Denison Mines

Wheeler River Project

Final Environmental Impact Statement

November 2024

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2011 – 2019 BASELINE HYDROLOGY SUMMARY REPORT - WHEELER RIVER PROJECT, DENISON MINES

Report prepared for:

DENISON MINES CORP.
230 22nd Street East, Suite 200
Saskatoon, SK
S7K 0E9, Canada

Report prepared by:

ECOMETRIX INCORPORATED
www.ecometrix.ca
Mississauga, ON

Ref. 19-2589
25 March 2020

EcoMetrix
INCORPORATED

2011 – 2019 BASELINE HYDROLOGY SUMMARY REPORT - WHEELER RIVER PROJECT, DENISON MINES

Fei Luo, PhD
Project Manager

Brian Fraser, MSc
Project Principal and Reviewer

EXECUTIVE SUMMARY

The Denison Mines Corp. (Denison) Wheeler River Project (Project) is located in north central Saskatchewan, in the eastern portion of the Athabasca Basin. It is situated approximately 35 kilometres northeast of Cameco Corporation's Key Lake Operation and 35 kilometres southwest of Cameco Corporation's McArthur River Operation. Hydrology baseline studies in the Project area are required to support feasibility engineering studies, technical assessments and environmental approvals processes. EcoMetrix Incorporated (EcoMetrix) was retained by Denison to implement hydrology baseline studies over the period 2016 through 2019 and to synthesize this more recent data with existing hydrological information for the study area. The current understanding of hydrological conditions in the study area based on the full hydrological data set is provided herein.

Project Site Setting

The Project site is located in the Athabasca Plain Ecoregion that extends south from Lake Athabasca to Cree Lake. The area is characterized as a morainal plain, with southwest trending drumlins and eskers and glaciofluvial outwash areas overlying Athabasca sandstones. Numerous interconnected lakes occur in the area, along with low-lying, poorly drained areas of muskeg. The area is in the subarctic climate zone with long, usually cold winters, and short, cool to mild summers. The ice-covered season extends from late October to late April or early May. Precipitation in the Project area is low throughout the year, and mostly occurs in the warmer months.

The Project area lies within the Wheeler River watershed, which is part of the Churchill River Basin. Surface water from the Project site is drained by two sub-basins of the Wheeler River, the Icelander River drainage and the Williams Lake drainage. Both drainages flow generally south into the northwest portion of Russell Lake. The estimated drainage areas of the Icelander River and the Williams Lake drainages are 371 km^2 and 78 km^2, respectively. Downstream of Russell Lake, the Wheeler River flows into the Geikie River, which subsequently discharges to Wollaston Lake.

2011 to 2014 Hydrological Characterization Program

Golder Associates (Golder) surveyed and summarized the hydrological characteristics of the Project site over the period 2011 to 2014. Water elevation survey locations were established at nine stream stations and eleven lake stations. Manual flow measurements were performed at each of the nine stream stations, and automated stream elevation instruments (level data loggers) were installed at all stream stations. Rating curves were established for each station based on the manual stream discharge measurements to permit estimation of hydrographic profiles for each location. The hydrological data collected during this period indicated that the average daily streamflow at the most downstream location in the Icelander River and the Williams Lake drainage areas ranged from 0.84 to

3.13 m^3/s and 0.067 to 1.5 m^3/s, respectively. Lake and pond surface water elevations ranged from 520.42 masl in the headwater lake of the Icelander River drainage to 488.24 masl at Russell Lake.

2016 to 2019 Hydrological Characterization Program

Hydrological surveys conducted between 2016 and 2019 built on the hydrological baseline work completed from 2011 to 2014. In addition to the previously established hydrometric stations, seven new stream stations and four new lake and pond stations were established. The scope of the 2016 to 2019 program included: the measurement of water level elevations at thirteen lakes and two ponds within the study area; the collection of manual streamflow measurements at seventeen watercourses to validate existing rating curves or establish rating curves for new monitoring locations; and, the installation of continuous streamflow monitoring equipment at eight stream locations in 2016 and elevation data loggers at two lake locations in 2018 and 2019. Six field programs were completed from fall 2016 to summer 2019 to capture seasonal flow conditions in spring, summer and fall. One winter field program was completed between March 15 and 19, 2018, to assess ice cover in the area and to gain a better understanding of winter baseflow conditions.

Key Hydrological Characteristics of the Study Area

Over the entire monitoring program (2011 to 2019), lake and pond surface water elevations ranged from 520.86 masl in the Icelander River drainage area headwater lake LA-8 to 487.99 masl at Russell Lake. In the Icelander River basin, water level elevations at the stream stations ranged from 520.84 masl at SA-11 to 492.55 masl at the most downstream station SA-1. In Williams River drainage area, water levels at stream stations ranged from 519.24 masl at SB-4, to 488.34 masl at the most downstream station. The hydrological data collected also indicated that the average daily streamflow at the most downstream location in the Icelander River and the Williams Lake drainage areas ranged from 0.655 to 3.23 m^3/s and 0.067 to 1.5 m^3/s, respectively.

Currently, continuous monitoring equipment is installed in stream stations SA-1, SA-4, SA-5, SA-6, SA-8, SA-9, SA-10, and SA-11, and lake station LA-1. For SA-1, SA-4, SA-5, SA-6 and SA-11, the water level data can be used to estimate stream flow using established rating curve relationships. Rating curves have not yet been established at other stations, as more manual stream measurements are needed over the range of expected flows to adequately characterize the relationship between stage and discharge.

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1.0 INTRODUCTION

EcoMetrix Incorporated (EcoMetrix) was retained by Denison Mines Corp. (Denison) to undertake hydrological baseline studies over the period 2016 through 2019 at the Wheeler River Project (Project) site that is located in the eastern portion of the Athabasca Basin region in northern Saskatchewan. Hydrology baseline studies in the Project area are required to support feasibility design and engineering studies, technical assessments and environmental approvals processes. The information collected over the period 2016 through 2019 has been synthesized with existing hydrological information in order to characterize the current understanding of hydrological conditions in the study area.

The Wheeler River hydrology baseline project started in 2011. Golder Associated Ltd. (Golder) collected and analyzed field data from 2011 through 2014 (Golder, 2014; see Appendix D). This current report builds on the earlier hydrological survey work, documents and analyzes all hydrologic data collected to date, serving as an updated hydrology baseline report for the Project. To avoid repetition, discussion about study design and monitoring methods presented herein focuses on the monitoring efforts started from 2016 and extending through 2019.

1.1 Site Location and General Area Description

The Project is located in north central Saskatchewan, in the south-eastern portion of the Athabasca Basin region (**Figure 1-1**). It is situated approximately 35 kilometres (km) northeast of Cameco Corporation's Key Lake Operation and 35 km southwest of Cameco's McArthur River Operation. Access to the Project site is by the provincial highway system to the Key Lake mill, then by the ore haul road between the Key Lake and McArthur River operations that leads to the eastern part of the property.

The Project site is located in the Athabasca Plain Ecoregion which extends south from Lake Athabasca to Cree Lake (ESWG, 1996). The area in which the Project is located is characterized as a morainal plain, with southwest trending drumlins and eskers and glaciofluvial outwash areas overlying Athabasca sandstones. Numerous interconnected lakes occur in the area, along with low-lying, poorly drained areas of muskeg.

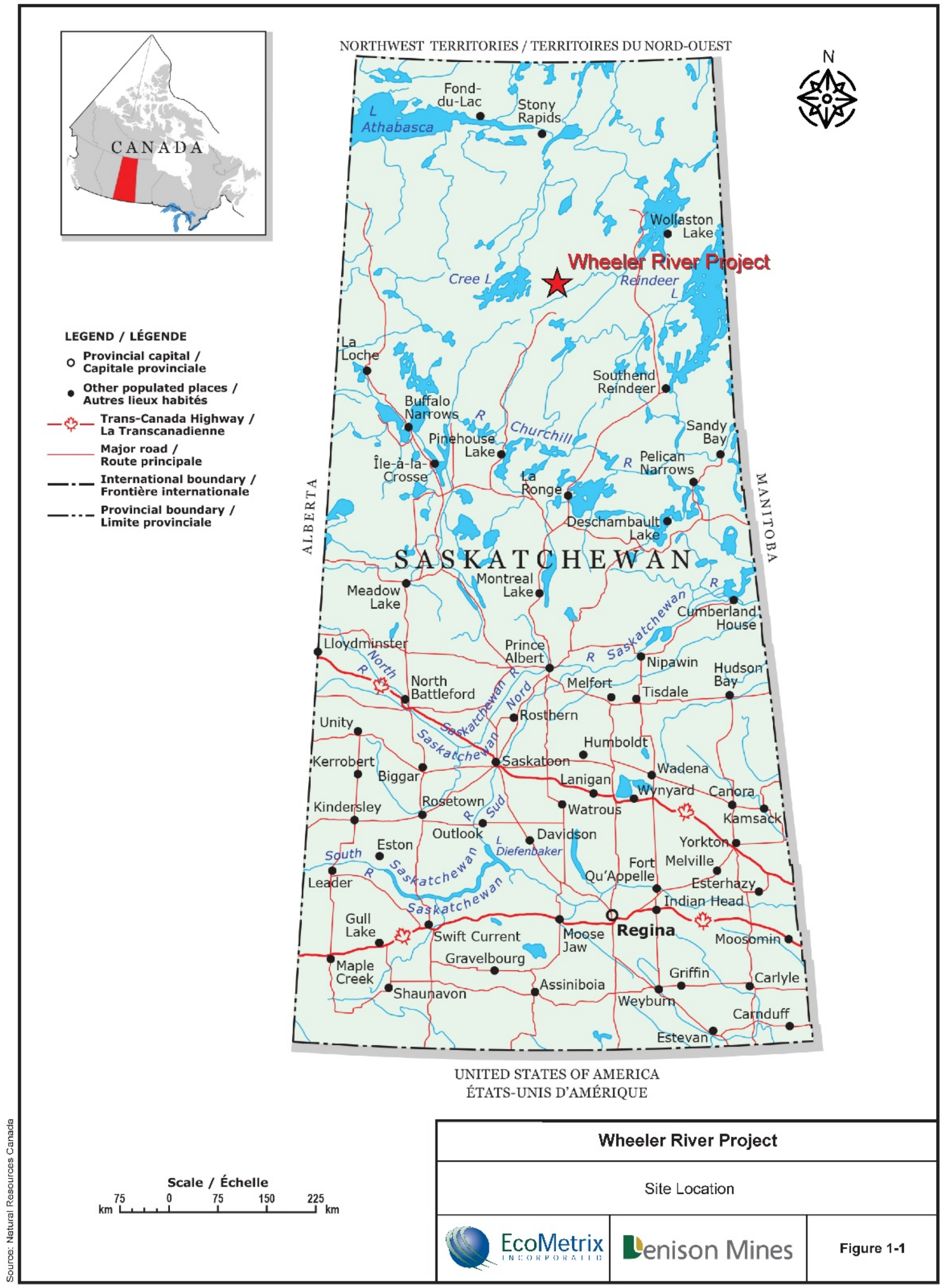

Figure 1-1: Location of the Wheeler River Project Site in north central Saskatchewan

1.2 Climate and Weather

Regional climatic characteristics are a function of various conditions, such as proximity to large bodies of water, altitude, and latitude. The Project site is in the subarctic climate zone that extends across mid and high latitude areas across the entirety of the country excluding coastal areas in the west. The subarctic climate zone is characterized by long, usually cold winters, and short, cool to mild summers. Precipitation in subarctic climates is typically low on an annual basis and precipitation occurs mostly in the warmer months in areas not influenced by coastal climate effects.

On a more local scale, climate conditions, such as temperature, precipitation, evaporation and other processes play a crucial role in the hydrological cycle. Historical climate data collected by Environment Canada and Climate Change (ECCC) weather stations near Key Lake are appropriate to characterize general climate and weather conditions for the Project site. There are three weather stations in the vicinity of Key Lake, though climate norm data were only available for Climate Station 4063755, and therefore data for this station were used to represent the Project site[1]. Data from Station 4063755 were not available subsequent to September 2018. Climate data collected at Station 4063753, situated approximately 1 km from Station 4063755, was used to represent the 2019 climate data for the Project site. Daily average monthly air temperatures are shown below in **Table 1-1**. On average, January is the coldest month and six months have average daily temperatures below 0°C. July is the warmest month with an average daily temperature of 16.3°C. The annual average daily temperature for the Key Lake Station is -2.3°C.

Table 1-1: Temperature norms (daily average per month, °C) reported for the Key Lake Weather Station

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Avg
-22.3	-18.7	-11.7	-1.9	6.5	13.3	16.3	14.7	8.0	0.0	-11.8	-19.5	-2.3

Precipitation is the primary input of surface water and as such, it provides important context for observed flow characteristics. **Figure 1-2** presents the precipitation record for the period 2011 through 2019, as well as historical averages for comparison. The data are presented on the basis of hydrological years that run from October 1 of one year to September 30 of the following year.

Total annual precipitation for the period 2011 through 2019 was on average 473 mm, similar to the total annual average precipitation reported for the period 1981 through 2010

[1] http://climate.weather.gc.ca/historical_data/search_historic_data_e.html

(483 mm). On average, precipitation is the greatest through the warmer months of the year (June, July, August) and relatively low during winter months extending into early spring.

Yearly observations for the period of 2011 through 2019 are provided below in **Section 1.3**, along with observations of local hydrology, as the precipitations significantly impact discharge in the monitoring station.

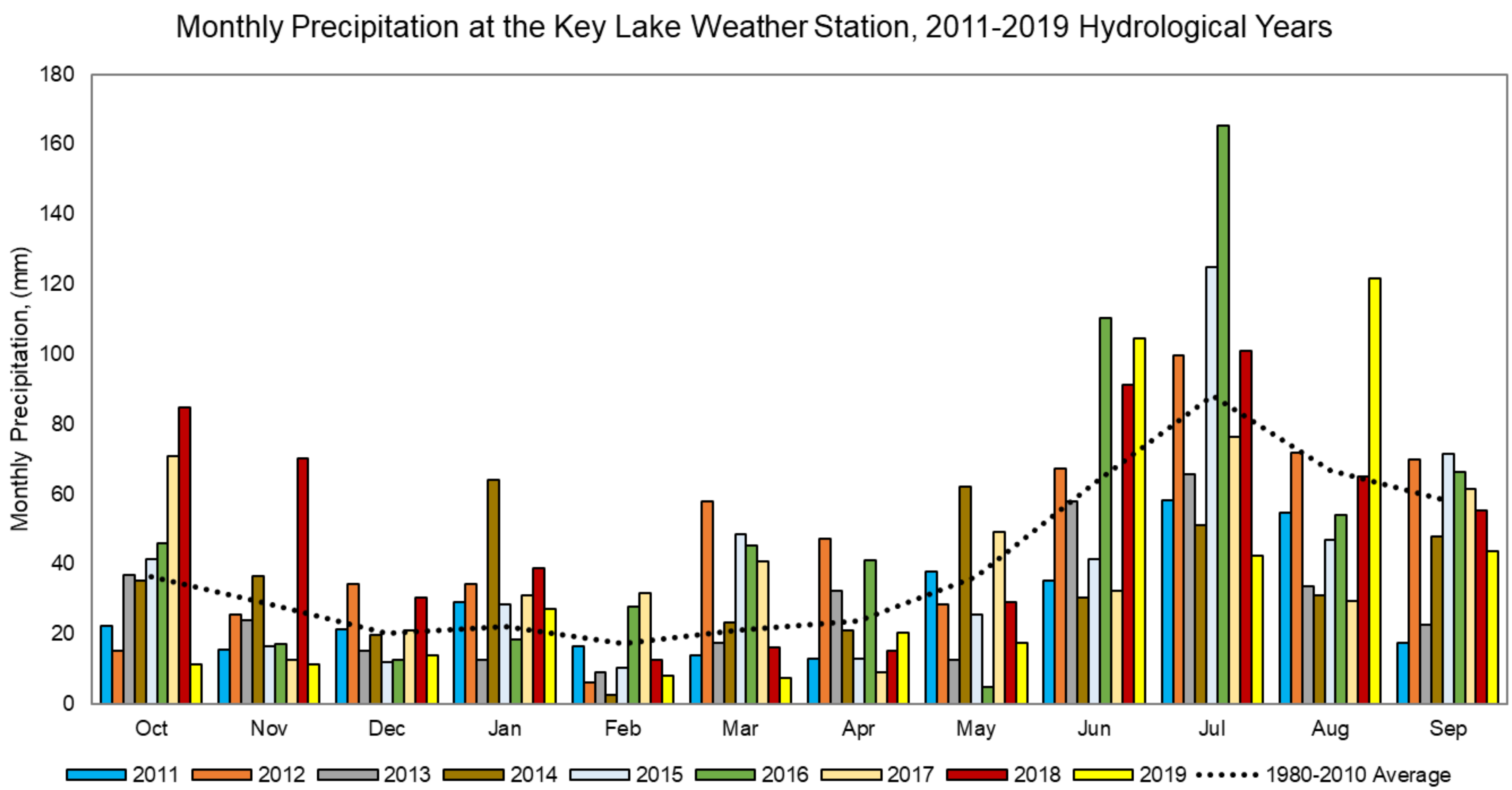

Figure 1-2: Key Lake Monthly Precipitation for Hydrological Years between 2011-2019 (ECCC, 2019).

1.3 Regional Hydrology

The Project site lies within the Wheeler River watershed, which is part of the Churchill River Basin. The Water Survey of Canada operates a hydrometric station on the Wheeler River downstream of Russell Lake (Station 06DA005). The station is located about 25 km east of the Project site and records flows from a contributing drainage area of 3,030 square kilometres (km^2). The hydrometric station has been in operation from 1973 to the present. Both real time and historical discharge and water level data are available in five minutes intervals. Although the drainage area of the hydrometric station is much larger than the drainage areas that are associated with surface water features on and around the Project site, as well as the Project site as a whole, the flow data collected at the station are relevant at the Project site level. The surface water features on the Project site are tributaries of the Wheeler River and land use on the Project site is characteristic of land use within the larger geographical area.

The mean monthly discharge rates at the Wheeler River for the period 2011 through 2019 are presented in **Figure 1-3**. Data corresponding to the period 1981 through 2010 are also presented in **Figure 1-3** for comparison. The data are presented on the basis of hydrological years that run from October 1 of one year to September 30 of the following year. It is noted that only provisional data are available for 2018 and 2019.

The annual average monthly discharge for the period 2011 through 2019 is on the order of 15 m^3/s, about 8% lower than the period 1981 through 2010. Average monthly flows for the period 2011 through 2019 ranged from 11.9 m^3/s in March to 19.6 m^3/s in June. The seasonal hydrograph for the river is represented by relatively low flows through the fall and winter, freshet-dominated flows that appear in May, peak in June and wane in July.

Yearly observations for period 2011 through 2019 are provided below, along with observations of annual precipitations:

- During the 2011 hydrological year (Oct 2010 to Sep 2011), the discharge at the Wheeler River monitoring station was slightly below the historical average throughout the winter (October–March) and remained well below average during the spring freshet (May and June), as well as the remainder of the summer and early fall. During this time, flows ranged from 58 percent (%) (September) to 82% (April) of the 1973-2009 normal. This observation may be in response to the low precipitation, as the precipitation during the 2011 hydrological year was less than average during most months, except January, May, and July. The low precipitation throughout most of the winter may have contributed to a smaller snowpack and a reduced spring freshet. Low summer and early fall precipitation may have also contributed to lower than normal flows during these periods.

- Precipitation during the 2012 hydrological year (Oct 2011 to Sep 2012) fluctuated around the 1981-2010 historical average, except in October and February when it was less than 50% of historical average, and in March and April when the precipitation was higher than twice the historical average. The discharge in the first half of the hydrological year did not correspond to the precipitation

- Precipitation during the 2013 hydrological year (Oct 2012-Sep 2013) was generally below the 1981-2010 historical average, except in April. This precipitation pattern contributed to a lower flow in the study area throughout the hydrological year of 2013, except between Oct to Dec 2012. The additional precipitation that was seen in April did not translate into higher river flows.

- During the late fall and winter of the 2014 hydrological year (Oct 2013-Mar 2014), the discharge at the Wheeler River monitoring station was well below normal. This did not correspond to the precipitation level, as the cumulative precipitation during this period of time was slightly higher than 1981-2010 historical normal, and in January 2014, snow fall was more than two times normal. Flows in the spring (April-May 2014) increased to almost the historical normal discharge, which may be a result from the May precipitation, which was 1.5 times compared to the historical average. It was a dry summer and early fall in the 2014 hydrological year; in contrast, the discharge in June and July 2014 surpassed the historical average, while it fell below average in the following two months.

- During the 2015 hydrological year, discharge was consistently less than the historical average. Peak discharge in May was 15.4 m^3/s, 30% below the historical average. Flows remained more than 30% below average during June to September. This flow pattern may be because the precipitation was near or below historical average in most months of this hydrological year. The snowfall in March exceeded the historical average by 130%, which may be the reason for increased discharge in April, despite low precipitation in that month. In July and September 2015, the precipitation was 40% and 23% above historical average, respectively; however, no increase in discharge was observed.

- Precipitation in the 2016 hydrological year (Oct 2015-Sep 2016) fluctuated around the 1981-2010 historical average from October to March, with the cumulative precipitation 15% above the historical average. In response, the late fall 2015 to winter 2016 discharge was below historical level, and the freshet-dominant flow in May 2016 increased to near the historical level, despite the precipitation was only 13% of the historical normal. Heavy rainfalls were observed at the monitoring station in June and July 2016, which could have been the reason for increased discharge from June to September to near or above the historical average.

- During the first quarter of 2017 hydrological year, the flow was above the 1981-2010 historical average, likely in response to the high amount of precipitation in the summer of 2016 and the above-historical-average rainfall in early fall 2016. The precipitation was all higher than average in the next quarter. However, the discharge data were not available from the hydrometric station in this period of time. From May to September, the monthly discharge rates in Wheeler River were all slightly above the historical average, despite the precipitation in the summer was lower than the historical average.

- During the first six months of the 2018 hydrological year, discharge in the Wheeler River was slightly above the historical average level, possibly corresponds to the high precipitation in the first quarter 2018 (50% above the historical average). From April through June, the discharge rate was similar to the historical average level, and slightly above average between July and September.

- During the 2019 hydrological year, despite the low precipitation in the first six months, the Wheeler River discharge was slightly above the historical average. The river discharge slowly decreased during the winter months, similar to the temporal trend in previous years. The discharge started to increase in May during the spring freshet and reached a peak of 24.9 m^3/s in September. The increased discharge over the summer and early fall corresponded to the high precipitation in June and August, which was more than 1.5 and 2 times, respectively, compared to the historical average.

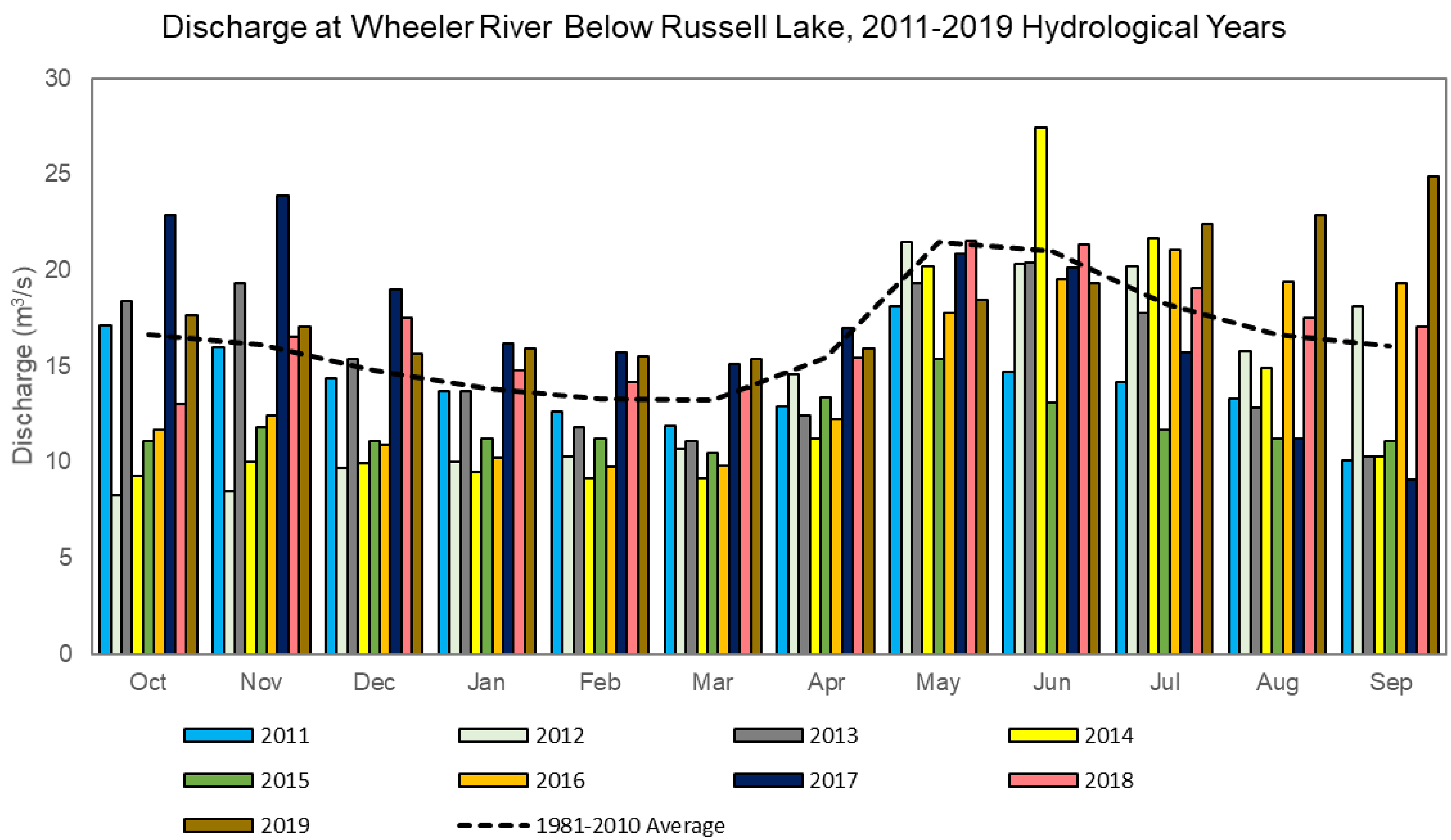

Figure 1-3: Wheeler River mean monthly discharge for the hydrological years between 2011 and 2019. (WSC 2019a, b).

1.4 Local Hydrology

As indicated above, the Project site lies within the Wheeler River watershed. Surface water from the Project area is drained by two sub-basins of the Wheeler River, the Icelander River drainage and the Williams Lake drainage (**Figure 1-4**). Both drainages flow generally south into the northwest portion of Russell Lake. The estimated drainage areas of the Icelander River drainage and the Williams Lake drainage are 371 km^2 and 78 km^2, respectively (**Appendix D**). Downstream of Russell Lake, the Wheeler River flows into the Geikie River which subsequently discharges to Wollaston Lake.

Hydrological information has been collected at the site by Denison since 2011. Details associated with the hydrological baseline program are described in **Section 3.0**.

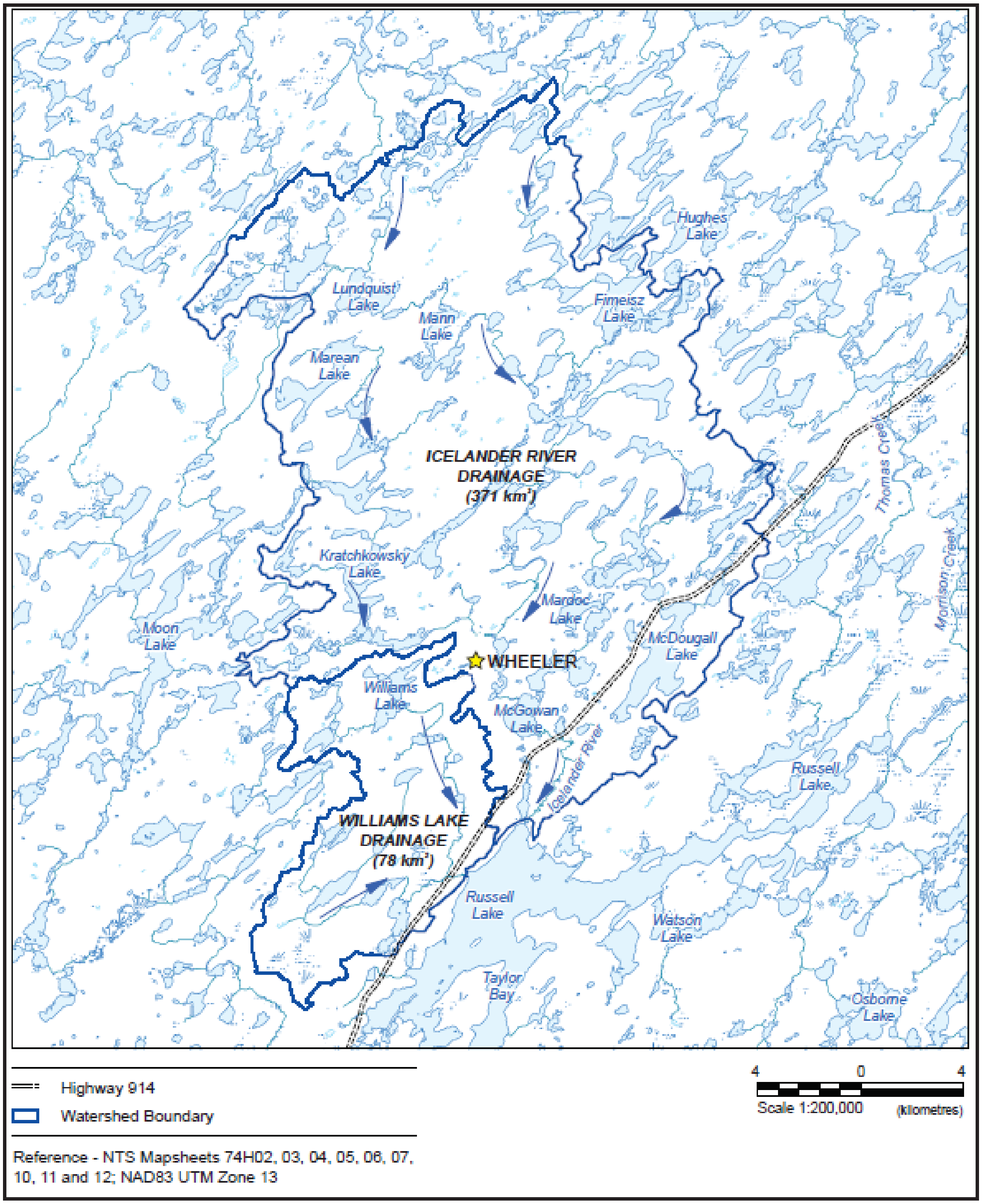

Figure 1-4: Overview of the local drainage areas, Wheeler River Project.

2.0 SCOPE OF THE HYDROLOGY BASELINE PROGRAM

Hydrology monitoring surveys were undertaken at the Project site between 2011 and 2014. The report associated with these efforts is provided as Appendix D of this current report (Golder, 2014). The data associated with the hydrological surveys completed at that time have been integrated with the data collected by EcoMetrix between 2016 and 2019 to provide a characterization of existing hydrologic conditions on the Project site over the entire period of record.

The Hydrology survey that was completed between 2016 and 2019 is described below. Other aquatic work completed between 2016 and 2019, including bathymetry, aquatic habitat characterization, stream morphology identification, etc., is provided in EcoMetrix (2020). The scope of the 2016 to 2019 hydrology program included: the measurement of water level elevations at thirteen lakes and two ponds within the study area; the collection of manual streamflow measurements at seventeen watercourses to validate existing rating curves or to establish rating curves for new monitoring locations; and, the installation of continuous streamflow monitoring equipment at eight stream locations and two lake locations in 2018. Four field programs were completed from fall 2016 to summer 2018 to capture seasonal flow conditions in spring, summer and fall. One additional winter field program was completed between March 15 and 19, 2018, to assess ice cover in the area and to gain a better understanding of winter baseflow conditions.

All monitoring activities that have been completed to date for which results are presented in this baseline study report are presented in **Table 2-1.** Corresponding monitoring locations in both streams and lakes are shown in **Figure 2-1**.

