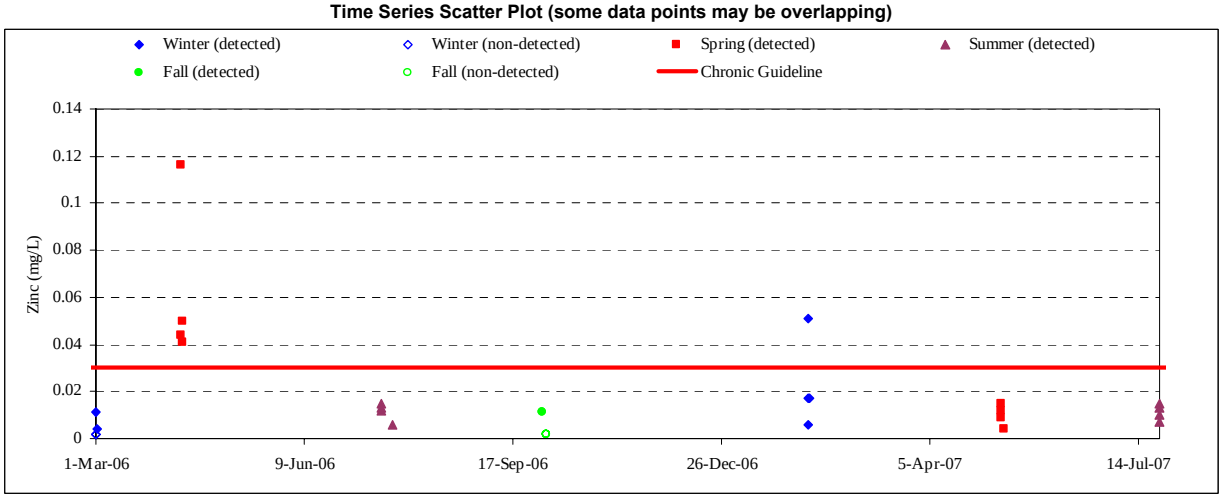


Figure G-3-4-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Redclay Creek

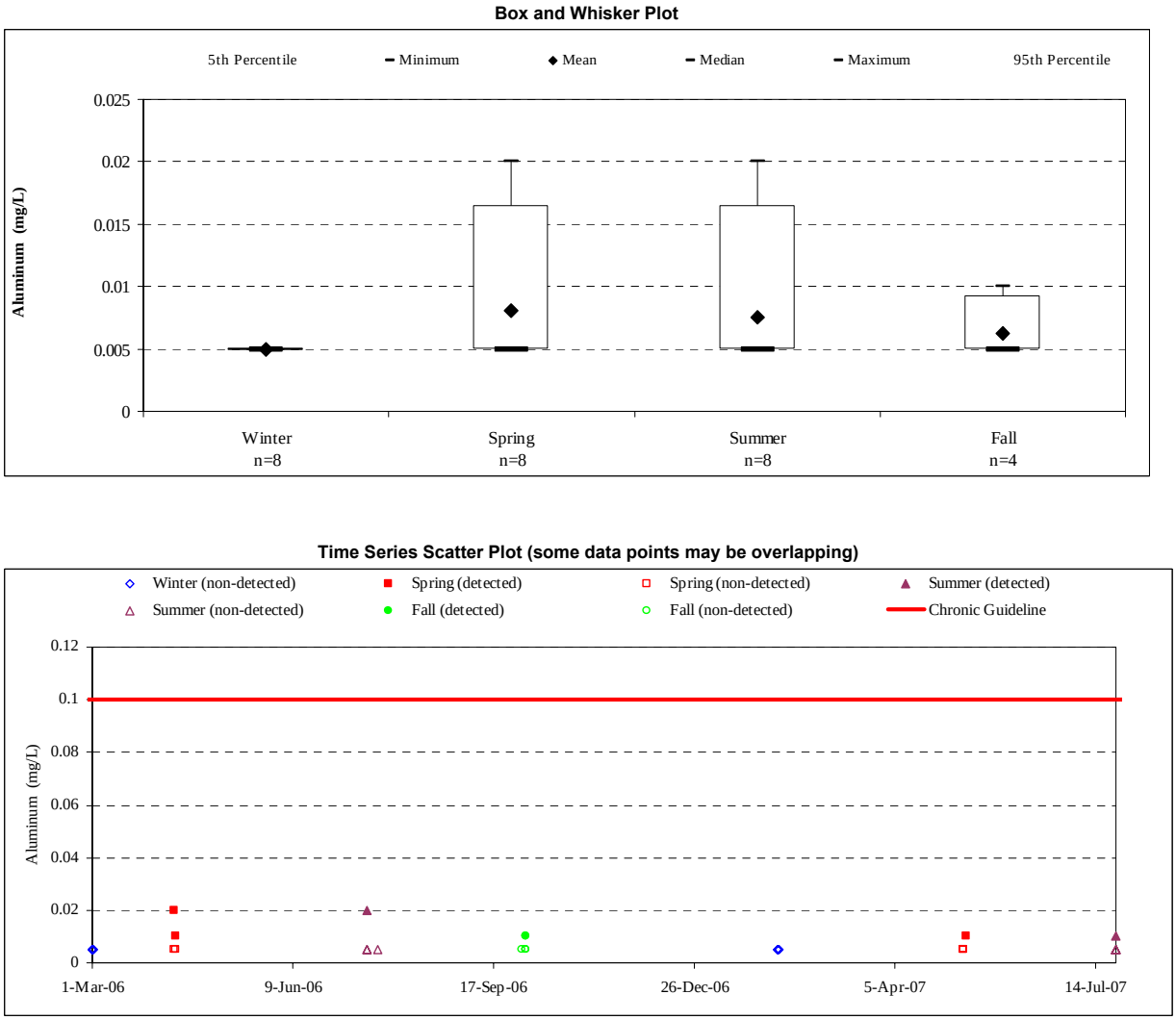
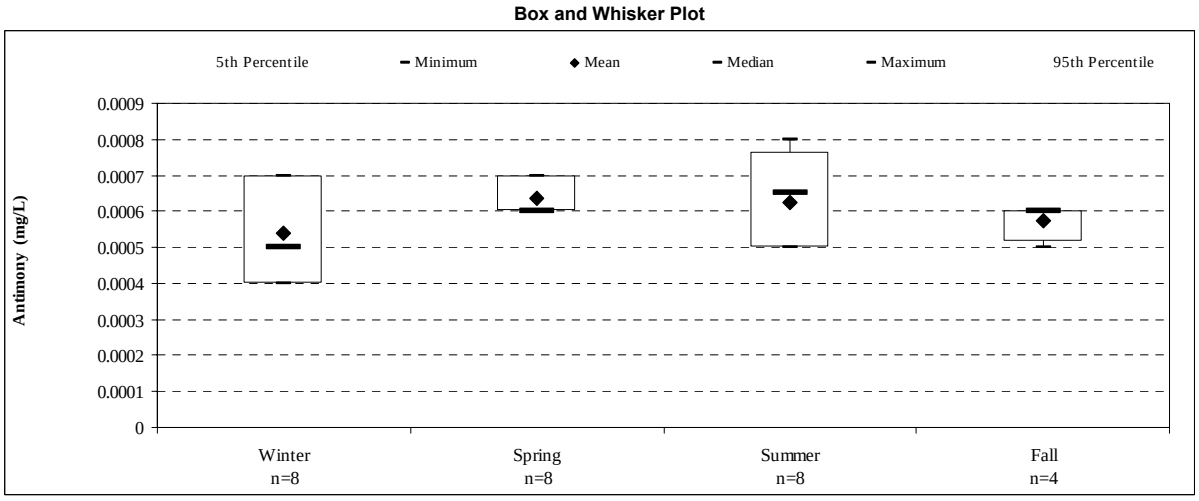


Figure G-3-4-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Redclay Creek



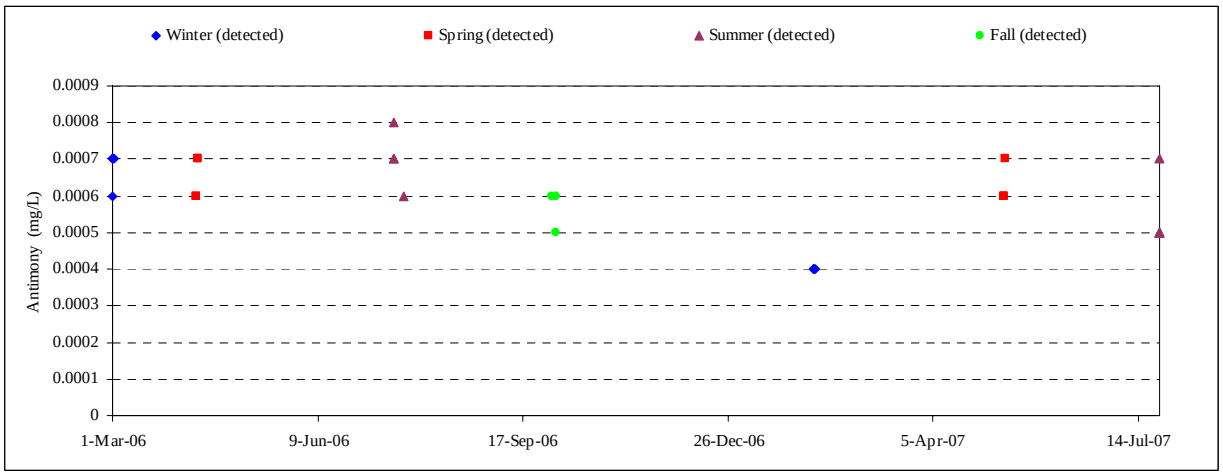
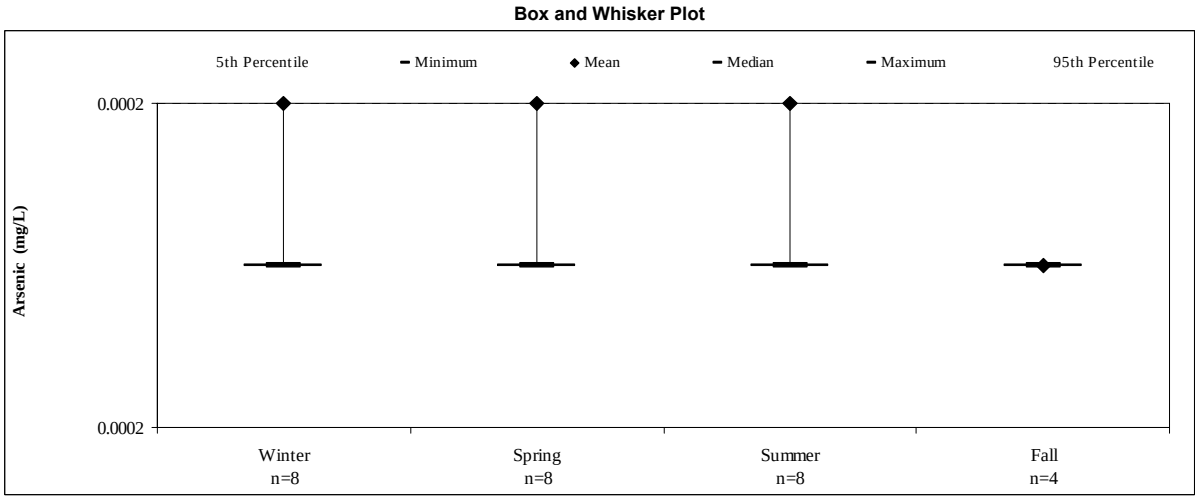


Figure G-3-4-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Redclay Creek



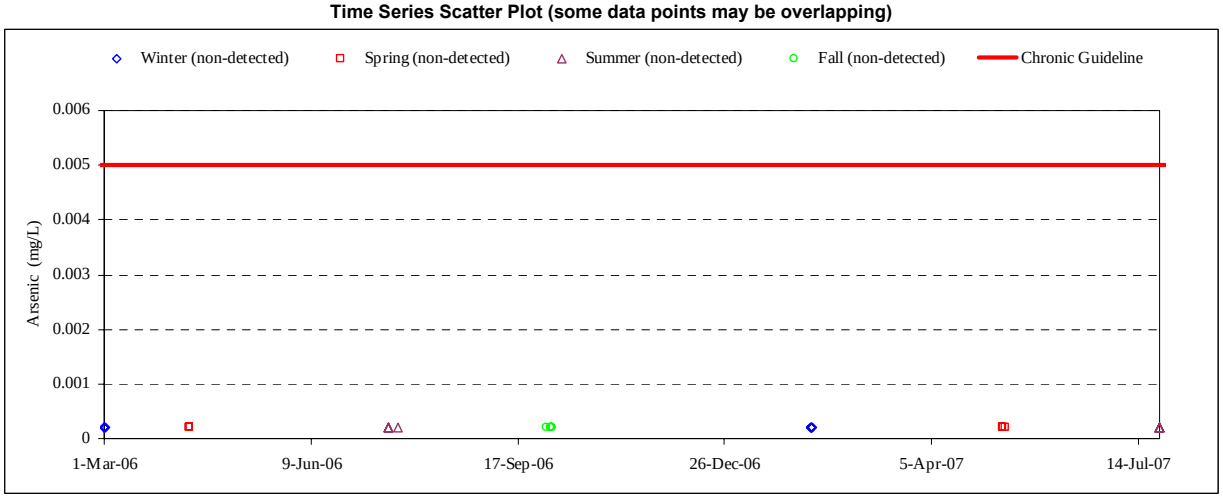
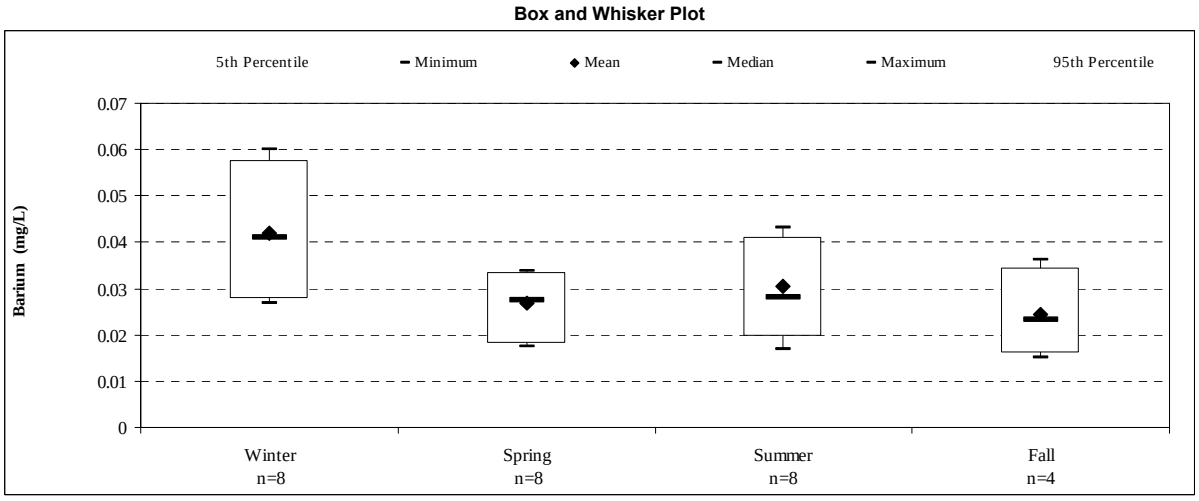


Figure G-3-4-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Redclay Creek



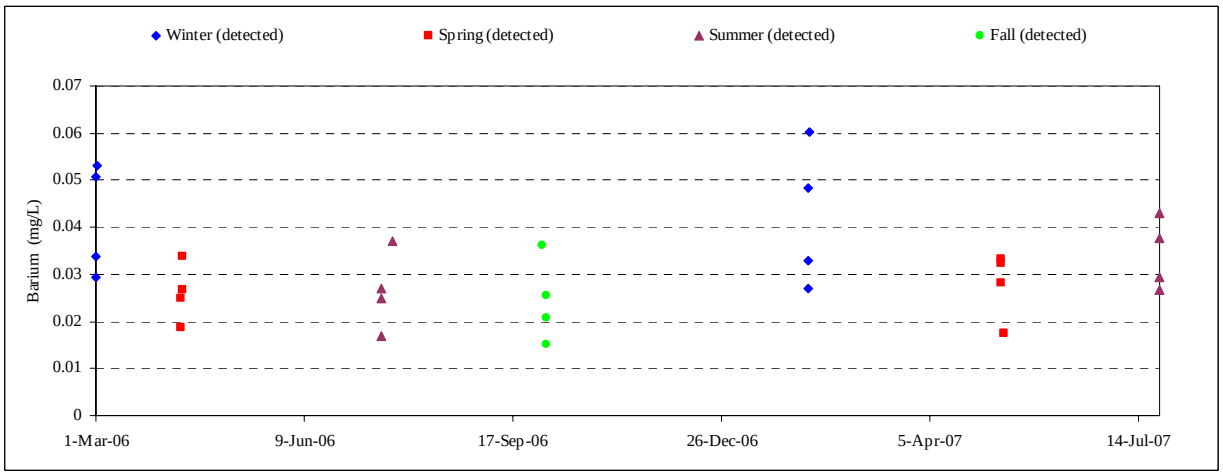
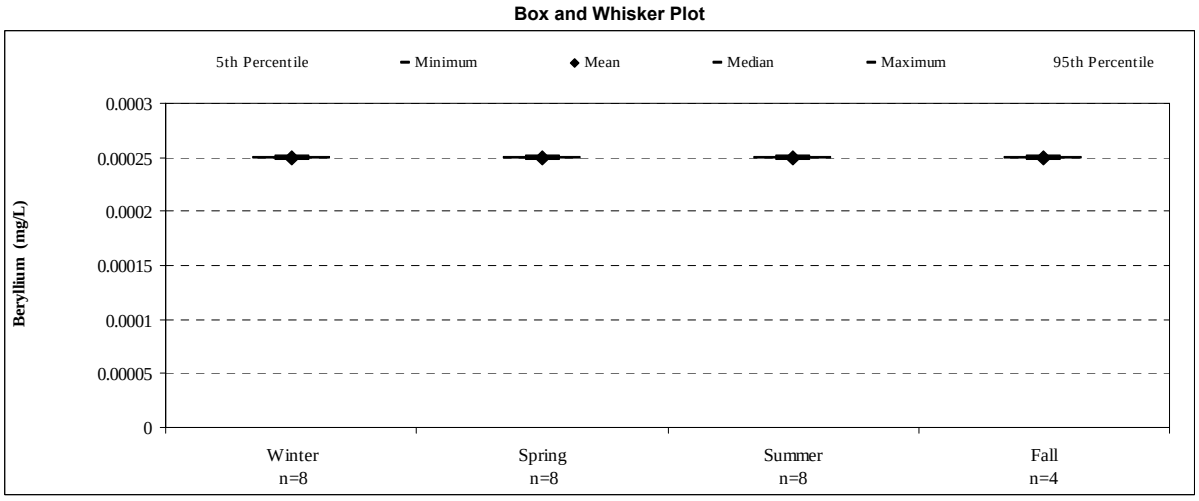


Figure G-3-4-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Redclay Creek



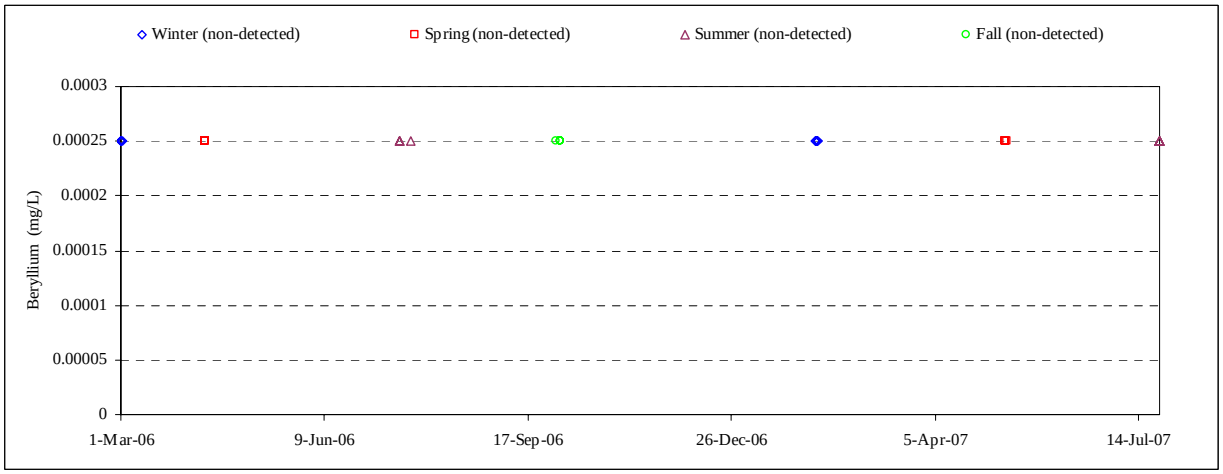
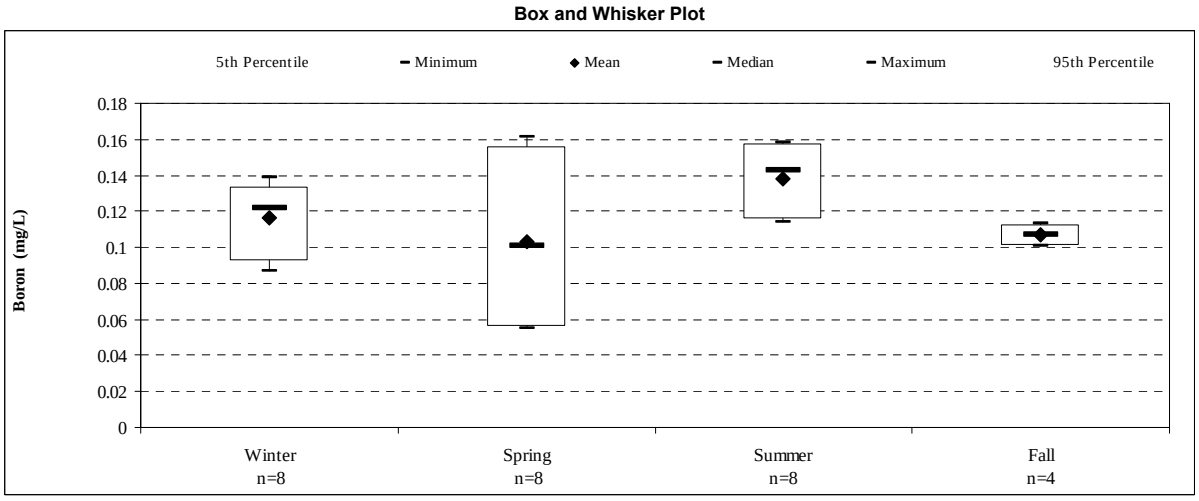


Figure G-3-4-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Redclay Creek



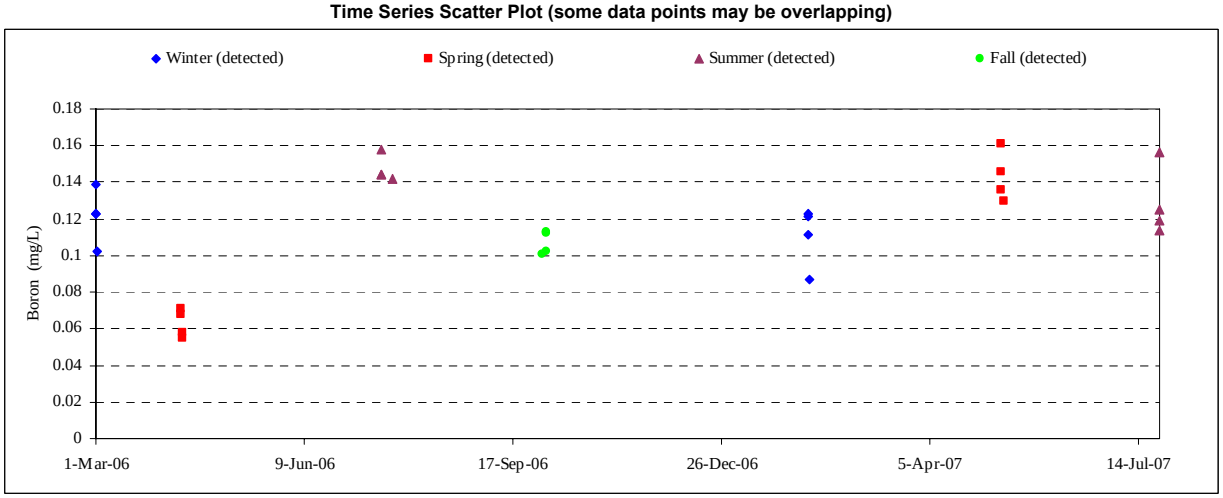
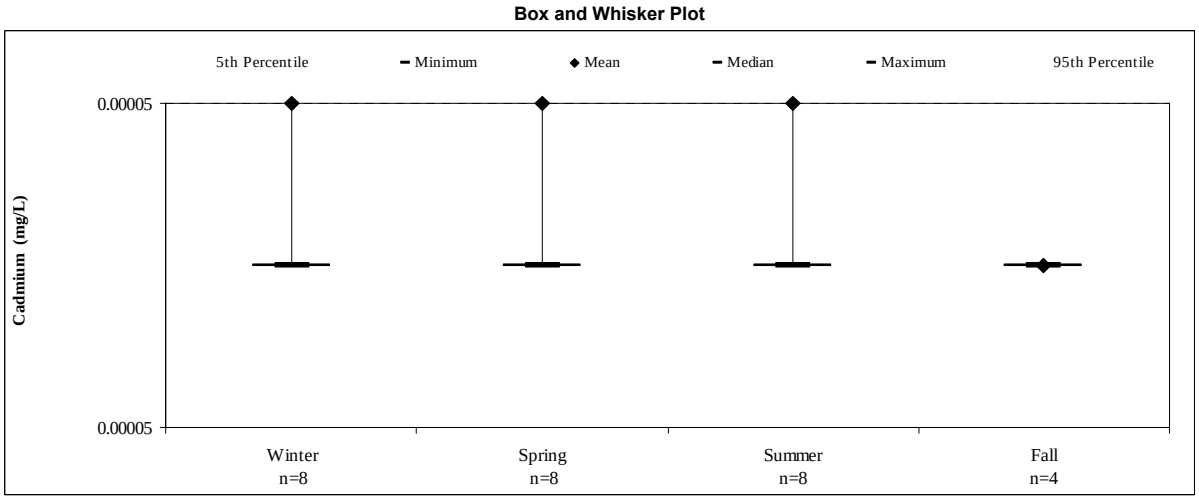


Figure G-3-4-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Redclay Creek



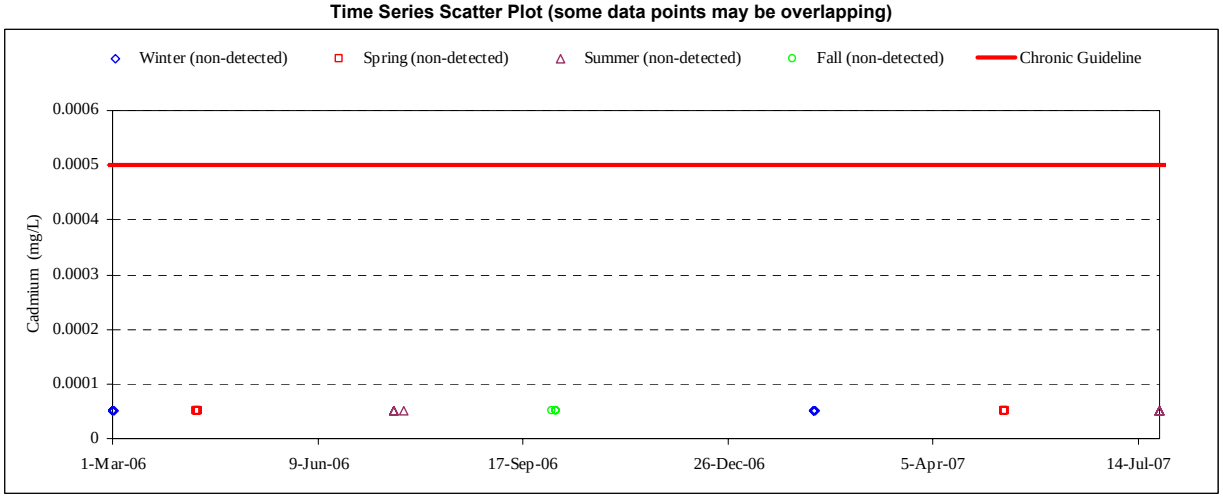
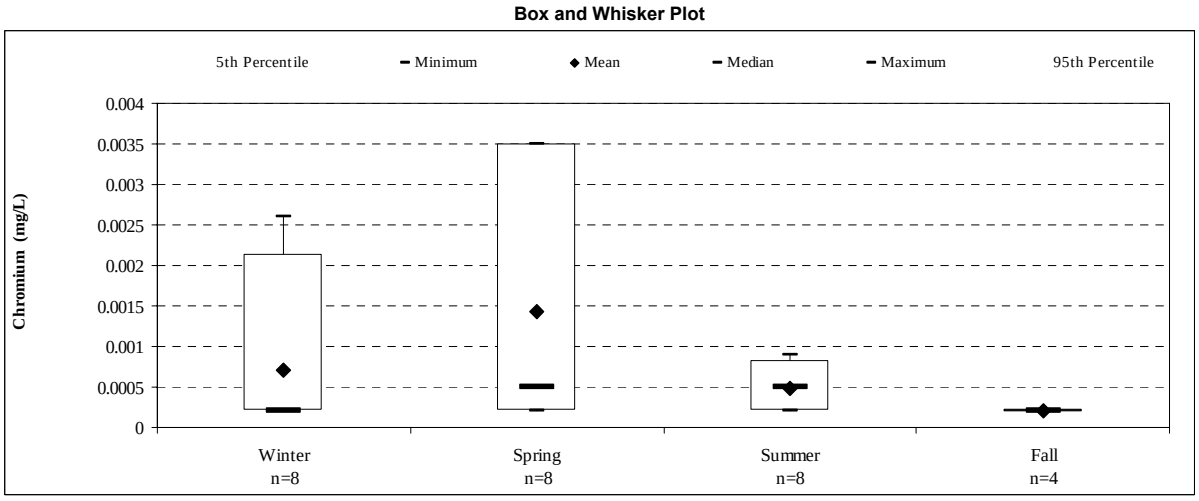


Figure G-3-4-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Redclay Creek



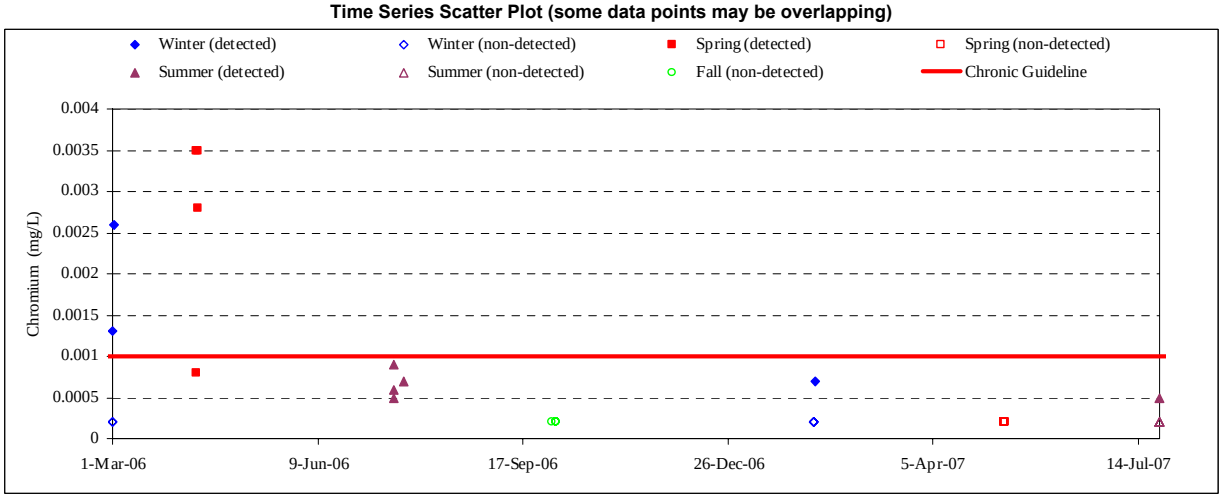
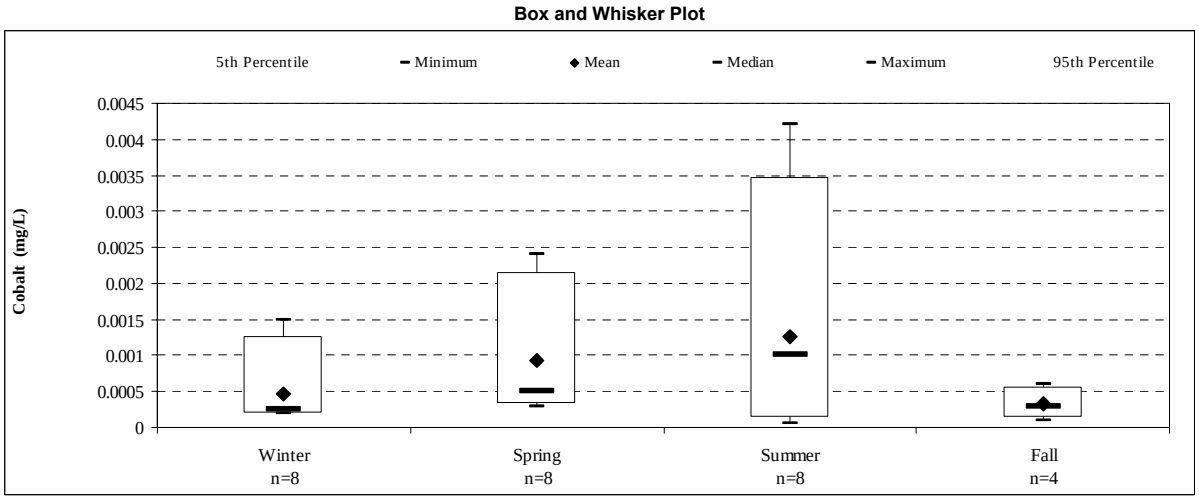


Figure G-3-4-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Redclay Creek



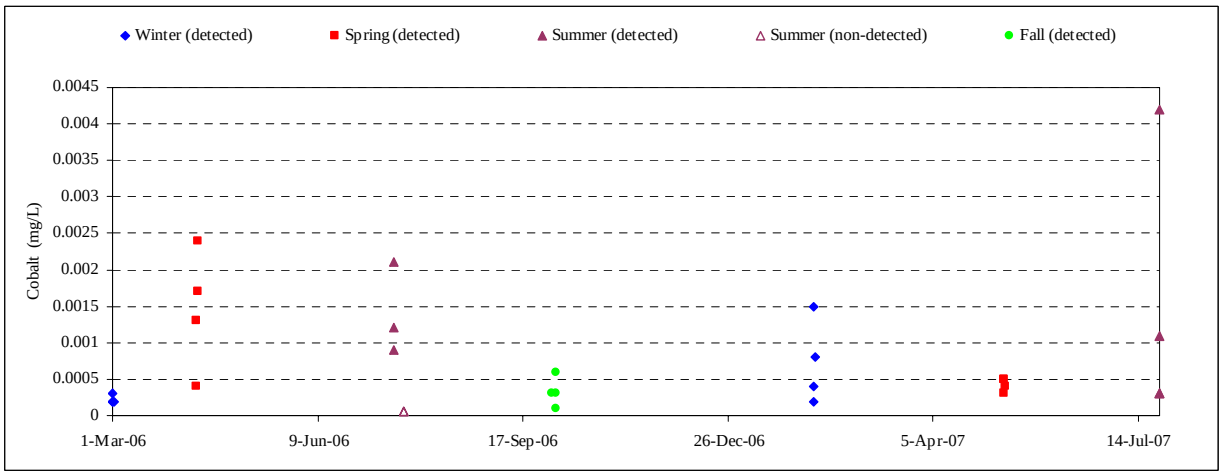
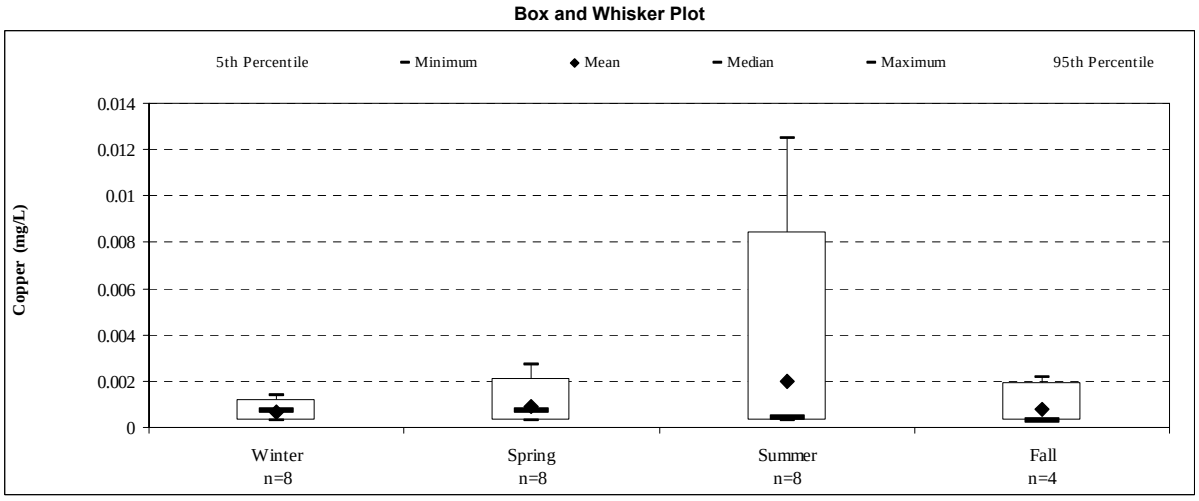


Figure G-3-4-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Redclay Creek



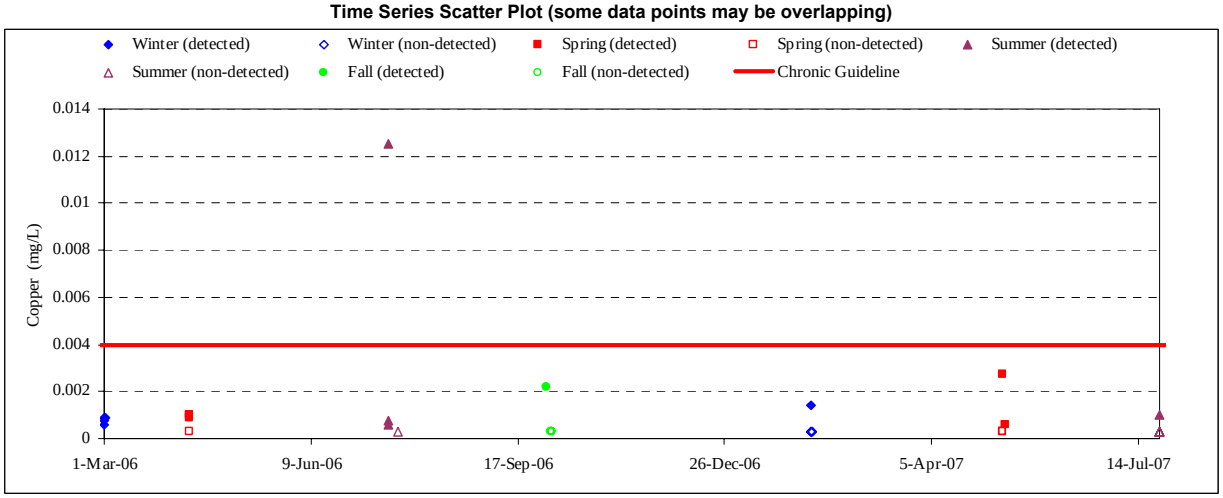
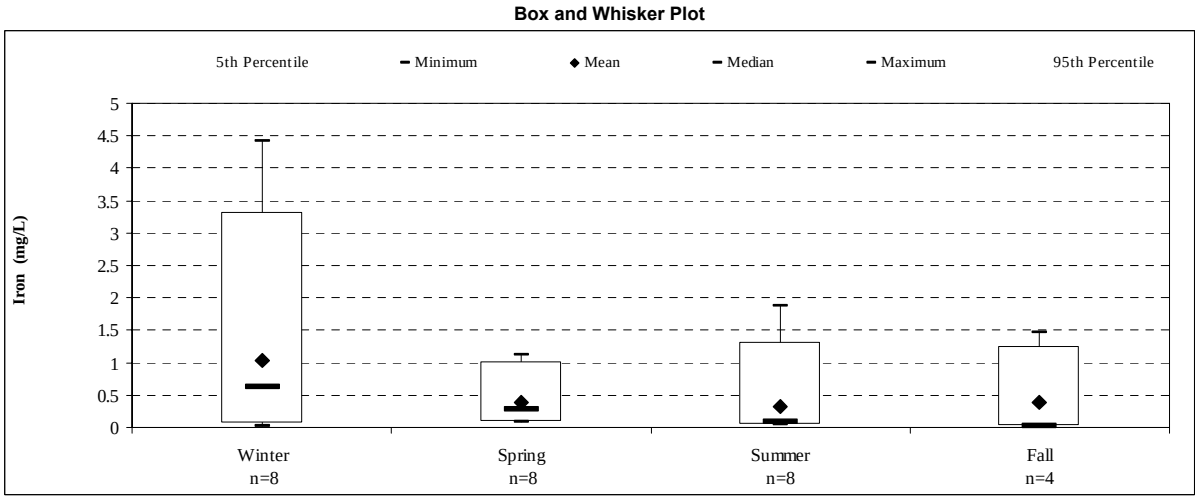


Figure G-3-4-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Redclay Creek



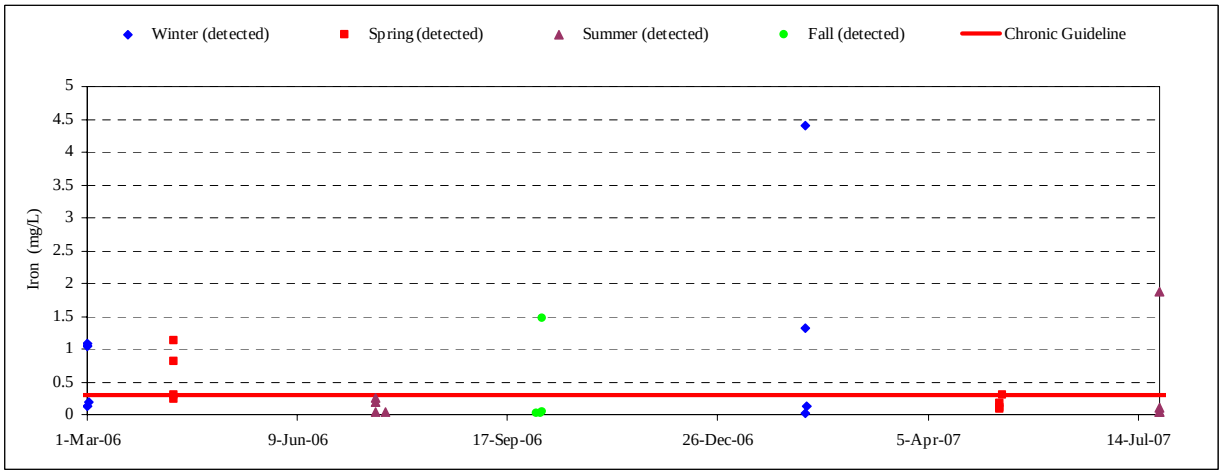
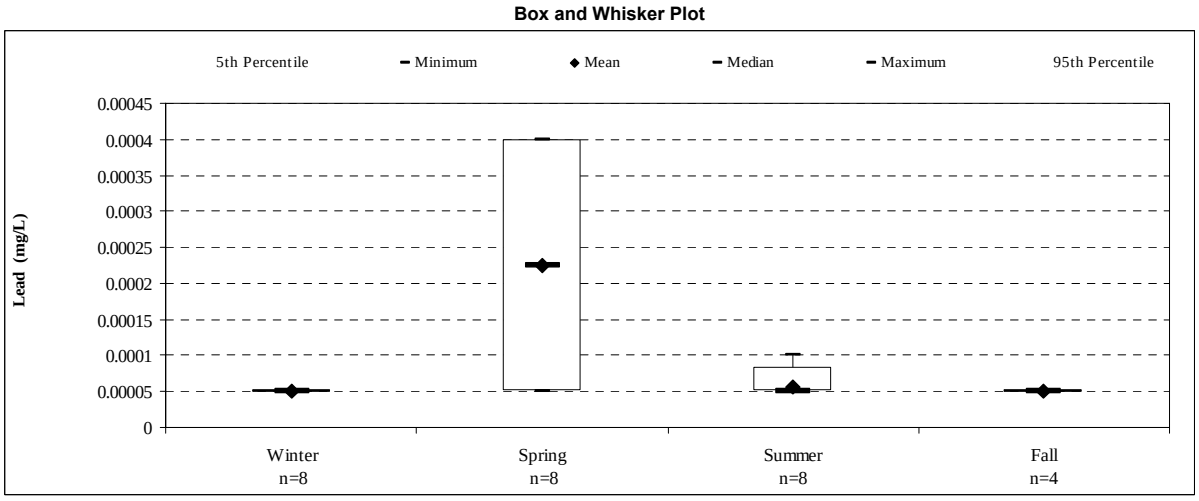


Figure G-3-4-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Redclay Creek



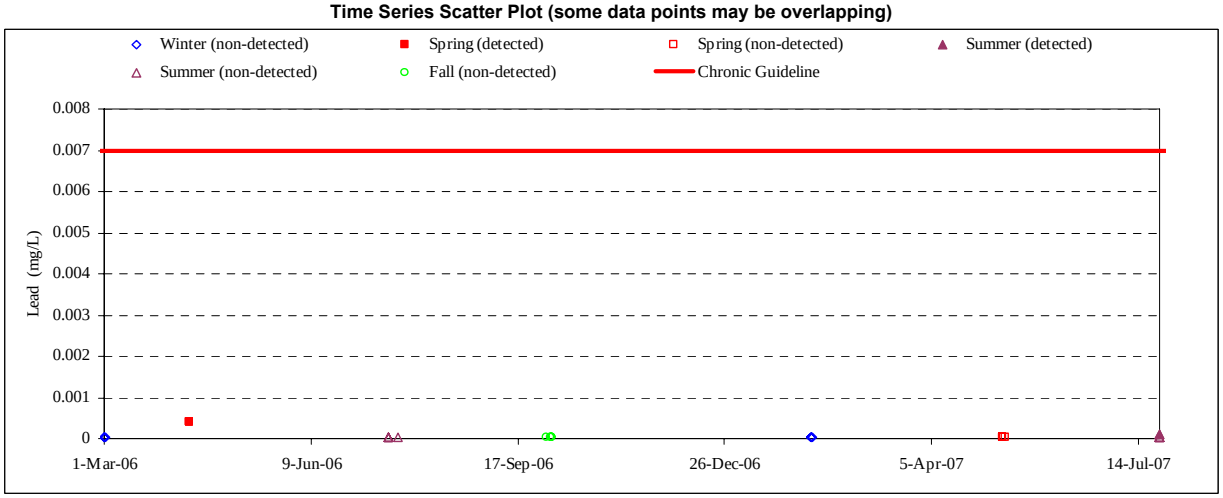
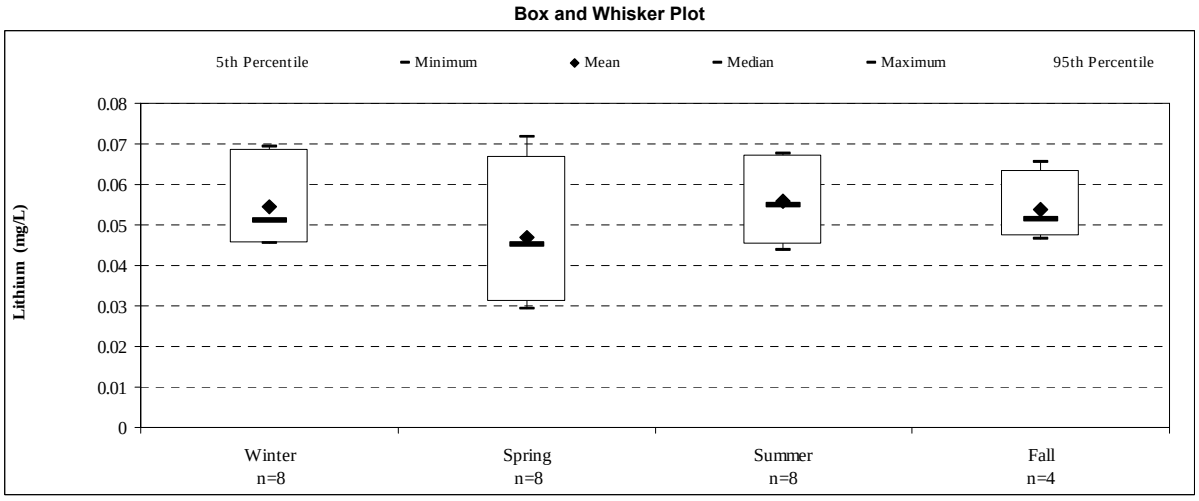


Figure G-3-4-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Redclay Creek



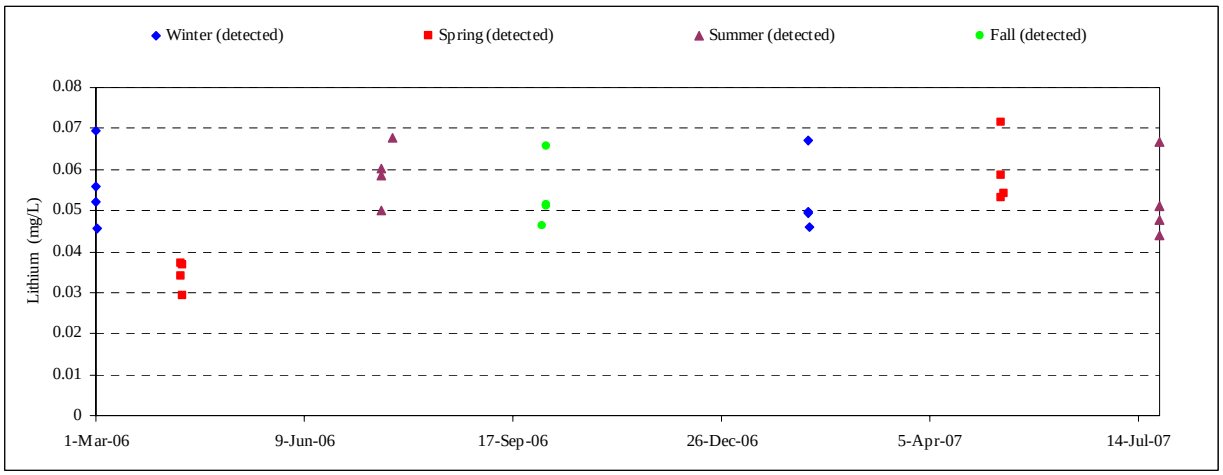
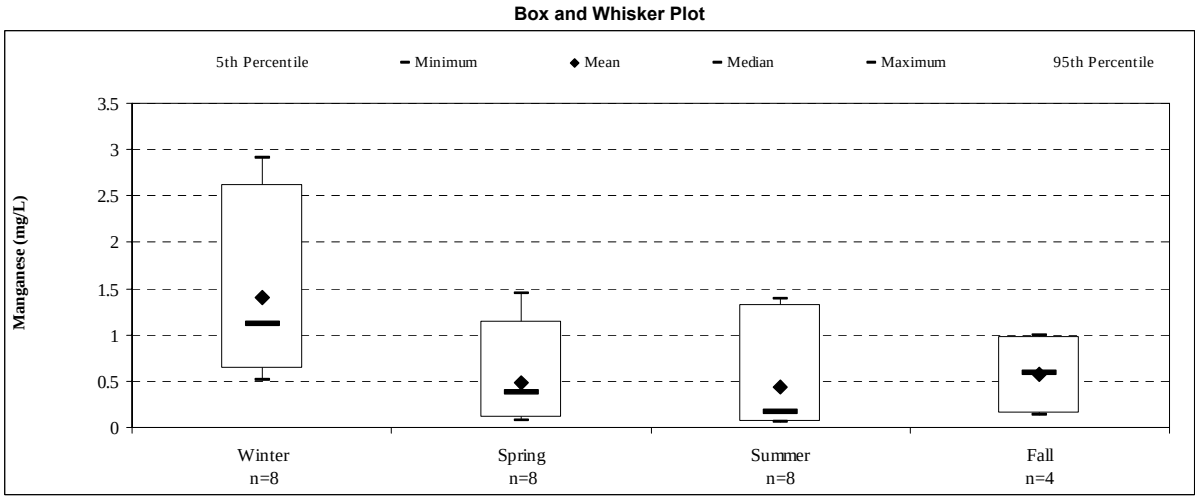


Figure G-3-4-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Redclay Creek



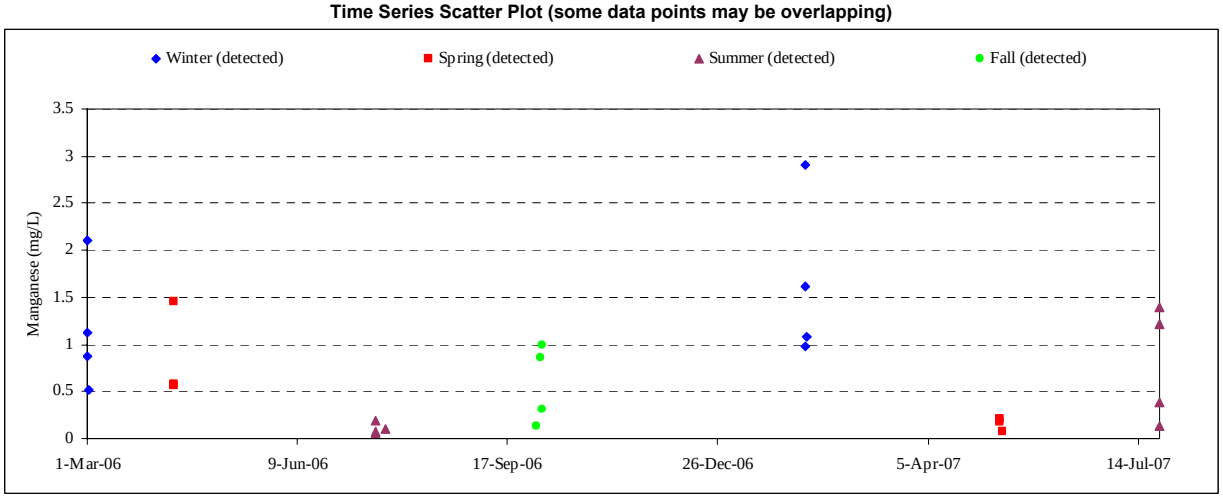
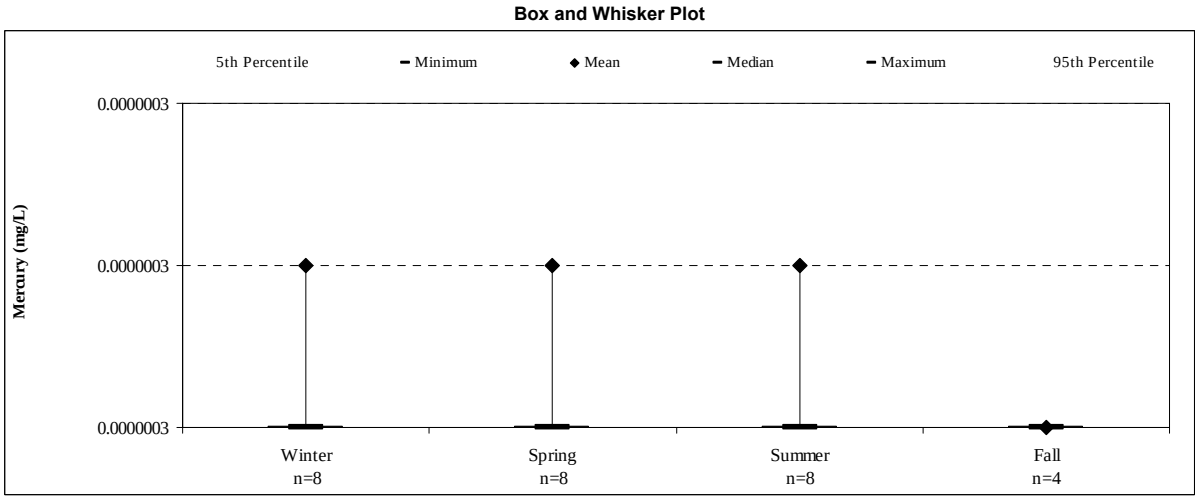


Figure G-3-4-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Redclay Creek



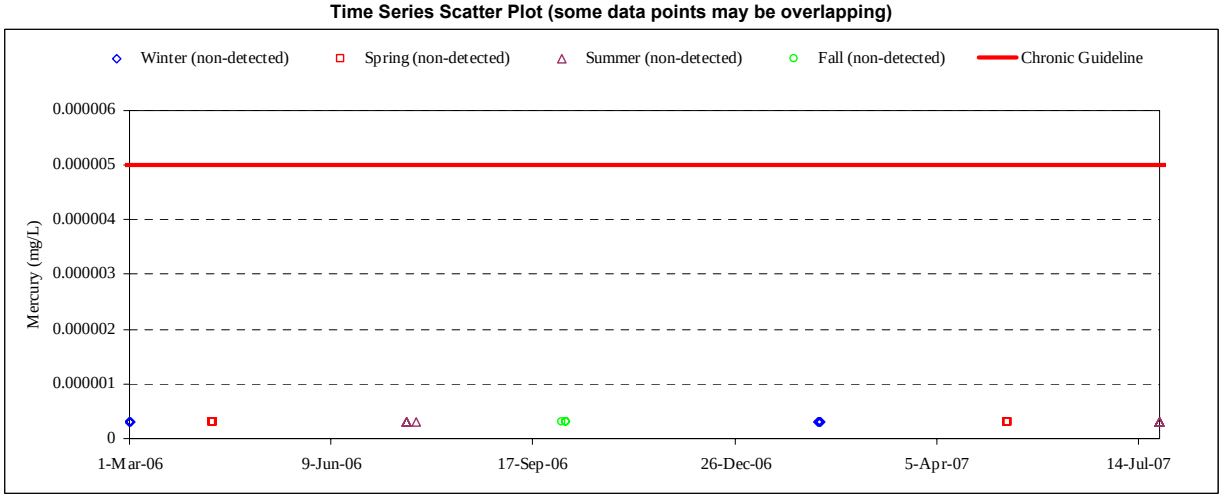
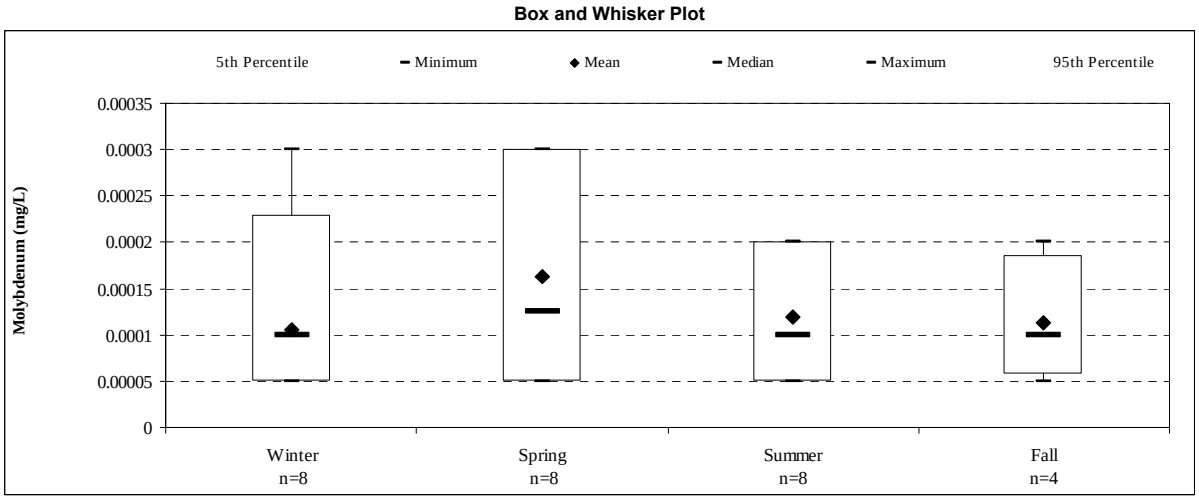


Figure G-3-4-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Redclay Creek



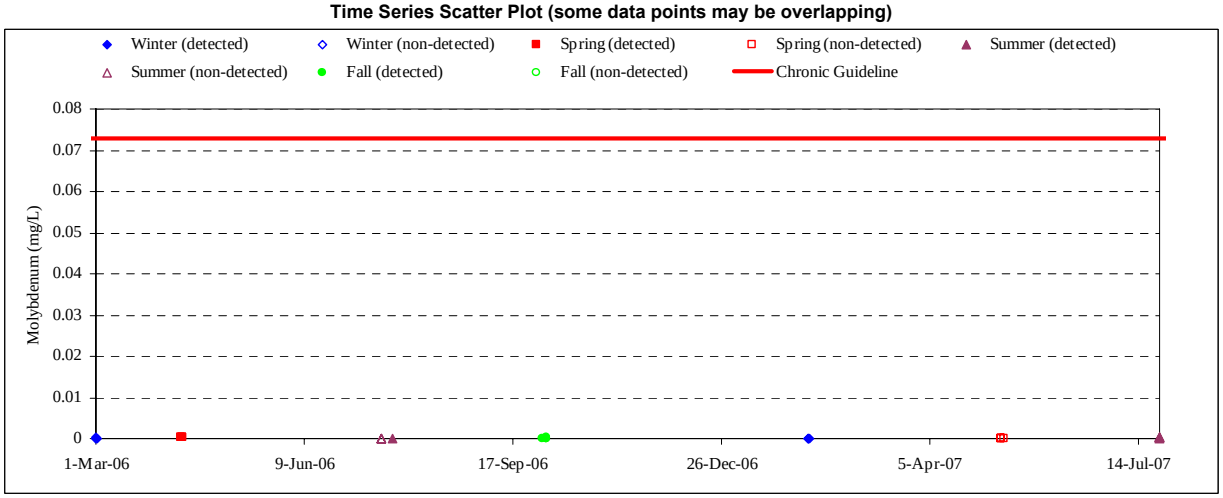
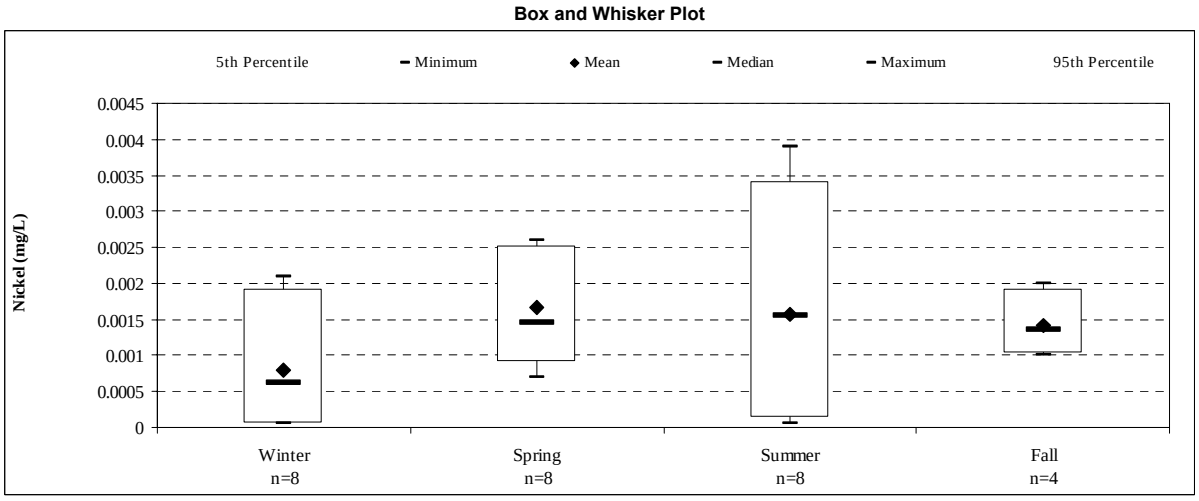


Figure G-3-4-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Redclay Creek



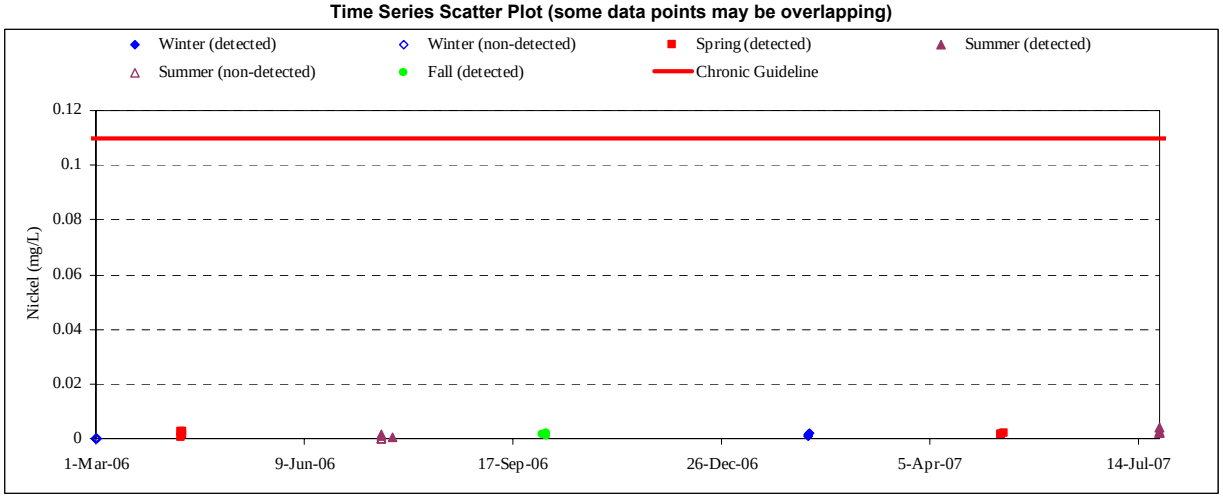
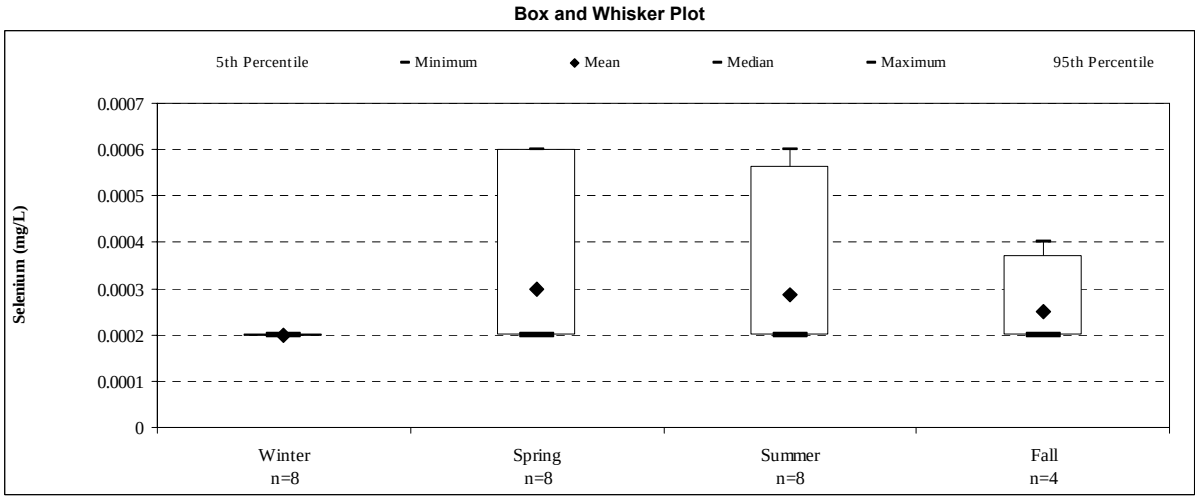


Figure G-3-4-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Redclay Creek



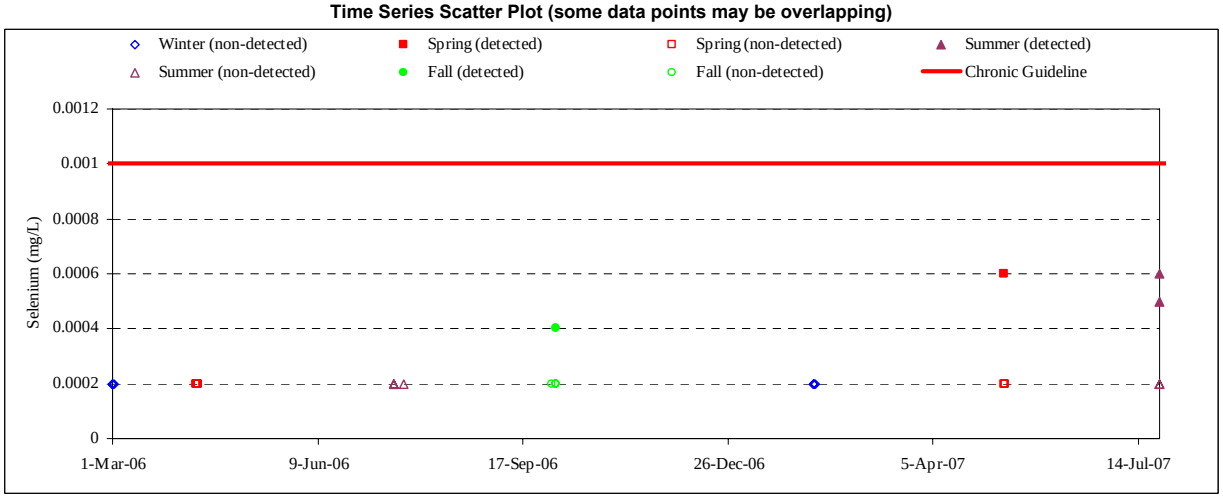
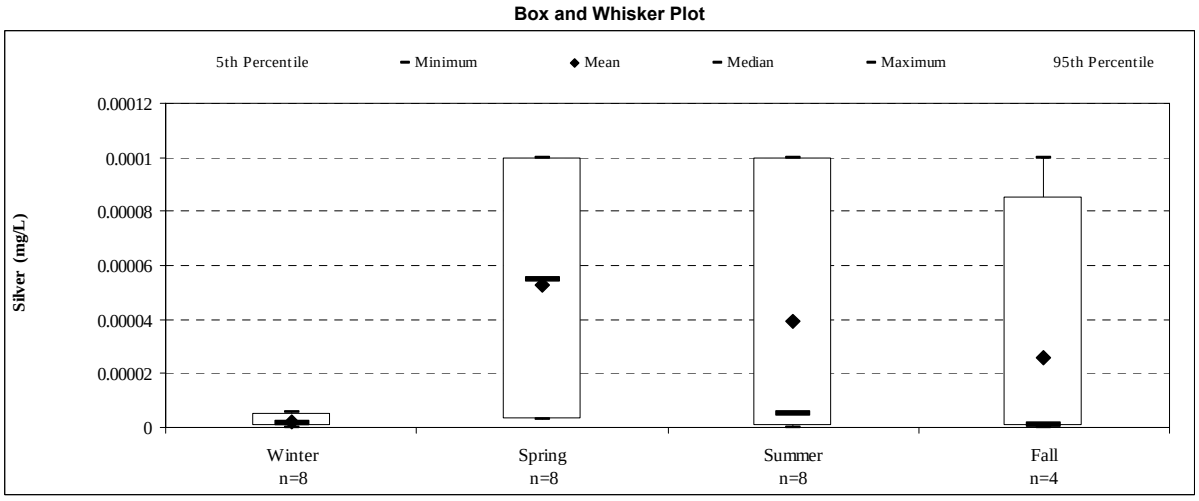


Figure G-3-4-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Redclay Creek



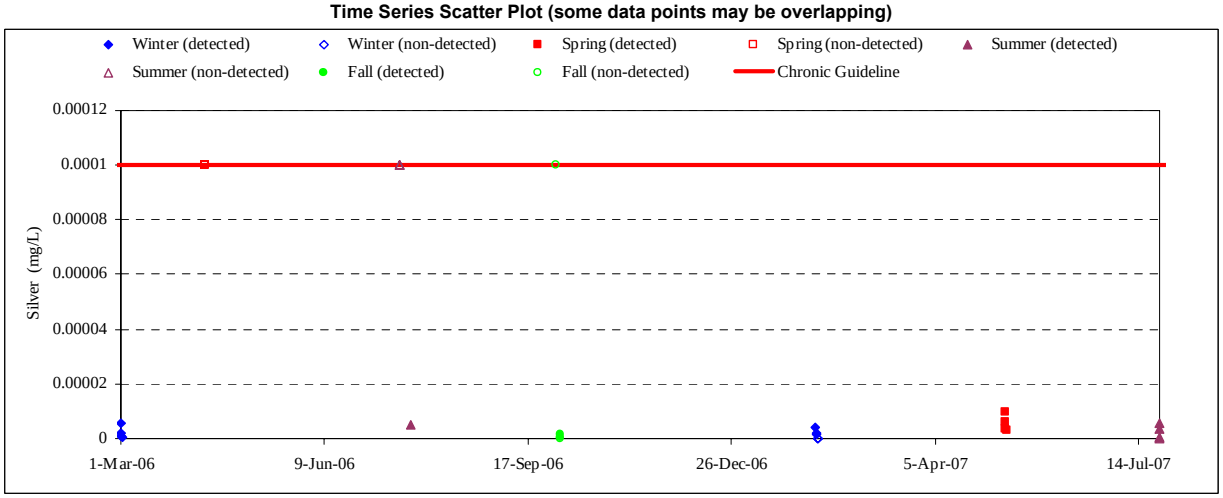
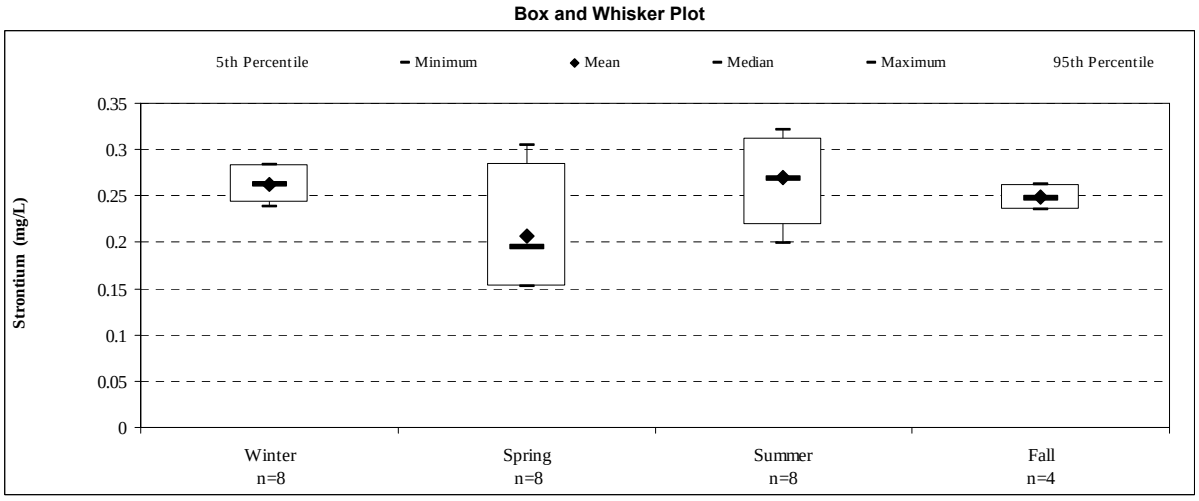


Figure G-3-4-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Redclay Creek



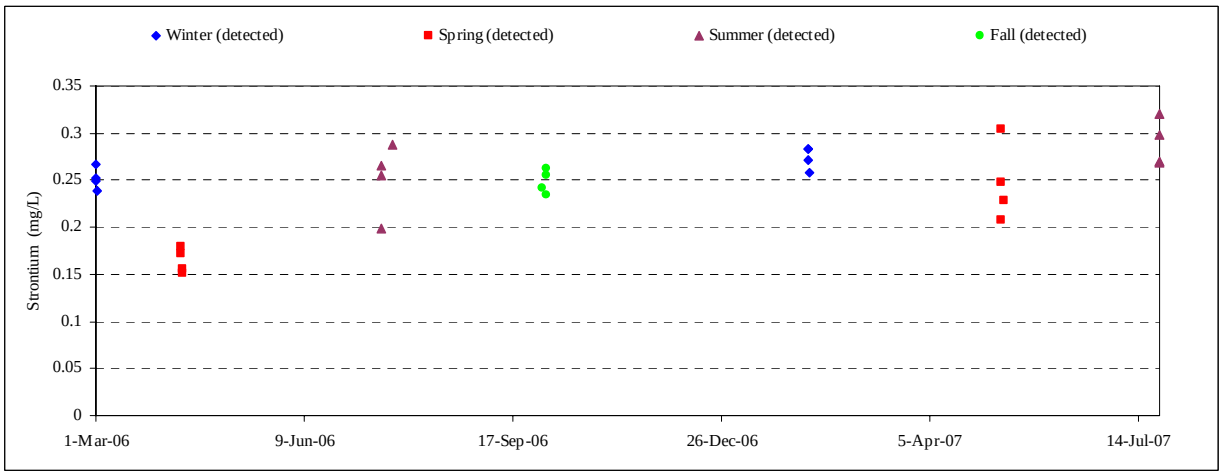
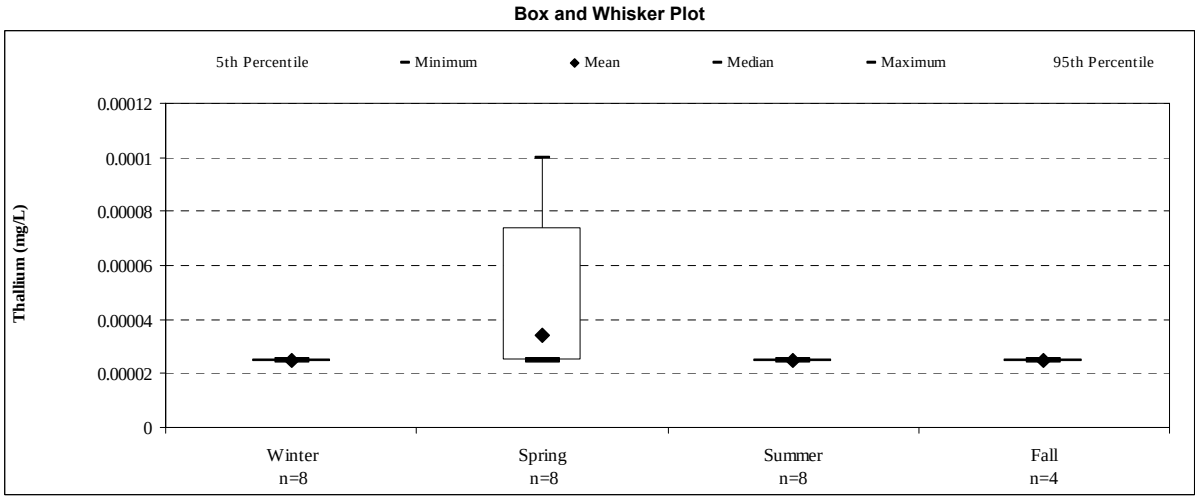


Figure G-3-4-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Redclay Creek



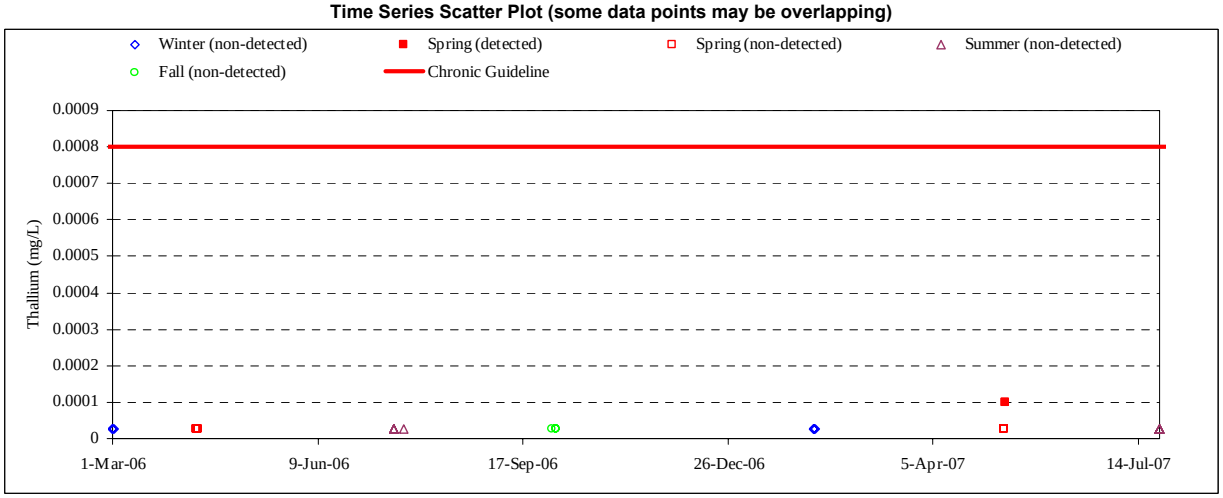
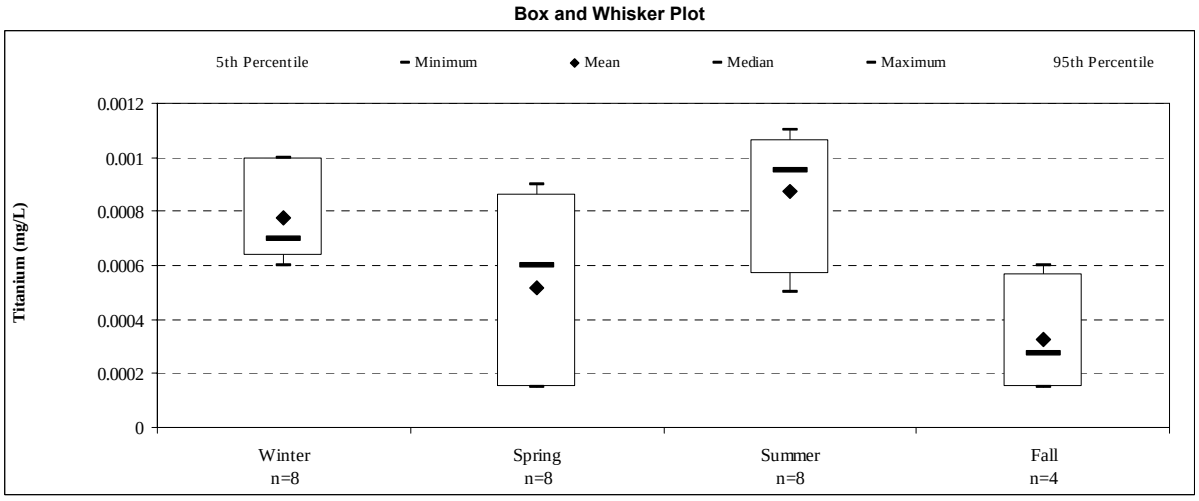


Figure G-3-4-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Redclay Creek



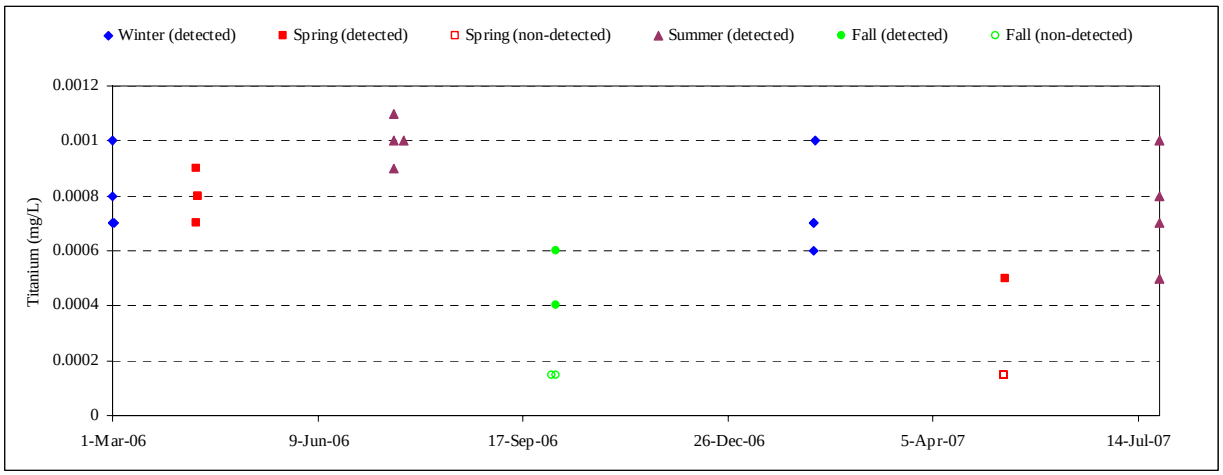
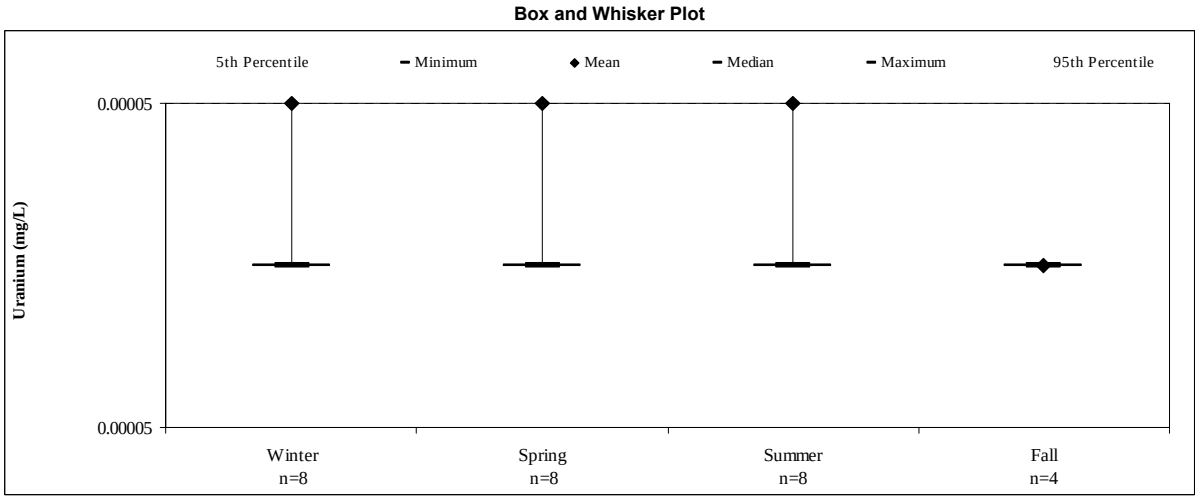


Figure G-3-4-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Redclay Creek



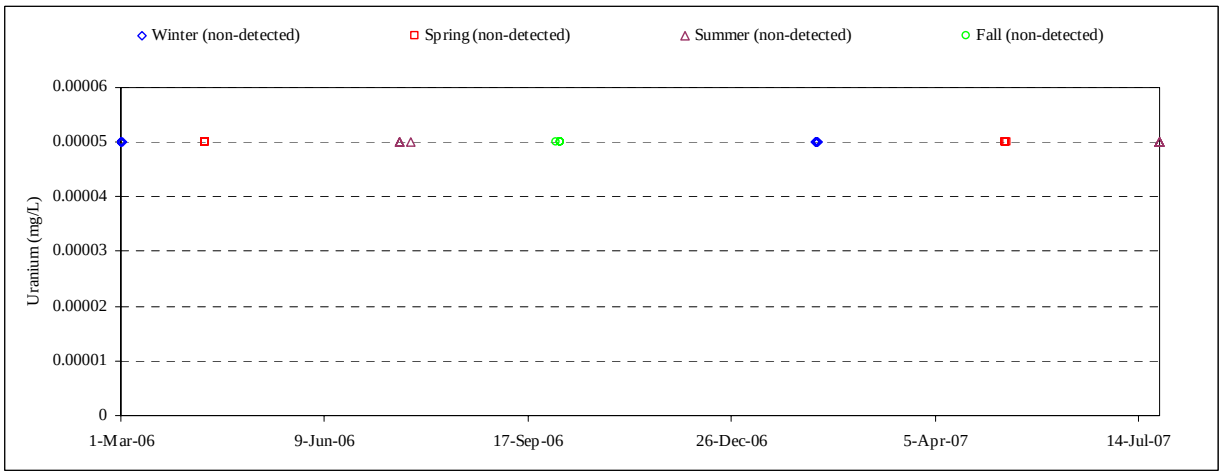
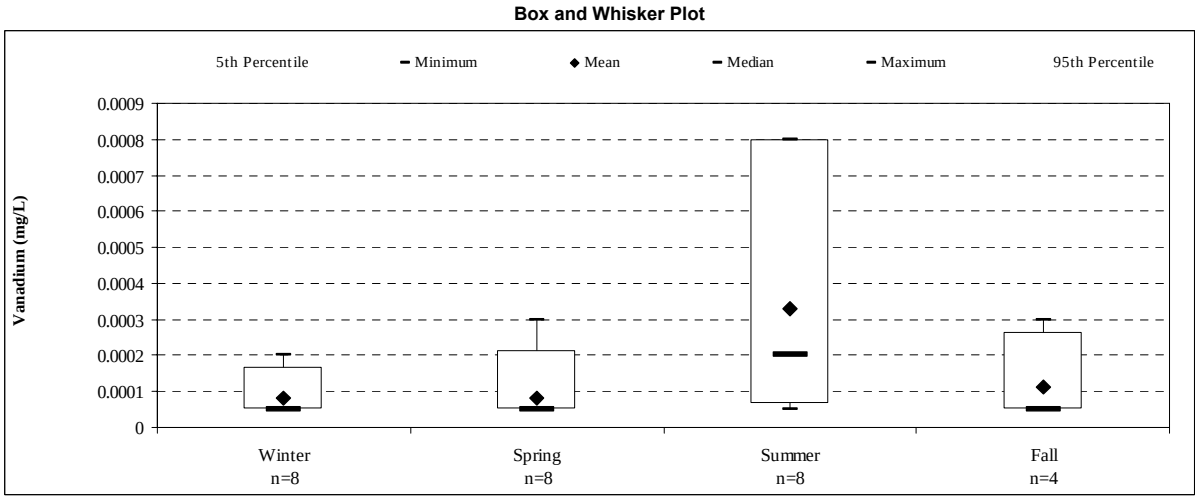


Figure G-3-4-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Redclay Creek



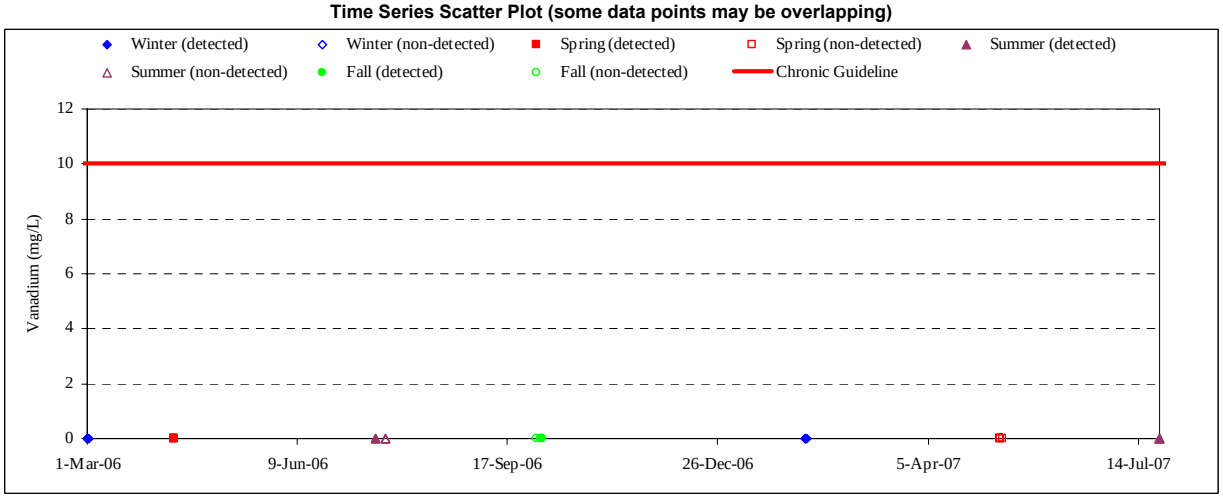
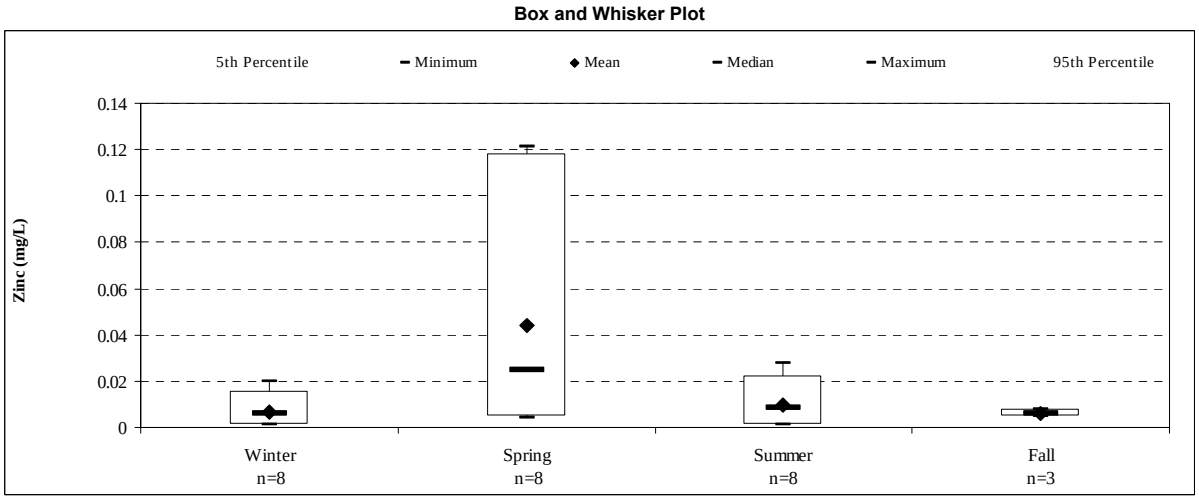


Figure G-3-4-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Redclay Creek



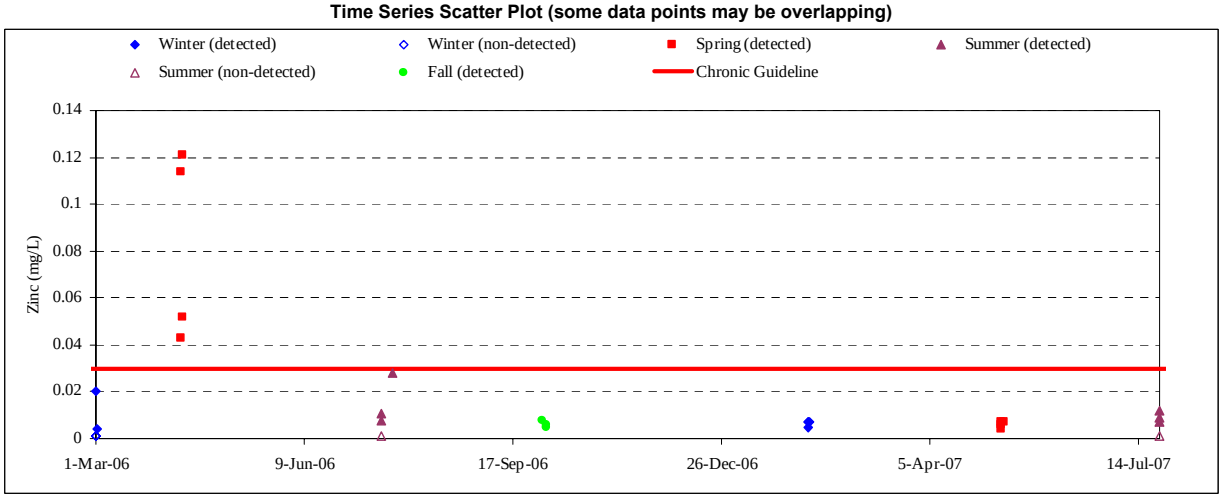
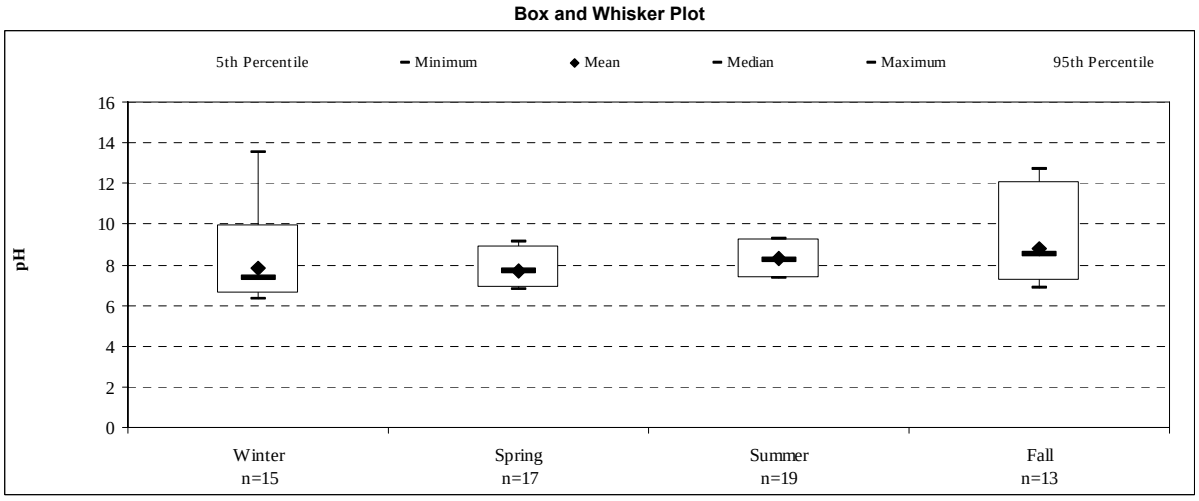


Figure G-3-5-1 Box Whisker and Time Series Scatter Plots of Observed pH in Unnamed Lakes within PRMA



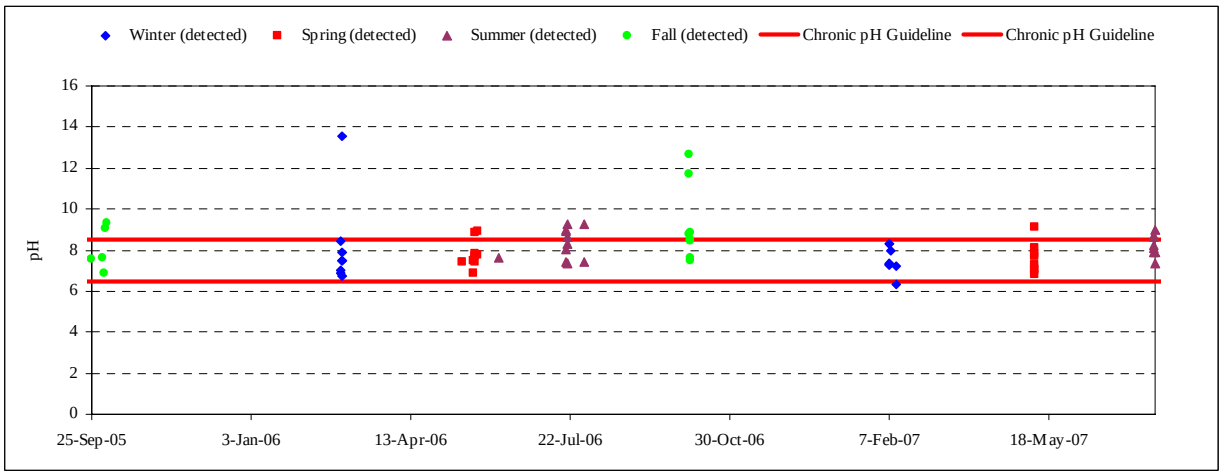
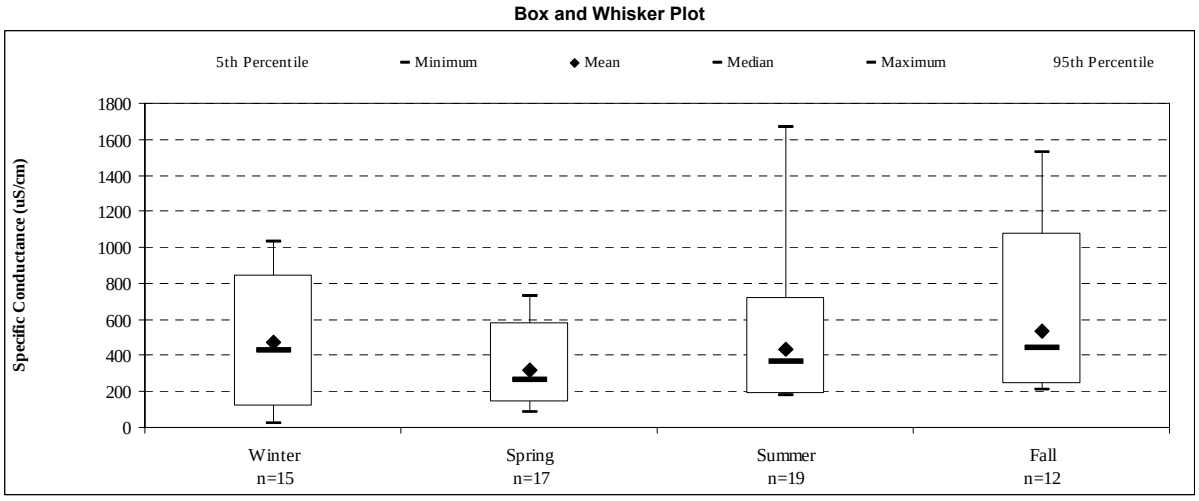


Figure G-3-5-2 Box Whisker and Time Series Scatter Plots of Observed Specific Conductance in Unnamed Lakes within PRMA



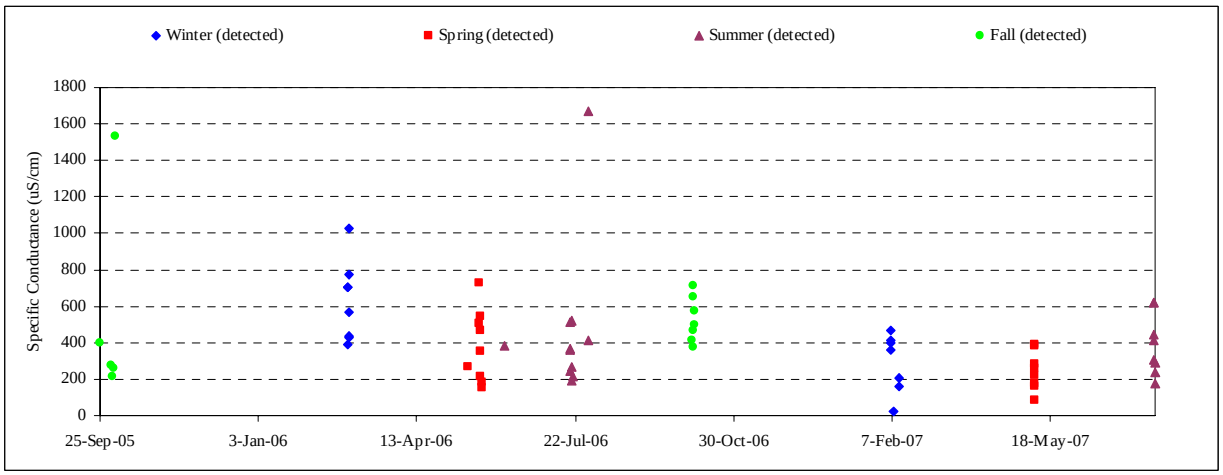
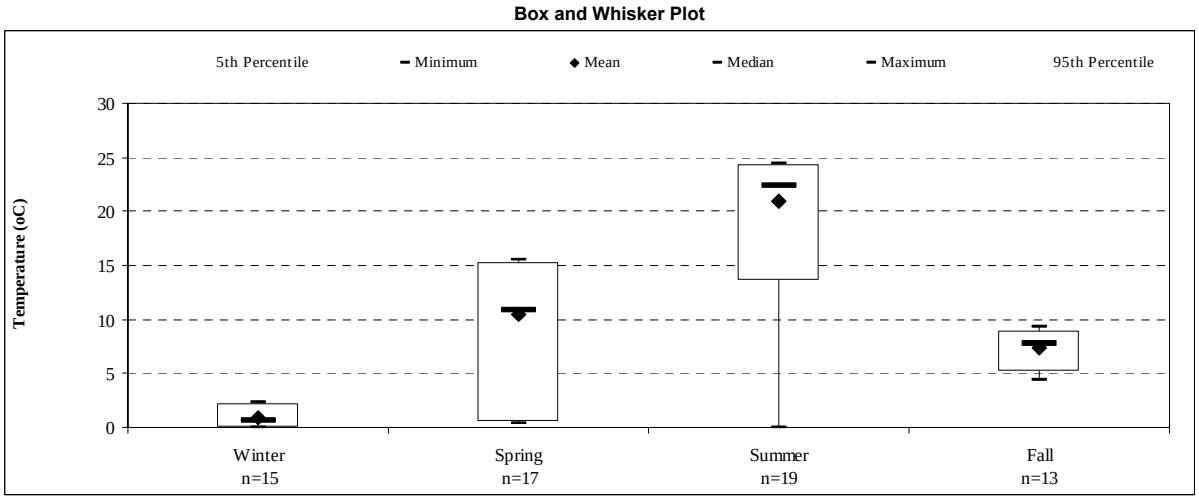


Figure G-3-5-3 Box Whisker and Time Series Scatter Plots of Observed Temperature in Unnamed Lakes within PRMA



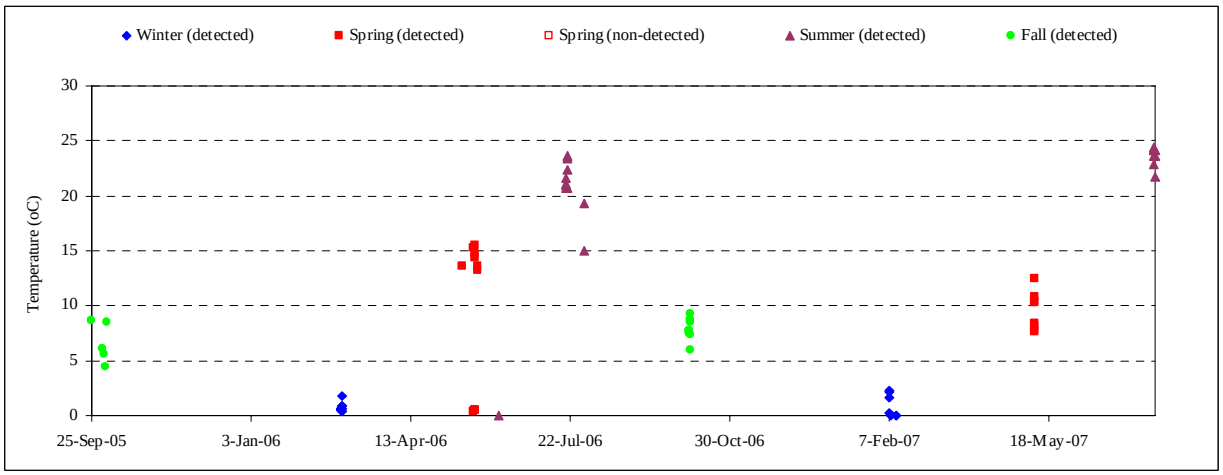
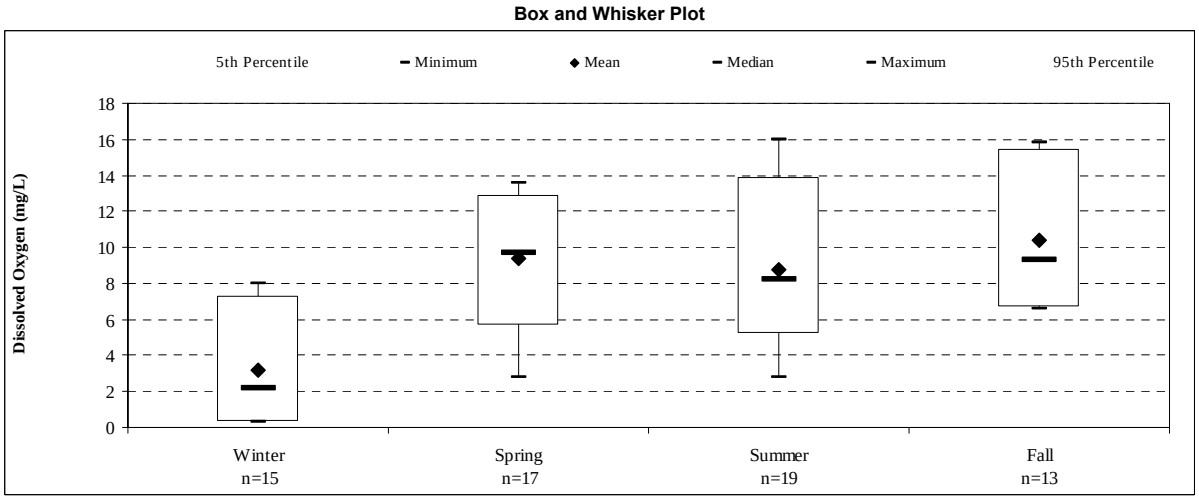


Figure G-3-5-4 Box Whisker and Time Series Scatter Plots of Observed Dissolved Oxygen Concentration in Unnamed Lakes within PRMA



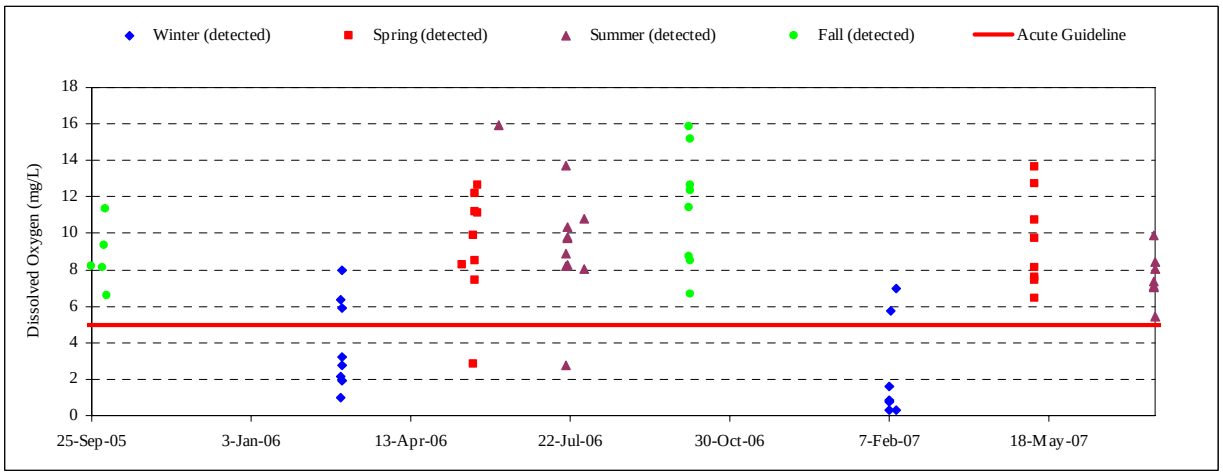
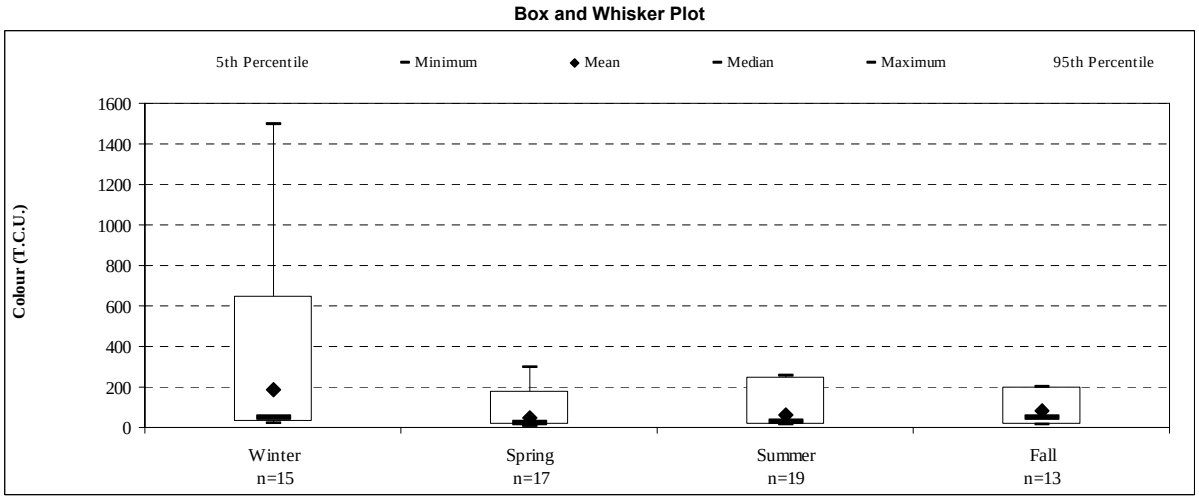


Figure G-3-5-5 Box Whisker and Time Series Scatter Plots of Observed Colour in Unnamed Lakes within PRMA



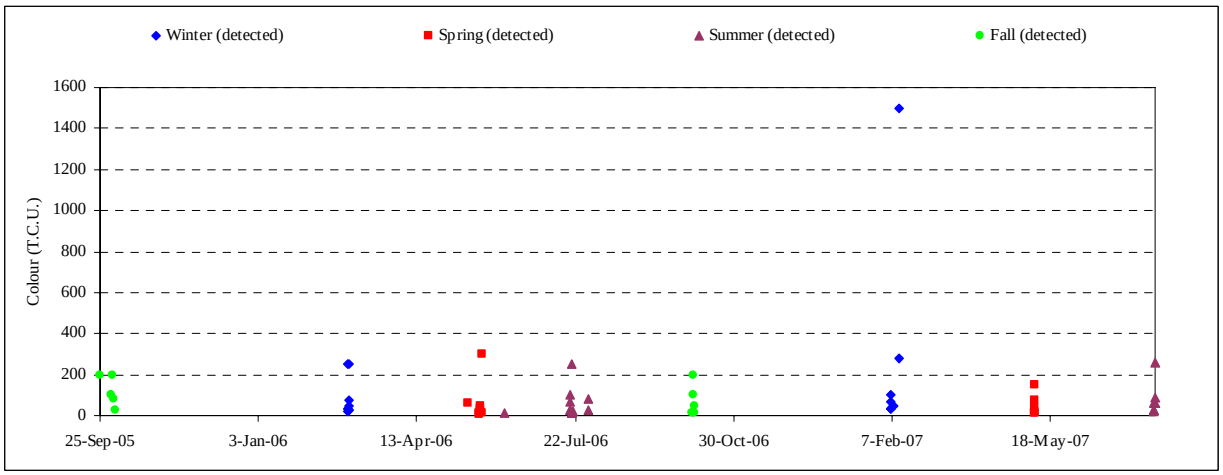
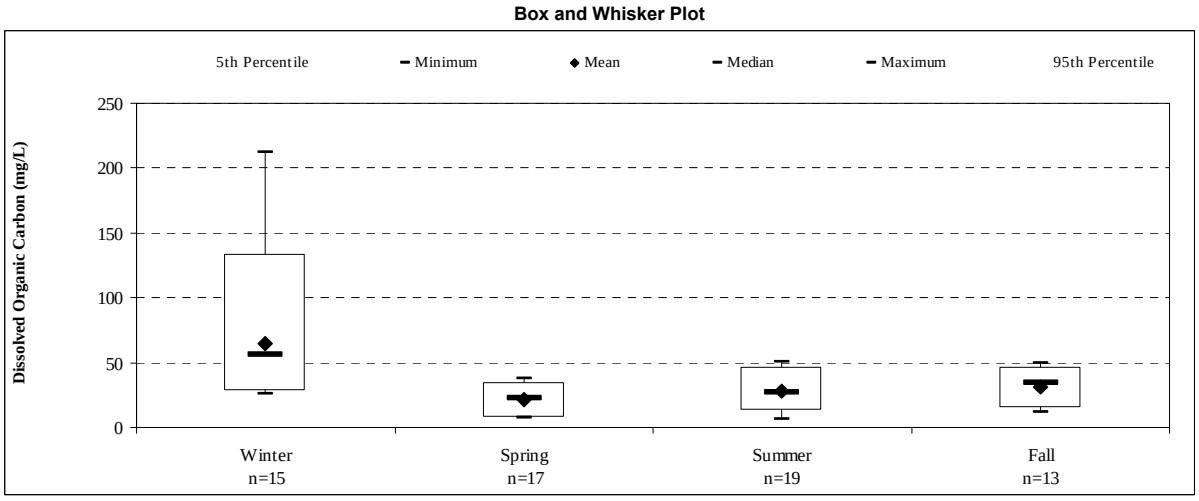


Figure G-3-5-6 Box Whisker and Time Series Scatter Plots of Observed Dissolved Organic Carbon in Unnamed Lakes within PRMA



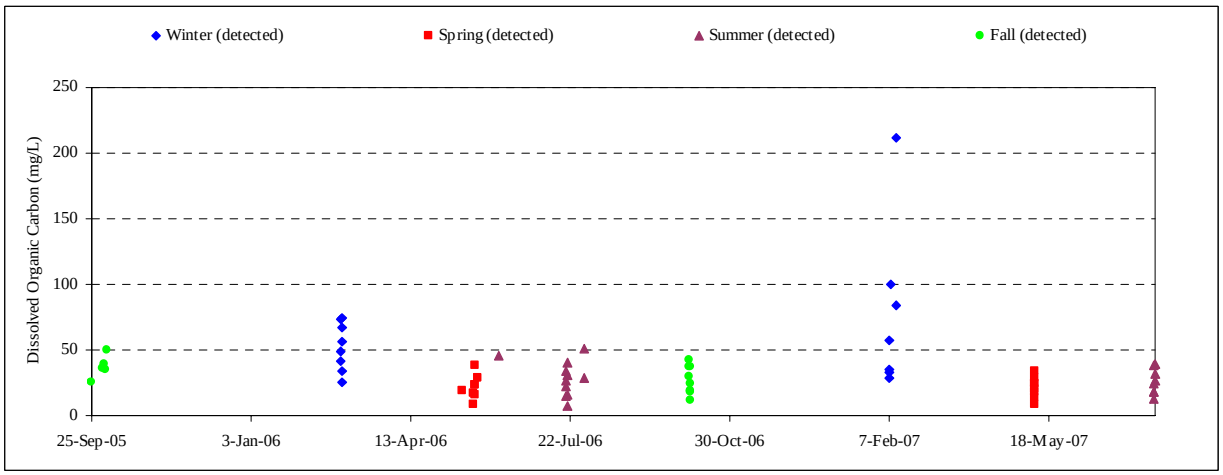
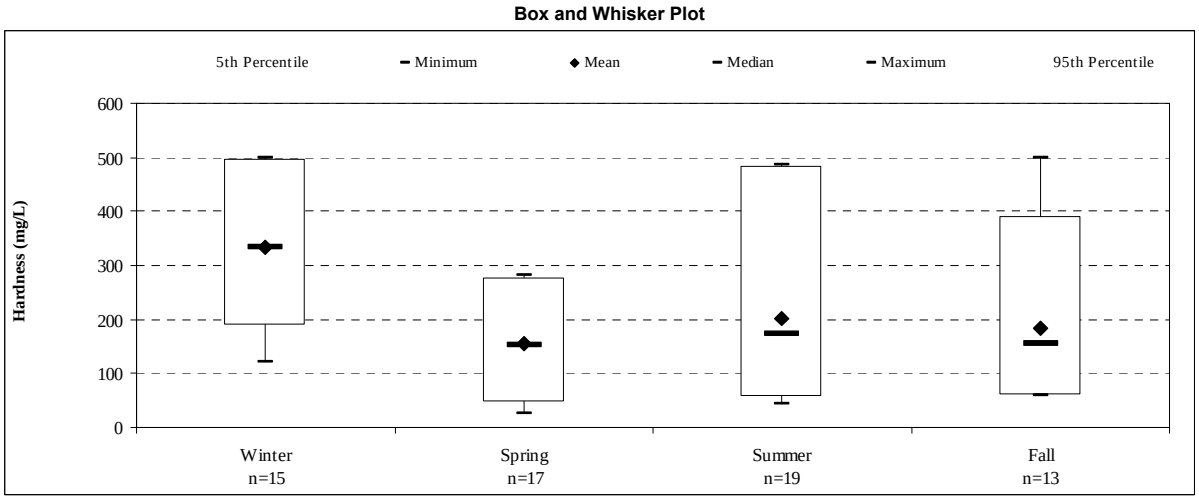


Figure G-3-5-7 Box Whisker and Time Series Scatter Plots of Observed Hardness in Unnamed Lakes within PRMA



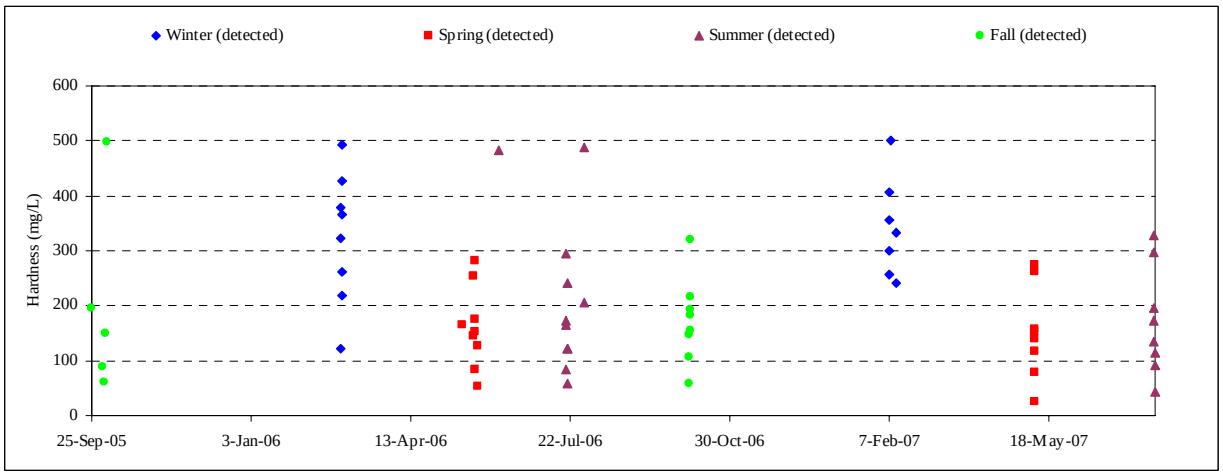
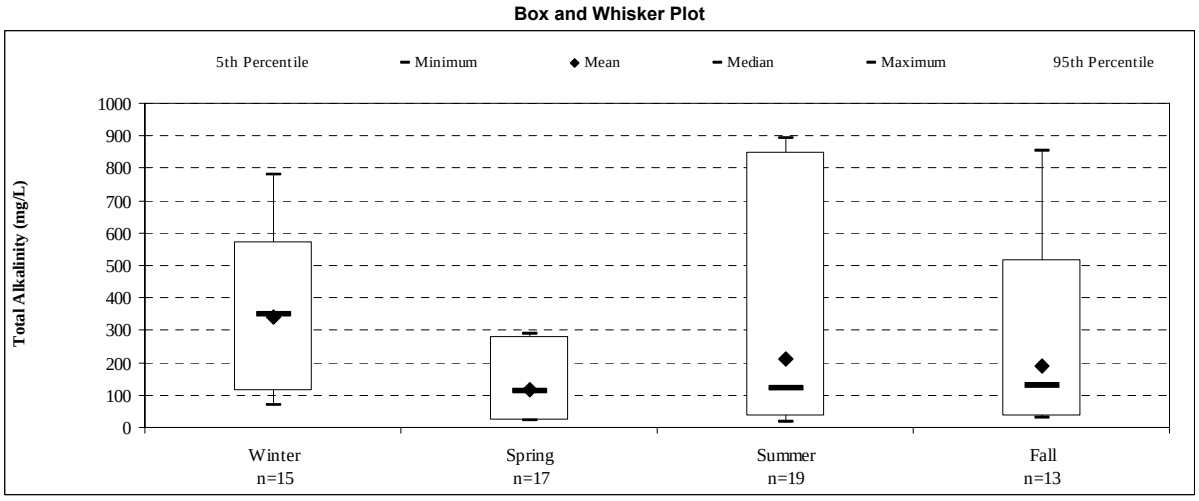


Figure G-3-5-8 Box Whisker and Time Series Scatter Plots of Observed Total Alkalinity in Unnamed Lakes within PRMA



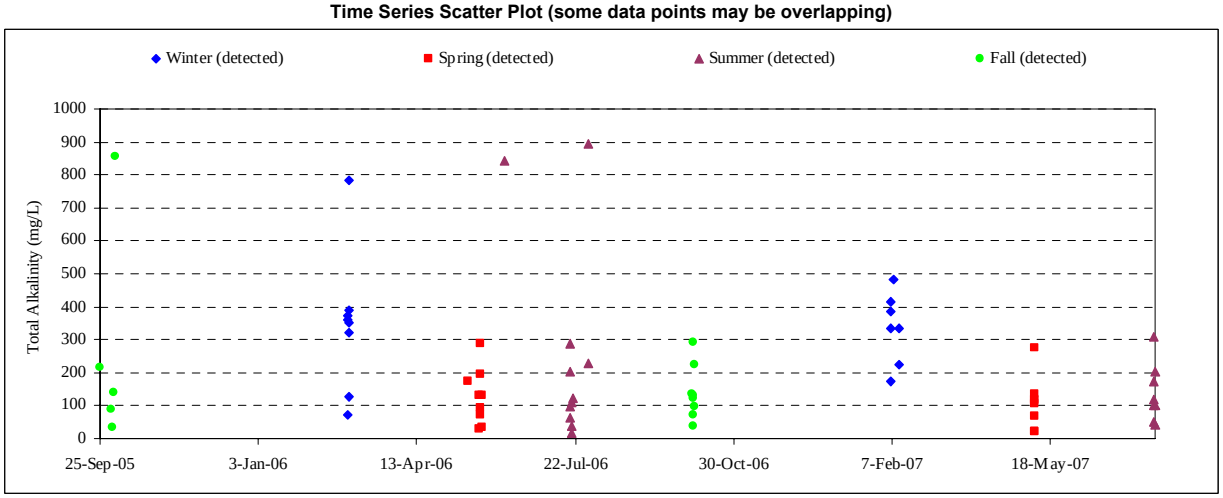
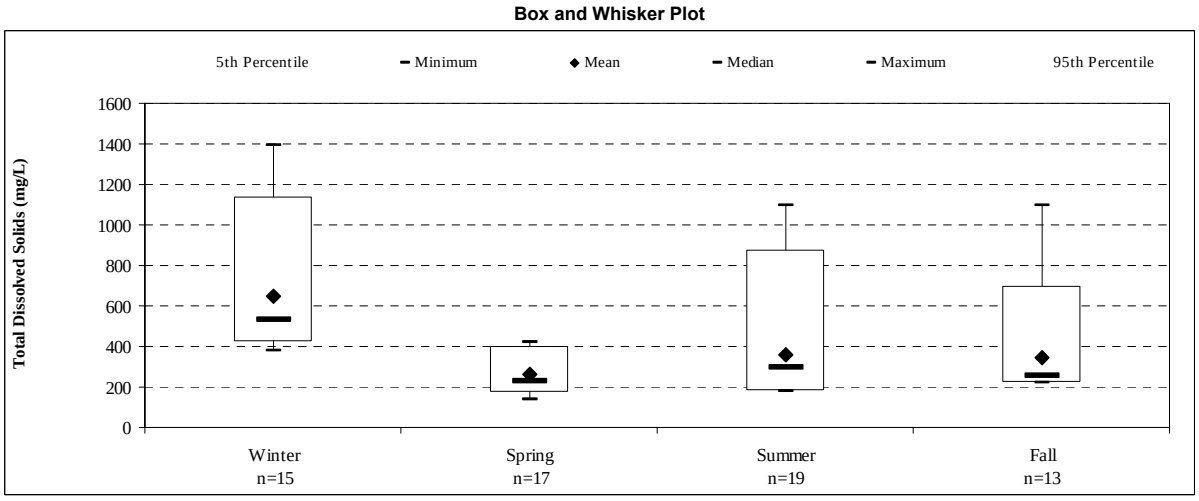


Figure G-3-5-9 Box Whisker and Time Series Scatter Plots of Observed Total Dissolved Solids in Unnamed Lakes within PRMA



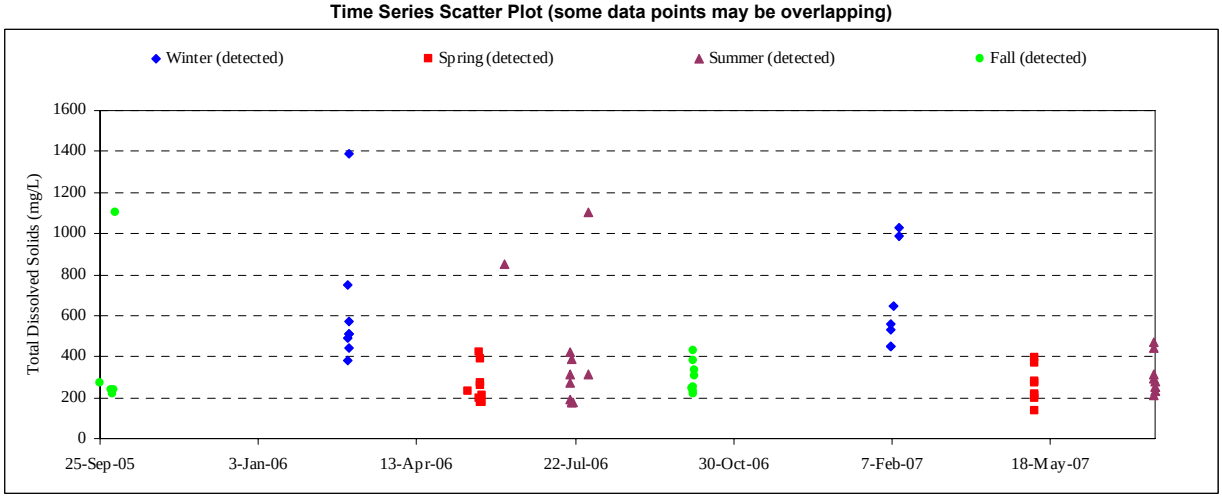
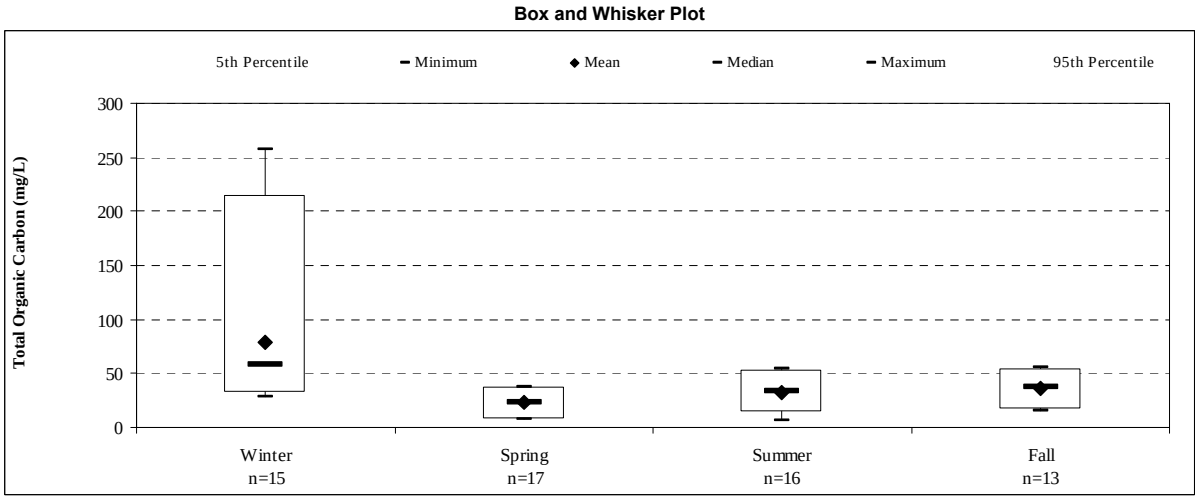


Figure G-3-5-10 Box Whisker and Time Series Scatter Plots of Observed Total Organic Carbon in Unnamed Lakes within PRMA



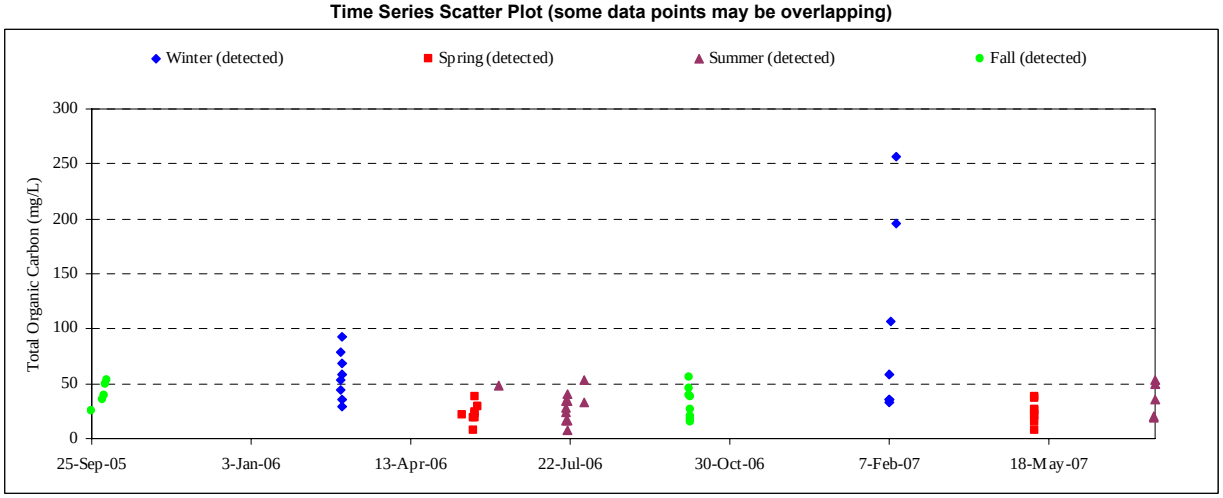
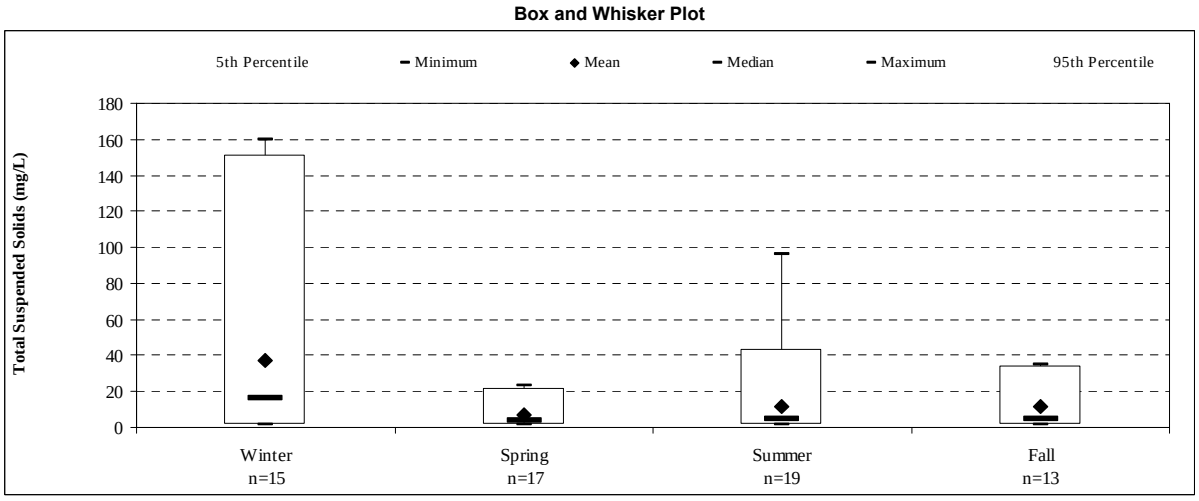


Figure G-3-5-11 Box Whisker and Time Series Scatter Plots of Observed Total Suspended Solids in Unnamed Lakes within PRMA



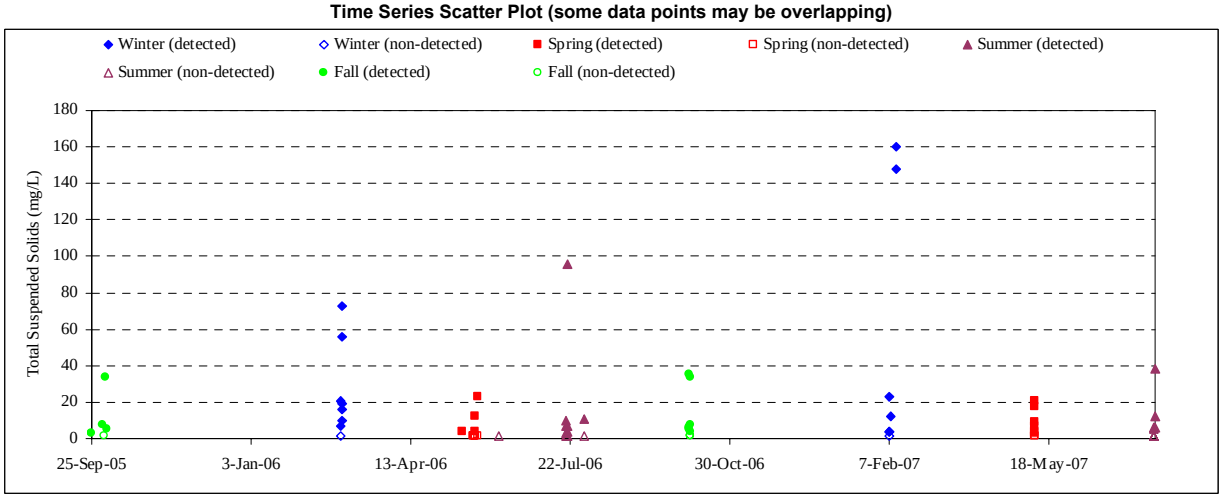
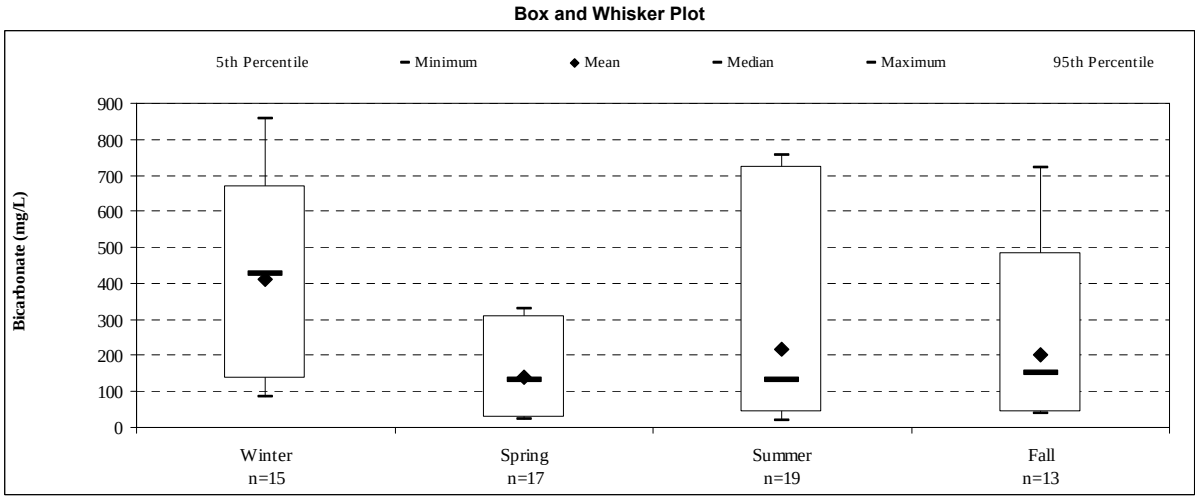


Figure G-3-5-12 Box Whisker and Time Series Scatter Plots of Observed Bicarbonate Concentration in Unnamed Lakes within PRMA



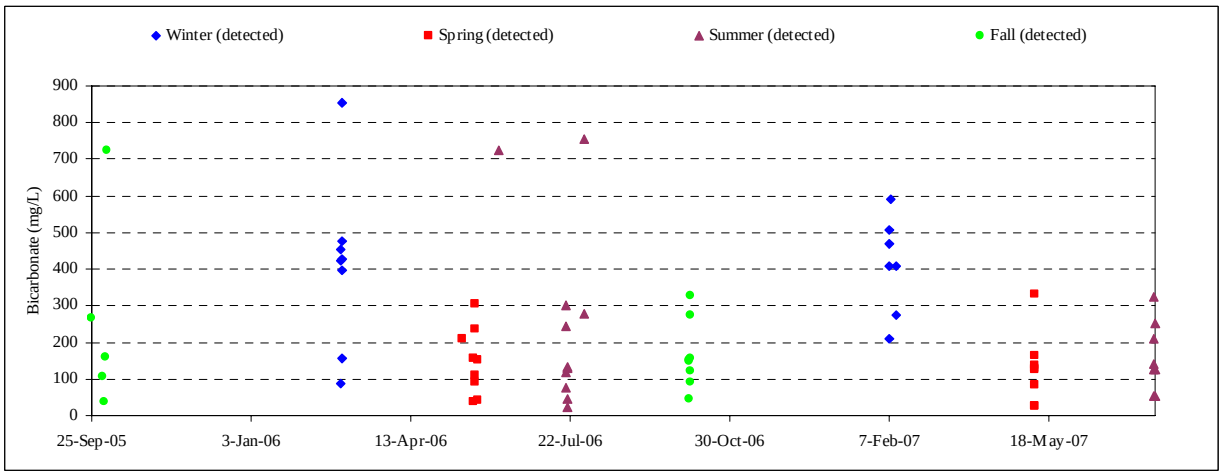
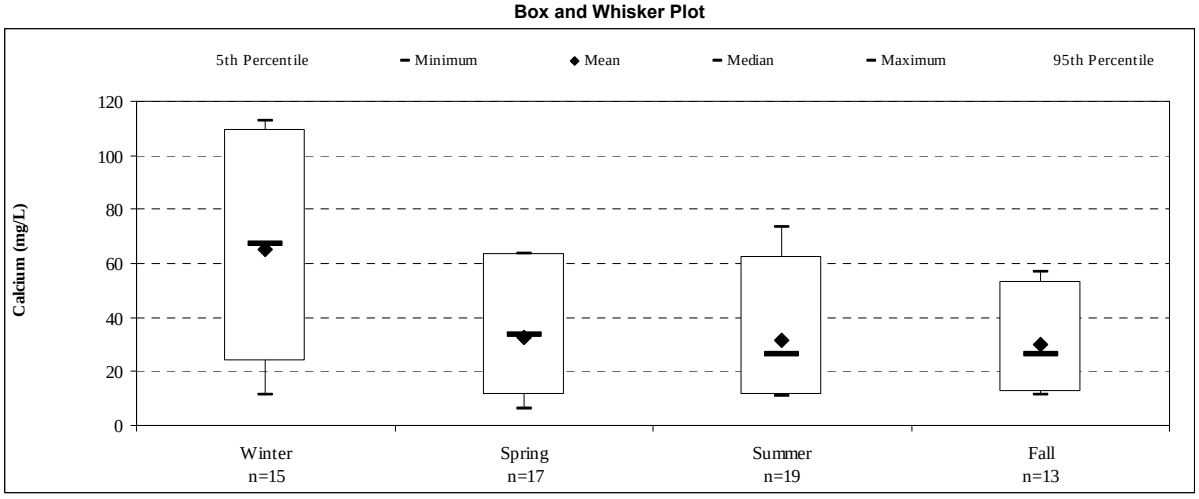


Figure G-3-5-13 Box Whisker and Time Series Scatter Plots of Observed Calcium Concentration in Unnamed Lakes within PRMA



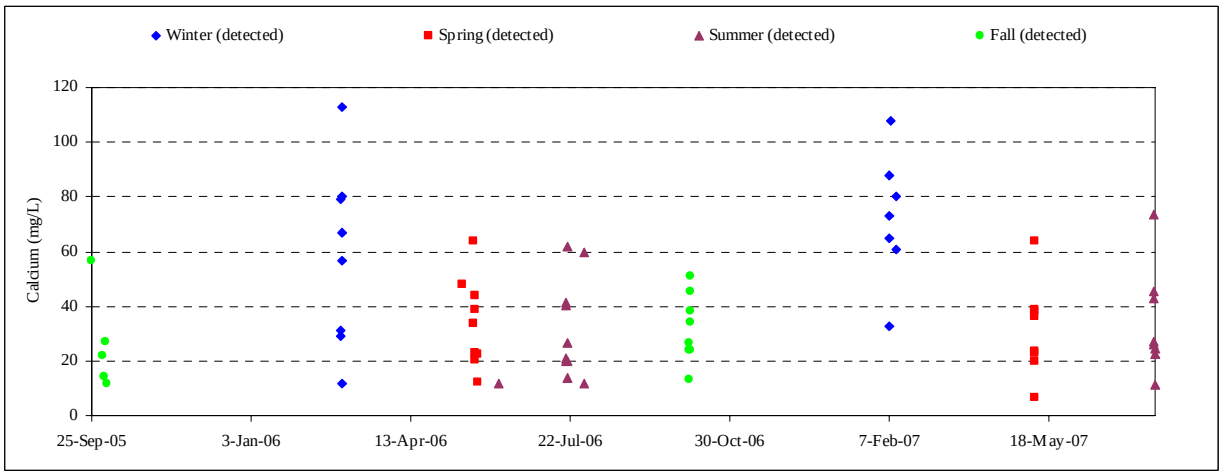
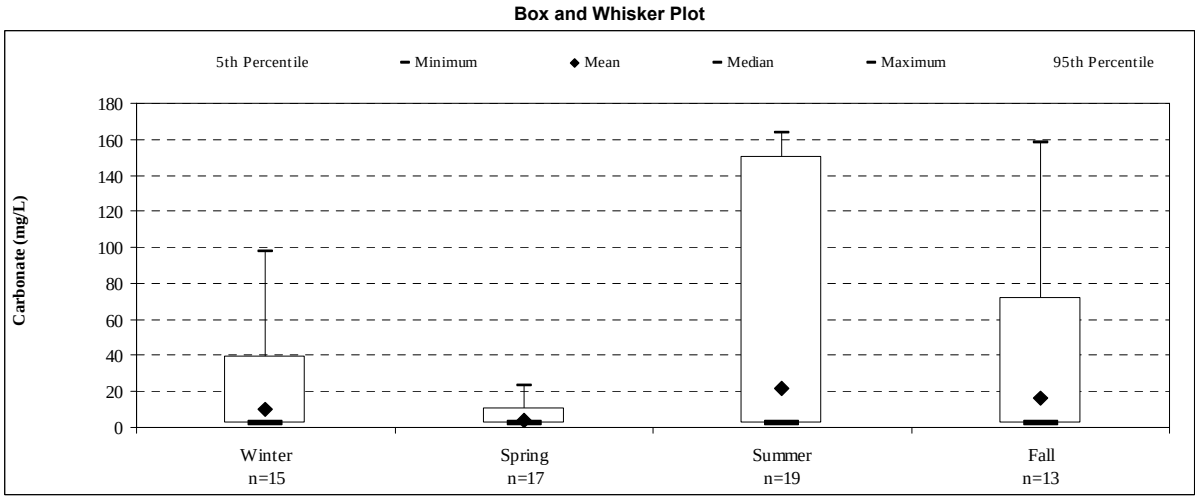


Figure G-3-5-14 Box Whisker and Time Series Scatter Plots of Observed Carbonate Concentration in Unnamed Lakes within PRMA



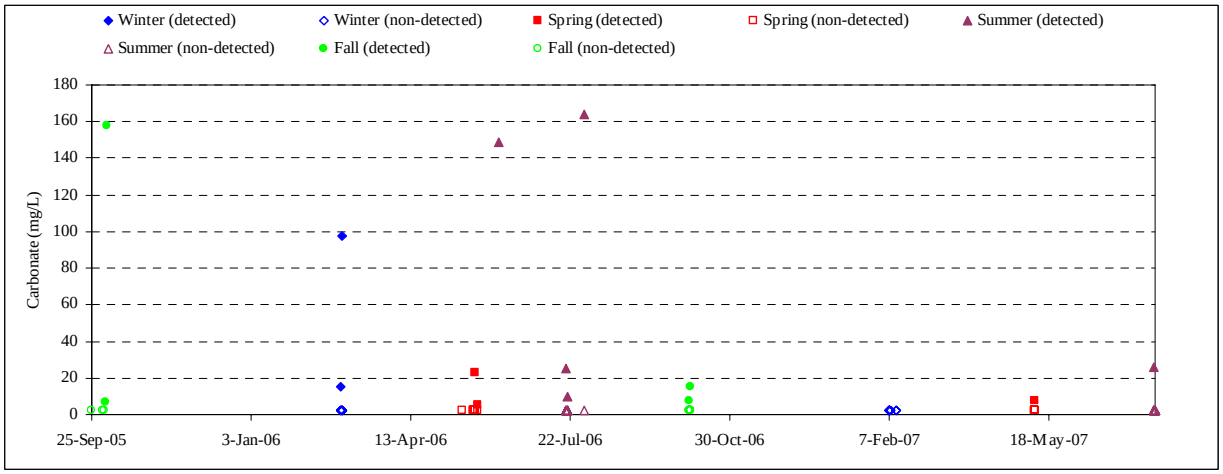
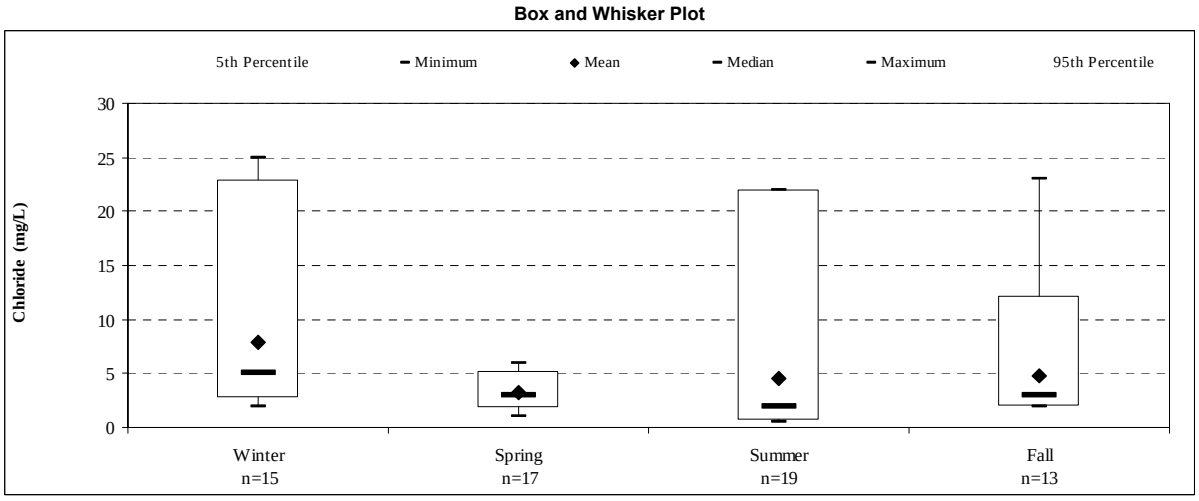


Figure G-3-5-15 Box Whisker and Time Series Scatter Plots of Observed Chloride Concentration in Unnamed Lakes within PRMA



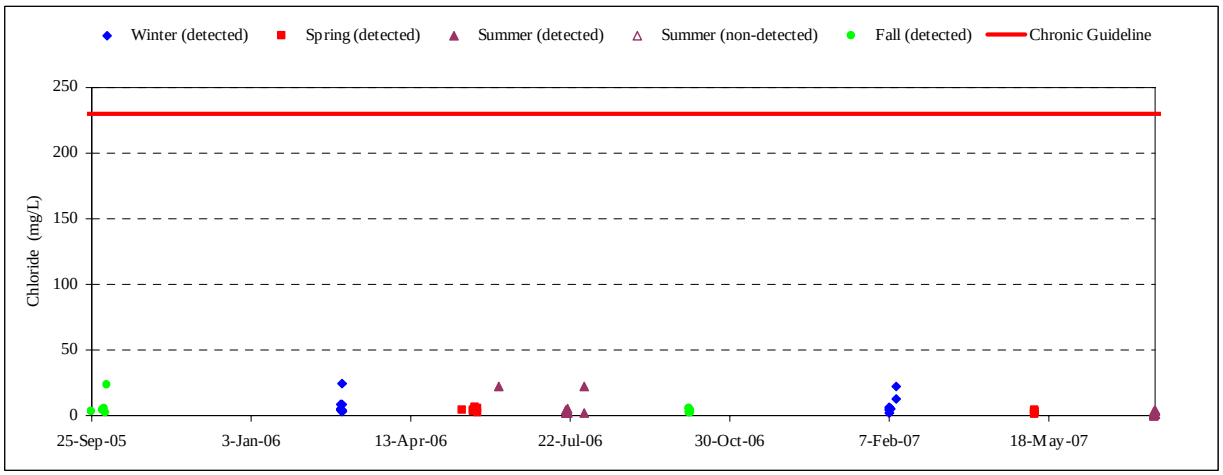
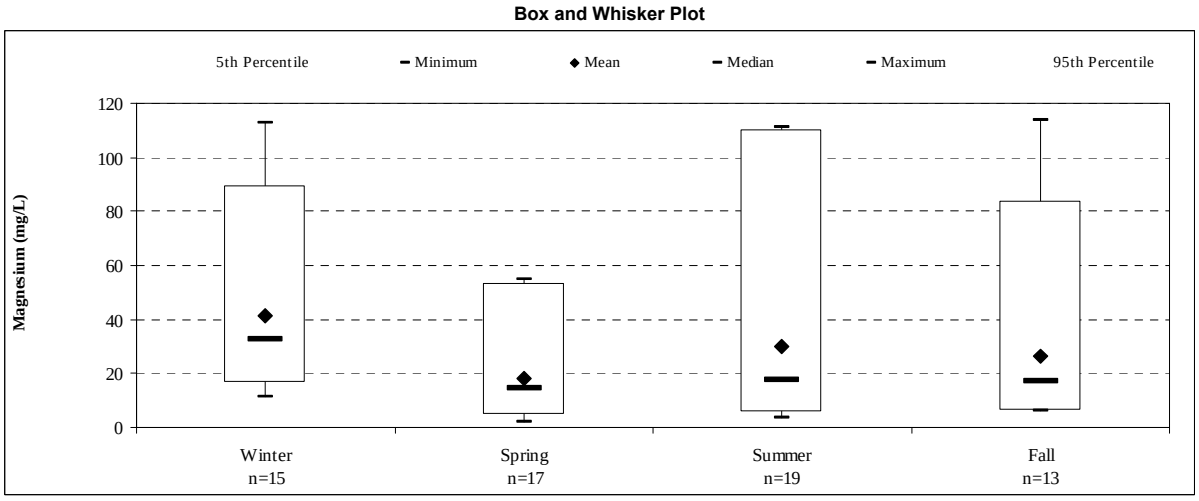


Figure G-3-5-16 Box Whisker and Time Series Scatter Plots of Observed Magnesium Concentration in Unnamed Lakes within PRMA



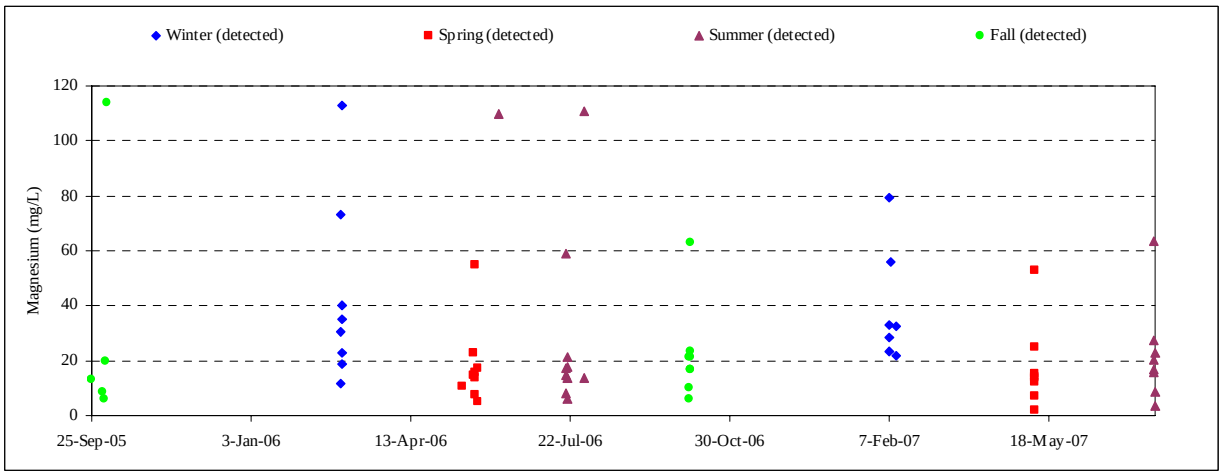
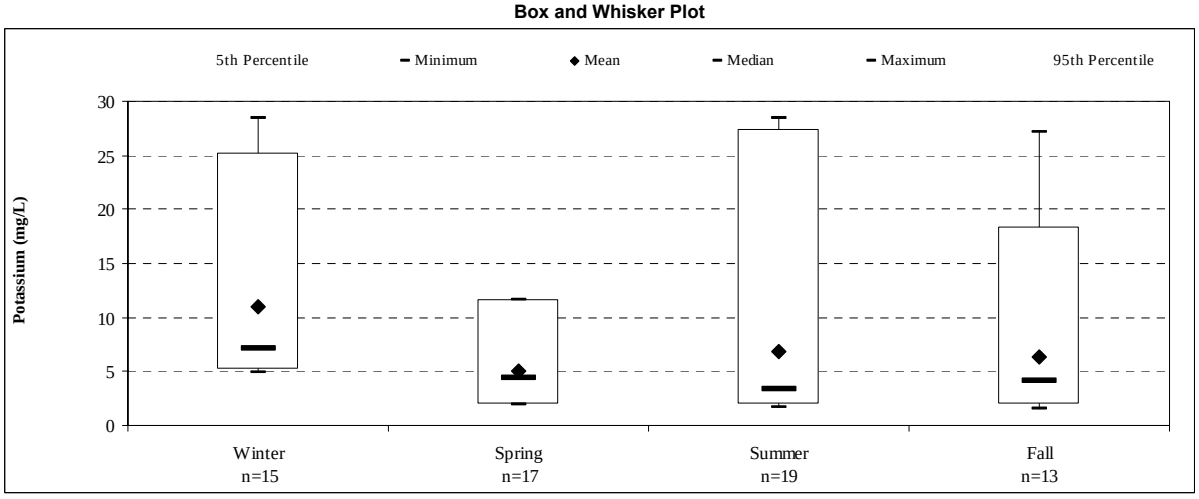


Figure G-3-5-17 Box Whisker and Time Series Scatter Plots of Observed Potassium Concentration in Unnamed Lakes within PRMA



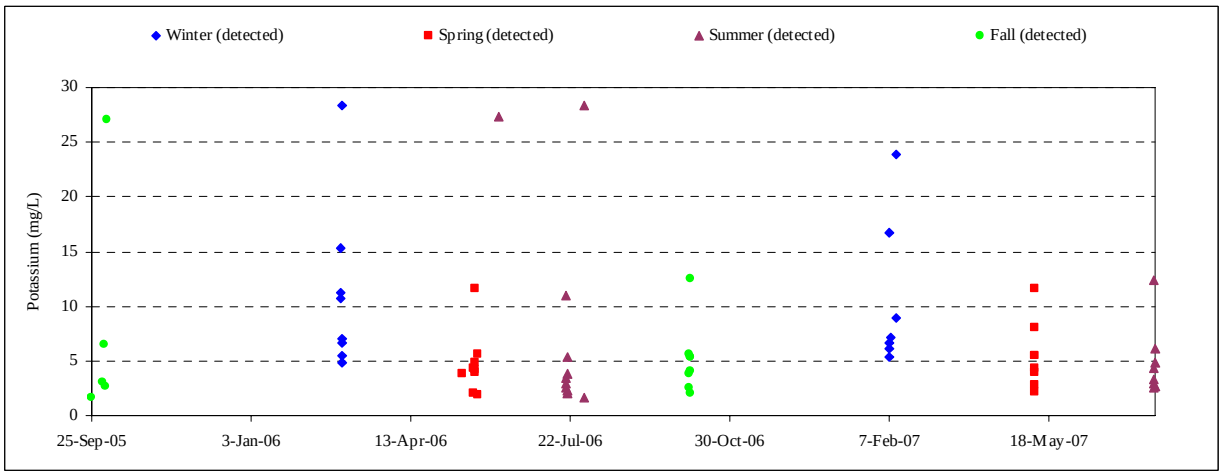
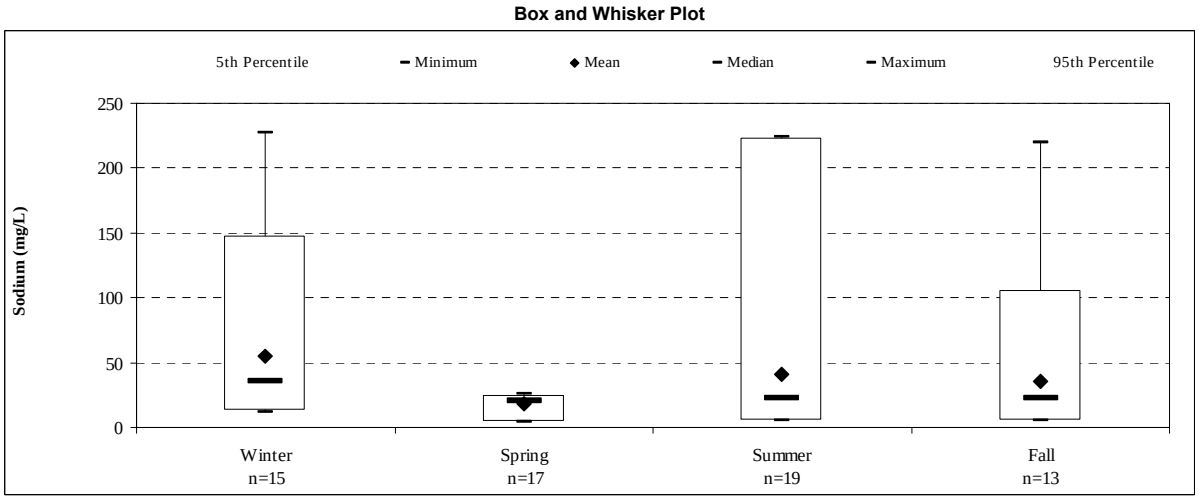


Figure G-3-5-18 Box Whisker and Time Series Scatter Plots of Observed Sodium Concentration in Unnamed Lakes within PRMA



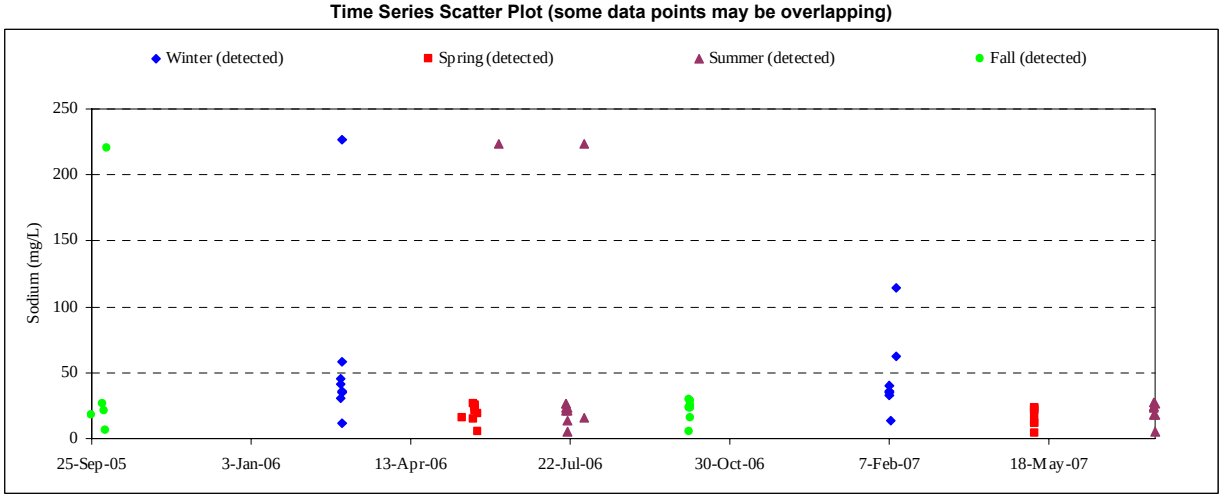
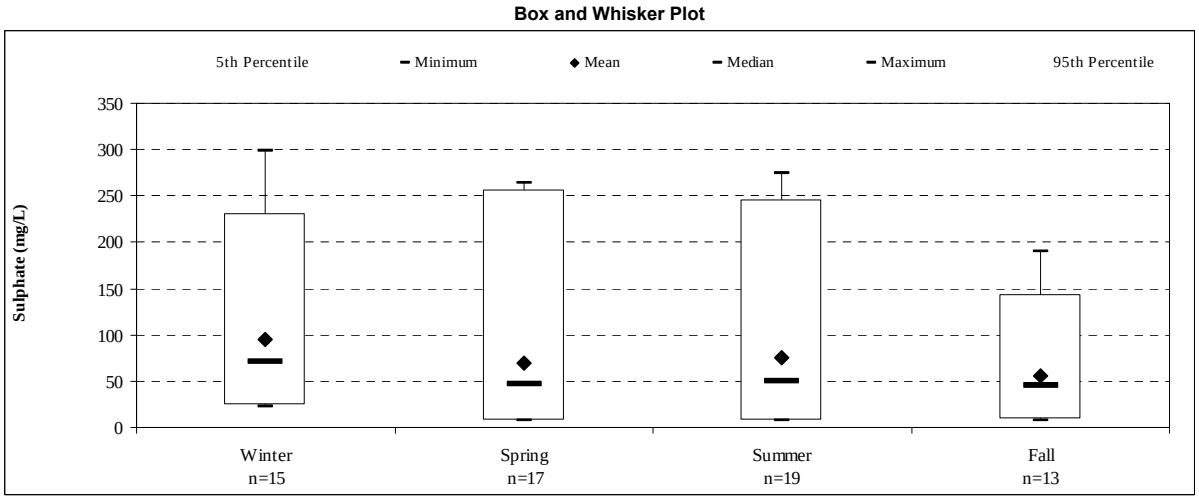


Figure G-3-5-19 Box Whisker and Time Series Scatter Plots of Observed Sulphate Concentration in Unnamed Lakes within PRMA



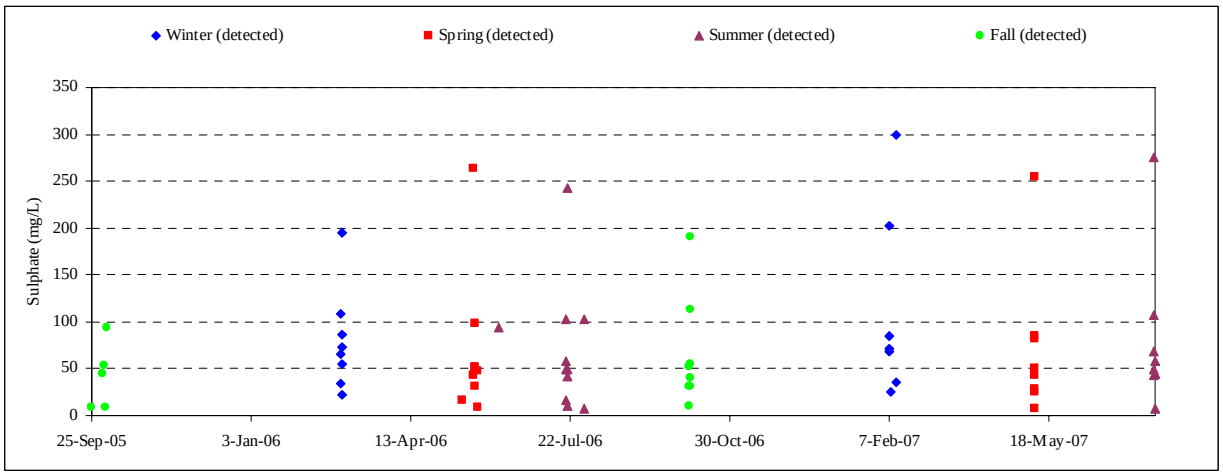
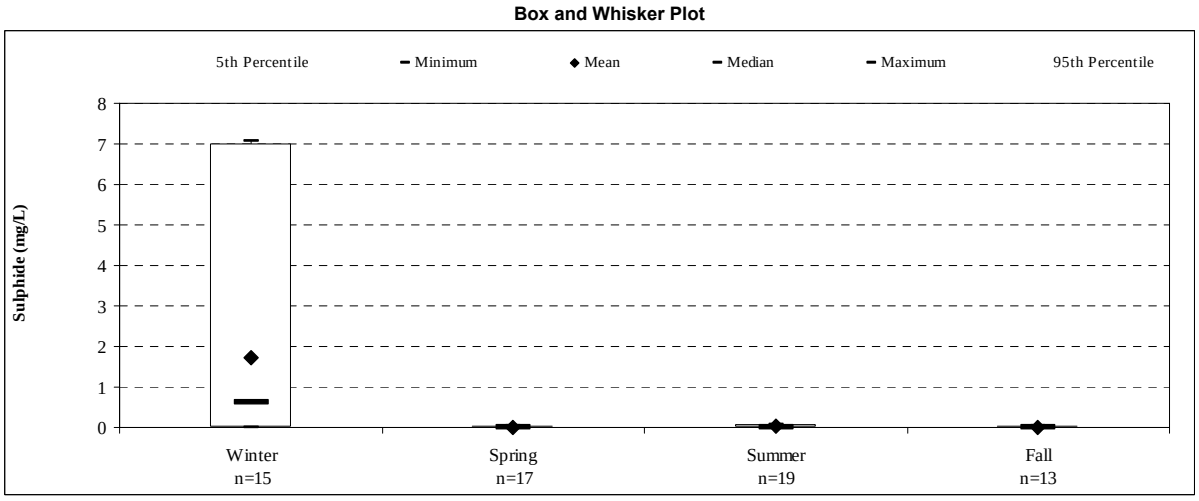


Figure G-3-5-20 Box Whisker and Time Series Scatter Plots of Observed Sulphide Concentration in Unnamed Lakes within PRMA



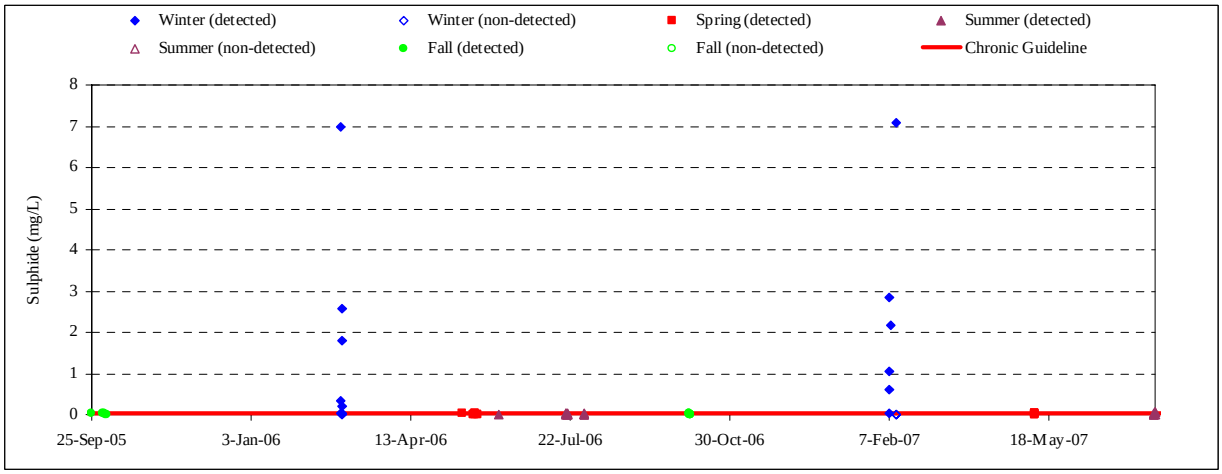
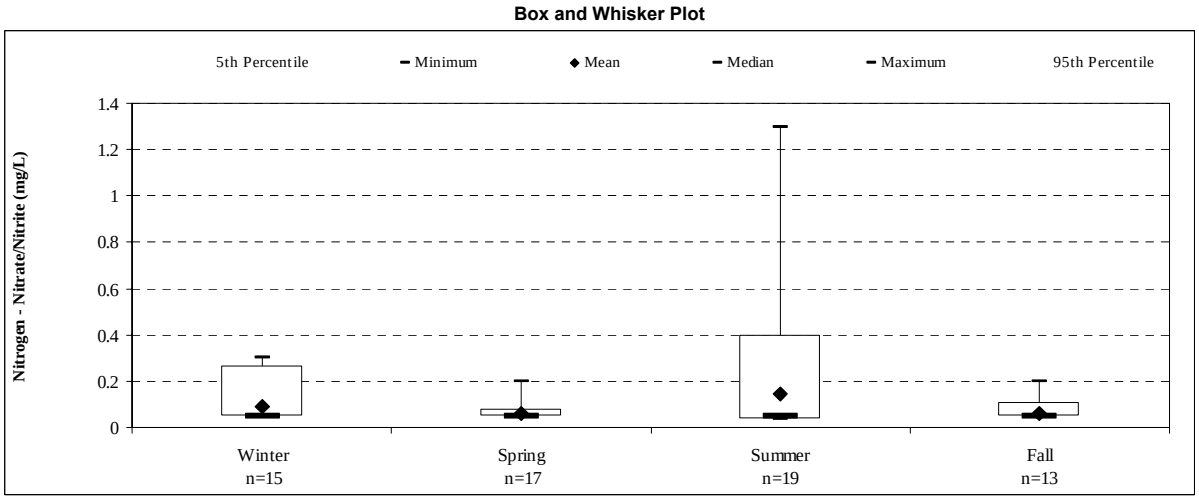


Figure G-3-5-21 Box Whisker and Time Series Scatter Plots of Observed Nitrate/Nitrite Concentration in Unnamed Lakes within PRMA



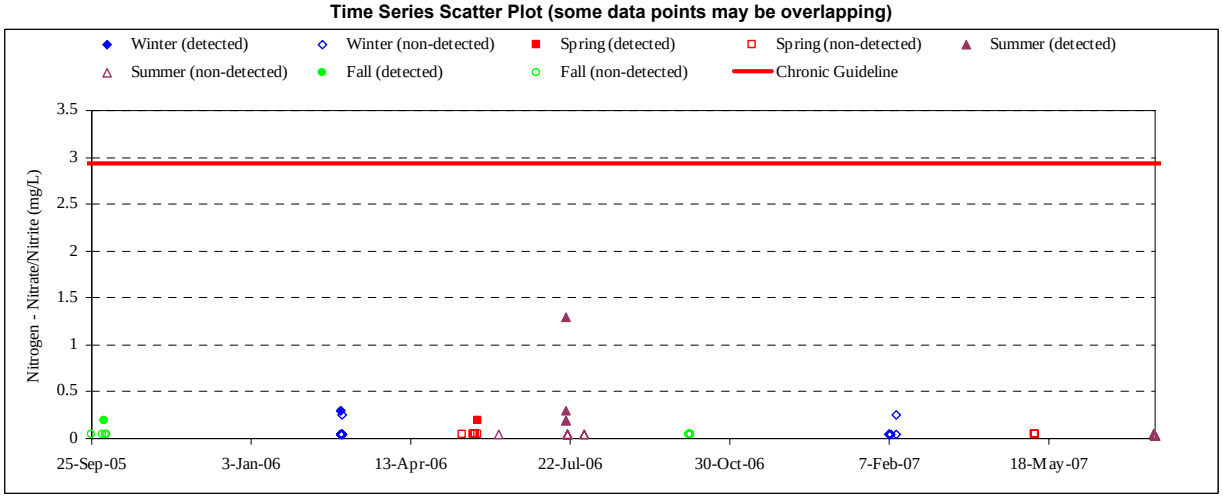
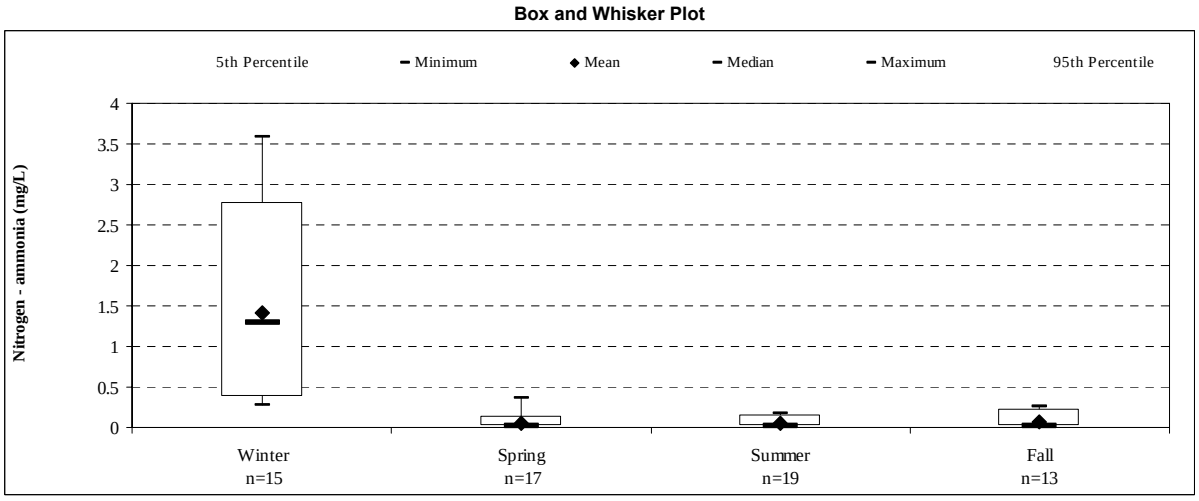


Figure G-3-5-22 Box Whisker and Time Series Scatter Plots of Observed Ammonia Concentration in Unnamed Lakes within PRMA



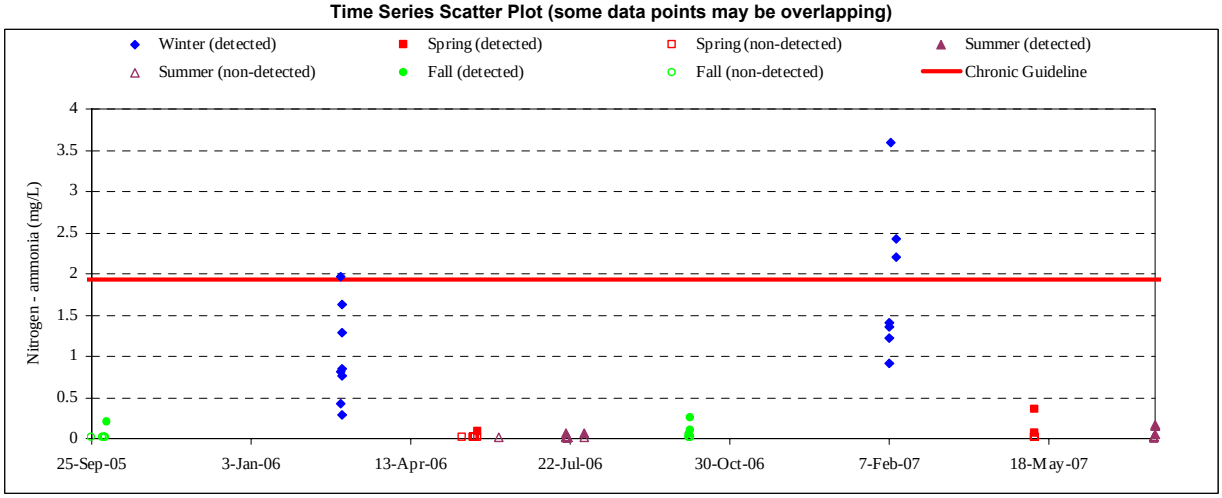
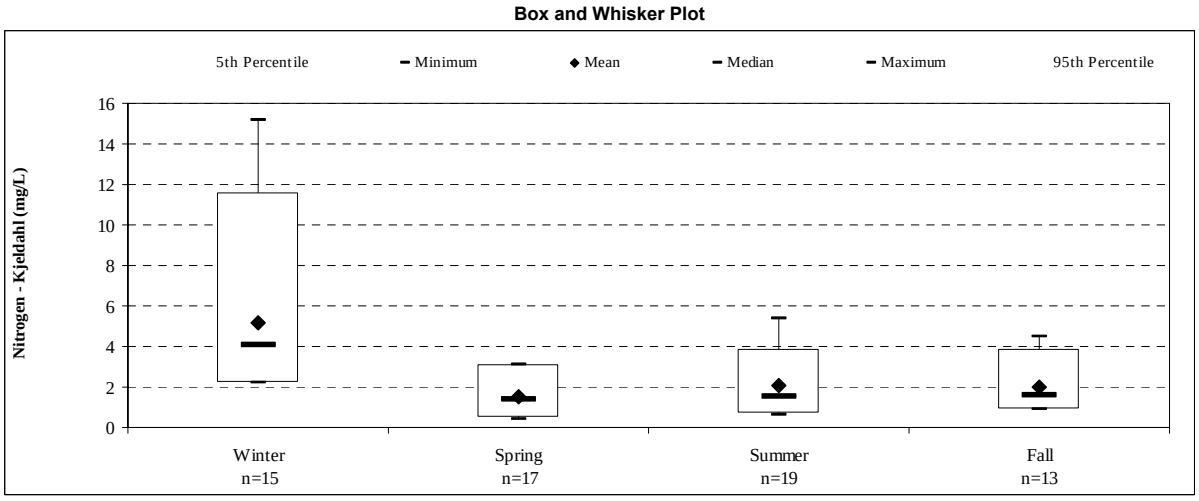


Figure G-3-5-23 Box Whisker and Time Series Scatter Plots of Observed Kjeldahl Nitrogen Concentration in Unnamed Lakes within PRMA