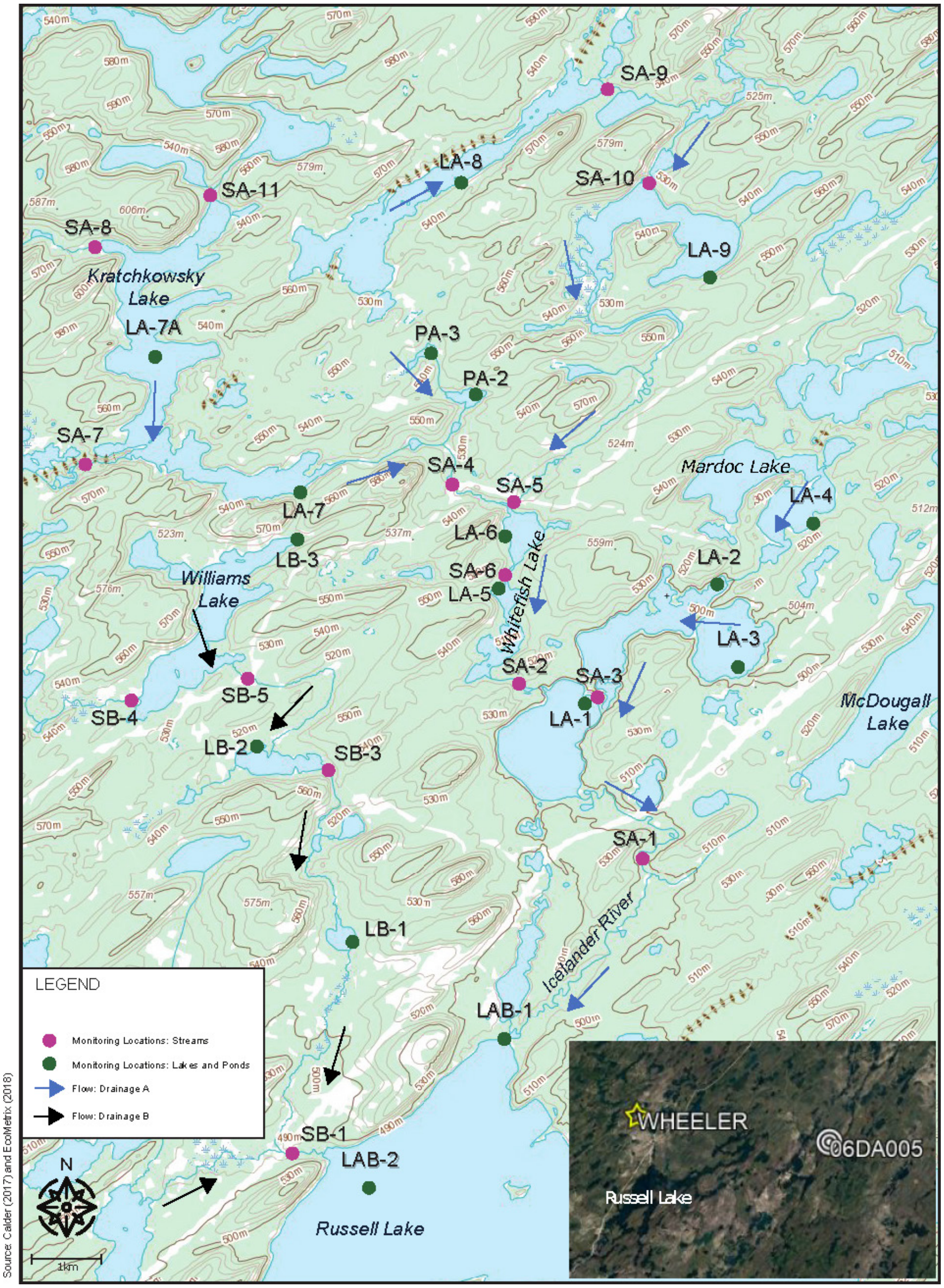

Figure 2-1: Hydrometric Monitoring Locations at Wheeler River Drainage. The location of the WSC hydrometric station 06DA005 downstream of Russell Lake is shown in the inset. Note: LA-5 and LA-6 are recognized as one waterbody (Whitefish Lake) by a local resident.

Table 2-1: Hydrology monitoring stations and monitoring activities

Station Name	Location (UTM NAD 83)	Instantaneous Discharge Measurements	Continuous Water Level Recording	Staff Gauge	Elevation Survey
Lake Level Monitoring Sites					
McGowan Lake (LA-1)	13 V 479399 6373215	-	-2019	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016, 2018, 2019
LA-2	13 V 480852 6375164	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
LA-3	13 V 481477 6373989	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
Mardoc Lake (LA-4)	13 V 481989 6376180	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
Whitefish Lake (LA-5)	13 V 477830 6374521	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
Whitefish Lake (LA-6)	13 V 477763 6375274	-		2011, 2012, 2013	2011, 2012, 2013, 2014, 2016, 2018, 2019
Kratchkowsky Lake (LA-7)	13 V 474851 6375402	-	2012, 2013	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016, 2017
LA-8	13 V 476253 6379929		-	-	2016, 2017
LA-9	13 V 479732 6379231		-	-	2016, 2017
PA-2	13 V 477082 6377227		-	-	2016
PA-3	13 V 476460 6377650		-	-	2016
LAB-1	13 V 478705 6368323	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
LB-1	13 V 476598 6369377	-	-	2011, 2012, 2013	2011, 2012, 2013, 2016
LB-2	13 V 474882 6371871	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016
Williams Lake (LB-3)	13 V 474925 6374767	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014, 2016

Station Name	Location (UTM NAD 83)	Instantaneous Discharge Measurements	Continuous Water Level Recording	Staff Gauge	Elevation Survey
Stream Discharge Monitoring Sites					
SA-1	13 V 480368 6371123	2011, 2012, 2013, 2014, 2016, 2017, 2018, 2019	2011, 2012, 2013, 2014, 2016, 2017, 2018, 2019	-	2011, 2012, 2013, 2014, 2016, 2017, 2018, 2019
SA-2	13 V 478524 6373216	2011, 2012, 2013, 2014, 2016, 2019	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014, 2016, 2019
SA-3	13 V 479415 6373234	2011, 2012, 2013, 2014, 2016, 2019	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014, 2016, 2019
Kratchowsky Creek Outlet (RC-1)	13 V 475468 6375987	2016, 2018, 2019	-		2016, 2019
SA-4	13V 476926 6375868	2011, 2012, 2013, 2014, 2016, 2017, 2018, 2019	2012, 2013, 2014, 2016, 2017, 2018, 2019	-	2011, 2012, 2013, 2014, 2016, 2017, 2018, 2019
SA-5	13 V 477804 6375716	2011, 2012, 2013, 2014	2012, 2013, 2014, 2019	-	2011, 2012, 2013, 2014
	13 V 477822 6375737	2016, 2017, 2018, 2019	2016, 2017, 2018, 2019		2016, 2017, 2018, 2019
SA-6	13 V 477861 6374749	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
	13 V 477863 6374742	2016, 2017, 2018, 2019	2016, 2017, 2018, 2019	-	2016, 2017, 2018, 2019
SA-7	Not recorded	2016	-	-	-
SA-8	13 V 471579 6378303	2016, 2017, 2018	2016, 2017, 2018, 2019	-	2016, 2017, 2018
	13V 471542 6378314	2019	2019	-	2019
SA-9	13 V 478226 6381589	2016, 2017, 2019	2016, 2017, 2018, 2019	-	2016, 2017, 2019
SA-10	13 V 479003 6380421	2016, 2017, 2019	2016, 2017, 2018, 2019	-	2016, 2017, 2019
SA-11	13 V 473026 6379260	2016, 2017, 2019	2016, 2017, 2018, 2019	-	2016, 2017, 2018, 2019
SB-1	13 V 476041 6366362	2011, 2012, 2013, 2014, 2016	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014, 2016
SB-3	13 V 475866 6371655	2011, 2012, 2013, 2014, 2016	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014, 2016
SB-4	13 V 472952 6372222	2011, 2012, 2013, 2014, 2016	2012, 2013, 2014	-	2011, 2012, 2013, 2014, 2016
SB-5	13 V 474615 6372695	2016	-	-	2016

2.1 2016 to 2019 Water Elevation Surveys

Water elevation surveys were undertaken between September 09 and 22, 2016; May 30 and June 1, 2017; March 15 and 18, 2018; June 29 and July 3, 2018, July 4 and 6, 2019 and August 28 and September 1, 2019. Where possible, water elevations at previously established stations were referenced to geodetic benchmarks established by Golder. A description of how the geodetic elevations and benchmarks were established is described in **Appendix D**.

New locations (Lake and pond stations: LA-8, LA-9, PA-2 and PA-3; Stream stations: SA-8, SA-9, SA-10, SA-11, and SB-5) were referenced to temporary benchmarks, each with an assumed elevation of 100 masl, and subsequently converted to geodetic elevations using new benchmarks established in May 2017. The survey results of the all benchmarks used for this project are presented in **Appendix A.**

2.2 2016 to 2019 Instantaneous Flow Measurements

Between 2016 and 2019, streamflow measurements were taken at seventeen locations within the study area using the mid-section method detailed in in **Appendix E** and **Appendix F**. The mid-section method involves measuring the channel area and water velocities of a stream at a cross section. The channel is divided into a number of vertical subsections, adequate to characterize the irregular geometry of the channel. The depth and average velocity are measured at each subsection and are applied to a sub-area whose width extends half way to the preceding and following observation points. The area of each subsection is determined by directly measuring width and depth. The average water velocity in each sub-section is estimated using the measured velocity at selected locations in the vertical. The total discharge within the stream is the sum of the individual subsection discharges.

2.3 2016 to 2019 Continuous Water Level Recording

Eight temporary streamflow monitoring stations (SA-1, SA-4, SA-5, SA-6, SA-8, SA-9, SA-10, and SA-11) were installed in the fall of 2016. The streamflow monitoring stations were established to obtain information on local watercourse flow characteristics. The location of each flow station is presented in **Table 2-1**.

The Solinst Level data logger instrumentation measures absolute pressure, and therefore compensation is required for atmospheric pressure fluctuations. Barometric pressure compensation is achieved using an additional device (e.g., Barologger) to measure barometric pressure. A barologger was installed and deployed adjacent the SA-4 station.

The data collected from the barologger were used to apply barometric pressure compensation to data collected from the Solinst Level data logger instrumentation.

Level data loggers were installed by Golder in 2013 and left in place at SA-1, SA-6, SB-1, and SB-4. In the fall of 2016, level data loggers were located and retrieved at SB-1 and SA-6; however, no level data loggers were not found at SB-4 and SA-1. The logger at SA-6 was redeployed at the same location, and the logger at SB-1 was redeployed at SA-1. As no instantaneous stream data was recorded between April 2014 to September 2016 to validate the continuous flow measurement, the level data logger data collected during this time period was not presented in this report.

Recorded data from the level data loggers deployed in the fall of 2016 at streams SA-1, SA-4, SA-5, SA-6, SA-8, SA-9, SA10, SA-11 and the site barologger at SA-4 were retrieved in the spring of 2017, and all level data loggers were re-deployed after data downloading. Data were downloaded again in the summer of 2018 and 2019. Most level data loggers were re-deployed, except the logger at SA-6, which was replaced in 2019 due to battery life, and the logger at SA-8 that was moved upstream to mitigate influence of backwater from the Kratchowsky Lake In July 2018, level data loggers were installed in McGowan Lake (LA-1) and Whitefish Lake (LA-6). In early October 2018, the level data logger was dislodged from McGowan Lake by ice, and hence was removed. The logger was re-installed to LA-1 in August 2019. The level data logger installed in LA-6 was not located during the 2019 survey.

Barometric compensation for the 2016 to 2019 field program was completed using the barologger at SA-4, with any gaps filled using transformed data from the Key Lake Climate Station (Climate ID = 4063757) at 57°15'23.000" N, 105°37'03.000" W. The Key Lake Climate Station has an hourly barometric pressure record. The data were linearly interpolated to 15-minute intervals to develop the barometric compensation for the level data logger data.

2.4 Rating Curve Development and Validation

Rating curves are used to transform results from level data loggers installed in water courses to discharge rates. Golder (2014) presented rating curves for the stream stations SA-1, SA-2, SA-3, SA-4, SA-5, SA-6, SB-1, SB-3, and SB-4, and the lake stations McGowan Lake (LA-1), LA-2, Whitefish Lake (LA-5, LA-6), Kratchkowsky Lake (LA-7) and LB-2. The manual flow measurements taken as part of the 2016 to 2019 field program were graphed along with Golder's measurements and rating curves were reviewed for suitability for use with the new installations. For lake stations, discharge at the outlet stream was used to correlate to the water elevation. In 2019, the monitored stream discharge was greater at a few locations within the Icelander River Drainage (Appendix B), and therefore, rating curves were adjusted accordingly. Rating curves are presented for each hydrometric station within the Icelander River Drainage in **Appendix C**.

Based on the data, manual measurements at SA-1, SA-2, SA-3, SA-4, and SA-6 between 2011 and 2019 appear to fit within stage-discharge relationships, despite a few outliers (shown in **Appendix C**). In 2016, the SA-5 hydrometric station was installed upstream of the 2011-2014 monitoring location, with similar channel width and gradient. The rating curve for SA-5 was shifted upstream based on the five manual flow measurements taken between 2016 and 2019 (**Appendix C**).

Stage-discharge curves established by Golder (2014, **Appendix D**) were validated or adjusted incorporating the most recent monitoring data. The curves were used to process hydrographs to reflect discharge at stream stations within each open water season. As the emphasis of this report is on the long-term discharge of streams, all flow rates were averaged for each day of monitoring and presented in **Appendix C**.

For stream stations SA-8, SA-9, and SA-10, the manual flow measurements obtained to date were not sufficient to develop a reliable rating curve for conversion from level to flow, as more high/low extreme flow conditions needed to be captured to reduce uncertainty. For these flow stations, water elevation results are presented in **Appendix C**. A preliminary stage-discharge relationship was developed at SA-11.

2.5 2018 Measurement of Ice Thickness

Ice thickness in McGowan Lake (LA-1), Whitefish Lake (LA-6) and Kratchkowsky Lake (LA-7) was measured between March 15 and 18, 2018, at the deepest point of the lake. An ice auger was used to drill through the ice and thickness was measured using a measuring tape.

3.0 EXISTING HYDROLOGICAL CONDITIONS

A description of existing hydrological conditions at the Project site in consideration of all baseline data collected to date is provided below. For the stream monitoring stations this includes consideration of the stream monitoring locations, stream discharge data, the relationship of local (measured) to regional hydrology for select locations and the effects of ice on local stream flows. For lake monitoring locations, this includes lake elevations and ice cover.

3.1 Streams

3.1.1 Stream Monitoring Locations

The following presents a discussion of the physical features and monitoring characteristics observed at each site.

3.1.1.1 Icelander River Drainage

SA-1

SA-1 is located close to the outlet of Icelander River drainage area at Russell Lake. It is the most downstream monitoring station in Icelander River drainage area with an estimated upstream area of approximately 371 km^2. The monitoring station is located at the transition between an upstream low gradient meandering channel section and a downstream higher gradient riffle channel section. The stream substrate is comprised of boulders, cobble, gravel, and sand, and is approximately 15 m wide at the cross-section. Although the banks are well defined and stable with shrubs and moss, the left bank has a notable floodplain vegetated with shrubs and black spruce. SA-1 has a good cross-section and monitoring station. The station is in a low gradient section immediately upstream of a high gradient section. SA-1 produces a good stage- discharge relationship and accurate hydrograph. The logger left by Golder in 2014 was not located in the 2016 site visit, and was presumed to be lost. The level data logger retrieved from SB-1 was installed in this station. A level data logger is currently in place at SA-1.

SA-2

Streamflow monitoring station SA-2 flows into the northwest end of McGowan Lake. The monitoring station at SA-2 is located several meters downstream of the transition between an upstream meandering channel and a downstream riffle section. The monitoring site has a cross-section width of approximately 11 m, and is relatively shallow with high velocity flow. The stream is generally steep with vertical banks and high velocities. The substrate of SA-2 is primarily composed of boulders and cobble, with well-defined and stable vertical banks vegetated with shrubs and trees. SA-2 produces a fair stage-discharge relationship as shown in Appendix C. The two outliers correspond to 2016 and July 2019 measurements that were taken in a different stream cross section. The rest of the measurements fit well to the established stage-discharge relationship. No continuous flow monitoring has been conducted at SA-2 since 2014.

SA-3

Streamflow monitoring station SA-3 flows from LA-2 to McGowan Lake (LA-1). The entire stream length has a sandy and silty bottom with well-defined vertical banks vegetated with shrubs, willows and jack pine. The monitoring station is located near the middle of the stream length and has a cross-sectional width of approximately 11 m. SA-3 produces a good stage-discharge relationship and therefore relatively accurate hydrograph. Due to the proximity to LA-1, flow/water levels at this station are believed to be affected by the water level at the lake, especially during the high flow conditions in 2019. No logger was installed at this location in monitoring program since 2014.

SA-4

The stream discharge monitoring station SA-4 drains Kratchkowsky Lake, and is to the east of SA-5 and flows into the northwest end of LA-6. The monitoring site is located upstream of the existing temporary bridge and a fast flowing and narrow channel section. The channel has a cross-section width of approximately 6 m. The channel substrate is composed of large angular cobble and boulders. SA-4 produces a good stage-discharge relationship, and hence an accurate hydrograph. A level data logger and a barologger are currently in place at SA-4.

SA-5

Station SA-5 is to the east of SA-4 and flows into the northwest end of LA-6. The monitoring station originally established by Golder was located downstream of a small temporary bridge in a straight and relatively steep section of the stream. The new flow station established in 2016 by EcoMetrix is in a similar location slightly upstream of the Golder station. The substrate at the cross-section is primarily boulders and small cobble overlain sand. The stream has a width of approximately 8 m and has stable vertical organic banks vegetated with shrubs. The new continuous flow station was installed on a straight run downstream of the removed bridge crossing in 2016. The level data logger is still in place, and the level data have been retrieved annually to monitor continuous flow conditions. Manual stream measurements at SA-5 have yielded a reasonable stage-discharge relationship.

SA-6

Streamflow monitoring Station SA-6 is in the channel that drains from LA-6 and is upstream of LA-5. It is recognized by local resident as a narrow connecting LA-5 and LA-6 (the south and north basins of Whitefish Lake), rather than a stream. It is a wide sandy-bottomed stream with vertical banks. Flow in this stream is deep and slow. Although the right bank is well defined, high, and vegetated with trees, sand, and moss, the left bank is low lying with muskeg, shrubs and black spruce. The continuous monitoring station was installed approximately halfway between LA-6 and LA-5 and is currently active. The cross-section has a width of approximately 14 m. Manual stream measurements at SA-6 have yielded a fair stage-discharge relationship. The level data logger was replaced in 2019 due to battery life.

SA-7

SA-7 is a narrow marshy stream that flows into Kratchkowsky Lake. The stream channel has vertical, undercut banks. Flow in the stream is slow and deep. The gradient at the location is low and it is within the backwater area associated with the lake inlet and therefore water elevations there are influenced by the lake. SA-7 was originally identified for continuous water level monitoring. However, considering the flow condition, no logger was installed at this location. Elevation benchmark was not established, and instantaneous flow was monitored only once in September 2016. This station was replaced by SA-11.

SA-8

Streamflow station SA-8 is located in an inlet channel at the northwestern end of Kratchkowsky Lake. It is a meandering, narrow sandy bottom stream with deep banks. Some areas of the bank are undercut. The continuous monitoring station was installed in a relatively straight, faster flowing section of the channel immediately upstream of the lake in September 2016. In 2019, it was noted that this station is subject to backwater effects owing to its proximity to the lake, and therefore the station was moved upstream (**Appendix F**). A rating curve has yet to be established for this station – more manual measurements that include high and low flow events are needed to establish a reliable elevation-discharge relationship.

SA-9

SA-9 was initially located at the outlet of LA-8 that is accessible by an existing ATV trail. The stream channel in this section is shallow and relatively narrow. The stream substrate is comprised mainly of sand, gravel, and cobble. The monitoring station was located in a pool upstream of the road crossing. Stream banks are shallow and the surrounding land is relatively flat. The area has recently been impacted by a forest fire, so this station is at greater risk of trees/debris falling into the channel and impacting existing flow characteristics. Although level data logger data has been available since September 2016, the stage and discharge data collected from this site are not yet sufficient to establish a reliable rating curve.

SA-10

SA-10 is located in a wide sandy bottom stream channel that flows into the northwest part of LA-9. The stream banks are vertical and the water is deep and slow-moving. The continuous monitoring station was located in a relatively straight section of the channel with wadable depths in 2016, at the time of installation. More stage and discharge data are required to establish a reliable rating curve.

SA-11

SA-11 is located at the northern-most inlet to Kratchkowsky Lake, and serves as a replacement station for SA-7. The stream substrate is comprised primarily of gravel and cobbles. The stream channel here is braided, though the monitoring station was located in an unbraided section immediately upstream of the lake. A level data logger was installed in September 2016, and is still recording continuous water level data. A preliminary stage and discharge relationship was developed in 2019 (**Appendix E**).

RC-1

Stream station RC-1 is situated immediately downstream of Kratchkowsky Lake. The stream banks were stable and the channel was meandering. The canopy was mostly dense with some partly open areas. Instream cover was diverse, afforded by boulders, deep pools, aquatic macrophytes, logs and trees, and undercut banks. Substrates were comprised of cobble, boulder, gravel and sand. Aquatic vegetation included sedges and burreed. Slight algae growth and sediment were observed overlying the substrate. This station encompasses the stream reach in the vicinity of the proposed mine road crossing. Discharge measurements have been recorded, but no level data logger has been installed at this location.

3.1.1.2 Williams Lake Drainage

SB-1

SB-1 is located close to the outlet of the Williams Lake drainage at Russell Lake. The monitoring station is located immediately upstream of the culverts at the McArthur River haul road. The stream in this area is marshy with a thick organic base. The stream bottom in the immediate vicinity of the monitoring station has been altered as result of the road crossing and consists sand, gravel and boulders. Signs of beaver activity were observed both upstream and downstream of the monitoring location during work completed in 2016-2018. The rating curve associated with SB-1 shows a relatively weak stage-discharge relationship, likely the result of stream morphology at this location. The level data logger installed in 2014 was retrieved from this location in 2016, and no continuous flow monitoring has been conducted since then.

SB-3

SB-3 is located in the outlet channel of LB-2. The stream substrate is comprised of organics, sand, cobbles and boulders. The banks are nearly vertical with moss and shrubs, and the width is approximately 3 m. Manual stream measurements at SB-3 have yielded a good stage-discharge relationship. Continuous flow monitoring was conducted between 2011 and 2014.

SB-4

SB-4 is located in an inlet channel of Williams Lake. The stream banks are shallow and poorly defined. The bottom of the stream consists of large angular cobbles and boulders. At the Golder continuous flow station, the width of the stream was approximately 5 m. Manual stream measurements at SB-4 have yielded a fair stage-discharge relationship and hydrograph between 2012 and 2014, according to Golder (2014). It is to EcoMetrix' understanding that continuous monitoring equipment was left at this location; however, the logger was not found and was assumed to be lost. No level data logger was installed at SB-4 since 2016.

SB-5

SB-5 is located at the outlet of Williams Lake. The stream substrate is composed of sand, gravel and cobbles. Gauging was conducted in a relatively straight section of the channel downstream of the camp road crossing and upstream of a low gradient pool and braid. SB-5 is accessible by road. No level data logger was installed at SB-5.

3.1.2 Stream Stage and Discharge

Stage and discharge measurements made between 2016 and 2019 were compiled in combination with results from 2011-2014 as appropriate and are presented in **Appendix B**. Detailed information associated with the monitoring completed between 2016 and 2019 that was largely focused in the Icelander River drainage, including station maps, updated flow and elevation measurements and rating curves (if established or updated), continuous flow measurements (if applicable); and, photographic records are provided in **Appendix C**.

The average monthly discharge from stream stations during the open water season in 2011, 2012, 2013, 2017, 2018 and 2019 are presented in **Figure 3-1**. It is apparent from the graph that the intra-annual flow pattern at each stream station is consistent with the flow pattern at the Wheeler River station. Stream discharge is highest during the freshet, with flows decreasing throughout the summer and into the fall and winter baseflow periods. Comments concerning flows measured in each monitoring year are provided below.

In 2011, the highest observed flows were in the spring during level data logger installation by Golder (2014). The spring peak flow rate was likely not captured at any site. The flow receded throughout May and June. At all sites a secondary peak was observed during July and early August, which corresponds to relatively high rainfall, although the monthly mean discharges were still lower than May. Flows receded again until September and remained static for the balance of the monitoring season.

The stream flows were considerably higher in 2012 monitoring season than those observed in 2011, especially in Stream SA-1. The spring peak discharge rate, which occurred shortly after the first discharge measurement, was approximately captured at all sites. Discharge peaked in mid-May, and remained high till August, responsive to the increasing precipitation in June and July. At SA-1, peak flow in July exceeded the spring peak flow rate. At most sites, flow rates reached seasonal lows in late August before rising again during September and October, and stayed at the level lower than the discharges measured in spring.

In 2013, discharge peaked in late June instead of May in earlier years, and steadily receded after the peak, until moderate runoff responses occurred in late August and early September. Flows receded to seasonal lows in late September and remain static till end of the open water season.

Although level data logger data was retrieved from SB-1 and SA-6 in 2014 and 2015, no instantaneous flow data were available during this time period to validate the logger data. Therefore, no hydrograph or monthly mean flow data are presented between winter 2014 to fall 2016.

In fall 2016, the discharge level exceeded previously reported spring peak in most streams, possibly in response to the high precipitation in summer and fall 2016, which exceeded the precipitation level during the spring.

In 2017, spring peaks occurred in mid-May, and they were approximately captured. At most sites, flows receded in the summer and reach the seasonal low in Mid-September. In late October, flows have recovered to almost the similar level as measured in the spring, likely due to the precipitation level that was higher than normal.

In 2018, spring peak flows occurred in Mid-May, and the discharge at most stations remained relatively high till early July, when discharge decreased at most of the stations, and increased again in mid- to late July. Discharge level at most stations receded in August till end of the open water season, corresponding to lower precipitation during these months.

To date, the level data logger data were collected till the end of August, 2019. There was no apparent spring peak, likely because of the low precipitation over the winter. Flow receded slightly in Late May and early June, and increased to its seasonal high flow in late June to early July, likely corresponds to high precipitation in late June.

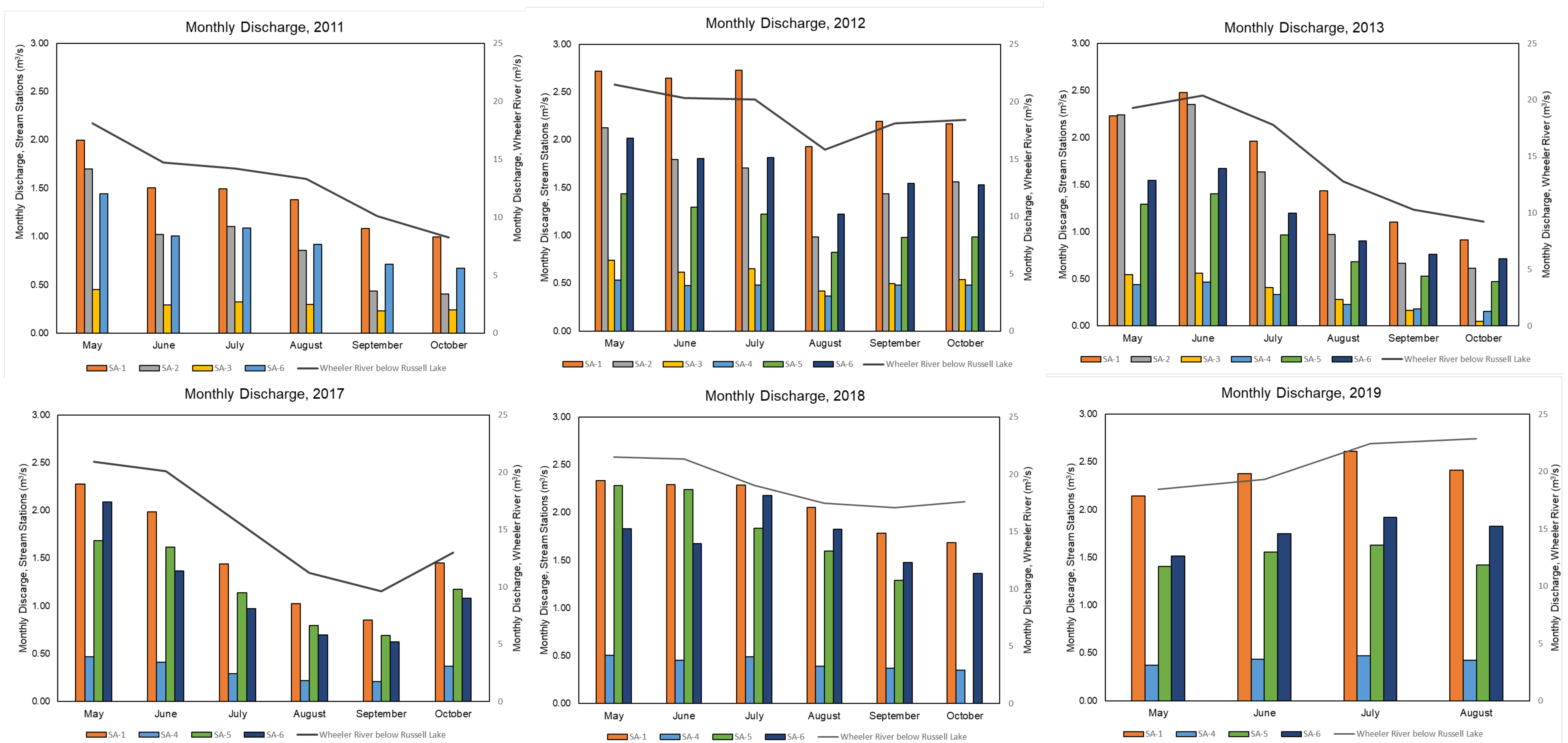

Figure 3-1: Monthly mean discharge at stream stations in the Wheeler River drainage area where level data logger was installed. A Canada Hydrometric Station is installed at Wheeler River downstream of Russell Lake (06DA005). Note: 1) Early ice-up was observed in SA-5 in October 2018, and therefore, the discharge in SA-5 was not plotted for this month; 2) Continuous discharge monitoring was updated to the last field trip in August 28-September 1, 2019.

3.1.3 Relationship to Regional Hydrology

Although the drainage area of the Water Survey of Canada (WSC, 2018a and 2018b) hydrometric station on the Wheeler River (3,030 km^2) is much larger than the drainage area associated with the site (371 km^2), these drainage areas are similar in terms of climate and geography. As shown in **Figure 3-1**, the flow patterns of at least a few stream stations are consistent with the flow pattern of the Wheeler River station at the WSC hydrometric station 06DA005. Therefore, a scaled relationship between flows at the WSC station 06DA005 and the project area could be established to project flows at the project area.

Golder (2014) provided examples of relationships between discharge for a subset of survey stations (SA-1, SB-3, SB-1) and WSC station 06DA005 using data measured between 2011 to 2013 (**Appendix D**). Such relationships can be developed for specific survey locations in the project area for the purpose of hindcasting and/or forecasting flows or developing site-specific flow statistics to support future project work, such as waste assimilative capacity assessments to support licensing. In this application, the flow data associated with WSC station 06DA005 and can be used to derive a watershed area adjusted low flow condition (7Q20) to assess the potential influence of mine site drainage on local receiving waters.

3.1.4 Effect of ice formation on discharge ratings

The formation of ice in stream channels affects stream flow and its measurement. Surface ice for example, changes streamflow from open-channel flow (i.e., flow having a free surface) to closed-conduit flow (i.e., flow not having a free surface). Under surface ice frictional resistance is increased because a water-ice interface replaces the water-air interface, hydraulic radius is decreased because of the additional wetted perimeter of the ice, and the cross-sectional area is decreased to a degree by the thickness of the ice (Rantz, 1982). As a result, the stream stage will therefore increase for a given discharge as the formation of surface ice causes a backwater effect. In these instances, an existing stage-discharge relationship that has been developed based on information collected in the ice-free season may not accurately represent winter flow conditions.

Rantz*,* (1982) describe three methods by which it is possible to compensate open-water discharge for ice effects. One such method is the discharge-ratio method whereby the open-water daily discharge is multiplied by a variable factor (K) to give the corrected discharge during periods of ice cover. The variable factor K, which varies from 0 to 1, is derived as the ratio of observed ice-covered discharge to the open-water rated discharge corresponding to the observed stage - K therefore varies with time and is a specific to each time a winter flow measurement is collected at each sampling location. The greater the ice cover the lower the K value. Golder (2014) calculated K for various stream survey locations in the project area in March 2014. These K values ranged from 0.3 to 0.8.