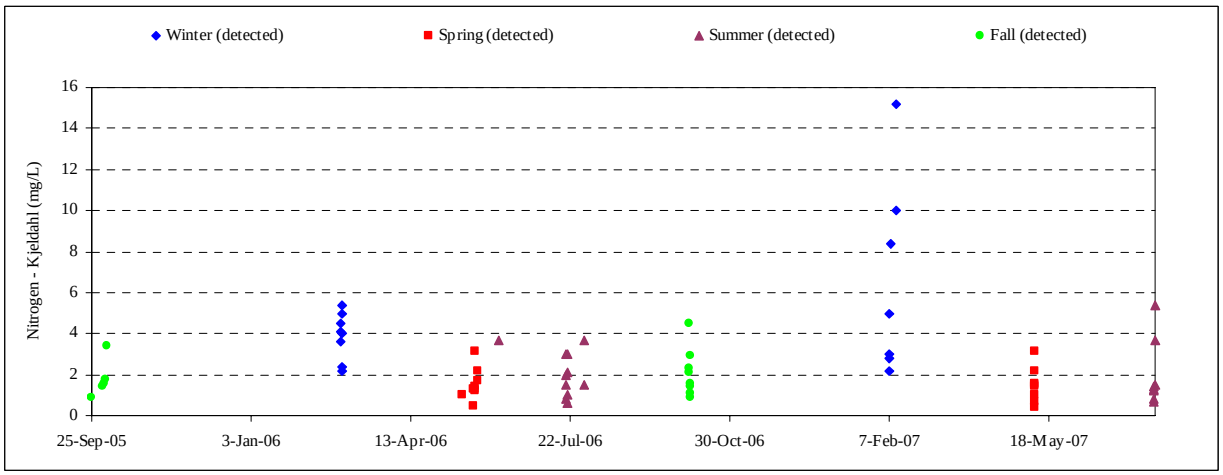
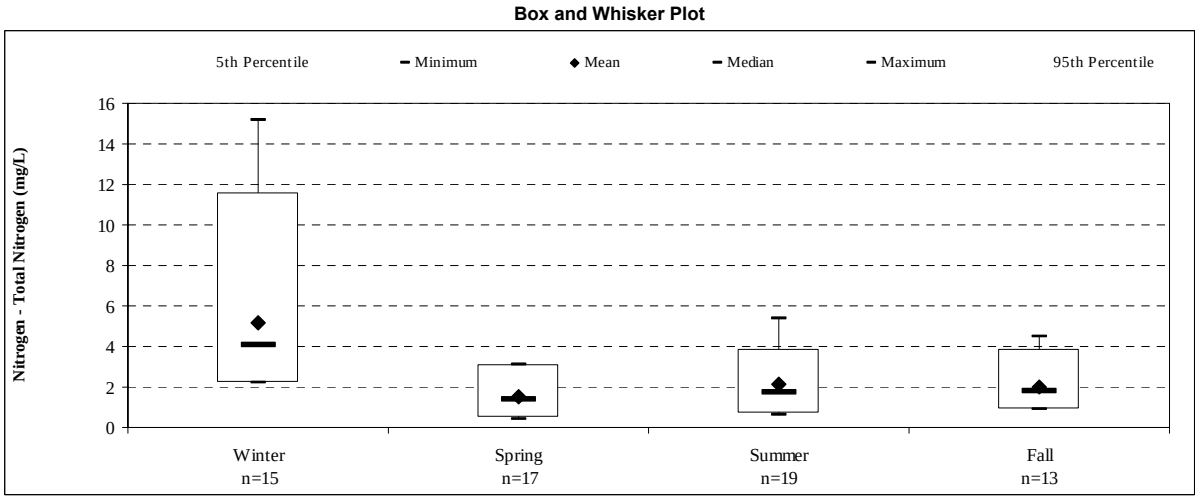


Figure G-3-5-24 Box Whisker and Time Series Scatter Plots of Observed Total Nitrogen Concentration in Unnamed Lakes within PRMA



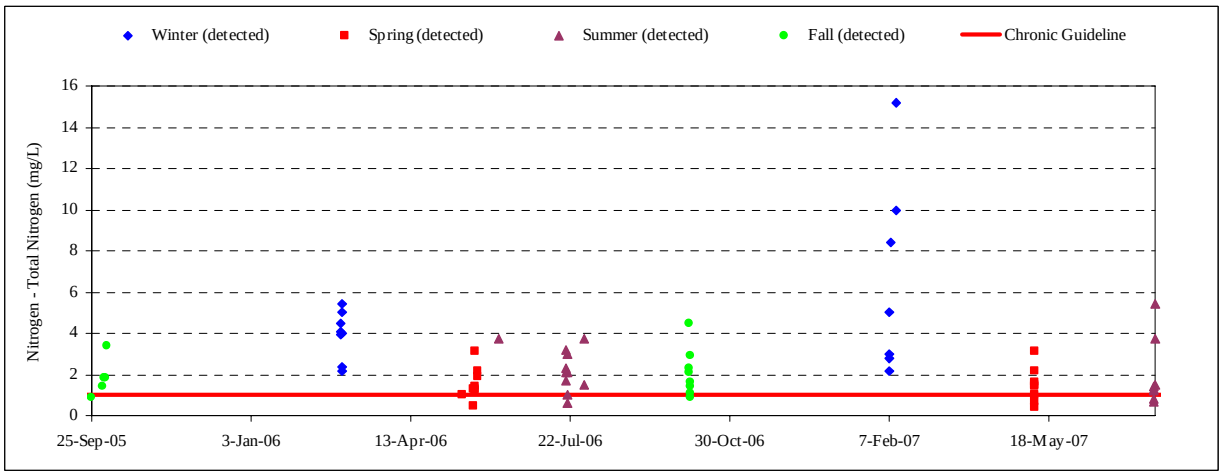
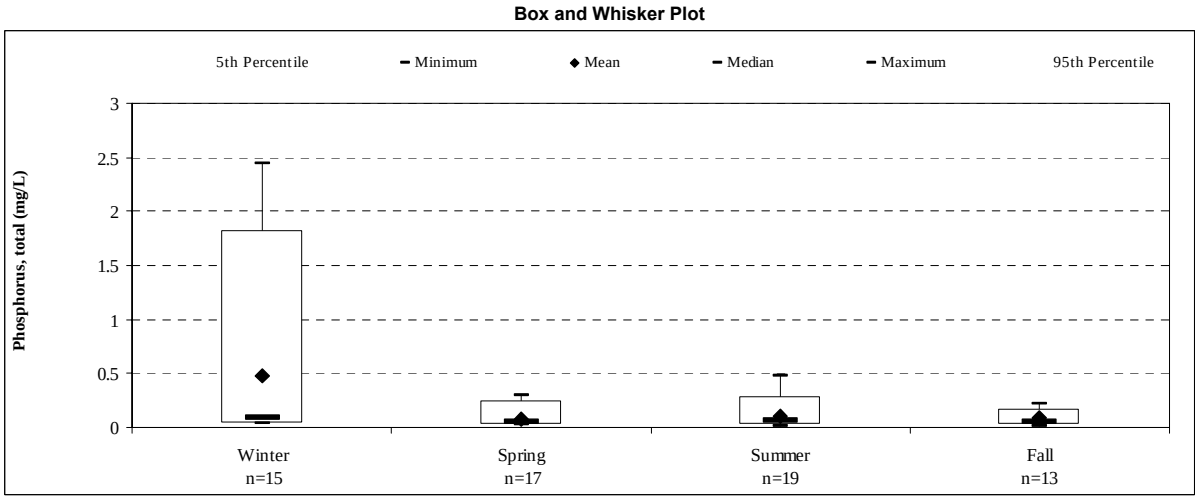


Figure G-3-5-25 Box Whisker and Time Series Scatter Plots of Observed Total Phosphorus Concentration in Unnamed Lakes within PRMA



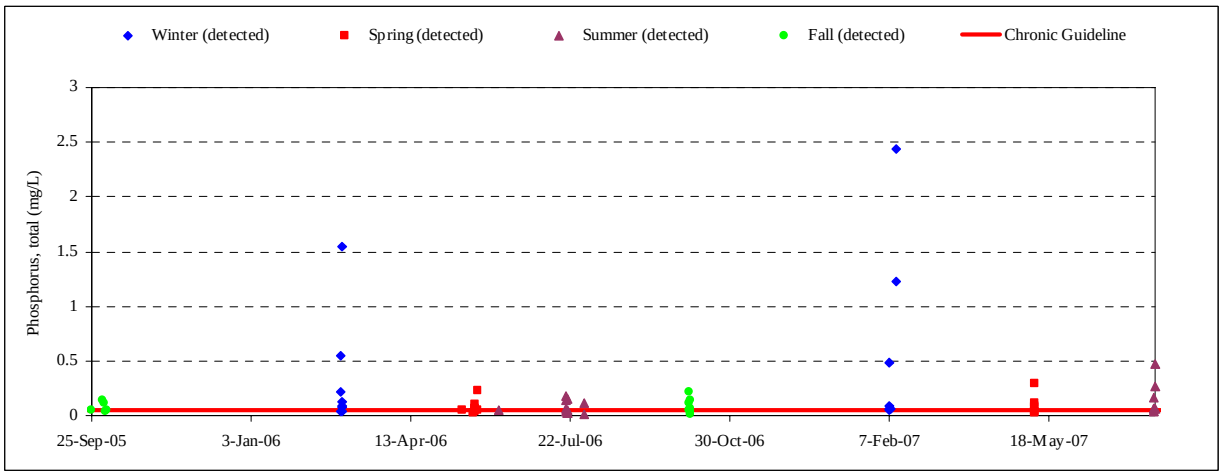
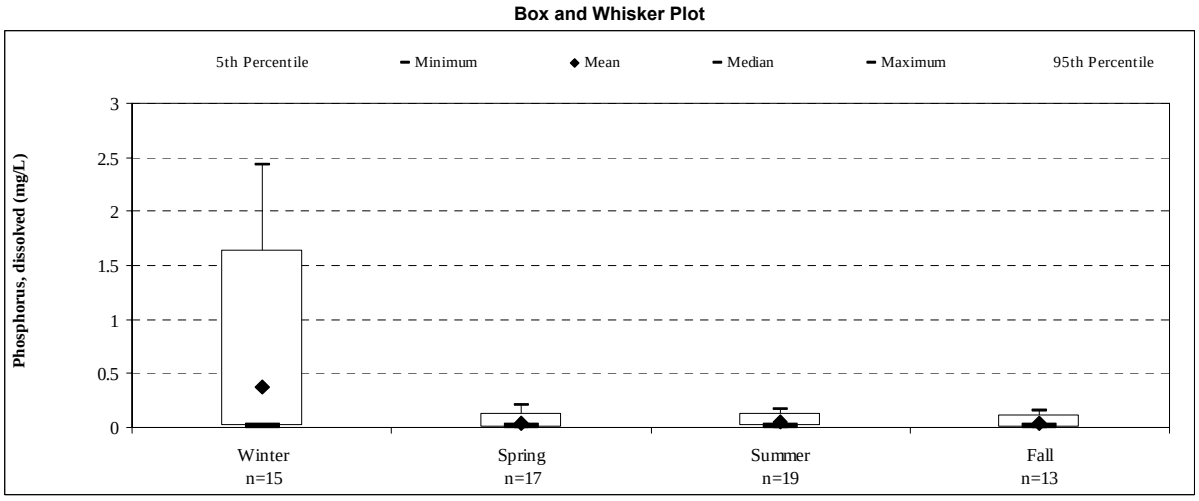


Figure G-3-5-26 Box Whisker and Time Series Scatter Plots of Observed Dissolved Phosphorus Concentration in Unnamed Lakes within PRMA



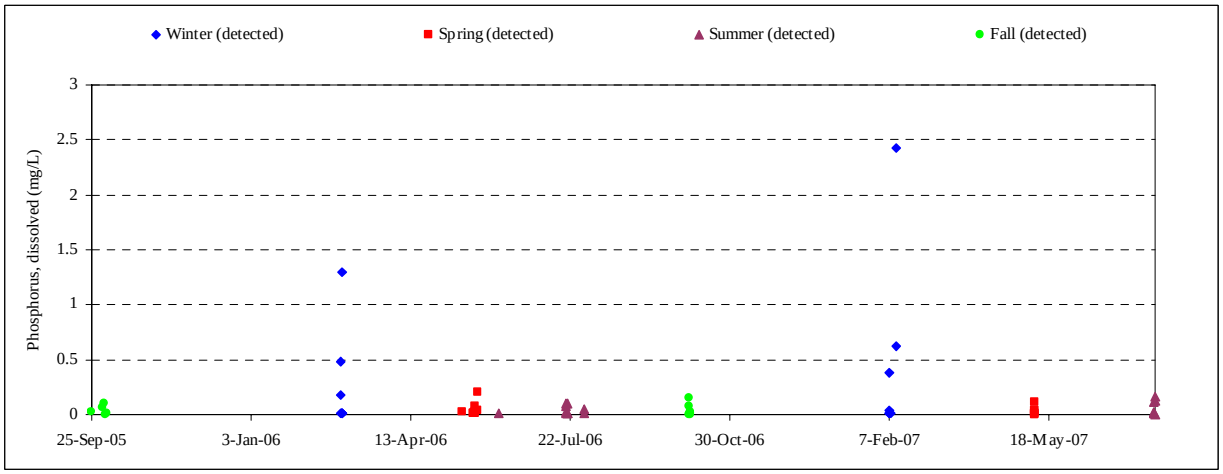
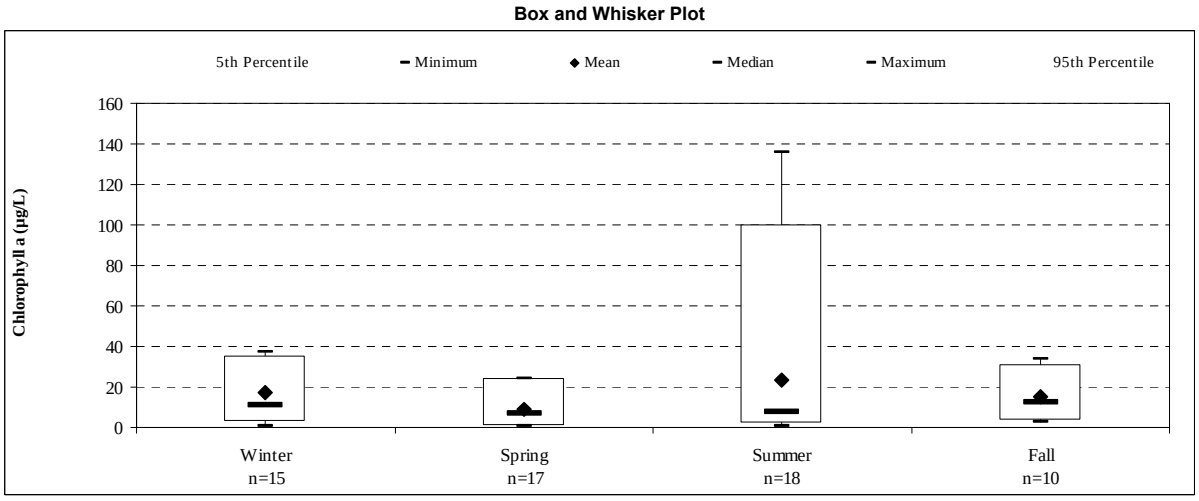


Figure G-3-5-27 Box Whisker and Time Series Scatter Plots of Observed Chlorophyll a in Unnamed Lakes within PRMA



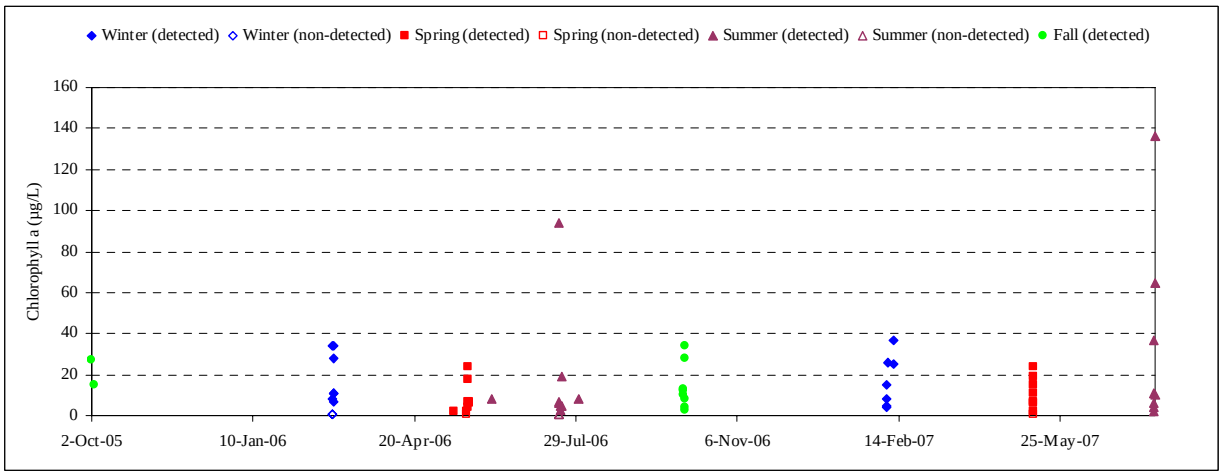
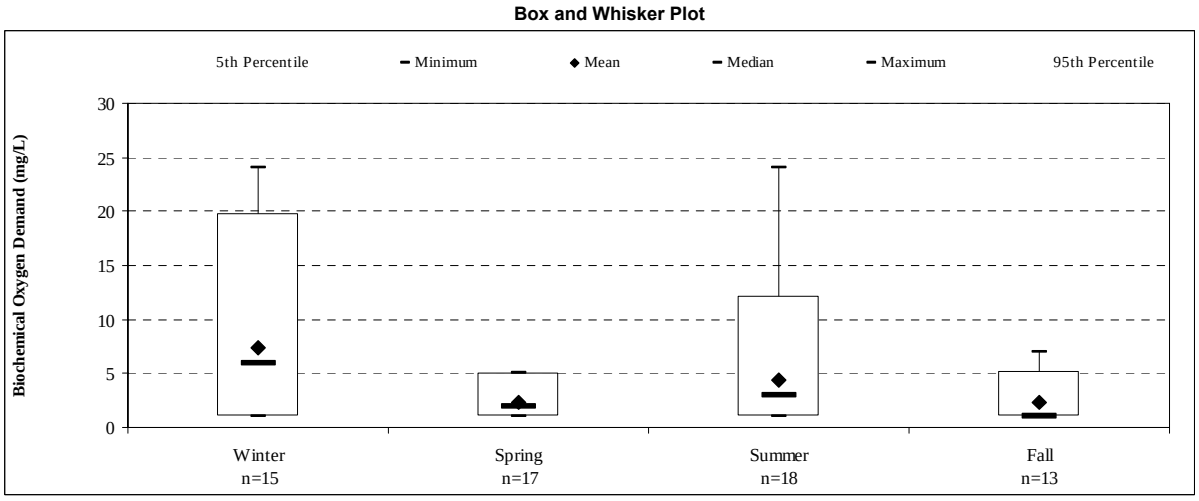


Figure G-3-5-28 Box Whisker and Time Series Scatter Plots of Observed Biochemical Oxygen Demand in Unnamed Lakes within PRMA



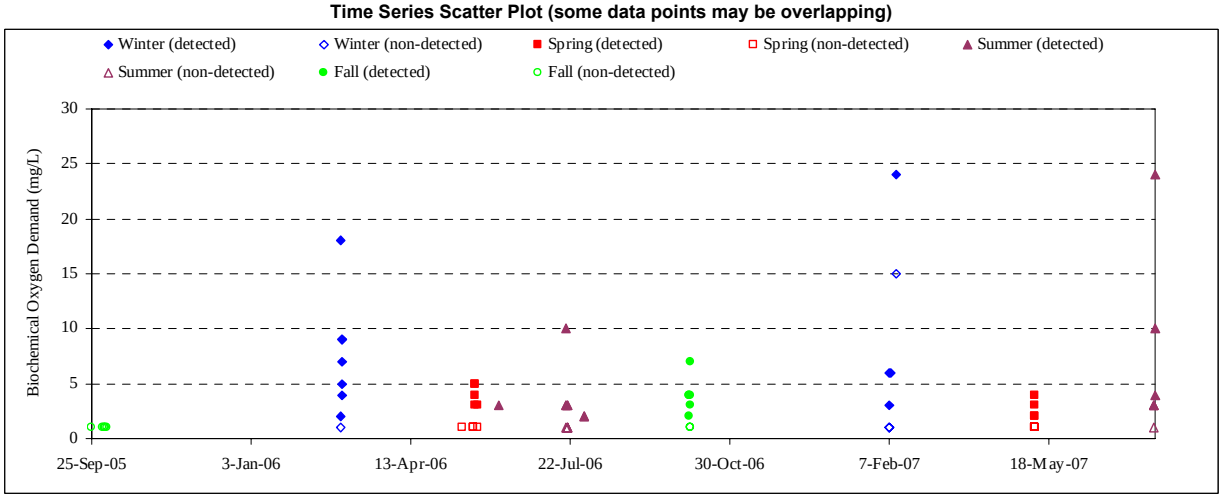
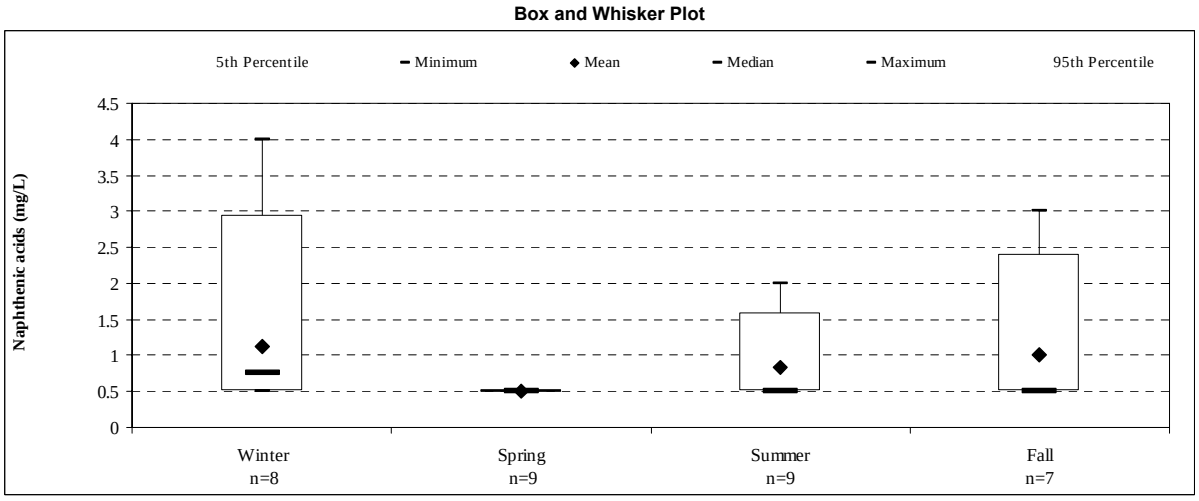


Figure G-3-5-29 Box Whisker and Time Series Scatter Plots of Observed Naphthenic acids Concentration in Unnamed Lakes within PRMA



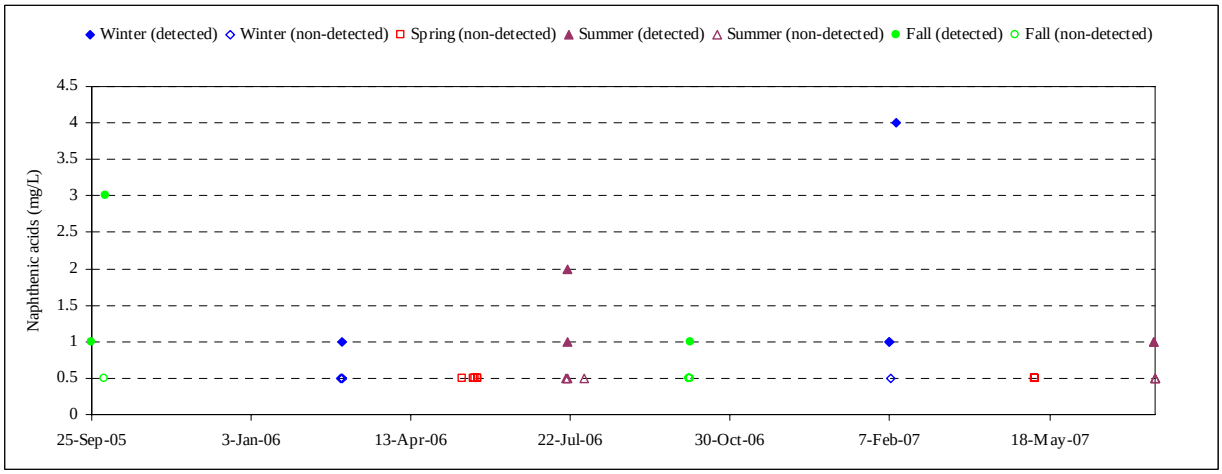
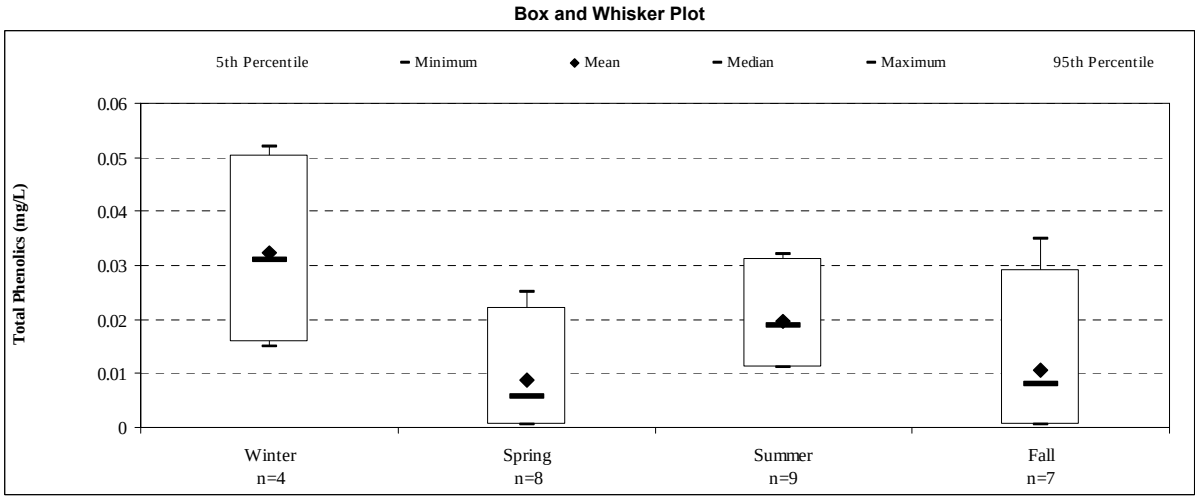


Figure G-3-5-30 Box Whisker and Time Series Scatter Plots of Observed Total Phenolics Concentration in Unnamed Lakes within PRMA



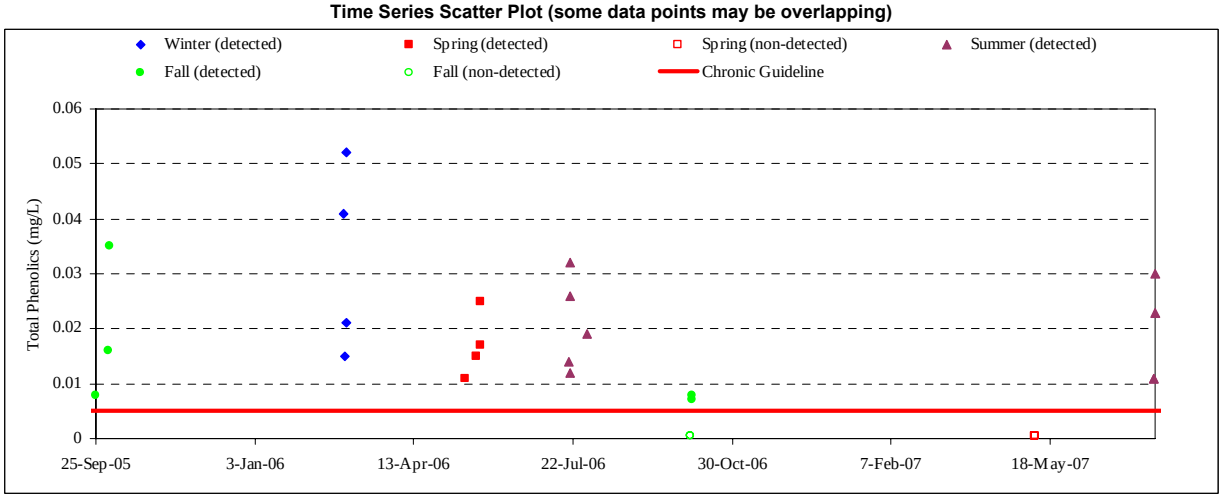
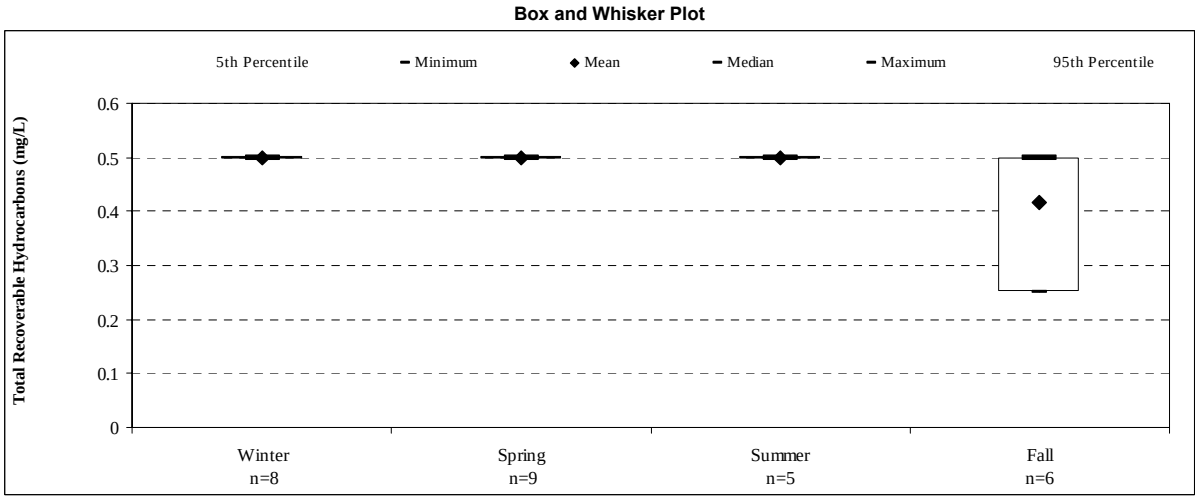


Figure G-3-5-31 Box Whisker and Time Series Scatter Plots of Observed Total Recoverable Hydrocarbons Concentration in Unnamed Lakes within PRMA



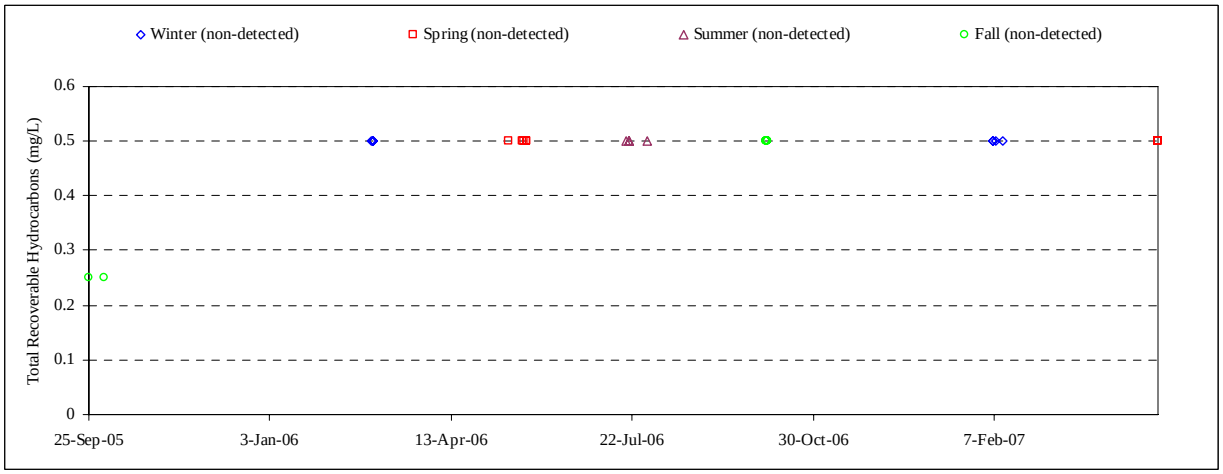
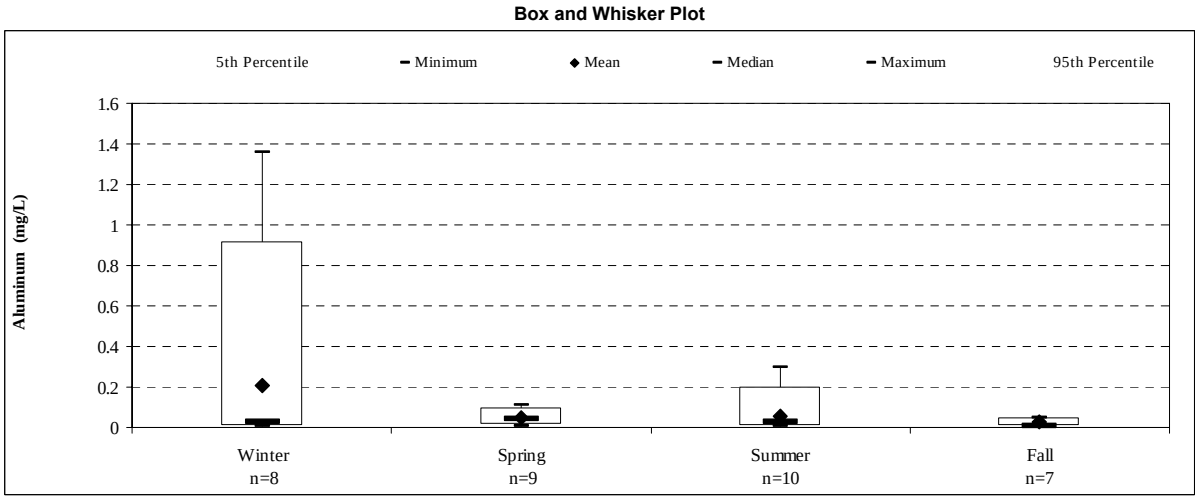


Figure G-3-5-62 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Total) Concentration in Unnamed Lakes within PRMA



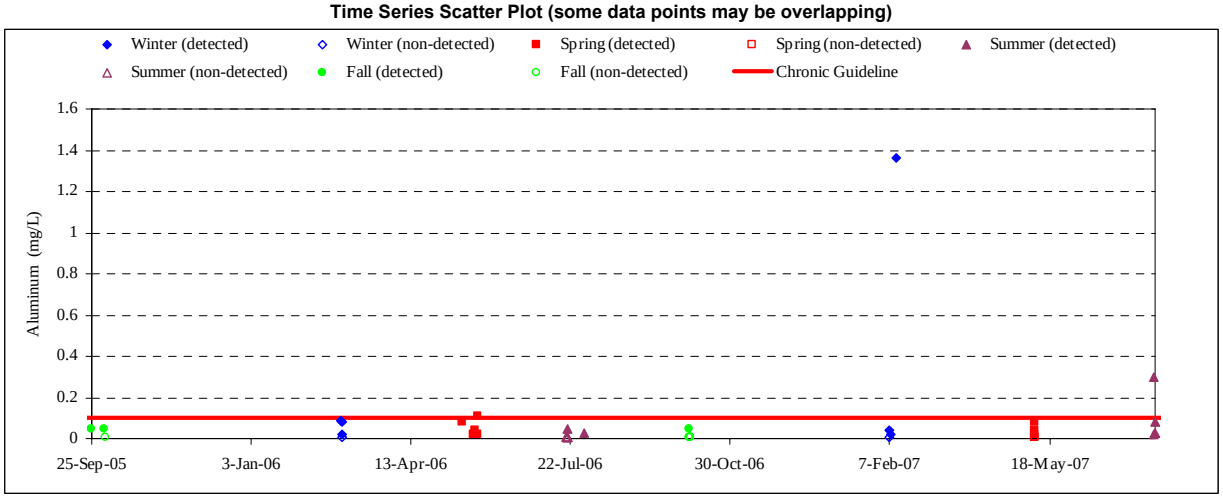
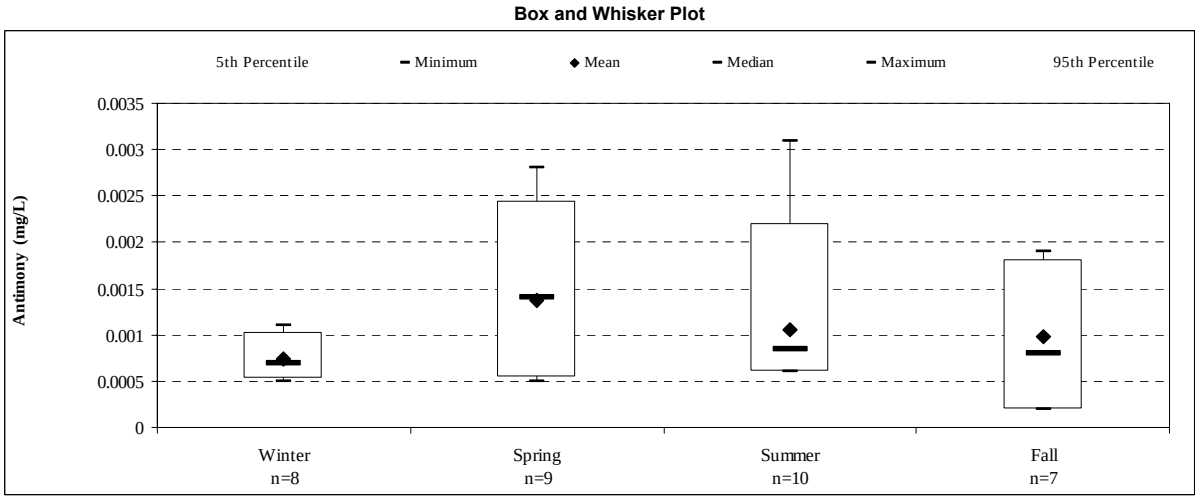


Figure G-3-5-63 Box Whisker and Time Series Scatter Plots of Observed Antimony (Total) Concentration in Unnamed Lakes within PRMA



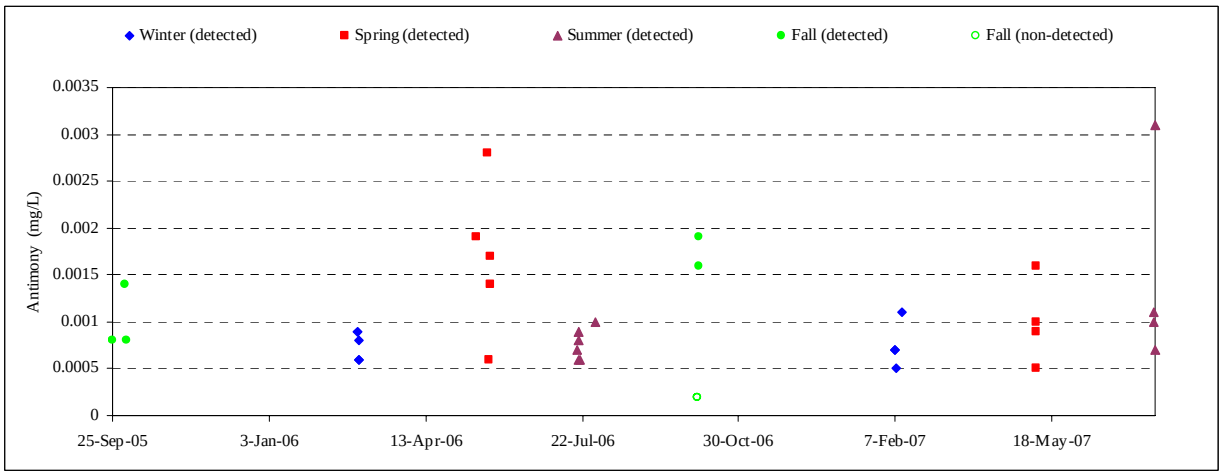
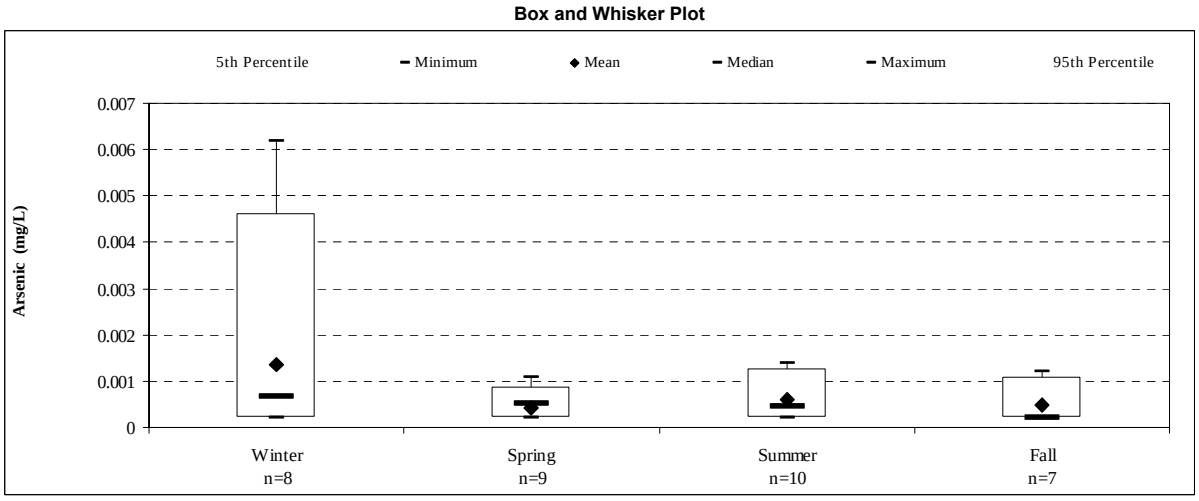


Figure G-3-5-64 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Total) Concentration in Unnamed Lakes within PRMA



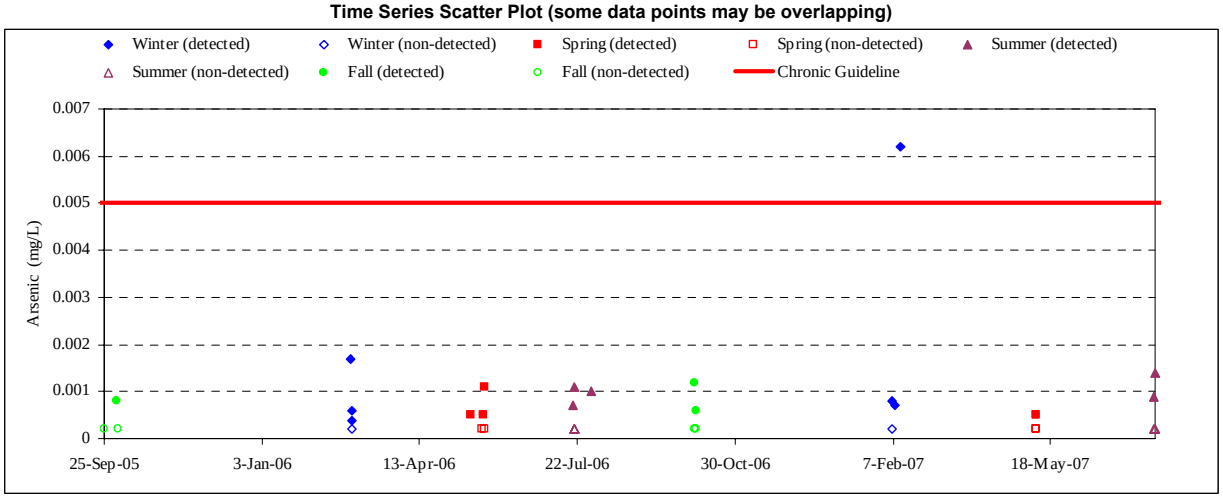
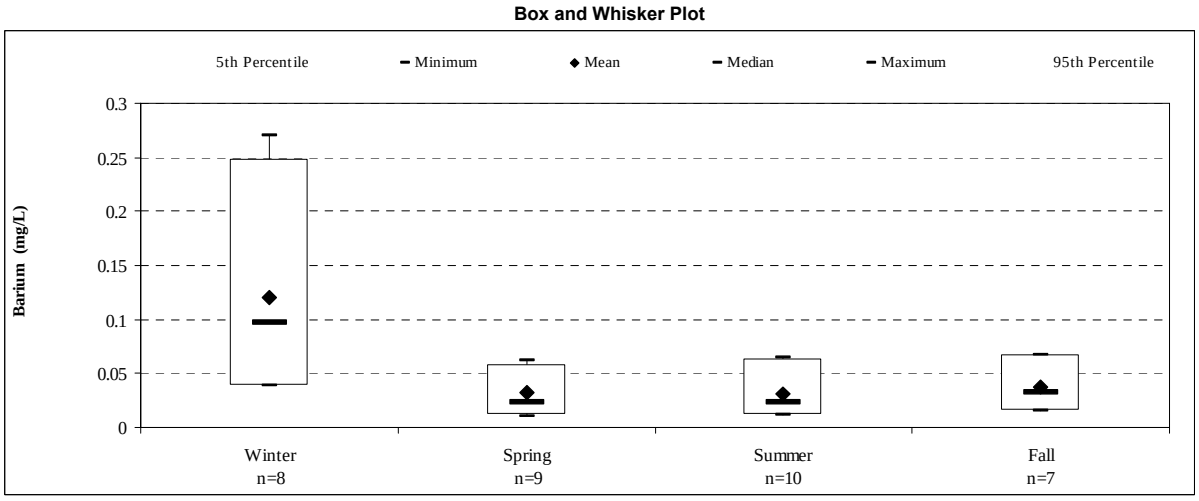


Figure G-3-5-65 Box Whisker and Time Series Scatter Plots of Observed Barium (Total) Concentration in Unnamed Lakes within PRMA



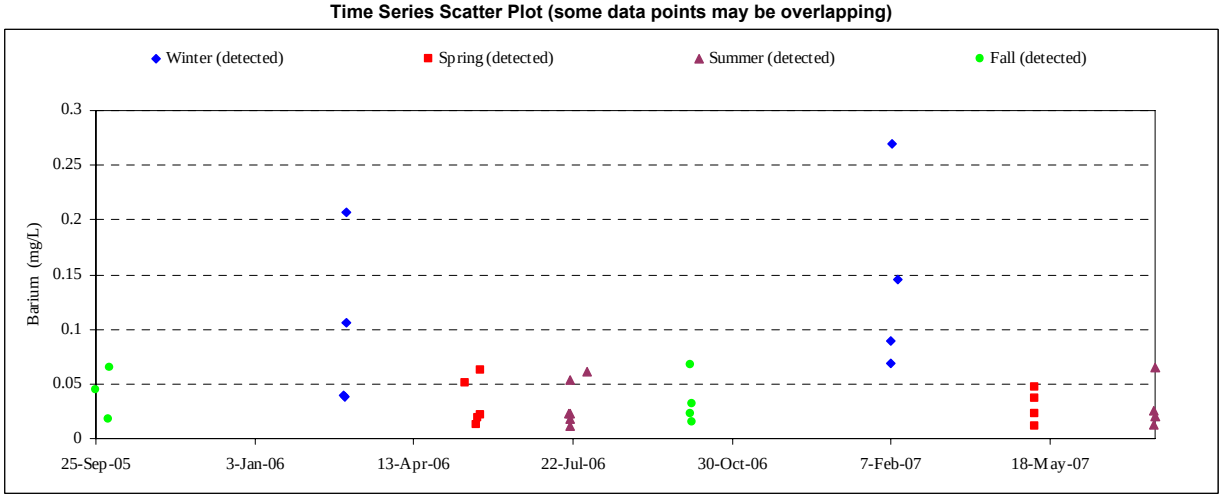
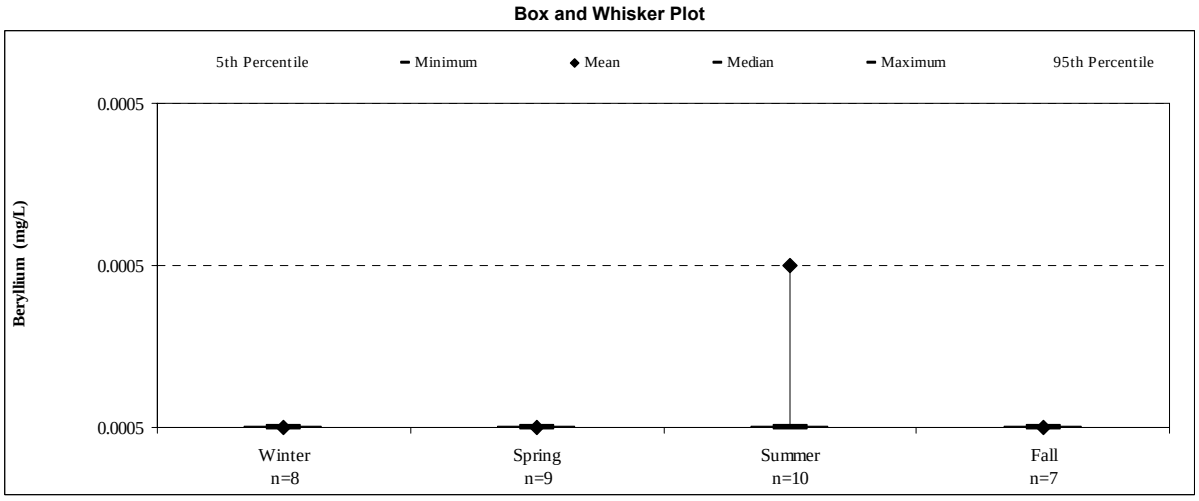


Figure G-3-5-66 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Total) Concentration in Unnamed Lakes within PRMA



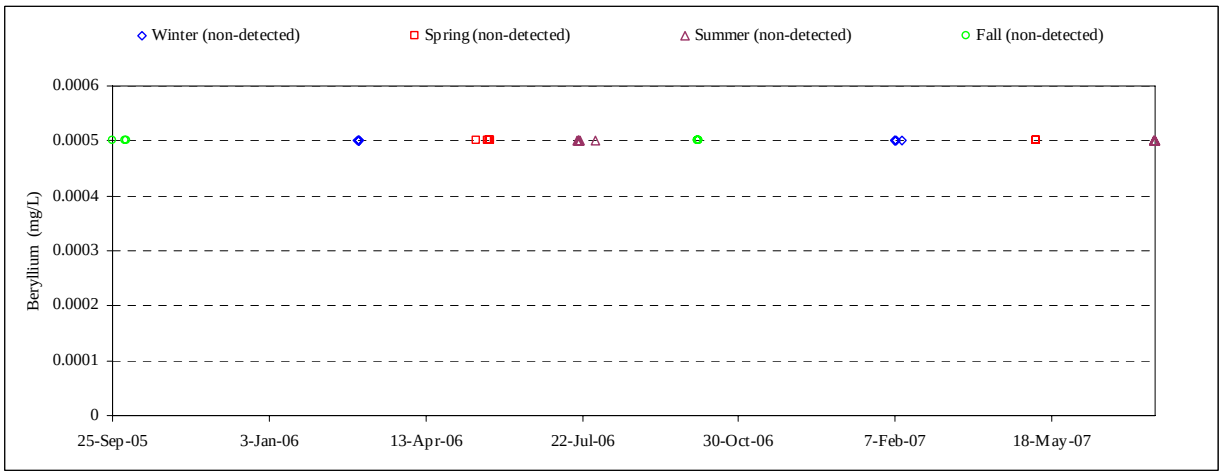
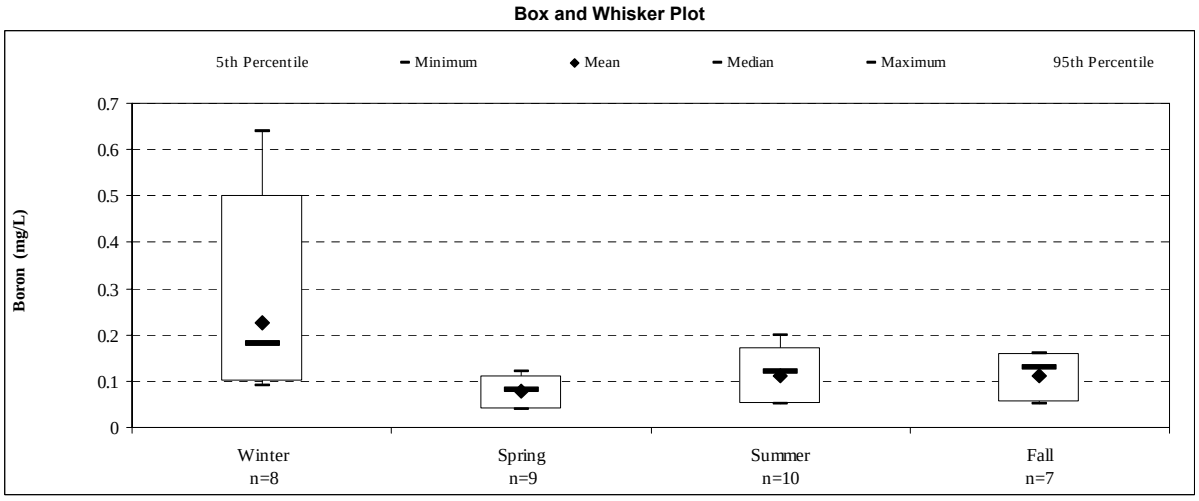


Figure G-3-5-67 Box Whisker and Time Series Scatter Plots of Observed Boron (Total) Concentration in Unnamed Lakes within PRMA



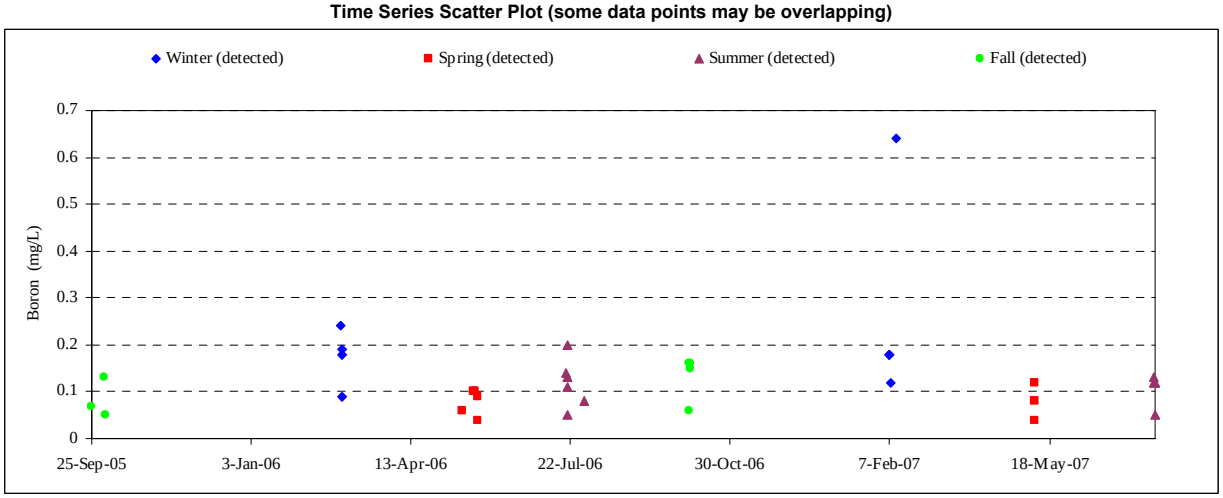
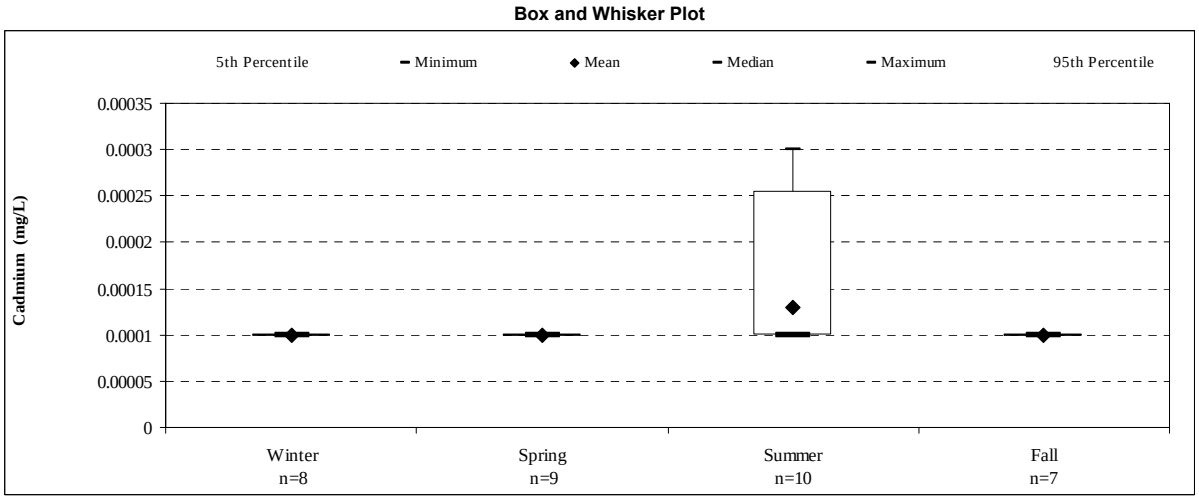


Figure G-3-5-68 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Total) Concentration in Unnamed Lakes within PRMA



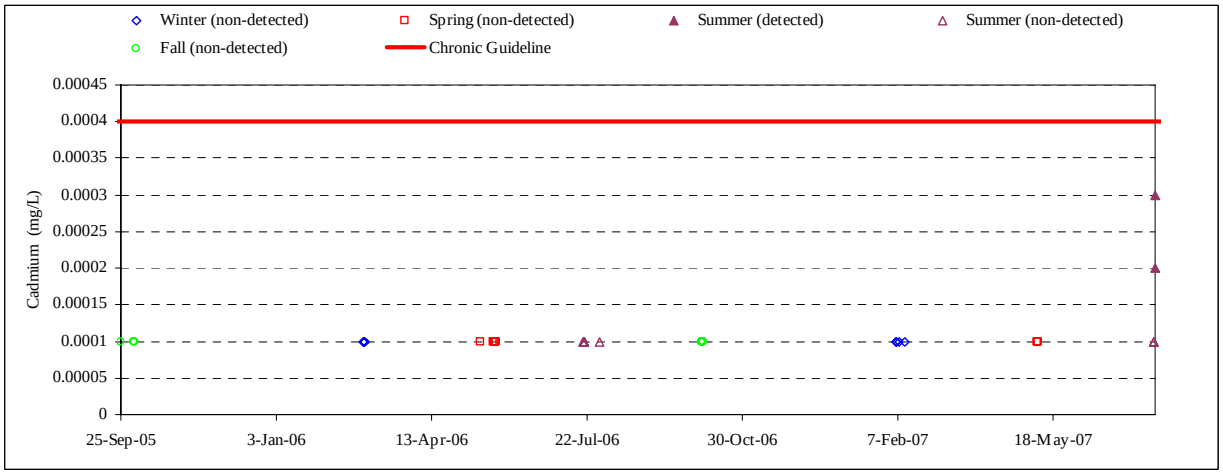
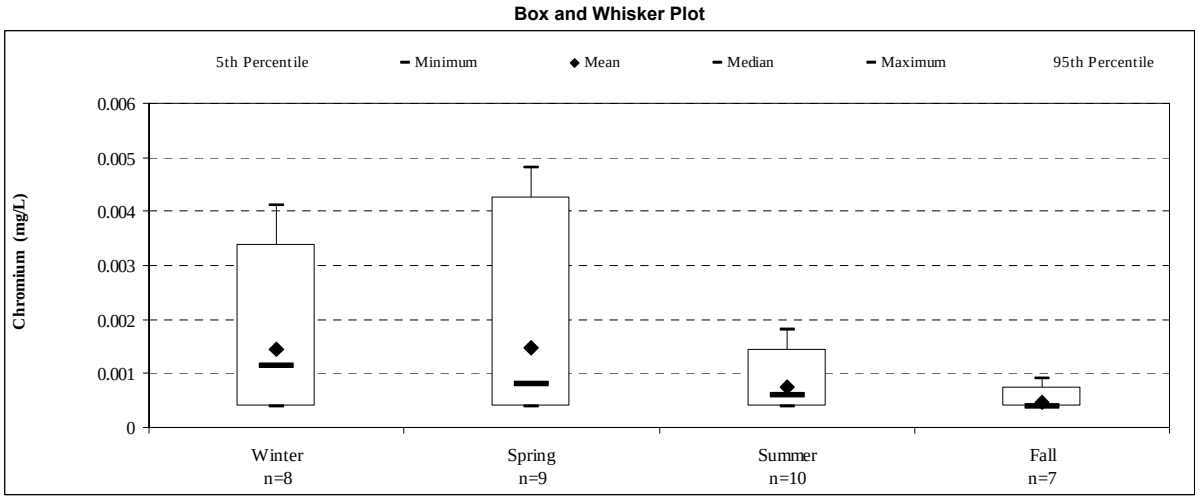


Figure G-3-5-69 Box Whisker and Time Series Scatter Plots of Observed Chromium (Total) Concentration in Unnamed Lakes within PRMA



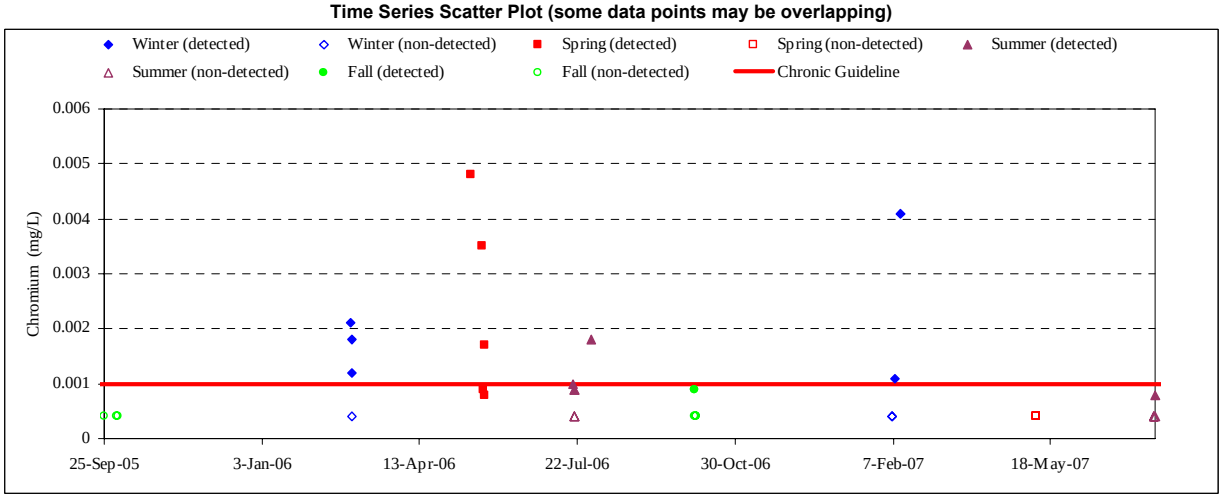
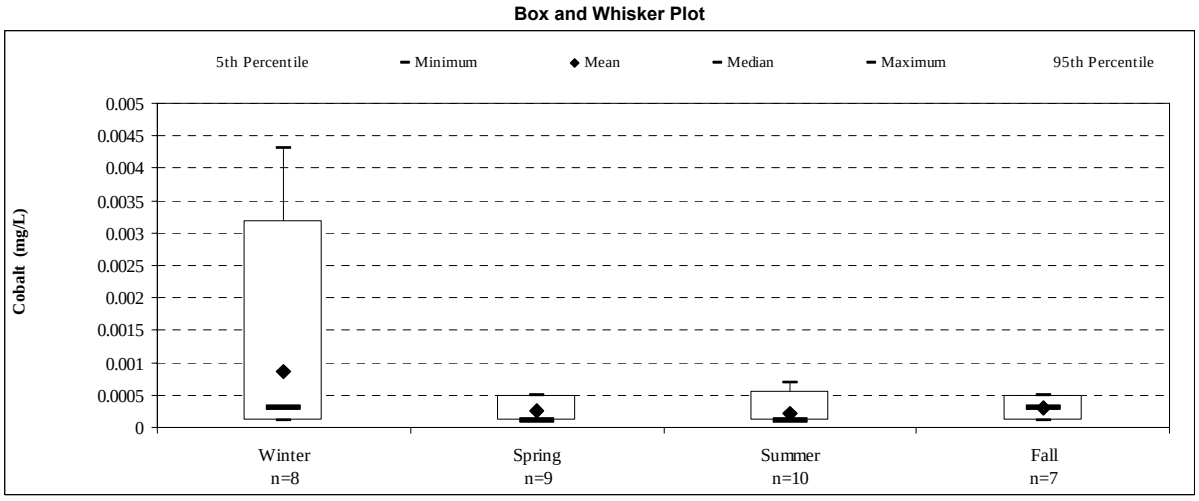


Figure G-3-5-71 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Total) Concentration in Unnamed Lakes within PRMA



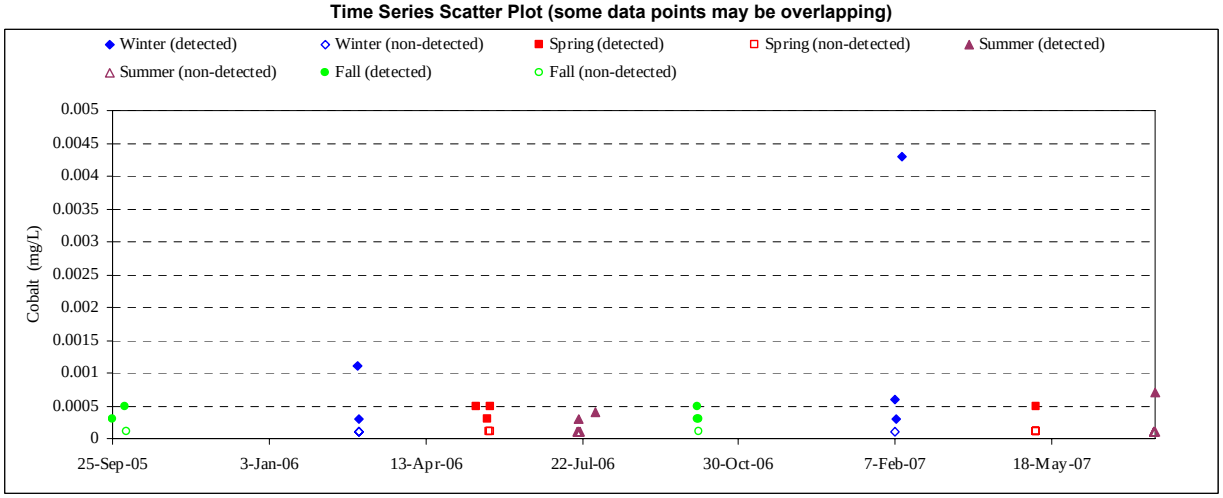
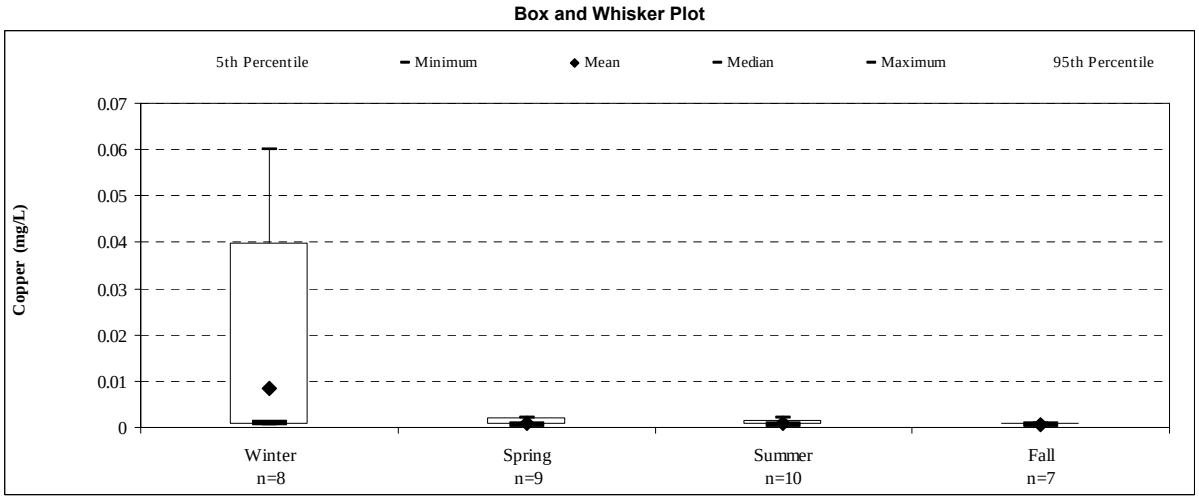


Figure G-3-5-72 Box Whisker and Time Series Scatter Plots of Observed Copper (Total) Concentration in Unnamed Lakes within PRMA



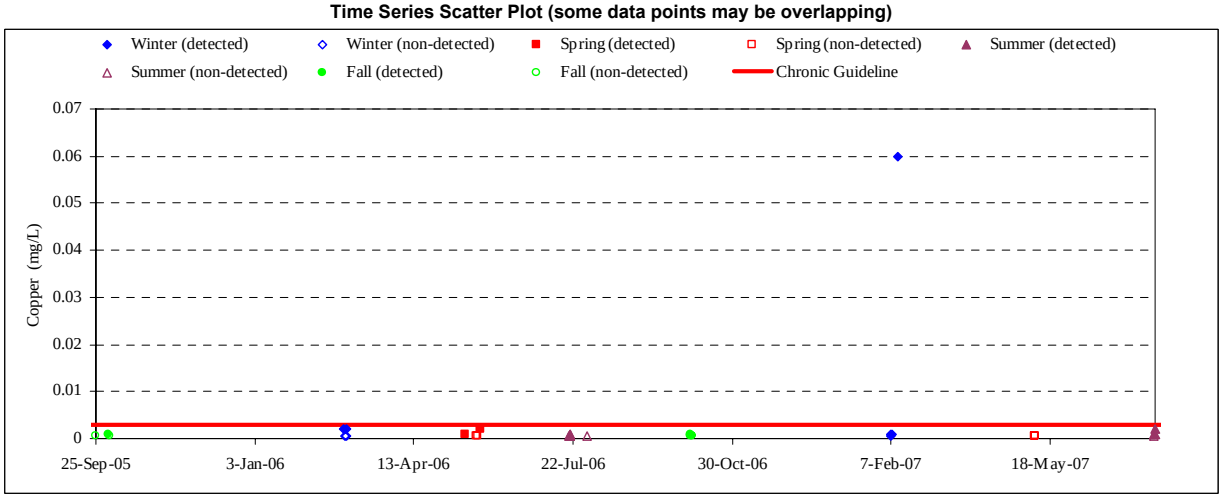
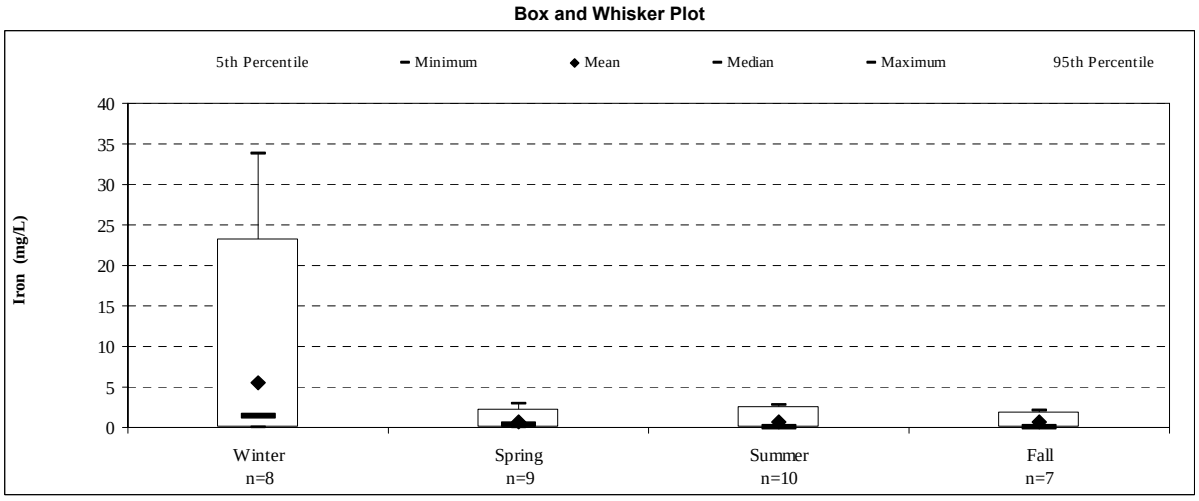


Figure G-3-5-73 Box Whisker and Time Series Scatter Plots of Observed Iron (Total) Concentration in Unnamed Lakes within PRMA



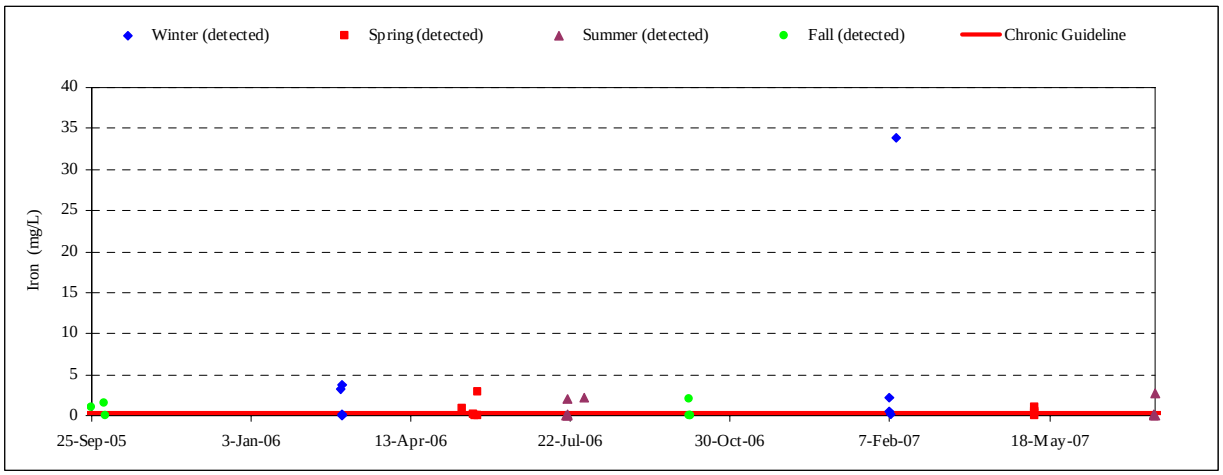
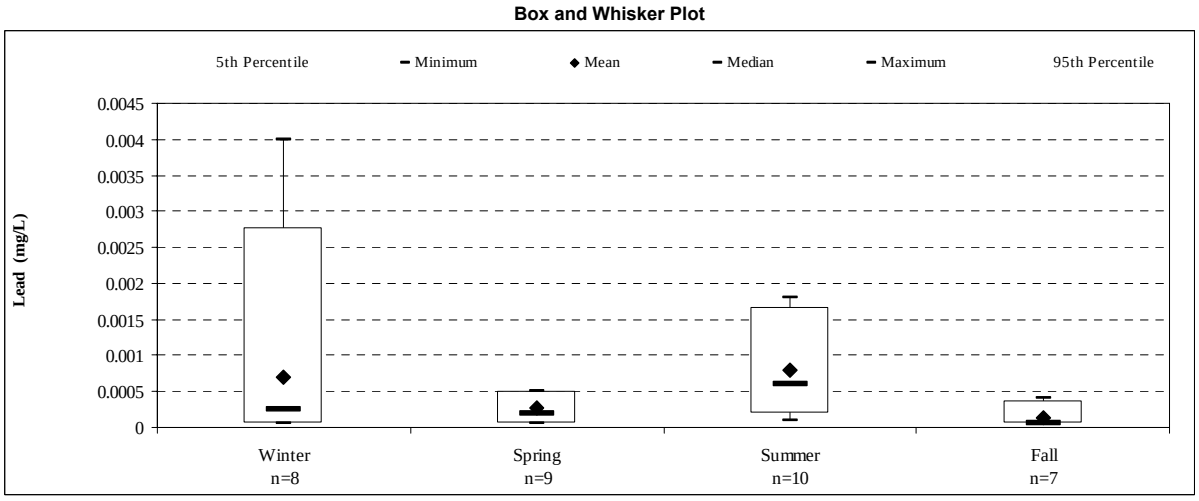


Figure G-3-5-74 Box Whisker and Time Series Scatter Plots of Observed Lead (Total) Concentration in Unnamed Lakes within PRMA



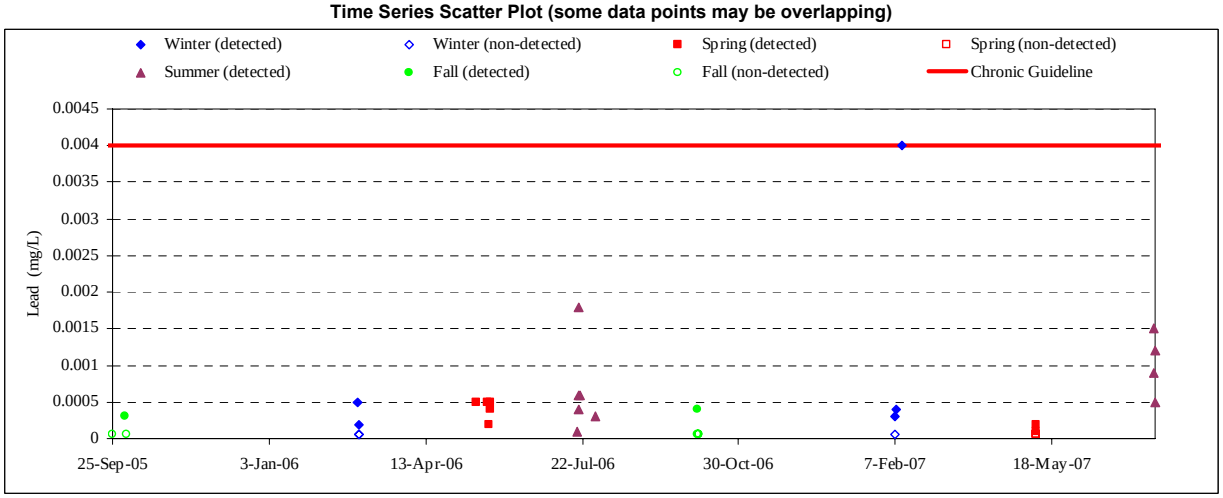
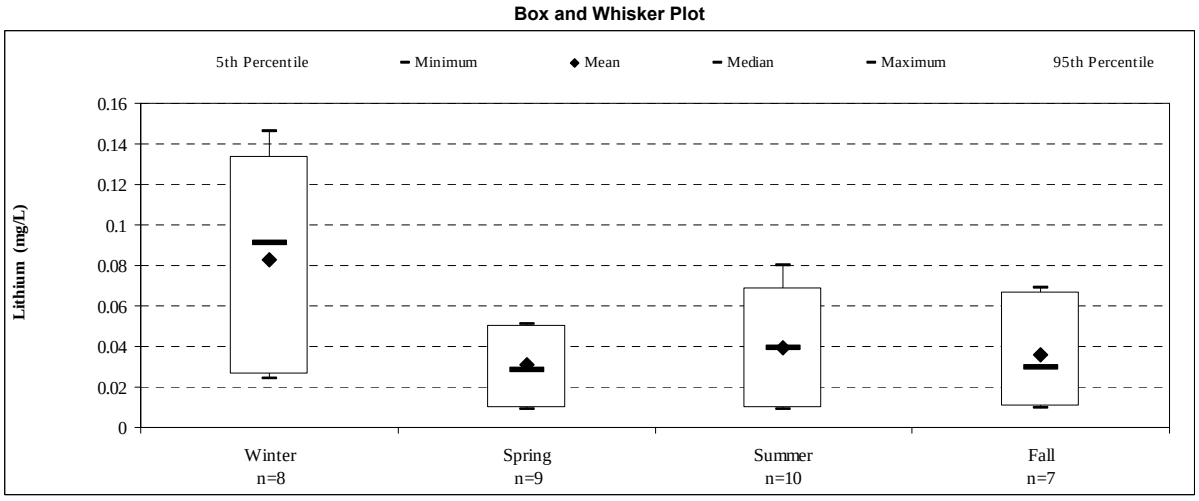


Figure G-3-5-75 Box Whisker and Time Series Scatter Plots of Observed Lithium (Total) Concentration in Unnamed Lakes within PRMA



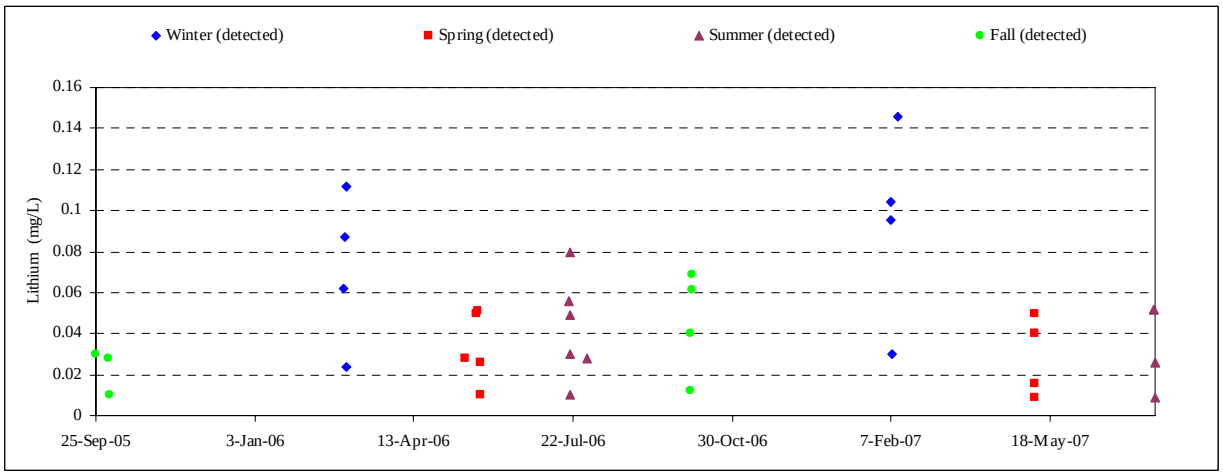
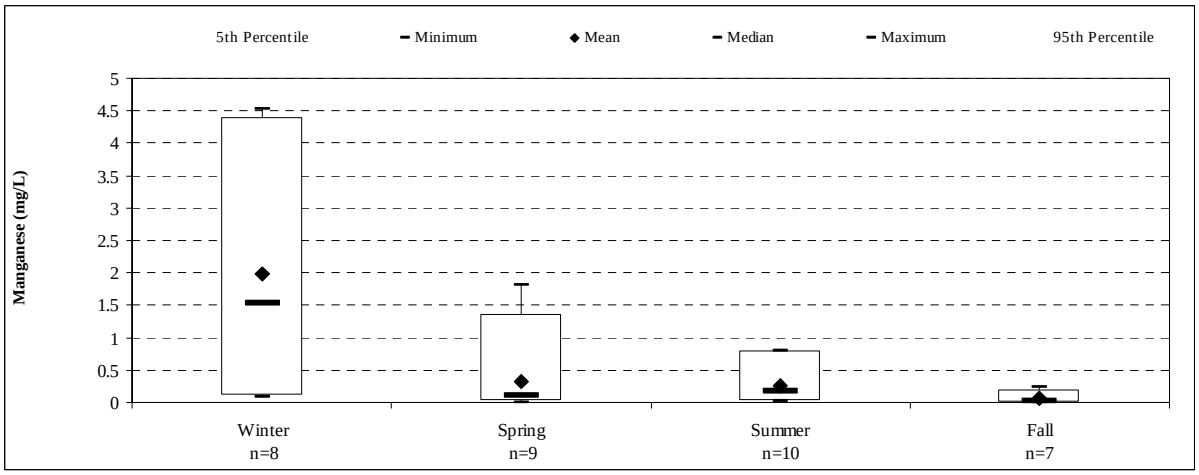


Figure G-3-5-76 Box Whisker and Time Series Scatter Plots of Observed Manganese (Total) Concentration in Unnamed Lakes within PRMA

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

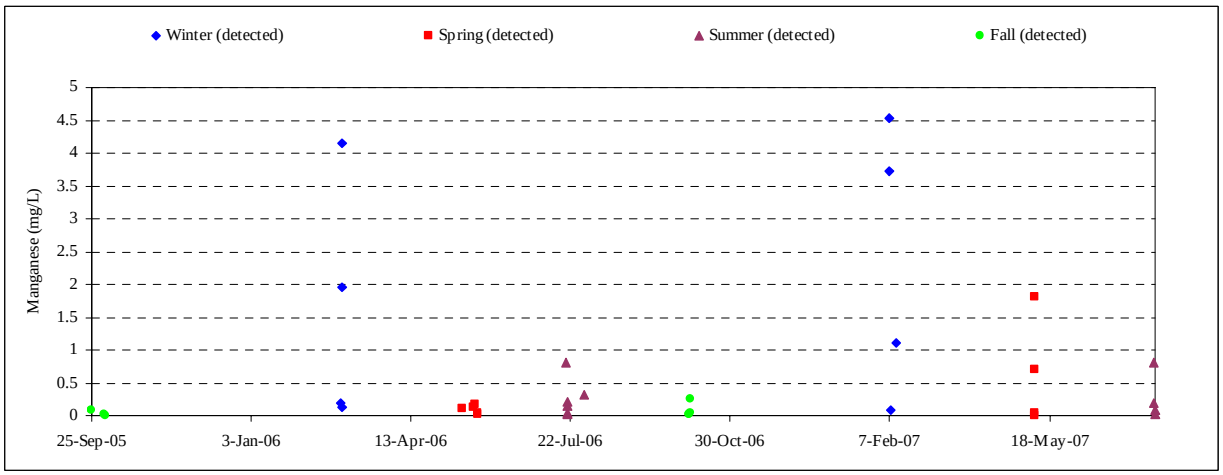
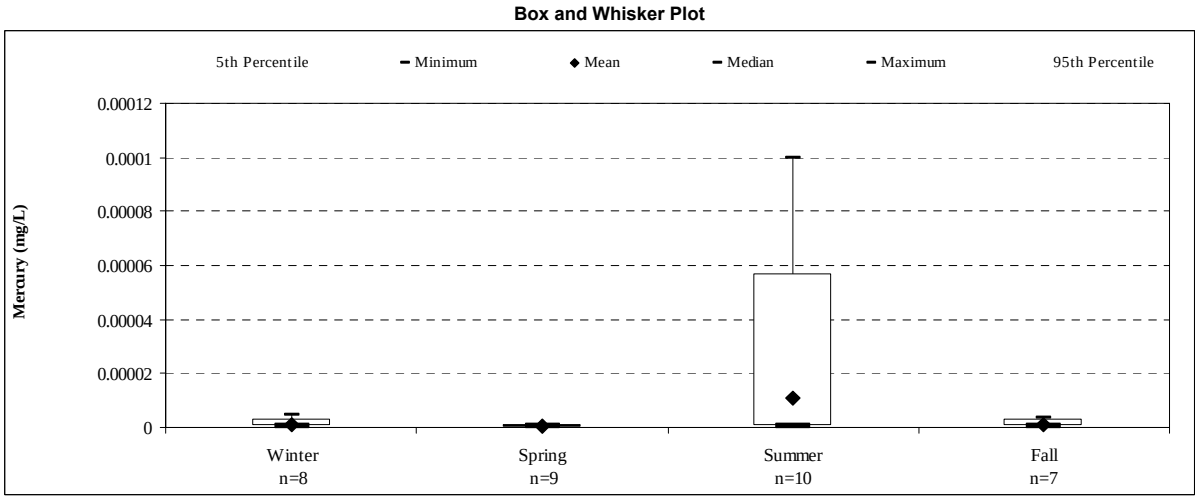


Figure G-3-5-77 Box Whisker and Time Series Scatter Plots of Observed Mercury (Total) Concentration in Unnamed Lakes within PRMA



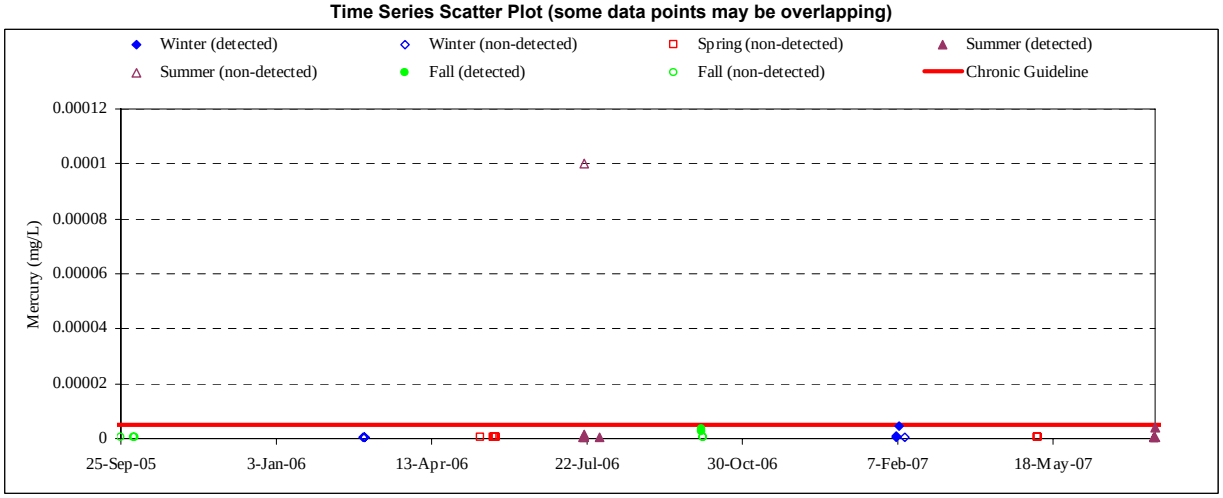
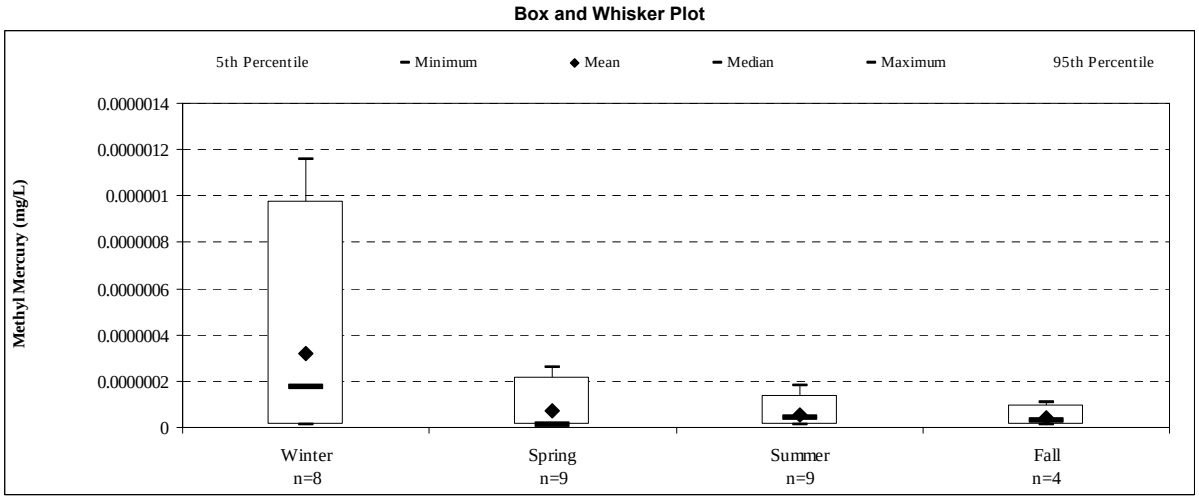


Figure G-3-5-78 Box Whisker and Time Series Scatter Plots of Observed Methyl Mercury (Total) Concentration in Unnamed Lakes within PRMA



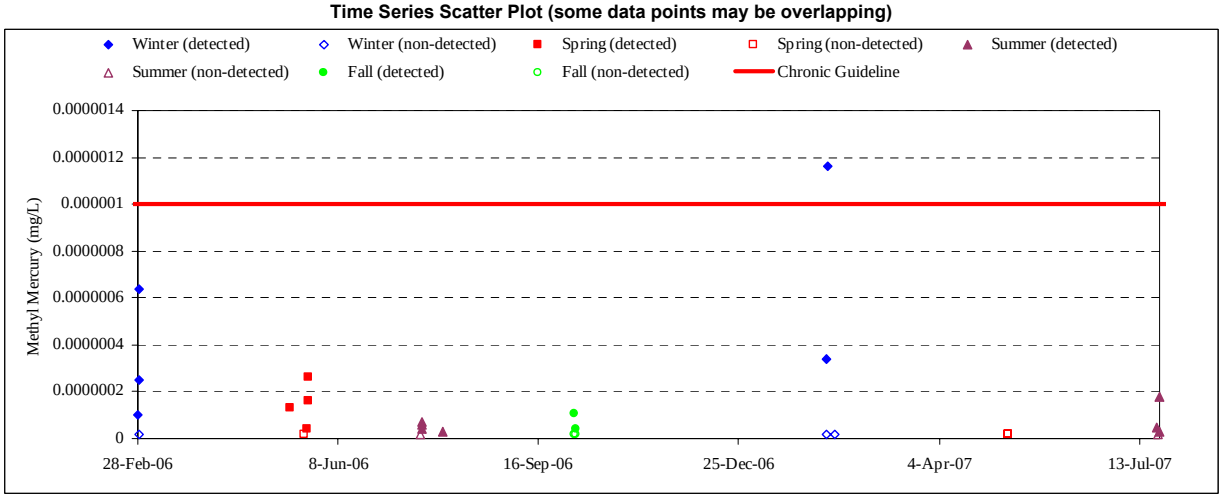
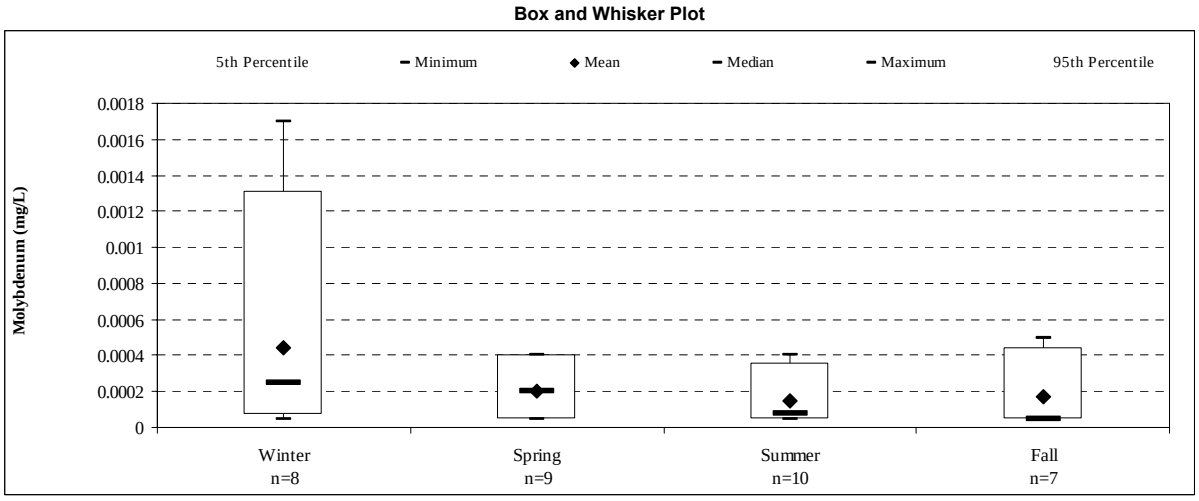


Figure G-3-5-79 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Total) Concentration in Unnamed Lakes within PRMA



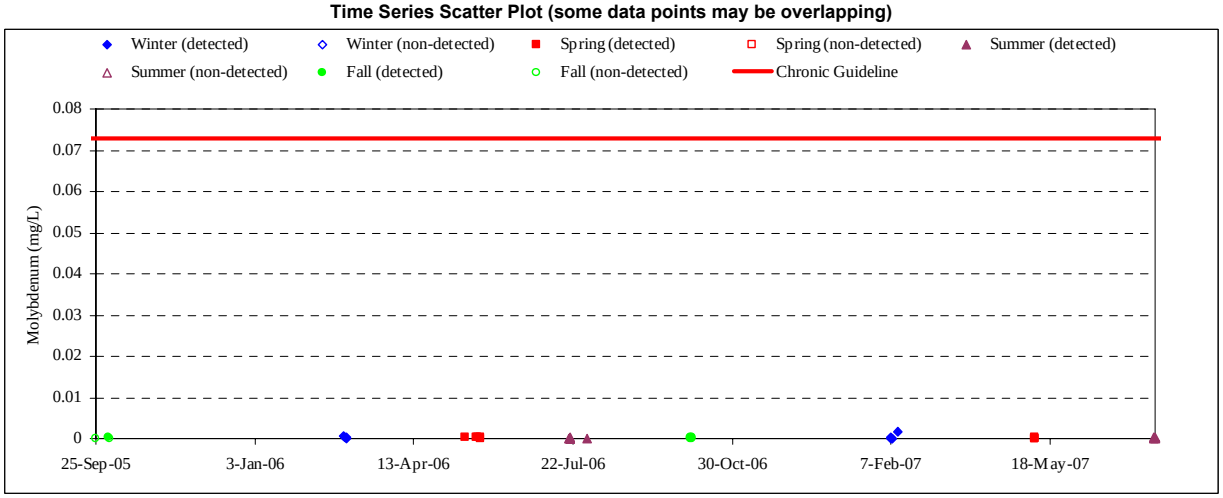
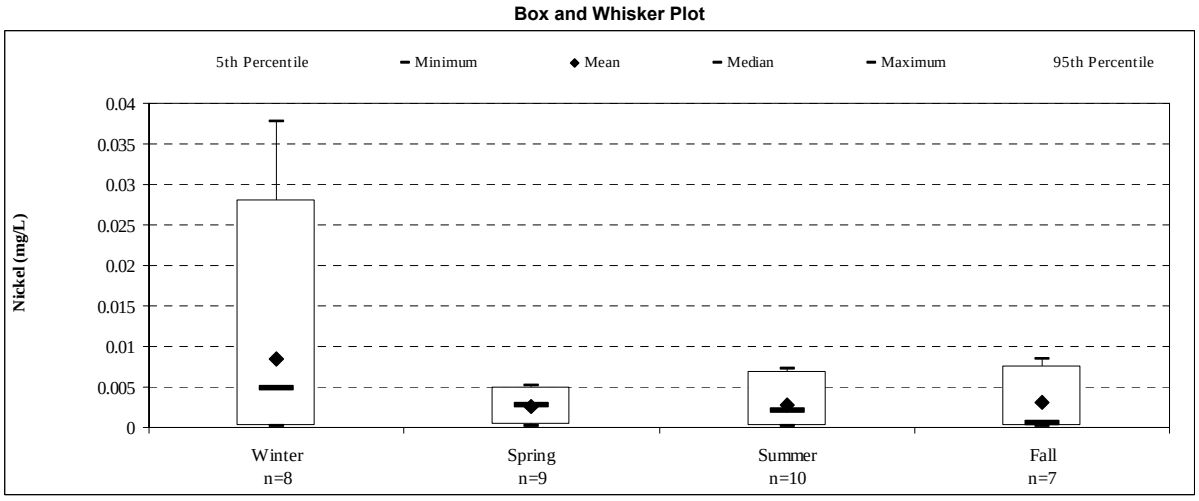


Figure G-3-5-80 Box Whisker and Time Series Scatter Plots of Observed Nickel (Total) Concentration in Unnamed Lakes within PRMA



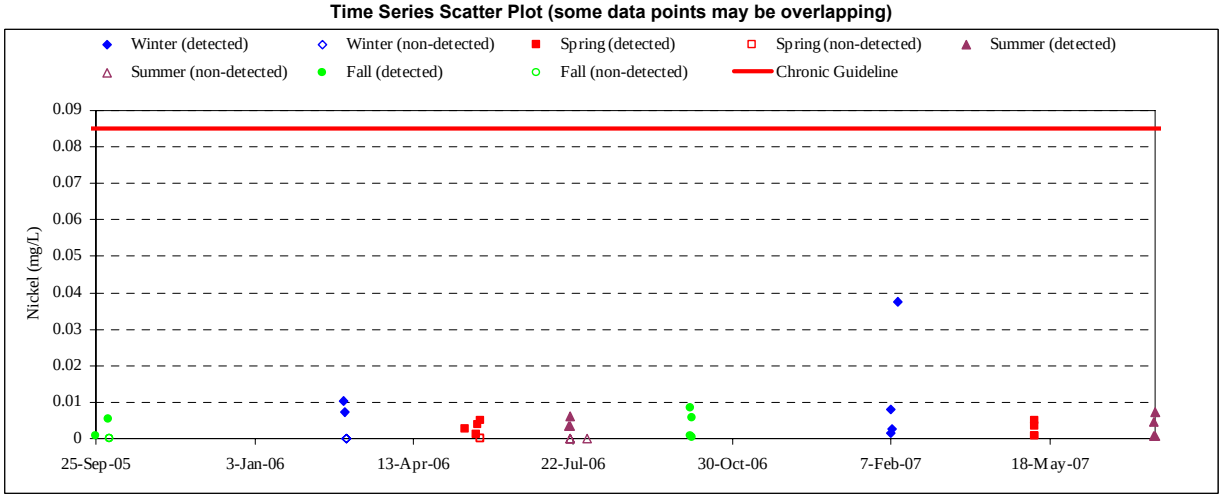
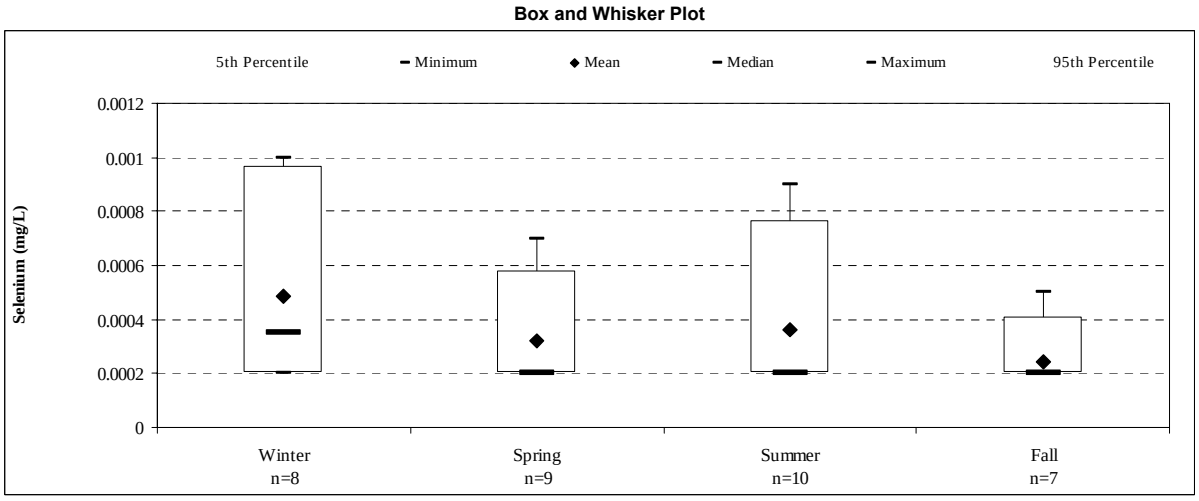


Figure G-3-5-81 Box Whisker and Time Series Scatter Plots of Observed Selenium (Total) Concentration in Unnamed Lakes within PRMA



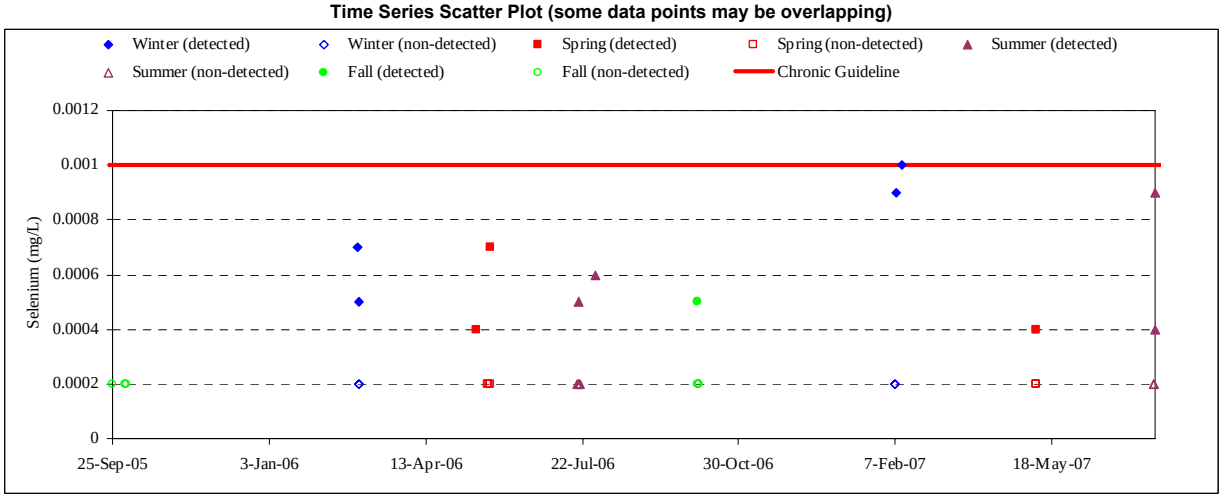
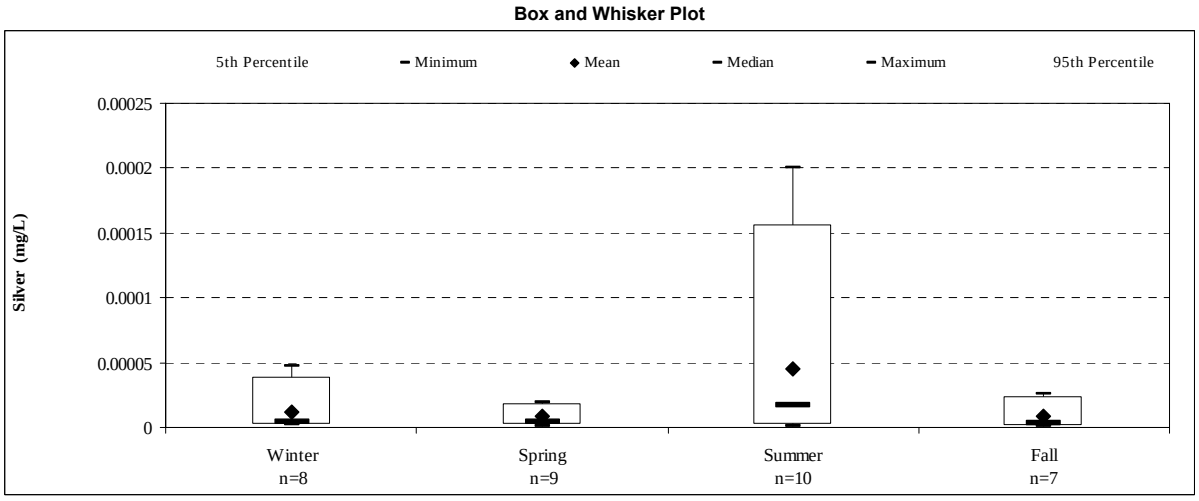


Figure G-3-5-83 Box Whisker and Time Series Scatter Plots of Observed Silver (Total) Concentration in Unnamed Lakes within PRMA



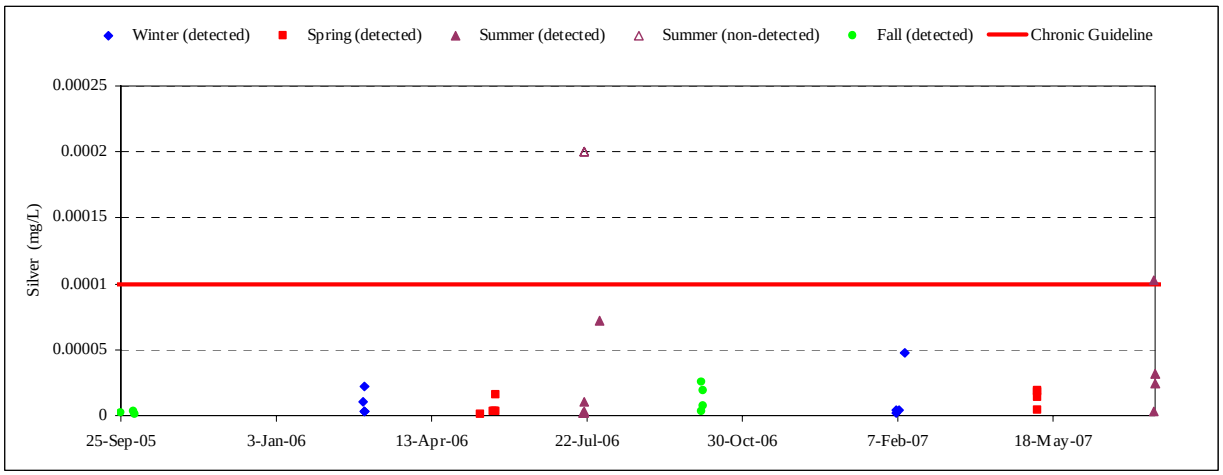
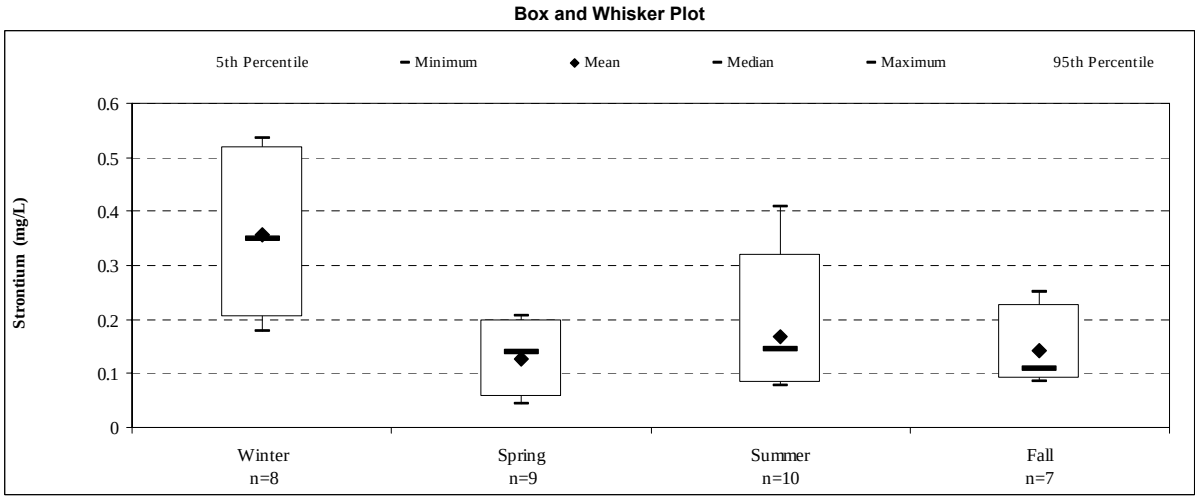


Figure G-3-5-84 Box Whisker and Time Series Scatter Plots of Observed Strontium (Total) Concentration in Unnamed Lakes within PRMA



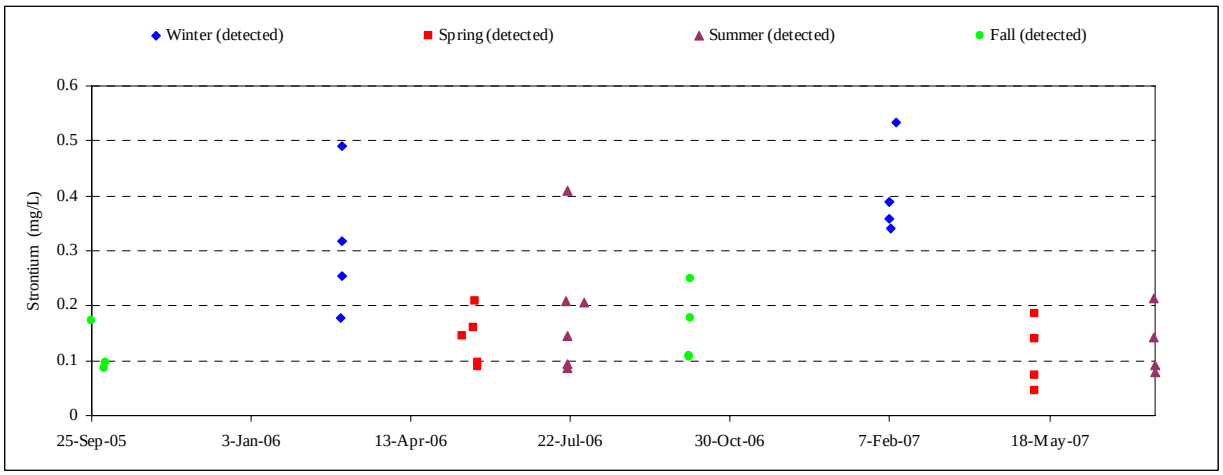
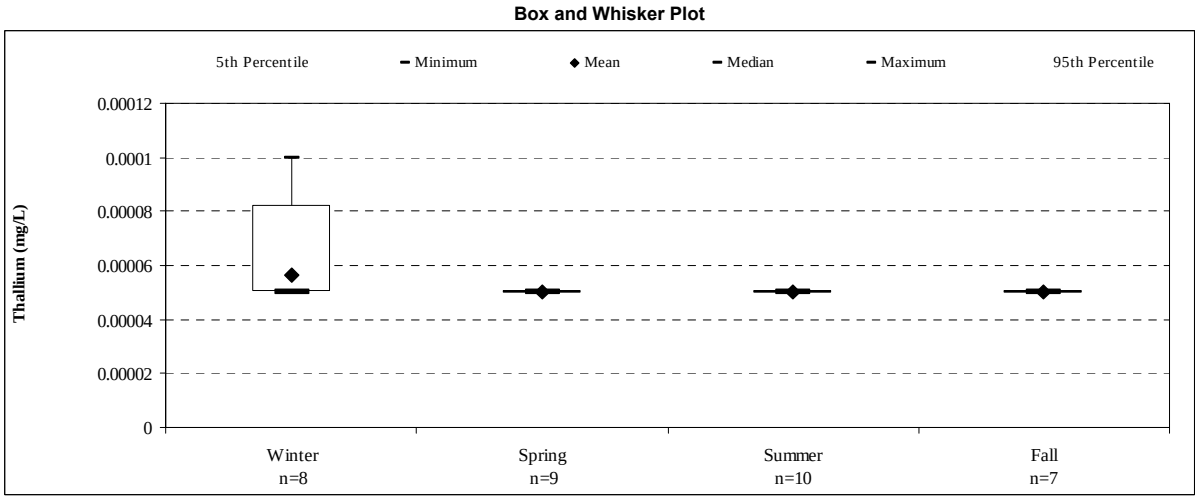


Figure G-3-5-86 Box Whisker and Time Series Scatter Plots of Observed Thallium (Total) Concentration in Unnamed Lakes within PRMA



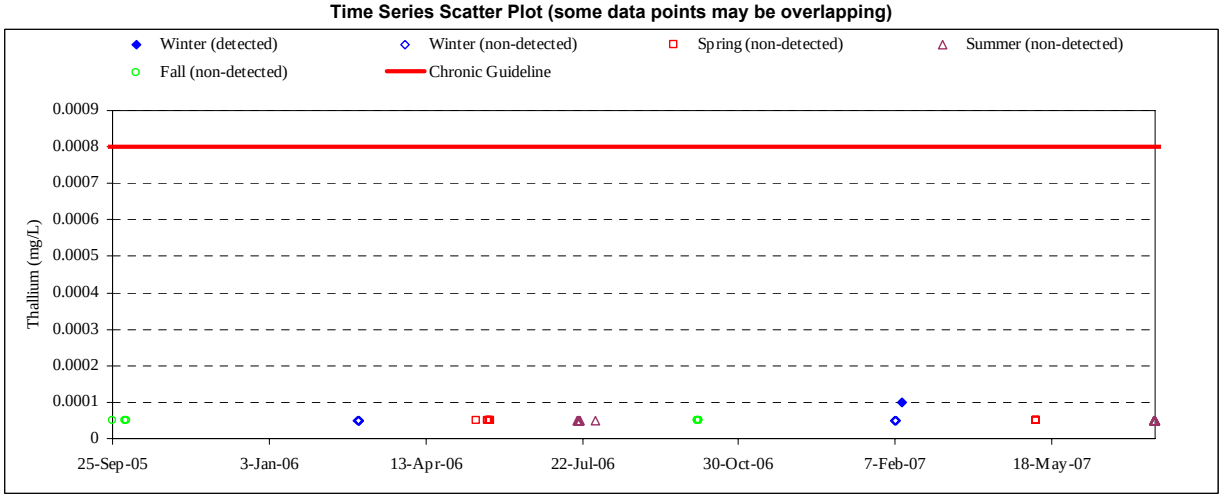
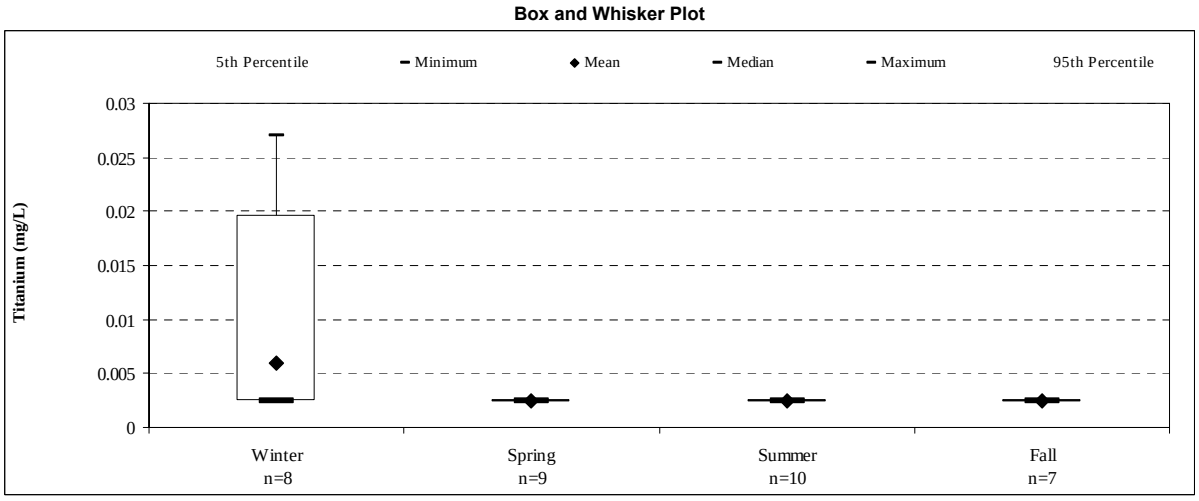


Figure G-3-5-87 Box Whisker and Time Series Scatter Plots of Observed Titanium (Total) Concentration in Unnamed Lakes within PRMA



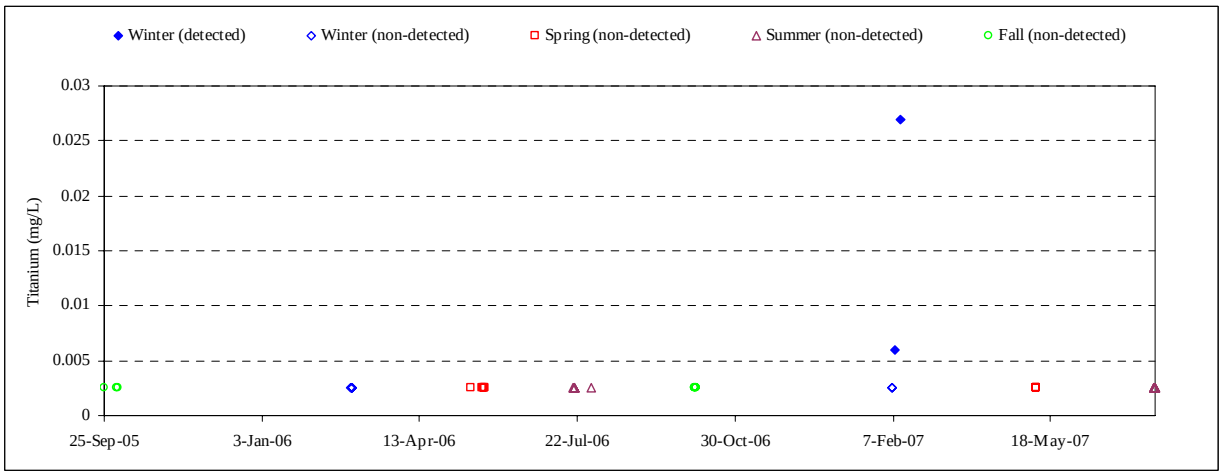
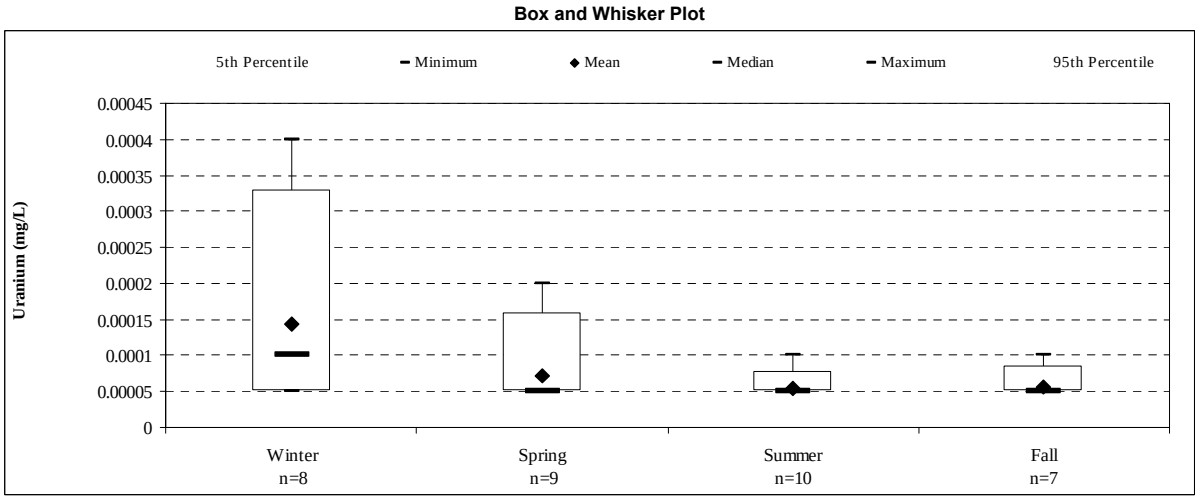


Figure G-3-5-88 Box Whisker and Time Series Scatter Plots of Observed Uranium (Total) Concentration in Unnamed Lakes within PRMA



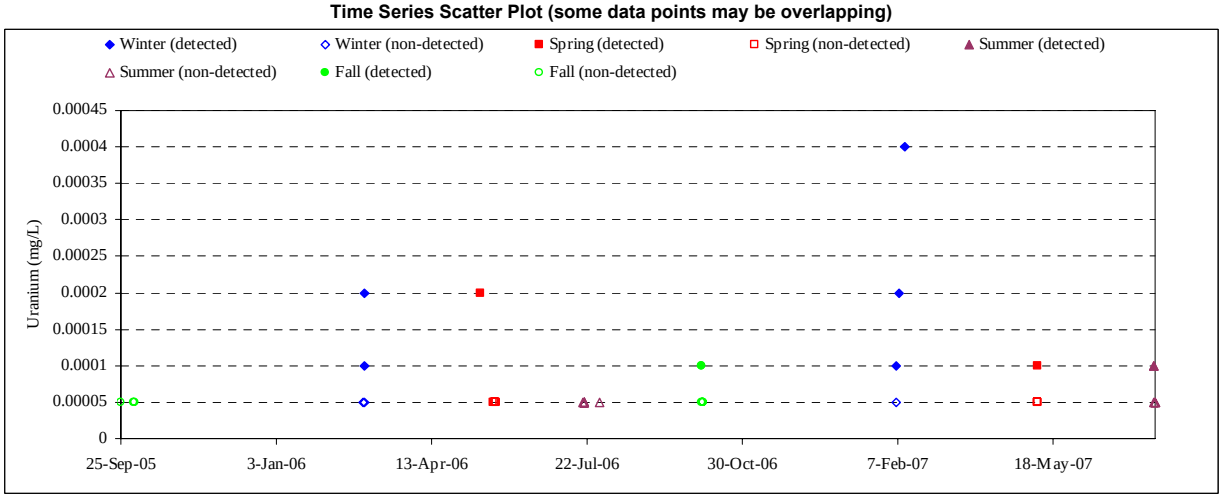
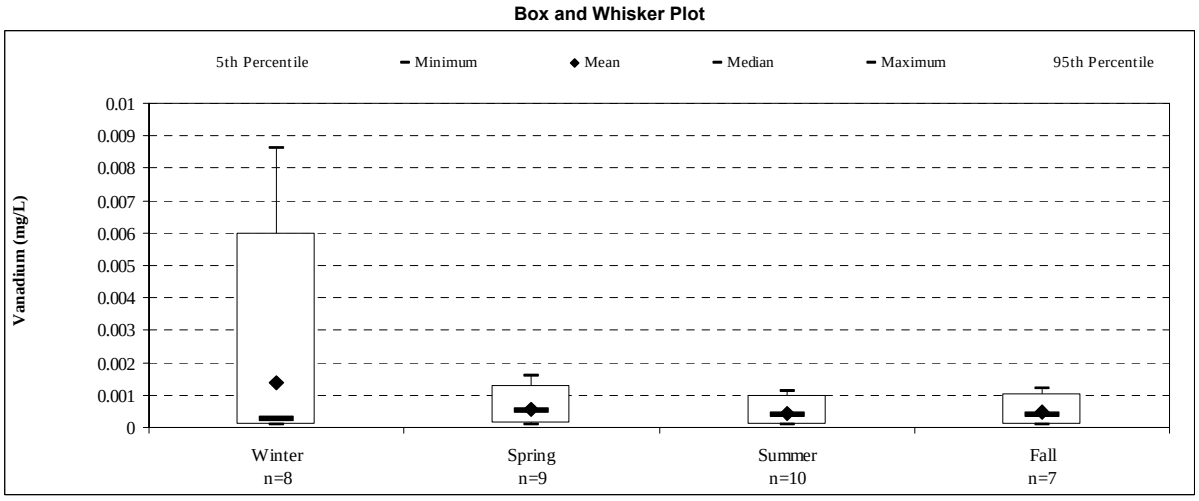


Figure G-3-5-89 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Total) Concentration in Unnamed Lakes within PRMA



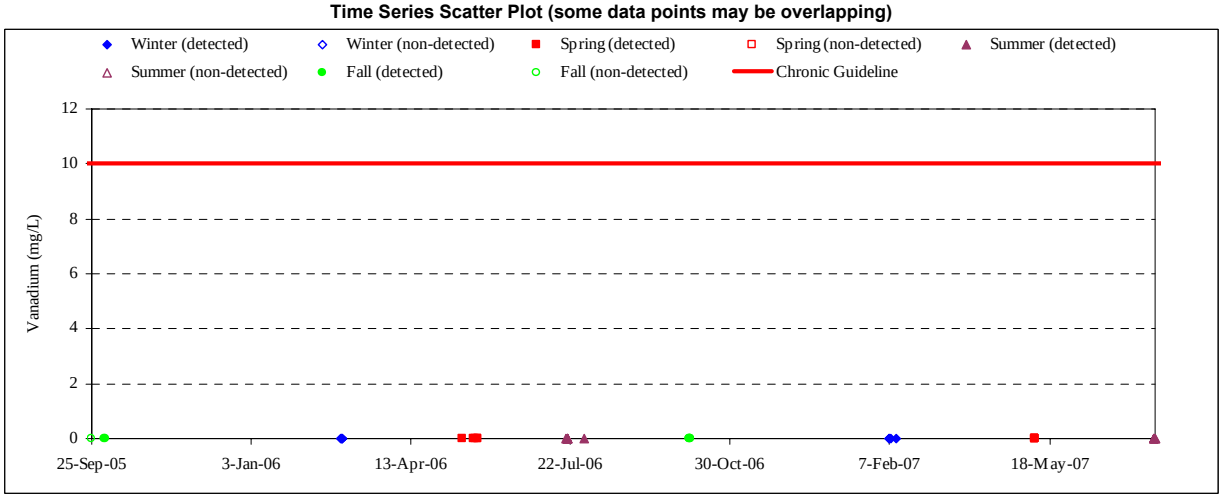
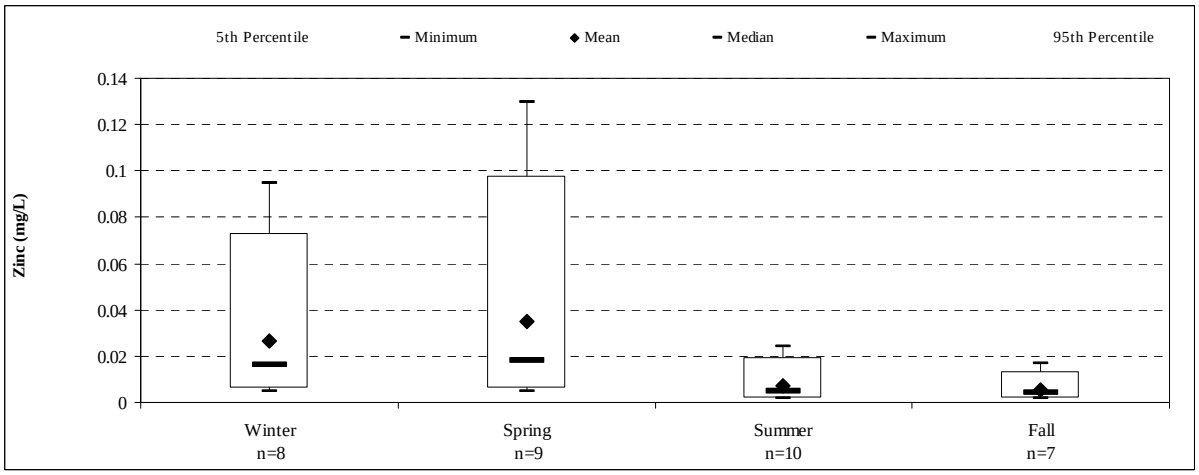


Figure G-3-5-90 Box Whisker and Time Series Scatter Plots of Observed Zinc (Total) Concentration in Unnamed Lakes within PRMA

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

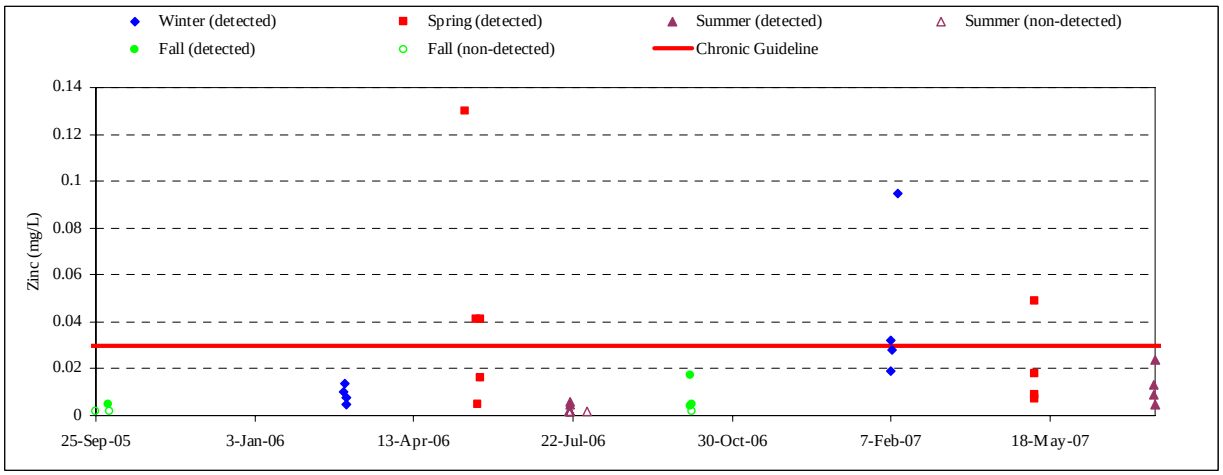
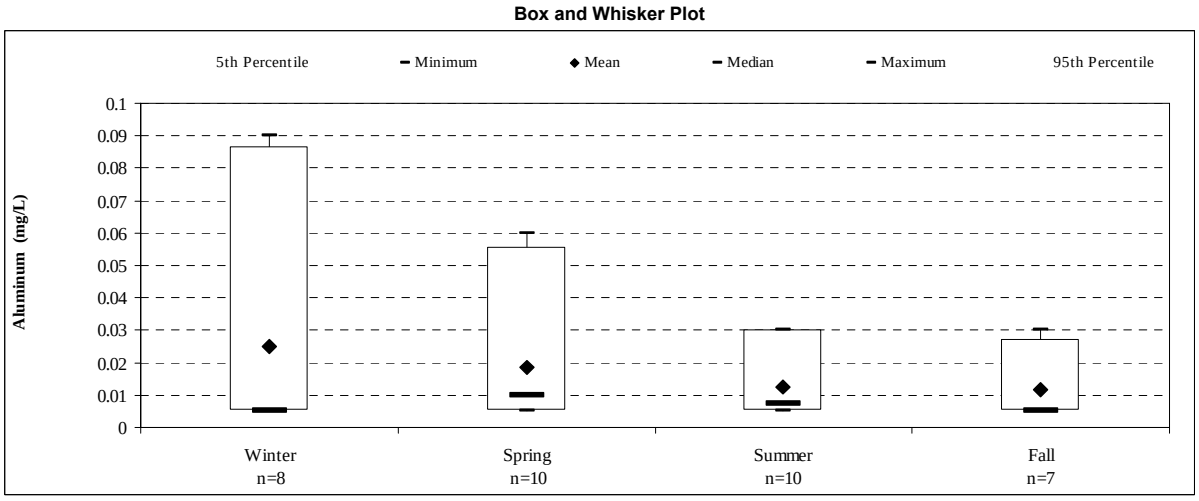


Figure G-3-5-91 Box Whisker and Time Series Scatter Plots of Observed Aluminum (Dissolved) Concentration in Unnamed Lakes within PRMA



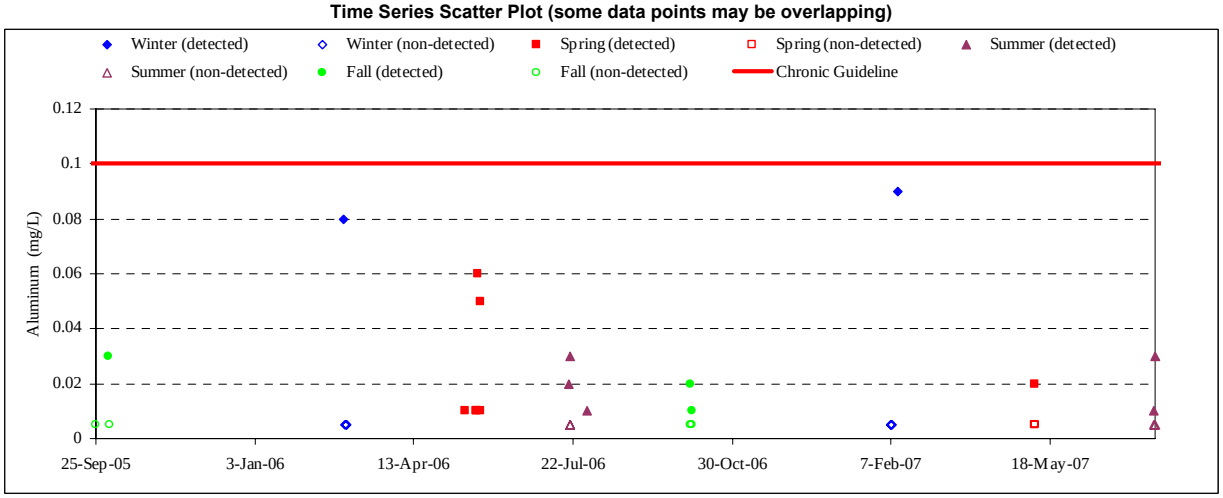
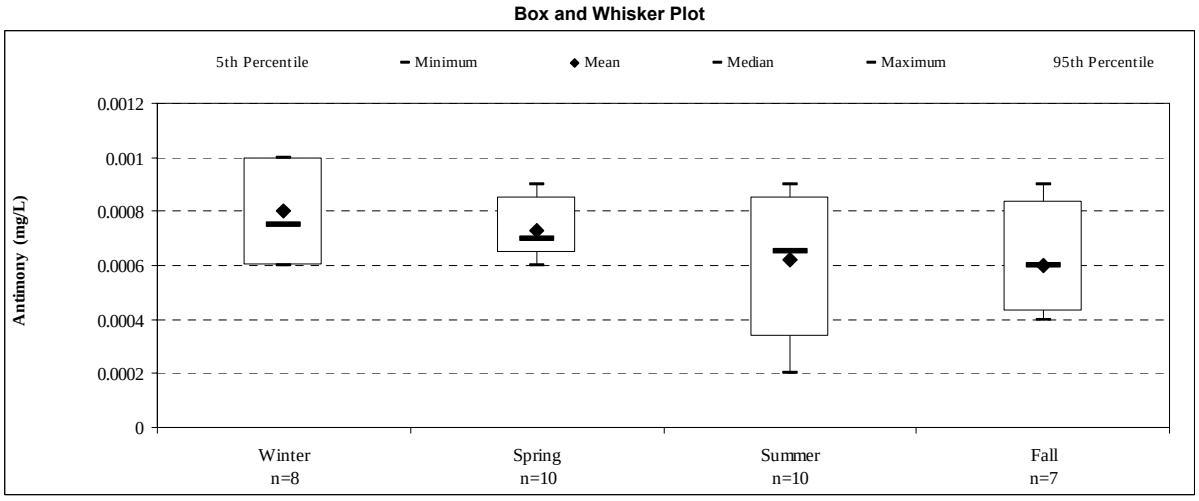


Figure G-3-5-92 Box Whisker and Time Series Scatter Plots of Observed Antimony (Dissolved) Concentration in Unnamed Lakes within PRMA



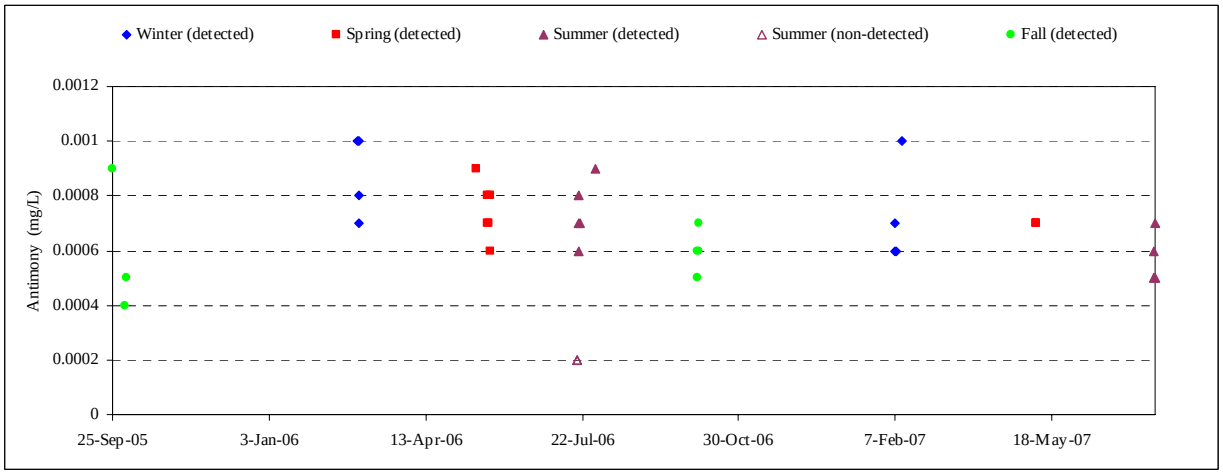


Figure G-3-5-93 Box Whisker and Time Series Scatter Plots of Observed Arsenic (Dissolved) Concentration in Unnamed Lakes within PRMA

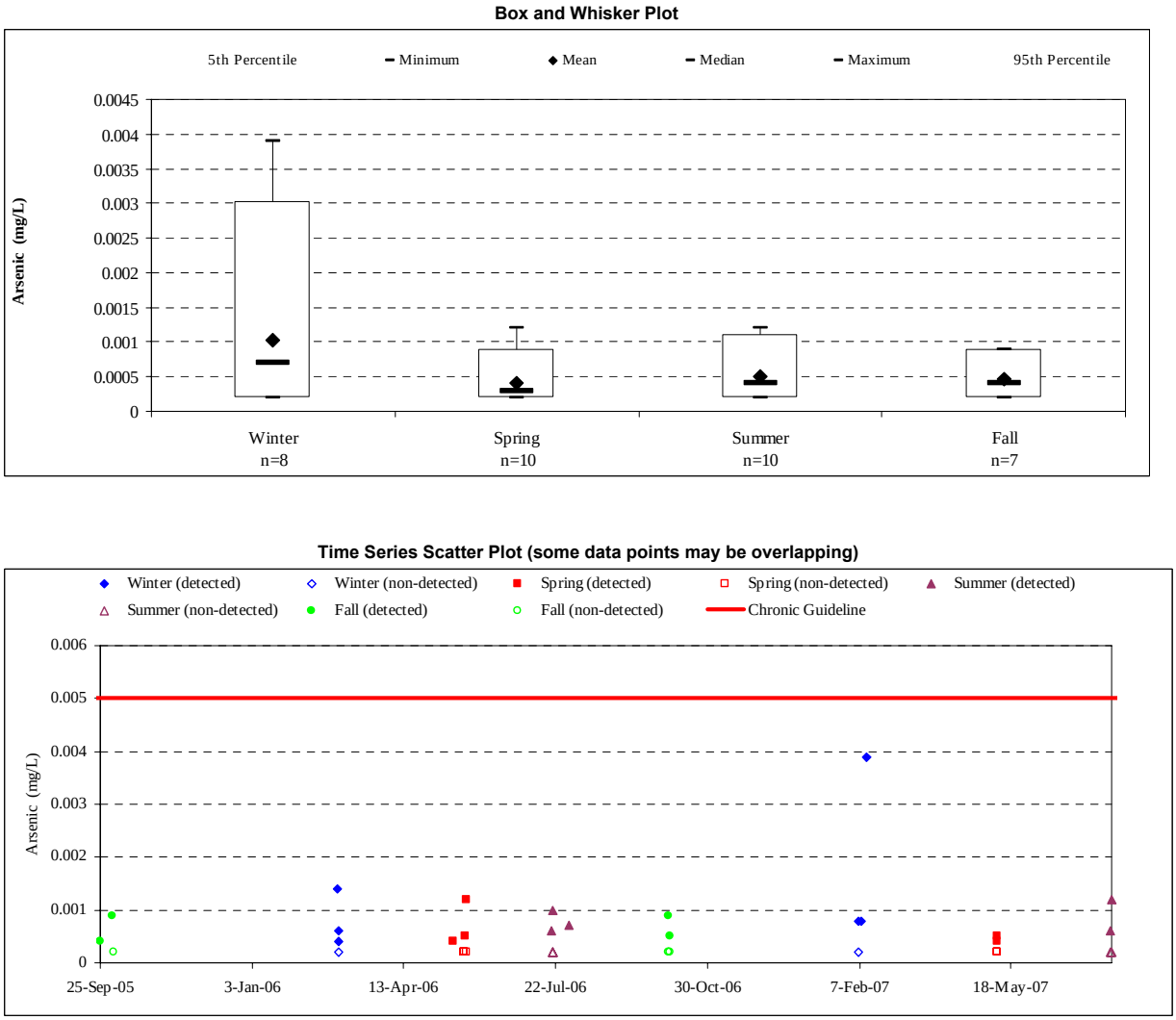
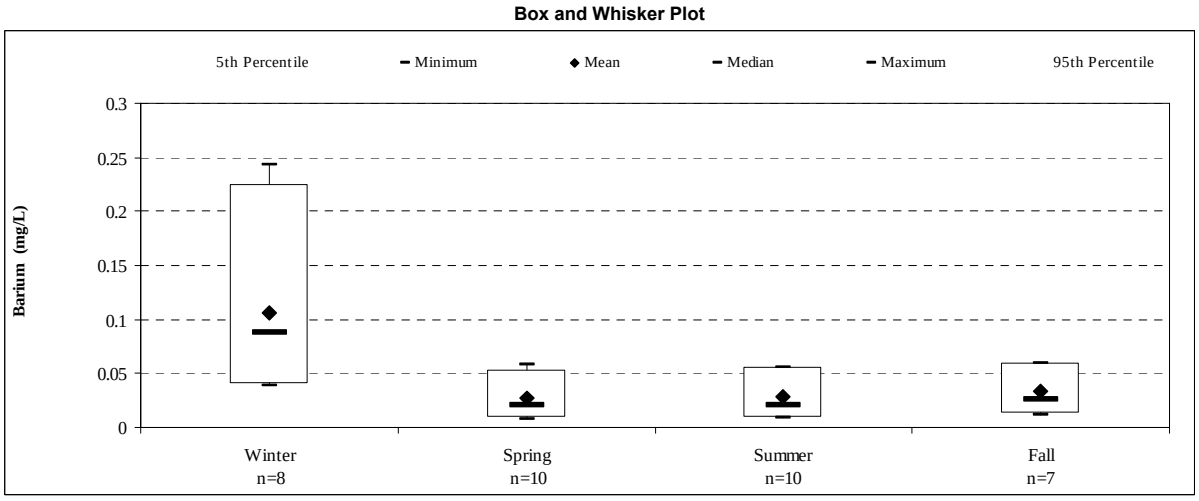


Figure G-3-5-94 Box Whisker and Time Series Scatter Plots of Observed Barium (Dissolved) Concentration in Unnamed Lakes within PRMA



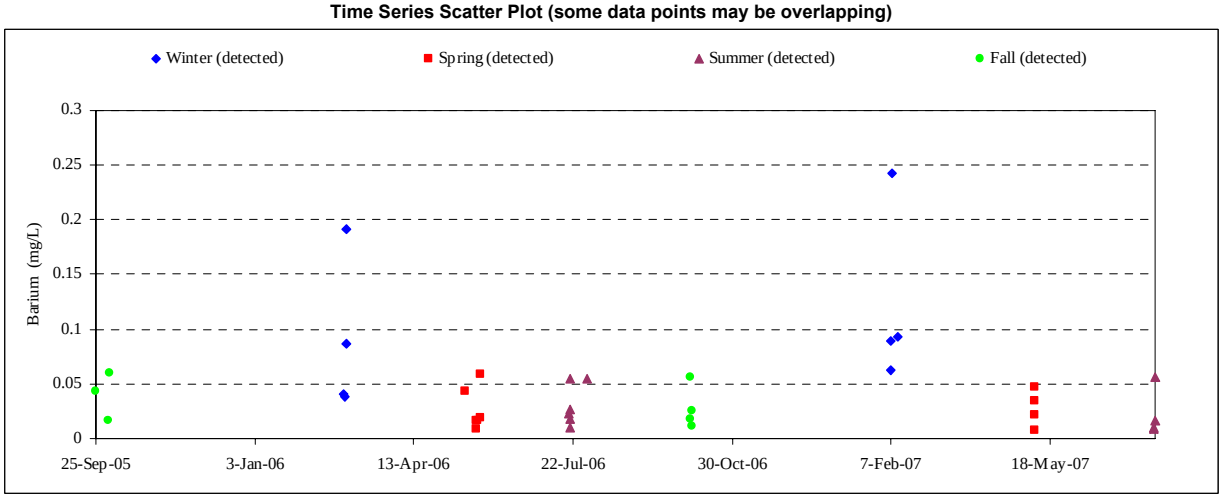
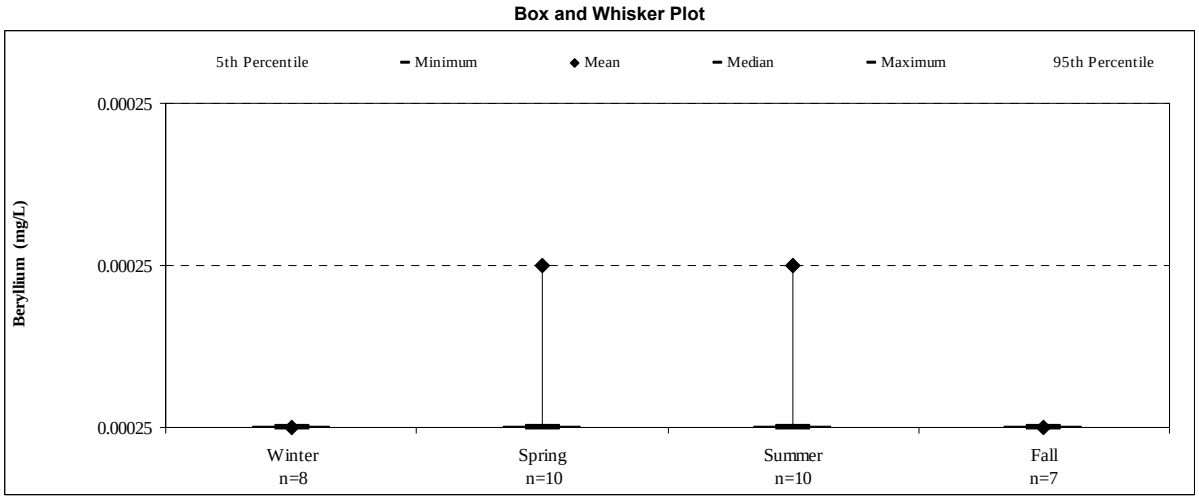


Figure G-3-5-95 Box Whisker and Time Series Scatter Plots of Observed Beryllium (Dissolved) Concentration in Unnamed Lakes within PRMA



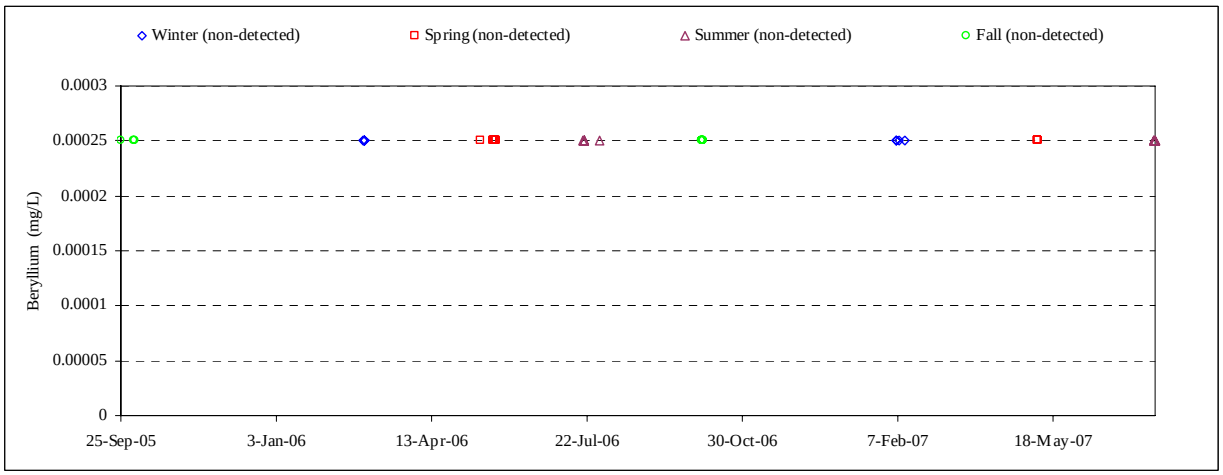
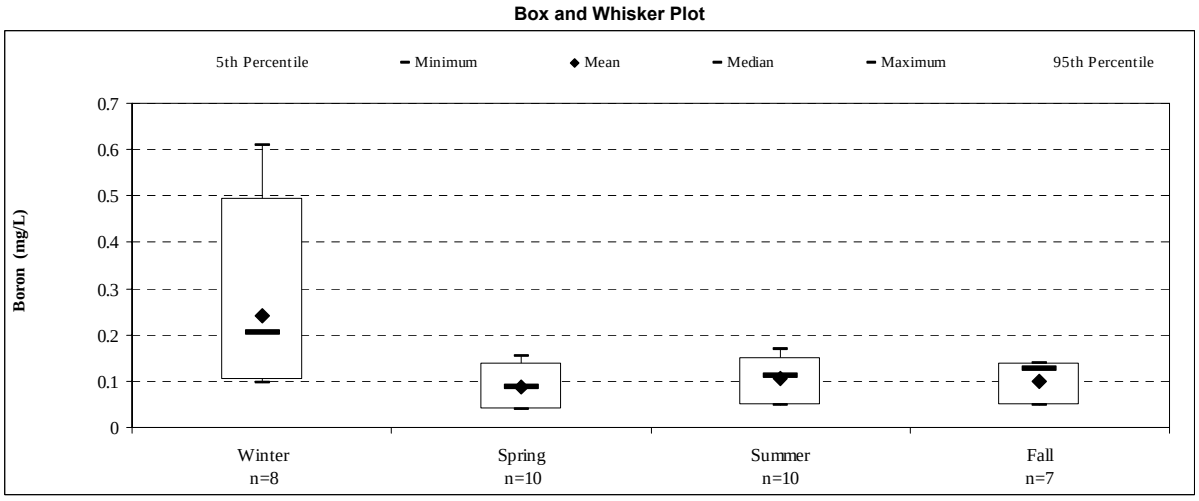


Figure G-3-5-96 Box Whisker and Time Series Scatter Plots of Observed Boron (Dissolved) Concentration in Unnamed Lakes within PRMA



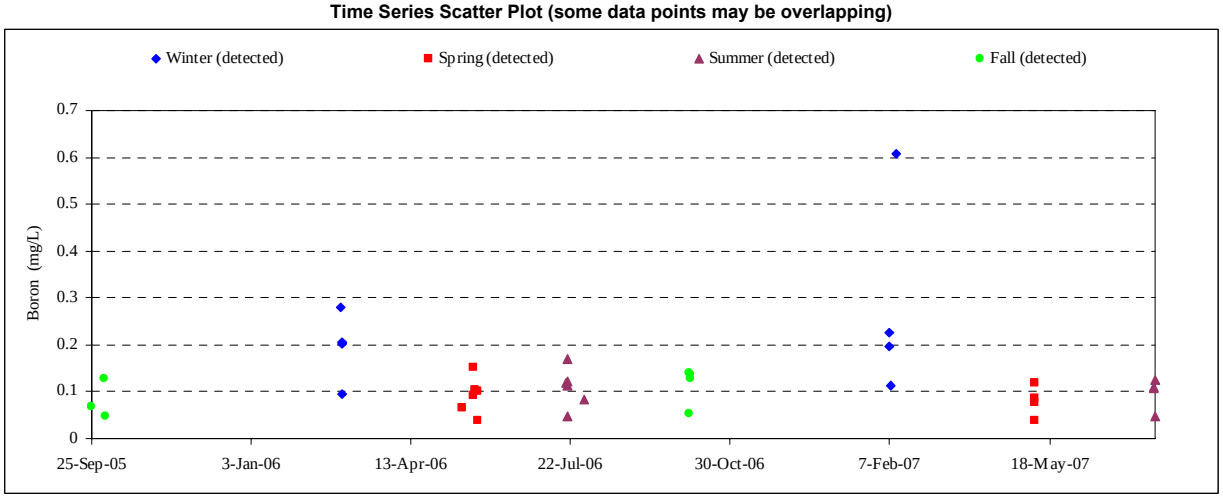
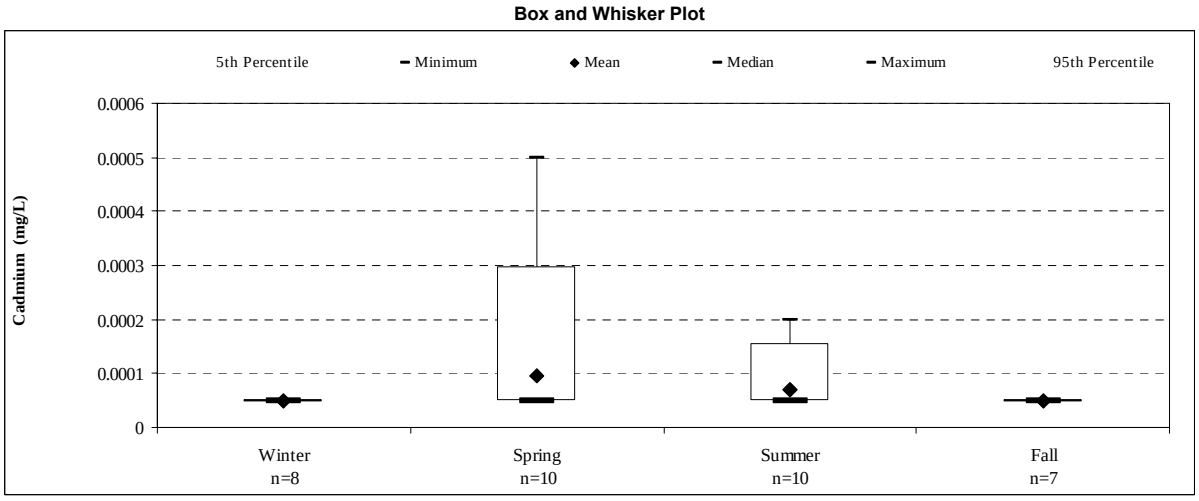


Figure G-3-5-97 Box Whisker and Time Series Scatter Plots of Observed Cadmium (Dissolved) Concentration in Unnamed Lakes within PRMA



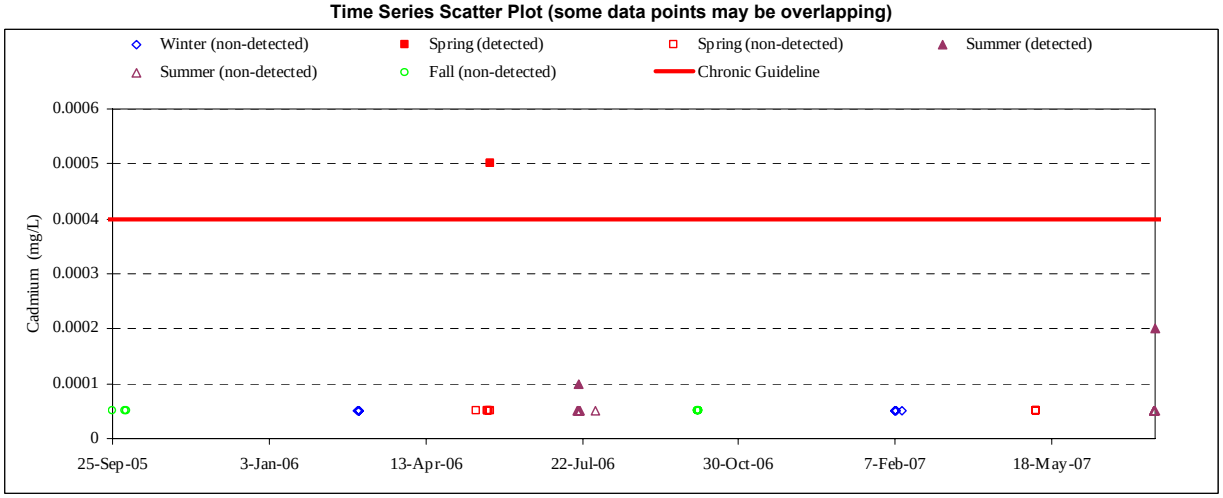


Figure G-3-5-98 Box Whisker and Time Series Scatter Plots of Observed Chromium (Dissolved) Concentration in Unnamed Lakes withir PRMA

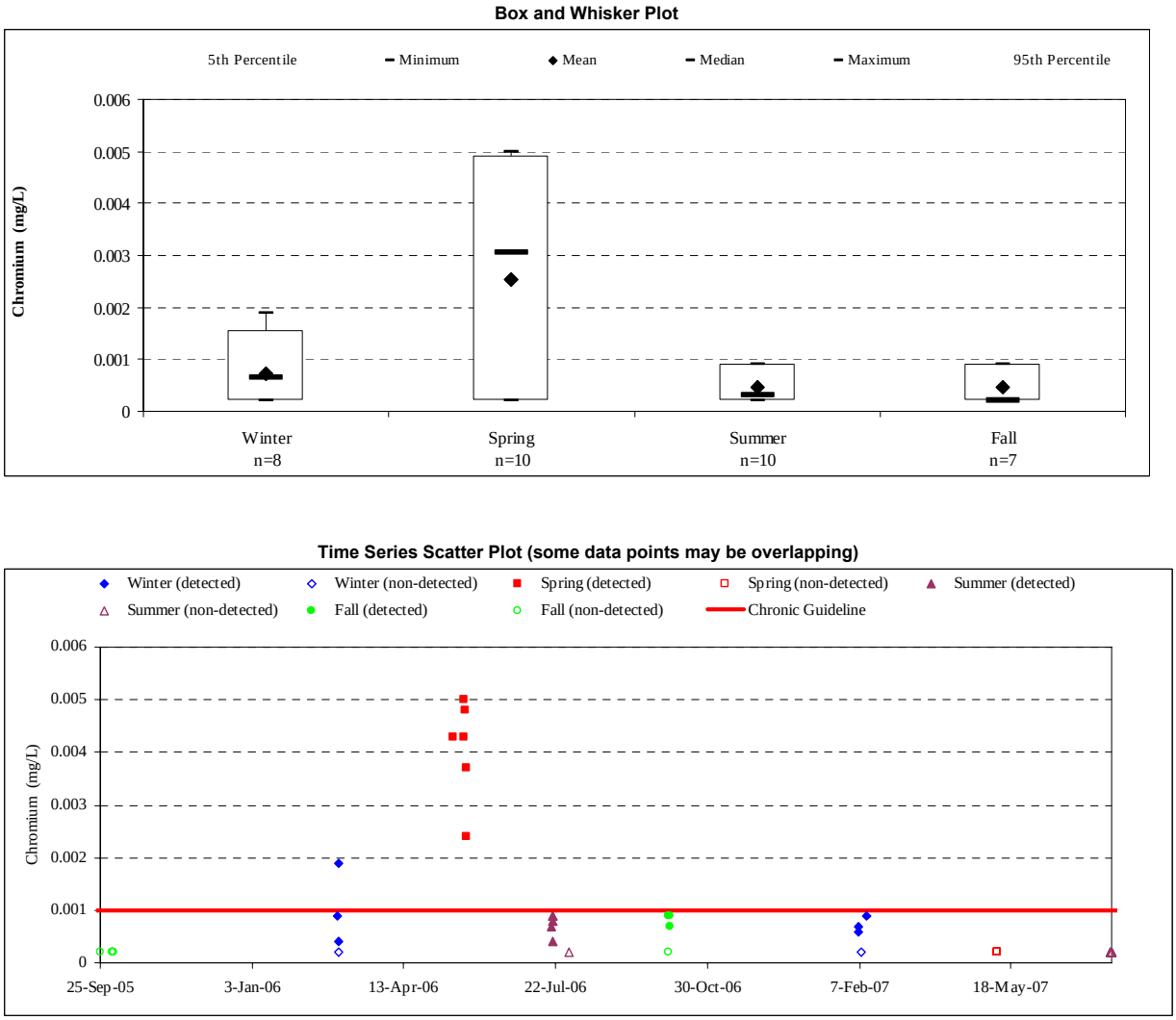
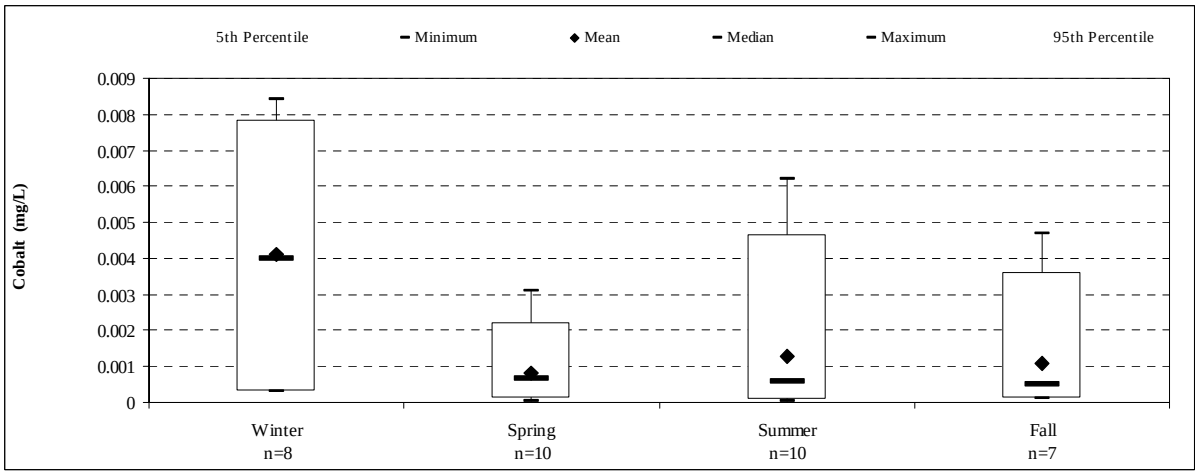


Figure G-3-5-100 Box Whisker and Time Series Scatter Plots of Observed Cobalt (Dissolved) Concentration in Unnamed Lakes within PRMA

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

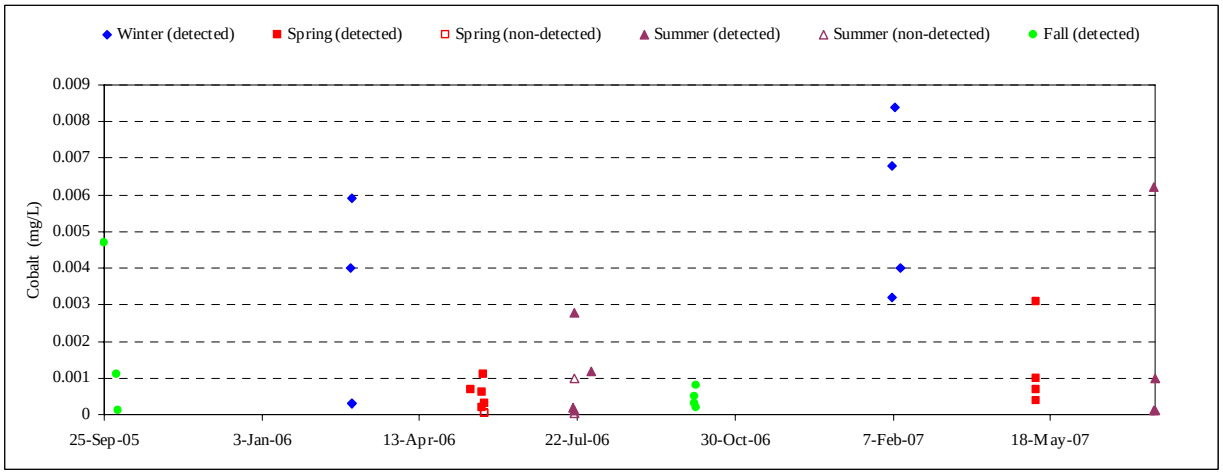
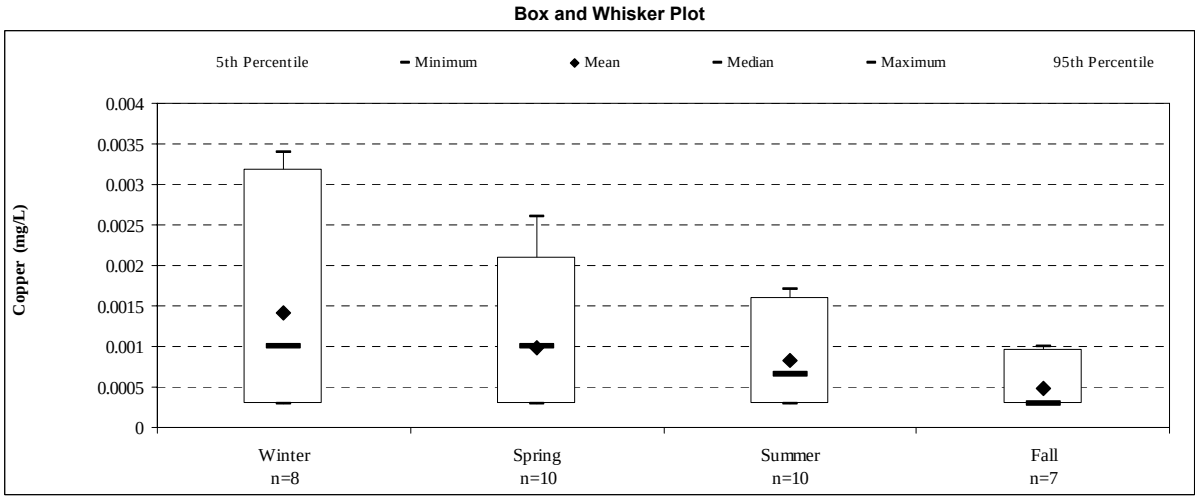


Figure G-3-5-101 Box Whisker and Time Series Scatter Plots of Observed Copper (Dissolved) Concentration in Unnamed Lakes within PRMA



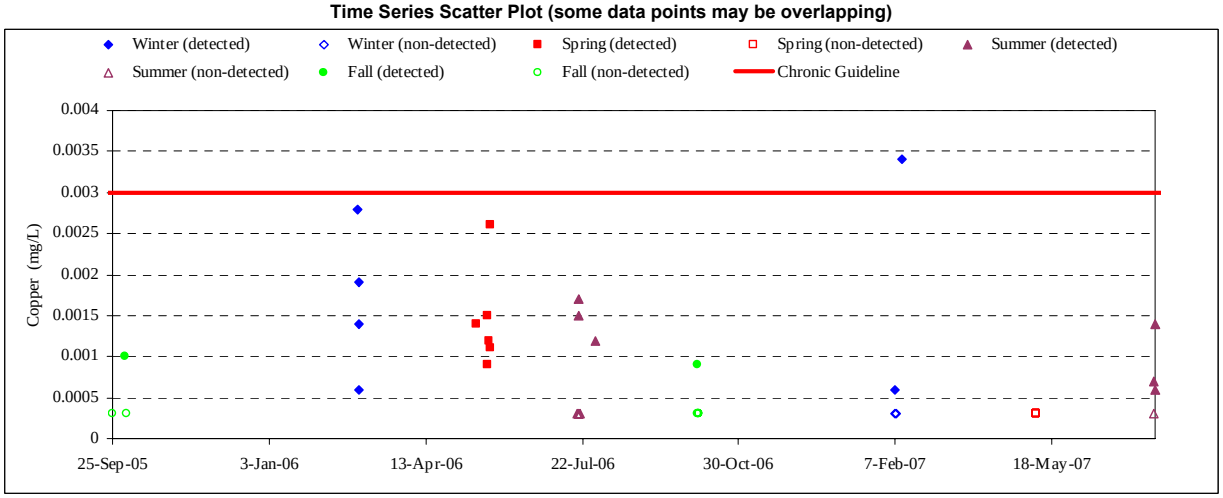
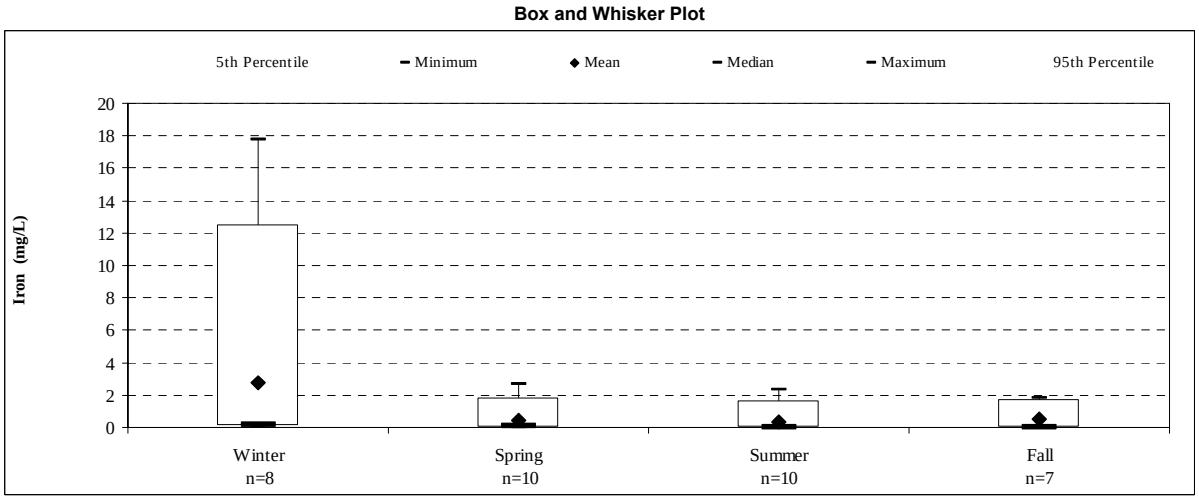


Figure G-3-5-102 Box Whisker and Time Series Scatter Plots of Observed Iron (Dissolved) Concentration in Unnamed Lakes within PRMA



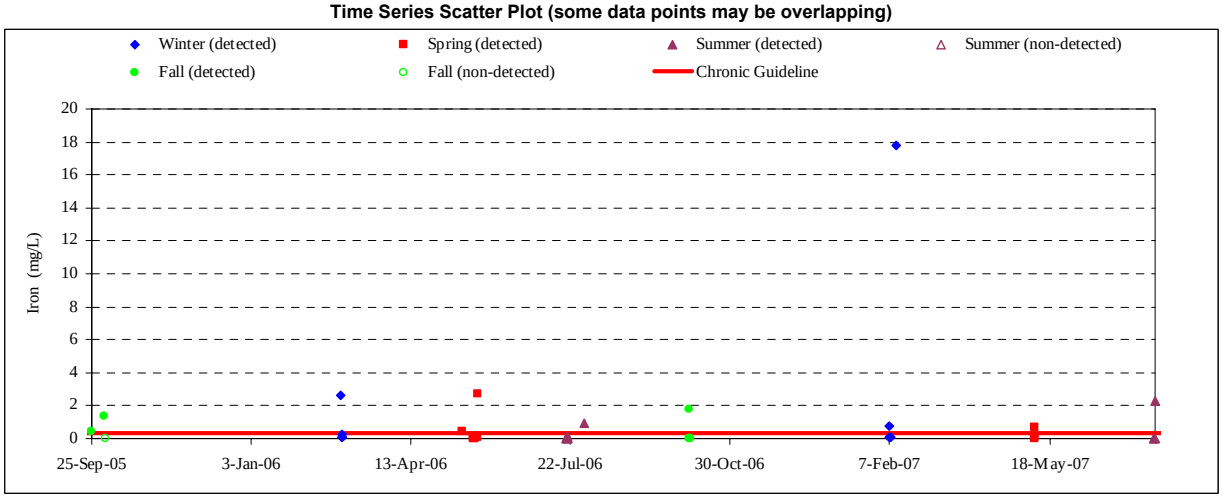
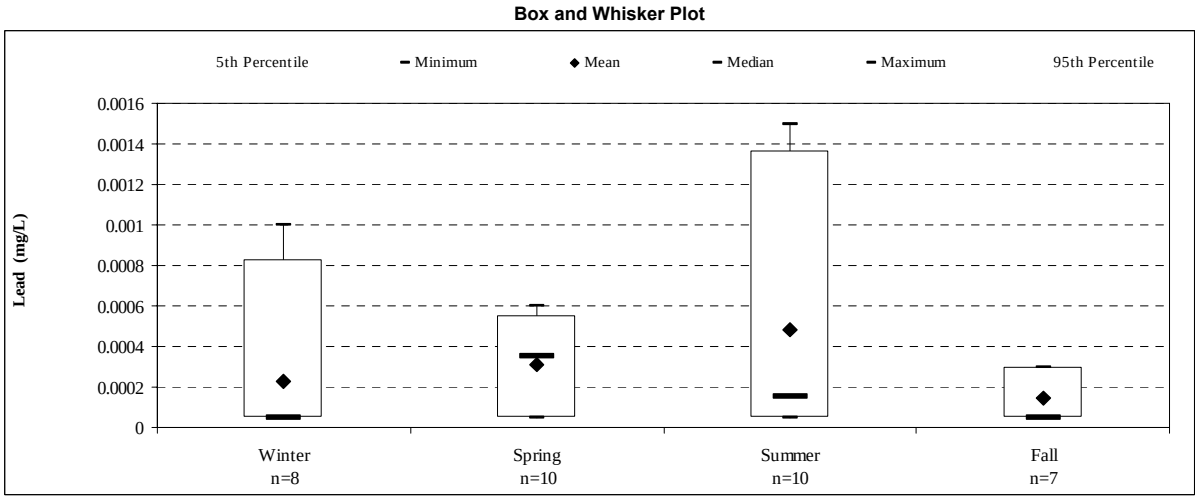


Figure G-3-5-103 Box Whisker and Time Series Scatter Plots of Observed Lead (Dissolved) Concentration in Unnamed Lakes within PRMA



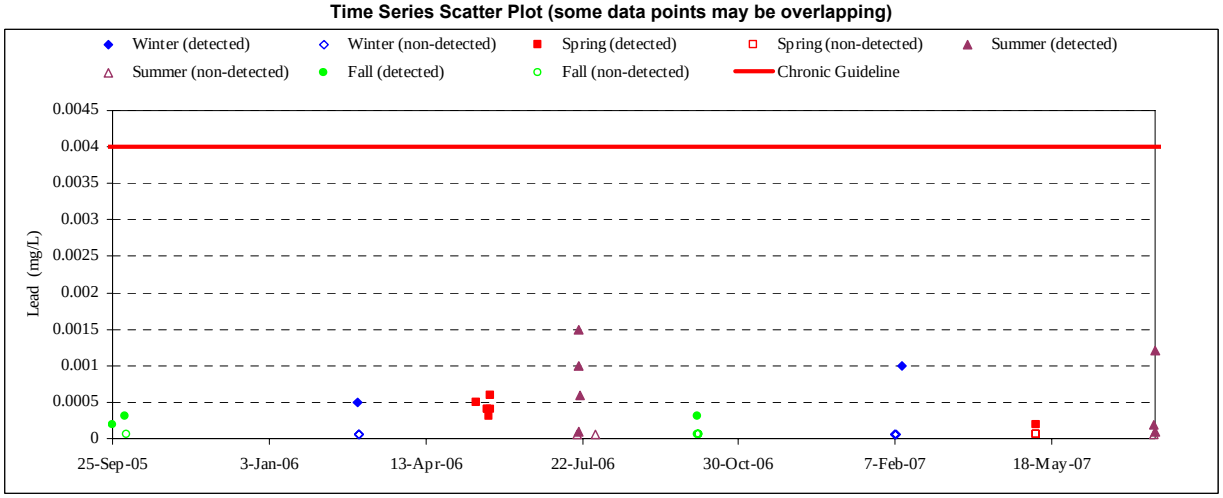
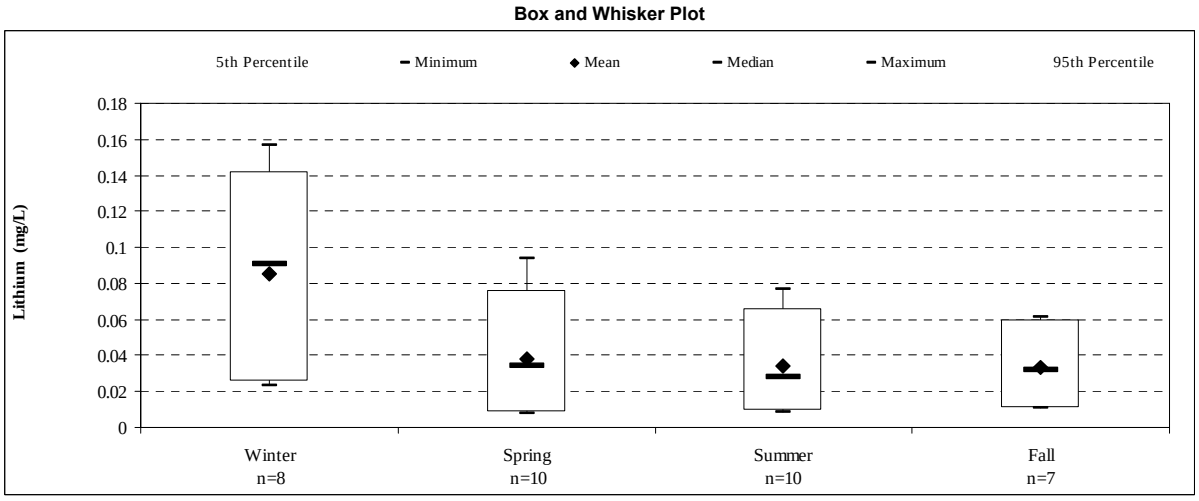


Figure G-3-5-104 Box Whisker and Time Series Scatter Plots of Observed Lithium (Dissolved) Concentration in Unnamed Lakes within PRMA



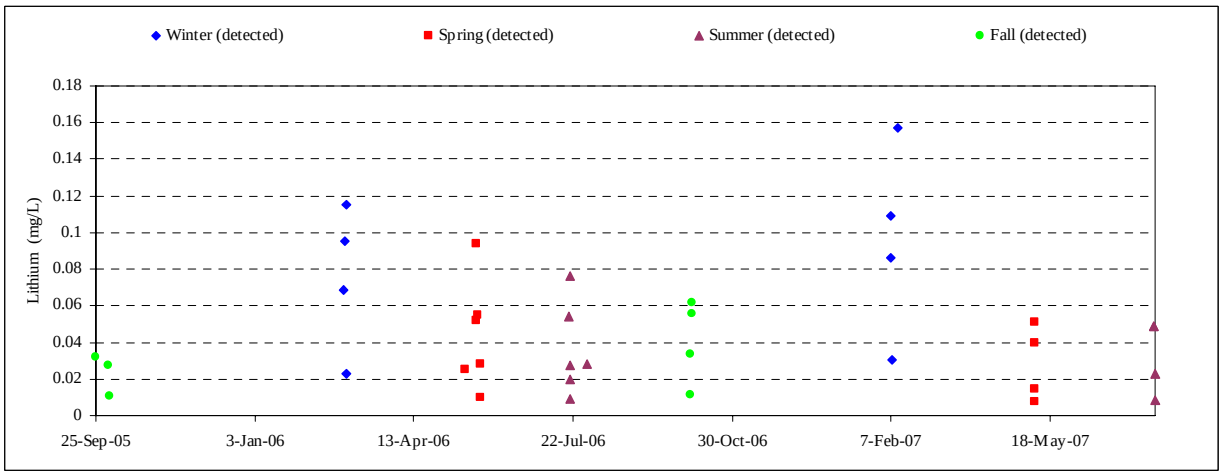
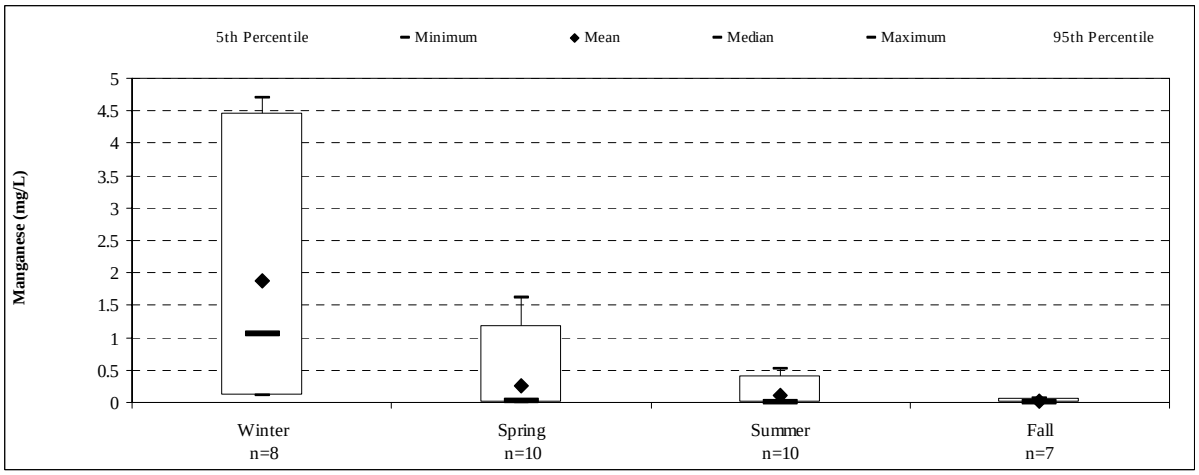


Figure G-3-5-105 Box Whisker and Time Series Scatter Plots of Observed Manganese (Dissolved) Concentration in Unnamed Lakes within PRMA

Box and Whisker Plot



Time Series Scatter Plot (some data points may be overlapping)