3.2 Lakes

3.2.1 Lake Elevation Measurements

The stages of McGowan Lake (LA-1), LA-2, LA-3, Mardoc Lake (LA-4), Whitefish Lake (LA-5 and LA-6), Kratchkowsky Lake (LA-7), LAB-1, LB-1, LB-2, and Williams Lake were measured during each site visit from 2011 to 2014, and in fall 2016. The compiled data are presented in **Appendix B, Table B-2**. In 2016, new survey stations were established at LA-8, LA-9, PA-2, and PA-3. The elevations of McGowan Lake and LA-6 were surveyed in 2018 and 2019. A summary of geodetic water level observed in all site visit are presented in **Table 3-1**. The difference between the minimum and maximum water levels were typically on the order of 0.4 m.

Table 3-1: Lake Water Level Summary during open water conditions, 2011-2019

Station	Minimum Measured Water Level (masl)	Maximum Measured Water Level (masl)
McGowan Lake (LA-1)	494.194	494.515
LA-2	494.467	494.654
LA-3	494.439	494.649
Mardoc Lake (LA-4)	498.507	498.649
LA-5	499.949	500.076
LA-6	499.943	500.118
Kratchkowsky Lake (LA-7)	520.424	520.536
LA-8	520.8	520.86
LA-9	514.25	514.28
LB-1	503.66	504.079
LB-2	510.392	510.573
Williams Lake (LB-3)	518.356	518.58
LAB-1	487.994	488.382
PA2	510.46	510.46
PA3	510.36	510.36

Based on the Wheeler River Project Provincial Technical Proposal and Federal Project Description, the anticipated mine water discharge location is the north basin of Whitefish Lake (LA-6;Denison, 2019). LA-6 drains through SA-6 to LA-5 as the only outlet, and as indictive above the stream reach represented by SA-6 is considered as a lake narrowing connecting two basins of Whitefish Lake (LA-5 and LA-6) by a local resident. The elevation of SA-6 correlates well with LA-6 (Appendix C, Appendix F) and therefore, level data logger installed in SA-6 is sufficient to represent the continuous discharge from LA-6.

The stage-discharge relationship established by Golder (2014) for McGowan Lake was validated with data collected in 2016 to 2019 (Appendix C), where discharge in SA-1 was measured to represent the discharge at McGowan Lake. This relationship can be used to calculate continuous discharge at LA-1 using the level data logger installed in August 2019.

3.2.2 Ice Thickness Measurements

Ice thickness has been measured at Project site lakes in March/April 2014 and again in March of 2018. This time of the year would generally be considered to be the period of maximum ice development, though year-to-year variability would be expected.

In 2014, ice thickness on study areas lakes was in the range of 0.70 m to 0.97 m with an average thickness of 0.83 m. Ice thickness values measured for McGowan Lake, LA-6, and Kratchkowsky Lake in March 2018 were 0.70, 0.71, and 0.70 m, respectively.

4.0 References

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Appendix A Ground Survey Results: Elevations of Benchmark at Each Monitoring Station

Table A-1 Information about benchmarks at each hydrometric station for elevation survey

Benchmark	Type	Northing (m)	Easting (m)	Elevation (m)
LA-2 BM1	Rebar	6375172.712	480842.634	497.339
LA-2 BM2	Rebar	6375174.795	480846.484	497.064
LA-2 BM3	Rebar	6375171.611	480846.491	496.34
LA-3 BM1	Rock	6373997.35	481487.807	496.134
LA-3 BM2	Rock	6373994.256	481487.899	496.034
LA-3 BM3	Rock	6373997.038	481478.058	494.831
Mardoc Lake (LA-4) BM1	Rebar	6376186.639	481994.794	500.365
Mardoc Lake (LA-4) BM2	Rebar	6376189.113	481991.522	500.252
Mardoc Lake (LA-4) BM3	Rebar	6376187.971	481988.774	499.699
LA-5 BM1	Rebar	6374540.225	477831.352	501.366
LA-5 BM2	Rebar	6374541.11	477824.823	501.014
LA-5 BM3	Rebar	6374538.032	477835.822	501.023
LA-6 BM1	Rebar	6375257.733	477749.298	502.388
LA-6 BM2	Rebar	6375254.317	477756.381	502.08
Kratchowsky Lake (LA-7) BM1	Rock	6375365.152	474859.273	522.374
Kratchowsky Lake (LA-7) BM2	Rock	6375370.136	474856.009	522.067
Kratchowsky Lake (LA-7) BM3	Rock	6375373.196	474852.454	521.8
LA-8 BM1	Rock	6379895.581	476250.738	523.991
LA-9 BM1	Rock	6379225.363	479725.394	515.312
PA-2 BM1	Rock	6377199.994	477105.453	511.303
PA-3 BM1	Rock	6377659.01	476450.79	517.851
LAB-1 BM1	Rebar	6368332.435	478695.192	489.243
LAB-1 BM2	Rebar	6368331.85	478688.921	489.745
LAB-1 BM3	Rebar	6368334.674	478697.583	489.597
LB-1 BM1	Rebar	6369366.788	476603.997	505.231
LB-1 BM2	Rebar	6369370.293	476602.209	505.04
LB-1 BM3	Rebar	6369363.85	476597.929	505.073
LB-2 BM1	Rebar	6371898.916	474903.385	511.767
LB-2 BM2	Rebar	6371901.778	474906.357	511.819
LB-2 BM3	Rebar	6371904.723	474900.057	511.806
Williams Lake (LB-3) BM1	Rebar	6374839.646	474884.439	520.159
Williams Lake (LB-3) BM2	Rebar	6374831.436	474893.291	519.42
Williams Lake (LB-3) BM3	Rebar	6374834.862	474895.379	520.021
SA-1 BM1	Rebar	6371129.601	480327.636	496.123
SA-1 BM2	Rock	6371125.303	480328.743	495.576
SA-1 BM3	Rebar	6371123.762	480357.257	494.361
SA-2 BM1	Rock	6373258.113	478533.16	498.369
SA-2 BM2	Rock	6373258.391	478529.59	498.354
SA-3/LA-1 BM1	Rebar	6373226.219	479403.75	495.714

Table A-1 Information about benchmarks at each hydrometric station for elevation survey

Benchmark	Type	Northing (m)	Easting (m)	Elevation (m)
SA-3/LA-1 BM2	Rebar	6373227.014	479408.484	495.55
SA-3/LA-1 BM3	Rebar	6373222.211	479402.381	495.616
SA-4 BM1	Rebar	6375855.114	476914.695	507.772
SA-4 BM2	Rock	6375853.025	476915.57	508.373
SA-5 BM1	Rebar	6375723.54	477791.074	502.58
SA-5 BM2	Rock	6375739.656	477807.701	502.045
SA-6 BM1	Rebar	6374757.968	477848.597	503.32
SA-6 BM2	Rebar	6374752.648	477849.463	503.205
SA-6 BM3	Rebar	6374746.296	477855.608	502.021
SA-8 TBM1	Nail	471581	6378307	521.17
SA-8 TBM2	Nail	471578	6378301	521.15
SA-8 TBM3	Nail	471586	6378314	521.13
SA-9 TBM1	Nail	478230	6381587	521.14
SA-9 TBM2	Nail	478231	6381591	520.86
SA-9 TBM3	Rock	478216	6381592	521.59
SA-10 TBM1	Nail	478999	6380421	515.01
SA-10 TBM2	Nail	479000	6380405	515.56
SA-10 TBM3	Nail	478997	6380406	515.8
SA-11 TBM1	Nail	473017	6379260	521.286
SA-11 TBM2	Rock	473018	6379272	521.025
SA-11 TBM3	Nail	473032	6379260	521.176
SB-1 BM1	Culvert	6366351.011	476038.945	489.602
SB-1 BM2	Culvert	6366355.284	476042.54	489.414
SB-1 BM3	Rock	6366375.139	476028.439	489.217
SB-3 BM1	Rebar	6371642.428	475847.211	511.473
SB-3 BM2	Rock	6371638.405	475838.409	511.897
SB-4 BM1	Rock	6372197.891	472953.818	520.307
SB-4 BM2	Rock	6372197.46	472955.741	520.205
SB-4 BM3	Rock	6372197.402	472957.726	520.305
SB-5 BM1	Nail	6372738.116	474631.507	518.673

Appendix B Stage and Discharge Measurement

Table B-1: Stream Elevation and Instantaneous Discharge Measurements

Location	Date	Elevation (Masl)	Discharge (m^3/s)	Source
Icelander River (SA-1)	14-May-11	492.714	2.307	Golder (2014)
	29-Jul-11	492.648	1.75	
	28-Oct-11	492.562	0.973	
	5-May-12	492.711	2.293	
	6-Aug-12	492.695	2.031	
	23-Oct-12	492.721	2.575	
	20-May-13	492.705	2.358	
	14-Aug-13	492.587	1.28	
	18-Oct-13	492.554	0.887	
	30-Mar-14	492.869	1.203	
	17-Sep-16	492.71	2.34	Calder (2017)
	31-May-17	492.72	2.43	
	2-Jul-19	494.043*	2.41	This report
	5-Jul-19	492.744	3.06	MWSI (2019)
	30-Aug-19	492.733	2.78	
SA-2	12-May-11	496.727	1.649	Golder (2014)
	30-Jul-11	496.698	1.387	
	27-Oct-11	496.667	0.809	
	8-May-12	496.748	2.008	
	8-Aug-12	*496.689*	1.305	
	24-Oct-12	496.734	2.03	
	21-May-13	496.727	1.842	
	14-Aug-13	496.66	0.863	
	16-Oct-13	496.641	0.741	
	24-Mar-14	496.805	1.18	
	16-Sep-16	496.46	2.24	Calder (2017)
	5-Jul-19	496.773	2.2095	MWSI (2019)
	30-Aug-19	496.748	1.9537	
SA-3	13-May-11	494.459	0.476	Golder (2014)
	29-Jul-11	494.392	0.37	
	28-Oct-11	494.322	0.239	
	4-May-12	494.473	0.528	
	5-Aug-12	494.443	0.478	
	23-Oct-12	494.487	0.578	
	20-May-13	494.482	0.564	
	14-Aug-13	494.344	0.255	
	16-Oct-13	494.243	0.051	
	24-Mar-14	494.248	0.362	
	16-Sep-16	494.43	0.44	Calder (2017)
	5-Jul-19	494.541	0.6219	MWSI (2019)
	30-Aug-19	494.506	0.5474	

Table B-1: Stream Elevation and Instantaneous Discharge Measurements

Location	Date	Elevation (Masl)	Discharge (m^3/s)	Source
SA-4	11-May-11	506.357	0.483	Golder (2014)
	30-Jul-11	506.314	0.335	
	31-Oct-11	506.31	0.199	
	4-May-12	506.348	0.466	
	5-Aug-12	506.329	0.361	
	22-Oct-12	506.367	0.497	
	19-May-13	506.369	0.519	
	13-Aug-13	506.277	0.276	
	17-Oct-13	506.249	0.206	
	23-Mar-14	506.381	0.33	
	10-Sep-16	506.35	0.49	Calder (2017)
	30-May-17	506.37	0.58	
	29-Jun-18	506.357	0.4845	This report
	4-Jul-19	506.387	0.6336	MWSI (2019)
	29-Aug-19	506.374	0.59	
SA-5	12-May-11	500.708	1.1	Golder (2014)
	30-Jul-11	500.668	0.858	
	29-Oct-11	500.609	0.476	
	4-May-12	500.717	1.111	
	5-Aug-12	500.684	1.026	
	22-Oct-12	500.718	1.269	
	19-May-13	500.726	1.381	
	13-Aug-13	500.629	0.616	
	17-Oct-13	500.622	0.507	
	23-Mar-14	500.798	0.886	
	9-Sep-16	500.9	1.27	Calder (2017)
	21-Sep-16	500.91	1.58	
	30-May-17	500.92	1.95	
	30-Jun-18	500.89	1.6567	This report
	4-Jul-19	500.955	1.6137	MWSI (2019)
	29-Aug-19	500.927	1.3589	
SA-6	13-May-11	500.084	1.631	Golder (2014)
	30-Jul-11	500.034	1.303	
	27-Oct-11	499.956	0.717	
	6-May-12	500.098	1.957	
	5-Aug-12	500.061	1.476	
	22-Oct-12	500.102	1.851	
	19-May-13	500.077	1.54	
	13-Aug-13	499.992	0.842	
	17-Oct-13	499.969	0.798	
	23-Mar-14	500.081	1.173	
	11-Sep-16	500.07	1.98	Calder (2017)
	31-May-17	500.08	1.77	
	30-Jun-18	500.125	1.56	This report
	4-Jul-19	500.125	2.27	MWSI (2019)
	29-Aug-19	500.11	2.02	
SA-7	15-Sep-16	No BM set	0.04	Calder (2017)

Table B-1: Stream Elevation and Instantaneous Discharge Measurements

Location	Date	Elevation (Masl)	Discharge (m^3/s)	Source
SA-8	15-Sep-16	520.6	0.01	Calder (2017)
	19-Sep-16	520.62	0.04	
	30-May-17	520.54	0.04	
	3-Jul-19	520.57	0.056	This report
	31-Aug-19	99.455**	0.0443	MWSI (2019)
SA-9	18-Sep-16	520.52	0.18	Calder (2017)
	1-Jun-17	520.49	0.16	
	31-Aug-19	520.55	0.1457	MWSI (2019)
SA-10	18-Sep-16	514.35	1.55	Calder (2017)
	31-May-17	514.31	1.22	
	31-Aug-19	514.34	1.31	MWSI (2019)
SA-11	19-Sep-16	520.73	0.42	Calder (2017)
	30-May-17	520.71	0.31	
	2-Jul-18	520.84	Not Measured	This report
	31-Aug-19	520.71	0.31	MWSI (2019)
Kratchowsky Creek Outlet (RC-1)	14-Sep-16	520.3	0.58	Calder (2017)
	15-Mar-18	-	0.2303	This report
	6-Jul-19	-	0.6041	MWSI (2019)
	1-Sep-19	520.56	0.5514	
SB-1	14-May-11	488.486	0.517	Golder (2014)
	31-Jul-11	489.027	0.186	
	30-Oct-11	488.418	0.217	
	3-May-12	488.524	0.644	
	6-Aug-12	488.522	0.358	
	23-Oct-12	488.599	0.578	
	18-May-13	488.484	0.547	
	12-Aug-13	488.335	0.158	
	19-Oct-13	488.85	0.277	
	27-Mar-14	488.823	0.289	
	17-Sep-16	488.55	0.64	Calder (2017)
SB-3	11-May-11	510.465	0.187	Golder (2014)
	31-Jul-11	510.406	0.109	
	30-Oct-11	510.389	0.082	
	5-May-12	510.506	0.235	
	8-Aug-12	510.456	0.136	
	21-Oct-12	510.517	0.255	
	20-May-13	510.476	0.209	
	14-Aug-13	510.421	0.107	
	17-Oct-13	510.414	0.08	
	25-Mar-14	510.423	0.09	
	11-Sep-16	510.47	0.2	Calder (2017)
SB-4	15-May-11	519.134	0.074	Golder (2014)
	1-Aug-11	518.964	0.008	
	30-Oct-11	519.07	0.018	
	5-May-12	519.219	0.109	
	6-Aug-12	519.144	0.032	
	21-Oct-12	519.245	0.099	
	21-May-13	519.185	0.114	
	15-Aug-13	519.074	0.007	
	17-Oct-13	519.115	0.036	
	11-Sep-16	519.21	0.12	Calder (2017)
SB-5	14-Sep-16	518.33	0.14	

* This may be an anomalous observation and therefore is not used in establishing stage-discharge curve.

** Referenced to local benchmark after moving measurement location.

Table B-2: Lake and Pond Surface Water Level Elevations

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (Masl)	Source
McGowan Lake (LA-1)	13-May-11	98.725	494.439	Golder (2014)
	29-Jul-11	98.613	494.327	
	28-Oct-11	98.504	494.218	
	4-May-12	98.709	494.423	
	5-Aug-12	98.672	494.386	
	23-Oct-12	98.734	494.448	
	21-May-13	98.726	494.44	
	14-Aug-13	98.551	494.265	
	16-Oct-13	98.48	494.194	
	25-Mar-14	98.584	494.298	
	16-Sep-16		494.39	Calder (2017)
	2-Jul-18	98.62	494.344	This report
	5-Jul-19		494.515	MWSI (2019)
	30-Aug-19		494.476	
LA-2	13-May-11	97.269	494.615	Golder (2014)
	30-Jul-11	97.256	494.602	
	29-Oct-11	97.203	494.549	
	4-May-12	97.264	494.61	
	6-Aug-12	97.274	494.62	
	23-Oct-12	97.308	494.654	
	20-May-13	97.278	494.624	
	13-Aug-13	97.197	494.543	
	16-Oct-13	97.121	494.467	
	26-Mar-14	97.236	494.582	
	13-Sep-16		494.58	Calder (2017)
LA-3	13-May-11	98.427	494.561	Golder (2014)
	30-Jul-11	98.433	494.567	
	29-Oct-11	98.427	494.561	
	4-May-12	98.472	494.606	
	6-Aug-12	98.456	494.59	
	23-Oct-12	98.485	494.619	
	20-May-13	98.459	494.593	
	13-Aug-13	98.387	494.521	
	16-Oct-13	98.305	494.439	
	26-Mar-14	98.515	494.649	
	18-Sep-16		494.57	Calder (2017)
Mardoc Lake (LA-4)	29-Jul-11	98.284	498.649	Golder (2014)
	30-Oct-11	98.152	498.517	
	4-May-12	98.223	498.588	
	5-Aug-12	98.248	498.613	
	6-Aug-12	98.257	498.622	
	23-Oct-12	98.262	498.627	
	20-May-13	98.259	498.624	
	13-Aug-13	98.164	498.529	
	16-Oct-13	98.142	498.507	
	27-Mar-14	98.249	498.614	
	13-Sep-16		498.62	Calder (2017)

Table B-2: Lake and Pond Surface Water Level Elevations

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (Masl)	Source
Whitefish Lake, South Basin (LA-5)	13-May-11	98.706	500.05	Golder (2014)
	31-Jul-11	98.67	500.014	
	27-Oct-11	98.605	499.949	
	6-May-12	98.73	500.074	
	5-Aug-12	98.693	500.037	
	22-Oct-12	98.728	500.072	
	21-May-13	98.729	500.073	
	13-Aug-13	98.625	499.969	
	17-Oct-13	98.606	499.95	
	23-Mar-14	98.732	500.076	
	12-Sep-16		500.06	Calder (2017)
Whitefish Lake, North Basin (LA-6)	13-May-11	97.675	500.063	Golder (2014)
	31-Jul-11	97.64	500.028	
	27-Oct-11	97.555	499.943	
	6-May-12	97.7	500.088	
	5-Aug-12	97.67	500.058	
	22-Oct-12	97.704	500.092	
	19-May-13	97.7	500.088	
	13-Aug-13	97.585	499.973	
	17-Oct-13	97.559	499.947	
	23-Mar-14	97.67	500.058	
	12-Sep-16	-	500.07	Calder (2017)
	30-Jun-18	97.718	500.106	This report
	29-Aug-19	-	500.118	MWSI (2019)
Kratchowsky Lake (LA-7)	29-Jul-11	98.108	520.482	Golder (2014)
	31-Oct-11	98.05	520.424	
	6-May-12	98.149	520.523	
	8-Aug-12	98.108	520.482	
	21-Oct-12	98.162	520.536	
	24-May-13	98.157	520.531	
	13-Aug-13	98.083	520.457	
	16-Oct-13	98.066	520.44	
	27-Mar-14	98.128	520.502	
	12-Sep-16	-	520.53	Calder (2017)
	30-May-17	-	520.53	
LA-8	20-Jan-00	-	520.86	Calder (2017)
	1-Jun-17	-	520.8	
LA-9	13-Sep-16	-	514.25	Calder (2017)
	31-May-17	-	514.28	
LAB-1	16-May-11	98.991	488.219	Golder (2014)
	1-Aug-11	98.891	488.119	
	30-Oct-11	98.776	488.004	
	9-May-12	99	488.228	
	6-Aug-12	98.939	488.167	
	23-Oct-12	98.987	488.215	
	21-May-13	99.005	488.233	
	12-Aug-13	98.879	488.107	
	19-Oct-13	98.766	487.994	
	25-Mar-14	99.154	488.382	
	22-Sep-16	-	488.26	Calder (2017)

Table B-2: Lake and Pond Surface Water Level Elevations

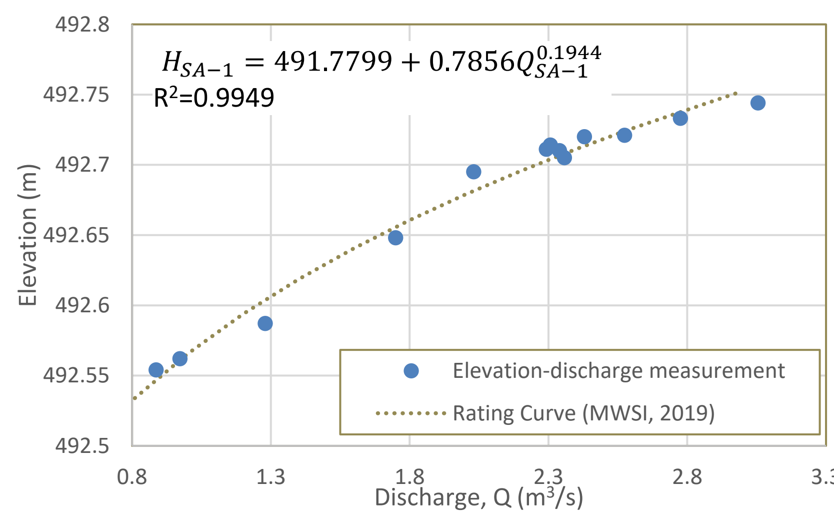
Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (Masl)	Source
LB-1	14-May-11	98.666	503.902	Golder (2014)
	1-Aug-11	98.807	504.043	
	30-Oct-11	98.648	503.884	
	6-May-12	98.636	503.872	
	6-Aug-12	98.651	503.887	
	21-Oct-12	98.617	503.853	
	19-May-13	98.843	504.079	
	14-Aug-13	98.509	503.745	
	17-Oct-13	98.471	503.707	
	11-Sep-16		503.66	Calder (2017)
LB-2	14-May-11	98.767	510.523	Golder (2014)
	29-Jul-11	98.689	510.445	
	30-Oct-11	98.636	510.392	
	5-May-12	98.771	510.527	
	6-Aug-12	98.745	510.501	
	21-Oct-12	98.817	510.573	
	21-May-13	98.756	510.512	
	14-Aug-13	98.699	510.455	
	17-Oct-13	98.651	510.407	
	25-Mar-14	98.777	510.533	
	11-Sep-16	-	510.54	Calder (2017)
Williams Lake (LB-3)	15-May-11	98.365	518.519	Golder (2014)
	29-Jul-11	98.284	518.438	
	29-Oct-11	98.203	518.356	
	5-May-12	98.361	518.515	
	5-Aug-12	98.37	518.524	
	21-Oct-12	98.426	518.58	
	19-May-13	98.38	518.534	
	13-Aug-13	98.278	518.432	
	17-Oct-13	98.233	518.387	
	25-Mar-14	98.233	518.463	
	11-Sep-16	-	518.57	Calder (2017)
PA-2	15-Sep-16	-	510.46	Calder (2017)
PA-3	15-Sep-16	-	517.36	Calder (2017)

Appendix C Summary of Hydrometric Monitoring Stations in the Icelander River Drainage Area

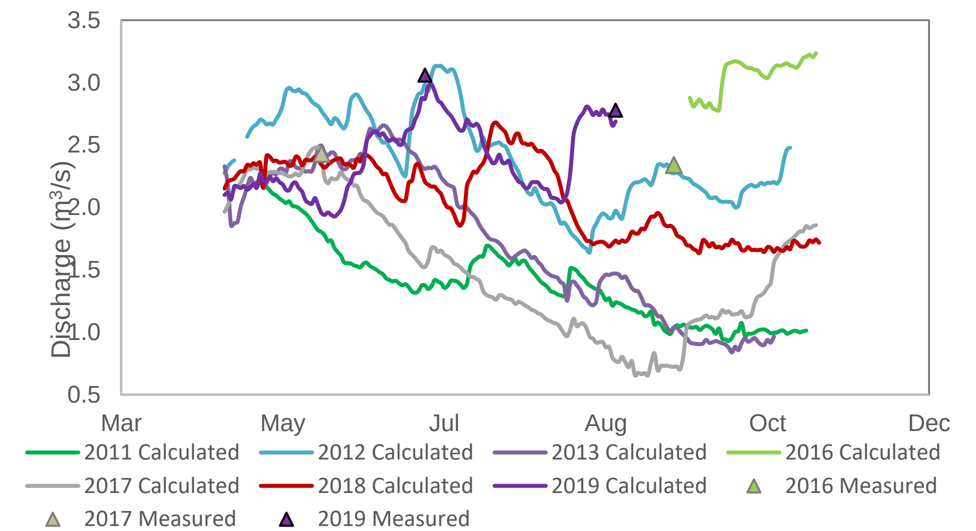
Appendix C: Summary of Hydrometric Monitoring Stations in the Icelander River Drainage Area

Station ID	SA-1	**Periods of continuous recording**	2011-2014, 2016-2019
GPS Coordinates	13 V 480368 6371123	**Instrument deployed**	Solinst levelogger, Serial number 1062051.
Access	By road	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2011-2014, 2016-2019	**Comments**	SA-1 produces good stage and discharge relationship and accurate hydrograph. The stage-discharge relationship was modified in 2019 to fit new high discharge observed in 2019.
Measurements	Elevation, instantaneous discharge, continuous discharge		

Map: SA-1 hydrometric monitoring station.



Stage – Discharge Curve



Continuous flow monitoring, 2011-14 and 2016-2019 open water season

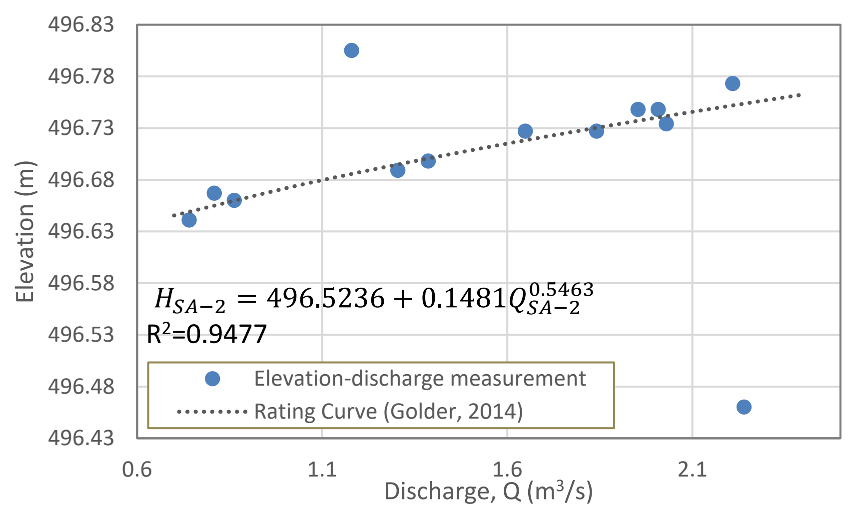
SA-1 facing downstream, May 2017.

SA-1 facing upstream, July 2018.

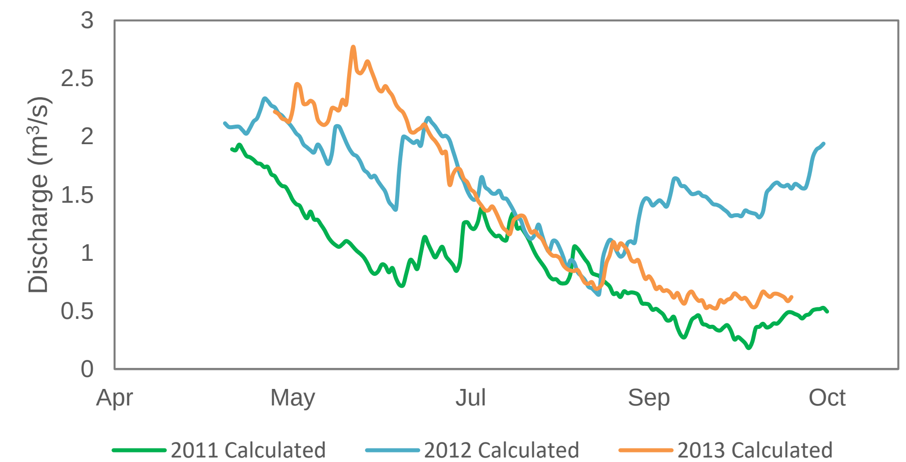
SA-1 facing downstream, July 2018.

Station ID	SA-2	**Periods of continuous recording**	2011-2013
GPS Coordinates	13 V 478524 6373216	**Instrument deployed**	N.A.
Access	By boat	**Active measurement**	N.A.
Periods of monitoring	2011-2014, 2016-2019	**Comments**	No continuous monitoring device is installed since 2014. Two outliers were observed in the stage-discharge curve as different cross section was used in 2016 and 2017. These two data points were not used to validate the stage-discharge relationship.
Measurements	Elevation, instantaneous discharge		

Map: SA-2 hydrometric monitoring station.



Stage – Discharge Curve



Continuous flow monitoring, 2011-2013 open water season

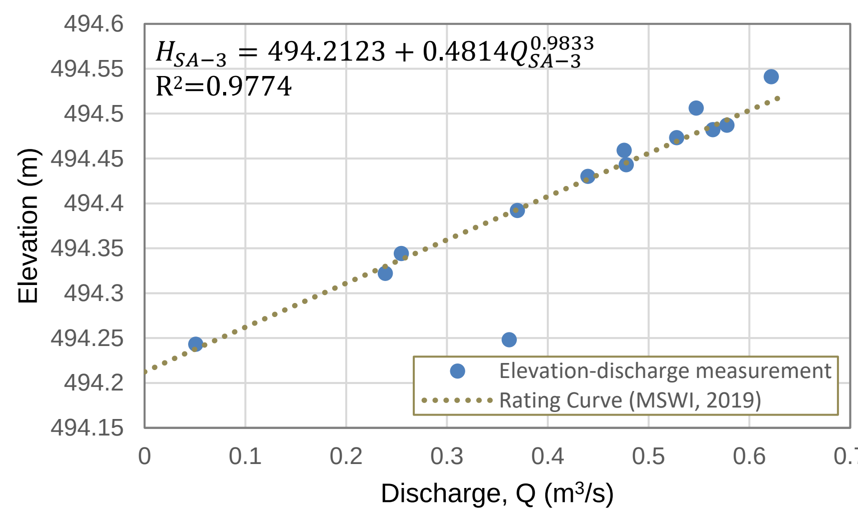
SA-2 facing upstream, May 2017.

SA-2 facing downstream, May 2017.

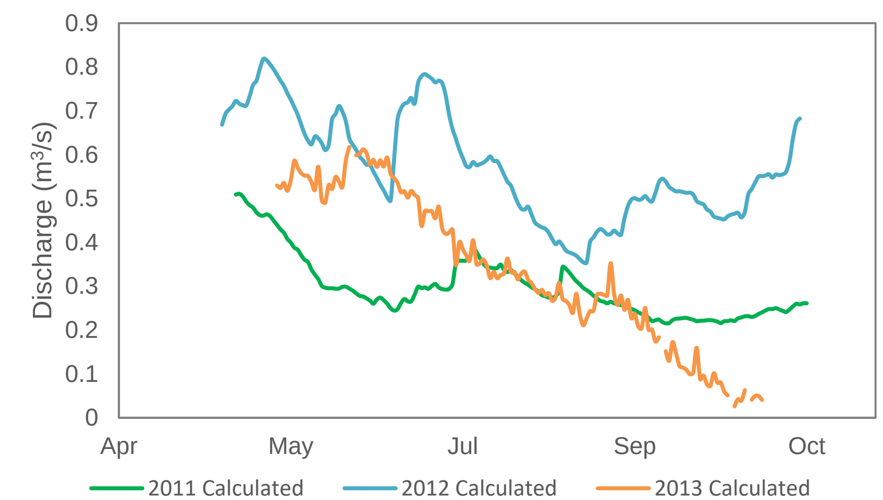
SA-2 facing upstream, March 2018.

Station ID	SA-3	**Periods of continuous recording**	2011-2013
GPS Coordinates	13 V 479415 6373234	**Instrument deployed**	N.A.
Access	By boat	**Active measurement**	N.A.
Periods of monitoring	2011-2014, 2016-2019	**Comments**	SA-3 produces good stage and discharge relationship. No continuous flow monitoring device was installed after 2014. The stage-discharge relationship was updated in 2019 with more recent monitoring data to expand the discharge range.
Measurements	Elevation, instantaneous discharge		

Map: SA-3 hydrometric monitoring station.