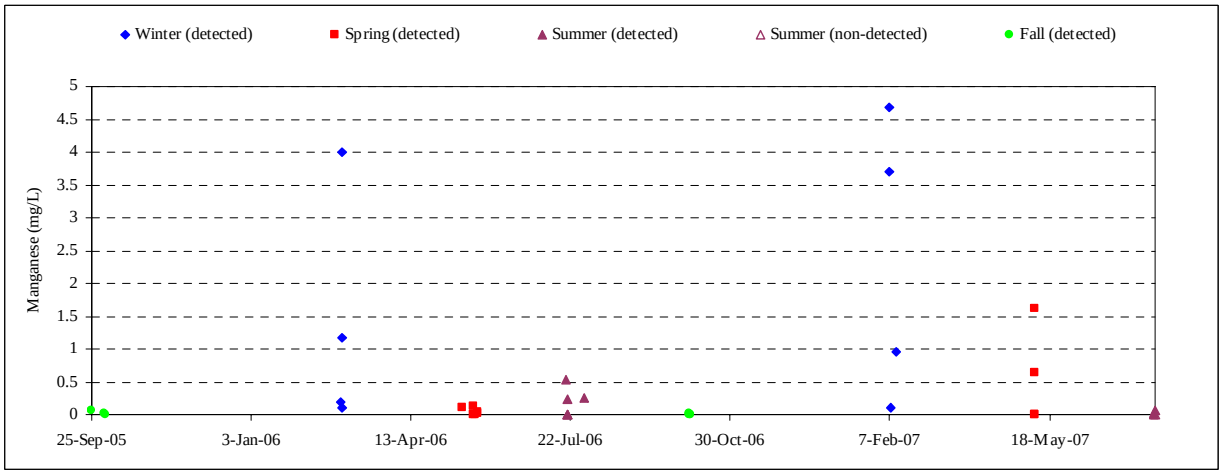
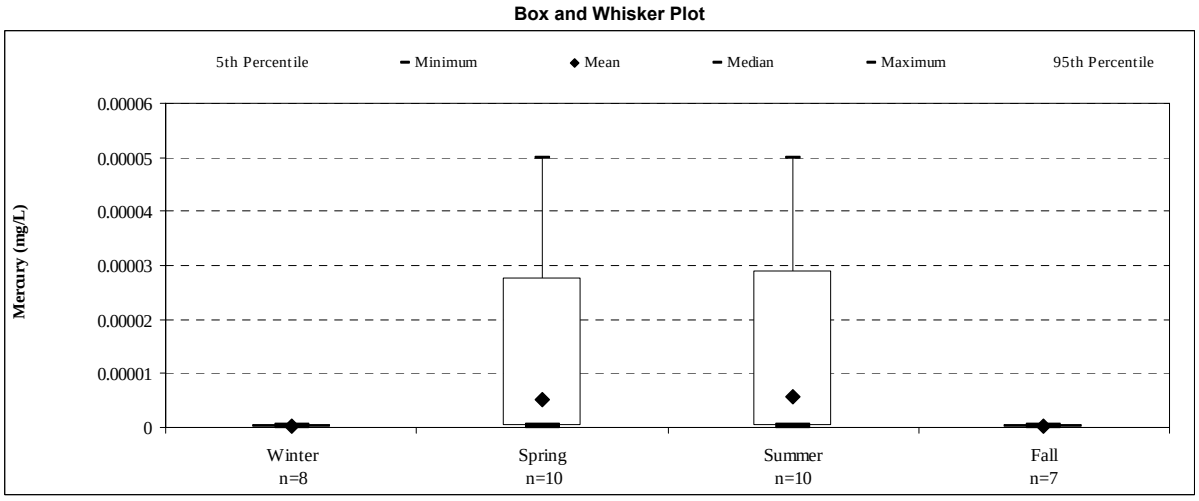


Figure G-3-5-106 Box Whisker and Time Series Scatter Plots of Observed Mercury (Dissolved) Concentration in Unnamed Lakes within PRMA



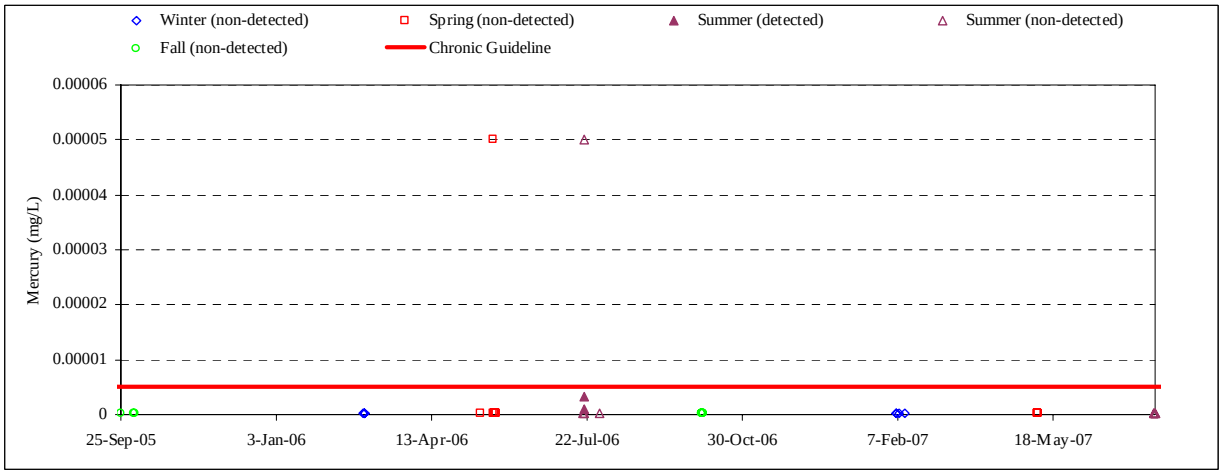
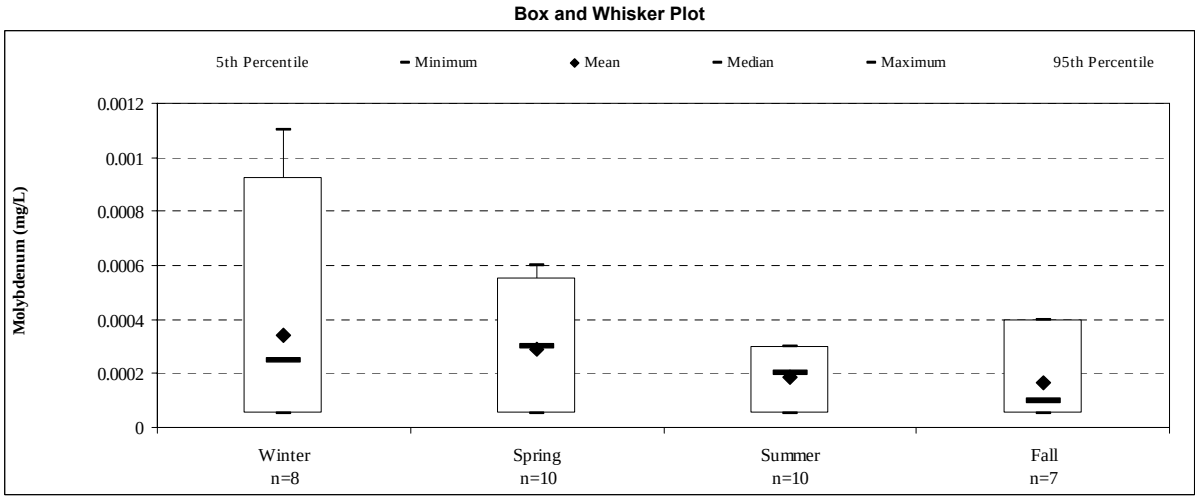


Figure G-3-5-107 Box Whisker and Time Series Scatter Plots of Observed Molybdenum (Dissolved) Concentration in Unnamed Lakes within PRMA



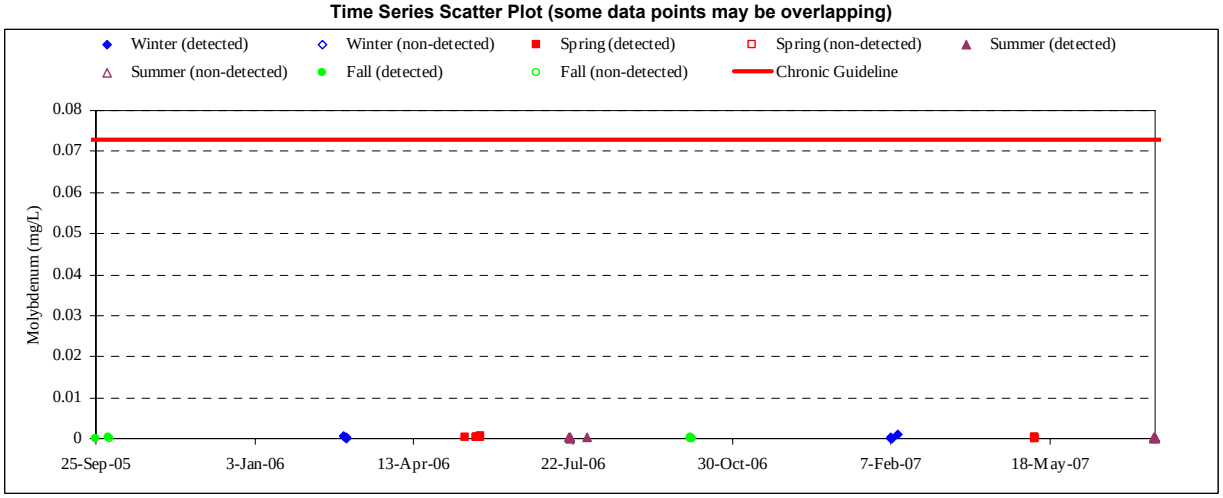
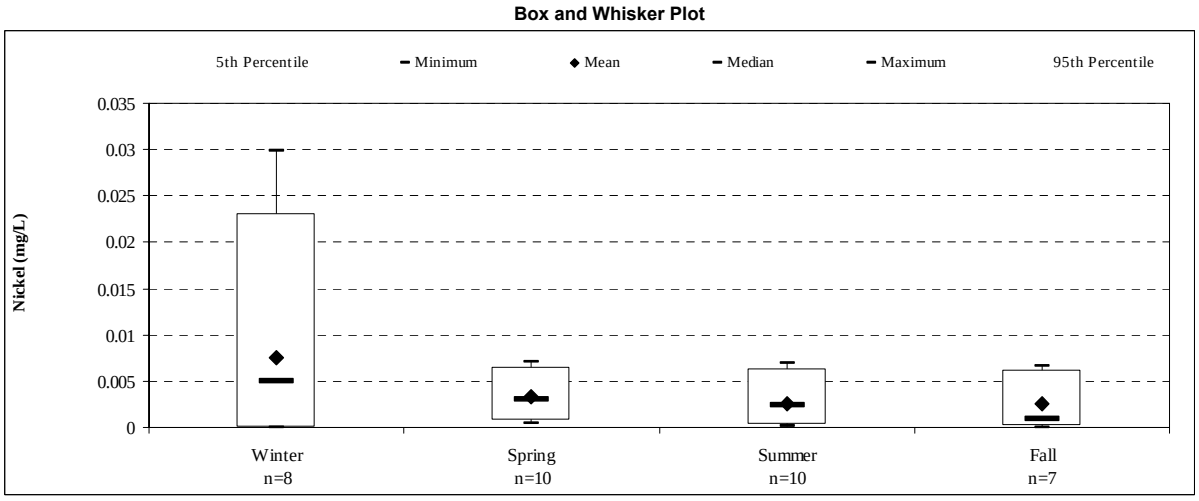


Figure G-3-5-108 Box Whisker and Time Series Scatter Plots of Observed Nickel (Dissolved) Concentration in Unnamed Lakes within PRMA



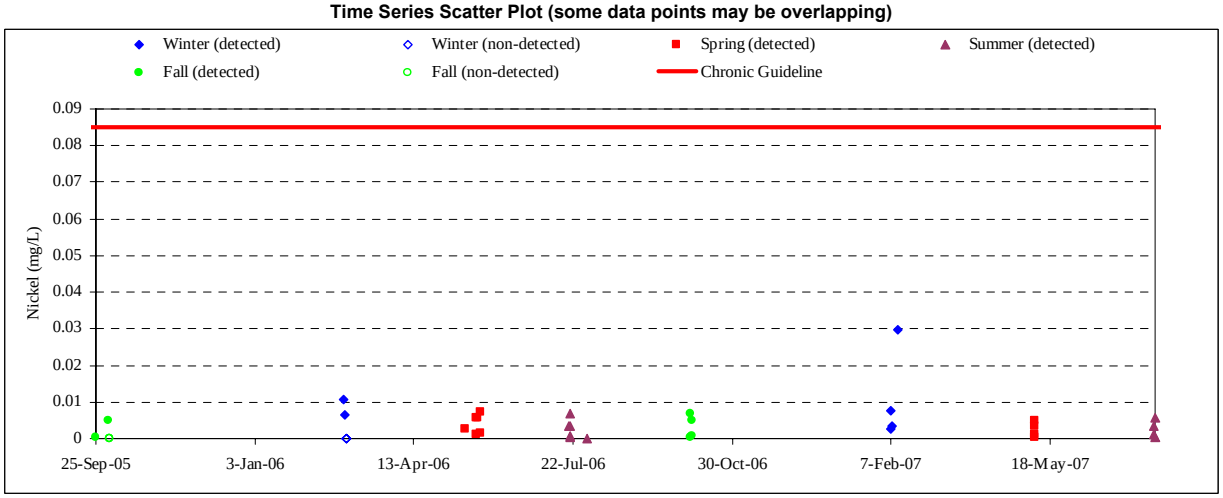
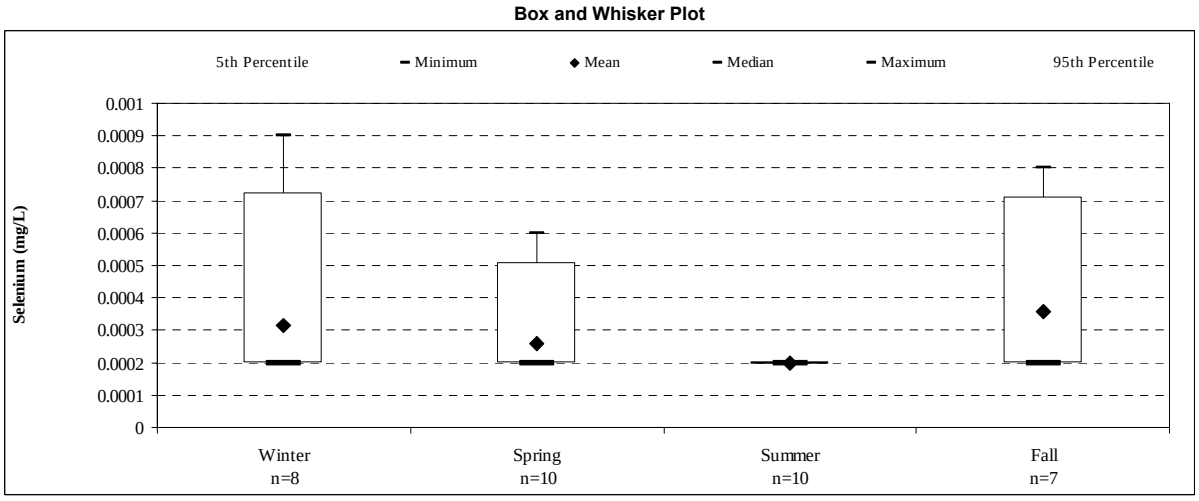


Figure G-3-5-109 Box Whisker and Time Series Scatter Plots of Observed Selenium (Dissolved) Concentration in Unnamed Lakes within PRMA



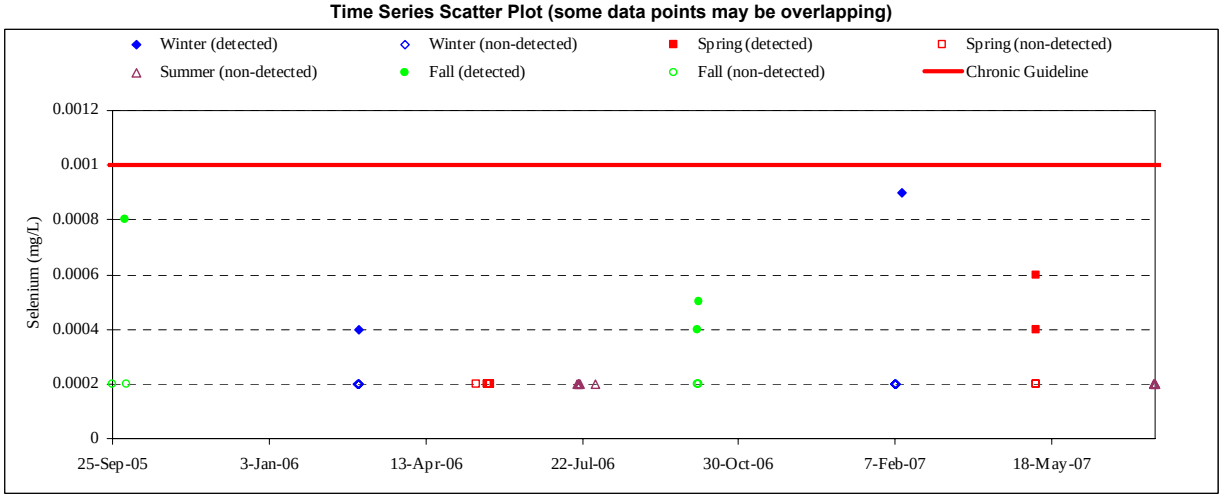
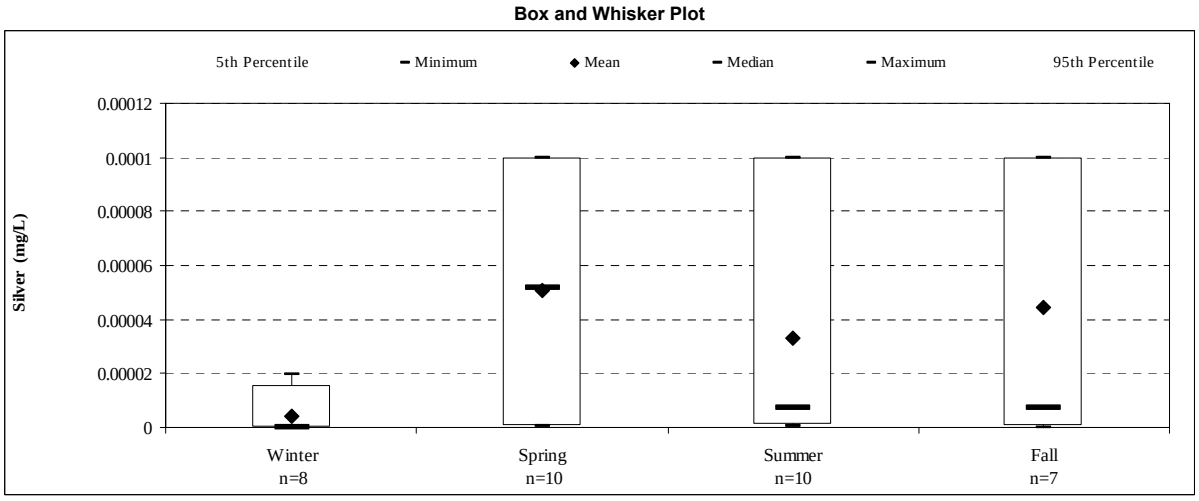


Figure G-3-5-111 Box Whisker and Time Series Scatter Plots of Observed Silver (Dissolved) Concentration in Unnamed Lakes within PRMA



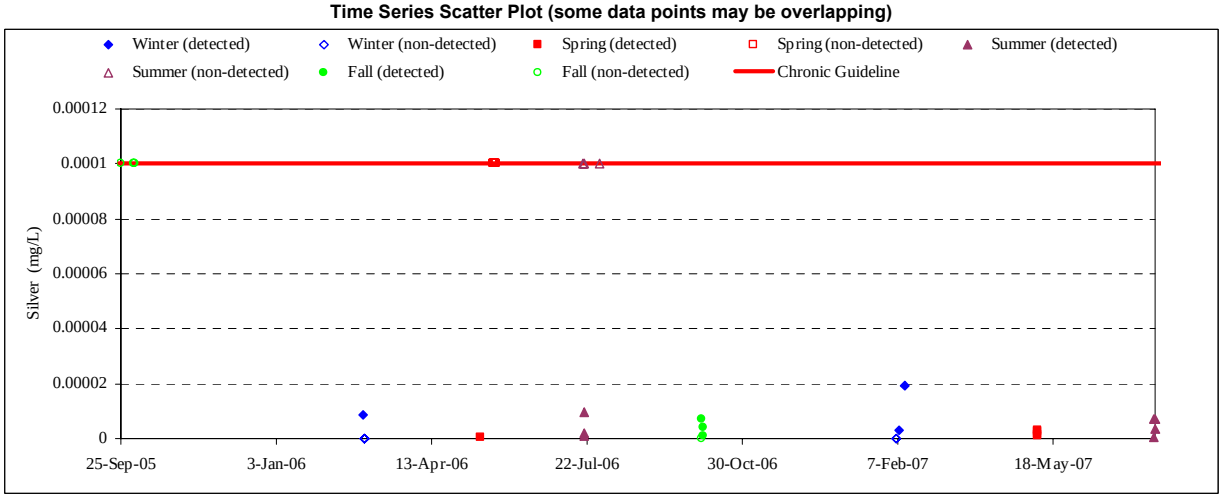
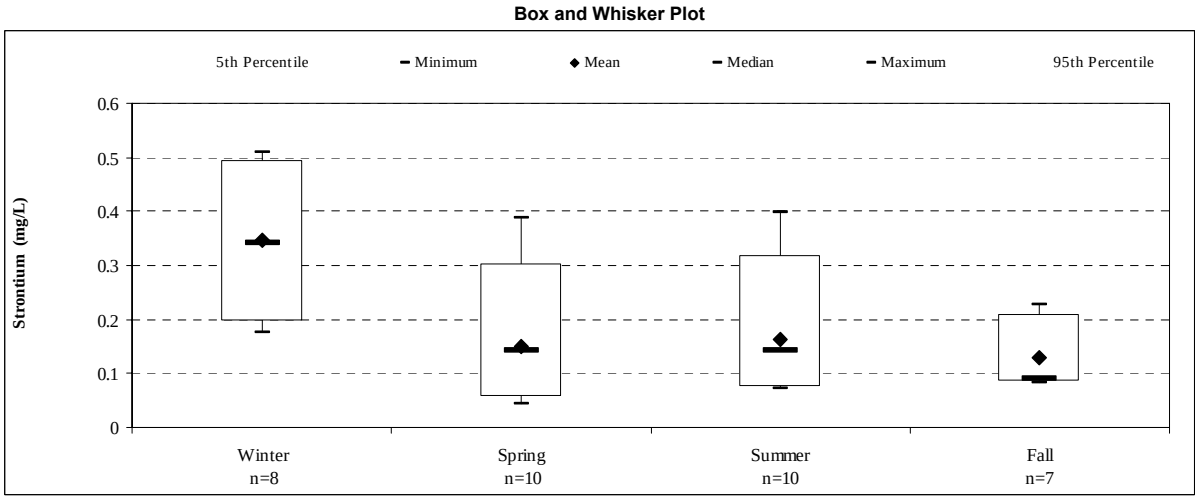


Figure G-3-5-112 Box Whisker and Time Series Scatter Plots of Observed Strontium (Dissolved) Concentration in Unnamed Lakes within PRMA



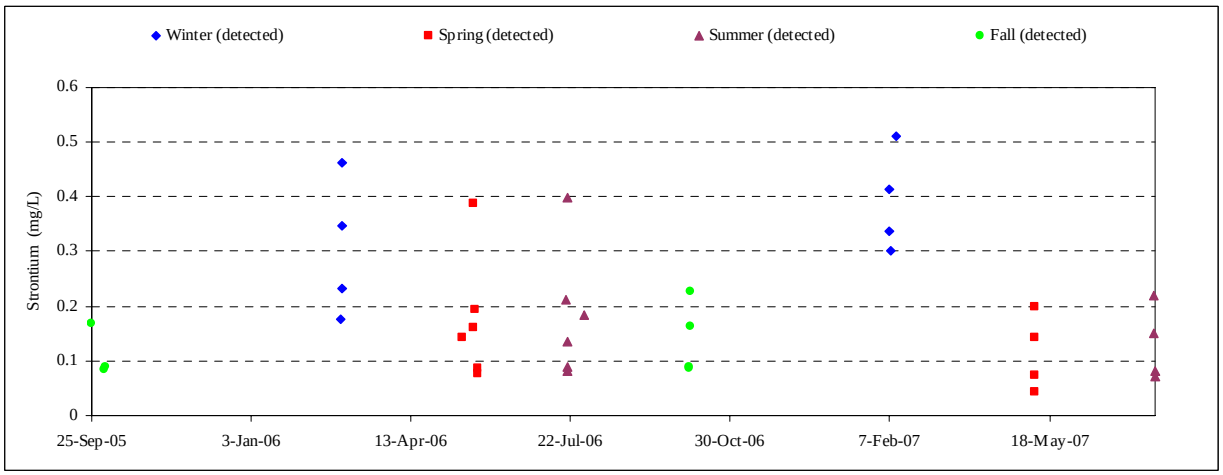
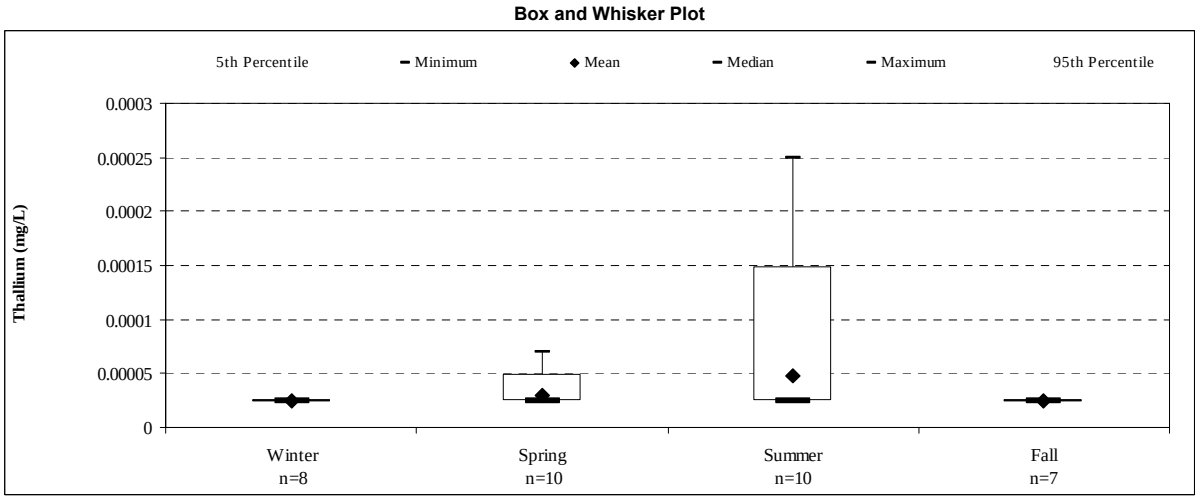


Figure G-3-5-114 Box Whisker and Time Series Scatter Plots of Observed Thallium (Dissolved) Concentration in Unnamed Lakes within PRMA



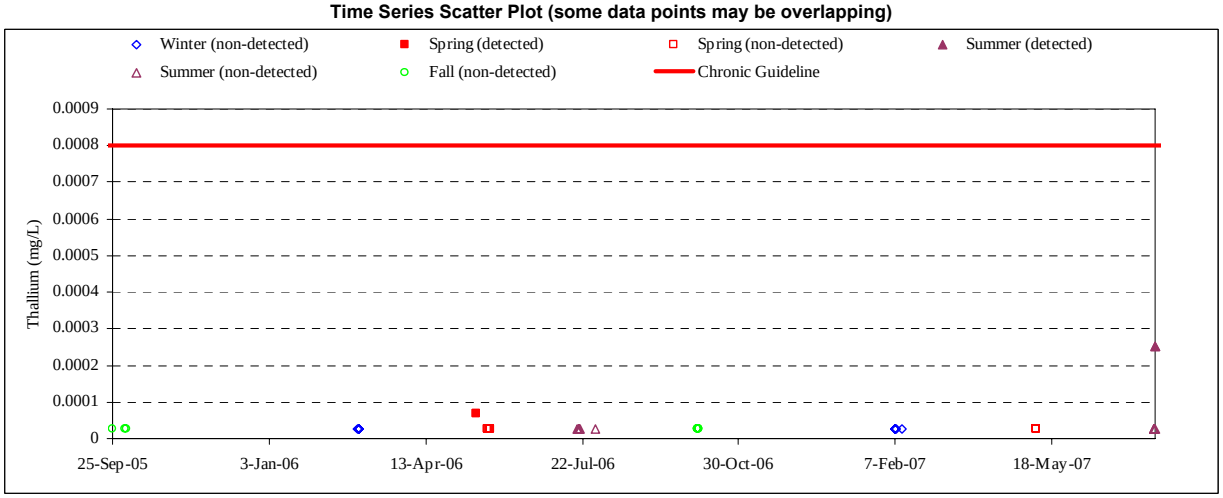
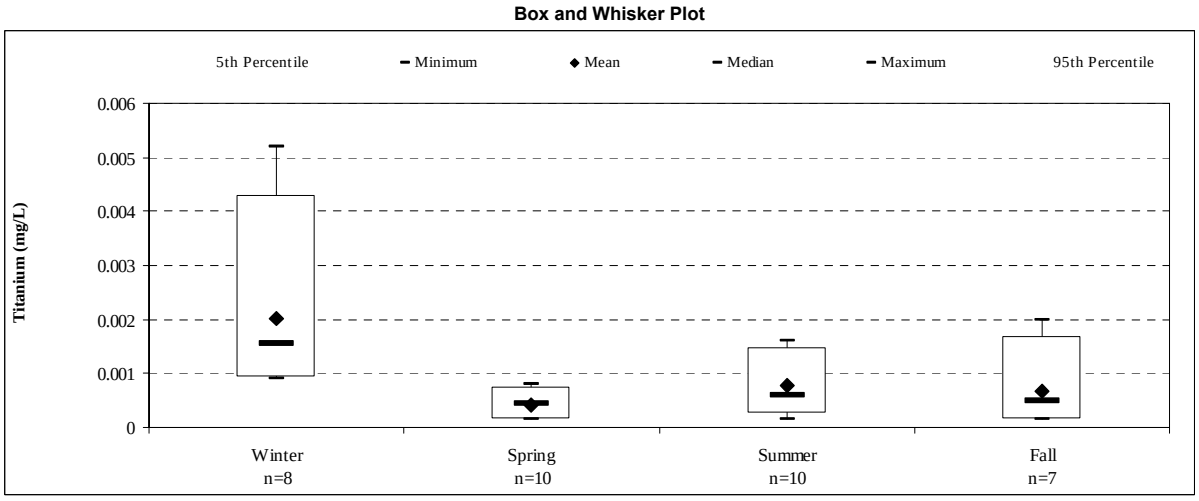


Figure G-3-5-115 Box Whisker and Time Series Scatter Plots of Observed Titanium (Dissolved) Concentration in Unnamed Lakes within PRMA



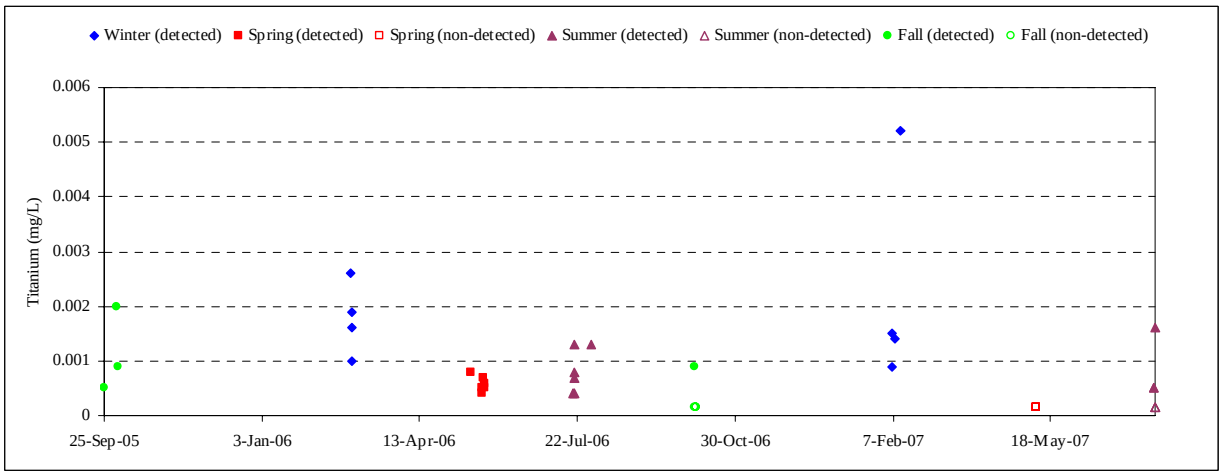
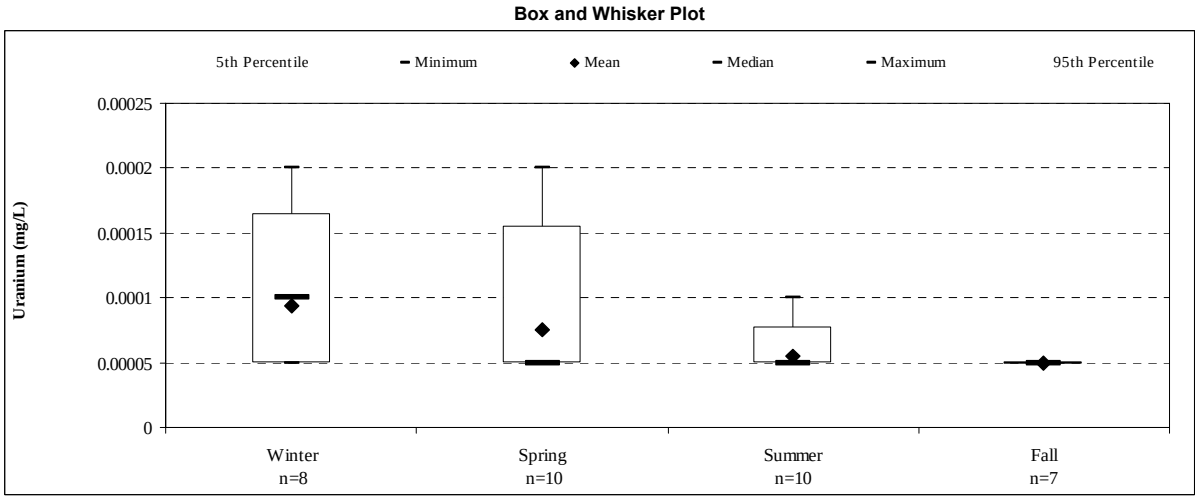


Figure G-3-5-116 Box Whisker and Time Series Scatter Plots of Observed Uranium (Dissolved) Concentration in Unnamed Lakes within PRMA



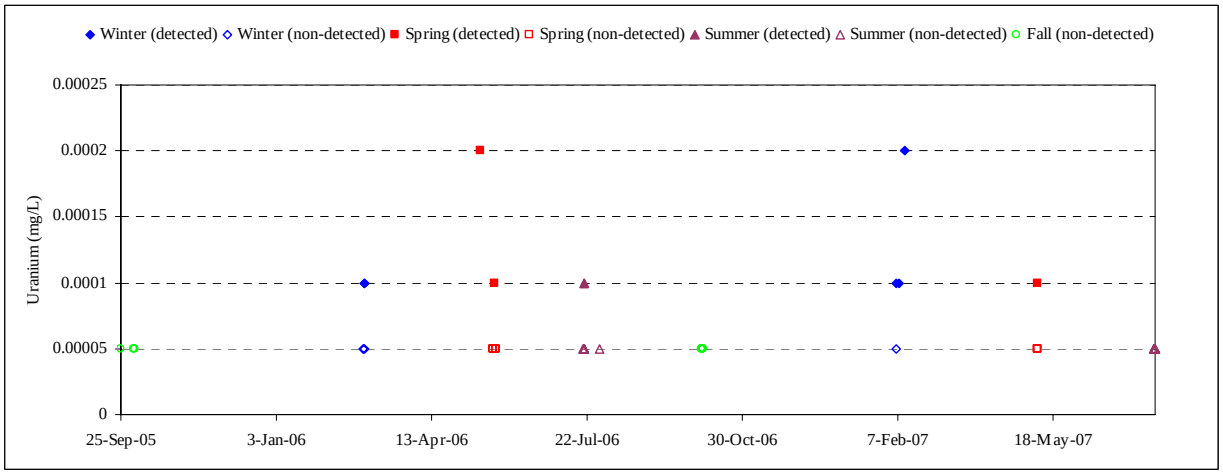
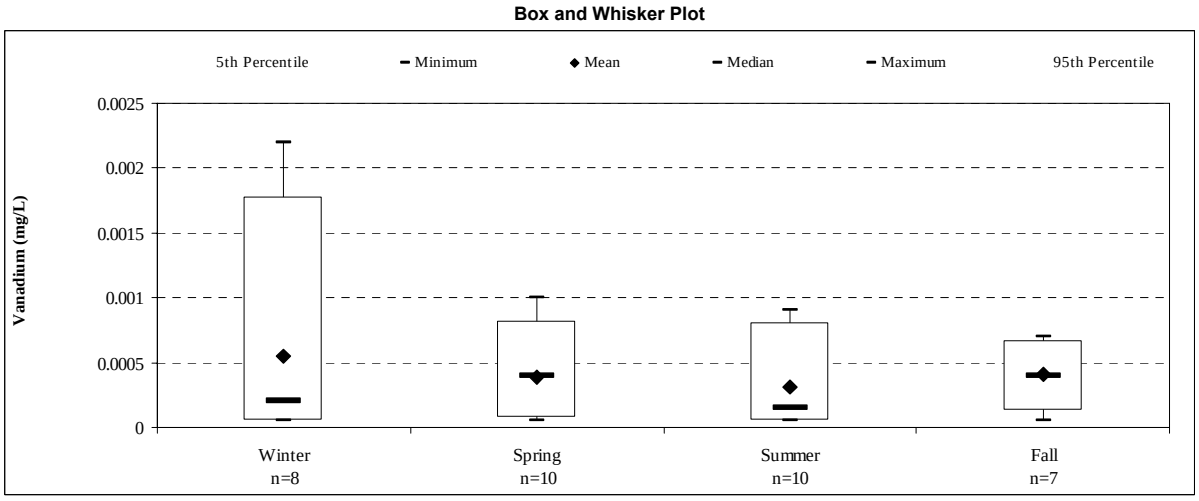


Figure G-3-5-117 Box Whisker and Time Series Scatter Plots of Observed Vanadium (Dissolved) Concentration in Unnamed Lakes within PRMA



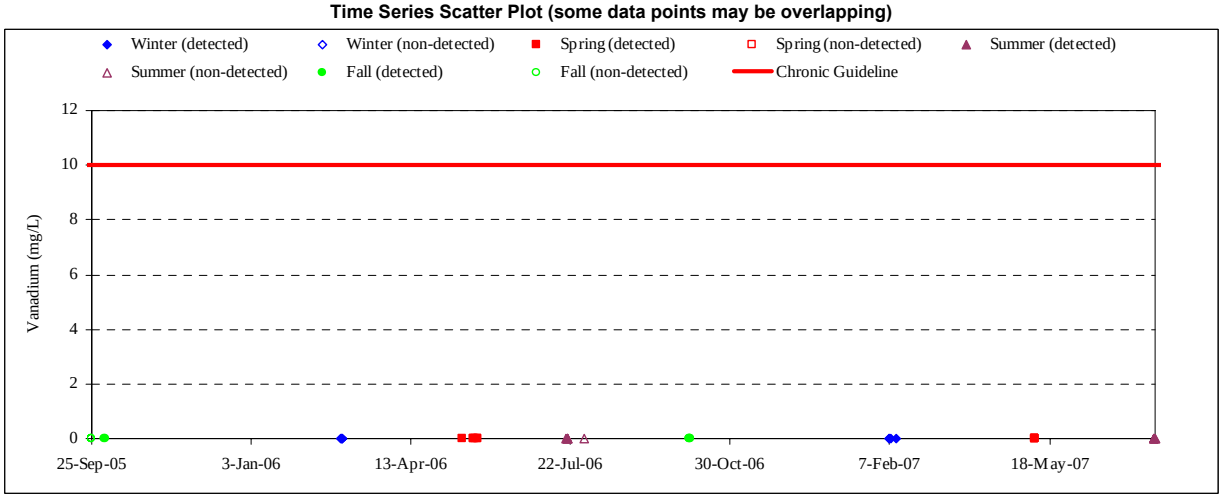
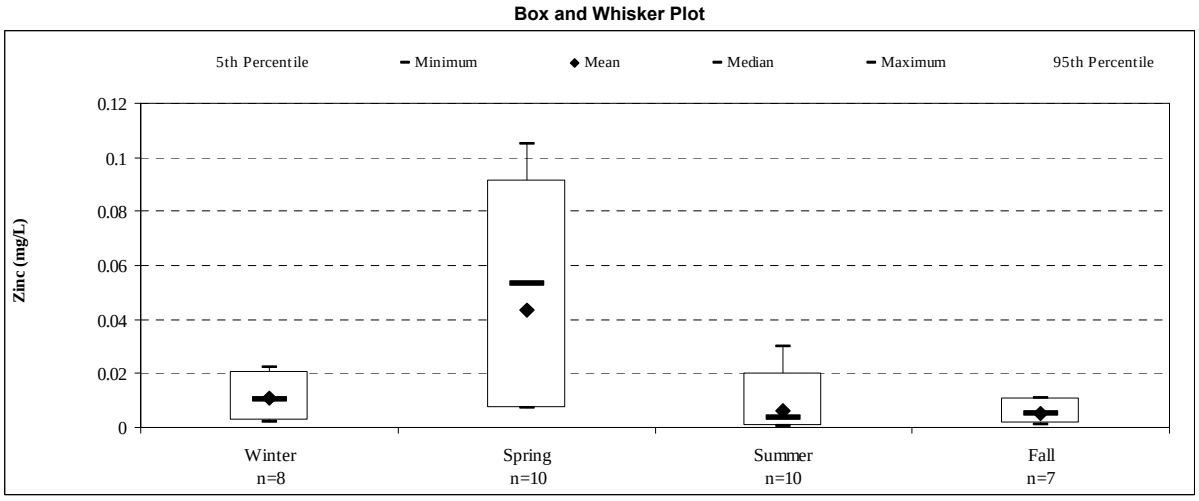
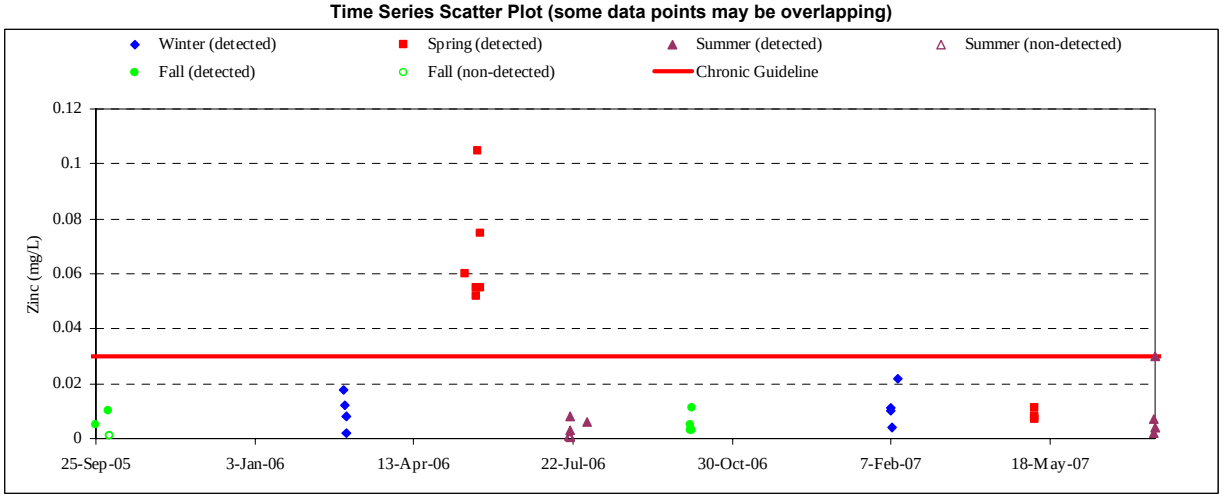


Figure G-3-5-118 Box Whisker and Time Series Scatter Plots of Observed Zinc (Dissolved) Concentration in Unnamed Lakes within PRMA





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AQUATIC HEALTH ENVIRONMENTAL SETTING REPORT FOR THE JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027-6600**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

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Appendix I Fish Tissue Metal and Polycyclic Aromatic Hydrocarbon Concentrations

4 AQUATIC HEALTH

4.1 INTRODUCTION

The Aquatic Health Environmental Setting Report (ESR) provides information on existing fish tissue quality in watercourses located within the Local Study Areas (LSAs) for the Jackpine Expansion Mining Area (JEMA) and Pierre River Mining Area (PRMA). The objectives of the Aquatic Health ESR are to:

- document existing fish tissue quality within the Project development area;
- compare measured fish tissue concentrations of metals and organic compounds to relevant aquatic toxicity effects benchmarks; and
- establish a benchmark against which predicted tissue concentrations of metals and organic compounds could be compared.

4.2 METHODS

4.2.1 Sample Collection

Fish tissue samples were collected between June 5 and 8, 2006 from Wapasu Creek and the Muskeg River, which are located within the LSA for the JEMA and the Pierre River, which is located within the LSA for the PRMA (Table 4.2-1). Fish tissue samples were also collected between May 28 and 31, 2007 from Redclay Creek and Big Creek, which are also located within the LSA for the PRMA (Table 4.2-1). Sample site locations are shown in Figure 4.2-1. Water quality data and fish habitat information has been collected from most of these sites during previous field sampling programs.

Table 4.2-1 Fish Tissue Sampling Sites

Location	Collection Date	Watercourse	Sample Site	Species Collected (Number of Samples Analyzed)	UTM Co-ordinates (NAD 83)	
					Easting	Northing
JEMA LSA	June 7, 2006	Wapasu Creek	38	white sucker (1), pearl dace (1), lake chub (1)	489589	6357329
	June 8, 2006	Wapasu Creek	26	white sucker (1)	488259	6359003
	June 8, 2006	Muskeg River	30	lake chub (1)	488232	6361778
PRMA LSA	June 5, 2006	Pierre River	19	lake chub (1), longnose sucker (1)	459477	6370942
			20	lake chub (1)	462237	6367483
	May 28, 2007	Redclay Creek	50	longnose sucker (1)	475883	6395035
	May 31, 2007	Big Creek	1	slimy sculpin (1), lake chub (1)	467822	6390180

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\8800\8820\Fig 4.2-1_FishTissue Sample Sites.dwg Nov 20, 2007 - 11:45am

R.12 R.11 R.10 R.9 R.8 R.7 W4M

T.101 T.100 T.99 T.98 T.97 T.96 T.95

Redclay Creek
Firebag River
Oakley Lake
Small Sandy Lake
Big Creek
Eymundson Creek
First Creek
Lease 17 East Creek
McClelland Lake Outlet Creek
McClelland Lake
Pierre River
Unnamed Creek
Athabasca River
Calumet River
Lillian Lake
Susan Lake
Calumet Lake
Fort Creek
Tar River
Joslyn Creek
Fort McKay Indian Reserve No.174C (IR174C)
Wapasu Creek
Muskeg River
Stanley Creek
Muskeg Creek
Kearl Lake
Shelley Creek
Jackpine Creek
Khahago Creek
Iyimimin Creek
Wesukem

50 1 19 20 30 26 38

	Eastings NAD83	Northings NAD83	Site #
YEAR 2006	459477	6370942	19
	462237	6367483	20
	488259	6359003	26
	488232	6361778	30
	489589	6357329	38
YEAR 2007	467822	6390180	1
	475883	6395035	50

LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- AQUATICS LOCAL STUDY AREA
- 2006 FISH TISSUE SAMPLING SITE
- 2007 FISH TISSUE SAMPLING SITE

4 0 4
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
FISH TISSUE SAMPLE SITES

Shell Canada Limited

PROJECT 06-1346-022.8800			FILE No. Fish-Tissue Sites
DESIGN	BG	19/07/07	SCALE AS SHOWN REV. 0
CADD	PSR	14/09/07	
CHECK	BG	14/09/07	FIGURE: 4.2-1
REVIEW	WES/TC	20/11/07	

All fish were captured using a backpack electrofishing unit. All of the captured lake chub (*Couesius plumbeus*), pearl dace *(Margariscus margarita)*, longnose sucker (*Catostomus catostomus*) and white sucker (*Catostomus commersoni*) were retained for analysis. Individual small-bodied fish (i.e., lake chub and pearl dace) of the same species, captured from the same site were combined to create composite samples. This was done to obtain the minimum sample weight of 22 g required for laboratory analysis. However, due to laboratory error, these composite samples (i.e., four composite samples of lake chub and a single composite sample of pearl dace) were combined into a single sample for the tissue chemistry analysis. As a result, this data is not presented since it does not provide an accurate representation of fish tissue metal concentrations within each of the LSAs. Individual white sucker and longnose sucker were submitted to the laboratory as individual samples.

Tissue analyses were done by ALS Laboratory Group (ALS) in Edmonton, Alberta. Whole-body samples were analyzed for total metals, Polycyclic Aromatic Hydrocarbons (PAHs) and alkylated PAHs. The individual metals and PAHs considered in the analysis are outlined in Table 4.2-2. The organic analyses (PAHs and alkylated PAHs) were conducted by Gas Chromatography/Mass Spectrometry (GC/MS), whereas the metals were analyzed using Inductively Coupled Plasma (ICP) Atomic Emission Spectrometric Analysis or atomic absorption.

Boron was initially included in the metal test list; however, due to a laboratory error, boron was omitted from the analysis. Surface water concentrations of boron in the region are generally well below the chronic effects benchmark of 5.4 mg/L (Shell 2005). Thus, the omission of boron from the test metal list does not affect aquatics health.

Table 4.2-2 Compounds Analyzed in Fish Samples

Total Metals	
aluminum (Al)	mercury (Hg)
antimony (Sb)	molybdenum (Mo)
arsenic (As)	nickel (Ni)
barium (Ba)	phosphorus (P)
beryllium (Be)	potassium (K)
cadmium (Cd)	selenium (Se)
calcium (Ca)	silver (Ag)
chromium (Cr)	sodium (Na)
cobalt (Co)	strontium (Sr)
copper (Cu)	thallium (Tl)
iron (Fe)	tin (Sn)
lead (Pb)	titanium (Ti)
magnesium (Mg)	vanadium (V)
manganese (Mn)	zinc (Zn)
PAHs and Alkylated PAHs	
naphthalene	C1 subst'd biphenyl
C1 subst'd naphthalenes	C2 subst'd biphenyl
C2 subst'd naphthalenes	chrysene
C3 subst'd naphthalenes	dibenzothiophene
C4 subst'd naphthalenes	C1 subst'd dibenzothiophene
acenaphthene	C2 subst'd dibenzothiophene
C1 subst'd acenaphthene	C3 subst'd dibenzothiophene
acenaphthylene	C4 subst'd dibenzothiophene
anthracene	fluoranthene
dibenzo(a,h) anthracene	C1 subst'd fluoranthene/pyrene
benzo(a) anthracene	fluorene
C1 subst'd benzo(a)anthracene/chrysene	C1 subst'd fluorene
C2 subst'd benzo(a)anthracene/chrysene	C2 subst'd fluorene
benzo(a)pyrene	indeno(c,d-123)pyrene
C1 subst'd benzo(b&k)fluoranthene/benzo(a)pyrene	phenanthrene
C2 subst'd benzo(b&k)fluoranthene/benzo(a)pyrene	C1 subst'd phenanthrene/anthracene
benzo(b)fluoranthene	C2 subst'd phenanthrene/anthracene
benzo(k)fluoranthene	C3 subst'd phenanthrene/anthracene
benzo(g,h,i)perylene	C4 subst'd phenanthrene/anthracene
biphenyl	pyrene

4.2.2 Data Handling and Analysis

Laboratory results were entered into a computer spreadsheet program and checked for transcription errors. Detection limits and units of analysis were also been checked for consistency within the laboratory report. Tissue metal concentrations were compared, where possible, with reference to relevant benchmarks described by Jarvinen and Ankley (1999) for 11 of the metals, and to the United States Environmental Protection Agency (U.S. EPA 2004) draft guideline for selenium.

Benchmarks are available for 12 of the 27 metals considered in the analysis. The metals with benchmarks include:

- aluminum;
- antimony;
- arsenic;
- cadmium;
- chromium;
- copper;
- lead;
- mercury;
- nickel;
- selenium;
- vanadium; and
- zinc.

The benchmark for selenium is derived from the U.S. EPA (2004) draft selenium guideline. This guideline defines the genus mean value for *Oncorhynchus* (Salmonidae), which includes economically important species in Alberta, as 10.66 µg/g dry weight. Using a moisture content of 75.8%, the U.S. EPA (2004) value of 10.66 µg/g dry weight translates into a wet weight concentration of 2.58 µg/g. This value was selected as the toxicological benchmark for selenium. The remaining 12 benchmarks discussed herein originate from Jarvinen and Ankley (1999).

The terms benchmarks, toxicological effects benchmarks and effects concentrations are used interchangeably in this report and refer to the values reported in Jarvinen and Ankley (1999) and U.S. EPA (2004). All fish tissue concentrations and benchmarks are reported as wet weight.

4.3 RESULTS

4.3.1 Metals

Fish tissue concentrations of antimony, beryllium, lead, molybdenum, silver, thallium and tin were below their respective detection limits in all samples (Appendix I, Table I-1). Observed concentrations for the remaining individual metals included in the fish tissue analysis are discussed below in more detail. All tissue metal concentrations are reported as wet weight.

4.3.1.1 Aluminum

Whole-body aluminum concentrations varied among fish species. In the JEMA, whole-body aluminum concentrations in white suckers from Wapasu Creek were 2 µg/g and less than 2 µg/g. In the PRMA, whole-body aluminum concentrations were highest in the sample of lake chub from Big Creek at 51 µg/g. The whole-body aluminum concentration in longnose sucker collected from Redclay Creek was 18 µg/g. Whole-body aluminum concentrations were lower in slimy

sculpin from Big Creek and longnose sucker from Redclay Creek at 4 and 5 µg/g, respectively.

Whole-body aluminum concentrations of 20 µg/g have been shown to reduce survival of Atlantic salmon (*Salmo salar*) alevins (Jarvinen and Ankley 1999). Except for lake chub, whole-body aluminum concentrations measured in all captured fish species were lower than the toxicological effects benchmark of 20 µg/g wet weight. The whole-body aluminum concentration in lake chub collected from Big Creek was above the 20 µg/g benchmark. This indicates that under existing natural conditions, aluminum concentrations in individual fish in the area can exceed the aluminum benchmark.

4.3.1.2 Arsenic

Whole-body arsenic concentrations varied among fish species. In the JEMA, arsenic was below the detection limit of 0.05 µg/g in white suckers from Wapasu Creek. In the PRMA, longnose sucker from Redclay Creek had a whole-body arsenic concentration of 0.11 µg/g. Longnose sucker from the Pierre River had a whole-body arsenic concentration of 0.06 µg/g. Arsenic was below the detection limit of 0.05 µg/g in lake chub and slimy sculpin from Big Creek.

Results of toxicity testing with arsenic indicate that carcass concentrations of 3.1 µg/g reduce growth, as assessed using juvenile rainbow trout (*Oncorhynchus mykiss)* (Jarvinen and Ankley 1999). The maximum concentration of arsenic observed in 2006 was 0.11 µg/g in longnose sucker collected from the Pierre River. Arsenic levels in fish tissues, therefore, were below the effects threshold.

4.3.1.3 Barium

In the JEMA, barium in white suckers from Wapasu Creek ranged from 0.2 to 1 µg/g. In the PRMA, whole-body barium concentrations were highest in lake chub from Big Creek at 2.4 µg/g, intermediate in longnose sucker from Redclay Creek at 1.8 µg/g, and lower in slimy sculpin from Big Creek at 0.9 µg/g and longnose sucker from the Pierre River at 0.5 µg/g. There are no tissue effects thresholds for barium.

4.3.1.4 Cadmium

Cadmium in white suckers from the JEMA were below the detection limit of 0.01 µg/g. In the PRMA, cadmium was detected only in longnose sucker from Redclay Creek with a whole-body cadmium concentration of 0.03 µg/g.

Results of toxicity testing with cadmium sulphate indicate that muscle tissue concentrations of 0.6 µg/g reduce reproduction, as assessed using adult rainbow trout (*Oncorhynchus mykiss)* (Jarvinen and Ankley 1999). Cadmium levels in fish tissues, therefore, were below effects thresholds in the JEMA and PRMA.

4.3.1.5 Chromium

Chromium in white suckers from the JEMA were below the detection limit of 0.1 µg/g. In the PRMA, whole-body chromium concentrations were 0.3 µg/g in lake chub and 0.2 µg/g in slimy sculpin and longnose sucker. Chromium in longnose sucker from the Pierre River was below the detection limit of 0.1 µg/g. Muscle tissue chromium residues of 0.58 µg/g did not effect the survival of rainbow trout (Jarvinen and Ankley 1999).

4.3.1.6 Cobalt

Cobalt was detected only in longnose sucker from the Pierre River, in which the whole-body cobalt concentration was 0.1 µg/g. There are no effects thresholds for cobalt.

4.3.1.7 Copper

In the JEMA, whole-body copper concentrations were 0.94 µg/g and 1.1 µg/g in white suckers from Wapasu Creek. In the PRMA, whole-body copper in longnose suckers ranged from 0.86 µg/g to 1.0 µg/g. Whole-body copper concentrations were similar in lake chub, slimy sculpin and longnose sucker at 0.81, 0.75 and 0.86 µg/g, respectively.

Brook trout with a tissue concentration of 3.4 µg/g did not show effects on growth, reproduction and survival from exposure to copper sulfate (Jarvinen and Ankley 1999). Copper levels in fish tissues, therefore, were below effects thresholds in the JEMA and PRMA.

4.3.1.8 Iron

In the JEMA, whole-body iron concentrations in white suckers were 120 and 8.0 µg/g, respectively. In the PRMA, whole-body iron concentrations in slimy sculpin and the longnose suckers were 20, 26 and 18 µg/g, respectively. Iron in lake chub was below the detection limit. There are no effects thresholds for iron.

4.3.1.9 Magnesium

In the JEMA, whole-body magnesium concentrations in white suckers were 245 and 279 µg/g, respectively. In the PRMA, whole-body magnesium concentrations in slimy sculpin and the longnose suckers were 295, 361 and 228 µg/g, respectively. Magnesium in lake chub was below the detection limit. There are no effects thresholds for magnesium.

4.3.1.10 Manganese

In the JEMA, whole-body manganese concentrations in white suckers were 1.5 and 2.4 µg/g, respectively. In the PRMA, whole-body manganese concentrations in slimy sculpin and the longnose suckers were 11, 4.0 and 4.9 µg/g, respectively. Manganese in lake chub was below the detection limit. There are no effects thresholds for magnesium.

4.3.1.11 Mercury

In the JEMA, whole-body mercury concentrations in white suckers were 0.05 and 0.13 µg/g, respectively. In the PRMA, whole-body mercury concentrations were 0.08 µg/g in both longnose suckers and 0.04 µg/g in lake chub and slimy sculpin.

A whole-body mercury concentration of 5.0 µg/g had no effects on the growth or survival of juvenile rainbow trout (Jarvinen and Ankley 1999). The maximum observed concentration of mercury was 0.13 µg/g in a white sucker collected from Wapasu Creek, located within the JEMA; therefore, mercury concentrations were below the tissue effects concentration.

4.3.1.12 Nickel

In the JEMA, whole-body nickel concentrations were 0.03 µg/g in white suckers. In the PRMA, nickel was highest in a single whole-body sample of lake chub at 0.26 µg/g. Whole-body nickel concentrations in slimy sculpin and the longnose suckers were 0.16, 0.20 and 0.15 µg/g, respectively. For comparison, a tissue nickel concentration of 0.82 µg/g following exposure to nickel chloride was reported to have no effect on rainbow trout survival (Jarvinen and Ankley 1999).

4.3.1.13 Selenium

In the JEMA, whole-body selenium concentrations were 0.06 µg/g in white suckers. In the PRMA, selenium concentrations were highest in longnose suckers at 0.93 and 0.86 µg/g, respectively. Whole-body selenium concentrations

in lake chub and slimy sculpin were lower at 0.61 and 0.59 µg/g, respectively. Whole-body selenium concentrations did not exceed the tissue effects benchmark of 2.58 µg/g (U.S. EPA 2004).

4.3.1.14 Strontium

In the JEMA, whole-body strontium concentrations in white suckers were 0.43 and 4.0 µg/g. In the PRMA, whole-body strontium concentrations were highest in lake chub at 15 µg/g. Whole-body strontium concentrations were 5.9 µg/g in slimy sculpin and 7.7 and 1.4 µg/g in longnose suckers. There are no effects thresholds for strontium.

4.3.1.15 Titanium

Whole-body titanium concentrations in white suckers within the JEMA were 0.24 and 0.33 µg/g, respectively. In the PRMA, titanium was detected in a single whole-body composite sample of slimy sculpin and longnose sucker. Whole-body titanium concentrations were 0.40 µg/g in slimy sculpin and 0.46 µg/g in longnose sucker from the Pierre River. Concentrations in lake chub from Big Creek and a longnose sucker from Redclay Creek were below the detection limit of 0.2 µg/g. There are no effects thresholds for titanium.

4.3.1.16 Vanadium

Vanadium was only detected in a single whole-body composite sample of lake chub from Big Creek, located within the PRMA. Whole-body vanadium in the composite sample of lake chub was 0.2 µg/g. Concentrations in all other samples were below the detection limit of 0.1 µg/g. For comparison, a vanadium tissue concentration of 0.41 µg/g was reported to cause a reduction in juvenile rainbow trout growth (Jarvinen and Ankley 1999).

4.3.1.17 Zinc

In the JEMA, whole-body zinc concentrations were 9.20 and 13.7 µg/g in white suckers from Wapasu Creek. In the PRMA, whole-body zinc concentrations were highest in lake chub from Big Creek at 40.4 µg/g. Whole-body zinc concentrations in slimy sculpin and the longnose suckers were lower at 18.0, 17.6 and 10.8 µg/g, respectively. A zinc tissue concentration of 60 µg/g was reported to have no effect on growth and survival of juvenile Atlantic salmon (whole-body concentrations) (Jarvinen and Ankley 1999).

4.3.2 Organic Compounds

Concentrations of PAHs and alkylated PAHs were below detection limits in all samples (Appendix I, Table I-2).

4.4 CONCLUSIONS

This ESR has provided information on whole-fish concentrations of metals and PAHs in waterbodies within the Jackpine Expansion Mining Area and Pierre River Mining Area. Results of the sampling program were summarized and compared, when possible, with relevant benchmarks for the protection of fish health.

Jackpine Expansion Mining Area

Tissue metal concentrations in fish collected from sites located within the JEMA LSA were low and were all below relevant benchmarks provided in Jarvinen and Ankley (1999) and the U.S. EPA (2004). Whole-body concentrations of PAHs and alkylated PAHs were below detection limits in all of the sampled fish.

Pierre River Mining Area

Metal levels in fish tissues collected from sites located within the PRMA LSA were low and generally below relevant thresholds, with the exception of aluminum. Aluminum in lake chub collected from Big Creek was above the effect threshold of 20 µg/g provided in Jarvinen and Ankley (1999). Whole-body concentrations of PAHs and alkylated PAHs were below detection limits in all of the sampled fish.

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APPENDIX I

FISH TISSUE METAL AND POLYCYCLIC AROMATIC HYDROCARBON CONCENTRATIONS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

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Table I-1 Metal Concentrations (µg/g) in Whole-Body Fish Samples Collected from Sites Located Within the Jackpine Expansion Mining Area in June 2006 and the Pierre River Mining Area in May 2007

Parameter	JEMA		PRMA				Effects Threshold Concentration[g] [ug/g wet weight]
	WHSC[a]	WHSC[b]	LKCH[c]	SLSC[d]	LNSC[e]	LNSC[f]	
aluminum (Al)	2.0	<2.0	**51**	4.0	5.0	18	20
antimony (Sb)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	9
arsenic (As)	<0.05	<0.05	<0.05	<0.05	0.06	0.11	3.1
barium (Ba)	0.20	1.0	2.4	0.90	1.8	0.50	–
beryllium (Be)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	–
cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.6
chromium (Cr)	<0.1	<0.1	0.3	0.2	0.2	<0.1	0.58
cobalt (Co)	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	–
copper (Cu)	1.1	0.94	0.81	0.75	1.0	0.86	3.4
iron (Fe)	120	8.0	<5.0	20	26	18	–
lead (Pb)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	4
magnesium (Mg)	245	279	<5	295	361	228	–
manganese (Mn)	1.5	2.4	<0.5	11	4.0	4.9	–
mercury (Hg)	0.13	0.05	0.04	0.04	0.08	0.08	0.8
molybdenum (Mo)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	–
nickel (Ni)	0.03	0.03	0.26	0.16	0.20	0.15	0.82
selenium (Se)	0.06	0.06	0.61	0.59	0.93	0.86	2.58
silver (Ag)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	–
strontium (Sr)	0.43	4.0	15	5.9	7.7	1.4	–
thallium (Tl)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	–
tin (Sn)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	–
titanium (Ti)	0.24	0.33	<0.2	0.40	<0.2	0.46	–
vanadium (V)	<0.1	<0.1	0.20	<0.1	<0.1	<0.1	0.41
zinc (Zn)	9.20	13.7	40.4	18.0	17.6	10.8	60

[a] WHSC = White sucker collected from Site 26 located in Wapasu Creek in 2006.

[b] WHSC = White sucker collected from Site 38 located in Wapasu Creek in 2006.

[c] LKCH = Lake chub collected from Big Creek in 2007.

[d] SLSC = Slimy sculpin collected from Big Creek in 2007.

[e] LNSC = Longnose sucker collected from Redclay Creek in 2007.

[f] LNSC = Longnose sucker collected from Unnamed Creek in 2006.

[g] Effects concentrations derived from Jarvinen and Ankley (1999). Selenium guideline derived from U.S. EPA (2004).

– = Tissue effects concentration not available.

Note: Bold values indicate exceedance of tissue effects concentration.

Table I-2 Polycyclic Aromatic Hydrocarbons and Alkylated Polycyclic Aromatic Hydrocarbon Concentrations (µg/g) in Whole-Body Fish Samples Collected from Sites Located Within the Jackpine Expansion Mining Area in June 2006 and the Pierre River Mining Area in May 2007

Parameter	JEMA		PRMA			
	WHSC[a]	WHSC[b]	LKCH[c]	SLSC[d]	LNSC[e]	LNSC[f]
naphthalene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd naphthalenes	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C2 subst'd naphthalenes	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C3 subst'd naphthalenes	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C4 subst'd naphthalenes	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
acenaphthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd acenaphthene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
acenaphthylene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
anthracene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
dibenzo(a,h) anthracene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
benzo(a) anthracene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd benzo(a) anthracene/chrysene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd benzo(a) anthracene/chrysene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
benzo(a)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
benzo(b)fluoranthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
benzo(k)fluoranthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
benzo(g,h,i)perylene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C1 subst'd biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
chrysene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
dibenzothiophene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C3 subst'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C4 subst'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
fluoranthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd fluoranthene/pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
fluorene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd fluorene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd fluorene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
indeno(c,d-123)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
phenanthrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C1 subst'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C2 subst'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C3 subst'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
C4 subst'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

[a] WHSC = White sucker collected from Site 26 located in Wapasu Creek in 2006.

[b] WHSC = White sucker collected from Site 38 located in Wapasu Creek in 2006.

[c] LKCH = Lake chub collected from Big Creek in 2007.

[d] SLSC = Slimy sculpin collected from Big Creek in 2007.

[e] LNSC = Longnose sucker collected from Redclay Creek in 2007.

[f] LNSC = Longnose sucker collected from Unnamed Creek in 2006.

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FISH AND FISH HABITAT ENVIRONMENTAL SETTING FOR THE JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

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5 FISH HABITAT

5.1 INTRODUCTION

The main objectives of this study were to characterize the fish and fish habitat in watercourses and waterbodies that may potentially be affected by the Shell Canada Limited (Shell) Jackpine Mine Expansion & Pierre River Mine Project (the Project) and to provide the data and information necessary to assess any potential future changes caused by the development of the Project.

The characterization of fish and fish habitat included a:

- description of the habitats of the watercourses and waterbodies in the Project areas;
- discussion of the suitability of the habitats in relation to the needs of the various life stages of fish species and benthic invertebrates;
- description of the fish communities present in these areas; and
- description of the benthic invertebrate communities in these areas.

The scope of work for the fish and fish habitat environmental setting study included the compilation and review of available information for watercourses and waterbodies near the Project, and the survey and assessment of fish and fish habitat within watercourses and waterbodies with the potential to be directly affected by the Project.

5.1.1 Approach

The fish and fish habitat environmental setting includes a description of the fish habitats, fish communities and benthic invertebrate communities in watercourses and waterbodies that may potentially be affected by the Project. The geographic area of focus for the Project includes two Local Study Areas (LSAs), one for the Jackpine Expansion Mining Area (JEMA) and one for the Pierre River Mining Area (PRMA). One Regional Study Area (RSA) was used to encompass the entire Project (Figure 5.1-1). The information collected for the fish and fish habitat environmental setting consists of all the available information concerning fish and fish habitat in the defined LSAs including:

- all historical information collected in past studies;
- recent information collected by Shell or other oil sands operators; and
- information collected during field studies conducted specifically for the Project.

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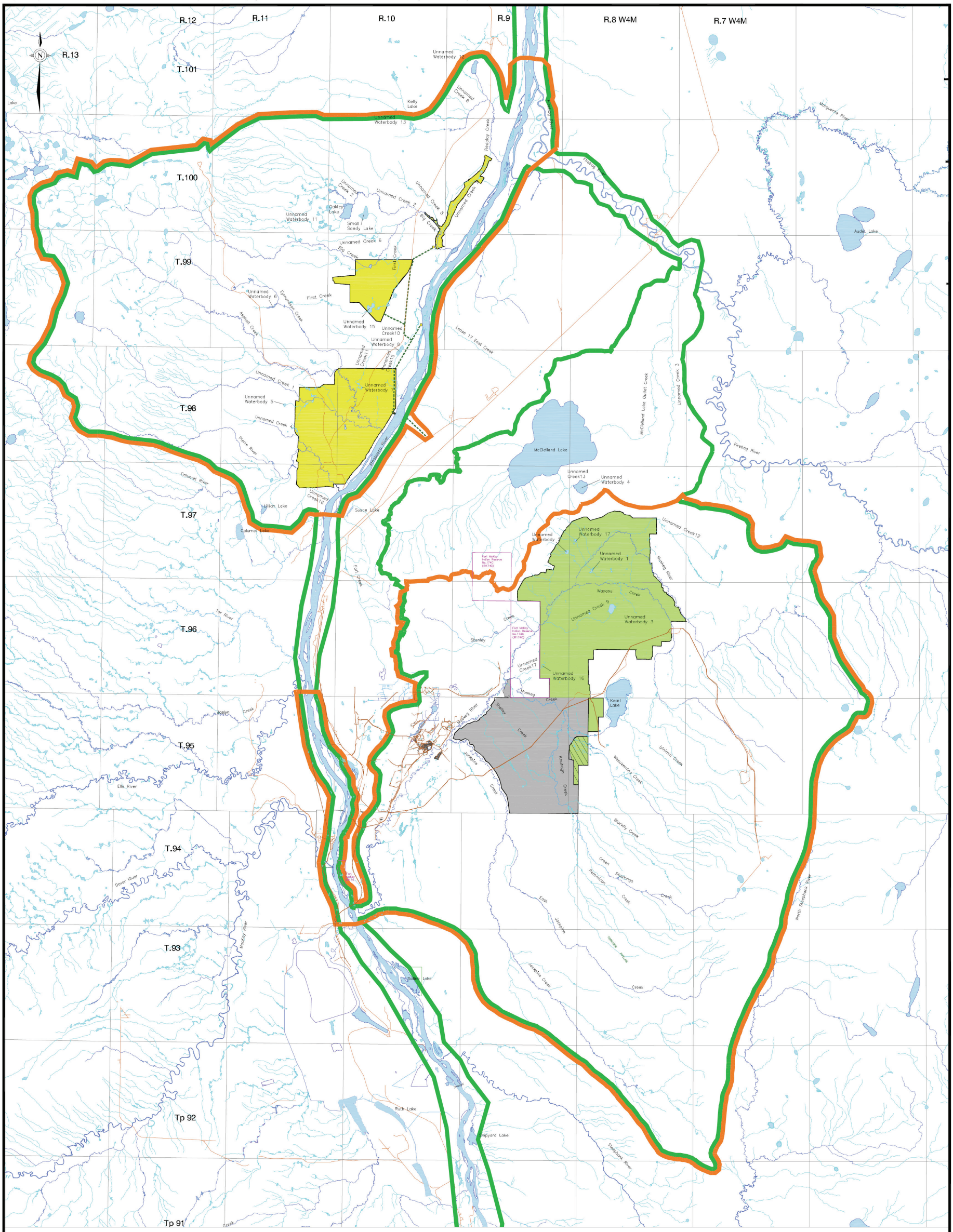

LEGEND

- PIERRE RIVER MINE
- JACKPINE MINE EXPANSION
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

5 0 5
SCALE KM

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
FISH AND FISH HABITAT
LOCAL AND REGIONAL STUDY AREAS

Shell Canada Limited

PROJECT 08.1346.0006.5180			FILE No. Fish LSA RSA	
DESIGN	MK	21/11/08	SCALE AS SHOWN	REV. 2
CADD	PSR	27/11/08	**FIGURE: 5.1-1(REVISED)**	
CHECK	MK	28/11/08		
REVIEW	TC	21/04/09		

All of the historical and recent information for the LSAs was compiled and reviewed. Field studies were then completed to collect current data for watercourses and waterbodies potentially affected by the Project for which historical or recent information was not available. This information was summarized to provide the description of existing fish and fish habitat in the watercourses and waterbodies in the LSAs.

The evaluation of the suitability of aquatic habitats for use by fish and benthic invertebrates was based on the life history needs of the different fish species and benthic invertebrate genera that are indigenous to the LSAs. For fish species, the following habitat components were considered when evaluating habitat conditions and their suitability for use by different fish life stages:

Life Cycle Stage	Habitat Component
Spawning adult	Spawning habitat
Fry (young-of-the-year)	Nursery habitat
Juvenile	Rearing habitat
Adult	Feeding habitat
All stages	Overwintering habitat
All stages	Migration routes

The evaluation of the potential suitability of the available habitats for use by fish was based on an assessment of habitat use potential, which evaluates how well the habitat can provide the physical environment indigenous fish species need to complete their life cycle. Habitat use potential is not necessarily based on whether a particular fish species or life stage uses the habitat. It is based on how well that habitat meets the requirements of a particular species or life stage that could potentially use the habitat. Habitat use potential was assessed by life stage for sport fish and non-sport fish because information is available that describes the habitat requirements for different life stages of these species. For forage species, habitat use potential was assessed with less emphasis on species or life stages because less is known of the habitat requirements for different species or life stages, or because different species or life stages do not markedly differ.

The common and scientific names of fish species, the four letter code and the classification of each species relative to the categories of sport fish, non-sport fish and forage fish is provided in Appendix J, Table J-1.

The fish and fish habitat environmental setting information, as well as information from other aquatic components, will be used to prepare the Project Environmental Impact Assessment (EIA).

5.2 METHODS

The methods used for the fish and fish habitat environmental setting study included a literature review of the available data for all watercourses and waterbodies in the LSAs and RSA and field investigations to evaluate the current environmental setting conditions of fish habitat, fish communities and benthic invertebrate communities in the systems that may potentially be affected by the Project. All existing and current environmental setting data was then used to provide a description of fish and fish habitat diversity in watercourses and waterbodies potentially affected by the Project.

5.2.1 Literature Review

This report summarizes existing information (historical and current) for watercourses and waterbodies in the LSAs and RSA. Several fish and fish habitat studies have been completed in the Oil Sands Region, including historical studies dating back to the 1970s and more recent studies conducted for resource agencies, industry and multi-stakeholder groups. The sources used to compile all available fish and fish habitat data were:

- government resource agencies, such as Alberta Sustainable Resource Development (ASRD) and Alberta Environment (AENV);
- environmental departments of various private industries, such as oil and gas or pulp and paper industries;
- environmental research by consultants working for industry;
- government research programs such as the Alberta Oil Sands Environmental Research Program (AOSERP) and the Northern River Basins Study (NRBS); and
- research conducted by multi-stakeholder groups created to study or monitor environmental conditions in the Oil Sands Region, such as the Oil Sands Regional Aquatics Monitoring Program (RAMP) and the Cumulative Environmental Management Association (CEMA).

5.2.2 Fish and Fish Habitat Field Surveys

5.2.2.1 Sampling Timing and Locations

Seasonal field surveys were conducted to assess seasonal use of the watercourses and waterbodies by fish species for various life stages. Data were collected during the winter, spring, summer and fall (Table 5.2-1) from the selected study sites within the JEMA and PRMA development areas.

Table 5.2-1 Sampling Dates for the Environmental Setting Field Study

Study Area	Season	Survey Dates
RSA	spring	May 26 to June 10, 2006
	summer	July 29 to August 9, 2006; July 21 to July 26, 2007
	fall	September 22 to October 6, 2005; September 24 to October 3, 2006
	winter	February 23 to March 2, 2006; February 18 to February 28, 2007
JEMA LSA	spring	April 26 to June 10, 2006
	summer	July 29 to August 9, 2006
	fall	September 22 to October 18, 2005
	winter	February 23 to March 2, 2006
PRMA LSA	spring	May 26 to June 10, 2006; May 5 to June 1, 2007
	summer	July 29 to August 9, 2006; July 21 to July 26, 2007
	fall	September 22 to October 18, 2005; September 24 to October 3, 2006
	winter	February 23 to March 2, 2006; February 18 to February 28, 2007

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The waterbodies that were included in the study consist of discrete basins and were examined in their entirety. Watercourses were examined at selected sites considered to be representative of conditions in each of the watercourses. The field sampling site locations for the two study areas are presented in Figure 5.2-1 and Figure 5.2-2. Table 5.2-2 presents the details of the sampling site locations.

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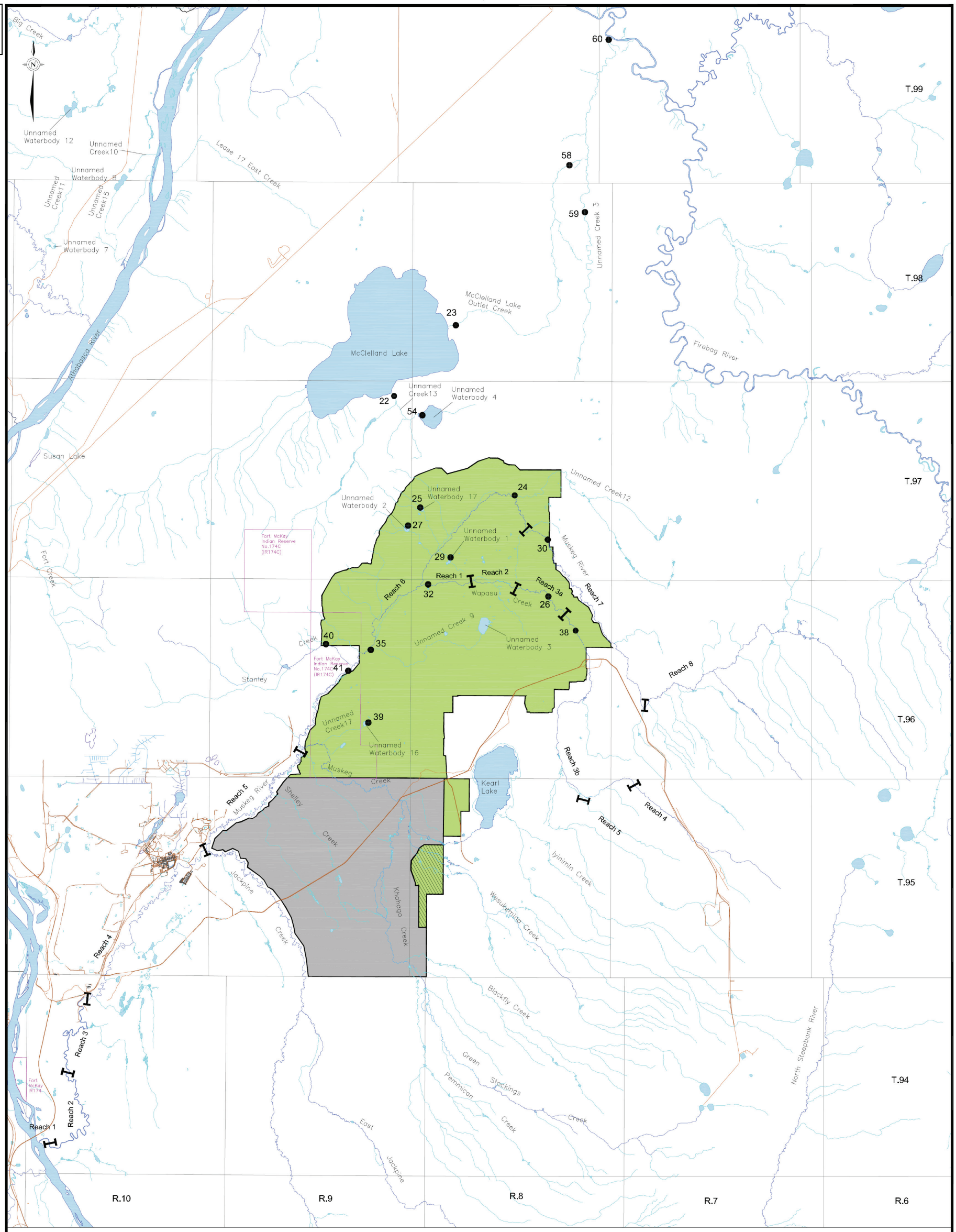

LEGEND

- ROAD
- JACKPINE MINE EXPANSION
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- 7 FISH AND FISH HABITAT SAMPLING SITE
- REACH BREAK

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

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PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
FISH AND FISH HABITAT SITES IN THE REGIONAL AND LOCAL STUDY AREAS FOR THE JACKPINE EXPANSION MINING AREA

Shell Canada Limited

PROJECT 08.1346.0006.5180			FILE No.	LSA–RSA
DESIGN	MK	21/11/08	SCALE AS SHOWN	REV. 0
CADD	PSR	04/12/08	**FIGURE: 5.2-1(REVISED)**	
CHECK	MK	04/12/08		
REVIEW	TC	21/04/09		

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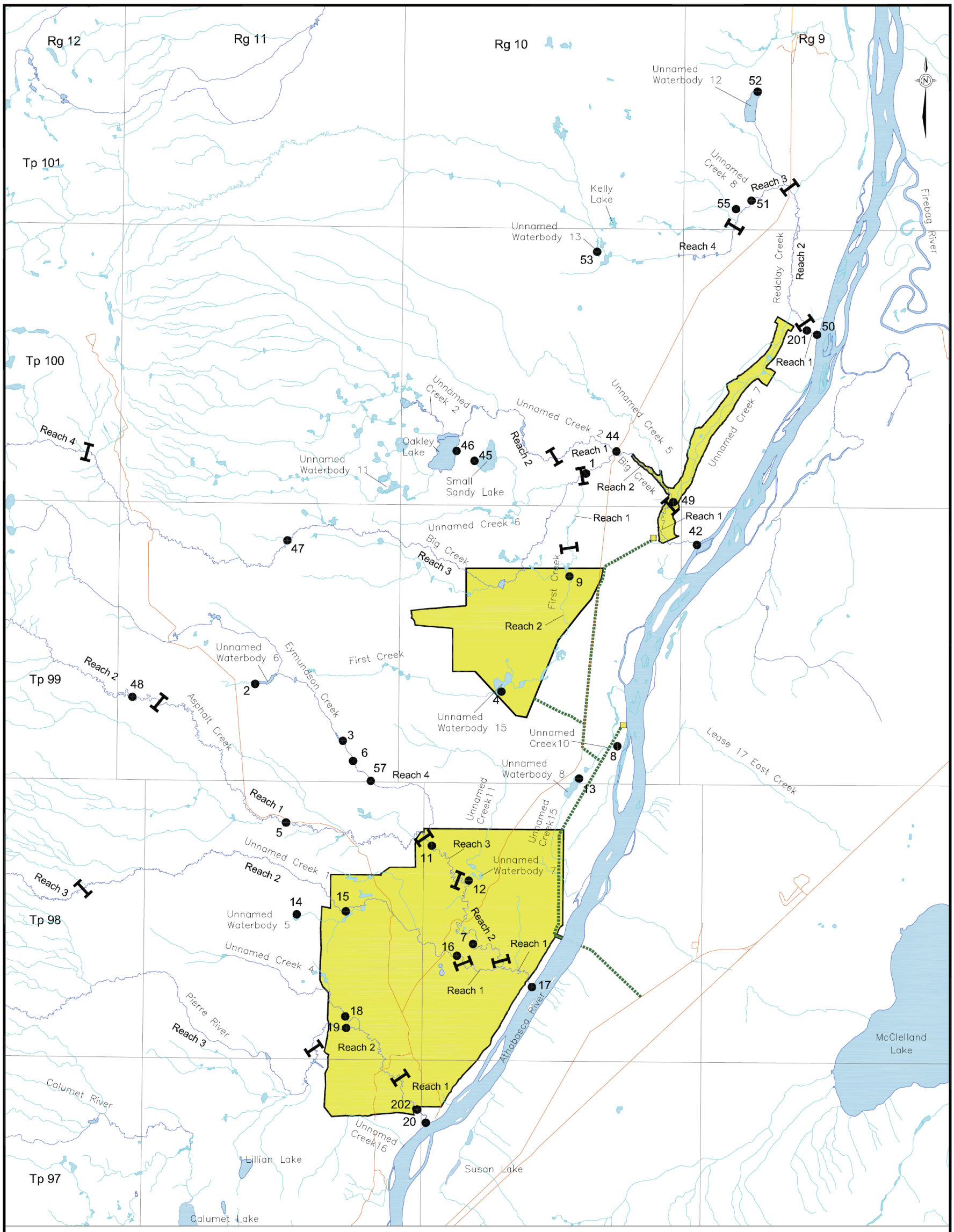


LEGEND

- ROAD
- PROPOSED ACCESS
- PIERRE RIVER MINE
- 7 FISH AND FISH HABITAT SAMPLING SITE
- REACH BREAK

2.5 0 2.5
SCALE KM

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
FISH AND FISH HABITAT SITES IN THE LOCAL STUDY AREA FOR THE PIERRE RIVER MINE

Shell Canada Limited

PROJECT 08.1346.0006.5180			FILE No. Fish/Habitat –LSA	
DESIGN	MK	21/11/08	SCALE AS SHOWN	REV. 0
CADD	PSR	27/11/08	**FIGURE: 5.2-2(REVISED)**	
CHECK	MK	28/11/08		
REVIEW	TC	21/04/09		

Table 5.2-2 Details of Fish and Fish Habitat Site Locations for the Environmental Setting Field Study (2005 to 2007)

Study Area	Watershed	Watercourse or Waterbody	Site	UTM Co-ordinates (NAD 83)[a]						Total Length Surveyed [m]
				Sample Point[b]		Surveyed Section				
						Upstream Boundary		Downstream Boundary		
				Easting	Northing	Easting	Northing	Easting	Northing	
RSA	McClelland Lake Drainage Area	McClelland Lake Outlet Creek	60	–	–	491124	6386391	491138	6386372	300
			23	–	–	483878	6372367	483741	6372261	218
		Unnamed Creek 3	59	–	–	490038	6377830	–	–	100
		Unnamed Creek 13	22	–	–	480822	6368613	480727	6368799	196
		Unnamed Waterbody 4	54	482744	6367921	–	–	–	–	–
JEMA LSA	Muskeg River	Muskeg River	41	–	–	478709	6355615	478487	6355369	508
			30	–	–	488305	6361589	488232	6361778	300
		Stanley Creek	40	–	–	477268	6356689	477400	6356669	174
		Wapasu Creek	32	482385	6359588	–	–	–	–	–
			26	–	–	488429	6358795	488259	6359003	364
			38	–	–	489706	6357090	489589	6357329	301
		Unnamed Creek 9	35	–	–	479666	6356419	479585	6356392	93
		Unnamed Creek 12	24	–	–	486729	6363927	486615	6363945	82
		Unnamed Waterbody 1	29	483448	6360749	–	–	–	–	–
		Unnamed Waterbody 2	27	481370	6362275	–	–	–	–	–
		Unnamed Waterbody 16	39	479378	6352753	–	–	–	–	–
		Unnamed Waterbody 17	25	482073	6363263	–	–	–	–	–
PRMA LSA	Pierre River	Pierre River	20	–	–	462241	6367725	462237	6367483	340
			202[c]	462215	6367762	–	–	–	–	–
			19	–	–	459386	6370701	459477	6370914	309
		Unnamed Creek 4	18	–	–	459320	6371385	459425	6371201	313
	Eymundson Creek	Eymundson Creek	17	–	–	465780	6372551	465938	6372227	569
			7	–	–	463872	6373831	463882	6373732	257
			11	–	–	462347	6377232	462448	6377165	300
			57	–	–	460213	6379609	460317	6379435	300

Table 5.2-2 Details of Fish and Fish Habitat Site Locations for the Environmental Setting Field Study (2005 to 2007) (continued)

Study Area	Watershed	Watercourse or Waterbody	Site	UTM Co-ordinates (NAD 83)[a]						Total Length Surveyed [m]
				Sample Point[b]		Surveyed Section				
						Upstream Boundary		Downstream Boundary		
				Easting	Northing	Easting	Northing	Easting	Northing	
PRMA LSA (continued)	Eymundson Creek (continued)	Eymundson Creek (continued)	6	–	–	459607	6380364	459698	6380128	313
			3	–	–	459159	6380990	459342	6380836	308
		Asphalt Creek	5	–	–	457066	6378143	457360	6377978	329
			48	–	–	451904	6382366	452002	6382374	306
		Unnamed Creek 1	16	–	–	463101	6373367	463323	6373320	320
			15	–	–	459227	6374947	459445	6374874	304
		Unnamed Creek 11	12	–	–	463774	6376148	463735	6375947	310
		Unnamed Waterbody 5	14	457708	6374642	–	–	–	–	–
		Unnamed Waterbody 6	2	456732	6382937	–	–	–	–	–
	Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	8	–	–	468697	6380599	468921	6380645	225
		Unnamed Waterbody 8	13	467296	6379020	–	–	–	–	–
	Big Creek	Big Creek	42	–	–	471386	6387782	471694	6387684	324
			1	–	–	467668	6390071	467822	6390180	345
			47	–	–	457411	6387849	457411	6387849	300
		First Creek	9	–	–	467340	6386435	467245	6386587	257
		Unnamed Creek 2	44	–	–	468747	6391003	468885	6390953	275
		Unnamed Creek 7	49	471035	6389363	–	–	–	–	–
		Oakley Lake	46	462633	6391097	–	–	–	–	–
		Small Sandy Lake	45	464135	6390388	–	–	–	–	–
		Unnamed Waterbody 15	4	464873	6382555	–	–	–	–	–
	Redclay Creek	Redclay Creek	50	–	–	475625	6395101	475883	6395035	326
			201[c]	475764	6395066	–	–	–	–	–
			51	–	–	473815	6399834	473599	6399721	322
		Unnamed Creek 8	55	–	–	472965	6399485	473059	6399424	134
		Unnamed Waterbody 12	52	473700	6403474	–	–	–	–	–
		Unnamed Waterbody 13	53	468194	6397878	–	–	–	–	–

[a] Universal Transverse Mercator (UTM) Projection Co-ordinates – North American Datum (NAD) 1983.

[b] Waterbody surveyed in its entirety – UTM co-ordinates provided for one sample point.

[c] Fish fence location.

– = Not applicable.

Jackpine Expansion Mining Area

Muskeg River Watershed

Watercourses

Muskeg River Mainstem

The sampling sites for the Muskeg River were established along the upper extent of the river, which corresponds to the portion of the river next to the proposed JEMA development (Figure 5.2-1). Two watercourse study sites (Sites 41 and 30) were established to correspond, in part, to previously established river Reaches 4 and 5, respectively. The two sites were examined during fall 2005 and the winter, spring and summer of 2006. Thermographs were installed to continuously monitor water temperatures at the two locations throughout the spring and summer of 2006.

Wapasu Creek

Three watercourse sample sites were established on Wapasu Creek (Figure 5.2-1). This watercourse has previously been divided into five reaches. Site 32 was located within Reach 1, while both Sites 26 and 38 were located within Reach 3. The three sites were examined during fall 2005 and winter, spring and summer of 2006. Thermographs were installed to continuously monitor water temperatures at Sites 32 and 38 throughout the spring and summer of 2006.

Stanley Creek

One watercourse sample site was established on Stanley Creek (Site 40) (Figure 5.2-1). This site was examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed to continuously monitor water temperatures at this site throughout the spring and summer of 2006.

Unnamed Tributaries to the Muskeg River

Two watercourse sampling sites were established on unnamed tributaries to the Muskeg River (Figure 5.2-1). The watercourse sites were established on Unnamed Creek 9 (Site 35) and Unnamed Creek 12 (Site 25). Both sites were examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed at Site 35 to continuously monitor water temperatures throughout the spring and summer of 2006.

Waterbodies

Unnamed Waterbodies

Three waterbody sampling sites were established within unnamed tributary drainages to the Muskeg River. The waterbody sites were established on Unnamed Waterbody 1 (Site 29), Unnamed Waterbody 2 (Site 27) and Unnamed

Waterbody 17 (Site 25) (Figure 5.2-1). All three sites were examined during fall 2005 and winter, spring and summer of 2006.

One waterbody sample site was established on Unnamed Waterbody 16 (Site 39), which was located within the Muskeg Creek drainage. This site was examined during fall 2005 and winter, spring and summer of 2006.

Pierre River Mining Area

Pierre River Watershed

Watercourses

Pierre River Mainstem

The Pierre River was divided into three reaches. Two watercourse sampling sites were established on the Pierre River (Sites 20 and 19) (Figure 5.2-2). Site 20 was located at the confluence of the Pierre and Athabasca rivers, within Reach 1 and Site 19 was located within Reach 2. These sites were examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed to continuously monitor water temperatures at Site 19 throughout the spring and summer of 2006.

A counting fence was installed on the Pierre River about 350 m upstream of the confluence with the Athabasca River (Site 202) during the spring 2006. This fence was monitored for approximately one month and a thermograph was installed to continuously monitor water temperatures.

Unnamed Tributary to the Pierre River

One watercourse sampling site was established on Unnamed Creek 4 (Site 18) (Figure 5.2-2). This site was examined during fall 2005 and winter, spring and summer of 2006.

Waterbodies

There were no waterbody sites established within the Pierre River watershed.

Eymundson Creek Watershed

Watercourses

Eymundson Creek

Eymundson Creek was divided into four reaches. Six watercourse sampling sites were established on Eymundson Creek (Figure 5.2-2). Site 17 was located at the confluence of Eymundson Creek and the Athabasca River, within Reach 1. Site 7 was located about 2 km upstream of this confluence, within Reach 2. Site 11 was established downstream of the confluence of Asphalt Creek, within Reach 3.

Site 6 was established within Reach 4. These sites were examined during fall 2005 and winter, spring and summer of 2006. Thermographs were installed to continuously monitor water temperatures at Sites 17, 11 and 6 throughout the spring and summer of 2006.

Two additional watercourse sampling locations (Sites 3 and 57) were examined and later removed from the program due to their close proximity to Site 6. Site 3 was located about 1 km upstream of Site 6 and was sampled during fall 2005. Site 57 was located about 1 km downstream of Site 6 and was sampled during fall 2006. Both sites were within Reach 4.

Asphalt Creek

Asphalt Creek was divided into two reaches. Two watercourse sample sites were established on Asphalt Creek, Sites 5 and 48, each within Reaches 1 and 2, respectively (Figure 5.2-2). Site 5 was examined during fall 2005 and winter, spring and summer of 2006. Site 48 was examined during fall 2006 and winter, spring and summer of 2007. A thermograph was installed at Site 5 to continuously monitor water temperatures throughout the spring and summer of 2006. A thermograph was installed at Site 48 to continuously monitor water temperatures throughout the spring and summer of 2007.

Unnamed Tributaries to Eymundson Creek

One watercourse sampling site (Site 12) was established on Unnamed Creek 11 (Figure 5.2-2). This site was examined during fall 2005 and winter, spring and summer of 2006.

Two watercourse sampling sites (Sites 16 and 15) were established on Unnamed Creek 1 (Figure 5.2-2). These sites were examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed at Site 15 to continuously monitor water temperatures throughout the spring and summer of 2006.

Waterbodies

Unnamed Waterbodies

One waterbody sampling site (Site 2) was established on Unnamed Waterbody 6 (Figure 5.2-2). This site was examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed at Site 2 to continuously monitor water temperatures throughout the spring and summer of 2006.

A waterbody sampling site (Site 14) was established on Unnamed Waterbody 5 (Figure 5.2-2). This site was examined during fall 2005 and winter, spring and summer of 2006.

Unnamed Tributaries to the Athabasca River

Watercourses

One watercourse sample site (Site 8) was sampled on Unnamed Creek 10 during fall 2005 and winter, spring and summer of 2007 (Figure 5.2-2). A thermograph was installed at Site 8 to continuously monitor water temperatures throughout the spring and summer of 2007.

Waterbodies

One waterbody sample site (Site 13) was established on Unnamed Waterbody 8 and was sampled during fall 2005 and winter, spring and summer of 2006 (Figure 5.2-2).

Big Creek Watershed

Watercourses

Big Creek Mainstem

Big Creek was divided into four reaches. Three watercourse sample sites were established on Big Creek (Sites 42, 1 and 47) (Figure 5.2-2). Site 1 was located just downstream from the confluence of First Creek, within Reach 2. This site was examined during fall 2005 and winter, spring and summer of 2007. Site 42 was located at the confluence of Big Creek with the Athabasca River, in Reach 1. Site 47 was located in Reach 3. Sites 42 and 47 were examined during fall 2006 and winter, spring and summer of 2007. Thermographs were installed at all three sites to continuously monitor water temperatures throughout the spring and summer of 2007.

First Creek

First Creek was divided into two reaches. One watercourse sample site was established on First Creek (Site 9), within Reach 2 (Figure 5.2-2). Site 9 was examined during the fall 2005 and winter, spring and summer of 2007. A thermograph was installed to continuously monitor water temperatures throughout the spring and summer of 2007.

Unnamed Tributaries to Big Creek

Two sites were established at unnamed watercourses within the Big Creek drainage (Figure 5.2-2). Site 44 was established on Unnamed Creek 2 and Site 49 was established on Unnamed Creek 7, both located just upstream of their respective confluences with Big Creek. Both sites were sampled during fall 2006 and winter, spring and summer of 2007. Thermographs were installed at Sites 44 and 46 to continuously monitor water temperatures throughout the spring and summer of 2007.

Waterbodies

Oakley Lake

Site 49 was situated on Oakley Lake, a waterbody within the Unnamed Creek 2 drainage (Figure 5.2-2). This site was examined during fall 2006 and winter, spring and summer of 2007. A thermograph was installed at Site 49 to continuously monitor water temperatures throughout the spring and summer of 2007.

Small Sandy Lake

Site 45 was located on Small Sandy Lake, a waterbody located at the headwaters of a small unnamed tributary to Big Creek (Figure 5.2-2). This site was examined during fall 2006 and winter, spring and summer of 2007. A thermograph was installed at Sites 45 to continuously monitor water temperatures throughout the spring and summer of 2007.

Unnamed Waterbodies

One waterbody sample site was established within the First Creek drainage at Unnamed Waterbody 15 (Site 4) (Figure 5.2-2). This site was also examined during fall 2005 and winter, spring and summer of 2007. A thermograph was installed to continuously monitor water temperatures throughout the spring and summer of 2007.

Redclay Creek Watershed

Watercourses

Redclay Creek Mainstem

Redclay Creek was divided into four reaches. Two watercourse sites (Sites 50 and 51) were established on Redclay Creek (Figure 5.2-2). Site 50 was located in Reach 1, just upstream of the confluence of Redclay Creek and the Athabasca River. Site 51 was located within Reach 3. Both sites were sampled during fall 2006 and winter, spring and summer of 2007. Thermographs were installed at both sites to continuously monitor water temperatures throughout the spring and summer of 2007.

A two-way fyke net was installed on Redclay Creek about 130 m upstream of the confluence with the Athabasca River (Site 201) during spring 2006 and 2007 (Figure 5.2-2). The nets were monitored for approximately one month and a thermograph was installed to continuously monitor water temperatures.

Unnamed Tributaries to Redclay Creek

One watercourse site (Site 55) was established on Unnamed Creek 8, a tributary to the upper end of Reach 3 of Redclay Creek (Figure 5.2-2). This site was sampled during fall 2006 and winter, spring and summer of 2007. A

thermograph was installed to continuously monitor water temperatures throughout the spring and summer of 2007.

Waterbodies

Unnamed Waterbodies

Site 53 was established on Unnamed Waterbody 13, the headwaters of a tributary to Reach 4 of Redclay Creek (Figure 5.2-2). This site was sampled during fall 2006 and winter, spring and summer of 2007. A thermograph was installed to continuously monitor water temperatures throughout the spring and summer of 2007.

One waterbody site (Site 52) was established on Unnamed Waterbody 10 at the headwaters of a tributary to the lower end of Reach 3 of Redclay Creek (Figure 5.2-2). This site was sampled during fall 2006 and winter, spring and summer of 2007. A thermograph was installed to continuously monitor water temperatures throughout the spring and summer of 2007.

Regional Study Area

Based on its relatively close proximity to JEMA and the limited amount of existing data, study sites were established within the McClelland Lake drainage area.

McClelland Lake Drainage Area

Watercourses

McClelland Lake Outlet Creek

Two sites were established on McClelland Lake outlet creek (Sites 23 and 60) (Figure 5.2-1). Site 23 was located just downstream of the outlet of McClelland Lake and was examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed at Site 23 to continuously monitor water temperatures throughout the spring and summer of 2006. Site 60 was located just upstream of the confluence with the Firebag River and was examined during fall 2006 and the winter, spring and summer of 2007. A thermograph was installed at Site 60 to continuously monitor water temperatures throughout the spring and summer of 2007.

Unnamed Watercourses

One watercourse sample site was established on Unnamed Creek 3 during fall 2006 (Sites 59) (Figure 5.2-1). Site 59 was located about 4 km upstream of its confluence with the McClelland Lake Outlet Creek. This site was examined during fall 2006 and the winter, spring and summer of 2007.

One watercourse sample site was established on McClelland Lake's inlet, Unnamed Creek 13 (Site 22) (Figure 5.2-1). This site was examined during fall 2005 and winter, spring and summer of 2006. A thermograph was installed at Site 22 to continuously monitor water temperatures throughout the spring and summer of 2006.

Waterbodies

Unnamed Waterbodies

A waterbody sample site was established at Unnamed Waterbody 4 (Site 54) (Figure 5.2-1). This site was examined during the winter, spring and summer of 2006 and the fall of 2007. A thermograph was installed at Site 54 to continuously monitor water temperatures throughout the spring and summer of 2006.

5.2.2.2 Sampling Methods

Various field sampling techniques were used to assess fish and fish habitat for the selected watercourse and waterbodies. The sampling technique employed for a selected watercourse or waterbody was dependent on the information requirements and site-specific habitat conditions. The seasonal sampling activities that were completed at each of the selected field sampling sites are outlined in Table 5.2-3.

In general, the seasonal field assessments for watercourses included:

- habitat mapping of all relevant instream and bank habitat characteristics to provide an inventory of available spawning, rearing, feeding and overwintering habitats;
- description of riparian vegetation;
- measurement of average channel dimensions;
- identification of features that may affect fish movements;
- measurement of stream discharge to help evaluate habitat use potential and fish migration potential;
- measurement of water quality field parameters (pH [±0.1], conductivity [±1 µS/cm], temperature [±0.1°C] and dissolved oxygen [±0.1 mg/L]);
- monitoring seasonal water temperatures;
- fish inventory to determine the fish community present;
- investigation of under-ice habitat and overwintering potential;
- spring and fall spawning surveys to determine spawning use (if sport fish or non-sport fish determined to be present);

- photographs documenting available habitat types and general stream morphology; and
- aerial videography of area.

In general, the seasonal field assessment of the waterbody sites included the following:

- habitat mapping of the waterbody basin and shoreline characteristics (including distribution of aquatic macrophytes);
- bathymetry transects to determine or confirm basin dimensions and depths;
- description of riparian vegetation;
- examination of outlet channels to evaluate fish passage potential;
- measurement of water quality field parameters (pH [±0.1], conductivity [±1 µS/cm], temperature [±0.1°C] and dissolved oxygen [±0.1 mg/L]) along a vertical profile or series of profiles at various depths;
- fish inventory to determine the fish community present;
- spawning surveys (if sport fish or non-sport fish determined to be present);
- photographs documenting available habitat types and general basin morphology; and
- aerial videography of area.

Details of the various field sampling activities are provided below for habitat evaluation and fish sampling techniques.

Table 5.2-3 Summary of Field Sampling Activities

Study Area	Watershed	Watercourse or Waterbody	Sampling Site[a]	Sampling Activity by Year and Season							
				2005	2006				2007		
				Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
RSA	McClelland Lake Drainage Area	McClelland Lake Outlet Creek	60	–	–	–	–	–	♦	Δ ■ ▲	Δ ■ ▲ ●
			23	Δ ■ ●	♦	Δ ■ *	Δ ■	–	–	–	–
		Unnamed Creek 3	59	–	–	–	–	–	♦	Δ ■ ▲ *	Δ ■ ▲ ●
		Unnamed Creek 13	22	Δ ▲ ● ■ ○	♦	Δ ■ *	Δ ■	–	–	–	–
		Unnamed Waterbody 4	54	–	♦	Δ ■	Δ ■ ●	■ Δ ○ ●	–	–	–
JEMA LSA	Muskeg River	Muskeg River	41	Δ ● ■	♦	Δ ■ ▲ *	Δ ■	–	–	–	–
			30	Δ ▲ ● ■	♦	Δ ■ ▲ *	Δ ■	–	–	–	–
		Stanley Creek	40	Δ ▲ ● ■	♦	Δ ■ *	Δ ■	–	–	–	–
		Wapasu Creek	32	Δ ▲ ■ ○	♦	Δ ■ *	Δ ■ ●	–	–	–	–
			26	Δ ▲ ● ■	♦	Δ ■ ▲	Δ ■ ▲	–	–	–	–
			38	Δ ▲ ● ■ ○	♦	Δ ■ □ ▲ *	Δ ■ ▲	–	–	–	–
		Unnamed Creek 9	35	Δ ▲ ● ■ ○	♦	Δ ■ *	Δ ■	–	–	–	–
		Unnamed Creek 12	24	Δ ■ ● ○	♦	Δ ■ *	Δ ■	–	–	–	–
		Unnamed Waterbody 1	29	Δ ● ■	♦	Δ ■	Δ ■	–	–	–	–
		Unnamed Waterbody 2	27	Δ ● ■	♦	Δ ■	Δ ■	–	–	–	–
		Unnamed Waterbody 16	39	Δ ■	♦	Δ ■	Δ ■ ●	–	–	–	–
		Unnamed Waterbody 17	25	Δ ● ■	♦	Δ ■	Δ ■	–	–	–	–
PRMA LSA	Pierre River	Pierre River	20	Δ ■ ▲ ● ○	♦	Δ ■ ▲ *	Δ ■ ▲	–	–	–	–
			202[b]	–	–	Δ ■ ▲	–	–	–	–	–
			19	Δ ■ ▲ ● ○	♦	Δ ■ *	Δ ■ ▲	–	–	–	–
		Unnamed Creek 4	18	Δ ■ ▲ ●	♦	Δ ■	Δ ■	–	–	–	–
	Eymundson Creek	Eymundson Creek	17	Δ ■ ▲ ● ○	♦	Δ ■ ▲ □ *	Δ ■ ▲	–	–	–	–
			7	Δ ■ ▲ ●	–	Δ ■ ▲ □	Δ ■ ▲	–	♦	–	–
			11	Δ ■ ▲ ● ○	♦	Δ ■ ▲ *	Δ ■ ▲	–	–	–	–
			57	–	–	–	–	● ■ Δ ▲ ○	–	–	–
			6	Δ ■ ●	♦	Δ ■ *	Δ ■	○	–	–	–
			3	Δ ■ ▲ ●	–	–	–	–	–	–	–
		Asphalt Creek	5	Δ ■ ▲ ●	♦	Δ ■ ▲ *	Δ ■ ▲	–	–	–	–
			48	–	–	–	–	● ■ Δ ▲ ○	♦	Δ ■ ▲ □ *	Δ ■ ▲
		Unnamed Creek 1	16	Δ ■ ▲ ●	♦	Δ ■ ▲ □	Δ ■ ▲	–	–	–	–
			15	Δ ■ ▲ ● ○	♦	Δ ■ ▲ *	Δ ■ ▲	–	–	–	–
		Unnamed Creek 11	12	Δ ■ ▲ ●	♦	Δ ■ ▲ *	Δ ■	–	–	–	–
		Unnamed Waterbody 5	14	Δ ■ ●	♦	Δ ■	Δ ■	–	–	–	–
		Unnamed Waterbody 6	2	Δ ■ ● ○	♦	–	–	–	♦	Δ ■ *	Δ

Table 5.2-3 Summary of Field Sampling Activities (continued)

Study Area	Watershed	Watercourse or Waterbody	Sampling Site[a]	Sampling Activity by Year and Season							
				2005	2006				2007		
				Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
PRMA LSA (continued)	Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	8	Δ ■ ●	–	–	–	–	♦	Δ ■	Δ ■
		Unnamed Waterbody 8	13	Δ ■ ●	♦	Δ ■	Δ ■	–	–	–	–
	Big Creek	Big Creek	42	–	–	–	–	● ■ Δ ▲ ○	♦	Δ ■ *	Δ ■
			1	Δ ■ ▲ ●	–	–	–	–	–	Δ ■ ▲ □ *	Δ ■ ▲
			47	–	–	–	–	● ■ Δ ▲ ○	♦	Δ ■ ▲ *	Δ ■ ▲
		First Creek	9	Δ ■ ▲ ●	–	–	–	○	♦	Δ ■ *	Δ ■
		Unnamed Creek 2	44	–	–	–	–	Δ ♦	–	Δ ■ ▲ □ *	Δ ■ ▲
		Unnamed Creek 7	49	–	–	–	–	■ Δ ○	♦	Δ ■	Δ ●
		Oakley Lake	46	–	–	–	–	● ■ Δ ○	♦	Δ ■ *	–
		Small Sandy Lake	45	–	–	–	–	■ Δ ○	♦	Δ ■	–
		Unnamed Waterbody 15	4	Δ ■ ● ○	–	–	–	–	♦	Δ ■ *	Δ ■
	Redclay Creek	Redclay Creek	50	–	–	–	–	● ■ Δ ▲ ○	–	▲ □	Δ ■ ▲
			201[b]	–	–	Δ ■ ▲	–	–	–	Δ ■ ▲ *	–
			51	–	–	–	–	● ■ Δ ▲ ○	♦	Δ ■ ▲ □	Δ ■ ▲
		Unnamed Creek 8	55	–	–	–	–	● ■ Δ ▲ ○	♦	Δ ■ ▲ □	Δ ■ ▲
		Unnamed Waterbody 12	52	–	–	–	–	■ Δ ○ ●	♦	Δ ■ *	Δ ■
		Unnamed Waterbody 13	53	–	–	–	–	■ Δ ○ ●	♦	Δ ■ *	Δ ■ ●

[a] See Figures 5.2-1 and 5.2-2 for sampling site locations.

[b] Fish fence location.

– = Not sampled.

Field Sampling activities:

Δ Water quality.

■ Fish sampling.

▲ Discharge measurement.

● Habitat mapping.

□ Spawning survey.

♦ Overwintering assessment.

○ Benthic invertebrate sampling.

* Thermograph.

Habitat Evaluation

Habitat Mapping

Watercourses

Watercourse sites were mapped using the protocols outlined in the Golder "Stream Habitat Classification and Rating System" (Golder 1997g). This habitat mapping system is derived from the peer-reviewed literature (Hawkins et al. 1993) and protocols accepted by ASRD (RL&L 1986). Detailed habitat maps were generated for each sampling site for a distance of ten times the channel width or 300 m, when access was sufficient.

The location and extent of all instream habitat types and shoreline/bank characteristics of the watercourse were mapped to provide an inventory of available habitats. The length of the watercourse at each site was divided into a continuous series of habitat types, termed channel units. A channel unit is a distinct section of the channel with specific characteristics of water depth, velocity and cover for fish. Typical channel units include riffle, pool and run habitats. Pool and run channel units were further classified as Class 1, 2 or 3 habitats, depending on their depth and available cover for fish, with Class 1 habitats being the deepest (more than 1.5 m), Class 2 being moderately deep (0.75 to 1.5 m) and Class 3 being shallow (less than 0.75 m).

The recorded physical characteristics of each channel unit included:

- channel unit type and class;
- maximum water depth;
- water velocity at representative channel units;
- substrate particle size or sizes (visually estimated according to the size criteria presented in Appendix K);
- presence of aquatic vegetation;
- presence of debris piles (small and large woody debris);
- cover for fish, including both instream (velocity shelter) and overhead (visual isolation) cover;
- beaver dams and other features that might impede fish movements;
- bank and shoreline features, including areas of unstable bank and areas of overhanging vegetation or undercut banks;
- riparian plant community composition; and
- channel dimensions, including mean channel width and wetted width.

Representative photographs were taken at each sampling site to illustrate physical characteristics such as bank conditions, bank profiles, riparian areas and channel characteristics.

The habitat use potential for the sampling sites was evaluated, in part, based on the characteristics of the available habitats. The types and proportions of the available channel units, combined with general water depths and substrate material, provides an indication of the potential suitability of the habitat for use by fish relative to the habitat requirements of the different fish species and life stages (e.g., spawning, rearing and feeding).

Waterbodies

Waterbodies were mapped using the protocols outlined in the Golder "Lake Habitat Mapping" (Golder 1997d) and "Basic Limnology and Bathymetry Procedures" (Golder 1997e). These procedures were based on existing habitat and bathymetric techniques (BC Ministry of Environment 1995; RIC 1996). Habitat maps were developed to show the location and extent of habitat features such as shoreline characteristics, substrate type and the distribution of aquatic vegetation.

The recorded physical characteristics of each waterbody included:

- identification and distribution of aquatic macrophytes (submergent, emergent and floating-leaved vegetation);
- substrate particle size;
- shoreline slope and stability; and
- riparian vegetation.

Aquatic macrophytes were identified to the genus level (see Appendix J for common and scientific names of plant species).

The habitat use potential for the waterbodies was evaluated, in part, based on the characteristics of the available habitats. The proportions of the available habitat types and depths (i.e., littoral and pelagial zones), combined with substrate material, vegetation distribution and shoreline development, provides an indication of the potential suitability of the habitats for use by fish in the waterbody relative to the habitat requirements of the different fish species and life stages.

Discharge Measurement and Water Quality

Discharge and Field Water Quality Parameters

Stream discharge and water quality field parameters were measured during seasonal sampling activities. Discharge measurements were conducted according to the protocol in Golder "Stream Discharge Measurement Methods" (Golder 1997f). This protocol is based on accepted hydrometric methods (Environment Canada 1981). Measurements were done using a calibrated tagline to determine horizontal stations and a Marsh-McBirney Flowmate 2000 velocity meter and top setting-wading rod to measure water depth and velocity.

In watercourses, water quality parameters were measured mid-stream and approximately 0.3 m below the surface. In waterbodies, water quality parameters were measured at one or more locations along vertical profiles including the deepest location in each waterbody.

Continuous Temperature Monitoring

Water temperature was continuously monitored in 17 sites from the end of April through to August 2006 and in 12 additional sites from the end of April through to August 2007. Temperature was monitored using Onset Optic Stowaway Tidbit thermographs consisting of dataloggers programmed to record water temperature every four hours. The thermographs were stationed on the bottom of the watercourse in deep pools or thalweg areas that would likely contain water throughout the sampling period.

Overwintering Assessment

Watercourses

The winter field assessment of watercourse sampling sites included the following:

- measurement of snow thickness, ice thickness and under-ice water depth;
- measurement of water depth and velocity along a transect to determine average depth and velocity;
- measurement of stream discharge at selected sites using the under-ice protocol in Golder "Stream Discharge Measurement Methods" (Golder 1997f);
- measurement of water quality field parameters; and
- underwater video, when appropriate, to document habitat conditions.

Waterbodies

The winter habitat assessment for waterbodies included: measurement of snow thickness, ice thickness and under-ice water depth, and measurement of water quality field parameter profiles.

Fish Inventory

Fish Sampling

A fish inventory was completed at each watercourse and waterbody sampling site to determine the fish communities present. A variety of sampling techniques were used to determine the species and life stages that use these systems.

Fish sampling techniques employed during field investigations included:

- backpack electrofishing in wadeable watercourses and nearshore areas of waterbodies;
- portable electrofishing in waterbodies;
- baited minnow traps in both watercourses and waterbodies;
- gill netting in waterbodies;
- under-water video in both watercourses and waterbodies;
- kick net sampling to detect spawning activity in wadeable watercourses and fringes of waterbodies; and
- spring fish fence/fyke net installation.

Fish sampling methods were employed as habitat conditions allowed. The specific sampling techniques used at each of the different sampling sites are detailed in Table 5.2-4 for the winter period and in Table 5.2-5 for the open-water seasons.

Backpack electrofishing was conducted for the seasonal surveys during the open-water period at sampling sites on watercourses and the fringes of waterbodies using a Smith-Root Model 15-D backpack unit. Minnow trapping and gill netting was done during all seasonal surveys. Gillnets were set in waterbodies having suitable depths. The number and dimensions of gill nets used during sampling are provided in Table 5.2-6.

The winter fish inventory for watercourse sampling sites was completed using standard Gee minnow traps (baited) and underwater video. The video was obtained using an Aqua-VU Z-120 under-water video camera equipped with

infra-red lighting and recorded using a Sony TRV350 digital hand camera. Minnow traps were used at sites where water depths were sufficient to allow the trap to be placed under the ice (generally more than or equal to 0.4 m). Sampling was conducted at each watercourse as conditions permitted.

The winter fish inventory for waterbodies included minnow trapping, underwater video and the use of single-panel gill nets with 5.1-cm mesh (stretch-measure) Sampling was completed at each site as conditions permitted.

All fish captured during sampling activities were identified and enumerated by species. Fish observed, but not captured while electrofishing also were recorded. Sport and non-sport fish were identified to life stage (i.e., fry, juvenile or adult). Fork length (mm) and body weight (g) were measured for all individuals of sport and non-sport fish species and for a representative sub-sample of individuals of forage fish species. Sex and state of maturity of captured fish also were recorded if these could be discerned from external examination.

Table 5.2-4 Winter Fish Sampling Methods and Effort

Study Area	Watershed	Watercourse or Waterbody	Sampling Site[a]	Gill Netting			Minnow Trapping			Under Water Video Effort [minutes]
				Number of panels	Duration of Set [hr]	Effort [panel–hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	
RSA	McClelland Lake Drainage Area	McClelland Lake Outlet Creek	60	–	–	–	2	1.2	2.3	39.2
			23	–	–	–	1	1.0	1.0	–
		Unnamed Creek 3	59	–	–	–	–	–	–	–
		Unnamed Creek 13	22	–	–	–	–	–	–	–
		Unnamed Waterbody 4	54	–	–	–	2	3.8	7.7	40.3
JEMA LSA	Muskeg River	Muskeg River	41	–	–	–	2	1.3	2.5	–
			30	–	–	–	1	0.9	0.9	–
		Stanley Creek	40	–	–	–	2	1.0	2.1	–
		Wapasu Creek	32	–	–	–	2	20.5	41.1	21.0
			26	–	–	–	2	0.9	1.7	–
			38[b]	–	–	–	–	–	–	–
		Unnamed Creek 9	35[b]	–	–	–	–	–	–	–
		Unnamed Creek 12	24	–	–	–	2	1.1	2.2	60.0
		Unnamed Waterbody 1	29	2	2.5	5	–	–	–	–
		Unnamed Waterbody 2	27[b]	–	–	–	–	–	–	–
		Unnamed Waterbody 16	39	–	–	–	2	1.6	3.2	10.6
		Unnamed Waterbody 17	25	–	–	–	–	–	–	17.3
PRMA LSA	Pierre River	Pierre River	20	–	–	–	–	–	–	30.0
			202[c]	–	–	–	–	–	–	–
			19	–	–	–	2	2.6	5.2	37.0
		Unnamed Creek 4	18	–	–	–	2	1.1	2.2	–
	Eymundson Creek	Asphalt Creek	5[b]	–	–	–	–	–	–	–
			48[b]	–	–	–	–	–	–	–
		Eymundson Creek	17[b]	–	–	–	–	–	–	–
			7[b]	–	–	–	–	–	–	–
			11[b]	–	–	–	–	–	–	–
			6[b]	–	–	–	–	–	–	–
		Unnamed Creek 1	16[b]	–	–	–	–	–	–	–
			15[b]	–	–	–	–	–	–	–
		Unnamed Creek 11	12[b]	–	–	–	–	–	–	–
		Unnamed Waterbody 5	14	–	–	–	2	17.0	34.0	–
		Unnamed Waterbody 6	2	–	–	–	3	0.9	2.8	–

Table 5.2-4 Winter Fish Sampling Methods and Effort (continued)

Study Area	Watershed	Watercourse or Waterbody	Sampling Site[a]	Gill Netting			Minnow Trapping			Under Water Video Effort [minutes]
				Number of panels	Duration of Set [hr]	Effort [panel–hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	
PRMA LSA (continued)	Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	8	–	–	–	2	1.3	2.6	–
		Unnamed Waterbody 8	13	–	–	–	2	3.5	7.0	–
	Big Creek	Big Creek	42[b]	–	–	–	–	–	–	–
			1[d]	–	–	–	–	–	–	–
			47[b]	–	–	–	–	–	–	–
	Big Creek (continued)	First Creek	9[b]	–	–	–	–	–	–	–
		Unnamed Creek 2	44[d]	–	–	–	–	–	–	–
		Unnamed Creek 7	49[b]	–	–	–	–	–	–	–
		Oakley Lake	46	–	–	–	3	0.9	2.7	83.3
		Small Sandy Lake	45	–	–	–	3	1.0	3.0	49.0
		Unnamed Waterbody 15	4[b]	–	–	–	–	–	–	–
	Redclay Creek	Redclay Creek	50[b]	–	–	–	–	–	–	–
			201[c]	–	–	–	–	–	–	–
			51[b]	–	–	–	–	–	–	–
		Unnamed Creek 8	55	–	–	–	3	1.3	3.8	–
		Unnamed Waterbody 12	52	–	–	–	3	1.3	4.0	–
		Unnamed Waterbody 13	53 [b]	–	–	–	–	–	–	–

[a] See Figures 5.2-1 and 5.2-2 for sampling site locations.

[b] Site frozen to bottom or insufficient depth for sampling.

[c] Fish fence site.

[d] No winter access.

– = Not sampled.

Table 5.2-5 Open-Water Fish Sampling Methods and Effort

Watershed	Watercourse or Waterbody	Sampling Site[(a)]	Season	Backpack Electrofishing		Gill Netting			Minnow Trapping			Kick Net Sampling		
				Length of Stream or Shoreline [m]	Effort [s]	Number of Panels	Duration of Set [hr]	Effort [panel-hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	Area [m^2]	Number of Kicks	Effort [m^2]
McClelland Lake Drainage Area	McClelland Lake Outlet Creek	60	spring	–	–	–	–	–	2	1.0	2.1	–	–	–
			summer	300	522	–	–	–	2	1.8	3.6	–	–	–
		23	spring	–	–	–	–	–	3	1.4	4.3	–	–	–
			summer	–	–	–	–	–	3	1.2	3.5	–	–	–
			fall	200	210	–	–	–	2	3.4	6.9	–	–	–
	Unnamed Creek 3	59	spring	–	–	–	–	–	2	1.4	2.8	–	–	–
			summer	300	350	–	–	–	2	1.3	2.7	–	–	–
	Unnamed Creek 13	22	spring	–	–	–	–	–	3	1.2	3.5	–	–	–
			summer	–	–	–	–	–	3	1.0	3.0	–	–	–
			fall	120	292	–	–	–	2	3.9	7.8	–	–	–
	Unnamed Waterbody 4	54	spring	350	984	7	0.9	6.42	3	1.1	3.2	–	–	–
			summer	350	711	–	–	–	3	1.1	3.4	–	–	–
			fall	–	–	–	–	–	3	1.4	4.3	–	–	–
Muskeg River	Muskeg River	41	spring	500	749	–	–	–	3	3.0	9.0	–	–	–
			summer	500	564	–	–	–	3	0.8	2.4	–	–	–
			fall	500	767	–	–	–	2	1.8	3.6	–	–	–
		30	spring	300	709	–	–	–	3	2.0	5.9	–	–	–
			summer	260	729	–	–	–	3	1.3	3.8	–	–	–
			fall	200	959	–	–	–	2	22.2	44.4	–	–	–
	Stanley Creek	40	spring	–	–	–	–	–	3	1.1	3.4	–	–	–
			summer	–	–	–	–	–	3	0.8	2.5	–	–	–
			fall	70	271	–	–	–	2	2.0	4.0	–	–	–
	Wapasu Creek	32	spring	–	–	–	–	–	3	0.8	2.4	–	–	–
			summer	–	–	–	–	–	3	1.0	3.0	–	–	–
			fall	–	–	–	–	–	2	1.4	2.9	–	–	–
		26	spring	300	695	–	–	–	3	1.7	5.2	–	–	–
			summer	200	1015	–	–	–	3	1.1	3.3	–	–	–
			fall	300	901	–	–	–	3	21.4	64.1	–	–	–
		38	spring	200	1911	–	–	–	3	1.5	4.6	3	20	60
			summer	200	926	–	–	–	3	1.2	3.7	–	–	–
			fall	250	1143	–	–	–	2	21.9	43.9	–	–	–
	Unnamed Creek 9	35	spring	150	392	–	–	–	3	1.2	3.5	–	–	–
			summer	–	–	–	–	–	3	1.0	3.0	–	–	–
			fall	150	242	–	–	–	1	3.5	3.5	–	–	–

Table 5.2-5 Open-Water Fish Sampling Methods and Effort (continued)

Watershed	Watercourse or Waterbody	Sampling Site[a]	Season	Backpack Electrofishing		Gill Netting			Minnow Trapping			Kick Net Sampling		
				Length of Stream or Shoreline [m]	Effort [s]	Number of Panels	Duration of Set [hr]	Effort [panel-hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	Area [m^2]	Number of Kicks	Effort [m^2]
Muskeg River (continued)	Unnamed Creek 12	24	spring	–	–	–	–	–	3	0.6	1.9	–	–	–
			summer	15	253	–	–	–	3	1.0	3.0	–	–	–
			fall	120	238	–	–	–	2	2.8	5.5	–	–	–
	Unnamed Waterbody 1	29	spring	–	–	7	1.9	13.53	3	23.3	70.0	–	–	–
			summer	900	350	6	1.5	8.90	3	1.3	3.9	–	–	–
			fall	–	–	5	0.4	1.83	1	2.5	2.5	–	–	–
	Unnamed Waterbody 2	27	spring	–	–	–	–	–	2	18.6	37.2	–	–	–
			summer	900	350	–	–	–	3	0.9	2.8	–	–	–
			fall	–	–	5	3.1	15.75	3	20.2	60.6	–	–	–
	Unnamed Waterbody 16	39	spring	–	–	–	–	–	3	23.7	71.1	–	–	–
			summer	740	350	–	–	–	3	1.7	5.1	–	–	–
			fall	–	–	–	–	–	1	1.9	1.9	–	–	–
	Unnamed Waterbody 17	25	spring	–	–	–	–	–	3	17.6	52.7	–	–	–
			summer	–	–	–	–	–	3	1.1	3.3	–	–	–
			fall	–	–	5	2.2	10.83	3	2.2	6.5	–	–	–
Pierre River	Pierre River	20	spring	300	2,398	–	–	–	3	2.5	7.6	–	–	–
			summer	280	960	–	–	–	3	2.0	5.9	–	–	–
			fall	190	609	–	–	–	3	7.3	21.8	–	–	–
		19	spring	–	–	–	–	–	3	0.7	2.0	–	–	–
			summer	300	638	–	–	–	3	1.4	4.3	–	–	–
			fall	–	477	–	–	–	3	5.1	15.2	–	–	–
	Unnamed Creek 4	18	spring	300	1395	–	–	–	3	3.2	9.7	–	–	–
			summer	300	748	–	–	–	3	1.3	3.8	–	–	–
			fall	200	562	–	–	–	1	21.9	21.9	–	–	–
Eymundson Creek	Eymundson Creek	17	spring	300	1,249	–	–	–	3	1.5	4.6	3	5	15
			summer	300	990	–	–	–	3	1.3	4.0	–	–	–
			fall	270	609	–	–	–	3	5.1	15.2	–	–	–
		7	spring	300	1,146	–	–	–	3	1.5	4.5	3	10	30
			summer	200	695	–	–	–	3	1.0	3.0	–	–	–
			fall	300	1,446	–	–	–	3	6.1	18.2	–	–	–
		11	spring	300	2,098	–	–	–	3	1.7	5.0	–	–	–
			summer	300	790	–	–	–	3	2.0	5.9	–	–	–
			fall	200	677	–	–	–	2	3.8	7.7	–	–	–

Table 5.2-5 Open-Water Fish Sampling Methods and Effort (continued)

Watershed	Watercourse or Waterbody	Sampling Site[(a)]	Season	Backpack Electrofishing		Gill Netting			Minnow Trapping			Kick Net Sampling		
				Length of Stream or Shoreline [m]	Effort [s]	Number of Panels	Duration of Set [hr]	Effort [panel-hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	Area [m^2]	Number of Kicks	Effort [m^2]
Eymundson Creek (continued)	Eymundson Creek (continued)	57	fall	250	508	–	–	–	3	1.5	4.4	–	–	–
		6	spring	150	719	–	–	–	3	1.7	5.0	–	–	–
			summer	300	640	–	–	–	3	1.4	4.3	–	–	–
			fall	222	590	–	–	–	3	4.2	12.5	–	–	–
		3	fall	300	416	–	–	–	3	4.1	12.3	–	–	–
	Asphalt Creek	5	spring	300	1,771	–	–	–	3	1.6	4.8	–	–	–
			summer	300	738	–	–	–	3	1.6	4.7	–	–	–
			fall	210	713	–	–	–	3	4.4	13.1	–	–	–
		48	spring	300	1,277	–	–	–	2	1.3	2.5	1	10	10
			summer	300	764	–	–	–	3	1.1	3.3	–	–	–
			fall	300	948	–	–	–	3	2.5	7.6	–	–	–
	Unnamed Creek 1	16	spring	300	796	–	–	–	3	1.5	4.4	3	5	15
			summer	200	809	–	–	–	3	1.0	3.1	–	–	–
			fall	160	567	–	–	–	3	4.7	14.1	–	–	–
		15	spring	300	859	–	–	–	3	1.3	3.8	–	–	–
			summer	–	–	–	–	–	3	1.6	4.9	–	–	–
			fall	300	1,077	–	–	–	3	13.5	40.4	–	–	–
	Unnamed Creek 11	12	Spring	300	1,026	–	–	–	3	1.4	4.1	–	–	–
			summer	200	619	–	–	–	3	1.3	4.0	–	–	–
			fall	240	521	–	–	–	3	19.1	57.4	–	–	–
	Unnamed Waterbody 5	14	spring	620	435	7	1.5	10.50	3	1.6	4.7	–	–	–
			summer	620	760	6	1.1	6.50	3	1.0	3.0	–	–	–
			fall	–	–	5	2.3	11.75	3	2.7	8.0	–	–	–
	Unnamed Waterbody 6	2	spring	–	–	5	1.3	6.33	3	1.4	4.2	–	–	–
			fall	–	–	5	4.3	21.50	3	4.7	14.1	–	–	–
Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	8	spring	–	–	–	–	–	2	1.0	2.0	–	–	–
			summer	–	–	–	–	–	1	1.2	1.2	–	–	–
			fall	–	–	–	–	–	3	17.4	52.3	–	–	–
	Unnamed Waterbody 8	13	spring	300	958	7	1.4	9.92	3	1.0	2.9	–	–	–
			summer	300	2,315	6	2.2	13.00	3	2.1	6.4	–	–	–
			fall	–	–	5	3.2	16.17	3	3.8	11.5	–	–	–
Big Creek	Big Creek	42	spring	–	–	–	–	–	2	20.9	41.8	–	–	–
			summer	–	–	–	–	–	2	5.0	10.1	–	–	–
			fall	270	1,040	–	–	–	3	2.5	7.6	–	–	–
		1	spring	300	974	–	–	–	2	1.8	3.5	1	10	10
			summer	300	964	–	–	–	2	1.5	3.0	–	–	–
			fall	199	650	–	–	–	3	5.9	17.6	–	–	–

Table 5.2-5 Open-Water Fish Sampling Methods and Effort (continued)

Watershed	Watercourse or Waterbody	Sampling Site[(a)]	Season	Backpack Electrofishing		Gill Netting			Minnow Trapping			Kick Net Sampling		
				Length of Stream or Shoreline [m]	Effort [s]	Number of Panels	Duration of Set [hr]	Effort [panel-hr]	Number of Traps	Duration of Set [hr]	Effort [trap-hr]	Area [m^2]	Number of Kicks	Effort [m^2]
Big Creek (continued)	Big Creek (continued)	47	spring	300	716	–	–	–	2	1.3	2.6	–	–	–
			summer	300	567	–	–	–	3	1.1	3.2	–	–	–
			fall	–	–	–	–	–	3	2.1	6.3	–	–	–
	First Creek	9	spring	–	–	–	–	–	2	17.7	35.3	–	–	–
			summer	–	–	–	–	–	2	0.6	1.3	–	–	–
			fall	120	509	–	–	–	4	11.4	45.4	–	–	–
	Unnamed Creek 2	44	spring	300	732	–	–	–	2	1.1	2.1	1	10	10
			summer	300	682	–	–	–	2	1.3	2.6	–	–	–
			fall	300	400	–	–	–	3	1.6	4.8	–	–	–
	Unnamed Creek 7	49	spring	–	–	–	–	–	1	1.0	1.0	–	–	–
			fall	–	–	–	–	–	2	0.6	1.1	–	–	–
	Oakley Lake	46	spring	–	–	5	1.3	6.25	3	1.8	5.5	–	–	–
			fall	–	–	–	1.2	–	3	0.8	2.5	–	–	–
	Small Sandy Lake	45	spring	–	–	–	–	–	2	1.5	3.0	–	–	–
			fall	–	–	–	1.3	–	2	1.5	3.1	–	–	–
	Unnamed Waterbody 15	4	spring	–	–	–	–	–	2	17.6	35.2	–	–	–
			summer	–	–	–	–	–	2	0.9	1.7	–	–	–
			fall	–	–	1	5.3	5.30	3	6.0	18.1	–	–	–
Redclay Creek	Redclay Creek	50	spring	–	–	–	–	–	2	32.8	65.6	1	10	10
			summer	300	396	–	–	–	2	0.8	1.6	–	–	–
			fall	300	2002	–	–	–	3	2.9	8.8	–	–	–
		51	spring	300	864	–	–	–	2	1.5	3.1	1	5	5
			summer	300	9	–	–	–	3	1.4	4.2	–	–	–
			fall	300	805	–	–	–	3	2.0	6.0	–	–	–
	Unnamed Creek 8	55	spring	300	350	–	–	–	2	1.5	3.0	2	5	10
			summer	300	596	–	–	–	3	1.2	3.6	–	–	–
			fall	300	732	–	–	–	3	3.2	9.7	–	–	–
	Unnamed Waterbody 12	52	spring	–	–	–	–	–	2	2.3	4.5	–	–	–
			summer	–	–	–	–	–	3	1.4	4.3	–	–	–
			fall	–	–	–	–	–	3	1.5	4.4	–	–	–
	Unnamed Waterbody 13	53	spring	–	–	–	–	–	2	1.9	3.8	–	–	–
			summer	–	–	–	–	–	2	1.0	2.0	–	–	–
			fall	–	–	–	–	–	3	1.0	2.9	–	–	–

(a) See Figures 5.2-1 and 5.2-2 for sampling site locations.
– = Not sampled.

Table 5.2-6 Dimensions of Gill Nets Used During the Fish and Fish Habitat Field Surveys

Study Area	Waterbody	Sampling Site[a]	Season	Number of Panels[b]	Mesh Sizes[c] [cm]
RSA	Unnamed Waterbody 4	54	spring	7	2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2
			summer	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
JEMA LSA	Unnamed Waterbody 1	29	spring	7	2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2
			summer	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
			fall	5	2.5, 5.1, 7.6, 10.2, 12.7
			winter	2	6.4, 8.9
	Unnamed Waterbody 2	27	fall	5	2.5, 3.8, 6.4, 8.9, 11.4
	Unnamed Waterbody 16	39	summer	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
	Unnamed Waterbody 17	25	spring	7	2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2
			fall	5	2.5, 3.8, 6.4, 8.9, 11.4
PRMA LSA	Oakley Lake	46	spring	5	2.5, 3.8, 6.4, 8.9, 11.4
			fall	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
	Small Sandy Lake	45	fall	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
	Unnamed Waterbody 5	14	spring	7	2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2
			summer	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
			fall	5	2.5, 3.8, 6.4, 8.9, 11.4
	Unnamed Waterbody 6	2	spring	5	2.5, 3.8, 6.4, 8.9, 11.4
			fall	5	2.5, 3.8, 6.4, 8.9, 11.4
	Unnamed Waterbody 8	13	spring	7	2.5, 3.8, 5.1, 6.4, 7.6, 8.9, 10.2
			summer	6	2.5, 5.1, 7.6, 10.2, 12.7, 15.2
			fall	5	2.5, 3.8, 6.4, 8.9, 11.4
	Unnamed Waterbody 15	4	fall	1	2.5

[a] See Figures 5.2-1 and 5.2-2 for sampling site locations.

[b] Panel Dimensions = 15.2 m long x 1.8 m deep.

[c] Stretch-measure.

Spawning Survey

Spawning surveys were conducted only in sites where habitat conditions were suitable enough for large-bodied species, such as sport fish and non-sport fish (i.e., sucker species) and where the field crew could adequately conduct the survey (i.e., safe wading conditions). The method consisted of sampling in potential spawning habitats to check for the presence of incubating eggs.

The emphasis on spring spawning surveys was based on the known biology of large-bodied fish species indigenous to the LSAs. All sport fish and non-sport fish species that were documented to spawn in these watersheds do so in the spring. These include Arctic grayling, northern pike, longnose sucker and white sucker. Mountain whitefish is the only species that might spawn in these watersheds in the fall, but their presence has not been confirmed.

Potential spawning habitats are defined by the biology of indigenous fish species. The majority of sport and non-sport fish prefer to spawn in higher velocity water over coarse substrates. Other species, for example northern pike, prefer slow-moving water with aquatic vegetation to which they attach their eggs. All sampling sites possess one or both types of spawning habitat used by the different spring spawning species.

Spawning surveys were sampled by using a small-mesh kick net to collect incubating eggs. Swift flowing rocky habitats were sampled by placing the net on top of the substrate and disturbing the substrate upstream of the net. This technique causes light objects, such as fish eggs, to float downstream into the net. Areas of aquatic vegetation were sampled by sweeping the net through the vegetation to pick up eggs attached to the vegetation.

If eggs were collected, they were enumerated by species and location. The eggs were identified by measuring egg diameter and checking for any identifying features, such as oil globules.

Seasonal Migrant Survey (Counting Stations)

Sampling of fish that are seasonal migrants from the Athabasca River was based on the use of counting stations installed on the Pierre River at Site 202 (spring 2006) and on Redclay Creek at Site 201 (spring 2006 and 2007). Photos of each can be found in Appendix T. The counting stations were located upstream of the watercourse mouth far enough to ensure that fish captured were migrating into or out of the watercourse and not simply using the confluence area. The Pierre River fish counting fence was located 350 m upstream from the mouth; the Redclay Creek fish counting fence was located 130 m upstream from the mouth.

All fish captured during sampling activities were identified and enumerated by species. Sport and non-sport fish were identified to life stage (i.e., fry, juvenile or adult). Fork length (mm) and body weight (g) were measured for all individuals of sport and non-sport fish species and for a representative sub-sample of individuals of forage fish species. Sex and state of maturity of captured fish also were recorded if these could be discerned from external examination. Captured

fish were marked with a caudal lobe punch and released in the direction of their original travel.

The Pierre River counting fence was equipped with both upstream and downstream trap boxes, to capture fish entering and leaving the watercourse and extended across the wetted width of the watercourse. The trap box frames were constructed of aluminum (each trap box measuring 1.5 m wide, 1.5 m high and 1.8 m long) with vertical free-floating 13-mm galvanized 1.5-m conduit pipes. The main lead of the fence consisted of the same vertical free-floating galvanized conduit pipes, with wing extensions constructed of timber and metal wire mesh. The gap spacing in the trap boxes and fence wings was 19 mm and the wire mesh spacing on the wings was 13 by 26 mm. The fence was secured and reinforced with sandbags and rebar. The fence was installed on May 3, 2006 and removed June 1, 2006 for a total effort of 29 days.

In the spring of 2006, the Redclay Creek counting fence was equipped with two fyke nets, one facing upstream and one facing downstream. The fence wings extended 100% across the wetted width of the watercourse. The mesh size was 1.9 mm in the nets and wings. In the spring of 2006, the fence was installed April 28 and removed May 27 for a total effort of 29 days.

In the spring of 2007, water levels at Redclay Creek were high and resulted in modifications to the counting fence design. Two fyke nets were positioned upstream, to capture fish entering the watercourse. The fence wings extended, on average, 80% across the wetted width, due to high flows and flooded conditions. The mesh size was 1.9 mm in the nets and wings. In the spring of 2007, the fence was installed May and removed June 1 for a total effort of 26 days.

At both locations, water temperature was monitored for the duration of the counting programs using data loggers. Water levels were monitoring using an installed staff gage and discharge was recorded at the onset of the program and during any significant change in water level (i.e., 2 cm).

5.2.2.3 Data Analysis

All fish habitat and fish community data collected during sampling were entered into a database. Data files were checked and verified against original field data to confirm the accuracy of data entry.

Sampling effort was recorded for all sampling activities to allow calculation of Catch-Per-Unit-Effort (CPUE). Sampling effort for electrofishing was recorded as duration (seconds) of active electrofishing; all electrofishers were equipped

with timers that recorded the number of seconds during which electrical current was applied to the water. CPUE was calculated as the number of fish captured per 100 seconds (s). Effort for minnow trapping and gill netting was recorded as number of traps or panels set and duration (hours) of set. The CPUE was calculated as the number of fish captured per trap-hour.

5.2.3 Diversity of Fish and Fish Habitat

Aquatic ecosystem diversity was addressed as part of the environmental setting study through the assessment of the diversity of the fish and fish habitat present in the LSAs. This was done for watercourses and waterbodies in the two study areas that could be affected by the Project. Fish and fish habitat diversity was assessed through an examination of:

- fish species diversity;
- fish habitat diversity; and
- ecosystem diversity, as represented by trophic levels.

These three aspects of the aquatic ecosystem were selected as being suitable representatives of diversity based on Hurlbert (1971) and Pielou (1975), as described by Legendre and Legendre (1998). Fish species diversity and fish habitat diversity were examined at the watercourse or waterbody level and at the watershed ecosystem level. Specific characteristics of fish communities and fish habitats were selected as indicators of diversity. A ranking system was developed to summarize the available information for the selected diversity indicators and to categorize the diversity of fish and fish habitat. The temporal boundary for the analysis was defined as the period of record for each watercourse or waterbody and includes all historical, current and environmental setting data. Fish and fish habitat diversity was assessed for five watercourses and four waterbodies in the JEMA and 14 watercourses and eight waterbodies in the PRMA (Table 5.2-7).

Table 5.2-7 Watercourses and Waterbodies Assessed for Fish and Fish Habitat Diversity

Study Area	Watershed	Watercourse or Waterbody	Waterbody
JEMA	Muskeg River	Muskeg River	Unnamed Waterbody 1
		Stanley Creek	Unnamed Waterbody 2
		Wapasu Creek	Unnamed Waterbody 16
		Unnamed Creek 9	Unnamed Waterbody 17
		Unnamed Creek 12	
PRMA	Pierre River	Pierre River	–
		Unnamed Creek 4	
	Eymundson Creek	Eymundson Creek	Unnamed Waterbody 5
		Asphalt Creek	Unnamed Waterbody 6
		Unnamed Creek 1	
		Unnamed Creek 11	
	Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	Unnamed Waterbody 8
	Big Creek	Big Creek	Oakley Lake
		First Creek	Small Sandy Lake
		Unnamed Creek 2	Unnamed Waterbody 15
		Unnamed Creek 7	–
	Redclay Creek	Redclay Creek	Unnamed Waterbody 12
		Unnamed Creek 8	Unnamed Waterbody 13

– = Not sampled.

5.2.3.1 Fish Species Diversity

Three indicators were selected to assess fish species diversity:

- species richness;
- species overlap; and
- presence or absence of listed species (i.e., species listed by federal or provincial agencies at some level of risk).

Species richness indices are essentially measures of the number of species present (Magurran 1988). Species richness was selected as an indicator because the number of species present is typically proportional to the number of available niches (Hutchinson 1957; 1965) and provides a link between species diversity and environmental diversity (Legendre and Legendre 1998). Species richness is typically greater in larger waterbodies and higher order streams and in regions where species pools are large; therefore, these factors were included in the assessment. Species richness was determined for each watercourse and

waterbody by comparison of the number of species documented to occur in the system to the total number of species known for the entire study area in which the system occurs. The following formula was used for each resource:

Species Richness (%) = (No. of species / No. of species in study area) x 100

For example, species richness at Site 4 (Unnamed Waterbody 15) was calculated by comparing the number of species in the lake to the total number of species in PRMA.

Species overlap refers to the proportion of species present in an ecosystem (or other defined habitat area) that are also found in other ecosystems. Species overlap thus provides a measure of the specificity of the environmental conditions (both biotic and abiotic) in that particular ecosystem. An ecosystem that contains species that are not found in other ecosystems (i.e., contains unique species), would score higher than one that contains species found in other ecosystems. Species overlap was assessed for each watercourse and waterbody by comparison of the number of non-unique species present in the system to the total number of species in the system, as follows:

Species Overlap (%) = ([total No. of species – No. unique species] / total No. of species) x 100.

For example, species overlap at Site 4 (Unnamed Waterbody 15) was calculated by comparing the number of species present in the lake that are present elsewhere in PRMA (i.e., are not unique) to the total number of species in the lake.

The presence of listed species (i.e., provincial General Status of Alberta Wild Species (ASRD 2005) or the federal Species at Risk Act (COSEWIC 2007)) has important ecological, social and regulatory implications. Certain species may be rare in the LSA due to low reproductive rates, limited dispersal capabilities, specialized habitat requirements, because they are difficult to capture or because the LSA occurs at the limit of their distribution range. These conditions may make these species more vulnerable to disturbance and emphasize their need for special consideration. Therefore, an important aspect of preserving diversity is the identification and possible maintenance of sustainable populations of rare or otherwise listed species.

A ranking system was developed to summarize the available information for the selected indicators and categorize the fish species diversity for the selected waterbodies and watercourses. A scale of one (1) to four (4) was devised for each of the three species diversity indicators. Species richness and overlap were

ranked using quartiles (i.e., 25% intervals) and the presence of listed species was ranked in accordance with ASRD's four main definitions of general status categories for the identification of species at risk (ASRD 2005). Table 5.2-8 provides a summary of the indicators and the rankings used to categorize fish species diversity.

Table 5.2-8 Indicators and Ranking Categories for Fish Species Diversity

Indicator	Ranking Description
species richness	1 very low – less than 25% of total potential species present 2 low – 25 to 49% of total potential species present 3 moderate – 50 to 75% of total potential species present 4 high – more than 75% of total potential species present
unique species (species overlap)	1 very low – more than 75% of species present are shared with one or more other resource, or no fish detected 2 low – 50 to 75% of species present are shared with one or more other resource 3 moderate – 25 to 49% of species present are shared with one or more other resource 4 high –less than 25% of species present are shared with one or more other resource
presence of listed species	1 secure – there are no "At Risk", "May be at Risk", or "Sensitive" species present or the status of the species present is not determined 2 sensitive – at least one species present that is not at risk of extinction or extirpation, but may require special attention or protection to prevent it from becoming at risk 3 may be at risk – at least one species may be at risk of extinction or extirpation and is therefore a candidate for detailed risk assessment 4 at risk – at least one species known to be "At Risk" after a formal detailed status assessment and designation as "Endangered" or "Threatened" in Alberta

A general ranking of species diversity was then derived by multiplying the individual ranks for each of the three indicators. The general ranking of the watercourses and waterbodies has a minimum value (score) of one, indicating low contribution to the local fish species diversity and a maximum of 64, which denotes a high contribution. Table 5.2-9 summarizes the general ranking system used for categorizing the selected watercourses and waterbodies according to their diversity at the fish species level.

Table 5.2-9 General Ranking for Fish Species-Level Indicators of Diversity

Indicator	Ranking Description
fish species diversity ranking	1 very low – total score 1 to 3 2 low – total score 4 to 8 3 moderate – total score 9 to 27 4 high – total score 28 to 64

5.2.3.2 Fish Habitat Diversity

Five indicators were used in the assessment of fish habitat diversity:

- watercourse habitat unit diversity index;
- waterbody habitat diversity index;
- waterbody area;
- waterbody maximum depth; and
- stream order.

Two of these indicators were applicable to the watercourses that were included in the assessment and three were applicable to the waterbodies.

The "Watercourse Habitat Unit Diversity Index" assesses habitat diversity by examination of habitat variation and habitat composition, as represented by the types and distribution of channel units. In a given length of watercourse, habitat variation refers to the number of discrete channel units present and habitat composition refers to the number of different channel unit types present. The assumption for this indicator is that a higher number of different types of habitat units can accommodate a higher number of species and a wider range of life stages and therefore promotes species diversity.

The habitat assessment for watercourses was based on the habitat maps prepared for each sampling site. At each site, the length of channel examined was divided into a series of discrete channel units and each unit was assigned a channel unit type, as per the habitat mapping protocol (Golder 1997g). There are 18 possible channel unit types defined for watercourses (principle examples of channel unit types include riffle, Class 1, 2 or 3 run and Class 1, 2 or 3 pool). For the diversity assessment, 17 channel unit types were considered useable by fish and were included as the number of possible channel unit types (the waterfall channel unit type was excluded). The Watercourse Habitat Unit Diversity Index was calculated as follows:

$$\text{Habitat Unit Diversity} = \frac{\text{Number of Discrete Channel Units/100 m of stream} \times \text{Number of Channel Unit Types}}{\text{Number of Possible Channel Unit Types}}$$

Similarly, the "Waterbody Habitat Diversity Index" also assesses habitat diversity by examination of habitat variation and habitat composition. Habitat variation refers to the number of habitats present per area of waterbody and

habitat composition refers to the number of different habitat types present in the waterbody. This assessment was based on the habitat maps prepared for the waterbodies that show the location and extent of all habitat types, as per the habitat mapping protocol (Golder 1997d). The total number of possible waterbody habitat types is 20 (examples of habitat types include littoral, pelagial zone, submergent vegetation and emergent vegetation). The formula used to calculate the Waterbody Habitat Diversity Index was:

$$\text{Habitat Diversity} = \frac{\text{Number of Discrete Habitats/100 m}^2 \text{ x Number of Habitat Types}}{\text{Number of Possible Habitat Types}}$$

The remaining habitat indicators (i.e., waterbody area, waterbody depth and stream order) were selected based on the premise that, to a certain extent, larger watercourses and waterbodies are capable of supporting a higher level of diversity (Chase and Leibold 2002; Post et al. 2000; Vannote et al. 1980). Watercourse size was represented by stream order. Waterbody size was represented by a combination of waterbody area and maximum depth.

All watercourses and waterbodies were evaluated on a scale of one (1) to four (4) for each relevant habitat indicator. Table 5.2-10 summarizes the indicators and the ranking categories used to assess the diversity of habitats in waterbodies and watercourses and their potential to support a diversity of fish.

Table 5.2-10 Indicators and Ranking Categories for Habitat Diversity

Indicator	Ranking Description	
watercourse habitat unit diversity index	1	very low – <0.25
	2	low – 0.25 to 0.4
	3	moderate – 0.5 to 1.4
	4	high – >1.4
waterbody habitat diversity index	1	very low – <0.25
	2	low – 0.25 to 0.4
	3	moderate – 0.5 to 1.4
	4	high – >1.4
waterbody size	1	very low potential – area <0.01 km^2 or maximum depth <2 m
	2	low potential – area 0.01 to 0.10 km2 or maximum depth 2 to 6 m
	3	moderate potential – area 0.11 to 10.00 km2 or maximum depth 7 to 40 m
	4	high potential – area >10.00 km2 or maximum depth >40 m
stream order at mouth	1	very low potential – first order
	2	low potential – second order
	3	moderate potential – third order
	4	high potential – fourth and higher order

A general ranking of habitat diversity was then derived by multiplying the individual ranks for each of the two habitat diversity indicators relevant to a watercourse or waterbody. The general habitat diversity ranking has a minimum value (score) of 1 and a maximum of 16. Table 5.2-11 summarizes the general ranking system used for categorizing the selected watercourses and waterbodies according to their diversity at the fish habitat level.

Table 5.2-11 General Ranking for Fish Habitat-Level Indicators of Diversity

Indicator	Ranking Description
fish habitat diversity ranking	1 very low – total score 1 to 2 2 low – total score 3 to 4 3 moderate – total score 5 to 9 4 high – total score 10 to 16

5.2.3.3 Ecosystem-Level Indicators of Diversity

Diversity may be assessed at higher levels of system organization, such as at the ecosystem, community or guild level. A guild is described as a group of species that exploit the same class of environmental resources in the same manner (Begon et al. 1990). The ratio of predatory fish species to trophic generalists/prey species was used in this assessment as a method of assessing diversity at the community and guild level. The ratio of predatory fish species to trophic generalists/prey species is an indication of the diversity potential and the functioning of an ecosystem. To maintain a sustainable population, large-bodied top predators require a higher degree of habitat diversity and complexity, and overall habitat quality Because of these stricter trophic and habitat requirements, they are usually more sensitive to changes in the ecosystem than most generalist species (Rieman and McInthyre 1993). Table 5.2-12 shows the ranking system devised to assess the status of predator/prey ratios.

Table 5.2-12 Ranking Categories for Predator to Prey Species Ratios

Indicator	Ranking Description
predator to prey/forage guild ratio	1 very low (no relationship) – no predator species, or no fish species detected 2 low – one predator species, one prey/forage guild species 3 moderate – one predator species, two or more prey/forage guild species 4 high – two or more predator species, two or more prey/forage guild species

For the purpose of this study, predators have been defined as those fish species that have a predominantly piscivorous diet (i.e., feed mainly on fish) at the adult stage of their life cycle. Within the LSAs, these species include bull trout, burbot, northern pike and walleye. Prey species were considered to be the forage fish guild and suckers.

5.2.3.4 Overall Fish and Fish Habitat Diversity

Once species, habitat and ecosystem diversity have been determined, an overall fish and fish habitat diversity value was assigned to each watercourse and waterbody. An average value was derived from the general rankings for species, habitat and ecosystem diversity.

5.2.4 Benthic Invertebrates

5.2.4.1 Literature Review

This report summarizes available benthic invertebrate data (historical and current) for watercourses and waterbodies in the LSAs and RSA. Several benthic invertebrate studies have been completed in the Oil Sands Region, including historical studies dating back to the late 1970s, as well as more recent baseline studies conducted to support oil sands developments. The sources used to compile available benthic invertebrate community data included the following:

- government-sponsored research programs, such as the Alberta Oil Sands Environmental Research Program (AOSERP);
- environmental departments of various private industries, such as the oil and gas industry;
- environmental research done by consultants working for industry; and
- research conducted by multi-stakeholder groups created to study or monitor environmental conditions in the Oil Sands Region, such as the oil sands RAMP and CEMA.

5.2.4.2 Data Included and Summary Methods

Historical benthic invertebrate data were collected over a 28-year period (1979 to 2006; Table 5.2-13) in the Project area. Nearly all available historical data in this area were collected in the Muskeg River basin and adjacent watersheds (Figures 5.2-3 and 5.2-4); the only previous sampling in the PRMA was conducted in 2001 in Lillian Lake. In JEMA, 124 site data sets (i.e., taxon lists with associated abundance values for a single site sampled during one event) are

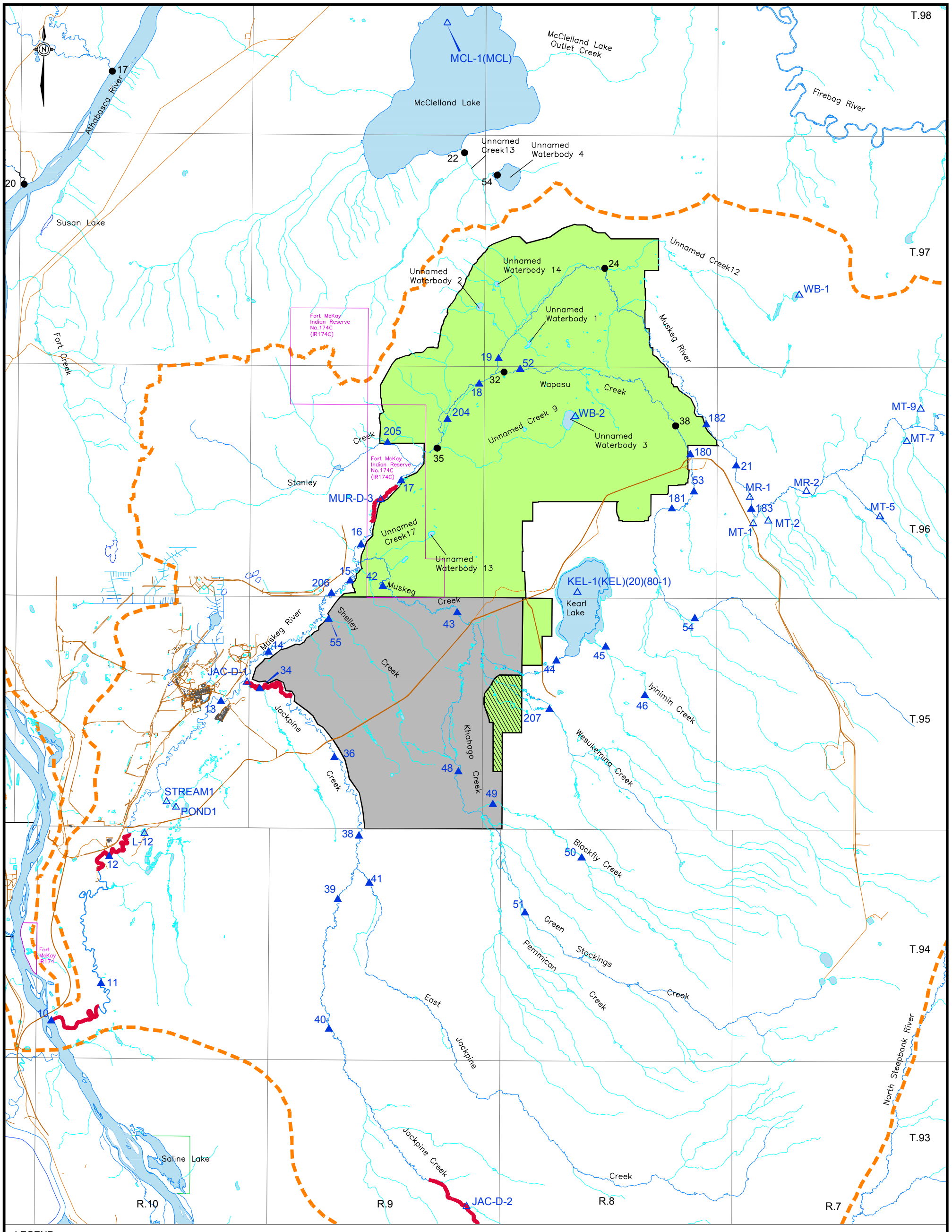
available, collected from 61 sites (55 in watercourses and six in waterbodies), which reflects repeated sampling at several sites.

Table 5.2-13 Summary of Historical Baseline Benthic Invertebrate Data Available for the Jackpine Expansion Mining Area and Pierre River Mining Area

Watercourse or Waterbody	Number of Sites Sampled														
	1979	1981	1985	1988	1995	1997	1998	2000	2001	2002	2003	2004	2005	2006	Total
Jackpine Expansion Mining Area															
Firebag River	–	–	–	–	–	–	–	–	–	–	1	1	1	1	**4**
McClelland Lake	–	–	–	–	–	–	–	–	–	1	1	1	1	1	**5**
Muskeg River watershed	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Muskeg River	3	–	5	6	3	3	3	2	4	3	5	3	3	3	**46**
Jackpine Creek	–	3	–	2	2	–	–	–	2	1	2	2	2	2	**18**
East Jackpine Creek	–	–	–	1	–	–	–	–	–	–	–	–	–	–	**1**
Shelley Creek	–	–	–	–	–	–	–	–	1	–	–	–	–	–	**1**
Stanley Creek	–	–	–	–	–	–	–	–	1	–	–	–	–	–	**1**
Wapasu Creek	–	–	2	1	–	2	–	–		–	–	–	–	–	**5**
Muskeg Creek watershed	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Muskeg Creek	–	–	3	3	1	–	–	–	2	–	–	–	–	–	**9**
Khahago Creek	–	–	1	1	1	–	–	–	1	–	–	–	–	–	**4**
Green Stockings Creek	–	–	1	1		–	–	–		–	–	–	–	–	**2**
Blackfly Creek	–	–	1	1	1	–	–	–	1	–	–	–	–	–	**4**
Wesukemina Creek	–	–	–	–	–	–	–	–	1	–	–	–	–	–	**1**
Kearl Lake	–	–	1	1	1	–	–	–	1	1	1	1	1	1	**9**
Iyinimin Creek	–	–	1	1	1	–	–	–	1	–	–	–	–	–	**4**
Unnamed Tributary 1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Unnamed Tributary 2	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Unnamed Tributary 5	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Unnamed Tributary 7	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Unnamed Tributary 9	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Stream 1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Pond L12	–	1	–	–	–	–	–	–	–	–	–	–	–	–	**1**
Pond 1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Waterbody 1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Waterbody 2	–	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
Pierre River Mining Area															
Lillian Lake	–	–	–	–	–	–	–	–	1	–	–	–	–	–	**1**

– = No data collected.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\FISH-BENTHICS\Figure 5.2-3 benthic_invertebrate_sampling_sites-JEMA.dwg Nov 29, 2007 - 4:59pm



LEGEND

- ROAD
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- 7 FISH AND FISH HABITAT SAMPLING SITE
- LOCAL STUDY AREA
- MT-2 HISTORICAL BENTHIC INVERTEBRATE SAMPLING SITE (APPROXIMATE LOCATIONS)
- 41 HISTORICAL BENTHIC INVERTEBRATE SAMPLING SITE (APPROXIMATE LOCATIONS) (SITES LABELLED BASED ON RAMP HISTORICAL DATA IN GOLDER 2003)
- RAMP STUDY REACHES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

3 0 3
SCALE KILOMETRES

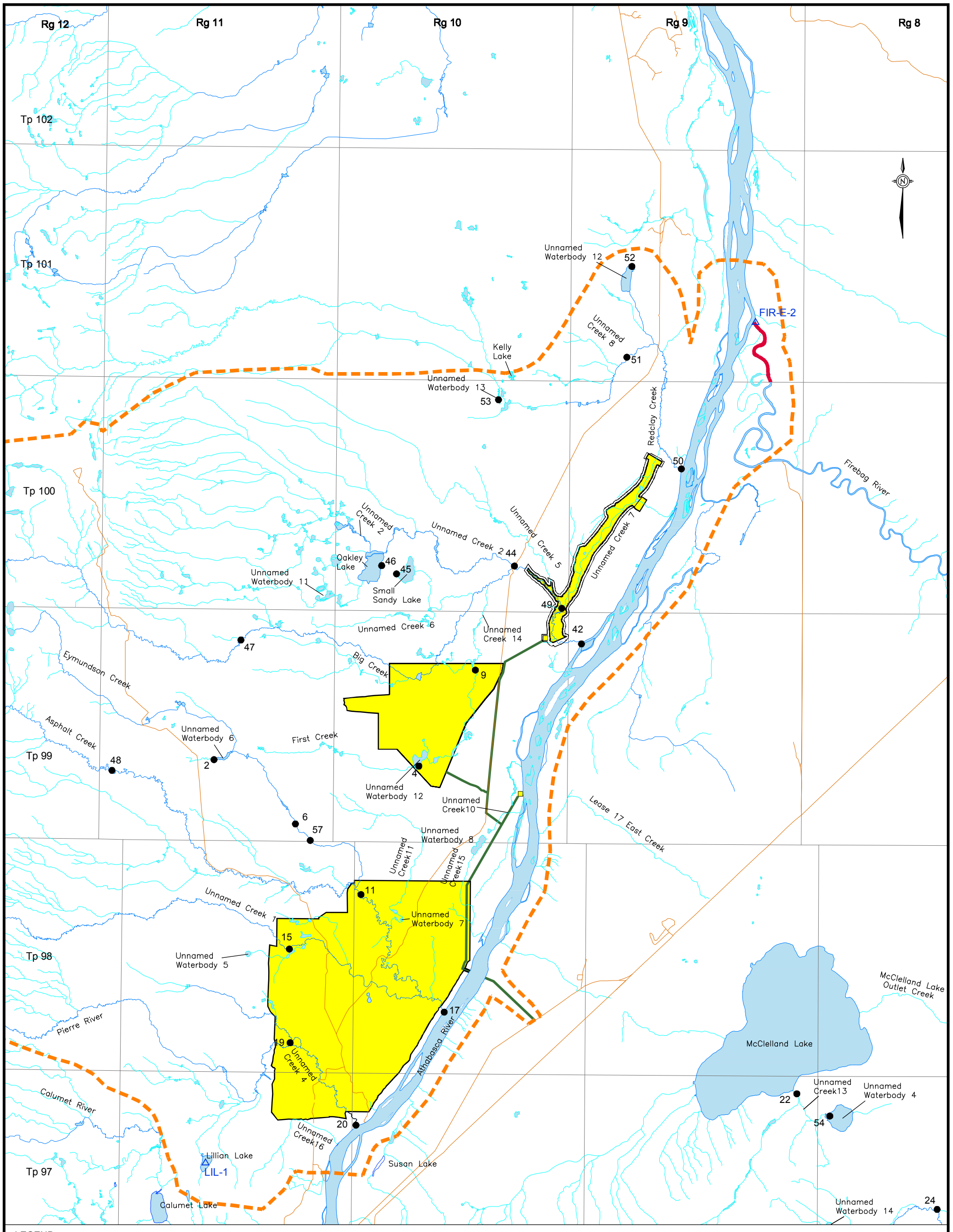
PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
BENTHIC INVERTEBRATE SAMPLING SITES IN THE JACKPINE EXPANSION MINING AREA

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. benthic invertebrates	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 2
CADD	PSR	19/11/07	**FIGURE: 5.2-3**	
CHECK	AS	19/11/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\FISH-BENTHICS\Figure 5.2-4 benthic_invertebrate_sampling_sites-PRMA.dwg Nov 19, 2007 - 10:11am



LEGEND

- ROAD
- PROPOSED ACCESS
- PIERRE RIVER MINING AREA
- 7 2005/2006 BENTHIC INVERTEBRATE SAMPLING SITE
- LOCAL STUDY AREA
- △MT-2 HISTORICAL BENTHIC INVERTEBRATE SAMPLING SITE (APPROXIMATE LOCATIONS)
- RAMP STUDY REACHES

3 0 3
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
BENTHIC INVERTEBRATE SAMPLING SITES IN THE PIERRE RIVER MINING AREA

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. benthic invertebrates	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 2
CADD	PSR	19/11/07	FIGURE: 5.2-4	
CHECK	AS	19/11/07		
REVIEW	WES/TC	20/11/07		

Historical data were collected using a variety of sampling devices in streams, reflecting the habitat types sampled. Sites in waterbodies and depositional stream habitat were sampled using a 6 x 6 x 6" (15 x 15 x 15 cm) Ekman grab. Erosional sites were sampled using a Neill cylinder, Hess sampler or Surber sampler, each of 1 ft^2 (0.093 m^2) bottom area, or a D-frame kick net. Sampler screen mesh sizes and laboratory screen mesh sizes included 180, 210 and 250 µm, which represents a relatively narrow range. Number of samples collected per site ranged from one to five, or 15 samples in a 2 to 4 km reach during RAMP surveys. Level of taxonomic identification varied among studies, especially for the Chironomidae, but all studies provided at least family-level data.

Since most of the historical data were collected in the late summer or fall, the literature review was restricted to this period (August to October). Only studies conducted using a standard quantitative bottom sampling device (Ekman grab, Neill cylinder, Hess sampler, Surber sampler) were included, which resulted in the exclusion of only a small amount of data collected in the late 1970s. This allowed for the conversion of data to densities (numbers/m^2) from the abundance data (numbers/sample).

The data summarized in this section were obtained primarily from electronic files compiled for summary reports (Golder 2003c, 2006), from electronic files from the original baseline reports (AXYS 2005) or from electronic files from original Environmental Impact Assessment (EIA) documents (Golder 2002c; Imperial Oil 2005). Other data were either manually entered from the original report (O'Neil et al. 1982) or from electronic files created from tables from Adobe™ Portable Document Files (PDFs) of the report (RAMP 2007). Data entered from original reports and from electronic files created from PDFs were checked for accuracy by comparing the entered data with the original report. Any discrepancies found were corrected.

Summary data from the 2006 RAMP Technical Report (RAMP 2007) were used only where previous RAMP raw data were unavailable, because the PDF files of this report do not include raw data from the current or previous RAMP sampling years. Raw RAMP data from previous RAMP reports exists for 2003 and earlier. Summary data from tables in the RAMP 2006 Technical Report were reported as means without a measure of variation (e.g., standard error or standard deviation) and benthic invertebrate richness was only reported as mean richness (i.e., mean number of taxa at a site), rather than total richness (i.e., total taxa recorded at a given sampling site). Relative density (percent composition) of major taxonomic groups also do not add up to 100% in some columns in the RAMP 2006 Technical Report, which may be the result of rounding to the nearest whole

number; however, some discrepancies are greater than would be expected from rounding alone.

Historical benthic invertebrate data were summarized in terms of mean total density (numbers/m²), taxonomic richness (total number taxa per site and mean number of taxa per site, at the lowest level of identification) and relative density of major invertebrate taxa (as a percentage of the total density).

5.2.4.3 Environmental Field Survey

Sampling Locations and Timing

Benthic invertebrate samples were collected in fall 2005 and 2006 in selected watercourses and waterbodies in the LSA (Figures 5.2-3 and 5.2-4). Table 5.2-3 has details of the environmental setting sampling program. Since a large amount of historical benthos data are available for JEMA, the 2005 and 2006 baseline field programs focused on PRMA, which has not been sampled previously, except for a single site in Lillian Lake.

Sampling Methods

Benthic invertebrates were sampled according to Golder Associates' Technical Procedure 8.6-1 (available upon request). Five samples were collected at each site. In erosional watercourse habitat, samples were collected using a Neill cylinder or Surber sampler (both with a bottom area of 0.093 m²) equipped with a 210 µm diameter sampling mesh. Depositional watercourse habitats and waterbodies were sampled using an Ekman grab (bottom area 0.023 m²). Samples collected with the Ekman grab were sieved through a 250 µm mesh sieve to remove fine sediments. Samples were preserved in 10% neutral buffered formalin immediately after collecting.

At each depositional watercourse and waterbody sampling location an additional sediment grab was collected for laboratory analysis of particle size and Total Organic Carbon (TOC). These samples were double-bagged and frozen before shipping to the ALS Laboratory Group, Environmental Division, Edmonton (formerly Enviro-Test Laboratories) for analysis.

Additional supporting data collected at each watercourse site included:

- exact site location as Universal Transverse Mercator (UTM) using a handheld Global Positioning System (GPS) unit;
- field water quality (pH, conductivity, dissolved oxygen and water temperature) using a field-calibrated water quality meter;

- aquatic plant (macrophyte) cover (visual estimate);
- current velocity (Marsh-McBirney current velocity meter); and
- water depth (wading rod of current velocity meter).

Additional supporting data collected at each waterbody site included:

- exact location of each sampling point as UTM using a handheld GPS unit;
- field water quality (pH, conductivity, dissolved oxygen and water temperature) using a field calibrated water quality meter;
- aquatic plant cover (visual estimate); and
- water depth at each sample point (weighted sounding line).

Laboratory Methods

Benthic invertebrate samples were sent to J. Zloty, Ph.D. for enumeration and taxonomic identification. Samples were processed according to standard methods based on recommendations of AENV (AENV 1990) and Environment Canada (Environment Canada 2002). First, samples were elutriated to remove sand and gravel. The remaining organic material was separated into coarse (more than 1 mm) and fine size (250 µm to 1 mm) fractions using sieves. The entire course fractions were sorted, and fine fractions were subsampled using the method developed by (Wrona et al. 1982). All remaining material was preserved for random checks of sorting efficiency. Quality Control (QC) procedures included the resorting of randomly selected samples (i.e., 10% of the total number of samples) to evaluate efficiency.

Benthic invertebrates were identified to the lowest practical level recommended by AENV (AENV 1990), typically genus for most invertebrates. The exceptions were the Oligochaeta (bristle worms) and mollusk group (Sphaeriidae), which were identified to family, and the Nematoda (round worms), zooplankton, Ostracoda (seed shrimp) and Hydrachnidia (water mites) which were identified to major group. Immature or damaged specimens were identified to family, or subfamily and tribe for the Chironomidae (midges), as the condition of the specimens allowed.

Data Analysis

Benthic invertebrate data were initially checked for data entry errors by the taxonomist, by double checking each number entered. Data entry errors were corrected as necessary. Pupae, terrestrial and non-benthic taxa were removed

from the data set and abundances were converted to densities (number of organisms per square metre [organism/m²]).

Benthic invertebrate community data were summarized as total density (organism/m²), taxonomic richness (total number of taxa per site and mean number of taxa per site), Simpson's Diversity Index (SDI), evenness (a distribution measure of density among taxa present), community composition (relative density as a percent of the total density) at the level of major taxon, and Chironomidae composition at the subfamily and tribe level.

5.3 REGIONAL RESULTS

5.3.1 Fish and Fish Habitat

5.3.1.1 Literature Review

Athabasca River

The LSAs and RSA includes the section of the Athabasca River extending from Fort McMurray downstream to Embarras Portage. The amount of existing information for the Athabasca River is considered sufficient to adequately describe the fish and fish habitat in this watercourse. Therefore, the Athabasca River was not included in the field surveys conducted for the environmental setting; fish and fish habitat information was provided by a literature review.

There is a considerable amount of fisheries information for the lower Athabasca River, particularly in the section extending from a short distance upstream of Fort McMurray (i.e., Cascade Rapids) downstream to the Firebag River confluence (Aquatic Environments Ltd. 1976; Berry 1986; Boerger 1986; Bond 1980; Bond and Berry 1980; BOVAR 1996; CNRL 2002; D.A.Westworth and Associates Ltd. 1990; Golder 1996a; Golder 1996b; Golder 1998; Golder 1999a; Golder 2000; Golder 2001a; Golder 2001b; Golder 2002b; Golder 2002d; Golder 2003a; Golder 2003b; Golder 2004a; Golder 2004b; Golder 2004c Jacobson and Boag 1995; Jones et al. 1978a; Jones et al. 1978b; McCart et al. 1977; Mill et al. 1997; RAMP 2004; RAMP 2005; RAMP 2006; RL&L 1994; RL&L 2001; RL&L 2002; RL&L and Golder 2003; Shell 2002; Tripp and McCart 1979a; Tripp and McCart 1979b; TrueNorth Energy 2001; Wallace and McCart 1984; Westworth and Associates 2002). This information is pertinent to the portion of the Athabasca River within the RSA.

Most studies of the lower Athabasca River have been conducted during the open-water season (April though November) and provide information on use by various fish species for spawning, nursery, rearing and feeding. Investigations of

overwintering use have been limited. One historical study (McCart et al. 1977) included winter sampling, as have recent studies initiated by RAMP (Golder 1999a; Golder 2002d) and CEMA (Golder 2004a; RL&L and Golder 2003).

Fish Habitat

With respect to mesohabitat, the lower Athabasca River is a large volume, low-gradient mainstem river that provides turbid, cool-water habitat for fish. The river is wide but generally shallow with dynamic shifting-sand channels. Most of the river is a single large channel, but islands and sandbars are common, resulting in several sections with multiple channels and areas of high velocity with coarse substrate.

An analysis of habitat composition is available for a section of the lower Athabasca River that corresponds to the upper half of the RSA (Golder 1996b; Golder 1998; Golder 1999a; Golder 2002d; RL&L 1994). The Athabasca River in the RSA is dominated by sandy, erosional bank habitats (65% of total shoreline length). Depositional bank habitats composed of fine sediments constituted 18% of the available shoreline and as a result a total of 83% of the shoreline consists of fine sediment, including sand. The remaining 17% of the bank habitats were composed of rocky material and exposed hardened oil sands, including armoured and canyon habitats.

Special habitat features present in the portion of the lower Athabasca River in the RSA include backwaters and snyes associated with islands, sandbars and certain bank habitat types with irregular shorelines (Golder 1996b; Golder 1998). Several tributary confluences also were present and identified as significant habitat features that were found to influence fish distribution. Rapids were not found in the RSA but two sets of rapids are present in the Athabasca River upstream of the RSA. Cascade and Mountain rapids are located upstream of Fort McMurray and provide a unique and significant habitat feature in the lower Athabasca River (i.e., swift turbulent flow with rocky substrate) that has been documented or suspected to provide spawning habitat for some sport fish and non-sport fish species (Golder 2004a; Tripp and McCart 1979a; Westworth and Associates 2002). The presence of these rapids influences the distribution of some fish species during the spring and fall spawning seasons and also influences seasonal movements of fish in the RSA.

“Fish-habitat associations” were analyzed during inventory studies by recording species, life stage and bank habitat type for each fish captured and comparing the level of use for each habitat type to the level of availability (Golder 1998; Golder 1999a) With respect to the main sport fish species, depositional habitats associated with large backwaters were found to provide important habitat for goldeye, lake whitefish, northern pike and walleye and certain types of armoured

bank habitat were selected for use by goldeye, lake whitefish and walleye. Northern pike also showed a preference for tributary confluence areas throughout the open-water period, as did walleye in the spring and lake whitefish during the fall migration. Erosional bank habitats were used by all species, but in low proportion compared to their high level of availability.

Fish Populations

The lower Athabasca River supports various life-history activities by several sport fish species, a few non-sport fish species and a number of forage species. The Athabasca River in the RSA provides juvenile rearing habitat and adult feeding habitat for regionally significant commercial, subsistence and sport fish and also provides some nursery, spawning and overwintering habitat. The Athabasca River in the LSAs and RSA provides an important migratory route for fish populations from Lake Athabasca to access known spawning areas at the rapids in the mainstem river upstream of Fort McMurray or in tributary watercourses and also provides a downstream dispersion corridor for larval fish drifting to downstream nursery areas.

In total, 31 fish species have been documented to occur in the lower Athabasca River (Table 5.3-1), including 12 sport fish species, two non-sport fish species and 17 forage species. Although 31 species are present, the fish fauna in the mainstem lower Athabasca River is dominated by a few species. Table 5.3-1 shows the 11 species that are common or abundant (including seasonally abundant); this includes four sport fish species, two sucker species and five forage fish. The remaining 20 species are either uncommon or rare in the mainstem river, although nine of these 20 species are common or abundant in tributary watercourses within the region.

Past inventory studies and the current fish population monitoring program being conducted by RAMP have, to a large extent, focused on sport and non-sport fish species. Therefore, long-term data are available only for these large-bodied fish.

The following species accounts provide a summary of fish use of the lower Athabasca River by the four sport fish species and two sucker species that are common, abundant or seasonally abundant.

Table 5.3-1 Fish Species of the Lower Athabasca River

Category	Species	Abundance Rating[a]
sport fish	Arctic grayling	U
	bull trout	R
	burbot	U
	cisco	R
	goldeye	A
	Lake trout[b]	R
	Lake whitefish	S
	mountain whitefish	U
	northern pike	C
	rainbow trout	R
	walleye	A
	yellow perch	U
non-sport fish	longnose sucker	A
	white sucker	A
forage fish	brassy minnow	R
	brook stickleback	U
	emerald shiner	A
	fathead minnow	U
	finescale dace	R
	flathead chub	A
	lowa darter	R
	Lake chub	C
	longnose dace	U
	ninespine stickleback	R
	northern redbelly dace	R
	pearl dace	U
	river shiner	R
	slimy sculpin	U
	spoonhead sculpin	U
	spottail shiner	A
	trout-perch	A

(a) Abundance Rating (Golder 2004a):

A = Abundant; typically present in large numbers during spring, summer and fall.

C = Common; typically present in moderate numbers during spring, summer and fall.

U = Uncommon; typically present in low numbers during spring summer and fall.

S = Seasonal; abundant in one season, otherwise uncommon.

R = Rare; present irregularly and in very low numbers.

(b) Not collected in any previous study but capture reported by anglers to ASRD (L. Rhude, pers. comm. 2003).

Lake Whitefish

Lake whitefish is one of the key sport fish species in the lower Athabasca River and is one of the most abundant large-bodied fish in the river during the fall; abundance is low in spring and summer seasons (Golder 2003a). Studies by RAMP indicate year-to-year variability in lake whitefish abundance and some population parameters, but no specific trends to indicate any population changes over the monitoring period (1997 to 2006) (Golder 2003a,b; RAMP 2004, 2005, 2006, 2007).

Lake whitefish spawn in the fall, at which time they move to suitable spawning areas in lakes or rivers. In the Oil Sands Region, a large migration of lake whitefish occurs between Lake Athabasca and known spawning grounds at Mountain and Cascade rapids. The migration typically begins in late August and peaks in mid-September, at which time lake whitefish become one of the most abundant, large-bodied species in the lower Athabasca River. Spawning tends to occur in mid-October, with the post-spawning downstream migration beginning in late October. Some fish remain close to the spawning grounds after spawning for a number of weeks. However, most fish return back to Lake Athabasca quickly after initiating downstream movements.

Most lake whitefish fry that hatch in the Athabasca River appear to drift downstream to nursery areas in Lake Athabasca or the Peace-Athabasca Delta. Drifting fry have been recorded moving downstream under the river ice in early April (Golder 2004a). A small amount of nursery activity has been recorded in the lower Athabasca River and is primarily associated with the mouths of a few tributaries (Golder 2004a).

The abundance of juvenile and adult lake whitefish is very low in the lower Athabasca River other than during the fall spawning migration. A small amount of rearing and feeding activity occurs for this species in selected habitats in the Athabasca River or in the lower portions of some of the larger tributaries, such as the Firebag, McKay, Steepbank and Clearwater rivers (Golder 2004b). Lake whitefish are considered occasional migrants in the Muskeg River and are occasionally found near the river mouth in association with the Athabasca River, using the Muskeg River to a limited extent for seasonal rearing and feeding activities.

Most lake whitefish overwinter in the Peace-Athabasca Delta or Lake Athabasca, but a small number of fish spend all or part of the winter in the Athabasca River.

Walleye

Walleye is one of the key sport fish species in the lower Athabasca River and is one of the more abundant large-bodied fish in the Athabasca River within the region (Golder 2003a,b). Walleye abundance is typically highest in the spring, with decreasing abundance through the summer, fall and winter. Studies by RAMP indicate year-to-year variability in walleye abundance and some population parameters (e.g., length, frequency and growth), but no specific trends to indicate any population changes over the monitoring period (1997 to 2006) (Golder 2003a,b; RAMP 2004, 2005, 2006, 2007).

Walleye typically spawn shortly after ice break-up at water temperatures between 6.7 and 8.9°C (Scott and Crossman 1998). Spawning has not been documented in the Athabasca River in the Oil Sands Region, but it is suspected to occur based on the spring migration patterns and the presence of fry later in the year. Potential walleye spawning grounds are considered to occur in the Athabasca River at Mountain and Cascade rapids, at Richardson Lake in the Peace-Athabasca Delta, and in some of the larger tributary watercourses (e.g., the Clearwater River).