Stage – Discharge Curve



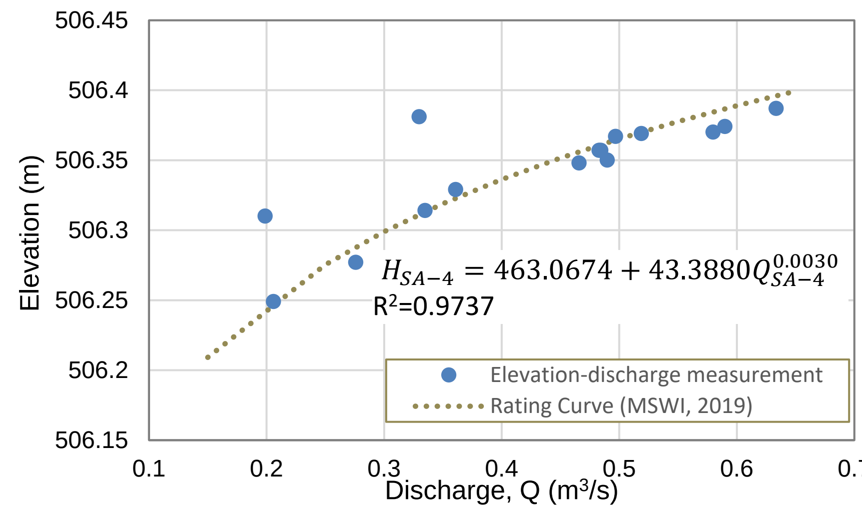
Continuous flow monitoring, 2011-2013 open water season

SA-3 facing upstream, September 2016.

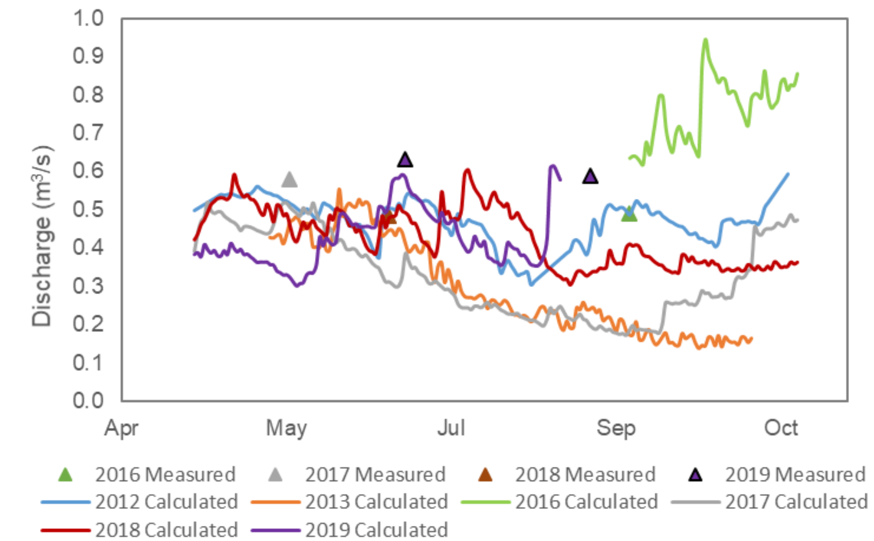
SA-3 facing downstream, September 2016.

Station ID	SA-4	**Periods of continuous recording**	2012-2014, 2016-2019
GPS Coordinates	13V 476926 6375868	**Instrument deployed**	Solinst levelogger, Serial number 2065001; Solinst barologger, serial number 2064922.
Access	By road	**Active measurement**	Continuous flow measurement
Periods of monitoring	2011-2014, 2016-2019	**Comments**	SA-4 produces a good stage-discharge relationship and hence an accurate hydrograph.
Measurements	Elevation, instantaneous discharge, continuous discharge		

Map: SA-4 hydrometric monitoring station.



Stage – Discharge Curve



Continuous flow monitoring, 2012-2014 and 2016-2019 open water season

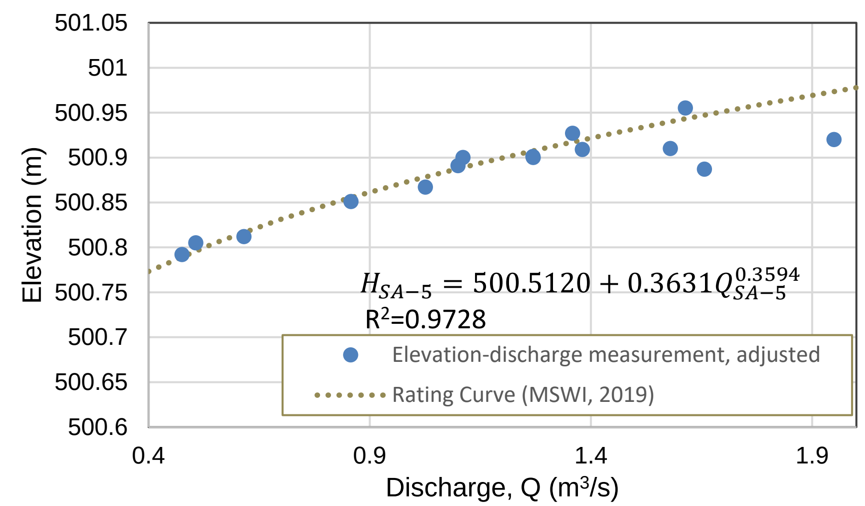
SA-4 facing upstream, June 2018.

SA-4 facing downstream, June 2018.

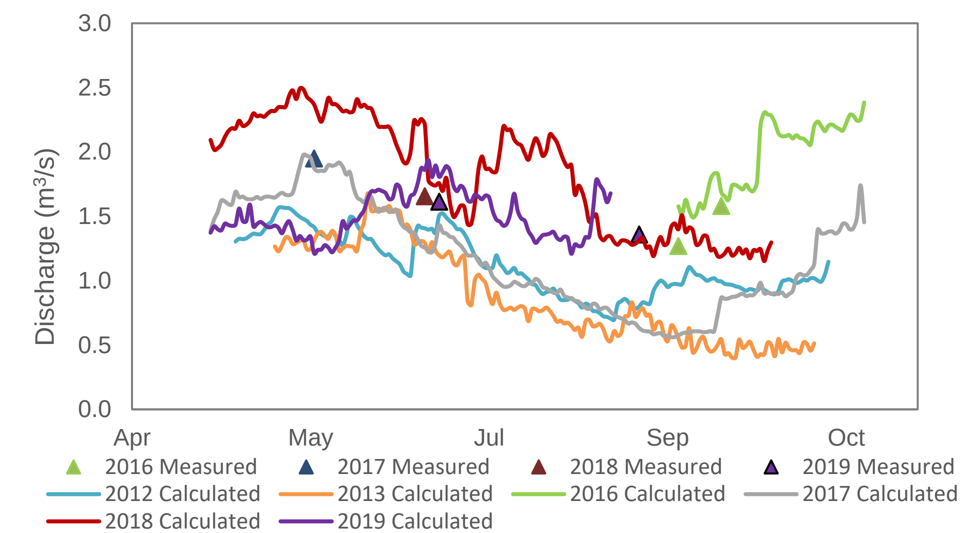
SA-4 facing upstream, March 2018.

Station ID	SA-5	**Periods of continuous recording**	2012-2014, 2016-2019
GPS Coordinates	13 V 477822 6375737	**Instrument deployed**	Solinst levelogger, Serial number 2064994
Access	By road	**Active measurement**	Continuous flow measurement
Periods of monitoring	2011-2014, 2016-2019	**Comments**	The monitoring station was moved upstream from previous location in 2016. The rating curve was adjusted to accommodate this change. SA-5 produces a fair stage-discharge relationship and hence hydrograph.
Measurements	Elevation, instantaneous discharge, continuous discharge		

Map: SA-5 hydrometric monitoring station.



Stage – Discharge Curve



Continuous flow monitoring, 2012-2014 and 2016-2019 open water season

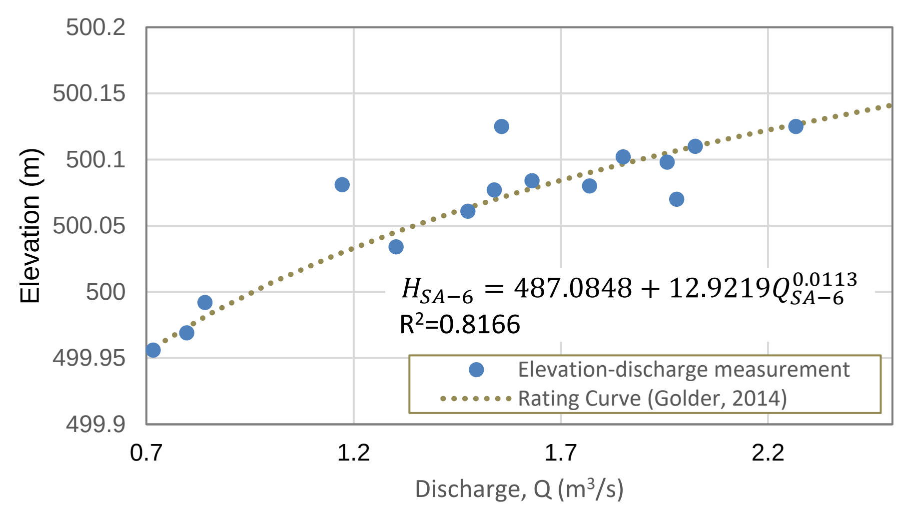
SA-5 facing upstream, May 2017.

SA-5 facing downstream, May 2017.

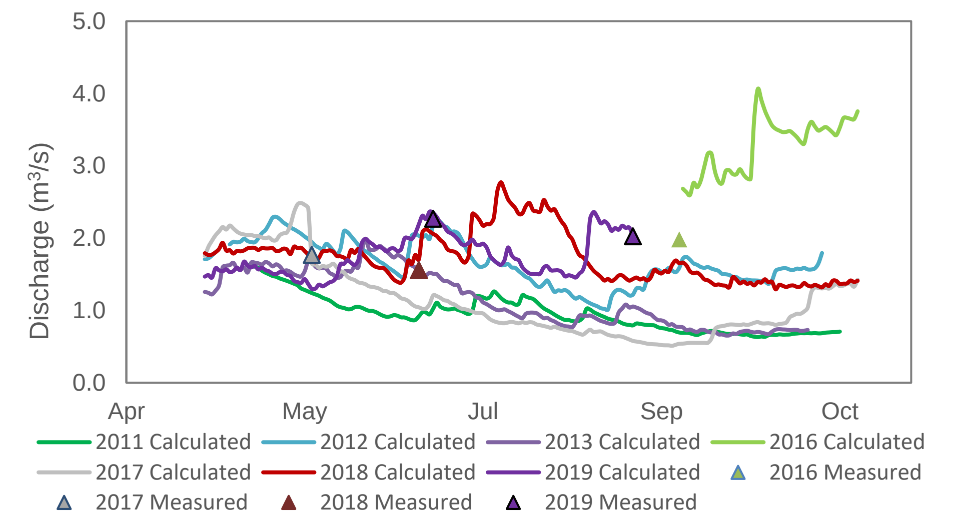
SA-5 cross section, July 2019.

Station ID	SA-6	**Periods of continuous recording**	2011-2014, 2016-2019
GPS Coordinates	13 V 477863 6374742	**Instrument deployed**	Solinst levelogger, Serial number 1061428 (2016-2019). New logger deployed in August 2019 (Serial number 2110527).
Access	By road	**Active measurement**	Continuous flow measurement
Periods of monitoring	2011-2014, 2016-2019	**Comments**	SA-6 produced a fair stage-discharge relationship. SA-6 is recognized by local residence as a narrow connecting LA-5 and LA-6 as one lake (See LA-6 below).
Measurements	Elevation, instantaneous discharge, continuous discharge		

Map: SA-6 hydrometric monitoring station.



Stage – Discharge Curve



Continuous flow monitoring, 2012-2014 and 2016-2019 open water season

SA-6 facing upstream, March 2018.

Station ID	SA-7	**Periods of continuous recording**	N.A.
GPS Coordinates	13 V 472315 6375473	**Instrument deployed**	N.A.
Access	By boat	**Active measurement**	N.A.
Periods of monitoring	2016	**Comments**	SA-7 was a new station monitored since 2016. It is a narrow marshy stream and not suitable for continuous flow monitoring. This station was replaced by SA-11 in 2017.
Measurements	Elevation, instantaneous discharge.		

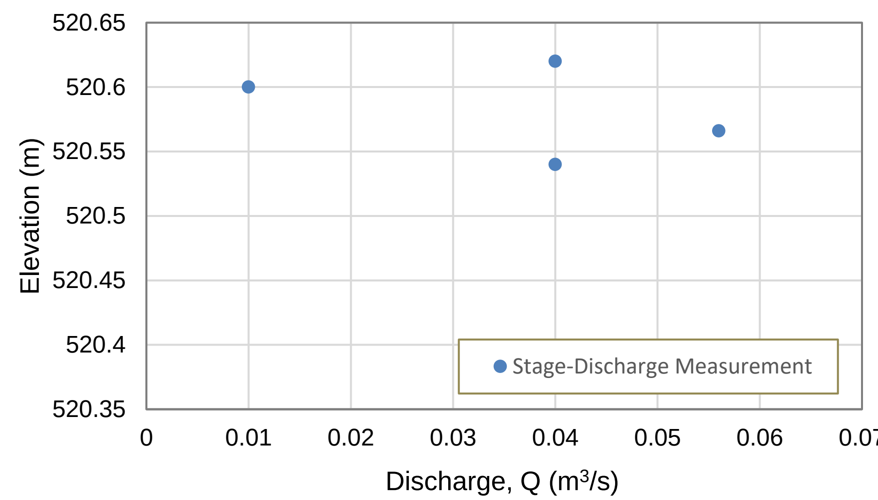
Map: SA-7 hydrometric monitoring station

SA-7 facing upstream, September 2016.

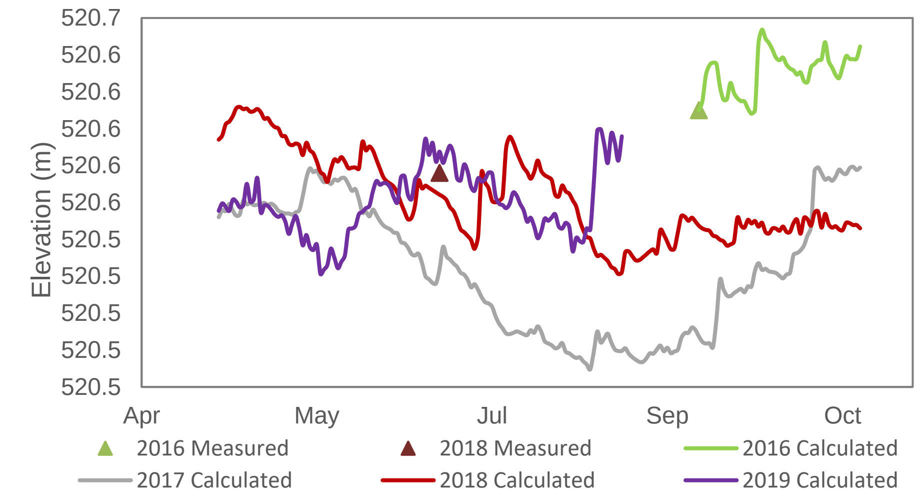
SA-7 facing downstream, September 2016.

Station ID	SA-8	**Periods of continuous recording**	2016-2019
GPS Coordinates	13 V 471579 6378303	**Instrument deployed**	Solinst levelogger, Serial number 2064996
Access	By boat	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2016-2019	**Comments**	SA-8 is a new flow station has been monitored since 2016. It is a narrow stream with deep banks. More extreme flow data is required to establish a reliable rating curve. This station is believed to be impacted by elevation at the Kratchkowsy lake, and the station is moved upstream in 2019.
Measurements	Elevation, instantaneous discharge, continuous flow monitoring.		

Map: SA-8 hydrometric monitoring station



Stage – Discharge Relationship



Levelogger elevation results, 2016-2019 open water season

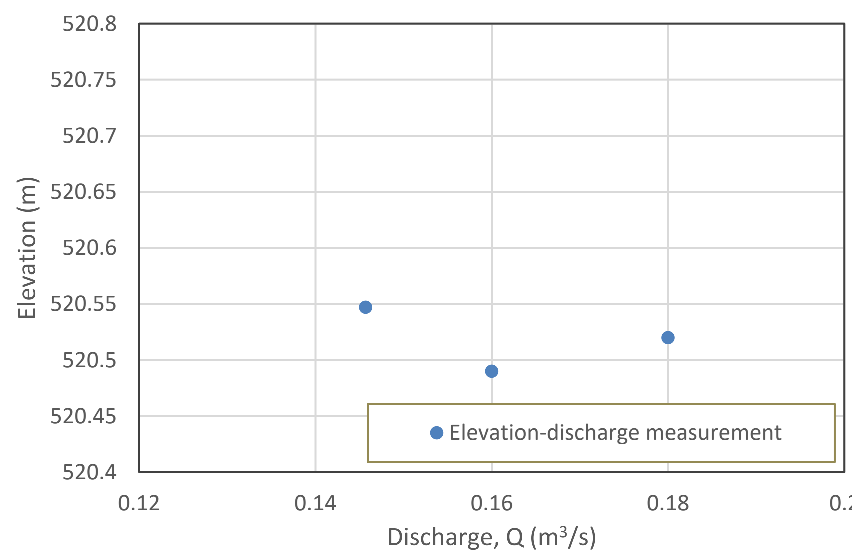
SA-8 facing upstream, September 2016.

SA-8 Hydrometric station, 2016-2019

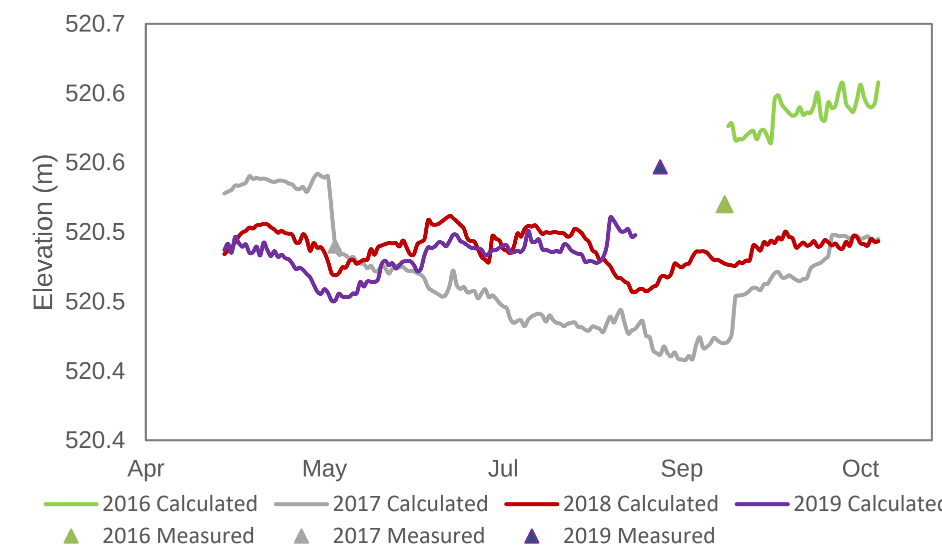
SA-8 new hydrometric station, Aug 2019.

Station ID	SA-9	**Periods of continuous recording**	2016-2019
GPS Coordinates	13 V 478226 6381589	**Instrument deployed**	Solinst levelogger, serial number 2065002
Access	By road	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2016-2019	**Comments**	SA-9 was initially located at the outlet of a small lake downstream of LA-8. For access purpose, it was relocated to the outlet of LA-8 accessible by an existing ATV road. More stage and discharge data are required to establish a reliable rating curve.
Measurements	Elevation, instantaneous discharge, continuous flow monitoring.		

Map: SA-9 hydrometric monitoring station



Stage – Discharge Relationship



Levelogger elevation results, 2016-2019 open water season

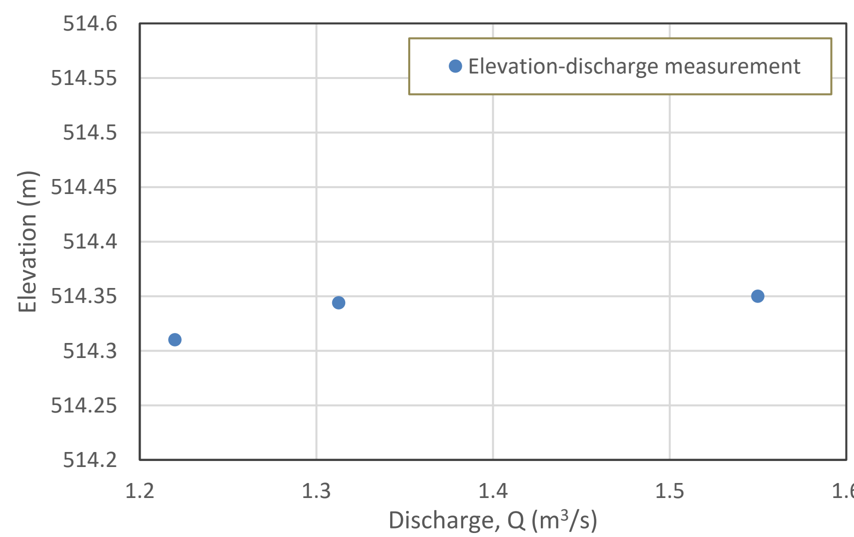
SA-9 facing upstream, Sep 2016.

SA-9 facing downstream, Sep 2016.

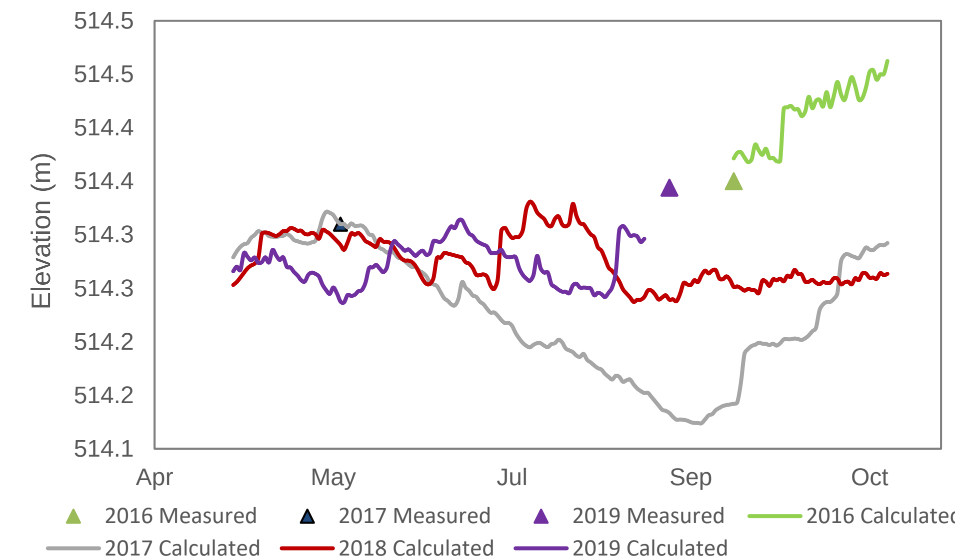
SA-9 cross section, Aug 2019.

Station ID	SA-10	**Periods of continuous recording**	2016-2019
GPS Coordinates	13 V 479003 6380421	**Instrument deployed**	Solinst levelogger, serial number 2065023
Access	By boat	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2016-2019	**Comments**	More stage and discharge data are required to establish a reliable rating curve.
Measurements	Elevation, instantaneous discharge, continuous flow monitoring.		

Map: SA-10 hydrometric monitoring station



Stage – Discharge Relationship



Levelogger elevation results, 2016-2019 open water season

c

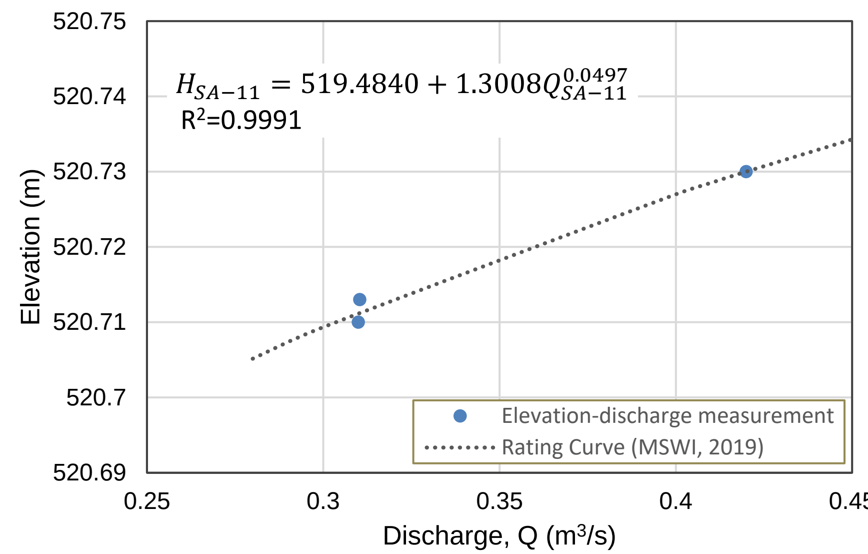
SA-10 facing upstream, September 2016.

SA-10 facing downstream, September 2016.

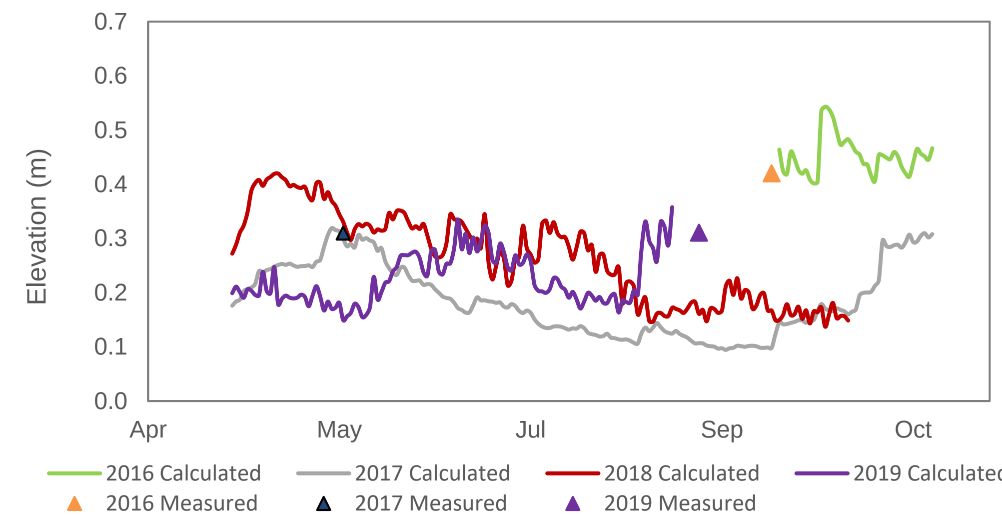
SA-10 cross section, Aug 2019

Station ID	SA-11	**Periods of continuous recording**	2016-2019
GPS Coordinates	13 V 473026 6379260	**Instrument deployed**	Solinst levelogger, serial number 2065010
Access	By boat	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2016-2018 (EcoMetrix and Calder)	**Comments**	SA-11 is added to replace SA-7. A preliminary stage-discharge relationship is developed at SA-11. Validation is recommended to demonstrate accuracy of this relationship.
Measurements	Elevation, instantaneous discharge, continuous flow monitoring.		

Map: SA-11 hydrometric monitoring station



Stage – Discharge Relationship



Levelogger elevation results, 2016-2019 open water season

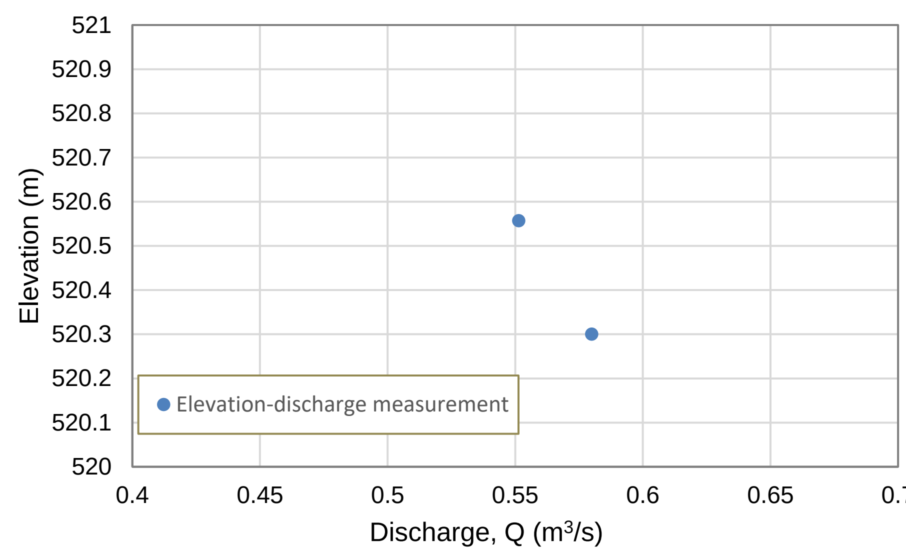
SA-11 facing upstream, September 2016

SA-11 facing downstream, September 2016.

SA-11 cross section, Aug 2019.

Station ID	RC-1 (Kratchkowsky Lake Outlet)	**Periods of continuous recording**	N.A.
GPS Coordinates	13 V 475468 6375987	**Instrument deployed**	N.A.
Access	By road	**Active measurement**	N.A.
Periods of monitoring	2016, 2018 (EcoMetrix and Calder)	**Comments**	RC-1 is situated immediately downstream of Kratchkowsky Lake. As it is accessible by a road crossing, it was the only location with instantaneous flow measured during the winter, 2018.
Measurements	Elevation, instantaneous discharge.		

Map: RC-1 hydrometric monitoring station



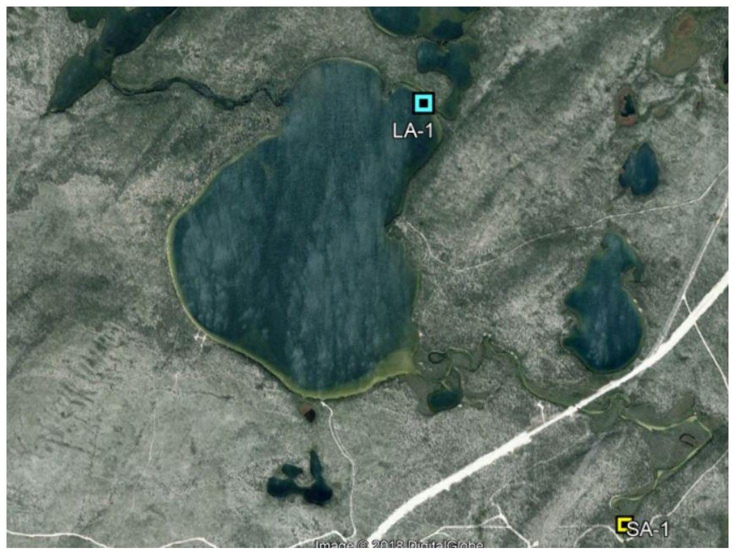
Stage – Discharge Relationship

RC-1 facing upstream, September 2016

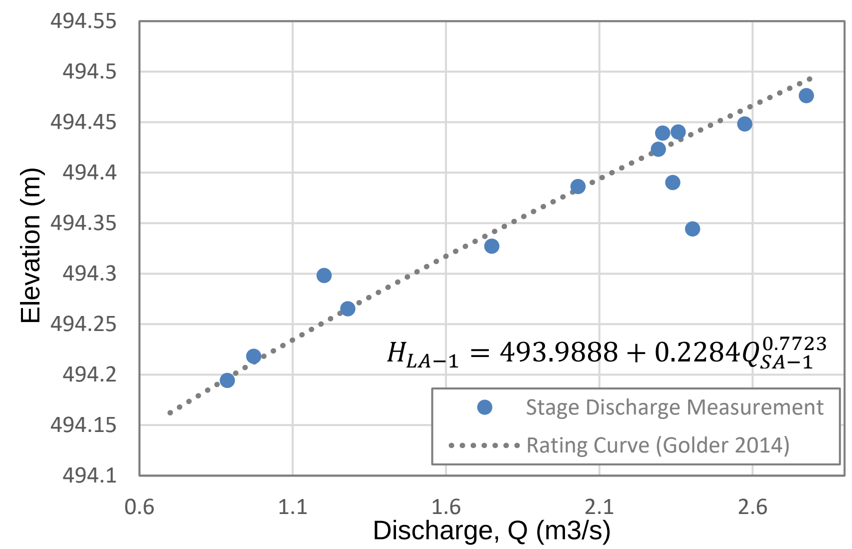
RC-1 facing downstream, September 2016.