Although some fry drift downstream to nursery areas, use of the lower Athabasca River as nursery habitat is common during the spring and summer. Walleye nursery activity in the lower Athabasca River has been noted in shallow, slow water habitats and in tributary mouths. Downstream movement of fry begins in late summer, although some fry remain in the area into October. During the open-water period, juvenile rearing and adult feeding activity occurs in the lower Athabasca River and some of its larger tributaries.

A spring spawning migration from Lake Athabasca consists of both juvenile and adult fish with individuals moving into several areas within the Peace-Athabasca Delta to spawn, the most important of which is Richardson Lake (Kristensen 1979). After spawning, Peace-Athabasca Delta walleye migrate into the Athabasca River and its tributaries to summer feeding habitats (Mill et al. 1997). Migrations into tributary watercourses consist primarily of juvenile fish and post-spawning males.

Radio telemetry studies of walleye tagged within the Oil Sands Region in the fall showed most individuals remained in the area throughout the winter (Golder 1999a, RL&L and Golder 2003, Golder 2004c). In late spring and early summer, the majority of these fish appear to move downstream to areas in or near the Athabasca Delta. Subsequently, there is a return, upstream migration in the Athabasca river in the fall, which may be a feeding movement associated with walleye following the large fall migration of lake whitefish.

Overwintering habitat for walleye includes areas with adequate depth to avoid freezing, adequate Dissolved Oxygen (DO) levels and no strong currents. Walleye actively feed during the winter. Sites in the lower Athabasca River used by overwintering walleye were characterized by shallow water depths, slow velocities and fine substrates.

Goldeye

Goldeye is one of the key sport fish species in the lower Athabasca River and is one of the more abundant large-bodied fish in the lower Athabasca River

(Golder 2003c). Studies by RAMP indicate year-to-year variability in goldeye abundance and some population parameters, but no specific trends to indicate any population changes over the monitoring period (1997 to 2006) (RAMP 2007).

There is a major upstream movement of juvenile and adult goldeye in the Athabasca River from Lake Athabasca in the spring. Based on the presence of adult fish in the spring, it is possible that some goldeye spawning occurs in the river. However, spawning by this species has never been intensively studies in the lower Athabasca River, but is known to occur downstream in the Peace-Athabasca Delta.

Goldeye fry have rarely been recorded in the lower Athabasca River, either due to lack of spawning or to downstream drift of the eggs or fry (Golder 2004a). Nursery activity has been recorded downstream in the Peace-Athabasca Delta.

Juvenile and adult goldeye have similar habitat requirements, but may use different areas. For some populations, adult fish are known to move from spawning areas to other locations for summer feeding. In the Oil Sands Region, both juvenile and adult goldeye rear and feed extensively in the lower Athabasca River during the open-water period, primarily using large backwaters and other low-velocity habitats or, less frequently, the lower portions of some of the larger tributaries, such as the Ells, McKay, Steepbank, Clearwater and Christina rivers (Golder 2004b).

Overwintering for goldeye occurs primarily in Lake Athabasca although some fish remain to overwinter in the lower Athabasca River. Goldeye abundance in the lower Athabasca River declines in the fall with most fish moving downstream to the Peace-Athabasca Delta and perhaps beyond in December through February (RL&L and Golder 2003, Golder 2004c).

Northern Pike

Northern pike is one of the key sport fish species of the lower Athabasca River (Golder 2003a). Monitoring studies by RAMP indicate little year-to-year variability in northern pike abundance in the Athabasca River (Golder 2003a,b; RAMP 2004, 2005, 2006, 2007). While variability in some population parameters were observed, no specific trends were identified to indicate any population changes over the monitoring period (1997 to 2006) (RAMP 2007).

The critical time for spawning in the Athabasca River and some of its tributaries is identified as the last half of May. Northern pike spawn in the spring at water temperatures in the range of 4.4 to 11.1ºC (Scott and Crossman 1998). It is presumed that there is a spring migration of northern pike from overwintering

areas in Lake Athabasca into the lower Athabasca River**.** However, **s**upporting evidence for this hypothesis is limited. Northern pike tagged in Lake Athabasca have been recaptured in the lower reaches of the Athabasca River, near the confluence of the Embarras and Athabasca rivers (Kristensen 1981). Radio-telemetry studies conducted on northern pike captured during the spring and fall in the lower Athabasca River showed most overwinter in the Athabasca River mainstem (RL&L and Golder 2003; Golder 2004c). Spring migrations have been recorded in several Athabasca River tributaries, including the Muskeg River, Pierre River and Jackpine Creek (Golder 2004b). Suitable northern pike spawning habitat is sparse in the lower Athabasca River and spawning activity has not been documented in the mainstem of the river (Golder 2004b). All documented spawning by this species in the region has been located in tributary watercourses (Golder 2004b).

Nursery activity for northern pike occurs mainly in the spawning tributaries, but fry have been recorded in the lower Athabasca River irregularly and in low abundance (Golder 2004a). Northern pike use the Athabasca River in the region and its tributaries for rearing and feeding habitat.

Recent studies indicate that in the Oil Sands Region, northern pike from tributary watercourses move into the lower Athabasca River in the fall (RL&L and Golder 2003, Golder 2004c). The majority of these fish then overwinter in the river with some individuals exhibiting homing behaviour to overwintering sites (Golder 2004c). Northern pike that overwinter in the lower Athabasca River select areas with shallow depths, slow velocities and fine substrates, but also show some selection of areas with coarser substrates.

Longnose Sucker

The longnose sucker population uses both the lower Athabasca River and Lake Athabasca for its life history activities. Longnose sucker use the lower Athabasca River as spawning, nursery, rearing and feeding habitat and as a migration route. They also use tributary watersheds for spawning, nursery, rearing and feeding activities. Although overwintering activity occurs in Lake Athabasca, some overwintering has been documented in the Athabasca River.

Radio telemetry studies on longnose sucker movements in the lower Athabasca River suggest some individuals remain resident in the area through the winter while others appear to use the area primarily as a spring spawning migration route (Golder 2001c, 2002d, 2004c). Of 22 longnose sucker radio-tagged in the spring of 2000 near Fort McMurray, 16 were found to inhabit the lower Athabasca River only during the spawning period. It is unknown whether these fish moved downstream to Lake Athabasca or whether they moved upstream or

into tributaries outside the area surveyed when they exited the area (Golder 2001c). In a later study, the majority of longnose sucker radio-tagged in the fall of 2003 remained in the lower Athabasca River over the winter period (Golder 2004c).

Spawning activity for longnose sucker in the lower Athabasca River has been documented to occur at Mountain and Cascade rapids. Spawning runs have also been identified in several Athabasca River tributaries.

As with spawning, nursery activity occurs for longnose sucker fry in the Athabasca River and in tributary streams. Juvenile rearing and adult feeding activity also occurs in both the mainstem river and tributaries during the open-water period.

Overwintering for much of the longnose sucker population occurs in Lake Athabasca; however, some of the longnose sucker that are present in the Athabasca River in the fall also remain to overwinter in the river (Golder 2002e; Golder 2004a).

White Sucker

The white sucker population is known to use both the lower Athabasca River and Lake Athabasca for its life history activities. However, unlike the other main sport and non-sport fish species, white sucker has seldom been the target of fisheries studies and less is known about the life history of this species. White sucker use the lower Athabasca River as nursery, rearing and feeding habitat and as a migration route. They also use tributary watersheds for spawning, nursery, rearing and feeding activities. Overwintering activity has not been studied for this species but is believed to occur primarily in Lake Athabasca.

A spring migration occurs for white sucker from Lake Athabasca to the lower Athabasca River that includes juvenile and adult fish. Spawning runs of white sucker have been identified in several lower Athabasca River tributaries.

Nursery activity occurs for white sucker fry in the lower Athabasca River and in tributary streams. Juvenile rearing and adult feeding activity also occurs in both the mainstem river and tributaries during the open-water period.

Overwintering for the white sucker population is believed to occur in Lake Athabasca. However, a small number of white sucker have been captured in the Athabasca River in the winter (RL&L Environmental Services Ltd. and Golder Associates Ltd. 2003) indicating some overwintering also occurs in the river.

McClelland Lake Drainage

Fish Habitat

McClelland Lake is the largest lake within the RSA (Figure 5.1-1) and has an area of 29.86 km^2 (Golder 2002c). The water depth is generally shallow (less than 2 m); however, there is a 5.5 m deep depression located in the southeast bay of the lake (Golder 2001b). The lake bottom consists of sand covered by a layer of organic material (Golder 2001b). Submergent macrophytes are common throughout the lake and emergent vegetation occurs in small isolated patches (Golder 2001b). The lake is bordered predominantly by aspen forest, with small areas of conifers and wetlands habitat. The largest wetlands habitat borders the southwest bay where the McClelland Lake Fen connects to McClelland Lake. A smaller wetlands area also exists along the northeast shore of the lake at the location of the lake outflow. There is a small satellite waterbody (Unnamed Waterbody 4) located to the south of McClelland Lake that drains to McClelland Lake by way of a small watercourse channel (Unnamed Creek 13). This waterbody is shallow throughout with substrate composed of fine sediments and organic material.

Spring and summer DO levels in McClelland Lake are high, but DO depletion occurs during the winter (Golder 2001b). In winter, the deeper region of McClelland Lake likely provides sufficient under-ice depth for overwintering fish; however, measurable DO concentrations could not be detected (Golder 2001b). The unnamed satellite waterbody was less than or equal to 1.2 m deep under-ice and also exhibited extremely low winter DO levels (0.1 mg/L) (Golder 2001b). Overwintering capability for both waterbodies was considered low (Golder 2001b).

The McClelland Lake outflow stream is a small, low-gradient and often undefined channel that drains towards the Firebag River. Fish migration from the Firebag River is considered unlikely due to the small size of the creek and presence of sections of undefined channel and extensive beaver dams and woody debris (Golder 2001b). The inlet stream (Unnamed Creek 13) draining the unnamed satellite waterbody (Unnamed Waterbody 4) is poorly defined and had no apparent flow during previous studies (Golder 2001b).

Overall, McClelland Lake provides suitable habitat for some forage fish species, some sucker life stages (with the exception of spawning) and some sport fish species (i.e., species that prefer shallow, weedy lakes for all life stages). McClelland Lake has potential spawning, rearing and feeding habitat for northern pike, as well as limited habitat for overwintering (based on depth). However, the absence of large-bodied fishes suggests that access to McClelland Lake is lacking

and that the available habitat can only be utilized by forage fishes. Low DO levels during the winter also limit its use by larger fish species (Golder 2002c).

Fish Population

No large-bodied fish (i.e., sport fish or non-sport fish) were captured during extensive gill-net sampling in McClelland Lake (Golder 2001b). Brook stickleback and lake chub were the only fish species captured in the lake (Golder 2001b). Similar capture success was reported by AENV (Fish and Wildlife Division) during previous fish inventories of the lake (Golder 2001b). Brook stickleback and pearl dace were captured in the McClelland Lake outlet channel in the spring (Golder 2002c). In the 2002 winter survey, water quality was sampled in the lake and it was determined that DO conditions are not likely sufficient to support an overwintering population of sport fish. The outlet channel was frozen to the bed (Golder 2002c), indicating a lack of overwintering habitat. Residents from the community of Fort McKay also have indicated that there are no large-bodied fish in McClelland Lake at present. One person's father had told them that there used to be fish in McClelland Lake, but one year it froze to the bottom and all the fish died (Golder 2001b).

Lower Firebag River

Fish Habitat

Overall, the mainstem Firebag River in the RSA is considered to provide high-quality habitat for fish and has been described as an excellent watercourse for sport fish production (Golder 2004b; Griffiths 1973). Sekerak and Walder (1980) examined the lower 123 km of the Firebag River and established six reaches, the lower two of which are within the RSA (Figure 5.1-1).

The lower-most reach included the first 13 km of the Firebag River mainstem and was described as low gradient and consisting of mostly long, wide pools (Golder 2004b; Psutka 1979; Sekerak and Walder 1980). Substrate within the first reach was dominated by fines (95%) with some gravel (5%) (Psutka 1979). Spawning potential for most fish species was considered poor due to unstable substrate, with the exception of some grassy shallows available for northern pike and forage fish (Psutka 1979; Sekerak and Walder 1980). This reach likely provides a migration route to access upstream habitat, as well as cover for forage fish, adult feeding and possible overwintering habitat (Psutka 1979; Sekerak and Walder 1980).

The second reach of the Firebag River mainstem extended to the mouth of the Marguerite River and was about 32 km in length (Golder 2004b). This reach also was low gradient, although slightly higher that the first reach (Psutka 1979).

Pools dominated the habitat type, interspersed with gravel bars, limestone outcrops and occasional riffles (Psutka 1979; Sekerak and Walder 1980). Substrate within this reach was dominated by fines (70%) and gravel (25%) with small amounts of larger substrate (Psutka 1979). Spawning habitat potential was rated as poor, due to the large amount of fine substrate (Psutka 1979). The presence of riffles and gravels, however, suggests spawning habitat potential may be higher than that reported by Psutka (1979). Rearing habitat potential was rated as moderate based on low velocities and cover, but feeding habitat potential was rated as high (Psutka 1979). Overwintering habitat potential was considered to be possible at the deep pools at river bends (Psutka 1979).

Fish Population

Fifteen fish species are known to occur in the first two reaches of the Firebag River mainstem, of which nine occur in Reach 1 and twelve occur in Reach 2 (Table 5.3-2) (RAMP 2004). The fish community is dominated by six species that are abundant and widespread in the Firebag River, including two sport species (Arctic grayling and northern pike), two sucker species (longnose and white sucker) and three forage species (lake chub, longnose dace and slimy sculpin). Walleye is also widespread in the Firebag River but occurs in relatively low abundance.

Table 5.3-2 Known Fish Species Distribution of the Firebag River Reaches

Species		Reach 1 [0 to 13 km]	Reach 2 [13 to 45 km]
Common Name	**Scientific Name**		
Arctic grayling	*Thymallus arcticus*	–	●
brook stickleback	*Culaea inconstans*	–	●
burbot	*Lota lota*	–	●
goldeye	*Hiodon alosoides*	●	–
lake chub	*Couesius plumbeus*	●	●
lake whitefish	*Coregonus clupeaformis*	●	●
longnose dace	*Rhinichthys cataractae*	–	●
longnose sucker	*Catostomus catostomus*	●	●
mountain whitefish	*Prosopium williamsoni*	●	–
northern pike	*Esox lucius*	●	●
pearl dace	*Margariscus margarita*	–	●
slimy sculpin	*Cottus cognatus*	–	●
spoonhead sculpin	*Cottus ricei*	●	–
walleye	*Sander vitreus*	●	●
white sucker	*Catostomus commersonii*	●	●
Number of Species		**9**	**12**

● = Fish species documented.

– = Not documented.

5.3.1.2 Environmental Field Survey

Based on its relatively close proximity to the JEMA and limited amount of existing data, study sites were established within the McClelland Lake drainage area.

McClelland Lake Drainage Area

Watercourses

One watercourse site on the inlet to McClelland Lake (Site 22) and two watercourse sites on McClelland Lake Outlet Creek (Sites 23 and 60) were surveyed to assess seasonal fish habitat use potential (Figure 5.2-1). In addition, a tributary to McClelland Lake Outlet Creek, Unnamed Creek 3, was surveyed (Site 59) (Figure 5.2-1). The results for the open-water seasonal and winter habitat measurements are presented in Tables 5.3-3 and 5.3-4.

McClelland Lake Outlet Creek

Habitat Assessment

Site 60

McClelland Lake Outlet Creek at Site 60 had an irregular meandering and occasionally confined channel. The surveyed section of the watercourse was located within a mature deciduous forest of spruce and was bordered by grass/forbs and shrubs.

Table 5.3-3 Open-Water Seasonal Habitat Conditions at Watercourse Sampling Sites in the McClelland Lake Drainage Area

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Water Quality Field Parameters			
				Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
McClelland Lake Outlet Creek	60	spring	0.53	6.0	–[c]	253	7.84
		summer	0.50	14.9	12.25	271	8.47
	23	spring	–[b]	20.8	–[c]	245	7.07
		summer	–[b]	14.9	1.99	233	7.14
		fall	–[b]	5.0	4.30	227	6.87
Unnamed Creek 3	59	spring	0.44	8.3	–[c]	265	7.62
		summer	0.25	16.2	8.70	331	8.02
Unnamed Creek 13	22	spring	–[b]	14.8	6.87	219	6.91
		summer	–[b]	16.1	1.86	410	6.95
		fall	0.02	4.4	3.80	336	4.54

[a] See Figures 5.2-1 for sample site locations.

[b] Site conditions did not allow measurement (water too deep or substrate too soft for gear and/or safe wading).

[c] Data not obtained due to equipment malfunction.

- = Not measured.

Table 5.3-4 Winter Habitat Conditions at Watercourse Sampling Sites in the McClelland Lake Drainage Area

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Water Velocity [m/s]		Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Quality Field Parameters			
			Mean	Range			Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L].	Conductivity [µS/cm]	pH
McClelland Lake Outlet Creek	60	0.40	0.34	0.22 to 0.43	0.50	0.40	0.29	0.12 to 0.33	0.0	12.06	159	7.35
	23	–[b]	–[b]	–[b]	–[b]	0.40	0.35[c]	n/a	0.2	2.07	504	6.30
Unnamed Creek 3	59	–[b]	–[b]	–[b])	0.50	0.2	0.195	0.18 to 0.21	0.0	12.06	199	7.53
Unnamed Creek 13	22	–[b]	–[b]	–[b]	0.3	0.50	0.2[c]	n/a	0.0	1.99	283	7.10

[a] See Figure 5.2-1 for sample site locations.

[b] No measurable discharge.

[c] Point measurement.

– = Not measured.

n/a – Not applicable.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix L, Figure L-1). Site 60 consisted of various classes of run and riffle habitat having a maximum water depth of 0.85 m and an average channel width of 5.38 m. Substrate throughout the surveyed reach consisted of organics, silt/clay, sand, gravel, cobble and boulders. Both stream banks were approximately 80 to 100% unstable throughout the surveyed area. Unstable banks are defined as those with the potential to collapse instream, affecting instream habitat or producing sedimentation (Golder 1997g). Instream cover was abundant and provided by woody debris, substrate, turbidity and depth/turbulence. Overhead cover was moderate and consisted of woody debris, undercut banks and overhanging grasses, shrubs and trees.

Discharge was recorded in the spring (0.53 m^3/s) and summer (0.50 m^3/s) (Table 5.3-3). The DO, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.3-3). Water temperature at Site 60 was continuously monitored from May 18, 2007 to July 26, 2007 (Appendix S, Figure S-1) using a thermograph. Water temperature fluctuated between 6.4 and 16.6°C throughout this time period. The peak water temperature (16.6°C) was recorded on July 21, 2007.

During the winter survey, the discharge at Site 60 was 0.40 m^3/s (Table 5.3-4). Under-ice water depths ranged from 0.12 to 0.33 m and averaged 0.29 m. Water velocities ranged from 0.22 to 0.43 m/s. The mean ice thickness was 0.40 m. The DO level at the time of the survey was 12.06 mg/L.

Based on the habitat available at Site 60, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; low to moderate for nursery, rearing and feeding; high for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; high for nursery, rearing and feeding; high for spawning.
- Forage fish: moderate for overwintering; moderate for nursery, rearing and feeding; high for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.

Site 23

The watercourse had a winding and unconfined channel. The surveyed section of the watercourse was located within muskeg bog and was bordered by aquatic vegetation, primarily sedges and grass/forbs, shrubs and mixedwood forest of poplar, birch, black spruce and tamarack.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix L, Figure L-2). Site 23 consisted of flat habitat with an average depth of 0.50 m, a maximum depth of 0.60 m and an average channel width of 2.81 m. Substrate throughout the surveyed reach consisted of organics. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by aquatic vegetation and woody debris. Overhead cover was limited and consisted of overhanging grasses. Approximately 90% of the surveyed area contained aquatic macrophytes.

Discharge during the open-water period was not recorded due to access limitations. The pH and conductivity levels were suitable for all fish species throughout the open-water period. Water temperatures exceeded 20°C in the spring and DO levels were low in the summer and fall (Table 5.3-3). Water temperature at Site 23 was continuously monitored from June 2, 2006 to August 4, 2006 (Appendix S, Figure S-2) using a thermograph. The water temperature fluctuated between 13.9 and 23.4°C throughout this time period. The peak water temperature (23.4°C) was recorded on July 22, 2006.

During the winter survey, discharge could not be measured at Site 23 during the time of the survey due to insufficient water depths across the transect. The mean ice thickness was 0.40 m (Table 5.3-4). Under-ice water depth was 0.35 m. The DO level at the time of the survey (February 23, 2006) was 2.1 mg/L. Conductivity was higher in the winter compared to the open-water period, indicating that groundwater may constitute a higher portion of the winter flow.

Based on the habitat available at Site 23, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; low for nursery, rearing and feeding; low to nil for spawning.
- Forage fish: moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.3-5 and CPUE data are presented by sampling technique in Table 5.3-6.

Table 5.3-5 Fish Species Captured at Sampling Sites in the McClelland Lake Drainage Area

Watercourse or Waterbody	Sampling Site[a]	Season	Number of Fish by Species[b] [c]					Total
			Forage Fish					
			BRST	FNDC	LKCH	NRDC	PRDC	
McClelland Lake Outlet Creek	23	Spring	2	–	8	–	–	**10**
		Summer	–	2	10	–	–	**12**
		Fall	7	–	–	–	16	**23**
	species total		**9**	**2**	**18**	**0**	**16**	**45**
Unnamed Creek 3	59	Summer	4	4	2	3	1	**14**
	species total		**4**	**4**	**2**	**3**	**1**	**14**
Unnamed Creek 13	22	Spring	9	–	23	–	–	**32**
		Fall	10	–	–	–	42	**52**
	species total		**19**	**0**	**23**	**0**	**42**	**84**
Unnamed Waterbody 4	54	Winter	3	–	–	–	–	**3**
	species total		**3**	**0**	**0**	**0**	**0**	**3**

[a] See Figure 5.2-1 for sampling site locations.

[b] All sampling methods combined.

[c] BRST = brook stickleback, FNDC = finescale dace, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace.

– = None available.

Table 5.3-6 Catch-Per-Unit-Effort Results for Sampling Sites in the McClelland Lake Drainage Area

Watercourse or Waterbody	Sampling Site[a]	Season	Forage Fish[b]				
			BRST	FNDC	LKCH	NRDC	PRDC
Backpack Electrofishing [Number/100s]							
McClelland Lake Outlet Creek	60	summer	0.00	0.00	0.00	0.00	0.00
	23	fall	1.90	0.00	0.00	0.00	5.71
Unnamed Creek 3	59	summer	0.71	0.71	0.00	0.00	0.18
Unnamed Creek 13	22	fall	2.74	0.00	0.00	0.00	0.68
Unnamed Waterbody 4	54	spring	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00
Minnow Trapping [Number/trap-hr]							
McClelland Lake Outlet Creek	60	spring	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00
	23	spring	0.46	0.00	1.84	0.00	0.00
		summer	0.00	0.57	2.86	0.00	0.00
		fall	0.44	0.00	0.00	0.00	0.58
		winter	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 3	59	spring	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.75	1.12	0.00
Unnamed Creek 13	22	spring	2.55	0.00	6.52	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00
		fall	0.26	0.00	0.00	0.00	5.12
Unnamed Waterbody 4	54	spring	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00
		winter	0.39	0.00	0.00	0.00	0.00
Gill Netting [Number/panel-hr]							
Unnamed Waterbody 4	54	spring	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-1 for sampling site locations.

[b] BRST = brook stickleback, FNDC = finescale dace, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Site 60
Site 60 was surveyed for sport, non-sport and forage fish during the winter, spring and summer seasons (Tables 5.3-5 and 5.3-6). No fish were captured at this site.

Site 23
Site 23 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons (Tables 5.3-5 and 5.3-6). No fish were captured during winter sampling. Brook stickleback and lake chub were captured during the spring. Finescale dace and lake chub were captured during the summer. During the fall, brook stickleback and pearl dace were captured.

Unnamed Creek 3

Habitat Assessment
Site 59
Unnamed Creek 3 at Site 59 was influenced by extensive beaver activity. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs, shrubs and muskeg.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix L, Figure L-3). Site 59 consisted of impoundment and flat habitat having maximum water depth of 0.7 m. An average channel width could not be calculated, due to poor channel definition. Substrate throughout the surveyed reach consisted of organics. Instream cover was abundant and provided by woody debris, aquatic vegetation, turbidity and depth/turbulence. Overhead cover was limited and consisted of woody debris and overhanging grasses and shrubs.

Discharge was recorded in the spring (0.44 m^3/s) and summer (0.25 m^3/s) (Table 5.3-3). The DO, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.3-3). Water temperature at Site 59 was continuously monitored from May 18, 2007 to July 26, 2007 (Appendix S, Figure S-3) using a thermograph. Water temperature fluctuated between 7.4 and 21.0°C throughout this time period. The peak water temperature (21.0°C) was recorded on July 18, 2007.

During the winter, there was no measurable flow at Site 59 at the time of the survey. Under-ice water depths ranged from 0.18 to 0.21 m and averaged 0.20 m (Table 5.3-4). The mean ice thickness was 0.2 m. The DO level at the time of the survey was 12.06 mg/L.

Based on the habitat available at Site 59, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; low for nursery, rearing and feeding; low for spawning.
- Forage fish: high for overwintering; high for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.

Fish Population

Site 59

Site 59 was surveyed for sport, non-sport and forage fish during the spring and summer seasons (Table 5.3-5 and 5.3-6). Although no fish were captured in the spring, summer sampling resulted in the capture of five forage fish species: brook stickleback, finescale dace, lake chub, northern redbelly dace and pearl dace.

Unnamed Creek 13

Habitat Assessment

Site 22

Unnamed Creek 13 is one of the inlets to McClelland Lake (Figure 5.2-1). The watercourse at Site 22 had a winding and unconfined channel. The surveyed section of the watercourse was located within muskeg bog and was bordered by grass/forbs, some shrubs and a coniferous forest, dominated by tamarack.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix L, Figure L-4). Site 22 consisted of run, pool and flat habitat with an average depth of 0.7 m, a maximum depth of 1.0 m and an average channel width of 9.06 m. Substrate throughout the surveyed reach consisted organics. Both stream banks were stable throughout the surveyed area. Instream cover was limited and provided by aquatic vegetation and depth/turbulence. Overhead cover was abundant and consisted of overhanging grasses.

Discharge during the open-water period was recorded only in the fall due to access limitations and was 0.02 m^3/s at the time of the survey. Open-water seasonal water quality was suitable for use by all fish species in the spring but DO levels were low in the summer and fall (Table 5.3-3). Water temperature at Site 22 was continuously monitored from June 2, 2006 to August 3, 2006 (Appendix S, Figure S-4) using a thermograph. Spring water temperatures

fluctuated between 12.5 and 17.1°C. The water temperature fluctuated between 14.1 and 17.9°C throughout summer, until the thermograph was removed on August 3, 2006. The peak water temperature (17.9°C) was recorded on July 24, 2006.

During the winter survey, discharge could not be measured at Site 22 at the time of the survey due to insufficient water depths across the transect. The mean ice thickness was 0.50 m (Table 5.3-4). Under-ice water depth was 0.20 m. The DO level at the time of the survey was 2.0 mg/L.

Based on the habitat available at Site 22, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.3-5 and CPUE data are presented by sampling technique in Table 5.3-6.

Site 22

Site 22 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field seasons. A winter fish assessment was not conducted due to unsuitable water depths. Brook stickleback and lake chub were captured during spring sampling. No fish were captured during the summer and brook stickleback and pearl dace were captured during the fall.

Waterbody

One waterbody, Unnamed Waterbody 4 (Site 54), within the McClelland Lake drainage area was surveyed to assess fish and fish habitat (Figure 5.2-1).

Unnamed Waterbody 4

Habitat Assessment

The results for the open-water and winter seasonal habitat measurements are presented in Tables 5.3-7 and 5.3-8.

Site 54

Unnamed Waterbody 4 (Site 54) has a perimeter of approximately 3.8 km and an approximate surface area of 0.85 km^2. The waterbody was dominated by shallow littoral habitat, with an abundance of submergent and emergent vegetation throughout (Appendix L, Figure L-5). The waterbody shoreline is predominately sedges, surrounded by a spruce and tamarack forest. The average and maximum depths recorded throughout the open-water seasons were 0.97 and 1.2 m, respectively.

Spring and fall water quality was suitable for use by all fish species, but temperatures approached 20°C during the summer. The DO levels were suitable to support fish throughout the open-water season (Table 5.3-7). Water quality conditions were profiled at one location during the spring.

Winter habitat conditions were measured at five locations dispersed throughout the waterbody. Water quality results at each of the sampling station are presented in Table 5.3-8. Water depths below the ice at the five stations ranged from 1.00 to 1.20 m and averaged 1.06 m. Ice thickness was 0.50 m. Temperatures ranged from 0.01 to 1.6°C. The DO levels were low throughout the waterbody at the time of the survey, ranging from 1.10 to 1.48 mg/L and averaging 1.26 mg/L.

Based on the habitat available at Site 54, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Table 5.3-7 Open-Water Seasonal Habitat Conditions at Waterbody Sampling Sites in the McClelland Lake Drainage Area

Waterbody	Sampling Site[(a)]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 4	54	spring	point	1	0.91	0.50	15.9	9.75	325	8.07
			point	2	0.88	0.50	16.5	9.31	326	8.05
			profile	3	1.00	0.50	16.0	9.34	325	8.04
						0.90	15.9	9.60	324	8.03
			point	4	1.15	0.50	16.1	9.32	327	8.06
		summer	point	1	1.00	0.80	18.3	10.55	350	7.65
			point	2	1.20	0.70	18.4	9.89	370	7.50
			point	3	0.90	0.70	19.1	8.61	356	7.35
			point	4	0.85	0.70	21.3	6.80	272	7.17
		fall	point	1	0.70	0.20	10.2	6.58	321	7.62
			point	2	1.10	0.40	10.5	8.21	322	7.81
			point	3	1.00	0.40	10.5	8.63	320	7.92

(a) See Figure 5.2-1 for sample site locations.

Table 5.3-8 Winter Habitat Conditions at Waterbody Sampling Sites in the McClelland Lake Drainage Area

Waterbody	Sampling Site[(a)]	Station	Point or Profile	Ice Thickness [m]	Water Quality Field Parameters					
					Maximum Water Depth [m]	Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 4	54	1	point	0.50	1.00	0.30	0.1	1.35	571	6.92
		2	point	0.50	1.20	0.30	1.6	1.10	511	6.84
		3	point	0.50	1.00	0.30	0.0	1.23	551	6.82
		4	point	0.50	1.10	0.30	0.8	1.14	511	6.85
		5	point	0.50	1.00	0.30	0.1	1.48	549	6.96

(a) See Figure 5.2-1 for sample site locations.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.3-5 and CPUE data are presented by sampling technique in Table 5.3-6.

Site 54

Site 54 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. Three brook stickleback were captured during the winter survey and no fish were captured during spring, summer and fall. No fish were observed during winter underwater videography.

5.3.2 Benthic Invertebrates

5.3.2.1 Literature Review

Athabasca River

The Athabasca River is a large river with mostly sand substrate which shifts often throughout the year; small areas of erosional habitat occur along the margins of the river. Historical surveys in the Athabasca River have found total invertebrate density to be variable (Golder 2003c). Densities in erosional habitats ranged from less than 4,000 to 6,000 organisms/m² during spring and summer, and up to 24,000 organisms/m² in the fall. Densities in depositional habitats ranged from less than 5,000 to 103,000 organisms/m².

Taxonomic richness in the Athabasca River has been reported to be similar in erosional and depositional habitats (Golder 2003c). Nine to 16 benthic invertebrate families were reported from erosional habitat sites, while seven to 17 invertebrate families were reported from depositional sites. Midges (Chironomidae) were usually the dominant group in depositional areas, with low richness in other invertebrate groups. Bristle worms (Oligochaeta), round worms (Nematoda), stoneflies (Plecoptera) and caddisflies (Trichoptera) were common in erosional habitats.

McClelland Lake Drainage

The historical literature for the benthic invertebrate community of McClelland Lake consists of reports from multi-stakeholder groups (Golder 2003c; RAMP 2007), summarizing data collected between 2002 and 2006.

The benthic community of McClelland Lake was dominated by midges (Chironomidae), scuds (Amphipoda), bristle worms (Oligochaeta) and seed shrimp (Ostracoda) (Table 5.3-9). Mean benthic invertebrate density ranged from 3,504 to 40,526 organisms/m², with all but one site having low densities,

below 10,000 organisms/m². Total benthic invertebrate richness was 26 taxa/site in 2002. Total richness could not be calculated from 2003 to 2006 because the RAMP (2007) report did not contain any raw data and only reported mean richness. Mean richness ranged from 6.0 to 23.0 taxa/site for McClelland Lake. Both mean invertebrate density and mean richness were highest in 2006 compared to other years of sampling.

A benthic invertebrate taxon list for the McClelland Lake watershed, compiled from previous reports and the 2005 to 2006 environmental setting field surveys, is provided in Appendix U, Table U-2.

Table 5.3-9 Historical Benthic Invertebrate Community Data for McClelland Lake

Variable	McClelland Lake				
	MCL	MCL-1	MCL-1	MCL-1	MCL-1
study	Golder (2003b)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)
date	September 2002	September 2003	September 2004	September 2005	September 2006
habitat	waterbody	waterbody	waterbody	waterbody	waterbody
Density					
mean density [numbers/m²]	6,306	4,823	3,504	8,874	40,526
SE mean density [numbers/m²]	1,999	–	–	–	–
Richness					
total richness [no. taxa/site]	26	–	–	–	–
mean richness [no. taxa/site]	9.8	11.0	6.0	11.0	23.0
SE mean richness [no.taxa/site]	1.8	–	–	–	–
Mean Relative Density [%]					
Oligochaeta	14	19	7	12	3
Chironomidae	58	39	24	27	91
Ostracoda	10	8	15	29	1
Gastropoda	0	0	0	0	0
Pelecypoda	2	8	6	9	<1
other Diptera	0	0	0	1	0
Amphipoda	11	22	21	7	<1
Ephemeroptera	1	2	8	7	1
other (includes Trichoptera and Plecoptera)	3	0	9	4	3

– = Not available; SE = standard error of the mean.

Notes: Some numbers are rounded for presentation purposes; therefore, it may appear that the percentages do not add up to 100.

Golder 2003c data were obtained from CEMA database (Golder 2006a).

RAMP 2007 raw data were not provided in the report; therefore, data were obtained from tables in the report.

Lower Firebag River

The historical literature for the benthic invertebrate community of the Firebag River consists of RAMP monitoring data (RAMP 2007), collected between 2003 and 2006.

The erosional section of the Firebag River near its mouth was dominated by the midges and mayflies (Table 5.3-10). Mean benthic invertebrate density ranged from 11,930 to 18,871 organisms/m², which is in the low to moderate range compared to other watercourses in the Oil Sands Region. Mean benthic invertebrate density ranged from 38 to 43 taxa/site, which is similar to richness values documented in other moderate-sized rives in the region. Total benthic invertebrate richness was not available because the RAMP (2007) report did not include raw data, and reported mean richness only.

Table 5.3-10 Historical Benthic Invertebrate Community Data for the Firebag River

Variable	Firebag River			
	FIR-E-2	FIR-E-2	FIR-E-2	FIR-E-2
study	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)
date	September 2003	September 2004	September 2005	September 2006
habitat	erosional	erosional	erosional	erosional
Density				
mean density [numbers/m²]	11,930	16,024	12,335	18,871
SE mean density [numbers/m²]	–	–	–	–
Richness				
total richness [no. taxa/site]	–	–	–	–
mean richness [no. taxa/site]	39	38	38	43
SE mean richness [no. taxa/site]	–	–	–	–
Relative Density [%]				
Oligochaeta	4	6	5	6
Chironomidae	63	48	35	65
Ostracoda	<1	<1	<1	<1
Gastropoda	1	<1	0	<1
Pelecypoda	3	3	2	<1
Other Diptera	1	0	<1	4
Amphipoda	<1	<1	0	0
Ephemeroptera	9	12	15	9
other (including Trichoptera and Plecoptera)	16	17	21	23

– = No data/not applicable; SE = standard error of the mean.

Notes: RAMP 2007 data are from data tables in text since no raw data are provided in the report.

Percentages under "Relative Density" are reproduced from RAMP (2007); some percentages do not add up to 100.

5.3.2.2 Environmental Field Survey

Athabasca River

Since a large amount of historical benthic invertebrate data are available for the Athabasca River, no additional sampling was conducted as part of the environmental setting survey for the Project.

McClelland Lake Drainage

Unnamed Creek 13 (Site 22)

Benthic Invertebrate Habitat

One depositional site (Site 22) was sampled for benthic invertebrates in Unnamed Creek 13, located in an inflow stream to McClelland Lake, during fall 2005. Mean depth at this site was 0.81 m and current velocity was negligible (Table 5.3-11). Field-measured water quality in Unnamed Creek 13 was typical of the Oil Sands Region (i.e., pH in the slightly alkaline range, moderate conductivity) with the exception of DO (3.7 mg/L), which was low. The bottom substrate at this site was dominated by the silt and clay fractions, and had a high moisture content of 90%. The TOC was also high (i.e., 34.7%). High TOC, along with the stagnant conditions indicated by the current velocity measurement, may account for the low DO concentration measured during the environmental setting survey.

Table 5.3-11 Benthic Invertebrate Habitat Characteristics for the McClelland Lake Watershed, Fall 2005 and 2006

Parameter	Units	McClelland Lake Watershed	
		Unnamed Creek 13	Unnamed Waterbody 4
		Site 22	Site 54
habitat type	–	depositional	waterbody
date	–	October 18, 2005	September 28, 2006
Field Supporting Data			
easting	m	480627	482111
northing	m	6368895	6367864
mean depth	m	0.81	0.70
mean current velocity	m/s	0.00	–
macrophyte cover	%	0	40
Field Water Quality			
dissolved oxygen	mg/L	3.7	6.6
conductivity	µS/cm	340	321
pH	–	7.3	7.6
water temperature	°C	1.6	10.2
Substrate			
sand	%	11	–
silt	%	48	–
clay	%	41	–
moisture content	%	90	–
total organic carbon	%	34.7	–

– = No data/not applicable.

Note: UTM co-ordinates are Zone 12 V, NAD 83.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Creek 13 (Site 22) was 18,974 ± 4,421 organisms/m² during fall 2005 (Table 5.3-12, Figure 5.3-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness for Unnamed Creek 13 was 19 taxa/site and mean (±1 SE) richness was

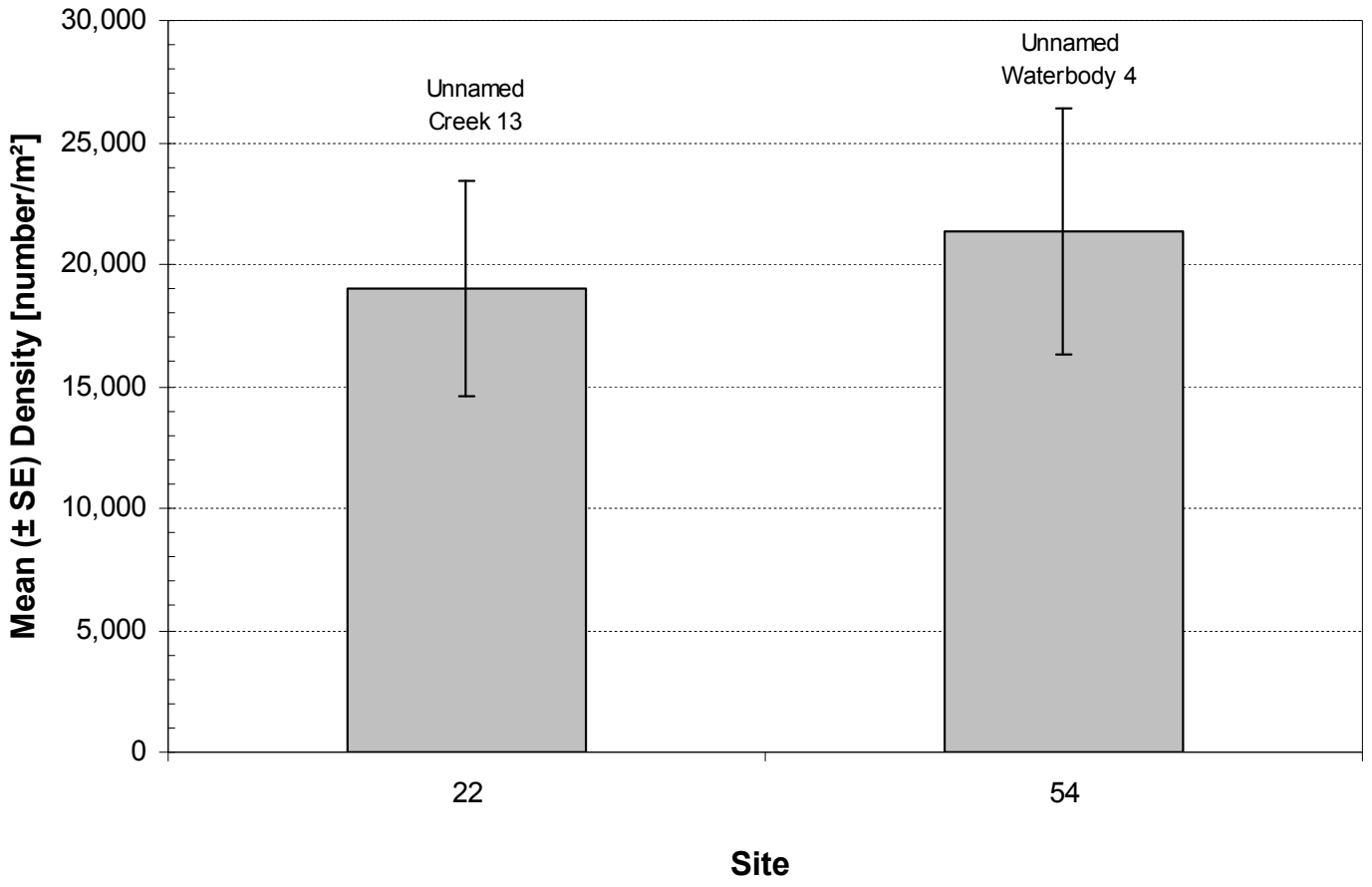
10.8 ± 1.4 taxa/site (Figure 5.3-2). Both density and richness were in the low to moderate range compared to other watercourses in the Oil Sands Region.

The value of SDI was 0.71 (Table 5.3-12, Figure 5.3-3), indicating a diverse benthic invertebrate community. The evenness value was 0.18 (Figure 5.3-4), indicating that a few taxa accounted for the majority of the total benthic invertebrate density in Unnamed Creek 13. Accordingly, the benthic community was dominated by the midges (Chironomidae) and seed shrimp, which together accounted for 95% of the total density at the site (Figure 5.3-5). The midge community was dominated by the tribe Chironomini and the subfamily Tanypodinae (Figure 5.3-6).

Table 5.3-12 Environmental Setting Benthic Invertebrate Community Data for the McClelland Lake Watershed, Fall 2005 and 2006

Variable	McClelland Lake Watershed	
	Unnamed Creek 13	Unnamed Waterbody 4
	Site 22	Site 54
date	October 18, 2005	September 28, 2006
habitat	depositional	depositional
Density		
mean density [numbers/m²]	18,974	21,319
SE mean density [numbers/m²]	4,421	5,041
Richness		
total richness [no. taxa/site]	19	36
mean richness [no. taxa/site]	10.8	19.4
SE mean richness [no. taxa/site]	1.4	1.8
Diversity		
Simpson's Diversity Index (SDI) [1-D]	0.71	0.88
evenness	0.18	0.23
Relative Density [%]		
Oligochaeta	1	2
Chironomidae	82	60
Ostracoda	13	9
Gastropoda	1	4
Pelecypoda	1	4
Other Diptera	0	4
Amphipoda	0	6
Ephemeroptera	0	7
other (includes Trichoptera and Plecoptera)	2	5

Note: SE = standard error of the mean.



ERROR BARS REPRESENT ±1STANDARD ERROR OF THE MEAN.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MEAN BENTHIC INVERTEBRATE DENSITY IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. mean BI density	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
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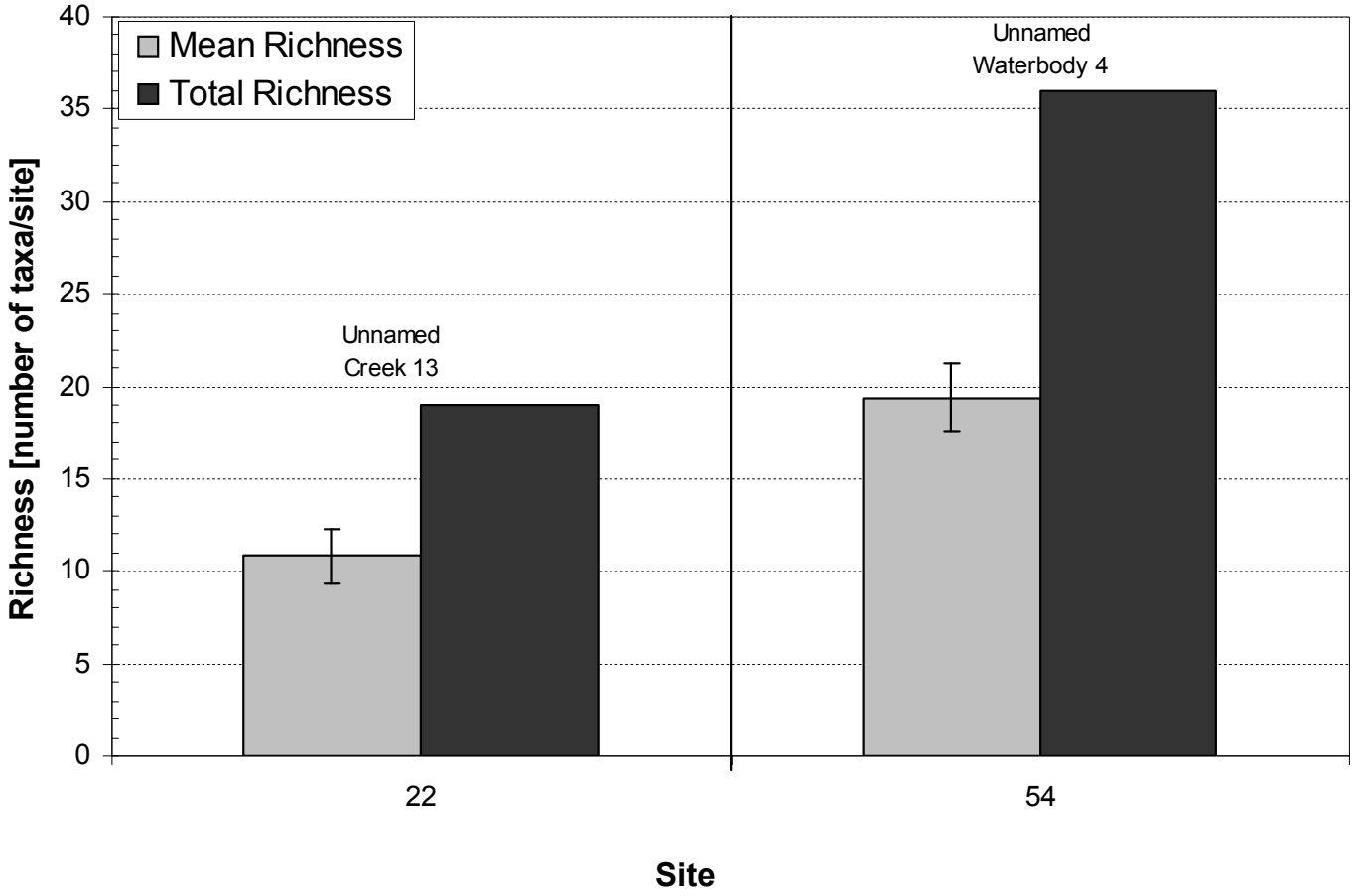
REVIEW	WES/TC	20/11/07		



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PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MEAN AND TOTAL BENTHIC INVERTEBRATE RICHNESS IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. mean BI density	
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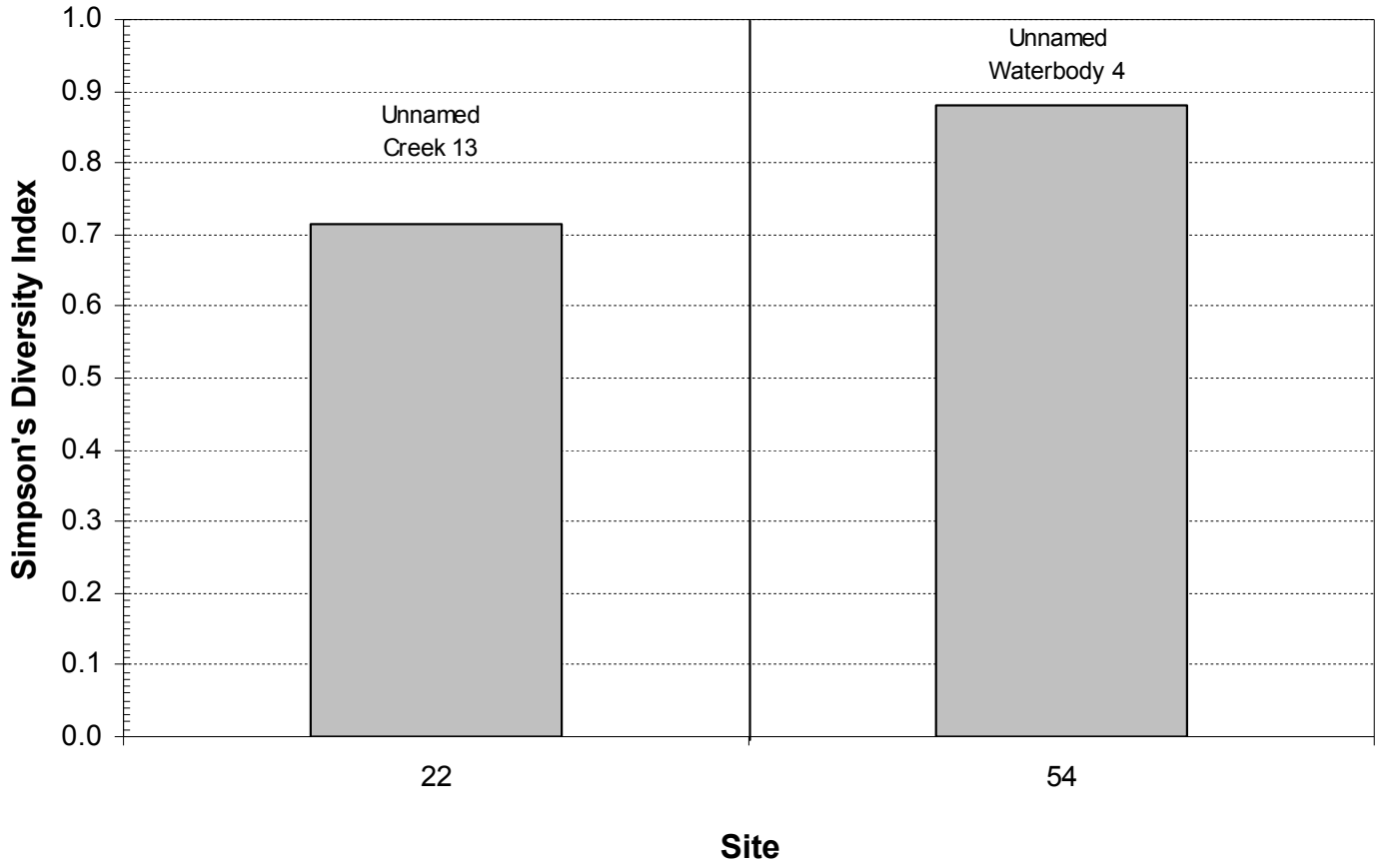
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE **SIMPSON'S DIVERSITY INDEX VALUES FOR BENTHIC INVERTEBRATES IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006**

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. Simpson's Diversity	
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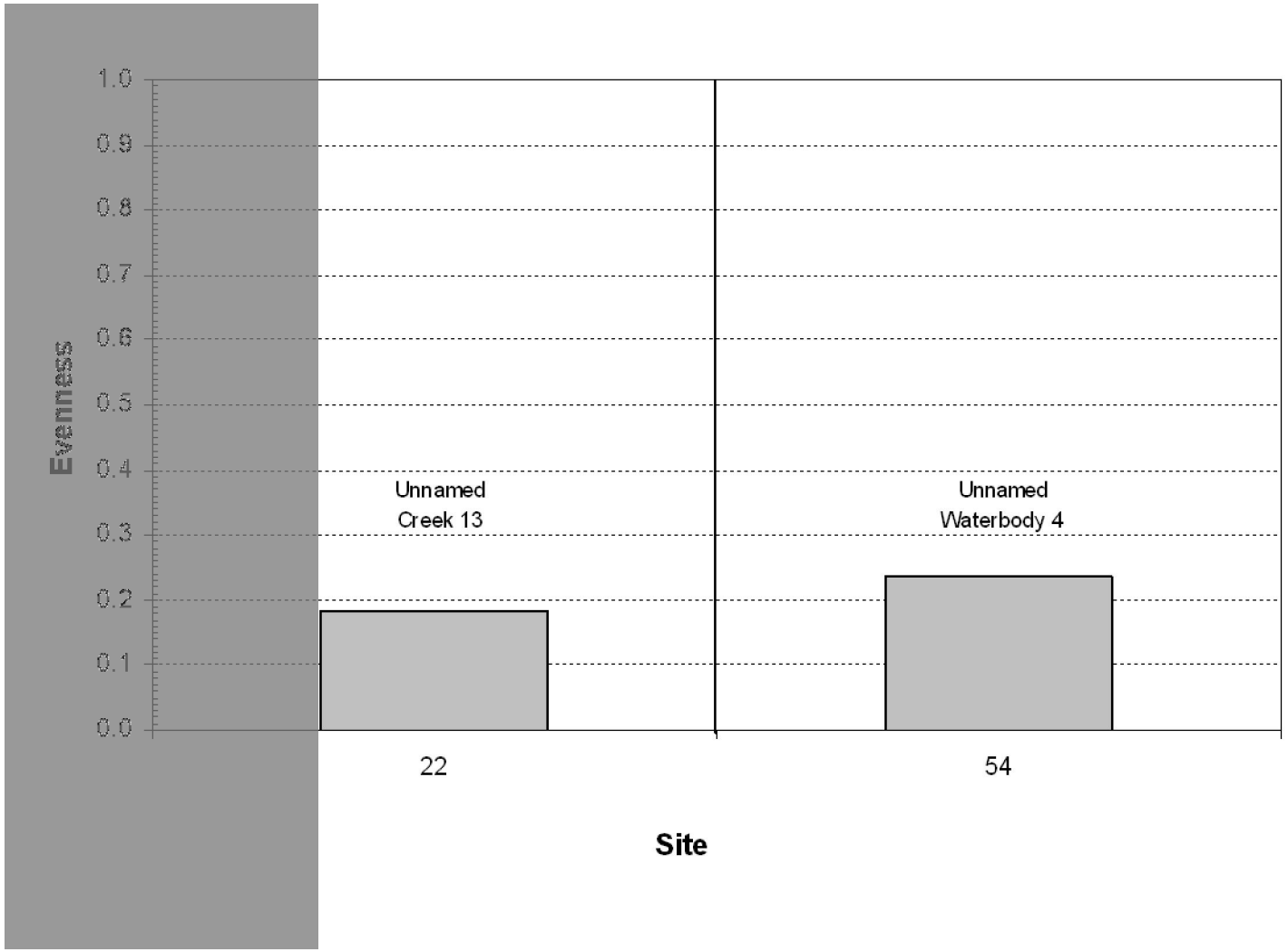
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

EVENNESS VALUES FOR BENTHIC INVERTEBRATES IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No.	Evenness Values	
DESIGN	JS	05/10/07	SCALE	AS SHOWN	REV. 0
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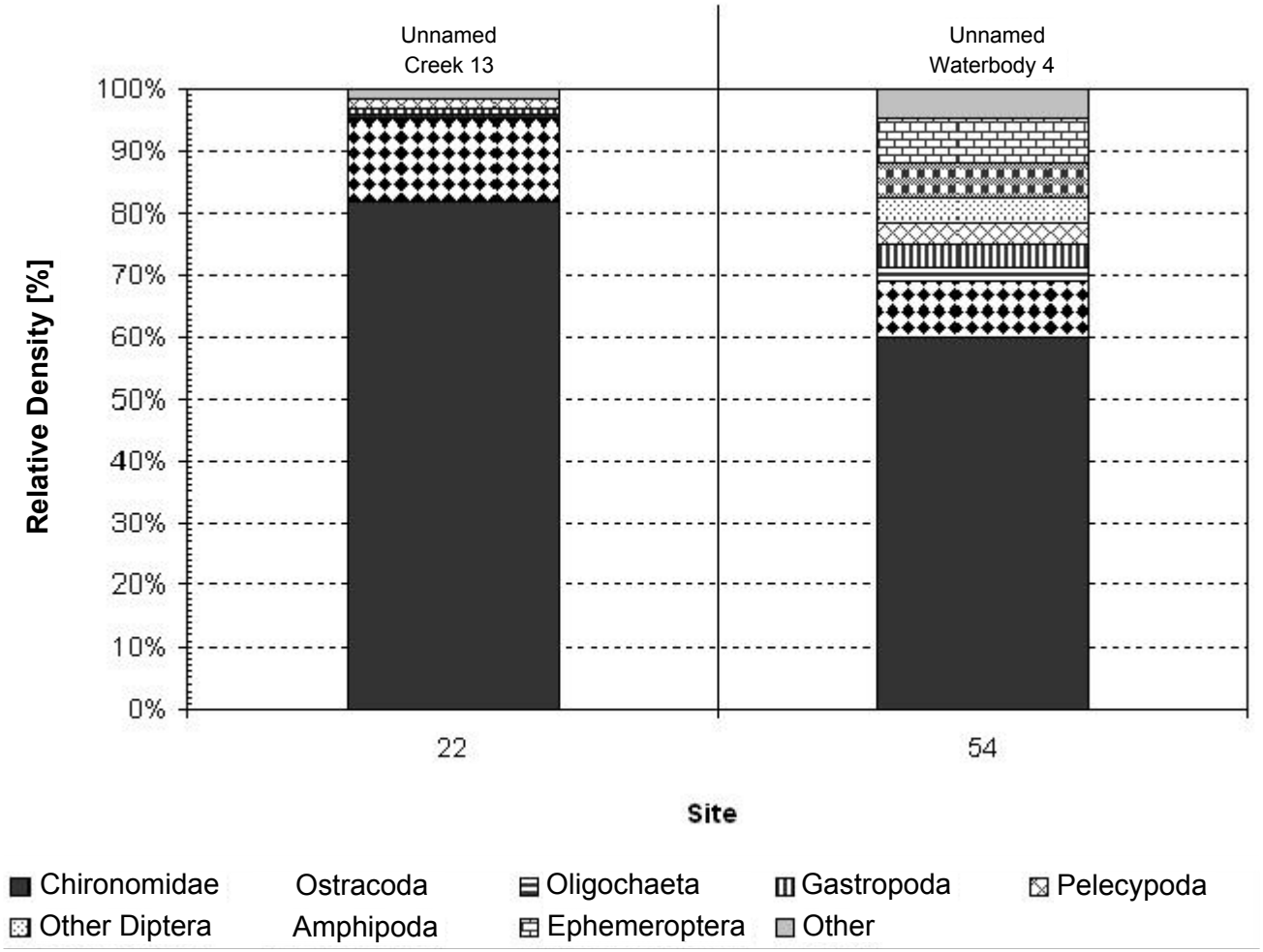
REVIEW	WES/TC	20/11/07			



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE BENTHIC INVERTEBRATE DENSITY IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. Relative Bl density	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
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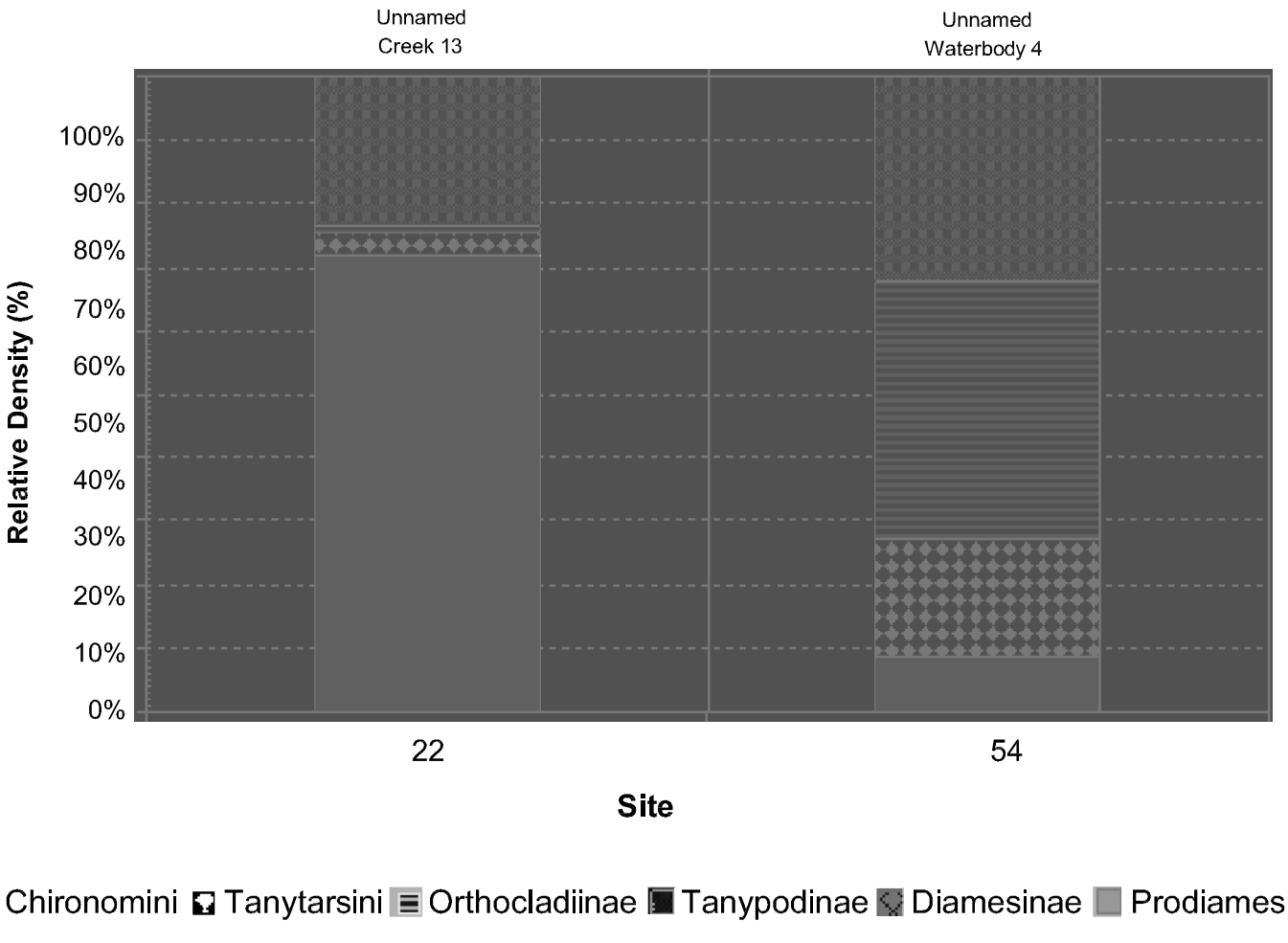
CHECK	JS	05/10/07		
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE CHIRONOMIDAE DENSITY IN THE McCLELLAND LAKE WATERSHED AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. Relative Bl density	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
CADD	TY	19/11/07	FIGURE: 5.3-6	
CHECK	JS	05/10/07		
REVIEW	WES/TC	20/11/07		

Unnamed Waterbody 4 (Site 54)

Benthic Invertebrate Habitat

One site in Unnamed Waterbody 4 (Site 54) was sampled for benthic invertebrates in fall 2005. Mean depth at this site was 0.70 m (Table 5.3-11) and aquatic macrophytes covered 40% of the bottom substrate where benthic invertebrate samples were collected. Detailed sediment data are not available for this location; however, based on field observations, bottom substrates consisted of fine sediments, with a moderate to high organic content. Field-measured water quality parameters in Unnamed Waterbody 4 were typical of waterbodies in the Oil Sands Region.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Waterbody 4 (Site 54) was 21,319 ± 5,041 organisms/m² (Table 5.3-12, Figure 5.3-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 36 taxa/site and mean (±1 SE) richness was 19.4 ± 1.8 taxa/site (Figure 5.3-2). Both density and richness were in the moderate range compared to other waterbodies in the Oil Sands Region.

The value of the SDI was 0.88 (Table 5.3-12, Figure 5.3-3) for Unnamed Waterbody 4, indicating a diverse benthic invertebrate community. Evenness for this site was 0.23 (Figure 5.3-4), which indicates that the total density of benthic invertebrates is dominated by a few taxa. The benthic invertebrate community was dominated by the midges (Chironomidae), which accounted for 60% of the total density (Figure 5.3-5). Other common groups included seed shrimp, snails (Gastropoda), fingernail clams (Pelecypoda), dipterans other than midges, scuds and mayflies (Ephemeroptera). The midge community was dominated by the Tanytarsini, Orthocladiinae and Tanypodinae (Figure 5.3-6).

Lower Firebag River

Benthic invertebrate samples were not collected in the Firebag River for the environmental field survey, because the section of this river within the LSA is already being monitored by RAMP.

5.4 JACKPINE EXPANSION MINING AREA RESULTS

5.4.1 Fish and Fish Habitat

The following section provides a summary of the fish habitat characteristics, fisheries resources and benthic invertebrate community data for watercourses and waterbodies within the JEMA LSA. Included are the results from the literature review and field study.

5.4.1.1 Literature Review

The JEMA LSA encompassed the Muskeg River watershed. Fish and fish habitat information is available for the following aquatic resources within the watershed:

Muskeg River Watershed

- The Muskeg River mainstem:
- Five named tributary drainages to the Muskeg River:
  - Jackpine Creek;
  - Shelley Creek;
  - Stanley Creek;
  - Wapasu Creek; and
  - Muskeg Creek, including:
    - Khahago Creek;
    - Green Stockings Creek;
    - Pemmican Creek;
    - Blackfly Creek;
    - Wesukemina Creek;
    - Kearl Lake; and
    - Iyinimin Creek (Kearl Lake inlet stream).
- Several unnamed tributary drainages to the Muskeg River:
  - one unnamed watercourse containing three interconnected waterbodies;
  - one unnamed watercourse containing one small waterbody; and
  - seven unnamed watercourses in the Muskeg River headwaters.
- Unnamed Waterbody 3.

Muskeg River Watershed

Muskeg River Mainstem

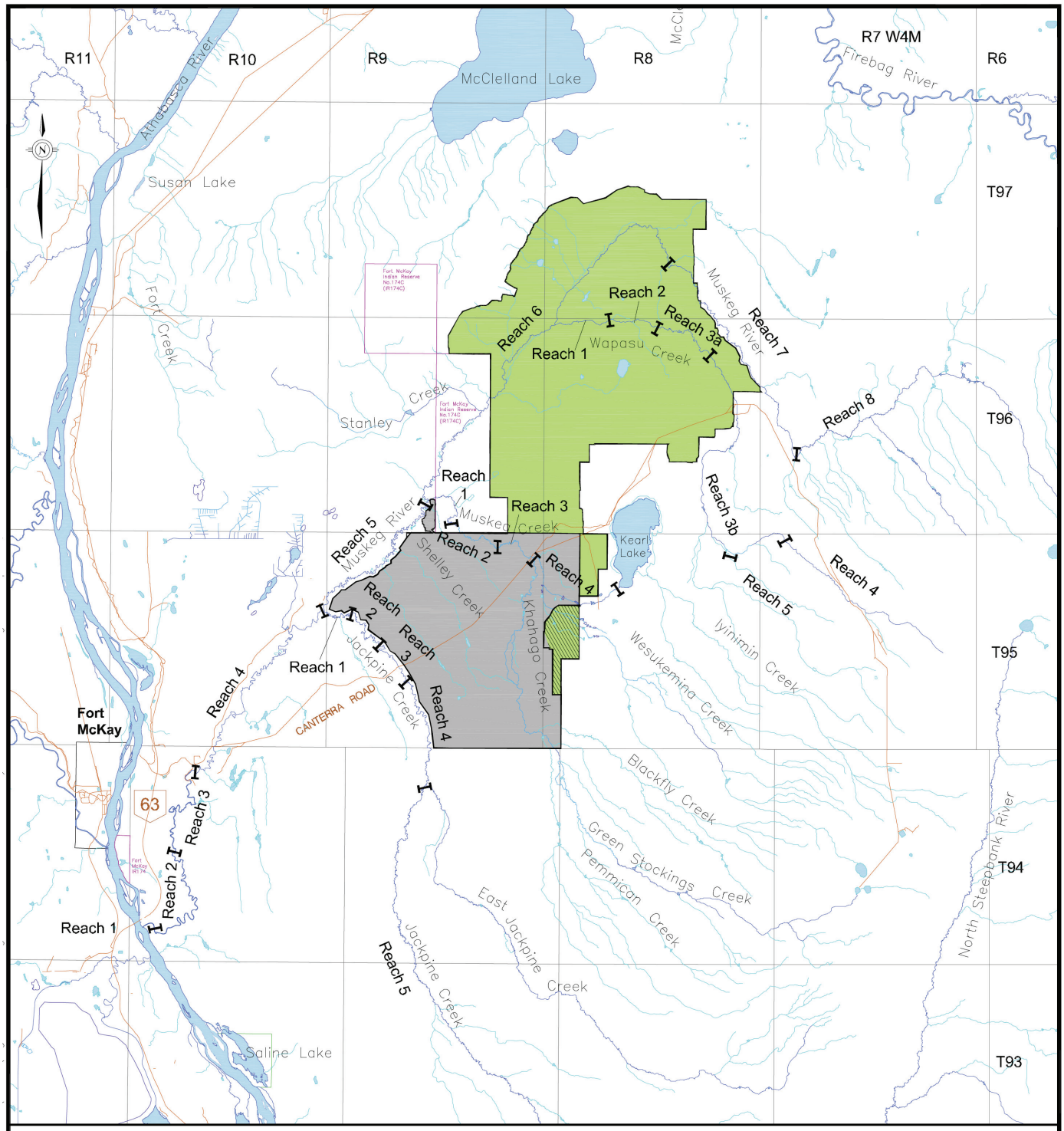
Fish Habitat

During the earliest historical studies, the mainstem Muskeg River was divided longitudinally from the river mouth to the headwaters into six distinct reaches (Bond and Machniak 1979; Sekerak and Walder 1980; Walder et al. 1980). Based on further habitat evaluations and reach sub-divisions suggested by Sekerak and Walder (1980), one of these reaches was divided into three reaches (Golder 2005), providing a total of eight reaches (Figure 5.4-1). Reach classifications were based on stream gradient, flow characteristics, substrate and channel form. Habitat mapping of representative areas within these reaches has been conducted by O'Neil et al. (1982), Beak (1986), RL&L (1989b), Golder (1996b), (Golder 2006b), Komex (1997) and Imperial Oil (2005). A description of the habitat characteristics of each of the eight reaches is provided below.

Reach 1, in the area of the river mouth, is a fairly straight reach that extends for 0.5 km (Golder 1996b; O'Neil et al. 1982; RL&L 1989b). Reach 1 has a high gradient (3.5 m/km) and consists of run, riffle and pool habitats. The reach is primarily characterized by fast, shallow, low-quality runs, and includes occasional riffle and pool habitats. Substrate composition is mainly gravel and cobble with some boulder and fine sediment. Cobble and boulder substrates are dominant in the higher gradient areas (i.e., riffle habitats) (Golder 2002a). Near the mouth, the river banks are less than 1 to 3 m high with sections of unstable bank, resulting in some in-river debris from fallen bank material. Reach 1 is considered to provide moderate spawning potential, good nursery and rearing habitat and poor adult feeding habitat. Limitations in spawning habitat occur due to low riffle frequency and limitations in feeding habitat occur due to a lack of deeper runs and pools.

The next 8.5 km of the river comprise Reach 2, which has an irregular meander pattern. Reach 2 has a high gradient (3.2 m/km) and is characterized by a mix of run, riffle and pool habitats. Substrate composition is mainly gravel with some cobble and boulder, as well as a small amount of fine sediment. In Reach 2, there are cliffs that range from 10 to 20 m in height (Imperial Oil 2005); consequently, Reach 2 is referred to as the "canyon reach". Sections of unstable bank do occur, providing a moderate level of cover due to in-river debris. Reach 2 is considered to provide good spawning, nursery and rearing habitat, and moderate adult feeding habitat. Limitations in feeding habitat occur to some extent due to limited availability of deep, slow habitats.

JPME R1
ERRATA



LEGEND

- RIVER OR STREAM
- PUBLIC ROADWAY
- JACKPINE MINE EXPANSION
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- REACH BREAK

5 0 5
SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MUSKEG RIVER MAINSTEM AND TRIBUTARY HABITAT REACHES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

Shell Canada Limited

PROJECT 08.1346.0006.5180			FILE No. Reaches of the MU	
DESIGN	MK	21/11/08	SCALE AS SHOWN	REV. 0
CADD	PSR	28/11/08	FIGURE: 5.4-1(REVISED)	
CHECK	MK	28/11/08		
REVIEW	TC	21/04/09		

The next upstream reach, Reach 3, is 7.5 km in length and has an irregular meander pattern. Reach 3 has a much reduced gradient (1.0 m/km) compared to Reach 2. Reach 3 is characterized by run habitats interspersed with occasional riffles and pools (RL&L 1989b). The runs are deep and slow and comprise a large portion of the length of river in this reach, with riffle and pool habitats much less frequent than Reach 2 (Golder 1997b). Fine sediments occur in low velocity habitats and rocky substrates occur in riffle habitats. Overall, the substrate consists primarily of gravels and fines, with some cobble and boulder. The banks are generally stable and a moderate level of cover is present due to woody debris and overhanging vegetation. Although good spawning habitat occurs in the riffle habitats, the localized nature of these habitats reduces the overall spawning potential for this reach. Reach 3 is considered to provide good nursery, rearing and feeding habitats.

Reaches 4 (18.5 km in length), 5 (18.2 km in length) and 6 (26.8 km in length) represent the most common type of habitat in the Muskeg River mainstem (Imperial Oil 2005). These reaches comprise a low-gradient segment (0.3 m/km) that is flat and poorly drained and is dominated by low stable banks and substrates composed of fine sediment (RL&L 1989b; Sekerak and Walder 1980). Reach 4 extends from the upper boundary of Reach 3 to the confluence of Jackpine Creek, Reach 5 extends from Jackpine Creek to the Muskeg Creek confluence and Reach 6 extends from Muskeg Creek to the boundary with Reach 7 (Figure 5.4-1).

The river in these three reaches is primarily composed of slow, relatively deep meandering runs (Golder 2006b; Imperial Oil 2005). Substrate in the runs consists mainly of organic debris and silt with a few large boulders (Golder 2006b) (Imperial Oil 2005). Riffle habitats are infrequent and isolated, but there are a few that occur in association with cobble substrate (Imperial Oil 2005). Riffle frequency decreases moving upstream from Reach 4 to Reach 6, while the frequency of beaver dams and impoundments increases (Imperial Oil 2005; Sekerak and Walder 1980).

Historically, researchers have considered these three reaches to provide limited habitat potential with moderate to poor ratings for most fish species and life stages. Limitations include poor habitat and substrate diversity and poor fish passage potential due to blockages associated with beaver dams, with habitat limitations increasing in severity moving upstream from Reach 4 to 6. Habitats are considered most suitable for species or life stages that use slow moving habitats with fine sediments.

Reach 7 is 13 km in length and has a moderate gradient (2.8 m/km), exhibiting an increase in gradient compared to Reaches 4, 5 and 6. This reach also contains a high amount of debris and numerous beaver dams (Sekerak and Walder 1980). As a result, habitats consist primarily of slow-flowing runs and pools with fine

sediment for substrate. Occasional riffle habitats with gravel, cobble and boulder substrate still occur in Reach 7 but are infrequent. Bank stability is high and a high degree of cover is available from in-river debris and overhanging vegetation.

Reach 7 is considered to provide poor spawning, nursery, rearing and feeding habitats for fish species able to access these habitats. Habitat limitations include poor habitat and substrate diversity and poor fish passage potential. Habitats are considered most suitable for forage fish and large-bodied species or life stages that use slow moving habitats with fine sediments.

Reach 8 is 29 km in length and has a high gradient (4.2 m/km). Although the gradient increases in this reach, it also contains a high amount of debris and numerous beaver dams and impoundments (Sekerak and Walder 1980). As a result, habitats consist entirely of slow-flowing runs and pools with fine sediment for substrate. Bank stability is high and a high degree of cover is available from in-river debris and overhanging vegetation.

Reach 8 is considered to provide poor spawning, nursery, rearing and feeding habitats for fish species able to access these habitats. Habitat limitations include poor habitat and substrate diversity and poor fish passage potential. Habitats are considered most suitable for forage fish and sucker species or life stages that use slow moving habitats with fine sediments.

In general, the habitat potential of the lower 16.5 km of the mainstem Muskeg River (i.e., Reaches 1, 2 and 3) during the open-water period is high. In contrast, habitat limitations for the remaining 105.5 km of the mainstem river result in poor habitat potential in the middle (Reach 4, 5 and 6) and upper (Reach 7 and 8) reaches of the river (Figure 5.4-1) (Imperial Oil 2005). Extensive beaver activity likely impedes fish movements in the upper reaches of the river, further reducing the potential for these reaches to support a diverse fish species assemblage (Imperial Oil 2005).

Overwintering conditions in the Muskeg River were not investigated in the historical studies, but have been in some of the more recent surveys. Winter habitat conditions were investigated in the lower river in Reach 3 and Reach 4, where under-ice water depths were found to be suitable to support fish use; however, low discharge and low Dissolved Oxygen (DO) levels resulted in poor conditions for overwintering (Beak 1986; Golder 1997b). One winter investigation in the upper river in Reaches 7 and 8 (AMEC 2004) found the river to be completely frozen at the sites surveyed, with no overwintering potential. Another study (Imperial Oil 2005) found overwintering potential at some sites in Reaches 6, 7 and 8, with conditions limited due to either shallow depths or low DO levels.

A summary of historical water quality data from 1985 to 2003 (AXYS 2005) provides additional information regarding overwintering conditions in the Muskeg River with respect to DO levels. The data indicates highly variable winter DO concentrations, with conditions generally better in the lower river compared to further upstream. Winter DO levels in the lower river ranged from 1.3 to 13.9 mg/L, with median values for the period of record of 9.4 and 6.5 mg/L for Reach 1 and Reach 3, respectively. Dissolved Oxygen levels in Reach 5 ranged from 0.05 to 9.8 mg/L, with a median value of 2.6 mg/L.

Overwintering habitat, where present, is generally suitable for use by forage fish species (Golder 1997a). The potential for large fish to overwinter in the Muskeg River system has been described as poor by RL&L (1989b), who assessed winter water quality in the Muskeg River and several tributaries. Data from winter 1997 support these conclusions as most of the small watercourses sampled in the Muskeg River system that year were frozen to near the bottom and oxygen levels were low (Golder 1997b). However, some pools sampled in the Muskeg River mainstem in one year had oxygen levels and depths acceptable for large fish species (Shell 1998), indicating that general overwintering habitat is occasionally present in some locations.

Overall, the data indicate that overwintering conditions in the mainstem Muskeg River are variable but limited, with overwintering habitat present in some locations but not others and only in some winters. When present, overwintering habitat is primarily suitable for use by small-bodied forage fish due to shallow under-ice depths and/or low DO levels. Lack of reliable overwintering habitat was considered an important limiting factor in the upper river, particularly for resident fish (Imperial Oil 2005).

Fish Population

A total of 26 fish species have been reported from the Muskeg River, including 10 sport species, two sucker species and 14 forage fish species (Table 5.4-1). These species have been divided into three classes based on their general abundance and distribution, including seven resident species that are typically abundant with wide distributions, five regular migrant species that use the river during the open-water period for part of their life-cycle (Imperial Oil 2005) and 14 restricted species that occur in low abundance with restricted distributions (AXYS 2005). Of the five regular migrant species, three species are primarily migrant but also have a small portion of their populations that are resident (Table 5.4-1). In the past, white sucker, longnose sucker, lake chub and Arctic grayling were most frequently reported as the dominant species in the mainstem Muskeg River (AXYS 2005; Shell 2005); however, a notable decline in Arctic grayling abundance has been documented in recent RAMP investigations and this species is no longer common in the watershed (RAMP 2004, RAMP 2007).

Table 5.4-1 Known Fish Species of the Muskeg River Watershed and Their Distribution Class

Classification	Species		General Distribution Class[(a)]		
	Common Name	Scientific Name	Resident	Regular Migrant	Restricted
sport fish	Arctic grayling	*Thymallus arcticus*	–	●	–
	bull trout	*Salvelinus confluentus*	–	–	●
	burbot	*Lota lota*	–	–	●
	goldeye	*Hiodon alosoides*	–	–	●
	lake cisco	*Coregonus artedi*	–	–	●
	lake whitefish	*Coregonus clupeaformis*	–	–	●
	mountain whitefish	*Prosopium williamsoni*	–	●	–
	northern pike	*Esox lucius*	●	●	–
	walleye	*Sander vitreus*	–	–	●
	yellow perch	*Perca flavescens*	–	–	●
non-sport fish	longnose sucker	*Catostomus catostomus*	●	●	–
	white sucker	*Catostomus commersonii*	●	●	–
forage fish	brook stickleback	*Culaea inconstans*	●	–	–
	emerald shiner	*Notropis atherinoides*	–	–	●
	fathead minnow	*Pimephales promelas*	●	–	–
	finescale dace	*Phoxinus neogaeus*	–	–	●
	flathead chub	*Platygobio gracilis*	–	–	●
	lake chub	*Couesius plumbeus*	●	–	–
	longnose dace	*Rhinichthys cataractae*	●	–	–
	ninespine stickleback	*Pungitius pungitius*	–	–	●
	northern redbelly dace	*Phoxinus eos*	–	–	●
	pearl dace	*Margariscus margarita*	●	–	–
	slimy sculpin	*Cottus cognatus*	●	–	–
	spoonhead sculpin	*Cottus ricei*	●	–	–
	spottail shiner	*Notropis hudsonius*	–	–	●
	trout-perch	*Percopsis omiscomaycus*	–	–	●
		Subtotal of species	*10*	*5*	*14*
Total species			**26**		

(a) Distribution Class:
Resident – wide distribution, year-round use by all life stages.
Regular Migrant – moderate to wide distribution, seasonal use by some life stages.
Restricted – limited distribution, rare or irregular use by some life stages.

– = Not applicable.

Seven forage fish species are considered resident in the Muskeg River (Table 5.4-1), including brook stickleback, fathead minnow, lake chub, longnose dace, pearl dace, slimy sculpin and spoonhead sculpin (AXYS 2005; Golder 2002a; Golder 2006b; Shell 2005). These forage fish species are believed to use the watershed for spawning, nursery, rearing, feeding and overwintering habitat (Imperial Oil 2005). In addition, it is considered that three large-bodied species (i.e., northern pike, longnose sucker and white sucker) are resident to a limited extent at various locations in the watershed (Shell 2005).

Five fish species are considered to be regular migrants and have been reported to use the Muskeg River during the open-water period for part of their life cycle. These species include Arctic grayling, mountain whitefish, northern pike, longnose sucker and white sucker (Shell 2005). Spring spawning and summer juvenile rearing and adult feeding are the principal habitat uses for these species (Shell 2005). The spring spawning and summer feeding immigrations of these species into the Muskeg River and subsequent fall emigrations have been documented in several counting fence surveys (Bond and Machniak 1979; Golder 1996b; Golder 1997a; Golder 1998; Golder 2006b).

A summary of the spring counting fence data (Table 5.4-2) indicates that there has been a large decline in the number of regular migrants using the Muskeg River watershed over time. Although direct comparison of the counting fence results is complicated by between year differences in methodology (particularly fence location and duration), the data from 1976, 1977, 2003 and 2006 utilized the same methods and provide an indication of the changes that have occurred over time. Noteable declines have occurred for all five regular migrant species, although the decline has not been as severe for northern pike as it has for the other four species. Based on RAMP results for counting fences, habitat surveys and spawning surveys, one possible reason for the decline was identified as an increase in the level of beaver activity in the watershed as it relates to impediments to fish passage and changes in spawning habitat for species which prefer swift flowing water with rocky substrate (Golder 2001c; Golder 2003a). In particular, changes in accessibilty and habitat characteristics have been recorded in Jackpine Creek and Muskeg Creek, which contain documented spawning sites for Arctic grayling and/or suckers.

Table 5.4-2 Summary of Muskeg River Spring Counting Fence Data for Regular Migrant Species

Species	Number of Fish by Year[a]						
	1976	1977	1995	1998	2001	2003	2006
Arctic grayling	383	172	63	2	0	2	2
longnose sucker	5,028	2,645	344	13	12	209	674
mountain whitefish	134	67	0	1	0	4	3
northern pike	286	492	129	0	35	106	135
white sucker	4,508	4,355	300	2	79	881	431
Total	10,339	7,731	836	18	126	1,202	1,245

[a] Upstream and downstream migrants combined.

The restricted distribution category is the largest category of Muskeg River fish species and includes species that occur in the watershed irregularly, in small numbers and with limited distrtibutions. It consists of 14 species, including seven sport species (bull trout, burbot, goldeye, lake cisco, lake whitefish, walleye, yellow perch) and seven forage species (emerald shiner, finescale dace, flathead chub, ninespine stickleback, northern redbelly dace, spottail shiner and trout-perch) (Table 5.4-1) (Imperial Oil 2005). These species were most often present near the river mouth in association with the Athabasca River (Bond and Machniak 1979; Golder 2002a; Imperial Oil 2005; RL&L 1989b). The sport fish were observed to use the Muskeg River to a limited extent for seasonal rearing and feeding activities (Imperial Oil 2005). The seven forage species included in the restricted category were found either in the lower portion of the Muskeg River or in small numbers in the one or more tributary streams (Golder 2006b; Imperial Oil 2005).

Fish distribution and habitat use varies along the eight different reaches of the Muskeg River mainstem. Fish species diversity has been reported to decline along the length of the Muskeg River due to habitat changes and increasing distance from the Athabasca River which is a typical pattern of fish distribution in similar sized tributaries. The number of species declined in each successive reach moving up the Muskeg River (Table 5.4-3). The fish community in Reaches 6, 7 and 8 is considerably less diverse than in the lower watershed (Imperial Oil 2005). Access to the Athabasca for overwintering, migration and recolonization plays a role in the higher diversity in the lower reaches.

Table 5.4-3 Fish Species Distribution in Muskeg River Reaches

Species	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
Arctic grayling	□●	◆□●	◆□●	◆□●	–	–	–	–
brook stickleback	❖	❖	❖	❖	❖	❖	❖⛆	❖
bull trout	□❖	□❖	–	–	–	–	–	–
burbot	□●	□❖	–	–	–	–	–	–
emerald shiner	❖	❖	–	–	–	–	–	–
fathead minnow	❖	❖	❖	❖	❖	❖	–	–
finescale dace[(a)]	–	–	–	–	–	–	–	–
flathead chub[(a)]	–	–	–	–	–	–	–	–
goldeye	❖	❖	–	–	–	–	–	–
lake chub	❖	❖	❖	❖	❖	❖	❖⛆	❖
lake cisco	❖	❖	–	–	–	–	–	–
lake whitefish	□●	●	●	–	–	–	–	–
longnose dace	❖	❖	❖	❖	–	–	–	–
longnose sucker	◆□●	◆□●	◆□●	◆□●	◆□●	◆□●	◆□●	–
mountain whitefish	□●	□●	□●	□●	–	–	–	–
ninespine stickleback	❖	–	–	–	–	–	–	–
northern pike	□●	◆□●	◆□●	◆□●	◆□●	□	–	–
northern redbelly dace	❖	❖	❖	❖	–	–	–	–
pearl dace	❖	❖	❖	❖	❖	❖	❖⛆	❖
slimy sculpin	❖	❖	❖	❖	❖	–	–	–
spoonhead sculpin	❖	❖	❖	❖	❖	–	–	–
spottail shiner	❖	–	–	–	–	–	–	–
trout-perch	❖	❖	❖	❖	❖	–	–	–
walleye	□●	□●	□●	–	–	–	–	–
white sucker	□●	◆□●	◆□●	◆□●	◆□●	◆□●	◆□●	□●
yellow perch	□❖	□❖	–	–	–	–	–	–
Number of Species	**24**	**22**	**16**	**14**	**10**	**7**	**5**	**4**

[(a)] Species recorded in tributaries but not in mainstem Muskeg River.

Documented Fish Use:

- ❖ Present – life stages unspecified.
- ◆ Spawning and incubation.
- □ Nursery or rearing (fry or juvenile).
- ● Adult feeding.
- ⛆ Overwintering.

– = Not recorded.

As described previously, the habitat potential was higher for the lower three reaches of the river compared to the middle and upper reaches. These three reaches composed only 15% of the length of the watercourse, but together they supported 24 of the 26 species known to use the watershed. Reach 1 includes the river mouth and recieves use by all resident and migrant species, as well as most of the restricted species (Table 5.4-3). This reach is used for nursery, rearing and feeding activites by a variety of species, as well as sucker spawning activity. Reach 2 also receives use by all resident and migrant species, but being slightly removed from the Athabasca River receives use by a smaller portion of the restricted species than Reach 1. Reach 2 is used for nusery, rearing and feeding

activities by a variety of species, as well as spawning activity by species that prefer the abundant swift flowing rocky habitats, including Arctic grayling and suckers. A limited amount of northern pike spawning also occurs in Reach 2 in local areas where small vegetated side channels occur.

Use by all resident and migrant species continues into Reach 3, but species diversity continues to decline in this reach as fewer restricted species are present (Table 5.4-3). Reach 3 is used for nursery, rearing and feeding activites by a variety of species, as well as spawning by Arctic grayling, suckers and northern pike. Spawning use is limited in this reach, occurring in localized areas that provide suitable habitat such as riffle habitats (Arctic grayling and suckers) or areas with inundated vegetation (northern pike).

Habitat potential was described by all researchers (Beak 1986; Bond and Machniak 1977; Bond and Machniak 1979; Golder 1996a; Golder 1996b; Golder 1997a; Golder 2002a; Griffiths 1973; RL&L 1988; O'Neil et. al. 1982; RL&L 1989b; RL&L 1994; RRCS 1974; Sekerak and Walder 1980; Walder et al. 1980) as limited further upstream; only half of the species that use the watershed were found in Reach 4 (Imperial Oil 2005). Use of Reach 4 occurs for all resident and migrant species, but only for two restricted species (Table 5.4-3). Reach 4 is used for nursery, rearing and feeding by these species, as well as spawning by Arctic grayling, suckers and northern pike. Spawning use is limited for Arctic grayling and suckers and occurs in the occassional low-quality riffle habitats present in the reach. Only limited spawning use has been recorded for northern pike, although areas with inundated vegetation occur throughout the reach.

The distribution of several species ends in Reaches 4, 5 or 6 at one of the three main tributaries that converge with the river in this reach. Some species reach their distribution limit at Jackpine Creek (top of Reach 4), some at Muskeg Creek (top of Reach 5) and some at Wapasu Creek (middle of Reach 6). Most of these species also were found to use the tributary where their mainstem distribution ends. This indicates that Reaches 4, 5 and 6 are a migration route for these species as they move between these tributaries and the downstream reaches (Imperial Oil 2005).

Species diversity declines further in Reach 5 where use occurs for six of the seven resident species, three of the five migrant species and one of the restricted species. Northern pike is the only sport species that occurs past Reach 4. Reach 5 is used for nursery, rearing and feeding by the species present, as well as spawning by northern pike and suckers. As in Reach 4, spawning use is limited for suckers and occurs in the occassional low-quality riffle habitats. Limited

spawning use has been recorded for northern pike, although areas with inundated vegetation occur throughout the reach.

The fish community in Reach 6 is similar to Reach 5, but with fewer resident species present. Reach 6 is used for nursery, rearing and feeding by most of the species present. Use by northern pike is limited to nursery and rearing by younger life stages. Spawning use occurs for suckers, with spawning limited to the occassional low-quality riffle habitats present in the reach.

The distributions of only a few fish species continue past the Wapasu Creek confluence and into the uppermost reaches of the Muskeg River. The fish community in Reach 7 consists of sucker and forage fish, with no sport fish present. The only migrant species present are longnose and white sucker and only three resident forage species are present. Reach 7 is used for nursery, rearing and feeding by these species, as well as sucker spawning, with spawning limited to the occassional low-quality riffle habitats present in the reach.

The fish community in Reach 8 shows the lowest diversity of any of the Muskeg River reaches, consisting of white sucker and three resident forage fish species. Reach 8 is used for nursery, rearing and feeding by the species present.

Overwintering use of the mainstem Muskeg River has not been well documented or investigated. A few winter habitat investigations have been completed, but little fish sampling has been conducted. Overwintering use has been recorded in Reach 7 for the three resident forage fish species known to be present in that reach (Table 5.4-3). Additional overwintering would occur elsewhere in the river for resident fish, but this has not been documented.

Muskeg River Tributaries

The Muskeg River has five named tributary drainages, which include the larger tributaries (Table 5.4-4). The Muskeg River also has several smaller unnamed tributary drainages. The named tributary drainages, plus nine unnamed tributary drainages, were studied historically (Beak 1986; Bond and Machniak 1977; Bond and Machniak 1979; Golder 1996a; Golder 1996b; Golder 1997a; Golder 1997b; Golder 1997c; Golder 1999b; Golder 2001b; Golder 2002a; Golder 2002e; Golder 2003b; Imperial Oil 2005; Komex 1997; RL&L 1988; Lombard North Group 1973; O'Neil et. al. 1982; R.Webb Environmental Services Ltd. 1980; RL&L 1989b; RL&L 1994; RRCS 1974; Sekerak and Walder 1980; Walder et al. 1980).

Table 5.4-4 Fish Species Distribution in Muskeg River Tributaries

Species	Unnamed Tributary Drainage[a]	Jackpine Creek Drainage[b]	Shelley Creek	Muskeg Creek Drainage[c]	Kearl Lake	Stanley Creek	Wapasu Creek	Unnamed Tributary Drainage[d]	Unnamed Headwater Tributaries[e]
Arctic grayling	–	◆□●	–	–	–	–	–	–	–
brook stickleback	❖	❖	❖	❖	❖⛆	❖	❖	❖	❖
bull trout	–	–	–	–	–	–	–	–	–
burbot	–	–	–	–	–	–	–	–	–
emerald shiner	–	❖	–	–	–	–	–	–	–
fathead minnow	❖	❖	–	❖	❖	–	❖	–	–
finescale dace[a]	❖	–	❖	❖	–	–	–	–	❖
flathead chub[a]	–	❖	–	–	–	–	–	–	–
goldeye	–	–	–	–	–	–	–	–	–
lake chub	❖	❖	❖	❖	❖	–	❖	–	❖
lake cisco	–	–	–	–	–	–	–	–	–
lake whitefish	–	–	–	–	–	–	–	–	–
longnose dace	–	❖	–	–	–	–	–	–	–
longnose sucker	□●	◆□●	□	□●	□	–	□●	–	–
mountain whitefish	–	□●	–	–	–	–	–	–	–
ninespine stickleback	–	–	–	–	–	–	–	–	–
northern pike	□	◆□●	–	●	□●⛆	–	–	–	–
northern redbelly dace	–	❖	–	–	–	–	–	–	–
pearl dace	❖	❖	–	◆❖	❖	–	❖	❖	❖
slimy sculpin	❖	❖	–	❖	–	–	–	–	–
spoonhead sculpin	–	❖	–	❖	–	–	–	–	–
spottail shiner	–	–	–	❖	–	–	–	–	–
trout-perch	–	❖	–	–	–	–	–	–	–
walleye	–	–	–	–	–	–	–	–	–
white sucker	□●	◆□●	–	◆□●	□●⛆	–	□●	–	□
yellow perch	–	–	–	–	–	–	–	–	–
Number of Species	**9**	**16**	**4**	**11**	**7**	**1**	**6**	**2**	**5**

[a] Tributary to Muskeg River lower Reach 4. Includes three unnamed waterbodies.
[b] Includes East Jackpine Creek.
[c] Includes Khahago, Pemmican, Green Stockings, Blackfly, Wesukemina and Iyinimin creeks.
[d] Tributary to Muskeg River Reach 6. Includes an unnamed waterbody.
[e] Seven tributaries to Muskeg River Reach 8. Species present in one or more of these tributaries.

Documented Fish Use:
❖ Present – life stages unspecified.
◆ Spawning and incubation.
□ Nursery or rearing (fry or juvenile).
● Adult feeding.
⛆ Overwintering.
– = Not recorded.

The studied tributary drainages in the Muskeg River watershed consist of:

- one unnamed tributary to Reach 4;
- Jackpine Creek, including:
  - East Jackpine Creek; and
  - unnamed tributary.
- Shelley Creek;
- Muskeg Creek, including:
  - Khahago Creek;
  - Blackfly Creek;
  - Green Stockings Creek;
  - Pemmican Creek;
  - Wesukemina Creek; and
  - Iyinimin Creek.
- Kearl Lake;
- Stanley Creek;
- Wapasu Creek;
- one unnamed tributary to Reach 6;
- one unnamed isolated waterbody (Waterbody 3); and
- seven unnamed headwater tributaries to Reach 8.

Unnamed Tributary to Muskeg River Reach 4

Fish Habitat

This unnamed drainage consists of a watercourse and three interconnected waterbodies located at the lower end of the drainage. The drainage has a moderate potential to support fish due to the presence and depth of the waterbodies (R.Webb Environmental Services Ltd. 1980). The watercourse itself is intermittent and the best habitat occurs in the 0.9 km long section downstream of the interconnected waterbodies where the flow is more constant (R.Webb Environmental Services Ltd. 1980). This section of the lower channel consists of shallow run habitats and beaver ponds. The substrate is dominated by fine sediments, but some embedded cobble and boulder occurs near the watercourse mouth.

During surveys conducted in 2003 and 2004, the presence of woody debris, instream and overhanging vegetation and undercut banks provided good cover as

well as spawning and rearing habitat for a variety of forage fish species (AXYS 2005). Shallow depth likely limits the quality of habitat for large-bodied species as well as overwintering potential in some or most years (AXYS 2005).

Historical data indicates the three waterbodies had maximum depths of 13.4 to 22.3 m (R.Webb Environmental Services Ltd. 1980), however, surveys in 2003 and 2004 found maximum depths of 10.9 to 20.0 m (AXYS 2005). These waterbodies provide habitat for small and large-bodied fish, but access to the waterbodies from the Muskeg River is limited by blockages to fish passage, particularly beaver dams (R.Webb Environmental Services Ltd. 1980). Habitat conditions in the three waterbodies are limited by low DO levels. During the open-water seasons, the waterbodies were found to be stratified with low DO levels at depths greater than 1.5 m and anoxic conditions at depths greater than 6 m. Overwintering capability is variable but generally limited by low DO levels. Although one of the three waterbodies was found to have sufficient DO in one winter to provide overwintering habitat (AXYS 2005; R.Webb Environmental Services Ltd. 1980), AXYS (2005) found the waterbodies to be anoxic at depths greater than 0.5 m in another winter. The three waterbodies were considered to provide low to moderate habitat for forage fish species but limited habitat for large-bodied fish due to poor DO conditions, poor overwintering potential and limited access (AXYS 2005).

An additional muskeg pond located within the drainage and situated about 3 km upstream from the three interconnected waterbodies was surveyed in 2003/2004 (AXYS 2005). A maximum depth of 1.3 m was recorded, with moderate to low DO levels in the summer and fall and winter DO levels of 0.01 to 0.07 mg/L (AXYS 2005). This waterbody was designated as low habitat quality for forage fish species due to shallow depth, poor connectivity and high potential for frequent summer and winter kills (AXYS 2005).

Fish Population

The drainage for the unnamed creek with the three interconnected waterbodies was reported to support nine fish species (Table 5.4-4): one sport species (northern pike), two sucker species and six forage species (AXYS 2005; R.Webb Environmental Services Ltd. 1980). Nursery, rearing and feeding activity were observed for suckers and forage fish in some of the waterbodies and in the lower portion of the watercourse (AXYS 2005; R.Webb Environmental Services Ltd. 1980). Northern pike rearing activity was also recorded in the lower watercourse (AXYS 2005). Drift net sampling showed the presence of sucker and minnow eggs or larvae in the lower watercourse, indicating some use of the watercourse for spawning. This drainage was one of the few places in the Muskeg River watershed that was found to support finescale dace (Imperial Oil 2005). Although fish sampling was not conducted in the muskeg pond located in the upper portion

of the watercourse, finescale dace were visually observed in August 2004 (AXYS 2005).

Jackpine Creek

Fish Habitat

Jackpine Creek has five distinct reaches that differ mainly in gradient (Bond and Machniak 1979; O'Neil et. al. 1982). Reach 1 (0.0 to 3.4 km from the creek mouth) has a low gradient that results primarily in slow runs and tortuous meanders dominated by sand/silt substrate (Golder 1996b; Golder 2006b; RL&L 1989b). Beaver activity is abundant within this area (Golder 1996b; RL&L 1989b). Reach 2 (3.4 to 7.4 km) has a slightly higher gradient, more habitat diversity (Golder 2006b). Beaver dams also are common in this stretch of creek resulting in flat flow characteristics interspersed with run-riffle-pool sequences. In Reach 3 (7.4 to 9.4 km), the stream gradient is higher and cobble/gravel substrate is common. Riffle/run/pool sequences were at one time predominant in Reach 3, but recent beaver activity has resulted in an increased number of impoundment and alteration of some riffle/run habitat to pool habitats (Golder 2001c). Reach 4 (9.4 to 21.0 km) has a moderate gradient and similar flow and meander pattern to Reach 2. Reach 5 (21.0 to 69.0 km) of Jackpine Creek is similar to Reach 1 (Golder 1997b). Jackpine Creek has the highest quality of fish habitat of all Muskeg River tributaries (Imperial Oil 2005).

Jackpine Creek has limited habitat potential along most of its length. Low-quality habitats occur near the creek mouth and in the upper reaches (Imperial Oil 2005). Habitat limitations include low habitat diversity, lack of spawning habitat for species that prefer rocky substrates due to the presence of fine sediments and extensive beaver activity blocking fish movements (Imperial Oil 2005). Some northern pike spawning habitat occurs in the lower reaches. Reaches 2, 3 and 4 comprise part of the lower and middle portion of Jackpine Creek and have increased habitat diversity and were historically considered to have moderate to excellent spawning habitat for Arctic grayling and suckers due to the presence of rocky substrates, as well as important rearing habitat for all fish species (Imperial Oil 2005). More recent habitat investigations indicated that habitat and substrate diversity has been reduced due to increased beaver activity resulting in increased pool habitat and sediment deposition (Golder 2001c). Adult feeding habitat is limited due to shallow water depths (Imperial Oil 2005).

Overwintering conditions in Jackpine Creek are variable, but are generally poor due shallow water depths and low DO levels. In some years, winter discharge volume and DO were found to be sufficient to sustain small-bodied fish but under-ice depths in the watercourse channel were generally too shallow for large fish, except at the mouth of the creek where overwintering conditions were suitable for all fish species (Imperial Oil 2005). Deeper overwintering habitat

may be available in the beaver pond areas. However, winter DO data indicates that overwintering conditions would be unsuitable in most years. A summary of historical water quality data from 1985 to 2004 (AXYS 2005) provides information regarding overwintering conditions in Jackpine Creek with respect to DO levels. Winter DO levels ranged from 0.18 to 10.6 mg/L, with a median value for the period of record of 0.97 mg/L. The data indicates that winter DO levels are highly variable but are generally quite low.

Fish Population

Numerous fish inventory surveys have been conducted on Jackpine Creek (Bond and Machniak 1977; Bond and Machniak 1979; Golder 1996b; Golder 1997a; Golder 2006b; O'Neil et. al. 1982; RL&L 1989b; Sekerak and Walder 1980). Fish access to Jackpine Creek is variable due to extensive beaver activity near the mouth of the creek (Shell 1998).

Jackpine Creek has been reported to support 16 species: three sport fish (Arctic grayling, mountain whitefish, northern pike), two sucker species (longnose and white sucker) and 11 forage species (brook stickleback, emerald shiner, fathead minnow, flathead chub, lake chub, longnose dace, northern redbelly dace, pearl dace, slimy sculpin, spoonhead sculpin and trout-perch) (Golder 2006b; Imperial Oil 2005). It provides important spawning, nursery and rearing habitat for Arctic grayling, longnose sucker and white sucker (Imperial Oil 2005). To a lesser extent, the creek also provides summer feeding habitat for Arctic grayling and suckers (Imperial Oil 2005). Northern pike and mountain whitefish also used the watercourse to a lesser extent for some life stages (Imperial Oil 2005).

The 10 most commonly captured species include Arctic grayling, brook stickleback, fathead minnow, lake chub, longnose dace, longnose sucker, mountain whitefish, pearl dace, slimy sculpin and white sucker (Golder 1998). Investigations by RAMP indicate that use of the creek by large-bodied species has declined in recent years (RAMP 2004), including a notable decline in Arctic grayling numbers. A comparison of historical (O'Neil 1982) and recent (AXYS 2005) counting fence data for Jackpine Creek (Table 5.4-5) demonstrates the decline in the use of the creek by Arctic grayling and suckers. Recent intensive fish sampling activities conducted by Shell (2007) show lake chub as the dominant species, with other relatively common species being brook stickleback, pearl dace, slimy sculpin and white sucker, along with longnose sucker in some areas.

Table 5.4-5 Sumary of Jackpine Creek Spring Counting Fence Data

Species	Number of Fish by Year[a]	
	1981	2004
Arctic graying	989	8
northern pike	1	3
longnose sucker	584	78
white sucker	852	22
Total	2,426	111

[a] Upstream and downstream migrants combined.

East Jackpine Creek

Fish Habitat

East Jackpine Creek forms the eastern branch of upper Jackpine Creek. East Jackpine Creek habitat has been described as having low diversity with habitat conditions best suited to forage fish species in its lower reach (RL&L 1989a). A survey conducted in the upper reach described this area of the stream as being suitable for forage and non-sport fish species and of low suitability for sport fish species (Suncor 2000).

Fish Population

Brook stickleback, longnose sucker and pearl dace are the only fish species that have been captured from East Jackpine Creek (Golder 2002a).

Unnamed Tributary to Jackpine Creek

Fish Habitat

This unnamed tributary to Jackpine Creek originates in a fen within Lease 13 and flows northwest to the confluence with Jackpine Creek (AXYS 2005). This stream has been described as providing low to moderate quality habitat for forage fish species (AXYS 2005). Habitat quality was limited by low flows, shallow depth and poor connectivity (AXYS 2005).

Fish Population

Brook stickleback occur in this watercourse, primarily occupying beaver pond habitats, and one white sucker was captured near the Jackpine Creek confluence that may have been using the confluence backwater as refuge or feeding habitat (AXYS 2005).

Shelley Creek

Fish Habitat

Shelley Creek is a small tributary with a narrow channel and extensive beaver activity. Habitat diversity is low to moderate, with pool and run habitats and

occasional riffle habitats (Golder 2006b; Imperial Oil 2005). Habitat potential is limited by the lack of deep water areas, absence of rocky substrates and by numerous fish passage barriers. Lack of winter discharge and low DO levels limit overwintering habitat suitability (Imperial Oil 2005). The middle and upper portions of Shelley Creek have been removed by Jackpine Mine–Phase 1.

Fish Population

Shelley Creek supports four fish species. It is used by three forage species (lake chub, brook stickleback and finescale dace) and also is used for rearing habitat by longnose sucker (Golder 2006b; Imperial Oil 2005).

Stanley Creek

Fish Habitat

Stanley Creek is a small intermittent watercourse that lacks a defined channel in some locations. It has been described as a small, ephemeral stream with a poorly defined channel and substrates of organic debris, sand and silt, with localized areas of cobble and boulder (Golder 1996a; Golder 1996b). The stream consists of mainly run habitat, with limited pool and riffle habitats (Golder 1996a). As a result, habitat conditions are poor and fish passage is limited. Stanley Creek has been described as having poor habitat potential for fish of any kind (Golder 1996b; Golder 2002a; Imperial Oil 2005).

Fish Population

Stanley Creek has a very limited fish community. Only brook stickleback was reported from this creek (Golder 1996a).

Wapasu Creek

Fish Habitat

Wapasu Creek is a tributary of the mainstem Muskeg River located in the eastern portion of the Muskeg River watershed (Golder 2002a). Golder (1999b) reported that habitat in Wapasu Creek consists primarily of low-quality pools and runs. Substrate composition varies, but is dominated by sand and silt, with localized areas of boulder, cobble and gravel (Golder 2002a). The quality of fish habitat within the surveyed section of Wapasu Creek was reported to be limited by the low water levels experienced at the time of assessment and by the extensive amounts of instream woody debris (Golder 1999c). The habitat within Wapasu Creek was described as best suited to forage fish and smaller coarse fish (non-sport fish) species (Golder 2002a). Wapasu Creek was considered to provide poor overwintering habitat due to a lack of deep pools (Golder 1999b).

One previous study (Golder 2003b) examined movements of forage fish in Wapasu Creek in the spring and fall to determine if the forage species typically

found in these small watercourses migrated seasonally to and from the Muskeg River. Dead brook stickleback and lake chub were found in the early spring following melting of the river ice. These fish had attempted to overwinter in Wapasu Creek, but winter conditions were not suitable. It is likely that forage fish use Wapasu Creek for overwintering, but the habitat conditions are unsuitable in some years or in some locations.

Based on the habitat characteristics, fish capture data and historical information, Wapasu Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for forage fish and non-sport fish species (Golder 2002a).

Fish Population

Wapasu Creek supports six fish species, consisting of two sucker species and four forage species: longnose sucker, white sucker, brook stickleback, lake chub, pearl dace and fathead minnow (Golder 2002a; Imperial Oil 2005). Both sucker species use Wapasu Creek as rearing and feeding habitat, with white sucker more widely distributed than longnose sucker.

Muskeg Creek

Fish Habitat

Muskeg Creek consists mainly of moderate-quality run and pool habitats, except for a high-gradient section in the middle of Muskeg Creek that contains riffle habitats (Golder 2006b; Shell 1998). The potential of the habitats in the Muskeg Creek to support fish is limited for sport fish but was fair to good for suckers and small-bodied forage fish. Some spawning habitat is present for species that use swift-flowing rocky habitats. Potential spawning habitat is limited in extent to small riffle areas, but overall spawning potential is good in relation to other Muskeg River tributaries, with the exception of Jackpine Creek (Imperial Oil 2005).

Muskeg Creek has some potential to provide overwintering habitat because winter DO levels were reported to be sufficient to support fish (Imperial Oil 2005). However, due to low winter discharge and shallow under-ice depths, Muskeg Creek provides overwintering habitat of limited suitability (Imperial Oil 2005).

Fish Population

Muskeg Creek supports eleven fish species: one sport fish species (northern pike), two sucker species (longnose and white sucker) and eight forage fish species (brook stickleback, fathead minnow, finescale dace, lake chub, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner) (Golder 2006b; Imperial Oil 2005). Northern pike are not typically present in the watercourse

and may use it primarily as a corridor to move between Kearl Lake and the Muskeg River (Imperial Oil 2005). Longnose and white sucker use the creek for rearing and feeding and white sucker were historically known to spawn in the upper reaches, although recent increases in beaver activity in the creek have affected the amount of available sucker spawning habitat (Imperial Oil 2005).

The Muskeg Creek drainage also includes Kearl Lake as well as six small watercourses: Khahago Creek, Pemmican Creek, Green Stockings Creek, Blackfly Creek, Wesukemina Creek and Iyinimin Creek. These watercourses are small streams with low habitat diversity, substrates composed mainly of fine sediment and extensive beaver activity creating migration barriers. They provide poor habitat potential for most fish species and low to moderate habitat potential of some small-bodied species (Imperial Oil 2005). A brief description of those watercourses is provided below.

Khahago Creek

Fish Habitat

Khahago Creek is a tributary to Muskeg Creek and has low-quality habitat characterized by deep, slow flats and runs dominated by organic/silt substrate. The banks are flat, with riparian vegetation cover consisting of willows and grasses (Beak 1986). More recently, Golder (2006b) conducted habitat surveys on Khahago Creek. Between the two established survey sites, habitat was mainly composed of riffle and run habitat at one site and run and impoundment habitat at the other site (Golder 2006b).

Fish Population

Nine fish species have been documented in Khahago Creek. This includes seven forage species (brook stickleback, finescale dace, lake chub, pearl dace, slimy sculpin, spoonhead sculpin and fathead minnow) and two non-sport fish species (longnose sucker and white sucker) (Golder 2006b; Imperial Oil 2005).

Blackfly Creek

Fish Habitat

Blackfly Creek is a tributary of Khahago Creek and has higher-quality habitat due to a higher gradient. It flows through an area where white spruce provides overhead cover and in-stream cover provided by dead snags is abundant. The channel type is described as a mainly shallow, swift run with sand substrates, having localized areas of gravel and cobble in riffle habitats (Golder 1996b). Based on the habitat characteristics and fish capture data, Blackfly Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for some forage fish and non-sport fish species (Golder 2002a).

There was no measurable flow when the creek was examined during the winter of 1985; therefore, overwintering potential was considered to be low (Beak 1986).

Fish Population

Few fish were captured during any survey period on the creek (Beak Associates Consulting Ltd. 1986; RL&L Environmental Services Ltd. 1989a). Four forage fish species have been captured from the stream, including brook stickleback, finescale dace, pearl dace and lake chub (Golder 2002a; Golder 2006b).

Green Stockings Creek

Fish Habitat

Green Stockings Creek is a tributary stream of Khahago Creek. The habitat in Green Stockings Creek contained some pool-run-riffle sequences (RL&L Environmental Services Ltd. 1989a) with substrates of fine sediments and small deposits of gravel and cobbles in riffle areas (Suncor 2000). No flow was measured during the winter of 1985, therefore overwintering potential was considered to be low (Beak Associates Consulting Ltd. 1986). Based on the habitat characteristics and fish capture data, Green Stockings Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for some forage fish and non-sport fish species (Golder 2002a).

Fish Population

Few fish were captured during any survey period on the creek (Beak Associates Consulting Ltd. 1986; RL&L Environmental Services Ltd. 1989a). Brook stickleback, finescale dace and pearl dace are the only fish species captured from the stream (Golder 2002a; Golder 2006b).

Pemmican Creek

Fish Habitat

Pemmican Creek is a tributary of Khahago Creek. Pemmican Creek has been described as a narrow meandering creek with sections of beaver dams and flooded areas (Golder 1996a). The habitat consists mainly of impoundment pools and runs, with some natural pool habitats (Golder 1996a). The substrate consists of fines sediments due to the presence of the numerous beaver dams (Golder 1996a). Based on the habitat characteristics and fish capture data, Pemmican Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for some forage fish and non-sport fish species (Golder 2002a).

Fish Population

Brook stickleback, pearl dace and longnose sucker are the only fish species using this stream (Golder 2002a; Imperial Oil 2005).

Wesukemina Creek

Fish Habitat

Wesukemina Creek is a tributary of Muskeg Creek (Golder 2002a). Some sections of Wesukemina Creek that have been surveyed consists of low and moderate quality pool habitats with substrates of sand and silt (Golder 1996a). More recently, habitat surveys have indicated this watercourse also contains run, riffle and pool habitat with diverse substrate (Golder 2006b). Based on the habitat characteristics and fish capture data, Wesukemina Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for some forage fish and non-sport fish species (Golder 2002a).

Fish Population

Seven fish species have been documented in Wesukemina Creek. Of the seven, five were forage fish (brook stickleback, finescale dace, lake chub, pearl dace and slimy sculpin) and two were non-sport fish (longnose sucker and white sucker) (Golder 2002a; Golder 2006b).

Iyinimin Creek

Fish Habitat

Iyinimin Creek is a tributary stream that flows into the southeastern portion of Kearl Lake. The lower reach of the creek was described as having a low gradient and habitat similar to that of Muskeg Creek (Golder 1996b). The upper reaches of Iyinimin Creek have a higher gradient and the habitat is similar to that of Blackfly Creek (Golder 1996b). The creek was described as having mainly run habitats with sporadic pools and riffles (Golder 1996b). Substrates consist of silt and sand with occasional patches of gravel and cobble in riffle areas (Golder 1996b). Based on the habitat characteristics and fish capture data, Iyinimin Creek was assessed as a watercourse of low-quality habitat for sport fish species and of low to moderate quality for some forage fish and non-sport fish species (Golder 2002a).

Fish Population

Few fish were captured during any survey period on Iyinimin Creek (RL&L 1989a). Brook stickleback and pearl dace have been captured from Iyinimin Creek (Golder 2002a).

Kearl Lake

Fish Habitat

Kearl Lake is connected to the Muskeg River by way of an outlet to Muskeg Creek and receives inflow from Iyinimin Creek (Golder 2002a; Imperial Oil 2005). Kearl Lake has been described as a shallow (maximum depth 2.5 m), mesotrophic to eutrophic waterbody with substrates of organic material and an

abundance of submergent and emergent aquatic vegetation (Golder 2002a; Imperial Oil 2005). It has abundant aquatic plants and substrates composed entirely of fine sediments. Kearl Lake provides marginal habitat for fish species such as northern pike, suckers and small-bodied forage fish. Spawning habitat is available only for species that prefer fine sediments and aquatic vegetation. Rearing and feeding habitat also is limited, except for species that prefer shallow, weedy habitats (Imperial Oil 2005).

Kearl Lake has variable overwintering potential and may provide overwintering habitat in some years but not in others (Imperial Oil 2005). Sufficient depth and DO were available to provide overwintering habitat during early winter in 1995 (Golder 1996a), but the lake was without oxygen during late winter in 1989 (RL&L 1989a). Shallow depths and high content of organic material likely consume oxygen during the winter (Imperial Oil 2005) and it is likely that the lake experiences oxygen depletion by the late winter in most years. Winter kills were predicted due to the lack of DO and presence of hydrogen sulphide gas in the late winter 1989 survey.

Kearl Lake provides feeding and rearing habitat for longnose and white sucker, as well as habitat for forage fish species (RL&L 1989a). The waterbody was considered to be suitable habitat for northern pike during the open water season and northern pike have recently been observed in Kearl Lake. However the large number of beaver dams present in Muskeg Creek and the Muskeg River were thought to inhibit movements of fish into Kearl Lake (Golder 2002a).

Based on the habitat characteristics and fish capture data, Kearl Lake was assessed as a waterbody of low- to moderate-quality habitat for sport fish species and of moderate quality for a variety of forage fish and non-sport fish species (Golder 2002a).

Fish Population

Historical reports indicate Kearl Lake is used by seven fish species, including one sport fish, two sucker species and four forage fish species. Species captured include northern pike, longnose sucker, white sucker, brook stickleback, fathead minnow, lake chub and pearl dace (Golder 2002a). Traditional users and local residents also report the capture of lake whitefish, mountain whitefish and walleye from Kearl Lake (Golder 2002a).

White sucker and brook stickleback were the most frequently captured fish species in Kearl Lake (RL&L 1989a). Longnose sucker have been recorded in the lake, but their abundance level is lower than that of white sucker. Northern pike occur in Kearl Lake occasionally and it is likely that the presence of this species depends on fish passage conditions in Muskeg Creek.

Unnamed Tributaries to Muskeg River Reach 6

Information for an unnamed tributary drainage within Reach 6 of the Muskeg River was documented by Imperial Oil (2005). A waterbody at the headwaters of this tributary was also examined.

Fish Habitat

This watercourse consisted primarily of shallow run habitat and beaver impoundments with occasional riffles (Imperial Oil 2005). Fines and organic material dominated the substrate composition, except in the occasional riffle areas, where cobble and boulder substrate was present (Imperial Oil 2005).

No overwintering habitat potential was found in the defined channel areas due to the absence of flow, however, overwintering habitat potential might exist in the beaver impoundment areas (Imperial Oil 2005).

Overall fish use potential in the tributary during the open-water season was rated as nil for sport fish, nil to low for sucker spawning and feeding, low to moderate for other sucker life stages and low to high for forage fish (Imperial Oil 2005).

The unnamed waterbody at the headwaters of this tributary was described as shallow and uniform, with an average depth of 0.6 m (Imperial Oil 2005). The substrate consisted of fines and organic material with emergent vegetation along the shoreline and in the basin (Imperial Oil 2005).

Overwintering potential within the unnamed waterbody was limited to forage fish due to shallow under-ice water depths (Imperial Oil 2005). The overall habitat use potential during the open-water season was rated as nil to poor for sport fish, nil to moderate for sucker species and poor to moderate for forage fish (Imperial Oil 2005).

Fish Population

Brook stickleback and pearl dace were the only species documented in this tributary drainage (Imperial Oil 2005). Brook stickleback was also documented in the unnamed waterbody (Imperial Oil 2005).

Unnamed Headwater Tributaries to Muskeg River Reach 8

There is existing information for seven unnamed tributaries to Reach 8 of the upper Muskeg River. This section provides a brief summary of all seven watercourses.

Fish Habitat

These first and second order watercourses consisted of shallow run habitat with some moderately deep run habitat, flat habitat, pools and beaver dam impoundments (Imperial Oil 2005). Substrate was composed primarily of fines and organic material with aquatic macrophytes present (Imperial Oil 2005). Most of the watercourses were found to be frozen to bottom during the winter surveys, providing no overwintering habitat potential. Although two watercourses were not frozen to bottom, lack of under ice water depth and low DO levels limit their overwintering habitat potential to forage fish only.

The overall habitat use potential during the open-water season for all seven watercourses was rated as nil for sport fish, nil to moderate for sucker species and low to high for forage species (Imperial Oil 2005).

Fish Population

The fish species assemblage recorded within these seven tributaries combined includes brook stickleback, lake chub, pearl dace and white sucker (juveniles), although not all of these species were present in each watercourse (Imperial Oil 2005).

Unnamed Waterbody 3

This unnamed waterbody is located within JEMA at the headwaters of Unnamed Creek 9 and referred to as Unnamed Waterbody 3 in this report. This small, isolated waterbody was surveyed by Imperial Oil (2005).

Fish Habitat

Imperial Oil (2005) describes this waterbody as shallow and uniform, with a maximum depth of 1.4 m. The substrate is composed of fines and organic material and submergent vegetation was abundant, with water lily covering almost the entire basin (Imperial Oil 2005).

During the winter, the waterbody was completely frozen to bottom, therefore, no overwintering potential was found (Imperial Oil 2005). The overall habitat use potential during the open-water season was rated as nil for sport fish and sucker species and poor to moderate for forage species (Imperial Oil 2005).

Fish Population

No fish were captured in this waterbody (Imperial Oil 2005). Due to poor connectivity and no overwintering habitat, this waterbody is likely non fish-bearing (Imperial Oil 2005).

5.4.1.2 Environmental Field Surveys

Fish habitat characteristics and fish population data collected specifically for the Project are presented in the following sections for selected watercourses and waterbodies in the JEMA LSA. Results include data from the habitat evaluation (habitat mapping, overwintering assessment, discharge and water quality surveys) and fish inventory (fish sampling and spawning survey).

Muskeg River Watershed

Watercourses

Muskeg River Mainstem

Habitat Assessment

The Muskeg River was surveyed at two sites (Sites 41 and 30) (Figure 5.2-1) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.4-6 and 5.4-7.

Site 41

Site 41 was located within Reach 4 of the Muskeg River and had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a muskeg bog and was bordered by grass/forbs, shrubs and coniferous forest. The surrounding vegetation was predominantly willows and grasses, with some black spruce.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-1). Site 41 consisted entirely of one deep run habitat having a maximum water depth of 1.9 m and a channel width of 11.20 m. Substrate throughout the site consisted of clay, silt and sand. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris, aquatic vegetation and depth/turbulence. Overhead cover was limited and consisted of grasses, shrubs, undercut banks and woody debris. Approximately 25% of the surveyed area contained aquatic macrophytes.

Discharge could only be measured during the open-water period in the spring due to access limitations and was 0.03 m^3/s at the time of the survey (Table 5.4-6). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.4-6). Water temperature at Site 41 was continuously monitored from June 10, 2006 to August 6, 2006 (Appendix S, Figure S-5) using a thermograph. Water temperatures fluctuated between 12.7 and 21.4°C during this time. The peak water temperature (21.4°C) was recorded on June 28, 2006.

During the winter, the discharge of the Muskeg River at Site 41 at the time of the survey was 1.64 m^3/s (Table 5.4-7). The wetted width of the river at the site was 7.3 m. Under-ice water depths ranged from 0.90 to 1.95 m and averaged 1.18 m. Water velocities ranged from 0.00 to 1.35 m/s. The mean ice thickness was 0.27 m. The DO level at the time of the survey was 1.5 mg/L. Conductivity was notably higher in the winter compared to the open-water period, indicating that groundwater likely constitutes a portion of the winter flow.

Based on the habitat available at Site 41, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering, high for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Table 5.4-6 Open-Water Seasonal Habitat Conditions at Watercourse Sampling Sites in the Muskeg River Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Muskeg River	41	spring	0.03	13.8	6.70	301	8.18
		summer	–[b]	14.7	10.54	357	7.53
		fall	–[b]	4.0	6.97	348	7.46
	30	spring	0.33	15.0	–[c]	278	7.69
		summer	–[b]	13.9	10.05	313	7.87
		fall	0.42	1.9	9.90	288	7.98
Stanley Creek	40	spring	–[b]	14.8	–[c]	337	7.20
		summer	–[b]	15.7	3.80	484	7.46
		fall	0.04	2.3	8.57	933	7.72
Wapasu Creek	32	spring	–[b]	14.6	–[c]	178	6.83
		summer	–[b]	13.1	4.09	245	7.35
		fall	–[b]	5.0	6.12	275	7.30
	26	spring	0.35	12.9	–[c]	193	7.53
		summer	0.30	14.2	8.86	215	8.04
		fall	0.30	6.9	8.95	239	8.14
	38	spring	0.33	15.4	–[c]	149	7.36
		summer	0.33	14.4	8.86	212	7.84
		fall	0.02	5.8	9.30	139	7.40
Unnamed Creek 9	35	spring	–[b]	9.2	0.39	550	6.71
		summer	–[b]	13.3	5.66	349	7.27
		fall	0.01	3.7	7.77	270	7.46
Unnamed Creek 12	24	spring	–[b]	14.8	–[c]	281	7.16
		summer	–[b]	12.8	3.79	433	7.31
		fall	–[b]	0.7	6.33	395	7.39

[a] See Figure 5.2-1 for sample site locations.

[b] Site conditions did not allow measurement (water too deep or substrate too soft for gear and/or safe wading).

[c] Data not obtained due to equipment malfunction.

- = Not measured.

Table 5.4-7 Winter Habitat Conditions at Watercourse Sampling Sites in the Muskeg River Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Water Velocity [m/s]		Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Quality Field Parameters			
			Mean	Range			Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Muskeg River	41	1.64	0.27	0.00 to 1.35	–	0.27	1.18	0.90 to 1.95	0.0	1.48	558	7.44
	30	0.02	0.00	0.00 to 0.05	0.40	0.37	0.52	0.20 to 1.20	0.0	6.23	586	7.84
Stanley Creek	40	–[b]	0.01	0.01	0.30	0.45	0.35	–	0.0	1.47	594	7.48
Wapasu Creek	32	0.00	0.00	0.00 to 0.00	0.30	0.50	0.53	0.00 to 0.80	0.1	2.40	334	6.31
	26	–[c]	–	–	0.40	0.35	0.60	0.35 to 0.75	0.0	6.32	705	7.96
	38	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]
Unnamed Creek 9	35	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]	–[d]
Unnamed Creek 12	24	–[e]	–[e]	–[e]	–[e]	0.43	0.78	–[e]	0.0	6.63	500	7.65

[a] See Figure 5.2-1 for sample site locations.

[b] Not enough water depth across transect.

[c] No measurable discharge.

[d] Frozen to bottom.

[e] Not sampled due to construction activities.

- = Not measured.

Site 30

The watercourse at Site 30 was located within Reach 5 of the Muskeg River and had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a muskeg bog and was bordered by grass/forbs and dense shrubs, which were predominately willows.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-2). Site 30 consisted entirely of run habitat. Average water depth and average channel width for the surveyed area was 0.8 and 6.95 m, respectively. Substrate throughout the surveyed reach consisted of sand and silt. Both stream banks were stable throughout the surveyed area. Instream cover was limited and provided by woody debris, aquatic vegetation and depth/turbulence. Overhead cover was abundant and consisted of grasses, shrubs and undercut banks.

Discharge in the open-water period was measured in the spring (0.33 m^3/sec) and fall (0.42 m^3/sec) (Table 5.4-6). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.4-6). Water temperature at Site 30 was continuously monitored from June 8, 2006 to August 6, 2006 (Appendix S, Figure S-6) using a thermograph. The water temperature fluctuated between 13.0 and 22.6°C throughout this time period. The peak water temperature (22.6°C) was recorded on June 28, 2006.

During the winter, the discharge of the Muskeg River at Site 30 at the time of the survey was 0.02 m^3/s (Table 5.4-7). The wetted width of the river at the site was 5.5 m. Under-ice water depths ranged from 0.20 to 1.20 m and averaged 0.52 m. Mean water velocities ranged from 0.00 to 0.05 m/s. The mean ice thickness was 0.37 m. Dissolved oxygen level at the time of the survey was 6.2 mg/L. Conductivity was notably higher in the winter compared to the open-water period, indicating that groundwater likely constitutes a portion of the winter flow.

Based on the habitat available at Site 30, the seasonal habitat use potential was rated as follows:

- Sport fish: moderate for overwintering; low for nursery, rearing, feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: moderate for overwintering; low for nursery, rearing, feeding; nil for spawning.
- Forage fish: high for overwintering; high for nursery, rearing, feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Tables 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 41

Site 41 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were captured during winter sampling. During the spring, brook stickleback and white sucker were captured in low abundance. During the summer, brook stickleback, white sucker and lake chub were captured in low abundance. Brook stickleback was the only species present during the fall survey.

Site 30

Site 30 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were captured during the winter sampling. During the spring, white sucker, brook stickleback and lake chub were captured. Brook stickleback and lake chub were captured during summer sampling. In the fall, longnose sucker, brook stickleback and pearl dace were captured.

Table 5.4-8 Fish Species Captured at Sampling Sites in the Muskeg River Watershed

Watercourse	Sampling Site[a]	Season	Number of Fish by Species and Life Stage[b][c]													
			Sport Fish			Non–Sport Fish						Forage Fish			Unknown	Total
			NRPK			LNSC			WHSC			BRST	LKCH	PRDC		
			F[d]	J[d]	A[d]	F	J	A	F	J	A					
Muskeg River	41	spring	–	–	–	–	–	–	–	1	–	1	–	–	1	**3**
		summer	–	–	–	–	–	–	–	1	–	1	1	–	–	**3**
		fall	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	30	spring	–	–	–	–	–	–	–	1	–	29	19	–	–	**49**
		summer	–	–	–	–	–	–	–	–	–	1	4	–	–	**5**
		fall	–	–	–	1	3	–	–	–	–	9	–	2	–	**15**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*1*	*3*	*0*	*0*	*3*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**4**			**3**			**42**	**24**	**2**	**1**	**76**
Stanley Creek	40	spring	–	–	–	–	–	–	–	–	–	20	137	–	–	**157**
		summer	–	–	–	–	–	–	–	–	–	1	8	–	–	**9**
		fall	–	–	–	–	–	–	–	–	–	2	–	2	–	**4**
		winter	–	–	–	–	–	–	–	–	–	1	–	–	–	**1**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**24**	**145**	**2**	**0**	**171**
Wapasu Creek	32	spring	–	–	–	–	–	–	–	–	–	12	3	7	–	**22**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		fall	–	–	–	–	–	–	–	–	–	3	–	–	–	**3**
		winter	–	–	–	–	–	–	–	–	–	5	9	–	–	**14**
	26	spring	–	–	–	–	–	–	–	4	–	37	6	6	–	**53**
		summer	–	–	–	–	–	–	3	–	–	1	–	–	–	**4**
		fall	–	–	–	–	7	1	–	–	–	6	–	1	–	**15**
		winter	–	–	–	–	–	–	–	–	–	4	–	–	–	**4**

Table 5.4-8 Fish Species Captured at Sampling Sites in the Muskeg River Watershed (continued)

Watercourse	Sampling Site[a]	Season	Number of Fish by Species and Life Stage[b][c]													
			Sport Fish			Non–Sport Fish						Forage Fish			Unknown	Total
			NRPK			LNSC			WHSC			BRST	LKCH	PRDC		
			F[d]	J[d]	A[d]	F	J	A	F	J	A					
Wapasu Creek (continued)	38	spring	–	–	–	–	1	–	–	6	–	26	11	9	–	**53**
		summer	–	–	–	–	8	–	–	2	–	15	8	1	–	**34**
		fall	–	–	–	–	8	–	–	–	–	7	–	7	1	**23**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*24*	*1*	*3*	*12*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**25**			**15**			**116**	**37**	**31**	**1**	**225**
Unnamed Creek 9	35	spring	–	–	–	–	–	–	–	–	–	22	–	–	–	**22**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		fall	–	–	–	–	–	–	–	–	–	5	1	–	–	**6**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**27**	**1**	**0**	**0**	**28**
Unnamed Creek 12	24	spring	–	–	–	–	–	–	–	–	–	1	2	–	–	**3**
		summer	–	–	–	–	–	–	–	–	–	4	76	–	–	**80**
		fall	–	–	–	–	1	–	–	–	–	10	–	34	–	**45**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**1**			**0**			**15**	**78**	**34**	**0**	**128**
Unnamed Waterbody 1	29	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		summer	–	1	–	–	–	–	–	–	–	–	–	–	–	**1**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**1**			**0**			**0**			**0**	**0**	**0**	**0**	**1**

Table 5.4-8 Fish Species Captured at Sampling Sites in the Muskeg River Watershed (continued)

Watercourse	Sampling Site[a]	Season	Number of Fish by Species and Life Stage[b][c]												
			Sport Fish			Non–Sport Fish						Forage Fish			Unknown	Total
			NRPK			LNSC			WHSC			BRST	LKCH	PRDC		
			F[d]	J[d]	A[d]	F	J	A	F	J	A					
Unnamed Waterbody 2	27	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**0**	**0**	**0**	**0**	**0**
Unnamed Waterbody 16	39	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**0**	**0**	**0**	**0**	**0**
Unnamed Waterbody 17	25	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**0**	**0**	**0**	**0**	**0**

[a] See Figure 5.2-1 for sampling site locations.

[b] All sampling methods combined.

[c] Fish Species: NRPK = northern pike, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, LKCH = lake chub, PRDC = pearl dace.

[d] Life Stage: F = Fry, J = Juvenile, A = Adult.

n/a = Not applicable.

– = None.

Table 5.4-9 Catch-Per-Unit-Effort Results for Sampling Sites in the Muskeg River Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]	Non-Sport Fish		Forage Fish			Unknown
			NRPK	LNSC	WHSC	BRST	LKCH	PRDC	
Backpack Electrofishing [Number/ 100 s]									
Muskeg River	41	spring	0.00	0.00	0.13	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.18	0.00	0.18	0.00	0.00
		fall	0.00	0.00	0.00	0.13	0.00	0.00	0.00
	30	spring	0.00	0.00	0.00	1.13	0.28	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.55	0.00	0.00
		fall	0.00	0.31	0.00	0.83	0.00	0.10	0.00
Stanley Creek	40	fall	0.00	0.00	0.00	0.74	0.00	0.37	0.00
Wapasu Creek	26	spring	0.00	0.00	0.58	3.17	0.86	0.86	0.00
		summer	0.00	0.00	0.30	0.10	0.00	0.00	0.00
		fall	0.00	0.78	0.00	0.00	0.00	0.00	0.00
	38	spring	0.00	0.05	0.26	0.94	0.05	0.37	0.00
		summer	0.00	1.30	0.22	1.40	0.86	0.11	0.00
		fall	0.00	0.70	0.00	0.35	0.00	0.09	0.09
Unnamed Creek 9	35	spring	0.00	0.00	0.00	2.30	0.00	0.00	0.00
		fall	0.00	0.00	0.00	1.65	0.41	0.00	0.00
Unnamed Creek 12	24	summer	0.00	0.00	0.00	0.79	0.00	0.00	0.00
		fall	0.00	0.42	0.00	1.26	0.00	1.26	0.00
Unnamed Waterbody 1	29	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 2	27	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 16	39	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 17	25	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.4-9 Catch-Per-Unit-Effort Results for Sampling Sites in the Muskeg River Watershed (continued)

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]	Non-Sport Fish		Forage Fish			Unknown
			NRPK	LNSC	WHSC	BRST	LKCH	PRDC	
Minnow Trapping [Number/ Trap-hr]									
Muskeg River	41	spring	0.00	0.00	0.00	0.11	0.00	0.00	0.11
		summer	0.00	0.00	0.00	0.41	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30	spring	0.00	0.00	0.20	4.20	3.40	0.00	0.00
		summer	0.00	0.00	0.00	0.27	0.00	0.00	0.00
		fall	0.00	0.02	0.00	0.05	0.00	0.02	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stanley Creek	40	spring	0.00	0.00	0.00	5.80	39.71	0.00	0.00
		summer	0.00	0.00	0.00	0.40	3.20	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.25	0.00
		winter	0.00	0.00	0.00	0.48	0.00	0.00	0.00
Wapasu Creek	32	spring	0.00	0.00	0.00	4.90	1.22	2.86	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	1.05	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.12	0.22	0.00	0.00
	26	spring	0.00	0.00	0.00	2.78	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.03	0.00	0.09	0.00	0.02	0.00
		winter	0.00	0.00	0.00	2.33	0.00	0.00	0.00
	38	spring	0.00	0.00	0.22	1.74	2.17	0.43	0.00
		summer	0.00	0.00	0.00	0.55	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.07	0.00	0.14	0.00
Unnamed Creek 9	35	spring	0.00	0.00	0.00	5.65	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.29	0.00	0.00	0.00
Unnamed Creek 12	24	spring	0.00	0.00	0.00	0.55	1.09	0.00	0.00
		summer	0.00	0.00	0.00	0.66	25.05	0.00	0.00
		fall	0.00	0.00	0.00	1.24	0.00	5.49	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 1	29	summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.4-9 Catch-Per-Unit-Effort Results for Sampling Sites in the Muskeg River Watershed (continued)

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]	Non-Sport Fish		Forage Fish			Unknown
			NRPK	LNSC	WHSC	BRST	LKCH	PRDC	
Unnamed Waterbody 2	27	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 16	39	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 17	25	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gill Netting [Number/ Panel-hr]									
Unnamed Waterbody 1	29	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.11	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 2	27	fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 17	25	fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-1 for sampling site locations.

[b] Fish Species: NRPK = northern pike, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, LKCH = lake chub, PRDC = pearl dace.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Stanley Creek

Habitat Assessment

One site on Stanley Creek was surveyed (Site 40) (Figure 5.2-1) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat measurements are presented in Tables 5.4-6 and 5.4-7.

Site 40

The watercourse at Site 40 had a meandering and unconfined channel. The surveyed section of the watercourse was located within a muskeg bog and the banks were bordered by emergent aquatic vegetation, such as cattails and sedges, as well as grass/forbs and some shrubs. Beyond the banks was a black spruce/tamarack forest.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-3). Site 40 consisted of run habitat with an average depth of 0.7 m, a maximum depth of 0.9 m and an average channel width of 1.67 m. Substrate throughout the surveyed reach consisted of organics. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris and aquatic vegetation. Overhead cover was limited and consisted of overhanging grasses and undercut banks. Approximately 80% of the surveyed area was covered with aquatic vegetation.

Discharge was recorded in the open-water period only in the fall due to access limitations and was 0.04 m^3/s at the time of the survey. The pH and conductivity levels were suitable for use by all fish species throughout the open-water season. Dissolved oxygen levels were low in the summer (Table 5.4-6). Water temperature at Site 40 was continuously monitored from June 9, 2006 to August 6, 2006 (Appendix S, Figure S-7) using a thermograph. The water temperature fluctuated between 12.5 and 22.8°C throughout this time period. The peak water temperature (22.8°C) was recorded on June 28, 2006.

During the winter survey, discharge could not be measured at Stanley Creek at Site 40 since most of the channel was frozen to the bottom; however, one point measurement was attained. Under-ice water depth at the point measurement was 0.35 m (Table 5.4-7). The mean ice thickness was 0.45 m. The DO level at the time of the survey was 1.5 mg/L.

Based on the habitat available at Site 40, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Tables 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 40

Site 40 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. One brook stickleback was captured during winter sampling. Brook stickleback and lake chub were captured during the spring and summer. During the fall, brook stickleback and pearl dace were captured.

Wapasu Creek

Habitat Assessment

Three sites in Wapasu Creek were surveyed (Sites 32, 26 and 38) (Figure 5.2-1) to assess seasonal fish habitat use potential. The results for the open-water and winter seasonal habitat measurements are presented in Table 5.4-6 and Table 5.4-7.

Site 32

The watercourse at Site 32 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within muskeg bog and was bordered by grass/forbs, dense shrubs, mostly willows and black spruce forest.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-4). Site 32 consisted entirely of one unconfined run habitat. Substrate throughout the study area consisted of organics. Approximately 80% of the surveyed area contained aquatic macrophytes.

Discharge during the open-water period could not be measured due to access limitations. Seasonal water quality was suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.4-6). Water temperature at Site 32 was continuously monitored from June 8, 2006 to August 6, 2006 (Appendix S, Figure 5-8) using a thermograph. The water temperature fluctuated between 12.0 and 19.0°C throughout this time period. The peak water temperature (19.0°C) was recorded on July 23, 2006.

The winter discharge of Wapasu Creek at Site 32 at the time of the survey was 0 m^3/s (Table 5.4-7). The mean ice thickness was 0.50 m. The wetted width of the river at the site was 10.4 m. Under-ice water depths ranged from 0 to 0.80 m and averaged 0.53 m. The DO level at the time of the survey was 2.4 mg/L.

Based on the habitat available at Site 32, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring submergent vegetation.

Site 26

The watercourse at Site 26 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a burnt mixedwood forest. The watercourse was bordered by grass and forbs and shrubs consisting mostly of willow and alder.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-5). Site 26 consisted of riffle and run habitat having an average depth of 0.7 m, a maximum depth of 1.2 m and an average channel width of 6.17 m. Substrate throughout the surveyed reach consisted of clay/silt, sand, gravel, cobble and boulder. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by substrate, woody debris and depth/turbulence. Overhead cover was limited and consisted of overhanging grasses and undercut banks.

Discharge during the open-water period was recorded in the spring (0.35 m^3/s), summer (0.30 m^3/s) and fall (0.30 m^3/s). Seasonal water quality was suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.4-6).

During the winter, there was no measurable discharge on Wapasu Creek at Site 26 at the time of the survey (Table 5.4-7). The mean ice thickness was 0.35 m. The wetted width of the river at the site was 6.10 m. Under-ice water depths ranged from 0.35 to 0.75 m and averaged 0.60 m. Dissolved oxygen level at the time of the survey was 6.3 mg/L. Conductivity was higher in the winter compared to the open-water period, indicating that groundwater may constitute a higher portion of the winter flow.

Based on the habitat available at Site 26, the seasonal habitat use potential was rated as follows:

- Sport fish: high for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: high for overwintering; high for nursery, rearing and feeding; moderate for spawning.
- Forage fish: high for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 38

The watercourse at Site 38 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a burnt coniferous forest. The watercourse was bordered primarily by grass and forbs with some shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-6). Site 38 consisted primarily of run habitat, but a few riffles were present as well. The surveyed section had an average depth of 0.8 m, a maximum depth of 1.3 m and an average channel width of 5.04 m. Substrate throughout the surveyed reach consisted of clay/silt, sand, gravel, cobble and boulder. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by substrate, woody debris, aquatic vegetation and depth/turbulence. Overhead cover was limited and consisted of overhanging grasses and undercut banks. Approximately 20% of the surveyed area was covered with aquatic vegetation.

Discharge during the open-water period was recorded in the spring (0.33 m^3/s), summer (0.33 m^3/s) and fall (0.02 m^3/s). The DO, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.4-6). Water temperature at Site 38 was continuously monitored from June 7, 2006 to August 5, 2006 (Appendix S, Figure S-9) using a thermograph. The water temperature fluctuated between 12.7 and 22.4°C throughout this time period. The peak water temperature (22.4°C) was recorded on June 28, 2006.

The winter field survey determined that overwintering habitat within Site 38 on Wapasu Creek was limited. The site was frozen to the bottom at the time of sampling.

Based on the habitat available at Site 38, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 32

Site 32 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. Brook stickleback and lake chub were captured during winter sampling but no fish were observed during underwater videography. Brook stickleback, lake chub and pearl dace were captured during the spring. No fish were captured during the summer and only brook stickleback were captured in the fall.

Site 26

Site 26 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. Brook stickleback were captured during winter sampling. Brook stickleback, lake chub, pearl dace and four white sucker fry were captured during the spring. Three white sucker fry and one brook

stickleback were captured during the summer. In the fall, brook stickleback, pearl dace and longnose sucker were captured.

Site 38
Site 38 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field seasons. A winter fish assessment was not conducted as the watercourse was frozen to the bottom. Brook stickleback, lake chub, pearl dace, white sucker and longnose sucker were captured during the spring and summer. Brook stickleback, pearl dace and longnose sucker were captured from this location in the fall.

Kick net spawning surveys were conducted at this location. Twenty separate sampling events covering approximately 60 m^2 yielded no eggs.

Unnamed Creek 9

Habitat Assessment
Site 35
The watercourse at Site 35 had a straight and unconfined channel. The surveyed section of the watercourse was located within a muskeg bog and was bordered primarily by grasses and sedges surrounded by black spruce and willows.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-7). Site 35 consisted entirely of one shallow run habitat having an average water depth of 0.5 m and an average channel width of 1.38 m. Substrate throughout the surveyed reach consisted of organics. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris and aquatic vegetation. Overhead cover was limited and consisted of grasses and woody debris. About 86% of the surveyed area contained aquatic macrophytes.

Discharge could only be measured during the open-water period in the fall due to access limitations and was 0.01 m^3/s at the time of the survey (Table 5.4-6). The DO and conductivity levels were suitable to support all fish species throughout the open-water season (Table 5.4-6). Water temperature at Site 35 was continuously monitored from June 9, 2006 to August 6, 2006 (Appendix S, Figure S-10) using a thermograph. The water temperature fluctuated between 10.0 and 20.7°C throughout this time period. The peak water temperature (20.7°C) was recorded on July 6, 2006.

There was no overwintering habitat within Site 35 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 35, the seasonal habitat use potential for Unnamed Creek 9 was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Tables 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 35

Site 35 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field seasons. A winter fish assessment could not be completed because the watercourse at this location was frozen to the bottom. During the spring, brook stickleback was the only species present. No fish were captured in the summer. Brook stickleback and lake chub were captured during the fall survey.

Unnamed Creek 12

Habitat Assessment

Site 24

The watercourse at Site 24 had an unconfined, meandering channel. The surveyed section of the watercourse was located within muskeg bog and was bordered by a fen with aquatic vegetation such as cattails and sedges. The fen was surrounded by willows and black spruce.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix M, Figure M-8). Site 24 consisted of run and flat habitat having an average water depth of 0.6 m and an average channel width of 1.83 m. Substrate throughout the surveyed reach consisted of organics. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris and aquatic vegetation. Overhead cover was limited and consisted of overhanging grasses. Approximately 70% of the surveyed area contained aquatic macrophytes.

Discharge could not be measured during the open-water period due to access limitations. Seasonal water quality was suitable for use by all fish species throughout the open-water period (Table 5.4-6). Water temperature at Site 24 was continuously monitored from June 3, 2006 to August 4, 2006 (Appendix S, Figure S-11) using a thermograph. The water temperature fluctuated between 9.6 and 19.5°C throughout this time period. The peak water temperature (19.5°C) was recorded on July 22, 2006.

During the winter survey, discharge could not be measured due to construction activity (pumping water out of the watercourse). The mean ice thickness was 0.43 m (Table 5.4-7). Under-ice water depth averaged 0.78 m. Dissolved oxygen level at the time of the winter survey was 6.6 mg/L. Conductivity was higher in the winter compared to the open-water period, indicating that groundwater may constitute a higher portion of the winter flow.

Based on the habitat available at Site 24, the seasonal habitat use potential for Unnamed Creek 12 was rated as follows:

- Sport fish: high for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: high for overwintering; high for nursery, rearing and feeding; nil for spawning.
- Forage fish: high for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 24

Site 24 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were captured in the winter and no fish were observed during the underwater videography session. During the spring, brook stickleback and lake chub were the only species present, but in low abundance. Brook stickleback and lake chub were captured in the summer. Brook stickleback, pearl dace and a single juvenile longnose sucker were captured during the fall survey.

Waterbodies

Four unnamed waterbodies within the Muskeg River watershed were surveyed, they include Unnamed Waterbody 1 (Site 29), Unnamed Waterbody 2 (Site 27), Unnamed Waterbody 16 (Site 39) and Unnamed Waterbody 17 (Site 25) (Figure 5.2-1). The results for the open-water season and winter habitat measurements are presented in Tables 5.4-10 and 5.4-11.

Unnamed Waterbody 1

Habitat Assessment

Site 29

Unnamed Waterbody 1 (Site 29) had a perimeter of approximately 1.3 km and an approximate surface area of 0.05 km^2. Shallow littoral habitat dominated the south end of the waterbody and was present along the shoreline, but most of the waterbody consisted of deeper pelagial zone habitat (Appendix M, Figure M-9). Submerged and floating aquatic vegetation was present in the shallow zones. The average and maximum depths recorded throughout the open-water seasons are 10.6 and 26.1 m, respectively.

Water quality was suitable for use by all fish species and DO levels near the surface were suitable to support fish throughout the open-water season (Table 5.4-10). Water quality conditions were profiled at one location during the spring and four locations during the summer. The DO levels during the spring profile remained stable with depth. In the summer, DO declined markedly with depth. In one summer profile, DO was 10.94 mg/L at the surface, 2.64 mg/L at 5 m and 0.23 mg/L at 12.2 m.

Winter habitat conditions were measured at 11 locations dispersed throughout the waterbody. Depth profiles were recorded at two of the 11 locations. Water quality results at each of the sampling stations are presented in Table 5.4-11. Water depths below the ice at the 11 stations ranged from 1.00 to 9.40 m and averaged 4.66 m. Ice thickness was 0.50 m. Temperatures ranged from 0.3 to 4.0°C. The DO levels were variable throughout the waterbody at the time of the survey, ranging from 0.40 to 7.65 mg/L and averaging 3.05 mg/L. Levels were highest within 2 m of the surface, ranging from 3.75 to 7.65 mg/L and lowest near the substrate, ranging from 0.40 to 1.50 mg/L.

Table 5.4-10 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Muskeg River Watershed

Waterbody	Sampling Site[(a)]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 1	29	spring	point	1	10.80	0.50	14.1	9.54	240	8.04
			profile	2	17.90	0.50	14.5	9.36	240	8.00
						1.00	14.5	9.35	240	8.00
						1.50	14.5	9.33	240	7.99
						2.00	14.4	9.36	240	7.98
						2.50	14.2	9.32	240	7.97
						3.00	13.6	9.11	241	7.92
						3.50	10.1	9.21	246	7.68
						4.00	9.1	9.03	248	7.63
						4.50	7.9	8.45	250	7.58
						5.00	6.2	6.25	268	7.54
			point	3	7.00	0.50	14.6	7.96	240	9.41
			point	4	3.00	0.50	14.7	9.26	240	8.00
		summer	point	1	1.20	0.10	19.2	10.47	265	7.95
			profile	1	12.20	1.00	18.1	10.94	265	8.04
						2.00	18.0	10.66	264	8.00
						3.00	17.7	10.27	265	7.91
						4.00	11.9	8.30	272	7.57
						5.00	7.5	2.64	295	7.43
						6.00	6.1	1.84	298	7.33
						7.00	5.5	1.18	301	7.25
						8.00	4.7	0.30	328	7.17
						9.00	4.4	0.18	384	7.03
						10.00	4.4	0.19	411	7.10
						11.00	4.4	0.22	418	7.12
						12.00	4.4	0.23	422	7.14

Table 5.4-10 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Muskeg River Watershed (continued)

Waterbody	Sampling Site[(a)]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 1 (continued)	29 (continued)	summer (continued)	profile	2	6.00	1.00	19.2	10.99	263	7.92
			profile			2.00	19.2	10.91	267	7.90
			profile			3.00	19.1	10.86	267	7.89
			profile			4.00	18.9	10.75	257	7.82
			profile			5.00	13.0	12.43	265	7.63
			profile			6.00	12.0	9.13	287	7.35
			profile	3	3.30	1.00	19.0	9.11	258	7.79
			profile			2.00	19.1	10.00	256	7.88
			profile			3.00	19.1	10.05	256	7.85
			profile	4	2.90	1.00	19.1	10.53	270	7.92
			profile			2.00	19.1	10.70	270	7.92
		fall	point		26.10	1.00	6.4	8.28	254	7.70
Unnamed Waterbody 2	27	spring	point	1	0.74	0.50	16.1	10.37	232	8.65
			point	2	0.55	0.50	15.9	9.90	230	8.49
			profile	3	0.70	0.50	16.3	10.56	232	8.63
						0.60	16.3	10.24	233	8.64
			point	4	0.58	0.50	16.7	10.36	233	8.64
		summer	point	1	0.70	0.50	18.8	15.47	212	9.02
			point	1	1.00	0.10	17.5	14.08	211	8.89
			point	2	0.90	0.10	17.4	14.48	209	8.92
			point	3	0.80	0.10	17.5	13.90	212	8.85
			point	4	0.90	0.10	17.6	13.90	182	8.87
		fall	point	1	0.62	0.30	5.7	11.51	279	8.66
			point	2	0.30	0.30	5.3	11.31	281	8.67
			point	3	0.90	0.30	5.4	11.15	282	8.65

Table 5.4-10 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Muskeg River Watershed (continued)

Waterbody	Sampling Site[a]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 2	27 (continued)	fall (continued)	point	4	0.80	0.30	5.0	11.24	280	8.69
			point	5	0.72	0.30	5.3	11.30	280	8.68
			point	6	0.78	0.30	5.5	11.41	279	8.71
			point	7	0.78	0.30	5.4	11.30	279	8.71
			point	8	0.70	0.30	5.4	11.32	280	8.72
			point	9	0.82	0.30	5.4	11.25	280	8.69
			point	10	0.74	0.30	5.4	11.30	280	8.70
Unnamed Waterbody 16	39	spring	point	1	0.30	0.20	18.8	10.14	288	8.42
		summer	point	1	0.50	0.30	19.4	14.84	337	8.39
		fall	point	1	2.20	0.50	4.7	9.40	363	8.14
Unnamed Waterbody 17	25	spring	point	1	0.35	0.30	21.1	9.91	198	8.87
			point	2	0.30	0.30	21.1	7.92	220	8.31
		summer	point	1	0.50	0.30	19.7	10.82	282	7.19
		fall	point	1	–	–	5.3	11.94	250	8.71

[a] See Figure 5.2-1 for sampling site locations.

– = Not recorded or measured.

Table 5.4-11 Winter Habitat Conditions at Waterbody Sampling Sites in the Muskeg River Watershed

Waterbody	Sampling Site[(a)]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 1	29	1	profile	0.50	4.01	0.70	0.5	7.65	288	6.87
						1.00	0.6	6.86	296	6.84
						1.50	1.6	1.50	334	6.66
						2.00	2.4	0.96	366	6.59
						3.00	3.2	0.80	395	6.58
						4.00	3.4	0.73	420	6.54
						5.00	3.6	0.76	457	6.54
						6.00	3.8	0.67	573	6.72
						7.00	4.0	0.66	580	7.19
		1	point	0.50	1.90	1.50	0.9	4.09	359	7.99
		2	point	0.50	1.70	1.50	0.5	4.38	255	7.65
		3	point	0.50	1.00	1.00	0.7	4.37	263	7.63
		4	profile	0.50	6.50	1.00	0.3	4.36	276	7.58
						2.00	1.1	3.75	299	7.53
						3.00	2.7	0.40	359	7.17
						4.00	2.6	0.44	391	7.16
						5.00	3.6	0.61	402	7.13
		5	point	0.50	9.40	1.00	1.0	2.44	305	7.26
		6	point	0.50	5.10	1.00	0.9	5.25	273	7.67
		7	point	0.50	7.70	1.00	0.6	4.87	254	7.61
		8	point	0.50	–	1.00	0.8	4.82	253	7.61
		9	point	0.50	–	1.00	1.0	4.76	252	7.63
		10	point	0.50	–	1.00	0.5	4.93	253	7.63

Table 5.4-11 Winter Habitat Conditions at Waterbody Sampling Sites in the Muskeg River Watershed (continued)

Waterbody	Sampling Site[(a)]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 2	27	8	point	0.60	0.80	0.15	1.5	1.15	323	6.40
		10	point	0.55	0.85	0.15	1.1	1.14	322	6.58
		11	point	0.60	0.90	0.15	0.8	0.88	335	6.72
		35	point	0.50	0.80	0.30	0.2	1.85	323	10.12
		36	point	0.50	0.85	0.30	0.2	1.10	322	–
		38	point	0.50	0.85	0.30	0.1	1.50	330	10.95
		39	point	0.50	0.90	0.30	0.1	1.60	335	11.30
		42	point	0.50	0.85	0.30	0.2	1.50	341	11.27
		44	point	0.50	0.90	0.30	0.2	1.32	335	11.46
		46	point	0.50	0.90	0.30	0.1	0.95	331	12.00
		47	point	0.50	0.90	0.30	0.9	0.82	326	11.80
		49	point	0.50	0.90	0.30	1.1	0.73	329	11.54
		50	point	0.50	0.90	0.30	0.7	0.78	338	11.50
		51	point	0.50	0.90	0.30	0.2	0.65	306	12.45
Unnamed Waterbody 16	39	30	point	0.40	0.70	0.15	0.2	1.34	780	6.76
		31	point	0.40	0.80	0.20	0.1	1.16	783	6.80
		32	point	0.40	0.75	0.15	0.0	1.25	800	6.95
Unnamed Waterbody 17	25	12	point	0.50	0.70	0.15	0.0	1.10	661	6.55
		13	point	0.50	0.75	0.15	0.1	1.20	672	6.64
		21	point	0.50	0.70	0.15	0.4	1.37	672	6.66

[(a)] See Figure 5.2-1 for sampling site locations.

– = Not measured.

Based on the habitat available at Site 29, the seasonal habitat use potential was rated as follows:

- Sport fish: low to moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low to moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Tables 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 29

Site 29 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were captured during winter, spring and fall. One juvenile northern pike was captured during the summer. No fish were observed during the winter underwater videography session.

Unnamed Waterbody 2

Habitat Assessment

Site 27

Unnamed Waterbody 2 (Site 27) had a perimeter of approximately 1.2 km and an approximate surface area of 0.08 km^2. The waterbody was dominated by shallow littoral habitat with little emergent vegetation (Appendix M, Figure M-10). The average and maximum depths recorded throughout the open-water seasons are 0.76 and 1.0 m, respectively. The substrate consisted of organics and silt.

During the open-water period, water quality was suitable for use by all fish species (Table 5.4-10). Water quality conditions were profiled at one location during the spring.

Winter habitat conditions were measured at 14 locations dispersed throughout the waterbody. Water quality results at each of the sampling stations are presented in Table 5.4-11. Water depths below the ice at the 14 stations ranged from 0.30 to 1.50 m and averaged 0.87 m. Ice thickness ranged from 0.50 to 0.60 m. Temperatures ranged from 0.1 to 1.5°C. The DO levels were low throughout the

waterbody at the time of the survey, ranging from 0.65 to 1.85 mg/L and averaging 1.14 mg/L.

Based on the habitat available at Site 27, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Tables 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 27

Site 27 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field seasons. A winter fish assessment was not be completed because of unsuitable winter DO levels. No fish were captured during spring, summer and fall sampling.

Unnamed Waterbody 16

Habitat Assessment

One waterbody (Unnamed Waterbody 16) on an unnamed tributary to Muskeg Creek was surveyed (Site 39) to assess winter fish habitat use potential. The results for the open-water seasonal and winter habitat measurements are presented in Tables 5.4-10 and 5.4-11.

Site 39

Unnamed Waterbody 16 (Site 39) had a perimeter of approximately 0.8 km and with an approximate surface area of 0.05 km^2. Shallow littoral habitat was present throughout the waterbody (Appendix M, Figure M-11). The average and maximum depths recorded throughout the open-water seasons were 1.0 and 2.2 m, respectively.

Spring and fall water quality was suitable for use by all fish species, but temperatures approached 20°C during the summer. Dissolved oxygen levels were suitable to support fish throughout the open-water season (Table 5.4-10).

Winter habitat conditions were measured at three locations dispersed throughout the waterbody. Water quality results at each of the sampling station are presented in Table 5.4-11. Water depths below the ice at the three stations ranged from 0.70 to 0.80 m and averaged 0.75 m. Ice thickness was 0.40 m. Temperatures ranged from 0.0 to 0.2°C. Dissolved oxygen levels were low throughout the waterbody at the time of the survey, ranging from 1.16 to 1.34 mg/L and averaging 1.25 mg/L.

Based on the habitat available at Site 39, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 39

Site 39 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were captured during any of these surveys. No fish were observed during the winter underwater videography session.

Unnamed Waterbody 17

Habitat Assessment

Site 25

Unnamed Waterbody 17 (Site 25) has a perimeter of approximately 0.8 km and an approximate surface area of 0.04 km^2. The waterbody was dominated by shallow littoral habitat with patches of emergent vegetation (Appendix M, Figure M-12). Submergent vegetation was present throughout the lake. The

average and maximum depths recorded throughout the open-water seasons are 0.38 and 0.5 m, respectively. The substrate consisted of organics and silt.

Water temperatures approached 20°C during the spring and summer. Dissolved oxygen levels were suitable to support fish throughout the open-water season (Table 5.4-10). The waterbody was too shallow to conduct a water quality profile.

Winter habitat conditions were measured at three locations dispersed throughout the waterbody. Water quality results at each of the sampling stations are presented in Table 5.4-11. Water depths below the ice at the three locations ranged from 0.70 to 0.75 m and averaged 0.72 m. Ice thickness was 0.50 m. Temperatures ranged from 0.0 to 0.4°C. Dissolved oxygen levels were low throughout the waterbody at the time of the survey, ranging from 1.10 to 1.37 mg/L, averaging 1.22 mg/L.

Based on the habitat available at Site 25, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low to moderate for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.4-8, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.4-9.

Site 25

Site 25 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field seasons. No fish were observed during the winter underwater videography. No fish were captured during the spring, summer and fall.

5.4.2 Diversity of Fish and Fish Habitat

The following sections provide the results of the assessment of fish and fish habitat diversity in the JEMA LSA. The assessment was based on selected indicators of fish species diversity, habitat diversity and ecosystem diversity.

5.4.2.1 Fish Species Diversity

The results of the fish species diversity assessment for the watercourses and waterbodies potentially affected by the Project in the JEMA LSA are presented in Table 5.4-12 for the three species diversity indicators: species richness, species overlap and listed species. A numerical rank (from 1 to 4) was determined for each of these three indicators and a general rank for each watercourse or waterbody was assigned based on the value obtained by multiplying the three individual ranks.

Fish species diversity was ranked as high for the Muskeg River mainstem and the remaining sampled watercourses and waterbodies within the JEMA LSA were ranked as very low. Species richness was ranked as high for the Muskeg River mainstem and very low for the remaining watercourses and waterbodies. There were 17 unique species identified in the Muskeg River, however, no unique species were identified in the remaining watercourses and waterbodies. Within the Muskeg River, three species were identified as sensitive (Arctic grayling, bull trout and northern redbelly dace), and one species may be at risk (spoonhead sculpin). The remaining watercourses and waterbodies did not have listed species (Table 5.4-12).

5.4.2.2 Fish Habitat Diversity

The results of the habitat diversity assessment for the watercourses and waterbodies potentially affected by the Project in the JEMA LSA are presented in Table 5.4-13. Results are presented for the assessment of the selected fish habitat diversity indicators. A numerical rank (from 1 to 4) was determined for each of these indicators and used to calculate an average rank for each watercourse or waterbody.

Table 5.4-12 Ranking of Watercourses and Waterbodies in the Jackpine Expansion Mining Area According to Indicators of Fish Species Diversity

Watercourse or Waterbody	Fish Species Richness		Fish Species Overlap		General Status of Fish Species[a]		Fish Species Diversity Ranking
	Number of Species and % of Potential Species	Ranking	Number of Unique Species and % of Overlapping Species	Ranking	Status Rating	Ranking (Highest Risk Status)	
Muskeg River	24 of 26 potential species - 92%	4	17 unique species, 35% overlap	3	3 sensitive[b]; 1 may be at risk[c]	3	4 – high (score =36)
Stanley Creek	3 of 26 potential species - 12%	1	no unique species, 100% overlap	1	none	1	1 - very low (score =1)
Wapasu Creek	6 of 26 potential species - 23%	1	no unique species, 100% overlap	1	none	1	1 - very low (score =1)
Unnamed Creek 9	2 of 26 potential species - 8%	1	no unique species, 100% overlap	1	none	1	1 - very low (score =1)
Unnamed Creek 12	4 of 26 potential species - 15%	1	no unique species, 100% overlap	1	none	1	1 - very low (score =1)
Unnamed Waterbody 1	1 of 26 potential species - 4%	1	no unique species, 100% overlap	1	none	1	1 - very low (score =1)
Unnamed Waterbody 2	0 of 26 potential species - 0%	1	no unique species, 100% overlap	1	no fish detected	1	1 - very low (score =1)
Unnamed Waterbody 16	0 of 26 potential species - 0%	1	no unique species, 100% overlap	1	no fish detected	1	1 - very low (score =1)
Unnamed Waterbody 17	0 of 26 potential species - 0%	1	no unique species, 100% overlap	1	no fish detected	1	1 - very low (score =1)

[a] From: The General Status of Alberta Wild Species 2000 (AENV 2000).

[b] Arctic grayling, bull trout, northern redbelly dace.

[c] Spoonhead sculpin.

Table 5.4-13 Ranking of Watercourses and Waterbodies in the Jackpine Expansion Mining Area According to Indicators of Fish Habitat Diversity

Watercourse or Waterbody	Watercourse Habitat Unit Diversity Index		Stream Order at Mouth		Waterbody Habitat Diversity Index		Waterbody Size			Fish Habitat Diversity Ranking
	Habitat Unit Diversity	Ranking	Stream Order	Ranking	Habitat Diversity	Ranking	Area [km^2]	Maximum Depth [m]	Ranking	
Muskeg River	0.58	3-moderate	4th	4-high	n/a	n/a	n/a	n/a	n/a	4–high (score =12)
Stanley Creek	0.54	3-moderate	2nd	2-low	n/a	n/a	n/a	n/a	n/a	3–moderate (score =6)
Wapasu Creek	1.36	3-moderate	3rd	3-moderate	n/a	n/a	n/a	n/a	n/a	3–moderate (score =9)
Unnamed Creek 9	0.06	1-very low	1st	1-very low	n/a	n/a	n/a	n/a	n/a	1-very low (score =1)
Unnamed Creek 12	0.59	3-moderate	2nd	2-low	n/a	n/a	n/a	n/a	n/a	3–moderate (score =6)
Unnamed Waterbody 1	n/a	n/a	n/a	n/a	0.02	1-very low	0.05	26.1	2-low	1-very low (score =2)
Unnamed Waterbody 2	n/a	n/a	n/a	n/a	0	1-very low	0.08	1	1-very low	1-very low (score =2)
Unnamed Waterbody 16	n/a	n/a	n/a	n/a	0.01	1-very low	0.05	2.2	2-low	1-very low (score =2)
Unnamed Waterbody 17	n/a	n/a	n/a	n/a	0.01	1-very low	0.04	0.9	1-very low	1-very low (score =2)

n/a = Not applicable.

Overall, habitat diversity was ranked as high for the Muskeg River, due to a moderate habitat unit diversity ranking and a high stream order at the mouth. Wapasu Creek, Stanley Creek and Unnamed Creek 12 were ranked as having moderate habitat diversity. The remaining watercourses and all the waterbodies had a very low habitat diversity ranking.

5.4.2.3 Ecosystem-Level Indicators of Diversity

Ecosystem diversity was assessed for each of the selected watercourses and waterbodies based on the ratio of predator species to prey species. Table 5.4-14 presents the number of predator (piscivorous) species and prey (forage fish) species in each of the watercourses and waterbodies and the ecosystem diversity ranking.

The ecosystem diversity in the Muskeg River was rated as high, due to a high number of predator species, as well as prey species. Predator species in the Muskeg River include bull trout, burbot, northern pike and walleye. The remaining watercourses and waterbodies lack either a predator species or a prey species and were consequently rated as having very low ecosystem diversity.

Table 5.4-14 Ranking of Watercourses and Waterbodies in the Jackpine Expansion Mining Area for Predator to Prey Species Ratio

Watercourse or Waterbody	Predator to Prey/Forage Guild Ratio	
	Number of Predator/Prey Species	Ranking
Muskeg River	4 predator/20 prey	4–high
Stanley Creek	0 predator/3 prey	1–very low
Wapasu Creek	0 predator/6 prey	1–very low
Unnamed Creek 9	0 predator/2 prey	1–very low
Unnamed Creek 12	0 predator/4 prey	1–very low
Unnamed Waterbody 1	1 predator/0 prey	1–very low
Unnamed Waterbody 2	0 predator/0 prey	1–very low
Unnamed Waterbody 16	0 predator/0 prey	1–very low
Unnamed Waterbody 17	0 predator/0 prey	1–very low

5.4.2.4 Fish and Fish Habitat Diversity Summary

The overall fish and fish habitat diversity of each of the selected watercourses and waterbodies was assessed by combining the general rankings for species, habitat and ecosystem-level diversity indicators (Table 5.4-15). The contribution of each watercourse or waterbody to fish and fish habitat diversity in the study areas was categorized as very low, low, moderate or high based on the ranking

they received in the evaluation of each of the species, habitat and ecosystem indicators.

Based on the ranking system used for this assessment, the Muskeg River provides significant contribution to fish and fish habitat diversity in the JEMA LSA. The Muskeg River was ranked as high for all diversity indicators and consequently received a high overall fish and fish habitat diversity ranking. Wapasu Creek, Stanley Creek and Unnamed Creek 12 provide the next highest contribution to fish and fish habitat diversity, however, the overall fish and fish habitat diversity of each of these watercourses were ranked as low. Habitat diversity was ranked as moderate for Wapasu Creek, Stanley Creek and Unnamed Creek 12, but species diversity and ecosystem diversity for all three watercourses was ranked as very low. The overall diversity of fish and fish habitat for Unnamed Creek 9 and all waterbodies was ranked as very low, as they all received very low rankings for all diversity indicators.

Table 5.4-15 Summary of Fish and Fish Habitat Diversity Rankings for Watercourses and Waterbodies in the Jackpine Expansion Mining Area

Watercourse or Waterbody	Ranking			
	Species Diversity	Habitat Diversity	Ecosystem Diversity	Overall Diversity
Muskeg River	high	high	high	high
Wapasu Creek	very low	moderate	very low	low
Stanley Creek	very low	moderate	very low	low
Unnamed Creek 9	very low	very low	very low	very low
Unnamed Creek 12	very low	moderate	very low	low
Unnamed Waterbody 1	very low	very low	very low	very low
Unnamed Waterbody 2	very low	very low	very low	very low
Unnamed Waterbody 16	very low	very low	very low	very low
Unnamed Waterbody 17	very low	very low	very low	very low

5.4.3 Benthic Invertebrates

This section provides a summary of the benthic invertebrate community data for the watercourses and waterbodies within the JEMA LSA. Included are the results of the literature review and environmental setting field surveys conducted in 2005 and 2006.

5.4.3.1 Literature Review

Historical and recent benthic invertebrate community data are available for the following watercourses and waterbodies in the Muskeg River watershed:

- Muskeg River mainstem;
- five named tributaries to the Muskeg River:
  - Jackpine Creek (including East Jackpine Creek);
  - Shelley Creek;
  - Stanley Creek;
  - Wapasu Creek;
  - Muskeg Creek, including:
    - Khahago Creek;
    - Green Stockings Creek;
    - Blackfly Creek;
    - Wesukemina Creek;
    - Kearl Lake;
    - Iyinimin Creek (Kearl Lake inlet stream); and
- several unnamed tributaries and small lakes in the Muskeg River watershed.

Muskeg River

The benthic invertebrate community of the Muskeg River is one of the most studied in the Oil Sands Region. The literature for Muskeg River benthic invertebrate communities includes reports from development companies, consultants (Beak 1986; Golder 1996b; Golder 2002e; Imperial Oil 2005; Komex 1997; RL&L 1989b; Suncor 1996), government agencies (Crowther and Lade 1981) and multi-stakeholder groups (Golder 1999b; Golder 2001c; Golder 2002e; RAMP 2007). Benthic invertebrate data are available for the period extending from 1979 to 2005. A detailed description of benthic invertebrate data collected in the Muskeg River from 1979 to 2001 was provided by Golder (2003c). In terms of habitat characteristics relevant to benthic invertebrates, there are two distinct reaches in the Muskeg River: (1) the lower 15 km of erosional habitat and (2) the middle and upper reaches of the river consisting almost entirely of depositional habitat. Erosional and depositional benthic communities are described separately below.

At erosional sites sampled in the lower section of the Muskeg River, mean benthic invertebrate densities were typically low to moderate, ranging from 1,259 to 21,230 organisms/m² (Table 5.4-16). Total richness was usually high, ranging from 30 to 71 taxa/site. The benthic community was often dominated by midges and bristle worms, but other dipterans and mayflies were also occasionally dominant. There were no obvious upstream-downstream or temporal trends in community characteristics in this reach.

Considerably more data are available for depositional sites in the mid to upper reaches of the Muskeg River. Benthic invertebrate density was higher and more variable in these reaches compared to erosional habitats, ranging from 1,952 to 62,247 organisms/m² (Table 5.4-16). Total richness was in most cases lower than in erosional habitat, with a range of 11 to 67 taxa/site. Depositional communities were more strongly dominated by midges than erosional communities. Other dominant taxa in depositional habitat included bristle worms and occasionally fingernail clams and seed shrimp.

There was a weak spatial trend of decreasing density in the upstream direction, likely reflecting a gradual change in habitat conditions along the river (Table 5.4-16). Richness did not appear to change along the river, with the possible exception of highest richness at the farthest downstream depositional site (MUR-D), which was only apparent in 2001 and 2002 (total richness data are not available for other years for this site). Temporal trends were generally absent at the two RAMP sites with multiple years of data (MUR-D/MUR-D-2 and MUR-D-3), with the possible exception of declining total density and increasing density of bristle worms over time at site MUR-D/MUR-D-2.

Table 5.4-16 Historical Benthic Invertebrate Community Data for the Muskeg River

Erosional Habitat

Variable	Muskeg River													
	10a[a]	10b[a]	10c[a]	10[a]								11[a]	12[a]	15[a]
	MUR1[b]	MUR2[b]	MUR3[b]	30[b]	MUR-E[b]							1[b]	2[b]	3[b]
study	Golder (1999c)	Golder (1999c)	Golder (1999c)	Golder (1996b)	Golder (2001c)	Golder (2002a)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	Crowther and Lade (1981)	Crowther and Lade (1981)	Crowther and Lade (1981)
date	September 21, 1998	September 21, 1998	September 21,1998	September 30, 1995	October 6, 2000	September 13, 2001	September 2002	September 2003	September 2004	September 2005	September 2006	September 15, 1979	September 15, 1979	August 16, 1979
habitat	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional	erosional
Density														
mean density [numbers/m²]	12,637	21,230	16,434	1,259	10,662	4,920	7,754	11,343	18,757	2,849	11,131	8,965	7,495	6,472
SE mean density [numbers/m²]	3,501	1,128	2,152	117	889	775	–	–	–	–	–	–	–	–
Richness														
total richness [no. taxa/site]	53	53	53	30	71	65	–	–	–	–	–	41	45	38
mean richness [no. taxa/site]	37.0	42.4	41.8	20.0	29.5	26.7	39.0	32.0	31.0	32.0	30.0	–	–	–
SE mean richness [no.taxa/site]	1.9	1.3	1.9	0.6	1.5	1.4	–	–	–	–	–	–	–	–
Relative Density [%]														
Oligochaeta	17	9	5	42	2	7	15	4	17	7	4	<1	2	<1
Chironomidae	39	28	34	9	30	25	37	58	37	20	31	51	11	12
Ostracoda	5	3	<1	1	1	<1	3	<1	0	0	<1	0	0	0
Gastropoda	1	5	2	0	<1	<1	<1	<1	0	0	0	<1	<1	<1
Pelecypoda	2	7	8	<1	1	3	5	1	3	2	0	1	5	4
other Diptera	4	5	5	5	1	2	3	3	6	22	2	2	1	18
Amphipoda	0	0	0	0	<1	0	<1	<1	0	0	0	0	<1	40
Ephemeroptera	16	13	12	11	50	24	5	5	9	21	24	7	12	3
other (includes Trichoptera and Plecoptera)	16	30	33	30	15	39	29	27	29	28	36	38	68	23

Depositional Habitat

Variable	Muskeg River														
	12[a]							–					13[a]	14[a]	
	MUR-D[b]		MUR-D-2[b]					MUR-D-3[b]					18[b]	5[b]	
study	Golder (2001c)	Golder (2002d)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RL&L (1989b)	Golder (1996b)	Beak (1986)	RL&L (1989b)
date	October 6, 2000	September 20, 2001	September 2002	September 2003	September 2004	September 2005	September 2006	September 2002	September 2003	September 2004	September 2005	September 2006	October 17, 1988	September 30, 1995	October 15, 1985	October 17, 1988
habitat	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional
Density																
mean density [numbers/m²]	58,434	62,247	34,672	12,635	10,440	11,948	26,888	9,905	13,566	7,190	15,887	6,039	2,026	17,452	32,917	3,046
SE mean density [numbers/m²]	11,445	11,035	–	–	–	–	–	–	–	–	–	–	762	9,482	13,374	1,728
Richness																
total richness [no. taxa/site]	65	67	–	–	–	–	–	–	–	–	–	–	17	32	32	20
mean richness [no. taxa/site]	24.3	26.1	21	14	10	17	24	12	17	9	11	15	8.7	17.0	22.0	10.0
SE mean richness [no.taxa/site]	1.4	1.5	–	–	–	–	–	–	–	–	–	–	2.7	5.6	3.5	2.1
Relative Density [%]																
Oligochaeta	11	5	5	7	12	24	32	0	3	18	4	18	27	15	3	10
Chironomidae	73	82	69	81	74	44	55	66	65	27	79	54	45	59	89	12
Ostracoda	1	2	5	0	<1	10	<1	4	1	7	1	0	0	2	0	0
Gastropoda	1	3	1	<1	0	<1	1	<1	1	2	<1	<1	0	<1	0	2
Pelecypoda	7	1	3	1	1	<1	0	28	17	18	8	0	20	2	0	3
other Diptera	3	2	2	3	8	5	3	0	2	2	1	1	5	8	1	23
Amphipoda	0	<1	<1	1	<1	<1	<1	<1	1	5	<1	1	0	<1	1	0
Ephemeroptera	<1	1	2	1	<1	6	1	0	5	5	2	3	1	<1	6	5
other (includes Trichoptera and Plecoptera)	4	4	8	4	4	8	3	1	5	10	5	7	2	13	<1	45

Table 5.4-16 Historical Benthic Invertebrate Community Data for the Muskeg River (continued)

Depositional Habitat (Continued)

Variable	Muskeg River															
	206[a]	15[a]		16[a]		17[a]	204[a]	18[a]		19[a]		182[a]	21[a]	-	183[a]	-
	MUR-4[b]	4[b]		3[b]		35[b]	MUR-USC[b]	2[b]		1[b]		5[b]	4 (Lower)[b]	MR-1[b]	3 (Upper)[b]	MR-2[b]
study	Golder (2002e)	Beak (1986)	RL&L (1989b)	Beak (1986)	RL&L (1989b)	Golder (1996b)	Golder (2002e)	Beak (1986)	RL&L(1989b)	Beak (1986)	RL&L(1989b)	Komex (1997)	Komex (1997)	Imperial Oil (2005)	Komex (1997)	Imperial Oil (2005)
date	September 30, 2001	October 15, 1985	October 17, 1988	October 15, 1985	October 17, 1988	September 30, 1995	September 30, 2001	October 15, 1985	October 17, 1988	October 15, 1985	October 17, 1988	August 7, 1997	August 7, 1997	October 2, 2003	August 7, 1997	October 5, 2003
habitat	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional	depositional
Density																
mean density [numbers/m²]	8,621	30,460	10,000	41,624	5,345	5,038	15,586	15,675	16,034	38,003	18,721	11,629	11,534	5,745	6,345	1,952
SE mean density [numbers/m²]	3,746	8,365	3,143	11,674	2,200	–	8,864	1,126	4,656	8,200	7,905	2,322	1,388	2,253	1,712	231
Richness																
total richness [no. taxa/site]	31	41	27	31	18	11	40	22	14	31	21	19	20	33	20	12
mean richness [no. taxa/site]	12.4	24.3	18.0	21.7	10.0	–	19.4	14.7	9.7	24.0	14.0	9.8	12.0	13.8	11.0	6.4
SE mean richness [no.taxa/site]	2.4	3.2	0.6	2.3	2.1	–	2.9	0.3	0.7	2.3	2.5	1.0	0.5	2.9	0.8	0.5
Relative Density [%]																
Oligochaeta	4	2	14	5	11	19	3	15	2	35	4	2	14	0	2	0
Chironomidae	32	93	58	93	66	74	65	73	65	51	67	82	69	85	48	93
Ostracoda	20	<1	1	0	0	2	9	0	2	1	2	0	<1	0	3	0
Gastropoda	8	<1	<1	0	1	2	2	<1	<1	<1	<1	<1	<1	<1	3	0
Pelecypoda	16	<1	3	<1	11	2	9	2	30	7	11	1	1	1	<1	<1
other Diptera	4	2	16	1	3	1	2	0	<1	<1	4	4	2	4	12	6
Amphipoda	1	<1	4	<1	1	0	1	<1	0	0	2	0	0	<1	0	0
Ephemeroptera	1	2	1	<1	5	0	6	<1	<1	3	9	0	<1	8	6	0
other (includes Trichoptera and Plecoptera)	15	1	4	<1	1	2	4	8	1	2	<1	11	13	2	26	1

[a] Golder (2003c) site number.

[b] Original site identifier.

– = No data/not applicable; SE = standard error of the mean.

Notes: Sites are ordered downstream to upstream.

Some numbers are rounded for presentation purposes. Therefore it may appear that percentages do not add up to 100.

Crowther and Lade (1981) - means are based on data from one replicate only, also Chironomidae are only identified to subfamily/tribe level thus richness values are underestimates.

Komex (1997) - Chironomidae are only identified to subfamily/tribe level; thus richness values are underestimates.

Golder (1996b) - Site 17 had only one replicate collected so data are based on only one replicate.

RL&L (1989b) - Site 15 and 16 percent composition calculations based on only two replicates since one replicate sample for each of these sites had no organisms present.

RAMP (2007) data are from data tables in text since no raw data are provided in the report.

Data for RAMP (2007) for the Muskeg River (MUR) stream reaches are based on two replicates instead of the usual 10 replicates per reach for the RAMP program due to high flows in the Muskeg River during the 2006 sampling period.

A benthic invertebrate taxon list for the Muskeg River watershed, compiled from previous reports and the 2005 to 2006 environmental setting field surveys, is provided in Appendix U, Table U-3.

Tributaries of the Muskeg River

Jackpine Creek

The historical literature for the benthic invertebrate community of Jackpine Creek consists of reports from development companies and consultants (Golder 1996b; Golder 2002a; O'Neil et al. 1982; RL&L 1989b) and multi-stakeholder groups (RAMP 2007). Data were collected between 1981 and 2006.