RC-1 cross section, August 2019.

Station ID	McGowan Lake	**Periods of continuous recording**	2011-2014, 2019
GPS Coordinates	13 V 479399 6373215	**Instrument deployed**	Solinst levelogger, serial number 2110528 (installed August 2019).
Access	By road	**Active measurement**	Continuous flow monitoring
Periods of monitoring	2011-2014 (Golder), 2016, 2018 (EcoMetrix and Calder)	**Comments**	Discharge at SA-1 is used as the outlet of LA-1 to evaluate the stage-discharge relationship. A new data logger is installed in LA-1 in August 2019.
Measurements	Elevation, instantaneous discharge (SA-1), continuous flow monitoring (June -Oct, 2018)		



Map: McGowan Lake hydrometric monitoring station

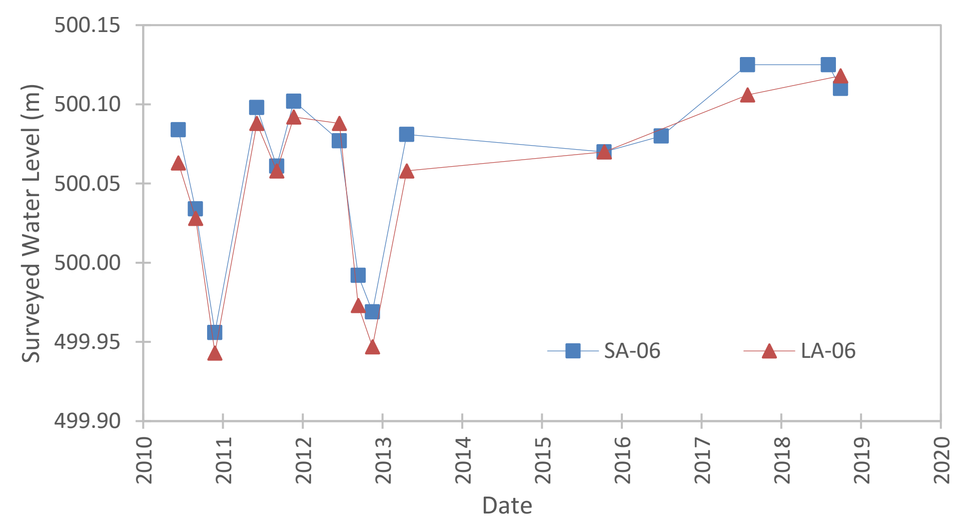


Stage – Discharge Curve

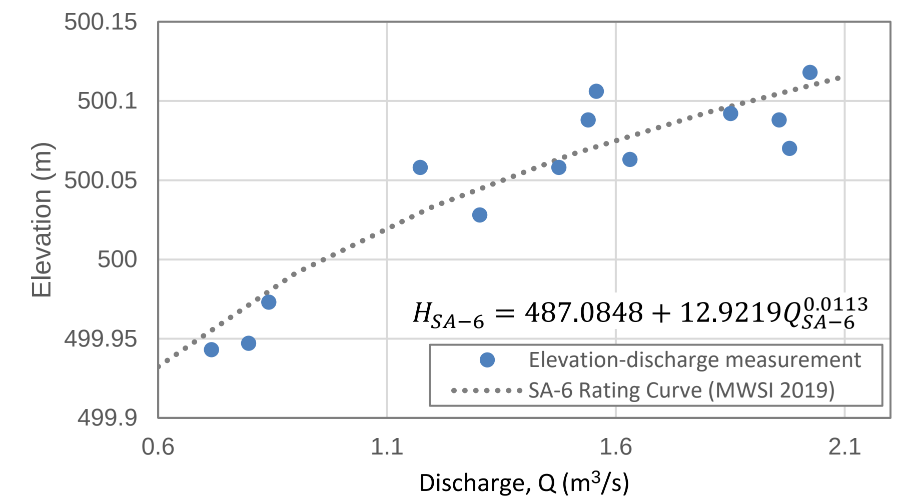
McGowan Lake photo, Sep 2016.

Station ID	LA-6	Periods of continuous recording	2011-2014
GPS Coordinates	13 V 477763 6375274	Instrument deployed	N.A.
Access	By road	Active measurement	N.A.
Periods of monitoring	2011-2014 (Golder), 2016, 2018 (EcoMetrix and Calder)	Comments	Both water level and discharge at SA-6 is representative to LA-6, and therefore level logger installed in SA-6 is used to continuously record discharge at this location. In addition, LA-5 and LA-6 is recognized as one lake (Whitefish Lake), and SA-6 is recognized as a narrow in this lake.
Measurements	Elevation, instantaneous discharge (SA-6), continuous flow monitoring (2018)		

Map: LA-6 hydrometric monitoring station



Water Elevation of LA-6 and SA-6



Stage – Discharge Curve

LA-6 photo, Sep 2016.

LA-6 photo, Aug 2019.

Appendix D 2012-2014 Baseline Hydrology Summary Report. Golder Associates

May 2014

DENISON MINES - WHEELER RIVER PROJECT

2012 - 2014 Baseline Hydrology Summary Report

Submitted to:
Mr. Lawson Forand
Exploration Manager
Denison Mines Corp.
Suite 200 - 320 - 22nd Street East
Saskatoon, SK
S7K 0E9

REPORT

Report Number: 12-1362-0050/5000

Distribution:

2 Copies Denison Mines Corporation.

2 Copies Golder Associates Limited.

Golder Associates

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FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Background Information

In 2011, Golder Associates Ltd. (Golder) was retained by Denison Mines Corp. (Denison) to undertake a hydrological baseline program as part of a pre-feasibility study of the Phoenix deposit at the Wheeler River property (the Project) near Key Lake, Saskatchewan. Golder completed hydrological investigations during the open water season of 2011, 2012, and 2013 as well as one during the ice covered season in 2014. The work was to collect the necessary hydrological baseline data to support various project requirements including environmental assessments, regulatory permitting, and providing design basis information for engineered structures such as fresh water diversions, water management systems, sedimentation ponds, and cross-drainage structures.

This report summarizes the baseline study design, methods and presents the results from the 2011 to 2013 field seasons as well as winter data collected in March 2014. This report builds on a similar interim report produced following the 2013 field season.

1.2 Site Information

The Project is located in north central Saskatchewan, in the south-eastern portion of the Athabasca Basin region, approximately 35 kilometres (km) northeast of Cameco Corporation's (Cameco's) Key Lake Operation and 35 km southwest of Cameco's McArthur River Operation. The site is accessible from the Key Lake – McArthur River haul road. The general Project area is characterized as a morainal plain with southwest trending drumlins and eskers, and glaciofluvial outwash areas, overlying Athabasca sandstones. Numerous interconnected lakes occur in the area, along with low-lying, poorly drained areas of muskeg. The Project is located in the Athabasca Plain Ecoregion which is characterized by jack pine, birch and poplar, and dense spruce forests.

1.3 Climate and Weather

Climate conditions play an important role in the local hydrological cycle by governing the primary inputs and outputs to the surface water environment, including precipitation and evaporation. Environment Canada (EC 2013) has collected data from two weather stations near Key Lake, which can be used to represent general conditions for the Project.

Runoff is a function of several environmental conditions, including rainfall and snow accumulation, evaporation from open water surfaces, evapotranspiration from terrestrial areas, and soil types (infiltration). Although discharge is not exclusively a function of local precipitation, it can provide important context for observed flow characteristic. Figure 1 presents the precipitation record for Key Lake (compiled from two Environment Canada weather stations at Key Lake; EC 2011) for the 2010-2011, 2011-2012, and 2012-2013 hydrological years (October 1 to September 30) and historical averages. The first six months of the 2013-2014 hydrological year are also presented.

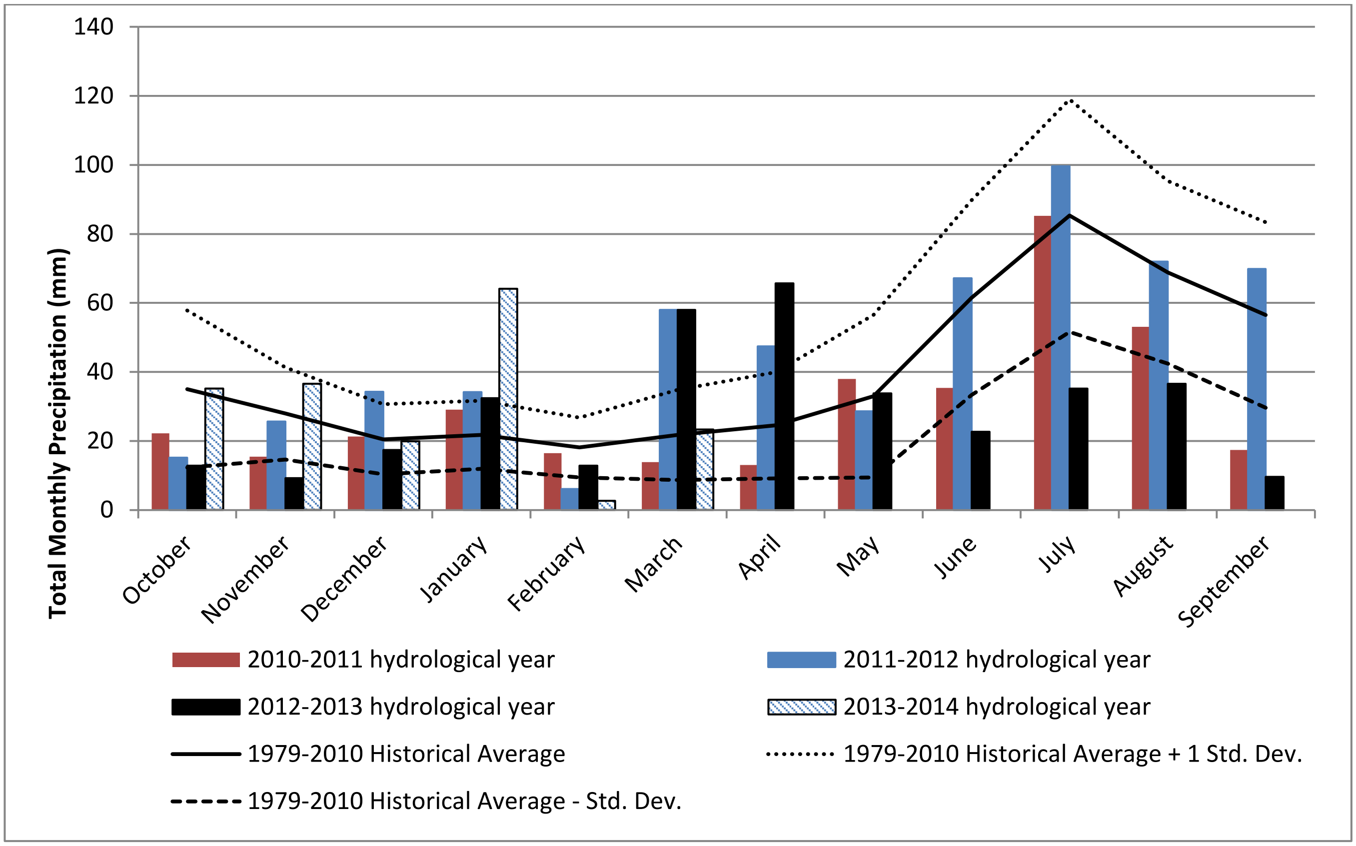


Figure 1: Key Lake Total Precipitation for Hydrological Years between 2010 and 2013 (EC 2013)

Precipitation during the 2010-2011 hydrological year was less than average during all months except January, May and July when precipitation was above average (January) or near average (May and July). The low precipitation throughout most of the winter would contribute to a smaller snowpack and a reduced spring freshet. Low summer and early fall precipitation would contribute to lower than normal flows during these periods.

Precipitation during the 2011-2012 hydrological year was generally near the 1979-2010 historical average. While cumulative precipitation from October to March was within 20% of the historical average, precipitation in March and April was more than twice the historical average. Near normal values were observed throughout the rest of the summer and early fall; the generally high precipitation rates in June through September could result in secondary peak flow events in summer and early fall.

Precipitation during the 2012-2013 hydrological year was below the 1979-2010 historical average. Cumulative precipitation from October to February was 30% below average. However, total precipitation of over twice the historic average during March and April resulted in cumulative precipitation of 20% above normal values by May. The summer of 2013 was dry with precipitation rates well below the historic average.

Precipitation during the first half of the 2013-2014 hydrological year was above the 1979-2010 historical average. Cumulative precipitation from October to March was 25% above average and snowfall during January was three times normal.

1.4 Regional Hydrology

Water Survey of Canada (WSC 2014a, 2014b) operates a hydrometric station on the Wheeler River, downstream of Russell Lake (Station 06DA005). The station is located about 25 km east of the Project site and records flows from a contributing drainage area of 3,030 square kilometres (km^2). The hydrometric station has been in operation from 1973 to the present and real time discharge and water level data are available. While the drainage area is much larger than those near the site (<371 km^2), the drainage areas relevant to the Project are tributaries to the Wheeler River and are thus expected to exhibit similar flow characteristics.

The mean monthly discharge rates at the Wheeler River for the hydrological years (October 1 to September 30) of 2010-2011 and 2011-2012 (WSC 2014a) as well as 2012-2013 and 2013-2014 (WSC 2014b) are presented in Figure 2.

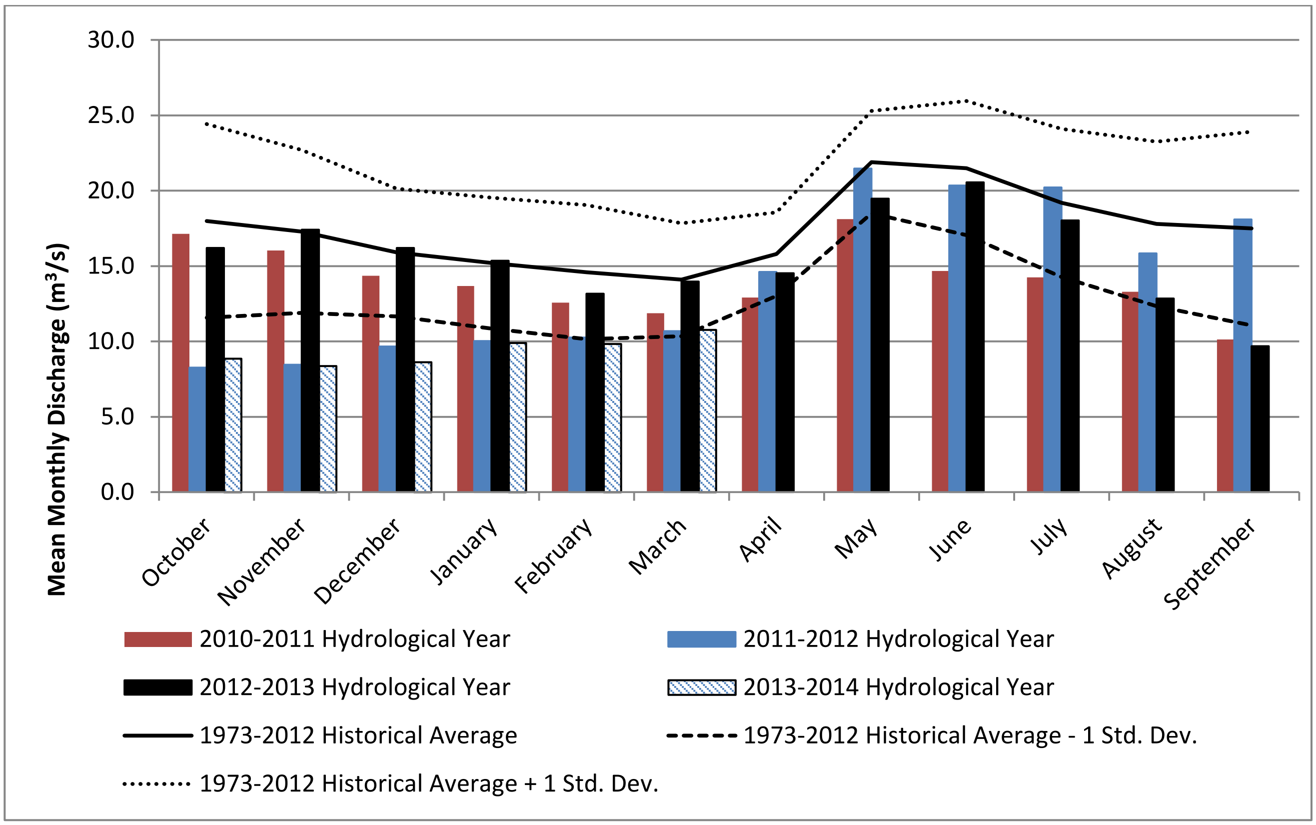


Figure 2: Wheeler River Mean Monthly Discharge for the Hydrological Years Between 2010 and 2013 (WSC 2013, 2014).

Although only provisional data that are subject to revision are available for 2012-2013 and 2013-2014 (Figure 2) these flow rates provide important context to the corresponding flow rates observed near the Project.

During the 2010-2011 hydrological year, discharge at the Wheeler River monitoring station was slightly below the historical average throughout the winter (October–March) and remained well below average during the spring freshet (May and June) and the remainder of the summer and early fall. During this time, flows ranged from 58 percent (%) (September) to 82% (April) of the 1973-2009 normal.

During the 2011-2012 hydrological year, discharge was below the historical average for the winter (January-March). Peak discharge in May approached the historical monthly average of 22 m^3/s, and remained near average during June, July, and September.

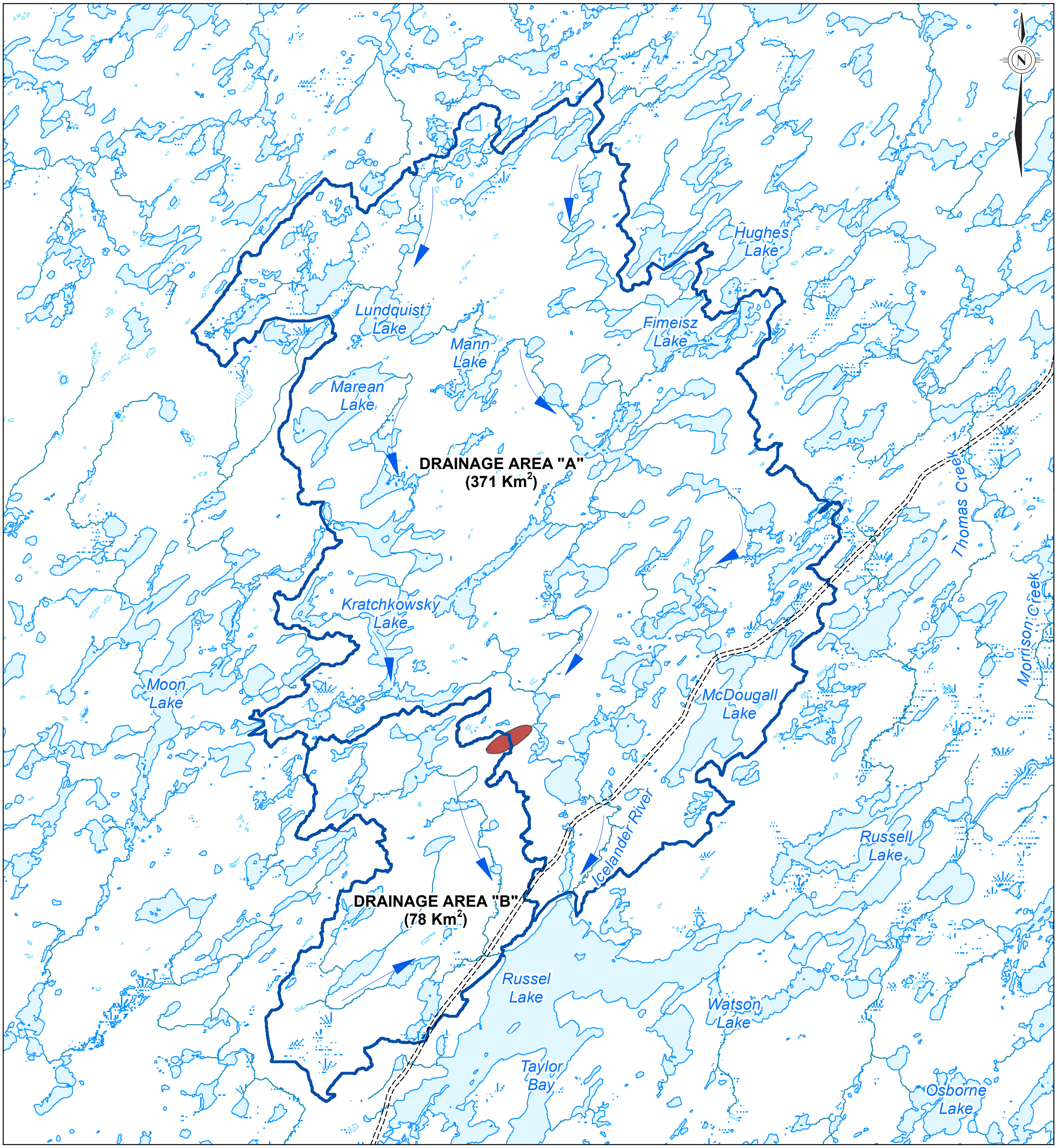
During the winter (October–March) of 2012-2013, discharge at the Wheeler River monitoring station was near or slightly below the historical average. Additional precipitation in April and March (Figure 1) were not matched by a similar streamflow response and discharge remained near but below average until July. In August and September discharge fell well below normal during late summer to 55% of the historical average by September.

During the winter (October–March) of 2013-2014, discharge at the Wheeler River monitoring station was slightly below the normal and rose slightly throughout the winter. The gradual increase in discharge over the winter is likely due to a combination of increased base flow and decreased lake storage. Base flow reaching the stream network is expected to have increased during the fall when evaporative demands ceased and base flow contributions originating in remote terrestrial uplands were free to flow slowly to the stream network. Above average snowfall shown on Figure 1 may also have contributed to higher flow between lakes by depressing the ice surface and decreasing lake storage volume. While flows recovered slightly throughout the winter, they remained one standard deviation below the mean. This increase in flows over winter from the very low levels in the fall of 2013 was also observed in flow data from Project monitoring stations.

2.0 LOCAL HYDROLOGY

2.1 Introduction

The Project is associated with two drainage areas that discharge into Russell Lake (Figure 3). Drainage Area A, with an estimated drainage area of 371 km^2, extends north and east of the Project area while Drainage Area B, with an estimated drainage area of 78 km^2, drains areas south of the Project. The drainage divide between Drainage Area A and Drainage Area B intersects the approximate location of the ore zone (Figure 3). Hydrological monitoring stations were established at six streams and seven lakes in Drainage Area A, and three streams and lakes in Drainage Area B during the 2011 to 2013 field programs; the monitored streams and lakes have been arbitrarily named (Figure 4). The monitored lakes and streams were selected to provide information on all the waterbodies potentially affected by the project and to characterise the general streamflow regime in the area. Table 1 provides the locations and monitoring activities at each waterbody.



LEGEND

- ==== MCARTHUR RIVER MINE ACCESS ROAD
- ORE ZONE
- WATERSHED BOUNDARY

4 0 4

SCALE 1:200,000 KILOMETRES

PROJECT

DENISON MINES CORP.
WHEELER RIVER PROPERTY

TITLE

DRAINAGE AREAS ASSOCIATED WITH THE PROJECT

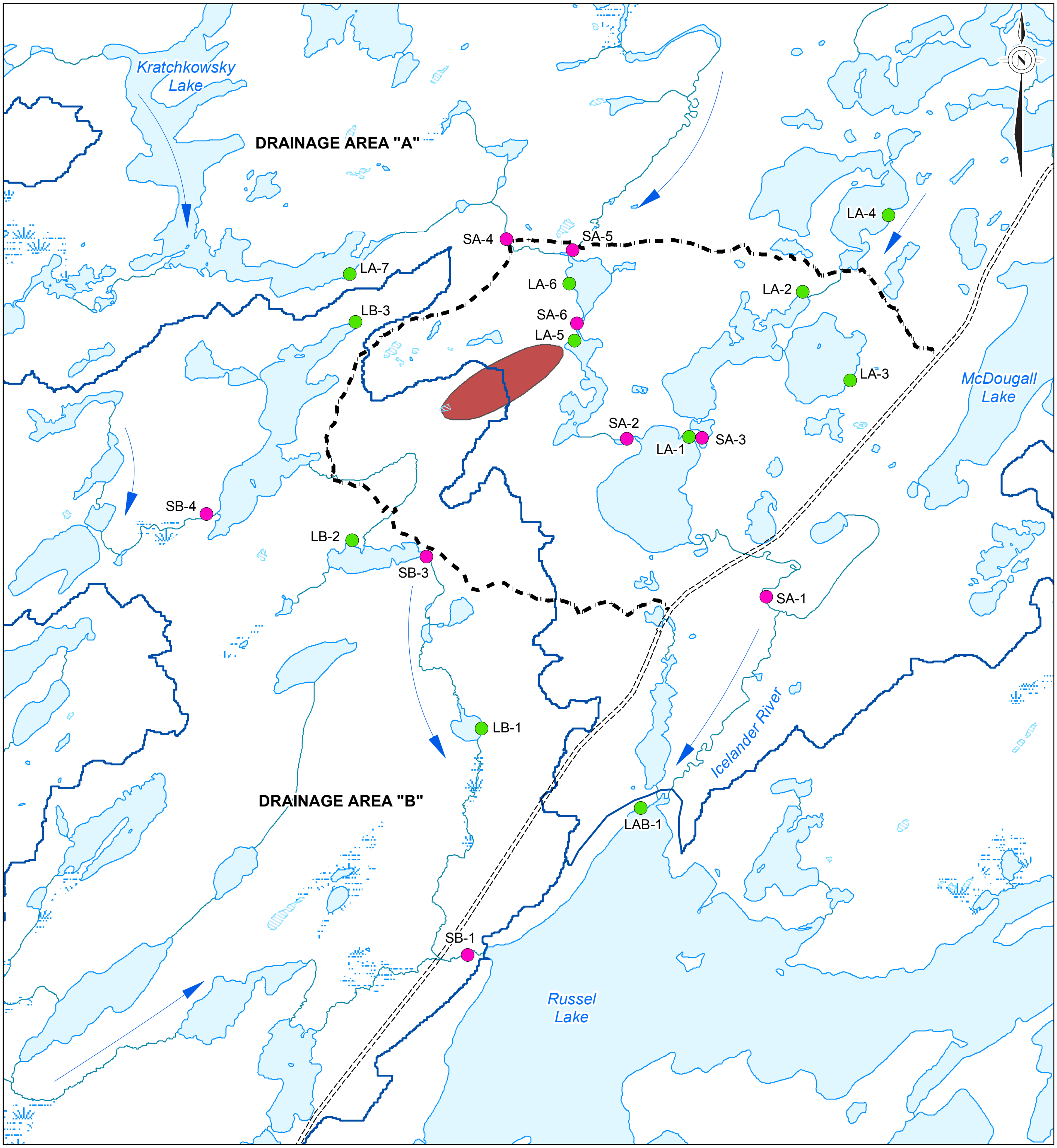
REFERENCE

NTS MAPSHEETS 74H02,03,04,05,06,07,10,11,12
NAD83 UTM ZONE 13

Golder Associates
Saskatoon, Saskatchewan

PROJECT		12-1362-0050	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	LMR/ANK	23/01/14	FIGURE: 3	
CHECK	RP	29/05/14		
REVIEW	BT	29/05/14		

G:\CLIENTS\DENISON MINES\Wheeler River\Figures\12-1362-0050\Hydrology\12-1362-0050 - Aquatic Baseline Watersheds.mxd Date: 5/29/2014 1:14:12 PM



2 0 2

SCALE 1:75,000 KILOMETRES

LEGEND

- ==== MCARTHUR RIVER MINE ACCESS ROAD
- ORE ZONE
- WATERSHED BOUNDARY
- TRAIL
- LAKE MONITORING STATION
- STREAM MONITORING STATION

NOTE

THE GEOGRAPHIC LOCATIONS OF THE MONITORING STATIONS HAVE BEEN ALTERED FOR GRAPHICAL REPRESENTATION.

REFERENCE

NTS MAPSHEETS 74H02,03,04,05,06,07,10,11,12
NAD83 UTM ZONE 13

PROJECT

DENISON MINES CORP.
WHEELER RIVER PROPERTY

TITLE

STREAM AND LAKE MONITORING SITES

Golder Associates
Saskatoon, Saskatchewan

PROJECT	12-1362-0050		FILE No.
DESIGN			SCALE AS SHOWN REV. 0
GIS	LMR/JRC	28/01/13	FIGURE: 4
CHECK	RP	29/05/14	
REVIEW	BT	29/05/14	

Table 1: Hydrology Monitoring Stations

Station Name	Location (UTM NAD 83)	Instantaneous Discharge Measurements	Continuous Water Level Recording	Staff Gauge	Elevation Survey
Lake Level Monitoring Sites					
LA-1	13 V 479387 6373208	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-2	13 V 480852 6375164	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-3	13 V 479387 6373208	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-4	13 V 481989 6376180	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-5	13 V 477830 6374521	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-6	13 V 477763 6375274	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LA-7	13 V 474851 6375402	-	2012, 2013	2011, 2012, 2013	2011, 2012, 2013, 2014
LAB-1	13 V 478705 6368323	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LB-1	13 V 476598 6369377	-	-	2011, 2012, 2013	2011, 2012, 2013
LB-2	13 V 474882 6371871	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
LB-3	13 V 474925 6374767	-	-	2011, 2012, 2013	2011, 2012, 2013, 2014
Stream Discharge Monitoring Sites					
SA-1	13 V 480368 6371123	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SA-2	13 V 478524 6373216	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SA-3	13 V 479415 6373234	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SA-4	13 V 476929 6375866	2011, 2012, 2013, 2014	2012, 2013, 2014	-	2011, 2012, 2013, 2014
SA-5	13 V 477804 6375716	2011, 2012, 2013, 2014	2012, 2013, 2014	-	2011, 2012, 2013, 2014
SA-6	13 V 477861 6374749	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SB-1	13 V 476041 6366362	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SB-3	13 V 475866 6371655	2011, 2012, 2013, 2014	2011, 2012, 2013, 2014	-	2011, 2012, 2013, 2014
SB-4	13 V 472952 6372222	2011, 2012, 2013, 2014	2012, 2013, 2014	-	2011, 2012, 2013, 2014

Three field programs were completed each open water season in 2011, 2012, and 2013. The field programs were timed to capture the spring peak flows (spring program), summer, and fall, immediately prior to freeze-up. One additional winter field program was completed between March 22 and April 1, 2014. Table 2 indicates the dates of each field program.

Table 2: Field Program Dates

	2011	2012	2013	2014
Spring	May 11 - May16	May 3 – May 9	May 18 – 24	-
Summer	July 27 - July 31	August 5 – August 8	August 12 – 15	-
Fall	October 27 - October 31	October 21 – October 25	October 16 – 19	-
Winter	-	-	-	March 22 – April 1

2.2 Methods

2.2.1 Instantaneous Streamflow Monitoring

At each stream monitoring site, instantaneous streamflow measurements were taken during the spring, summer and fall field campaigns. A suitable cross-section was selected at each stream based on the following characteristics: good bank control, straight channel, most laminar flow, and accessibility. A tag line (a cable marked at regular intervals) was used to divide the channel into vertical segments, with each segment measuring approximately 5% of the channel width or less than 10% of the flow, for streams more than 2 m wide. The depth and velocity at each segment across the channel was measured using a SonTek Flow Tracker current meter attached to a top-set wading rod. The velocity was measured at a depth of 60% (for depths less than 0.75 m) or at 20% and 80% of the depth (for depths greater than 0.75 m). For each section, the product of the mean of the depths and the flow velocity was multiplied by the width of the section to determine the total discharge. This was repeated for each consecutive section across the stream and the total discharge for the stream was then obtained by summing the partial discharges (velocity-area method). The mid-section method was used for discharge calculations (Terzi 1981). Instantaneous winter streamflow measurements were collected for each stream monitoring site observed to have flowing water during the 2014 winter field program. Methods were similar to those used in the summer with the substitution of “effective” flow depth for open water depth to account for the influence of ice cover on flow. Standard methods for the observation of streamflow under ice were followed (Terzi 1981).