Jackpine Creek is mostly depositional, with short reaches of erosional habitat mostly in its lower reaches. The benthic invertebrate community of Jackpine Creek was usually dominated by the midges (Table 5.4-17). Bristle worms, other dipterans and mayflies occasionally accounted for a significant proportion of the benthic community. Mean benthic invertebrate density was highly variable ranging from 1,216 to 104,103 organisms/m², with just over half (55%) of the sites having mean densities below 5,000 organisms/m². There was a wide overlap in density ranges between erosional and depositional habitats. Total benthic invertebrate richness ranged from 15 to 53 taxa/site and mean richness ranged from 7.0 to 30.2 taxa/site. Erosional sites tended to have higher richness values than depositional sites.

Table 5.4-17 Historical Benthic Invertebrate Community Data for Jackpine Creek

Variable	Jackpine Creek																	
	–					34[a]			36[a]		38[a]		39[a]	–				40[a]
	JAC-D-1[b]					17[b]		JAC-1[b]	L4[b]	JAC-2[b]	L5[b]	S4[b]	16[b]	JAC-D-2[b]				L6[b]
study	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RL&L (1989b)	Golder (1996b)	Golder (2002a)	O'Neil et al. (1982)	Golder (2002a)	O'Neil et al. (1982)	Golder (1996b)	RL&L (1989b)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	O'Neil et al. (1982)
date	September, 2002	September, 2003	September, 2004	September, 2005	September, 2006	October 17, 1988	September 30, 1995	September 12, 2001	September 29, 1981	September 23, 2001	September 29, 1981	September 30, 1995	October 17, 1988	September 1, 2003	September 1, 2004	September 1, 2005	September 1, 2006	September 29, 1981
habitat	depositional	depositional	depositional	depositional	depositional	depositional	erosional	depositional	erosional	depositional	depositional	erosional	depositional	depositional	depositional	depositional	depositional	depositional
Density																		
mean density [numbers/m²]	28,172	4,017	9,230	7,417	9,331	4,080	2,684	1,216	26,227	2,394	91,276	1,919	13,621	4,787	3,448	2,957	5,012	104,103
SE mean density [numbers/m²]	–	–	–	–	–	1,873	269	990	4,567	728	7,821	749	2,580	–	–	–	–	18,687
Richness																		
total richness [no. taxa/site]	–	–	–	–	–	20	37	25	34	53	24	32	23	–	–	–	–	15
mean richness [no. taxa/site]	15.0	11.0	15.0	7.0	12.0	11.3	22.7	7.4	25.3	30.2	13.4	19.0	17.0	12.0	10.0	12.0	16.0	9.0
se mean richness [no.taxa/site]	–	–	–	–	–	1.2	1.3	3.7	0.9	1.7	0.7	5.2	2.3	–	–	–	–	0.7
Mean Relative Density [%]																		
Oligochaeta	0	4	1	5	0	10	5	28	6	4	4	8	<1	3	6	2	4	1
Chironomidae	88	66	69	69	86	65	50	40	73	20	83	36	87	67	3	44	63	92
Ostracoda	<1	0	2	4	0	1	<1	0	0	0	0	2	<1	<1	1	3	1	0
Gastropoda	<1	0	<1	0	0	<1	<1	0	<1	<1	0	<1	<1	0	0	<1	<1	0
Pelecypoda	1	3	<1	<1	<1	7	2	6	<1	<1	1	0	4	<1	<1	<1	<1	<1
other Diptera	2	6	7	5	8	5	11	18	1	3	3	5	4	4	46	11	7	2
Amphipoda	0	<1	<1	0	0	3	0	0	0	0	<1	0	<1	0	0	0	0	<1
Ephemeroptera	<1	0	2	1	1	8	11	2	7	27	1	17	1	<1	2	1	6	3
other (includes Trichoptera and Plecoptera)	6	8	16	16	5	2	21	6	13	46	7	32	3	12	10	36	7	2

(a) Golder (2003c) site number.

(b) Original site identifier.

– = No data/not applicable; SE = standard error of the mean.

Notes: Sites are ordered downstream to upstream.

Some numbers are rounded for presentation purposes. Therefore it may appear that percentages do not add up to 100.

RL&L (1989b) - Site 34 percent composition calculations were based on only two samples because one sample from each of these sites had no organisms present.

RAMP (2007) data are from data tables in text since no raw data are provided in the report.

East Jackpine Creek

The historical literature for the benthic invertebrate community of East Jackpine Creek consists of one report (RL&L 1989b), including data collected in 1988.

The benthic invertebrate community at a depositional site in East Jackpine Creek was dominated by the midges, which accounted for 91% of total density (Table 5.4-18). Mean benthic invertebrate density was 19,784 organisms/m². Total benthic invertebrate richness was 19 taxa/site and mean richness was 11.3 taxa/site. Both density and richness were in the low to moderate range compared to benthic communities in other watercourses in the Oil Sands Region.

Shelley Creek

The historical literature for the benthic invertebrate community of Shelley Creek consists of one report (Golder 2002a), including data collected at one site in September 2001.

The benthic invertebrate community at the site sampled in Shelly Creek was dominated by the midges (Table 5.4-18). Seed shrimp and fingernail clams were also abundant at this site. Mean benthic invertebrate density was 23,328 organisms/m². Total benthic invertebrate richness was 25 taxa/site and mean richness was 12.8 taxa/site. Both density and richness were in the low to moderate range compared to benthic communities in other watercourses in the Oil Sands Region.

Stanley Creek

The historical literature for the benthic invertebrate community of Stanley Creek consists of one report (Golder 2002b), including data collected at one site in October 2001.

The benthic invertebrate community at the site sampled in Stanley Creek was dominated by the midges (Table 5.4-18). Bristle worms, seed shrimp and other dipterans were also abundant at this site. Mean benthic invertebrate density was 6,259 organisms/m². Total benthic invertebrate richness was 17 taxa/site and mean richness was 10.2 taxa/site. Both density and richness were in the low range compared to benthic communities in other watercourses in the Oil Sands Region.

Table 5.4-18 Historical Benthic Invertebrate Community Data for East Jackpine Creek, Shelley Creek, Stanley Creek and Wapasu Creek

Variable	East Jackpine Creek	Shelley Creek	Stanley Creek	Wapasu Creek				
	41[a]	55[a]	205[a]	52[a]	180[a]	53[a]	181[a]	54[a]
	15[b]	SHC-1[b]	STC-HS[b]	7[b]	1 (Lower)[b]	6[b]	2 (Upper)[b]	19[b]
study	RL&L (1989b)	Golder (2002a)	Golder (2002e)	Beak (1986)	Komex (1997)	Beak (1986)	Komex (1997)	RL&L (1989b)
date	October 17, 1988	September 11, 2001	October 2, 2001	October 15, 1985	August 7, 1997	October 15, 1985	August 7, 1997	October 17, 1988
habitat	depositional	depositional	depositional	depositional	erosional	erosional	erosional	depositional
Density								
mean density [numbers./m²]	19,784	23,328	6,259	19,138	4,477	115,998	6,372	216
SE mean density [numbers/m²]	6,086	7,811	1,761	3,012	2,089	54,049	986	75
Richness								
total richness [no. taxa/site]	19	25	17	15	22	33	25	5
mean richness [no. taxa/site]	11.3	12.8	10.2	10.7	13.2	24.0	17.2	2.3
SE mean richness [no.taxa/site]	0.9	1.3	1.0	2.0	1.1	1.5	0.6	0.3
Mean Relative Density [%]								
Oligochaeta	1	3	7	36	7	<1	3	0
Chironomidae	91	72	74	35	50	20	60	56
Ostracoda	3	9	9	21	1	0	5	0
Gastropoda	<1	<1	1	0	<1	0	0	0
Pelecypoda	3	6	0	5	3	<1	2	0
other Diptera	<1	1	9	0	7	59	3	11
Amphipoda	0	0	0	0	2	0	1	0
Ephemeroptera	0	0	0	0	3	1	3	17
other (includes Trichoptera and Plecoptera)	1	10	1	3	27	21	23	17

[a] Golder (2003c) site number.

[b] Original site identifier.

Notes: SE = standard error of the mean.

Wapasu Creek sites are ordered downstream to upstream.

Komex (1997) - Chironomidae are only identified to subfamily/tribe level thus richness values are underestimates.

RL&L (1989b) - Percent composition calculations for Site 54 were based on only two samples, because one sample from each of these sites had no organisms present.

Wapasu Creek

The historical literature for the benthic invertebrate community of Wapasu Creek consists of reports by (Beak 1986), (Komex 1997; RL&L 1989b), including data collected between 1985 and 1997.

Both erosional and depositional sites were sampled in Wapasu Creek. The benthic invertebrate community of Wapasu Creek was dominated by midges, other dipterans, bristle worms and seed shrimp, with no consistent pattern among sites or habitat in the order of dominance by the taxa present (Table 5.4-18). Mean benthic invertebrate density was highly variable, ranging from 216 to 115,998 organisms/m², with three of the five sites having less than 6,500 organisms/m². Total benthic invertebrate richness ranged from 5 to 33 taxa/site and mean richness ranged from 2.3 to 24 taxa/site. The farthest upstream site (Site 54/19) had considerably lower density and richness compared to all other sites.

Muskeg Creek

The historical literature for the benthic invertebrate community of Muskeg Creek consists of reports by (Beak 1986), (Golder 1996b; Golder 2002a; RL&L 1989b), including data collected between 1985 and 2001.

Three sites have been sampled in this watercourse, including two depositional sites (Sites 44 and 43; with the exception of the 1985 samples, which were collected at an erosional location) and one erosional site (Site 42). The benthic invertebrate community in Muskeg Creek was dominated by midges, bristle worms and fingernail clams (Table 5.4-19). Other groups were occasionally abundant. Mean benthic invertebrate density was highly variable ranging from 2,083 to 87,182 organisms/m², with most sites having greater than 5,000 organisms/m². Total benthic invertebrate richness ranged from 15 to 59 taxa/site and mean richness ranged from 6.8 to 42.0 taxa/site. There were no obvious upstream-downstream trends in benthic community characteristics and ranges of benthic community variables exhibited a wide overlap between the two habitat types.

Table 5.4-19 Historical Benthic Invertebrate Community Data for Muskeg Creek

Variable	Muskeg Creek								
	44[a]				43[a]			42[a]	
	9[b]			MUC-2[b]	10[b]		MUC-1[b]	11[b]	
study	Beak (1986)	RL&L (1989b)	Golder (1996b)	Golder (2002a)	Beak (1986)	RL&L (1989b)	Golder (2002a)	Beak (1986)	RL&L (1989b)
date	October 15, 1985	October 17, 1988	September 30, 1995	September 19, 2001	October 15, 1985	October 17, 1988	September 11, 2001	October 15, 1985	October 17, 1988
habitat	erosional	depositional	depositional	depositional	depositional	depositional	depositional	erosional	erosional
Density									
mean density [numbers/m²]	21,637	17,385	25,146	4,233	44,856	2,083	7,603	87,182	3,132
SE mean density [numbers/m²]	5,998	5,555	12,367	2,045	7,580	596	6,223	19,561	1,102
Richness									
total richness [no. taxa/site]	32	23	16	15	32	16	34	59	33
mean richness [no. taxa/site]	21.3	15.7	12.7	6.8	25.3	9.3	10.2	42.0	18.7
SE mean richness [no.taxa/site]	0.7	1.2	0.7	1.0	0.9	1.5	4.1	1.7	1.3
Mean Relative Density [%]									
Oligochaeta	2	8	6	0	4	14	16	<1	5
Chironomidae	94	70	64	35	91	66	64	86	12
Ostracoda	<1	1	7	1	0	1	0	0	0
Gastropoda	0	<1	0	<1	0	0	0	<1	9
Pelecypoda	<1	14	3	60	1	5	7	0	3
other Diptera	2	2	1	1	1	8	2	4	13
Amphipoda	0	1	<1	1	0	<1	<1	0	0
Ephemeroptera	<1	<1	0	0	2	2	2	1	6
other (includes Trichoptera and Plecoptera)	1	4	20	2	1	4	9	9	52

[a] Golder (2003c) site number.

[b] Original site identifier.

Notes: SE = standard error of the mean.
Sites are ordered upstream to downstream.
Some numbers are rounded for presentation purposes. Therefore it may appear that percentages do not add up to 100.

Tributaries and Waterbodies of Muskeg Creek

Khahago Creek

The historical literature for the benthic invertebrate community of Khahago Creek consists of reports by (Beak 1986), (Golder 1996b; Golder 2002a; RL&L 1989b), including data collected between 1985 and 2001.

The benthic invertebrate community of depositional sites in Khahago Creek was dominated by the midges, which accounted for at least 71% of the total density (Table 5.4-20). Bristle worms and fingernail clams were common in some years. Mean benthic invertebrate density ranged from 7,586 to 12,514 organisms/m², which is in the low range compared to other small watercourses in the Oil Sands Region. Total benthic invertebrate richness was low to moderate, ranging from 17 to 36 taxa/site. Mean richness ranged from 10.3 to 17.0 taxa/site. There was no apparent trend over time in benthic community variables at the site sampled in Khahago Creek.

Green Stockings Creek

The historical literature for the benthic invertebrate community of Green Stockings Creek consists of reports by (Beak 1986) and (RL&L 1989b), including data collected between 1985 and 1988.

Different habitat was sampled at the same location by the two studies. The benthic invertebrate community in Green Stockings Creek was dominated by the midges, which accounted for 79 to 84% of the total density (Table 5.4-20). Bristle worms and other dipterans were also common. Mean benthic invertebrate density ranged from 12,657 to 16,451 organisms/m². Total benthic invertebrate richness ranged from 18 to 32 taxa/site and mean richness ranged from 12.0 to 23.3 taxa/site.

Blackfly Creek

The historical literature for the benthic invertebrate community of Blackfly Creek consists of reports by Beak (1986), Golder 1996b; 2002b); and RL&L (1989b), including data collected between 1985 and 2001.

Table 5.4-20 Historical Benthic Invertebrate Community Data for Khahago Creek, Green Stockings Creek, Blackfly Creek and Wesukemina Creek

Variable	Khahago Creek				Green Stockings Creek		Blackfly Creek				Wesukemina Creek
	48[a]				51[a]		50[a]			49[a]	207[a]
	14[b]			KHC-1[b]	13[b]		12[b]		BLC-HS[b]	55[b]	WEC-SKL[b]
study	Beak (1986)	RL&L (1989b)	Golder (1996b)	Golder (2002a)	Beak (1986)	RL&L (1989b)	Beak (1986)	RL&L (1989b)	Golder (2002e)	Golder (1996b)	Golder (2002e)
date	October 15, 1985	October 17, 1988	September 30, 1995	September 24, 2001	October 15, 1985	October 17, 1988	October 15, 1985	October 17, 1988	October 2, 2001	September 30, 1995	October 1, 2001
habitat	depositional	depositional	depositional	depositional	erosional	depositional	erosional	erosional	depositional	erosional	depositional
Density											
mean density [numbers./m²]	9,339	12,514	9,515	7,586	12,657	16,451	45,206	453	10,233	5,942	62,638
SE mean density [numbers/m²]	2,991	1,287	3,750	2,514	3,761	2,862	11,066	295	2,909	1,952	14,151
Richness											
total richness [no. taxa/site]	17	23	18	36	32	18	41	18	29	27	37
mean richness [no. taxa/site]	10.3	17.0	11.0	16.6	23.3	12.0	31.7	10.0	15.8	19.0	17.4
SE mean richness [no.taxa/site]	2.3	2.0	1.7	1.8	3.5	0.6	2.8	4.0	2.0	1.0	1.2
Mean Relative Density [%]											
Oligochaeta	6	2	9	<1	11	5	1	<1	5	6	<1
Chironomidae	71	84	75	79	79	84	58	17	80	64	75
Ostracoda	2	1	5	1	0	1	0	0	4	2	17
Gastropoda	0	1	0	2	0	0	0	<1	0	0	<1
Pelecypoda	6	5	0	<1	0	4	0	0	0	<1	3
other Diptera	<1	1	2	2	2	5	9	11	2	3	<1
Amphipoda	1	3	0	4	0	0	0	0	0	0	0
Ephemeroptera	0	3	1	10	1	0	2	<1	0	3	2
other (includes Trichoptera and Plecoptera)	13	1	8	2	8	1	29	72	8	22	2

[a] Golder (2003c) site number.

[b] Original site identifier.

Notes: SE = standard error of the mean.
Some numbers are rounded for presentation purposes. Therefore it may appear that percentages do not add up to 100.
RL&L (1989b) - Site 48 (Aug 1988) percent composition calculations were based on only two samples because one sample from each of these sites had no organisms present.

Mostly erosional sites were sampled in Blackfly Creek. The benthic invertebrate community of this watercourse was dominated by the midges and caddisflies (Trichoptera; included in the "Other" category) (Table 5.4-20). Chironomid dominance was more pronounced at the depositional location sampled in 2001 compared to the erosional locations sampled during other years. Mean benthic invertebrate density was highly variable ranging from 453 to 45,206 organisms/m². Total benthic invertebrate richness ranged from 18 to 41 taxa/site and mean richness ranged from 10.0 to 31.7 taxa/site.

Wesukemina Creek

The historical literature for the benthic invertebrate community of Wesukemina Creek consists of one report by (Golder 2002b), including data collected at one site in 2001.

The benthic invertebrate community of Wesukemina Creek was dominated by the midges and seed shrimp, which together accounted for 92% of total density (Table 5.4-20). Mean benthic invertebrate density was 62,638 organisms/m². Total benthic invertebrate richness was 37 taxa/site and mean richness was 17.4 taxa/site.

Kearl Lake

The historical literature for the benthic invertebrate community of Kearl Lake consists of reports by Beak (1986), Golder (1996b); RL&L (1989b) and RAMP (Golder 2002e; Golder 2003c; RAMP 2007), including data collected on nine occasions between 1985 and 2006.

The benthic invertebrate community of Kearl Lake was dominated by midges and scuds; bristle worms, fingernail clams and seed shrimp were occasionally abundant as well (Table 5.4-21). The frequent co-dominance by scuds is indicative of the abundant aquatic plant growth in this lake. Mean benthic invertebrate density ranged from 795 to 17,405 organisms/m², which is in the typical range for lakes in the region. Total benthic invertebrate richness ranged from 8 to 27 taxa/site and mean richness ranged from 5.0 to 17.0 taxa/site. Although the highest values for both density and richness were reported by the most recent survey, the available data do not provide clear evidence of temporal trends, with the possible exception of a declining trend in the relative proportion of midges over time.

Table 5.4-21 Historical Benthic Invertebrate Community Data for Kearl Lake and Iyinimin Creek

Variable	Kearl Lake									Iyinimin Creek			
	–	20	80-1	KEL	KEL	KEL-1	KEL-1	KEL-1	KEL-1	8 (45)[a]			IYC-HS (46)[a]
study	Beak (1986)	R.L.&L (1989b)	Golder (1996b)	Golder (2002d)	Golder (2003b)	RAMP (2007)	RAMP (2007)	RAMP (2007)	RAMP (2007)	Beak (1986)	RL&L (1989b)	Golder (1996b)	Golder (2002e)
date	October 1985	October 1988	Fall 1995	September 19, 2001	September 6, 2002	September 2003	September 2004	September 2005	September 2006	October 15, 1985	October 17, 1988	September 30, 1995	October 1, 2001
habitat	waterbody	waterbody	waterbody	waterbody	waterbody	waterbody	waterbody	waterbody	waterbody	erosional	erosional	erosional	depositional
Density													
mean density [numbers/m²]	7,356	9,052	1,251	795	8,681	5,366	5,690	12,691	17,405	24,877	537	648	22,793
SE mean density [numbers/m²]	3,868	767	992	226	1,563	–	–	–	–	1,855	290	137	7,297
Richness													
total richness [no. taxa/site]	20	17	8	22	27	–	–	–	–	44	17	17	38
mean richness [no. taxa/site]	12.7	10.7	5.0	5.9	9.0	8.0	7.0	12.0	17.0	31.0	9.3	10.7	19.8
SE mean richness [no.taxa/site]	2.3	2.2	1.5	1.3	1.0	–	–	–	–	1.0	3.2	0.3	2.6
Mean Relative Density [%]													
Oligochaeta	3	5	20	0	<1	6	5	2	5	8	2	4	12
Chironomidae	80	64	80	68	42	46	20	45	42	50	8	62	83
Ostracoda	0	1	<1	9	6	4	4	1	<1	0	2	0	2
Gastropoda	1	2	0	1	<1	0	0	0	0	0	0	0	0
Pelecypoda	6	6	0	4	4	6	9	4	23	0	0	0	0
other Diptera	<1	0	0	0	<1	1	0	0	0	3	3	6	1
Amphipoda	6	21	0	14	46	36	58	25	23	0	0	0	0
Ephemeroptera	0	<1	0	1	1	0	0	0	2	<1	5	2	0
other (includes Trichoptera and Plecoptera)	3	1	<1	3	1	2	2	16	2	39	81	25	3

[a] Golder (2003c) site number.

– = Not available; SE = standard error of the mean.

Notes: Some numbers are rounded for presentation purposes; therefore it may appear that the percentages do not add up to 100.
RAMP 2001 (Golder 2002d) data were obtained from CEMA database (Golder 2006).
RAMP 2002 (Golder 2003b) data were obtained from CEMA database (Golder 2006).
Golder 2002d data were obtained from CEMA database (Golder 2006).
RAMP 2007 raw data were not provided in the report; therefore data were obtained from tables in the report.

Iyinimin Creek

Iyinimin Creek is the inlet stream to Kearl Lake. The historical literature for the benthic invertebrate community of Iyinimin Creek consists of reports by Beak (1986), Golder (1996b; 2002b); and RL&L (1989b), including data collected between 1985 and 2001.

The benthic invertebrate community of an erosional site in Iyinimin Creek was dominated by the midges and stoneflies (Plecoptera; included in the "Other" category) (Table 5.4-21). The depositional site sampled in this stream was dominated by midges. Other dipterans and bristle worms were occasionally abundant. Mean benthic invertebrate density ranged from 537 to 24,877 organisms/m², displaying a large year-to-year variation at the erosional site. Total benthic invertebrate richness ranged from 17 to 44 taxa/site and mean richness ranged from 9.3 to 31.0 taxa/site.

Unnamed Tributaries in the Muskeg River Watershed

The historical literature for the benthic invertebrate community of the unnamed tributaries in the Muskeg River watershed consists of reports by AXYS (2005); and Imperial Oil (2005), including data collected in 2003.

The unnamed tributaries were dominated by the midges (Chironomidae) and the other Diptera (flies), bristle worms (Oligochaeta) and clams (Pelecypoda) at various sites (Table 5.4-22). Mean benthic invertebrate density ranged from 748 to 56,685 organisms/m^2, with most sites consisting of fewer than 3,000 organisms/m². Total benthic invertebrate richness ranged from 5 to 53 taxa/site, with most sites consisting of less than 25 taxa/site. Mean richness ranged from 1.6 to 19.5 taxa/site, with most sites consisting of greater than 8.0 taxa/site.

Unnamed Waterbodies in the Muskeg River Watershed

The historical literature for the benthic invertebrate community of small unnamed watercourses and waterbodies in the Muskeg River watershed consist of reports by AXYS (2005); Imperial Oil (2005); and O'Neil et al. (1982), including data collected in 1981 and 2003.

Table 5.4-22 Historical Benthic Invertebrate Community Data for Unnamed Watercourses and Unnamed Waterbodies in the Muskeg River Watershed

Variable	Watercourse						Waterbody			
	Unnamed Tributary 1	Unnamed Tributary 2	Unnamed Tributary 5	Unnamed Tributary 7	Unnamed Tributary 9	Stream 1	Pond	Waterbody 1	Waterbody 2	Pond 1
	MT-1	MT-2	MT-5	MT-7	MT-9	–	L12	WB-1	WB-2	-
study	Imperial Oil (2005)	Imperial Oil (2005)	Imperial Oil (2005)	Imperial Oil (2005)	Imperial Oil (2005)	AXYS (2005)	O'Neil et al. (1982)	Imperial Oil (2005)	Imperial Oil (2005)	AXYS (2005)
date	October 2, 2003	October 3, 2003	October 5, 2003	October 3, 2003	October 5, 2003	October 11, 2003	September 28, 1981	October 4, 2003	October 3, 2003	October 9, 2003
habitat	depositional	depositional	depositional	depositional	depositional	depositional	waterbody	waterbody	waterbody	waterbody
Density										
mean density [numbers/m²]	2,184	748	1,049	1,987	2,872	56,685	9,454	2,090	495	128,069
SE mean density [numbers/m²]	478	69	650	594	517	7,721	1,401	359	91	25,076
Richness										
total richness [no. taxa/site]	23	26	5	16	23	53	11	23	12	9
mean richness [no. taxa/site]	9.6	8.2	1.6	8.0	11.2	19.5	7.3	8.3	3.7	5.4
SE mean richness [no.taxa/site]	0.4	0.6	0.6	0.8	1.6	1.2	0.9	0.9	0.4	0.8
Relative Density [%]										
Oligochaeta	3	3	0	4	3	12	0	2	1	3
Chironomidae	86	67	93	30	52	61	33	65	45	41
Ostracoda	2	1	0	0	0	0	0	0	0	0
Gastropoda	0	1	0	0	0	1	0	0	0	0
Pelecypoda	0	7	0	49	32	7	33	3	11	0
other Diptera	4	6	4	12	7	8	1	28	0	<1
Amphipoda	1	0	0	4	1	1	32	0	19	0
Ephemeroptera	0	1	0	0	0	1	0	<1	0	0
other (includes Trichoptera and Plecoptera)	3	12	3	2	4	9	1	1	25	56

Notes: – = Not available; SE = standard error of the mean.
O'Neil et al. (1982) - Chironomidae were only identified to family level; richness values are based on counts from original data.
Imperial Oil (2005) - relative density for Site MT-5 is based on 4 replicates because one replicate contained no organisms.

The benthic communities of unnamed watercourses were dominated by midges and fingernail clams (Table 5.4-22). These two groups, plus scuds, other Diptera, water mites (Hydracarina; in the "Other" category) and roundworms (Nematoda; in the "Other" category) were dominant in unnamed waterbodies. Mean benthic invertebrate density ranged from 748 to 56,685 organisms/m^2 in watercourses and from 495 to 128,069 organisms/m^2 in waterbodies. With the exception of data collected by AXYS (2005) density was in the low range of less than 10,000 organisms/m^2. Total benthic invertebrate richness was highly variable, ranging from 5 to 53 taxa/site in watercourses and from 9 to 23 taxa/site in waterbodies. As typically observed, watercourses tended to have more taxa than waterbodies.

5.4.3.2 Environmental Field Survey

Muskeg River Watershed

Watercourses

Muskeg River (Site 24)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in depositional habitat in the Muskeg River (Site 24) during fall 2005, in a reach that has not been sampled previously. Mean depth at this site was 0.74 m (Table 5.4-23) and current velocity was negligible. Field-measured water quality parameters were typical of the Oil Sands Region for the fall season. The bottom substrate was dominated by the silt and clay fractions, and had a high moisture content. Total organic carbon content was also high, measuring 32.9%, which likely accounts for the relatively low DO concentration measured at this site.

Table 5.4-23 Benthic Invertebrate Habitat Characteristics for the Muskeg River Watershed, Fall 2005

Parameter	Units	Muskeg River Watershed			
		Muskeg River	Wapasu Creek		Unnamed Creek 9
		Site 24	Site 38	Site 32	Site 35B
habitat type	-	depositional	depositional	depositional	depositional
date	-	October 18, 2005	October 15, 2005	October 13, 2005	October 13, 2005
Field Supporting Data					
easting	m	486689	489887	482407	479591
northing	m	6363929	6356808	6359551	6356400
mean depth	m	0.74	0.61	0.40	0.36
mean current velocity	m/s	0.00	–	0.00	0.08
wetted channel width	m	–	6.0	–	12.6
macrophyte cover	%	0	0	0	0
Field Water Quality					
dissolved oxygen	mg/L	6.3	9.5	6.1	7.8
conductivity	µS/cm	395	213	275	270
pH	–	7.4	7.6	7.3	7.5
water temperature	°C	0.7	4.3	5.0	3.7
Substrate					
Laboratory					
sand	%	12	–	40	–
silt	%	42	–	39	–
clay	%	46	–	21	–
moisture content	%	92	–	91	–
total organic carbon	%	32.9	–	35.1	–

– = No data/not applicable.

Notes: UTM co-ordinates are Zone 12 V, NAD 83.

Multiple sites on a watercourse are listed left to right from upstream to downstream.

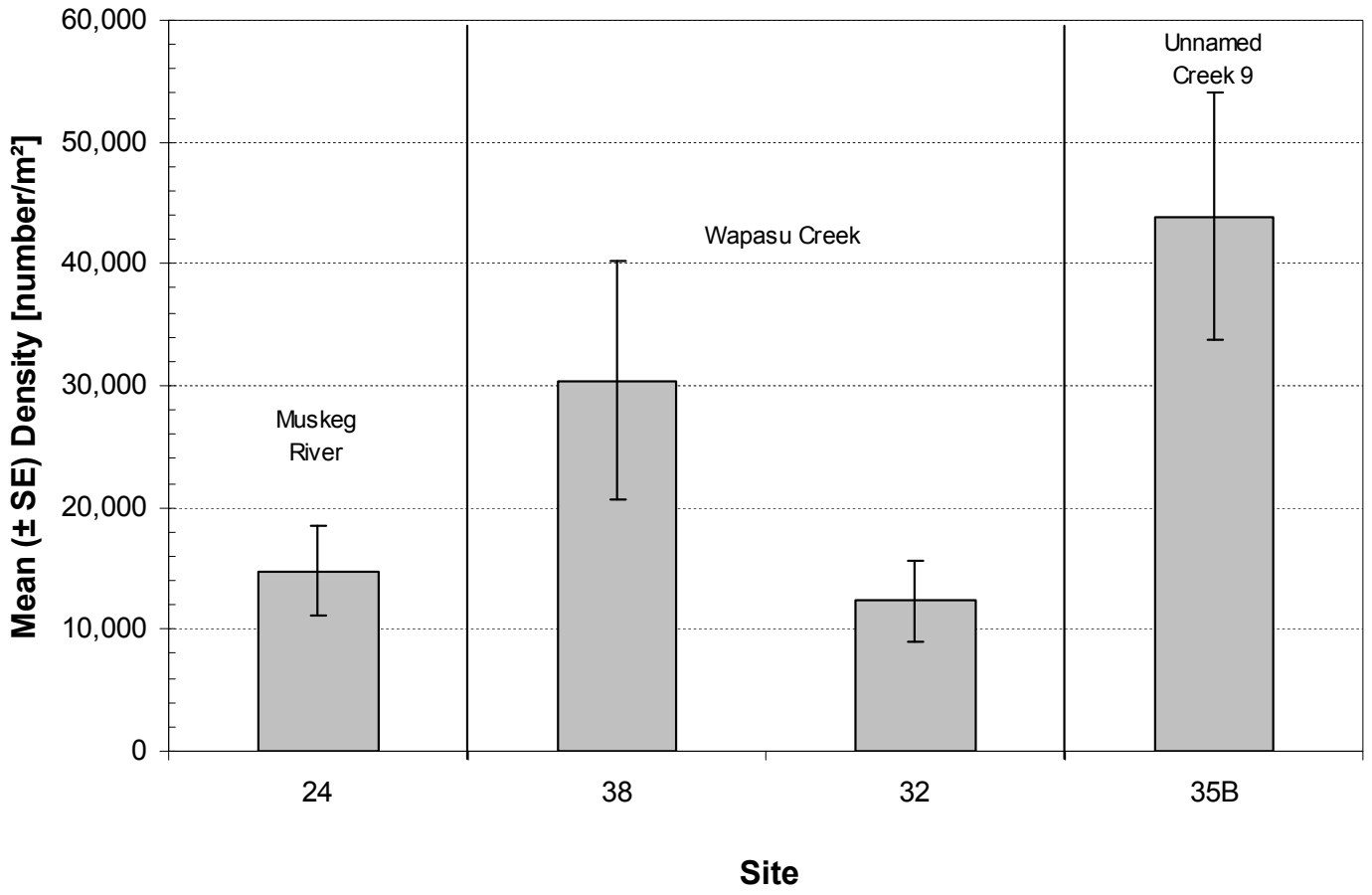
Benthic Invertebrate Community

Mean (± 1 SE) benthic invertebrate density for the Muskeg River (Site 24) was 14,810 ± 3,608 organisms/m² (Table 5.4-24, Figure 5.4-2; raw data are provided in Appendix U, Table U-1), which is in the low to moderate range compared to other watercourses in the region. Total taxonomic richness was 30 taxa/site and mean (±1 SE) richness was 15.0 ± 1.8 taxa/site (Figure 5.4-3). These values fall within the ranges reported by previous surveys of the mid to upper reaches of the Muskeg River.

Table 5.4-24 Benthic Invertebrate Community Data for the Muskeg River Watershed, Fall 2005

Variable	Muskeg River Watershed			
	Muskeg River	Wapasu Creek		Unnamed Creek 9
	Site 24	Site 38	Site 32	Site 35B
date	October 18, 2005	October 15, 2005	October 13, 2005	October 13, 2005
habitat	depositional	depositional	depositional	depositional
Density				
mean density [numbers/m²]	14,810	30,405	12,310	43,871
SE mean density [numbers/m²]	3,608	9,758	3,342	10,156
Richness				
total richness [no. taxa/site]	30	39	28	37
mean richness [no. taxa/site]	15.0	18.0	13.8	18.4
SE mean richness [no. taxa/site]	1.8	1.2	1.6	1.9
Diversity				
Simpson's Diversity Index (SDI) [1-D]	0.87	0.90	0.84	0.84
evenness	0.27	0.25	0.23	0.17
Relative Density [%]				
Oligochaeta	8	26	7	3
Chironomidae	45	60	72	61
Ostracoda	30	3	8	26
Gastropoda	<1	0	1	1
Pelecypoda	<1	2	4	1
other Diptera	<1	6	2	2
Amphipoda	8	<1	1	0
Ephemeroptera	0	0	0	0
other (includes Trichoptera and Plecoptera)	8	3	4	7

Note: SE = standard error of the mean.



ERROR BARS REPRESENT ±1STANDARD ERROR OF THE MEAN.

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

MEAN BENTHIC INVERTEBRATE DENSITY IN THE JACKPINE EXPANSION MINING AREA, FALL 2005

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. mean_BI_densityJEMA	
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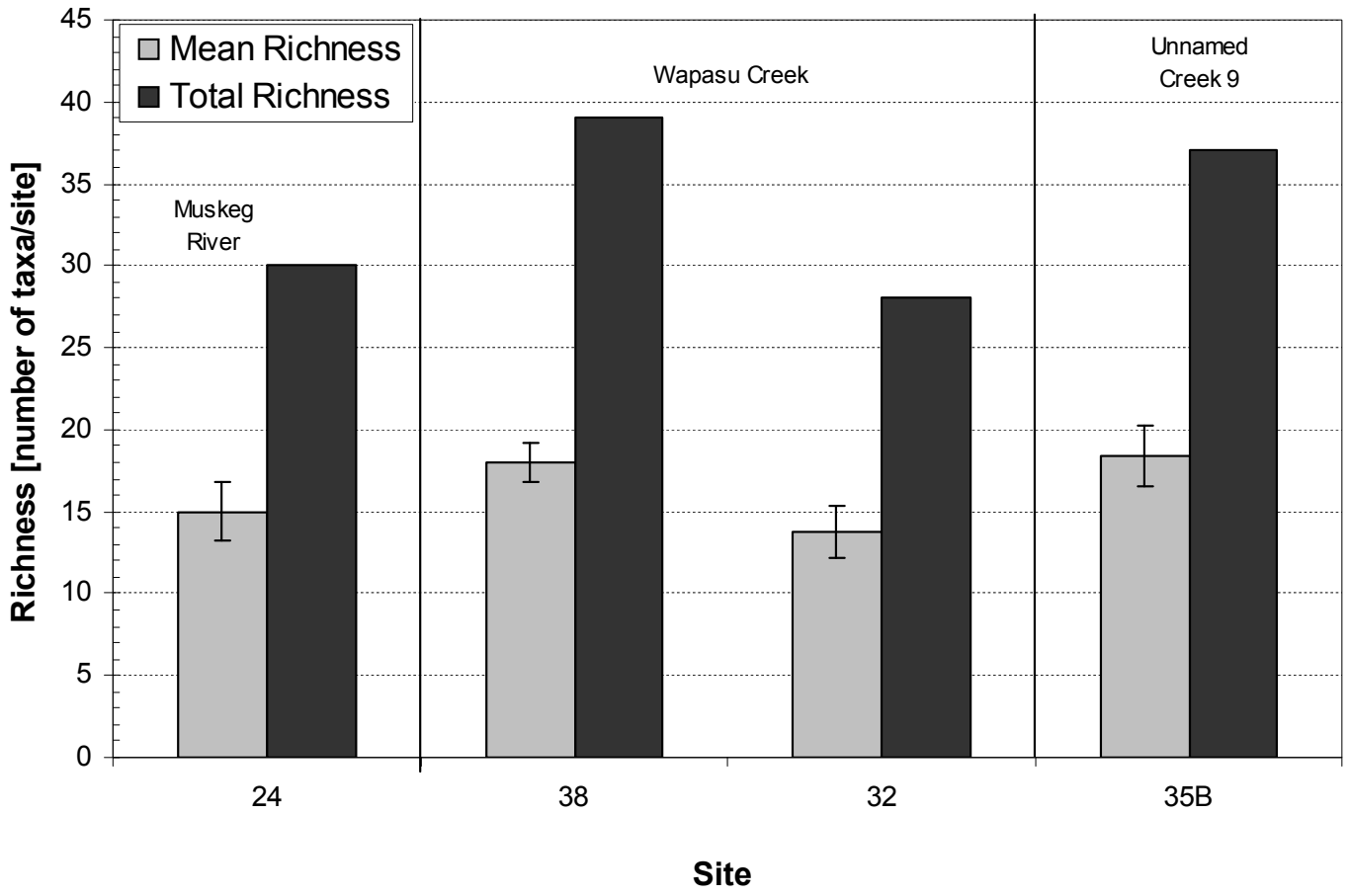
CADD	TY	11/10/07	FIGURE: 5.4-2	
CHECK	AS	11/10/07		
REVIEW	WES/TC	20/11/07		



ERROR BARS REPRESENT ±1STANDARD ERROR OF THE MEAN.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MEAN AND TOTAL BENTHIC INVERTEBRATE RICHNESS IN THE JACKPINE EXPANSION MINING AREA, FALL 2005

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. meanBI_richnessJEMA	
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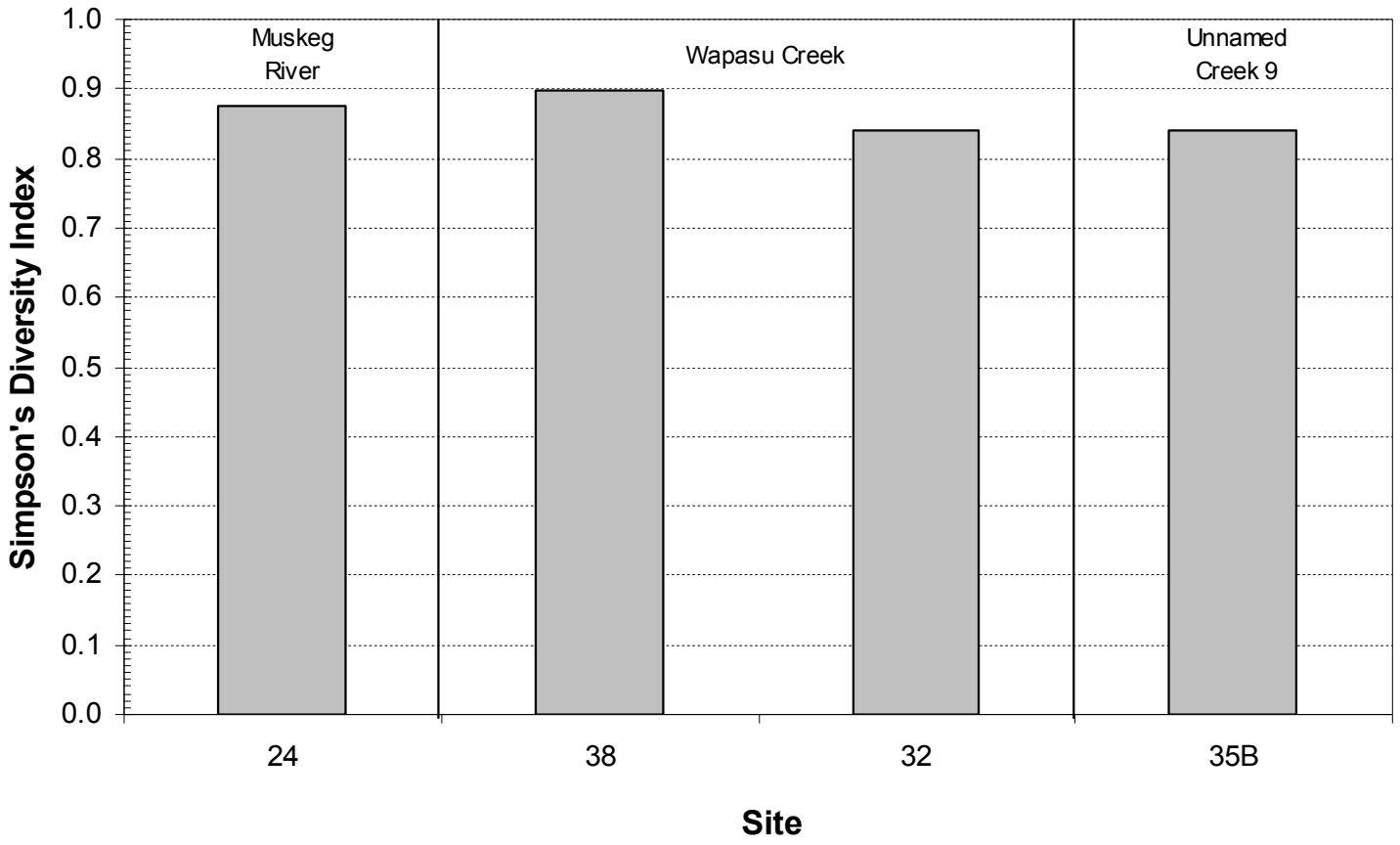
CADD	TY	11/10/07	FIGURE: 5.4-3	
CHECK	JS	05/10/07		
REVIEW	WES/TC	20/11/07		

Diversity, quantified using the SDI, takes into account both the density and taxonomic richness of benthic invertebrates at a site. The SDI is expressed as a number between one and zero, with one representing high diversity and zero representing low diversity. The SDI for the Muskeg River (Site 24) was 0.87 (Table 5.4-24, Figure 5.4-4) indicating a diverse benthic invertebrate community.

Evenness is a measure of how evenly benthic invertebrate density at a site is distributed among the taxa present. Evenness is also expressed as a value between one and zero, with one representing high evenness and zero representing low evenness (i.e., dominance by one or a few taxa). Evenness for the Muskeg River (Site 24) was 0.27, which is low and indicates that only a few of the taxa present (i.e., midges and seed shrimp) account for the majority of individuals collected (Table 5.4-24, Figure 5.4-5).

The dominant taxa in the Muskeg River (Site 24) were the midges and seed shrimp (Table 5.4-24, Figure 5.4-6), accounting for 91% of the total density. The midges were dominated by the Chironomini, Tanytarsini and Tanypodinae (Figure 5.4-7).



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE **SIMPSON'S DIVERSITY INDEX FOR BENTHIC INVERTEBRATES IN THE JACKPINE EXPANSION MINING AREA, FALL 2005**

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No.	Simpson'sBI_JEMA
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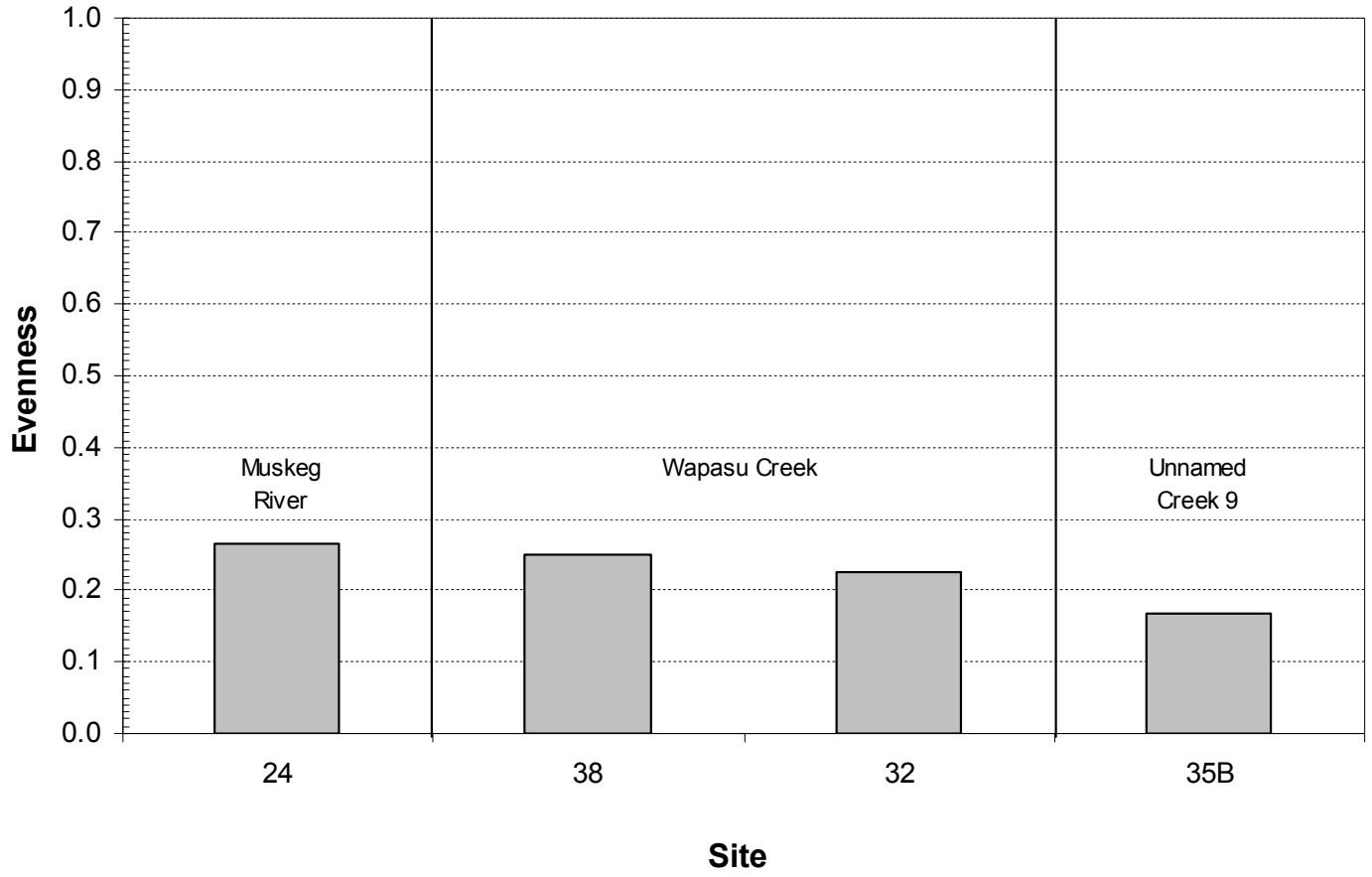
CHECK	JS	05/10/07		
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

EVENESS VALUES FOR BENTHIC INVERTEBRATES IN THE JACKPINE EXPANSION MINING AREA, FALL 2005

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No.	EvennessBI_JEMA
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
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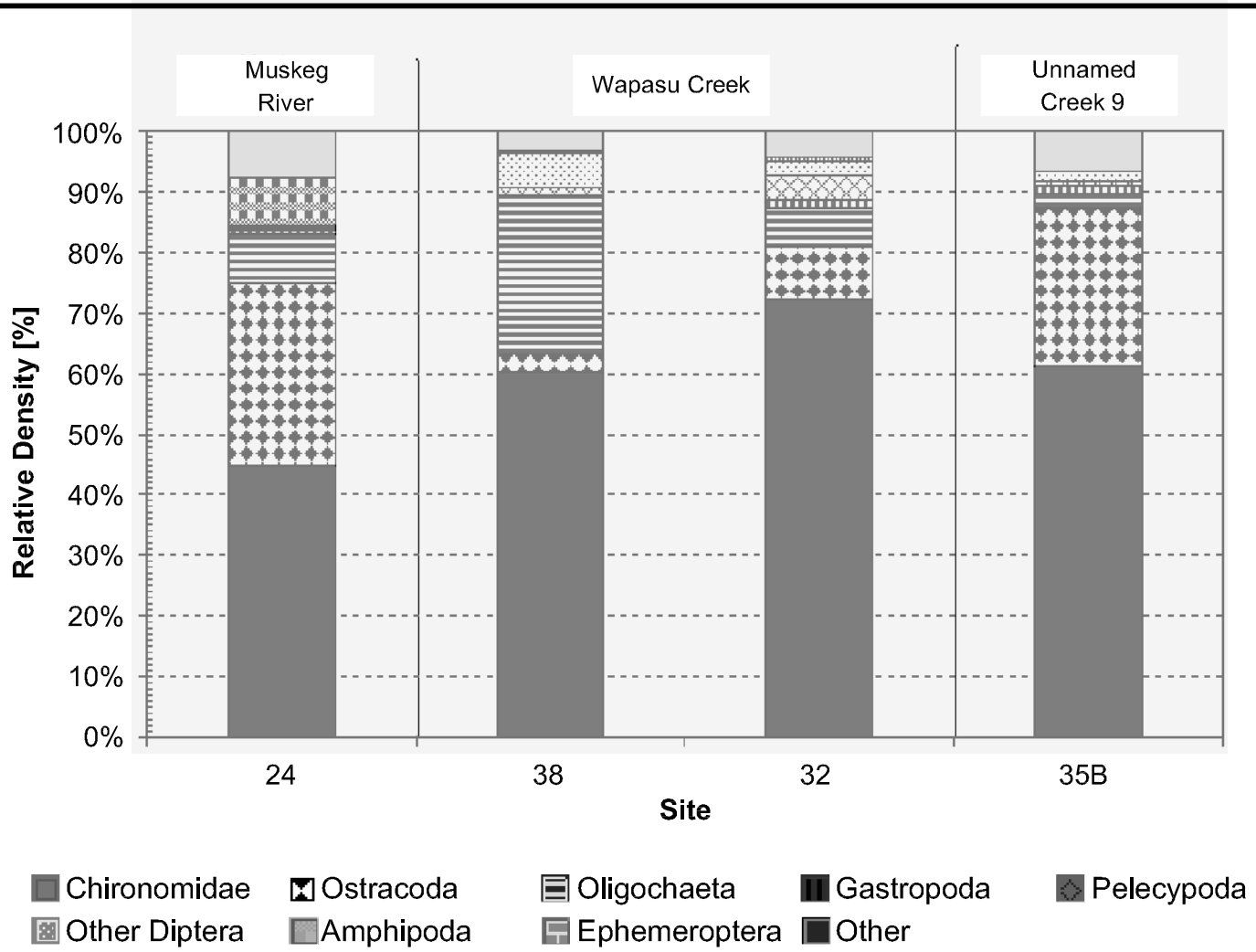
CHECK	JS	05/10/07		
REVIEW	WES/TC	20/11/07		



PROJECT

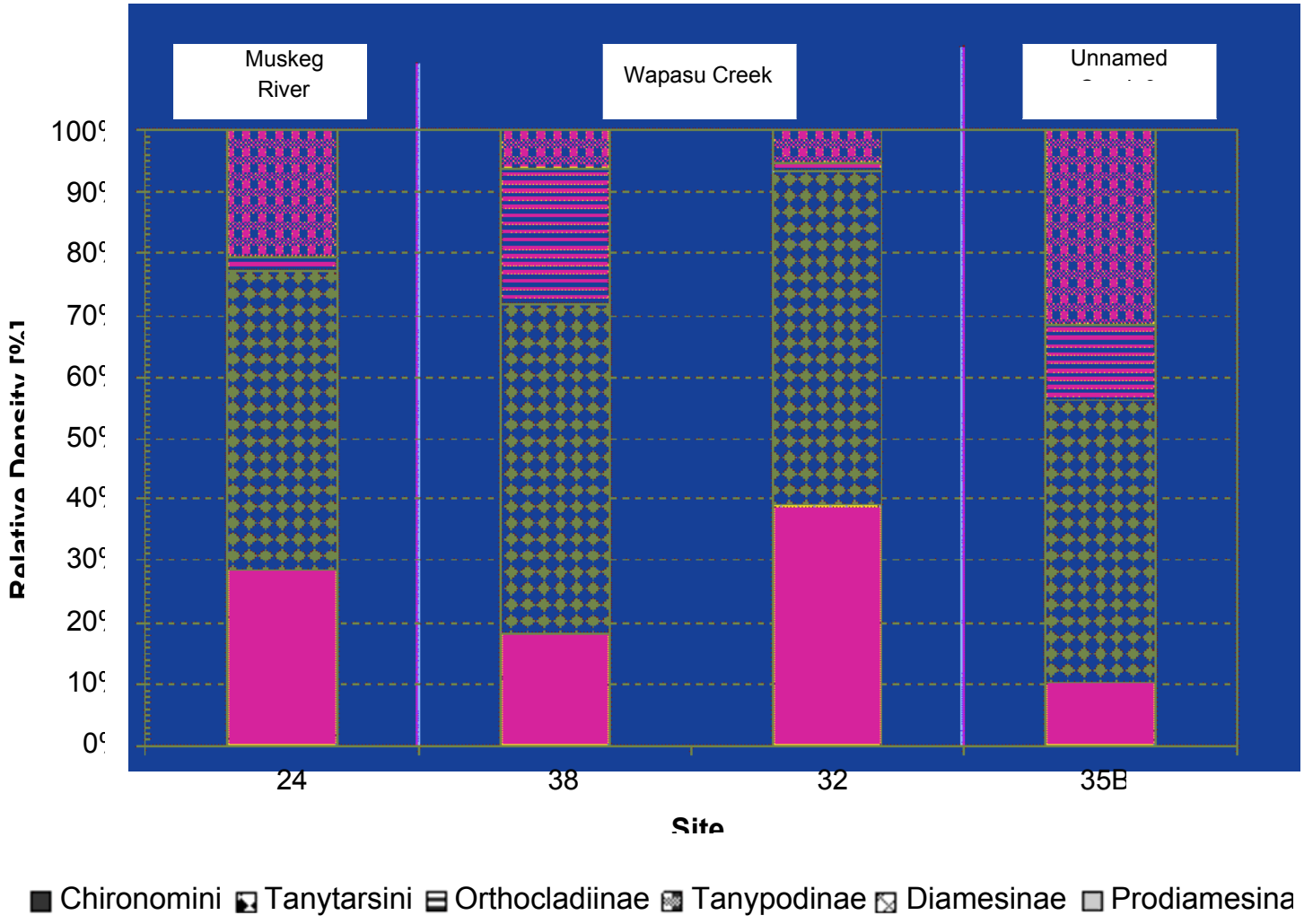
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE BENTHIC INVERTEBRATE DENSITY IN THE JACKPINE EXPANSION MINING AREA, FALL 2005

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. RelativeBI_Dens..JEMA	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
CADD	TY	19/11/07	FIGURE: 5.4-6	
CHECK	JS	09/10/07		
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE CHIRONOMIDAE DENSITY IN THE JACKPINE EXPANSION MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. RelativeChiron..._JEMA	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07	**FIGURE: 5.4-7**	
CHECK	JS	09/10/07		
REVIEW	WES/TC	20/11/07		

Wapasu Creek (Sites 38 and 32)

Benthic Invertebrate Habitat

Two depositional sites were sampled for benthic invertebrates in Wapasu Creek (Sites 38 and 32) during fall 2005. Mean depth at these sites ranged from 0.40 m (Site 32) to 0.61 m (Site 38); current velocity was negligible at both sites (Table 5.4-23). Field-measured water quality parameters were typical of watercourses in the Oil Sands Region for the fall sampling season. The bottom substrate at Site 32 was dominated by the sand and silt fractions, and had a high moisture content. Total organic carbon content was also high at this site, measuring 35.1%. Detailed sediment data are not available for Site 38; however, based on field observations, bottom substrates consisted of fine sediments, with a moderate to high organic content.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density at the two sites sampled in Wapasu Creek (Sites 38 and 32) ranged from 12,310 ± 3,342 organisms/m² (Site 32) to 30,405 ± 9,758 organisms/m² (Site 38) (Table 5.4-24, Figure 5.4-2; raw data are provided in Appendix U, Table U-1,). Total taxonomic richness was moderate, ranging from 28 taxa/site (Site 32) to 39 taxa/site (Site 38) and mean (±1 SE) richness ranged from 13.8 ± 1.6 taxa/site (Site 32) to 18.0 ± 1.2 taxa/site (Site 38) (Figure 5.4-3).

Values of the SDI were high in Wapasu Creek, ranging from 0.84 (Site 32) to 0.90 (Site 38) (Table 5.4-24, Figure 5.4-4) indicating a diverse benthic invertebrate community. Evenness was low for both sites, ranging from 0.23 (Site 32) to 0.25 (Site 38) (Figure 5.4-5), indicating that the a few taxa accounted for the majority of the total density in Wapasu Creek. The dominant taxa were the midges and bristle worms (Figure 5.4-6). The midges present in Wapasu Creek were dominated by the Chironomini, Tanytarsini and Orthocladiinae (Figure 5.4-7).

Unnamed Creek 9 (Site 35B)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Creek 9 (Site 35B) during fall 2005, in depositional habitat. Mean depth at this site was 0.36 m and mean current velocity was 0.08 m/s (Table 5.4-23). Field-measured water quality parameters were typical of the Oil Sands Region during the fall season. Detailed sediment data are not available for this site; however, based on field observations, bottom substrates consisted of fine sediments, with a moderate to high organic content.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Creek 9 (Site 35B) was 43,871 ± 10,156 organisms/m², which is relatively high for small a stream in this region (Table 5.4-24, Figure 5.4-2; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 37 taxa/site and mean (±1 SE) richness was 18.4 ± 1.9 taxa/site (Figure 5.4-3).

The value of the SDI was 0.84 (Figure 5.4-4), which is indicative of a diverse benthic invertebrate community. Evenness was 0.17 (Figure 5.4-5), indicating that the majority of the density was accounted for by a few taxonomic groups. The dominant taxa in Unnamed Creek 9 were the midges and seed shrimp, which together accounted for 87% of the total density (Figure 5.4-6). The midges were dominated by the Tanytarsini and Tanypodinae (Figure 5.4-7).

5.5 PIERRE RIVER MINING AREA RESULTS

5.5.1 Fish and Fish Habitat

The following section provides a summary of the fish habitat characteristics, fisheries resources and benthic invertebrate community data for watercourses and waterbodies within the PRMA LSA. Included are the results from the literature review and field study.

5.5.1.1 Literature Review

Historic and/or recent fish and fish habitat information is available for the following aquatic resources in the PRMA LSA:

- the Pierre River;
- Lillian Lake;
- Eymundson Creek;
- Unnamed Creek 2; and
- Redclay Creek.

Pierre River

Fish Habitat

Available habitat information for the Pierre River is limited. Griffiths (1973) reported that the Pierre River had little or no favourable sport fish habitat. RL&L (1994) described the mouth of the Pierre River as low gradient, depositional and

consisting of run habitat with silt and sand substrate. Overwintering habitat for the lower Pierre River was evaluated by Golder (Golder 2002b) and the mouth of the Pierre River was determined to be frozen to the bottom, indicating a lack of overwintering potential.

Fish Population

Twelve fish species were captured in the Pierre River, including five sport fish species (Arctic grayling, burbot, mountain whitefish, northern pike and walleye), two sucker species (longnose and white sucker) and five forage species (brook stickleback, flathead chub, lake chub, slimy sculpin and trout-perch) (Aquatic Environments Ltd. 1976; Golder 2004b).

Most fish use information for the Pierre River is from a spring counting fence study conducted at the river mouth. The most numerous sport fish species captured in the spring run in the Pierre River was northern pike. Most northern pike captured were adults with a small number of juveniles. Adults were in spawning condition, therefore it was considered possible that northern pike use the Pierre River for spawning, nursery and rearing, as well as for summer feeding habitat (Golder 2004b).

Arctic grayling was the second most common sport fish species captured, with nearly equal numbers of adult and juvenile fish. In addition, Arctic grayling fry were captured during the summer in the lower reach of the Pierre River (Herbert 1979). Arctic grayling may use the Pierre River for spawning, nursery and rearing and feeding habitat (Golder 2004b). Burbot, mountain whitefish and walleye were found in the Pierre River in low numbers suggesting a small amount of use by these species for rearing and feeding habitat (Golder 2004b).

Lillian Lake

Fish Habitat

Available information for Lillian Lake is limited. Golder (2002b) describes this waterbody as small (0.21 km^2) with a maximum depth of 3.4 m. This waterbody was determined to have some overwintering potential for small-bodied fish species tolerant of low DO conditions (Golder 2002b). The overall fish habitat potential at Lillian Lake was rated as moderate for forage fish and nil for large-bodied fish (Golder 2002b).

Fish Population

Brook stickleback was the only species reported in Lillian Lake (Golder 2002b).

Eymundson Creek

Fish Habitat

Available information for Eymundson Creek is limited. Griffiths (1973) described Eymundson Creek as having poor fish habitat over most of its length. A short section in the middle of the creek was described as having improved habitat conditions. Some sections of the surveyed area had silt banks, sand bars and windfalls, while others had a higher gradient and riffles with boulder substrate. Habitat in the middle section consisted of swift-flowing water over rocky substrates (Golder 2004b).

Based on Griffiths (1973) description of Eymundson Creek, the watercourse provides habitat for forage fish and possibly some seasonal habitat for large-bodied fish species from the Athabasca River (Golder 2004b). Golder (2002c) examined overwintering potential in lower Eymundson Creek and found the creek mouth was frozen to the bottom. As such, overwintering habitat was considered unavailable (Golder 2004b).

Fish Population

Flathead chub was the only species captured during the limited fish sampling conducted by Griffiths (1973). Angling was the only sampling method used.

Redclay Creek

Fish Habitat

Griffiths (1973) evaluated the entire length of Redclay Creek using a synoptic overflight. The watercourse was described as having poor fish habitat in the lower and upper reaches, although the middle section had improved habitat and was rated as fair.

Griffiths (1973) conducted a ground survey of one site in the middle section of Redclay Creek. A portion of the surveyed site was found to have a low gradient and fine sediment substrate, but where the channel gradient was steeper, the habitats consisted of riffles and pools with some rocky substrate. Pool substrate consisted of sand and silt and riffle substrate consisted of moss-covered boulders and gravel (Golder 2004b).

The presence of adult and juvenile Arctic grayling during the summer demonstrates that Redclay Creek provides summer rearing and feeding habitat for this species (Golder 2004b).

Fish Population

Arctic grayling is the only species captured in Redclay Creek (Griffiths 1973). However, angling was the only capture method used; therefore, suckers and small-bodied forage fish were not targeted for capture.

Unnamed Creek 2

Fish Habitat

The only habitat assessment of Unnamed Creek 2 was provided by Griffiths (1973), consisting of a synoptic overflight (ground surveys were not conducted to assess habitat). Based on the overflight, Griffiths (1973) described Unnamed Creek 2 as having poor sport fish habitat potential.

The presence of sucker fry in the summer suggests that sucker species may use the watercourse for nursery habitat and possibly spawning habitat (Golder 2004b). The presence of lake chub demonstrates that Unnamed Creek 2 provides habitat for this species (Golder 2004b).

Fish Population

Two previous reports reported information on fish use of Unnamed Creek 2 (Griffiths 1973; Herbert 1979). Only lake chub and unidentified sucker fry have been captured in this watercourse.

5.5.1.2 Environmental Field Survey

Fish habitat characteristics and fish population data collected specifically for the Project are presented in the following sections for selected watercourses and waterbodies in the PRMA LSA. Results include data from the habitat evaluation (habitat mapping, overwintering assessment, discharge and water quality surveys) and fish inventory (fish sampling and spawning survey).

Pierre River Watershed

The Pierre River mainstem was surveyed at two sites (Sites 20 and 19), which correspond to the Reach 1 and 2, respectively (Figure 5.2-2). In addition, an unnamed watercourse (Unnamed Creek 4) was surveyed at one site (Site 18) (Figure 5.2-2).

Watercourses

Pierre River

Habitat Assessment

Two watercourse sites on the Pierre River (Sites 20 and 19) were surveyed to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-1 and 5.5-2.

Site 20

The watercourse at Site 20 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest, consisting of poplar, birch and spruce. The banks of the watercourse were bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix N, Figure N-1). Site 20 consisted of riffle and run habitat having an average water depth of 0.4 m, a maximum water depth of 0.7 m and an average channel width of 10.63 m. Substrate throughout the surveyed reach consisted of clay/silt, sand, gravel and cobble. Both stream banks were stable throughout the surveyed area. Instream cover was limited and provided by substrate, woody debris and depth/turbulence. Overhead cover was limited and consisted of overhanging grasses. About 5% of the surveyed area contained aquatic macrophytes.

Discharge during the open-water period was measured during the spring (0.09 m^3/s), summer (0.34 m^3/s) and fall (0.10 m^3/s) (Table 5.5-1). Seasonal water quality was suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.5-1). Water temperature at Site 20 was continuously monitored from April 29, 2006 to August 1, 2006 (Appendix S, Figure S-12) using a thermograph. The water temperature fluctuated between 4.4 and 20.9°C throughout this time period. The peak water temperature (20.9°C) was recorded on June 27, 2006.

Table 5.5-1 Open-Water Seasonal Habitat Conditions at Watercourse Sampling Sites in the Pierre River Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Pierre River	20	spring	0.09	12.6	–[c]	338	7.76
		summer	0.34	13.4	14.26	402	8.15
		fall	0.10	5.8	9.50	374	8.08
	19	spring	–	16.2	–[c]	341	6.82
		summer	0.16	13.8	12.59	410	7.58
		fall	0.07	7.8	8.00	350	7.54
Unnamed Creek 4	18	spring	–[b]	15.3	–[c]	377	7.14
		summer	–[b]	13.3	7.63	366	6.96
		fall	0.04	8.4	8.50	370	7.54

[a] See Figure 5.2-2 for sampling site locations.

[b] Not measured, water levels too high, too deep to access mid-channel.

[c] Data not obtained due to equipment malfunction.

– = Not measured.

The winter field survey determined that there was no overwintering habitat within Site 20 at the time of the survey. The site was frozen to the bottom (Table 5.5-2).

Table 5.5-2 Winter Habitat Conditions at Watercourse Sampling Sites in the Pierre River Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Velocity [m/s]		Water Quality Field Parameters			
					Mean	Range	Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Pierre River	20	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	19	0.00	0.30	0.50	0.54	0.30 to 1.00	0.00	0.00 to 0.00	0.5	2.30	–[d]	7.11
Unnamed Creek 4	18	–[c]	0.40	0.50	0.85	n/a	0.00	0.00 to 0.00	0.5	2.16	621	7.25

[a] See Figure 5.2-2 for sampling site locations.

[b] Not measured, frozen to bottom.

[c] Not measured, not enough water depth across transect.

[d] Data not obtained due to equipment malfunction.

n/a = Not applicable.

Based on the habitat available at Site 20, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 19

The watercourse at Site 19 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar, birch and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix N, Figure N-2). Site 19 consisted of impoundment and flat habitat having an average water depth of 1.3 m, a maximum water depth of 1.5 m and an average channel width of 9.20 m. Substrate throughout the surveyed reach consisted of organics, clay/silt and sand. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris, aquatic vegetation and depth/turbulence. Overhead cover was limited and consisted of overhanging grasses. Approximately 60% of the surveyed area contained aquatic macrophytes.

Discharge during the open-water period was measured during summer (0.16 m^3/s) and fall (0.07 m^3/s), but not in the spring due to access limitations. (Table 5.5-1). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.5-1). Water temperature at Site 19 was continuously monitored from June 5, 2006 to August 3, 2006 (Appendix S, Figure S-14) using a thermograph. The water temperature fluctuated between 12.9 and 22.3°C throughout this time period. The peak water temperature (22.3°C) was recorded on June 29, 2006.

During the winter survey, there was no measurable discharge for the Pierre River at Site 19 (Table 5.5-2). The mean ice thickness was 0.50 m. Under-ice water depth ranged between 0.30 and 1.0 m and averaged 0.54 m. Dissolved oxygen level at the time of the survey was 2.3 mg/L.

Based on the habitat available at Site 19, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-3, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-4.

Site 20

Site 20 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted as the watercourse at this location was frozen to the bottom at the time of the survey. Arctic grayling, burbot, longnose sucker, brook stickleback, lake chub, pearl dace, slimy sculpin and trout-perch were captured during spring sampling (Table 5.5-3). Only lake chub were captured during summer sampling. In the fall, longnose sucker, lake chub and northern redbelly dace were captured.

Site 19

Site 19 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. No fish were captured during winter sampling. Longnose sucker, brassy minnow, brook stickleback, fathead minnow, lake chub and pearl dace were captured during the spring (Table 5.5-3). Only lake chub were captured during the summer. In the fall, longnose sucker, brook stickleback, lake chub and pearl dace were captured.

Table 5.5-3 Fish Species Captured at Sampling Sites in the Pierre River Watershed

Watercourse	Sampling Site[a]	Season	Number of Fish by Species and Life Stage[b] [c]																								
			Sport Fish									Non–Sport Fish						Forage Fish								Unknown	Total
			ARGR			BURB			NRPK			LNSC			WHSC			BRMN	BRST	FTMN	LKCH	LNDC	NRDC	PRDC	SLSC	TRPR		
			F[d]	J[d]	A[d]	F	J	A	F	J	A	F	J	A	F	J	A											
Pierre River	20	spring	–	1	–	–	1	–	–	–	–	–	14	–	–	–	–	–	1	–	35	–	–	6	9	3	–	**70**
		summer	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	11	10	–	–	–	–	2	**24**
		fall	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–	–	18	–	4	–	–	–	–	**28**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	19	spring	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	7	1	2	175	–	–	10	–	–	–	**201**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12	–	–	–	–	–	–	**12**
		fall	–	–	–	–	–	–	–	–	–	–	9	–	–	–	–	–	–	11	–	4	–	–	80	–	–	–	**104**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**
	202[e]	spring	–	–	–	–	–	–	–	–	–	–	3	1	–	4	–	–	–	–	–	144	–	–	–	–	1	–	–	**153**
	life stage total		*0*	*1*	*0*	*0*	*1*	*0*	*0*	*1*	*0*	*0*	*38*	*1*	*0*	*4*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**1**			**1**			**1**			**39**			**4**			**7**	**13**	**2**	**399**	**10**	**4**	**96**	**10**	**3**	**2**	**592**
Unnamed Creek 4	18	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	22	3	6	–	–	–	–	–	–	**31**
		summer	–	–	–	–	–	–	–	–	–	–	3	–	–	–	1	–	–	2	–	1	–	–	–	–	–	–	**7**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–	–	–	**3**
		winter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	**5**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*0*	*0*	*0*	*1*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	***n/a***
	species total		**0**			**0**			**0**			**3**			**1**			**0**	**31**	**3**	**7**	**0**	**1**	**0**	**0**	**0**	**0**	**46**

[a] See Figure 5.2-2 for sampling site locations.

[b] All sampling methods combined.

[c] Fish Species: ARGR = arctic grayling, BURB = burbot, NRPK = northern pike, LNSC = longnose sucker, WHSC = white sucker, BRMN = brassy minnow, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, NRDC = northern redbelly dace, PRDC = pearl dace, SLSC = slimy sculpin, TRPR = trout perch.

[d] Life Stage: F = Fry, J = Juvenile, A = Adult.

[e] Fish fence site.

n/a = Not applicable.

– = No fish captured.

Table 5.5-4 Catch-Per-Unit-Effort Results for Sampling Sites in the Pierre River Watershed

Watercourse	Sampling Site[a]	Season	Sport Fish[b]			Non-Sport Fish		Forage Fish										UNKN
			ARGR	BURB	NRPK	LNSC	WHSC	BRMN	BRST	FNDC	FTMN	LKCH	LNDC	NRDC	PRDC	SLSC	TRPR	
Backpack Electrofishing [Number/100 s]																		
Pierre River	20	spring	0.04	0.04	0.00	0.58	0.00	0.00	0.04	0.00	0.00	1.29	0.00	0.00	0.25	0.38	0.13	0.00
		summer	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.94	0.00	0.00	0.00	0.00	0.21
		fall	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	2.46	0.00	0.49	0.00	0.00	0.00	0.00
	19	summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	0.00
Unnamed Creek 4	18	spring	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.22	0.43	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.40	0.13	0.00	0.13	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minnow Trapping [Number/Trap-hr]																		
Pierre River	20	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.05	0.00	0.00	0.00	0.00
	19	spring	0.00	0.00	0.00	2.98	0.00	3.47	0.50	0.00	0.99	86.84	0.00	0.00	4.96	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.92	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.00	14.56	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 4	18	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	2.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-2 sampling site locations.

[b] Fish Species: ARGR = arctic grayling, BURB = burbot, NRPK = northern pike, LNSC = longnose sucker, WHSC = white sucker, BRMN = brassy minnow, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, NRDC = northern redbelly dace, PRDC = pearl dace, SLSC = slimy sculpin, TRPR = trout perch.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Fish Fence (Site 202)

A counting fence was installed 350 m upstream from the confluence of Pierre River with the Athabasca River and was maintained from April 29, 2006 to May 31, 2006. In addition to the fence, two minnow traps were set and checked on a daily basis. The fish fence captured one adult longnose sucker moving downstream on May 19, 2006 (Table 5.5-5). The minnow traps captured three longnose sucker, four white sucker, 144 lake chub and one slimy sculpin (Table 5.5-5). The results from this site differ significantly from the counting fence results reported during previous sampling by Golder (2004b) at this location, which captured sport fish such as northern pike, Arctic grayling, burbot, mountain whitefish and walleye.

Discharge was measured when water levels fluctuated significantly (Table 5.5-6). Field-level water quality data were recorded daily throughout the operation of the counting fence. (Table 5.5-6). Water temperature was continuously monitored from April 29, 2006 to June 2, 2006 (Appendix S, Figure S-13) using a thermograph. Daily average water temperatures fluctuated between 4.3 and 14.1°C.

Table 5.5-5 Fish Species Captured During the Fish Fence Operation at Pierre River, 2006

Date Checked	Trap Type	Trap # or Direction	Non-Sport Fish Species[a]		Forage Fish	
			LNSC	WHSC	LKCH	SLSC
April 30, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
May 1, 2006	minnow trap	1	–	2	–	–
		2	–	–	–	1
May 2, 2006	n/a	n/a	–[b]	–[b]	–[b]	–[b]
May 3, 2006	minnow trap	1	–	–	–	–
		2	–	1	–	–
May 4, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 5, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 6, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 7, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 8, 2006	minnow trap	1	–	–	6	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–

Table 5.5-5 Fish Species Captured During the Fish Fence Operation at Pierre River, 2006 (continued)

Date Checked	Trap Type	Trap # or Direction	Non-Sport Fish Species[a]		Forage Fish	
			LNSC	WHSC	LKCH	SLSC
		downstream	–	–	–	–
May 9, 2006	n/a	n/a	–[b]	–[b]	–[b]	–[b]
May 10, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 11, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 12, 2006	minnow trap	1	–	–	12	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 13, 2006	minnow trap	1	–	–	17	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 14, 2006	minnow trap	1	–	1	20	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 15, 2006	minnow trap	1	–	–	15	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 16, 2006	minnow trap	1	1	–	21	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 17, 2006	minnow trap	1	–	–	5	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 18, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 19, 2006	minnow trap	1	–	–	5	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	1	–	–	–
May 20, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 21, 2006	minnow trap	1	1	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–

Table 5.5-5 Fish Species Captured During the Fish Fence Operation at Pierre River, 2006 (continued)

Date Checked	Trap Type	Trap # or Direction	Non-Sport Fish Species[a]		Forage Fish	
			LNSC	WHSC	LKCH	SLSC
May 22, 2006	minnow trap	1	1	–	1	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 23, 2006	minnow trap	1	–	–	–	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 24, 2006	minnow trap	1	–	–	6	–
		2	–	–	5	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 25, 2006	minnow trap	1	–	–	7	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 26, 2006	minnow trap	1	–	–	10	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 27, 2006	minnow trap	1	–	–	1	–
		2	–	–	–	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 28, 2006	minnow trap	1	–	–	2	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 29, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 30, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
May 31, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
June 1, 2006	minnow trap	1	–	–	–	–
		2	–	–	1	–
	fyke net	upstream	–	–	–	–
		downstream	–	–	–	–
Species Total			**4**	**4**	**144**	**1**

[a] Fish Species: LNSC = longnose sucker, WHSC = white sucker, LKCH = lake chub, SLSC = slimy sculpin.

[b] Could not access traps due to weather.

n/a = Not applicable.

– = No fish captured.

Table 5.5-6 Water Temperature, Water Quality and Discharge Data During the Fish Fence Operation, Pierre River, 2006

Date	Discharge [m^3/s]	Water Quality Parameters				
		Water Temperature [°C]		Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
		Minimum	Maximum			
April 29, 2006	0.29	7.1	10.2	11.68	475	8.27
April 30, 2006	–	6.2	10.3	–	–	8.22
May 1, 2006	–	5.6	8.6	12.16	348	8.28
May 2, 2006	–[(a)]	4.2	6.4	–[(a)]	–[(a)]	–[(a)]
May 3, 2006	–	2.4	7.0	13.27	339	8.14
May 4, 2006	–	4.6	8.5	12.48	342	8.11
May 5, 2006	0.24	5.1	9.8	12.57	351	8.13
May 6, 2006	–	6.1	10.8	12.08	352	8.24
May 7, 2006	–	7.1	11.7	9.27	388	8.04
May 8, 2006	0.25	7.3	11.4	11.42	367	8.24
May 9, 2006	–[(a)]	7.5	9.7	–[(a)]	–[(a)]	–[(a)]
May 10, 2006	–	6.7	10.8	12.40	368	8.17
May 11, 2006	–	6.3	12.0	12.39	375	8.22
May 12, 2006	0.28	7.4	12.9	8.16	373	–
May 13, 2006	–	8.1	12.5	–	–	–
May 14, 2006	–	9.0	13.1	12.85	315	7.96
May 15, 2006	0.20	8.4	14.0	12.97	312	7.99
May 16, 2006	–	8.1	14.3	13.71	267	7.95
May 17, 2006	–	10.4	14.5	12.92	311	7.96
May 18, 2006	–	9.9	15.4	12.59	314	7.69
May 19, 2006	0.59	10.1	13.7	11.45	245	8.31
May 20, 2006	–	7.7	11.3	12.06	400	8.30
May 21, 2006	–	7.9	10.2	10.98	400	7.74
May 22, 2006	0.36	7.6	13.9	10.76	399	7.86
May 23, 2006	–	10.3	19.4	10.72	399	7.94
May 24, 2006	–	9.5	12.6	10.63	401	7.93
May 25, 2006	–	8.4	11.3	10.89	400	7.96
May 26, 2006	–	8.5	10.9	10.87	397	7.99
May 27, 2006	0.31	6.4	11.7	11.26	395	8.03
May 28, 2006	–	8.1	12.5	11.18	395	7.98
May 29, 2006	–	9.8	13.4	10.72	398	8.00
May 30, 2006	–	10.2	12.9	10.34	391	8.11
May 31, 2006	0.15	9.1	14.5	11.69	400	7.97

[(a)] No access to fish fence site due to weather.

– = No measurement.

Unnamed Creek 4

Habitat Assessment

One unnamed tributary to the Pierre River, Unnamed Creek 4, was surveyed at Site 18 to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-1 and 5.5-2.

Site 18

Unnamed Creek 4 at Site 18 had an irregular meandering and a frequently confined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar, birch and spruce and the banks were bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix N, Figure N-3). Site 18 consisted of run and flat habitat having an average water depth of 0.85 m and an average channel width of 3.24 m. Substrate throughout the surveyed reach consisted of clay/silt, sand. Both stream banks were approximately stable throughout the surveyed area. Instream cover was abundant and provided by woody debris and inundated vegetation. Overhead cover was limited and consisted of overhanging grasses.

Discharge was measured during the fall (0.04 m^3/s) (Table 5.5-1), but not in the spring and summer due to stream accessibility. Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.5-1).

Discharge could not be measured in Unnamed Creek 4 at Site 18 at the time of the winter survey due to insufficient water depths across the entire transect. The mean ice thickness was 0.50 m (Table 5.5-2). Under-ice water depth at the point location was 0.85 m. Dissolved oxygen level at the time of the survey was 2.2 mg/L.

Based on the habitat available at Site 18, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, moderate for spawning for species requiring aquatic vegetation.

Fish Population

Site 18

Site 18 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. Numbers of fish recorded by species and

life stage are presented in Table 5.5-3, sampling effort is presented in Table 5.2-4 and 5.2-5 and CPUE data are presented by sample technique in Table 5.5-4. Brook stickleback were captured during the winter. Brook stickleback, fathead minnow and lake chub were captured during the spring. Longnose sucker, white sucker, brook stickleback and lake chub were captured during the summer. In the fall, brook stickleback and northern redbelly dace were captured.

Eymundson Creek Watershed

Watercourses

Eymundson Creek Mainstem

Habitat Assessment

Six watercourse sites on Eymundson Creek (Sites 17, 7, 11, 57, 6 and 3), a tributary to the Athabasca River, were surveyed to assess seasonal fish habitat use potential. Each site occurs within one of the four reaches established on Eymundson Creek (Figure 5.2-2). The results for the open-water season and winter habitat conditions are presented in Tables 5.5-7 and 5.5-8, respectively.

Site 17

The watercourse at Site 17 had an irregular meandering and a frequently confined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar, birch and spruce and the banks were bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-1). Site 17 consisted of run and flat habitat having an average water depth of 0.6 m and an average channel width of 20.25 m. Substrate throughout the surveyed reach consisted of clay/silt, sand and some gravel. Both stream banks were approximately 25% unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris and depth/turbulence. Overhead cover was limited and consisted of overhanging grasses.

Table 5.5-7 Open-Water Habitat Conditions at Watercourse Sampling Sites in the Eymundson Creek Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Eymundson Creek	17	spring	0.27	11.7	11.11	440	8.65
		summer	0.88	12.3	12.17	310	7.84
		fall	0.49	4.7	9.01	301	7.92
	7	spring	0.23	12.7	10.62	352	7.93
		summer	0.54	13.3	9.46	340	7.96
		fall	0.38	6.5	11.90	273	8.02
	11	spring	0.20	10.1	–[c]	299	7.31
		summer	0.60	11.0	12.02	332	7.63
		fall	0.30	5.5	9.07	231	7.71
	57	fall	0.00	7.1	5.78	403	7.06
	6	spring	–[b]	14.1	12.40	227	6.38
		summer	–[b]	13.2	6.67	255	7.00
		fall	–[b]	5.6	6.96	297	7.11
	3	fall	0.01	2.4	9.35	271	7.38
Asphalt Creek	5	spring	0.18	12.3	–[c]	301	7.37
		summer	0.70	13.3	13.01	351	7.38
		fall	0.17	4.8	13.50	313	7.61
	48	spring	0.34	12.5	9.36	344	7.50
		summer	0.18	15.0	12.23	278	8.13
		fall	0.15	5.5	10.96	378	7.93
Unnamed Creek 1	16	spring	0.06	11.3	9.59	520	8.12
		summer	0.33	12.1	8.90	209	7.35
		fall	0.17	6.3	11.90	206	7.55
	15	spring	0.05	12.3	10.46	500	7.77
		summer	0.35	13.1	13.50	211	7.05
		fall	0.13	5.8	8.96	240	7.20
Unnamed Creek 11	12	spring	0.00	14.8	–[c]	314	7.11
		summer	–[b]	14.8	6.69	403	7.48
		fall	0.04	8.7	8.20	396	7.59

[a] See Figure 5.2-2 for sampling site locations.

[b] Site conditions did not allow measurement (too shallow, water too deep or substrate too soft for gear and/or safe wading).

[c] Data not obtained due to equipment malfunction.

– = No measurement.

Table 5.5-8 Winter Habitat Conditions at Watercourse Sampling Sites in the Eymundson Creek Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Velocity [m/s]		Water Quality Field Parameters			
					Mean	Range	Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Eymundson Creek	17	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	7	–[c]	0.45	0.35	0.15	–	–[c]	–[c]	0.0	1.69	1,493	7.33
	11	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	6	–[c]	0.40	0.75	0.30	–	–[c]	–[c]	0.2	1.03	853	6.59
Asphalt Creek	5	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	48	–[b]	0.48	0.25	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
Unnamed Creek 1	16	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	15	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
Unnamed Creek 11	12	–[b]	–	–	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]

[a] See Figure 5.2-2 for sampling site locations.

[b] Not measured, frozen to bottom.

[c] No measurable flow or discharge.

– = Not measured.

Discharge was measured during spring (0.27 m^3/s), summer (0.88 m^3/s) and fall (0.49 m^3/s) (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.5-7). Water temperature at Site 17 was continuously monitored from June 6, 2006 to August 1, 2006 (Appendix S, Figure S-15) using a thermograph. The water temperature fluctuated between 10.5 and 21.8°C throughout this time period. The peak water temperature (21.8°C) was recorded on June 16, 2006.

The winter field survey determined that there was no overwintering habitat within Site 17 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 17, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 7

The watercourse at Site 7 had an irregular meandering and unconfined channel. The watercourse had a low gradient with moderate velocities and shallow to moderate depths. The surveyed section of the watercourse was located within a mixedwood forest and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-2). Site 7 consisted of run and riffle habitat, with a small boulder garden section, having an average water depth of 0.5 m, a maximum water depth of 1.0 m and an average channel width of 10.07 m. Substrate throughout the surveyed reach consisted of sand, gravel and cobble. Both stream banks were approximately 20% unstable throughout the surveyed area. Instream cover was abundant and provided by substrate, woody debris and depth/turbulence. Overhead cover was abundant and consisted of overhanging grasses and undercut banks.

Discharge was measured during spring (0.23 m^3/s), summer (0.54 m^3/s) and fall (0.38 m^3/s) (Table 5.5-7). Seasonal water quality was suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.5-7).

Discharge could not be measured in Eymundson Creek at Site 7 at the time of the winter survey as there was no measurable flow. The mean ice thickness was 0.35 m (Table 5.5-8). Average under-ice water depth was 0.15 m. Dissolved oxygen level at the time of the survey was 1.69 mg/L. Conductivity was notably higher in the winter compared to the open-water period, indicating that groundwater constitutes a higher portion of the winter flow.

Based on the habitat available at Site 7, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; high for nursery, rearing and feeding; moderate for spawning.
- Forage fish: low for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 11

The watercourse at Site 11 had an irregular meandering and unconfined channel throughout. The surveyed section of the watercourse was located within a mixedwood forest containing poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-3). Site 11 consisted of run habitat having an average water depth of 0.3 m, a maximum depth of 0.7 m and an average channel width of 8.92 m. Substrate throughout the surveyed reach consisted of clay/silt and sand. Both stream banks were approximately 20% unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris. Overhead cover was abundant and consisted of overhanging grasses and undercut banks.

Discharge was measured during spring (0.20 m^3/s), summer (0.60 m^3/s) and fall (0.30 m^3/s) (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species throughout the open-water season (Table 5.5-7). Water temperature at Site 11 was continuously monitored from June 7, 2006 to August 2, 2006 (Appendix S, Figure S-16) using a thermograph. The water temperature fluctuated between 10.4 and 22.7°C throughout this time period. The peak water temperature (22.7°C) was recorded on June 16, 2006.

The winter field survey determined that there was no overwintering habitat within Site 11 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 11, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 57

Site 57 was only surveyed in the fall and was later removed from the sampling program due to its close proximity to Site 6. The watercourse at this location had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-4). Site 57 consisted of flat and impoundment pool habitat having an average water depth of 1.8 m, a maximum water depth of 2.0 m and an average channel width of 5.40 m. Substrate throughout the surveyed reach consisted of organics and clay/silt. Both stream banks were 100% unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris, aquatic vegetation and depth/turbulence. Overhead cover was limited and consisted of woody debris, undercut banks, overhanging grasses and overhanging trees and shrubs. About 30% of the surveyed area contained aquatic macrophytes.

No measurable discharge was recorded at the time of the fall survey (Table 5.5-7). Fall water quality was suitable for use by all fish species and DO levels were suitable to support fish (Table 5.5-7).

Based on the habitat available at Site 57, the seasonal habitat use was as follows:

- Sport fish: low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.

- Non-sport fish: low for nursery, rearing and feeding; nil for spawning.
- Forage fish: high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring aquatic vegetation.

Site 6

The watercourse at Site 6 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar, birch and spruce and was bordered predominately by grass/forbs with some shrubs present.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-5). Site 6 consisted of impoundments and flat habitat having an average water depth of 1.0 m, a maximum depth of 1.2 m and an average channel width of 16.67 m. Substrate throughout the surveyed reach consisted of organics and clay/silt. Both stream banks were stable throughout the surveyed area. Instream cover was limited and provided by woody debris, depth/turbulence and vegetation. Overhead cover was limited and consisted of overhanging grasses. About 75% of the surveyed area contained aquatic macrophytes.

Discharge was not recorded due to stream access issues. Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.5-7). Water temperature at Site 6 was continuously monitored from June 3, 2006 to August 3, 2006 (Appendix S, Figure S-17) using a thermograph. The average daily water temperature fluctuated between 12.5 and 22.1°C throughout this time period. The peak water temperature (22.1°C) was recorded on July 21, 2006.

Discharge could not be measured in Eymundson Creek at Site 6 at the time of the winter survey since most of the channel was frozen to the bottom. Under-ice water depth at the point measurement was 0.30 m. The mean ice thickness was 0.75 m (Table 5.5-8). Dissolved oxygen level at the time of the survey was 1.0 mg/L. Conductivity was notably higher in the winter compared to the open-water period, indicating that groundwater constitutes a higher portion of the winter flow.

Based on the habitat available at Site 6, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning.

- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Site 3

Site 3 was only surveyed in the fall and was later removed from the sampling program due to its close proximity to Site 6. The watercourse at this location exhibited an unconfined, meandering channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar, birch and spruce and was bordered predominately by grass and forbs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix T, Figure T-6). Site 3 consisted of run, flat and impoundment habitat having both average and maximum water depths of 0.4 m and an average channel width of 15.33 m. Substrate throughout the surveyed reach consisted of organics and clay/silt. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris, depth/turbulence and aquatic vegetation. Overhead cover was limited and consisted of overhanging grasses and undercut banks.

Discharge was measured during the fall and was 0.01 m^3/s at the time of the survey (Table 5.5-7). Fall water quality was suitable for use by all fish species (Table 5.5-7).

Based on the habitat available at Site 3, the seasonal habitat use was as follows:

- Sport fish: low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low for nursery, rearing and feeding; nil for spawning.
- Forage fish: moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Table 5.5-9 Fish Species Captured at Sampling Sites in the Eymundson Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Number of Fish by Species and Life Stage[b] [c]																		Total
			Sport Fish						Non-Sport Fish						Forage Fish						
			ARGR			BURB			LNSC			WHSC			BRST	FTMN	LKCH	NRDC	PRDC	TRPR	
			F[d]	J[d]	A[d]	F	J	A	F	J	A	F	J	A							
Eymundson Creek	17	spring	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	5	6
	7	spring	–	–	–	–	–	–	–	–	–	–	1	–	–	–	2	–	–	–	3
		summer	–	2	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	4
		fall	–	–	–	–	–	–	–	1	–	–	–	–	–	–	5	–	–	–	6
	11	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	27	–	–	–	27
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7	–	1	–	8
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	31	–	–	–	31
	57	fall	–	–	–	–	–	–	–	–	–	–	–	–	21	4	–	–	–	–	25
	6	spring	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	4
		summer	–	–	–	–	–	–	–	–	–	–	–	–	15	–	–	–	–	–	15
		fall	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	–	–	20
	3	fall	–	–	–	–	–	–	–	–	–	–	–	–	74	–	–	6	–	–	80
	life stage total		*0*	*2*	*0*	*1*	*0*	*0*	*0*	*1*	*0*	*0*	*1*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**2**			**1**			**1**			**1**			**134**	**4**	**74**	**6**	**1**	**5**	**229**
Asphalt Creek	5	spring	–	–	–	–	–	–	–	–	–	–	–	–	2	–	24	–	–	–	26
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	34	–	–	–	34
	48	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	2
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	31	–	–	–	31
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**			**0**			**0**			**0**			**2**	**0**	**92**	**0**	**0**	**0**	**94**
Unnamed Creek 1	16	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	2
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	4
	15	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	2
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**			**0**			**0**			**0**			**0**	**0**	**6**	**0**	**2**	**0**	**8**
Unnamed Creek 11	12	spring	–	–	–	–	–	–	–	–	–	–	–	–	18	–	65	–	–	–	83
		summer	–	–	–	–	–	–	–	–	–	–	–	–	9	–	6	–	–	–	15
		fall	–	–	–	–	–	–	–	–	1	–	–	–	7	–	–	–	6	–	14
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**			**0**			**1**			**0**			**24**	**0**	**71**	**0**	**6**	**0**	**112**
Unnamed Waterbody 6	2	fall	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	3
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**			**0**			**0**			**0**			**3**	**0**	**0**	**0**	**0**	**0**	**3**

[a] See Figure 5.2-2 for sampling site locations.

[b] All sampling methods combined.

[c] Fish Species: ARGR = arctic grayling, BURB = burbot, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace, TRPR = trout perch.

[d] Life Stage: F = Fry, J = Juvenile, A = Adult.

n/a = Not applicable.

– = No fish captured.

Table 5.5-10 Catch-Per-Unit-Effort Results for Sampling Sites in the Eymundson Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]		Non-Sport Fish	Forage Fish							
			ARGR	BURB	WHSC	BRST	FTMN	LKCH	LNSC	NRDC	PRDC	SLSC	TRPR
Backpack Electrofishing [Number/100 s]													
Eymundson Creek	17	spring	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7	spring	0.00	0.00	0.09	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
		summer	0.29	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.35	0.07	0.00	0.00	0.00	0.00
	11	spring	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.13	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	3.84	0.00	0.00	0.00	0.00	0.00
	57	fall	0.00	0.00	0.00	3.94	0.59	0.00	0.00	0.00	0.00	0.00	0.00
	6	spring	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	2.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	fall	0.00	0.00	0.00	9.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asphalt Creek	5	spring	0.00	0.00	0.00	0.11	0.00	0.23	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	0.00	0.00	0.00
	48	spring	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 1	16	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00
	15	spring	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 11	12	spring	0.00	0.00	0.00	1.36	0.00	4.09	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.81	0.00	0.81	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.58	0.00	0.00
Unnamed Waterbody 5	14	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.5-10 Catch-Per-Unit-Effort Results for Sampling Sites in the Eymundson Creek Watershed (continued)

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]		Non-Sport Fish	Forage Fish							
			ARGR	BURB	WHSC	BRST	FTMN	LKCH	LNSC	NRDC	PRDC	SLSC	TRPR
Minnow Trapping [Number/Trap-hr]													
Eymundson Creek	17	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11	spring	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	57	fall	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	0.00	0.00
	6	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	fall	0.00	0.00	0.00	2.69	0.00	0.00	0.00	0.49	0.00	0.00	0.00
Asphalt Creek	5	spring	0.00	0.00	0.00	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.00
	48	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 1	16	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	15	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 11	12	spring	0.00	0.00	0.00	0.98	0.00	5.66	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	1.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.05	0.00	0.00

Table 5.5-10 Catch-Per-Unit-Effort Results for Sampling Sites in the Eymundson Creek Watershed (continued)

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]		Non-Sport Fish	Forage Fish							
			ARGR	BURB	WHSC	BRST	FTMN	LKCH	LNSC	NRDC	PRDC	SLSC	TRPR
Unnamed Waterbody 5	14	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 6	2	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gill Netting [Number/Panel-hr]													
Unnamed Waterbody 5	14	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 6	2	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-2 for sampling site locations.

[b] Fish Species: ARGR = arctic grayling, BURB = burbot, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace, TRPR = trout perch.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Site 17

Site 17 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. No fish were captured during the winter, summer and fall. In the spring, a single burbot (fry) and five trout-perch were captured.

Kick net spawning surveys were conducted during the spring at this location. Five separate sampling events covering approximately 15 m^2 yielded no eggs.

Site 7

Site 7 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Winter sampling could not be conducted, as the site was frozen to the bottom. White sucker and lake chub were captured during spring sampling. During summer, two Arctic grayling (juveniles) and lake chub were captured. Longnose sucker and lake chub were captured during the fall.

Kick net spawning surveys were conducted at this location. Ten separate sampling events covering approximately 30 m^2 yielded no eggs.

Site 11

Site 11 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Lake chub was the only species captured during spring and fall sampling. Lake chub and pearl dace were both present during the summer.

Site 57

Site 57 was surveyed for sport, non-sport and forage fish during the fall field survey. Brook stickleback and fathead minnow were captured during the survey.

Site 6

Site 6 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted due to unsuitable water depths in the watercourse at the time of sampling. Brook stickleback was the only species captured during the spring, summer and fall.

Site 3

Site 3 was surveyed for sport, non-sport and forage fish during the fall field survey. Brook stickleback and northern redbelly dace were captured during the survey.

Asphalt Creek

Habitat Assessment

Two watercourse sites on Asphalt Creek, tributary to Eymundson Creek, were surveyed (Sites 5 and 48) (Figure 5.2-2) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat measurements are presented in Tables 5.5-7 and 5.5-8.

Site 5

The watercourse at Site 5 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-7). Site 5 consisted of run habitat having an average water depth of 0.7 m, a maximum water depth of 1.1 m and an average channel width of 11.17 m. Substrate throughout the surveyed reach consisted of sand, gravel and cobble. Both stream banks were approximately 25% unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris, depth/turbulence and aquatic vegetation. Overhead cover was limited and consisted of woody debris, overhanging grasses and undercut banks.

Discharge was recorded in the spring (0.18 m^3/s), summer (0.70 m^3/s) and fall (0.17 m^3/s) (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-7). Water temperature at Site 5 was continuously monitored from June 6, 2006 to August 2, 2006 (Appendix S, Figure S-18) using a thermograph. The water temperature fluctuated between 8.9 and 23.6°C throughout this time period. The peak water temperature (23.6°C) was recorded on June 16, 2006.

The winter field survey determined that there was no overwintering habitat within Site 5 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 5, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; moderate for spawning.

- Forage fish: nil for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.

Site 48

The watercourse at Site 48 had an irregular meandering and occasionally confined channel. The surveyed section of the watercourse was located within a mixed mature forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix T, Figure T-8). Site 48 consisted of run and riffle habitat, with an average water depth of 0.3 m, a maximum water depth of 0.7 m and an average channel width of 9.38 m. The substrate consisted of organics, clay/silt, sand, gravel, cobble and boulders. The stream banks were approximately 85% unstable throughout the surveyed area. Instream cover was available in moderate abundance and was composed of woody debris, substrate and turbidity. Overhead cover also was moderately abundant and was provided by undercut banks, overhanging vegetation and woody debris.

Discharge was recorded in the spring (0.34 m^3/s), summer (0.18 m^3/s) and fall (0.15 m^3/s) (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-7). Water temperature at Site 48 was continuously monitored from May 27 to July 25, 2007 (Appendix S, Figure S-19) using a thermograph. The water temperature fluctuated between 5.7 and 21.6°C throughout this time period, resulting in an average temperature of 14.4°C. The peak water temperature (21.6°C) was recorded on July 13, 2007.

The winter field survey determined that there was no overwintering habitat within Site 48 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 48, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning.

- Forage fish: nil for overwintering; high for nursery, rearing and feeding; moderate for spawning.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Site 5

Site 5 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Two lake chub were captured during the spring and no fish were captured during the summer and fall. Brook stickleback was the only species captured during the spring, summer and fall.

Site 48

Site 48 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field survey seasons. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Lake chub was the only species caught in the spring, summer and fall sampling seasons.

Kick net spawning surveys were conducted during the spring at this location. Ten separate sampling events covering approximately 10 m^2 yielded no eggs.

Unnamed Creek 1

Habitat Assessment

Unnamed Creek 1, a tributary to Eymundson Creek, was surveyed at two locations (Sites 16 and 15) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-7 and 5.5-8.

Site 16

Unnamed Creek 1 at Site 16 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce was bordered by grass/forbs and shrubs of willow and alder.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-9). Site 16 consisted of run, riffle and flat habitat with an average water depth of 0.7 m, a

maximum water depth of 1.0 m and an average channel width of 7.00 m. Substrate throughout the surveyed reach consisted of clay/silt, sand, gravel and cobble. Approximately 20% of both stream banks were unstable throughout the surveyed area. Instream cover was abundant and provided by substrate, woody debris and depth/turbulence. Overhead cover was abundant and consisted of overhanging grasses and undercut banks.

Discharge was recorded in the spring (0.06 m^3/s), summer (0.33 m^3/s) and fall (0.17 m^3/s) (Table 5.5-7). Seasonal water quality was suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.5-7).

The winter field survey determined that there was no overwintering habitat within Site 16 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 16, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring aquatic vegetation.

Site 15

Unnamed Creek 1 at Site 15 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-10). Site 15 consisted of run and riffle habitat having maximum water depth of 0.3 m and an average channel width of 3.59 m. Substrate throughout the surveyed reach consisted of clay/silt, sand and a little bit of gravel. Approximately 20% of both stream banks were unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris. Overhead cover was limited and consisted of overhanging grasses and undercut banks.

Discharge was recorded in the spring (0.05 m^3/s), summer (0.35 m^3/s) and fall (0.13 m^3/s) (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-7). Water temperature at Site 15 was continuously monitored from June 6, 2006 to August 2, 2006 (Appendix S, Figure S-20) using a thermograph. The water temperature fluctuated between 9.7 and 22.3°C throughout this time period. The peak water temperature (22.3°C) was recorded on June 16, 2006.

The winter field survey determined that there was no overwintering habitat within Site 15 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 15, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; low for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; low for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Site 16

Site 16 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Pearl dace were captured during the spring sampling and lake chub were captured during the fall. No fish were captured during the summer sampling.

Kick net spawning surveys were conducted at this location. Five separate sampling events covering approximately 15 m^2 yielded no eggs.

Site 15

Site 15 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Two

lake chub were captured during the spring and no fish were captured during the summer and fall. Brook stickleback was the only species captured during the spring, summer and fall.

Unnamed Creek 11

Habitat Assessment

One site on Unnamed Creek 11, a tributary to Eymundson Creek, was surveyed. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-7 and 5.5-8.

Site 12

Unnamed Creek 11 at Site 12 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs, mostly willows.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix O, Figure O-11). Site 12 consisted of run habitat having a maximum water depth of 1.1 m and an average channel width of 0.90 m. Substrate throughout the surveyed reach consisted of organics and clay/silt. Both stream banks were stable throughout the surveyed area. Instream cover was abundant and provided by woody debris, depth/turbulence and aquatic vegetation. Overhead cover was abundant and consisted of overhanging grasses.

Discharge was recorded in the spring (no measurable discharge) and fall (0.04 m^3/s) but not in the summer due to access issues (Table 5.5-7). Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species and DO levels were suitable to support fish throughout the open-water season (Table 5.5-7). Water temperature at Site 12 was continuously monitored from June 9, 2006 to August 2, 2006 (Appendix S, Figure S-21) using a thermograph. The water temperature fluctuated between 10.1 and 22.9°C throughout this time period. The peak water temperature (22.9°C) was recorded on June 16, 2006.

The winter field survey determined that there was no overwintering habitat within Site 12 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 12, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: nil for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Site 12

Site 12 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. A winter fish assessment was not conducted because the watercourse was frozen to the bottom at the time of sampling. Brook stickleback and lake chub were the only species captured during the spring and summer. Longnose sucker, brook stickleback and pearl dace were captured during the fall.

Waterbodies

Two waterbodies, Unnamed Waterbody 5 and Unnamed Waterbody 6, within the Eymundson Creek watershed were surveyed to assess seasonal fish habitat use potential.

Unnamed Waterbody 5

Habitat Assessment

Unnamed Waterbody 5 drains into an unnamed tributary of Unnamed Creek 1. The results for the open-water and winter habitat conditions are presented in Tables 5.5-11 and 5.5-12.

Site 14

Unnamed Waterbody 5 (Site 14) has a perimeter of approximately 0.7 km and an approximate surface area of 0.04 km^2. The waterbody was dominated by shallow littoral habitat with emergent vegetation with a small limnetic zone located near the centre (Appendix O, Figure O-12). The waterbody shore slope was moderate to steep and was surrounded by a mixedwood forest of poplar, spruce and tamarack. The average and maximum depths recorded throughout the open-water seasons were 2.18 m and 4.63 m, respectively. The substrate consisted of organics and silt.

Table 5.5-11 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Eymundson Creek Watershed

Waterbody	Sampling Site[(a)]	Season	Station	Point or Profile	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 5	14	spring	1	profile	4.30	0.50	19.5	10.25	1,456	9.20
						1.00	17.8	10.31	1,459	9.20
						1.50	15.8	11.40	1,473	9.19
						2.00	12.7	9.57	1,536	9.18
						2.50	11.4	7.75	1,568	9.17
						3.00	10.7	4.94	1,594	9.15
						3.50	9.2	3.08	1,651	9.12
						4.00	7.3	1.31	1,728	9.08
			2	point	2.90	0.50	19.3	10.03	1,460	9.18
			3	point	1.30	0.50	20.0	10.31	1,458	9.13
		summer	1	point	0.80	0.50	19.2	11.49	1,641	9.25
			2	profile	4.20	1.00	18.6	12.13	1,655	9.24
						2.00	18.4	11.17	1,651	9.24
						3.00	18.2	10.17	1,653	9.23
			3	profile	2.90	1.00	19.3	11.04	1,694	9.28
						2.00	19.4	11.23	1,637	9.26
			4	profile	3.40	1.00	19.0	10.29	1,695	9.24
						2.00	19.2	9.09	1,634	9.25
						3.00	19.4	11.60	1,691	9.28
			5	point	3.40	1.00	19.4	11.01	1,681	9.34
		fall	1	point	0.60	0.30	9.1	7.32	1,534	9.33
			2	point	1.02	0.30	8.7	6.41	1,532	9.33
			3	point	0.79	0.30	8.9	6.44	1,532	9.33
			4	point	2.09	0.30	8.5	6.45	1,531	9.34
			5	point	1.84	0.30	8.1	6.50	1,532	9.30
			6	point	1.54	0.30	8.0	6.51	1,532	9.34
			7	point	1.77	0.30	8.2	6.53	1,531	9.34
			8	point	0.92	0.30	8.7	6.68	1,532	9.33
			9	point	0.85	0.30	8.7	6.72	1,532	9.33

Table 5.5-11 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Eymundson Creek Watershed (continued)

Waterbody	Sampling Site[a]	Season	Station	Point or Profile	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 5 (continued)	14 (continued)	fall (continued)	10	profile	4.63	0.30	9.4	6.49	1,531	9.33
						0.50	8.3	6.74	1,534	9.33
						1.00	8.3	6.55	1,532	9.33
						1.50	7.6	6.35	1,529	9.33
						2.00	7.5	6.13	1,532	9.33
						2.50	7.5	6.02	1,533	9.33
						3.00	7.4	6.05	1,533	9.35
						3.50	7.4	5.94	1,533	9.34
						4.00	7.3	5.62	1,534	9.34
						4.50	7.1	5.34	1,534	9.32
Unnamed Waterbody 6	2	spring	1	point	1.50	1.50	10.3	–[b]	279	7.73
		summer	1	point	0.20	0.20	20.4	–[b]	306	6.91
		fall	1	point	1.15	0.30	5.3	9.30	213	6.93
			2	point	1.12	0.30	5.4	9.31	211	6.86
			3	point	1.26	0.30	5.4	9.34	212	6.85
			4	point	1.15	0.30	5.6	9.41	211	6.84
			5	point	1.09	0.30	5.6	9.41	212	6.82
			6	point	1.14	0.30	5.5	9.39	211	6.85
			7	point	1.29	0.30	5.7	9.41	210	6.88
			8	profile	1.32	0.30	6.0	9.27	209	6.87
						0.50	5.9	9.11	211	6.86
						1.00	5.8	9.10	209	6.87
						1.20	5.4	9.03	211	6.90
			9	point	1.32	0.30	5.7	9.24	210	6.81
			10	point	1.30	0.30	5.9	9.31	212	6.85

[a] See Figure 5.2-2 for sample site locations.

[b] Not measured.

Table 5.5-12 Winter Habitat Conditions at Waterbody Sampling Sites in the Eymundson Creek Watershed

Waterbody	Sampling Site[a]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 5	14	1	profile	0.45	3.65	0.75	1.4	2.61	1,043	14.55
						1.20	1.9	2.35	1,066	13.72
						1.80	2.2	1.87	1,076	15.23
						2.30	2.3	1.79	1,075	13.62
						2.80	2.4	1.97	1,080	14.00
						3.30	2.6	1.83	1,087	14.38
						3.65	2.8	1.49	1,083	14.27
		2	point	0.45	4.00	0.75	1.4	2.50	1,025	11.31
		3	point	0.45	1.60	0.75	0.5	1.65	959	11.53
		4	point	0.45	1.20	0.75	0.5	1.35	791	12.70
Unnamed Waterbody 6	2	1	point	0.50	0.70	–	0.1	1.66	337	6.95
		2	point	0.50	1.25	0.80	0.8	3.19	479	6.86
		3	point	0.50	1.20	0.80	0.3	3.97	445	6.74
		4	point	0.50	1.20	0.80	1.2	4.03	487	6.37

JPME R2 ERRATA

(a) See Figure 5.2-2 for sample site locations.

(b) Data not obtained due to equipment malfunction.

– = Not measured.

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Water temperature and was suitable for use by all fish species; however pH was above the guideline for the protection of aquatic wildlife (i.e., >8.5) (Table 5.5-11). Dissolved oxygen levels near the surface were suitable to support fish throughout the open-water season. Water quality conditions were profiled at one location during the spring, three locations during the summer and one location during the fall. The DO levels during the spring and fall profiles remained stable with depth. In the spring, DO decline markedly with depth. In this profile, DO was 10.3 mg/L at the surface, 4.94 mg/L at 3 m and 1.31 mg/L at 4.3 m.

Winter habitat conditions were measured at four locations dispersed throughout the waterbody. A depth profile was recorded at one of the four locations. Water quality results at each of the sampling station are presented in Table 5.5-12. Water depths below the ice at the four stations ranged from 0.75 to 3.65 m and averaged 2.61 m. Ice thickness was 0.45 m. Temperatures ranged from 0.5 to 2.8°C. Dissolved oxygen levels were low throughout the waterbody at the time of the survey, ranging from 1.35 to 2.61 mg/L and averaging 1.94 mg/L. Levels were highest within 1.2 m of the surface, ranging from 2.35 to 2.61 mg/L and lowest near the substrate, ranging from 1.49 to 1.83 mg/L.

Based on the habitat available at Site 14 the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Site 14

Site 14 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. No fish were captured.

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Unnamed Waterbody 6

Habitat Assessment

Unnamed Waterbody 6 drains into Eymundson Creek. The results for the open-water and winter habitat measurements are presented in Table 5.5-11 and Table 5.5-12.

Site 2

Unnamed Waterbody 6 (Site 2) has a perimeter of approximately 2.2 km and an approximate surface area of 0.07 km^2. The waterbody was dominated by shallow littoral habitat, with submergent and emergent aquatic vegetation along the shore (Appendix O, Figure O-13). The waterbody was surrounded by a shallow to moderate slope and mixedwood forest. The average and maximum depths recorded throughout the open-water seasons were 1.22 and 1.55 m, respectively, although the depths were significantly reduced during the summer, with a maximum depth of 0.20 m. The substrate consisted of silt and organics.

Spring and fall water quality was suitable for use by all fish species, but temperatures approached 20°C during the summer. Dissolved oxygen levels were suitable to support fish in the fall (Table 5.5-11).

Winter habitat conditions were measured at four locations dispersed throughout the waterbody. Water quality results at each of the sampling station are presented in Table 5.5-12. Water depths below the ice at the four stations ranged from 0.70 to 1.25 m and averaged 1.09 m. Ice thickness was 0.50 m. Temperatures ranged from 0.1 to 1.2°C. Dissolved oxygen levels were low throughout the waterbody at the time of the survey, ranging from 1.66 to 4.03 mg/L and averaging 3.21 mg/L.

Based on the habitat available at Site 2, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, nil to low for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; low for nursery, rearing and feeding; low to moderate for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; moderate to high for spawning.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-9, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-10.

Site 2

Site 2 was surveyed for sport, non-sport and forage fish during the winter, spring and fall field surveys using minnow traps and gill nets. Shallow water depth (maximum 0.2 m) prevented sampling during the summer season. Only brook stickleback were captured in the fall.

Unnamed Tributaries to the Athabasca River

Watercourses

Unnamed Creek 10

Habitat Assessment

One watercourse site was surveyed on Unnamed Creek 10 (Site 8), a tributary of the Athabasca River, to assess seasonal fish habitat use potential. The results for the open-water and winter habitat measurements are presented in Table 5.5-13 and Table 5.5-14.

Site 8

Unnamed Creek 10 at Site 8 had no defined channel and was a shallow to moderately deep flooded area created by beaver activity. The surveyed section of the watercourse was surrounded by a mixedwood forest of poplar and spruce and had an abundance of inundated grasses and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix P, Figure P-1). Site 8 consisted of pool habitat having maximum water depth of 0.9 m. An average channel width could not be calculated, due to poorly defined channel. Substrate throughout the surveyed reach consisted of silt and organics. Instream cover was abundant and provided by instream vegetation. Overhead cover was moderate and consisted of overhanging shrubs and grasses.

There was no recordable discharge in the spring, summer or fall sampling seasons (Table 5.5-13). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-13).

During the winter there was no measurable discharge or flow. Under-ice water depth was 0.4 m (Table 5.5-14). The ice thickness was 0.45 m and the snow depth was 0.4 m. The DO level at the time of the survey was 4.21 mg/L.

Table 5.5-13 Open-Water Habitat Conditions at Watercourse Sampling Sites in the Athabasca River Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Water Quality Field Parameters			
				Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Creek 10	8	spring	–[b]	7.9	8.06	400	7.45
		summer	–[b]	20.0	–[c]	395	7.68
		fall	–[b]	8.7	4.8	355	7.56

[a] See Figure 5.2-2 for sample site locations.

[b] Site conditions did not allow measurement (water too deep or substrate too soft for gear and/or safe wading).

[c] Data not obtained due to equipment malfunction.

- = Not measured.

Table 5.5-14 Winter Habitat Conditions at Watercourse Sampling Sites in the Athabasca River Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Water Velocity [m/s]		Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Quality Field Parameters			
			Mean	Range			Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Creek 10	8	0[b]	0[b]	0[b]	0.4	0.45	0.4	n/a	0.2	4.21	336	7.24

[a] See Figure 5.2-2 for sample site locations.

[b] No measurable flow.

n/a = Not applicable.

Based on the habitat available at Site 8, the seasonal habitat use potential was rated as follows:

- Sport fish: low to moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low to moderate for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Forage fish: high for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate to high for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-15, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-16.

Site 8

Site 8 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. Only forage fish species were captured. During the summer sampling season, brook stickleback and lake chub were captured. In the fall, brook stickleback and pearl dace were captured. During the winter sampling season, brook stickleback and lake chub were captured. No fish were captured during the spring survey.

Table 5.5-15 Fish Species Captured at Sampling Sites in the Athabasca River Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Number of Fish by Species[b][c]				Total
			Forage Fish				
			BRST	LKCH	NRDC	PRDC	
Unnamed Creek 10	8	spring	–	–	–	–	**0**
		summer	1	–	1	–	**2**
		fall	11	–	–	166	**177**
		winter	4	10	–	–	**14**
	species total		16	10	1	166	**193**
Unnamed Waterbody 8	13	spring	–	–	–	–	**0**
		summer	–	–	–	–	**0**
		fall	–	–	–	–	**0**
		winter	–	–	–	–	**0**
	species total		0	0	0	0	**0**

[a] See Figure 5.2-2 for sampling site locations.

[b] All sampling methods combined.

[c] Fish Species: BRST = brook stickleback, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace.

– = No fish captured.

Table 5.5-16 Catch-Per-Unit-Effort Results for Sampling Sites in the Athabasca River Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Forage Fish[b]			
			BRST	LKCH	NRDC	PRDC
Backpack Electrofishing [Number/100s]						
Unnamed Waterbody 8	13	spring	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00
Minnow Trapping [Number/Trap-hr]						
Unnamed Creek 10	8	spring	0.00	0.00	0.00	0.00
		summer	0.83	0.00	0.83	0.00
		fall	0.21	0.00	0.00	3.17
		winter	1.52	3.79	0.00	0.00
Unnamed Waterbody 8	13	spring	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00
Gill Netting [Number/Panel-hr]						
Unnamed Waterbody 8	13	spring	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00

[a] See Figure 5.2-2 for sampling site locations.

[b] Fish Species: BRST = brook stickleback, LKCH = lake chub, NRDC = northern redbelly dace, PRDC = pearl dace.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Waterbody

Unnamed Waterbody 8

Habitat Assessment

Unnamed Waterbody 8 (Site 13), located on an unnamed tributary of the Athabasca River, was surveyed to assess seasonal fish habitat use potential. The results for the open-water and winter habitat conditions are presented in Tables 5.5-17 and 5.5-18.

Site 13

Unnamed Waterbody 8 (Site 13) has a perimeter of approximately 2.4 km and an approximate surface area of 0.20 km^2. The waterbody was dominated by a moderately shallow littoral habitat with very little emergent vegetation (Appendix P, Figure P-2). The shoreline was a shallow to moderate slope and was surrounded by mixedwood forest and muskeg. The average and maximum depths recorded throughout the open-water seasons were 0.86 and 1.40 m, respectively. The substrate consisted of organics.

Water quality parameters were suitable for use by all fish species in the open-water season (Table 5.5-17). Water quality conditions were profiled at one location during the fall and DO remained stable with depth.

Winter habitat conditions were measured at four locations dispersed throughout the waterbody. Water quality results at each of the sampling station are presented in Table 5.5-18. Water depths below the ice at the four stations ranged from 0.90 to 1.20 m and averaged 1.05 m. Ice thickness averaged 0.63 m. Temperatures ranged from 0.2 to 1.9°C. Dissolved oxygen levels were variable throughout the waterbody at the time of the survey, ranging from 2.46 to 8.76 mg/L and averaging 5.94 mg/L.

Based on the habitat available at Site 13, the seasonal habitat use potential was rated as follows:

- Sport fish: moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: moderate for overwintering; moderate for nursery, rearing and feeding; nil for spawning.
- Forage fish: high for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring aquatic vegetation.

Table 5.5-17 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Athabasca River Watershed

Waterbody	Sampling Site[a]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 8	13	spring	point	1	0.67	0.50	19.2	11.16	236	8.93
			point	2	0.39	0.30	19.8	9.15	238	8.88
		summer	point	1	1.40	0.90	18.3	–[b]	247	9.20
		fall	point	1	0.73	0.30	4.3	11.41	258	9.03
			point	2	0.94	0.30	4.3	11.32	257	9.05
			point	3	1.01	0.30	4.3	11.26	259	9.08
			point	4	1.04	0.30	4.3	11.26	258	9.08
			profile	5	1.12	0.30	4.3	11.35	259	9.11
						0.50	4.3	11.47	258	9.01
						1.00	4.3	11.43	258	9.11
						1.10	4.3	11.10	259	9.08
			point	6	0.78	0.30	4.5	11.47	257	9.04
			point	7	0.92	0.30	4.1	11.34	259	9.01
			point	8	0.96	0.30	4.7	11.49	258	9.06
			point	9	0.58	0.30	4.6	11.18	259	9.03
			point	10	0.59	0.30	4.9	11.23	260	9.05

[a] See Figure 5.2-2 for sample site locations.

[b] Data not obtained due to equipment malfunction.

– = Not measured.

Table 5.5-18 Winter Habitat Conditions at Waterbody Sampling Sites in the Athabasca River Watershed

Waterbody	Sampling Site[(a)]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 8	13	1	point	0.70	1.20	0.90	1.9	8.76	480	7.80
		2	point	0.70	1.10	0.80	0.8	8.43	483	8.01
		3	point	0.60	1.00	0.80	0.9	4.09	336	8.00
		4	point	0.50	0.90	0.70	0.2	2.46	418	7.81

(a) See Figure 5.2-2 for sample site locations.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-15, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-16.

Site 13

Site 13 was surveyed for sport, non-sport and forage fish during the winter, spring, summer and fall field surveys. No fish were captured during these surveys. No fish were observed during the winter underwater videography session.

Big Creek Watershed

Watercourses

Big Creek

Habitat Assessment

Three watercourse sites on Big Creek, a tributary to the Athabasca River, were surveyed (Sites 42, 1 and 47) to assess seasonal fish habitat use potential within the first three of the four reaches. The results for the open-water and winter habitat conditions are presented in Table 5.5-19 and Table 5.5-20.

Site 42

Big Creek at Site 42 was located within Reach 1 and had an irregular meandering and occasionally confined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-1). Site 42 consisted of run and flat habitat having maximum water depth of 0.65 m and an average channel width of 9.50 m. Substrate throughout the surveyed reach consisted of organics, silt, sand, gravel and cobble. Beaver activity within the surveyed portion was evident with the presence of two beaver dams. Both stream banks were approximately 100% unstable throughout the surveyed area. Instream cover was moderate and provided by aquatic vegetation, woody debris, substrate and turbidity. Overhead cover was moderate and consisted of woody debris, under-cut banks and overhanging shrubs and trees.

Table 5.5-19 Open-Water Habitat Conditions at Watercourse Sampling Sites in the Big Creek Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Water Quality Field Parameters			
				Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Big Creek	42	spring	–[c]	10.3	–[b]	341	7.70
		summer	–[c]	17.7	–[b]	359	8.32
		fall	0.21	6.5	8.78	360	8.13
	1	spring	0.40	13.3	10.40	365	7.55
		summer	0.25	18.7	–[b]	345	8.30
		fall	0.26	4.3	8.96	300	7.89
	47	spring	0.50	7.1	10.98	262	7.06
		summer	0.10	16.7	11.64	412	7.81
		fall	0.16	8.5	10.30	392	7.69
First Creek	9	spring	–[c]	11.3	3.24	278	7.22
		summer	–[c]	19.2	7.01	250	7.28
		fall	0.00	7.5	5.85	235	6.99
Unnamed Creek 2	44	spring	0.24	12.8	–[b]	363	7.70
		summer	0.03	11.6	–[b]	379	8.35
		fall	0.04	5.3	11.51	374	8.25
Unnamed Creek 7	49	spring	–[c]	10.2	14.83	508	7.44
		summer	–[c]	20.8	–[b]	345	7.49
		fall	–[c]	8.8	6.40	369	7.50

[a] See Figure 5.2-2 for sample site locations.

[b] Data not obtained due to equipment malfunction.

[c] Site conditions did not allow measurement (water too deep or substrate too soft for gear and/or safe wading).

– = Not measured.

Table 5.5-20 Winter Habitat Conditions at Watercourse Sampling Sites in the Big Creek Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Water Velocity [m/s]		Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Quality Field Parameters			
			Mean	Range			Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Big Creek	42	0[b]	0[b]	0[b]	0.32	0.84	0.03	–	0.0	7.26	245	7.19
	1	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
	47	–[b]	–[b]	–[b]	0.20	0.76	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
First Creek	9	–[b]	–[b]	–[b]	0.85	–	0.03	–	1.2	2.57	220	6.99
Unnamed Creek 2	44	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
Unnamed Creek 7	49	–[b]	–[b]	–[b]	0.30	0.49	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]

[a] See Figure 5.2-2 for sample site locations.

[b] Site conditions did not allow measurement (open water, frozen to bottom, no measurable flow).

– = Not measured.

Discharge was recorded in the fall (0.21 m^3/s) (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-19). Water temperature at Site 42 was continuously monitored from May 23, 2007 to July 25, 2007 (Appendix S, Figure S-23) using a thermograph. Water temperature fluctuated between 8.3 and 20.6°C throughout this time period. The peak water temperature (20.6°C) was recorded on July 18, 2007.

During the winter survey, two of the three water quality stations were frozen to the bottom, while the remaining station had an under-ice water depth of 0.03 m (Table 5.5-20). The mean ice thickness was approximately 0.84 m and the mean snow depth was 0.32 m. The DO level at the time of the survey was 7.26 mg/L.

Based on the habitat available at Site 42, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; moderate for nursery, rearing and feeding; low to moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; moderate for nursery, rearing and feeding; low to moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Forage fish: low for overwintering; high for nursery, rearing and feeding; low to moderate for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.

Site 1

Site 1 was located within Reach 2 of Big Creek and had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest dominated by spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-2). Site 1 consisted of run and riffle habitat having maximum water depth of 0.8 m and an average channel width of 7.67 m. Substrate throughout the surveyed reach consisted of silt, sand, gravel and cobble. Both stream banks were approximately 0 to 2% unstable throughout the surveyed area. Instream cover was moderate and provided by woody debris, depth and turbulence. Overhead cover was also moderate and consisted of overhanging vegetation, undercut banks, woody debris and root wads.

Discharge was recorded in the spring (0.40 m^3/s), summer (0.25 m^3/s) and fall (0.26 m^3/s) (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-19). Water temperature at Site 1 was continuously monitored from May 31, 2007 to July 23, 2007 (Appendix S, Figure S-24) using a thermograph. Water temperature fluctuated between 8.3 and 21.1°C throughout this time period. The peak water temperature (21.1°C) was recorded on July 20, 2007.

A winter survey could not be conducted at Site 1 because the site was not accessible during the winter season. Overwintering potential was assessed based on conditions observed during the remaining seasons and during the winter at other sites located within the watershed.

Based on the habitat available at Site 1, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; low to moderate for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; low to moderate for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low to nil for spawning for species requiring emergent vegetation.

Site 47

Site 47 was located within Reach 3 of Big Creek and had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-3). Site 47 consisted entirely of run habitat having maximum water depth of 0.30 m and a channel width of 7.40 m. Substrate throughout the surveyed reach consisted of organics, sand and gravel. Both stream banks were approximately 100% unstable throughout the surveyed area. Instream cover was moderate and provided by woody debris, substrate and turbidity. Overhead cover also was moderate and consisted of woody debris, undercut banks and overhanging trees and shrubs.

Discharge was recorded in the spring (0.50 m^3/s), summer (0.10 m^3/s) and fall (0.16 m^3/s) (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-19). Water temperature at Site 47 was continuously monitored from May 16 to July 25, 2007 (Appendix S, Figure S-25) using a thermograph. Water temperature fluctuated between 3.7 and 21.1°C throughout this time period. The peak water temperature (21.1°C) was recorded on July 13, 2007.

The winter field survey determined that there was no overwintering habitat within Site 47 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 47, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low to moderate for nursery, rearing and feeding; nil low for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low to moderate for nursery, rearing and feeding; nil low for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; low to moderate for spawning.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 42

Site 42 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. No fish were captured in the spring and summer seasons. In the fall, one sport fish species (burbot), two non-sport fish species (longnose sucker and white sucker) and six forage fish species (lake chub, longnose dace, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner) were captured.

Table 5.5-21 Fish Species Captured at Sampling Sites in the Big Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Number of Fish by Species[b][c]											Total
			Sport Fish	Non-Sport fish		Forage Fish								
			BURB[d]	LNSC[d]	WHSC[d]	BRST	FTMN	LKCH	LNDC	PRDC	SLSC	SPSC	SPSH	
Big Creek	42	fall	1	5	2	–	–	6	5	19	5	1	2	**46**
	1	spring	–	3	–	–	5	5	–	–	18	–	–	**31**
		summer	–	6	–	–	–	19	–	–	15	–	–	**40**
		fall	–	–	–	–	–	4	–	–	4	–	–	**8**
		species total	*1*	*14*	*2*	*0*	*5*	*34*	*5*	*19*	*42*	*1*	*2*	**125**
Unnamed Creek 2	44	spring	–	1	–	1	9	2	–	–	10	–	–	**23**
		summer	–	1	–	–	2	–	–	–	5	–	–	**8**
		fall	–	1	–	–	–	–	–	–	14	–	–	**15**
		species total	*0*	*3*	*0*	*1*	*11*	*2*	*0*	*0*	*29*	*0*	*0*	*46*
Unnamed Creek 7	49	fall	–	1	–	3	–	–	–	–	–	–	–	**4**
		species total	*0*	*1*	*0*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	**4**
Oakley Lake	46	spring	–	–	–	6	–	–	–	–	–	–	–	**6**
		fall	–	–	1	2	–	1	–	–	–	–	–	**4**
		winter	–	–	–	110	–	147	–	–	–	–	–	**257**
		species total	*0*	*0*	*1*	*118*	*0*	*148*	*0*	*0*	*0*	*0*	*0*	**267**
Unnamed Waterbody 15	4	spring	–	–	–	3	–	–	–	–	–	–	–	**3**
		species total	*0*	*0*	*0*	*3*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	**3**

[a] See Figure 5.2-2 for sampling site locations.

[b] All sampling techniques combined.

[c] Fish Species: BURB = burbot, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, PRDC = pearl dace, SLSC = slimy sculpin, SPSC = spoonhead sculpin, SPSH = spottail shiner.

[d] Life stage unknown.

– = None captured.

Table 5.5-22 Catch-Per-Unit-Effort Results for Sampling Sites in the Big Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]	Non-Sport Fish		Forage Fish							
			BURB	LNSC	WHSC	BRST	FTMN	LKCH	LNDC	PRDC	SLSC	SPSC	SPSH
Backpack Electrofishing [Number/100 s]													
Big Creek	42	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.10	0.48	0.19	0.00	0.00	0.58	0.48	1.83	0.48	0.10	0.19
	1	spring	0.00	0.31	0.00	0.00	0.51	0.51	0.00	0.00	1.85	0.00	0.00
		summer	0.00	0.31	0.00	0.00	0.00	0.52	0.00	0.00	1.56	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00
First Creek	9	fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 2	44	spring	0.00	0.14	0.00	0.14	1.23	0.27	0.00	0.00	1.37	0.00	0.00
		summer	0.00	0.15	0.00	0.00	0.29	0.00	0.00	0.00	0.73	0.00	0.00
		fall	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00
Minnow Trapping [Number/Trap-hr]													
Big Creek	42	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	1.00	0.00	0.00	0.00	4.66	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	47	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
First Creek	9	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 2	44	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.5-22 Catch-Per-Unit-Effort Results for Sampling Sites in the Big Creek Watershed (continued)

Watercourse or Waterbody	Sampling Site[a]	Season	Sport Fish[b]	Non-Sport Fish		Forage Fish							
			BURB	LNSC	WHSC	BRST	FTMN	LKCH	LNDC	PRDC	SLSC	SPSC	SPSH
Unnamed Creek 7	49	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.88	0.00	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oakley Lake	46	spring	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.80	0.00	0.40	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	42.26	0.00	56.47	0.00	0.00	0.00	0.00	0.00
Small Sandy Lake	45	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 15	4	spring	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gill Netting [Number/Panel-hr]													
Oakley Lake	46	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small Sandy Lake	45	fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 15	4	fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-2 for sampling site locations.

[b] Fish Species: BURB = burbot, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, PRDC = pearl dace, SLSC = slimy sculpin, SPSC = spoonhead sculpin, SPSH = spottail shiner.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Site 1
Site 1 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. In the spring, sampling activities resulted in the capture of longnose sucker, fathead minnow, lake chub and slimy sculpin. During the summer, longnose sucker, lake chub and slimy sculpin were again captured. In the fall, only lake chub and slimy sculpin were captured.

Kick net spawning surveys were conducted during the spring at this location. Ten separate sampling events covering approximately 10 m^2 yielded no eggs.

Site 47
Although Site 47 was surveyed for sport, non-sport and forage fish during the spring, summer and fall seasons, no fish were captured.

First Creek

Habitat Assessment
One watercourse site on First Creek, a tributary to Big Creek, was surveyed (Site 9) to assess seasonal fish habitat use potential. The results for the open-water and winter habitat conditions are presented in Tables 5.5-19 and 5.5-20.

Site 9
First Creek at Site 9 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-4). Site 9 consisted of run and pool habitat having maximum water depth of 0.59 m and an average channel width of 4.94 m. Substrate throughout the surveyed reach consisted of organics. Both stream banks were stable throughout the surveyed area. Instream cover was moderate and provided by instream and aquatic vegetation. Overhead cover was limited and consisted of overhanging grasses.

Discharge was recorded in the fall (0.00 m^3/s) (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season, although low DO levels in the spring and fall may only be suitable for forage fish and other low DO tolerant fish (Table 5.5-19). Water temperature at Site 9 was continuously monitored from May 26, 2007 to July 25, 2007 (Appendix S, Figure S-26) using a thermograph. Water temperature fluctuated between 5.8 and 23.8°C throughout this time period. The peak water temperature (23.8°C) was recorded on July 20, 2007.

The winter field survey within Site 9 determined that although the site was not frozen to the bottom, there was no measurable flow, maximum water depth was 0.03 m and DO was 2.57 mg/L (Table 5.5-20).

Based on the habitat available at Site 9, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; moderate for spawning.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 9

Site 9 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. No fish were captured.

Unnamed Creek 2

Habitat Assessment

One watercourse site on Unnamed Creek 2, a tributary to Big Creek, was surveyed (Site 44) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-19 and 5.5-20.

Site 44

Unnamed Creek 2 at Site 44 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-5). Site 44 consisted of riffle and run habitat having maximum water depth of 0.47 m and an

average channel width of 3.30 m. Substrate throughout the surveyed reach consisted of organics, clay/silt, sand, gravel, cobble and boulder. The stream banks ranged from 60 to 100% unstable throughout the surveyed area. Instream cover was abundant and provided by woody debris, substrate and turbidity. Overhead cover also was abundant and consisted of woody debris, undercut banks, overhanging grasses and overhanging shrubs and trees.

Discharge was recorded in the spring (0.24 m^3/s), summer (0.03 m^3/s) and fall (0.04 m^3/s) (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-19). Water temperature at Site 44 was continuously monitored from May 28 to July 23, 2007 (Appendix S, Figure S-27) using a thermograph. Water temperature fluctuated between 5.7 and 17.6°C throughout this time period. The peak water temperature (17.6°C) was recorded on May 31, 2007.

A winter survey could not be conducted at Site 44 because the site was not accessible during the winter season. Overwintering potential was assessed based on conditions observed during the remaining seasons and during the winter at other sites located within the watershed.

Based on the habitat available at Site 44, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate to high for nursery, rearing and feeding; moderate to high for spawning.
- Forage fish: moderate for overwintering; moderate to high for nursery, rearing and feeding; moderate to high for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 44

Site 44 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. No sport fish were captured at this site. One non-sport fish species, longnose sucker, was captured in all three sampling

seasons at this site. Four forage fish species (brook stickleback, fathead minnow, lake chub and slimy sculpin) also were captured at this site.

Kick net spawning surveys were conducted during the spring at this location. Ten separate sampling events covering approximately 10 m^2 yielded no eggs.

Unnamed Creek 7

Habitat Assessment

One watercourse site on Unnamed Creek 7, a tributary to Big Creek, was surveyed (Site 49) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-19 and 5.5-20.

Site 49

Unnamed Creek 7 at Site 49 was a large marsh area with no defined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and muskeg.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix Q, Figure Q-6). Site 49 consisted of flat habitat having maximum water depth of 0.20 m. Average channel width could not be calculated due to poor channel definition. Substrate throughout the surveyed reach consisted of organics. Instream cover was moderate and provided by instream vegetation. Overhead cover was limited and consisted of overhanging grasses.

There was no measurable flow in all seasons (Table 5.5-19). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season, although the summer temperature did reach 20.8°C (Table 5.5-19).

The winter field survey determined that there was no overwintering habitat within Site 49 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 49, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.

- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; nil to low for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 49

Site 49 was surveyed for sport, non-sport and forage fish during the spring and fall field surveys. Sampling conditions were not suitable during the winter (frozen to bottom) and summer surveys (too shallow, maximum depth 0.15 m). No fish were captured in the spring, however, longnose sucker and brook stickleback were both captured in the fall.

Waterbodies

Oakley Lake

Habitat Assessment

Oakley Lake (Site 46), a waterbody located at the upper portion of Unnamed Creek 2 was surveyed to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-23 and 5.5-24.

Site 46

Oakley Lake (Site 46) has a surface area of 0.83 km^2. The habitat map (Appendix Q, Figure Q-7) illustrates all habitat features observed during the habitat survey as well as seasonal photos. A shallow littoral zone was present along the shoreline and the centre consisted of a deeper pelagial zone habitat. Submerged and floating aquatic vegetation as well as emergent vegetation was present in the shallow areas. The average and maximum depths recorded throughout the open-water seasons are 1.16 and 2.25 m, respectively.

Water quality was suitable for use by all fish species and DO levels near the surface were suitable to support fish throughout the open-water season (Table 5.5-23). Water quality conditions were profiled at one location during the spring. Surface water quality was recorded at three locations during the fall.

Table 5.5-23 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Big Creek Watershed

Waterbody	Sampling Site[a]	Season	Station	Point or Profile	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Oakley Lake	46	spring	1	profile	2.25	2.20	10.6	11.55	398	7.51
						2.00	10.5	–[b]	398	7.52
						1.50	11.0	–[b]	396	7.56
						1.00	10.9	–[b]	397	7.58
						0.50	11.2	–[b]	396	7.61
		fall	1	point	0.40	0.40	10.6	9.50	375	7.99
			2	point	0.60	0.20	11.1	9.64	375	7.94
			3	point	1.40	0.40	10.8	9.62	375	7.91
Small Sandy Lake	45	spring	1	profile	2.40	2.00	11.8	–[b]	606	8.47
						1.50	11.8	–[b]	606	8.48
						1.00	11.8	–[b]	606	8.51
						0.50	11.8	–[b]	605	8.51
		fall	1	point	0.20	0.50	11.8	12.97	531	8.87
			2	point	1.20	0.50	11.4	12.09	532	8.85
			3	point	1.50	0.50	11.2	11.33	532	8.83
Unnamed Waterbody 15	4	spring	1	point	0.50	0.50	15.0	6.73	133	6.88
		summer	1	point	0.60	0.35	24.3	–[b]	154	7.76
			2	point	0.60	0.55	24.1	–[b]	155	8.50
			3	point	0.90	0.40	23.9	–[b]	156	7.92
		fall	1	point	1.15	0.30	5.3	9.30	213	6.93
			2	point	1.12	0.30	5.4	9.31	211	6.86
			3	point	1.26	0.30	5.4	9.34	212	6.85
			4	point	1.15	0.30	5.6	9.41	211	6.84
			5	point	1.09	0.30	5.6	9.41	212	6.82
			6	point	1.14	0.30	5.5	9.39	211	6.85
			7	point	1.29	0.30	5.7	9.41	210	6.88
			8	profile	1.32	0.30	6.0	9.27	209	6.87
						0.50	5.9	9.11	211	6.86
						1.00	5.8	9.10	209	6.87
						1.20	5.4	9.03	211	6.90
			9	point	1.32	0.30	5.7	9.24	210	6.81
			10	point	1.30	0.30	5.9	9.31	212	6.85

[a] See Figure 5.2-2 for sample site locations.

[b] Data not obtained due to equipment malfunction.

Table 5.5-24 Winter Habitat Conditions at Waterbody Sampling Sites in the Big Creek Watershed

Waterbody	Sampling Site[(a)]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Oakley Lake	46	1	profile	0.68	1.30	0.70	1.8	1.47	371	7.18
						1.20	3.0	1.12	384	7.21
		2	profile	0.70	1.20	0.70	0.4	3.51	363	7.15
						1.00	2.1	2.86	378	7.16
		3	profile	0.75	1.30	0.80	0.4	2.00	362	7.15
						1.20	3.1	0.69	400	7.27
Sandy Lake	45	1	profile	0.80	1.90	1.80	2.8	0.32	498	7.47
						0.90	0.8	1.30	481	7.40
		2	profile	0.80	1.60	0.90	1.9	0.35	485	7.35
						1.50	2.5	0.15	500	7.48
		3	profile	0.80	1.90	0.90	0.2	0.26	464	7.52
						1.80	2.2	0.10	488	7.55
Unnamed Waterbody 15	4	1	point	0.82	0.03	0.03	0.4	0.40	1,094	6.59

(a) See Figure 5.2-2 for sample site locations.

Winter habitat conditions were profiled at three locations at Oakley Lake. Depth and water quality results at each of the sampling stations are presented in Table 5.5-24. Water depths below the ice at the three stations ranged from 1.2 to 1.3 m and averaged 1.3 m. Ice thickness was between 0.68 and 0.75 m. Temperatures ranged from 0.4 to 3.1 °C. Dissolved oxygen levels at the time of the survey, ranged from 0.69 to 3.51 mg/L and averaged 1.94 mg/L.

Based on the habitat available at Site 46, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 46

Oakley Lake was surveyed for sport, non-sport and forage fish during the winter, spring and fall field surveys. A summer field survey was not conducted due to a no-fly zone established in the area. One non-sport fish species (white sucker) and two forage fish species (brook stickleback and lake chub) were captured at this site.

Small Sandy Lake

Habitat Assessment

Small Sandy Lake (Site 45), a waterbody at the headwaters of a tributary to Big Creek, was surveyed to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-23 and 5.5-24.

Site 45

Small Sandy Lake (Site 45) had an approximate surface area of 0.45 km^2. The average and maximum depths recorded throughout the open-water seasons are 1.33 and 2.40 m, respectively. The habitat map (Appendix Q, Figure Q-8)

illustrates all habitat features observed during the habitat survey as well as seasonal photos.

Water quality during the open-water season was suitable for use by all fish species and DO levels near the surface were suitable to support fish in the fall season (Table 5.5-23). Water quality conditions were profiled at one location during the spring and measured at three locations during the fall.

Winter habitat conditions were measured at three locations dispersed throughout the waterbody. Depth profiles were recorded at all three locations. Water quality results at each of the sampling stations are presented in Table 5.5-24. Water depths below the ice at the three stations ranged from 1.60 to 1.90 m and averaged 1.80 m. Ice thickness was 0.80 m. Temperatures ranged from 0.2 to 2.8°C. Dissolved oxygen levels were variable throughout the waterbody at the time of the survey, ranging from 0.10 to 1.30 mg/L and averaging 0.41 mg/L.

Based on the habitat available at Site 45, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Catch per unit effort data are presented in Table 5.5-22.

Site 45

Small Sandy Lake was surveyed for sport, non-sport and forage fish during the winter, spring and fall field surveys. A summer field survey was not conducted due to a no-fly zone established in the area. No fish were captured during the spring or fall surveys conducted.

Unnamed Waterbody 15

Habitat Assessment

One waterbody on First Creek was surveyed (Site 4) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat measurements are presented in Tables 5.5-23 and 5.5-24.

Site 4

Unnamed Waterbody 15 (Site 4) has a perimeter of approximately 2.7 km and an approximate surface area of 0.26 km^2. The habitat map for this waterbody (Appendix Q, Figure Q-9) illustrates all habitat features observed during the habitat survey as well as seasonal photos. A shallow littoral zone was present along the shoreline and the centre consisted of a deeper pelagial zone habitat. Submerged and floating aquatic vegetation as well as emergent vegetation was present in the shallow areas. The average and maximum depths recorded throughout the open-water seasons are 1.05 and 1.32 m, respectively.

Dissolved oxygen, pH and conductivity levels were suitable to support all fish species throughout the open-water season (Table 5.5-23). Water quality conditions were measured at one location during the spring and three locations during the summer. Dissolved oxygen was 6.73 mg/L in the spring and ranged from 9.03 to 9.41 mg/L in the fall. The average water temperature in the spring, summer and fall was 15.00, 24.1 and 5.6°C, respectively. Water temperature at Site 4 was continuously monitored from May 17 to July 21, 2007 (Appendix S, Figure S-28) using a thermograph. Water temperature fluctuated between 8.0 and 24.7°C throughout this time period. The peak water temperature (24.7°C) was recorded on July 13, 2007.

Winter habitat conditions were measured at one location. Water quality results are presented in Table 5.5-24. The maximum water depth below the ice was 0.03 m, the ice thickness was 0.82 m, the water temperature was 0.4 °C and the DO was 0.40 mg/L.

Based on the habitat available at Site 4, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low to moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate to high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-21, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-22.

Site 4

Unnamed Waterbody 15 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Sampling could not be conducted during the winter survey, due to the shallow water depth (0.03 m). Brook stickleback was the only fish species captured at Site 4 in the spring survey. No fish were captured during the summer and fall surveys.

Redclay Creek Watershed

Watercourses

Redclay Creek Mainstem

Habitat Assessment

Two watercourse sites on Redclay Creek, a tributary to the Athabasca River, were surveyed (Sites 50 and 51) to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-25 and 5.5-26.

Site 50

Redclay Creek at Site 50 had a sinuous and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

Table 5.5-25 Open-Water Habitat Conditions at Watercourse Sampling Sites in the Redclay Creek Watershed

Watercourse	Sampling Site[a]	Season	Discharge [m^3/s]	Water Quality Field Parameters			
				Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Redclay Creek	50	spring	0.73	–[b]	–[b]	–[b]	–[b]
		summer	0.26	19.4	–[b]	452	8.18
		fall	0.36	6.2	11.03	442	8.07
	51	spring	0.75	12.2	7.52	507	7.20
		summer	0.17	13.5	–[b]	462	8.19
		fall	0.28	8.0	11.95	451	8.11
Unnamed Creek 8	55	spring	0.22	9.9	8.19	512	7.21
		summer	0.07	12.0	–[b]	276	7.73
		fall	0.09	6.8	7.91	485	7.40

[a] See Figure 5.2-2 for sample site locations.

[b] Data not obtained due to equipment malfunction.

Table 5.5-26 Winter Habitat Conditions at Watercourse Sampling Sites in the Redclay Creek Watershed

Watercourse	Sampling Site[a]	Discharge [m^3/s]	Water Velocity [m/s]		Mean Snow Depth [m]	Mean Ice Thickness [m]	Water Depth [m]		Water Quality Field Parameters			
			Mean	Range			Mean	Range	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
RedClay Creek	50	0[b]	0[b]	0[b]	–[b]	–[b]	0[b]	0[b]	–[b]	–[b]	–[b]	–[b]
	51	0.00	0.10	0.01 to 0.19	0.17	0.38	0.26	0.12 to 0.28	0.0	12.83	293	7.25
Unnamed Creek 8	55	0.00	0.19	0.13 to 0.22	–[c]	–[c]	0.13	0.12 to 0.14	1.4	8.84	319	7.09

[a] See Figure 5.2-2 for sample site locations.

[b] Frozen to bottom.

[c] Not applicable due to open water conditions at time of survey.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix R, Figure R-1). Site 50 consisted of riffle and run habitats having a maximum water depth of 0.83 m and an average channel width of 10.30 m. Substrate throughout the surveyed reach consisted of organics, clay/silt, sand, gravel, cobble and boulder. Both stream banks were approximately 100% unstable throughout the surveyed area. Instream cover was moderate and provided by woody debris, aquatic vegetation, turbidity, depth/ turbulence and substrate. Overhead cover was moderate and consisted of woody debris, undercut banks and overhanging grasses, shrubs and trees.

Discharge was recorded in the spring (0.73 m^3/s), summer (0.26 m^3/s) and fall (0.36 m^3/s) (Table 5.5-25). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-25).

The winter field survey determined that there was no overwintering habitat within Site 50 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 50, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.

Site 51

Redclay Creek at Site 51 had a sinuous and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix R, Figure R-2). Site 51 consisted of riffle and run habitat having maximum water depth of 1.01 m and an average channel width of 7.27 m. Substrate throughout the surveyed reach consisted of organics, sand, gravel, cobble and boulders. The stream banks ranged from 70 to 100% unstable throughout the surveyed area. Instream cover was moderate and provided by woody debris, substrate, turbidity and

depth/turbulence. Overhead cover was abundant and consisted of woody debris, undercut banks and overhanging grasses, shrubs and trees.

During the open-water season, discharge was recorded in the spring (0.75 m^3/s), summer (0.17 m^3/s) and fall (0.28 m^3/s) (Table 5.5-25). Dissolved oxygen, temperature, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-25).

During the winter survey, there was no measurable discharge of Redclay Creek at Site 51 (Table 5.5-26). The wetted width of the watercourse at the site was 0.35 m. Under-ice water depths ranged from 0.12 to 0.28 m and averaged 0.26 m. Water velocities ranged from 0.01 to 0.19 m/s. The mean ice thickness was 0.38 m. The DO level at the time of the survey was 12.83 mg/L.

Based on the habitat available at Site 51, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; high for spawning for species requiring rocky habitat, nil for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; high for nursery, rearing and feeding; moderate to high for spawning.
- Forage fish: moderate for overwintering; high for nursery, rearing and feeding; high for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-27, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-28.

Site 50

Site 50 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Winter sampling was not possible, as the site was frozen to bottom. Trout-perch was the only species caught in the spring survey, while longnose sucker, lake chub, longnose dace, pearl dace and slimy sculpin were captured in the fall survey. No fish were caught during the summer field survey.

Table 5.5-27 Fish Species Captured at Sampling Sites in the Redclay Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Number of Fish by Life Stage and Species[b] [c]																												
			Sport Fish Non–Sport Fish																				Forage Fish									
			BURB				NRPK				WALL				LNSC				WHSC				BRST	FNDC	FTMN	LKCH	LNDC	NRDC	PRDC	SLSC	TRPR	Total
			F[d]	J[d]	A[d]	U[d]	F	J	A	U	F	J	A	U	F	J	A	U	F	J	A	U										
Redclay Creek	50	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	**2**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	18	2	–	3	24	–	**48**
	51	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	3	31	1	–	–	–	–	11	–	**47**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	3	–	**5**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	29	1	**31**
	201[e]	spring	–	4	–	–	–	1	17	11	–	–	3	2	–	–	2	1	–	–	2	–	4	–	–	15	1	–	–	2	–	**65**
	life stage total		*0*	*4*	*0*	*0*	*0*	*1*	*17*	*11*	*0*	*0*	*3*	*2*	*0*	*1*	*2*	*4*	*0*	*0*	*2*	*1*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**4**				**29**				**5**				**7**				**3**				**7**	**31**	**1**	**33**	**3**	**0**	**3**	**69**	**3**	**198**
Unnamed Creek 8	55	spring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	1	–	–	–	–	–	**4**
		summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11	–	1	1	–	1	7	3	–	**24**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	5	–	–	2	2	–	8	1	–	**19**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**				**0**				**0**				**1**				**0**				**19**	**0**	**1**	**4**	**2**	**1**	**15**	**4**	**0**	**47**
Unnamed Waterbody 12	52	summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7	–	–	–	–	–	–	–	–	**7**
		fall	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	31	–	–	–	–	–	2	–	–	**33**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**				**0**				**0**				**0**				**0**				**38**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**40**
Unnamed Waterbody 13	53	summer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	4	–	–	**6**
	life stage total		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	species total		**0**				**0**				**0**				**0**				**0**				**2**	**0**	**0**	**0**	**0**	**0**	**4**	**0**	**0**	**6**

[a] See Figure 5.2-2 for sampling site locations.

[b] All sampling methods combined.

[c] Fish Species: BURB = burbot, NRPK = northern pike, WALL = walleye, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FNDC = finescale dace, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, NRDC = northern redbelly dace, PRDC = pearl dace, SLSC = slimy sculpin, TRPR = trout perch.

[d] Life Stage: F = Fry, J = Juvenile, A = Adult, U = Unknown

[e] Fish fence site.

n/a = Not applicable.

– = No fish captured.

Table 5.5-28 Catch-Per-Unit-Effort Results for Sampling Sites in the Redclay Creek Watershed

Watercourse or Waterbody	Sampling Site[a]	Season	Non-Sport Fish[b]		Forage Fish								
			LNSC	WHSC	BRST	FNDC	FTMN	LKCH	LNDC	NRDC	PRDC	SLSC	TRPR
Backpack Electrofishing [Number/100s]													
Redclay Creek	50	summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.05	0.00	0.00	0.00	0.00	0.90	0.10	0.00	0.15	1.20	0.00
	51	spring	0.00	0.00	0.23	0.46	0.12	0.00	0.00	0.00	0.00	1.27	0.00
		summer	11.11	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.00
		fall	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	0.12
Unnamed Creek 8	55	spring	0.00	0.00	0.45	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.84	0.50	0.00
		fall	0.14	0.00	0.14	0.00	0.00	0.27	0.27	0.00	0.82	0.14	0.00
Minnow Trapping [Number/Trap-hr]													
Redclay Creek	50	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	51	spring	0.32	0.00	0.32	8.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek 8	55	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	2.52	0.00	0.28	0.28	0.00	0.28	0.56	0.00	0.00
		fall	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 12	52	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fall	0.00	0.00	7.09	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00
		winter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Waterbody 13	53	spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		summer	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00
		fall	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Figure 5.2-2 for sampling site locations.

[b] Fish Species: BURB = burbot, NRPK = northern pike, WALL = walleye, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, FNDC = finescale dace, FTMN = fathead minnow, LKCH = lake chub, LNDC = longnose dace, NRDC = northern redbelly dace, PRDC = pearl dace, SLSC = slimy sculpin, TRPR = trout perch.

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of individual values.

Kick net spawning surveys were conducted during the spring at this location. Ten separate sampling events covering approximately 10 m^2 yielded no eggs.

Site 51

Site 51 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Winter sampling was not conducted due to insufficient water depth. No sport fish species were captured, but two non-sport fish, longnose sucker and white sucker, were captured. Forage fish species caught included brook stickleback, finescale dace, fathead minnow, slimy sculpin and trout-perch.

Kick net spawning surveys were conducted during the spring at this location. Five separate sampling events covering approximately 5 m^2 yielded no eggs.

Fish Fence (Site 201)

A counting fence was installed 130 m upstream of the confluence with the Athabasca River and was maintained from April 28 to May 27, 2006 and from May 6, 2007 to June 1, 2007. In addition to the fence, two minnow traps were set and checked on a daily basis in 2006. In 2006, the fish fence captured one adult white sucker in the upstream fyke net and two walleye in each of the fyke nets. The minnow traps captured four juvenile burbot, as well as four brook stickleback, 15 lake chub, one longnose dace and two slimy sculpin. In 2007, the fish fence captured 29 northern pike, three walleye, three longnose sucker and one white sucker (Table 5.5-29). No minnow traps were set during the 2007 fish fence operation.

Discharge was measured when water levels fluctuated significantly. Field-level water quality data were recorded daily throughout the operation of the counting fence (Table 5.5-30). Water temperature was continuously monitored at the fish fence site from April 28 to May 27, 2006 and May 6 to July 22, 2007 (Appendix S, Figures S-29, S-30 and S-31) using a thermograph. Daily average water temperatures fluctuated between 2.4 and 14.1°C in 2006 and between 5.9 and 19.0°C in 2007.

Table 5.5-29 Fish Species Captured During the Fish Fence Operation at Redclay Creek, 2006 and 2007

Date Checked	Trap Type	Trap # or Direction	Sport–Fish[a]			Non–Sport Fish		Forage Fish			
			BURB	NRPK	WALL	LNSC	WHSC	BRST	LKCH	LNDC	SLSC
2006 Data											
April 29, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	1	–	–	–	–	–	–	–	1
		2	–	–	–	–	–	–	–	–	–
April 30, 2006	fyke net	downstream	–	–	–	–	–	–	1	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 1, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	1	–	–	–	–	–	1	–	–
		2	–	–	–	–	–	–	–	–	–
May 2, 2006	n/a	n/a	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]
May 3, 2006	fyke net	downstream	–	–	–	–	–	–	1	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	1	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 4, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	2	–	–	–	–	–	–	–	–	–
		1	–	–	–	–	–	–	–	–	–
May 5, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	1	1	–	–
		2	–	–	–	–	–	–	–	–	–
May 6, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	–	–
		2	–	–	–	–	–	–	–	–	–
May 7, 2006	fyke net	downstream	–	–	–	–	–	–	1	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 8, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	1	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	–	–
		2	–	–	–	–	–	–	–	–	–

Table 5.5-29 Fish Species Captured During the Fish Fence Operation at Redclay Creek, 2006 and 2007 (continued)

Date Checked	Trap Type	Trap # or Direction	Sport–Fish[a]			Non–Sport Fish		Forage Fish			
			BURB	NRPK	WALL	LNSC	WHSC	BRST	LKCH	LNDC	SLSC
May 9, 2006	n/a	n/a	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]	_[b]
May 10, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	–	–
		2	–	–	–	–	–	–	–	–	–
May 11, 2006	fyke net	downstream	–	–	–	–	–	–	1	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 12, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	1	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	1	–
		2	–	–	–	–	–	–	–	–	–
May 13, 2006	fyke net	downstream	–	–	1	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	–	–
		2	1	–	–	–	–	–	–	–	–
May 14, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 15, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 16, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 17, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	1	1	–	1
		2	–	–	–	–	–	–	–	–	–
May 18, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–

Table 5.5-29 Fish Species Captured During the Fish Fence Operation at Redclay Creek, 2006 and 2007 (continued)

Date Checked	Trap Type	Trap # or Direction	Sport–Fish[a]			Non–Sport Fish		Forage Fish			
			BURB	NRPK	WALL	LNSC	WHSC	BRST	LKCH	LNDC	SLSC
May 19, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 20, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	1	1	–	–
		2	–	–	–	–	–	–	–	–	–
May 21, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	1	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 22, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 23, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	1	–	–
		2	–	–	–	–	–	–	1	–	–
May 24, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 25, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 26, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 27, 2006	fyke net	downstream	–	–	–	–	–	–	–	–	–
		upstream	–	–	–	–	–	–	–	–	–
	minnow trap	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
2006 Species Subtotal			*4*	*0*	*2*	*0*	*1*	*4*	*15*	*1*	*2*

Table 5.5-29 Fish Species Captured During the Fish Fence Operation at Redclay Creek, 2006 and 2007 (continued)

Date Checked	Trap Type	Trap # or Direction	Sport–Fish[a]			Non–Sport Fish		Forage Fish			
			BURB	NRPK	WALL	LNSC	WHSC	BRST	LKCH	LNDC	SLSC
2007 Data											
May 7, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 8, 2007	n/a	n/a	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]
May 9, 2007	n/a	n/a	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]	–[c]
May 10, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 11, 2007	fyke net	1	–	–	–	–	1	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 12, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 13, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 14, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 15, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	1	–	–	–	–	–	–	–
May 16, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	1	–	–	–	–	–	–
May 17, 2007	fyke net	1	–	3	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 18, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	1	–	–	–	–	–	–	–
May 19, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	2	–	–	–	–	–
May 20, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 21, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	2	2	–	–	–	–	–	–
May 22, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 23, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	–	–	–	–	–	–	–	–
May 24, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	2	–	–	–	–	–	–	–
May 25, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	4	–	–	–	–	–	–	–

Table 5.5-29 Fish Species Captured During the Fish Fence Operation at Redclay Creek, 2006 and 2007 (continued)

Date Checked	Trap Type	Trap # or Direction	Sport–Fish[a]			Non–Sport Fish		Forage Fish			
			BURB	NRPK	WALL	LNSC	WHSC	BRST	LKCH	LNDC	SLSC
May 26, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	4	–	–	–	–	–	–	–
May 27, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	5	–	–	–	–	–	–	–
May 28, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	2	–	1	–	–	–	–	–
May 29, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	1	–	–	–	–	–	–	–
May 30, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	1	–	–	–	–	–	–	–
May 31, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	1	–	–	–	–	–	–	–
June 1, 2007	fyke net	1	–	–	–	–	–	–	–	–	–
		2	–	2	–	–	–	–	–	–	–
2007 Species Subtotal			*0*	*29*	*3*	*3*	*1*	*0*	*0*	*0*	*0*
Species Total			**4**	**29**	**5**	**3**	**2**	**4**	**15**	**1**	**2**

[a] Fish Species: BURB = burbot, NRPK = northern pike, WALL = walleye, LNSC = longnose sucker, WHSC = white sucker, BRST = brook stickleback, LKCH = lake chub, LNDC = longnose dace, SLSC = slimy sculpin.

[b] No access to fish fence site due to poor weather conditions.

[c] No access to fish fence due to unsafe boating conditions (debris and high flow).

n/a = Not applicable.

– = No fish captured.

Table 5.5-30 Water Temperature, Water Quality and Discharge Data During the Fish Fence Operation at Redclay Creek, 2006 and 2007

Date	Water Temperature [°C]		Staff Guage [m]	Discharge [m^3/s]	Water Quality Parameters		
	Minimum	Maximum			Dissolved Oxygen [mg/L]	pH	Conductivity [µS/cm]
2006 Data							
April 28, 2006	7.1	9.3	0.545	0.479	11.17	8.20	407
April 29, 2006	7.1	9.4	–	–	10.73	8.03	–
April 30, 2006	6.2	9.2	–	–	–	7.97	–
May 1, 2006	5.6	7.7	0.545	0.364	11.64	7.96	394
May 2, 2006	4.2	5.7	_[a]	_[a]	_[a]	_[a]	_[a]
May 3, 2006	2.4	7.0	–	–	–	–	–
May 4, 2006	4.6	8.5	–	–	11.81	7.96	372
May 5, 2006	5.1	9.8	0.485	0.509	11.70	8.22	376
May 6, 2006	7.0	10.2	–	–	11.90	7.98	379
May 7, 2006	7.1	10.8	–	–	11.97	8.19	362
May 8, 2006	7.3	10.5	0.535	0.513	11.55	8.05	391
May 9, 2006	7.5	9.0	_[a]	_[a]	_[a]	_[a]	_[a]
May 10, 2006	6.7	9.8	–	–	12.28	8.14	384
May 11, 2006	6.3	9.9	–	–	12.25	–	400
May 12, 2006	7.4	11.9	0.540	0.401	11.95	8.08	405
May 13, 2006	8.1	11.5	–	–	–	–	–
May 14, 2006	9.0	12.2	–	–	13.66	7.91	302
May 15, 2006	8.4	12.9	0.540	0.354	13.62	7.94	296
May 16, 2006	8.1	12.6	–	–	13.92	7.92	292
May 17, 2006	10.4	12.3	–	–	13.14	7.86	312
May 18, 2006	9.9	14.1	–	–	13.08	7.87	310
May 19, 2006	10.1	12.4	0.550	1.279	12.26	8.26	415
May 20, 2006	7.7	10.2	–	–	12.29	8.24	417
May 21, 2006	7.9	9.3	–	–	10.89	7.69	420
May 22, 2006	7.6	13.7	0.535	0.540	11.12	7.72	428
May 23, 2006	10.4	13.0	–	–	10.64	7.89	430
May 24, 2006	9.6	12.1	–	–	10.76	7.91	432
May 25, 2006	8.4	9.9	–	–	11.33	7.92	431
May 26, 2006	8.5	9.6	–	–	10.58	7.83	428
May 27, 2006	6.4	8.2	–	–	–	–	–
2007 Data							
May 5, 2007	–	–	–	–	10.25	7.95	–
May 6, 2007	3.1	6.4	–	–	11.60	7.21	404
May 7, 2007	4.4	5.3	–	–	9.75	7.25	424
May 8, 2007	3.4	7.3	_[b]	_[b]	_[b]	_[b]	_[b]
May 9, 2007	5.0	6.3	–	–	12.52	7.47	455
May 10, 2007	3.9	7.7	–	–	12.88	7.27	469
May 11, 2007	6.6	9.0	–	–	9.52	7.39	472
May 12, 2007	6.9	7.8	–	–	11.19	7.21	481
May 13, 2007	6.3	9.4	–	–	11.35	7.43	479
May 14, 2007	6.9	10.0	–	–	9.73	7.27	491
May 15, 2007	7.0	10.6	–	–	11.55	7.53	492
May 16, 2007	8.4	11.4	–	–	9.17	7.39	495
May 17, 2007	7.2	9.4	–	–	5.30	7.21	503
May 18, 2007	5.8	8.6	–	–	7.75	7.51	489
May 19, 2007	6.1	8.0	–	–	[c]	7.69	493
May 20, 2007	6.7	8.9	–	–	[c]	7.72	489
May 21, 2007	8.0	9.8	–	–	[c]	7.57	508
May 22, 2007	7.3	10.9	–	–	[c]	7.74	491
May 23, 2007	9.2	11.1	–	–	[c]	7.78	492
May 24, 2007	8.4	11.7	–	–	5.64	7.57	495

Table 5.5-30 Water Temperature, Water Quality and Discharge Data During the Fish Fence Operation, Redclay Creek, 2006 and 2007(continued)

Date	Water Temperature [°C]		Staff Guage [m]	Discharge [m^3/s]	Water Quality Parameters		
	Minimum	Maximum			Dissolved Oxygen [mg/L]	pH	Conductivity [µS/cm]
May 25, 2007	9.1	13.1	–	–	6.03	7.55	495
May 26, 2007	10.5	14.6	–	–	–	7.72	495
May 27, 2007	12.1	13.5	–	–	10.24	7.53	503
May 28, 2007	11.0	12.6	0.610	0.927	–	7.55	488
May 29, 2007	9.1	13.2	–	–	–	7.58	493
May 30, 2007	10.4	15.3	–	–	–	7.62	497
May 31, 2007	12.5	17.0	–	–	8.90	7.62	497
June 1, 2007	11.6	16.5	–	–	–	7.61	501

(a) No access to fish fence site due to poor weather conditions.

(b) No access to fish fence due to unsafe boating conditions (debris and high flow).

– = No measurement.

Unnamed Creek 8

Habitat Assessment

One watercourse site (Site 55) was established on an unnamed tributary (Unnamed Creek 8) within the Redclay Creek watershed and was surveyed to assess seasonal fish habitat use potential.

Site 55

Unnamed Creek 8 at Site 55 had an irregular meandering and unconfined channel. The surveyed section of the watercourse was located within a mixedwood forest of poplar and spruce and was bordered by grass/forbs and shrubs.

The habitat map shows the location and extent of all habitat features that occur in the study area as well as seasonal photos (Appendix R, Figure R-3). Site 55 consisted of riffle, run and pool habitat having maximum water depth of 0.80 m and an average channel width of 4.62 m. Substrate throughout the surveyed reach consisted of organics, sand, gravel, cobble and boulder. The stream banks were approximately 80 to 100% unstable throughout the surveyed area. Instream cover was moderate and provided by woody debris, substrate, turbidity and depth/turbulence. Overhead cover was moderate and consisted of woody debris, undercut banks and overhanging grasses, shrubs and trees.

Discharge was recorded in the spring (0.22 m^3/s), summer (0.07 m^3/s) and fall (0.09 m^3/s) (Table 5.5-25). Dissolved oxygen, pH and conductivity levels were suitable to support fish throughout the open-water season (Table 5.5-25).

During the winter survey, there was no measurable discharge of Unnamed Creek 8 at Site (Table 5.5-26). The wetted width of the watercourse at the site was 0.75 m. Under-ice water depths ranged from 0.12 to 0.14 m and averaged 0.13 m. Water velocities ranged from 0.13 to 0.22 m/s. The DO level at the time of the survey was 8.84 mg/L. The surface water temperature was 1.4˚C.

Based on the habitat available at Site 55, the seasonal habitat use potential was rated as follows:

- Sport fish: low for overwintering; moderate for nursery, rearing and feeding; moderate for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: low for overwintering; moderate for nursery, rearing and feeding; high for spawning.
- Forage fish: moderate to high for overwintering; high for nursery, rearing and feeding; high for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-27, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-28.

Site 55

Site 55 was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Winter sampling was not conducted due to insufficient water depth. No sport fish were caught at this site. One non-sport fish species, longnose sucker, was caught at this site during the fall survey. Forage fish were caught throughout the spring, summer and fall surveys and included brook stickleback, fathead minnow, lake chub, longnose dace, northern redbelly dace, pearl dace and slimy sculpin.

Kick net spawning surveys were conducted during the spring at this location. Five separate sampling events covering approximately 10 m^2 yielded no eggs.

Waterbodies

Unnamed Waterbody 12

Habitat Assessment

A waterbody site on an unnamed tributary to Redclay Creek was surveyed (Site 52) to assess seasonal fish habitat use potential. The results for the

open-water season and winter habitat conditions are presented in Tables 5.5-31 and 5.5-32.

Site 52

Unnamed Waterbody 12 (Site 52) has an approximate surface area of 0.37 km^2. Appendix R (Figure R-4) contains the habitat map for this waterbody, which illustrates all habitat features observed during the habitat survey as well as seasonal photos. Shallow water with emergent vegetation was present at the north and south areas of the waterbody, with submergent vegetation dominating the remainder of the waterbody. The average and maximum depths recorded throughout the open-water seasons are 0.56 and 1.00 m, respectively.

Dissolved oxygen, pH and conductivity levels were suitable for use by all fish throughout the open-water season (Table 5.5-31). Water quality conditions were measured at one location during the spring, three locations during the summer survey and three locations during the fall survey. Water temperature at Site 52 was continuously monitored from May 18, 2007 to July 21, 2007 (Appendix S, Figure S-5) using a thermograph.

Table 5.5-31 Open-Water Habitat Conditions at Waterbody Sampling Sites in the Redclay Creek Watershed

Waterbody	Sampling Site[a]	Season	Point or Profile	Station	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [°C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 12	52	spring	point	1	0.50	0.50	12.3	–[b]	334	8.11
		summer	point	1	0.60	0.30	22.9	–[b]	268	8.51
			point	2	0.60	0.30	22.7	–[b]	272	8.26
			point	3	0.60	0.30	23.1	–[b]	271	8.42
		fall	point	1	0.30	0.30	11.3	11.20	291	8.50
			point	2	0.35	0.35	11.2	11.55	290	8.58
			point	3	1.00	0.50	11.1	11.20	289	8.58
Unnamed Waterbody 13	53	spring	point	1	0.50	0.50	8.4	–[b]	552	7.44
		summer	point	1	0.50	0.25	25.1	–[b]	558	9.50
		fall	point	1	0.25	0.20	11.7	12.31	462	7.92
			point	2	0.50	0.50	11.8	11.98	455	8.01
			point	3	0.45	0.45	9.9	10.33	444	7.76

[a] See Figure 5.2-2 for sample site locations.

[b] Data not obtained due to equipment malfunction.

– = No Measurement.

Table 5.5-32 Winter Habitat Conditions at Waterbody Sampling Sites in the Redclay Creek Watershed

Waterbody	Sampling Site[a]	Station	Point or Profile	Ice Thickness [m]	Maximum Water Depth [m]	Water Quality Field Parameters				
						Sample Depth [m]	Temperature [˚C]	Dissolved Oxygen [mg/L]	Conductivity [µS/cm]	pH
Unnamed Waterbody 12	52	1	point	0.60	0.45	0.40	2.2	0.81	441	6.70
		2	point	0.55	0.45	0.40	1.9	1.20	461	6.81
		3	point	0.60	0.40	0.30	0.6	2.05	454	6.94
Unnamed Waterbody 13	53	1	point	0.35	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]

[a] See Figure 5.2-2 for sample site locations.

[b] Frozen to bottom.

– = No measurement.

Winter habitat conditions were measured at three locations dispersed throughout the waterbody. Water quality results at each of the sampling stations are presented in Table 5.5-32. Water depths below the ice at the three stations ranged from 0.40 to 0.45 m and averaged 0.43 m. Mean ice thickness was 0.58 m. Temperatures ranged from 0.6 to 2.2°C. Dissolved oxygen levels ranged from 0.81 to 2.1 mg/L, averaging 1.35 mg/L.

Based on the habitat available at Site 52, the seasonal habitat use potential was rated as follows:

- Sport fish: low to nil for overwintering; low to moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring emergent vegetation.
- Non-sport fish: low to nil for overwintering; low to moderate for nursery, rearing and feeding; low for spawning.
- Forage fish: low for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, high for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-27, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-28.

Site 52

Unnamed Waterbody 12 (Site 52) was surveyed for sport, non-sport and forage fish during the spring, summer, fall and winter field surveys. No sport fish or non-sport fish species were captured at this site. Brook stickleback and pearl dace were the only forage fish caught at this site during the fall survey and only brook stickleback was captured in the summer survey. No fish were captured in the spring and winter surveys.

Unnamed Waterbody 13

Habitat Assessment

One waterbody site (Site 53) at the headwaters of a small tributary to Redclay Creek was surveyed to assess seasonal fish habitat use potential. The results for the open-water season and winter habitat conditions are presented in Tables 5.5-31 and 5.5-32.

Site 53

Unnamed Waterbody 13 (Site 53) had an approximate surface area of 0.04 km^2. The habitat map for this waterbody (Appendix R, Figure R-5) illustrates all

habitat features observed during the habitat survey as well as seasonal photos. At the time of the habitat survey, the entire the waterbody consisted of shallow littoral habitat. Submerged and floating aquatic vegetation dominated the surface area, with some isolated emergent vegetation. The average and maximum depths recorded throughout the open-water seasons are 0.44 and 0.50 m, respectively.

Dissolved oxygen, pH and conductivity levels were suitable for use by all fish species (Table 5.5-31). Water quality conditions were measured at one location during the spring, one location during the summer and three locations during the fall. Water temperature at Site 52 was continuously monitored from May 18, 2007 to July 21, 2007 (Appendix S, Figure S-5) using a thermograph. Water temperature fluctuated between 8.1 and 27.0 °C throughout this time period. The peak water temperature (27.0°C) was recorded on July 18, 2007.

There was no overwintering habitat within Site 53 at the time of the survey. The site was frozen to the bottom.

Based on the habitat available at Site 53, the seasonal habitat use potential was rated as follows:

- Sport fish: nil for overwintering; low for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, low for spawning for species requiring emergent vegetation.
- Non-sport fish: nil for overwintering; low for nursery, rearing and feeding; low for spawning.
- Forage fish: nil for overwintering; moderate for nursery, rearing and feeding; nil for spawning for species requiring rocky habitat, moderate for spawning for species requiring aquatic vegetation.

Fish Population

Numbers of fish recorded by species and life stage are presented in Table 5.5-27, sampling effort is presented in Table 5.2-4 and 5.2-5, and CPUE data are presented by sampling technique in Table 5.5-28.

Site 53

Unnamed Waterbody 13 (Site 53) was surveyed for sport, non-sport and forage fish during the spring, summer and fall field surveys. Winter sampling was not possible, as the waterbody was frozen to bottom. No sport fish were caught at this site. During the summer sampling survey, brook stickleback and pearl dace were caught. No fish were captured during the fall and spring surveys.

5.5.2 Diversity of Fish and Fish Habitat

The following sections provide the results of the assessment of fish and fish habitat diversity in the PRMA LSA. The assessment was based on selected indicators of fish species diversity, habitat diversity and ecosystem diversity.

5.5.2.1 Fish Species Diversity

The results of the fish species diversity assessment for the watercourses and waterbodies potentially affected by the Project in the PRMA LSA are presented in Table 5.5-33 for the three species diversity indicators: species richness, species overlap and listed species. A numerical rank (from 1 to 4) was determined for each of these three indicators and a general rank for each watercourse or waterbody was assigned based on the value obtained by multiplying the three individual ranks.

The overall species diversity was ranked as low to very low for all watercourses and waterbodies with the PRMA LSA (Table 5.5-33). Fish species richness was ranked as very low to low in most watercourses and all waterbodies. The exceptions are Eymundson Creek and Redclay Creek, which both ranked as moderate and Pierre River, which ranked as high. Although a few unique species were found in Big Creek, Eymundson Creek, Pierre River and Redclay Creek, all rankings remained very low, as more than 75% of the species present are shared with other watercourses or waterbodies. Within the PRMA LSA, two listed sensitive species exist (Arctic grayling and northern redbelly dace), one species maybe at risk (spoonhead sculpin). Big Creek had the only spoonhead sculpin within the PRMA LSA. Northern redbelly dace were captured in Unnamed Creeks 4, 8 and 10, while both northern redbelly dace and Arctic grayling were found in Eymundson Creek and Pierre River.

5.5.2.2 Fish Habitat Diversity

The results of the habitat diversity assessment for the watercourses and waterbodies potentially affected by the Project in the PRMA LSA are presented in Table 5.5-34. Results are presented for the assessment of the selected fish habitat diversity indicators. A numerical rank (from 1 to 4) was determined for each of these indicators and used to calculate an average rank for each watercourse or waterbody.

Table 5.5-33 Ranking of Watercourses and Waterbodies in the Pierre River Mining Area According to Indicators of Fish Species Diversity

Watershed	Watercourse or Waterbody	Fish Species Richness		Fish Species Overlap		Listed Species		Fish Species Diversity Ranking
		Number of Species and % of Potential Species	Ranking	Number of Unique Species and % of Overlapping Species	Ranking	Listed Species	Ranking (Highest Risk Status)	
Pierre River	Pierre River	17 of 21 potential species - 81%	4	2 unique species, 90% overlap	1	2 sensitive - arctic grayling, northern redbelly dace	2	2 - low (score=8)
	Unnamed Creek 4	6 of 21 potential species - 29%	2	no unique species, 100% overlap	1	1 sensitive - northern redbelly dace	2	2 - low (score=4)
Eymundson Creek	Eymundson Creek	12 of 21 potential species - 57%	3	1 unique species, 95% overlap	1	2 sensitive - arctic grayling, northern redbelly dace	2	2 - low (score=6)
	Asphalt Creek	2 of 21 potential species - 10%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Creek 1	2 of 21 potential species - 10%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Creek 11	4 of 21 potential species - 19%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Waterbody 5	0 of 21 potential species - 0%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Waterbody 6	1 of 21 potential species - 5%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	4 of 21 potential species - 19%	1	no unique species, 100% overlap	1	1 sensitive - northern redbelly dace	2	1 - very low (score=2)
	Unnamed Waterbody 8	0 of 21 potential species - 0%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)

Table 5.5-33 Ranking of Watercourses and Waterbodies in the Pierre River Mining Area According to Indicators of Fish Species Diversity (continued)

Watershed	Watercourse or Waterbody	Fish Species Richness		Fish Species Overlap		Listed Species		Fish Species Diversity Ranking
		Number of Species and % of Potential Species	Ranking	Number of Unique Species and % of Overlapping Species	Ranking	Listed Species	Ranking (Highest Risk Status)	
Big Creek	Big Creek	10 of 21 potential species - 48%	2	2 unique species, 90% overlap	1	1 may be at risk - spoonhead sculpin	3	2 - low (score=6)
	First Creek	0 of 21 potential species - 0%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Creek 2	5 of 21 potential species - 24%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Creek 7	2 of 21 potential species - 10%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Oakley Lake	3 of 21 potential species - 14%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Small Sandy Lake	0 of 21 potential species - 0%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Waterbody 15	1 of 21 potential species - 5%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
Redclay Creek	Redclay Creek	14 of 21 potential species - 67%	3	1 unique species, 95% overlap	1	1 sensitive - Arctic grayling	2	2 - low (score=6)
	Unnamed Creek 8	8 of 21 potential species - 38%	2	no unique species, 100% overlap	1	1 sensitive - northern redbelly dace	2	2 - low (score=4)
	Unnamed Waterbody 12	2 of 21 potential species - 10%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)
	Unnamed Waterbody 13	2 of 21 potential species - 10%	1	no unique species, 100% overlap	1	none	1	1 - very low (score=1)

Table 5.5-34 Ranking of Watercourses and Waterbodies in the Pierre River Mining Area According to Indicators of Fish Habitat Diversity

Watershed	Watercourse or Waterbody	Watercourse Habitat Unit Diversity Index		Stream Order at Mouth		Waterbody Habitat Diversity Index		Waterbody Size			Fish Habitat Diversity Ranking
		Habitat Unit Diversity	Ranking	Stream Order	Ranking	Habitat Diversity	Ranking	Area [km^2]	Maximum Depth [m]	Ranking	
Pierre River	Pierre River	0.7	3 - moderate	3rd	3 - moderate	n/a	n/a	n/a	n/a	n/a	3 - moderate (score=9)
	Unnamed Creek 4	0.37	2 - low	1st	1 - very low	n/a	n/a	n/a	n/a	n/a	1 - very low (score=2)
Eymundson Creek	Eymundson Creek	1.23	3 - moderate	4th	4 - high	n/a	n/a	n/a	n/a	n/a	4 - high (score=12)
	Asphalt Creek	0.39	2 - low	4th	4 - high	n/a	n/a	n/a	n/a	n/a	3 - moderate (score=8)
	Unnamed Creek 1	0.48	3 - moderate	3rd	3 - moderate	n/a	n/a	n/a	n/a	n/a	3 - moderate (score=9)
	Unnamed Creek 11	0.04	1 - very low	1st	1 - very low	n/a	n/a	n/a	n/a	n/a	1 - very low (score=1)
	Unnamed Waterbody 5	n/a	n/a	n/a	n/a	0.02	1 - very low	0.04	4.63	2 - low	1 - very low (score=2)
	Unnamed Waterbody 6	n/a	n/a	n/a	n/a	0.03	1 - very low	0.07	1.6	1 - very low	1 - very low (score=1)
Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	0.03	1 - very low	1st	1 - very low	n/a	n/a	n/a	n/a	n/a	1 - very low (score=1)
	Unnamed Waterbody 8	n/a	n/a	n/a	n/a	0.01	1 - very low	0.20	1.12	2 - low	1 - very low (score=2)
Big Creek	Big Creek	0.11	1 - very low	3rd	3 - moderate	n/a	n/a	n/a	n/a	n/a	2 - low (score=3)
	First Creek	0.55	3 - moderate	2nd	2 - low	n/a	n/a	n/a	n/a	n/a	3 - moderate (score=6)
	Unnamed Creek 2	0.39	2 - low	2nd	2 - low	n/a	n/a	n/a	n/a	n/a	2 - low (score=4)
	Unnamed Creek 7	0.08	1 - very low	2nd	2 - low	n/a	n/a	n/a	n/a	n/a	1 - very low (score=2)
	Oakley Lake	n/a	n/a	n/a	n/a	0	1 - very low	0.83	0.9	2 - low	1 - very low (score=2)
	Small Sandy Lake	n/a	n/a	n/a	n/a	0	1 - very low	0.45	1	2 - low	1 - very low (score=2)
	Unnamed Waterbody 15	n/a	n/a	n/a	n/a	0.01	1 - very low	0.26	1.32	2 - low	1 - very low (score=2)
Redclay Creek	Redclay Creek	0.65	3 - moderate	2nd	2 - low	n/a	n/a	n/a	n/a	n/a	3 - moderate (score=6)
	Unnamed Creek 8	0.79	3 - moderate	1st	1 - very low	n/a	n/a	n/a	n/a	n/a	2 - low (score=3)
	Unnamed Waterbody 12	n/a	n/a	n/a	n/a	0	1 - very low	0.37	1	2 - low	1 - very low (score=2)
	Unnamed Waterbody 13	n/a	n/a	n/a	n/a	0.02	1 - very low	0.04	0.4	1 - very low	1 - very low (score=1)

n/a = Not applicable.

Overall fish habitat diversity was ranked as high for Eymundson Creek, due to a moderate habitat unit diversity ranking and a high stream order at the mouth. First Creek, within the Big Creek watershed, was ranked as having moderate fish habitat diversity. Both Asphalt Creek and Unnamed Creek 1, within the Eymundson Creek watershed, were ranked as having moderate fish habitat diversity. Pierre River and Redclay Creek were also ranked as having moderate fish habitat diversity. The remaining watercourses had low to very low fish habitat diversity. All of the surveyed waterbodies within the PRMA LSA had very low fish habitat diversity.

5.5.2.3 Ecosystem-Level Indicators of Diversity

Ecosystem diversity was assessed for each of the selected watercourses and waterbodies based on the ratio of predator species to prey species. Table 5.5-35 presents the number of predator (piscivorous) species and prey (forage fish) species in each of the watercourses and waterbodies and the ecosystem diversity ranking.

The ecosystem diversity in Pierre River and Redclay Creek was rated as high, due to a high number of predator species, as well as prey species. In both watercourses, predator species included burbot, northern pike and walleye. In both Big Creek and Eymundson Creek, ecosystem diversity was ranked as moderate, due to the presence of one predator species and multiple prey. The predator species in both Pierre River and Eymundson Creek was burbot. The remaining watercourses and all waterbodies lack a predator species and were consequently rated as having very low ecosystem diversity.