2.2.2 Staff Gauge and Elevation Measurements

Water level measurements were collected at each monitoring site. Primarily elevation measurements were collected using an engineer’s rod and level and at some sites secondary elevation measurements were recorded using a staff gauge. At each site, up to three benchmarks were established using the highest point on a large, stable boulder, or a 1.5 m length of rebar driven into the ground. The benchmarks were spray painted, marked as BM1, BM2 or BM3 with flagging tape, and the location was recorded.

An engineer’s rod and level were used to measure water elevations relative to BM1 at each location, which was assigned an arbitrary elevation of 100.000 m. The three benchmarks were used for quality control and to confirm benchmark stability. The water level was measured at the lake surface or at the streamflow monitoring location; if waves affected the accuracy of the reading, the potential error was also recorded. Staff gauges were installed using 2 m lengths of rebar or T-bar and the top (1.000 m) of the staff gauge was measured relative to the local BM1 to monitor potential staff gauge movement between site visits, particularly over winter when ice can disturb the staff gauges.

To convert arbitrary benchmark datums into the geodetic datum, survey results from the 2012 Denison Wheeler River Ground Survey Summary were integrated (Appendix A). This survey used Real Time Kinematic (RTK) GPS to determine the geodetic elevation of the benchmarks. While elevation data were collected for all benchmarks at each site, the vertical error associated with the RTK survey is greater than that associated with the rod and level survey. Therefore, the geodetic elevation of the benchmark with the most accurate reading, i.e., lowest positional dilution of precision (PDOP) value at each site was used to calculate the elevations of the other benchmarks at the site using rod and level survey results.

2.2.3 Continuous Water Level Recording

Water level was continuously measured using a pressure transducer/data logger system. Leveloggers, manufactured by Solinst Canada Ltd, were programmed to record water levels at 30 minute intervals. At each 30 minute interval, the Levelogger records total pressure (atmospheric pressure and water pressure) acting on the sensor, which is internally compensated for temperature. A barologger was also installed near the Denison Mines Wheeler River Exploration Camp. The barologger was only exposed to atmospheric pressure, thereby allowing for barometric compensation of the Levelogger data. The resultant water pressure is related to height of water above the sensor and thus water elevation.

Each Levelogger was secured inside a bracket consisting of a small aluminum pipe that was welded to an aluminum plate or a 0.5 m pin. The plate or pin was fixed in place in the streambed, at or near the discharge measurement cross-section. The elevation of the top of the sensor bracket was measured relative to BM1 during the elevation survey to monitor potential movement between site visits. The sensor's water level measurement and coincident water elevation survey relative to BM1 were used to adjust the continuous water level data to the BM1 datum. An open water stage-discharge rating curve derived from coincident measurements of water depth (stage) and stream discharge was applied to the continuous water level record to derive a continuous discharge record for each site during the open water season.

2.3 Results

2.3.1 Streams

Stage and discharge measurements (Appendix B) were used to create stage-discharge curves for each streamflow monitoring site, as presented in Appendix C. While the three data points typically cover the range of flows and levels observed for the 2011, 2012, and 2013 monitored seasons, the curves are preliminary and discharge records are subject to modification as more measurements are collected and the stage-discharge curves are refined. The hydrograph and instantaneous discharge measurements for streams are provided in Appendix D. Photographs for all streamflow monitoring locations are provided in Appendix E.

In 2011, all hydrographs reflect highest observed flows in the spring during installation. The rising limb of the hydrograph, and spring peak flow rate was not captured at any site. The flow receded throughout May and June, and at all sites a secondary peak was observed during July and early August, which corresponds to relatively high rainfall (Figure 1). Flows receded again until September and remained static for the balance of the monitoring season.

Flows were considerably higher for the 2012 monitoring season than those observed in 2011. In 2012, the spring peak discharge rate, which occurred shortly after the first discharge measurement, was approximately captured at all sites. Discharge peaked in mid-May, and while it generally receded until late August, several other runoff events occurred, and at some sites, reached or exceeded the spring peak flow rate. At most sites, flow rates reached seasonal lows in late August before rising again during September and October to rates approaching those measured in the spring.

Flows were high relative to previous years during spring 2013 but a dry summer meant that by fall, flows were well below those observed in fall 2012 and similar to those observed in fall 2011. Discharge peaked in late June and steadily receded until moderate runoff responses occurred in late August and early September. Flows receded to seasonal lows in late September.

Flows rose above fall 2013 levels through the winter of 2013-2014. The increase in flow through the streams was not matched by increased lake levels. Increased winter flows are expected to result from decreased lake storage due in part to high snow load accumulated on the ice covered lake surfaces.

The following presents a discussion of the physical features and monitoring characteristics observed at each site.

SA-1

SA-1 is the most downstream monitoring station in Drainage Area A with an estimated upstream area of approximately 371 km^2. The monitoring station is located at the transition between an upstream low gradient meandering channel section and a downstream higher gradient riffle channel section. The stream substrate is composed of boulders, cobble and sand and is approximately 15 m wide at the cross-section. Although the banks are well defined and stable with shrubs and moss, the left bank has a notable floodplain vegetated with shrubs and black spruce. SA-1 is a good cross-section and monitoring station, and produces a good stage-discharge relationship and accurate hydrograph.

SA-2

Streamflow monitoring station SA-2 flows into the northwest end of LA-1. The monitoring station at SA-2 is located several meters downstream of the transition between an upstream meandering channel and a downstream riffle section. The monitoring site has a cross-section width of approximately 11 m, is relatively shallow with high velocity flow. The substrate is primarily composed of boulders and cobble, with well-defined and stable vertical banks vegetated with shrubs and trees. SA-2 produces a fair stage-discharge relationship; however the slope is nearly linear, so it may overestimate low and high flows. Further measurements at extreme flows would help verify the accuracy of this rating curve.

SA-3

Streamflow monitoring station SA-3 flows from LA-2 to LA-1. The entire stream length has a sandy and silty substrate with well-defined high vertical banks vegetated with shrubs, willows and jack pine. The monitoring station is located near the middle of the stream length and has a cross-sectional width of approximately 11 m and is shallow. SA-3 produces a good stage-discharge relationship and therefore relatively accurate hydrograph.

SA-4

The stream discharge monitoring station SA-4 drains LA-7, and is to the east of SA-5 and flows into the northwest end of LA-6. The monitoring site is located upstream of the existing temporary bridge and a fast flowing, narrow channel section. The channel has a cross-section width of approximately 6 m. The channel bottom is composed of large angular cobble and boulders. SA-4 produces a poor stage-discharge relationship, likely due to the coarse substrate which increases the stage at low discharge.

SA-5

Station SA-5 is to the west of SA-4 and flows into the northwest end of LA-6. The monitoring station is located downstream of a small temporary bridge in a straight and relatively steep section of the stream. The substrate at the cross-section is primarily boulders and cobble with some sand. The stream has a width of approximately 8 m and has stable vertical organic banks vegetated with shrubs. SA-5 produces a fair stage-discharge relationship and therefore hydrograph.

SA-6

Streamflow monitoring Station SA-6 drains from LA-6 and is upstream of SA-2. The stream section at this monitoring site is characterized by a sandy substrate, slow, deep, and laminar flow, and vertical banks. Although the right bank is well defined, high, and vegetated with trees, sand, and moss, the left bank is low lying with muskeg, shrubs and black spruce. The cross-section has a width of approximately 14 m. SA-6 produces a very good stage-discharge relationship and hydrograph.

SB-1

SB-1 is the most downstream monitored stream in Drainage Area B. The monitoring station is located immediately upstream of the culverts on the Key Lake-McArthur River haul road. The location is characterized by a thick organic substrate, and anthropogenically altered, stable, sand, gravel, and boulder banks with grass, while the channel sections upstream and downstream of the road is generally classified as wetland. The cross-section is approximately 9 m wide and flow is typically deep with gentle laminar flow. SB-1 produces a poor stage-discharge relationship; spring discharge elevations are considerably lower for the corresponding discharge rates than summer and fall measurements. Beaver activity immediately upstream of the culverts affected the stage-discharge relationship during the summer of 2011. Beaver activity approximately 90 m downstream of the culverts resulted in affected water levels from early July and throughout the remainder of the 2013 open water season.

SB-3

Streamflow station SB-3 is located downstream of LB-2. The monitoring station is located in a narrow deep section of the stream with a substrate composed of cobble, boulder, sand and organics. The cross-section has vertical banks with moss and shrubs and a width of approximately 3 m. Although the right bank gains relief within several meters of the stream, the left bank is low lying and reflects flood plain characteristics for tens of meters. SB-3 produces a good stage-discharge relationship and hydrograph.

SB-4

Streamflow Station SB-4 flows into the southwest end of LB-3. The stream flows through low-lying muskeg and is poorly defined. A relatively controlled section was identified as suitable for the streamflow monitoring station;

however both banks are poorly defined, the substrate consists of angular cobbles and boulders, and the stream is surrounded by muskeg. This section of the stream is approximately 5 m wide, has organic banks, and an organic substrate with emergent aquatic vegetation. During the spring site visit, the channel upstream and downstream was blocked with ice. The low velocity and boulder substrate at the cross-section introduce considerable error into discharge measurements. Nevertheless, SB-4 produces a fair stage-discharge relationship and hydrograph. The flow characteristics here differ somewhat from the corresponding flow dynamics in Drainage Area A and SB-3, likely due to the flow characteristics through the muskeg, the buildup of ice during the winter and its gradual melting throughout the summer, and ice blockage during the spring and early summer. A Levelogger was not installed at this location during the 2011 open water season, and in 2012 an animal interfered with the continuous level measurements and disturbed measurements for a portion of July and August.

2.3.2 Relationship to Regional Hydrology

While the drainage area (3,030 km^2) of the Water Survey of Canada (WSC 2012a, 2012b) hydrometric station on the Wheeler River is much larger than those near the site (<371 km^2), the drainage areas relevant to the Project are climatically and physio-graphically similar to the other tributaries of the Wheeler River. As a result, a scaled relationship between flow observed at the larger streamflow stations and the Water Survey of Canada (WSC 2012a, 2012b) hydrometric station on the Wheeler River, downstream of Russell Lake (Station 06DA005) should be valid and could be used to simulate past daily flows in the Project Area based on the 1974-2012 record of flows in the Wheeler River, downstream of Russell Lake (Station 06DA005). A population of 509 samples of observed streamflow from station SA-1 collected over three years were regressed against WSC Station 06DA005 yielded Equation 1 with a correlation coefficient (R) of 0.972. A population of 509 samples of observed streamflow from station SB-3 were regressed against WSC Station 06DA005 yielded Equation 2 with a R= 0.903. A valid relationship between SB-1 and WSC station 06DA005 was not found based on the data collected to date.

$$Q_{SA1} = aQ_{06DA005}{}^{b} \qquad (1)$$

Where:

Q_{SA1} = Daily mean discharge for station SA-1 (m^3/s)
$Q_{06DA005}$= Daily mean discharge for WSC Station 06DA005 (m^3/s)
a = 0.091134488
b = 1.089166899

$$Q_{SB3} = aQ_{06DA005}{}^{b} \qquad (2)$$

Where:

Q_{SB3} = Daily mean discharge for station SB-3 (m^3/s)
$Q_{06DA005}$= Daily mean discharge for WSC Station 06DA005 (m^3/s)
a = 0.004426783
b = 1.272384298

2.3.3 Effect of Seasonal Ice Formation on Streamflow

The development of ice cover in stream channels causes a backwater which is influenced by the quantity and character of ice as well as the quantity of discharge flowing through the stream. Open water rating curves must be adapted to account for the backwater if they are to be applied during ice covered periods (USGS 1982). The backwater effect can be accounted for by comparison of streamflow data to weather records and nearby gaging stations as well as using adjustment factors. An adjustment factor, K, was derived as the ratio of observed ice covered discharge to the open water rated discharge corresponding to the observed stage. The K values observed during March 2014 are presented in Table 3. Late winter discharge could be estimated by multiplying the discharge read from the curves presented in Appendix C by the adjustment factor.

Table 3: Adjustment Factors (K) observed for Ice Covered Discharge

Station	Date	K
SA1	25-Mar-14	0.277
SA2	24-Mar-14	0.364
SA3	24-Mar-14	0.524
SA4	23-Mar-13	0.585
SA5	23-Mar-14	0.409
SA6	23-Mar-14	0.706
SB3	25-Mar-14	0.788

2.3.4 Lakes

Lake stage was measured during each site visit (Table 2), unless snow cover prevented the collection of accurate water level measurements in the spring and winter. In cases where discharge measurements were collected at the outflow channel, lake stage-discharge curves are presented in Appendix C. These data can be used to create continuous lake level records for the measurement periods. Additionally, a continuous water level sensor was installed at LA-7. Table 4 presents a summary of geodetic water levels at each monitored lake during open water conditions between 2011 and 2013. The difference between maximum and minimum water levels measured at the monitored lakes has typically been less than 0.3 m.

Table 4: Lake Water Level Summary

Station	Minimum Measured Water Level (masl)	Maximum Measured Water Level (masl)
LA-1	494.194	494.448
LA-2	494.467	494.654
LA-3	494.439	494.619
LA-4	498.507	498.649
LA-5	499.949	500.074
LA-6	499.943	500.092
LA-7	520.424	520.536
LB-1	503.707	504.079
LB-2	510.392	510.573
LB-3	518.356	518.580
LAB-1	487.994	488.233

masl = metres above sea level

Ice thickness was observed at the deepest point of each monitored lake between March 23, 2014 and April 1, 2014. Ice thickness observed at the end of March can be considered the maximum development of ice thickness for the winter of 2013-2014. Table 5 presents a summary of ice thicknesses. Observed lake ice thickness ranged from 0.70 m to 0.97 m with an average of 0.83 m.

Table 5: Lake Water Level Summary

Station	Ice Surface	Ice Thickness	Water Surface
LA-1	494.258	0.97	494.298
LA-2	494.582	0.76	494.582
LA-3	494.589	0.80	494.649
LA-4	498.634	0.82	498.614
LA-5	500.076	0.70	500.076
LA-6	500.058	0.94	500.058
LA-7	520.472	0.85	520.502
LB-1	n/a	n/a	n/a
LB-2	510.533	0.78	510.533
LB-3	518.463	0.82	518.463
LAB-1	488.332	0.83	488.382

masl = metres above sea level

3.0 CLOSURE

Golder Associates Ltd. appreciates the opportunity to assist Denison with this project. We trust that this report meets your needs at this time. Should you have any questions or comments, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Ross Phillips, M.Sc., B.A.Sc.
Junior Water Resources Engineer

Brent Topp, B.Sc., P.Geo.
Associate, Senior Hydrologist

RP/BT/pls

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APPENDIX A

Denison Wheeler River Ground Survey Summary

MEMORANDUM

TO Lawson Forand, Denison Mines Corp. **DATE** January 3, 2013

CC Clark Gamelin, Denison Mines Corp.

FROM Ashley Dubnick/Brent Topp **PROJECT No.** 12-1362-0050/1000

DENISON WHEELER RIVER GROUND SURVEY SUMMARY

Introduction

Golder Associates Ltd. (Golder) was retained by Denison Mines Corp. (Denison) to perform a hydrological baseline program as part of a pre-feasibility study of the Phoenix deposit at the Wheeler River property (the Project) near Key Lake, Saskatchewan. As part of the program, Golder has established a number of hydrological monitoring stations to collect the necessary hydrological baseline data to support various project requirements including environmental assessments, regulatory permitting, and providing design basis information for engineered designs, including fresh water diversions, water management systems, sedimentation ponds, and cross-drainage structures. To most accurately complete these hydrological assessments, models that incorporate the hydrological information and the LiDAR surface, collected in June, 2010, may be created. However, to accurately combine these datasets, a topographic survey of the hydrological station benchmarks is necessary. This technical memorandum presents a summary of the geodetic survey results completed at the Denison Wheeler River property.

Methods

The geodetic ground survey was completed on October 21 to 24, 2012 using a GPS Base Station and RTK GPS Rover with the following specifications:

GPS Base Station

- Sokkia GRX1 base station receiver integrated with GPS and GLONASS tracking in conjunction with Satel differential correction external radio.
- Satel radio transmission repeater used to increase signal quality and range.

RTK GPS Rover

- Sokkia GRX1 RTK rover receiver integrated with GPS and GLONASS tracking in conjunction with Satel differential correction internal radio.
- RTK GPS attached to a fixed-height carbon fibre pole.

Because the benchmark or the control points used for the LiDAR survey were not accessible or useable for the purposes of this ground survey, site control was established using planted iron pins at four locations. The base station reference point was established by averaging 2700 autonomous GPS readings and a site-specific geoid model was used for all surveys. Geodetic elevations at all benchmarks established at hydrometric monitoring stations were collected.

Results

Over the course of the survey, no horizontal error exceeded 0.037m to established control and no vertical error exceeded 0.012m to established control. Table 1 presents the greatest errors to established control observed on each day of the survey.

Table 1: Greatest Error to Established Control

	Northing (m)	Easting (m)	Elevation (m)
October 21, 2012	0.017	0.015	0.012
October 22, 2012	0.016	0.013	0.006
October 23, 2012	0.002	0.015	0.010
October 24, 2012	0.021	0.037	0.007

Ground survey results are presented in Table 2 and include the location and elevation of each point as well as indicators of the point quality.

Table 2: Geodetic Survey Results

Benchmark	Type	Location (WGS 84)			Point Quality			
		Northing (m)	Easting (m)	Elevation (m)	HDOP Avg	VDOP Avg	PDOP Avg	Sat Avg
GolderWR CP1	Rebar	6372855.249	474661.887	519.868	-	-	-	-
GolderWR CP2	Rebar	6374770.522	475606.918	540.993	-	-	-	-
GolderWR CP2	Rebar	6370859.443	477535.796	556.213	-	-	-	-
GolderWR CP2	Rebar	6370371.120	477093.253	558.542	-	-	-	-
LA-2 BM1	Rebar	6375172.712	480842.634	497.339	0.8637	1.4567	1.6935	13
LA-2 BM2	Rebar	6375174.795	480846.484	497.064	1.0822	1.6114	1.9415	12
LA-2 BM3	Rebar	6375171.611	480846.491	496.34	0.8806	1.4144	1.6662	14
LA-3 BM1	Rock	6373997.350	481487.807	496.134	0.6176	1.0483	1.2167	16
LA-3 BM2	Rock	6373994.256	481487.899	496.034	0.6212	1.0813	1.2474	16
LA-3 BM3	Rock	6373997.038	481478.058	494.831	0.6510	1.1243	1.2992	15
LA-4 BM1	Rebar	6376186.639	481994.794	500.365	0.8486	1.2003	1.4700	15
LA-4 BM2	Rebar	6376189.113	481991.522	500.252	0.8522	1.2156	1.4846	14
LA-4 BM3	Rebar	6376187.971	481988.774	499.699	0.8540	1.2233	1.4919	15
LA-5 BM1	Rebar	6374540.225	477831.352	501.366	0.7518	1.1807	1.3997	13
LA-5 BM2	Rebar	6374541.110	477824.823	501.014	0.7609	1.1976	1.4189	13
LA-5 BM3	Rebar	6374538.032	477835.822	501.023	0.7499	1.1325	1.3584	13
LA-6 BM1	Rebar	6375257.733	477749.298	502.388	0.9719	1.7615	2.0118	12
LA-6 BM2	Rebar	6375254.317	477756.381	502.08	0.9763	1.8564	2.0981	11
LA-7 BM1	Rock	6375365.152	474859.273	522.374	0.7420	1.0764	1.3074	16
LA-7 BM2	Rock	6375370.136	474856.009	522.067	0.7449	1.0884	1.3188	16
LA-7 BM3	Rock	6375373.196	474852.454	521.8	0.7528	1.1217	1.3509	15
LAB-1 BM1	Rebar	6368332.435	478695.192	489.243	0.6562	1.1309	1.3075	16
LAB-1 BM2	Rebar	6368331.850	478688.921	489.745	0.7115	1.1969	1.3924	16
LAB-1 BM3	Rebar	6368334.674	478697.583	489.597	0.6292	1.0883	1.2571	18
LB-1 BM1	Rebar	6369366.788	476603.997	505.231	0.6245	1.0322	1.2066	17

Benchmark	Type	Location (WGS 84)			Point Quality			
		Northing (m)	Easting (m)	Elevation (m)	HDOP Avg	VDOP Avg	PDOP Avg	Sat Avg
LB-1 BM2	Rebar	6369370.293	476602.209	505.04	0.5854	0.9346	1.1029	19
LB-1 BM3	Rebar	6369363.850	476597.929	505.073	0.6873	1.1251	1.3185	15
LB-2 BM1	Rebar	6371898.916	474903.385	511.767	0.7817	1.3143	1.5293	14
LB-2 BM2	Rebar	6371901.778	474906.357	511.819	0.7503	1.3058	1.5060	15
LB-2 BM3	Rebar	6371904.723	474900.057	511.806	0.7563	1.3243	1.5251	15
LB-3 BM1	Rebar	6374839.646	474884.439	520.159	0.8050	1.3752	1.5935	15
LB-3 BM2	Rebar	6374831.436	474893.291	519.42	0.8075	1.3649	1.5859	14
LB-3 BM3	Rebar	6374834.862	474895.379	520.021	0.8710	1.4123	1.6595	13
SA-1 BM1	Rebar	6371129.601	480327.636	496.123	0.6503	1.1645	1.3338	16
SA-1 BM2	Rock	6371125.303	480328.743	495.576	0.8882	1.4407	1.6926	15
SA-1 BM3	Rebar	6371123.762	480357.257	494.361	0.6567	1.1236	1.3015	15
SA-2 BM1	Rock	6373258.113	478533.160	498.369	0.7284	1.1748	1.3824	14
SA-2 BM2	Rock	6373258.391	478529.590	498.354	0.7223	1.1761	1.3802	14
SA-3/LA-1 BM1	Rebar	6373226.219	479403.750	495.714	0.6648	0.9753	1.1803	15
SA-3/LA-1 BM2	Rebar	6373227.014	479408.484	495.55	0.6932	1.1317	1.3274	14
SA-3/LA-1 BM3	Rebar	6373222.211	479402.381	495.616	0.7095	1.0651	1.2798	15
SA-4 BM1	Rebar	6375855.114	476914.695	507.772	0.7494	1.1259	1.3528	12
SA-4 BM2	Rock	6375853.025	476915.570	508.373	0.6744	1.0823	1.2752	13
SA-5 BM1	Rebar	6375723.540	477791.074	502.58	0.8335	1.5526	1.7626	13
SA-5 BM2	Rock	6375739.656	477807.701	502.045	0.7208	1.3664	1.5449	15
SA-6 BM1	Rebar	6374757.968	477848.597	503.32	0.7968	1.2055	1.4451	13
SA-6 BM2	Rebar	6374752.648	477849.463	503.205	0.6627	1.0256	1.2210	15
SA-6 BM3	Rebar	6374746.296	477855.608	502.021	0.7816	1.2429	1.4682	13
SB-1 BM1	Culvert	6366351.011	476038.945	489.602	0.7076	1.1207	1.3254	16
SB-1 BM2	Culvert	6366355.284	476042.540	489.414	0.7191	1.1384	1.3465	15
SB-1 BM3	Rock	6366375.139	476028.439	489.217	0.7107	1.2371	1.4268	15
SB-3 BM1	Rebar	6371642.428	475847.211	511.473	0.6569	0.9922	1.1900	16
SB-3 BM2	Rock	6371638.405	475838.409	511.897	0.6562	0.9889	1.1868	16
SB-4 BM1	Rock	6372197.891	472953.818	520.307	0.6084	1.1287	1.2822	17
SB-4 BM2	Rock	6372197.460	472955.741	520.205	0.7005	1.3090	1.4847	13
SB-4 BM3	Rock	6372197.402	472957.726	520.305	0.6243	1.1415	1.3011	16

HDOPAvg: Horizontal dilution of precision

VDOPAvg Vertical dilution of precision

PDOPAvg: Positional (3D) dilution of precision

SatAvg: average number of satellites

Closure

Golder Associates Ltd. appreciates the opportunity to assist Denison with this project. We trust that this report meets your needs at this time. Should you have any questions or comments, please do not hesitate to contact us.

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APPENDIX B

Stage and Discharge Measurements

Table B1: Lake Stage Measurements

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)
LA-1	13-May-11	98.725	494.439
	29-Jul-11	98.613	494.327
	28-Oct-11	98.504	494.218
	4-May-12	98.709	494.423
	5-Aug-12	98.672	494.386
	23-Oct-12	98.734	494.448
	21-May-13	98.726	494.44
	14-Aug-13	98.551	494.265
	16-Oct-13	98.48	494.194
	25-Mar-14	98.584	494.298
LA-2	13-May-11	97.269	494.615
	30-Jul-11	97.256	494.602
	29-Oct-11	97.203	494.549
	4-May-12	97.264	494.61
	6-Aug-12	97.274	494.62
	23-Oct-12	97.308	494.654
	20-May-13	97.278	494.624
	13-Aug-13	97.197	494.543
	16-Oct-13	97.121	494.467
	26-Mar-14	97.236	494.582
LA-3	13-May-11	98.427	494.561
	30-Jul-11	98.433	494.567
	29-Oct-11	98.427	494.561
	4-May-12	98.472	494.606
	6-Aug-12	98.456	494.59
	23-Oct-12	98.485	494.619
	20-May-13	98.459	494.593
	13-Aug-13	98.387	494.521
	16-Oct-13	98.305	494.439
	26-Mar-14	98.515	494.649

Table B1: Lake Stage Measurements (continued)

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)
LA-4	29-Jul-11	98.284	498.649
	30-Oct-11	98.152	498.517
	4-May-12	98.223	498.588
	5-Aug-12	98.248	498.613
	6-Aug-12	98.257	498.622
	23-Oct-12	98.262	498.627
	20-May-13	98.259	498.624
	13-Aug-13	98.164	498.529
	16-Oct-13	98.142	498.507
	27-Mar-14	98.249	498.614
LA-5	13-May-11	98.706	500.050
	31-Jul-11	98.67	500.014
	27-Oct-11	98.605	499.949
	6-May-12	98.73	500.074
	5-Aug-12	98.693	500.037
	22-Oct-12	98.728	500.072
	21-May-13	98.729	500.073
	13-Aug-13	98.625	499.969
	17-Oct-13	98.606	499.95
	23-Mar-14	98.732	500.076
LA-6	13-May-11	97.675	500.063
	31-Jul-11	97.64	500.028
	27-Oct-11	97.555	499.943
	6-May-12	97.7	500.088
	5-Aug-12	97.67	500.058
	22-Oct-12	97.704	500.092
	19-May-13	97.7	500.088
	13-Aug-13	97.585	499.973
	17-Oct-13	97.559	499.947
	23-Mar-14	97.67	500.058

Table B1: Lake Stage Measurements (continued)

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)
LA-7	29-Jul-11	98.108	520.482
	31-Oct-11	98.05	520.424
	6-May-12	98.149	520.523
	8-Aug-12	98.108	520.482
	21-Oct-12	98.162	520.536
	24-May-13	98.157	520.531
	13-Aug-13	98.083	520.457
	16-Oct-13	98.066	520.44
	27-Mar-14	98.128	520.502
LAB-1	16-May-11	98.991	488.219
	1-Aug-11	98.891	488.119
	30-Oct-11	98.776	488.004
	9-May-12	99	488.228
	6-Aug-12	98.939	488.167
	23-Oct-12	98.987	488.215
	21-May-13	99.005	488.233
	12-Aug-13	98.879	488.107
	19-Oct-13	98.766	487.994
	25-Mar-14	99.154	488.382
LB-1	14-May-11	98.666	503.902
	1-Aug-11	98.807	504.043
	30-Oct-11	98.648	503.884
	6-May-12	98.636	503.872
	6-Aug-12	98.651	503.887
	21-Oct-12	98.617	503.853
	19-May-13	98.843	504.079
	14-Aug-13	98.509	503.745
	17-Oct-13	98.471	503.707

Table B1: Lake Stage Measurements (continued)

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)
LB-2	14-May-11	98.767	510.523
	29-Jul-11	98.689	510.445
	30-Oct-11	98.636	510.392
	5-May-12	98.771	510.527
	6-Aug-12	98.745	510.501
	21-Oct-12	98.817	510.573
	21-May-13	98.756	510.512
	14-Aug-13	98.699	510.455
	17-Oct-13	98.651	510.407
	25-Mar-14	98.777	510.533
LB-3	15-May-11	98.365	518.519
	29-Jul-11	98.284	518.438
	29-Oct-11	98.203	518.356
	5-May-12	98.361	518.515
	5-Aug-12	98.37	518.524
	21-Oct-12	98.426	518.58
	19-May-13	98.38	518.534
	13-Aug-13	98.278	518.432
	17-Oct-13	98.233	518.387
	25-Mar-14	98.233	518.463

Table B2: Stream Stage and Discharge Measurements

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)	Discharge (m^3/s)
SA-1	14-May-11	97.793	492.714	2.307
	29-Jul-11	97.727	492.648	1.750
	28-Oct-11	97.641	492.562	0.973
	5-May-12	97.79	492.711	2.293
	6-Aug-12	97.774	492.695	2.031
	23-Oct-12	97.8	492.721	2.575
	20-May-13	97.784	492.705	2.358
	14-Aug-13	97.666	492.587	1.280
	18-Oct-13	97.633	492.554	0.887
	30-Mar-14	97.948	492.869	1.203
SA-2	12-May-11	98.37	496.727	1.649
	30-Jul-11	98.341	496.698	1.387
	27-Oct-11	98.31	496.667	0.809
	8-May-12	98.391	496.748	2.008
	8-Aug-12	*98.332*	*496.689*	1.305
	24-Oct-12	98.377	496.734	2.030
	21-May-13	98.37	496.727	1.842
	14-Aug-13	98.303	496.66	0.863
	16-Oct-13	98.284	496.641	0.741
	24-Mar-14	98.448	496.805	1.180
SA-3	13-May-11	98.745	494.459	0.476
	29-Jul-11	98.678	494.392	0.370
	28-Oct-11	98.608	494.322	0.239
	4-May-12	98.759	494.473	0.528
	5-Aug-12	98.729	494.443	0.478
	23-Oct-12	98.773	494.487	0.578
	20-May-13	98.768	494.482	0.564
	14-Aug-13	98.63	494.344	0.255
	16-Oct-13	98.529	494.243	0.051
	24-Mar-14	98.534	494.248	0.362

Table B2: Stream Stage and Discharge Measurements (continued)

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)	Discharge (m^3/s)
SA-4	11-May-11	98.577	506.357	0.483
	30-Jul-11	98.534	506.314	0.335
	31-Oct-11	98.53	506.31	0.199
	4-May-12	98.568	506.348	0.466
	5-Aug-12	98.549	506.329	0.361
	22-Oct-12	98.587	506.367	0.497
	19-May-13	98.589	506.369	0.519
	13-Aug-13	98.497	506.277	0.276
	17-Oct-13	98.469	506.249	0.206
	23-Mar-13	98.601	506.381	0.330
SA-5	12-May-11	98.129	500.708	1.100
	30-Jul-11	98.089	500.668	0.858
	29-Oct-11	98.03	500.609	0.476
	4-May-12	98.138	500.717	1.111
	5-Aug-12	98.105	500.684	1.026
	22-Oct-12	98.139	500.718	1.269
	19-May-13	98.147	500.726	1.381
	13-Aug-13	98.05	500.629	0.616
	17-Oct-13	98.043	500.622	0.507
	23-Mar-14	98.219	500.798	0.886
SA-6	13-May-11	96.753	500.084	1.631
	30-Jul-11	96.703	500.034	1.303
	27-Oct-11	96.625	499.956	0.717
	6-May-12	96.767	500.098	1.957
	5-Aug-12	96.73	500.061	1.476
	22-Oct-12	96.771	500.102	1.851
	19-May-13	96.746	500.077	1.540
	13-Aug-13	96.661	499.992	0.842
	17-Oct-13	96.638	499.969	0.798
	23-Mar-14	96.75	500.081	1.173

Table B2: Stream Stage and Discharge Measurements (continued)

Location	Date	Elevation (m) (Arbitrary Datum)	Elevation (m) (Geodetic)	Discharge (m^3/s)
SB-1	14-May-11	98.884	488.486	0.517
	31-Jul-11	99.425	489.027	0.186
	30-Oct-11	98.816	488.418	0.217
	3-May-12	98.922	488.524	0.644
	6-Aug-12	98.92	488.522	0.358
	23-Oct-12	98.997	488.599	0.578
	18-May-13	98.882	488.484	0.547
	12-Aug-13	98.733	488.335	0.158
	19-Oct-13	99.248	488.85	0.277
	27-Mar-14	99.221	488.823	0.289
SB-3	11-May-11	98.964	510.465	0.187
	31-Jul-11	98.905	510.406	0.109
	30-Oct-11	98.888	510.389	0.082
	5-May-12	99.005	510.506	0.235
	8-Aug-12	98.955	510.456	0.136
	21-Oct-12	99.016	510.517	0.255
	20-May-13	98.976	510.476	0.209
	14-Aug-13	98.921	510.421	0.107
	17-Oct-13	98.914	510.414	0.080
	25-Mar-14	98.923	510.423	0.090
SB-4	15-May-11	98.827	519.134	0.074
	1-Aug-11	98.657	518.964	0.008
	30-Oct-11	98.763	519.07	0.018
	5-May-12	98.912	519.219	0.109
	6-Aug-12	98.837	519.144	0.032
	21-Oct-12	98.938	519.245	0.099
	21-May-13	98.875	519.185	0.114
	15-Aug-13	98.764	519.074	0.007
	17-Oct-13	98.805	519.115	0.036

APPENDIX C

Open Water Stage-Discharge Curves for Lake Level and Streamflow Monitoring Stations

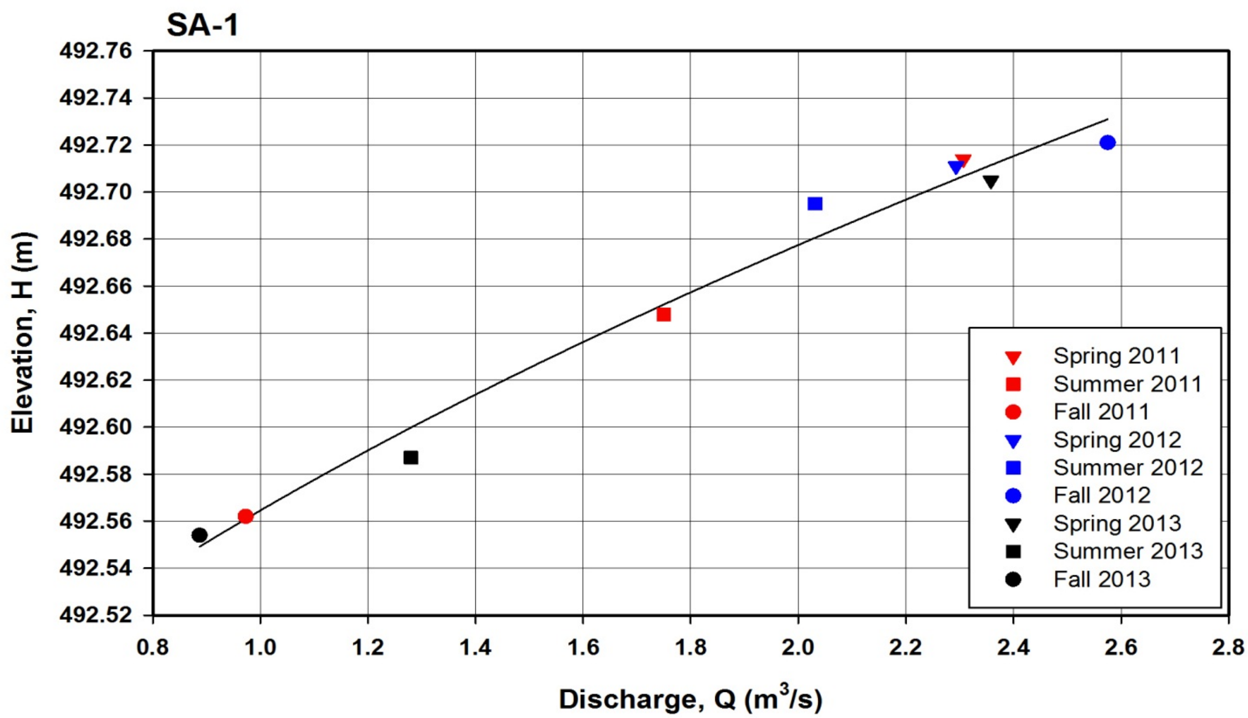

Figure C1: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-1.

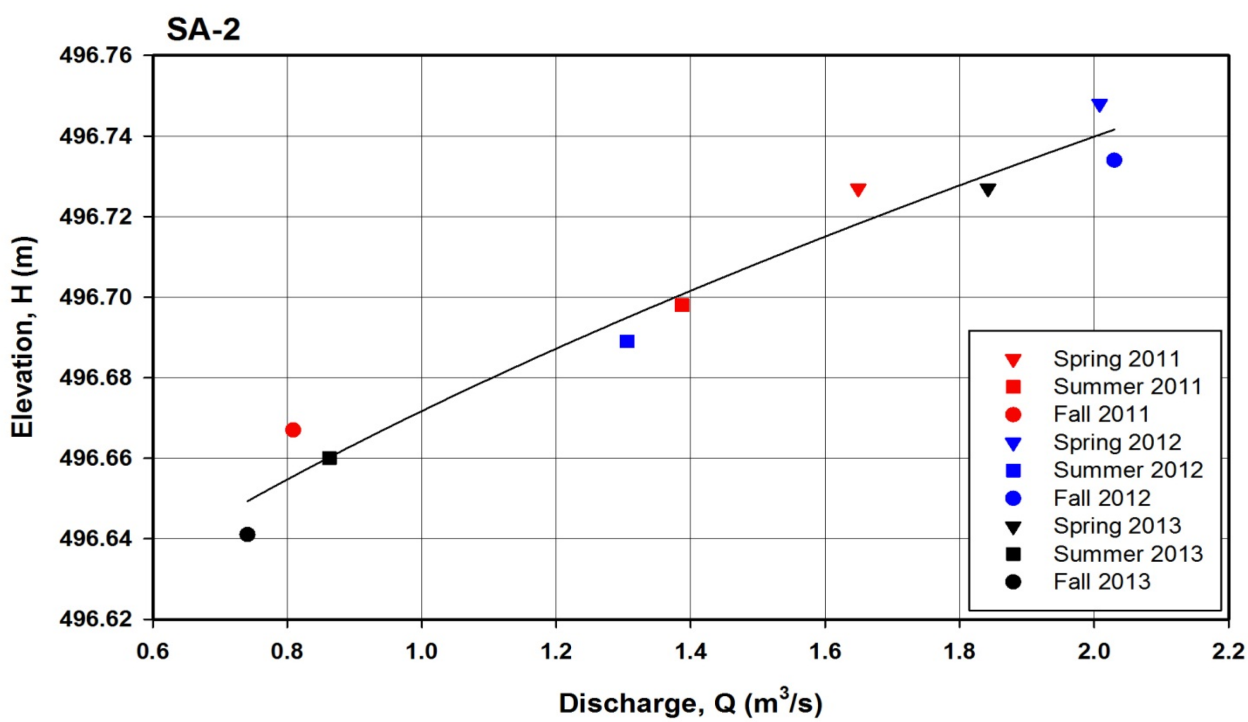

Figure C2: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-2.

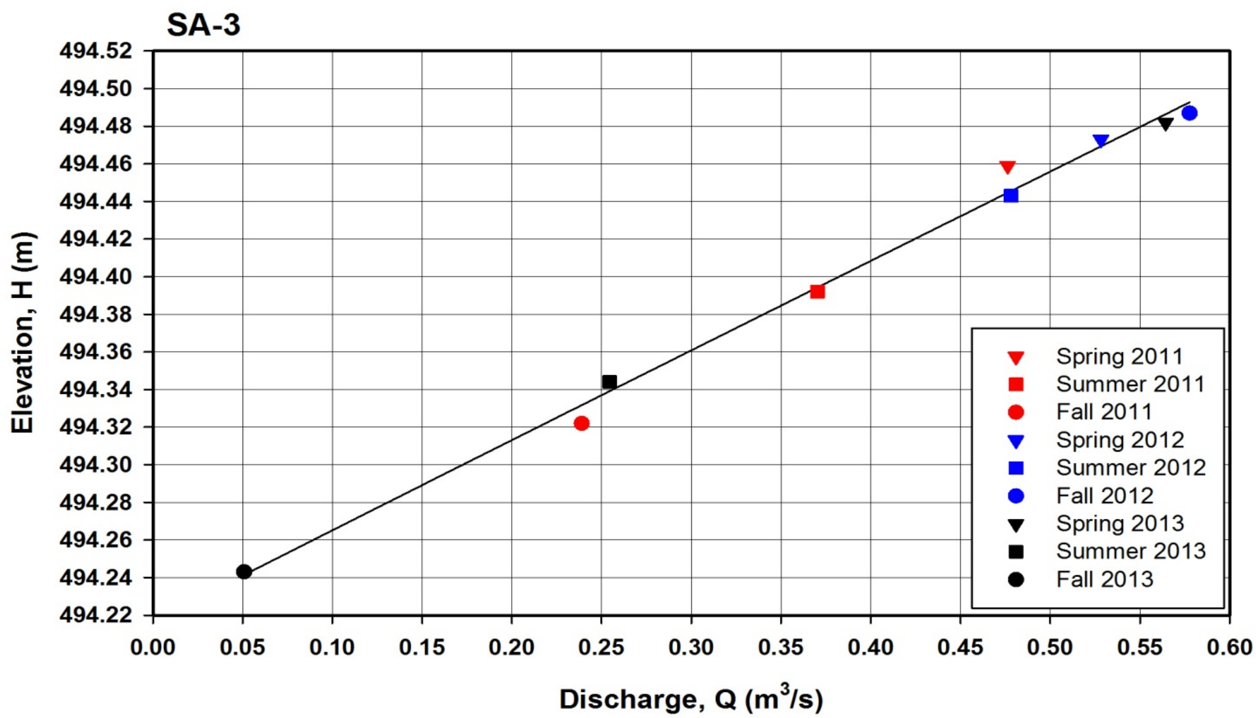

Figure C3: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-3.

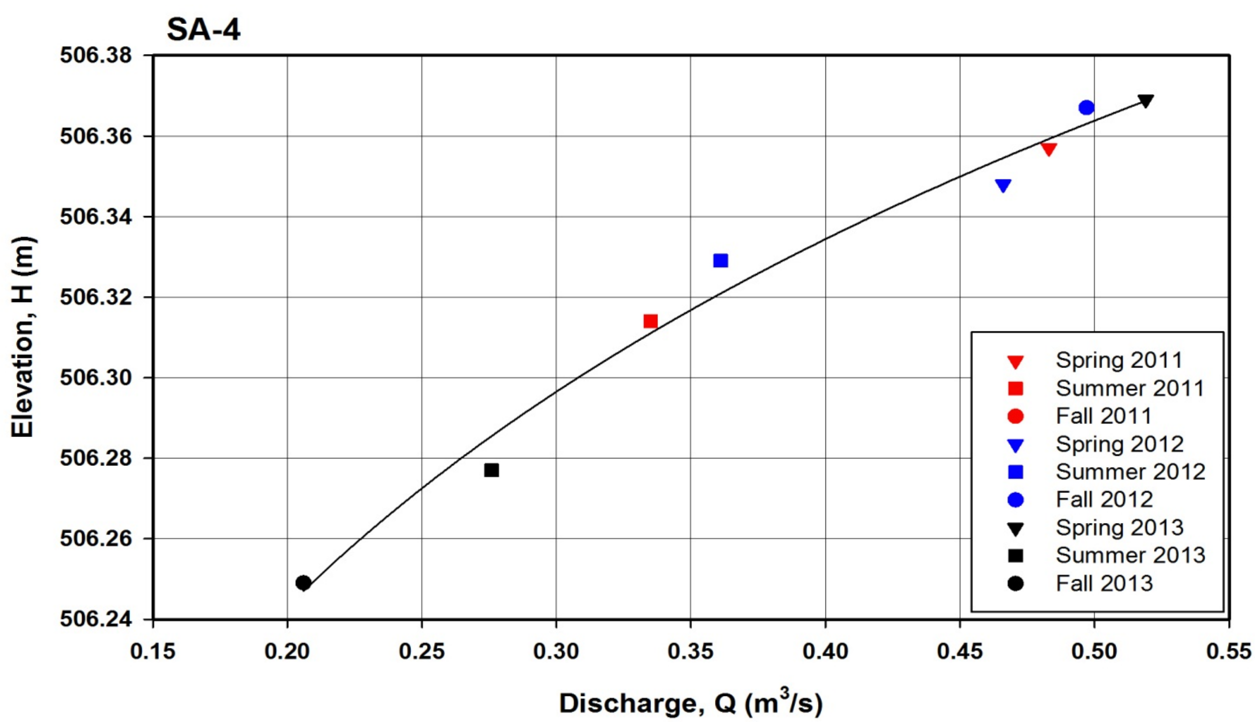

Figure C4: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-4.

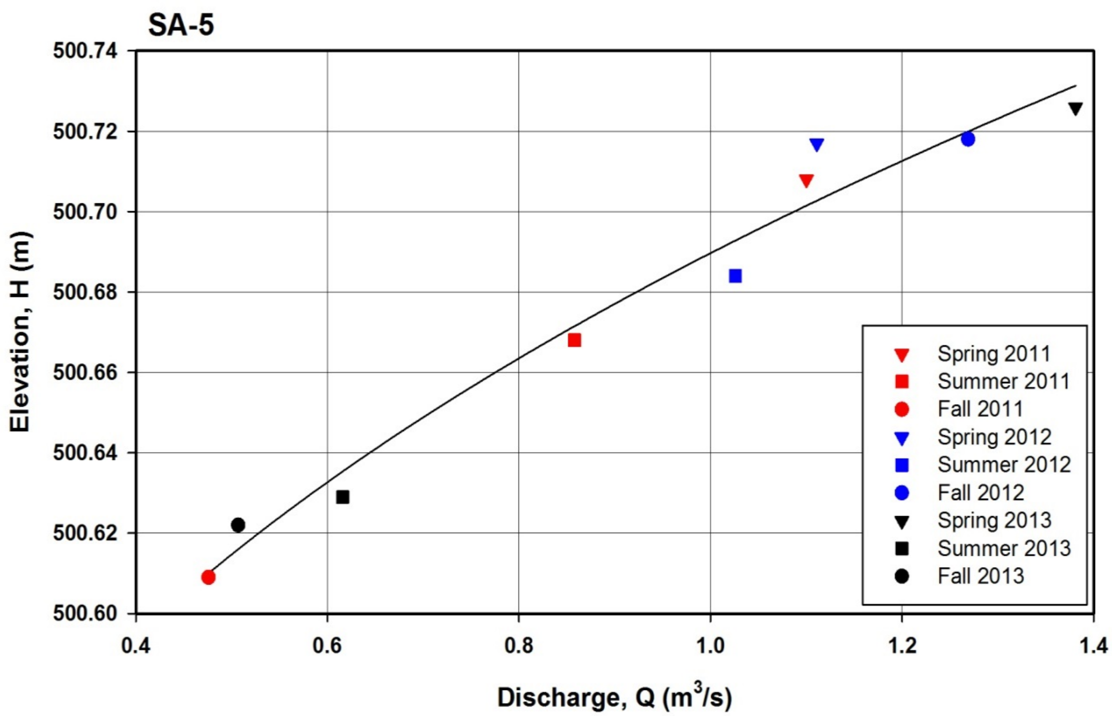

Figure C5: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-5.

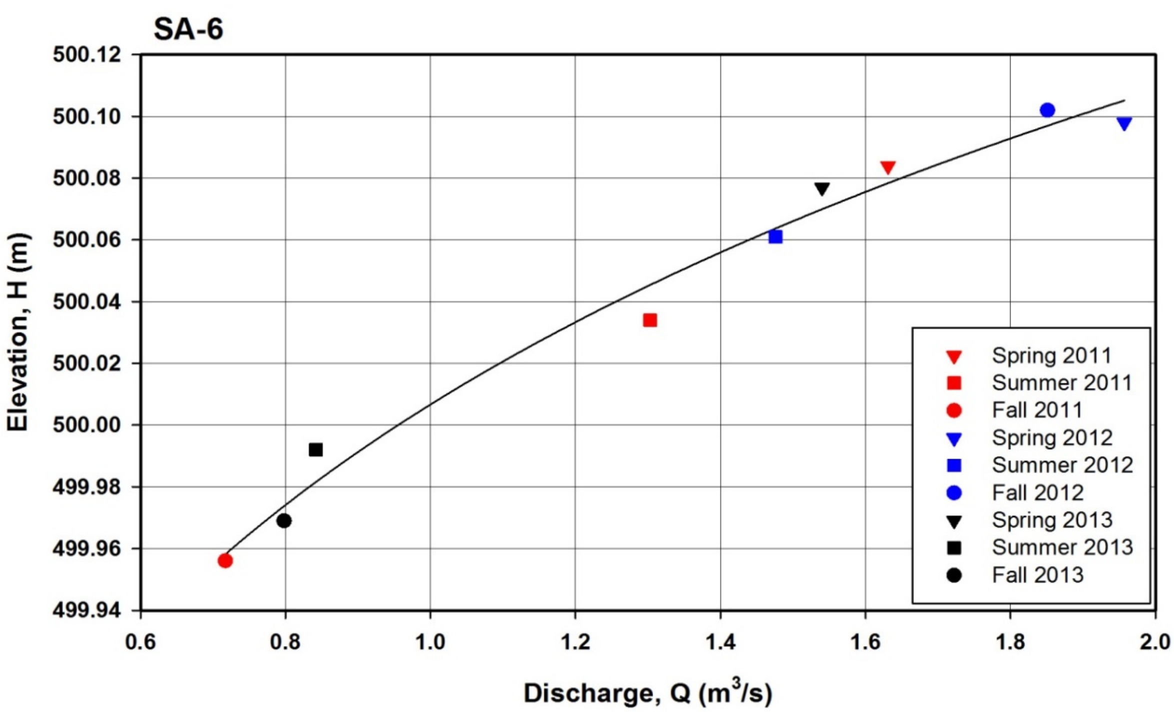

Figure C6: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SA-6.

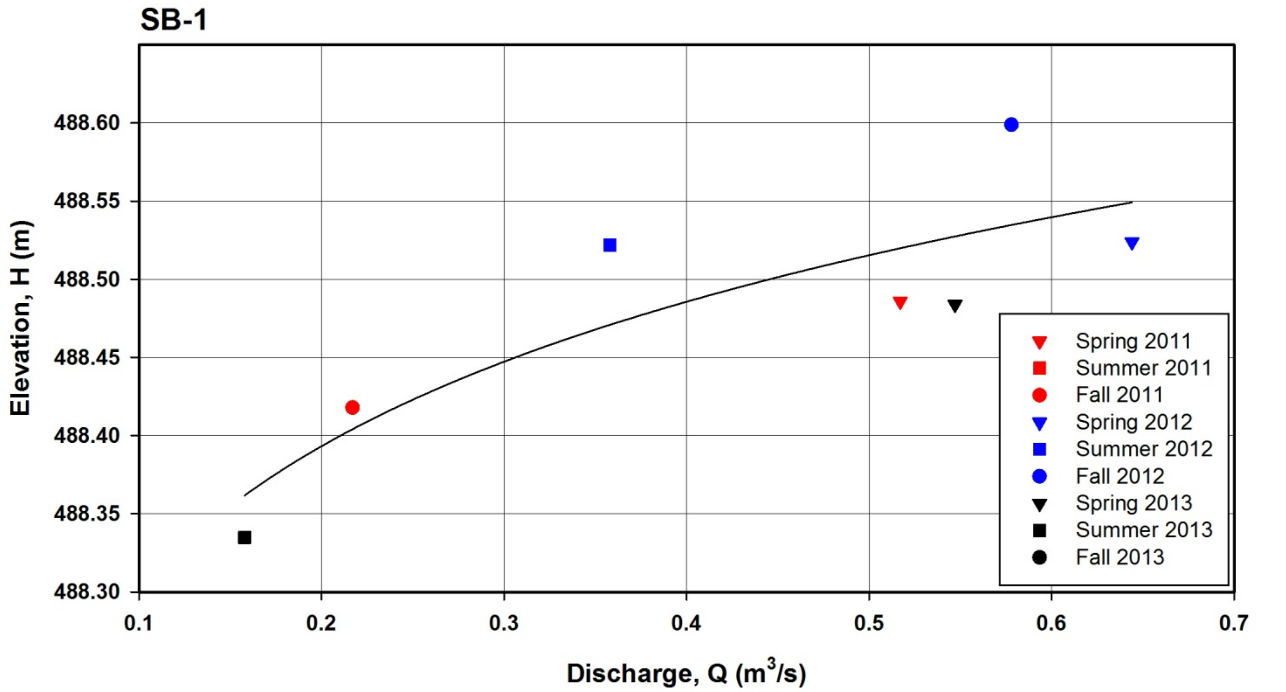

Figure C7: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SB-1.

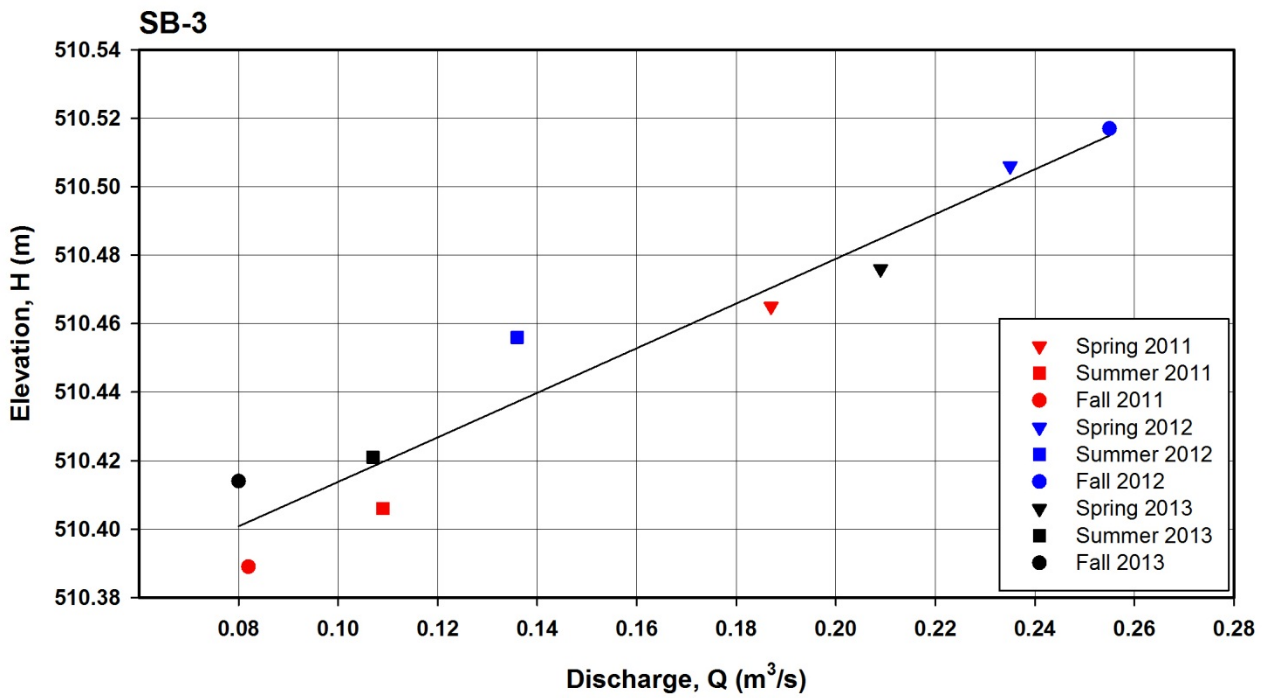

Figure C8: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SB-3.

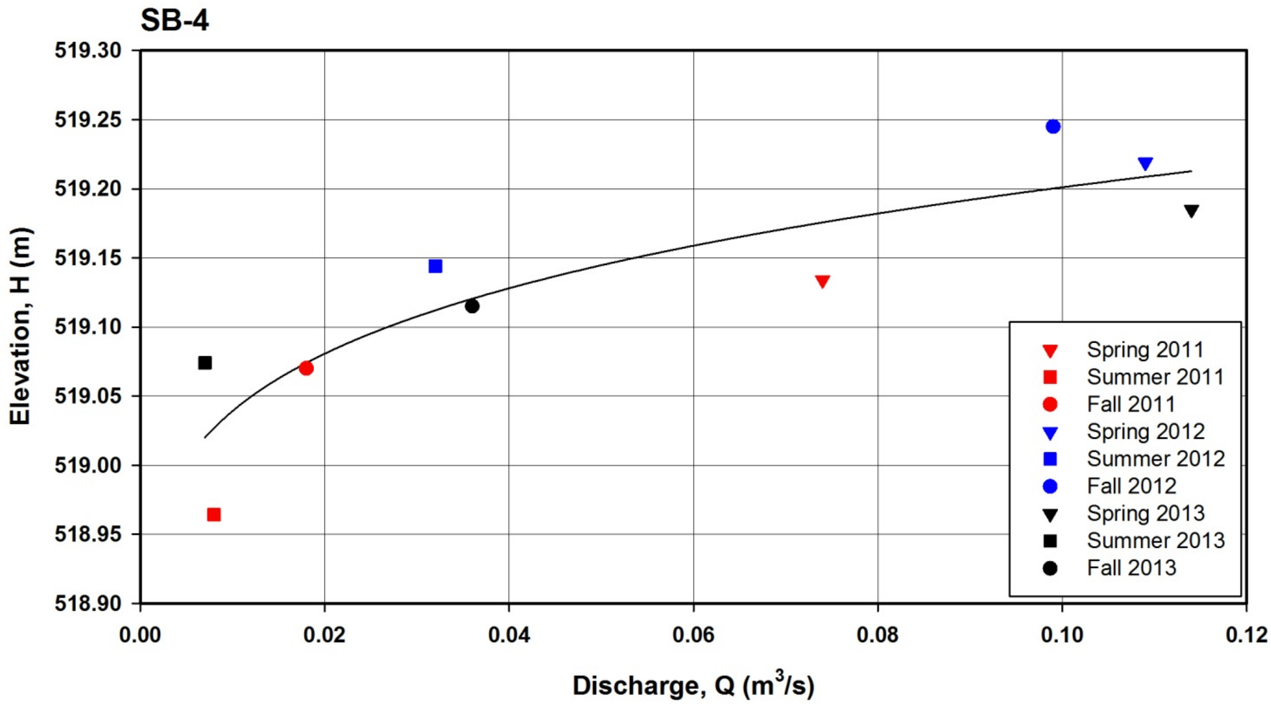

Figure C9: Relationship between Water Surface Elevation, H (m), and Discharge, Q (m^3/s), at Streamflow Station SB-4.

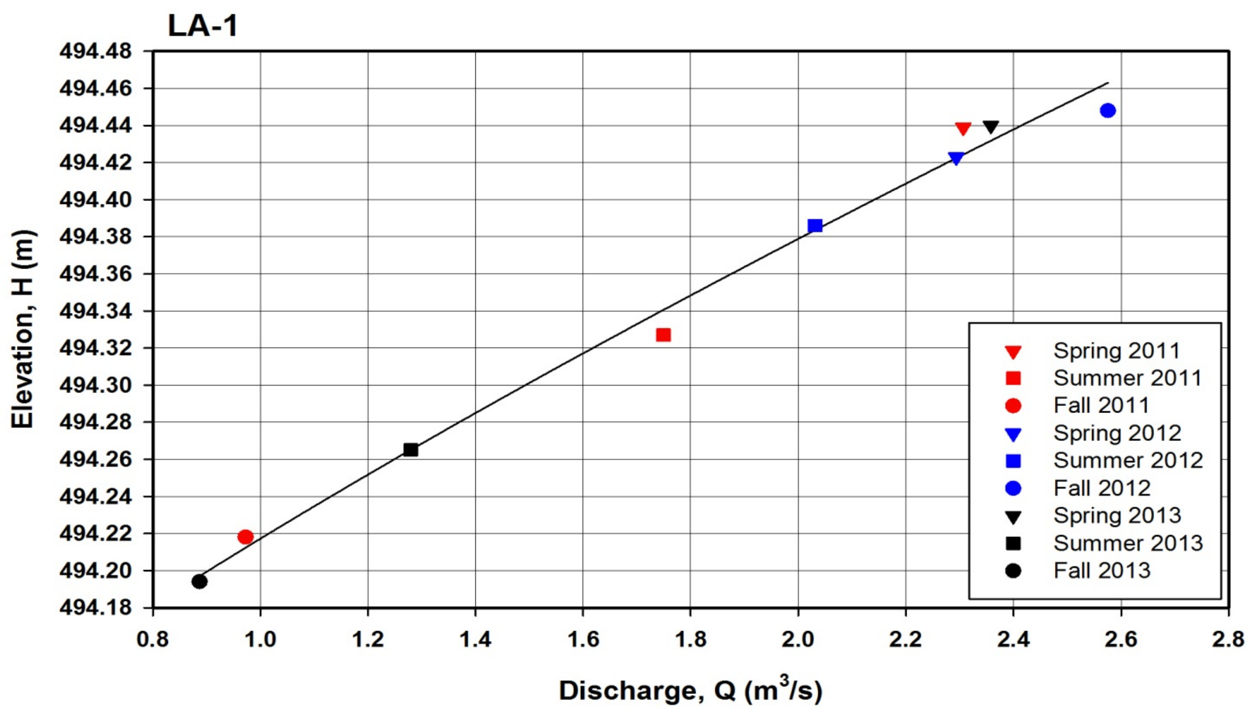

Figure C10: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m^3/s), at Lake Level Station LA-1.

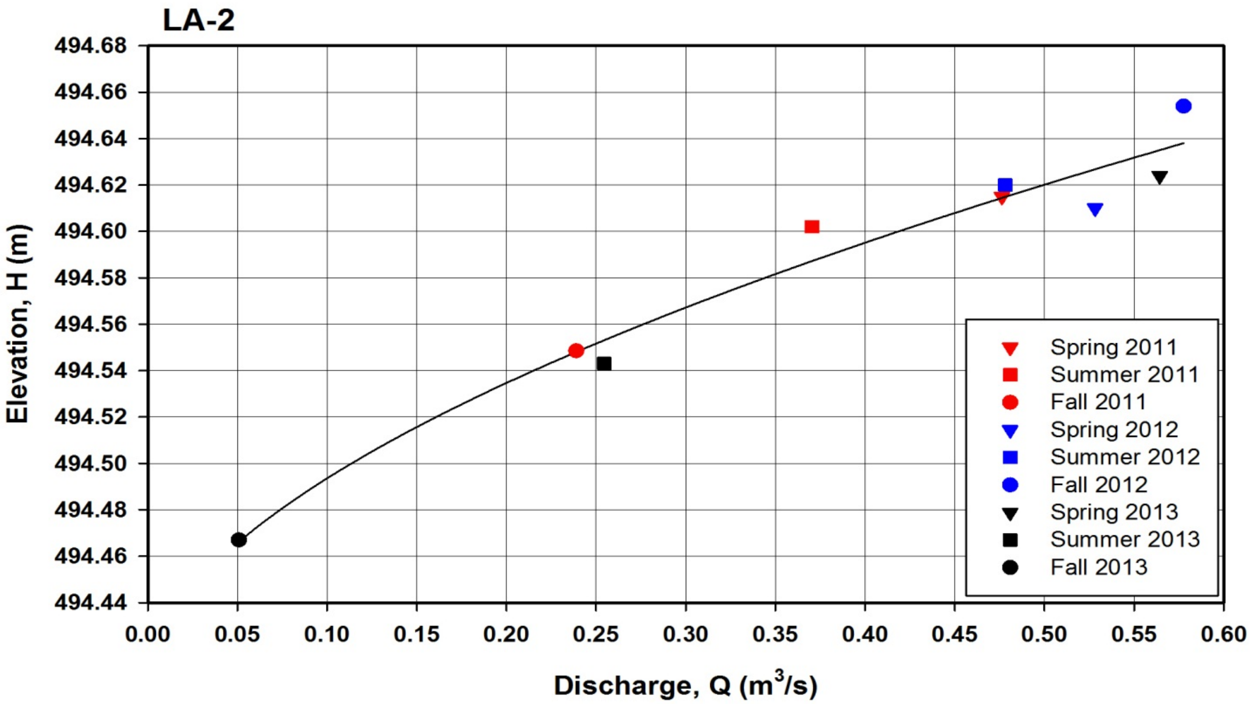

Figure C11: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m^3/s), at Lake Level Station LA-2.