Table 5.5-35 Ranking of Watercourses and Waterbodies in the Pierre River Mining Area for Predator to Prey Species Ratio

Watershed	Watercourse or Waterbody	Predator to Prey/Forage Guild Ratio	
		Number of Predator/Prey Species	Ranking
Pierre River	Pierre River	3 predator/14 prey	4 - high
	Unnamed Creek 4	0 predator/6 prey	1 - very low
Eymundson Creek	Eymundson Creek	1 predator/11 prey	3 - moderate
	Asphalt Creek	0 predator/2 prey	1 - very low
	Unnamed Creek 1	0 predator/2 prey	1 - very low
	Unnamed Creek 11	0 predator/4 prey	1 - very low
	Unnamed Waterbody 5	0 predator/0 prey	1 - very low
	Unnamed Waterbody 6	0 predator/1 prey	1 - very low
Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	0 predator/4 prey	1 - very low
	Unnamed Waterbody 8	0 predator/0 prey	1 - very low

Table 5.5-35 Ranking of Watercourses and Waterbodies in the Pierre River Mining Area for Predator to Prey Species Ratio (continued)

Watershed	Watercourse or Waterbody	Predator to Prey/Forage Guild Ratio	
		Number of Predator/Prey Species	Ranking
Big Creek	Big Creek	1 predator/9 prey	3 - moderate
	First Creek	0 predator/0 prey	1 - very low
	Unnamed Creek 2	0 predator/5 prey	1 - very low
	Unnamed Creek 7	0 predator/2 prey	1 - very low
	Oakley Lake	0 predator/3 prey	1 - very low
	Small Sandy Lake	0 predator/0 prey	1 - very low
	Unnamed Waterbody 15	0 predator/1 prey	1 - very low
Redclay Creek	Redclay Creek	3 predator/10 prey	4 - high
	Unnamed Creek 8	0 predator/8 prey	1 - very low
	Unnamed Waterbody 12	0 predator/2 prey	1 - very low
	Unnamed Waterbody 13	0 predator/2 prey	1 - very low

Fish and Fish Habitat Diversity Summary

The overall fish and fish habitat diversity of each of the selected watercourses and waterbodies was assessed by combining the general rankings for species, habitat and ecosystem-level diversity indicators (Table 5.5-36). The contribution of each watercourse or waterbody to fish and fish habitat diversity in the study areas was categorized as very low, low, moderate or high based on the ranking they received in the evaluation of each of the species, habitat and ecosystem indicators.

Based on the ranking system used for this assessment, Eymundson Creek, Pierre River and Redclay Creek provided the most significant contribution to fish and fish habitat diversity in the PRMA LSA. These three watercourses received a moderate overall fish and fish habitat diversity ranking, the highest overall ranking within the PRMA LSA. While the fish habitat in Eymundson Creek was ranked as high and the ecosystem diversity was ranked as moderate, both Pierre River and Redclay Creek were ranked as high for ecosystem diversity and moderate for habitat diversity. The overall fish and fish habitat diversity for the remaining watercourses was ranked as low to very low, while all waterbodies obtained a very low overall fish and fish habitat diversity ranking.

Table 5.5-36 Summary of Fish and Fish Habitat Diversity Rankings for Watercourses and Waterbodies in the Pierre River Mining Area

Watershed	Watercourse or Waterbody	Ranking			
		Species Diversity	Habitat Diversity	Ecosystem Diversity	Overall Diversity
Pierre River	Pierre River	low	moderate	high	moderate
	Unnamed Creek 4	low	very low	very low	very low
Eymundson Creek	Eymundson Creek	low	high	moderate	moderate
	Asphalt Creek	very low	moderate	very low	low
	Unnamed Creek 1	very low	moderate	very low	low
	Unnamed Creek 11	very low	very low	very low	very low
	Unnamed Waterbody 5	very low	very low	very low	very low
	Unnamed Waterbody 6	very low	very low	very low	very low
Unnamed Tributaries to the Athabasca River	Unnamed Creek 10	very low	very low	very low	very low
	Unnamed Waterbody 8	very low	very low	very low	very low
Big Creek	Big Creek	low	low	moderate	low
	First Creek	very low	moderate	very low	low
	Unnamed Creek 2	very low	low	very low	very low
	Unnamed Creek 7	very low	very low	very low	very low
	Oakley Lake	very low	very low	very low	very low
	Small Sandy Lake	very low	very low	very low	very low
	Unnamed Waterbody 15	very low	very low	very low	very low
Redclay Creek	Redclay Creek	very low	moderate	high	moderate
	Unnamed Creek 8	low	low	very low	low
	Unnamed Waterbody 12	very low	very low	very low	very low
	Unnamed Waterbody 13	very low	very low	very low	very low

5.5.3 Benthic Invertebrates

The following section provides a summary of the benthic invertebrate community data available for watercourses and waterbodies within the PRMA LSA. Included are the results of the literature review, and the 2005 and 2006 environmental setting field surveys.

5.5.3.1 Literature Review

Benthic invertebrate community information is available only for Lillian Lake, consisting of one report (Golder 2002c) describing data collected at one site in October 2001.

The benthic invertebrate community in Lillian Lake was dominated by midges and seed shrimps (Table 5.5-37). Mean benthic invertebrate density was

18,399 organisms/m², which is in the moderate range. Total richness was 37 taxa/site and mean richness was 10.4 taxa/site.

Table 5.5-37 Historical Benthic Invertebrate Community Data for Lillian Lake

Variable	Lillian Lake
	LIL-1
study	Golder (2002b)
date	16-October-2001
habitat	waterbody
Density	
mean density [numbers/m²]	18,399
SE mean density [numbers/m²]	8,035
Richness	
total richness [no. taxa/site]	37
mean richness [no. taxa/site]	10.4
SE mean richness [no.taxa/site]	2.1
Relative Density [%]	
Oligochaeta	7
Chironomidae	58
Ostracoda	24
Gastropoda	<1
Pelecypoda	6
other Diptera	0
Amphipoda	<1
Ephemeroptera	1
other (includes Trichoptera and Plecoptera)	4

Note: SE = standard error of the mean.

5.5.3.2 Environmental Field Survey

Pierre River Watershed

Watercourses

Pierre River Mainstem (Sites 19-1 and 20-1)

Benthic Invertebrate Habitat

Two sites were sampled for benthic invertebrates in the Pierre River mainstem (Sites 19-1 and 20-1) during fall 2005, both in depositional habitat. Mean depth at these sites ranged from 0.20 m (Site 20-1) to 0.58 m (Site 19-1) (Table 5.5-38). Mean current velocity ranged from 0.01 m/s (Site 19-1) to 0.16 m/s (Site 20-1). Aquatic macrophyte cover was absent to moderate (0 to 35%). Field-measured water quality parameters at Site 20-1 were typical of watercourses in the Oil Sands Region during the fall season. Bottom substrates at both sites were dominated by the sand fraction. Sediment TOC was low (less than 1%).

Benthic Invertebrate Community

A benthic invertebrate taxon list for the Pierre River watershed is provided in Appendix U, Table U-4.

Mean (±1 SE) benthic invertebrate density in the Pierre River was highly variable, ranging from 1,198 ± 324 organisms/m² (Site 20-1) to 63,190 ± 24,015 organism/m² (Site 19-1) (Table 5.5-39, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness ranged from 23 taxa/site (Site 20-1) to 40 taxa/site (Site 19-1) and mean (±1 SE) richness ranged from 7.2 ± 1.7 taxa/site (Site 20-1) to 18.0 ± 1.1 taxa/site (Site 19-1) (Figure 5.5-2). The lower density and richness at Site 20-1 may reflect the shallow water depth (possibly indicating recent exposure of the substrates) and higher sand content of bottom sediments at this site.

Table 5.5-38 Benthic Invertebrate Habitat Characteristics for the Pierre River and Eymundson Creek Watersheds in the Pierre River Mining Area, Fall 2005 and 2006

Parameter	Units	Pierre River Watershed		Eymundson Creek Watershed							
		Pierre River		Upper Eymundson Creek		Lower Eymundson Creek			Asphalt Creek	Unnamed Creek 1	Unnamed Waterbody 6
		Site 19-1	Site 20-1	Site 6	Site 57	Site 11	Site 17	Site 17-1	Site 48	Site 15-1	Site 2
habitat type	–	depositional	depositional	depositional	depositional	depositional	depositional	depositional	erosional	depositional	waterbody
date	–	September 26, 2005	September 27, 2005	October 15, 2005	October 1, 2006	October 18, 2005	October 18, 2005	September 28, 2005	October 2, 2006	September 27, 2005	October 2, 2005
Field Supporting Data											
easting	m	495439	462235	460186	460292	462333	465887	465790	451995	459432	456367
northing	m	6370826	6367477	6379618	6379514	6377320	6372314	6372547	6382451	6374861	6382839
mean depth	m	0.58	0.20	0.47	0.33	0.21	0.15	0.25	0.28	0.22	1.28
mean current velocity	m/s	0.01	0.16	0.00	–	0.18	0.27	0.30	0.40	0.25	–
wetted channel width	m	5.0	8.0	10.0	2.7	5.5	6.9	8.5	3.6	2.1	–
macrophyte cover	%	35	0	0	40	0	0	0	0	0	–
Field Water Quality											
dissolved oxygen	mg/L	–	9.2	6.3	5.8	11.3	11.3	9.2	11.0	9.1	8.7
conductivity	µS/cm	–	362	284	403	388	403	290	378	241	281
pH	–	–	8.1	7.0	7.1	7.9	8.0	7.9	7.9	7.1	7.8
water temperature	°C	–	3.9	4.6	7.1	0.5	0.8	4.0	5.5	4.6	5.6
Substrate											
Laboratory											
sand	%	74	90	–	–	–	88	–	–	82	–
silt	%	10	4	–	–	–	6	–	–	8	–
clay	%	16	6	–	–	–	6	–	–	11	–
moisture content	%	–	–	–	–	–	22	–	–	0	–
total organic carbon	%	0.7	0.8	–	–	–	0.5	–	–	0.6	–
Field											
sand/silt/clay (<2 mm)	%	–	–	–	–	–	–	–	70	–	–
small gravel (2 to 16 mm)	%	–	–	–	–	–	–	–	10	–	–
large gravel (16 to 25 mm)	%	–	–	–	–	–	–	–	10	–	–
small cobble (62 to 128 mm)	%	–	–	–	–	–	–	–	5	–	–
large cobble (128 to 256 mm)	%	–	–	–	–	–	–	–	5	–	–
boulder (>256 mm)	%	–	–	–	–	–	–	–	0	–	–
bedrock	%	–	–	–	–	–	–	–	0	–	–
embeddedness	%	–	–	–	–	–	–	–	15	–	–

– = No data/not applicable.

Notes: UTM co-ordinates are Zone 12 V, NAD 83.

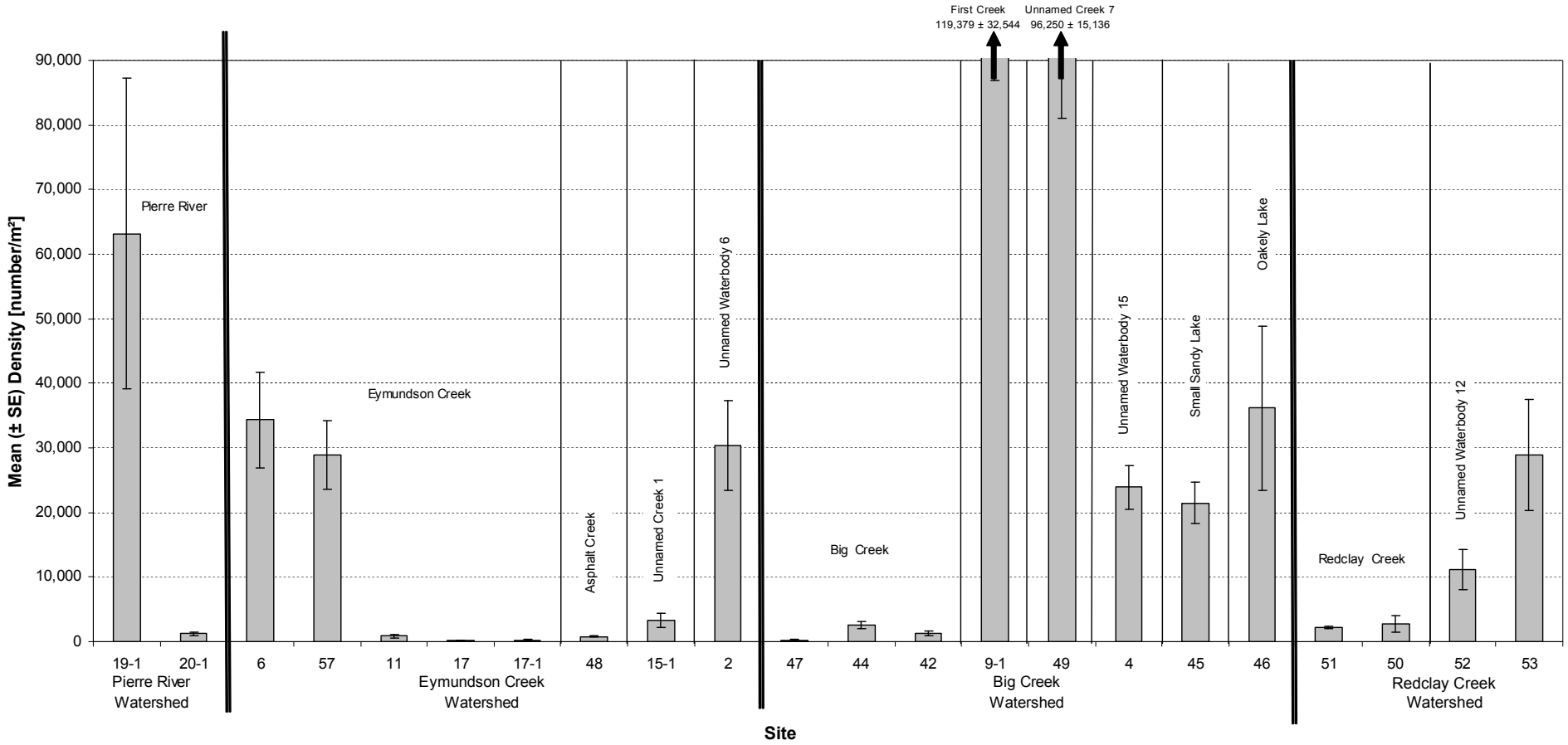
Multiple sites on a watercourse are listed left to right from upstream to downstream.

Erosional sites were not sampled for sediment quality analysis.

Table 5.5-39 Benthic Invertebrate Community Data for the Pierre River and Eymundson Creek Watersheds in the Pierre River Mining Area, Fall 2005 and 2006

Variable	Pierre River Watershed		Eymundson Creek Watershed							
	Pierre River		Upper Eymundson Creek		Lower Eymundson Creek			Asphalt Creek	Unnamed Creek 1	Unnamed Waterbody 6
	Site 19-1	Site 20-1	Site 6	Site 57	Site 11	Site 17	Site 17-1	Site 48	Site 15-1	Site 2
date	September 26, 2005	September 27, 2005	October 15, 2005	October 1, 2006	October 18, 2005	October 18, 2005	September 28, 2005	October 2, 2006	September 27, 2005	October 2, 2005
habitat	depositional	depositional	depositional	depositional	depositional	depositional	depositional	erosional	depositional	waterbody
Density										
mean density [numbers/m²]	63,190	1,198	34,379	28,914	853	121	224	781	3,207	30,414
SE mean density [numbers/m²]	24,015	324	7,419	5,339	298	16	121	106	1,100	6,912
Richness										
total richness [no. taxa/site]	40	23	27	33	12	5	5	26	10	33
mean richness [no. taxa/site]	18.0	7.2	13.0	15.6	4.0	1.8	1.4	14.6	4.8	15.6
SE mean richness [no. taxa/site]	1.1	1.7	1.2	1.5	0.7	0.4	0.5	0.9	0.2	2.2
Diversity										
Simpson's Diversity Index (SDI) (1-D)	0.85	0.86	0.57	0.76	0.79	0.47	0.34	0.82	0.46	0.87
evenness	0.17	0.31	0.09	0.13	0.40	0.38	0.30	0.22	0.18	0.23
Relative Density [%]										
Oligochaeta	19	34	7	9	7	75	30	<1	1	8
Chironomidae	72	39	27	25	78	25	70	18	99	59
Ostracoda	1	20	61	40	0	0	0	<1	0	9
Gastropoda	<1	0	<1	0	5	0	0	0	0	<1
Pelecypoda	<1	2	3	1	0	0	0	0	0	6
other Diptera	6	2	1	1	9	0	0	3	1	4
Amphipoda	0	0	<1	<1	0	0	0	0	0	3
Ephemeroptera	<1	<1	0	<1	0	0	0	37	0	0
other (includes Trichoptera and Plecoptera)	2	3	1	26	0	0	0	40	0	11

Note: SE = Standard error of the mean.



ERROR BARS REPRESENT ±1STANDARD ERROR OF THE MEAN.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

MEAN BENTHIC INVERTEBRATE DENSITY IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. MeanBI Dens..._PRMA	
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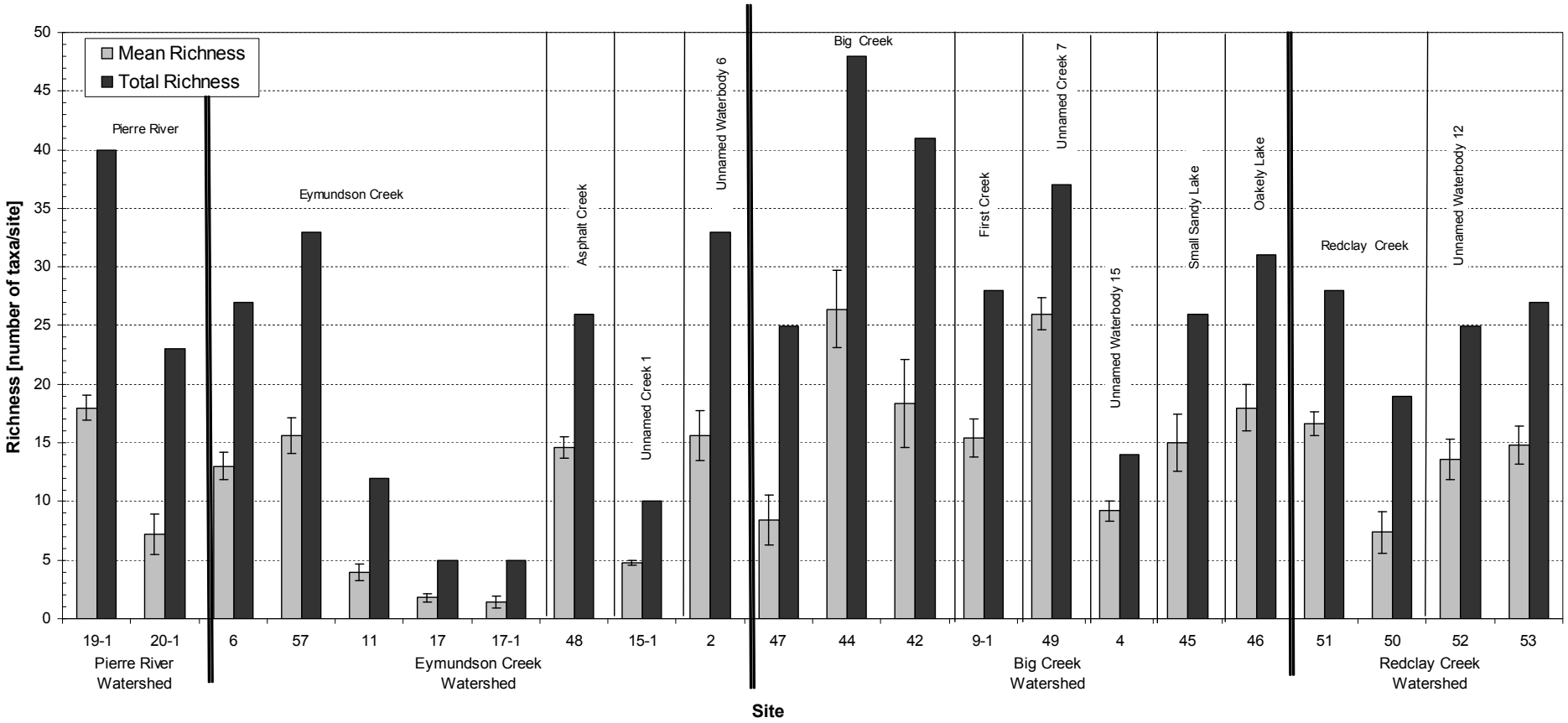
CHECK	JS	09/10/07		
REVIEW	WES/TC	20/11/07		



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PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

MEAN AND TOTAL BENTHIC INVERTEBRATE RICHNESS IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. MeanTotal Rich..PRMA	
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CADD	TY	18/11/07	**FIGURE: 5.5-2**	
CHECK	JS	09/10/07		
REVIEW	WES/TC	20/11/07		

The values of the SDI for the Pierre River ranged from 0.85 (Site 19-1) to 0.86 (Site 20-1) (Table 5.5-39, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness ranged from 0.17 (Site 19-1) to 0.31 (Site 20-1) (Figure 5.5-4) indicating that a few taxonomic groups accounted for the majority of the benthic invertebrate density. The benthic invertebrate community was dominated by midges and bristle worms, together accounting for 91% of the total density at Site 19-1 (Figure 5.5-5). In addition to these two taxa, seed shrimp were also dominant at Site 20-1, with the three taxa accounting for 93% of the total density. The midges at Site 19-1 were dominated by the Tanytarsini and the Orthocladiinae, while midges at Site 20-1 were dominated by the Orthocladiinae and the Chironomini (Figure 5.5-6).

Eymundson Creek Watershed

Watercourses

Eymundson Creek Mainstem (Sites 6, 57, 11, 17 and 17-1)

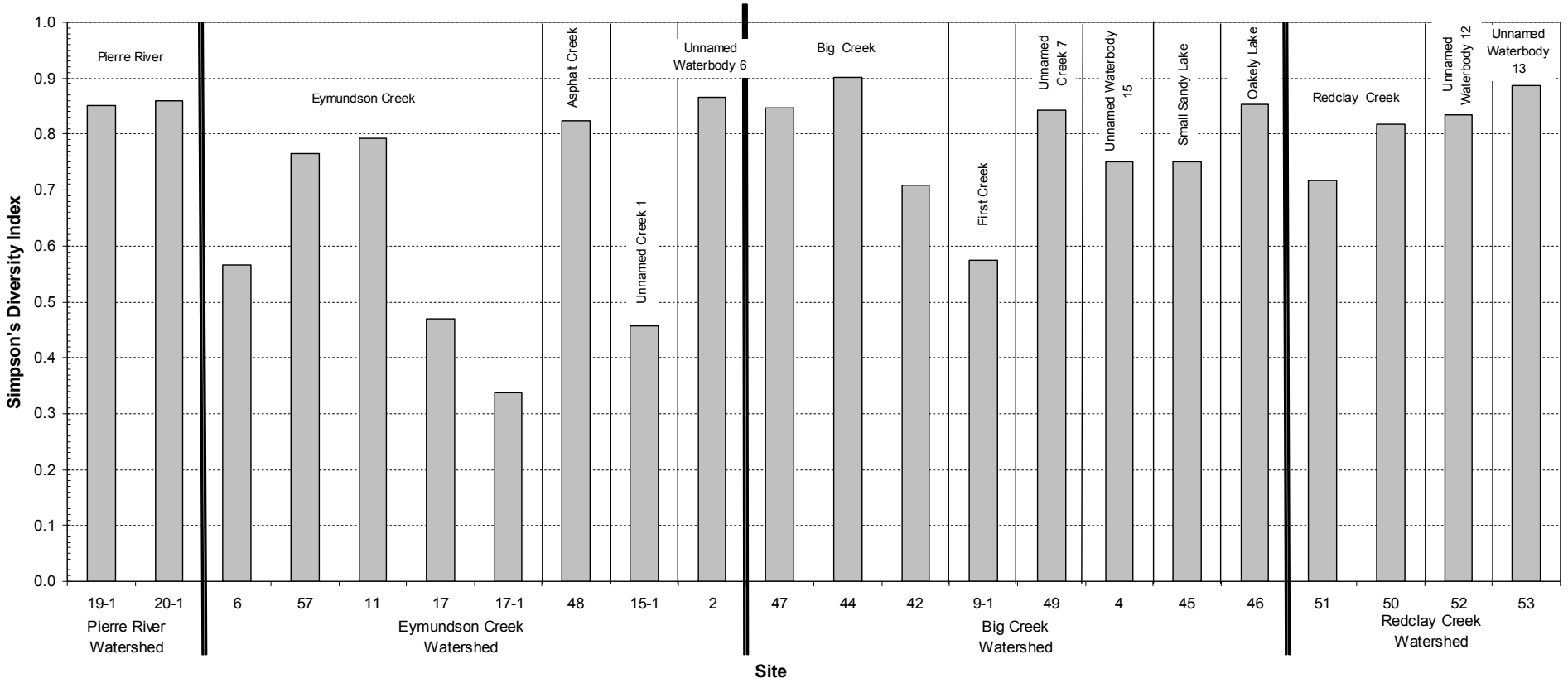
In the discussion below, Eymundson Creek is separated into two distinct reaches. Upper Eymundson Creek includes benthic invertebrate Sites 6 and 57 in fisheries Reach 4, and lower Eymundson Creek refers to Sites 11, 16 and 17-1 in Reaches 1, 2 and 3 (Figure 5.2-2 for locations of reach breaks). Below Asphalt Creek, the stream section referred to as Eymundson Creek is actually the lower part of Asphalt Creek. However, because this lower portion of the stream has traditionally been named Eymundson Creek, it is treated as such in this report.

Benthic Invertebrate Habitat

Upper Eymundson Creek (Sites 6 and 57)

Two sites were sampled for benthic invertebrates in Upper Eymundson Creek (Sites 6 and 57) one during fall 2005 and the other during fall 2006. Both sites were located in depositional habitat. Mean depth at these sites ranged from 0.33 m (Site 57) to 0.47 m (Site 6) and current velocity was negligible at both sites (Table 5.5-38). Macrophyte cover was absent to moderate (0 to 40%). Field-measured water quality parameters were typical of the fall season at both sites. Detailed sediment data are not available for these sites; however, based on field observations, bottom substrates consisted of fine sediments, with a moderate to high organic content.

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\FISH-BENTHICS\Figure 5.5-3 Simpson's Diversity Index for Benthic Invertebrate-PRMA.dwg Nov 19, 2007 - 2:11pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

SIMPSON'S DIVERSITY INDEX FOR BENTHIC INVERTEBRATES IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

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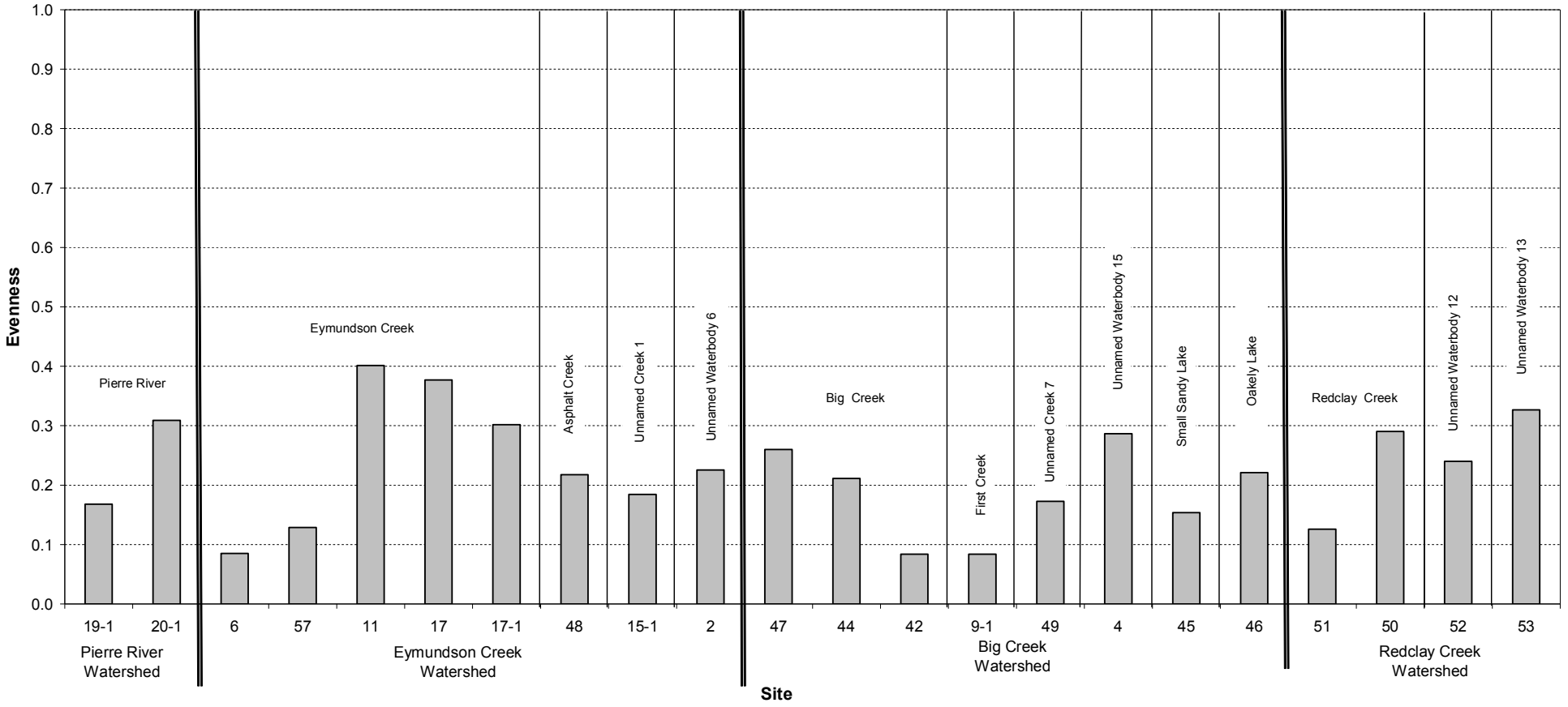
CHECK	AS	19/11/07		
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

EVENNESS VALUES FOR BENTHIC INVERTEBRATES IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. Eveness Values..PRMA	
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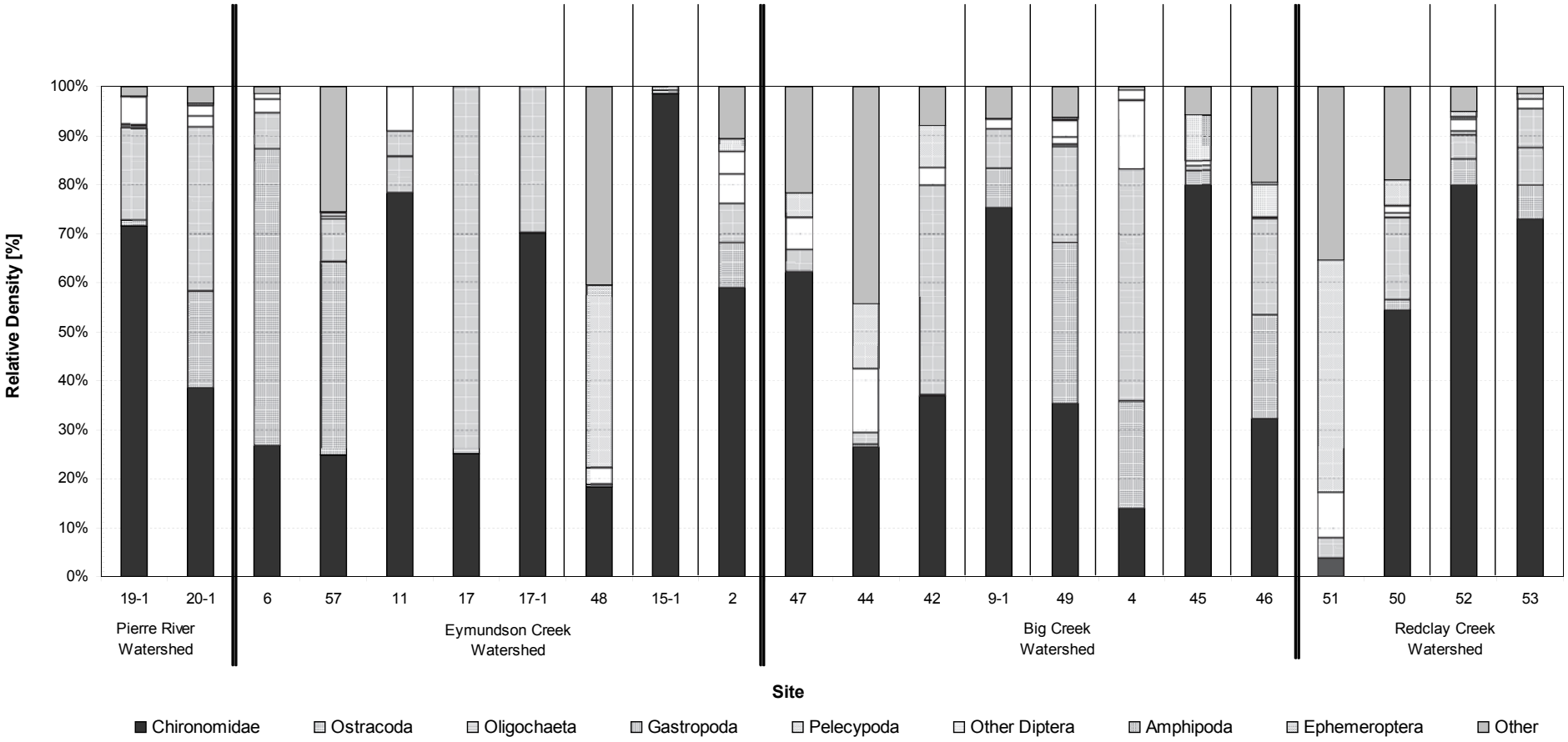
CADD	TRE	09/10/07	FIGURE: 5.5-4	
CHECK	JS	09/10/07		
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\FISH-BENTHICS\Figure 5.5-5 Relative Benthic Invertebrate Density-PRMA.dwg Nov 30, 2007 - 4:09pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE BENTHIC INVERTEBRATE DENSITY IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. RelativeBIDensity.PRMA	
DESIGN	JS	05/10/07	SCALE AS SHOWN	REV. 0
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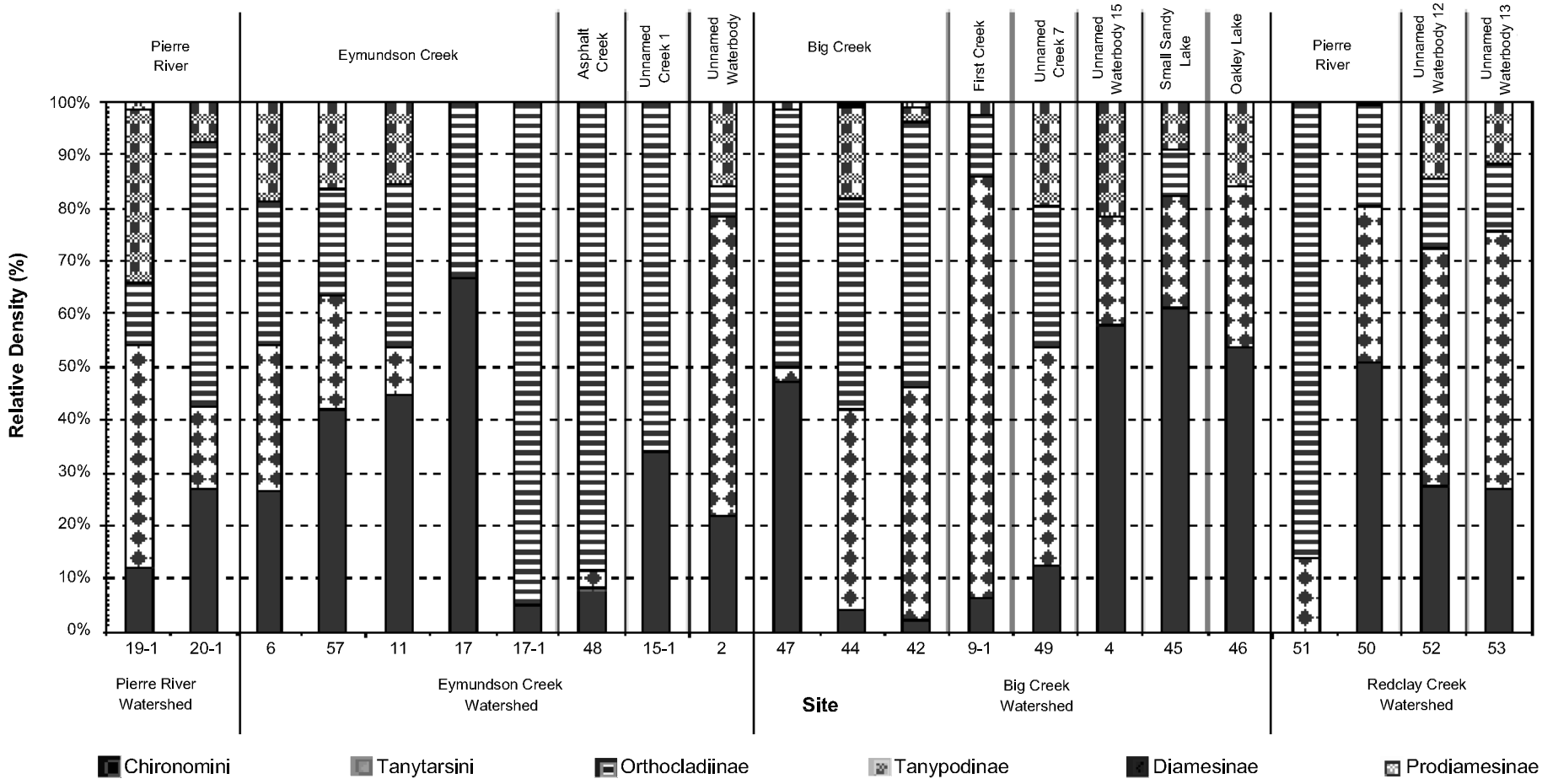
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

RELATIVE CHIRONOMIDAE DENSITY IN THE PIERRE RIVER MINING AREA, FALL 2005 AND 2006

Shell Canada Limited

PROJECT 05-1344-027.6100			FILE No. RelativeChiro...PRMA	
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CADD	TY	11/10/07	FIGURE: 5.5-6	
CHECK	JS	11/10/07		
REVIEW	WES/TC	20/11/07		

Lower Eymundson Creek (Sites 11, 17 and 17-1)
Three sites were sampled for benthic invertebrates in Lower Eymundson Creek (Sites 11, 17 and 17-1) during fall 2005, in depositional habitat. Mean depth at these sites ranged from 0.15 m (Site 17) to 0.25 m (Site 17-1) (Table 5.5-38). Mean current velocity ranged from 0.18 m/s (Site 11) to 0.30 m/s (Site 17-1). Field-measured water quality parameters were typical of the fall season at all sites, with the exception of DO concentration, which was high (11.3 mg/L) at Sites 11 and 17. The bottom substrate at Site 17 was dominated by the sand fraction and TOC was low, measuring 0.5%.

Benthic Invertebrate Community
A benthic invertebrate taxon list for the Eymundson Creek watershed is provided in Appendix U, Table U-4.

Upper Eymundson Creek (Sites 6 and 57)
Mean (±1 SE) benthic invertebrate densities in upper Eymundson Creek were similar, ranging from 28,914 ± 5,339 organisms/m² (Site 57) to 34,279 ± 7,419 organisms/m² (Site 6) (Table 5.5-39, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Taxonomic richness at these sites was also similar, with total richness ranging from 27 taxa/site (Site 6) to 33 taxa/site (Site 57) and mean (±1 SE) richness ranging from 13.0 ± 1.2 taxa/site (Site 6) to 15.6 ± 1.5 taxa/site (Site 57) (Figure 5.5-2).

The values for SDI in upper Eymundson Creek ranged from 0.57 (Site 6) to 0.76 (Site 57) indicating a moderate level of diversity (Table 5.5-39, Figure 5.5-3). Evenness values ranged from 0.09 (Site 6) to 0.13 (Site 57) (Figure 5.5-4) indicating that the majority of the total density at both sites was accounted for by only a few taxonomic groups.

The benthic invertebrate community in upper Eymundson Creek was dominated by seed shrimp and midges (Figure 5.5-5). At Site 6, these two taxa accounted for 88% of the total density. At Site 57, in addition to the seed shrimp and midges, the “other” group was also dominant, with all three groups accounting for 91% of the total density. The midge assemblages in upper Eymundson Creek were not dominated by any single group (Figure 5.5-6).

Lower Eymundson Creek (Sites 11, 17 and 17-1)
Mean (±1 SE) benthic invertebrate densities in lower Eymundson Creek were low, ranging from 121 ± 16 organsims/m² (Site 17) to 853 ± 298 organisms/m² (Site 11) (Table 5.5-39, Figure 5.5-1). Taxonomic richness was also low, with total richness ranging from 5 taxa/site (Sites 17 and 17-1) to 12 taxa/site (Site 11) and mean (±1 SE) richness ranging from 1.4 ± 0.5 taxa/site (Site 17-1) to 4.0 ± 0.7 taxa/site (Site 11) (Figure 5.5-2).

Values for SDI ranged from 0.34 (Site 17-1) to 0.79 (Site 11) indicating a variable level of diversity (Table 5.5-39, Figure 5.5-3). Evenness ranged from 0.30 (Site 17-1) to 0.40 (Site 11), within the low to moderate range (Figure 5.5-4).

The benthic invertebrate community in lower Eymundson Creek was dominated by midges and bristle worms, which make up 83% (Site 11) to 100% (Site 17 and 17-1) of the total density at a site (Figure 5.5-5). The midge community in lower Eymundson Creek was dominated by the Chironomini and Orthocladiinae (Figure 5.5-6).

Overall, the benthic invertebrate community in lower Eymundson Creek was more similar to that of Asphalt Creek than to the communities observed in upper Eymundson Creek.

Asphalt Creek (Site 48)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Asphalt Creek (Site 48) during fall 2006, in erosional habitat. Mean depth at this site was 0.28 m and mean current velocity was 0.40 m/s (Table 5.5-38). Field-measured water quality parameters are typical of the Oil Sands Region in the fall season. Visual estimates of the bottom substrate indicate that the substrate was dominated by the sand, silt and clay (fine) particle size fraction.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Asphalt Creek (Site 48) was 781 ± 106 organisms/m² (Table 5.5-39, Figure 5.5-1; raw data are provided in Appendix U, Table U-1), which is similar to the densities observed in lower Eymundson Creek. Total taxonomic richness was 26 taxa/per site and mean (±1 SE) richness was 14.6 ± 0.9 taxa/site (Figure 5.5-2).

The value of SDI was 0.82 in Asphalt Creek (Table 5.5-39, Figure 5.5-3) indicating a high level of diversity. Evenness was 0.22, indicating that the majority of the total density was accounted for by relatively few taxa (Figure 5.5-4). The benthic invertebrate community in Asphalt Creek was dominated by mayflies, midges and the "other" taxa group (Figure 5.5-5), with these three groups accounting for 95% of the total density. The midges in Asphalt Creek were dominated by the Orthocladiinae (Figure 5.5-6).

Unnamed Creek 1 (Site 15-1)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Creek 1 (Site 15-1) in fall 2005, in depositional habitat. Mean depth at this site was 0.22 m and mean current velocity was 0.25 m/s (Table 5.5-38). Field-measured water quality parameters were typical of the Oil Sands Region during the fall season. The bottom substrate was dominated by the sand fraction and TOC was low.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Creek 1 (Site 15-1) was 3,207 ± 1,100 organisms/m² (Table 5.3-39, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 10 taxa/site and mean (±1 SE) was 4.8 ± 0.2 taxa/site (Figure 5.5-2). Both density and richness fall in the low range compared to other streams in the region.

The value of SDI in Unnamed Creek 1 was 0.46 (Figure 5.5-3) indicating moderate diversity. Evenness was 0.18 (Figure 5.5-4) indicating that only a few taxa accounted for the majority of the total benthic invertebrate density. The benthic invertebrate community in Unnamed Creek 1 was dominated by midges, which accounted for 99% of the total density (Figure 5.5-5). The midges were dominated by the Orthocladiinae (Figure 5.5-6).

Waterbodies

Unnamed Waterbody 6 (Site 2)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Waterbody 6 (Site 2) in fall 2005. Mean depth was 1.28 m at this site (Table 5.5-38). Field-measured water quality parameters were typical of the Oil Sands Region in the fall season. No laboratory analysis was conducted for sediment particle size or TOC. Based on field observations, bottom substrates consisted primarily of fine sediments with moderate to high organic content.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Waterbody 6 (Site 2) was 30,414 ± 6,912 organisms/m² (Table 5.5-39, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 33 taxa/site and mean (±1 SE) richness was 15.6 ± 2.2 taxa/site (Figure 5.5-2).

The SDI value for Unnamed Waterbody 6 was 0.87 (Table 5.5-39, Figure 5.5-3) indicating a diverse benthic invertebrate community. Evenness was 0.23 (Figure 5.5-4) indicating that the total density at this site was accounted for by only a few taxa. The benthic invertebrate community was dominated by midges,

which accounted for 59% of the total density (Figure 5.5-5). The midge community was dominated by the Tanytarsini and to a lesser extent the Chironomini and Tanypodinae (Figure 5.5-9).

Big Creek Watershed

Watercourses

Big Creek Mainstem (Sites 47, 44 and 42)

Benthic Invertebrate Habitat

Three sites were sampled for benthic invertebrates in Big Creek (Sites 47, 44 and 42) during fall 2005, in erosional habitat. Mean depth at these sites ranged from 0.08 m (Site 44) to 0.17 m (Site 42) (Table 5.5-40). Mean current velocity at these sites ranged from 0.13 m/s (Site 44) to 0.28 m/s (Site 42). Field-measured water quality parameters were typical of the Oil Sands Region for the fall season. Based on visual estimates, bottom substrates were dominated by fine sediments at Sites 47 and 42. Substrates were coarser at Site 44. Total organic carbon content at Site 42 was low.

Benthic Invertebrate Community

A benthic invertebrate taxon list for the Big Creek and Redclay Creek watersheds is provided in Appendix U, Table U-5.

Mean (±1 SE) benthic invertebrate density in Big Creek was low, ranging from 258 ± 62 organisms/m² (Site 47) to 2,611 ± 560 organisms/m² (Site 44) (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness ranged from 25 taxa/site (Site 47) to 48 taxa/site (Site 44) and mean (±1 SE) richness ranged from 8.4 ± 2.1 taxa/site (Site 47) to 26.4 ± 3.3 taxa/site (Site 44) (Figure 5.5-2).

Table 5.5-40 Benthic Invertebrate Habitat Characteristics for the Big Creek and Redclay Creek Watersheds in the Pierre River Mining Area, Fall 2005 and 2006

Parameter	Units	Big Creek Watershed								Redclay Creek Watershed			
		Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
		Site 47	Site 44	Site 42	Site 9-1	Site 49	Site 4	Site 45	Site 46	Site 51	Site 50	Site 52	Site 53
habitat type	-	erosional	erosional	erosional	depositional	depositional	waterbody	waterbody	waterbody	erosional	depositional	waterbody	waterbody
date	-	September 29, 2006	September 27, 2006	September 30, 2006	September 25, 2005	September 30, 2006	October 3, 2005	September 28, 2006	September 29, 2006	September 26, 2006	September 27, 2006	September 25, 2006	September 25, 2006
Field Supporting Data													
easting	m	457381	468882	471640	467239	470874	464844	463981	462643	473775	475856	473824	468199
northing	m	6387858	6390970	6387770	6386514	6389179	6382605	6390578	6390866	6399819	6395032	6403415	6397863
mean depth	m	0.08	0.14	0.17	0.10	0.33	1.22	1.16	0.48	0.19	0.29	1.00	0.53
mean current velocity	m/s	0.25	0.13	0.28	0.05	–	–	–	–	0.27	0.03	–	–
wetted channel width	m	4.4	–	6.7	1.6	–	–	–	–	5.5	6.2	–	–
macrophyte cover	%	0	0	0	35	100	–	0	0	0	0	90	100
Field Water Quality													
dissolved oxygen	mg/L	10.3	11.5	8.8	5.9	6.4	9.3	12.1	9.5	12.0	11.0	11.2	10.3
conductivity	µS/cm	392	374	360	213	369	213	532	375	451	442	289	448
pH	-	7.7	8.3	8.1	6.9	7.5	6.9	8.9	7.9	8.1	8.1	8.6	7.9
water temperature	°C	8.5	5.3	–	8.1	8.8	5.3	11.4	11.0	8.0	6.2	11.1	10.2
Substrate													
Laboratory													
sand	%	–	–	92	47	–	2	–	–	–	28	–	–
silt	%	–	–	4	19	–	55	–	–	–	48	–	–
clay	%	–	–	4	35	–	43	–	–	–	24	–	–
moisture content	%	–	–	18	–	–	–	–	–	–	42	–	–
total organic carbon	%	–	–	0.5	24.6	–	26.4	–	–	–	2.5	–	–
Field													
sand/silt/clay [<2 mm]	%	80	40	80	–	–	–	–	–	30	–	–	–
small gravel [2 to 16 mm]	%	20	20	10	–	–	–	–	–	55	–	–	–
large gravel [16 to 25 mm]	%	0	30	5	–	–	–	–	–	10	–	–	–
small cobble [62 to 128 mm]	%	0	10	0	–	–	–	–	–	5	–	–	–
large cobble [128 to 256 mm]	%	0	0	0	–	–	–	–	–	0	–	–	–
boulder [>256 mm]	%	0	0	5	–	–	–	–	–	0	–	–	–
bedrock	%	0	0	0	–	–	–	–	–	0	–	–	–
embeddedness	%	0	0	0	–	–	–	–	–	0	–	–	–

– = No data/not applicable.

Notes: UTM co-ordinates are Zone 12 V, NAD 83.

Multiple sites on a watercourse are listed left to right from upstream to downstream.

Erosional sites were not sampled for sediment quality analysis.

Table 5.5-41 Benthic Invertebrate Community Data for the Big Creek and Redclay Creek Watersheds of the Pierre River Mining Area, Fall 2005 and 2006

Variable	Big Creek Watershed								Redclay Creek Watershed			
	Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
	Site 47	Site 44	Site 42	Site 9-1	Site 49	Site 4	Site 45	Site 46	Site 51	Site 50	Site 52	Site 53
date	September 29, 2006	September 27, 2006	September 30, 2006	September 26, 2005	September 30, 2006	October 3, 2005	September 28, 2006	September 29, 2006	September 26, 2006	September 27, 20-06	September 25, 2006	September 25, 2006
habitat	erosional	erosional	erosional	depositional	depositional	waterbody	waterbody	waterbody	erosional	depositional	waterbody	waterbody
Density												
mean density [numbers/m²]	258	2,611	1,269	119,379	96,250	23,897	21,483	36,147	2,129	2,767	11,129	28,845
SE mean density [numbers/m²]	62	560	365	32,544	15,136	3,362	3,280	12,703	175	1,231	3,120	8,574
Richness												
total richness [no. taxa/site]	25	48	41	28	37	14	26	31	28	19	25	27
mean richness [no. taxa/site]	8.4	26.4	18.4	15.4	26.0	9.2	15.0	18.0	16.6	7.4	13.6	14.8
SE mean richness [no. taxa/site]	2.1	3.3	3.7	1.6	1.3	0.9	2.4	2.0	1.0	1.8	1.7	1.7
Diversity												
Simpson's Diversity Index (SDI) (1-D)	0.85	0.90	0.71	0.57	0.84	0.75	0.75	0.85	0.72	0.82	0.83	0.89
evenness	0.26	0.21	0.08	0.08	0.17	0.29	0.15	0.22	0.13	0.29	0.24	0.33
Relative Density [%]												
Oligochaeta	5	2	43	8	19	47	1	19	4	17	5	8
Chironomidae	62	26	37	75	35	14	80	32	4	54	80	73
Ostracoda	0	<1	<1	8	33	22	3	21	0	2	5	7
Gastropoda	0	0	0	0	1	0	<1	0	0	0	1	8
Pelecypoda	0	<1	0	2	1	14	1	0	0	1	3	2
other Diptera	7	13	4	<1	3	2	0	0	9	2	0	0
Amphipoda	0	0	0	0	<1	<1	9	7	0	0	<1	0
Ephemeroptera	5	13	9	0	1	0	0	0	47	5	1	1
other (includes Trichoptera and Plecoptera)	22	44	8	7	6	1	6	20	35	19	5	1

Note: SE = standard error of the mean.

The values of the SDI ranged from 0.71 (Site 42) to 0.90 (Site 44) (Table 5.5-41, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness ranged from 0.08 (Site 42) to 0.26 (Site 47) (Figure 5.5-4), indicating that only a few taxa accounted for the total density in Big Creek. Midges were dominant at all sites, while the "other" group (mostly stoneflies) was also dominant at Sites 47 and 44. Bristle worms were also dominant at Site 42 (Figure 5.5-5). These three taxonomic groups accounted for 72 to 89% of the relative density. The midges were dominated by the Orthocladiinae at all sites, the Tanytarsini were also dominant at Sites 44 and 42, and the Chironomini were also dominant at Site 47 (Figure 5.5-6).

First Creek (Site 9-1)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates on First Creek (Site 9-1) during fall 2005, in depositional habitat. Mean depth at this site was 0.10 m and mean current velocity was 0.05 m/s (Table 5.5-40). Macrophyte cover was 35% in the area sampled for benthic invertebrates. Field-measured water quality parameters were typical of watercourses in the Oil Sands Region for the fall season, with the exception of DO (5.9 mg/L) which was low. The bottom substrate was dominated by the sand and clay fractions and TOC was high, at 24.6%.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in First Creek (Site 9-1) was high, 119,379 ± 32,544 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 28 taxa/site and mean (±1 SE) richness was 15.4 ± 1.6 taxa/site (Figure 5.5-2).

The SDI value for First Creek was 0.57 (Table 5.5-41, Figure 5.5-3), indicating a moderate diversity. Evenness was 0.08 (Figure 5.5-4) indicating that only a few taxa accounted for most of the total density at this site. The benthic invertebrate community was dominated by the midges, accounting for 75% of the total density (Figure 5.5-5). The midge community was dominated by the Tanytarsini (Figure 5.5-6).

Unnamed Creek 7 (Site 49)

Benthic Invertebrate Habitat

One site was sampled in depositional habitat in Unnamed Creek 7 (Site 49) during fall 2006. Mean depth at this site was 0.33 m and mean current velocity was negligible (Table 5.5-40). Aquatic macrophyte cover was 100% of the bottom, consisting of *Potamogeton* sp. (pondweed). Field-measured water quality parameters were typical of watercourses in the Oil Sands Region for the fall season, with the exception of low DO (6.5 mg/L). No laboratory analysis of

bottom substrates was conducted at Unnamed Creek 7, but based on field observations, substrates consisted of fine sediments.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density for Unnamed Creek 7 (Site 49) was high, 96,250 ± 15,136 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Taxonomic richness was 37 taxa/site and mean (±1 SE) richness was 26.0 ± 1.3 taxa/site (Figure 5.5-2).

The SDI value for Unnamed Creek 7 was 0.84 (Table 5.5-41, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness was 0.17 (Figure 5.5-4), indicating that a few of the taxa present accounted for the majority of the total density at this site. The benthic invertebrate community was dominated by midges, seed shrimp and bristle worms, accounting for 87% of the total density (Figure 5.5-5). The midge community present at this site was dominated by the Tanytarsini, Orthocladiinae and Tanypodinae (Figure 5.5-6).

Waterbodies

Unnamed Waterbody 15 (Site 4)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Waterbody 15 (Site 4) during fall 2005. Mean depth at this site was 1.22 m (Table 5.5-40). Field-measured water quality parameters were typical of waterbodies in the Oil Sands Region. The bottom substrate was dominated by the silt and clay fractions and TOC was high, measuring 26.4%.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density for Unnamed Waterbody 1 (Site 4) was 23,897 ± 3,362 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 14 taxa/site and mean (±1 SE) richness was 9.2 ± 0.9 taxa/site (Figure 5.5-2).

The SDI value for Unnamed Waterbody 15 was 0.75 (Table 5.5-41, Figure 5.5-3) indicating a diverse benthic invertebrate community. Evenness was 0.29, indicating that a few taxa account for the majority of the total density observed (Figure 5.5-4). The benthic invertebrate community was dominated by bristle worms, seed shrimp, midges and fingernail clams (Pelecypoda) (Figure 5.5-5). These four taxa accounted for 97% of the total benthic invertebrate density. The midge community was dominated by the Chironomini, Tanytarsini and Tanypodinae (Figure 5.5-6).

Small Sandy Lake (Site 45)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Small Sandy Lake (Site 45) during fall 2006. Mean depth at benthic invertebrate sampling sites was 1.16 m (Table 5.5-40). Field-measured water quality parameters were typical of the Oil Sands Region. No laboratory analysis of the bottom substrate were conducted at this site, but based on field observations substrates consisted of fine sediments.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Small Sandy Lake (Site 45) was 21,483 ± 3,280 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 26 taxa/site and mean (±1 SE) richness was 15.0 ± 2.4 taxa/site (Figure 5.5-2).

The value for SDI in Small Sandy Lake was 0.75, indicating a diverse benthic invertebrate community (Table 5.5-41, Figure 5.5-3). Evenness was 0.15 (Figure 5.3-4) indicating that a few taxa accounted for the majority of total density observed at this site. The benthic invertebrate community at this site was dominated by midges (Figure 5.5-5), which accounted for 80% of the total density. The midge community was dominated by the Chironomini and Tanytarsini (Figure 5.5-6).

Oakley Lake (Site 46)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Oakley Lake (Site 46) during fall 2006. Mean depth at benthic invertebrate sampling sites was 0.48 m (Table 5.5-40). Field-measured water quality parameters were typical of waterbodies in the Oil Sands Region. No laboratory analysis of sediment particle size or TOC was conducted at this site, but based on field observations substrates consisted of fine sediments.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Oakley Lake (Site 46) was 36,147 ± 12,703 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 31 taxa/site and mean (±1 SE) richness was 18.0 ± 2.0 taxa/site (Figure 5.5-2).

The value for SDI in Oakley Lake was 0.85, indicating a diverse benthic invertebrate community (Table 5.5-41, Figure 5.5-3). Evenness was 0.22 (Figure 5.3-4), indicating that a few taxa accounted for the majority of the total density observed. The benthic invertebrate community was dominated by midges, seed shrimp, bristle worms and the “other” taxonomic group, which

together accounted for 92% of the total density at this site (Figure 5.5-5). The midges were dominated by the Chironomini and Tanytarsini (Figure 5.5-6).

Redclay Creek Watershed

Watercourses

Redclay Creek (Sites 51 and 50)

Benthic Invertebrate Habitat

Two sites were sampled for benthic invertebrates in Redclay Creek (Sites 51 and 50) during fall 2006. Site 51 was in erosional habitat and Site 50 was in depositional habitat. Mean depth ranged from 0.19 m (Site 51) to 0.29 m (Site 50) and mean current velocity ranged from 0.03 m/s (Site 50) to 0.27 m/s (Site 51) (Table 5.5-40). Field-measured water quality parameters were typical of watercourses in the Oil Sands Region. The bottom substrate at Site 50 (depositional) was dominated by the silt fraction and TOC was low at 2.5%. The bottom substrate based on visual estimates at Site 51 (erosional) was dominated by small gravel.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate community density in Redclay Creek (Sites 51 and 50) ranged from 2,129 ± 175 organisms/m² (Site 51) to 2,767 ± 1,231 organisms/m² (Site 50) (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness ranged from 19 taxa/site (Site 50) to 28 taxa/site (Site 51) and mean (±1 SE) ranged from 7.4 ± 1.8 taxa/site (Site 50) to 16.6 ± 1.0 taxa/site (Site 50) (Figure 5.5-2).

The SDI values for Redclay Creek ranged from 0.72 (Site 51) to 0.82 (Site 50) (Table 5.5-41, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness ranged from 0.13 (Site 51) to 0.29 (Site 50) (Figure 5.5-4), indicating that the total density this site was mostly accounted for by only a few taxa. The benthic invertebrate community at Site 51 in the Redclay Creek was dominated by mayflies and the "other" taxonomic grouping, which consisted mainly of caddisflies and stoneflies (Figure 5.5-5). At Site 51, these taxa accounted for 82% of the total benthic invertebrate density. Site 50 was dominated by midges, bristle worms and the "other" taxonomic group, which was approximately 50% caddisflies. At Site 50, these taxa accounted for 90% of the total density. The midge community at Site 51 was dominated by the Orthocladiinae (Figure 5.5-6), while the midge community at Site 50 was dominated by the Chironomini and Tanytarsini.

Waterbodies

Unnamed Waterbody 12 (Site 52)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Waterbody 12 (Site 52) during fall 2006 with a mean depth of 1.00 m (Table 5.5-40). Aquatic macrophyte cover was 90% in areas where benthic invertebrate samples were collected. Field-measured water quality parameters were typical of waterbodies in the Oil Sands Region. No laboratory analysis of sediment particle size or TOC was conducted at this site, but based on field observations substrates consisted of fine sediments.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Waterbody 12 (Site 52) was 11,129 ± 3,120 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total benthic invertebrate richness was 25 taxa/site and mean (±1 SE) richness was 13.6 ± 1.7 taxa/site (Figure 5.5-2).

The SDI value for Unnamed Waterbody 12 was 0.83 (Table 5.5-41, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness was 0.24 (Figure 5.3-4), indicating that a few taxa accounted for the majority of the total density of organisms at this site. The benthic invertebrate community was dominated by midges, which accounted for 80% of the total density at this site (Figure 5.5-5). The midges were dominated by the Tanytarsini and Chironomini (Figure 5.5-6).

Unnamed Waterbody 13 (Site 53)

Benthic Invertebrate Habitat

One site was sampled for benthic invertebrates in Unnamed Waterbody 13 (Site 53) during fall 2006. Mean depth at the benthic invertebrate sampling site was 0.53 m (Table 5.5-40). Aquatic macrophyte cover was 100% in the area where benthic invertebrate samples were collected. Field-measured water quality parameters were typical of waterbodies in the Oil Sands Region. No laboratory analysis for particle size and TOC was conducted at this site, but based on field observations substrates consisted of fine sediments.

Benthic Invertebrate Community

Mean (±1 SE) benthic invertebrate density in Unnamed Waterbody 13 (Site 53) was 28,845 ± 8,574 organisms/m² (Table 5.5-41, Figure 5.5-1; raw data are provided in Appendix U, Table U-1). Total taxonomic richness was 27 taxa/site and mean (±1 SE) richness was 14.8 ± 1.7 taxa/site (Figure 5.5-2).

The SDI value for Unnamed Waterbody 13 was 0.89 (Table 5.5-41, Figure 5.5-3), indicating a diverse benthic invertebrate community. Evenness was 0.33 (Figure 5.5-4), indicating the majority of the total density at this site is accounted for by a few taxa. The benthic invertebrate community is dominated by midges, which accounted for 73% of the total density (Figure 5.5-5). The midge community was dominated by the Tanytarsini and the Chironomini (Figure 5.5-6).

5.6 SUMMARY

5.6.1 Jackpine Expansion Mining Area

5.6.1.1 Fish and Fish Habitat

Muskeg River Watershed

Watercourses

Muskeg River Mainstem

Muskeg River mainstem, a tributary to the Athabasca River, has historically been divided into eight reaches. Study sites for this Project were established within Reaches 6 and 7, as they are adjacent to the JEMA. Historically, Reaches 4, 5 and 6 have been described as low gradient, dominated by low stable banks and containing substrates composed of fine sediment. Reaches 4, 5 and 6 are composed of slow, relatively deep meandering runs. Reach 7 contains higher gradients, but habitat types are dominated by runs and pools, a result of the large amount of debris and beaver activity. Reach 7 also contains occasional riffle habitat units, which are absent from Reach 8. For this study, Sites 41 and 30 were located within Reaches 6 and 7, respectively. Both sites were located within an irregularly meandering channel through muskeg bog and consisted of one continuous run habitat unit.

Fish distribution and habitat use varies along the eight different reaches of the Muskeg River mainstem. Fish species diversity has been reported to decline along the length of the Muskeg River, with the number of species declining in each successive reach due to habitat changes and increasing distance from the Athabasca River, which is a typical pattern of fish distribution in similar sized tributaries. The fish community in Reaches 6, 7 and 8 is considerably less diverse than in the lower watershed (Imperial Oil 2005). Access to the Athabasca for overwintering, migration and recolonization plays a role in the higher diversity in the lower reaches.

In general, previous studies have found the habitat use potential of the lower 16.5 km of the mainstem Muskeg River (i.e., Reaches 1, 2 and 3) during the open-water period is high. In contrast, habitat limitations for the remaining 105.5 km of the mainstem river result in poor habitat potential in the middle (Reach 4, 5 and 6) and upper (Reach 7 and 8) reaches of the river. Extensive beaver activity likely impedes fish movements in the upper reaches of the river, further reducing the potential for these reaches to support a diverse fish species assemblage. Results from this study (Sites 30 and 41), support previous findings, but generally rate the open-water habitat use potential at sites studied as moderate. Water quality parameters were suitable to support all fish species. Instream and overhead cover varied from limited to abundant for both categories.

Overall, previous studies indicate that overwintering conditions in the mainstem Muskeg River are variable but limited, with overwintering habitat present in some locations but not others and only in some winters. When present, overwintering habitat is primarily suitable for use by small-bodied forage fish due to shallow under-ice depths and/or low DO levels. Lack of reliable overwintering habitat was considered an important limiting factor in the upper river, particularly for resident fish. Within Reach 6, results from this study found adequate under-ice water depths, however, low DO levels may limit the overwintering potential to species tolerant of such conditions. Results from Reach 7 indicate some limiting water depth, but adequate DO levels.

Historically, 26 fish species have been reported to occur in the Muskeg River mainstem, however, only 14 species have been reported in the middle and upper reaches (Reaches 4 to 8). Of these 14 fish species, five were captured during current field investigations. Recent captures include two non-sport fish, longnose sucker and white sucker, as well as three forage fish, brook stickleback, lake chub and pearl dace. The remaining fish species known to occur within the upper five reaches include Arctic grayling, fathead minnow, longnose dace, mountain whitefish, northern pike, northern redbelly dace, slimy sculpin and spoonhead sculpin. In addition, species recorded in the lower three reaches include bull trout, burbot, emerald shiner, goldeye, lake cisco, lake whitefish, ninespine stickleback, spottail shiner, trout-perch, walleye and yellow perch.

Of the species recorded in the Muskeg River mainstem, three are listed as sensitive (Arctic grayling, bull trout and northern redbelly dace) and one species may be at risk (spoonhead sculpin) (ASRD 2006). Habitat for Arctic grayling and bull trout is not present in the upper five reaches and they have not been documented to inhabit the upper five reaches. Spoonhead sculpin has been documented within Reaches 4, 5 and 6 and suitable habitat for this species also has been documented. Suitable habitat for northern redbelly dace is present

throughout all reaches and they have been documented within Reaches 4, 5 and 6.

The overall fish and fish habitat diversity for the entire Muskeg River mainstem is rated as high, due to high ratings for all diversity categories (species, habitat and ecosystem diversity).

Stanley Creek

Stanley Creek, a tributary to the Muskeg River, was surveyed at Site 40. The watercourse at this site was located within a muskeg bog. The watercourse had a meandering, unconfined channel with run habitat and organic substrate.

The open-water season habitat use potential at this site was generally low to moderate for sport fish, low for non-sport fish and moderate for forage fish. Historically, Stanley Creek has been described as having poor habitat potential for all fish species, due to poorly defined channel and intermittent flow.

Overwintering habitat use potential at Site 40 was nil for both sport and non-sport fish due to lack of suitable depth and DO levels. Overwintering potential for forage fish, however, was low as they are typically more tolerable of low oxygen and shallow depths.

The fish community using Stanley Creek is composed of forage fish. Previous studies have resulted in the capture of only brook stickleback. Current fish sampling for this study resulted in the capture of three forage fish species, brook stickleback, lake chub and pearl dace.

The overall diversity of fish and fish habitat in Stanley Creek was considered low. Both species and ecosystem diversity was rated as very low, however, habitat diversity was moderate.

Wapasu Creek

Wapasu Creek, a tributary to the Muskeg River, has previously been divided into five reaches. Site 32 is located within Reach 1, while both Sites 26 and 38 are located within Reach 3. All three sites are located within low gradient, irregular meandering channels. The watercourse at Site 32 was composed entirely of flat habitat with organic substrate. Sites 26 and 38 were both composed of run and riffle habitat units and substrate varied from silt/clay to boulders.

The open-water habitat use potential at Site 32, within Reach 1 was generally moderate for sport fish, low for non-sport fish and high for forage fish. The

open-water habitat potential within Reach 3 at both Sites 26 and 38 was generally moderate for sport and non-sport fish and moderate to high for forage fish.

Overwintering potential within Reach 1 at Site 32 was low for sport and non-sport fish due to low DO levels, but moderate for more tolerant forage fish. Overwintering habitat use potential at Site 26 was rated as high for sport, non-sport fish, and forage fish. There was limited overwintering potential at Site 38, as the watercourse was frozen to the bottom.

The fish community of Wapasu Creek is dominated by forage fish, with the occurrence of some large bodied, non-sport fish. Historically, six species have been recorded in Wapasu Creek, including longnose sucker, white sucker, brook stickleback, lake chub, pearl dace and fathead minnow. During current field investigations, five of these six species were captured (fathead minnow were not captured).

The overall fish and fish habitat diversity of Wapasu Creek was rated as low. Although both species and ecosystem diversity was very low, habitat diversity was found to be moderate.

Unnamed Creek 9

This unnamed tributary to the Muskeg River mainstem was sampled at Site 35. The watercourse at this site had an unconfined, straight channel within a muskeg bog and consisted of run habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

The open-water season habitat use potential at this site was generally low for sport fish and non-sport fish, but high for forage fish. There was no overwintering habitat use potential at Site 35, as it was frozen to the bottom at the time of the survey.

Forage fish species are expected to dominate the fish community within this watercourse, with few to no large-bodied or predator species. Fish sampling at Site 35 resulted in the capture of brook stickleback and lake chub. No sport fish or non-sport fish were captured. There was no historical information for this watercourse.

The overall diversity of fish and fish habitat for Unnamed Creek 9 was considered very low, due to very low ratings for all diversity categories (species, habitat and ecosystem diversity).

Unnamed Creek 12

This unnamed tributary to the upper end of Reach 4 of the Muskeg River mainstem was sampled at Site 24. The watercourse at this site had an unconfined, meandering channel within a muskeg bog and consisted of run and flat habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

The open-water season habitat use potential at Site 24 was generally moderate for both sport and non-sport fish species and high for forage fish species. Overwintering habitat use potential was high for sport, non-sport and forage fish.

The fish community within Unnamed Creek 12 is expected to be dominated by forage fish species with the potential for the occurrence of large-bodied and predator species. Fish species captured at this site include one non-sport fish, longnose sucker and three forage fish, brook stickleback, lake chub and pearl dace. No sport fish were captured.

The overall fish and fish habitat diversity rating for Unnamed Creek 12 was assessed as low. This was based on very low ratings for both species and ecosystem diversity (due to the number of forage fish species and lack of predators), but a moderate rating for habitat diversity.

Waterbodies

Unnamed Waterbody 1

Unnamed Waterbody 1 was located on a tributary to the Muskeg River. Unnamed Waterbody 1 (Site 29) was a relatively uniform waterbody, with a perimeter of approximately 1.3 km and an approximate surface area of 0.05 km^2. A shallow littoral zone surrounded the waterbody, with a deeper pelagic zone in the centre. The average and maximum depths recorded throughout the open-water seasons are 10.6 and 26.1 m, respectively.

Open-water season habitat use potential was generally moderate for both sport and non-sport fish species and high for forage fish. Overwintering habitat use potential was considered low to moderate for sport, non-sport and forage fish.

Although this waterbody was sampled during all seasons, only one fish was captured, a juvenile northern pike, in the summer survey. No existing fish information was available for this waterbody.

Overall fish and fish habitat diversity for Unnamed Waterbody 1 was considered very low, with all diversity categories (species, habitat and ecosystem diversity) rated as very low.

Unnamed Waterbody 2

Unnamed Waterbody 2 (Site 27) was a relatively shallow, uniform waterbody with a perimeter of approximately 1.2 km and an approximate surface area of 0.08 km^2. The average and maximum depths recorded throughout the open-water seasons are 0.76 and 1.0 m, respectively.

Open-water season habitat use potential was rated as low for all fish species, due to limitations such as lack of depth and limited cover. Overwintering habitat use potential was considered low to nil for both sport and non-sport fish and low for forage fish due to DO levels suitable only to low DO tolerant fish species.

No fish species were captured during field investigations at this waterbody. No existing fish information was available.

The overall diversity of fish and fish habitat for Unnamed Waterbody 2 was rated as very low, due to very low ratings for all diversity categories (species, habitat and ecosystem diversity).

Unnamed Waterbody 16

Unnamed Waterbody 16 (Site 39) was located on an unnamed tributary to Muskeg Creek. This waterbody was dominated by shallow littoral habitat, with a perimeter of approximately 0.8 km and with an approximate surface area of 0.05 km^2. The average and maximum depths recorded throughout the open-water seasons were 1.0 and 2.2 m, respectively.

Open-water habitat use potential at this waterbody was low to moderate for sport fish and low for non-sport fish. Forage fish habitat use potential during the open-water season was rated as moderate to high, due to their tolerance for high water temperature and the abundance of aquatic vegetation.

Overwintering habitat use potential at Unnamed Waterbody 16 was nil for both sport and non-sport fish and low for forage fish due to recorded low DO levels.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall fish and fish habitat diversity of Unnamed Waterbody 16 was assessed as very low, based on very low ratings for species, habitat and ecosystem diversity.

Unnamed Waterbody 17

Unnamed Waterbody 17 (Site 25) was a relatively shallow, uniform waterbody, dominated by littoral habitat with submergent vegetation. This waterbody had a perimeter of approximately 0.8 km and an approximate surface area of 0.04 km^2. The average and maximum depths recorded throughout the open-water season are 0.38 and 0.5 m, respectively.

Open-water season habitat use potential was nil to moderate for sport fish, nil to low for non-sport fish and low for forage fish. This was largely based on limitations such as shallow depth and high water temperatures recorded during the summer.

Overwintering habitat use potential within this waterbody was low to nil for both sport and non-sport fish and low for forage fish due to recorded low DO levels.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall diversity of fish and fish habitat in Unnamed Waterbody 17 was rated as very low. This was a result of very low ratings for species, habitat and ecosystem diversity.

5.6.1.2 Benthic Invertebrates

Muskeg River Watershed

Watercourses

Four watercourse sites were sampled in the Muskeg River watershed during the environmental survey, all of which were located in depositional habitat. One site was sampled in the Muskeg River, two sites in Wapasu Creek and one site in an unnamed tributary to the Muskeg River. Mean benthic invertebrate density ranged from 12,000 to 44,000 organisms/m^2 and total taxonomic richness ranged from 28 to 39 taxa/site, indicating rich benthic invertebrate communities of low to moderate density. The SDI and evenness values suggest diverse benthic invertebrate communities in these watercourses, with a few taxa accounting for the majority of the total density. The dominant taxa were midges, bristle worms and seed shrimp.

The sites sampled during the surveys had benthic communities similar to those documented by previous studies in the Muskeg River watershed. Historically, mean benthic invertebrate density ranged from 200 to 116,000 organisms/m² in watercourses and total taxonomic richness ranged from 4 to 59 taxa/site. The dominant taxa have historically been midges, bristle worms and fingernail clams.

Waterbodies

Several years of benthic invertebrate data are available for Kearl Lake and a smaller amount of data are available for small waterbodies in the Muskeg River watershed. Mean benthic invertebrate density in Kearl Lake ranged from 800 to 17,400 organisms/m², which is within the typical range for lakes in the region. Total benthic invertebrate richness ranged from 8 to 27 taxa/site. The benthic invertebrate community of Kearl Lake was dominated by midges and scuds, reflecting the abundant aquatic plant growth in this lake. Although the highest values for both density and richness were reported by the most recent survey, the available data do not provide clear evidence of temporal trends, with the possible exception of a declining trend in the relative proportion of midges over time.

Benthic communities of small watercourses in the Muskeg River watershed were characterized by highly variable density, low richness and dominance by midges, other dipterans, fingernail clams and scuds.

5.6.2 Pierre River Mining Area

5.6.2.1 Fish and Fish Habitat

Pierre River Watershed

Watercourses

Pierre River Mainstem

The Pierre River was divided into three reaches based on channel gradient and morphology. Two sites were established on the Pierre River to assess seasonal fish habitat potential. Site 20 was located within Reach 1, near the confluence with the Athabasca River and Site 19 was located within Reach 2. The watercourse at both sites exhibited a meandering, unconfined channel. While Site 20 was composed of riffle and run habitat units with variable substrate composition, Site 19 was composed of flat and impoundment habitat and fine substrate.

The open-water season habitat use potential at Site 20 was low to moderate for sport and non-sport fish and moderate for forage fish. The open-water season habitat potential at Site 19 ranged from nil to high for sport fish, depending on

life history function, and nil to moderate for non-sport fish. Habitat use potential was rated as high overall for forage fish. The increase in open-water habitat use potential from Site 20 to 19 was generally due to an increase in available cover from Site 20 to 19.

Overwintering habitat use potential was nil for all fish species at Site 20, as the watercourse was frozen to the bottom at the time of the winter survey. Site 19, however, was not frozen to the bottom. Overwintering habitat potential was low for sport and non-sport fish due to low DO levels and some limiting water depth, but moderate for the more tolerant forage fish species.

In addition to the two previous sites established on the Pierre River mainstem to assess fish habitat and sample the fish population, a fish fence was established at Site 202, about 350 m upstream from the river mouth. The fish counting fence was constructed and monitored in the spring of 2006. Although seasonal sport-fish migrants were not captured during the fish fence operation, historical information suggests sport fish such as Arctic grayling and northern pike use the Pierre River for spawning and rearing activities.

The fish community within the Pierre River is relatively diverse, with the occurrence of sport, non-sport and forage fish. Previous studies combined with fish sampling information from this project resulted in a fish species list of 17 species and include five sport fish (Arctic grayling, burbot, mountain whitefish, northern pike and walleye), two non-sport fish (longnose sucker and white sucker) and ten forage fish (brassy minnow, brook stickleback, fathead minnow, flathead chub, lake chub, longnose dace, northern redbelly dace, pearl dace, slimy sculpin and trout-perch).

The Pierre River has two listed sensitive species (Arctic grayling and northern redbelly dace). In addition, brassy minnow and mountain whitefish were determined to be unique species, as neither are found elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of the Pierre River was considered moderate. This was the result of averaging a low value for species diversity, a moderate value for habitat diversity, and a high value for ecosystem diversity.

Unnamed Creek 4

One survey site (Site 18) was located on Unnamed Creek 4, a tributary to Reach 2 of the Pierre River. The watercourse at Site 18 had an irregular meandering and a frequently confined channel composed of run and flat habitat.

This watercourse had only one reach, as channel gradient and channel morphology was relatively unchanged throughout.

The open-water season habitat use potential was rated as moderate for sport fish, low to moderate for non-sport fish and moderate for forage fish. Instream cover was abundant; however, overhead cover was found to be limited. There also was a lack of coarse substrate to fulfill some species spawning requirements.

Overwintering habitat use potential was found to be low for both sport and non-sport fish, due to low DO levels, but moderate for forage species tolerant of such conditions.

Existing fisheries information was not available and sampling at Site 18 resulted in the capture of six fish species. These captured fish included two non-sport fish (longnose sucker and white sucker) and four forage fish species (brook stickleback, fathead minnow, lake chub and northern redbelly dace).

One listed sensitive species, northern redbelly dace, occurred in Unnamed Creek 4 (ASRD 2006).

The overall diversity of fish and fish habitat for Unnamed Creek 4 was rated as very low. This overall rating was based on a low rating for species diversity and very low ratings for both habitat and ecosystem diversity.

Eymundson Creek Watershed

Watercourses

Eymundson Creek

Eymundson Creek was divided into four reaches based on channel gradient and morphology. Six survey sites (17, 7, 11, 57, 6 and 3) were established on this watercourse within Reaches 1, 2, 3 and 4. Eymundson Creek maintained an irregular, meandering channel pattern throughout its entirety, as was observed at all four sites. However, Site 17 was located in a frequently confined valley, while the remainder of the watercourse was relatively unconfined. The surveyed watercourse was composed of run and flat habitat at Site 17, run and riffle habitat at Site 7, run habitat at Site 11 and impoundment and flat habitat at Site 6.

The open-water season habitat potential at Eymundson Creek varied between sites. At Site 17, habitat potential, in general, was low to moderate for sport fish and non-sport fish and high for forage fish. Habitat use potential at Site 7 ranged from low to high for sport fish, depending on life history function, and moderate to high for non-sport fish. Habitat use potential was considered moderate for

forage fish. Site 11 was generally rated as low for all fish. Habitat use potential at Site 6 was generally moderate for sport fish, low for non-sport fish and moderate for forage fish.

Overwintering habitat use potential within surveyed sites on Eymundson Creek ranged from nil to low. Sites 17 and 11 had no overwintering potential, as the watercourse was frozen to the bottom during the winter survey. The overwintering habitat potential at Site 7 was rated as low to nil due to shallow water depth and low DO. Site 6 also had a shallow under-ice water depth and low DO unsuitable for sport and non-sport fish, but may be tolerable to some forage fish, resulting in a low overall rating.

The fish community found within Eymundson Creek was dominated by forage fish throughout, with the occurrence of sport-fish and non-sport fish in the lower reaches. Historical information indicates the occurrence of flathead chub in Eymundson Creek. Fish species captured during this study included: two sport fish (burbot and Arctic grayling), two non-sport fish (longnose sucker and white sucker) and six forage fish (brook stickleback, fathead minnow, lake chub, northern redbelly dace, pearl dace and trout-perch).

Two fish species found in Eymundson Creek are listed as sensitive (Arctic grayling and northern redbelly dace). In addition to listed species, one fish species was considered unique as it does not occur outside of this watercourse in the PRMA LSA. This unique species is the flathead chub, which was captured in a previous study.

The overall fish and fish habitat diversity of Eymundson Creek was considered moderate, due to averaging a low species diversity rating, a high habitat diversity rating and a moderate ecosystem diversity rating.

Asphalt Creek

Asphalt Creek was divided into two reaches, based on channel gradient and morphology. Sites 5 and 48 were situated within Reaches 1 and 2, respectively. Reach 1 at Site 5 had low gradient, irregular meandering, unconfined channel dominated by a single run habitat composition. Although similar, Reach 2 at Site 48 was occasionally confined and was composed of both run and riffle habitat.

Open-water seasonal habitat use potential within Asphalt Creek varied slightly between sites. Site 5 was rated as low to moderate for sport fish and non-sport fish and moderate to high for forage fish. Site 48 was rated as low to moderate for sport fish, moderate for non-sport fish and moderate to high for forage fish.

There was no overwintering habitat use potential within Asphalt Creek at Sites 5 and 48, as both were found to be frozen to the bottom during the winter survey.

The fish community documented in Asphalt Creek was composed of two forage fish species including brook stickleback and lake chub. There was no existing fish information available. There were no listed species found in this watercourse.

The overall diversity of fish and fish habitat in Asphalt Creek was rated as low. This conclusion was based on very low species diversity, moderate habitat diversity and very low ecosystem diversity.

Unnamed Creek 1

Unnamed Creek 1 was divided into three reaches and surveyed at two locations. Site 16 was located within the upper limits of Reach 1 and Site 15 was located within Reach 2. This watercourse had an irregular meandering and unconfined channel throughout both surveyed sites. Habitat composition also was similar at both sites, with Site 16 composed of run, riffle and flat habitat units and Site 15 was limited to run and riffle units within the surveyed section.

Open-water season habitat use potential differed between the two sites. Site 16 was generally low to moderate for sport fish, low for non-sport fish and moderate for forage fish habitat potential. Site 15 provided low habitat potential for both sport and non-sport fish, while there was low to moderate habitat use potential for forage fish.

There was no overwintering habitat use potential within Unnamed Creek 1 at the surveyed sites, as the watercourse was frozen to the bottom at both sites.

The fish community recorded in Unnamed Creek 1 was composed solely of forage fish. Sampling resulted in the capture of brook stickleback, lake chub and pearl dace. No existing fish information was available.

The overall fish and fish habitat diversity of Unnamed Creek 1 was assessed as low. This conclusion was based on very low species diversity, moderate habitat diversity and very low ecosystem diversity.

Unnamed Creek 11

Unnamed Creek 11, a tributary to Eymundson Creek, is located in the upper limits of Eymundson Creek's Reach 2. Unnamed Creek 11 consists of one reach as it was relatively uniform in channel gradient and morphology. One survey site

(Site 12) was located near the creek's confluence with Eymundson Creek. The watercourse at this site had an irregular meandering, unconfined channel dominated by run habitat.

Open-water habitat use potential was generally moderate for sport fish, low for non-sport fish and moderate for forage fish. There was no overwintering potential at the surveyed portion of this watercourse, as the watercourse was frozen to the bottom.

Based on sampling results, the fish community at this watercourse was composed mainly of forage fish with the occurrence of non-sport fish. Species captured include one non-sport fish (longnose sucker) and three forage fish (brook stickleback, lake chub and pearl dace).

The overall fish and fish habitat diversity of Unnamed Creek 11 is considered very low, due to very low diversity ratings for all three categories (species, habitat and ecosystem diversity).

Waterbodies

Unnamed Waterbody 5

Unnamed Waterbody 5 (Site 14) was a relatively shallow, uniform waterbody, dominated by littoral habitat with emergent vegetation. This waterbody had a perimeter of approximately 0.7 km and an approximate surface area of 0.04 km^2. The average and maximum depths recorded throughout the open-water seasons are 2.18 and 4.63 m, respectively.

Open-water season habitat use potential was generally moderate for sport fish, low for non-sport fish and moderate for forage fish. This was based on the availability and types of cover, spawning substrate and suitable water quality.

Overwintering habitat use potential within this waterbody was low for both sport and non-sport fish due to low DO levels. However, overwintering potential for forage fish was moderate based on their tolerance for low DO conditions.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall diversity of fish and fish habitat in Unnamed Waterbody 5 was considered very low. This was a result of very low ratings for species, habitat and ecosystem diversity.

Unnamed Waterbody 6

Unnamed Waterbody 6 (Site 2) was a relatively shallow, uniform waterbody, dominated by littoral habitat with submergent and emergent vegetation. This waterbody had a perimeter of approximately 2.2 km and an approximate surface area of 0.07 km^2. The average and maximum depths recorded throughout the open-water seasons were 1.22 and 1.55 m, respectively.

Open-water season habitat potential within this waterbody was low for both sport and non-sport fish and moderate to high for forage fish. These ratings were based on shallow depths and high water temperature readings during the summer.

Overwintering habitat potential for sport and non-sport fish was low due to reduced DO levels. Overwintering habitat use potential for forage fish was moderate due to some species tolerance of low DO levels.

The fish community of Unnamed Waterbody 6 is likely composed solely of forage fish. There was no existing fish information for this waterbody. Brook stickleback were captured during surveys of the waterbody. There were no listed species present.

The overall diversity of fish and fish habitat in Unnamed Waterbody 6 was rated as very low. This conclusion was based on very low ratings for species, habitat and ecosystem diversity.

Unnamed Tributaries to the Athabasca River

Watercourses

Unnamed Creek 10

One site was located on Unnamed Creek 10 (Site 8), a tributary to the Athabasca River. This site had no defined channel, lacked flow and was situated within a muskeg bog. This drainage was not divided into reaches as it was relatively uniform in gradient and morphology.

Open-water habitat use potential at this site was generally considered low for sport fish and non-sport fish and moderate for forage fish. This was largely based on the availability and amount of suitable cover and spawning substrate.

Overwintering habitat potential was low to moderate for both sport and non-sport fish due to shallow depth and DO conditions. However, the overwintering habitat use potential for forage fish was high due to their tolerance of these conditions.

The fish community documented within the surveyed site was composed of brook stickleback, lake chub, northern redbelly dace and pearl dace. Northern redbelly dace is listed as sensitive. The overall fish and fish habitat diversity was assessed as very low, as all three diversity ratings (species, habitat and ecosystem) were very low.

Waterbodies

Unnamed Waterbody 8

Unnamed Waterbody 8 (Site 13) was located at the headwaters of an unnamed tributary to the Athabasca River. This waterbody was relatively uniform and dominated by littoral habitat. This waterbody had a perimeter of approximately 2.4 km and an approximate surface area of 0.20 km^2. The average and maximum depths recorded throughout the open-water seasons are 0.86 and 1.40 m, respectively.

Open-water habitat use potential within this waterbody low for sport fish and non-sport fish and moderate for forage fish. This was based on the availability and amount of suitable cover and spawning substrate.

Overwintering habitat use potential was moderate for both sport and non-sport fish due to suitable depths and DO levels. Forage fish overwintering habitat potential was rated as high.

A fish community within Unnamed Waterbody 8 was not detected, as no fish were captured during the seasonal surveys. There was no existing fish information for this waterbody.

The overall fish and fish habitat diversity of Unnamed Waterbody 8 was rated as very low, with very low ratings for species, habitat and ecosystem diversity.

Big Creek Watershed

Watercourses

Big Creek

The mainstem of Big Creek consisted of four reaches, based on channel gradient and morphology. Three sites (42, 1 and 47) were situated within Reaches 1, 2 and 3, respectively. Reach 1 at Site 42 had an irregular meandering, occasionally confined channel and Reaches 2 and 3 at each respective site, had an irregular meandering, unconfined channel. Regarding habitat composition, Reach 1 (at Site 42) consisted of run and flat habitat, Reach 2 (at Site 1) consisted of run and riffle, while Reach 3 (at Site 47) was solely composed of run habitat.

Open-water habitat potential was generally moderate for all species within all sites surveyed. This was based on habitat components such as availability and types of cover, spawning substrate and water quality.

Overwintering habitat potential at Site 42 was rated as low for forage fish and low to nil for both sport and non-sport fish. As there was no access to Site 1, overwintering habitat use potential was based on conditions observed at Site 42 and conservatively rated as low for both sport and non-sport fish and moderate for forage fish. There was no overwintering potential within Site 47, as the watercourse was frozen to the bottom.

The fish community of Big Creek was composed of sport fish, non-sport fish and forage fish. Although no known historical information has been documented, fish sampling throughout each of the three survey sites resulted in the capture of one sport fish (burbot), two non-sport fish (longnose sucker and white sucker) and seven forage fish species (fathead minnow, lake chub, longnose dace, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner).

There are several notable fish species captured within this watercourse. Spoonhead sculpin is listed as may be at risk (ASRD 2006). In addition, spoonhead sculpin and spottail shiner were consider unique species, as they are not present elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of Big Creek was considered low. This rating was formulated by averaging a low rating for species diversity, a low rating for habitat diversity and a moderate rating for ecosystem diversity.

First Creek

First Creek, a tributary to Big Creek, was divided into two reaches. One survey site (Site 9) was situated within Reach 2. The watercourse at Site 9 had an irregular meandering, unconfined channel, composed of run and pool habitat.

Open-water habitat potential was generally low to moderate for sport fish, low for non-sport fish and moderate for forage fish. Consideration was given to the suitable cover, spawning conditions and water quality.

Overwintering potential was rated as low to nil for sport and non-sport fish and low for forage fish.

The fish assemblage of First Creek has no existing information and no fish were captured during the seasonal surveys.

The overall diversity of fish and fish habitat for First Creek was rated as low, due to very low species diversity, moderate habitat diversity and very low ecosystem diversity.

Unnamed Creek 2

Unnamed Creek 2, a tributary to Reach 2 of Big Creek, was divided into two reaches. Site 44 was established within Reach 1. This watercourse had an irregular meandering and unconfined channel and was composed of riffle and run habitat.

Open-water season habitat use potential was generally moderate for all fish species. This was based on habitat requirements for nursery, rearing and feeding, as well as spawning.

Overwintering potential was low for both sport and non-sport fish and moderate for forage fish species. This was based on conditions observed during open-season surveys, as the watercourse was not accessible during the winter survey.

The fish community within Unnamed Creek 2 has been documented in previous studies. In combination with sampling completed at the survey site, longnose sucker, brook stickleback, fathead minnow, lake chub and slimy sculpin have been documented in Unnamed Creek 2.

There are no listed species within this watercourse.

The overall fish and fish habitat diversity of Unnamed Creek 2 was considered very low. Species diversity was very low, habitat diversity was low and ecosystem diversity was very low.

Unnamed Creek 7

Unnamed Creek 7, a tributary to Big Creek, was surveyed at one site (Site 49), near its confluence with Big Creek. This watercourse at Site 49 was a large marsh with no defined channel and was solely composed of flat habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

Open-water habitat use potential within Big Creek at Site 49 was generally low for both sport and non-sport fish, but low to moderate for forage fish. Shallow depth and high water temperatures in the summer season limited to the overall habitat potential.

There was no overwintering habitat use potential within this watercourse at Site 49 as the watercourse was frozen through to the bottom.

No previous studies or historical information was available for this watercourse. However, sampling activities at Site 49 resulted in the capture of one non-sport fish species (longnose sucker) and one forage fish species (brook stickleback).

There were no listed species documented in this watercourse.

The overall fish and fish habitat diversity of Unnamed Creek 7 was assessed as very low, based on very low ratings for all diversity categories (species, habitat and ecosystem diversity).

Waterbodies

Oakley Lake

Oakley Lake, a waterbody located within the Unnamed Creek 2 drainage, had an approximate surface area of 0.83 km^2. Shallow littoral habitat surrounded the waterbody, but a deeper pelagic zone was present in the centre. The average and maximum depths recorded throughout the open-water season were 1.16 and 2.25 m, respectively.

Open-water habitat use potential was generally low to moderate for sport fish and non-sport fish and moderate for forage fish. Although spring and fall conditions were suitable, summer conditions were not documented due to a no-fly zone in the area, preventing access to the waterbody.

Overwintering habitat use potential was low for both sport and non-sport fish, and moderate for forage fish. Low DO levels were documented during the winter survey, thus limiting habitat use potential.

No historical information on the fish community within Oakley Lake was available, however, fish sampling results from this study indicate it is composed of forage and non-sport fish. Three fish species were captured, including brook stickleback, lake chub and white sucker.

The overall diversity of fish and fish habitat in this waterbody was considered very low, due to very low diversity for all categories (species, habitat and ecosystem).

Small Sandy Lake

Small Sandy Lake was located at the headwaters of a small tributary to Big Creek. This waterbody's surface area was approximately 0.45 km^2 and was a relatively shallow, uniform waterbody. The average and maximum depths were 1.44 and 2.40 m, respectively.

Open-water season habitat use potential was generally low to moderate for sport fish and non-sport fish and moderate for forage fish. Although spring and fall conditions were suitable, summer conditions were not documented due to a no-fly zone in the area, preventing access to the waterbody.

Overwintering habitat use potential was nil for both sport and non-sport fish and low for forage fish. Very low DO levels were documented during the winter survey, thus limiting the habitat potential.

No fish were captured during surveys of Small Sandy Lake. There was no existing information on this waterbody.

The overall fish and fish habitat diversity of this waterbody was rated as very low, due to very low diversity for all categories (species, habitat and ecosystem).

Unnamed Waterbody 15

Unnamed Waterbody 15 was located within Reach 2 of First Creek. This waterbody had a perimeter of approximately 2.7 km and an approximate surface area of 0.26 km^2. A shallow littoral zone with submerged, floating and emerged vegetation was present along the shoreline with a relatively deeper open-water habitat in the centre. The average and maximum depths were 1.05 and 1.32 m, respectively.

Open-water season habitat use potential was low to moderate for both sport and non-sport fish, while forage fish potential was moderate. Habitat considerations included available cover, spawning substrate and water quality.

Overwintering potential was nil for all species due to shallow depth (0.03 m) and low DO levels.

The fish community of Unnamed Waterbody 15 was composed of forage fish. Brook stickleback was the only species captured during the seasonal surveys. No existing fish information was found.

The overall fish and fish habitat diversity at Unnamed Waterbody 15 was considered very low. This was based on very low diversity for species, habitat and ecosystem categories.

Redclay Creek Watershed

Watercourses

Redclay Creek

Redclay Creek was separated into four reaches based on channel gradient and morphology. Two survey sites were located within Reach 1 (Site 50) and Reach 3 (Site 51). The watercourse at both sites had a sinuous, unconfined channel and was composed of riffle and run habitat.

Open-water season habitat use potential within Reach 1 (Site 50) was low for sport fish and moderate for both non-sport and forage fish species. Within Reach 3 (Site 51) the open-water season habitat potential was moderate for sport fish, moderate to high for non-sport and generally moderate for forage fish species.

Overwintering potential within Redclay Creek was nil for all fish at Site 50, as the watercourse was frozen to the bottom. Site 51 was not entirely frozen, but shallow depth resulted in low overwintering potential for sport and non-sport fish but moderate for potential for forage fish species.

In addition to the two previous sites established on Redclay Creek to assess fish habitat and sample the fish population, a fish fence was established at Site 201, about 130 m upstream from the stream mouth. The fish counting fence was constructed and monitored in the spring of 2006 and 2007. Seasonal migrants were captured during the spring of 2007, indicating this watercourse is used for spawning and rearing activities.

The fish community at Redclay Creek was composed of sport, non-sport and forage fish species. Previous studies documented Arctic grayling within Redclay Creek. Fish sampling from this project indicated Redclay Creek is used by three additional sport fish species (burbot, northern pike and walleye), two non-sport fish species (longnose sucker and white sucker) and eight forage fish species (brook stickleback, finescale dace, fathead minnow, lake chub, longnose dace, pearl dace, slimy sculpin and trout-perch).

One sensitive species was recorded in Redclay Creek, Arctic grayling (ASRD 2006). In addition, finescale dace is considered a unique species, as it was not found elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of Redclay Creek was rated as moderate. This resulted from averaging a low species diversity, a moderate habitat diversity and a high ecosystem diversity.

Unnamed Creek 8

Unnamed Creek 8, a tributary to Reach 2 of Redclay Creek was surveyed at one location (Site 55). The watercourse at this site had an irregular meandering channel and was composed of riffle, run and pool habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

Open-water habitat use potential was rated as low to moderate for sport fish, moderate to high for non-sport fish, and high for forage fish. Overwintering potential was considered low for sport and non-sport fish due to shallow under-ice water depths and moderate to high for forage fish.

The fish community within Unnamed Creek 8 was dominated by forage fish, but contained one non-sport fish species. The results from this study indicate the watercourse is used by longnose sucker as well as brook stickleback, fathead minnow, lake chub, longnose dace, northern redbelly dace, pearl dace and slimy sculpin. No previous data from previous studies were available for this watercourse.

One listed sensitive species, northern redbelly dace, are present in this watercourse (ASRD 2006).

The overall fish and fish habitat diversity of Unnamed Creek 8 was considered low, based on low species and habitat diversity and very low ecosystem diversity.

Waterbodies

Unnamed Waterbody 12

Unnamed Waterbody 12 was located at the headwaters of an unnamed tributary to the lower limits of Reach 2 of Redclay Creek. This waterbody was dominated by relatively shallow littoral habitat with submerged and emerged vegetation throughout and an approximate surface area of 0.37 km^2. The average and maximum depths recorded throughout the open-water seasons are 0.56 and 1.00 m, respectively.

Open-water season habitat use potential was low for both sport and non-sport fish and moderate for forage fish. Shallow depth and high water temperatures were limiting factors during the summer season.

Overwintering habitat use potential was low to nil for both sport and non-sport fish and low for forage fish. Shallow depth and low DO limited the potential to support overwintering forage fish species.

The fish community was limited to forage fish, as brook stickleback was the only species caught at this waterbody. No existing fish information was available.

The overall diversity of fish and fish habitat in Unnamed Waterbody 12 was assessed as very low, based on very low ratings for species, habitat and ecosystem diversity.

Unnamed Waterbody 13

Unnamed Waterbody 13 was located within Reach 4 of Redclay Creek. This waterbody was entirely shallow littoral habitat with abundant aquatic vegetation. The approximate surface area was 0.04 km^2. The average and maximum depths recorded throughout the open-water seasons are 0.44 and 0.50 m, respectively.

Open-water season habitat use potential was low for both sport and non-sport fish and low to moderate for forage fish. Shallow depth and high water temperatures limited the habitat potential.

There was no overwintering potential as the site was frozen to the bottom.

The fish community of Unnamed Waterbody 13 contained only forage fish. Seasonal surveys resulted in the capture of brook stickleback and pearl dace. There was no existing fish information available for this waterbody.

The overall fish and fish habitat diversity of Unnamed Waterbody 13 was rated as very low, based on very low species, habitat and ecosystem diversity.

5.6.2.2 Benthic Invertebrates

Pierre River Watershed

Watercourses

Two depositional watercourse sites were sampled in the Pierre River during the environmental setting survey. Mean benthic invertebrate density at these sites was highly variable, ranging from 1,200 to 63,000 organisms/m^2. Total taxonomic richness ranged from 23 to 40 taxa/site, indicating a rich benthic invertebrate community. The SDI and evenness values indicated a diverse

benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa were midges and bristle worms.

A literature review did not find additional benthic invertebrate community data for watercourses in the Pierre River watershed.

Eymundson Creek Watershed

Watercourses

Seven watercourse sites were sampled during the environmental survey in the Eymundson Creek watershed, six of which were in depositional habitat and one in erosional habitat (Asphalt Creek). Five sites were sampled in Eymundson Creek, one site in Asphalt Creek and one site in an unnamed creek. Mean benthic invertebrate density ranged from 100 to 34,000 organisms/m². Total taxonomic richness ranged from 5 to 33 taxa/site, indicating a range of low to high richness. The SDI values were also indicative of a wide range in diversity. Evenness was generally low, indicating that a few taxa accounted for the majority of the total density. The dominant taxa in were the seed shrimp, midges and bristle worms. Mayflies were also dominant at the erosional site.

A literature review did not find additional benthic invertebrate community data for watercourses in the Eymundson Creek watershed.

Waterbodies

One unnamed waterbody was sampled in the Eymundson Creek watershed during the environmental setting survey. Mean benthic invertebrate density was 30,000 organisms/m² and total taxonomic richness was 33 taxa/site, indicating a rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The benthic invertebrate community was dominated by the midges.

Historical data were available for one waterbody (Lillian Lake), which had a similar benthic invertebrate community to the unnamed waterbody sampled during the baseline environmental survey. Mean benthic invertebrate density was 18,000 organisms/m² and total taxonomic richness was 37 taxa/site. The benthic community in Lillian Lake was dominated by midges and seed shrimp.

Big Creek Watershed

Watercourses

Five watercourse sites were sampled in the Big Creek watershed during the environmental survey. The three sites sampled in Big Creek were located in erosional habitat, and single sites sampled in First Creek and an unnamed creek were located in depositional habitat. At erosional sites, benthic invertebrate density ranged from 250 to 2,600 organisms/m² and total taxonomic richness ranged from 25 to 48 taxa/site, indicating a rich benthic invertebrate community of low density. The SDI and evenness values were indicative of a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa in Big Creek were midges, bristle worms and stoneflies.

At the two sites located in depositional habitat, benthic invertebrate density ranged from 96,000 to 119,000 organisms/m² and total taxonomic richness ranged from 28 to 37 taxa/site, indicating a rich and abundant benthic invertebrate community. The SDI and evenness values indicated a moderate to highly diverse benthic invertebrate community where a few taxa accounted for the majority of the total density. The dominant taxa at these sites were midges, seed shrimp and bristle worms.

A literature review did not find additional benthic invertebrate community data for watercourses in the Big Creek watershed.

Waterbodies

Three waterbodies were sampled in the Big Creek watershed during the environmental survey. These included Small Sandy Lake, Oakley Lake and an unnamed waterbody. Mean benthic invertebrate density ranged from 21,000 to 36,000 organisms/m² and total taxonomic richness ranged from 14 to 31 taxa/site, indicating a moderately rich to rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa were midges, bristle worms and seed shrimp.

A literature review did not find additional benthic invertebrate community data for waterbodies in the Big Creek watershed.

Redclay Creek Watershed

Watercourses

Two sites were sampled in Redclay Creek during the environmental setting survey. One site was located in erosional habitat and the other in depositional habitat. Mean benthic invertebrate density ranged from 2,100 to

2,800 organisms/m² and total taxonomic richness ranged from 19 to 28 taxa/site, indicating moderately rich to rich benthic invertebrate communities of low density. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa at the erosional site were mayflies and caddisflies. The depositional site was dominated by midges, bristle worms and caddisflies.

A literature review did not find additional benthic invertebrate community data for watercourses in the Redclay Creek watershed.

Waterbodies

Two unnamed waterbodies were sampled in the Redclay Creek watershed during the environmental setting survey. Mean benthic invertebrate density ranged from 11,000 to 29,000 organisms/m² and total taxonomic richness ranged from 25 to 27 taxa/site, indicating a moderately rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The benthic invertebrate communities of these waterbodies were dominated by midges.

A literature review did not find additional benthic invertebrate community data for waterbodies in the Redclay Creek watershed.

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APPENDIX J

COMMON AND SCIENTIFIC NAMES OF FAUNA AND FLORA

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

LIST OF TABLES

Table J-1 Fish Species Codes and Common and Scientific Names 1
Table J-2 Common and Scientific Names of Plants 2

Table J-1 Fish Species Codes and Common and Scientific Names

Category	Taxonomic Family	Species		
		Code	Common Name	Scientific Name
sport fish	Esocidae	NRPK	northern pike	*Esox lucius*
	Gadidae	BURB	burbot	*Lota lota*
	Hiodontidae	GOLD	goldeye	*Hiodon alosoides*
	Percidae	WALL	walleye	*Sander vitreus*
		YLPR	yellow perch	*Perca flavescens*
	Salmonidae	ARGR	Arctic grayling	*Thymallus arcticus*
		BLTR	bull trout	*Salvelinus confluentus*
		CISC	cisco	*Coregonus artedi*
		LKTR	lake trout	*Salvelinus namaycush*
		LKWH	lake whitefish	*Coregonus clupeaformis*
		MNWH	mountain whitefish	*Prosopium williamsoni*
		RNTR	rainbow trout	*Oncorhynchus mykiss*
non-sport fish	Catostomidae	LNSC	longnose sucker	*Catostomus catostomus*
		WHSC	white sucker	*Catostomus commersonii*
forage fish	Cottidae	SLSC	slimy sculpin	*Cottus cognatus*
		SPSC	spoonhead sculpin	*Cottus ricei*
	Cyprinidae	BRMN	brassy minnow	*Hybognathus hankinsoni*
		EMSH	emerald shiner	*Notropis atherinoides*
		FTMN	fathead minnow	*Pimephales promelas*
		FNDC	finescale dace	*Phoxinus neogaeus*
		FLCH	flathead chub	*Platygobio gracilis*
		LKCH	lake chub	*Couesius plumbeus*
		LNDC	longnose dace	*Rhinichthys cataractae*
		NRDC	northern redbelly dace	*Phoxinus eos*
		PRDC	pearl dace	*Semotilus margarita*
		RVSH	river shiner	*Notropis blennius*
		SPSH	spottail shiner	*Notropis hudsonius*
	Gasterosteidae	BRST	brook stickleback	*Culaea inconstans*
		NNST	ninespine stickleback	*Pungitius pungitius*
	Percidae	IWDR	Iowa darter	*Etheostoma exile*
	Percopsidae	TRPR	trout-perch	*Percopsis omiscomaycus*

Table J-2 Common and Scientific Names of Plants

Common Name	Scientific Name (*Genus*)
Algae	
duckweed	*Lemna*
macrophytic algae	*Chara*
Submergent Aquatic Macrophytes	
coontail	*Ceratophyllum*
pond lily	*Nuphor*
pondweed	*Potamogeton*
water weed	*Elodea*
water milfoil	*Myriophyllum*
Emergent Aquatic Macrophytes	
cattail	*Typha*
bulrush	*Scirpus*
Riparian Terrestrial Vegetation	
willow	*Salix*
sedge grasses	*Carex*
tamarack	*Larix*

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APPENDIX K

SUBSTRATE PARTICLE SIZE CATEGORIES

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

LIST OF TABLES

Table K-1 Substrate Particle Size Ranges 1

Table K-1 Substrate Particle Size Ranges

Class Name	Size Range	
	Millimetres	Inches
clay/silt	<0.06	<0.0024
sand	0.06 to 2.0	0.0024 to 0.08
small gravel	2 to 8	0.08 to 0.3
medium gravel	8 to 32	0.3 to 1.3
large gravel	32 to 64	1.3 to 2.5
small cobble	64 to 128	2.5 to 5
large cobble	128 to 256	5 to 10
small boulder	256 to 762	10 to 30
large boulder	>762	>30
bedrock	–	–

– = Not measured.

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APPENDIX L

HABITAT MAPS FOR THE MCCLELLAND LAKE DRAINAGE AREA

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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Figure L-5 Habitat Map for Site 54 Unnamed Waterbody 4 5

Photo 1 - Upstream view of discharge site, February 2007.

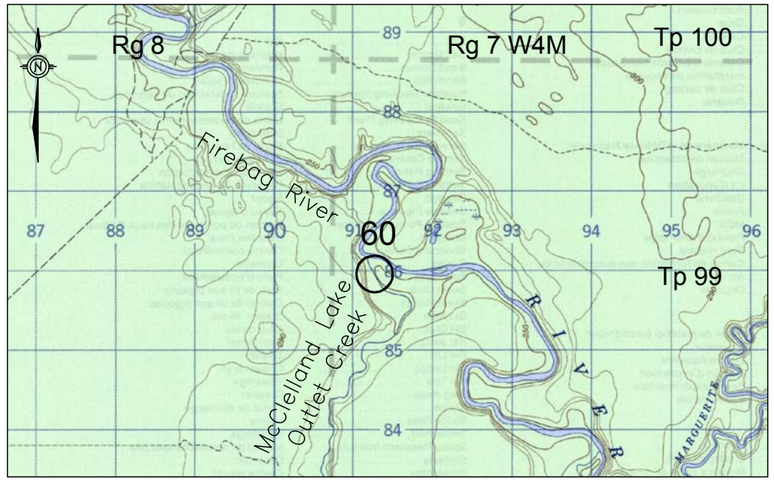


Photo 4 - View of the mouth of McClelland Lake Outlet Creek, July 2007.

Photo 2 - Aerial view of the confluence of McClelland Lake Outlet Creek and the Firebag River, May 2007.

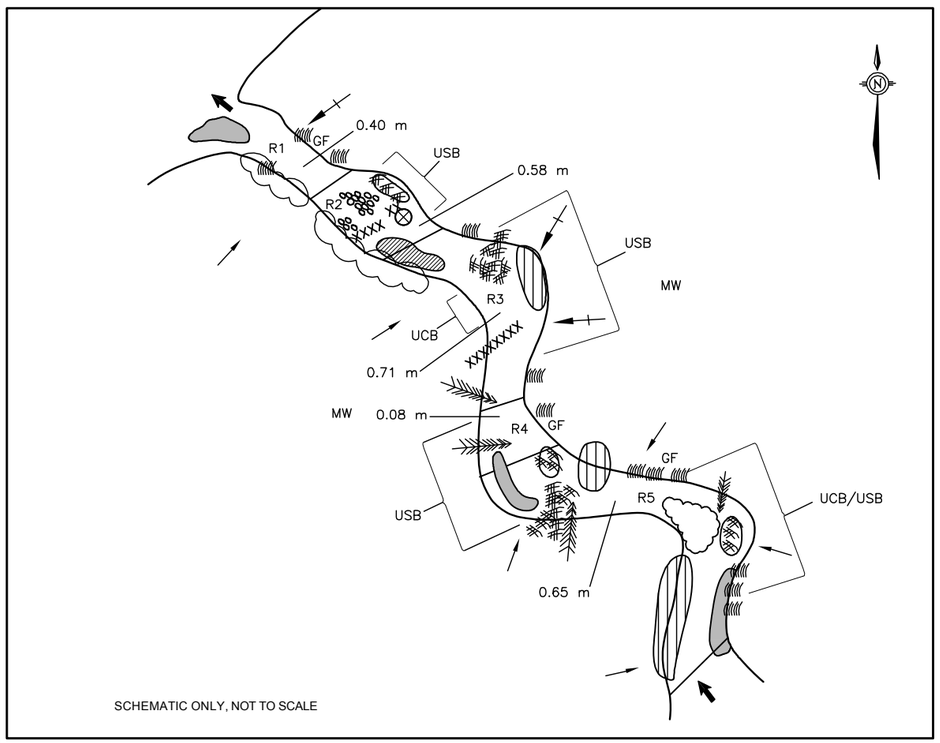


Photo 3 - Upstream view of discharge site, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

Exposed Bar – Fine	
Exposed Bar – Coarse	
Island	
Woody Debris Pile	
Root Wad	
Overhead Cover, High Quality	
Instream Cover, High Quality	
Overhanging Vegetation	
Tree, Shrub, Grass	
Undercut Bank (UCB) (fish cover)	
Unstable Bank (USB) (slumping or eroding)	
Ledge; Bedrock Intrusion, Vertical Drop	

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 60
McCLELLAND LAKE OUTLET CREEK

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Site 60
DESIGN	HF	01/08/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: L-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig L-1_Habitat Map for Site 60.dwg Nov 29, 2007 - 1:57pm

Photo 1 - Downstream view of survey section, February 2006.

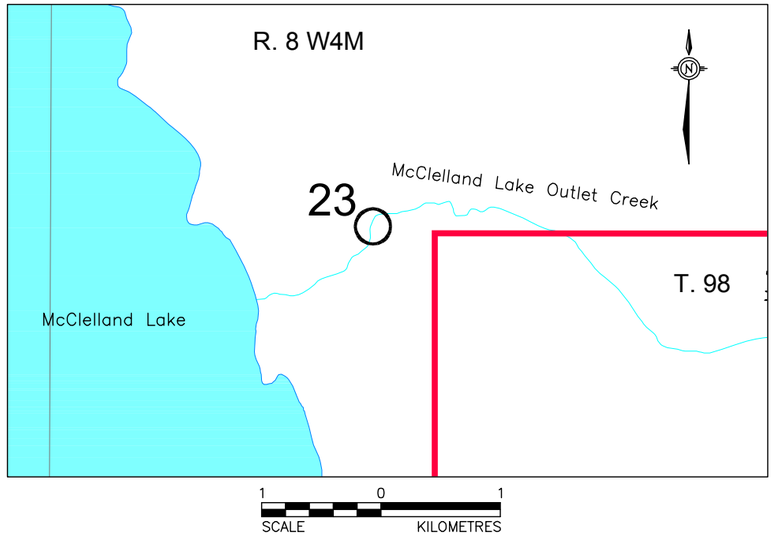


Photo 4 - View of right downstream bank showing fen habitat, August 2006.

Photo 2 - Downstream view of flat habitat with abundant inundated vegetation, June 2006.

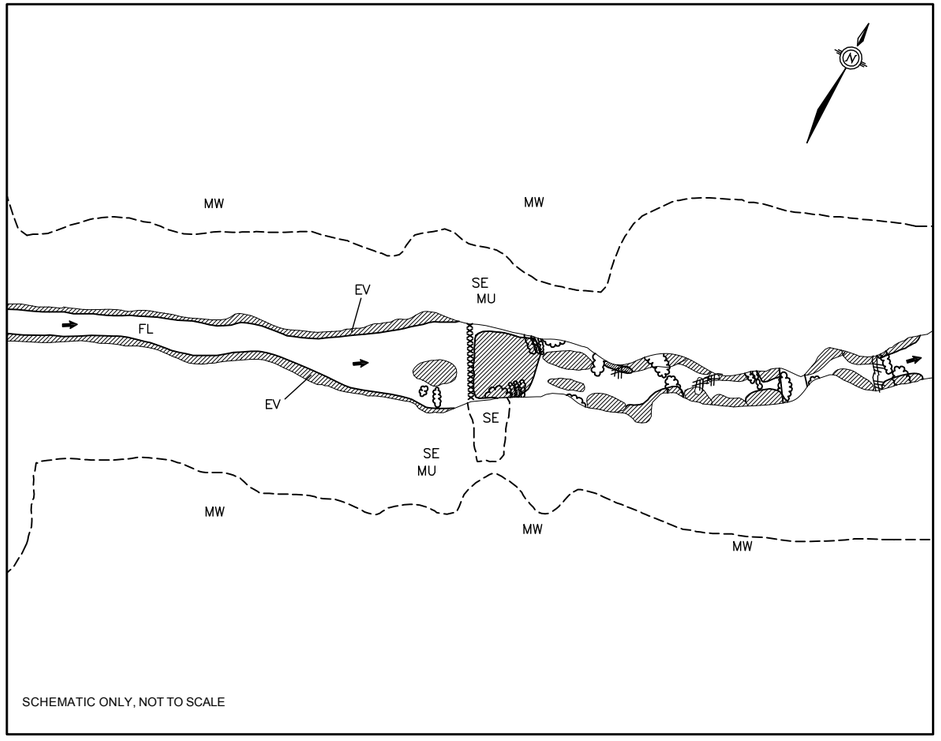


Photo 3 - Aerial view of McClelland Lake outlet, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 23 McCLELLAND LAKE OUTLET CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No. Habitat Site23 MLO		
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV.	0
CADD	TY	17/11/07			
CHECK	AS	26/10/07	**FIGURE: L-2**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig L-2_Habitat Map_Site23 McClelland Lake Outlet.dwg Nov 29, 2007 - 2:16pm

Photo 1 - Aerial view of Unnamed Creek 3, September 2006.

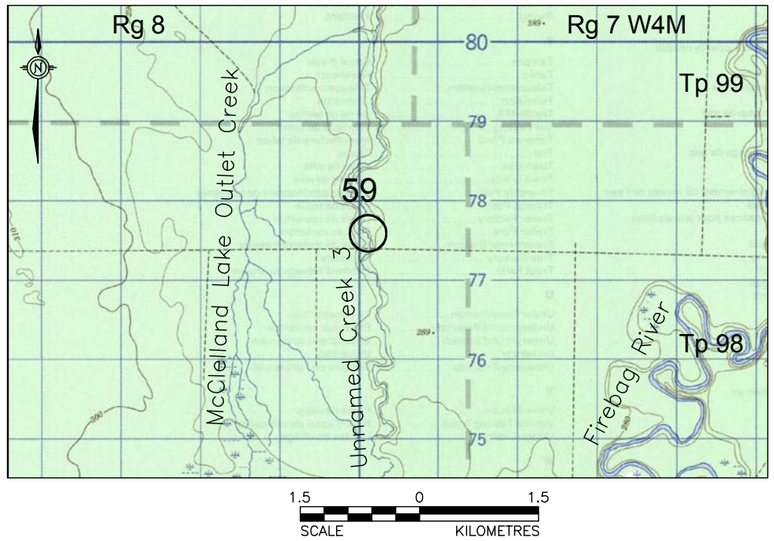


Photo 4 - View of side channel and marsh, July 2007.

Photo 2 - Upstream view of shelf ice, February 2007.

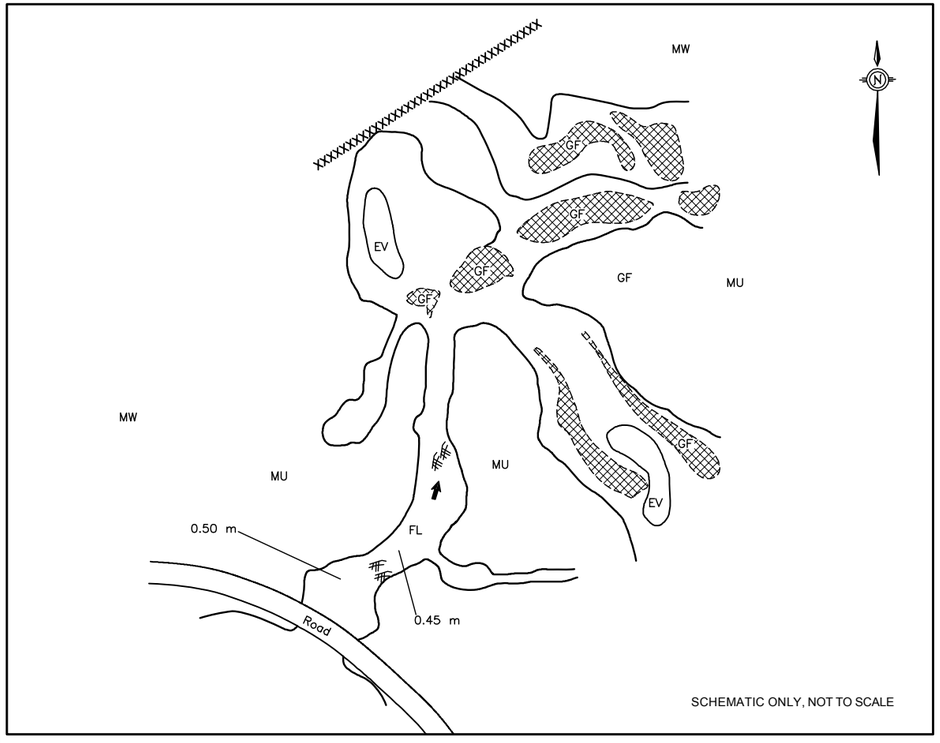


Photo 3 - Aerial view of surveyed section of Unnamed Creek 3, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 59 UNNAMED CREEK 3

Shell Canada Limited

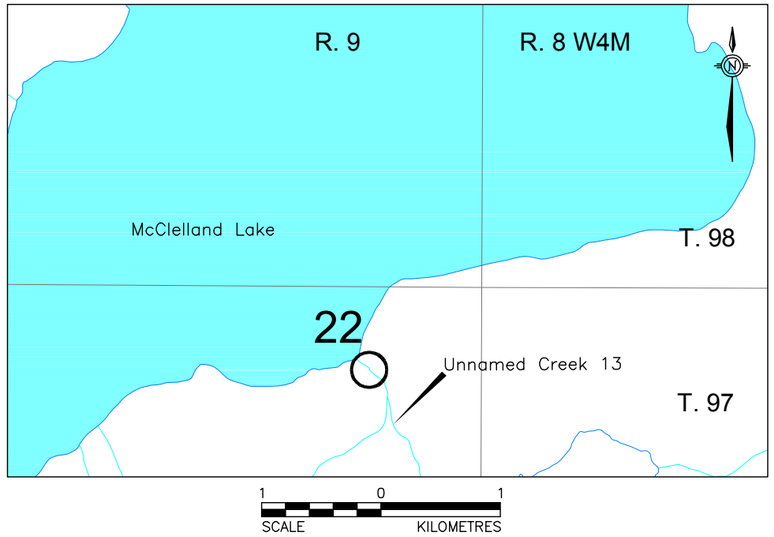
PROJECT 05-1344-027.6137			FILE No.	Hab Map Site 59	
DESIGN	HF	01/08/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: L-3

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig L-3_Habitat Map for Site 59.dwg Nov 29, 2007 - 2:28pm

Photo 1 - Downstream view of watercourse, February 2006.

Photo 2 - Pool (P3) habitat facing the left downstream bank, October 2005.



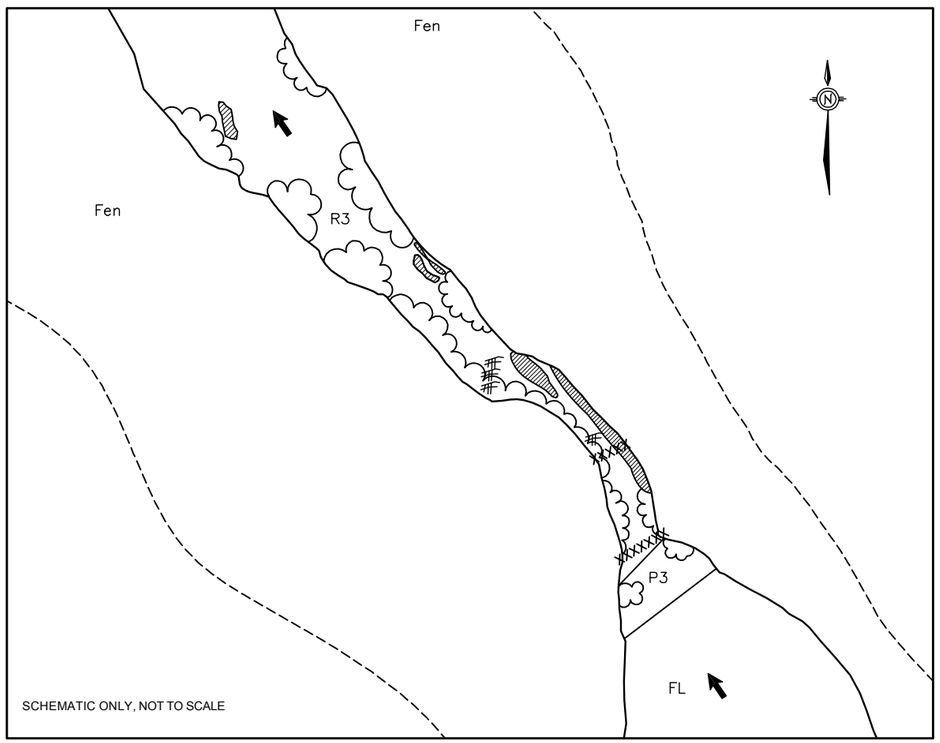


Photo 4 - Aerial view of Unnamed Creek 13, August 2006.

Photo 3 - Upstream aerial view of Unnamed Creek 13, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 22
UNNAMED CREEK 13

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.	Site 22
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: L-4

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig L-4_Habitat Map_Site22.dwg Nov 29, 2007 - 2:37pm

Photo 1 - Aerial view of Unnamed Waterbody 4, September 2006.

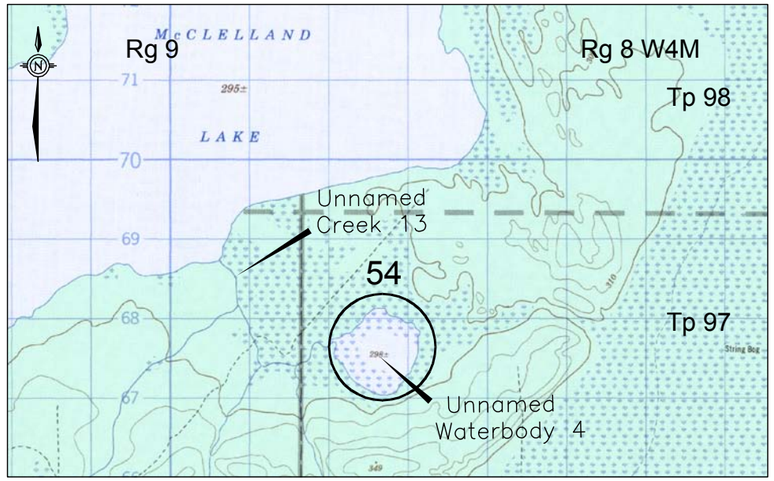


Photo 4 - Aerial view of vegetation in Unnamed Waterbody 4, August 2006.

Photo 2 - View of east shoreline of Unnamed Waterbody 4, February 2006.

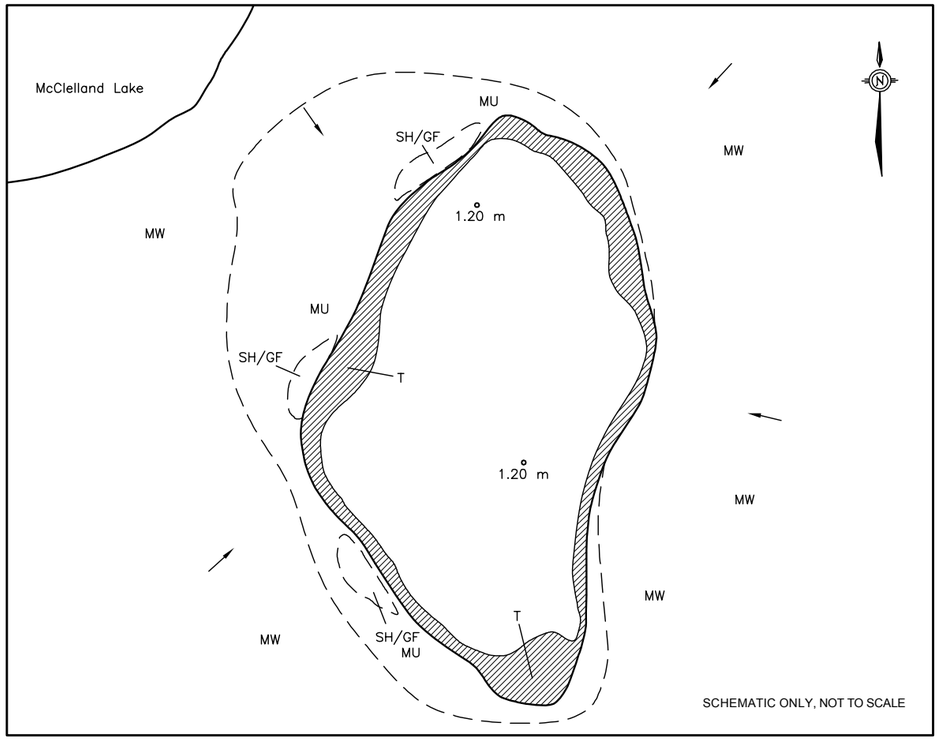


Photo 3 - View of east shoreline of Unnamed Waterbody 4, May 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m° Indicates Depth
- Direction of Flow
- BL Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating-Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 54
UNNAMED WATERBODY 4

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Site 54
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07			FIGURE: L-5
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig L-5_Habitat Map for Site 54 WB 4.dwg Nov 29, 2007 - 2:42pm

Golder Associates Ltd.

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Calgary, Alberta, Canada T2P 3T1
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Fax (403) 299-5606

APPENDIX M

HABITAT MAPS FOR THE MUSKEG RIVER WATERSHED

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

LIST OF FIGURES

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Figure M-5 Habitat Map for Site 26 Wapasu Creek 5
Figure M-6 Habitat Map for Site 38 Wapasu Creek 6
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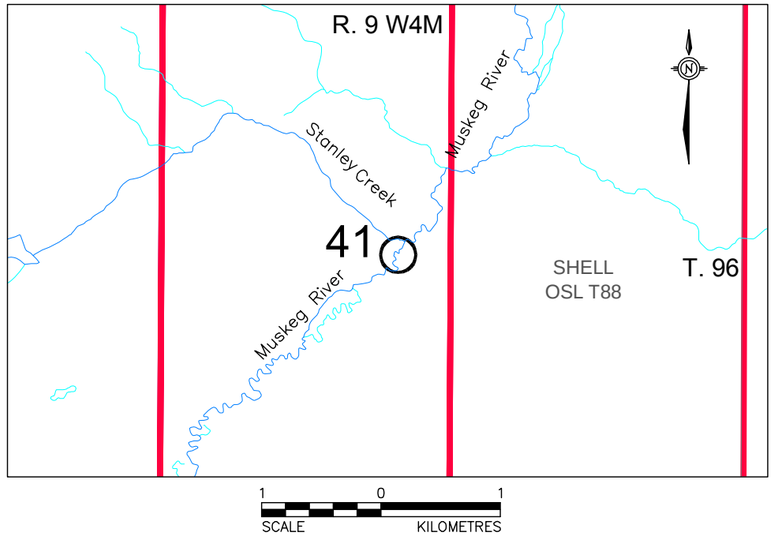
Figure M-10 Habitat Map for Site 27 Unnamed Waterbody 2 10
Figure M-11 Habitat Map for Site 39 Unnamed Waterbody 11
Figure M-12 Habitat Map for Site 25 Unnamed Waterbody 17 12

Photo 1 - Aerial view of surveyed section of Muskeg River, October 2005.

Photo 2 - Upstream view of surveyed section, February 2006.



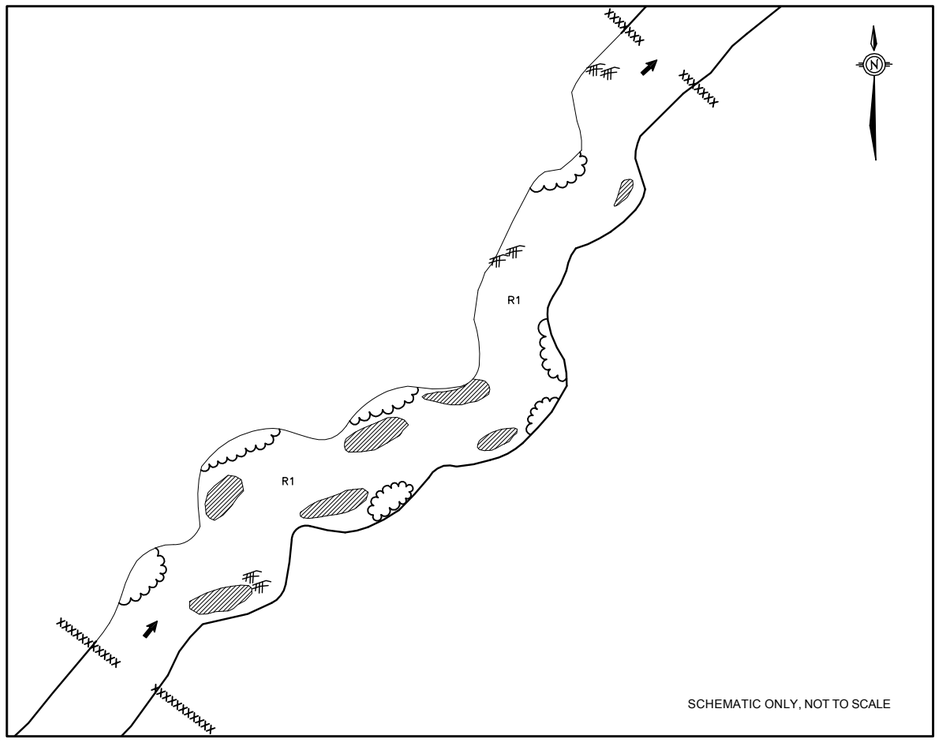


Photo 4 - View of run habitat typical of surveyed section, June 2006.

Photo 3 - View of run habitat typical of surveyed section, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 41 MUSKEG RIVER

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No. Habitat Map Site 41	
DESIGN	CS	01/03/06	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: M-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-1_Habitat Map_Site41 Muskeg River.dwg Nov 29, 2007 - 2:24pm

Photo 1 - Downstream view of site, February 2006.

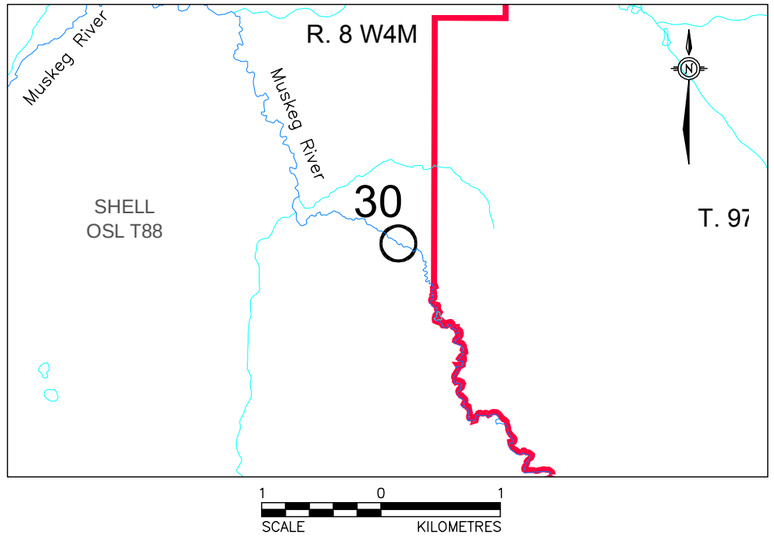


Photo 4 - Upstream view of typical run (R2) habitat with some overhanging vegetation, August 2006.

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Photo 2 - Downstream view of R2 habitat, woody debris and instream vegetation, October 2005.

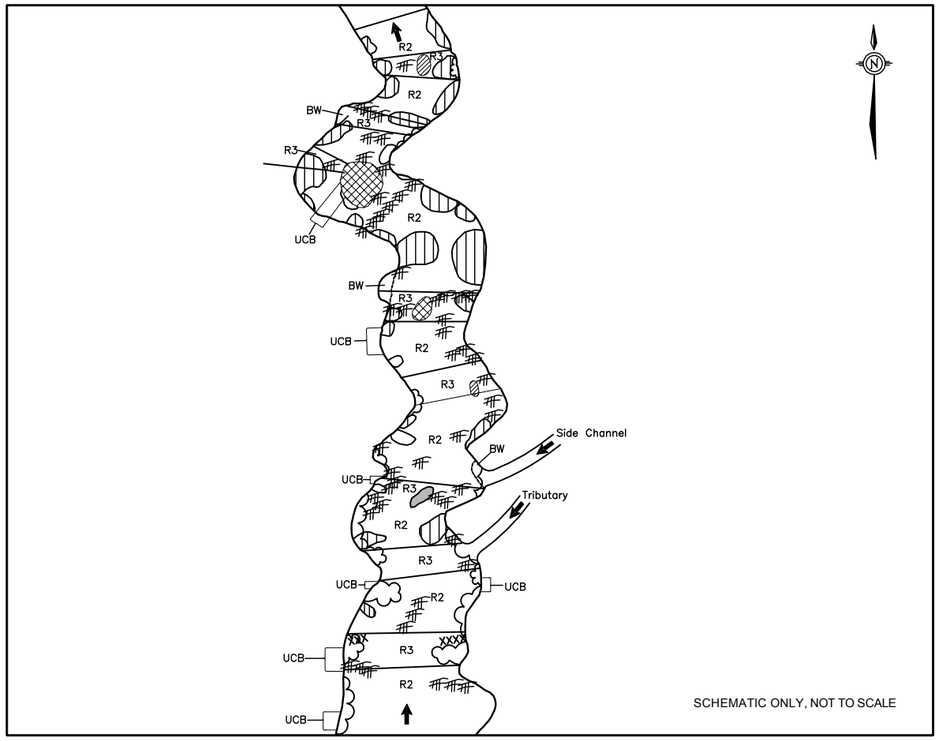


Photo 3 - Upstream view of broad run (R3) with grassy island., October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Silt/Mud Bar, exposed
- Gravel/Cobble Bar, exposed
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg
GF	Grass/Forbs
SE	Sedges
SH	Shrubs
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 30 MUSKEG RIVER

Shell Canada Limited

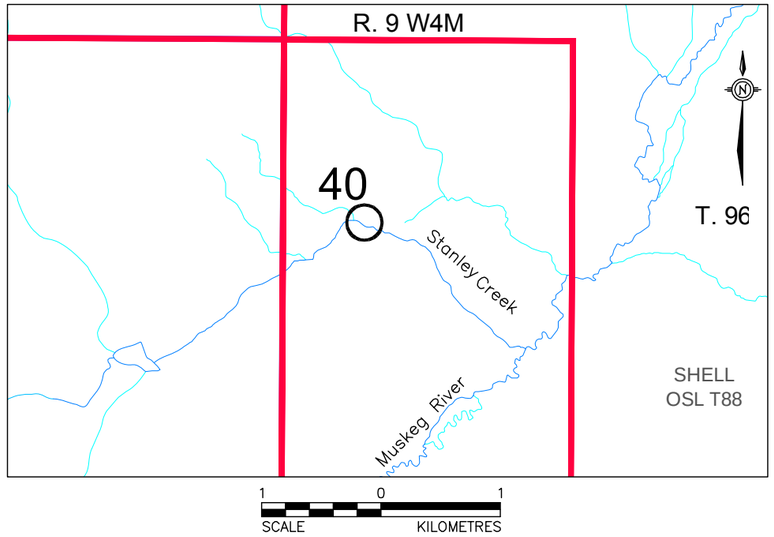
PROJECT 05-1344-027.6190			FILE No. Habitat Site30 MR	
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: M-2

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-2_Habitat Map_Site30 Muskeg Rive.dwg Nov 29, 2007 - 2:45pm

Photo 1 - Upstream view of wide undefined channel, October 2005.

Photo 2 - Aerial view of surveyed section, February 2006.



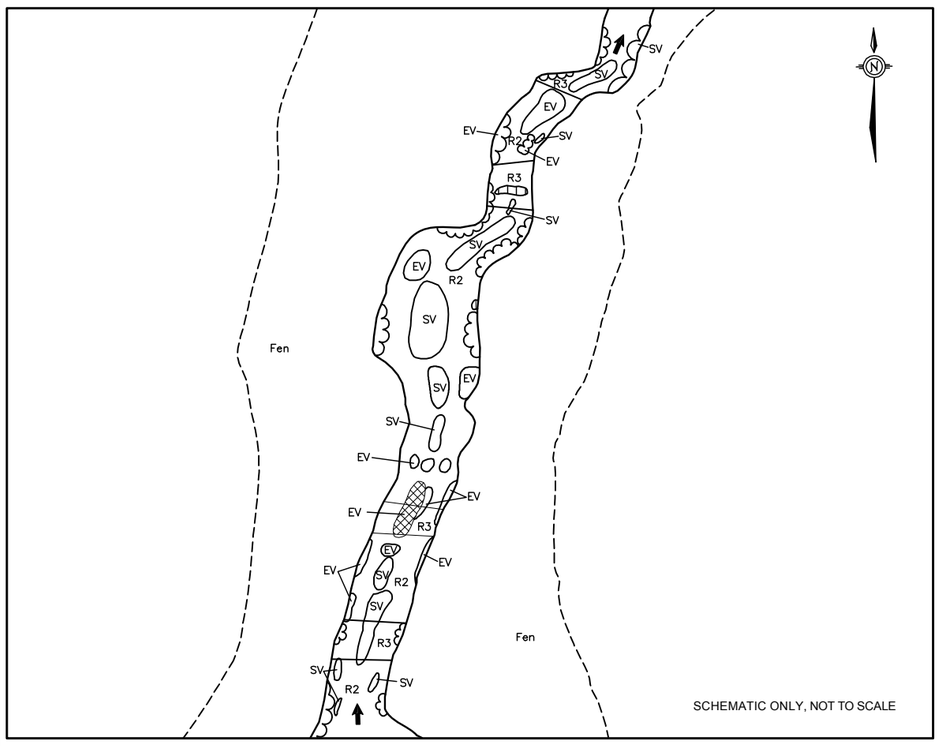


Photo 4 - Upstream view of surveyed section, August 2006.

Photo 3 - Upstream view of typical habitat with overhead cover, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 40 STANLEY CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No. Habitat Site40 SC	
DESIGN	CS	01/03/06	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: M-3

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-3_Habitat Map_Site40 Stanley Creek.dwg Nov 29, 2007 - 2:50pm

Photo 1 - Upstream view of surveyed section, February 2006.

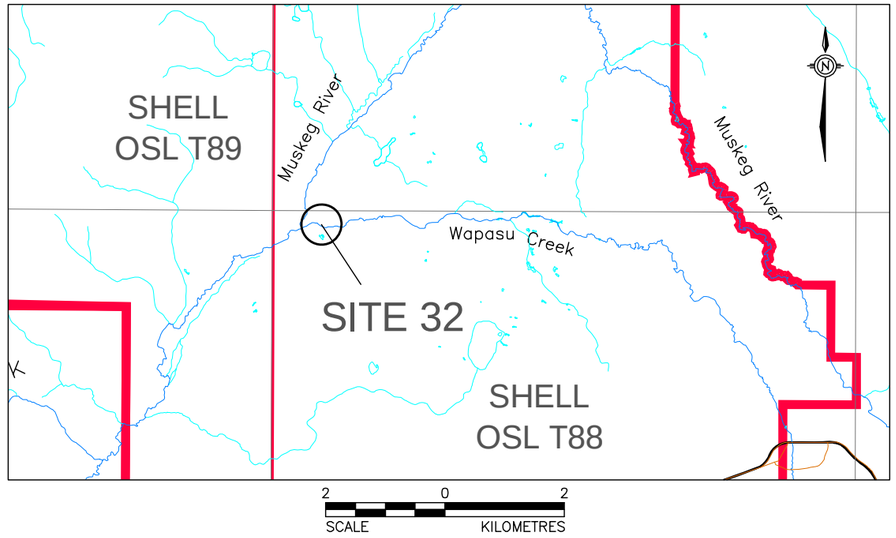


Photo 4 - Aerial view of surveyed section, August 2006.

Photo 2 - View of fen, August 2006.

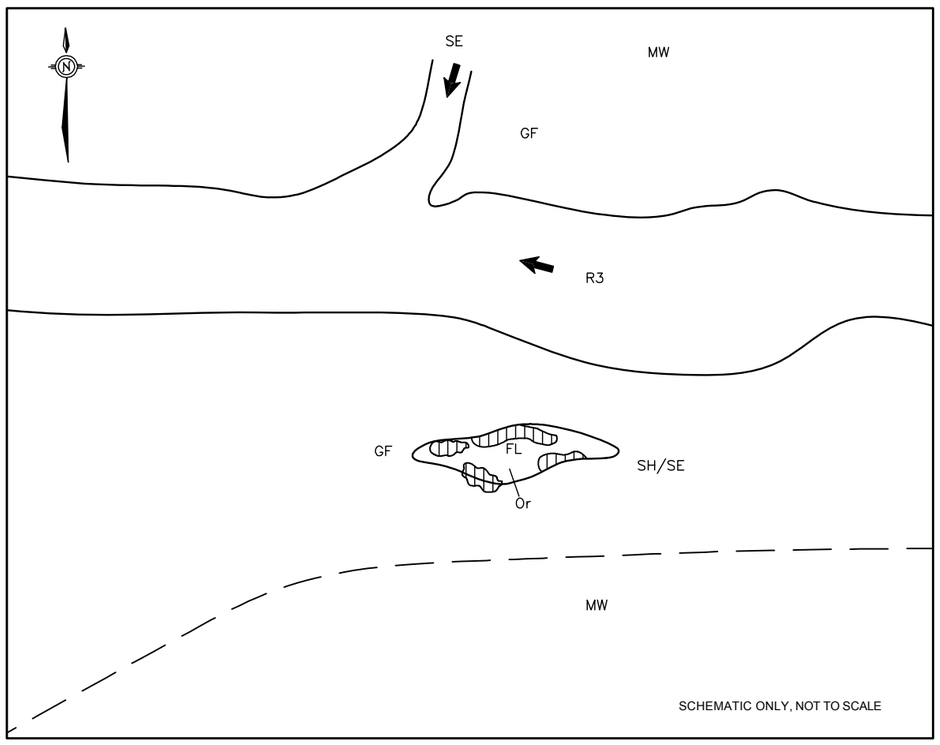


Photo 3 - Downstream view of surveyed section, May 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Silt/Mud Bar, exposed
- Gravel/Cobble Bar, exposed
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg
- GF Grass/Forbs
- SE Sedges
- SH Shrubs
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 32
WAPASU CREEK

Shell Canada Limited

PROJECT 05-1344-027.6132			FILE No.		SITE 32
DESIGN	CS	13/09/06	SCALE AS SHOWN		REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: M-4

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6132\Fig M-4_Site32 Wapasu Creek.dwg Nov 29, 2007 - 3:19pm

Photo 1 - Upstream view of surveyed section, February 2006.

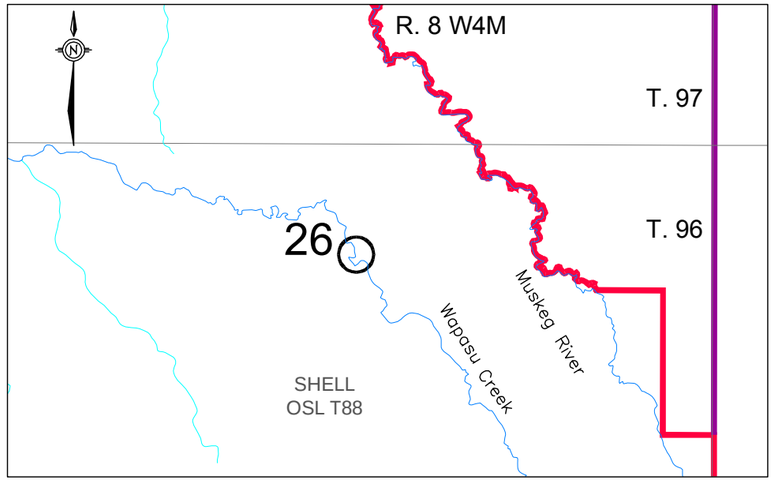


Photo 4 - Upstream view of woody debris and overhead cover, August 2006.

Photo 2 - Upstream view of riffle/run habitat, June 2006.

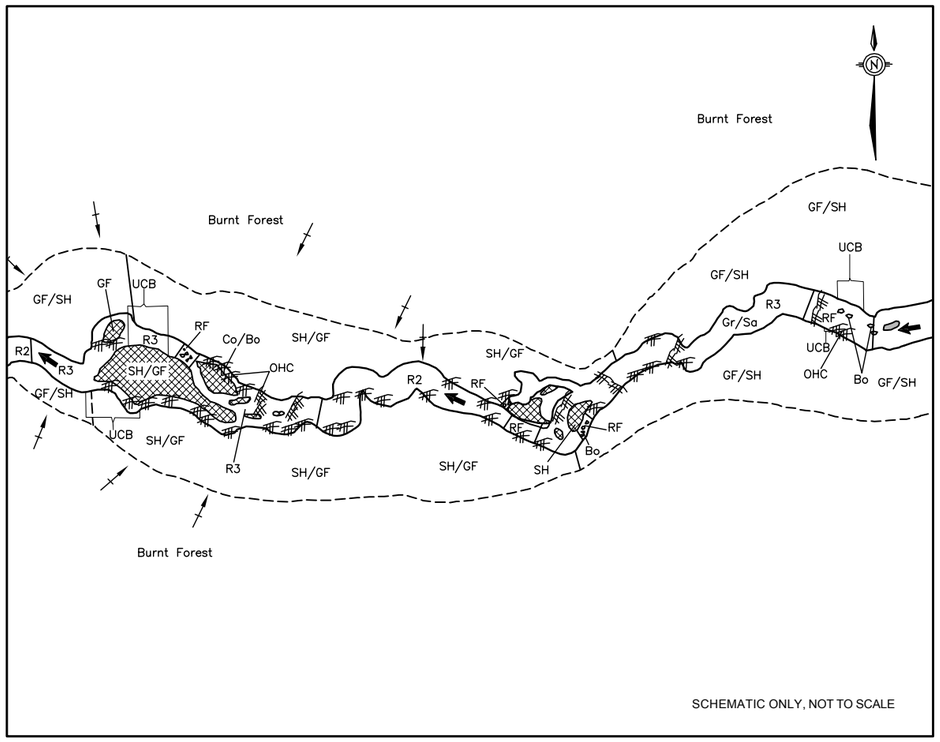


Photo 3 - View of typical run (R3) habitat, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Silt/Mud Bar, exposed
- Gravel/Cobble Bar, exposed
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality (OHC)
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg
- GF Grass/Forbs
- SE Sedges
- SH Shrubs
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 26 WAPASU CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No. Habitat Map Site26	
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07	**FIGURE: M-5**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-5_Habitat Map_Site26.dwg Nov 29, 2007 - 3:24pm

Photo 1 - Downstream view of woody debris and vegetated banks, October 2005.

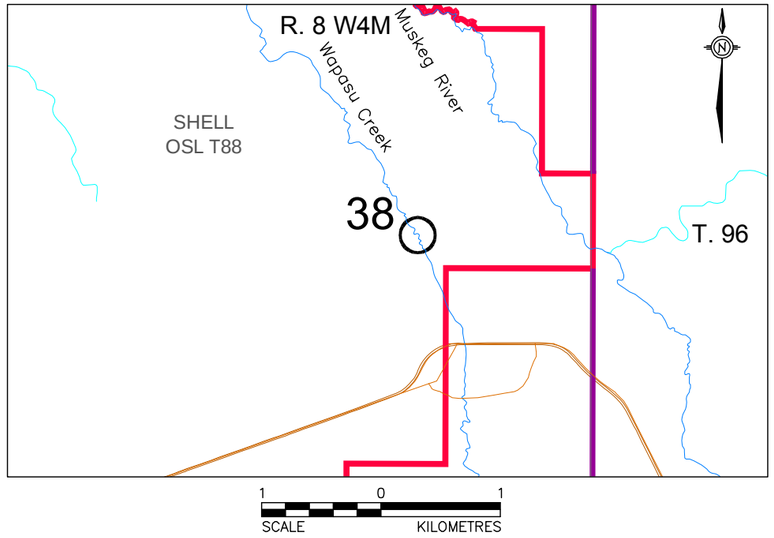


Photo 4 - Downstream view of pool at tail end of riffle habitat, August 2006.

Photo 2 - Upstream view of riffle habitat, October 2005.

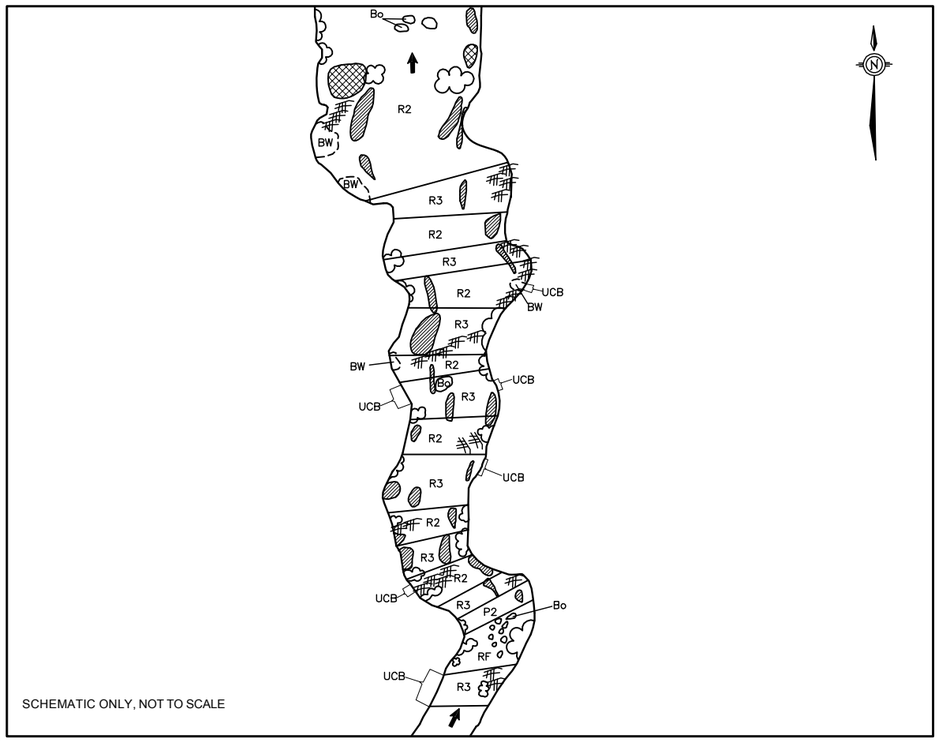


Photo 3 - Upstream view of surveyed section, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 38
WAPASU CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.Habitat Map Site 38	
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TY	18/11/07		
CHECK	AS	26/10/07	**FIGURE: M-6**	
REVIEW	WES/TC	20/11/07		

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Photo 1 - Downstream view from beaver dam of undefined channel, October 2005.

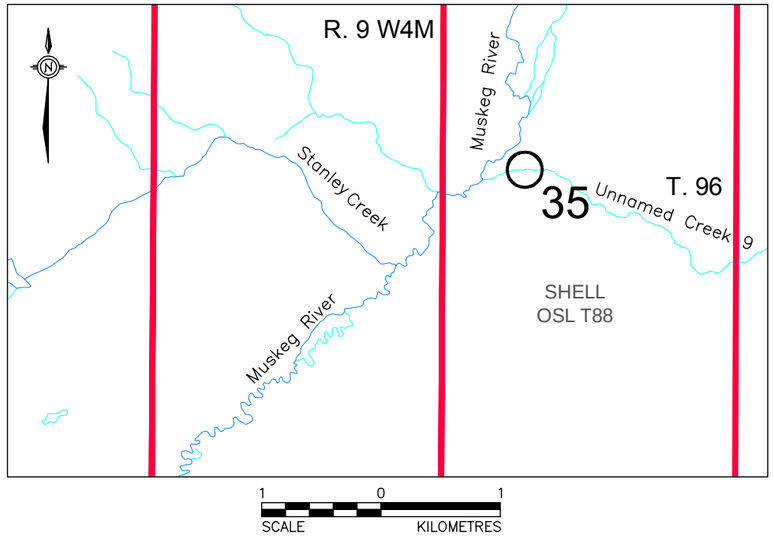


Photo 4 - Aerial view of Unnamed Creek 9, August 2006.

Photo 2 - Downstream view of surveyed section, February 2006.

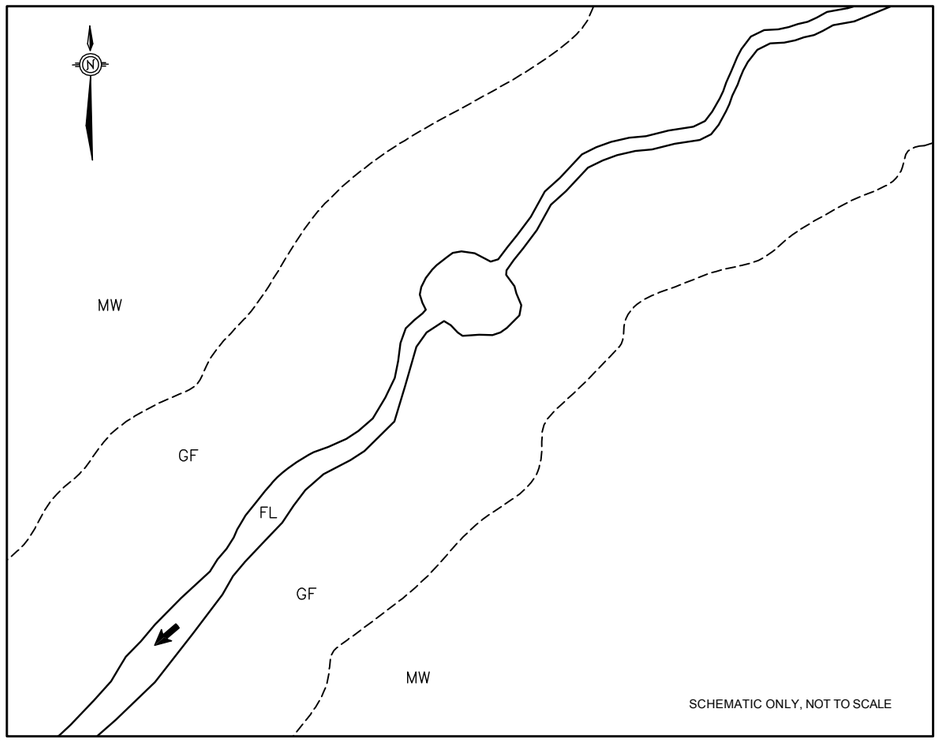


Photo 3 - Upstream view of flat habitat, May 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 35
UNNAMED CREEK 9

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No. Habitat Map Site35		
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV.	0
CADD	TY	18/11/07			
CHECK	AS	26/10/07	**FIGURE: M-7**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-7_Habitat Map_Site35.dwg Nov 29, 2007 - 3:30pm

Photo 1 - Upstream view of surveyed section, February 2006.

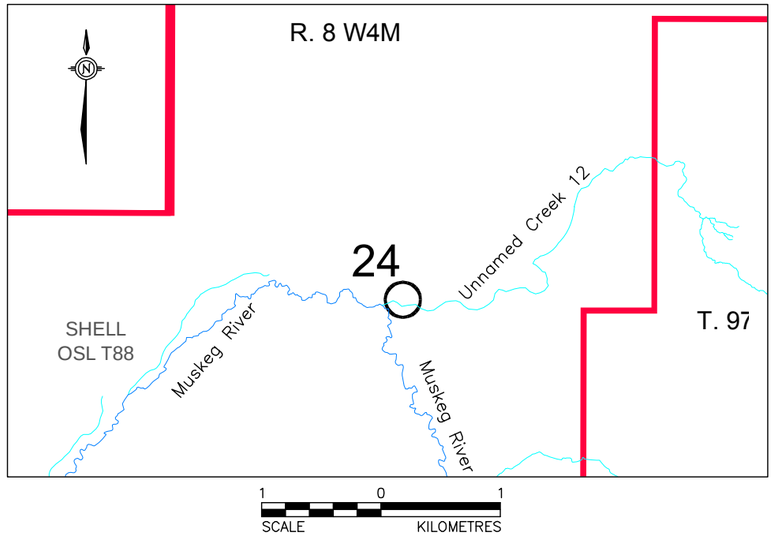


Photo 4 - Typical run habitat with undefined banks, August 2006.

Photo 2 - Aerial view of Unnamed Creek 12, June 2006.

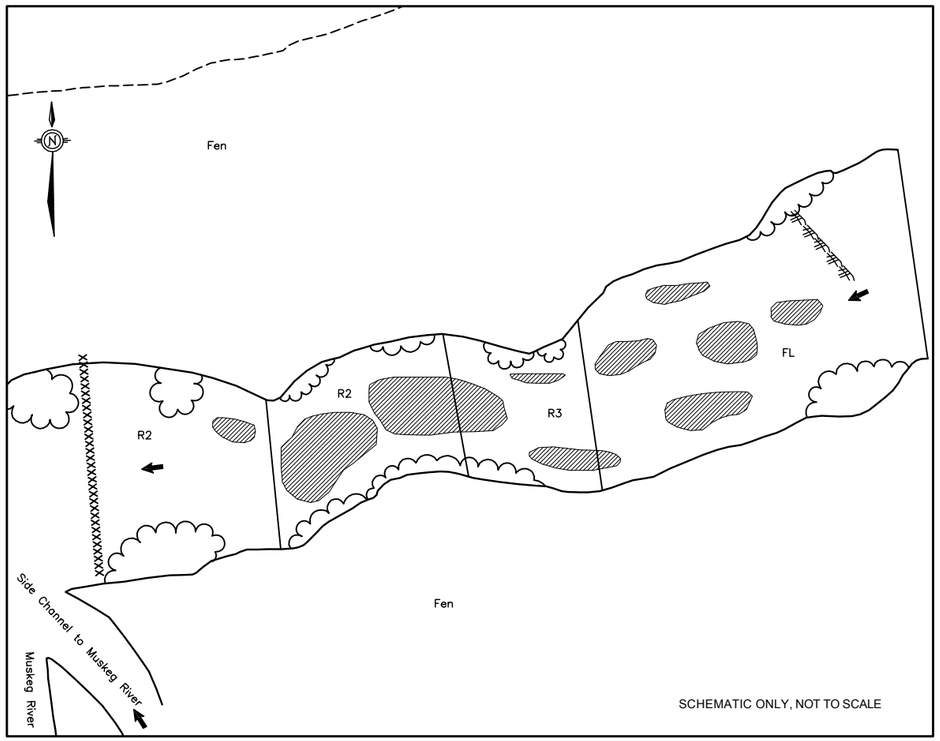


Photo 3 - View of sedge fen, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 24
UNNAMED CREEK 12

Shell Canada Limited

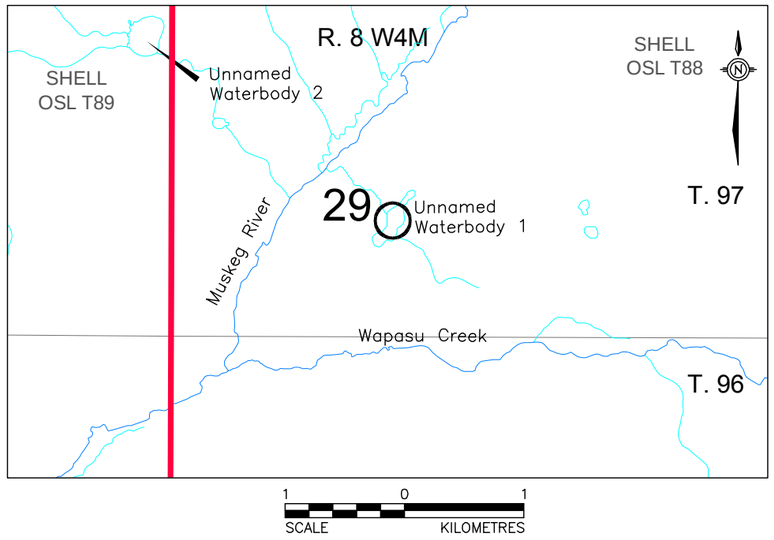
PROJECT 05-1344-027.6100			FILE No.	Habitat Map Site24
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: M-8

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig M-8_Habitat Map_Site24 Tributary to Muskeg River.dwg Nov 29, 2007 - 3:33pm

Photo 1 - Aerial view of Unnamed Waterbody 1, February 2006.

Photo 2 - View of lake outlet, October 2005.



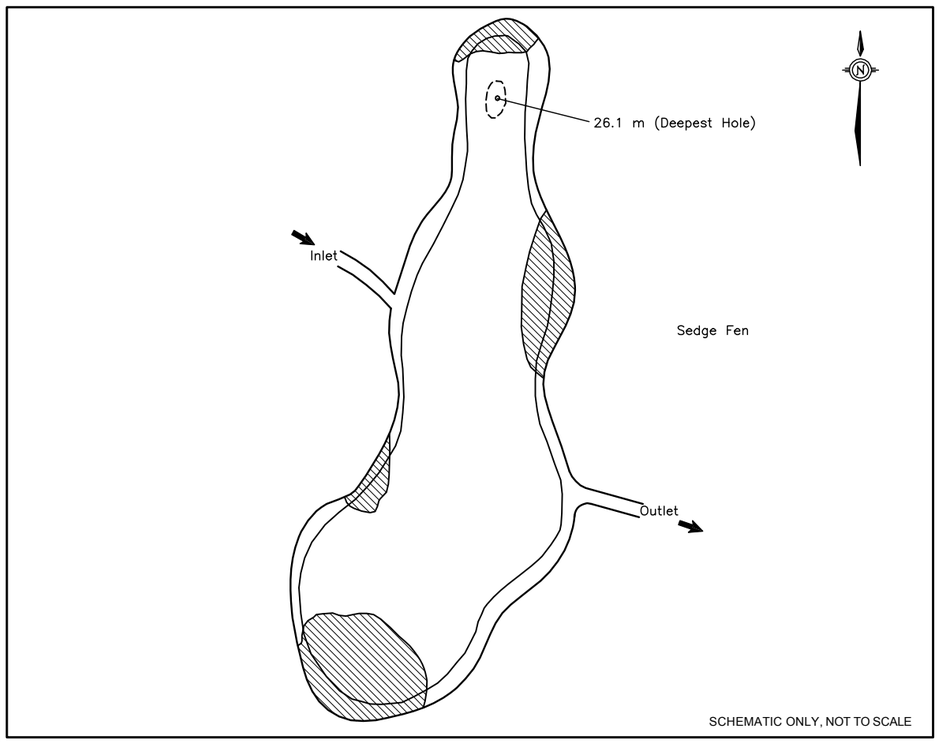


Photo 4 - Aerial view of Unnamed Waterbody 1, October 2005.

Photo 3 - View of north shoreline, May 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

0.61 m Indicates Depth
Direction of Flow
BL Beaverlodge
Exposed Bar – Fine
Exposed Bar – Coarse
Island
Woody Debris Pile
Overhead Cover, High Quality
Overhanging Vegetation
Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

	Shallow Slope	(0 to 5%)
	Intermediate Slope	(6 to 30%)
	Steep Slope	(31 to 70%)
	Very Steep Slope	(>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

Emergent Vegetation
Submergent or Floating–Leaved Vegetation
Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 29
UNNAMED WATERBODY 1

Shell Canada Limited

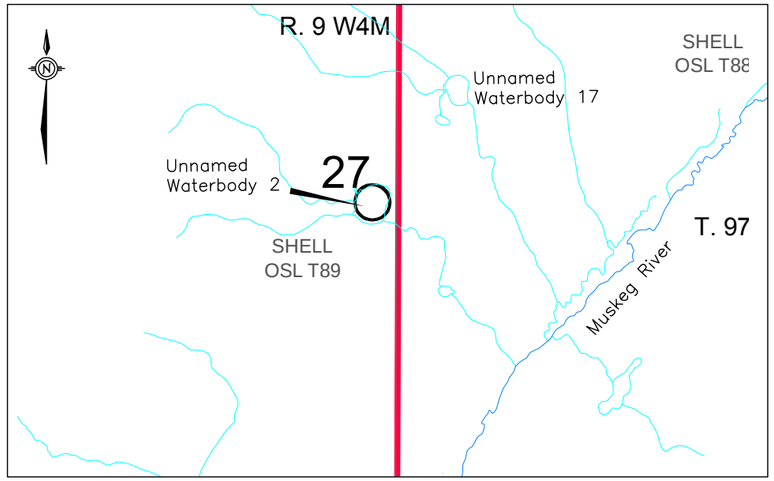
PROJECT 05–1344–027.6190			FILE No.		Lake_Site29
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: M-9

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig M–9_Lake_Site29 Waterbody #29–DeepLakeLake.dwg Nov 29, 2007 – 3:37pm

Photo 1 - View of south shore of Unnamed Waterbody 2, October 2005.

Photo 2 - View of irregular shoreline along the west shore, October 2005.



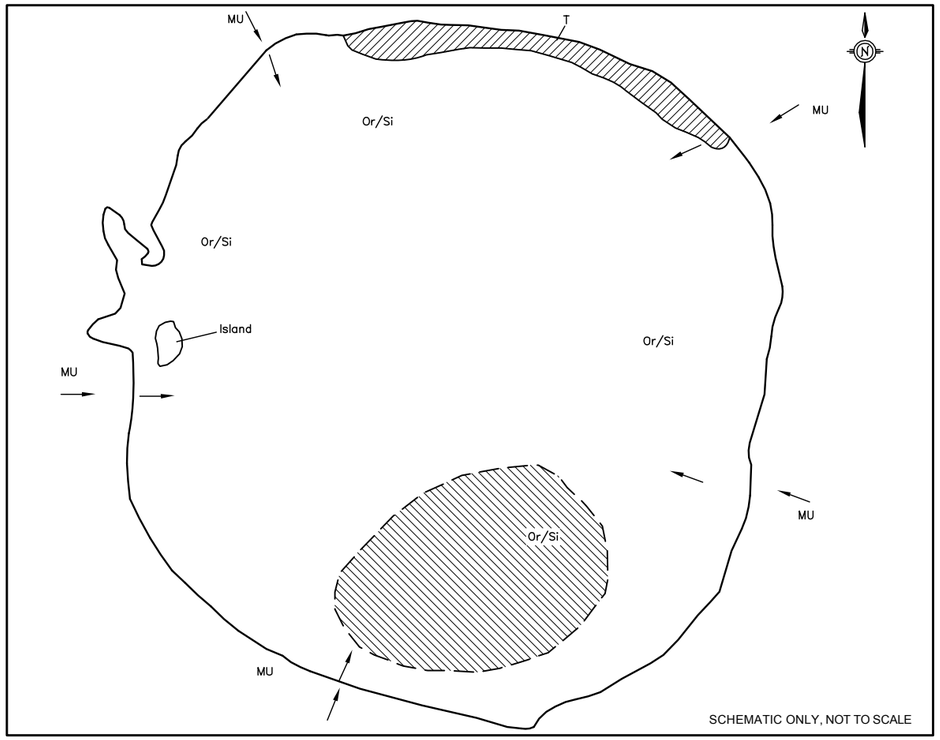


Photo 4 - View of north shoreline, May 2006.

Photo 3 - Aerial view of Unnamed Waterbody 2, February 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating–Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 27 UNNAMED WATERBODY 2

Shell Canada Limited

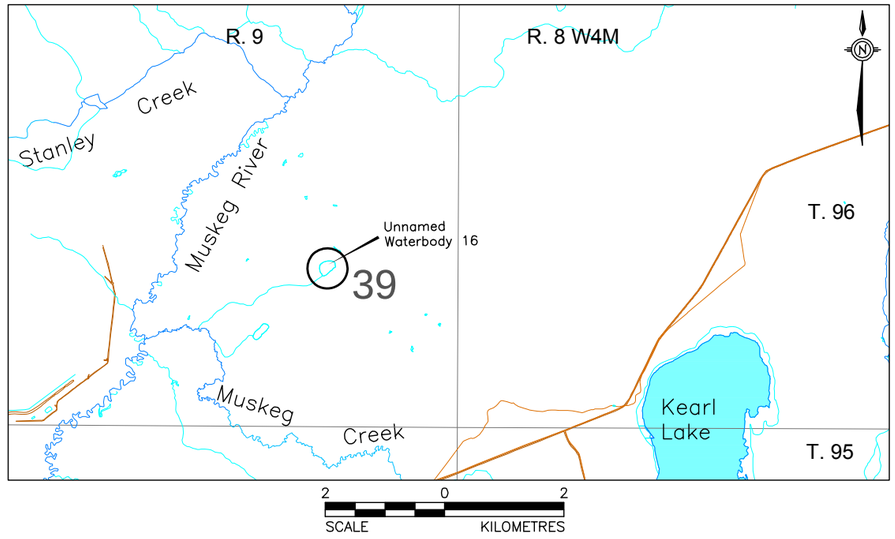
PROJECT 05–1344–027.6190			FILE No.		Lake_Site27
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: M-10

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig M–10_Lake_Site27 Unnamed Lake.dwg Nov 29, 2007 – 3:40pm

Photo 1 - View of west shoreline, June 2006.

Photo 2 - View of north shoreline, June 2006.



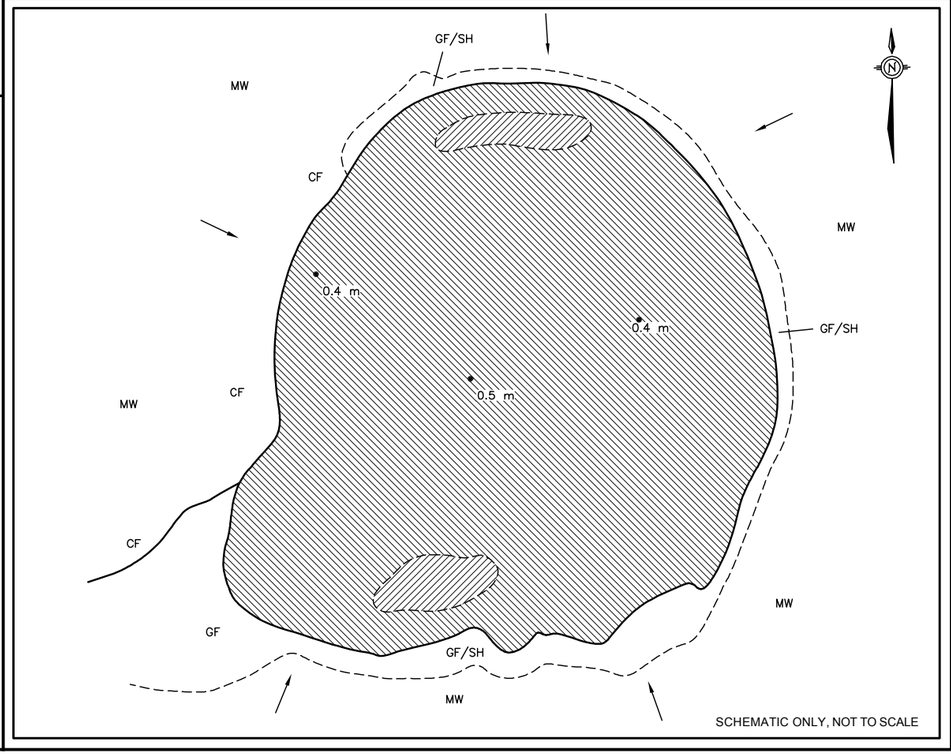


Photo 4 - View of south shoreline, June 2006.

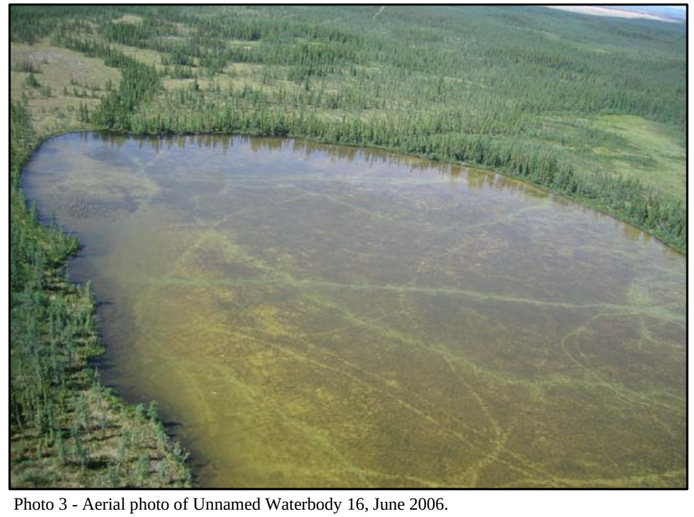


Photo 3 - Aerial photo of Unnamed Waterbody 16, June 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating–Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 39
UNNAMED WATERBODY 16

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.		Site 39
DESIGN	JS	13/09/06	SCALE	AS SHOWN	REV. 0
CADD	PSR	18/09/06			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: M-11

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig M–11 Site39_ Unnamed Waterbody16.dwg Nov 29, 2007 – 3:45pm

Photo 1 - Aerial view of Unnamed Waterbody 17, February 2006.

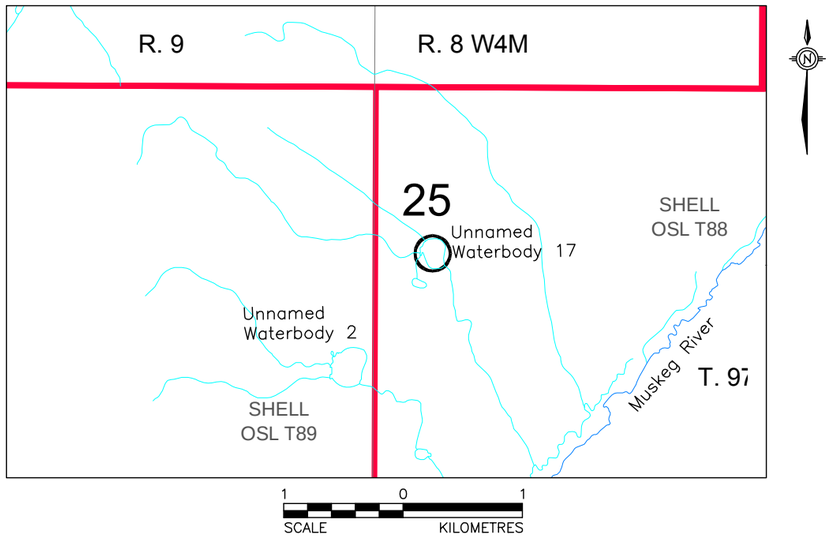


Photo 4 - View of aquatic vegetation (Typha latifolia) along shore near the access point, October 2005.

Photo 2 - View of north shoreline, June 2006.

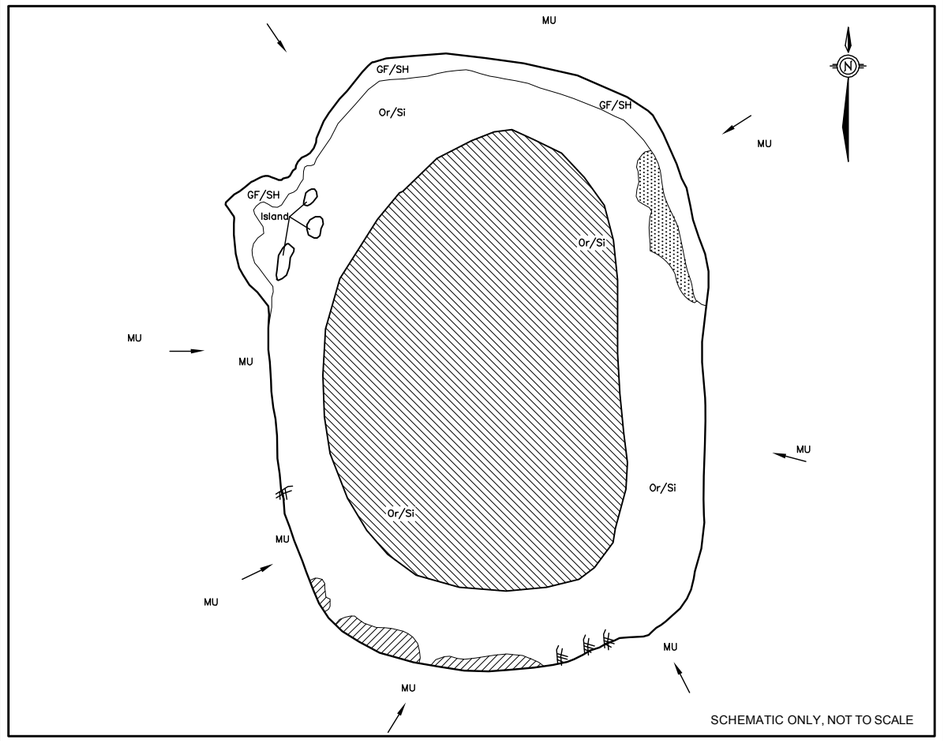


Photo 3 - Aerial view of Unnamed Waterbody 17, August 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating–Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 25 UNNAMED WATERBODY 17

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.	Lake_Site25	
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: M-12

Nov 29, 2007 – 3:48pm
L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig M–12_Lake_Site25 Unnamed Lake.dwg

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APPENDIX N

HABITAT MAPS FOR THE PIERRE RIVER WATERSHED

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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Figure N-3 Habitat Map for Site 18 Unnamed Creek 4 3

Photo 1 - Downstream view of woody debris and sand/silt bar, October 2005.

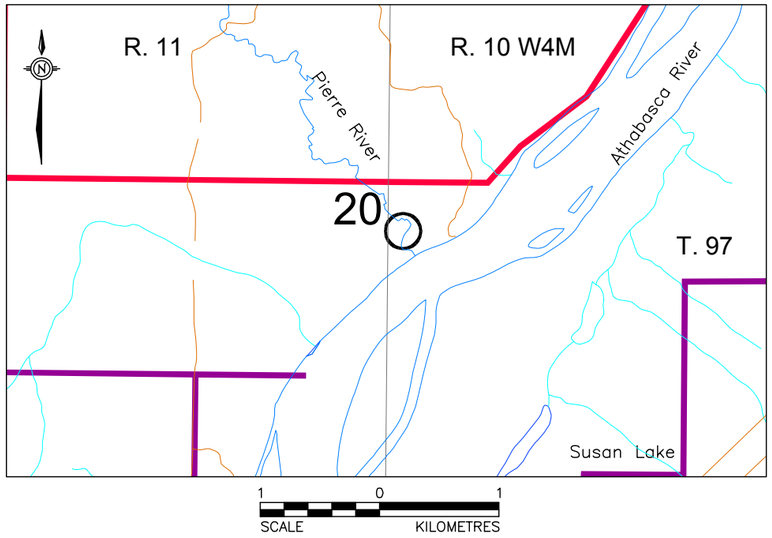

Photo 4 - Downstream view of run (R3) habitat with large woody debris, August 2006.

Photo 2 - View of right downstream bank, February 2006.

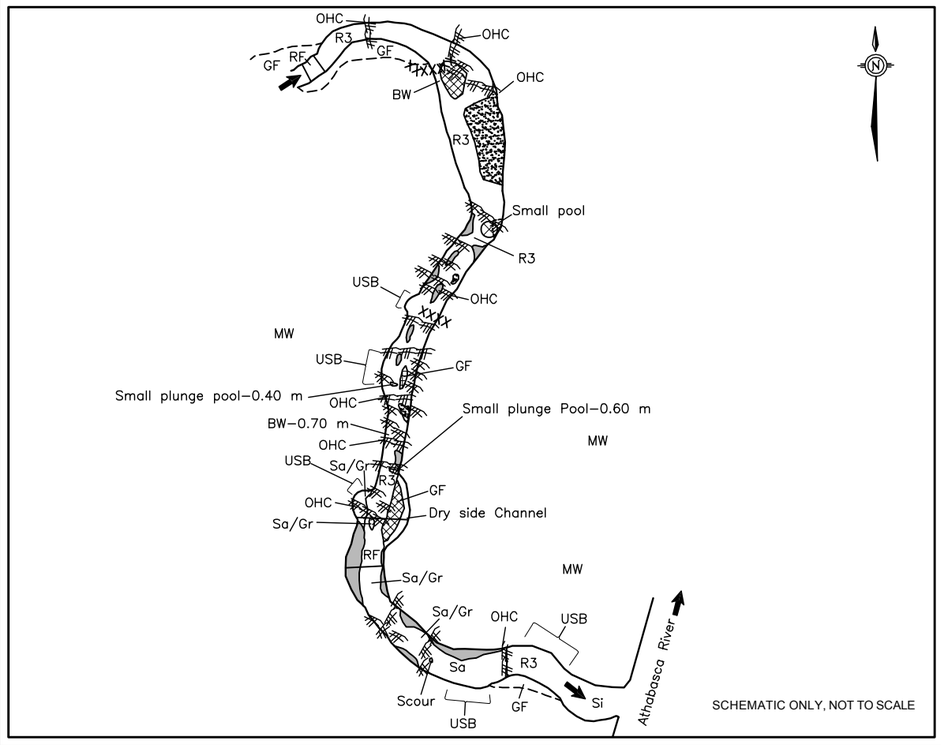

Photo 3 - Aerial view of upstream of lower reach of Pierre River, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality (OHC)
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
→	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 20
PIERRE RIVER

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site 20
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			FIGURE: N-1
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig N-1_Habitat Map_Site20.dwg Nov 29, 2007 - 3:51pm

Photo 1 - Downstream view of Pierre River, March 2006.

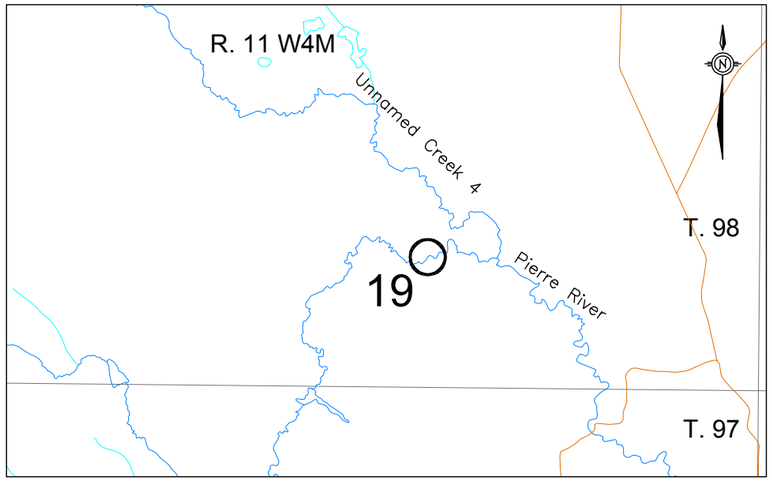

Photo 4 - Beaver dam at upstream end of surveyed section, August 2006.

Photo 2 - Side pond seeping into main channel, October 2005.

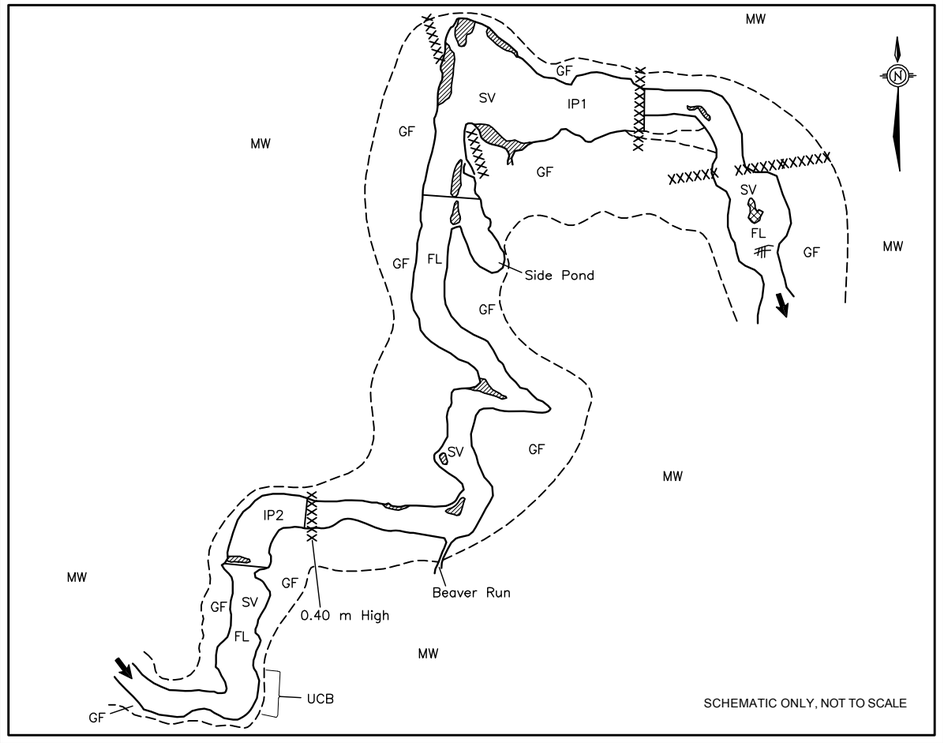

Photo 3 - Aerial view of surveyed section, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
➡	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 19
PIERRE RIVER

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site19
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: N-2

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig N-2_Habitat Map_Site19 Pierre River.dwg Nov 29, 2007 – 3:52pm

Photo 1 - Upstream view towards beaver dam in run habitat, March 2006.

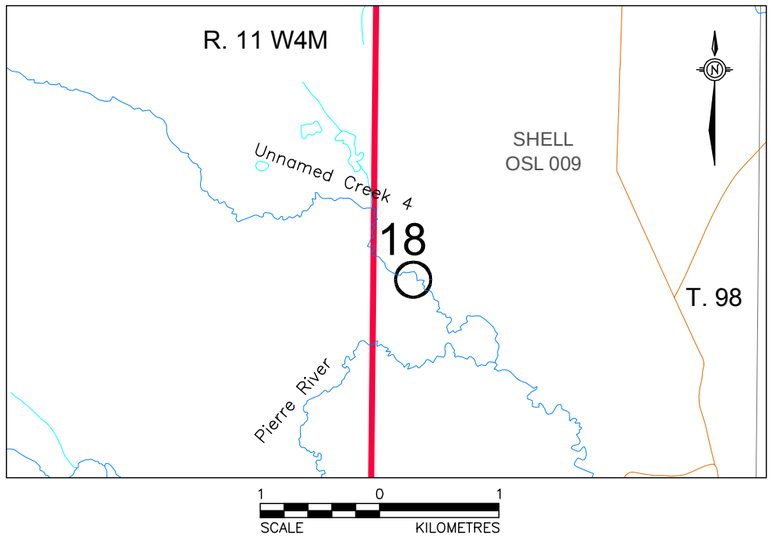

Photo 4 - Downstream view of surveyed section, June 2006.

Photo 2 - Overhanging grasses typical throughout the watercourse, August 2006.

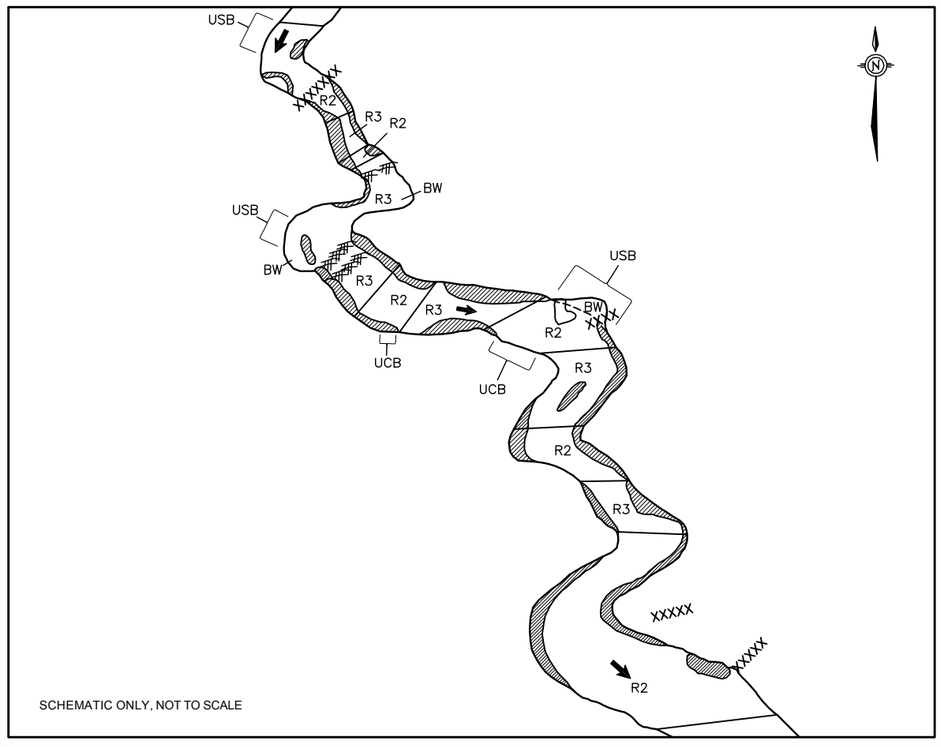

Photo 3 - Unstable slumping banks typical on sharp bends throughout the surveyed section, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
➡	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 18
UNNAMED CREEK 4

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site18
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			FIGURE: N-3
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig N-3_Habitat Map_Site18.dwg Nov 29, 2007 - 3:56pm

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APPENDIX O

HABITAT MAPS FOR THE EYMUNDSON CREEK WATERSHED

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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Photo 1 - Downstream view of watercourse, February 2006.

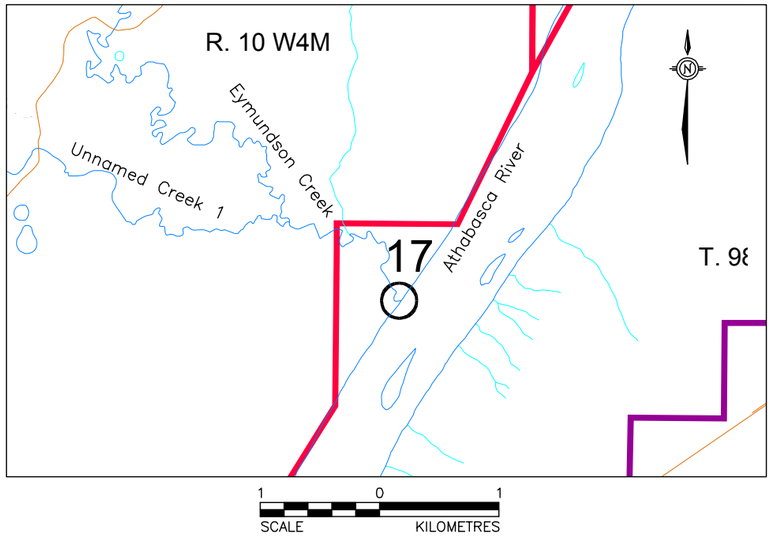


Photo 4 - Typical riparian vegetation of shrubs, grasses and forbs with mixed wood forest, October 2005.

Photo 2 - Downstream view of typical run (R3) habitat, June 2006.

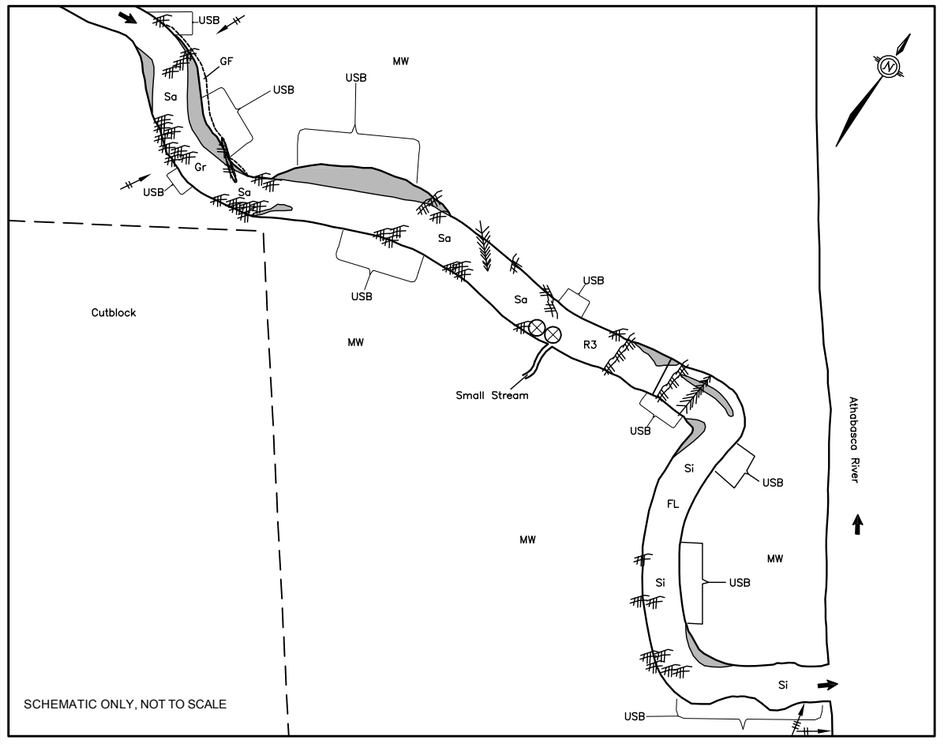


Photo 3 - Upstream view of run (R3) habitat with woody debris, August 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
➡	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 17 EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.	Habitat Map Site17	
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-1_Habitat Map_Site17.dwg Nov 29, 2007 - 3:59pm

Photo 1 - Aerial view of surveyed section of Eymundson Creek, March 2006.

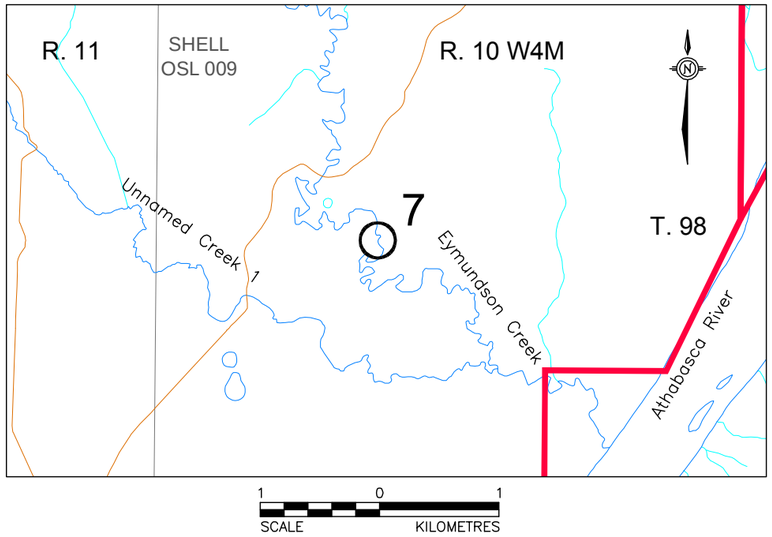
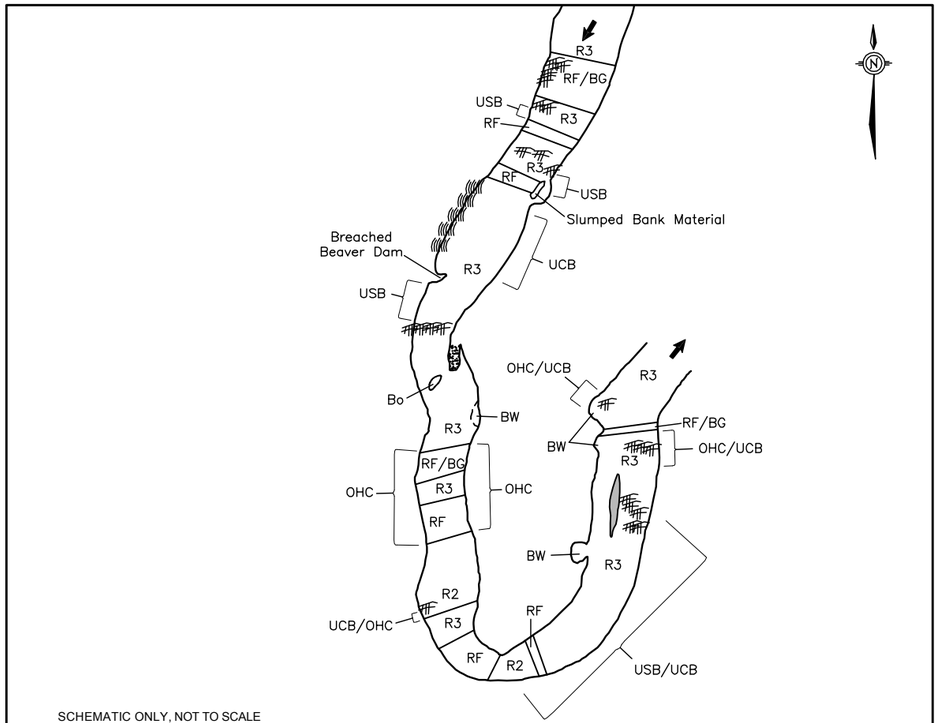


Photo 4 - Upstream view of instream woody debris piles, October 2005.

Photo 2 - Upstream view of riffle run habitat, June 2006.



SCHEMATIC ONLY, NOT TO SCALE

Photo 3 - Downstream view exhibiting typical site habitat, August 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality (OHC)
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
➡	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 7
EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site7
DESIGN	CS	02/03/06	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

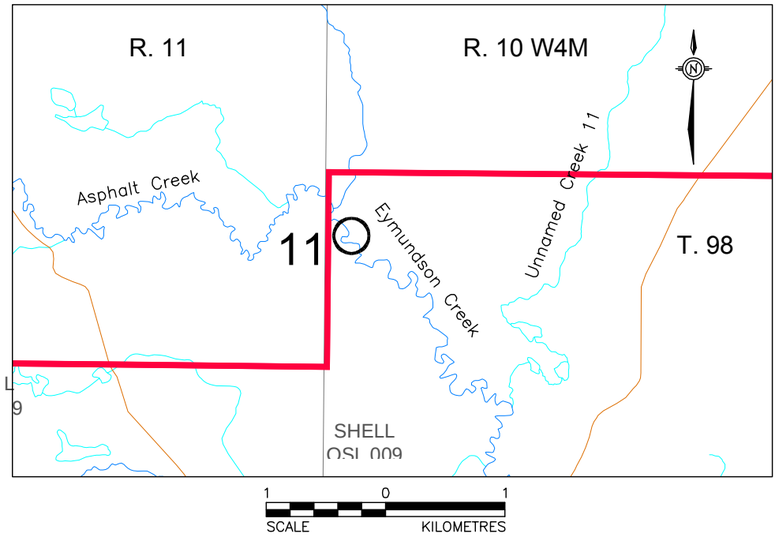
FIGURE: O-2

Nov 29, 2007 – 4:01pm

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-2_Habitat Map_Site7.dwg

Photo 1 - Downstream view of run habitat, February 2006.

Photo 2 - Downstream view from discharge site, June 2006.



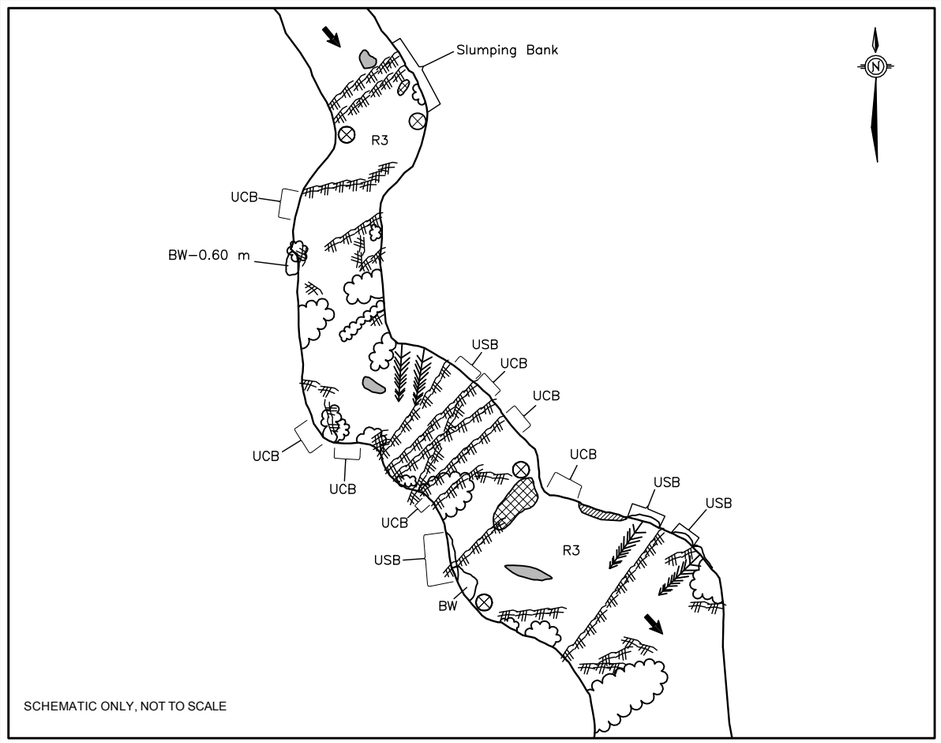


Photo 4 - Typical run (R3) habitat of the surveyed section, October 2005.

Photo 3 - Downstream view of Eymundson Creek, August 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 11
EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.		Site11
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-3

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig O–3_Habitat Map_Site11.dwg Nov 29, 2007 – 4:03pm

Photo 1 - Aerial view of surveyed section of Eymundson Creek, October 2006.

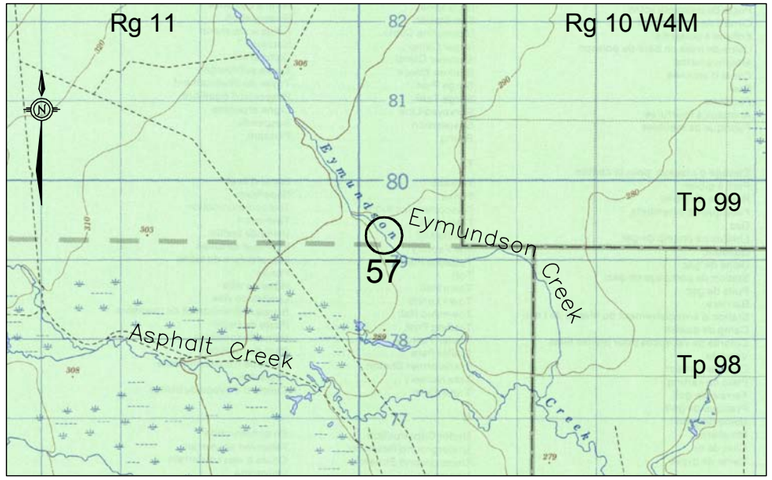


Photo 4 - Upstream view of beaver impoundment, October 2006.

Photo 2 - Downstream view from beaver impoundment, October 2006.

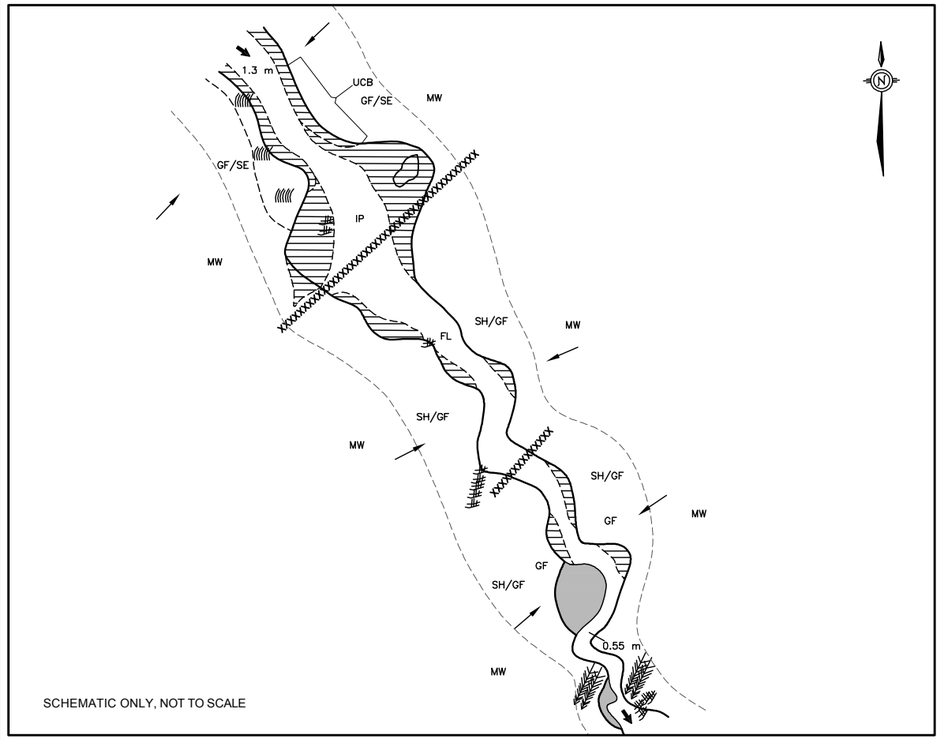


Photo 3 - View of flat habitat in surveyed section, October 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 57
EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.	Hab Map Site 57	
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07	**FIGURE: O-4**		
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig O-4_Habitat Map for Site 57.dwg Nov 29, 2007 - 4:05pm

Photo 1 - Downstream view of Eymundson Creek, March 2006.

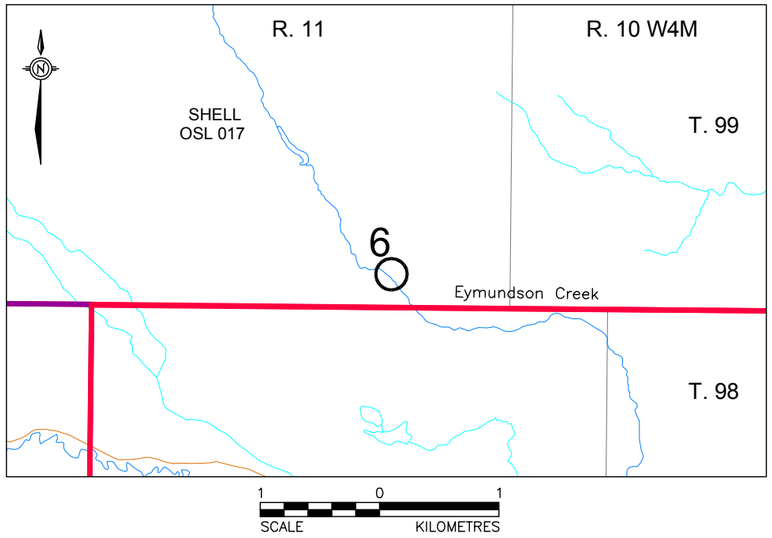


Photo 4 - Upstream view of typical habitat of Eymundson Creek, June 2006.

Photo 2 - Flat (F2) habitat with inundated vegetation, October 2005.

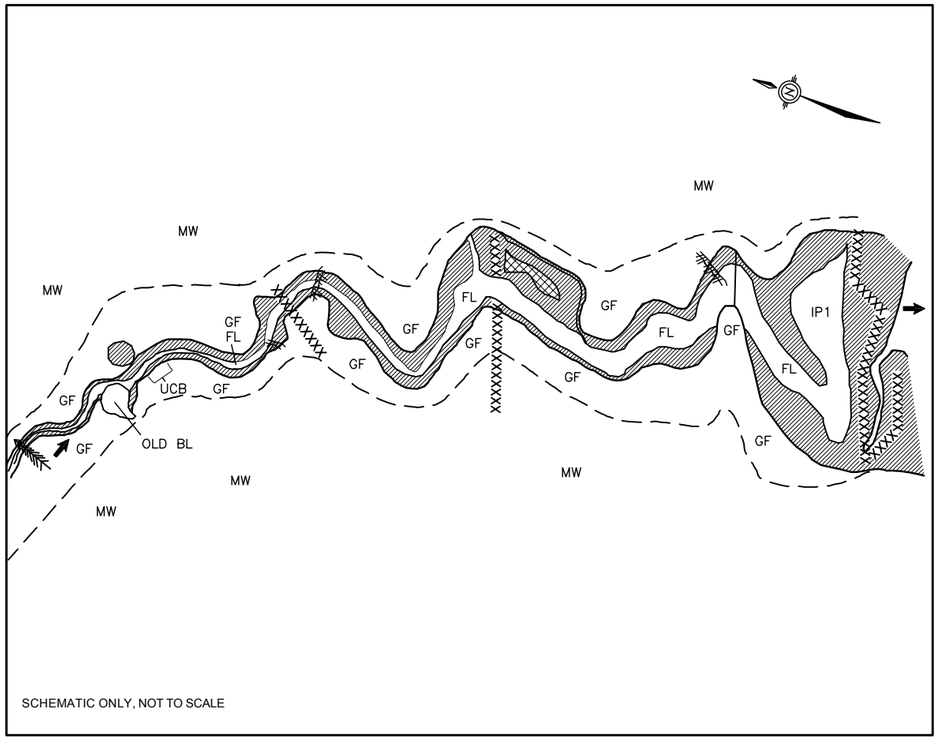


Photo 3 - Downstream view of meandering stream with inundated vegetation, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 6
EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site6
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07	**FIGURE: O-5**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-5_Habitat Map_Site6 Eymundson Creek.dwg Nov 29, 2007 - 4:07pm

Photo 1 - Narrow run (R3) with an abundance of inundated vegetation, October 2005.

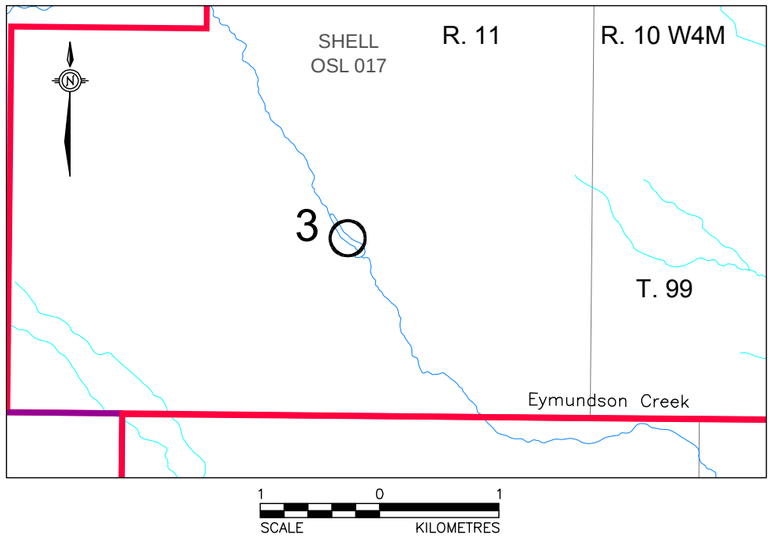


Photo 4 - Downstream view of abundant of inundated vegetation, October 2005.

Photo 2 - Upstream view of creek flowing around beaver dam, October 2005.

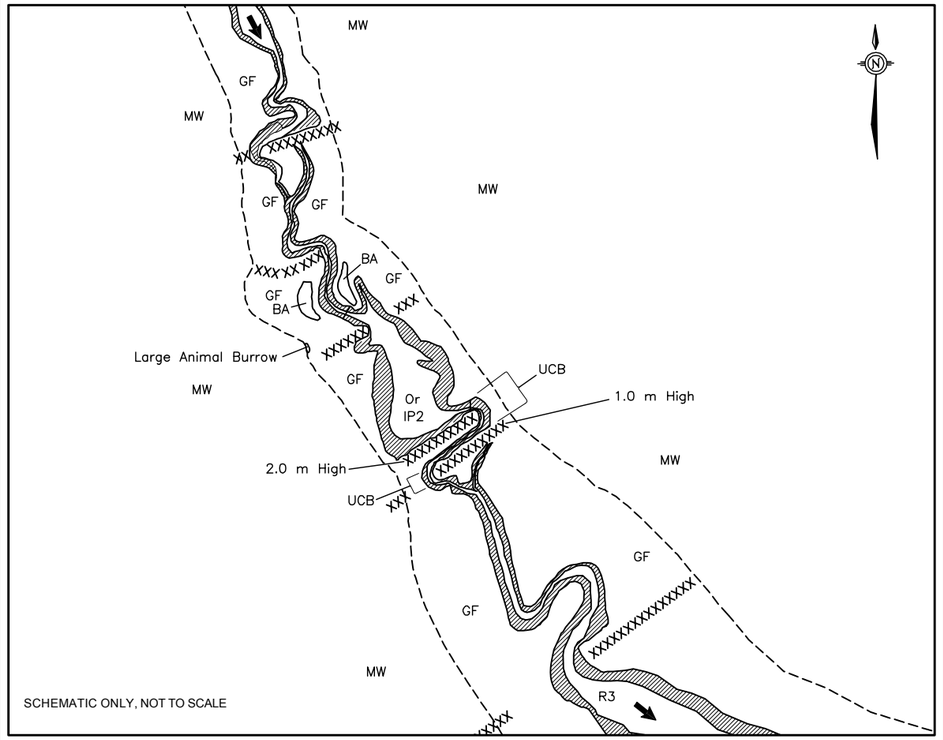


Photo 3 - Upstream view of the beginning of the impoundment (IP2), October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 3
EYMUNDSON CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site3
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07	FIGURE: O-6		
REVIEW	WES/TC	20/11/07			

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Photo 1 - Run (R3) habitat with woody debris, typical of surveyed section, October 2005.

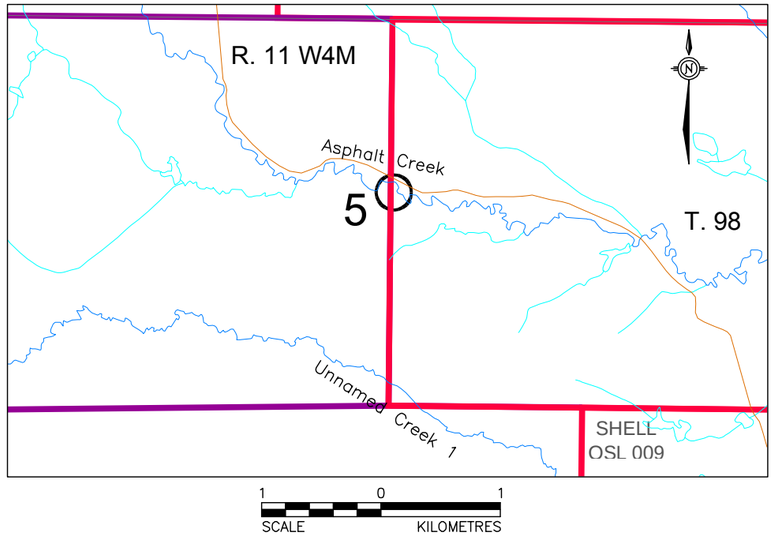

Photo 4 - Downstream view of surveyed section of run habitat with woody debris, October 2005.

Photo 2 - Steep banks typical of surveyed section, October 2005.

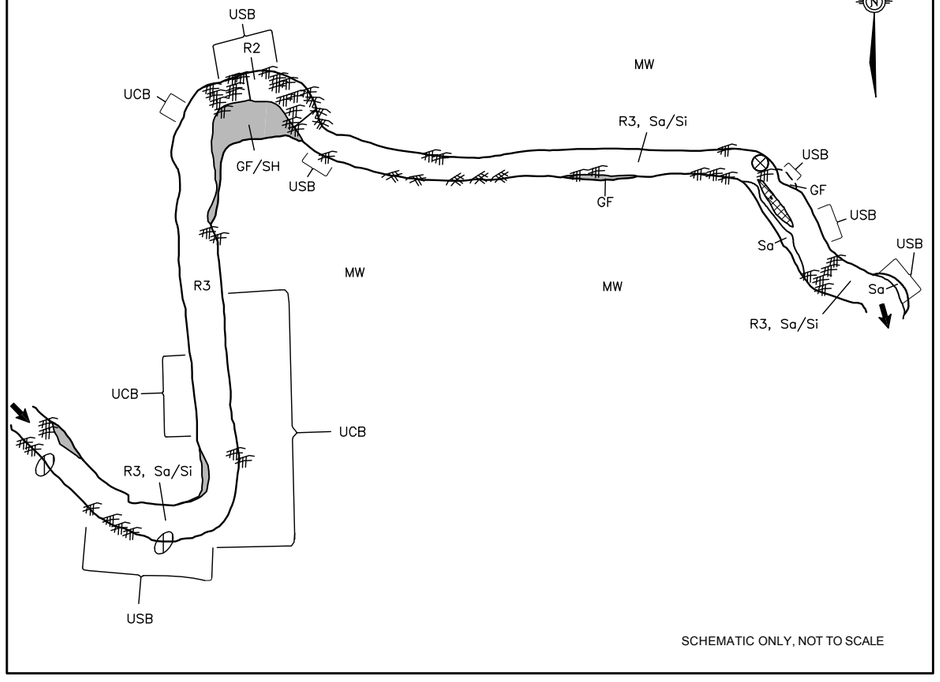

Photo 3 - Upstream view of surveyed section, March 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 5 ASPHALT CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site5
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-7

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-7_Habitat Map_Site5 Asphalt Creek.dwg Nov 29, 2007 - 4:12pm

Photo 1 - Upstream view of surveyed section of Asphalt Creek, February 2007.

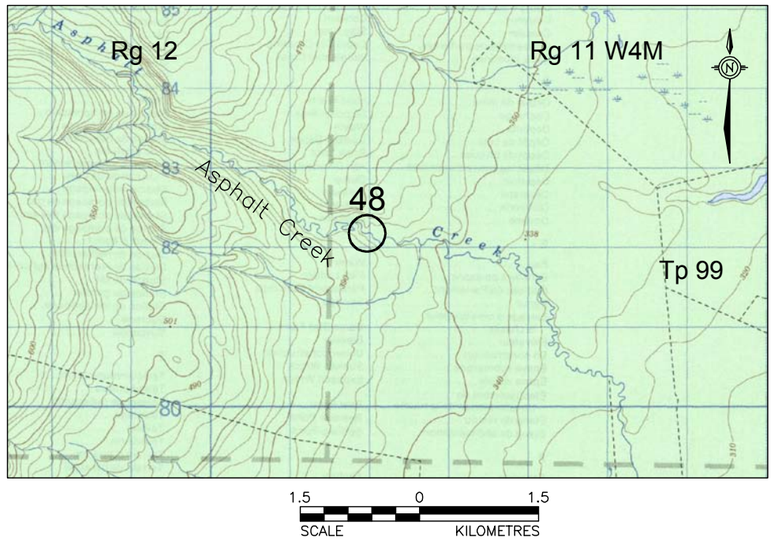

Photo 4 - Upstream view of riffle/run habitat, October 2006.

Photo 2 - Aerial view of Asphalt Creek, May 2007.

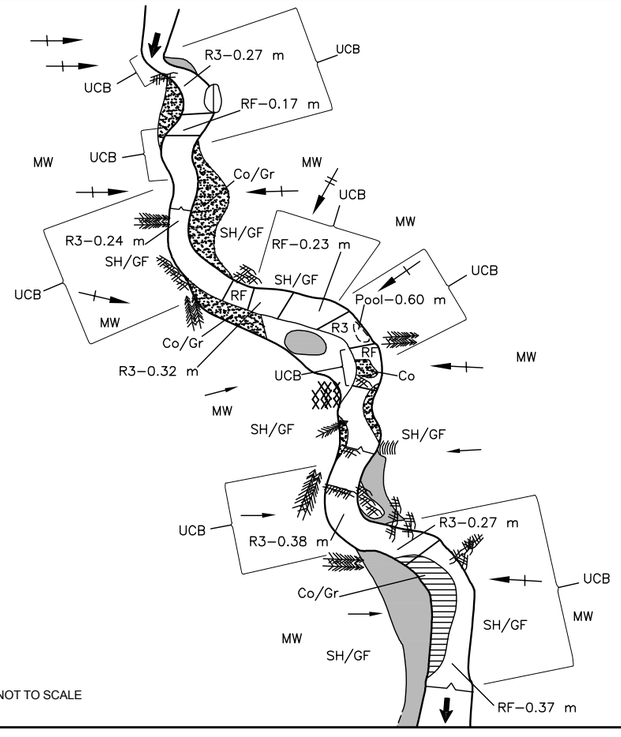

Photo 3 - Downstream view of run habitat, July 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 48
ASPHALT CREEK

Shell Canada Limited

PROJECT 05–1344–027.6137			FILE No.	Hab Map Site 48
DESIGN	HF	02/01/07	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: O-8

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OSL 009

Photo 1 - Downstream view of typical riffle (RF) habitat, June 2006.

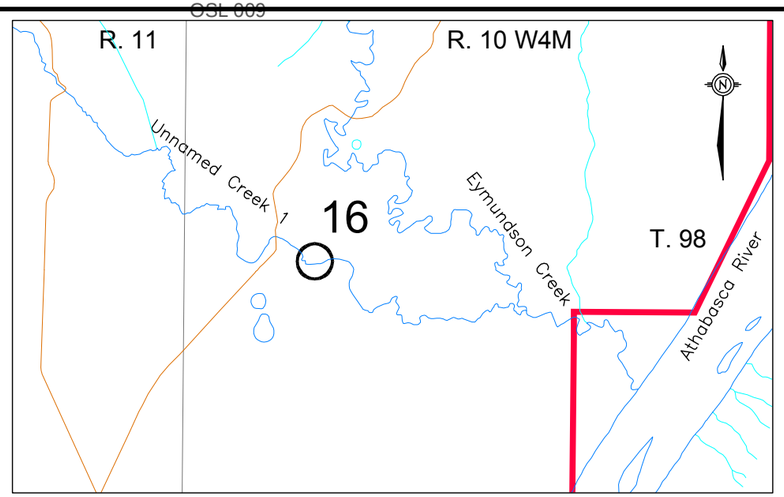
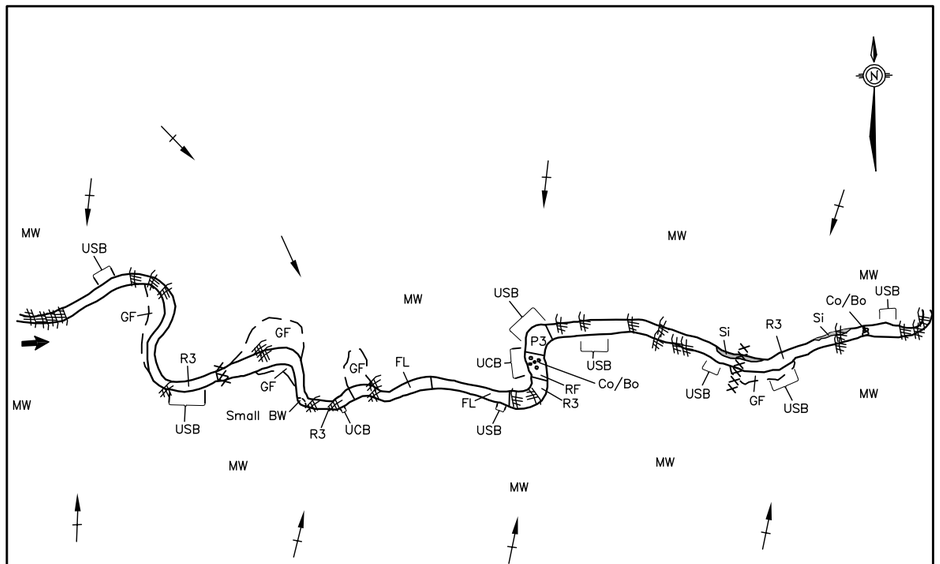


Photo 4 - Upstream view of surveyed watercourse, August 2006.

Photo 2 - Transition of riffle habitat in to pool habitat, October 2005.



SCHEMATIC ONLY, NOT TO SCALE

Photo 3 - Upstream view of debris jam in run (R3) habitat, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

Exposed Bar – Fine	
Exposed Bar – Coarse	
Island	
Woody Debris Pile	
Root Wad	
Overhead Cover, High Quality	
Instream Cover, High Quality	
Overhanging Vegetation	
Tree, Shrub, Grass	
Undercut Bank (UCB) (fish cover)	
Unstable Bank (USB) (slumping or eroding)	
Ledge; Bedrock Intrusion, Vertical Drop	

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 16
UNNAMED CREEK 1

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.		Site 16
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-9

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig O–9_Habitat Map_Site16.dwg Nov 29, 2007 – 4:18pm

Photo 1 - Downstream view at the end of the surveyed section, February 2006.

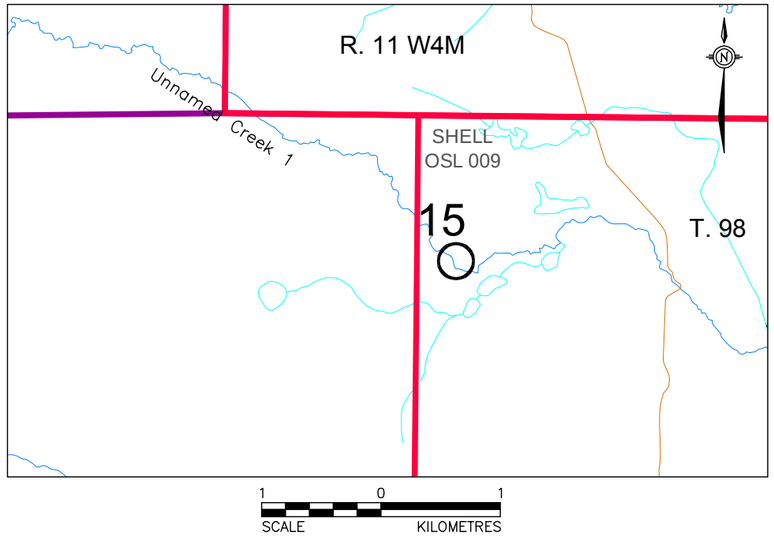


Photo 4 - Upstream view of surveyed section, August 2006.

Photo 2 - Downstream view of a backwater with unstable bank, October 2005.

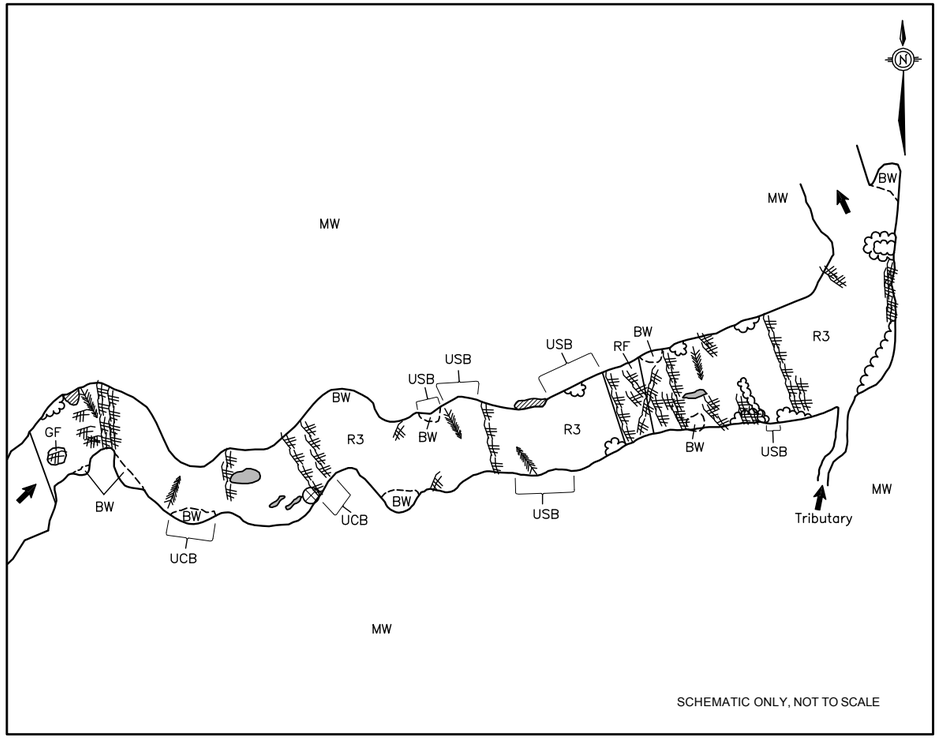


Photo 3 - Downstream view of typical run (R3) habitat, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 15
UNNAMED CREEK 1

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site15
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-10

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-10_Habitat Map_Site15 Unnamed Creek#1.dwg Nov 29, 2007 - 4:19pm

Photo 1 - Downstream view from the downstream boundary of the surveyed section, October 2005.

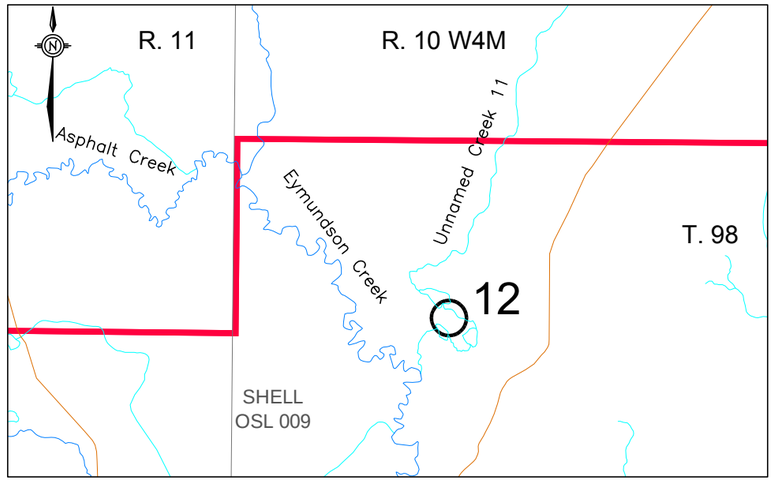


Photo 4 - Typical vegetated banks, August 2006.

Photo 2 - Downstream view of beaver impoundment, February 2006.

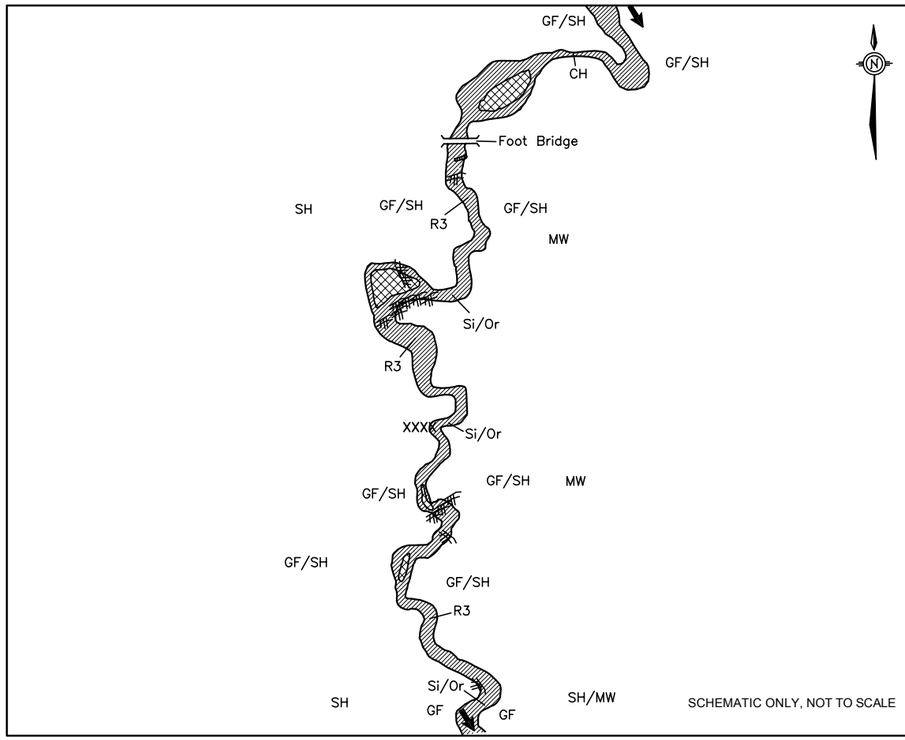


Photo 3 - Upstream view of typical site habitat, June 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 12 UNNAMED CREEK 11

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.	Site12
DESIGN	CS	07/11/05	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: O-11

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-11_Habitat Map_Site12.dwg Nov 30, 2007 - 3:10pm

Photo 1 - Aerial view of Unnamed Waterbody 5, February 2006.

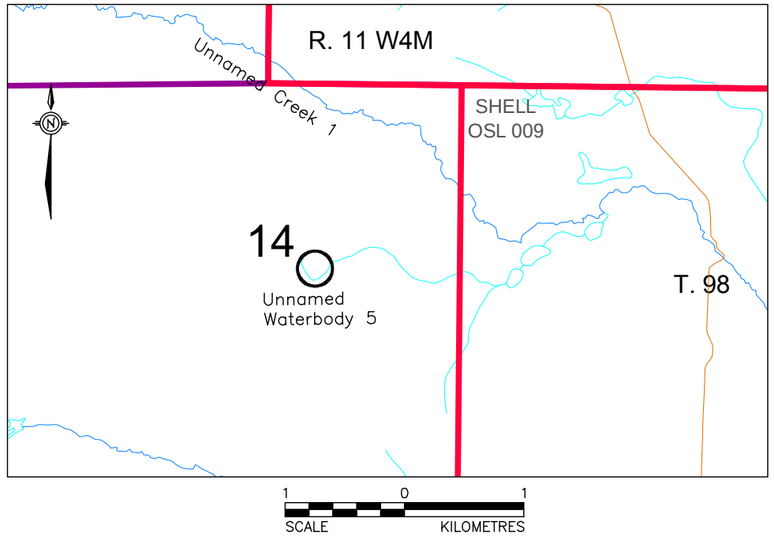


Photo 4 - Aerial view of Unnamed Waterbody 5, August 2006.

Photo 2 - View of inundated vegetation along the west shore, October 2005.

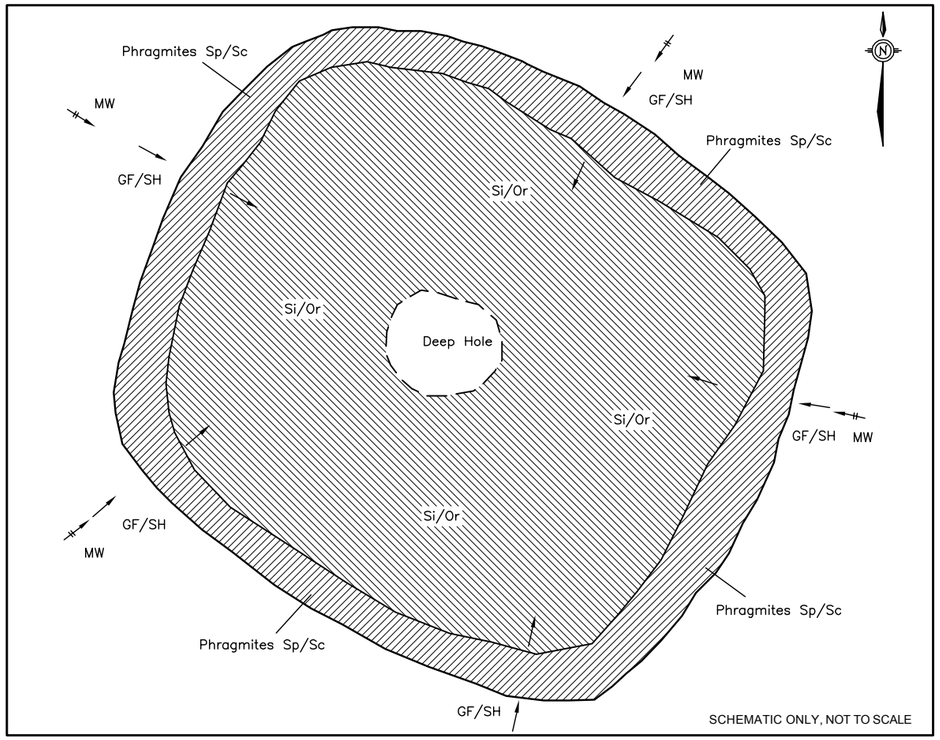


Photo 3 - View of south shore with mixed wood forest, June 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating-Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 14 UNNAMED WATERBODY 5

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site14
DESIGN	SMK	02/10/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-12

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-12_Lake_Site14Unnamed Lake.dwg Nov 29, 2007 - 4:25pm

Photo 1 - Aerial view of the south end of Unnamed Waterbody 6, October 2005.

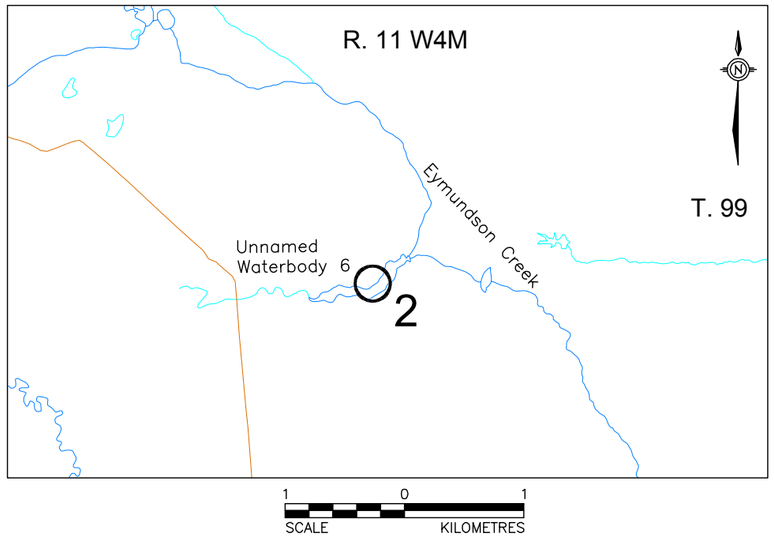


Photo 4 - Aerial view of Unnamed Waterbody 6, July 2007.

Photo 2 - Aerial view of the north end of Unnamed Waterbody 6, October 2005.

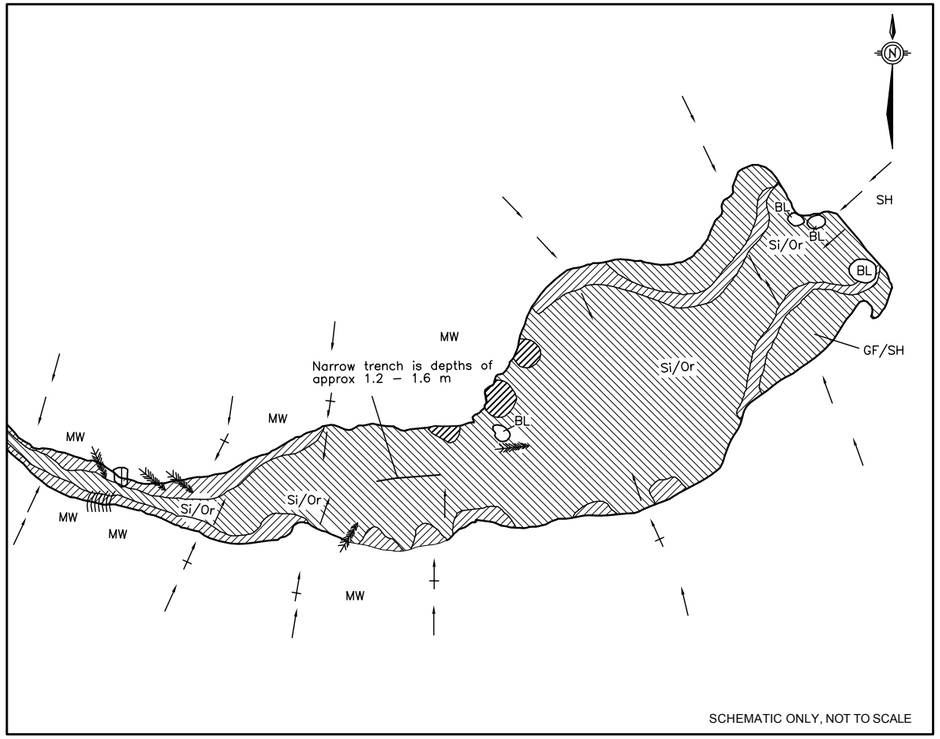


Photo 3 - Aerial view of Unnamed Waterbody 6, May 2007.

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LEGEND - LAKE HABITAT MAPPING SYSTEM

0.61 m° Indicates Depth
Direction of Flow
BL Beaverlodge
Exposed Bar – Fine
Exposed Bar – Coarse
Island
Woody Debris Pile
Overhead Cover, High Quality
Overhanging Vegetation
Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

Emergent Vegetation
Submergent or Floating-Leaved Vegetation
Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
HABITAT MAP FOR SITE 2 UNNAMED WATERBODY 6

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Lake_Site2
DESIGN	SMK	02/10/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: O-13

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig O-13_Lake_Site2 Unnamed Waterbody.dwg Nov 29, 2007 - 4:28pm

Golder Associates Ltd.

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APPENDIX P

HABITAT MAPS FOR TRIBUTARIES TO THE ATHABASCA RIVER

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

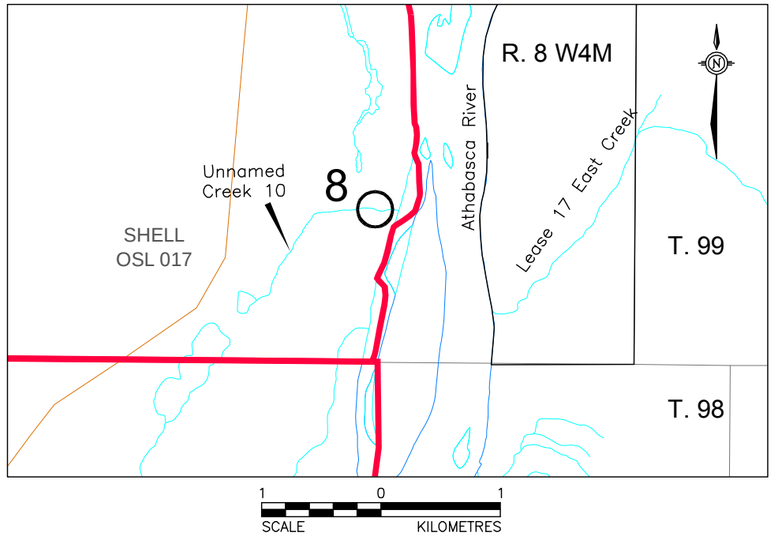
OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

LIST OF FIGURES

Figure P-1 Habitat Map for Site 8 Unnamed Creek.....1
Figure P-2 Habitat Map for Site 13 Unnamed Waterbody 8.....2

Photo 1 - Aerial view of Unnamed Creek 10, May 2007.

Photo 2 - Vegetation typical of the entire beaver flooded channel, October 2005.



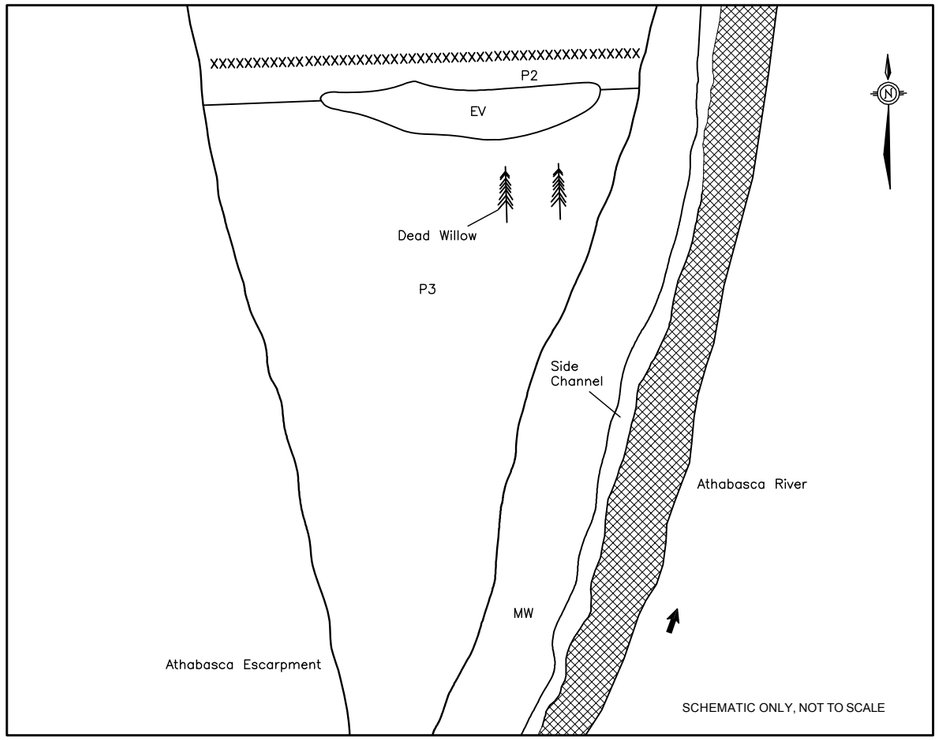


Photo 4 - Aerial view of Unnamed Creek 10, July 2007.

Photo 3 - Aerial view of Unnamed Creek 10, February 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
➔	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 8
UNNAMED CREEK 10

Shell Canada Limited

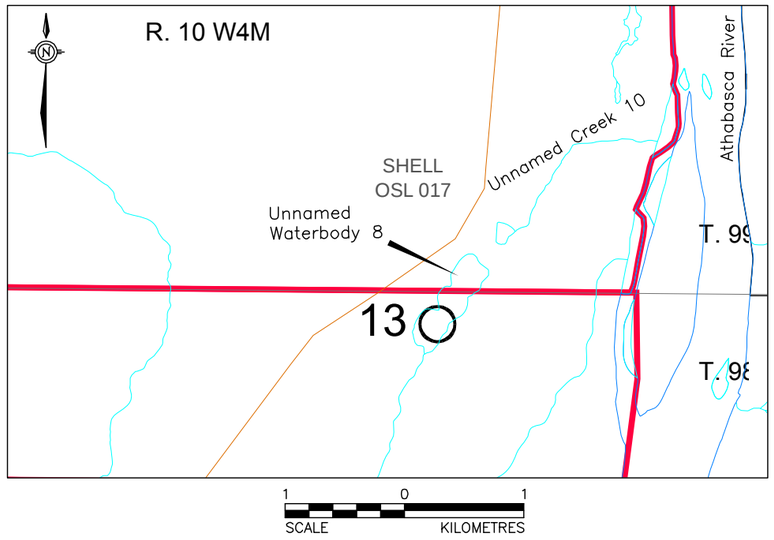
PROJECT 05–1344–027.6190			FILE No.		Site8
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: P-1

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6190\Fig P–1_Habitat Map_Site8.dwg Nov 29, 2007 – 4:31pm

Photo 1 - Aerial view of Unnamed Waterbody 8, February 2006.

Photo 2 - View of woody debris and beaver lodge along the southwest shore of Unnamed Waterbody 8, October 2005.



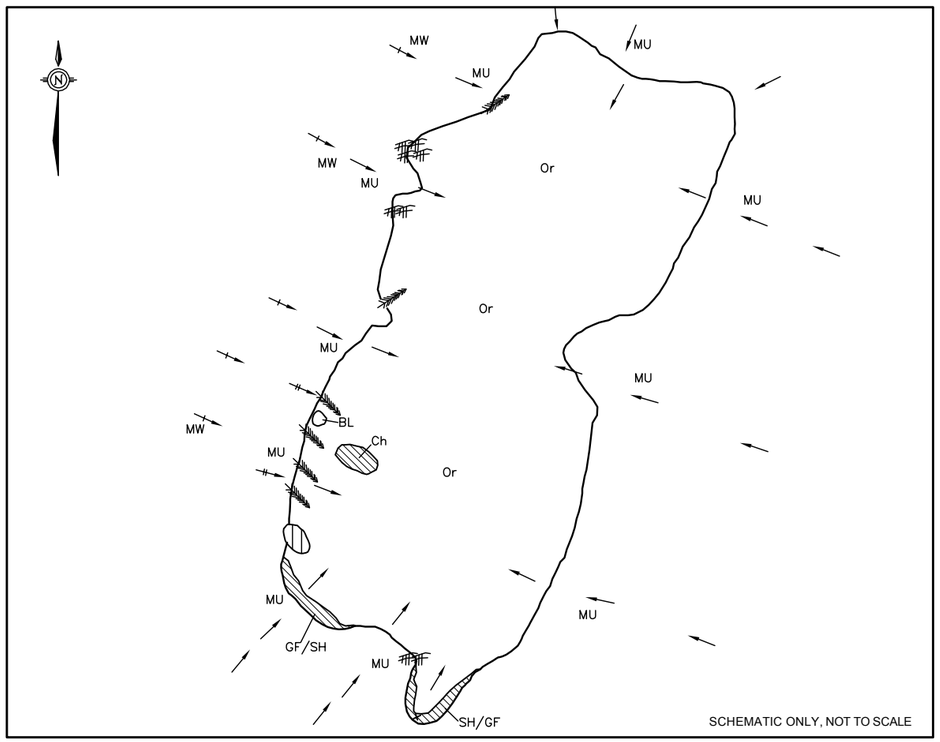


Photo 4 - Aerial view of Unnamed Waterbody 8, August 2006.

Photo 3 - View towards the south end of Unnamed Waterbody 8, June 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating-Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 13 UNNAMED WATERBODY 8

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Lake_Site13
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: P-2

Nov 29, 2007 – 4:33pm
L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig P-2_Lake_Site13 Unnamed Lake.dwg

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APPENDIX Q

HABITAT MAPS FOR THE BIG CREEK WATERSHED

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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Figure Q-8 Habitat Map for Site 45 Small Sandy Lake 8
Figure Q-9 Habitat Map for Site 4 Unnamed Waterbody 15 9

Photo 1 - Downstream view near mouth of Big Creek, September 2006.

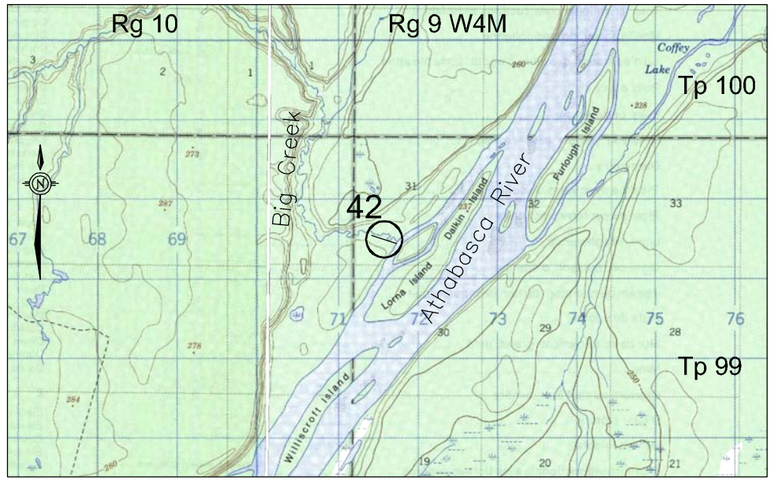


Photo 4 - View upstream of surveyed section, February 2007.

Photo 2 - Aerial view of surveyed section of Big Creek, July 2007.

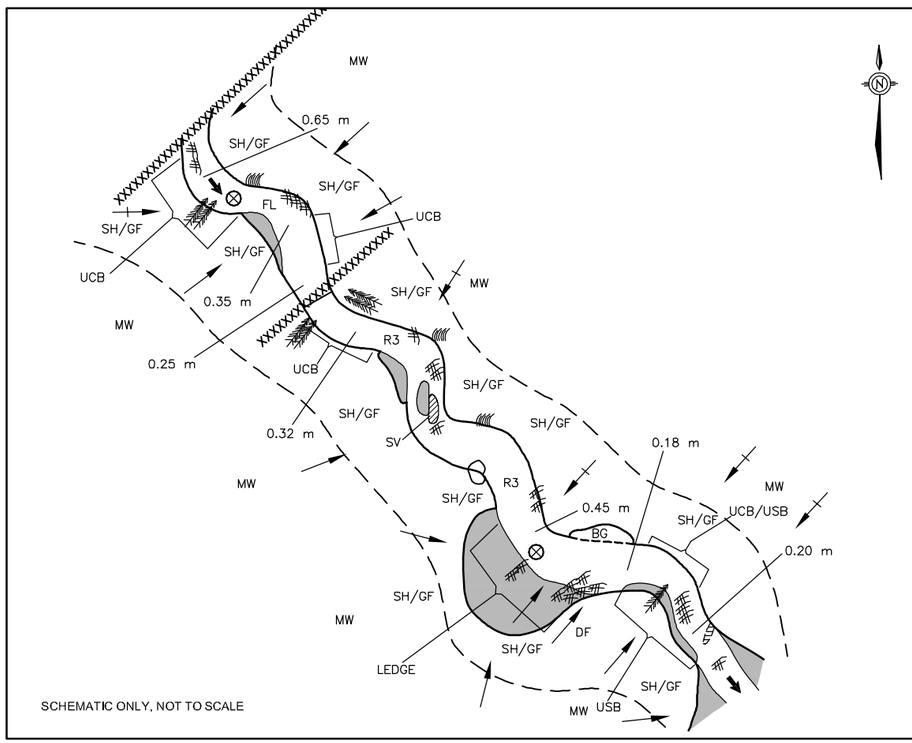


Photo 3 - Upstream view of woody debris, September 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 42
BIG CREEK

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.	Hab Map Site 42
DESIGN	HF	02/01/07	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: Q-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig Q-1_Habitat Map for Site 42.dwg Nov 18, 2007 - 10:54am

Photo 1 - Upstream view of alders providing overhead cover over riffle habitat, October 2005.

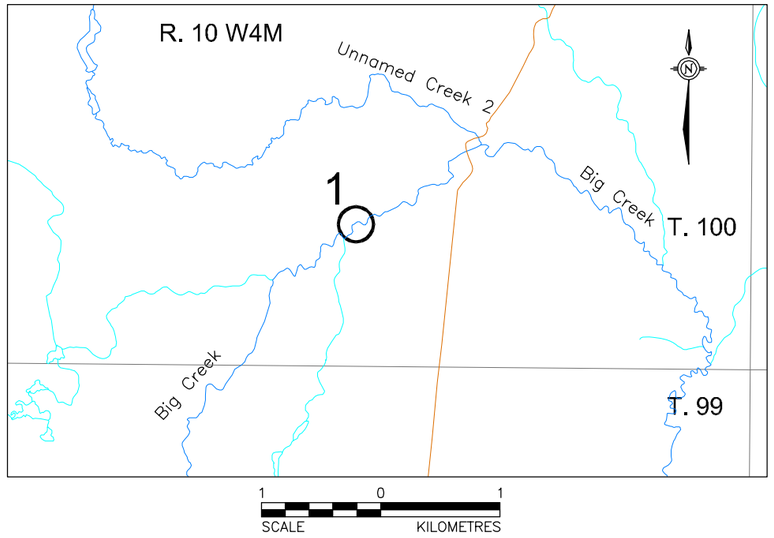
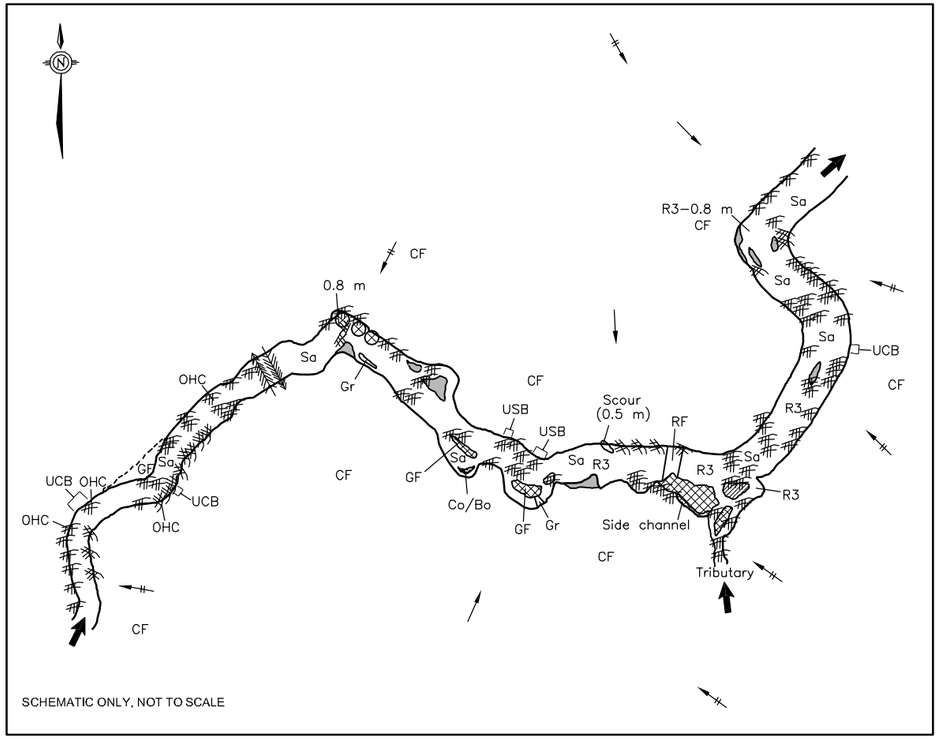


Photo 4 - Upstream view of riffle habitat, July 2007.

Photo 2 - Downstream view of run (R3) habitat with woody debris, October 2005.



SCHEMATIC ONLY, NOT TO SCALE

Photo 3 - Aerial view of surveyed section, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality (OHC)
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

IN	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 1
BIG CREEK

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.	Site1
DESIGN	CS	01/03/06	SCALE AS SHOWN	REV. 0
CADD	TY	17/11/07		
CHECK	AS	26/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: Q-2

Nov 18, 2007 – 10:59am

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Photo 1 - View of downstream end of surveyed section, September 2006.

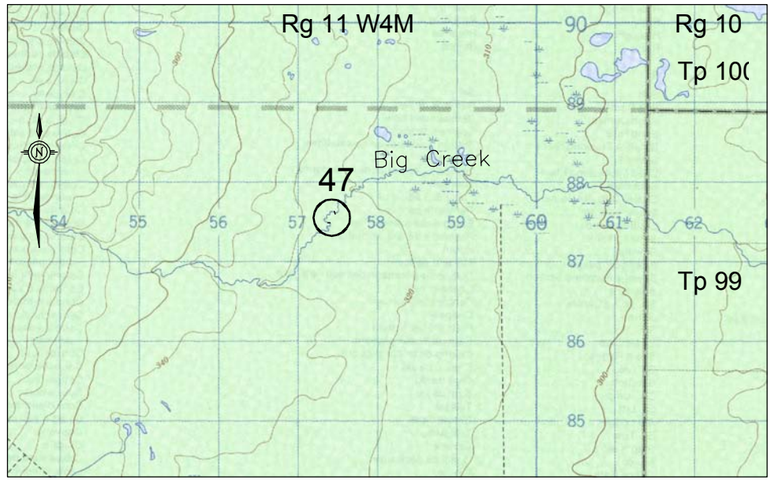

Photo 4 - Upstream view of shallow and turbid water in surveyed section, July 2007.

Photo 2 - View of surveyed section of Big Creek, February 2007.

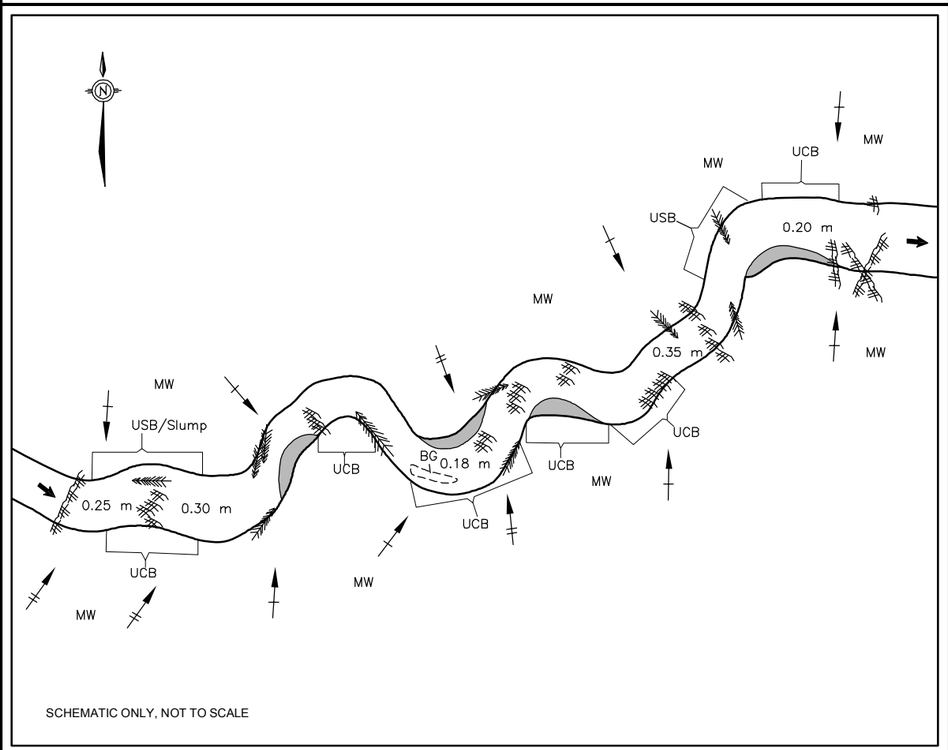

Photo 3 - Upstream view from discharge site, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 47
BIG CREEK

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.	Hab Map Site 47	
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TE	18/09/07			
CHECK	AS	26/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: Q-3

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Photo 1 - Aerial view of First Creek, February 2007.

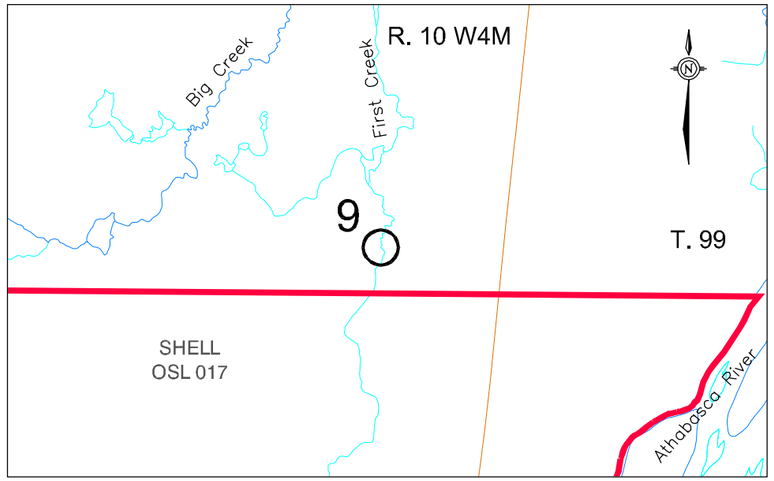

Photo 4 - View of pool (P3) habitat, July 2007.

Photo 2 - Upstream view of run (R3) habitat, May 2007.

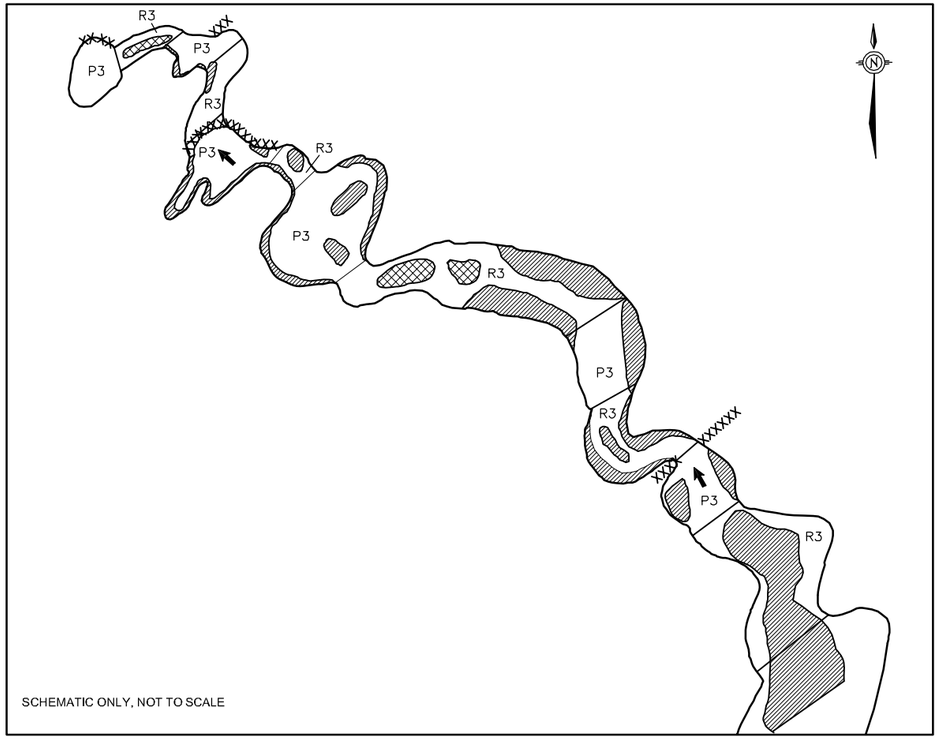

Photo 3 - View downstream of pool (P3) habitat with island of inundated vegetation, October 2005.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 9
FIRST CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Site9
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07			FIGURE: Q-4
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig Q-4_Habitat Map_Site9.dwg Nov 18, 2007 - 11:04am

Photo 1 - Upstream view of riffle habitat, September 2006.

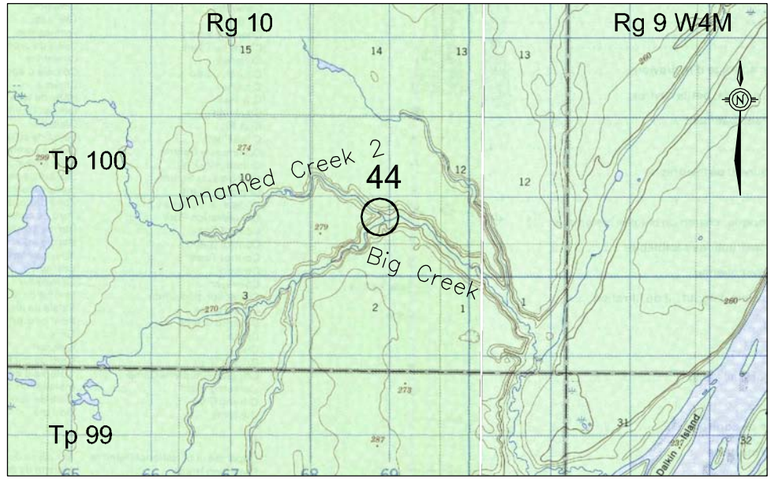

Photo 4 - Downstream view of downstream end of surveyed section, July 2007.

Photo 2 - Aerial view of openwater in Unnamed Creek, February 2007.

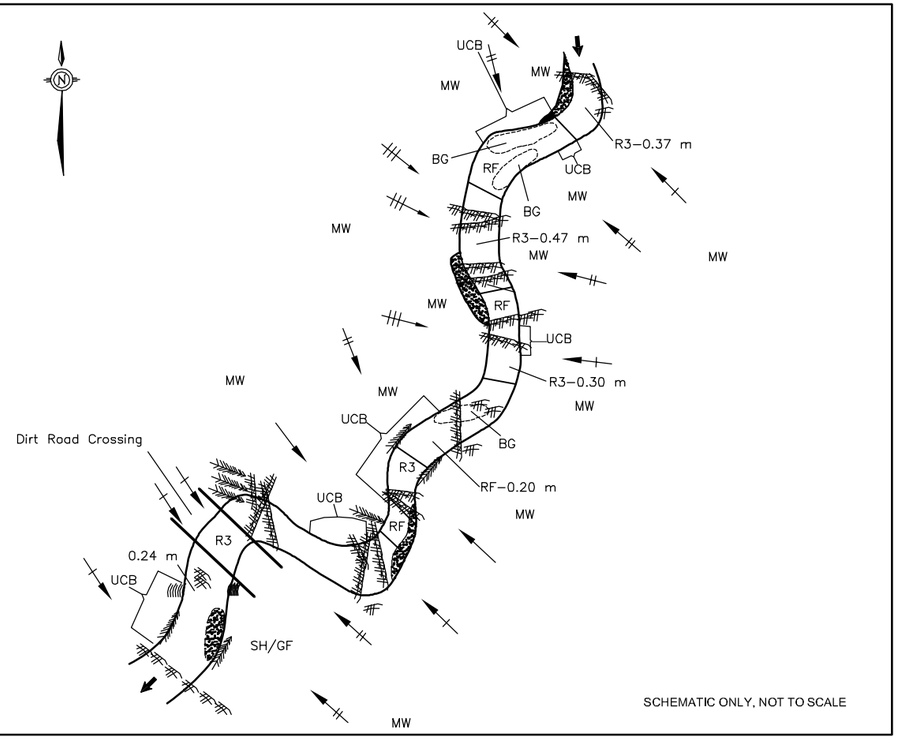

Photo 3 - View of surveyed section, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 44 UNNAMED CREEK 2

Shell Canada Limited

PROJECT 05–1344–027.6137			FILE No.	Hab Map Site 44	
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07	**FIGURE: Q-5**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6137\Fig Q–5_Habitat Map for Site 44.dwg Nov 18, 2007 – 11:05am

Photo 1 - View of watercourse inundated with vegetation, September, 2006

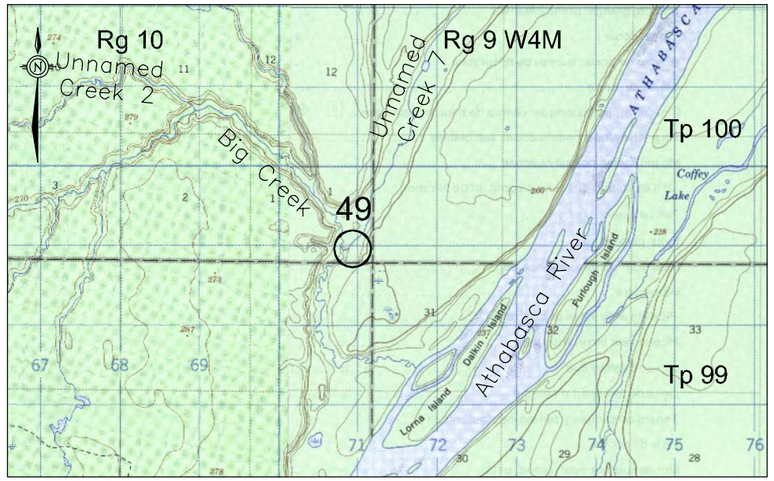

Photo 4 - View of surveyed section of Unnamed Creek 7, July 2007

Photo 2 - Aerial view of surveyed section of Unnamed Creek, February 2007.

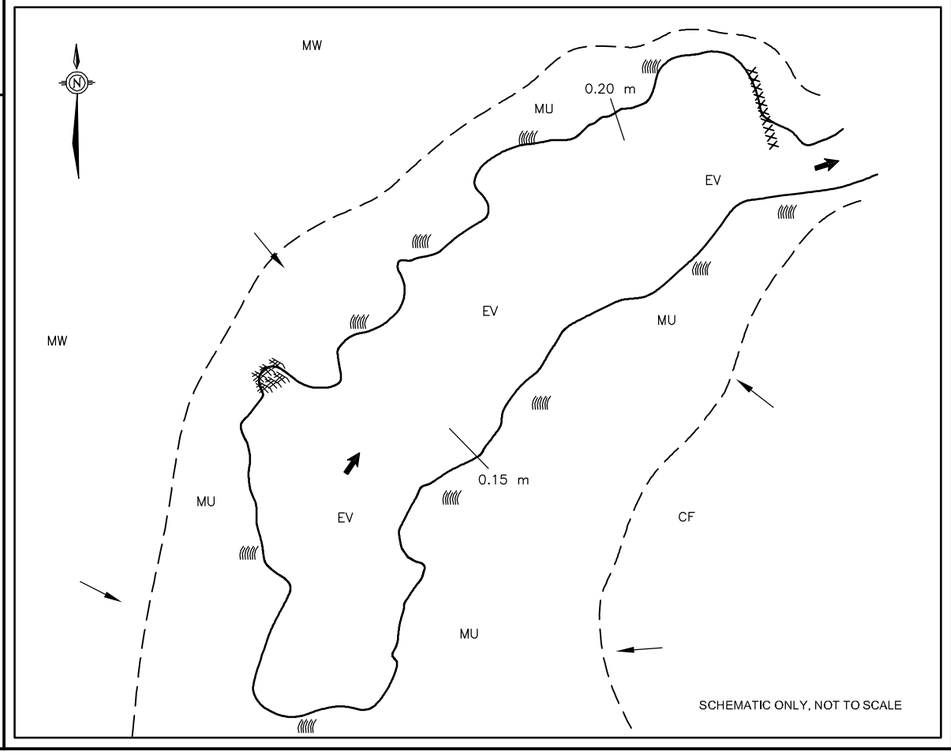

Photo 3 - Aerial view of downstream end of surveyed section of Unnamed Creek 7, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material
Si	Silt (<0.06 mm)
Sa	Sand (0.06 to 2 mm)
Gr	Gravel (2 to 64 mm)
Co	Cobble (64 to 256 mm)
Bo	Boulder (>256 mm)
Be	Bedrock

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 49
UNNAMED CREEK 7

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Site 49
DESIGN	HF	01/08/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	26/10/07	**FIGURE: Q-6**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig Q-6_Habitat Map for Site 49.dwg Nov 18, 2007 - 11:07am

Photo 1 - Aerial view of Oakley Lake, September 2006.

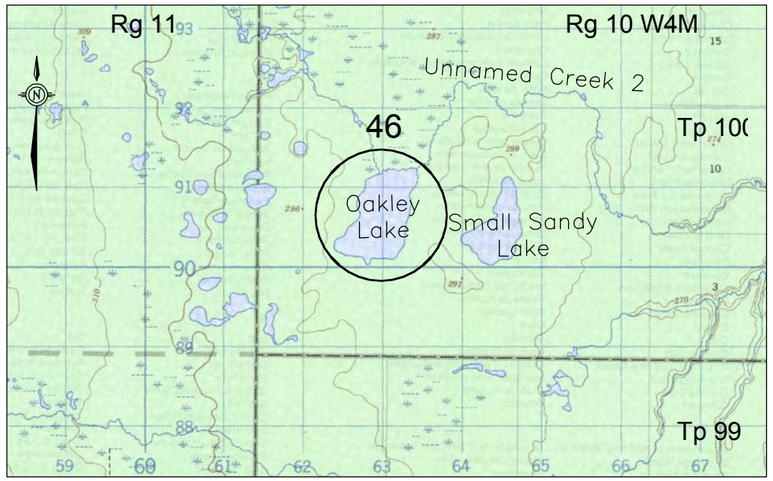

Photo 4 - View of south end of Oakley Lake, September 2006.

Photo 2 - Aerial view of outlet at northeast end of Oakley Lake, September 2006.

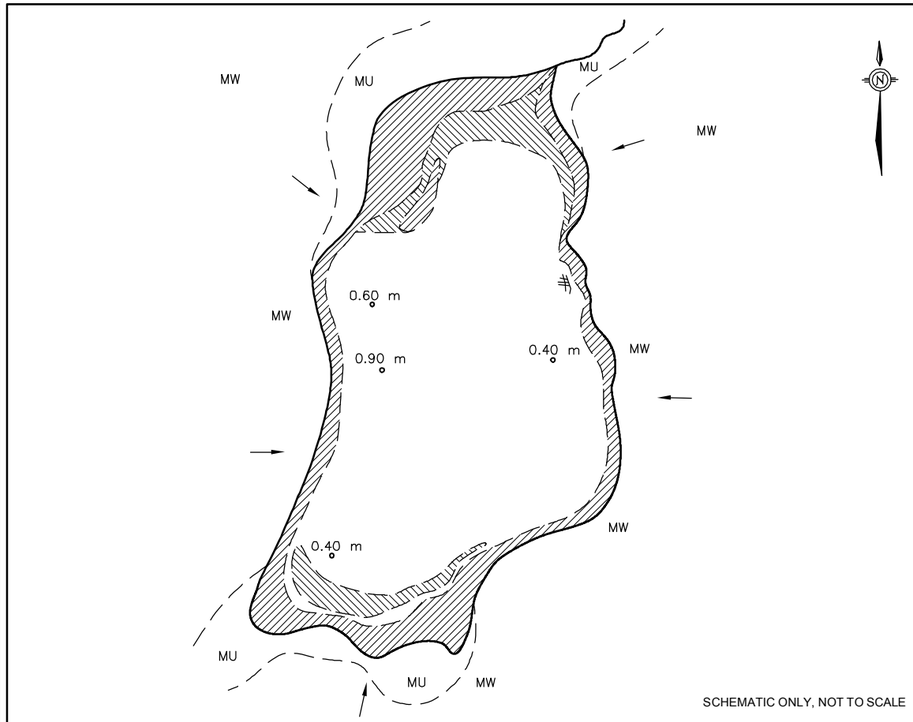

Photo 3 - View of Oakley Lake access site, February 2007.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating-Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 46 OAKLEY LAKE

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Hab Map Site 46
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	29/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: Q-7

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig Q-7_Habitat Map for Site 46.dwg Nov 29, 2007 - 4:41pm

Photo 4 - Aerial photo of Small Sandy Lake, July 2007.

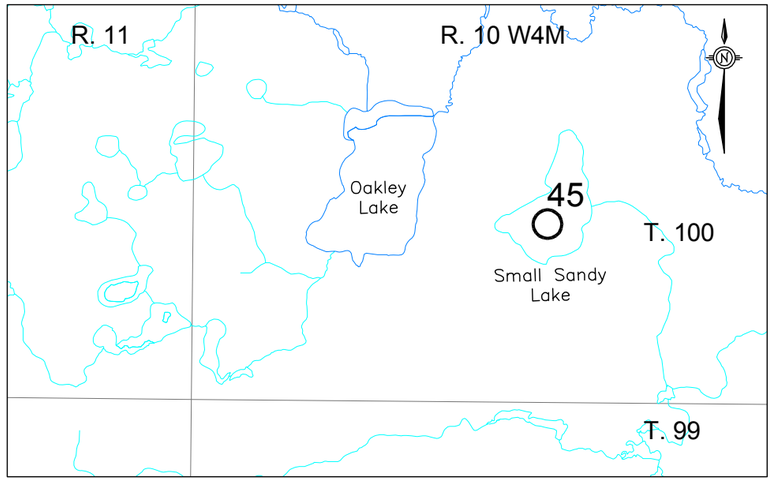

Photo 1 - Aerial photo of Small Sandy Lake, February 2007.

Photo 3 - Aerial photo of Small Sandy Lake, July 2007.

SCHEMATIC ONLY, NOT TO SCALE

Photo 2 - Aerial photo of Small Sandy Lake, February 2007.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating–Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)	S	Sagittaria (Arrowhead)
Ch	Chara (Muskgrass)	U	Utricularia (Bladderwort)
E	Elodea (Waterweed)		
Eq	Equisetum (Horsetail)		
H	Hippuris (Marestail)		
L	Lemna (Duckweed)		
M	Myriophyllum (Milfoil)		
N	Nuphar (Water Lily)		
Ny	Nymphaea (N. Water Lily)		
P	Potamogeton (Pondweed)		
Pg	Polygonum (Smartweed)		
R	Ranunculus (Buttercup)		

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 45 SMALL SANDY LAKE

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.		Lake_Site45
DESIGN	CS	24/08/07	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	29/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: Q-8

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig Q-8_Small Sandy Lake_Site 45 .dwg Nov 29, 2007 – 4:40pm

Photo 1 - Aerial view of Unnamed Waterbody 15, May 2007.

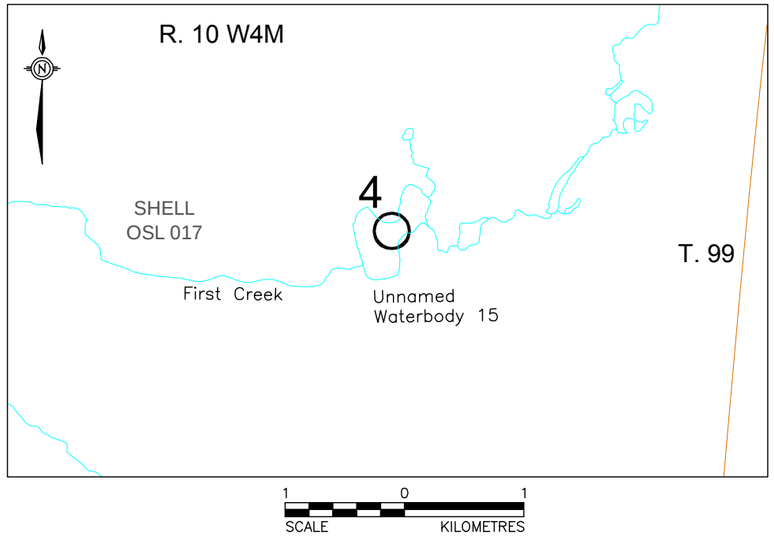

Photo 4 - View of the outlet facing east, October 2005

Photo 2 - Aerial view of Unnamed Waterbody 15, July 2007.

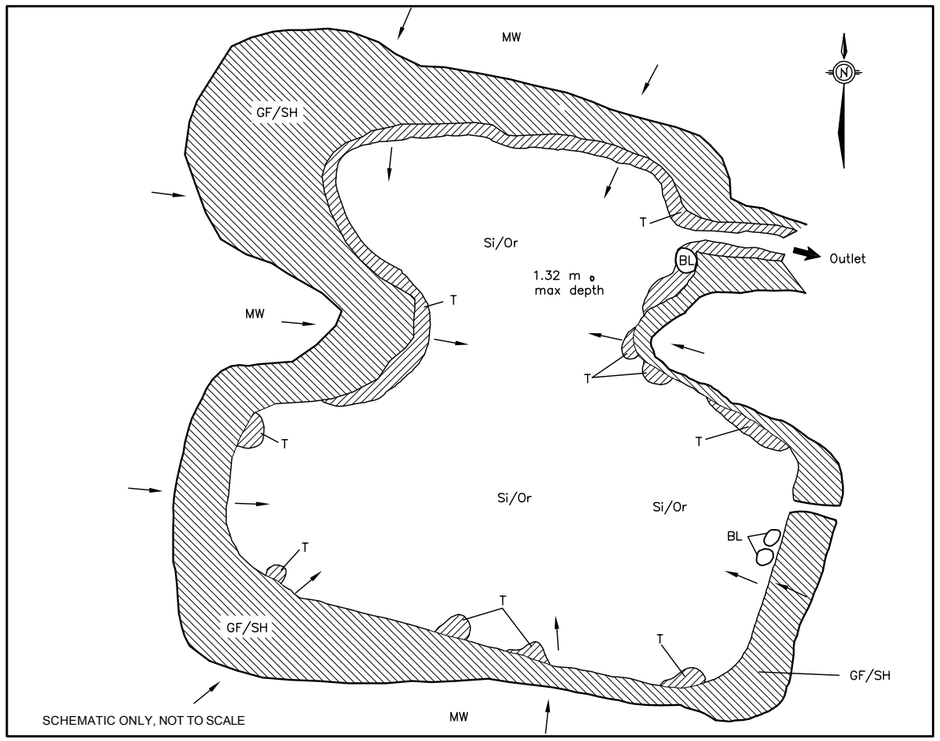

Photo 3 - View of the two beaver lodges present on the east shore of Unnamed Waterbody 15, October 2005.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality

Substrate

- Silt (<0.06 mm)
- Sand (0.06 to 2 mm)
- Gravel (2 to 64 mm)
- Cobble (64 to 256 mm)
- Boulder (>256 mm)

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

- GF — Grass/Forbs
- SH — Shrub
- DF — Deciduous Forest
- CF — Coniferous Forest
- MW — Mixedwood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating–Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

- E — Eleocharis (Spike Rush)
- J — Juncus (Rush)
- Sc — Scirpus (Bulrush)
- Sp — Sparganium (Burreed)
- T — Typha (Cattail)

Submergent Vegetation Type

- C — Ceratophyllum (Coontail)
- Ch — Chara (Muskgrass)
- E — Elodea (Waterweed)
- Eq — Equisetum (Horsetail)
- H — Hippuris (Marestail)
- L — Lemna (Duckweed)
- M — Myriophyllum (Milfoil)
- N — Nuphar (Water Lily)
- Ny — Nymphaea (N. Water Lily)
- P — Potamogeton (Pondweed)
- Pg — Polygonum (Smartweed)
- R — Ranunculus (Buttercup)
- S — Sagittaria (Arrowhead)
- U — Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 4 UNNAMED WATERBODY 15

Shell Canada Limited

PROJECT 05–1344–027.6190			FILE No.		Lake_Site4
DESIGN	CS	07/11/05	SCALE	AS SHOWN	REV. 0
CADD	TY	17/11/07			
CHECK	AS	29/10/07			FIGURE: Q-9
REVIEW	WES/TC	20/11/07			

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Golder Associates Ltd.

1000, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

APPENDIX R

HABITAT MAPS FOR THE REDCLAY CREEK WATERSHED

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

LIST OF FIGURES

Figure R-1 Habitat Map for Site 50 Redclay Creek 1
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Figure R-3 Habitat Map for Site 55 Unnamed Creek 8....3
Figure R-4 Habitat Map for Site 52 Unnamed Waterbody 12....4
Figure R-5 Habitat Map for Site 53 Unnamed Waterbody 13....5

Photo 1 - Aerial view of surveyed section of Redclay Creek, September 2006.

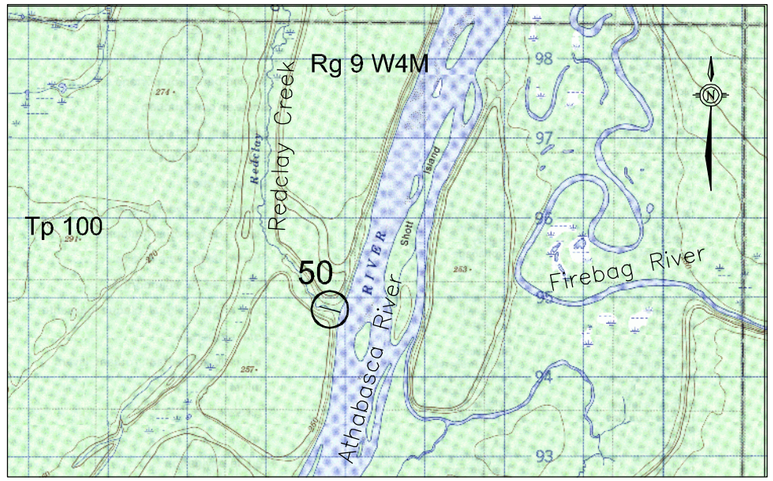

Photo 4 - View of mouth of Redclay Creek, July 2007.

Photo 2 - Upstream aerial view of instream woody debris, September 2006.

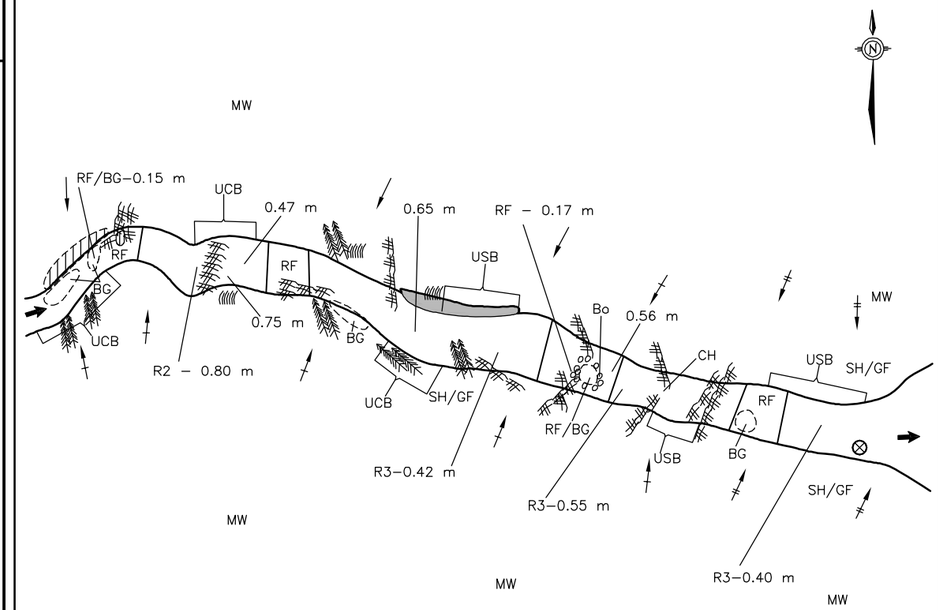

Photo 3 - View of typical habitat of surveyed section, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat; Slow, Laminar Flow, Depositional
P1	Class 1 Scour Pool; Slow, Deep
P2	Class 2 Scour Pool; Slow, Moderate Depth
P3	Class 3 Scour Pool; Slow, Shallow
IP1	Class 1 Impoundment Pool; Deep
IP2	Class 2 Impoundment Pool; Moderate Depth
IP3	Class 3 Impoundment Pool; Shallow
BW	Backwater; Slow, Reverse Flow
SN	Snye; Isolated Area of Zero Velocity
BG	Boulder Garden
1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop

	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
XX	Beaver Dam
BL	Beaverlodge
	Direction of Flow

Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 50 REDCLAY CREEK

Shell Canada Limited

PROJECT 05–1344–027.6137			FILE No. Hab Map Site 50		
DESIGN	HF	02/01/07	SCALE AS SHOWN	REV.	0
CADD	TE	18/09/07			
CHECK	AS	29/10/07	**FIGURE: R-1**		
REVIEW	WES/TC	20/11/07			

L:\2005\1344–OIL SANDS\05–1344–027–Shell Omnibus\6100\6137\Fig R–1_Habitat Map for Site 50.dwg Nov 18, 2007 – 12:59pm

Photo 1 - Downstream view of riffle habitat, September 2006.

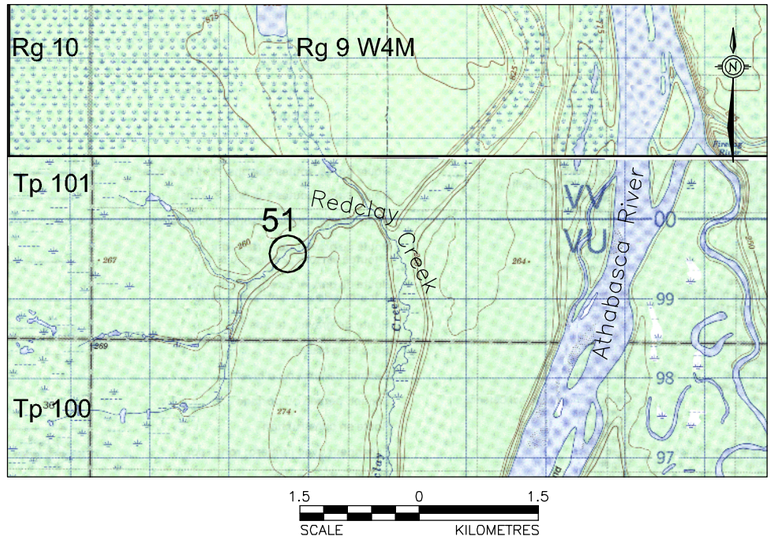

Photo 4 - Upstream view of discharge site, July 2007.

Photo 2 - Downstream view of downstream end of surveyed section with large woody debris, May 2007.

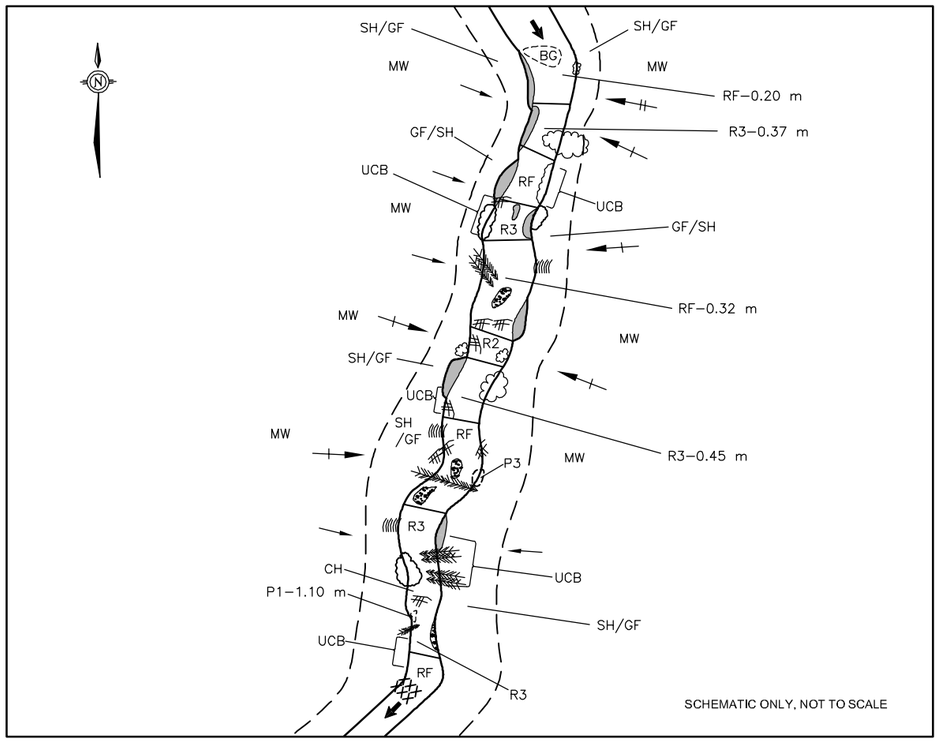

Photo 3 - Downstream view of downstream end of surveyed section, September 2006.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop
- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 51 REDCLAY CREEK

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No. Hab Map Site 51		
DESIGN	HF	02/01/07	SCALE AS SHOWN	REV.	0
CADD	TE	18/09/07			
CHECK	AS	29/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: R-2

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig R-2_Habitat Map for Site 51.dwg Nov 18, 2007 - 1:01pm

Photo 1 - Upstream view of riffle habitat, September 2006.

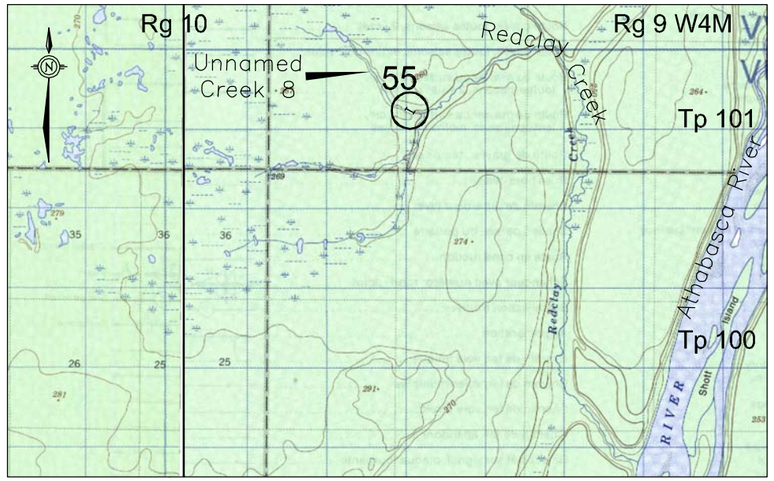

Photo 4 - View of typical habitat in surveyed section, July 2007.

Photo 2 - View of open water at access site, February 2007.

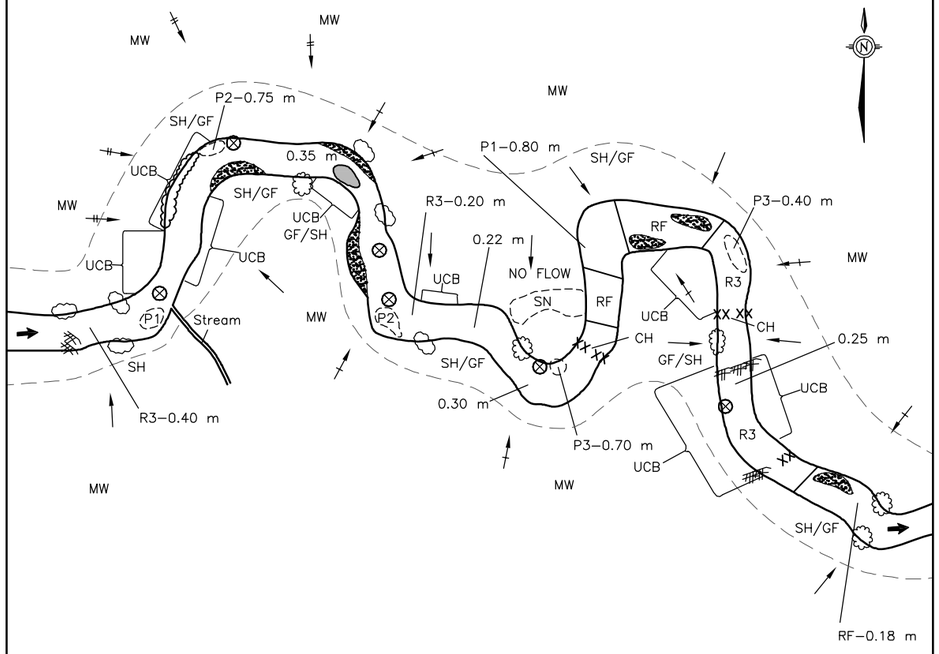

Photo 3 - View at discharge transect, May 2007.

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit / Habitat Type:

- FA Falls; Very Swift, Vertical Drop; Impassable to Fish
- CA Cascade; Very Swift, Turbulent; Passable to Fish
- CH Chute; Channel Restricted, Swift, Moderate Depth
- RA Rapids; Very Swift, Deep, With Cover
- RF Riffle; Swift, Shallow, Turbulent
- R1 Class 1 Run; Moderately Swift, Deep With Cover
- R2 Class 2 Run; Moderately Swift, Moderate Depth and Cover
- R3 Class 3 Run; Moderately Swift, Shallow, Limited Cover
- FL Flat; Slow, Laminar Flow, Depositional
- P1 Class 1 Scour Pool; Slow, Deep
- P2 Class 2 Scour Pool; Slow, Moderate Depth
- P3 Class 3 Scour Pool; Slow, Shallow
- IP1 Class 1 Impoundment Pool; Deep
- IP2 Class 2 Impoundment Pool; Moderate Depth
- IP3 Class 3 Impoundment Pool; Shallow
- BW Backwater; Slow, Reverse Flow
- SN Snye; Isolated Area of Zero Velocity
- BG Boulder Garden
- 1.5 m Indicates Channel Unit Depth
- | Channel Unit Divider

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Habitat Feature:

- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Root Wad
- Overhead Cover, High Quality
- Instream Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass
- Undercut Bank (UCB) (fish cover)
- Unstable Bank (USB) (slumping or eroding)
- Ledge; Bedrock Intrusion, Vertical Drop
- Inundated Vegetation
- SV Submergent Vegetation
- EV Emergent Vegetation
- TV Terrestrial Vegetation
- XX Beaver Dam
- BL Beaverlodge
- Direction of Flow

Vegetation Type:

- BA Bare
- OT Open Tundra
- MU Muskeg/Bog
- GF Grass/Forbs
- SE Sedges
- SH Shrub
- DF Deciduous Forest
- CF Coniferous Forest
- MW Mixedwood Forest

Substrate Particle Size:

- Or Organic Material
- Si Silt (<0.06 mm)
- Sa Sand (0.06 to 2 mm)
- Gr Gravel (2 to 64 mm)
- Co Cobble (64 to 256 mm)
- Bo Boulder (>256 mm)
- Be Bedrock

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 55 UNNAMED CREEK 8

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No. Hab Map Site 55	
DESIGN	HF	02/01/07	SCALE AS SHOWN	REV. 0
CADD	TE	18/09/07		
CHECK	AS	29/10/07		
REVIEW	WES/TC	20/11/07		

FIGURE: R-3

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig R-3_Habitat Map for Site 55.dwg Nov 18, 2007 - 1:02pm

Photo 1 - View of north end of Unnamed Waterbody 12, September 2006.

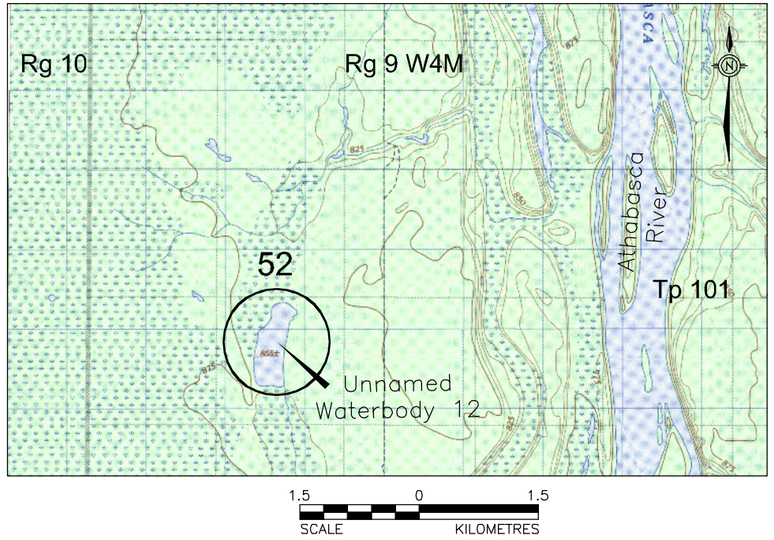

Photo 4 - Aerial view of Unnamed Waterbody 12, July 2007.

Photo 2 - Aerial view of south end of Unnamed Waterbody 12, Febuary 2007.

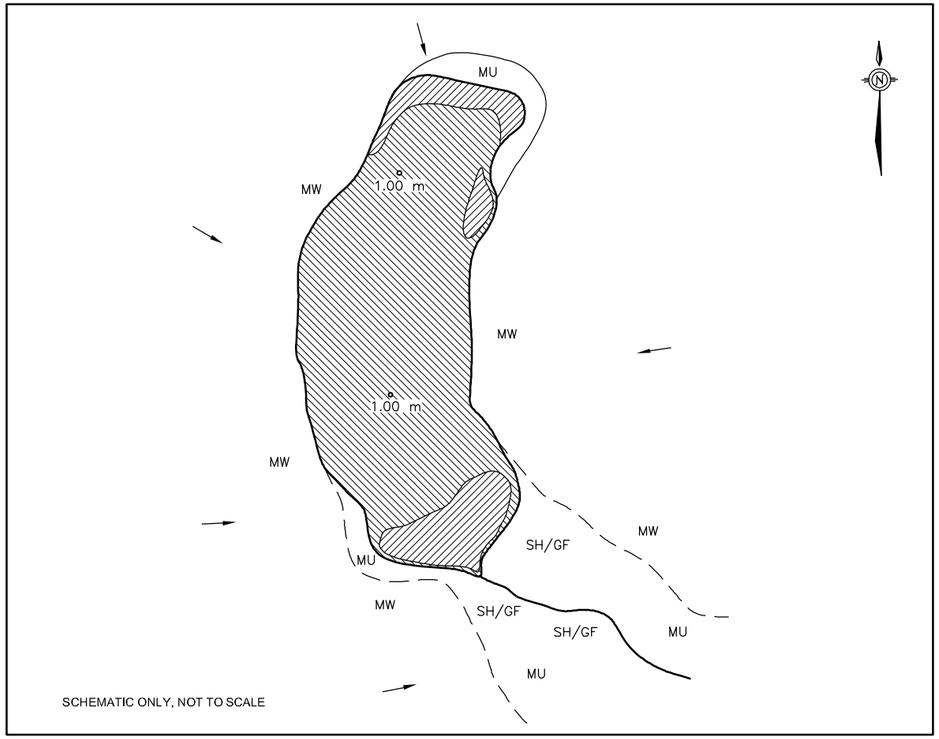

Photo 3 - Aerial view of south shoreline of Unnamed Waterbody 12, September 2006.

LEGEND - LAKE HABITAT MAPPING SYSTEM

- 0.61 m — Indicates Depth
- Direction of Flow
- BL — Beaverlodge
- Exposed Bar – Fine
- Exposed Bar – Coarse
- Island
- Woody Debris Pile
- Overhead Cover, High Quality
- Overhanging Vegetation
- Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

- Shallow Slope (0 to 5%)
- Intermediate Slope (6 to 30%)
- Steep Slope (31 to 70%)
- Very Steep Slope (>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixed Wood Forest

Aquatic Macrohyte Distribution

- Emergent Vegetation
- Submergent or Floating-Leaved Vegetation
- Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

HABITAT MAP FOR SITE 52
UNNAMED WATERBODY 12

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Site 52
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	29/10/07			FIGURE: R-4
REVIEW	WES/TC	20/11/07			

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig R-4_Habitat Map for Site 52.dwg Nov 18, 2007 - 1:04pm

Photo 1 - Aerial view of north shore of Unnamed Waterbody 13, September 2006.

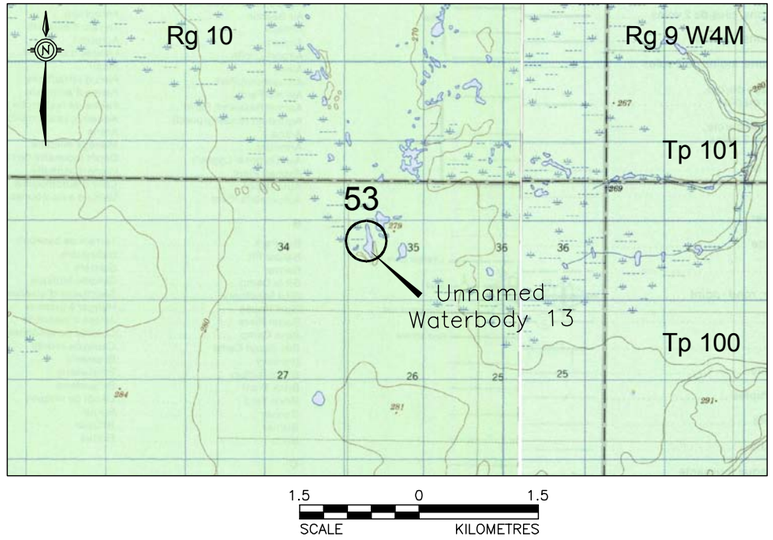

Photo 4 - Aerial view from north end of waterbody looking south, July 2007.

Photo 2 - View of northeast shore line, September 2006.

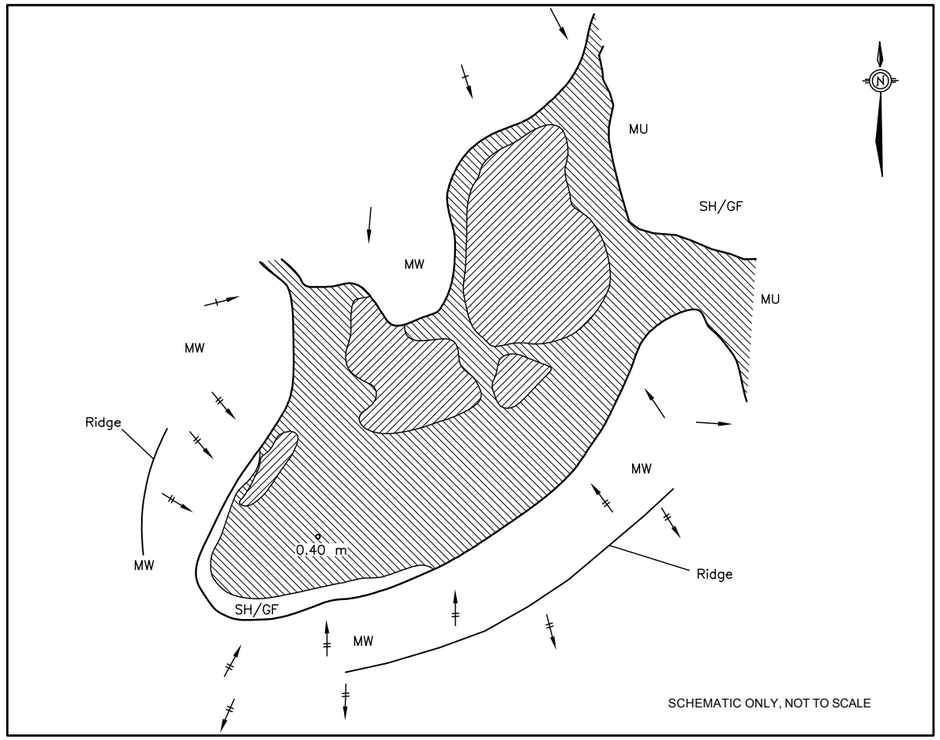

Photo 3 - View of north end of Unnamed Waterbody 13, February 2007.

LEGEND - LAKE HABITAT MAPPING SYSTEM

0.61 m° Indicates Depth
Direction of Flow
BL Beaverlodge
Exposed Bar – Fine
Exposed Bar – Coarse
Island
Woody Debris Pile
Overhead Cover, High Quality
Overhanging Vegetation
Tree, Shrub, Grass

Substrate Particle Size:

Or	Organic Material	
Si	Silt	(<0.06 mm)
Sa	Sand	(0.06 to 2 mm)
Gr	Gravel	(2 to 64 mm)
Co	Cobble	(64 to 256 mm)
Bo	Boulder	(>256 mm)
Be	Bedrock	

Shore / Bottom Slope

Shallow Slope	(0 to 5%)
Intermediate Slope	(6 to 30%)
Steep Slope	(31 to 70%)
Very Steep Slope	(>70%)

Upland Vegetation Type:

BA	Bare
OT	Open Tundra
MU	Muskeg/Bog
GF	Grass/Forbs
SE	Sedges
SH	Shrub
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixedwood Forest

Aquatic Macrohyte Distribution

Emergent Vegetation
Submergent or Floating–Leaved Vegetation
Inudated Terrestrial Vegetation

Emergent Vegetation Type

E	Eleocharis (Spike Rush)
J	Juncus (Rush)
Sc	Scirpus (Bulrush)
Sp	Sparganium (Burreed)
T	Typha (Cattail)

Submergent Vegetation Type

C	Ceratophyllum (Coontail)
Ch	Chara (Muskgrass)
E	Elodea (Waterweed)
Eq	Equisetum (Horsetail)
H	Hippuris (Marestail)
L	Lemna (Duckweed)
M	Myriophyllum (Milfoil)
N	Nuphar (Water Lily)
Ny	Nymphaea (N. Water Lily)
P	Potamogeton (Pondweed)
Pg	Polygonum (Smartweed)
R	Ranunculus (Buttercup)
S	Sagittaria (Arrowhead)
U	Utricularia (Bladderwort)

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
HABITAT MAP FOR SITE 53
UNNAMED WATERBODY 13

Shell Canada Limited

PROJECT 05-1344-027.6137			FILE No.		Site 53
DESIGN	HF	02/01/07	SCALE	AS SHOWN	REV. 0
CADD	TE	17/09/07			
CHECK	AS	29/10/07			
REVIEW	WES/TC	20/11/07			

FIGURE: R-5

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6137\Fig R-5_Habitat Map for Site 53.dwg Nov 29, 2007 - 4:46pm

Golder Associates Ltd.

1000, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

APPENDIX S

WATER TEMPERATURE MONITORING RESULTS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

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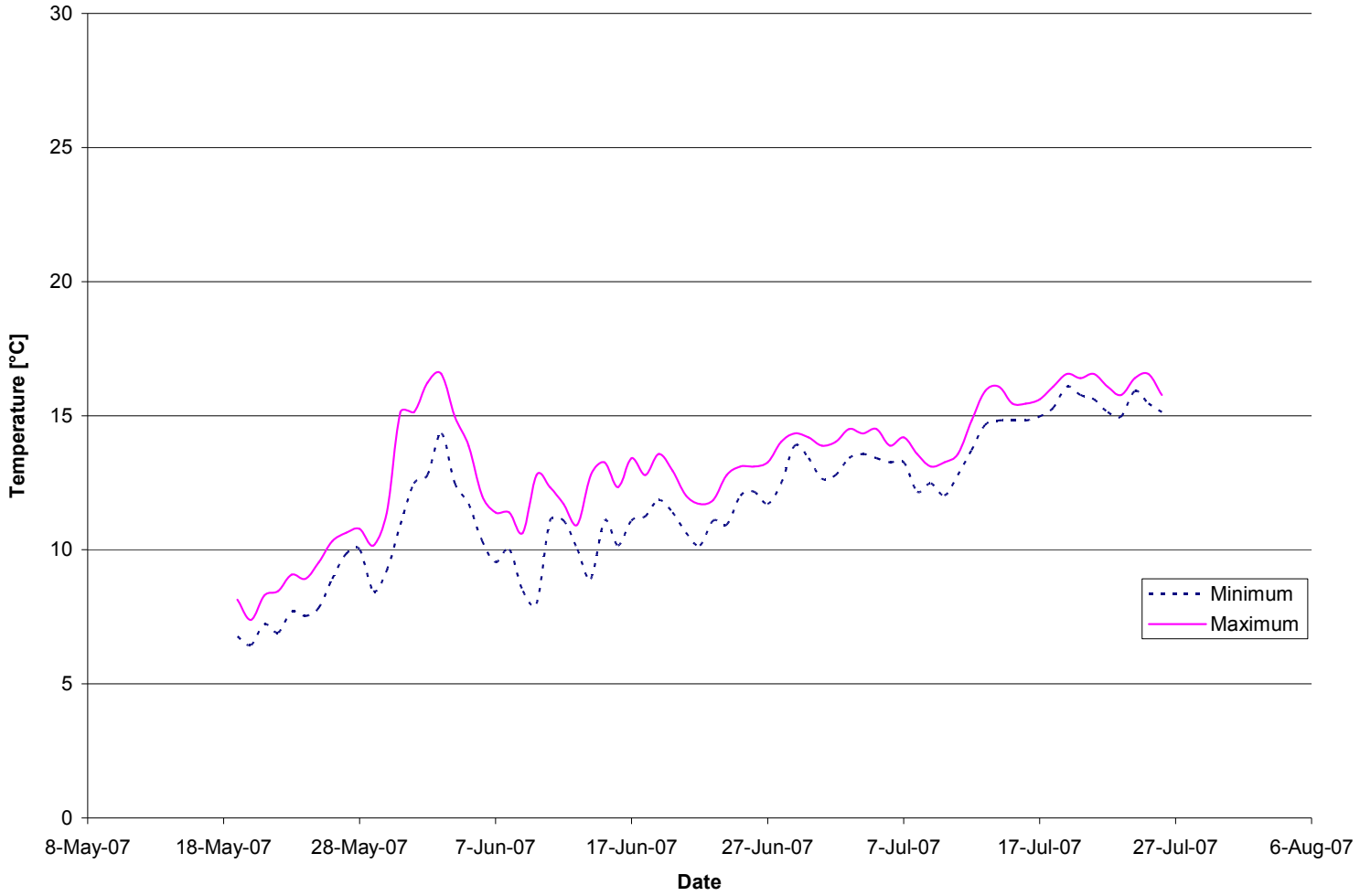
L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-1_Water Temp Monitoring Results, McClelland Lake Outlet Creek (Site 60).dwg Nov 29, 2007 - 4:46pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

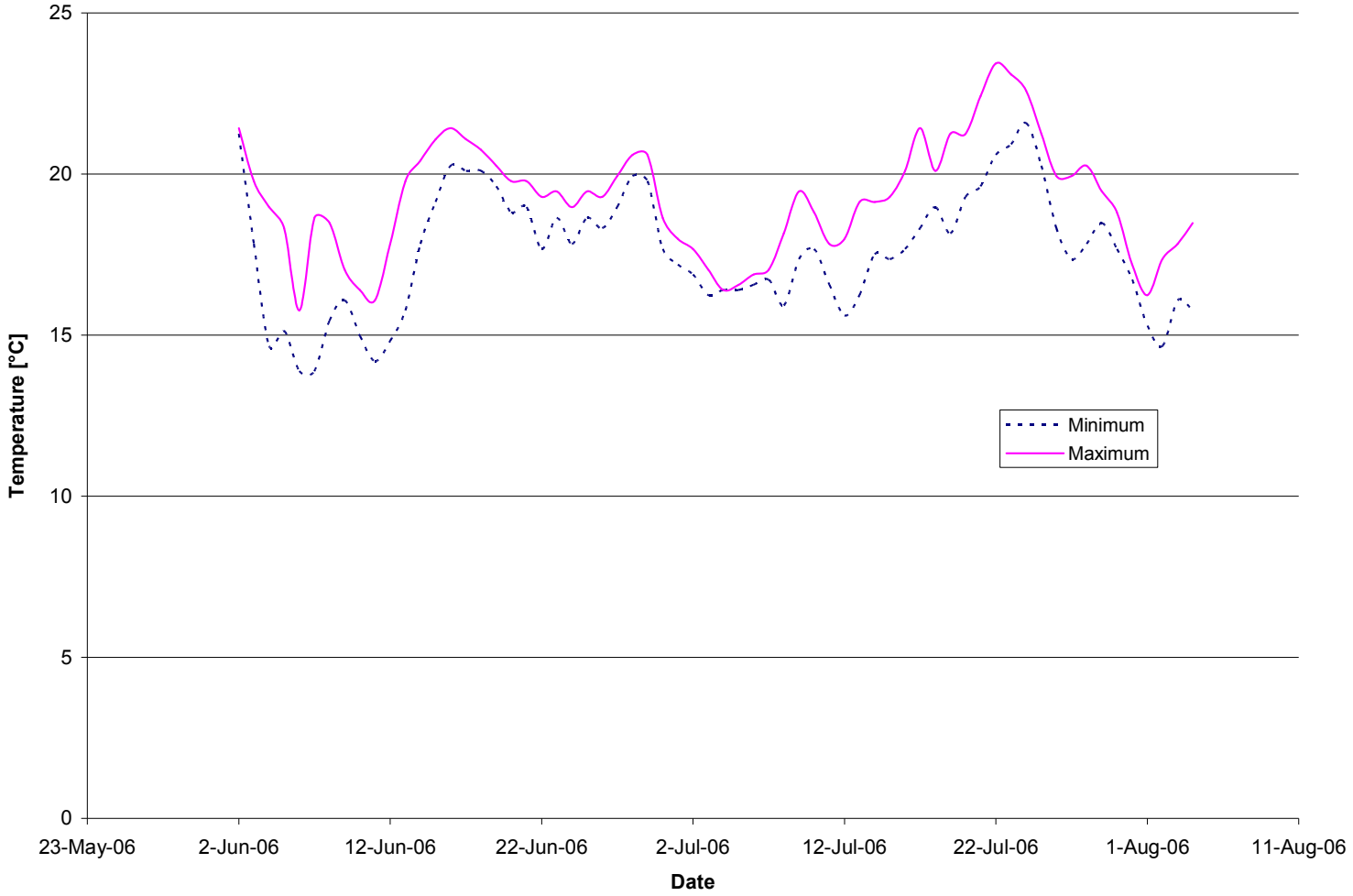
TITLE

WATER TEMPERATURE MONITORING RESULTS, McCLELLAND LAKE OUTLET CREEK (SITE 60)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 60
DESIGN	OM	17/11/07	SCALE	AS SHOWN REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		FIGURE: S-1
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-2_Water Temp Monitoring Results, McClelland Lake Outlet Creek (Site 23).dwg Nov 29, 2007 - 4:35pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, McCLELLAND LAKE OUTLET CREEK (SITE 23)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 23
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-2

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-3_Water Temp Monitoring Results, Unnamed Creek 3 (Site 59).dwg Nov 29, 2007 - 4:47pm

PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

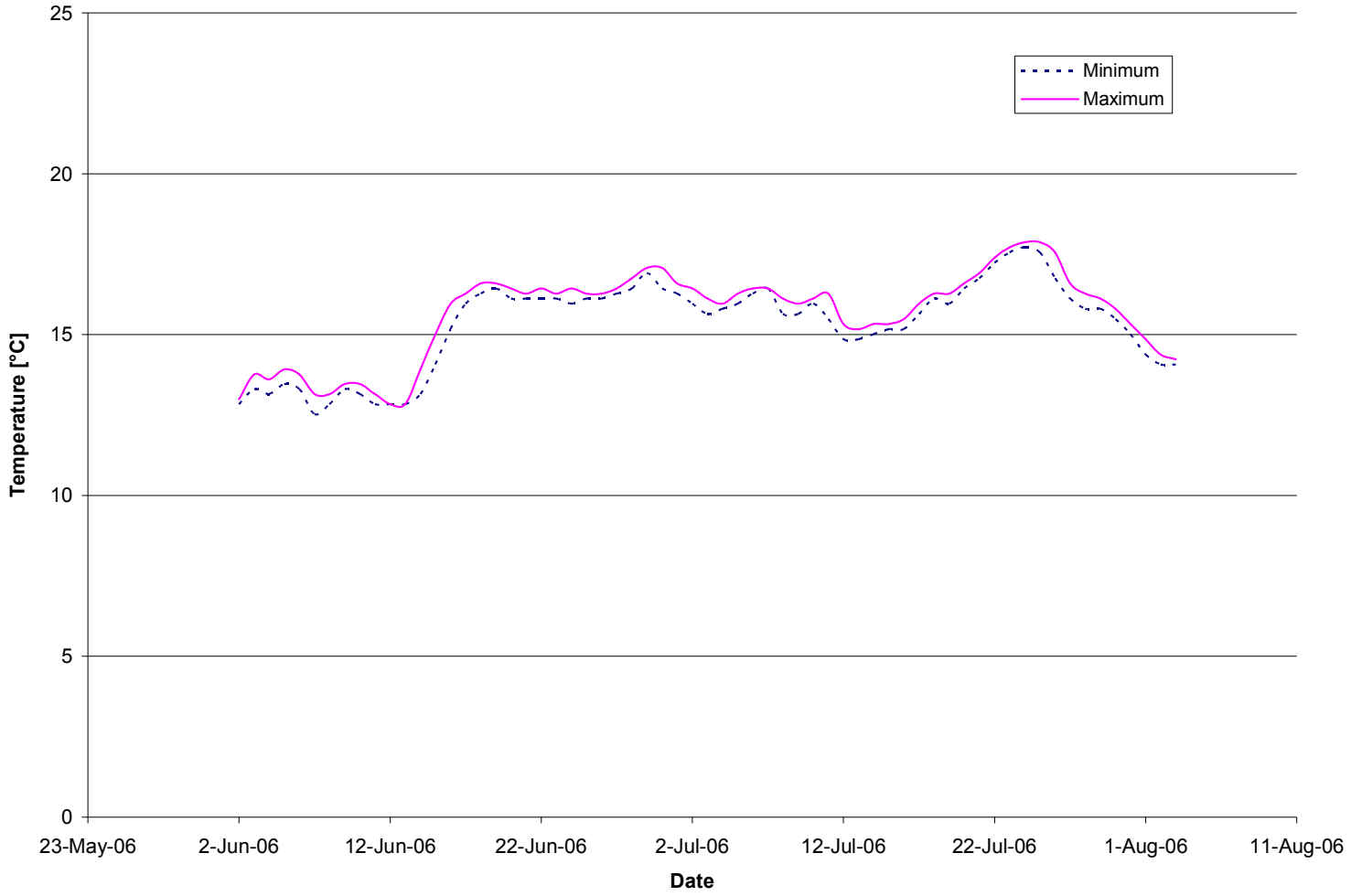
WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 3 (SITE 59)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 59
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-3

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-4_Water Temp Monitoring Results, Unnamed Creek 13 (Site 22).dwg Nov 29, 2007 - 4:48pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

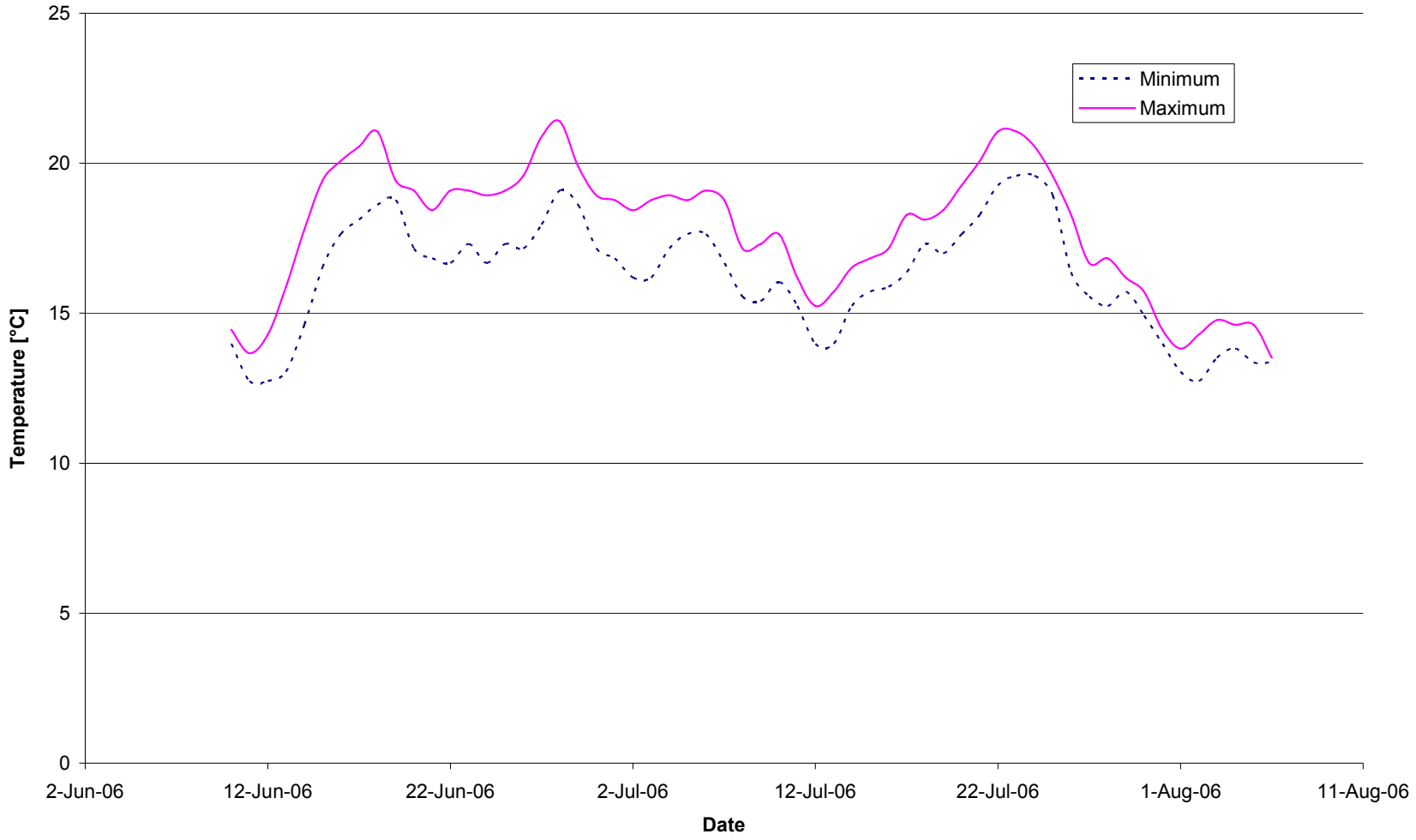
WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 13 (SITE 22)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 22
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-4

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-5_Water Temp Monitoring Results, Muskeg River (Site 41).dwg Nov 29, 2007 - 4:49pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

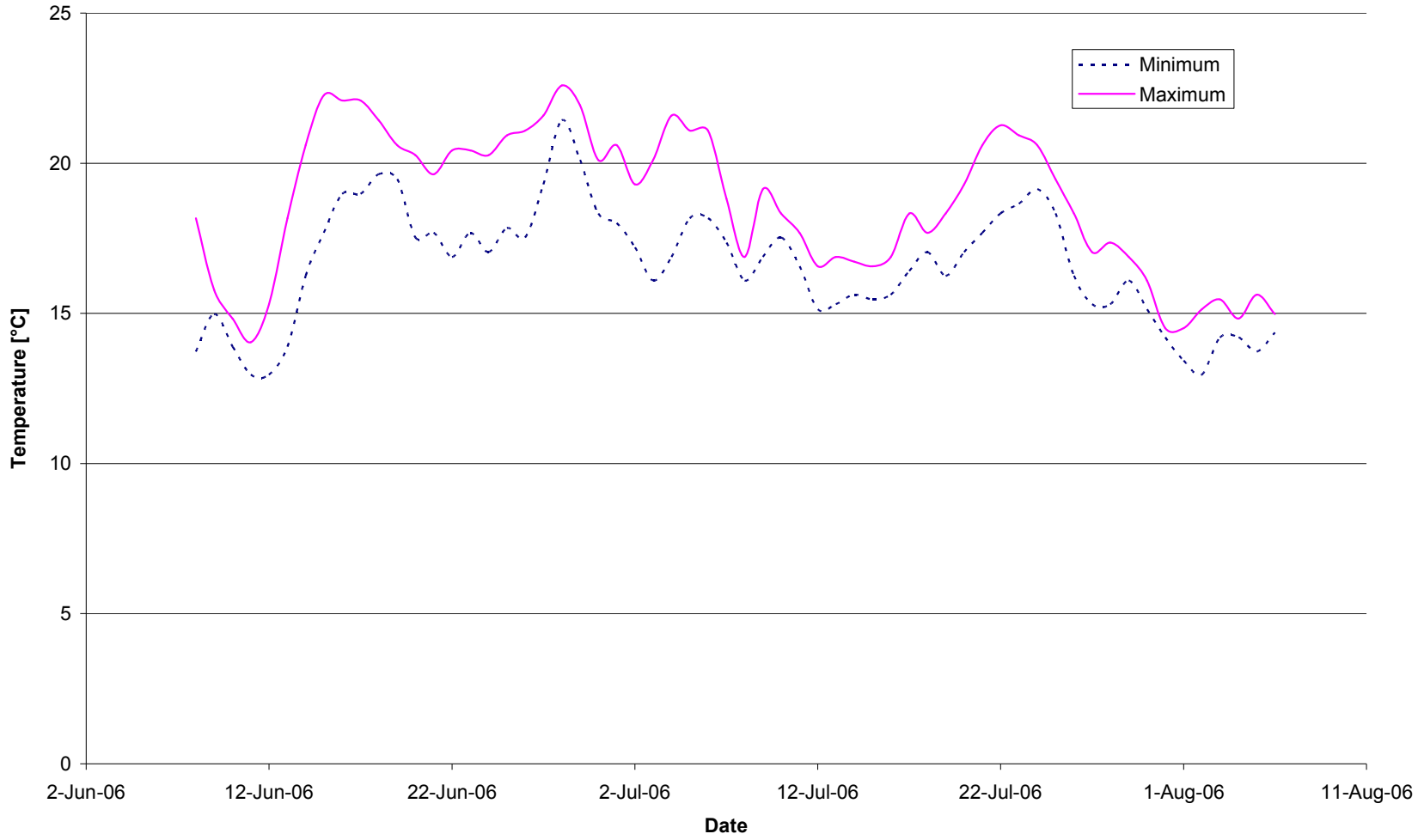
WATER TEMPERATURE MONITORING RESULTS, MUSKEG RIVER (SITE 41)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 41
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-5

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-6_Water Temp Monitoring Results, Muskeg River (Site 30).dwg Nov 29, 2007 - 4:49pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

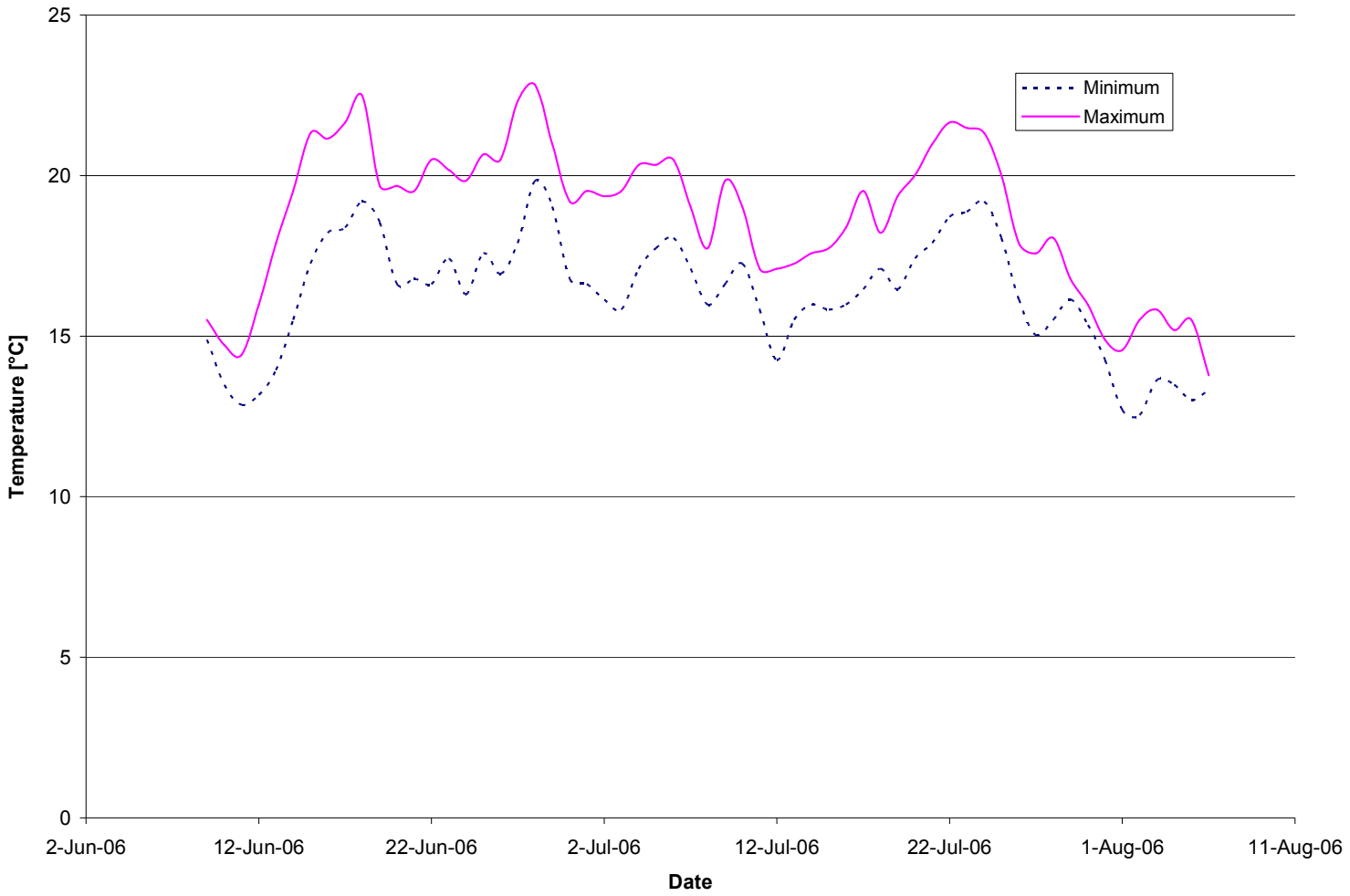
WATER TEMPERATURE MONITORING RESULTS, MUSKEG RIVER (SITE 30)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 30
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-6

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-7_Water Temp Monitoring Results, Stanley Creek (Site 40).dwg Nov 29, 2007 - 4:50pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

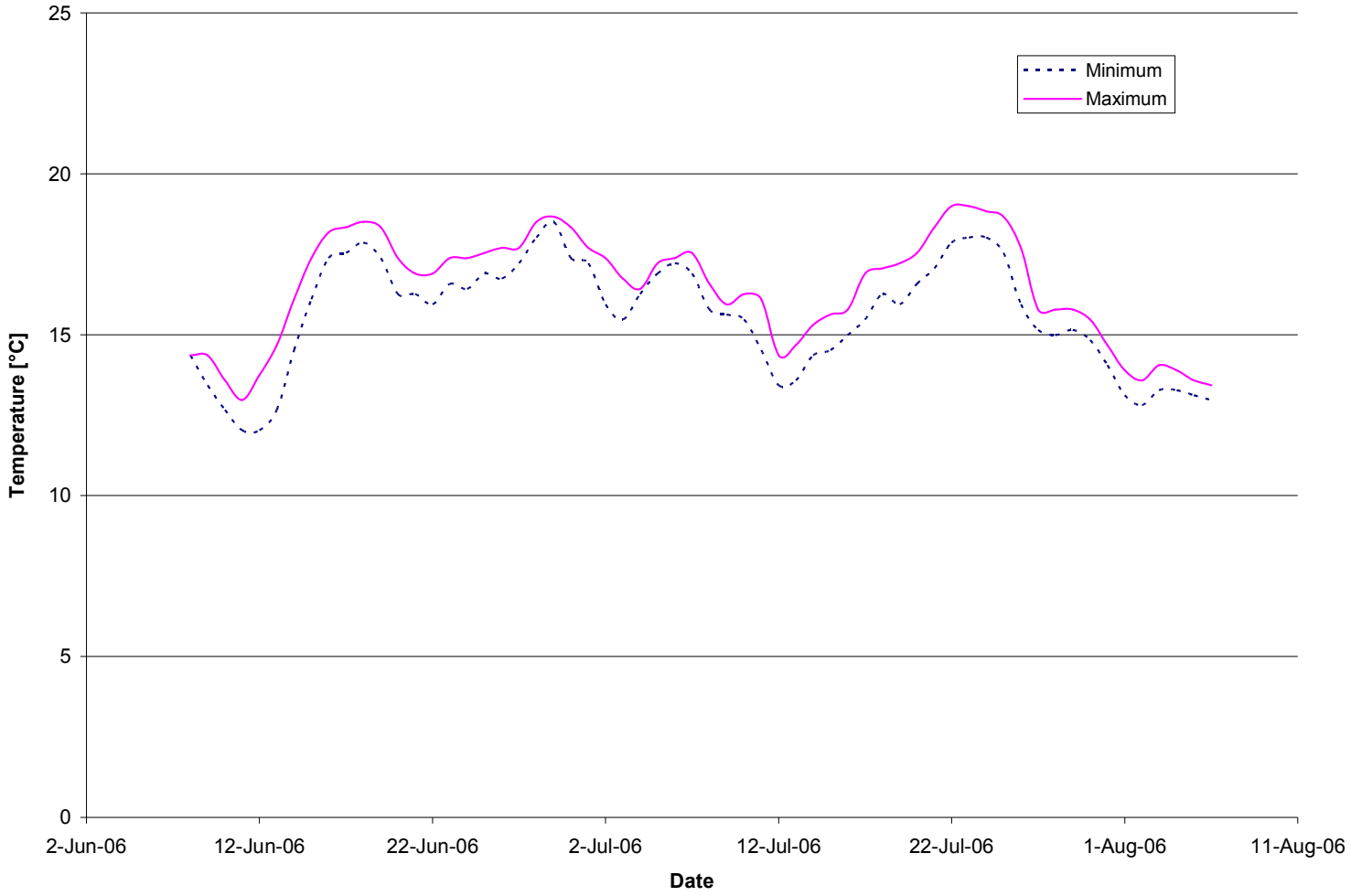
WATER TEMPERATURE MONITORING RESULTS, STANLEY CREEK (SITE 40)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 40
DESIGN	OM	17/11/07	SCALE	AS SHOWN REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-7

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-8_Water Temp Monitoring Results, Wapasu Creek (Site 32).dwg Nov 29, 2007 - 4:50pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

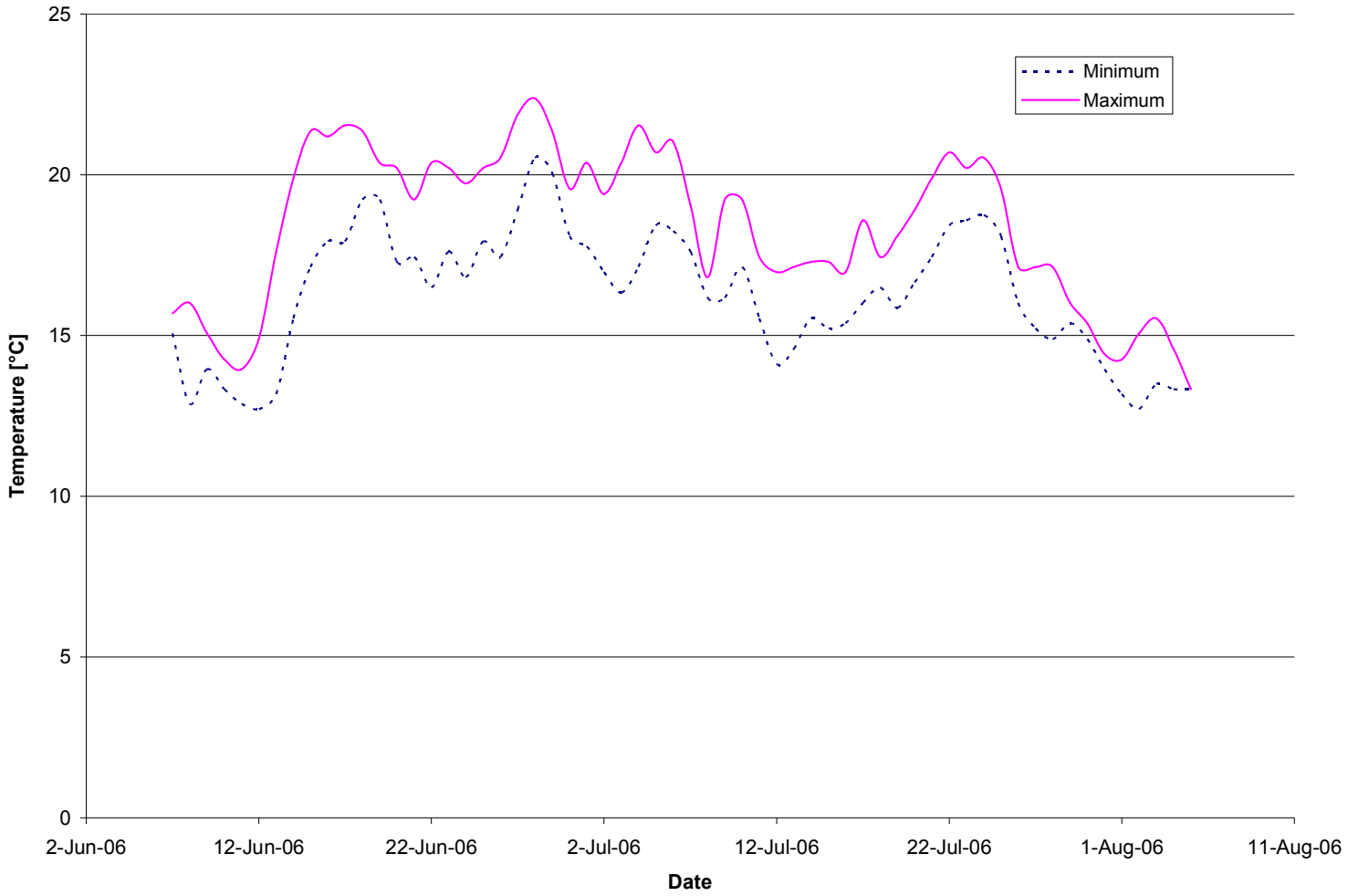
WATER TEMPERATURE MONITORING RESULTS, WAPASU CREEK (SITE 32)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 32
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-8

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-9_Water Temp Monitoring Results, Wapasu Creek (Site 38).dwg Nov 29, 2007 - 4:51pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

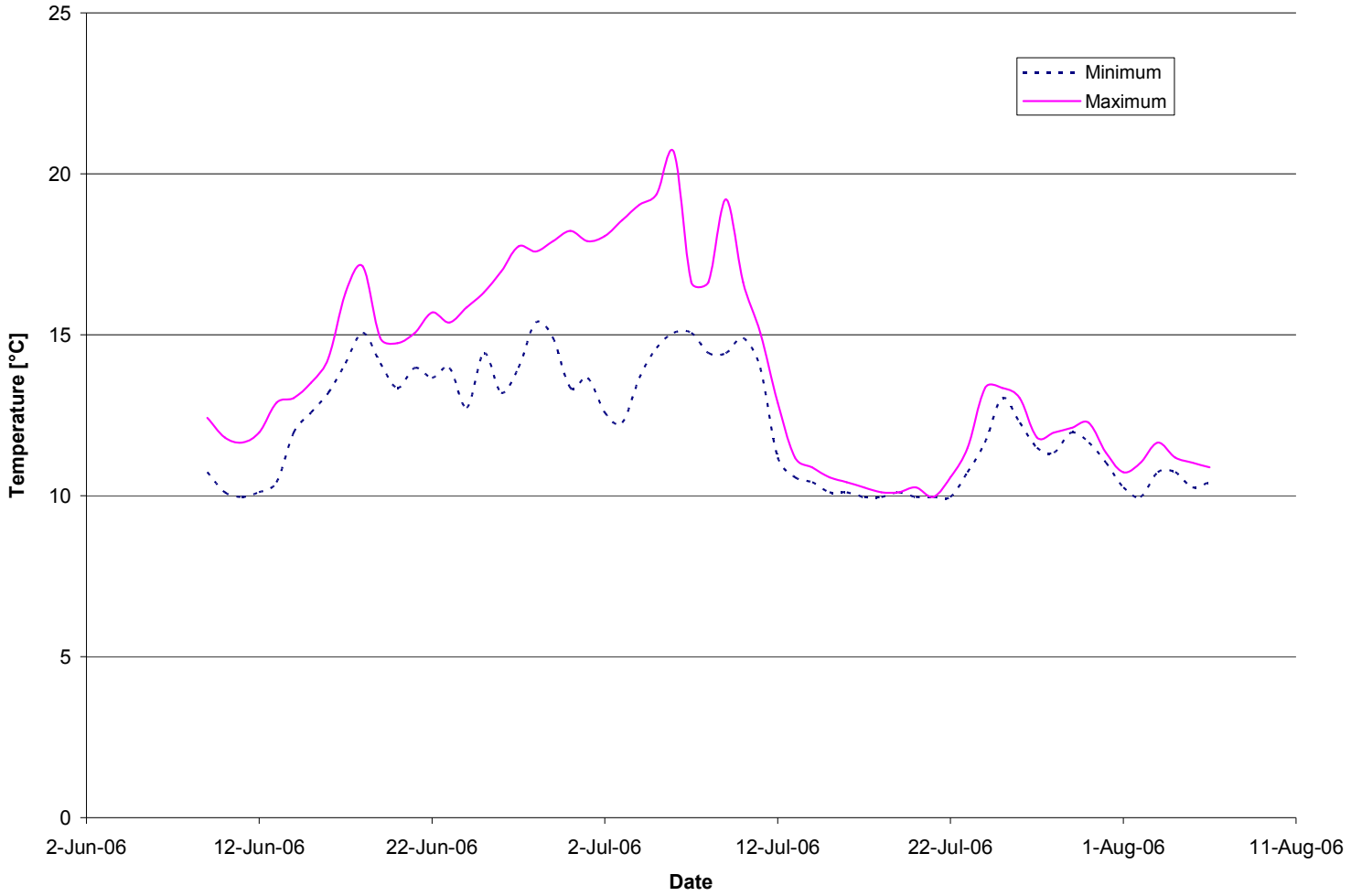
TITLE

WATER TEMPERATURE MONITORING RESULTS, WAPASU CREEK (SITE 38)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 38
DESIGN	OM	17/11/07	SCALE	AS SHOWN REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		FIGURE: S-9
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-10_Water Temp Monitoring Results, Unnamed Creek 9 (Site 35).dwg Nov 29, 2007 - 4:51pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 9 (SITE 35)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 35
DESIGN	OM	17/11/07	SCALE	AS SHOWN REV. 0
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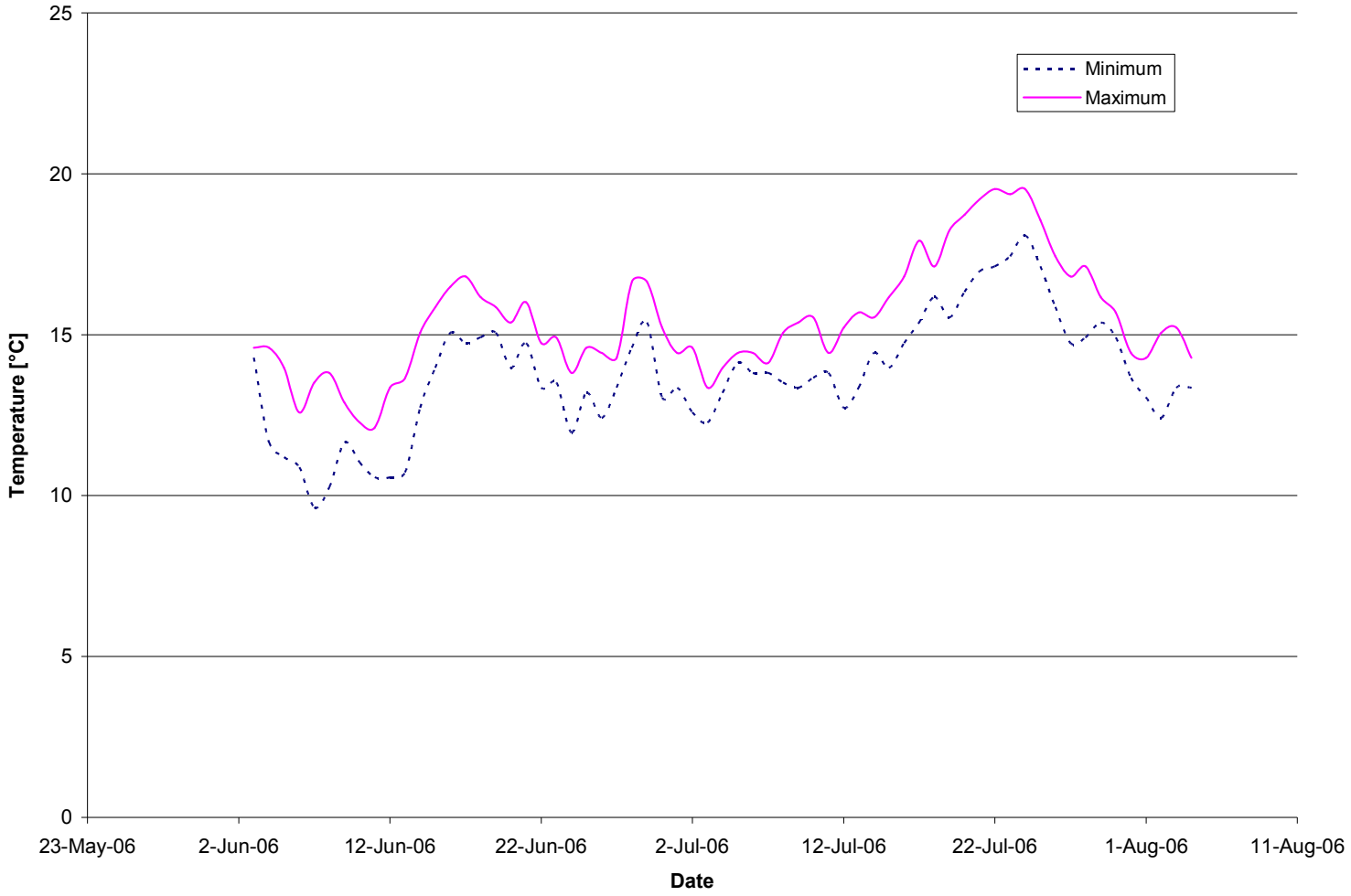
CHECK	OM	19/11/07		FIGURE: S-10
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

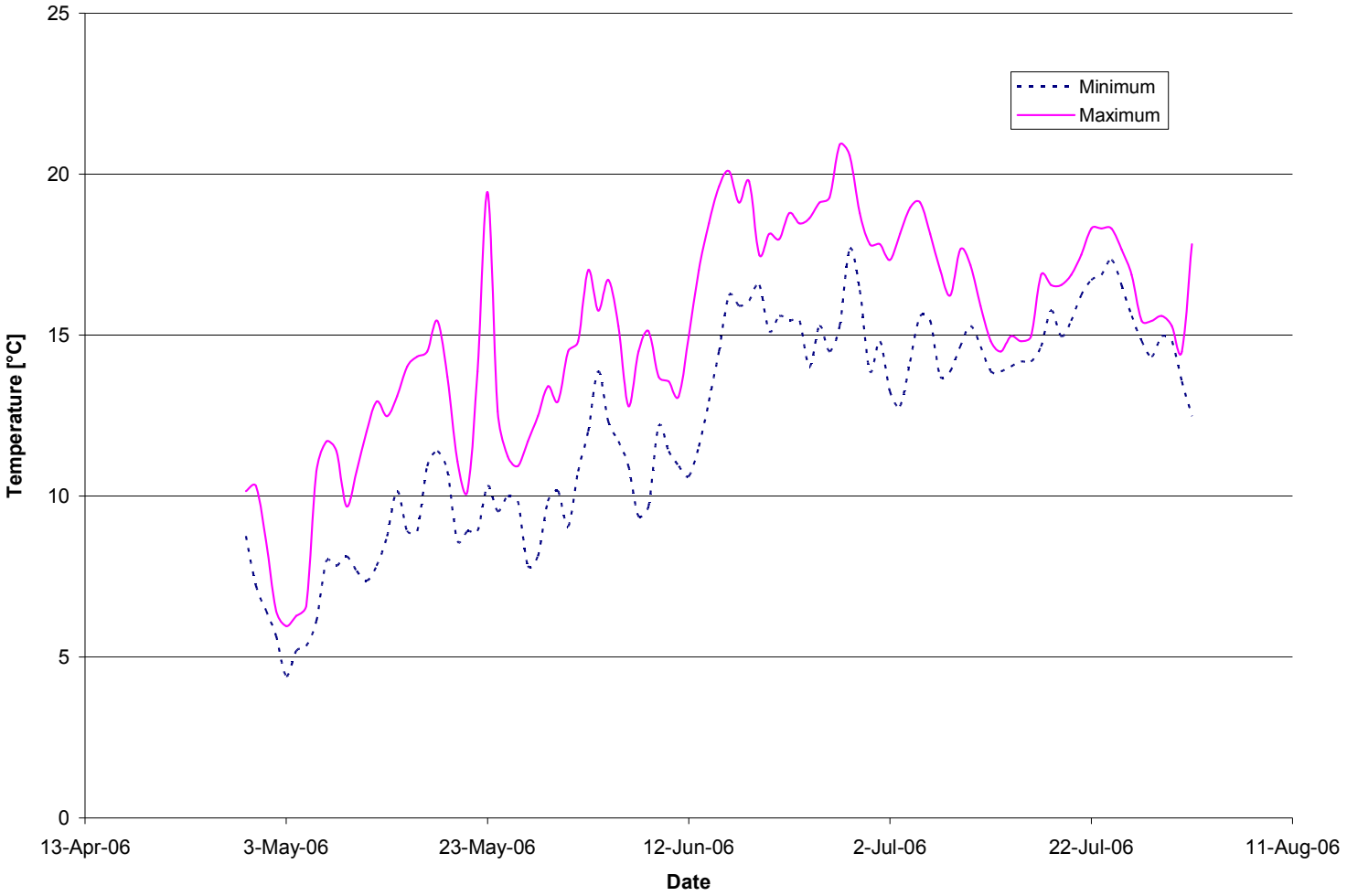
TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 12 (SITE 24)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 24
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		**FIGURE: S-11**
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-12_Water Temp Monitoring Results, Pierre River (Site 20).dwg Nov 29, 2007 - 4:52pm



PROJECT

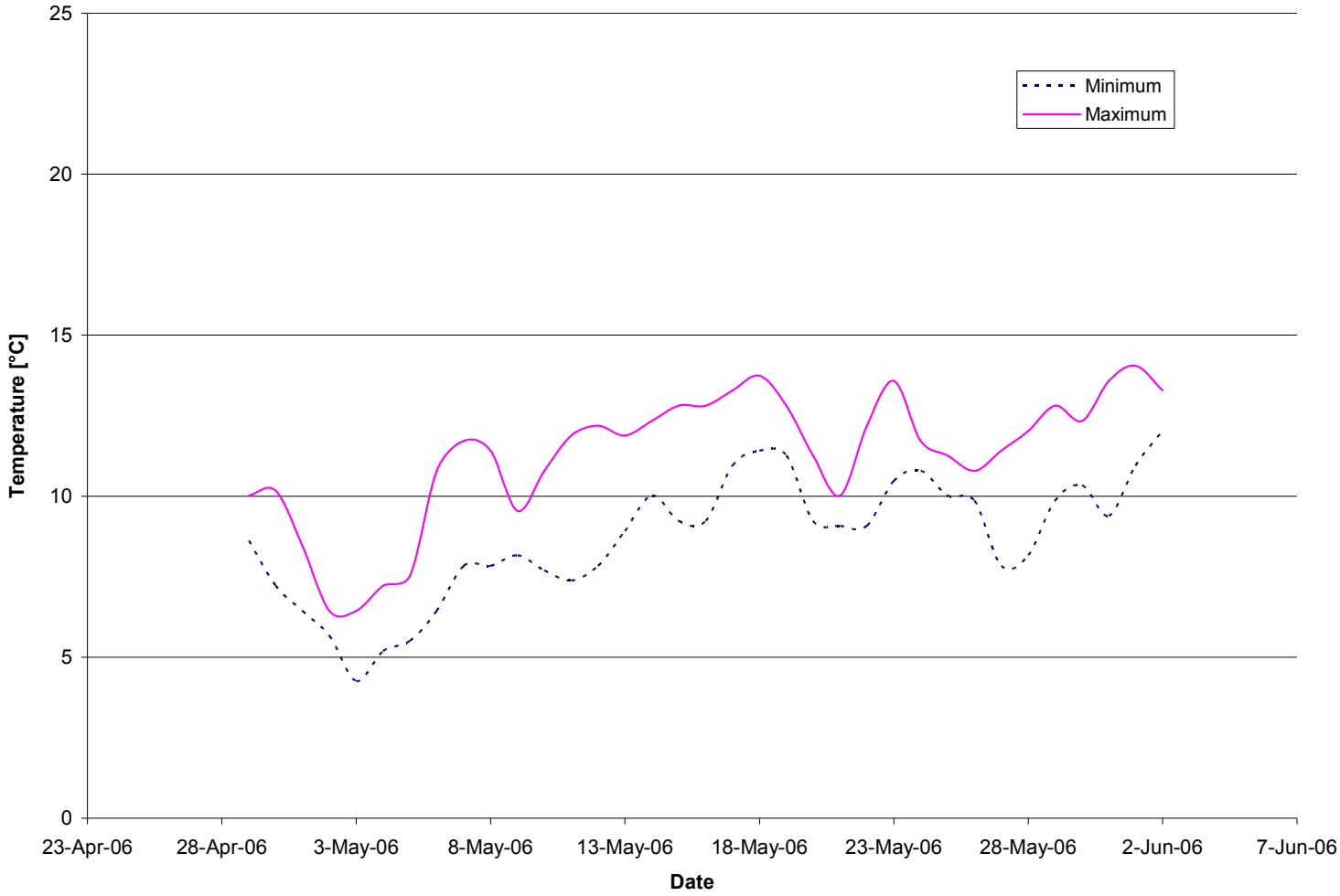
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, PIERRE RIVER (SITE 20)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 20
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07	**FIGURE: S-12**	
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

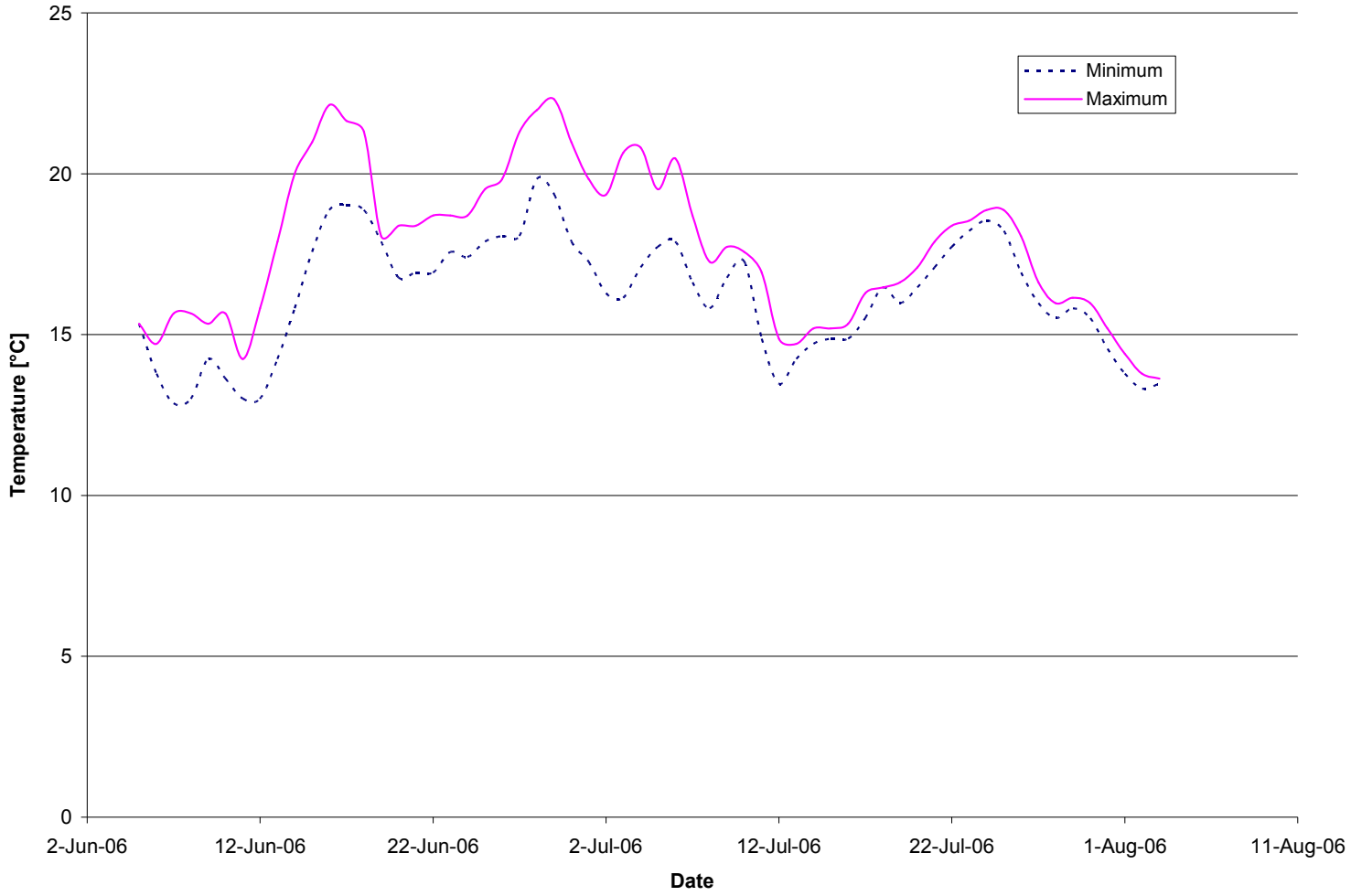
TITLE

WATER TEMPERATURE MONITORING RESULTS, PIERRE RIVER (SITE 202)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No. Water Temp-Site 202	
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-13



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

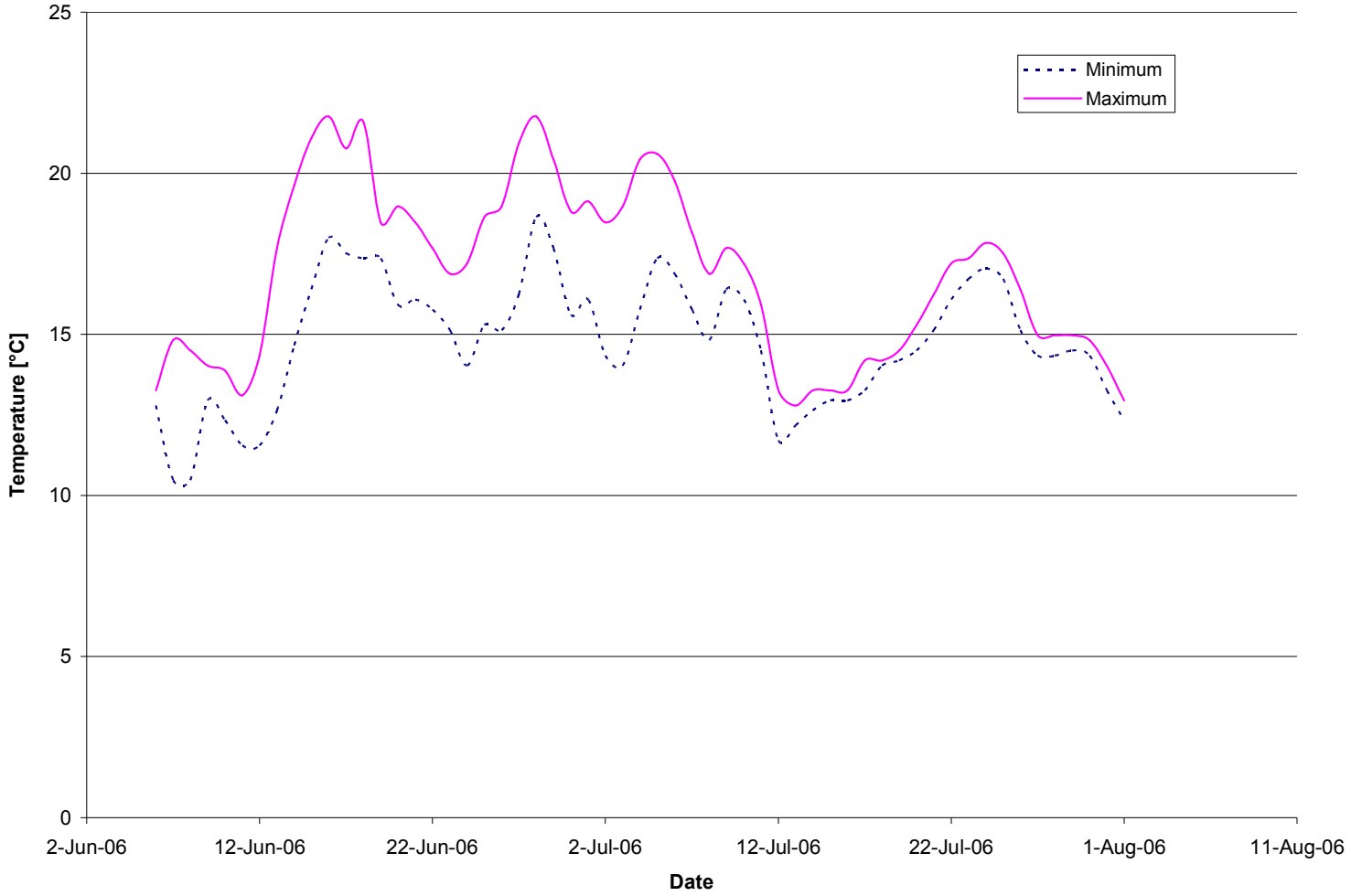
TITLE

WATER TEMPERATURE MONITORING RESULTS, PIERRE RIVER (SITE 19)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 19
DESIGN	OM	17/11/07	SCALE	AS SHOWN REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		FIGURE: S-14
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-15_Water Temp Monitoring Results, Eymundson Creek (Site 17).dwg Nov 29, 2007 - 4:54pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

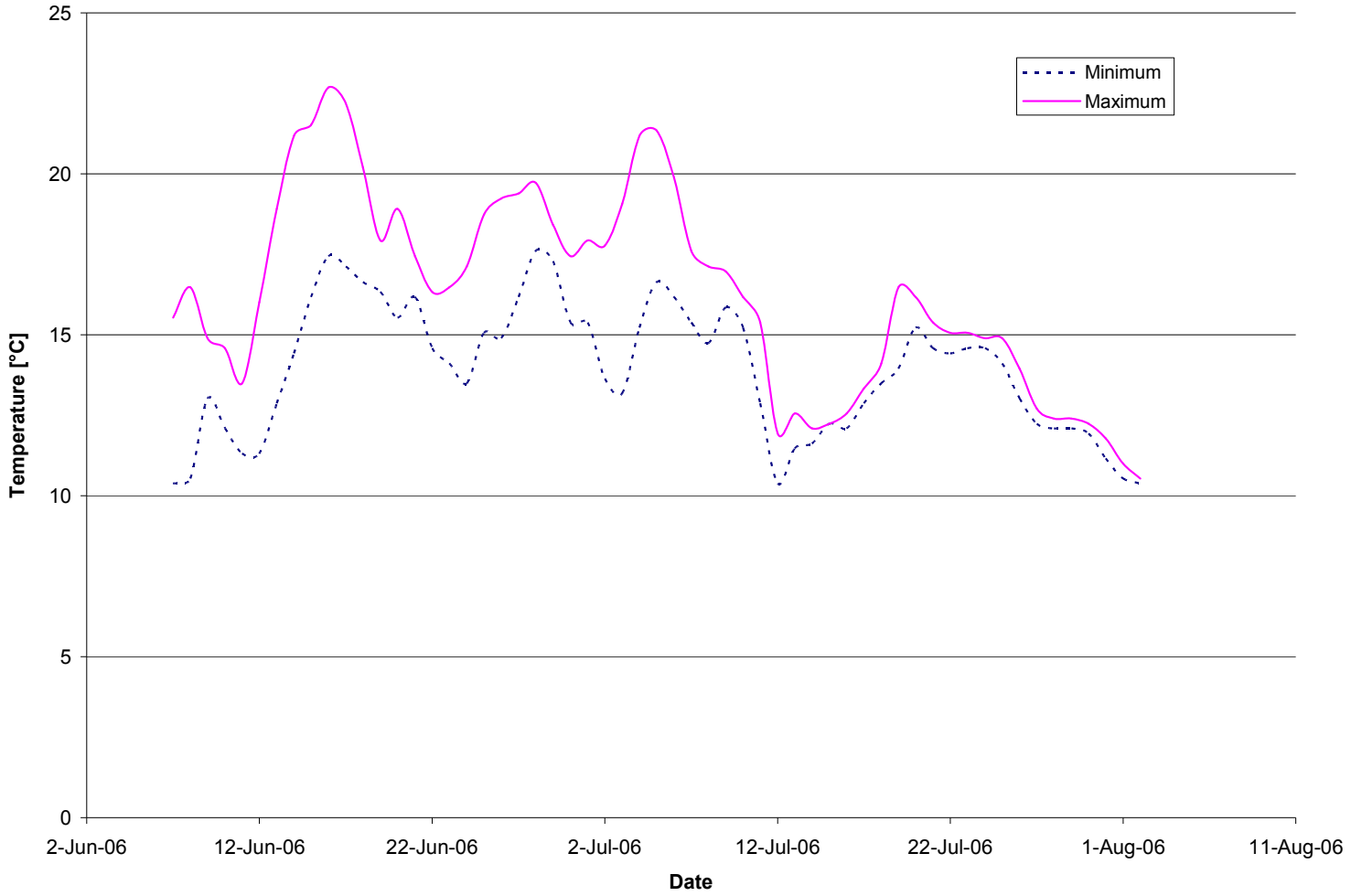
TITLE

WATER TEMPERATURE MONITORING RESULTS, EYMUNDSON CREEK (SITE 17)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 17
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-15



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

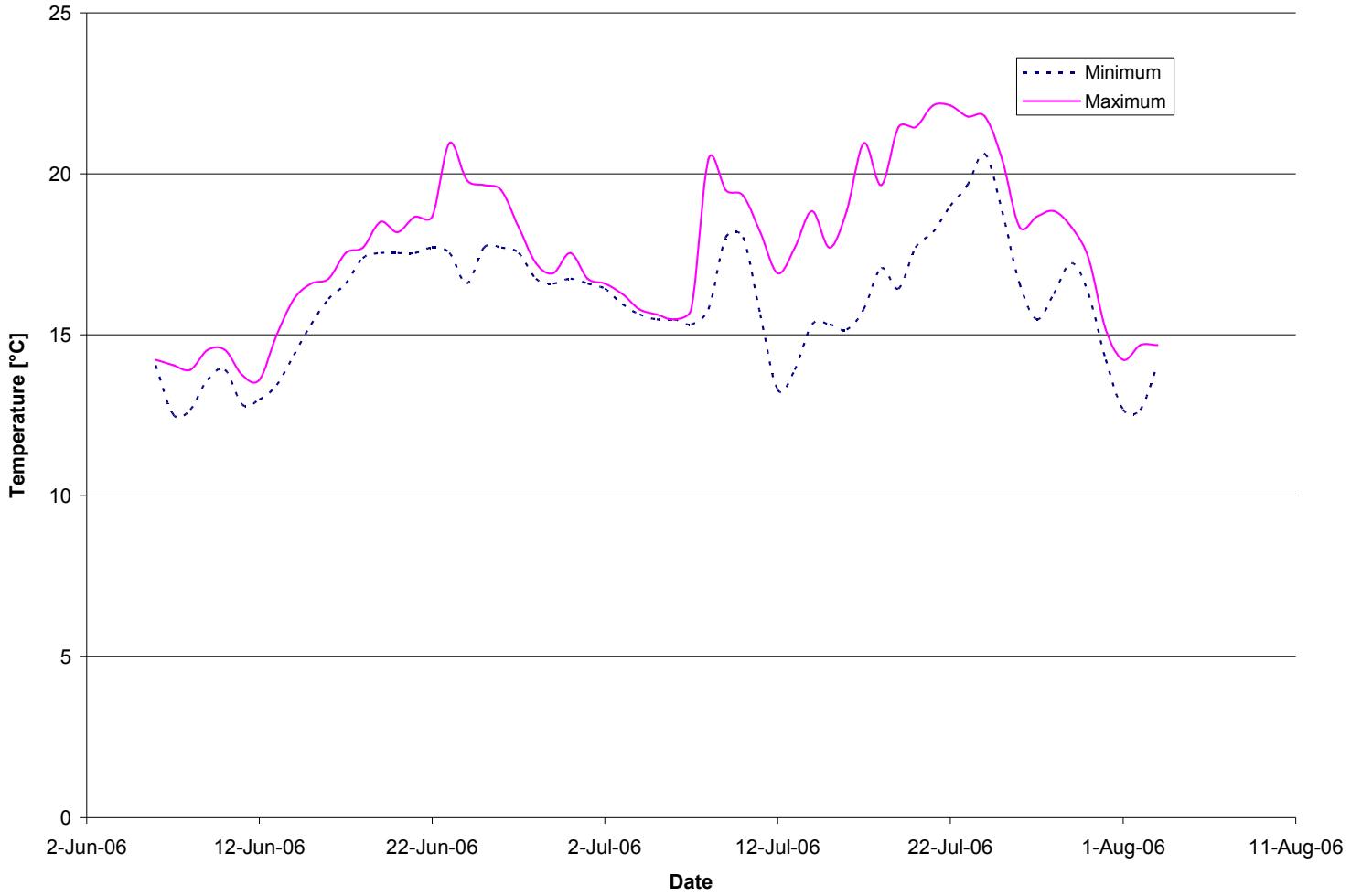
TITLE

WATER TEMPERATURE MONITORING RESULTS, EYMUNDSON CREEK (SITE 11)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 11
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07	**FIGURE: S-16**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-17_Water Temp Monitoring Results, Eymundson Creek (Site 6).dwg Nov 29, 2007 - 4:55pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

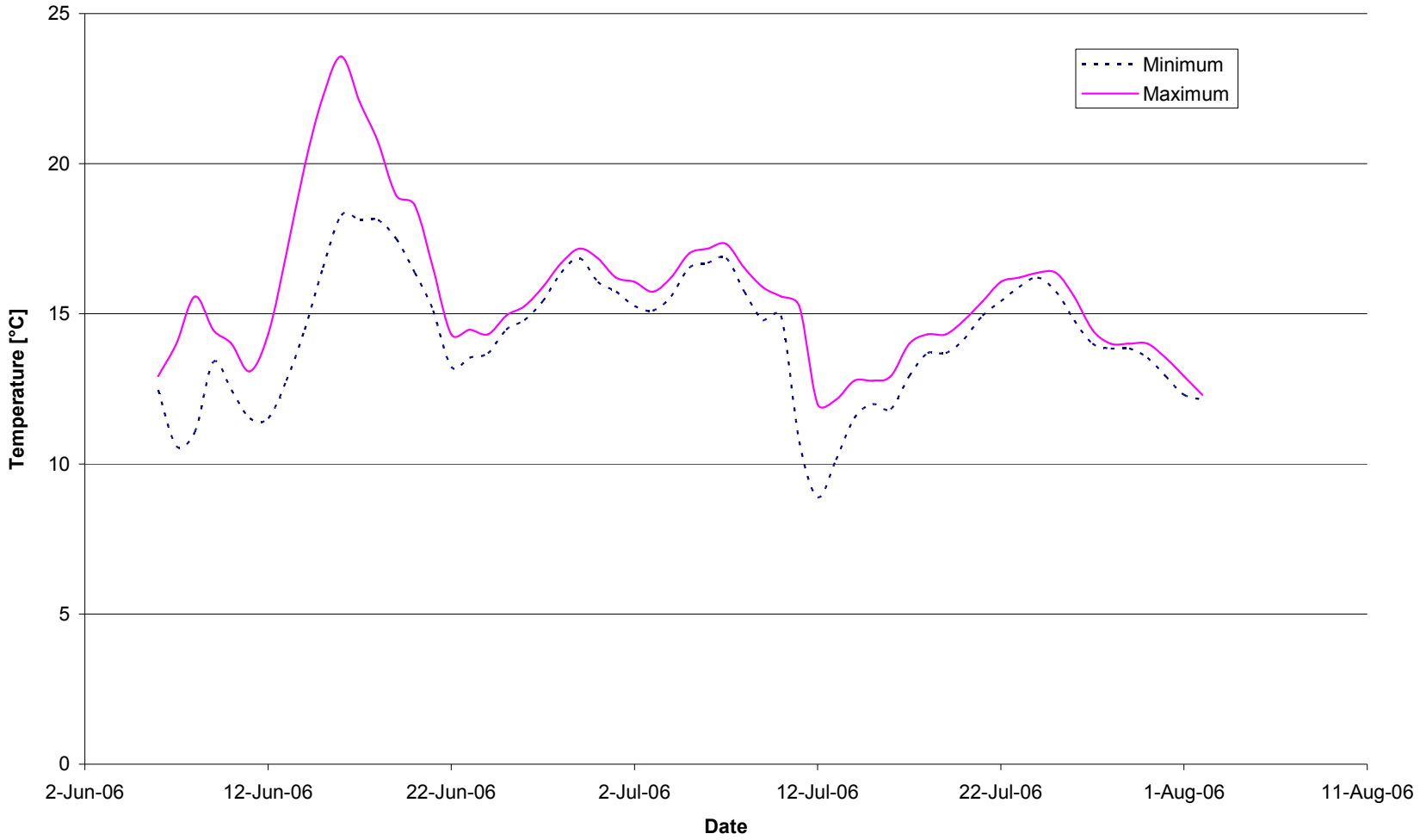
TITLE

WATER TEMPERATURE MONITORING RESULTS, EYMUNDSON CREEK (SITE 6)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 6
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07	**FIGURE: S-17**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-18_Water Temp Monitoring Results, Asphalt Creek (Site 5).dwg Nov 30, 2007 - 3:13pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

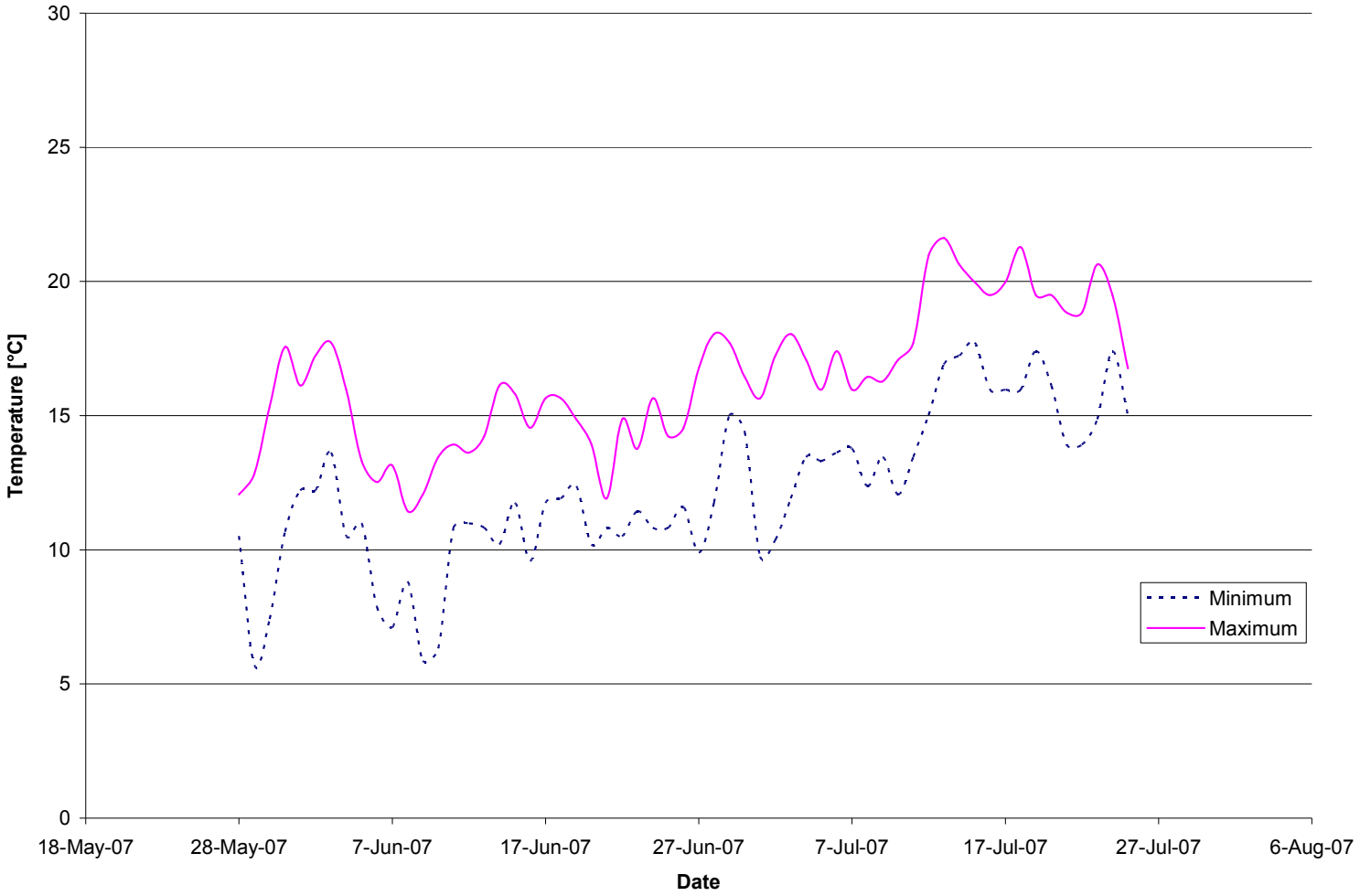
TITLE

WATER TEMPERATURE MONITORING RESULTS, ASPHALT CREEK (SITE 5)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 5
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07	**FIGURE: S-18**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-19_Water Temp Monitoring Results, Asphalt Creek (Site 48).dwg Nov 30, 2007 - 3:15pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, ASPHALT CREEK (SITE 48)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 48
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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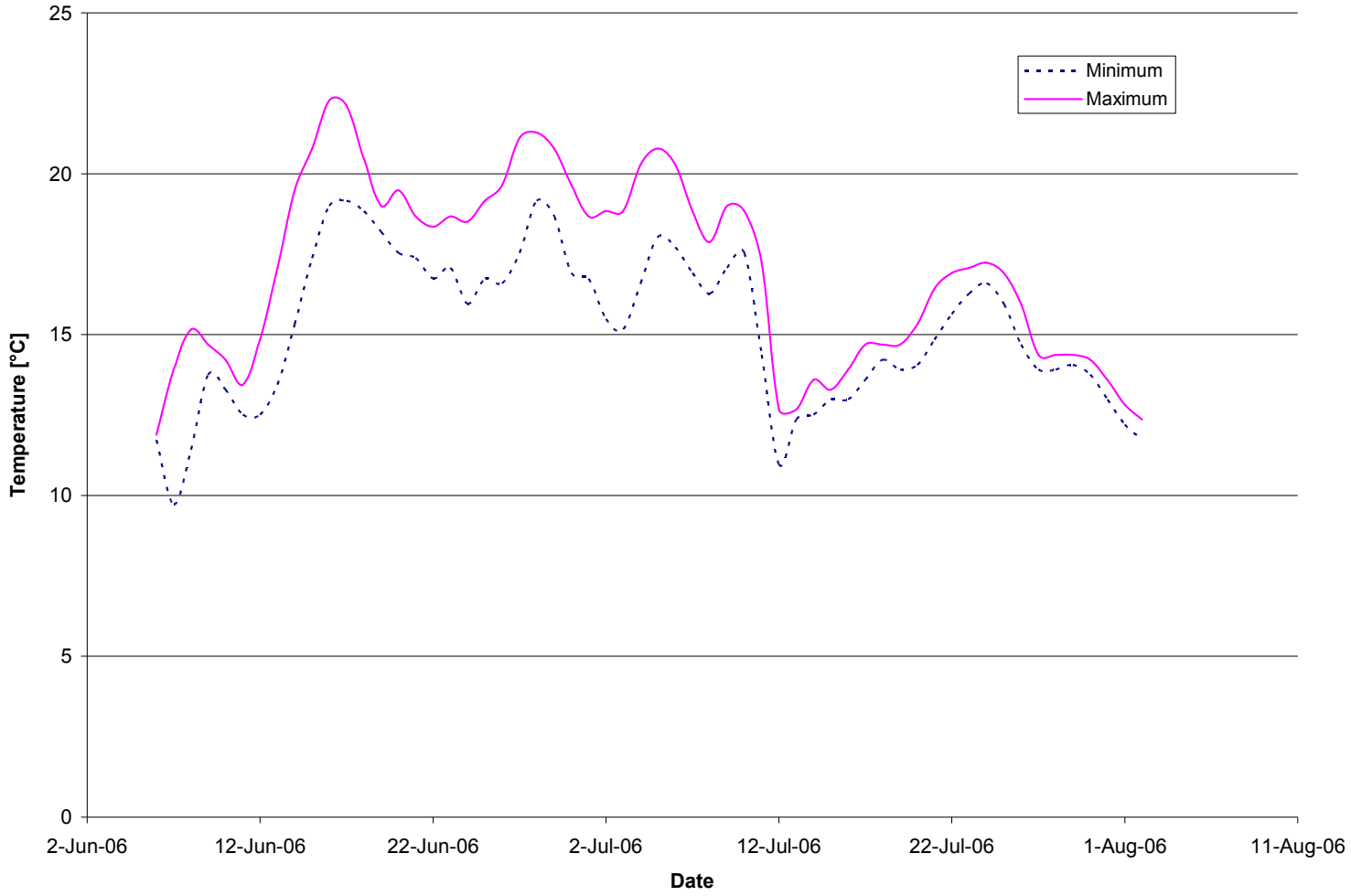
CHECK	OM	19/11/07		
REVIEW	WES/TC	20/11/07		

FIGURE: S-19



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

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Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 15
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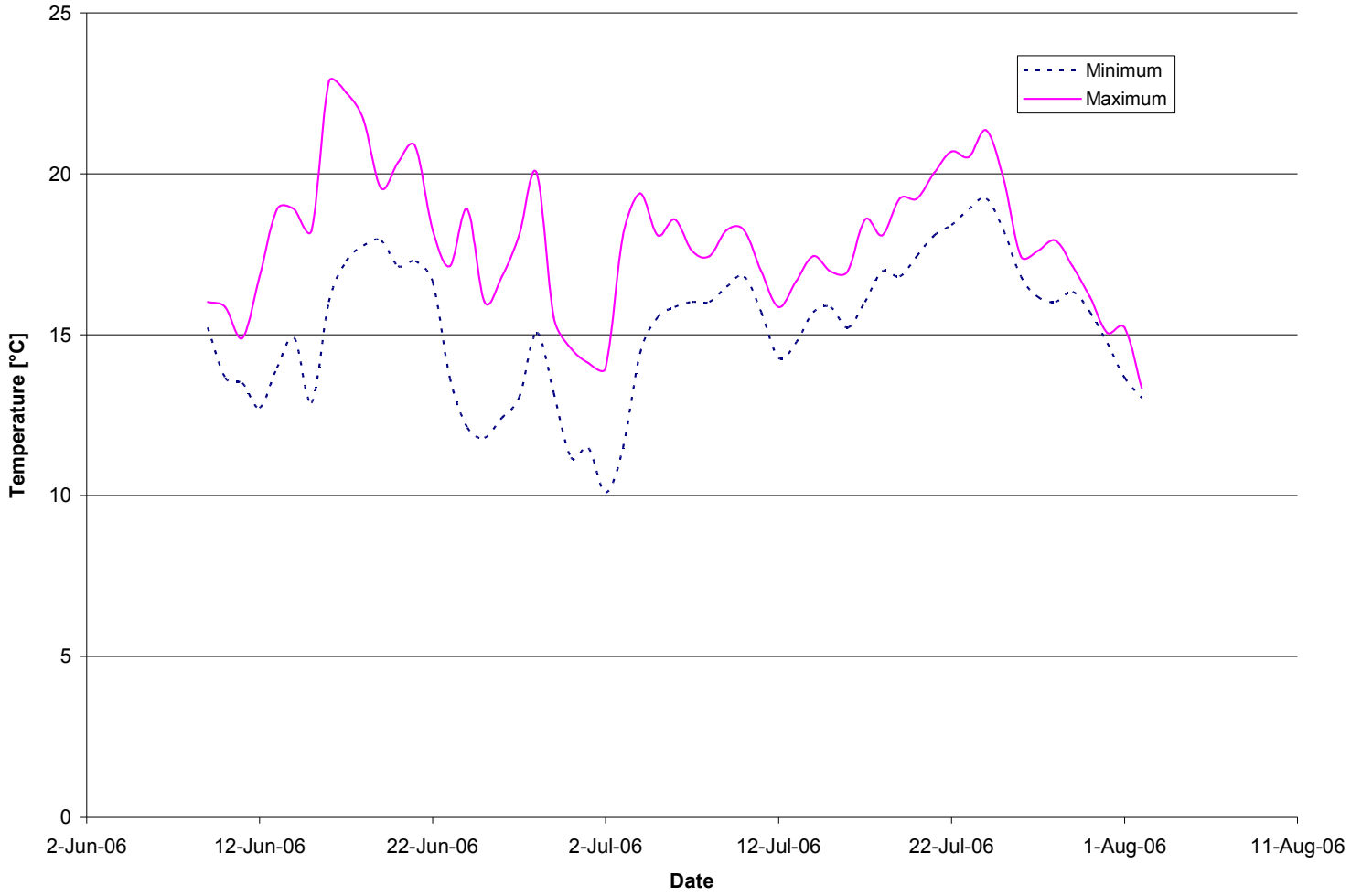

PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 11 (SITE 12)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 12
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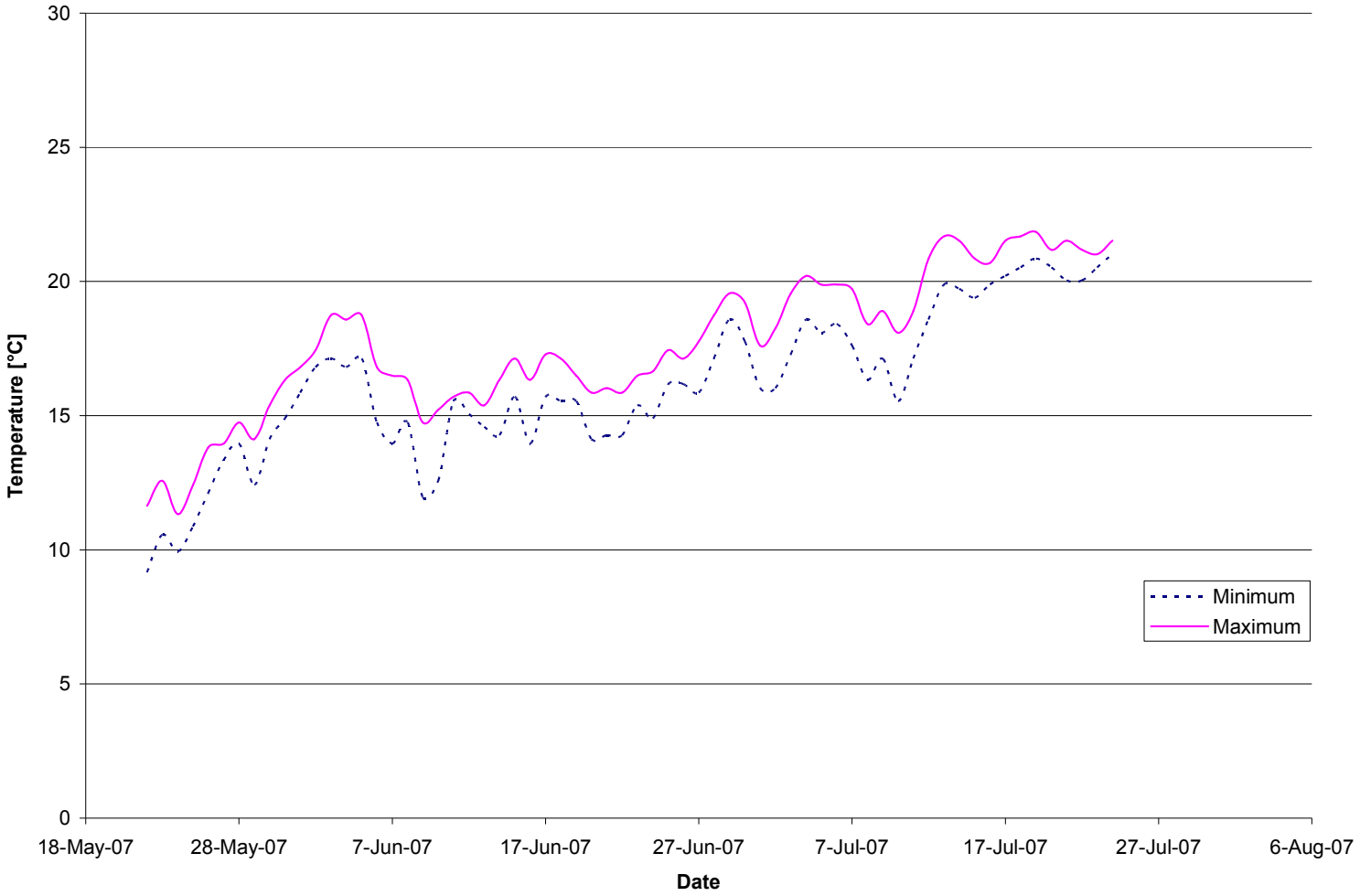

PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED WATERBODY 6 (SITE 2)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 2
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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REVIEW	WES/TC	20/11/07		

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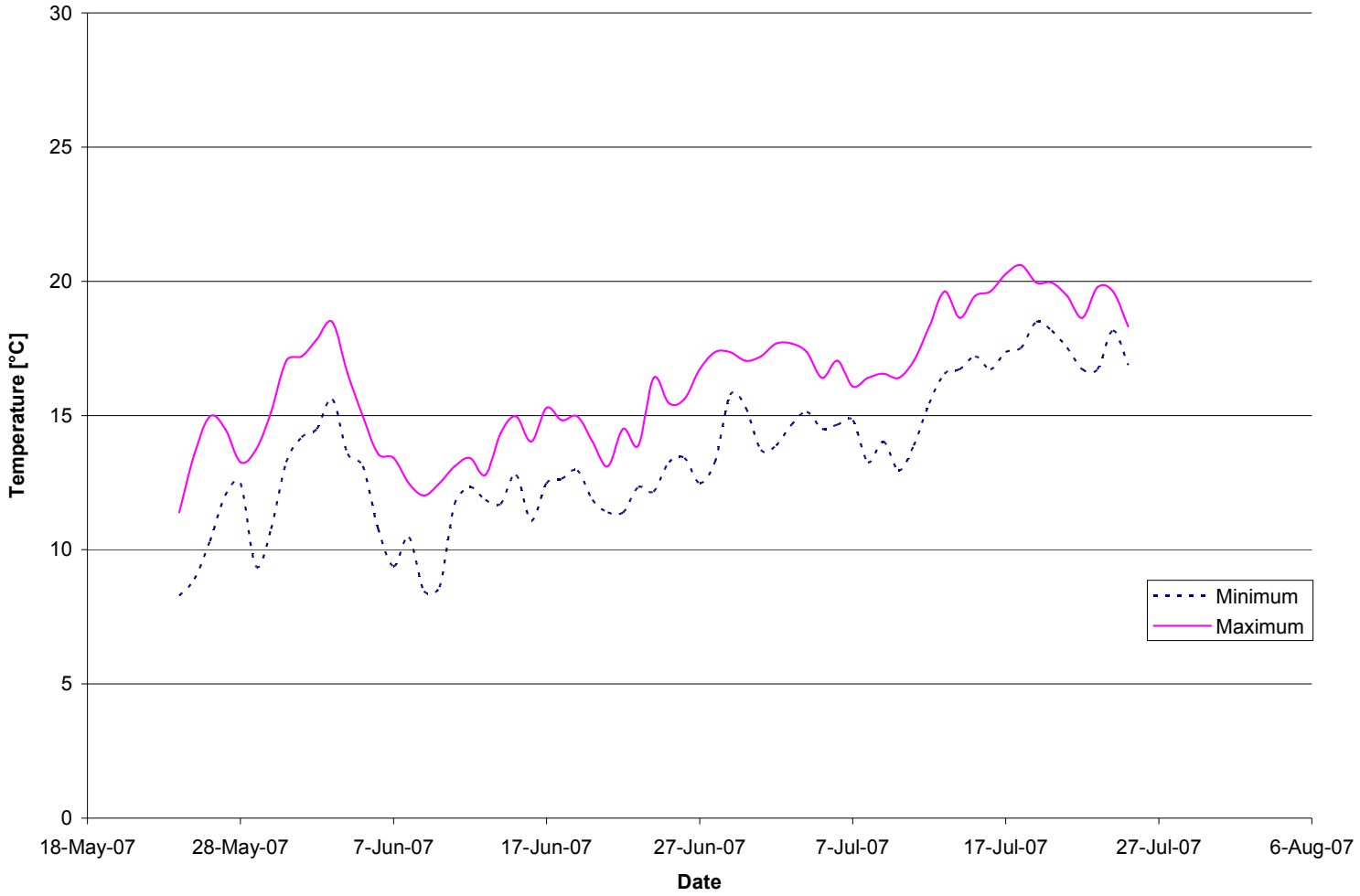

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, BIG CREEK (SITE 42)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 42
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REVIEW	WES/TC	20/11/07		

FIGURE: S-23

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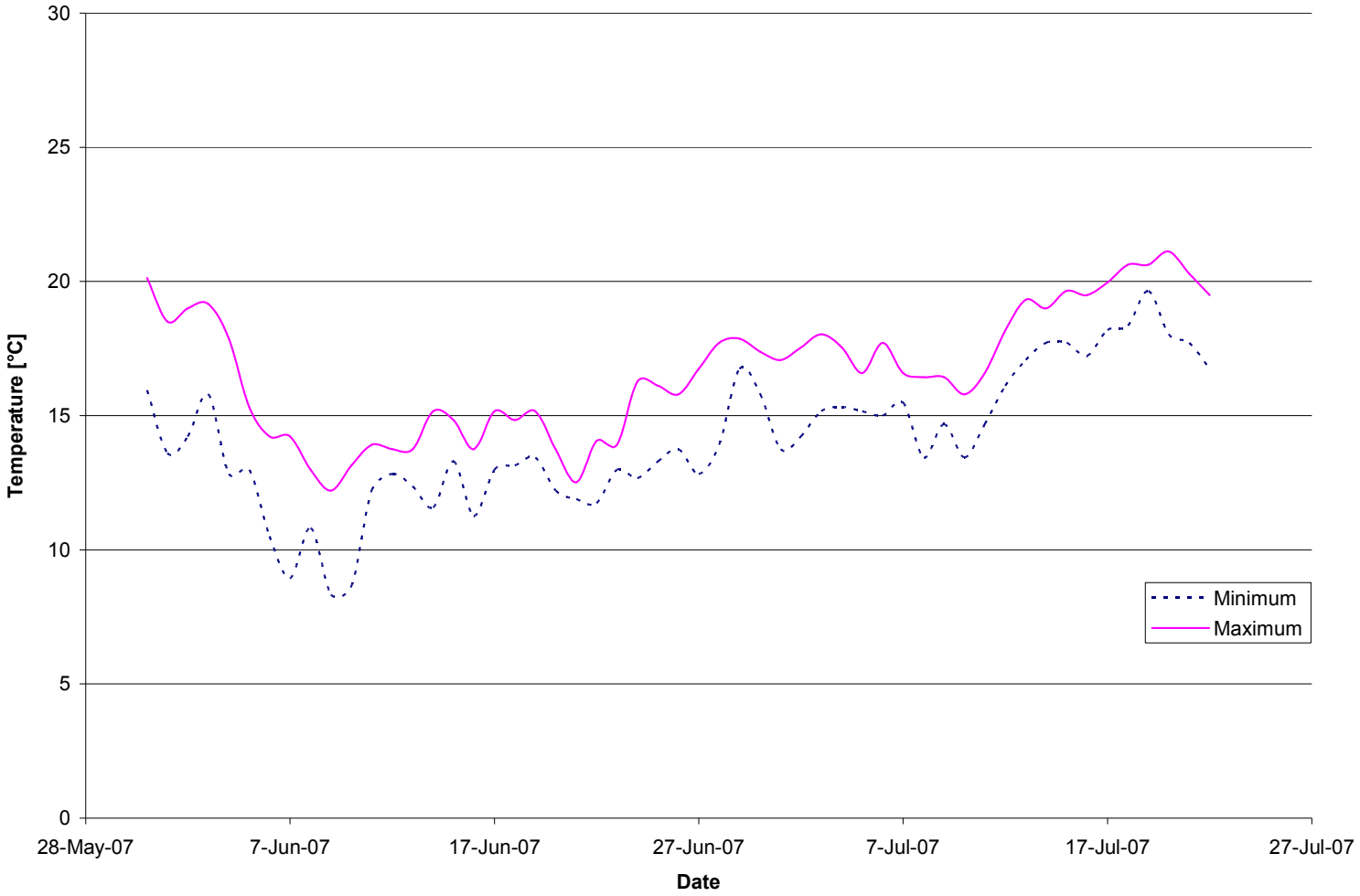

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, BIG CREEK (SITE 1)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 1	
DESIGN	OM	17/11/07	SCALE	AS SHOWN	REV. 0
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CHECK	OM	19/11/07			
REVIEW	WES/TC	20/11/07			

FIGURE: S-24

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-25_Water Temp Monitoring Results, Big Creek (Site 47).dwg Nov 29, 2007 - 4:57pm

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, BIG CREEK (SITE 47)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 47
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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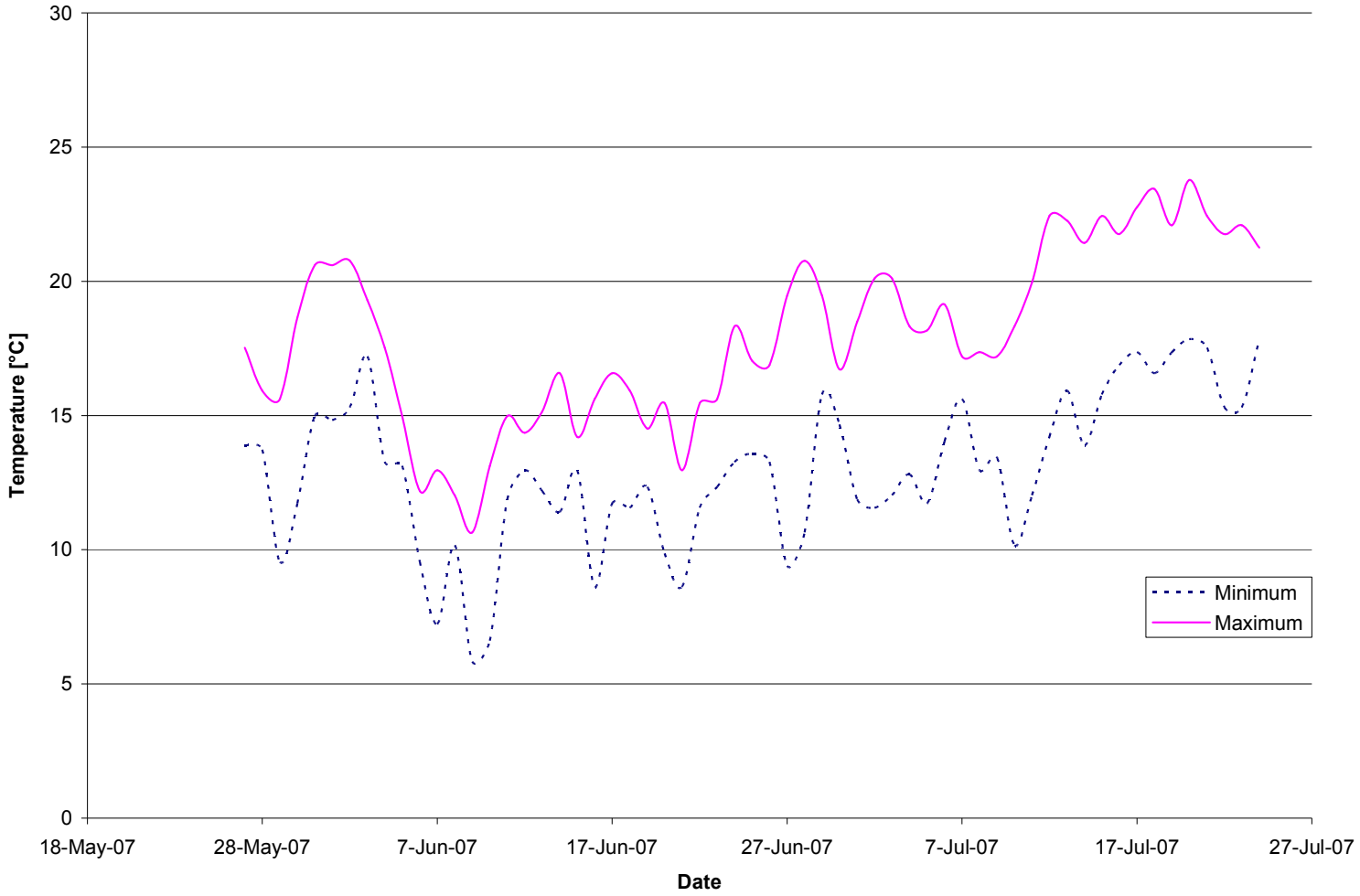
FIGURE: S-25

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-26_Water Temp Monitoring Results, First Creek (Site 9).dwg Nov 29, 2007 - 4:57pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, FIRST CREEK (SITE 9)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 9
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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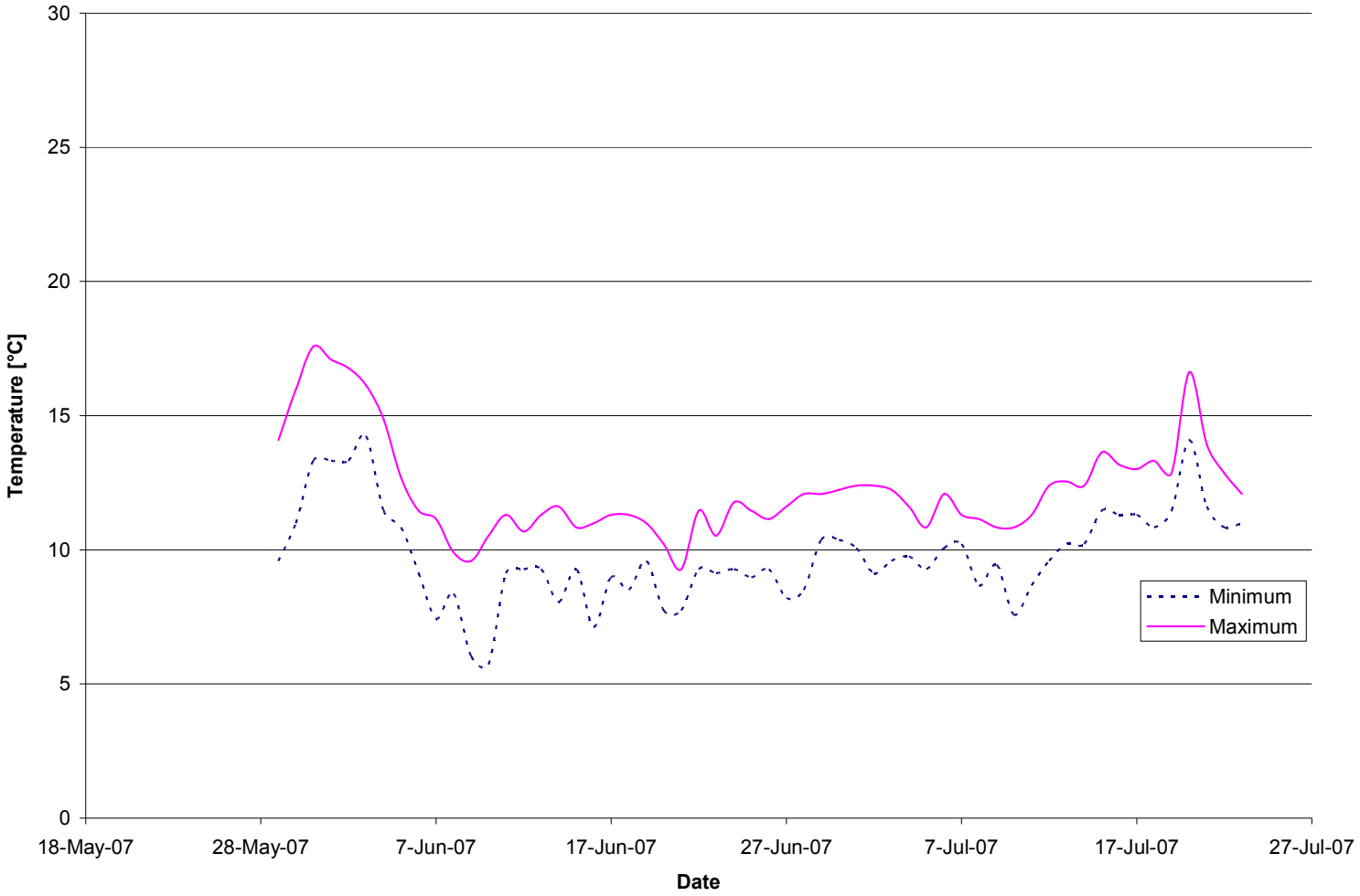
CHECK	OM	19/11/07	**FIGURE: S-26**	
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED CREEK 2 (SITE 44)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 44
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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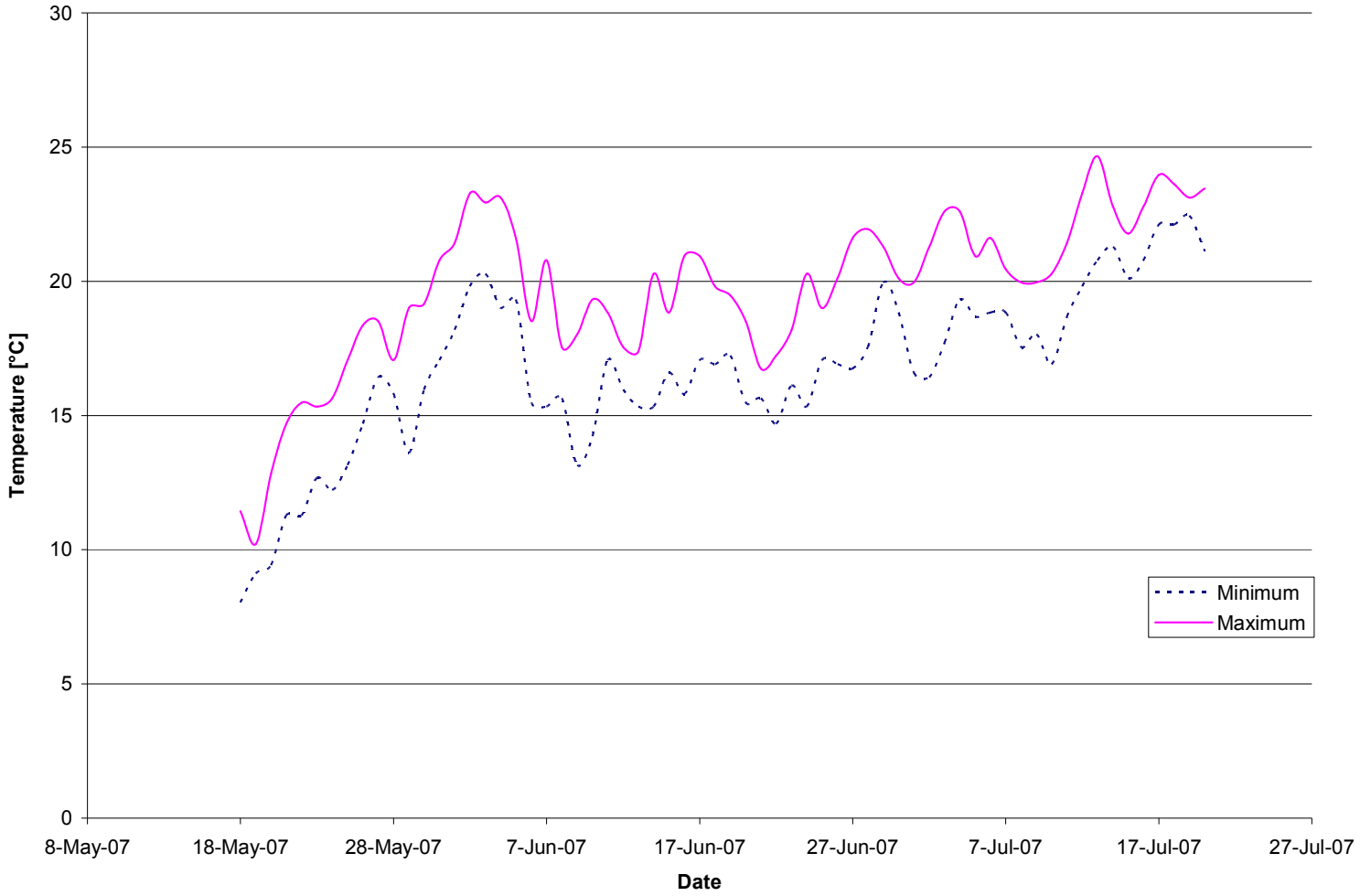
CHECK	OM	19/11/07	**FIGURE: S-27**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-28_Water Temp Monitoring Results, Unnamed Waterbody 15 (Site 4).dwg Nov 29, 2007 - 4:58pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED WATERBODY 15 (SITE 4)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 4
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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CHECK	OM	19/11/07		
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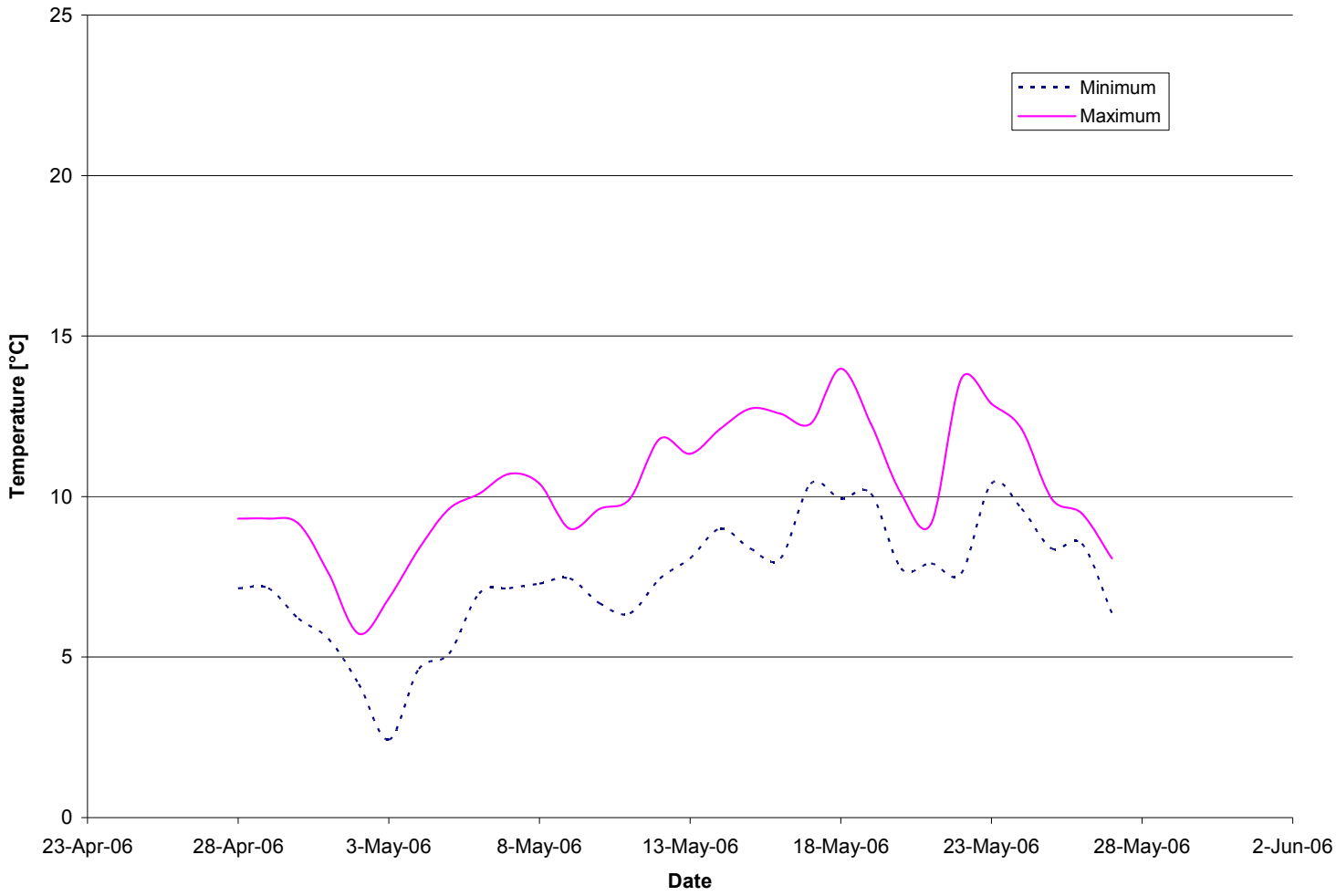
FIGURE: S-28

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-29_Water Temp Monitoring Results, Redclay Creek, 2006 (Site 201-Thermograph A).dwg Nov 29, 2007 - 4:59pm



PROJECT

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PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, REDCLAY CREEK, 2006 (SITE 201-THERMOGRAPH A)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No. Water Temp-Site 201	
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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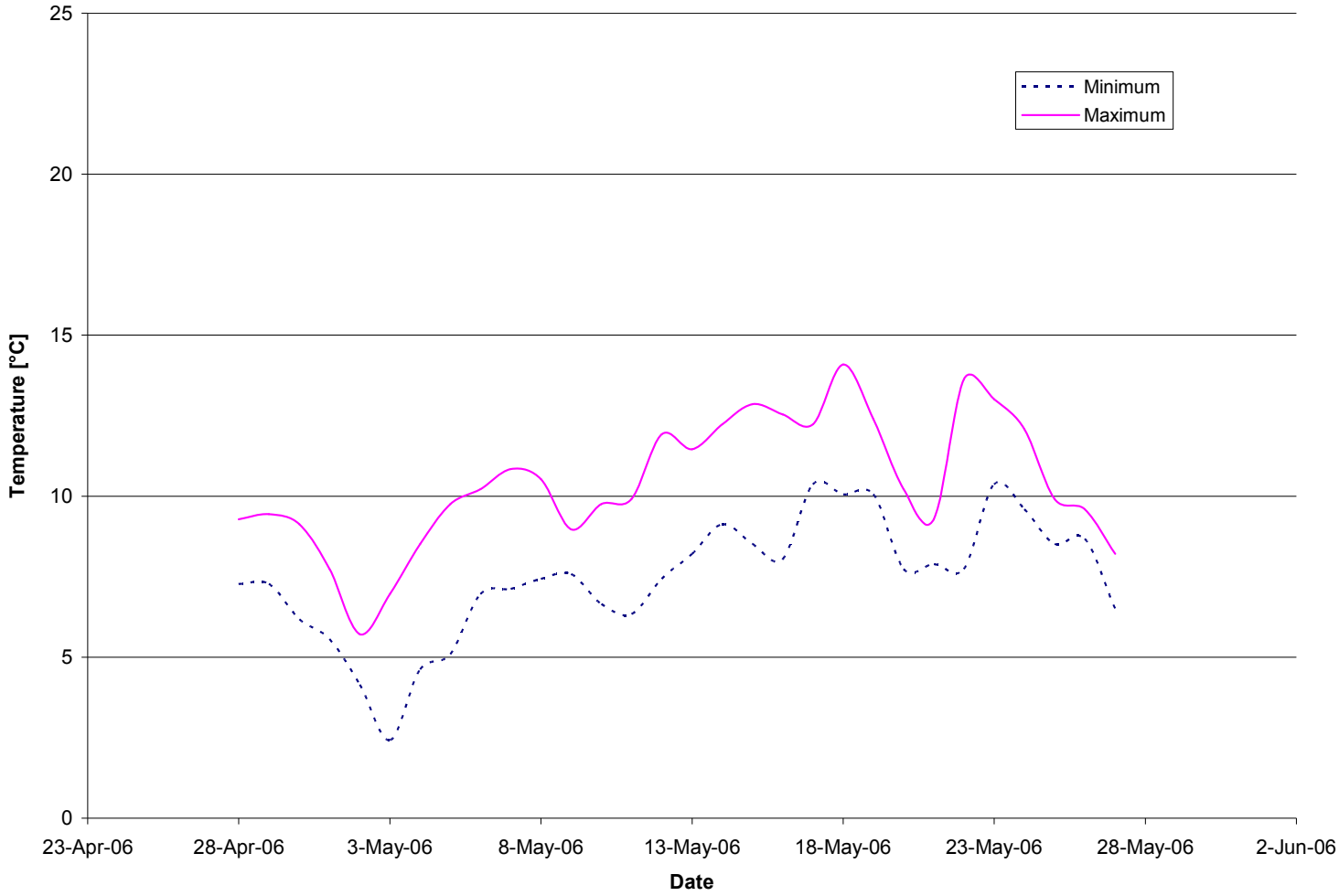
CHECK	OM	19/11/07	**FIGURE: S-29**	
REVIEW	WES/TC	20/11/07		



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, REDCLAY CREEK, 2006 (SITE 201-THERMOGRAPH B)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No. Water Temp-Site 201	
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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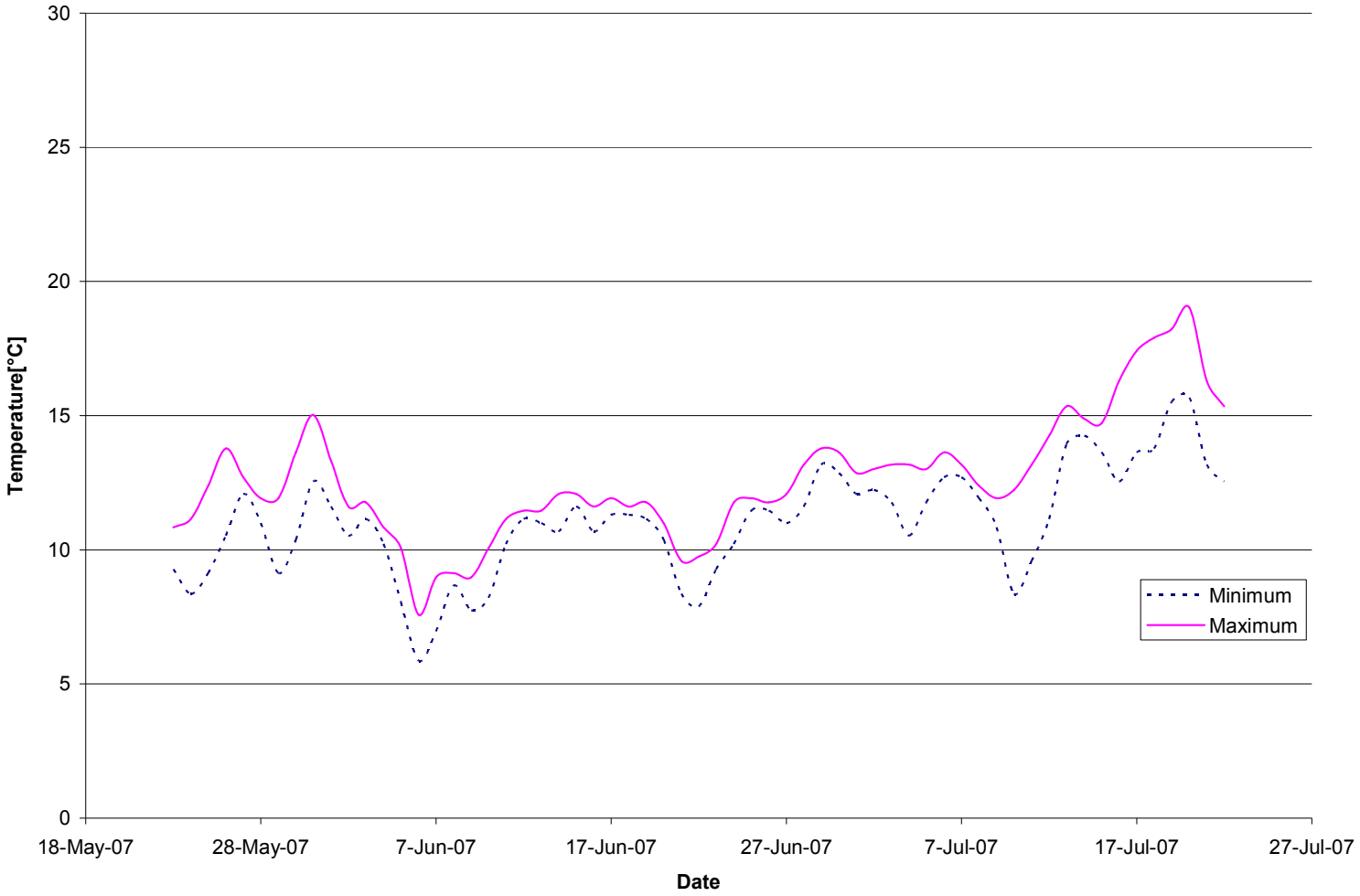
CHECK	OM	19/11/07	**FIGURE: S-30**	
REVIEW	WES/TC	20/11/07		

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig S-31_Water Temp Monitoring Results, Redclay Creek, 2007 (Site 201).dwg Nov 29, 2007 - 5:00pm



PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, REDCLAY CREEK, 2007 (SITE 201)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No. Water Temp-Site 201	
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
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CHECK	OM	19/11/07	**FIGURE: S-31**	
REVIEW	WES/TC	20/11/07		

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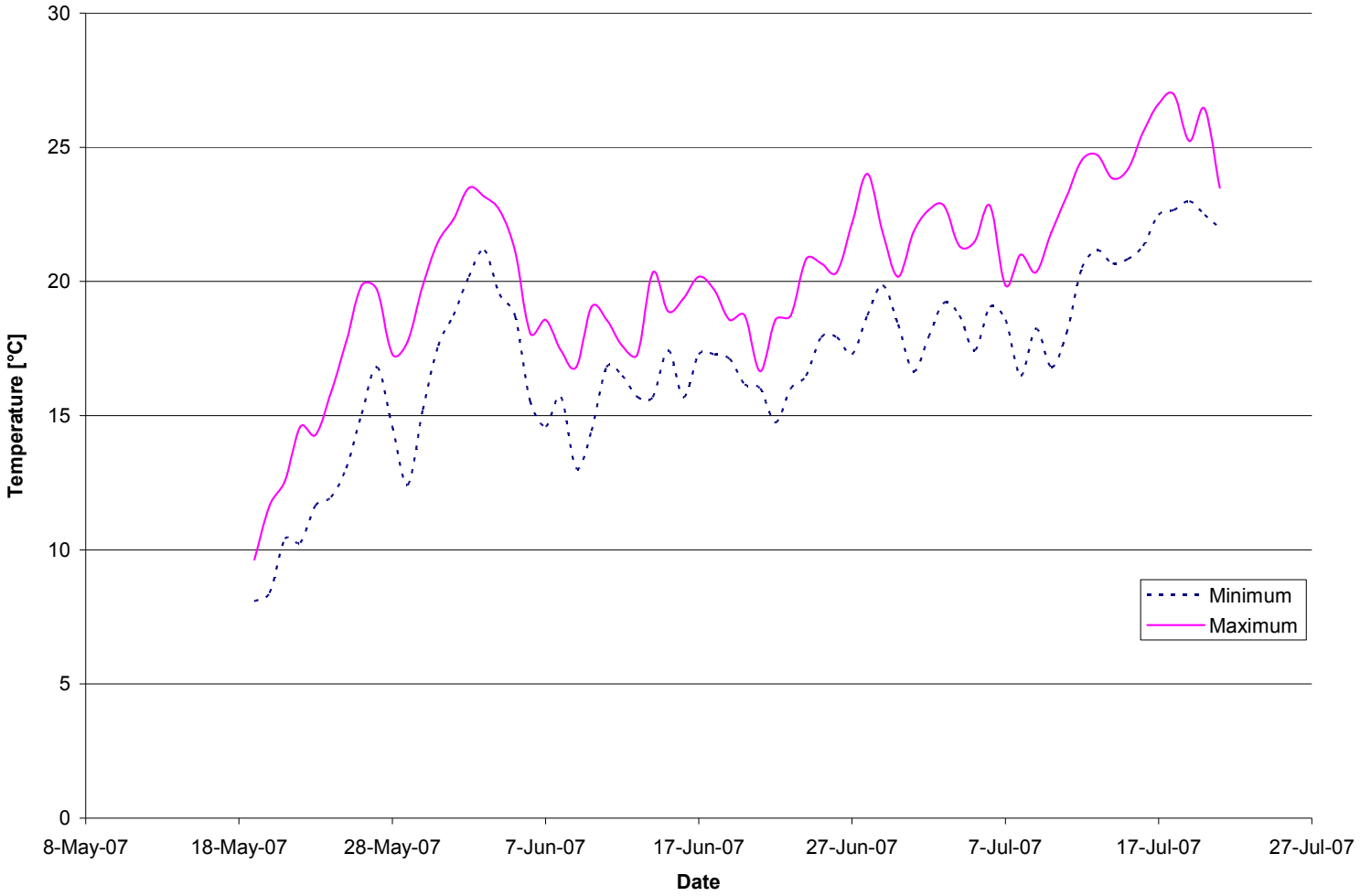

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

WATER TEMPERATURE MONITORING RESULTS, UNNAMED WATERBODY 13 (SITE 53)

Shell Canada Limited

PROJECT	05.1344.027.6100		FILE No.	Water Temp-Site 53
DESIGN	OM	17/11/07	SCALE AS SHOWN	REV. 0
CADD	TRE	19/11/07		
CHECK	OM	19/11/07	**FIGURE: S-32**	
REVIEW	WES/TC	20/11/07		

Golder Associates Ltd.

1000, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
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APPENDIX T

FISH FENCE PHOTOS

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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Photo 2 - Side view of Pierre River fish counting fence, May 2006.

Photo 3 - View inside trap box at Pierre River fish counting fence, May 2006.

Photo 4 - Downstream view of Redclay Creek fish counting fence, May 2006.

Photo 5 - Upstream view of Redclay Creek fish counting fence, May 2006.

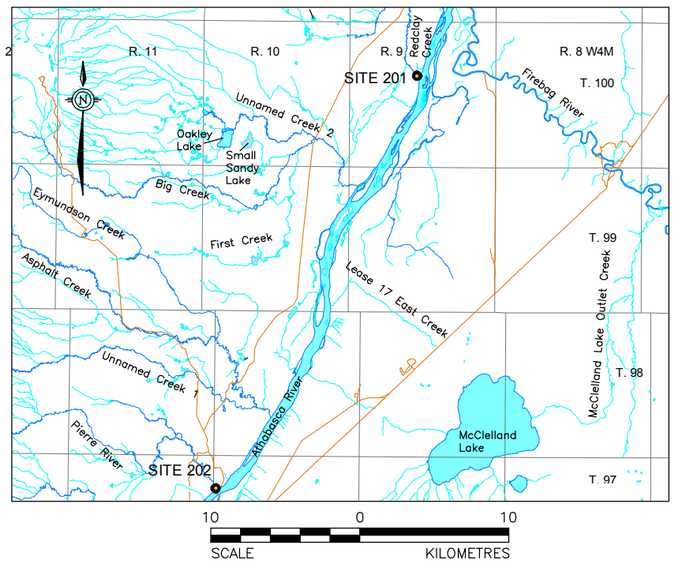

Photo 6 - Downstream view of fyke net at Redclay Creek fish counting fence, May 2007.

Photo 7 - View of fyke net at Redclay Creek fish counting fence, May 2007.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

FISH COUNTING FENCE AT PIERRE RIVER AND REDCLAY CREEK

Shell Canada Limited

PROJECT 05-1344-027.6190			FILE No.	Fish Fence Photos
DESIGN	MK	14/09/07	SCALE AS SHOWN	REV. 0
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CHECK	KM	17/09/07		
REVIEW	WES	30/11/07		

FIGURE: T-1

L:\2005\1344-OIL SANDS\05-1344-027-Shell Omnibus\6100\6190\Fig T-1_Fish Counting Fence at Pierre River and Redclay Creek.dwg Nov 30, 2007 - 7:43pm

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APPENDIX U

RAW BENTHIC INVERTEBRATE DATA

Submitted to:
Shell Canada Limited

Prepared by:
Golder Associates Ltd.

December 2007 **05-1344-027**

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, ASIA AND AUSTRALIA

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1 INTRODUCTION

This appendix contains raw data and species lists for benthic invertebrate data collected in the Jackpine Expansion Mining Area (JEMA) and the Pierre River Mining Area (PRMA) during the environmental setting surveys for the Project as described in the Fish and Fish Habitat Environmental Setting Report.

Figures U-1 and U-2 show the benthic invertebrate sites in JEMA and PRMA sampled during the environmental setting surveys. Data for these sites are included in Tables U-1 to U-6.

Tables U-1 to U-6 contain raw benthic invertebrate abundance data (number of organisms/per sample), date sampled and sampling device used for each site sampled for benthic invertebrates during the environmental setting surveys. These tables are separated by watersheds within the JEMA and PRMA.

Tables U-7 to U-10 contain taxa lists of the benthic invertebrates present in each watershed. Table V-8 also includes historical data for benthic invertebrate taxa present in the Muskeg River watershed.

Tables U-11 and U-12 contain results of the quality control methods from the benthic invertebrate taxonomist to measure sorting efficiency for samples from the 2005 and 2006 environmental setting surveys.

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–							40	10		8
Oligochaeta	Tubificidae	–	–		1	20						1	1
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*							2	11		
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*									1	
Nematoda	–	–	–	20					8	24	20		
Gastropoda	Ancylidae	–	*Ferrissia*							1			
Gastropoda	Hydrobiidae (d)	–	–			10		5					
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–			10			4	8			1
Gastropoda	Planorbidae	–	*Gyraulus*						4	2		1	
Gastropoda	Planorbidae	–	*Helisoma*								1		
Gastropoda	Planorbidae	–	*Menetus cooperi*								20		
Gastropoda	Valvatidae	–	*Valvata sincera*						28	14	31		
Pelecypoda	Sphaeriidae	–	–	3	6	12	4	1	4	32	73		
Hydracarina	–	–	–		20	10			8	24	10		1
Ostracoda	–	–	–	80	90	110	20	15	64	72	10	20	24
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–						32	48	20	22	16
Cladocera	Chydoridae	–	–						80	80	30	20	24
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–							8		10	

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006 (continued)

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Copepoda – Cyclopoida	–	–	–	30	40	20		5	32	112	70	60	64
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*						36		9	18	24
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*							1			
Ephemeroptera	Caenidae	–	*Caenis*						120	23	20	7	27
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*						4				
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006 (continued)

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*						4	1			1
Trichoptera	Polycentropodidae	–	*Polycentropus*						4	5	13		2
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006 (continued)

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*						20	14	20	5	19
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*									2	
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*	76	22	11	5	20	12		22	3	9
Diptera	Chironomidae	Chironomini	*Cladopelma*	315	230	310	70	125	16	8			8
Diptera	Chironomidae	Chironomini	*Cryptochironomus*	1		1							
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*		10			5					9
Diptera	Chironomidae	Chironomini	*Endochironomus*			10	5		8				
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006 (continued)

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*		1	1			4				
Diptera	Chironomidae	Chironomini	*Parachironomus*		10	10	10				10		
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*							17	10		
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–						4	8			
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*						8	16	10		
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Micropsectra*										
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*						12				8
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	15	30	20		10	128	32	20	12	40
Diptera	Chironomidae	Orthocladiinae (d)	–								10		
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*							8			
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-1 Benthic Invertebrate Data Collected in the McClelland Lake Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 and 2006 (continued)

			Watershed	McClelland Lake Watershed									
			River/stream	Unnamed Creek 13					Unnamed Waterbody 4				
			Original Site	22	22	22	22	22	54	54	54	54	54
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	20					176	201	120	10	136
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–						16		20		8
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*		20				12	25	10	1	8
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*							1			
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*	38	128	127	16	83	88	69	76	42	20
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*	1	5	1		2					
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**599**	**613**	**683**	**130**	**271**	**936**	**896**	**676**	**235**	**458**

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005

			Watershed	Muskeg River Watershed										
			River/stream	Muskeg River					Wapasu Creek					
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–				20		100	20	20	25	280
Oligochaeta	Lumbriculidae	–	–		12		15	1			12		
Oligochaeta	Naididae	–	–		10				60	20		5	
Oligochaeta	Tubificidae	–	–		30	5	85	15	122	62	60	10	240
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*	1			1		1				
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*		3	1							
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–		30				40	10	10	5	40
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*					2					
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*	1	1								
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*				1	1					
Pelecypoda	Sphaeriidae	–	–				5	5	6	7	11	6	4
Hydracarina	–	–	–		10	5	90						
Ostracoda	–	–	–	36	160	75	90	120	20	40	20		
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–			5							
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										
Copepoda – Cyclopoida	–	–	–				20	25		20	10	5	

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Muskeg River					Wapasu Creek				
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Harpacticoida	–	–	–	4	30				20				
Amphipoda	Gammaridae	–	*Gammarus lacustris*	1	1			3	1				
Amphipoda	Talitridae	–	*Hyalella azteca*	11	58		17	50					
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										
Plecoptera	Chloroperlidae	–	*Sweltsa*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Muskeg River					Wapasu Creek				
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										1
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										1
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*						1				
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*							2			
Hemiptera	Corixidae	–	*Sigara*							1			
Neuroptera	Sialidae	–	*Sialis*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Muskeg River					Wapasu Creek				
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*								10		40
Diptera	Empididae	–	*Chelifera*									5	
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–							30	10	10	
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*		1		7				1		
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*						20				
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*						2		1		5
Diptera	Tipulidae (d)	–	–								10		
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*						1				41
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–								10		
Diptera	Chironomidae	Chironomini	*Chironomus*		1					10			
Diptera	Chironomidae	Chironomini	*Cladopelma*	20	20	35	10						
Diptera	Chironomidae	Chironomini	*Cryptochironomus*					1					
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*						1				
Diptera	Chironomidae	Chironomini	*Dicrotendipes*	8	30			17					
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Muskeg River					Wapasu Creek				
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Chironomini	*Microtendipes*				2						
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*								50	10	
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*				20			20	40	5	40
Diptera	Chironomidae	Chironomini	*Phaenopsectra*	8					60			5	
Diptera	Chironomidae	Chironomini	*Polypedilum*								20		120
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*						1				1
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	8	100	20	5	30	20				
Diptera	Chironomidae	Tanytarsini	*Micropsectra*		20		6		182	120	100	50	240
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*							10			
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	8	40	15	70	65	40	30	110	15	120
Diptera	Chironomidae	Orthocladiinae (d)	–								10	15	
Diptera	Chironomidae	Orthocladiinae	*Brillia*							50			40
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*	4		5							
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*						20	20	50	10	80
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*							10			
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Muskeg River					Wapasu Creek				
			Original Site	24	24	24	24	24	38	38	38	38	38
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*							10			
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										40
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*						20			5	80
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–								10	5	80
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*		10	5	10	15				5	
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*						20		10		
Diptera	Chironomidae	Tanypodinae	*Procladius*	8	2	36	25	25			1		40
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**118**	**569**	**207**	**499**	**375**	**758**	**492**	**586**	**196**	**1,533**

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–										20
Oligochaeta	Lumbriculidae	–	–				1	1	5	1			
Oligochaeta	Naididae	–	–			10				10		20	
Oligochaeta	Tubificidae	–	–			90	20	15	5		10	20	40
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*			1		1				2	
Nematoda	–	–	–	10	11		11			3	20		
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–						5	5		20	
Gastropoda	Lymnaeidae	–	–									1	
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*								1		
Gastropoda	Planorbidae (d)	–	–			10				1	1	10	
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*		10					1	13		
Pelecypoda	Sphaeriidae	–	–	10		21		10	5	4	10		10
Hydracarina	–	–	–							11			60
Ostracoda	–	–	–		40	40	20	30	90	158	280	320	460
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–							12	60		20
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Copepoda – Cyclopoida	–	–	–	10					5	12		60	70
Copepoda – Harpacticoida	–	–	–						40	10	100		80
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*		4		3	1					
Collembola	–	–	–							10			
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*							1			
Trichoptera	Limnephilidae	–	*Nemotaulius*		2			1					
Trichoptera	Phryganeidae	–	*Ptilostomis*								1		
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*							5			
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–								10		
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*							1	21	11	21
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*							11			
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*								10		
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*	10									
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–		20		10						
Diptera	Chironomidae	Chironomini	*Chironomus*				1						
Diptera	Chironomidae	Chironomini	*Cladopelma*		20	20	10	30	55		40	20	10
Diptera	Chironomidae	Chironomini	*Cryptochironomus*					1	56	1			
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*		10	1				2			
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*	20	8	5	19	5	1				
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*	10		10		10					
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*	2	27	79	15	7					
Diptera	Chironomidae	Chironomini	*Stenochironomus*					10					
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*				10			49	50	20	40
Diptera	Chironomidae	Tanytarsini	*Micropsectra*	10	91	191	144	41	24	12		10	
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*		20		10						
Diptera	Chironomidae	Tanytarsini	*Stempellinella*				10						
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	10	1	60	10	20	92	115	320	270	320
Diptera	Chironomidae	Orthocladiinae (d)	–			10				10			
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*					5			20		
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-2 Benthic Invertebrate Data Collected in the Muskeg River Watershed During Environmental Surveys Conducted for the Jackpine Expansion Mining Area, Fall 2005 (continued)

			Watershed	Muskeg River Watershed									
			River/stream	Wapasu Creek					Unnamed Creek 9				
			Original Site	32	32	32	32	32	35B	35B	35B	35B	35B
			Date	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct	13-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*							11	10	50	31
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*						1	1	30		
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*						10	13	90	70	80
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*						1				
Diptera	Chironomidae	Tanypodinae (d)	–			1				1	20		10
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*						2	14	160	60	31
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*		21	6	3	20	21	33	260	354	242
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										1
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.				1			1			
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–	10		10							
			TOTAL	**102**	**285**	**565**	**298**	**208**	**418**	**519**	**1,537**	**1,318**	**1,546**

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–			70	60	20					
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–			30							8
Oligochaeta	Tubificidae	–	–	310	83	178	106	51		4	8	2	26
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*			1							
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–	20		20	1	20	1	1			2
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–				20						
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*	1									
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–					10				2	
Hydracarina	–	–	–										
Ostracoda	–	–	–	20		30				5	4	6	
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–		20								
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										
Copepoda – Cyclopoida	–	–	–	20	40		20	10	1				

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 (continued)

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*		20								
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–		1		1		1				
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										1
Plecoptera	Chloroperlidae	–	*Sweltsa*										

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 (continued)

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*	1									
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*					1					
Coleoptera	Haliplidae	–	*Haliplus*		4	21							
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										
Neuroptera	Sialidae	–	*Sialis*										

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 (continued)

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Dolichopodidae	–	*Rhaphium*	1							1		
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*			3							
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–		46	51	101	50					
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*	1	20			1					
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*		120								
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*	1		1	4					1	
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–		40	10	40	30				1	
Diptera	Chironomidae	Chironomini	*Chironomus*	5		1							
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*	1	3	10	1						
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 (continued)

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*								1		
Diptera	Chironomidae	Chironomini	*Paratendipes*				140						
Diptera	Chironomidae	Chironomini	*Phaenopsectra*					10					
Diptera	Chironomidae	Chironomini	*Polypedilum*		20		60	20	1			3	
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*	60	20		21						
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*									3	1
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*		20				3				
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*		20								
Diptera	Chironomidae	Tanytarsini	*Micropsectra*	80	760	60	100	180	1				
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*			10			2				
Diptera	Chironomidae	Tanytarsini	*Stempellina*		20								
Diptera	Chironomidae	Tanytarsini	*Stempellinella*	40	240								
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	60	1,340	60	140	110	14		1		
Diptera	Chironomidae	Orthocladiinae (d)	–		40		40		4	1		1	4
Diptera	Chironomidae	Orthocladiinae	*Brillia*						1				
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*		40	20	100	20	2	1			4
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*					10					
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*						4				

Table U-3 Benthic Invertebrate Data Collected in the Pierre River Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 (continued)

			Watershed	Pierre River Watershed									
			River/stream	Pierre River									
			Original Site	19-1	19-1	19-1	19-1	19-1	20-1	20-1	20-1	20-1	20-1
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*	40					1				
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*						3				
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*	40			20						
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*		60	40	20		6				
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–		60		20	10	2		1		
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*		41	10	20	60					
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*	180	644	202	120	191					
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.	20	20	10							
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–				20	1					
			TOTAL	**901**	**3,742**	**838**	**1,175**	**805**	**47**	**12**	**16**	**19**	**46**

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–		1								
Oligochaeta	Naididae	–	–		10		40	8	16	104		141	
Oligochaeta	Tubificidae	–	–	46	34	63	11	34	9	11		40	11
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*		1						1		
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*			1							1
Nematoda	–	–	–						120	72	474	141	10
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*		1								
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–	83	20		10	1			8	20	
Hydracarina	–	–	–	40	10				16				10
Ostracoda	–	–	–	680	190	660	830	192	336	272	32	460	200
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–		10								
Cladocera	Chydoridae	–	–						32	176		20	
Cladocera	Macrothricidae	–	–							96		80	
Copepoda – Calanoida	–	–	–										
Copepoda – Cyclopoida	–	–	–	160	40	20	10	24	120	536	56	320	90

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*	3						1		3	1
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*							2			
Ephemeroptera	Caenidae	–	*Caenis*										1
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*									2	
Odonata – Anisoptera	Aeshnidae	–	*Anax*					1					
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										
Plecoptera	Chloroperlidae	–	*Sweltsa*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*					1					
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*							2	1	1	
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										
Neuroptera	Sialidae	–	*Sialis*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*						1			3	1
Diptera	Ceratopogonidae	Ceratopogoninae	–							1	8		
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*		10	20	10		8		2	1	
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*		1								
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–					8				1	
Diptera	Chironomidae	Chironomini	*Chironomus*	1		1	10		62	3	32	110	84
Diptera	Chironomidae	Chironomini	*Cladopelma*		10	20	20	8		16	1		
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*							1	1		
Diptera	Chironomidae	Chironomini	*Endochironomus*	128	10	20	10		1			3	1
Diptera	Chironomidae	Chironomini	*Einfeldia*									20	1
Diptera	Chironomidae	Chironomini	*Glyptotendipes*	9			2						

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Chironomini	*Microtendipes*	2						1			
Diptera	Chironomidae	Chironomini	*Parachironomus*					8					
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*		10								10
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–						8				
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	80	10	20	50	16	16	32		21	
Diptera	Chironomidae	Tanytarsini	*Micropsectra*										
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	120			30	16		40		21	21
Diptera	Chironomidae	Orthocladiinae (d)	–					40			8		11
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*			40	30	8				20	
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*								8		
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Upper Eymundson Creek									
			Original Site	6	6	6	6	6	57	57	57	57	57
			Date	15-Oct	15-Oct	15-Oct	15-Oct	15-Oct	01-Oct	01-Oct	01-Oct	01-Oct	01-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*		50		40				16		
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*		1						8		
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										10
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*								1	22	
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*						16	8	8	20	
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–		10			8		8	1	20	
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*							8	8	20	
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*	9	20	21	31	49	10	4	17	44	11
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*									1	
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–							1	8	20	
			TOTAL	**1,361**	**449**	**886**	**1,134**	**422**	**771**	**1,395**	**699**	**1,575**	**474**

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–										
Oligochaeta	Tubificidae	–	–					13	3	1	2	2	2
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–										
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–	3									
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–										
Hydracarina	–	–	–										
Ostracoda	–	–	–										
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–										
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–	4	2								
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*		2								
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*					1					
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*					1					
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*										
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*							1			
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*	4			2	8		1			
Diptera	Chironomidae	Chironomini	*Saetheria*			8							
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*	1	1		1	8					1
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	4									
Diptera	Chironomidae	Tanytarsini	*Micropsectra*										
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*										
Diptera	Chironomidae	Orthocladiinae (d)	–										
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek									
			Original Site	11	11	11	11	11	17	17	17	17	17
			Date	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct	18-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*						1				
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*			30	4	4					
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*				1						
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*										
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–		2		1						
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*										
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–	8									
			TOTAL	**24**	**7**	**38**	**9**	**35**	**4**	**3**	**2**	**2**	**3**

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–				1				1	1	
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–					1					
Oligochaeta	Tubificidae	–	–		2								
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–						3	1	3	2	2
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–										
Hydracarina	–	–	–						2	6	1	5	4
Ostracoda	–	–	–									1	
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–										
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–						1	2	3		
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–								1	2	1
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*						16	36	31	26	16
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–						5		4	1	
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–							1	1		

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–								2		
Plecoptera	Nemouridae	–	*Nemoura*						5	20	14	16	4
Plecoptera	Nemouridae	–	*Zapada*								1		
Plecoptera	Perlodidae	–	*Isoperla*						1	1			
Trichoptera	Brachycentridae	–	*Brachycentrus*						8	10	3	7	2
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*								1		
Trichoptera	Hydropsychidae (d)	–	–								1	3	
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*						3	3	6	3	1
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–						1			1	1
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*								1		
Diptera	Empididae	–	*Chelifera*								1	3	
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*								2	1	
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*							2	1	2	1
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*										1
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*				1		1			2	1
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Micropsectra*										
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*							1			1
Diptera	Chironomidae	Orthocladiinae (d)	–									1	
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*						3	7	9	15	3
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										1
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Lower Eymundson Creek					Asphalt Creek				
			Original Site	17-1	17-1	17-1	17-1	17-1	48	48	48	48	48
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*						1			1	8
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										1
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*			1	6	14					
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*						1	1	3		
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–										
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*										
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–								5	2	
			TOTAL	**0**	**2**	**1**	**8**	**15**	**51**	**91**	**95**	**95**	**48**

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–							77	56	24	8
Oligochaeta	Tubificidae	–	–					2		11	44	56	24
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*							2	2		
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–						28	33	44	32	120
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										8
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–							50	92	112	
Hydracarina	–	–	–						4				32
Ostracoda	–	–	–							57	48	216	88
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–						2		12	40	
Cladocera	Chydoridae	–	–										
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–								8		8

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–							8	16	24	40
Copepoda – Harpacticoida	–	–	–								8		16
Amphipoda	Gammaridae	–	*Gammarus lacustris*							1	2	2	53
Amphipoda	Talitridae	–	*Hyalella azteca*							29	4		
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										1
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										1
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*							3			
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*						46				
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*						5	3	4	3	
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*			1							
Diptera	Tipulidae	–	*Hexatoma / Limnophila*					1					
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*						18		8		17
Diptera	Chironomidae	Chironomini	*Cladopelma*						24		68	16	
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*								24	8	32
Diptera	Chironomidae	Chironomini	*Endochironomus*										72
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*						8	15	48	20	8
Diptera	Chironomidae	Chironomini	*Microtendipes*									1	
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*	1	5	42	1				4	8	
Diptera	Chironomidae	Chironomini	*Saetheria*	4	7		5	1					
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*	5	4	9	13	1					
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*								16		
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*							98	28	80	96
Diptera	Chironomidae	Tanytarsini	*Micropsectra*			1							
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*							126	296	528	136
Diptera	Chironomidae	Orthocladiinae (d)	–										
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										8
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*									32	24
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-4 Benthic Invertebrate Data Collected in the Eymundson Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Eymundson Creek Watershed									
			River/stream	Unnamed Creek 1					Unnamed Waterbody 6				
			Original Site	15-1	15-1	15-1	15-1	15-1	2	2	2	2	2
			Date	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep	02-Oct	02-Oct	02-Oct	02-Oct	02-Oct
			Year	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*							20		8	8
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*	42	11	15	153	46					
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	1						17			
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–										1
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										24
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										8
Diptera	Chironomidae	Tanypodinae	*Procladius*				1		24	3	25	33	
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*						56				
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–	1									
			TOTAL	**54**	**27**	**68**	**173**	**51**	**215**	**553**	**857**	**1,243**	**833**

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–							1			
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–			1			5	8	3	16	
Oligochaeta	Tubificidae	–	–					1			1		
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–						1	1			4
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–										2
Hydracarina	–	–	–						3		9	16	4
Ostracoda	–	–	–								4		4
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–						1		1		
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										
Copepoda – Cyclopoida	–	–	–		4		4	1	3		5	40	8

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Harpacticoida	–	–	–						1				
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*						1		4		
Ephemeroptera	Baetidae	–	*Baetis*	2	2		4		70	52	15	16	53
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*						2	1		8	1
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–	2	2				38	27	54		58
Plecoptera	Chloroperlidae	–	*Sweltsa*								1		

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*	3	5	1	1						
Plecoptera	Nemouridae	–	*Zapada*	2	1				75	76	59	48	138
Plecoptera	Perlodidae	–	*Isoperla*		2		1		3	4	8		1
Trichoptera	Brachycentridae	–	*Brachycentrus*							1		8	
Trichoptera (d)	–	–	–						1				
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–							1			
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–	2	5		1		11	8	12	24	22
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*		1								
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*	1					1	6	6	2	5
Coleoptera	Dytiscidae	–	*Agabus*	1									
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*						1				
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										
Neuroptera	Sialidae	–	*Sialis*										1

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*		1				4	14	11	8	11
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–	1					2	4	6		4
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*						2				
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*	1	2			1	14	18	11	16	48
Diptera	Tipulidae	–	*Hexatoma / Limnophila*		1		1		9	6	5	16	5
Diptera	Tipulidae	–	*Ormosia*						1		1		
Diptera	Tipulidae	–	*Tipula*		1		1						
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*										
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*						2				
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*	11	7		21		3	4			12
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*						1				
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*	1									1
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Micropsectra*						21	15	7		24
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*					2	10	26	9	8	64
Diptera	Chironomidae	Orthocladiinae (d)	–		2	1	2		11	10	4		
Diptera	Chironomidae	Orthocladiinae	*Brillia*		1					2			
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*		4				1		1		
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*						4		1		
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*				1		11	1	2	16	4
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										4
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*					1	19	12	2	8	8

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek									
			Original Site	47	47	47	47	47	44	44	44	44	44
			Date	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*						1	4	1		
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*						2	1			
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*			3		11					
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*							3	1		
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*						2	2			
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*							6	4		28
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–		1				8	3	5	48	2
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*										
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*						1				
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*						1				
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*							1	1		
Terrestrial	–	–	–										
			TOTAL	**27**	**42**	**6**	**37**	**17**	**347**	**318**	**254**	**298**	**516**

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–								50		18
Oligochaeta	Lumbriculidae	–	–							25	40	8	12
Oligochaeta	Naididae	–	–	64	89	111	7	7			20		
Oligochaeta	Tubificidae	–	–	4	1	1		1	441	20	14		34
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*								1		
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–	2	1				60	120	50	100	
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–						47	131	1	13	18
Hydracarina	–	–	–	7	7	3	1		20				
Ostracoda	–	–	–	1		1			340	360	260	180	
Cladocera	Bosminidae	–	*Bosmina*					1					
Cladocera	Daphnidae	–	–						20				
Cladocera	Chydoridae	–	–		2			3					
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–	1	4			9	100	120		100	
Copepoda – Harpacticoida	–	–	–						20	280	90	320	10
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*					1					
Ephemeroptera	Baetidae	–	*Baetis*	8	18	2	3	2					
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–		1								
Ephemeroptera	Heptageniidae	–	*Heptagenia*	5	5	1							
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*			1							
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–					1					
Plecoptera	Capniidae	–	–		4								

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*	1									
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*	1									
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–	3	14	3		1					
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*				1						
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*	1									
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*	1									
Diptera	Dolichopodidae	–	*Rhaphium*								10		
Diptera	Empididae	–	*Hemerodromia*	4	1								
Diptera	Empididae	–	*Chelifera*	2	4	1	1						
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*							1		1	
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*								10		
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*								10		
Diptera	Tabanidae	–	*Chrysops*		1						10		
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*	3	4	1							
Diptera	Tipulidae	–	*Hexatoma / Limnophila*	1	2								
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–						60		10		10
Diptera	Chironomidae	Chironomini	*Chironomus*	1					93			2	8
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*					2					
Diptera	Chironomidae	Chironomini	*Paratendipes*	2									
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*					1					
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*						10	1	12	85	22
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										8
Diptera	Chironomidae	Tanytarsini (d)	–				1						
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*						42	21	41	101	
Diptera	Chironomidae	Tanytarsini	*Micropsectra*	1	3			6	460	3,721	2,370	1,805	372
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*			1		1					
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*	1				1					
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	24	8	5	3	18	40				
Diptera	Chironomidae	Orthocladiinae (d)	–	19	7	2	2	1	40		80	20	
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*	2					60			20	
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*	2	4	2	1	14					
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*	3	1								
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Big Creek					First Creek				
			Original Site	42	42	42	42	42	9-1	9-1	9-1	9-1	9-1
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*	8	3	1					20		
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*	2	4								
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*						1	20		20	
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*		1	1							
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*						25	81	30	4	
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*		1	1							
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*		1	1							
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*		1								
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	3	5				60	280	100	300	26
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–	2				1	1			5	
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*						41		80	85	9
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.		1	1							
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.		2					1			
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**179**	**200**	**140**	**20**	**71**	**1,981**	**5,182**	**3,309**	**3,169**	**547**

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15					
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–					20					
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–	460	284	148	390	340	144	84	264	236	420
Oligochaeta	Tubificidae	–	–	37	66	24	169	113	41	29	42	32	12
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*		1		2						
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*						2				
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*			1	2						
Nematoda	–	–	–	61	120	20	80	40					
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*		1			1					
Gastropoda	Planorbidae (d)	–	–	1	25	4	10	8					
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–	2	27	20	50	29	73	72	104	60	49
Hydracarina	–	–	–	220		50	20	20				4	12
Ostracoda	–	–	–	1,220	524	770	410	784	64	192	192	36	140
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–	40	20		40		104	92	136	88	164
Cladocera	Chydoridae	–	–	420	820	150	350	60		8		8	
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–		40				168	108	160	92	104

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15					
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Copepoda – Cyclopoida	–	–	–	900	400	234	290	20		60	32	8	
Copepoda – Harpacticoida	–	–	–			10	10	40					
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*	3			13						5
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*	7	12	4	8						
Ephemeroptera	Caenidae	–	*Caenis*	3	8	12							
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–		4								
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*	1		1	1						
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*	2	1			8					
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15					
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*	1			1						
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*	1	4	4							
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15					
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–	1					8		9	28	8
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*	204	105	4	36	52					
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*			8		1					
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*	2	17	4	2	1					
Diptera	Chironomidae	Chironomini	*Cladopelma*	22	61	88	32	212		108	16	24	16
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*	2	4		4						
Diptera	Chironomidae	Chironomini	*Endochironomus*	1			4						
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15					
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*						4		9	5	9
Diptera	Chironomidae	Chironomini	*Microtendipes*				4		8				
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*										1
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*	1									
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	502	144	104	132	80					
Diptera	Chironomidae	Tanytarsini	*Micropsectra*										
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	183	77	212	58	204		16	57	8	24
Diptera	Chironomidae	Orthocladiinae (d)	–										
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*	20	20								
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Unnamed Creek 7					Unnamed Waterbody 15				
			Original Site	49	49	49	49	49	4	4	4	4	4
			Date	30-Sep	30-Sep	30-Sep	30-Sep	30-Sep	03-Oct	03-Oct	03-Oct	03-Oct	03-Oct
			Year	2006	2006	2006	2006	2006	2005	2005	2005	2005	2005
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*	20		4	10						
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*	261	101	98	70	152					
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	180	104	70	4	28					
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–										2
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*	22		66	5	32					
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*	118	125	86	83	125		16	51	12	24
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*		21		7						
Diptera	Chironomidae	Tanypodinae	*Tanypus*	7	6	4	3	12					
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**4,925**	**3,142**	**2,200**	**2,300**	**2,382**	**616**	**785**	**1,072**	**641**	**990**

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Small Sandy Lake					Oakley Lake				
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–			8	8	2	352	18	112	409	56
Oligochaeta	Tubificidae	–	–							1			8
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*							1			
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*									2	
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–	80			62	4	113	24	128	313	88
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–					1					
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*								1		
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–			3	10	8				1	
Hydracarina	–	–	–	8			8	7	82	3		24	9
Ostracoda	–	–	–	40		6	24	13	304	24	240	288	56
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–					2					
Cladocera	Chydoridae	–	–					2	24	2	64	64	
Cladocera	Macrothricidae	–	–						928	9	176	752	
Copepoda – Calanoida	–	–	–		16	2	26	7					

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Small Sandy Lake					Oakley Lake				
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–	24		2	8	13		1	104	184	32
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*	8		4		16			1		4
Amphipoda	Talitridae	–	*Hyalella azteca*	96	41	8	54	27	22	42	16	34	17
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*						2	2		16	1
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*			3		3					
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Small Sandy Lake					Oakley Lake				
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*			1	1		1			2	
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*							1	1		
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*					2					
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed										
			River/stream	Small Sandy Lake					Oakley Lake					
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*						2			8	
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*									1	
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–								8		
Diptera	Chironomidae	Chironomini	*Chironomus*			8		4	26	1		21	
Diptera	Chironomidae	Chironomini	*Cladopelma*						8	3	24	40	
Diptera	Chironomidae	Chironomini	*Cryptochironomus*										
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*	262	314	121	264	195	9	2	8	52	
Diptera	Chironomidae	Chironomini	*Endochironomus*			8	2			2	10	6	18
Diptera	Chironomidae	Chironomini	*Einfeldia*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Small Sandy Lake					Oakley Lake				
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*	2			2		134	37	1	155	1
Diptera	Chironomidae	Chironomini	*Microtendipes*						25	12		33	
Diptera	Chironomidae	Chironomini	*Parachironomus*								8	16	
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*				2		16	2	8	65	8
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–						16			8	
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*							2		72	
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	40			8	5		1		8	
Diptera	Chironomidae	Tanytarsini	*Micropsectra*		1								
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*	112	56	56	34	26					
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	21	16		32	16	93	5	57	202	32
Diptera	Chironomidae	Orthocladiinae (d)	–										
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*				8						
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*			16	16	5					
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										

Table U-5 Benthic Invertebrate Data Collected in the Big Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2005 and 2006 (continued)

			Watershed	Big Creek Watershed									
			River/stream	Small Sandy Lake					Oakley Lake				
			Original Site	45	45	45	45	45	46	46	46	46	46
			Date	28-Sep	28-Sep	28-Sep	28-Sep	28-Sep	29-Sep	29-Sep	29-Sep	29-Sep	29-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*	16			2	2					
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*										
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	24	8	24	48	7					
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–		8	1	8	3				8	8
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*			32	24	21		1			
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*									1	
Diptera	Chironomidae	Tanypodinae	*Labrundinia*			24		5					
Diptera	Chironomidae	Tanypodinae	*Procladius*	13	4		10	2	3	9	20	8	49
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*						1				
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**746**	**464**	**327**	**661**	**398**	**2,161**	**205**	**987**	**2,793**	**387**

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Oligochaeta	Enchytraeidae	–	–		1								
Oligochaeta	Lumbriculidae	–	–									1	
Oligochaeta	Naididae	–	–	9	3	15	7	4	8		10	1	
Oligochaeta	Tubificidae	–	–									1	
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*										
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*										
Nematoda	–	–	–	1	1	1		1		16		1	8
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*										
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–										
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*										
Pelecypoda	Sphaeriidae	–	–						1			1	
Hydracarina	–	–	–		1	2		2		8		4	
Ostracoda	–	–	–							8	1		
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–										
Cladocera	Chydoridae	–	–										
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										
Copepoda – Cyclopoida	–	–	–	1	6	3	2	5	20	24	6	6	24

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*										
Amphipoda	Talitridae	–	*Hyalella azteca*										
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*	148	74	75	108	67					
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*										
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*		1		5						
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*										
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*						1				8
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*										
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–	7	5	2	5	3					
Plecoptera	Chloroperlidae	–	*Sweltsa*										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Leuctridae (d)	–	–				1						
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*	13	14	18	8	20					
Plecoptera	Perlodidae	–	*Isoperla*	4	6		4	4					
Trichoptera	Brachycentridae	–	*Brachycentrus*	26	25	27	54	57					
Trichoptera (d)	–	–	–				1	2	8	8			8
Trichoptera	Glossosomatidae	–	*Glossosoma*	1			1	1					
Trichoptera	Hydropsychidae (d)	–	–	2									
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*	1	1	1		1					
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*	3	2	5	4	5					
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*	1									
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*				1						
Neuroptera	Sialidae	–	*Sialis*										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*	19	11	14	17	22					
Diptera	Empididae	–	*Wiedemannia*					1					
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–		1								
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*	1		1							
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*		1	2	1					4	
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*				1						
Diptera	Chironomidae – Pupa	–	–										
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*										
Diptera	Chironomidae	Chironomini	*Cladopelma*										
Diptera	Chironomidae	Chironomini	*Cryptochironomus*							8			
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*										
Diptera	Chironomidae	Chironomini	*Endochironomus*										
Diptera	Chironomidae	Chironomini	*Einfeldia*										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*										
Diptera	Chironomidae	Chironomini	*Paracladopelma*									1	
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*							88	1	26	1
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*								5	2	
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Micropsectra*	2	1	3							8
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*									4	
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*						8	8		4	
Diptera	Chironomidae	Orthocladiinae (d)	–	1			2			8		2	
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*	3	2	5	1						
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*		2		1						
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*	2									

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Redclay Creek									
			Original Site	51	51	51	51	51	50	50	50	50	50
			Date	26-Sep	26-Sep	26-Sep	26-Sep	26-Sep	27-Sep	27-Sep	27-Sep	27-Sep	27-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Surber (0.093)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	A	B	C	D	E	A	B	C	D	E
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*	1	3	3	2						
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*										
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*	1		1							
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*			1			16	24			
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–									1	
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*										
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*										
Diptera	Chironomidae	Tanypodinae	*Procladius*										
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–	2									
			TOTAL	**249**	**161**	**179**	**226**	**195**	**62**	**200**	**23**	**59**	**57**

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Oligochaeta	Enchytraeidae	–	–										
Oligochaeta	Lumbriculidae	–	–										
Oligochaeta	Naididae	–	–	8	90		8			80	10	10	210
Oligochaeta	Tubificidae	–	–										
Hirudinea	Erpobdellidae	–	*Erpobdella punctata*										
Hirudinea	Erpobdellidae	–	*Nephelopsis obscura*							1			
Hirudinea	Erpobdellidae	–	*Helobdella stagnalis*										
Hirudinea	Glossiphoniidae	–	*Glossiphonia complanata*						1				1
Nematoda	–	–	–							16			
Gastropoda	Ancylidae	–	*Ferrissia*										
Gastropoda	Hydrobiidae (d)	–	–										
Gastropoda	Lymnaeidae	–	–										
Gastropoda	Lymnaeidae	–	*Lymnaea*						3				3
Gastropoda	Physidae	–	*Physa*										
Gastropoda	Planorbidae (d)	–	–		1				11	50	10	22	101
Gastropoda	Planorbidae	–	*Gyraulus*										
Gastropoda	Planorbidae	–	*Helisoma*										
Gastropoda	Planorbidae	–	*Menetus cooperi*										
Gastropoda	Valvatidae	–	*Valvata sincera*			1	3	1					
Pelecypoda	Sphaeriidae	–	–	1	4	7	1			1			100
Hydracarina	–	–	–	17	5			40	8	41			
Ostracoda	–	–	–	18	1	10	8		48	136	20	10	
Cladocera	Bosminidae	–	*Bosmina*										
Cladocera	Daphnidae	–	–		8								
Cladocera	Chydoridae	–	–	1	8					8			
Cladocera	Macrothricidae	–	–										
Copepoda – Calanoida	–	–	–										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Copepoda – Cyclopoida	–	–	–	42	152	30	96	34	48	216	140		210
Copepoda – Harpacticoida	–	–	–										
Amphipoda	Gammaridae	–	*Gammarus lacustris*		8			1					
Amphipoda	Talitridae	–	*Hyalella azteca*		2								
Collembola	–	–	–										
Ephemeroptera	Ameletidae	–	*Ameletus oregonensis*										
Ephemeroptera	Baetidae	–	*Baetis*										
Ephemeroptera	Baetidae	–	*Callibaetis*										
Ephemeroptera	Caenidae	–	*Caenis*	2	12	1	1	2	2	30	1	1	6
Ephemeroptera	Heptageniidae (d)	–	–										
Ephemeroptera	Heptageniidae	–	*Heptagenia*										
Ephemeroptera	Ephemerellidae	–	*Drunella grandis*										
Ephemeroptera	Leptohyphidae	–	*Tricorythodes*						8				
Ephemeroptera	Leptophlebiidae	–	–										
Ephemeroptera	Leptophlebiidae	–	*Leptophlebia*										
Odonata – Anisoptera	Corduliidae	–	*Cordulia shurtleffi*										
Odonata – Anisoptera	Libellulidae (d)	–	–										
Odonata – Anisoptera	Libellulidae	–	*Leucorrhinia*						1				
Odonata – Anisoptera	Libellulidae	–	*Libellula*										
Odonata – Anisoptera	Aeshnidae	–	*Anax*										
Odonata – Zygoptera	Coenagrionidae	–	*Enallagma*										
Plecoptera (d)	–	–	–										
Plecoptera	Capniidae	–	–										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m²]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	Family	Subfamily/Tribe	Genus/Species										
Plecoptera	Chloroperlidae	–	*Sweltsa*										
Plecoptera	Leuctridae (d)	–	–										
Plecoptera	Nemouridae (d)	–	–										
Plecoptera	Nemouridae	–	*Nemoura*										
Plecoptera	Nemouridae	–	*Zapada*										
Plecoptera	Perlodidae	–	*Isoperla*										
Trichoptera	Brachycentridae	–	*Brachycentrus*										
Trichoptera (d)	–	–	–										
Trichoptera	Glossosomatidae	–	*Glossosoma*										
Trichoptera	Hydropsychidae (d)	–	–										
Trichoptera	Hydropsychidae	–	*Cheumatopsyche*										
Trichoptera	Hydropsychidae	–	*Hydropsyche*										
Trichoptera	Leptoceridae	–	*Oecetis*										
Trichoptera	Limnephilidae (d)	–	–										
Trichoptera	Limnephilidae	–	*Limnephilus*										
Trichoptera	Limnephilidae	–	*Nemotaulius*										
Trichoptera	Phryganeidae	–	*Ptilostomis*										
Trichoptera	Limnephilidae	–	*Hesperophylax*										
Trichoptera	Phryganeidae	–	*Agrypnia*										
Trichoptera	Polycentropodidae	–	*Polycentropus*										
Trichoptera	Rhyacophilidae	–	*Rhyacophila*										
Coleoptera	Dytiscidae	–	*Agabus*										
Coleoptera	Dytiscidae	–	*Liodessus*										
Coleoptera	Elmidae	–	*Optioservus*										
Coleoptera	Chrysomelidae	–	*Donacia*										
Coleoptera	Haliplidae	–	*Haliplus*										
Hemiptera	Corixidae	–	*Cymatia americana*										
Hemiptera	Corixidae	–	*Callicorixa*										
Hemiptera	Corixidae	–	*Sigara*										

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Neuroptera	Sialidae	–	*Sialis*										
Diptera	Dolichopodidae	–	*Rhaphium*										
Diptera	Empididae	–	*Hemerodromia*										
Diptera	Empididae	–	*Chelifera*										
Diptera	Empididae	–	*Wiedemannia*										
Diptera	Chaoboridae	–	*Chaoborus*										
Diptera	Ceratopogonidae	Ceratopogoninae	–										
Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia*										
Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea*										
Diptera	Ceratopogonidae	Forcipomyiinae	*Atrichopogon*										
Diptera	Ceratopogonidae	–	*Culicoides*										
Diptera	Ceratopogonidae	–	*Probezzia*										
Diptera	Simuliidae	–	*Simulium*										
Diptera	Tabanidae	–	*Chrysops*										
Diptera	Tipulidae (d)	–	–										
Diptera	Tipulidae	–	*Dicranota*										
Diptera	Tipulidae	–	*Hexatoma / Limnophila*										
Diptera	Tipulidae	–	*Ormosia*										
Diptera	Tipulidae	–	*Tipula*										
Diptera	Chironomidae – Pupa	–	–		8								
Diptera	Chironomidae	Chironomini (d)	–										
Diptera	Chironomidae	Chironomini	*Chironomus*	12	15		15	29	8	19	102	1	47
Diptera	Chironomidae	Chironomini	*Cladopelma*		1								
Diptera	Chironomidae	Chironomini	*Cryptochironomus*		2			1					
Diptera	Chironomidae	Chironomini	*Demicryptochironomus*										
Diptera	Chironomidae	Chironomini	*Dicrotendipes*	31	79	21	9	28	61	170	34	13	43
Diptera	Chironomidae	Chironomini	*Endochironomus*				1			10			
Diptera	Chironomidae	Chironomini	*Einfeldia*	1			1	1					

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Chironomini	*Glyptotendipes*										
Diptera	Chironomidae	Chironomini	*Microtendipes*										
Diptera	Chironomidae	Chironomini	*Parachironomus*							49			11
Diptera	Chironomidae	Chironomini	*Paracladopelma*										
Diptera	Chironomidae	Chironomini	*Paralauterborniella*										
Diptera	Chironomidae	Chironomini	*Paratendipes*										
Diptera	Chironomidae	Chironomini	*Phaenopsectra*										
Diptera	Chironomidae	Chironomini	*Polypedilum*				1				110		
Diptera	Chironomidae	Chironomini	*Saetheria*										
Diptera	Chironomidae	Chironomini	*Sergentia / Tribelos*										
Diptera	Chironomidae	Chironomini	*Stenochironomus*										
Diptera	Chironomidae	Chironomini	*Stictochironomus*										
Diptera	Chironomidae	Tanytarsini (d)	–										
Diptera	Chironomidae	Tanytarsini	*Cladotanytarsus*	8					8				
Diptera	Chironomidae	Tanytarsini	*Paratanytarsus*	99	164	2	104	75	96	450	150	30	150
Diptera	Chironomidae	Tanytarsini	*Micropsectra*						9				
Diptera	Chironomidae	Tanytarsini	*Rheotanytarsus*										
Diptera	Chironomidae	Tanytarsini	*Stempellina*										
Diptera	Chironomidae	Tanytarsini	*Stempellinella*										
Diptera	Chironomidae	Tanytarsini	*Tanytarsus*	3	42		8	34	65	30	21	11	122
Diptera	Chironomidae	Orthocladiinae (d)	–		9		8						
Diptera	Chironomidae	Orthocladiinae	*Brillia*										
Diptera	Chironomidae	Orthocladiinae	*Corynoneura*										
Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Heterotrissocladius*										
Diptera	Chironomidae	Orthocladiinae	*Nanocladius*										
Diptera	Chironomidae	Orthocladiinae	*Orthocladius (Symposiocladius) lingicola*										
Diptera	Chironomidae	Orthocladiinae	*Parachironomus*						32				

Table U-6 Benthic Invertebrate Data Collected in the Redclay Creek Watershed During Environmental Surveys Conducted for the Pierre River Mining Area, Fall 2006 (continued)

			Watershed	Redclay Creek Watershed									
			River/stream	Unnamed Waterbody 12					Unnamed Waterbody 13				
			Original Site	52	52	52	52	52	53	53	53	53	53
			Date	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep	25-Sep
			Year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
			Sampling Device [m^2]	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)	Ekman (0.0232)
			Replicate	1	2	3B	4	5	#1	#2	#3	#4	#5
Major Taxon	**Family**	**Subfamily/Tribe**	**Genus/Species**										
Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*										
Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*										
Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*	1			24		32	8	1	2	100
Diptera	Chironomidae	Orthocladiinae	*Pseudosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Acricotopus*										
Diptera	Chironomidae	Orthocladiinae	*Rheosmittia*										
Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*	8			24						
Diptera	Chironomidae	Orthocladiinae	*Tvetenia*										
Diptera	Chironomidae	Orthocladiinae	*Cricotopus/Orthocladius*	46		1	8	8	64	25	40		
Diptera	Chironomidae	Orthocladiinae	*Zalutschia*										
Diptera	Chironomidae	Tanypodinae (d)	–								1		
Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*		8				25	70	10	10	120
Diptera	Chironomidae	Tanypodinae	*Clinotanypus*										
Diptera	Chironomidae	Tanypodinae	*Labrundinia*		8				8	33			
Diptera	Chironomidae	Tanypodinae	*Procladius*	15	61	21		1			2		1
Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*										
Diptera	Chironomidae	Tanypodinae	*Tanypus*										
Diptera	Chironomidae	Tanypodinae	*Thienemannimyia* gr.										
Diptera	Chironomidae	Diamesinae	*Potthastia longimana* gr.										
Diptera	Chironomidae	Diamesinae	*Diamesa*										
Diptera	Chironomidae	Diamesinae	*Pseudodiamesa*										
Diptera	Chironomidae	Prodiamesinae	*Prodiamesa*										
Terrestrial	–	–	–										
			TOTAL	**313**	**688**	**94**	**320**	**255**	**538**	**1,443**	**652**	**110**	**1,225**

Note: (d) = Damaged specimen identified to lowest level possible.
Blank cells indicate absence of taxon.
– = Invertebrates were not identified to this level.

Table U-7 Benthic Invertebrate Taxon List for the McClelland Lake Watershed, Fall 2005 and 2006

		Watershed	McClelland Lake Watershed	
		Waterbody	Unnamed Creek 13	Unnamed Waterbody 4
		Original Site	22	54
		Date	18-Oct	28-Sep
		Year	2005	2006
Major Taxon	**Family/Subfamily/Tribe**	**Genus/Species**		
Nematoda	–	–	P	P
Oligochaeta	Naididae	–		P
	Tubificidae	–	P	P
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*		P
		Helobdella stagnalis		P
Mollusca	–	–		
Gastropoda	Ancylidae	*Ferrissia*		P
	Hydrobiidae	–	P	
	Planorbidae	–	P	P
		Gyraulus		P
		Helisoma		P
		Menetus cooperi		P
	Valvatidae	*Valvata sincera*		P
Pelecypoda	Sphaeriidae	–	P	P
Hydracarina	–	–	P	P
Ostracoda	–	–	P	P
Amphipoda	Hyalellidae	*Hyalella azteca*		P
Ephemeroptera	Baetidae	*Callibaetis*		P
	Caenidae	*Caenis*		P
Odonata – Anisoptera	Corduliidae	*Cordulia shurtleffi*		P
Trichoptera	Phryganeidae	*Agrypnia*		P
	Polycentropodidae	*Polycentropus*		P
Diptera	Ceratopogonidae	–		
	Ceratopogoninae	*Culicoides*		P
		Bezzia		P
	Chironomidae	–		
	Chironomini	*Chironomus*	P	P
		Cladopelma	P	P
		Cryptochironomus	P	
		Dicrotendipes	P	P
		Endochironomus	P	P
		Microtendipes	P	P
		Polypedilum		P
	Tanytarsini	–		P
		Cladotanytarsus		P
		Rheotanytarsus		P
		Tanytarsus	P	P
	Orthocladiinae	–		P
		Corynoneura		P
		Cricotopus/Orthocladius	P	P
	Tanypodinae	–		P
		Ablabesmyia	P	P
		Clinotanypus		P
		Procladius	P	P
		Psectrotanypus	P	

Table U-7 Benthic Invertebrate Taxon List for the McClelland Lake Watershed, Fall 2005 and 2006 (continued)

		Watershed	McClelland Lake Watershed	
		Waterbody	Unnamed Creek 13	Unnamed Waterbody 4
		Original Site	22	54
		Date	18-Oct	28-Sep
		Year	2005	2006
Major Taxon	Family/Subfamily/Tribe	Genus/Species		
Total Taxa (genus as lowest level)			**18**	**39**
Total Taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	1	2
		Mollusca	3	7
		Ephemeroptera	0	2
		Odonata	0	1
		Plecoptera	0	0
		Trichoptera	0	2
		Coleoptera	0	0
		Chironomidae	11	17
		Other Diptera	0	2
		Other	3	6

Note: Blank cells indicate the absence of taxon.

Taxa with no individuals present in the sites sampled were excluded from the table.

P = present.

– = Invertebrates were not identified to this label.

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Porifera	–	*Spongilla*						C
Hydrozoa	Hydridae	*Hydra*					P	C
Turbellaria – Tricladida	–	–					P	
		Allocoela						I
		Dugesia tigrina						I(?)
Nematoda	–	–	P	P	P	P	P	F
Nematomorpha	–	–						F
Bryozoa	–	–						I
Oligochaeta	–	–					P	
	Enchytraeidae	–	P	P		P	P	I
	Lumbricidae	–					P	
	Lumbriculidae	–	P	P	P	P	P	
		Lumbriculus variegatus						C
	Naididae	–	P	P	P	P	P	
		Arcteonais lomondi						I
		Chaetogaster diaphanus						C
		Chaetogaster langi						I
		Dero digitata						I
		Nais behningi						C, LA
		Nais communis/variabilis						C
		Nais pardalis						C
		Nais pseudobtusa						I
		Nais simplex						C
		Pristina breviseta						I
		Pristina foreli						I
		Pristina longiseta						C
		Slavina appendiculata						C
		Specaria josinae						I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Oligochaeta (continued)	Naididae (continued)	*Stylaria lacustris*						I
		Uncinais uncinata						I
		Vejdovskyella comata						I
	Tubificidae	–	P	P	P	P	P	F, LA
		Limnodrilus claparedianus						I
		Limnodrilus hoffmeisteri						I
		Peloscolex						C
Hirudinea	–	–					P	
	Erpobdellidae	–					P	
		Dina						I(?)
		Dina parva					P	
		Dina/Moorebdella					P	
		Erpobdella punctata	P	P			P	C
		Mooreobdella fervida					P	
		Nephelopsis obscura					P	
	Glossiphoniidae	*Glossiphonia complanata*			P	P	P	I
		Glossiphonia heteroclita						I
		Helobdella stagnalis	P				P	C
		Placobdella ornata					P	
		Placobdella papillifera					P	I(?)
	Hirudinidae	*Haemopsis grandis*						I
	Piscicolidae	–						
		Piscicola						I
Mollusca	–	–						
Gastropoda	–	–					P	
	Ancylidae	*Ferrissia* *Ferrissia rivularis*					P	I
	Hydrobiidae	–				P	P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Gastropoda (continued)	Hydrobiidae (continued)	*Amnicola limosa*						I(?)
		Probythinella					P	
	Lymnaeidae	–				P	P	
		Lymnaea					P	I, LA
		Stagnicola					P	
	Physidae	*Physa*	P			P	P	C
	Planorbidae	–			P	P		
		Gyraulus					P	
		Gyraulus parvus						C
		Helisoma	P				P	I
		Promenetus					P	I
		Promenetus evacuous					P	
	Valvatidae	*Valvata lewisii*					P	C(?)
		Valvata sincera	P		P	P	P	
		Valvata tricarinata					P	
Pelecypoda	Sphaeriidae	–	P	P	P	P	P	
		Musculium					P	C
		Pisidium					P	F
		Pisidium/Sphaerium					P	
		Sphaerium					P	C
	Unionidae	*Lampsilis*						I
		Lampsilis radiata					P	
		Lasmigona complanata					P	
Hydracarina	–	–	P			P	P	
	Hygrobatidae	*Hygrobates*					P	
	Lebertiidae	*Lebertia*					P	
Copepoda – Harpacticoida	–	–	P	P		P	P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Ostracoda	–	–	P	P	P	P	P	F
	Candonidae	*Candona*					P	
	Cyclocypridae	*Cyclocypris*					P	
	Cypridae	–					P	
Amphipoda	–	–					P	
	Gammaridae	*Gammarus lacustris*	P	P			P	C, LA
	Hyalellidae	Hyalellidae						
		Hyalella azteca	P		P		P	C, LA
Collembola	–	–					P	
	Isotomidae	*Isotomus*					P	
Ephemeroptera	Ameletidae	*Ameletus*						I, LA
		Ameletus subnotatus					P	
	Baetidae	–					P	
		Acentrella					P	
		Baetis					P	C, LA
		Baetisca					P	
		Callibaetis					P	
		Callibaetis coloradensis						I
		Centroptilum					P	I
		Cloeon						I
		Pseudocloeon						I
	Baetiscidae	*Baetisca columbiana*						I(?)
		Baetisca obesa						I
	Caenidae	*Brachycercus*						C, LA
		Caenis					P	I
		Caenis sp.1					P	
		Caenis sp.2					P	
	Ephemerellidae	–					P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Ephemeroptera (continued)	Ephemerellidae (continued)	*Drunella grandis*					P	
		Ephemerella					P	
		Ephemerella aurivilli					P	I
		Ephemerella grandis ingens					P	
		Ephemerella inermis						I
		Ephemerella lita					P	
		Ephemerella marginata						I
		Ephemerella simplex						I, C
		Ephemerella spinifera					P	I
		Ephemerella tibialis						I
	Ephemeridae	*Ephemera cf. simulans*						I
		Hexagenia					P	
	Heptageniidae	–					P	
		Heptagenia					P	R, LA
		Rhithrogena						R
		Stenonema					P	
		Stenonema vicarium						R
		Stenacron interpunctatum						I
	Isonychiidae	*Isonychia*						I
	Leptophlebiidae	–					P	
		Leptophlebia					P	
		Leptophlebia cupida						F, A
		Leptophlebia nebulosa						F, A
		Paraleptophlebia					P	I
	Metretopodidae	*Metretopus borealis*						I, LA
	Siphlonuridae	–					P	
		Parameletus					P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Ephemeroptera (continued)	Siphlonuridae (continued)	*Siphlonurus*					P	C
		Siphlonurus alternatus						C
		Siphloplecton					P	
		Siphloplecton basale						I, LA
	Tricorythidae	*Tricorythodes*					P	
		Tricorythodes minutus						C, LA(?)
Odonata – Anisoptera	–	–					P	
	Aeshnidae	*Aeshna*					P	
		Aeshna eremita						C
		Aeshna interupta					P	I
		Aeshna umbrosa						C(?)
	Corduliidae	*Cordulia shurtleffi*						I
		Epitheca canis					P	I
		Somatochlora					P	
		Somatochlora minor						I
	Gomphidae	*Gomphus*					P	
		Ophiogomphus					P	
		Ophiogomphus colubrinus						R, LA
	Libellulidae	*Leucorrhinia hudsonica*						I
Odonata – Zygoptera	Calopterygidae	*Calopteryx aequabilis*					P	
	Coenagrionidae	–					P	
		Agrion aequabile						I
		Ceoenagrion resolutum						I
		Enallagma boreale					P	I
		Ischnura						I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Plecoptera	–	–					P	
	Capniidae	–					P	
		Capnia vernalis						I
	Chloroperlidae	–					P	
		Hastaperla					P	
		Hastaperla brevis					P	R, LA
		Paraperla					P	
	Leuctridae	*Leuctra cf. sara*						I(?)
	Nemouridae	*Amphinemura linda*						I
		Shipsa rotunda						C, LA
		Nemoura					P	
		Nemoura arctica						R, LA
		Zapada					P	
		Zapada cinctipes						F
	Perlidae	*Acroneuria*					P	
		Acroneuria lycorias						I
		Claassenia sabulosa					P	R, A(?)
		Paragnetina					P	
	Perlodidae	*Arcynopteryx*					P	R, LA
		Isogenoides					P	
		Isogenoides frontalis						I
		Isoperla					P	
		Isoperla fulva						I
		Isoperla fusca						R, LA(?)
		Skwala					P	
	Pteronarcyidae	*Pteronarcella dorsata*					P	
		Pteronarcys					P	
		Pteronarcys dorsata						R, A

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Plecoptera (continued)	Taeniopterygidae	*Taeniopteryx*					P	
		Taeniopteryx nivalis					P	C, LA
		Taeniopteryx parvula						I
Hemiptera	Corixidae	–					P	
		Callicorixa					P	
		Hesperocorixa atopodonta						C
		Hesperocorixa michiganensis						I
		Sigara					P	
		Sigara alternata						I, LA
		Sigara bicoloripennis						I
		Sigara conocephala						I
		Sigara decoratella						I
		Sigara mullettensis						I
		Sigara penniensis						I
		Sigara solensis						I, LA
		Trichocorixa naias						I
Melgaloptera	Sialidae	*Sialis*					P	I
Lepidoptera	–	*Nymphula*					P	
Trichoptera	–	–					P	
	Brachycentridae	–					P	
		Brachycentrus					P	R, LA
		Brachycentrus americanus					P	R, LA
		Micrasema					P	R, LA
	Glossosomatidae	–					P	
		Agapetus					P	I
		Glossosoma					P	R, LA
		Protoptila					P	I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Trichoptera (continued)	Helicopsychidae	*Helicopsyche*					P	
		Helicopsyche borealis					P	R
	Hydropsychidae	–					P	
		Arctopsyche						I
		Arctopsyche ladogensis					P	
		Cheumatopsyche					P	C, LA
		Cheumatopsyche annalis					P	
		Hydropsyche					P	R, LA
		Hydropsyche betteni					P	
		Hydropsyche bifida					P	C
		Hydropsyche recurvata					P	
		Hydropsyche simulans					P	
		Hydropsyche slossonae					P	C
		Potamyia flava					P	
	Hydroptilidae	–					P	
		Agraylea						I
		Dibusa						I
		Hydroptila					P	I
		Mayatrichia						I
		Ochrotrichia					P	I
		Neotrichia					P	
		Oxyethira					P	R, LA
	Lepidostomatidae	*Lepidostoma*					P	R, LA
	Leptoceridae	*Ceraclea*					P	
		Ceraclea annulicornis						I
		Ceraclea tarsipunctata						I
		Nectopsyche						I
		Oecetis					P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Trichoptera (continued)	Leptoceridae (continued)	*Oecetis avara*						I
	Limnephilidae	–					P	
		Anabolia bimaculata						I
		Asynarchus						C
		Glyphopsyche irrorata						I
		Grammotaulius					P	I
		Hesperophylax						I
		Limnephilus		P		P	P	C
		Limnephilus minusculus						I
		Moselyana					P	
		Nemotaulius			P		P	
		Nemotaulius hostilis						I
		Psychoglypha subborealis						I
	Philopotamidae	*Wormaldia gabriella*					P	R, LA
		Chimarra					P	
	Phryganeidae	*Agrypnia*					P	I
		Phryganea						I
		Ptilostomis		P		P	P	
		Ptilostomis semifasciata					P	I
	Polycentropodidae	*Neureclipsis*					P	
		Polycentropus					P	
		Polycentropus cinereus						I
		Polycentropus flavus						I
		Polycentropus plexus					P	
	Psychomyiidae	*Psychomyia*					P	
		Psychomyia flavida					P	
	Rhyacophilidae	*Rhyacophila*					P	I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Coleoptera	Chrysomelidae	*Donacia*		P			P	
	Dytiscidae	*Agabus*					P	I
		Agabus seriatus						I
		Carrhydrus crassipes						I
		Dytiscus harrissi						I
		Ilybius					P	I
		Liodessus					P	
	Elmidae	–					P	
		Dubiraphia					P	
		Dubiraphia robusta						I
		Optioservus					P	
		Optioservus fastidatus					P	R, LA
		Stenelmis					P	
	Gyrinidae	–					P	
		Gyrinus affinis						C, LA
		Gyrinus maculiventris						I
		Gyrinus minutus						I
		Gyrinus pectoralis						I
	Haliplidae	*Brychius*					P	I
		Haliplus				P	P	I
	Hydrophilidae	–						C
	Heteroceridae	–					P	
Diptera	–	–					P	
	Athericidae	*Atherix*					P	
		Atherix pachypus						R, LA
	Ceratopogonidae	–					P	F
	Ceratopogoninae	–		P		P		
		Bezzia	P	P		P	P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Diptera (continued)	Ceratopogoninae (continued)	*Bezzia/Probezzia*					P	
	Dasyheleinae	*Dasyhelea*		P		P		
	Forcipomyiinae	*Atrichopogon*				P		I
		Palpomyia tibialis					P	
	Chironomidae	–					P	
	Chironominae	–					P	
	Chironomini	–		P	P		P	
		Chironomus	P	P	P		P	
		Chironomus annularis group						I
		Chironomus cf. decorus						C
		Chironomus fluviatilis group						C
		Chironomus plumosus group					P	I
		Chironomus salinarius group						I
		Chironomus thumni group					P	I, LA
		Cladopelma	P		P	P	P	C
		Cryptochironomus	P		P	P	P	C
		Cryptocladopelma						I
		Cryptotendipes					P	I
		Demicryptochironomus		P			P	
		Dicrotendipes	P		P	P	P	
		Dicrotendipes cf. fumidus						C
		Dicrotendipes cf. modestus						I
		Dicrotendipes cf. neomodestus						I
		Dicrotendipes cf. nervosus						I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Diptera (continued)	Chironomini (continued)	*Endochironomus cf. subtendens*						C
		Glyptotendipes						I
		Microtendipes	P		P	P	P	
		Microtendipes cf. pedellus						C
		Nilothauma					P	
		Pagastiella					P	
		Parachironomus					P	C
		Paracladopelma		P			P	I
		Paralauterborniella					P	I
		Paratendipes	P	P			P	I
		Phaenopsectra	P	P			P	C
		Polypedilum		P	P		P	C
		Polypedilum breviantennatum group						I
		Polypedilum fallax group						I
		Saetheria					P	
		Sergentia / Tribelos		P	P			
		Stenochironomus			P			
		Stictochironomus					P	C
		Tribelos					P	
		Xenochironomus xenolabis						I
	Tanytarsini	–					P	
		Cladotanytarsus					P	C
		Micropsectra	P	P	P	P	P	F, A
		Paratanytarsus	P	P	P	P	P	C
		Rheotanytarsus					P	C, A
		Stempellina			P		P	C, LA
		Stempellinella		P	P		P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Diptera (continued)	Corynoneurini	*Tanytarsus*	P	P	P	P	P	F, A
		Tanytarsus/Micropsectra					P	
		Zavrelia						C
		–					P	
	Diamesinae	–					P	
		Diamesa					P	I
		Potthastia					P	
		Potthastia cf. gaedi						I
		Potthastia longimanus type					P	I
		Potthastia longimana gr.			P	P		
		Protanypus						I
		Pseudodiamesa						I
	Orthocladiinae/Diamesinae	–					P	
	Orthocladiinae	–		P	P	P	P	
		Orthocladiinae						I, LA
		Acricotopus				P		
		Acricotopus cf. senex						C
		Brillia		P			P	C
		Cardiocladius						C
		Corynoneura	P		P	P	P	F
		Cricotopus/Orthocladius		P		P	P	
		Cricotopus bicinctus						C, A
		Cricotopus cylindraceus group						I
		Cricotopus tremulus group						C, A
		Cricotopus nr. curtus						I
		Cricotopus trifascia group						I
		Cricotopus nostocicola						I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	Family/Subfamily Tribe	Taxon						
Diptera (continued)	Orthocladiinae (continued)	*Diplocladius cf. cultriger*						C
		Eukiefferiella					P	C
		Eukiefferiella cf. brevicalcar						I
		Eukiefferiella cg. claripennis						I, LA
		Eurycnemus						I
		Euryhapsis					P	
		Heterotrissocladius		P			P	
		Heterotrissocladius cf. latilaminus						C
		Krenosmittia					P	I
		Limnophyes						I
		Lopescladius					P	
		Metriocnemus						I
		Nanocladius		P			P	
		Nanocladius cf. distinctus						C
		Orthocladius						I
		Parakiefferiella					P	C
		Parametriocnemus		P			P	C
		Parametriocnemus cf. lundbecki						I
		Paratrichocladius						I, LA
		Psectrocladius				P	P	C
		Psectrocladius cf. simulans						I
		Pseudosmittia						I
		Rheocricotopus					P	I, LA
		Rheocricotopus nr. kenorensis						I, LA

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Diptera (continued)	Orthocladiinae (continued)	*Rheosmittia*					P	
		Synorthocladius					P	I
		Thienemanniella		P			P	C
		Tvetenia					P	
		Zalutschia				P		
	Pentaneurini	–					P	
	Podonominae	*Trichotanypus posticalis*						R
	Tanypodinae	–		P	P	P	P	
		Ablabesmyia	P	P		P	P	F
		Conchapelopia						I
		Labrundinia		P				I
		Larsia					P	C
		Nilotanypus					P	R, C
		Paramerina						I
		Procladius	P	P	P	P	P	F
		Psectrotanypus				P		
		Rheopelopia						I
		Thienemannimyia					P	I
		Thienemannimyia complex					P	C
	Dixidae	–					P	
		Paradixa						I
	Dolichopodidae	–					P	
		Rhaphium					P	
		–						
		Chelifera		P			P	C
		Hemerodromia		P			P	C
		Hemerodromia rogatoris						C
		Oreogeton					P	

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Diptera (continued)	Dolichopodidae (continued)	*Rhamphomyia*					P	LA
	Ephydridae	*Psilopa*						I
	Psychodidae	*Telmatoscopus*						I
		Psychoda					P	
	Simuliidae	–					P	
		Simulium					P	
		Simulium arcticum						I
		Simulium prob. aureum						C
		Simulium decorum						C
		Simulium euryadminiculum						I
		Simulium tuberosum complex						C, A
	Syrphidae	*Helophilus*						I
	Tabanidae	*Chrysops*		P			P	I
		Tabanus					P	
	Tipulidae	–		P				
		Antocha						I
		Dicranota					P	R, LA
		Eriocera					P	R, LA
		Hexatoma					P	
		Hexatoma / Limnophila		P				
		Holorusia						I
		Limnophila					P	
		Ormosia			P			
		Tipula					P	I

Table U-8 Benthic Invertebrate Taxon List for the Muskeg River Basin in Fall 2005 and Historically (continued)

		Waterbody	Muskeg River	Wapasu Creek	Wapasu Creek	Unnamed Creek 9	Muskeg River	
		Original Site	24	38	32	35B		
		Date	18-Oct	15-Oct	13-Oct	13-Oct		
		Year	2005	2005	2005	2005	Historical Data	Barton and Wallace (1980)
Major Taxon	**Family/Subfamily Tribe**	**Taxon**						
Total Taxa			**30**	**44**	**31**	**40**	**265**	**280**
Total Taxa (genus as lowest level)			**30**	**44**	**31**	**40**	**194**	**213**
Total Taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	4	4	3	4	5	14
		Mollusca	4	1	3	6	14	12
		Ephemeroptera	0	0	0	0	19	22
		Odonata	0	0	0	0	7	10
		Plecoptera	0	0	0	0	14	14
		Trichoptera	0	2	1	2	29	33
		Coleoptera	0	1	0	1	11	10
		Chironomidae	13	23	19	18	50	61
		Other Diptera	1	8	1	4	20	16
		Other	8	5	4	5	25	21

Notes: Taxa with no individuals present in the sites sampled were excluded from the table.

Blank cells indicate absence of taxon.

P = present.

F = frequently collected.

A = abundant.

I = infrequent.

R = restricted to lower reaches.

C = common.

LA = locally abundant.

(?) = taxonomic identification uncertain.

– = Invertebrates were not identified to this level.

Table U-9 Benthic Invertebrate Taxon List for the Pierre River and Eymundson Creek Watersheds, Fall 2005 and 2006

			Pierre River Watershed		Eymundson Creek Watershed							
		Waterbody	Pierre River		Upper Eymundson Creek		Lower Eymundson Creek			Asphalt Creek	Unnamed Creek 1	Unnamed Waterbody 6
		Original Site	19-1	20-1	6	57	11	17	17-1	48	15-1	2
		Date	26-Sep	27-Sep	15-Oct	01-Oct	18-Oct	18-Oct	28-Sep	02-Oct	27-Sep	02-Oct
		Year	2005	2005	2005	2006	2005	2005	2005	2006	2005	2005
Major Taxon	**Family/Subfamily/Tribe**	**Taxon**										
Nematoda	–	–	P	P		P				P		P
Oligochaeta	Enchytraeidae	–	P						P	P		
	Lumbriculidae	–			P							
	Naididae	–	P	P	P	P			P			P
	Tubificidae	–	P	P	P	P	P	P	P		P	P
Hirudinea	Erpobdellidae	*Nephelopsis obscura*			P	P						P
	Glossiphoniidae	*Glossiphonia complanata*			P	P						
		Helobdella stagnalis	P									
Mollusca	–	–										
Gastropoda	Hydrobiidae	–	P									
	Physidae	*Physa*	P									
	Planorbidae	–					P					P
		Helisoma			P							
Pelecypoda	Sphaeriidae	–	P	P	P	P						P
Hydracarina	–	–			P	P				P		P
Copepoda – Harpacticoida	–	–										P
Ostracoda	–	–	P	P	P	P				P		P
Amphipoda	Gammaridae	*Gammarus lacustris*										P
	Hyalellidae	*Hyalella azteca*			P	P						P
Ephemeroptera	Baetidae	*Baetis*								P		
		Callibaetis				P						
	Caenidae	*Caenis*	P			P						
	Heptageniidae	–								P		
	Leptophlebiidae	–	P	P								
Odonata – Anisoptera	Aeshnidae	*Anax*			P							
	Libellulidae	*Libellula*				P						
Odonata – Zygoptera	Coenagrionidae	*Enallagma*										P
Plecoptera	Capniidae	–		P						P		
	Nemouridae	–								P		
		Nemoura								P		
		Zapada								P		
	Perlodidae	*Isoperla*								P		
Trichoptera	Brachycentridae	*Brachycentrus*								P		
	Glossosomatidae	*Glossosoma*								P		
	Hydropsychidae	–								P		
		Hydropsyche								P		
	Limnephilidae	–								P		
		Nemotaulius			P							P
	Phryganeidae	*Ptilostomis*	P									
	Polycentropodidae	*Polycentropus*										P
Coleoptera	Chrysomelidae	*Donacia*	P									
	Haliplidae	*Haliplus*	P			P						
Diptera	Ceratopogonidae	–										

Table U-9 Benthic Invertebrate Taxon List for the Pierre River and Eymundson Creek Watersheds, Fall 2005 and 2006 (continued)

			Pierre River Watershed		Eymundson Creek Watershed							
		Waterbody	Pierre River		Upper Eymundson Creek		Lower Eymundson Creek			Asphalt Creek	Unnamed Creek 1	Unnamed Waterbody 6
		Original Site	19-1	20-1	6	57	11	17	17-1	48	15-1	2
		Date	26-Sep	27-Sep	15-Oct	01-Oct	18-Oct	18-Oct	28-Sep	02-Oct	27-Sep	02-Oct
		Year	2005	2005	2005	2006	2005	2005	2005	2006	2005	2005
Major Taxon	**Family/Subfamily/Tribe**	**Taxon**										
Diptera (continued)	Ceratopogoninae	–	P			P						
		Bezzia	P		P	P						
	Dasyheleinae	*Dasyhelea*	P									
	Chironomidae	–										
	Chironomini	–	P	P	P	P						
		Chironomus	P		P	P				P		P
		Cladopelma			P	P						P
		Cryptochironomus	P					P				
		Dicrotendipes				P						P
		Endochironomus			P	P						P
		Einfeldia				P						
		Glyptotendipes			P							P
		Microtendipes			P	P						P
		Paralauterborniella		P								
		Paratendipes	P									
		Phaenopsectra	P									
		Polypedilum	P	P	P	P	P	P	P	P	P	P
		Saetheria					P				P	
		Sergentia / Tribelos	P									
		Stenochironomus										
		Stictochironomus		P			P	P			P	
	Tanytarsini	–				P						
		Cladotanytarsus	P	P								P
		Micropsectra	P	P							P	
		Paratanytarsus	P		P	P	P					P
		Rheotanytarsus	P	P								
		Stempellina	P									
		Stempellinella	P									
		Tanytarsus	P	P	P	P				P		P
	Diamesinae	*Potthastia longimana* gr.	P									
	Orthocladiinae	–	P	P	P	P				P		
		Brillia		P								
		Corynoneura			P	P						P
		Cricotopus/Orthocladius	P	P		P				P	P	P
		Eukiefferiella								P		
		Heterotrissocladius	P	P		P				P		
		Nanocladius	P									P
		Parakiefferiella		P						P		
		Parametriocnemus	P	P	P	P				P		
		Psectrocladius		P	P	P						P
		Pseudosmittia	P			P		P				
		Rheocricotopus				P						
		Rheosmittia					P		P		P	

Table U-9 Benthic Invertebrate Taxon List for the Pierre River and Eymundson Creek Watersheds, Fall 2005 and 2006 (continued)

			Pierre River Watershed		Eymundson Creek Watershed							
		Waterbody	Pierre River		Upper Eymundson Creek		Lower Eymundson Creek			Asphalt Creek	Unnamed Creek 1	Unnamed Waterbody 6
		Original Site	19-1	20-1	6	57	11	17	17-1	48	15-1	2
		Date	26-Sep	27-Sep	15-Oct	01-Oct	18-Oct	18-Oct	28-Sep	02-Oct	27-Sep	02-Oct
		Year	2005	2005	2005	2006	2005	2005	2005	2006	2005	2005
Major Taxon	**Family/Subfamily/Tribe**	**Taxon**										
Diptera (continued)	Orthocladiinae	*Thienemanniella*					P					
	Tanypodinae	–	P	P	P	P	P					P
		Ablabesmyia	P			P						P
		Labrundinia										P
		Procladius	P		P	P					P	P
		Tanypus				P						P
	Dolichopodidae	*Rhaphium*	P	P								
	Empididae	*Chelifera*	P							P		P
		Hemerodromia					P			P		
	Simuliidae	*Simulium*								P		
	Tabanidae	*Chrysops*	P	P	P		P					
	Tipulidae	*Dicranota*								P	P	
		Hexatoma / Limnophila					P				P	
Total Taxa (genus as lowest level)			**44**	**25**	**29**	**38**	**12**	**5**	**5**	**29**	**10**	**34**
Total Taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	3	2	3	2	1	1	3	1	1	2
		Mollusca	3	1	2	1	1	0	0	0	0	2
		Ephemeroptera	2	1	0	2	0	0	0	2	0	0
		Odonata	0	0	1	1	0	0	0	0	0	1
		Plecoptera	0	1	0	0	0	0	0	5	0	0
		Trichoptera	1	0	1	0	0	0	0	5	0	2
		Coleoptera	2	0	0	1	0	0	0	0	0	0
		Chironomidae	24	16	15	23	7	4	2	9	7	19
		Other Diptera	6	2	2	2	3	0	0	4	2	1
		Other	3	2	5	6	0	0	0	3	0	7

Notes: Taxa with no individuals present in the sites sampled were excluded from the table.
Blank cells indicate absence of taxon.
P = Present.
– = Invertebrates were not identified to this level.

Table U-10 Benthic Invertebrate Taxon List for the Big Creek and Redclay Creek Watersheds, Fall 2005 and 2006

			Big Creek Watershed								Redclay Creek Watershed			
		Waterbody	Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
		Original Site	47	44	42	9-1	49	4	45	46	51	50	52	53
		Date	29-Sep	27-Sep	30-Sep	26-Sep	30-Sep	03-Oct	28-Sep	29-Sep	26-Sep	27-Sep	25-Sep	25-Sep
		Year	2006	2006	2006	2005	2006	2005	2006	2006	2006	2006	2006	2006
Major Taxon	**Family/Subfamily/ Tribe**	**Taxon**												
Nematoda	–	–		P	P	P	P		P	P	P	P		P
Oligochaeta	Enchytraeidae	–		P		P	P				P			
	Lumbriculidae	–				P						P		
	Naididae	–	P	P	P	P	P	P	P	P	P	P	P	P
	Tubificidae	–	P	P	P	P	P	P		P		P		
Hirudinea	Erpobdellidae	*Erpobdella punctata*				P	P			P				
		Nephelopsis obscura						P		P				P
	Glossiphoniidae	*Glossiphonia complanata*					P							P
Mollusca	–	–												
Gastropoda	Lymnaeidae	*Lymnaea*												P
	Physidae	*Physa*					P							
	Planorbidae	–					P		P				P	P
		Helisoma								P				
	Valvatidae	*Valvata sincera*											P	
Pelecypoda	Sphaeriidae	–		P		P	P	P	P	P		P	P	P
Hydracarina	–	–		P	P	P	P	P	P	P	P	P	P	P
Copepoda - Harpacticoida	–	–		P		P	P							
Ostracoda	–	–		P	P	P	P	P	P	P		P	P	P
Amphipoda	–	–												
Amphipoda	Gammaridae	*Gammarus lacustris*							P	P			P	
	Hyalellidae	*Hyalella azteca*					P	P	P	P			P	
Ephemeroptera	Ameletidae	*Ameletus oregonensis*		P	P									
	Baetidae	*Baetis*	P	P	P						P			
		Callibaetis					P							
	Caenidae	*Caenis*					P			P			P	P
	Ephemerellidae	*Drunella grandis*		P							P			
	Heptageniidae	–			P									
		Heptagenia			P									
	Leptophlebiidae	*Leptophlebia*			P							P		
	Tricorythidae	*Tricorythodes*												P
Odonata - Anisoptera	Libellulidae	–					P							
		Leucorrhinia					P							P
Odonata - Zygoptera	Coenagrionidae	*Enallagma*					P		P					
Plecoptera	–	–			P									
	Capniidae	–	P	P	P						P			
	Chloroperlidae	*Sweltsa*		P										
	Leuctridae	–									P			
	Nemouridae	*Nemoura*	P		P									
		Zapada	P	P							P			
	Perlodidae	*Isoperla*	P	P	P						P			
Megaloptera	Sialidae	*Sialis*		P	P									
Trichoptera	–	–		P	P						P	P		

Table U-10 Benthic Invertebrate Taxon List for the Big Creek and Redclay Creek Watersheds, Fall 2005 and 2006 (continued)

			Big Creek Watershed								Redclay Creek Watershed			
		Waterbody	Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
		Original Site	47	44	42	9-1	49	4	45	46	51	50	52	53
		Date	29-Sep	27-Sep	30-Sep	26-Sep	30-Sep	03-Oct	28-Sep	29-Sep	26-Sep	27-Sep	25-Sep	25-Sep
		Year	2006	2006	2006	2005	2006	2005	2006	2006	2006	2006	2006	2006
Major Taxon	**Family/Subfamily/ Tribe**	**Taxon**												
Trichoptera (continued)	Brachycentridae	*Brachycentrus*		P							P			
	Glossosomatidae	*Glossosoma*									P			
	Hydropsychidae	–		P							P			
		Cheumatopsyche			P									
		Hydropsyche									P			
	Leptoceridae	*Oecetis*							P	P				
	Limnephilidae	–	P	P										
		Hesperophylax	P		P									
	Phryganeidae	*Agrypnia*								P				
	Rhyacophilidae	*Rhyacophila*	P	P							P			
Coleoptera	Dytiscidae	*Agabus*	P				P							
		Liodessus									P			
	Elmidae	*Dubiraphia*												
		Optioservus		P										
	Haliplidae	*Haliplus*					P							
Diptera	Ceratopogonidae	–												
	Ceratopogoninae	–	P	P			P	P			P			
		Bezzia				P	P			P				
		Culicoides					P							
		Probezzia								P				
	Dasyheleinae	*Dasyhelea*				P								
	Chironomidae	–												
	Chironomini	–				P				P				
		Chironomus			P	P	P		P	P			P	P
		Cladopelma					P	P		P			P	
		Cryptochironomus										P	P	
		Dicrotendipes					P		P	P			P	P
		Endochironomus					P		P	P			P	P
		Einfeldia											P	
		Glyptotendipes						P	P	P				
		Microtendipes					P	P		P				
		Parachironomus												P
		Paracladopelma		P								P		
		Paralauterborniella			P									
		Paratendipes			P									
		Polypedilum	P	P	P			P	P	P		P	P	P
		Sergentia / Tribelos		P		P								
		Stenochironomus												
		Stictochironomus	P	P		P						P		
	Tanytarsini	–			P					P				
		Cladotanytarsus					P			P			P	P
		Micropsectra		P	P	P			P		P	P		P

Table U-10 Benthic Invertebrate Taxon List for the Big Creek and Redclay Creek Watersheds, Fall 2005 and 2006 (continued)

			Big Creek Watershed								Redclay Creek Watershed			
		Waterbody	Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
		Original Site	47	44	42	9-1	49	4	45	46	51	50	52	53
		Date	29-Sep	27-Sep	30-Sep	26-Sep	30-Sep	03-Oct	28-Sep	29-Sep	26-Sep	27-Sep	25-Sep	25-Sep
		Year	2006	2006	2006	2005	2006	2005	2006	2006	2006	2006	2006	2006
Major Taxon	**Family/Subfamily/ Tribe**	**Taxon**												
Diptera (continued)	Tanytarsini (continued)	*Paratanytarsus*				P	P		P	P			P	P
		Rheotanytarsus			P				P			P		
		Stempellinella			P									
		Tanytarsus	P	P	P	P	P	P	P	P		P	P	P
	Diamesinae	*Diamesa*		P										
		Potthastia longimana gr.			P	P								
		Pseudodiamesa		P										
	Prodiamesinae	*Prodiamesa*		P										
	Orthocladiinae	–	P	P	P	P					P	P	P	
		Acricotopus				P								
		Brillia	P	P										
		Corynoneura	P	P	P	P	P		P					
		Cricotopus/Orthocladius		P	P	P	P		P		P	P	P	P
		Eukiefferiella		P							P			
		Heterotrissocladius	P	P	P						P			
		Nanocladius			P				P					
		Orthocladius (Symposiocladius) lingicola		P										
		Parakiefferiella	P	P	P	P					P			
		Parametriocnemus		P	P						P			
		Psectrocladius				P	P		P				P	P
		Pseudosmittia		P	P									
		Rheocricotopus					P							
		Rheosmittia	P		P									
		Thienemanniella		P	P						P		P	
		Tvetenia		P	P									
	Tanypodinae	–	P	P	P	P		P	P	P		P		P
		Ablabesmyia					P		P	P			P	P
		Clinotanypus								P				
		Labrundinia							P				P	P
		Procladius				P	P	P	P	P			P	P
		Psectrotanypus					P							
		Tanypus					P			P				
		Thienemannimyia gr.			P									
	Dolichopodidae	*Rhaphium*				P								
	Empididae	*Chelifera*	P	P	P						P			
		Hemerodromia			P									
		Wiedemannia									P			
	Simuliidae	*Simulium*				P					P			
	Tabanidae	*Chrysops*		P	P	P								
	Tipulidae	*Dicranota*	P	P	P						P	P		
		Hexatoma / Limnophila	P	P	P									

Table U-10 Benthic Invertebrate Taxon List for the Big Creek and Redclay Creek Watersheds, Fall 2005 and 2006 (continued)

			Big Creek Watershed								Redclay Creek Watershed			
		Waterbody	Big Creek			First Creek	Unnamed Creek 7	Unnamed Waterbody 15	Small Sandy Lake	Oakley Lake	Redclay Creek		Unnamed Waterbody 12	Unnamed Waterbody 13
		Original Site	47	44	42	9-1	49	4	45	46	51	50	52	53
		Date	29-Sep	27-Sep	30-Sep	26-Sep	30-Sep	03-Oct	28-Sep	29-Sep	26-Sep	27-Sep	25-Sep	25-Sep
		Year	2006	2006	2006	2005	2006	2005	2006	2006	2006	2006	2006	2006
Major Taxon	**Family/Subfamily/ Tribe**	**Taxon**												
Diptera (continued)	Tipulidae (continued)	*Ormosia*		P										
		Tipula	P								P			
Total Taxa (genus as lowest level)			26	50	46	31	39	15	27	33	31	20	26	27
Total Taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	2	3	2	4	3	2	1	2	2	3	1	1
		Mollusca	0	1	0	1	3	1	2	2	0	1	3	3
		Ephemeroptera	1	3	5	0	2	0	0	1	2	1	1	2
		Odonata	0	0	0	0	3	0	1	0	0	0	0	1
		Plecoptera	4	4	4	0	0	0	0	0	4	0	0	0
		Trichoptera	3	5	3	0	0	0	1	2	6	1	0	0
		Coleoptera	1	1	0	0	2	0	0	0	1	0	0	0
		Chironomidae	10	22	23	16	16	7	17	17	8	10	17	15
		Other Diptera	5	6	5	5	3	1	0	2	6	1	0	0
		Other	0	5	4	5	7	4	5	7	2	3	4	5

Notes: Taxa with no individuals present in the sites sampled were excluded from the table.
Blank cells indicated absence of taxon.
P = present.
– = Invertebrates were not identified to this level.

Table U-11 Quality Control Data for Re-Sorted Benthic Invertebrate Samples, Fall 2005

Site-Sample	Sorting Efficiency [%]
2-D	[1-(48/(1243+48))]*100 = 96.3
4-A	[1-(25/(616+25))]*100 = 96.1
6-E	[1-(16/(422+16))]*100 = 96.3
9-1-C	[1-(110/(3309+110))]*100 = 96.8
15-1-D	[1-(3/(173+3))]*100 = 98.3
17-A	[1-(0/(4+0))]*100 = 100
20-A	[1-(0/(47+0))]*100 = 100
	Average efficiency = 97.8

Note: % sorting efficiency = [1-(# in QC re-sort/(# sorted originally + # in QC resort))]*100.

Table U-12 Quality Control Data for Re-Sorted Benthic Invertebrate Samples, Fall 2006

Site-Sample	Sorting Efficiency [%]
WB-52 - 4A	[1-(8/(184+8))]*100 = 95.8
WC-51 - A	[1-(7/(249+7))]*100 = 97.3
WC-44 - B	[1-(4/(318+4))]*100 = 98.8
WC-50 - E	[1-(0/(57+0))]*100 = 100
WB-54 - B	[1-(34/(896+34))]*100 = 96.3
WB-46 - B	[1-(4/(205+4))]*100 = 98.1
WC-42 - B	[1-(7/(200+7))]*100 = 96.6
	Average efficiency = 97.6

Note: % sorting efficiency = [1-(# in QC re-sort/(# sorted originally + # in QC resort))]*100.

6 GLOSSARY AND ABBREVIATIONS

6.1 GLOSSARY OF TERMS

Abiotic Non-living factors that influence an ecosystem, such as climate, geology and soil characteristics.

Acid Neutralizing Capacity (ANC) The equivalent capacity of a solution to neutralize strong acids. Acid Neutralizing Capacity can be calculated as the difference between non-marine base cations and strong anions. This is the principal variable used to quantify the acid-base status of surface waters. Acidification is often quantified by decreases in ANC, and susceptibility of surface waters to acidic deposition impacts is often evaluated on the basis of ANC.

Acid Pulse Acid pulse (or episodic acidification) refers to a rapid drop in pH in surface waters over a short period. It typically occurs in the spring, and may result from: (1) dilution of base cations in surface waters by large volumes of runoff from snow melt; and/or (2) release of acids stored in the snowpack that originated from industrial emissions.

Acute A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.

Alberta Environment (AENV) Provincial ministry that looks after the following: establishes policies, legislation, plans, guidelines and standards for environmental management and protection; allocates resources through approvals, dispositions and licenses and enforces those decisions; ensure water infrastructure and equipment are maintained and operated effectively; and prevents, reduces and mitigates floods, droughts, emergency spills and other pollution-related incidents.

Alberta Sustainable Resource Development (ASRD) Alberta Sustainable Resource Development (ASRD) is one of the Alberta Ministries whose mission is to encourage balanced and responsible use of Alberta's natural resources through the application of leading practices in management, science and stewardship. ASRD works with Albertans across the province to ensure a balance between the economic, environmental and social values of our province. They fight forest fires, manage fish and wildlife, oversee the development of Alberta's forests and manage the use of public lands.

Alevin	A newly-hatched fish in the larval stage, dependent upon a yolk sac for nutrients while their digestive system develops.
Alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. Alkalinity is expressed as an equivalent of calcium carbonate. Its composition is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.
Alluvial	Soil or earth material which has been deposited by running water, as in a riverbed, floodplain, or delta.
Anoxia	Little to no dissolved oxygen in the water sample. Waters with <2 mg/L of dissolved oxygen experience anoxia.
At Risk	Any species known to be "At Risk" after formal detailed status assessment and designation as "Endangered" or "Threatened" in Alberta.
Average Depth	Average depth of pools, riffles and runs, based on measurements taken across one to three transects within the surveyed stream section.
Average Wetted Wet Width	Average width of the water surface based on measurements taken across three to six transects.
Backwater	Discrete, localized area exhibiting reverse flow direction and, generally lower stream velocity than main current. Substrate similar to adjacent channel with more fines.
Bankfull Depth	The maximum depth of a channel within a rifle segment when flowing at a bank-full discharge.
Bankfull Width	The width of the stream, measured at the water surface elevation corresponding to the bankfull discharge. For undisturbed streams with a wide floodplain, this is equivalent to channel width.
Basal Aquifer	A water-bearing strata located at the lowest portion of a stratigraphic unit.
Baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
Baseline Case	The EIA assessment case that includes existing environmental conditions as well as existing and approved projects or activities.

Baseline Data (also Environmental Setting Data)	A quantitative level or value from which other data and observations of a comparable nature are referenced. Information accumulated concerning the state of a system, process or activity before the initiation of actions that may result in changes.
Basin	A geographic area drained by a single major stream; consists of a drainage system comprised of streams and often natural or man-made lakes.
Bathymetry	Measurement of the depth of an ocean or large waterbody.
Bed Slope	The inclination of the river channel bottom.
Bedrock	The body of rock that underlies gravel, soil or other surficial material.
Benthic Invertebrates	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.
Biodiversity	The variety of plant and animal life in a particular habitat (e.g., plant community or a country). It includes all levels of organization, from genes to landscapes and the ecological processes through which these levels are connected.
Biodiversity Ranking	The relative contribution of an ecosite phase/wetlands type to the overall biological diversity of an area..
Biotic	The living organisms in an ecosystem.
Blank Samples	Blank samples are samples collected in field and composed of deionized water

Bog	Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks. Mineral-poor, acidic and peat-forming wetlands that receive water only from precipitation.
Boreal	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.
Bottom Sediments	Substrates that lie at the bottom of a body of water. For example, the soft mud, silt, sand, gravel, rock and organic litter that make up a river bottom.
Bottom-Feeding Fish	Fish that feed on the substrates and/or organisms associated with the river bottom.
Box and Whisker Plots	Sub-sets of the data are grouped based on specific periods of time. Statistics are applied to the sub-groups and each one is displayed as a rectangle (the box) with bars (the whiskers) above, within or below each rectangle.
Canopy	An overhanging cover, shelter or shade. The tallest layer of vegetation in an area.
Catchment Area	The area of land from which water finds its way into a particular watercourse, lake or reservoir (Also termed “river basin” or “watershed.”
Channel	The bed of a stream or river.
Channel Cover	The vegetation that projects over the channel width of a stream and material that is in the stream. It is recorded as the percent of the channel width covered within a 50 m section of the stream at each site. Channel cover is arbitrarily divided into three levels: Crown: vegetation >1 m above the water surface; Overhanging: vegetation <1 m above the water surface; and Instream: material (debris, stumps, fallen trees) in the stream that can provide cover for fish.

Channel Regime	The morphological characteristics, including cross-section, longitudal slope and sinuosity, of a watercourse that is in long-term equilibrium.
Channel Unit	Distinct channel sections with specific characteristics of water depth, velocity and cover for fish.
Channel Width	The horizontal distance along a transect line from stream bank to stream bank (rooted vegetation to rooted vegetation) at the normal high water marks measured at right angles to the direction of flow.
Chironomids	A taxonomic family of invertebrates consisting of flies referred to as non-biting midges. The larval stage is aquatic and is included in the benthic invertebrate community.
Chronic	The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.
Community	Plant or animal species living in close association or interacting as a unit.
Concentration	Quantifiable amount of a chemical in environmental media.
Conductivity	A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.
Conifer	Trees in the division Pinophyta of the plant kingdom. These are cone-bearing trees with no true flower (e.g., white spruce, black spruce, balsam fir, jack pine and tamarack).
Connectivity	A measure of how connected or spatially continuous a corridor or matrix is.
Creek	A branch or small tributary of a river.
Critical Load	A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. For waterbody acidification, the critical load represents an estimate of the amount of acidic deposition below which significant adverse changes are not expected to occur in a lake's ecosystem.

Crown Closure	The ground cover area covered by a vertical projection of the tree crowns onto the ground for each identified storey.
Cubic metres per second (m3/s)	The standard measure of water flow in rivers (i.e., the volume of water in cubic metres that passes a given point in one second).
Deciduous	Tree species that lose their leaves at the end of the growing season.
Department of Fisheries and Oceans (DFO) (now Fisheries and Oceans Canada)	Responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans and inland waters; for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters; for leading and facilitating federal policies and program on oceans; and for safe effective and environmentally sound marine services responsive to the needs of Canadians in a global economy.
Deposit	Material left in a new position by a natural transporting agent such as water, wind, ice or gravity, or by the activity of man.
Depositional	Gentle slope with fines.
Development Area	Any area altered to an unnatural state. This represents all land and water areas included within activities associated with the development of oil sands leases.
Dewatering	Removal of groundwater from a geological formation using wells or drainage ditch systems.
Diffusive Transports	Process by which there is a net transport of matter from a region of high concentration to one of low concentration. Diffusion is a passive process resulting from the random movement of molecules as a result of their kinetic energy.
Discharge	In a stream or river, the volume of water that flows past a given point in a unit of time (e.g., m3/s).
Dissolved Organic Carbon (DOC)	The dissolved portion of organic carbon water; made up of humic substances and partly degraded plant and animal materials.
Dissolved Oxygen (DO)	Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L).
Diversity	The variety, distribution and abundance of different plant and animal communities and species within an area.
Drainage Basin	A region of land that eventually contributes water to a river or lake.

Duplicate Samples	A sample collected from the same sampling location using the same equipment and sampling technique and placed into an identically prepared and preserved container. Duplicates samples are analyzed independently as an indication of gross errors in sampling techniques.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit. For the purposes of assessment, the ecosystem must be defined according to a particular unit and scale.
Ekman Grab	Cube-shaped mechanical device with a spring-loaded opening that is lowered to the bottom of a waterbody and triggered to close as to collect a sample of the bottom substrate.
Electrofishing	A 'live' fish capture technique in which negative (anode) and positive (cathode) electrodes are placed in the water and an electrical current is passed between the electrodes. Fish are attracted (galvano-taxis) to the anode and become stunned (galvano-narcosis) by the current, allowing fish to be collected, measured and released.
Elevation	Measurement of the height of the land above sea level.
Endangered	A species facing immediate extinction or extirpation.
Entrenchment Ratio	The ratio of the width of the flood-prone area to the surface width of the bankfull channel which is used to describe the degree of vertical containment of a river channel.
Environmental Impact Assessment (EIA)	A review of the effects that a proposed development will have on the local and regional environment.
Environmental Setting	A quantitative level or value from which other data and observations of a comparable nature are referenced. Information accumulated concerning the state of a system, process or activity before the initiation of actions that may result in changes.
Ephemeral	A phenomenon or feature that lasts only a short time (e.g., an ephemeral stream is only present for short periods during the year).
Epilimnion	A freshwater zone of relatively warm water in which mixing occurs as a result of wind action and convection currents.
Erosion	The process by which material, such as rock or soil, is worn away or removed by wind or water.

Evaporation	The process by which water is changed from a liquid to a vapour.
Evaporation, Lake	Evaporation that occurs from a lake surface.
Evaporation, Potential	The maximum quantity of water capable of being evaporated from the soil and transpired from the vegetation of a specified region on a given time interval under existing climatic conditions and without limiting available surface moisture.
Evapotranspiration	A measure of the ability of the atmosphere to remove water from a location through the processes of evaporation and water loss from plants (transpiration).
Evapotranspiration, Areal	Evapotranspiration that occurs over a given area.
Evapotranspiration, Potential	The maximum quantity of water capable of being evaporated from the soil and transpired from the vegetation of a specified region in a given time interval under existing climatic conditions.
Fauna	An association of animals living in a particular place or at a particular time.
Fen	Sedge peat materials derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral rich waters. Minerotropic peat-forming wetlands that receive surface moisture from precipitation and groundwater. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.
Fines	Silt and clay particles.
Floodplain	The portion of the river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stages.
Fluvial	Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification, but massive, non sorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers.

Forage Fish	Small fish that provide food for larger fish (e.g., longnose sucker, fathead minnow).
Forest	A growth of trees and underbrush covering a tract of land.
Forest Landscape	Forested or formerly forested land not currently developed for non-forest use.
Forested	Closed canopy with greater than 20% tree coverage.
Fork Length	The length of a fish measured from the most anterior portion of the head to the tip of the shortest rays in the caudal fin (i.e., to the fork in the tail).
Frequency Analysis	A statistical procedure involved in interpreting the past record of a hydrological event to occurrences of that event in the future.
Fresh Water	Water with total dissolved solids concentration below 1,000 mg/L.
Geographic Information System (GIS)	Computer software designed to develop, manage, analyze and display spatially referenced data.
Geomorphic	The natural evolution of surface soils and landscape over long periods.
Geomorphical Processes	The origin and distribution of landforms, with the emphasis on the nature of erosional processes.
Geomorphology	The science of surface landforms and their interpretation on the basis of geology and climate. That branch of science that deals with the form of the earth, the general configurations of its surface and the changes that take place in the evolution of landforms.
Glaciofluvial (or Glacio-Fluvial)	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.
Glaciolacustrine (or Glacio-Lacustrine)	Sediments that were deposited in lakes that formed at the edge of glaciers when the glaciers receded. Glaciolacustrine sediments are commonly laminar deposits of fine sand, silt and clay.
Global Positioning System (GPS)	A system of satellites, computers and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.

Groundtruth or Groundtruthing	Visiting locations in the field to confirm or correct information produced from remote sources such as interpreted aerial photographs or classified satellite imagery.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Guild	A set of co-existing species that share a common resource.
Habitat	The place or environment where a plant or animal naturally or normally lives or occurs.
Headwater(s)	The source and upper reaches of a stream; also the upper reaches of a reservoir. The water upstream from a structure or point on a stream. The small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstem river and main tributaries.
Hydrologic Simulation Program – Fortran (HSPF)	The Hydrologic Simulation Program – Fortran (HSPF) model is a comprehensive, conceptual, continuous watershed simulation model designed to simulate the water quantity and water quality processes that occur in a watershed. The model can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently, using segment-specific meteorologic input data and watershed parameters.
Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
Hydrometric Station	A station where measurement of hydrological parameters is performed.
Indicator Parameter	The parameters representing indicating general and specific trends of water quality
Inductively Coupled Plasma (ICP)	This analytical method is an U.S. EPA designated method (Method 6010). The method determines metal concentrations within samples of groundwater, aqueous samples, leachates, industrial wastes, soils, sludges, sediments and other solid wastes. Some samples require chemical digestion before analysis.
Infiltration	The movement of groundwater or hydrothermal water into rock or soil through joints and pores. Infiltration is the main factor in recharge of groundwater reserves.

Influent	An inflow, especially a tributary.
Instream Flow Needs (IFN)	Amount of water needed in a watercourse for sustaining instream values (such as fisheries or related riverine resources) at an acceptable level based on appropriate study.
Invertebrate Drift	Collectively, stream invertebrates (almost wholly the aquatic larval stages of insects) that voluntarily or accidentally leave the substrate to move or float with the current, as well as terrestrial invertebrates that drop into the stream. Also, any detrital material transported in the water current.
Kick Net Sampling	Sampling of the streambed using a small mesh net with a long handle. The net is placed against the streambed and the substrate is disturbed (kicked) upstream of the net to dislodge fish eggs which float down into the net.
Lacustrine	Sediment that have been transported or deposited by water or wave action. Generally consisting of stratified sand, silt or clay deposited on a lake bed or moderately well sorted and stratified sand and coarser material.
Littoral Zone	The zone in a lake that is closest to the shore. It includes the part of the lake bottom and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.
Local Study Area (LSA)	Defines the spatial extent directly or indirectly affected by the project.
Lowland Areas	Areas with ground slopes of less than 0.5% and typically poorly drained.
Macrophytes	Plants large enough to be seen by the unaided eye. Aquatic macrophytes are plants that live in or in close proximity to water.
Mainstem	The main portion of a watercourse extending continuously upstream from its mouth, but not including any tributary watercourses.
Marsh	A non-peat-forming, nutrient-rich wetlands characterized by frequent flooding and fluctuating water levels.
Mature Forest	A forest greater than rotation age with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstorey trees; some with broken tops and other decay; numerous large snags and accumulations of downed woody debris.

Maximum Depth	The maximum depth of the surveyed section of the stream recorded for each pool, riffle and run.
May Be At Risk	Any species that "May Be At Risk" of extinction or extirpation and is therefore a candidate for detailed risk assessment.
Mean	Centroid value of a data population when viewing its probability distribution function (or histogram) as a mass distribution.
Meander	A randomized search pattern used in rare plant surveys to cover the range in micro-habitat variation within a larger ecosystem unit.
Mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).
Micro-Nutrient	A substance that is essential in minute amounts for the proper growth and metabolism of a living organism.
Microtox®	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (Photobacterium phosphoreum).
Mixedwood	A terrestrial forest type that is an assemblage of both deciduous and coniferous tree species.
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.
Not at Risk	A species that has been evaluated and found to be not at risk.
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 μm) and a fines (<44 μm) fraction, consisting of silts and clays.
Oil Sands Region	The Oil Sands Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP.

Oligotrophic	Trophic state classification for lakes characterized by low productivity and low nutrient inputs (particularly total phosphorus).
Open Canopy	Less than 6% tree cover.
Organic Soil	A soil order that have developed primarily on organic deposits. Soils containing high percentages of organic matter (fibric and humic inclusions).
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO2) and carbonates (e.g., CaCO3).
Overburden	Material below the soil profile and above the bituminous sand.
Overwintering Habitat	Habitat used during the winter as a refuge and for feeding.
Oxygenated Water	Water that is treated, combined, or infused with oxygen.
PAH(s)	Polycyclic Aromatic Hydrocarbon (PAH). A chemical byproduct of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.
Peatlands	Areas where there is an accumulation of peat material at least 40 cm thick. These are represented by bog and fen wetlands types.
Pelagial Zone	Deep-water zone(s) of a waterbody where aquatic plants do not grow due to lack of sufficient light penetration.
Pelagic	Inhabiting open water, typically well off the bottom. Sometimes used synonymously with limnetic to describe the open water zone (e.g., large lake environments).
pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
pH Value	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.

Piscivorous Diet	Feeding on fish.
Polycyclic Aromatic Hydrocarbons (PAH)	A chemical by-product of petroleum-related industry or incomplete combustion of organic matter. Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.
Pool: Run: Riffle Ratio	The ratio of pool: run: riffle based on the percentage of each stream type in the surveyed section of the stream. These habitat types are described as: Pool: a deep area of low current velocity; Run: a moderately deep area within the main current; and Riffle: a shallow area where the water surface is broken into waves by bed material.
Population	A collection of individuals of the same species that potentially interbreed.
Probable Effects Level	Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
Probable Maximum Flood (PMF)	The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that is reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and siting of structures and facilities that must be subject to almost no risk of flooding. The probable maximum flood is much larger than the 100-year flood.
Probable Maximum Precipitation (PMP)	The maximum amount of precipitation for a given period that can reasonably be expected to occur in a specific drainage basin.
Quality Assurance/Quality Control (QA/QC)	A set of practices that ensure the quality of a product or a result. For example, “Good Laboratory Practice” is part of QA/QC in analytical laboratories and involves such things as proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.
Rainshadow	A rainshadow is an area having relatively low precipitation due to the effect of a barrier, a mountain for example, that causes the prevailing winds to lose their moisture before reaching the area.

Rating Curve	A curve showing the relation between the discharge of a gauge, meter or other hydraulic structure or instrument and the pertinent hydraulic conditions affecting the discharge, such as pressure, hydrostatic head and velocity of approach. In hydrology, typically refers to a curve showing the relation between the discharge of a river or stream and the water level in the stream.
Reach	A comparatively short length of river, stream channel or shore. The length of the reach is defined by the purpose of the study.
Reach Break Analysis	Longitudinal division of a watercourse into different segments based on differences in fish habitat characteristics from morphological differences in parameters such as chemical pattern, flow regime, gradient and substrate.
Reaeration	Reaeration is the net rate of transfer of oxygen from the atmosphere to a body of water with a free surface. This transfer occurs at the air/water interface. The transfer of dissolved oxygen (DO) from the atmosphere to the surface of a waterbody is controlled by the transfer rate and the DO deficit.
Rearing Habitat	Habitat used by young fish for feeding and/or as a refuge from predators.
Recharge / Discharge Area	Areas that either contribute (recharge) or take away (discharge) to/from the overall volume of groundwater in an aquifer.
Reclamation	The restoration of disturbed land or wasteland to a state of useful capability. Reclamation is the initiation of the process that leads to a sustainable landscape (see definition), including the construction of stable landforms, drainage systems, wetlands, soil reconstruction, addition of nutrients and revegetation. This provides the basis for natural succession to mature ecosystems suitable for a variety of end uses.
Regional Aquatics Monitoring Program (RAMP)	RAMP was established to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region.
Regional Study Area (RSA)	Defines the spatial extent related to the cumulative effects resulting from the project and other regional developments.
Relative Abundance	The proportional representation of a species in a sample or a community.
Resuspension	The remixing of sediment particles and pollutants back into the water by storms, currents, organisms, and human activities, such as dredging.

Riffle A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle Habitat Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.

Riffle-Run-Pool A mixture of flows and depth and providing a variety of habitats. Pools are deep with slow water. Riffles are shallow with fast, turbulent water running over rocks. Runs are deep with fast water and little or no turbulence.

Riparian Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain or standing waterbody.

Riparian Area A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affects it.

Risk The likelihood or probability that the toxic effects associated with a chemical or physical agent will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect at a given time and the total number of individuals exposed to the factor. Risk is expressed as a fraction without units and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.

Run Habitat Areas of swiftly flowing water, without surface waves, that approximate uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.

Runoff The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.

Scatter Plots Scatter plots are used to determine how two parameters are correlated. The x-coordinate for a point in the scatter plot is defined by the observed values of one parameter; while, the y-coordinate of this point is defined by an associated value of another parameter.

Secure A species that is not “At Risk”, “May Be At Risk” or “Sensitive”.

Sedge Any plant of the genus Carex, perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stems, a spiked inflorescence and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.

Sediment Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.

Sediment Load (1) The soil particles transported through a channel by stream flow. (2) The total sediment, including bedload plus suspended sediment load, is the sediment being moved by flowing water in a stream at a specified cross-section.

Sediment Load, Total Also referred to as the total load, a term that refers to the total sediment (bed load plus suspended-sediment load) that is in transport. The term needs to be qualified, however, such as "annual suspended-sediment load" or "sand-size suspended-sediment load," and so on. It is not synonymous with total sediment discharge.

Sediment Sampling A field procedure relating to a method for determining the configuration of sediments.

Sediment Transport Transport rate of soil particles through a channel by stream flow.

Sediment Yield The amount of sediment transported by a stream system that may be measurable at a particular location. Usually expressed in volume or weight per unit of time.

Sedimentation The process of subsidence and deposition of suspended matter carried by water, wastewater or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.

Seepage Slow water movement in subsurface. Flow of water from man-made retaining structures. A spot or zone, where water oozes from the ground, often forming the source of a small spring.

Sensitive Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.

Seven-Day 10-Year Low Flow (7Q10)	The lowest average stream flow during a 7-day interval that is expected to occur once every 10 years on average.
Sinuosity	The ratio of the thalweg length (i.e., the line connecting the deepest points along a stream) to valley length, for a specific reach of a river or stream system. This is, in essence, a ratio of the stream's actual "running" length to its down-gradient length.
Snag	A naturally occurring, standing dead or dying tree often missing a top or most of the smaller branches. It plays an important role in providing habitat for a variety of forest-dwelling wildlife species as well as epiphytic lichens.
Snow Course Survey	Surveys to measure snow depth, snow densities and snow re-distribution in various terrain types.
Snye	A side channel of a river on non-flowing water connected to a flowing river channel only at its downstream end, generally formed in a side channel of a river or behind a peninsula (bar).
Spatial	Relates to definition and consideration of space in the EIA. The spatial boundaries define the area considered in the assessment.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species Abundance	The number of individuals of a particular species within a biological community (e.g., habitat).
Species Composition	The number and abundance of species found within a biological community.
Species Distribution	Where the various species in an ecosystem are found at any given time. Species distribution varies with season.
Species Diversity	A description of a biological community that includes both the number of different species and their relative abundance. Provides a measure of the variation in number of species in a region.
Species Richness	The number of different species occupying a given area.

Split Sample	Samples collected in the field that are divided into two samples. Split samples are quality control (QC) samples that are used to assess analytical variability and comparability.
Sport / Game Fish	Large fish caught for food or sport (e.g., northern pike, Arctic grayling).
Stream Flow	The movement of surface water in a stream channel, usually measured in cubic metres per second (m3/s). It describes the flow at a specific location along the watercourse. Runoff contributed by the entire land area to the stream can be used to describe flow.
Substrate	Material in the stream bed. The assemblage of material sizes include: Organic/Silt: organic material and/or fine material <0.006 mm diameter; Sand: material 0.06 to 2.0 mm diameter; Small Gravel: material 2 to 8 mm diameter; Large Gravel: material 8 to 32 mm diameter; Pebble: material 32 to 64 mm diameter; Cobble: material 64 to 256 mm diameter; and Boulder: material >256 mm diameter.
Surficial Bed Material	The top 3 to 6 cm of the bed material that is sampled using US Series Bed-Material Samplers.
Surficial Deposit	A geologic deposit (clay, silt or sand) that has been placed above bedrock. (See also "Overburden").
Swamp	Land having soils that are saturated with water for at least part of the year and which usually occur next to waterbodies or in areas in association with fluctuating water levels such as along peatland margins.
Terrestrial Vegetation	Forested or non-forested areas of the landscape with non-saturated and non-peat-forming soils. Excludes bogs, fens, swamps and marshes.
Thalweg	A line extending longitudinally along a watercourse following the deepest portion of the channel.
Thermograph	A type of thermometer that produces a continuous record of fluctuating temperature.
Threatened	A species likely to become endangered if limiting factors are not reversed.

Till	Sediments laid down by glacial ice.
Time Series Plots	Time series plots are used to show temporal trends. They are constructed by plotting the data in Cartesian coordinate, with date along the x (horizontal) axis and the values of each data point along the y (vertical) axis
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample. See filterable residue.
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl Nitrogen (TKN) is a common measure of ammonia and organic nitrogen that is used to assess the amount of nitrogen available for biological uptake.
Total Organic Carbon (TOC)	Total organic carbon is composed of both dissolved and particulate forms. Total organic carbon is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). Total organic carbon has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
Total Recoverable Hydrocarbons	A term that refers to groups of petroleum hydrocarbons recovered using a solvent-specific extraction procedure. Hydrocarbons may include a wide range of fuels, oils and greases.
Total Suspended Solids (TSS)	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Toxic Threshold	Almost all compounds (except genotoxic carcinogens) become toxic at some level with no evident harm or adverse effect below that level. Scientists refer to the level or concentration where they can first see evidence for an adverse effect on an organism as the toxic threshold. Genotoxic carcinogens exhibit some toxic potential at any level.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Transpiration	Transpiration is the process by which water is transferred from soil and plant surfaces to the atmosphere.
Trophic	Pertaining to part of a food chain, for example, the primary producers are a trophic level just as tertiary consumers are another trophic level.

Turbidity	An indirect measure of suspended particles, such as silt, clay, organic matter, plankton and microscopic organisms, in water.
Uncertainty	Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.
Universal Transverse Mercator (UTM)	The UTM system applies the Transverse Mercator projection to mapping the world, using 60 pre-defined standard zones to supply parameters. UTM zones are six degrees wide. Each zone exists in a north and south variant. The northern hemisphere projections for the UTM system consist of 120 zones (60 different zones with north and south variants of each). Originally developed for military use and now widely used in civil mapping.
Upland Areas	Areas that have typical ground slopes of 1 to 3% and are better-drainage.
Valley Slope	An area of land that is lower than the land on either side of it. An elongated depression cut by stream erosion and associated water erosion on its side slopes (stream valley).
Vulnerable	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Waterbodies	Stagnant body of water such as lakes, ponds
Watercourses	A watercourse is any flowing body of water. These include rivers, streams, and creeks.
Watershed	The entire surface drainage area that contributes water to a lake or river.
Wetlands	Wetlands are land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or "peatlands," and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.
Wetted Width	The width of the water surface measured at right angles to the direction of flow. Multiple channel widths are summed to obtain total wetted width.

Whole Effluent Toxicity (WET)	"WET" is a term used to describe the adverse effects or toxicity to a population of aquatic organisms caused by exposure to an effluent. This type of test can be used to evaluate the toxicity of effluents, storm water, or ambient surface waters. WET testing is used to assess and regulate the combined effects of all constituents of a complex effluent rather than the conventional methods of controlling the toxicity of single chemicals or constituents.
Young of the Year (YOY)	Fish at age 0, within the first year after hatching.

6.2 LIST OF ABBREVIATIONS

%	Percent
<	Less than (symbol)
≤	Less than or equal to (symbol)
µg/g	Micrograms per gram
7Q10	Lowest 7-day consecutive flow that occurs, on average, once every 10 years
AENV	Alberta Environment
ALS	ALS Laboratory Group
ASRD	Alberta Sustainable Resource Development
BOD	Biochemical Oxygen Demand
Ca2+	Calcium base cation (particle)
CaCO3	Calcium carbonate
CAEAL	Canadian Association for Environmental Analytical Laboratories
CCME	Canadian Council of Ministers of the Environment
CFA	Consolidated Frequency Analysis
cm	Centimetre
CONRAD	Canadian Oil Sands Network for Research and Development
CONRAD	Canadian Oil Sands Network for Research and Development
dam3	Dekametre cubed (thousand cubic metres) (unit)
DFO	Fisheries and Oceans Canada
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
e.g.	For example
EIA	Environmental Impact Assessment
ESR	Environmental Setting Report
FRQ	Frequency Analysis
g	Grams
GC/MS	Gas Chromatography / Mass Spectrometry
Golder	Golder Associates Ltd.
GPS	Global Positioning System
h	Hour
ha	Hectare
HEC-RAS	Hydrologic Engineering Center River Analysis System
HSPF	Hydraulic Simulation Program - Fortran
i.e.	That is

ICP	Inductively Coupled Plasma
IDF	Intensity-Duration-Frequency
ISQG	Interim Sediment Quality Guidelines
JEMA	Jackpine Expansion Mining Area
K+	Potassium base cation (particle)
km2	Square kilometre
L/s	Litres per second
LOEC	Lowest Observed Effect Concentration
LSA	Local Study Area
m3/s	Cubic metres per second
masl	Metres above sea level
MDL	Method detection limit
meq/L	Milliequivalents per litre
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
Mg2+	Magnesium base cation (particle)
mm	Millimetre
mm/h	Millimetre per hour
n	Sample size
Na+	Sodium base cation (particle)
NAD	North American Datum
ng/L	Nanograms per litre
NOEL	No Observed Effect Level
NSERC	National Science and Engineering Research Council
NTDB	National Topographic Database
PAH	Polycyclic Aromatic Hydrocarbon
PANH	Polycyclic aromatic nitrogen heterocycles
PEL	Probable Effects Level
PRMA	Pierre River Mining Area
QA/QC	Quality Assurance/Quality Control
RAMP	Regional Aquatics Monitoring Program
RSA	Regional Study Area
RTK	Real Time Kinematics
SOD	Sediment Oxygen Demand
TCU	True Colour Unit
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen

TOC	Total Organic Carbon
TSS	Total Suspended Solids
U.S. EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
W/m²	Watts per square metre
WDS	Water Data System
WET	Whole Effluent Toxicity
µeq/L	Microequivalent per litre
µg/g	Micrograms per gram
µg/L	Micrograms per litre
µS/cm	Microsiemens per centimetre
°C	Temperature in degrees Celsius (unit)

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