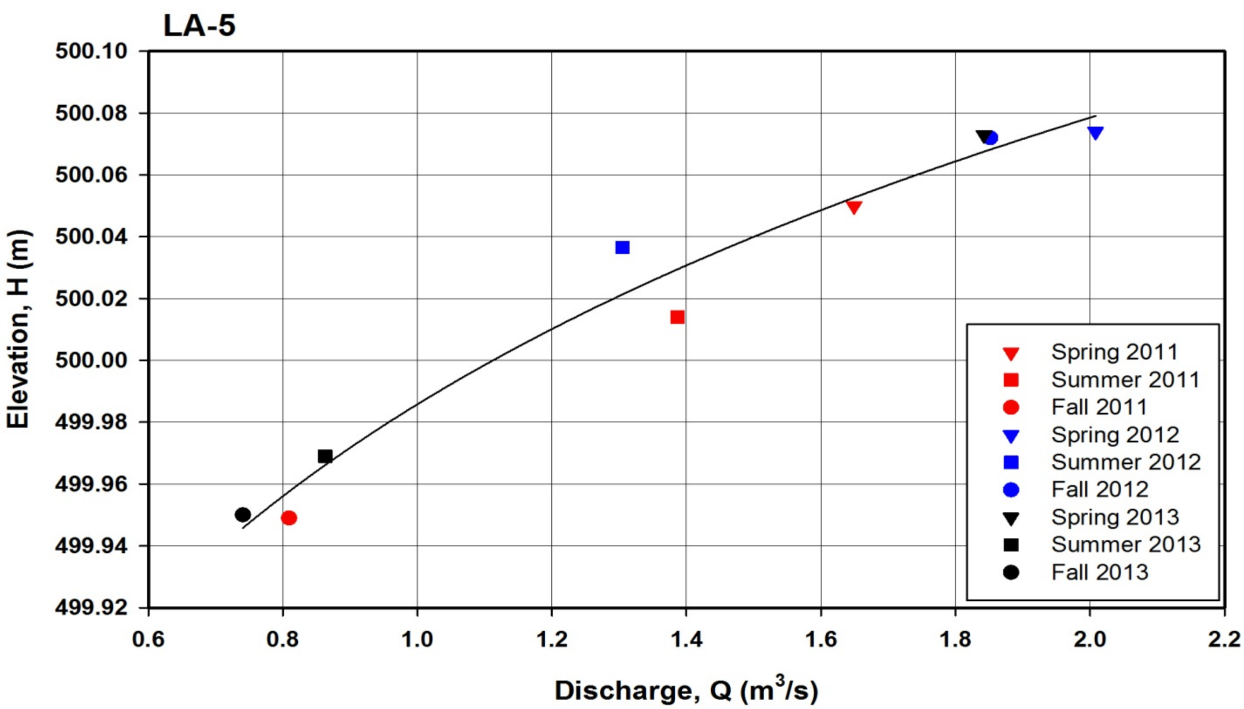

Figure C12: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m^3/s), at Lake Level Station LA-5.

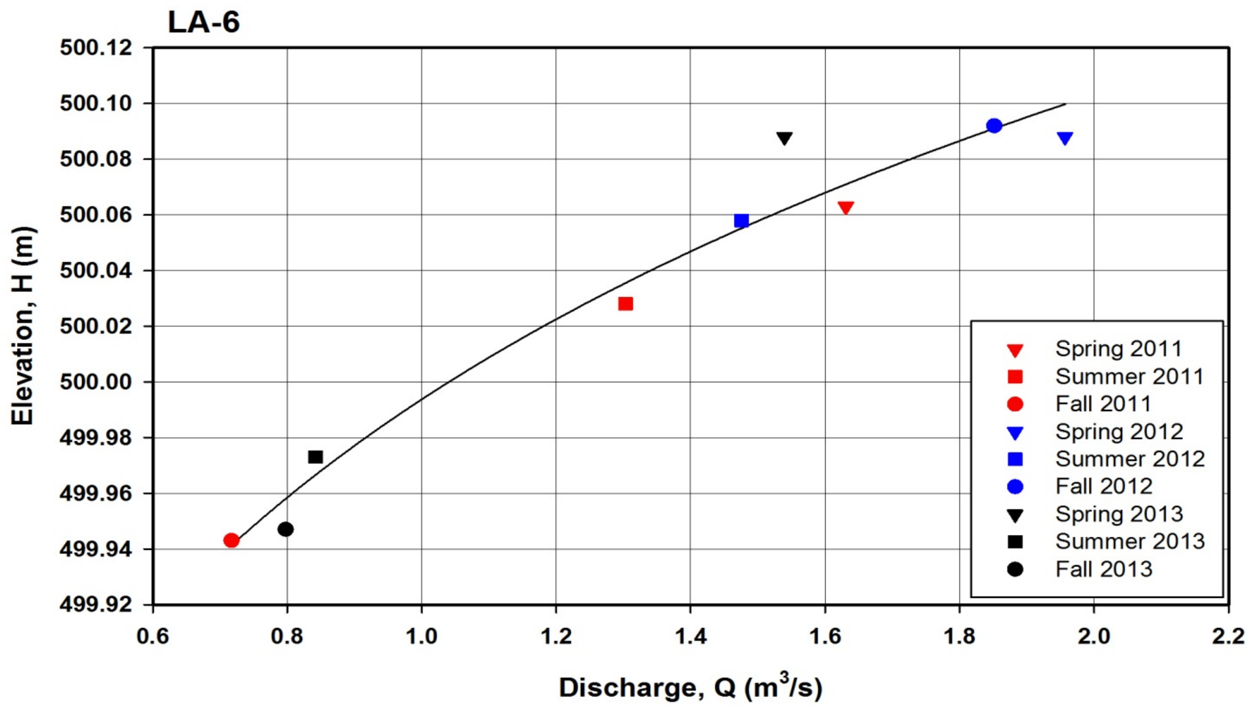

Figure C13: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m^3/s), at Lake Level Station LA-6.

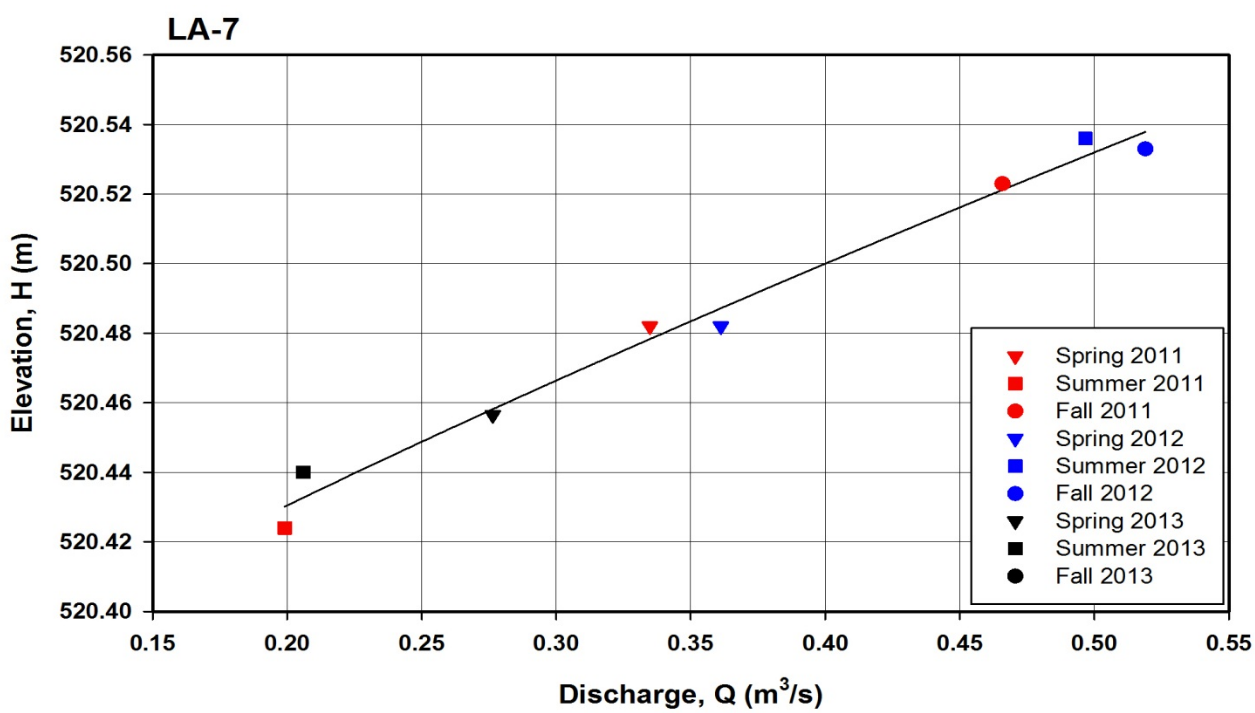

Figure C14: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m^3/s), at Lake Level Station LA-7.

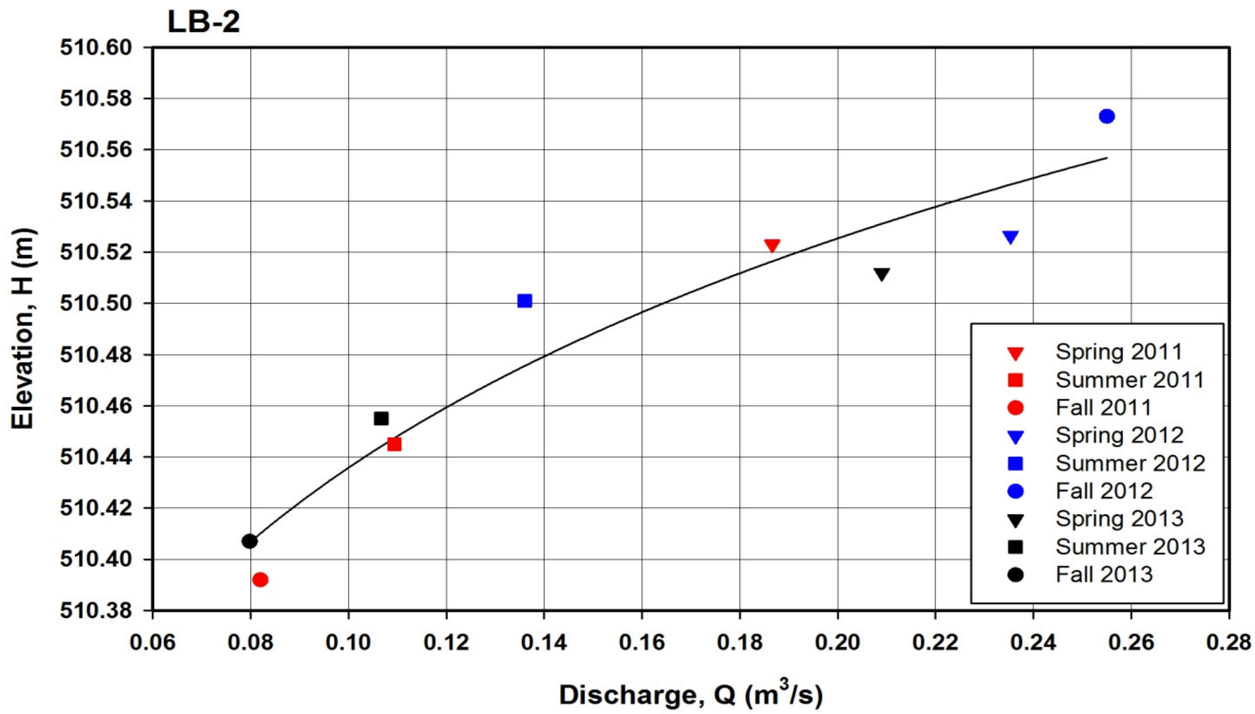

Figure C15: Relationship between Water Surface Elevation, H (m), and Outflow Discharge, Q (m³/s), at Lake Level Station LB-2.

Table C1: Open Water Stage-Discharge Equations

Site	Equation	R^2	Maximum Q	Minimum Q
SA-1	$H_{SFA1} = 492.3288 + 0.2358\ Q_{SA-1}^{0..5647}$	0.98	2.575	0.887
SA-2	$H_{SFA2} = 496.5236 + 0.1481 Q_{SA-2}^{0.5463}$	0.96	2.030	0.741
SA-3	$H_{SFA3} = 494.2166 + 0.4758\ Q_{SA-3}^{0.9914}$	0.99	0.578	0.051
SA-4	$H_{SFA4} = 463.0674 + 43.3880\ Q_{SA-4}^{0.0030}$	0.98	0.519	0.206
SA-5	$H_{SFA5} = 500.3430 + 0.3466\ Q_{SA-5}^{0.3517}$	0.97	1.381	0.476
SA-6	$H_{SFA6} = 487.0848 + 12.9219\ Q_{SA-6}^{0.0113}$	0.98	1.957	0.717
SB-1	$H_{SFB1} = 200.2805 + 288.3274\ Q_{SB-1}^{0.0005}$	0.74	0.644	0.158
SB-3	$H_{SFB3} = 510.3495 + 0.6573\ Q_{SB-3}^{1.0096}$	0.94	0.255	0.080
SB-4	$H_{SFB4} = 518.7461 + 0.7063\ Q_{SB-4}^{0.1911}$	0.79	0.114	0.007
LA-1	$H_{LLA1} = 493.9888 + 0.2284\ Q_{SA-1}^{0.7723}$	0.99	2.575	0.887
LA-2	$H_{LLA2} = 494.4063 + 0.3146\ Q_{SA-3}^{0.5570}$	0.96	0.578	0.051
LA-5	$H_{LLA5} = 483.1565 + 16.8293\ Q_{SA-2}^{0.0079}$	0.97	2.008	0.741
LA-6	$H_{LLA6} = 239.5643 + 260.4294\ Q_{SA-6}^{0.0006}$	0.98	1.957	0.717
LA-7	$H_{LLA7} = 520.3372 + 0.3401\ Q_{SA-4}^{0.0309}$	0.99	0.519	0.199
LB-2	$H_{LLB2} = 233.8270 + 276.9066\ Q_{SB-3}^{0.0005}$	0.93	0.255	0.080

* Where Q is discharge in m^3/s and H is water level in metres above mean sea level.

APPENDIX D

Hydrographs for Streamflow Monitoring Stations

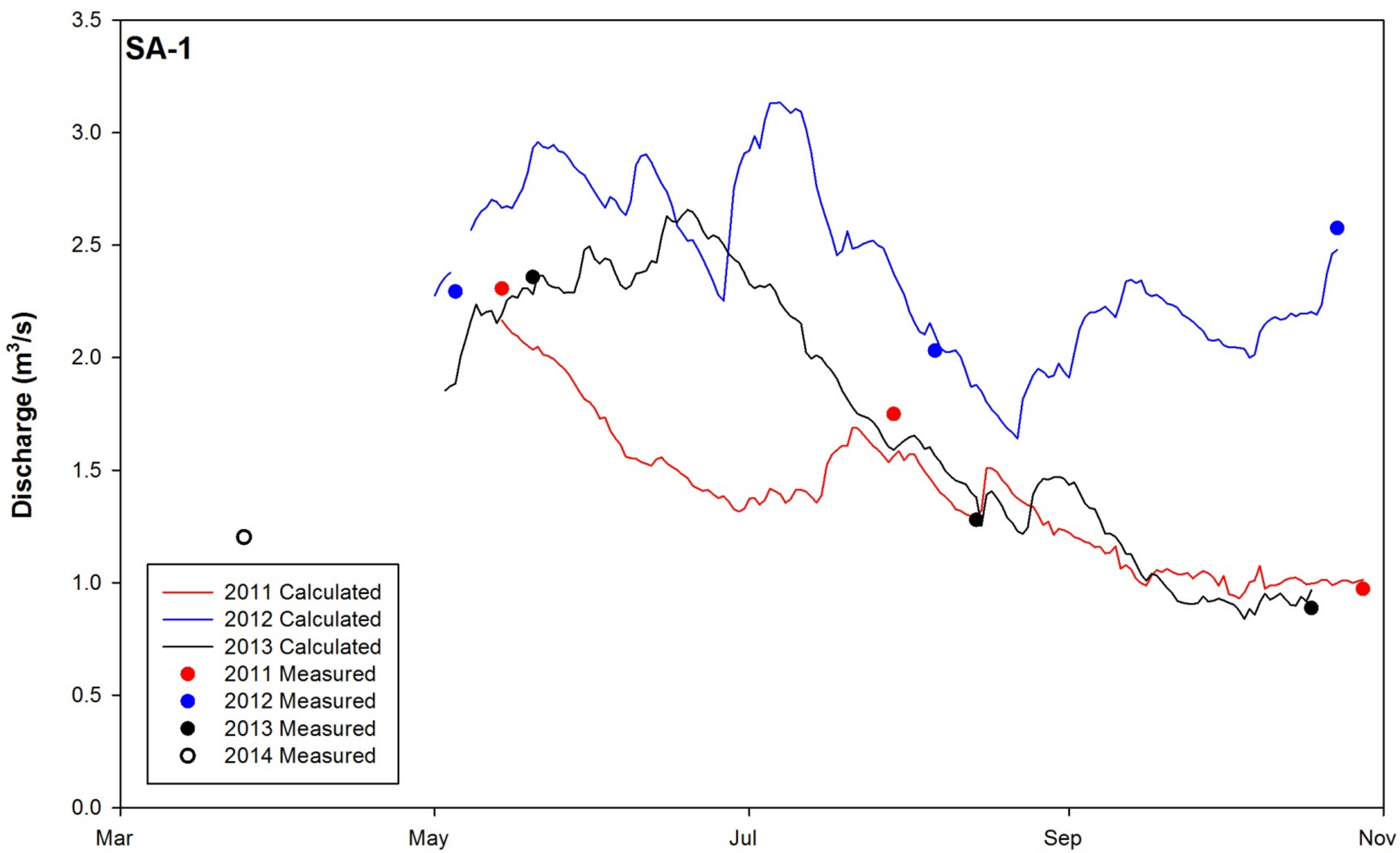

Figure D1: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-1.

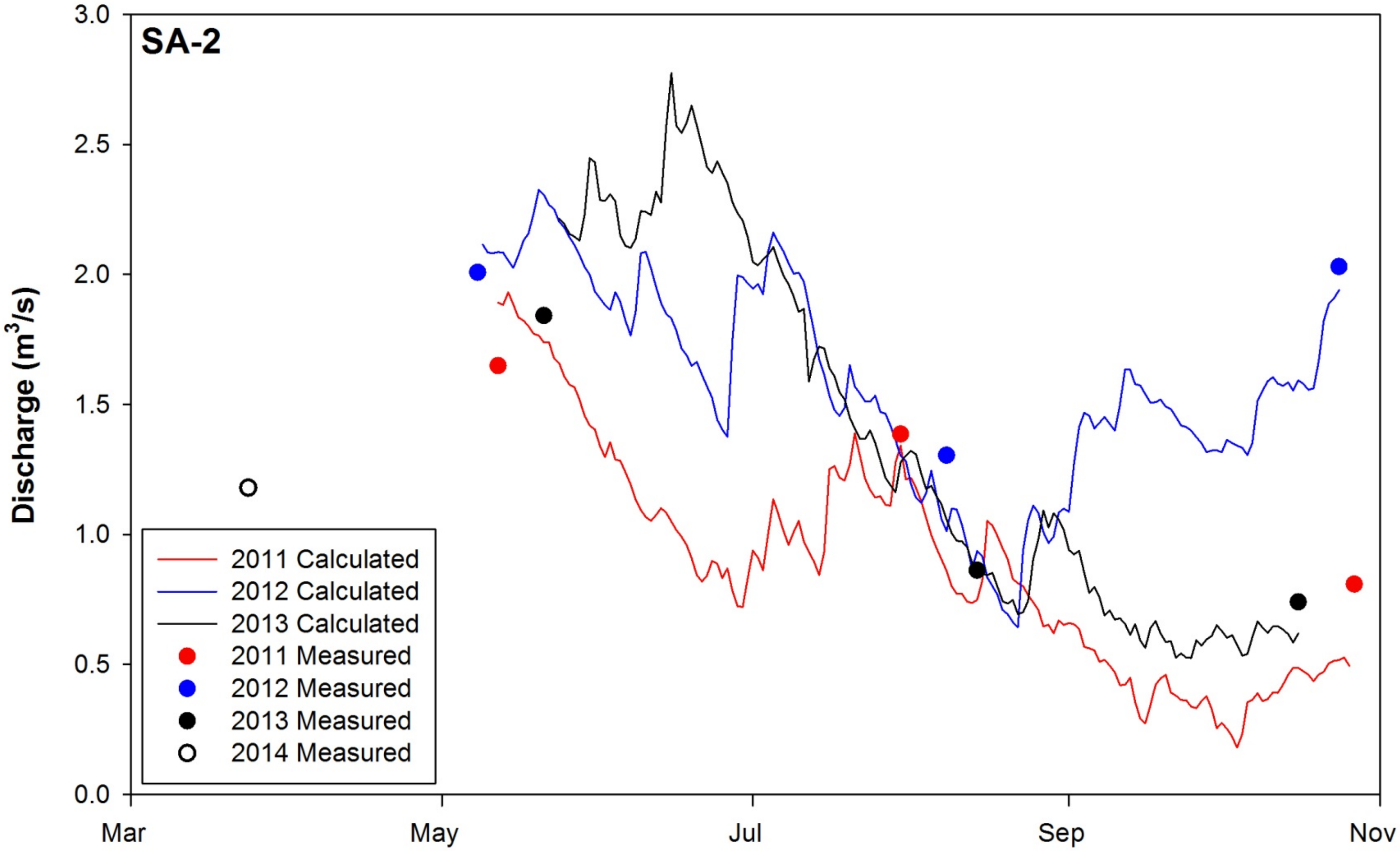

Figure D2: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-2.

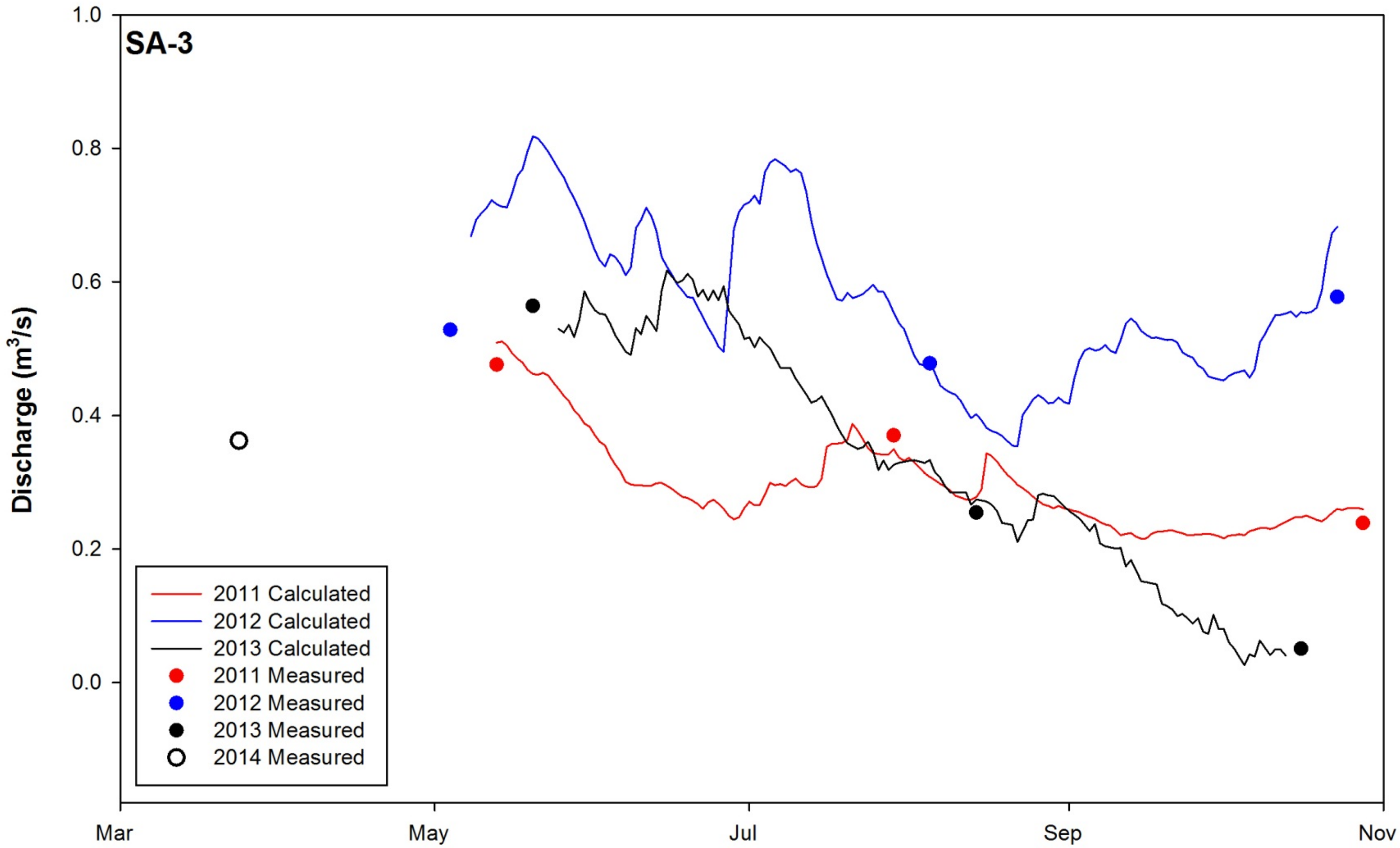

Figure D3: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-3.

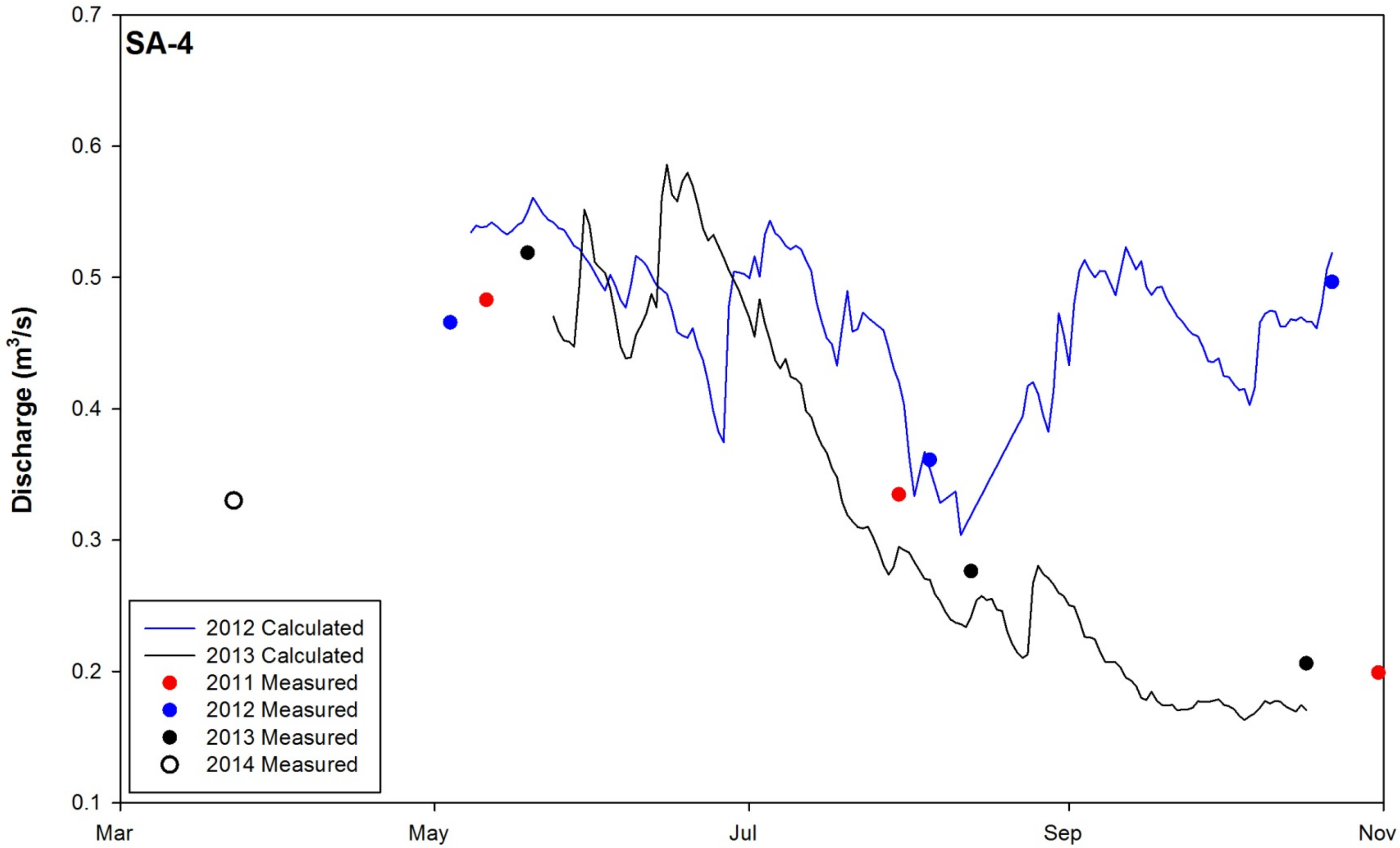

Figure D4: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-4.

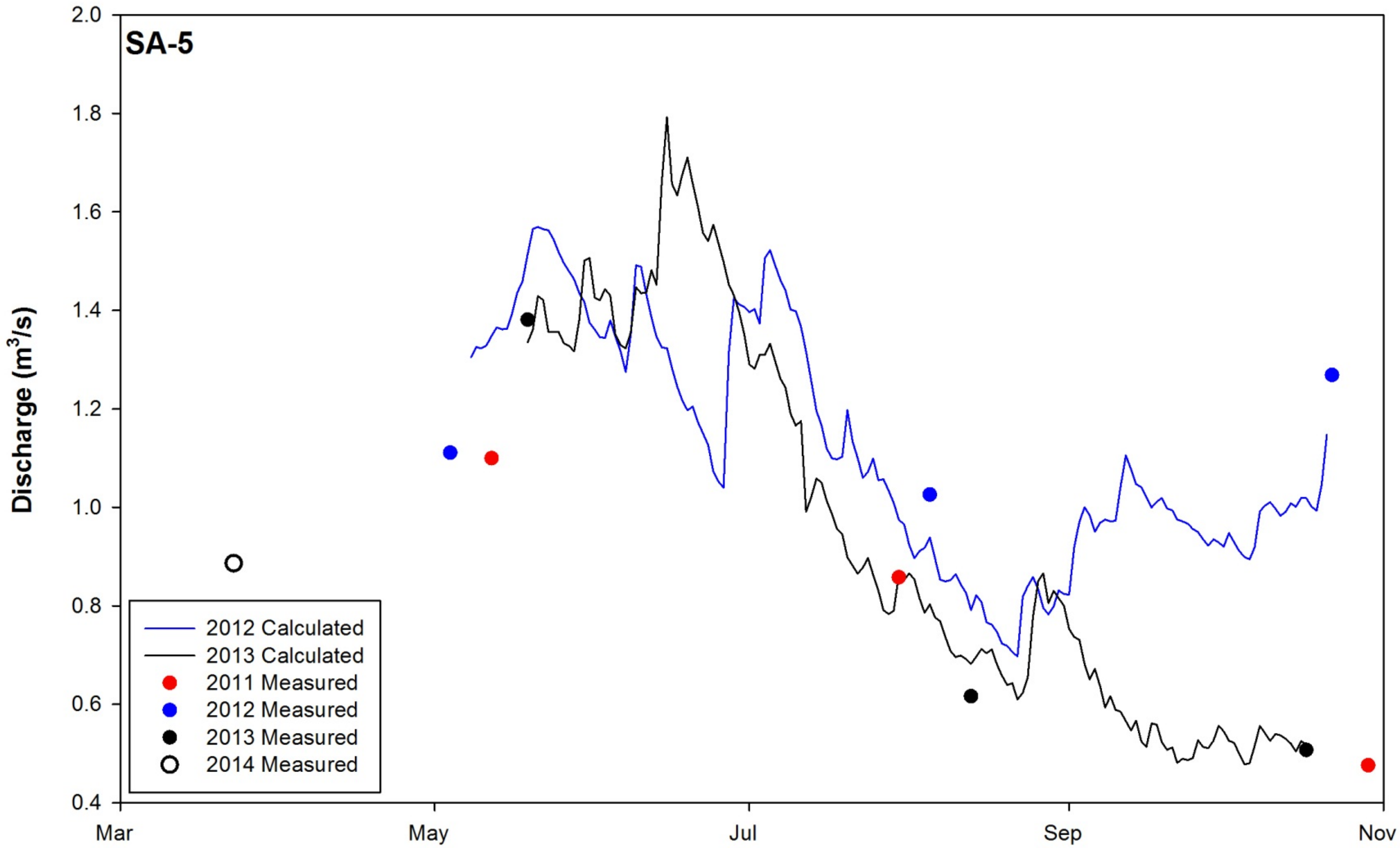

Figure D5: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-5.

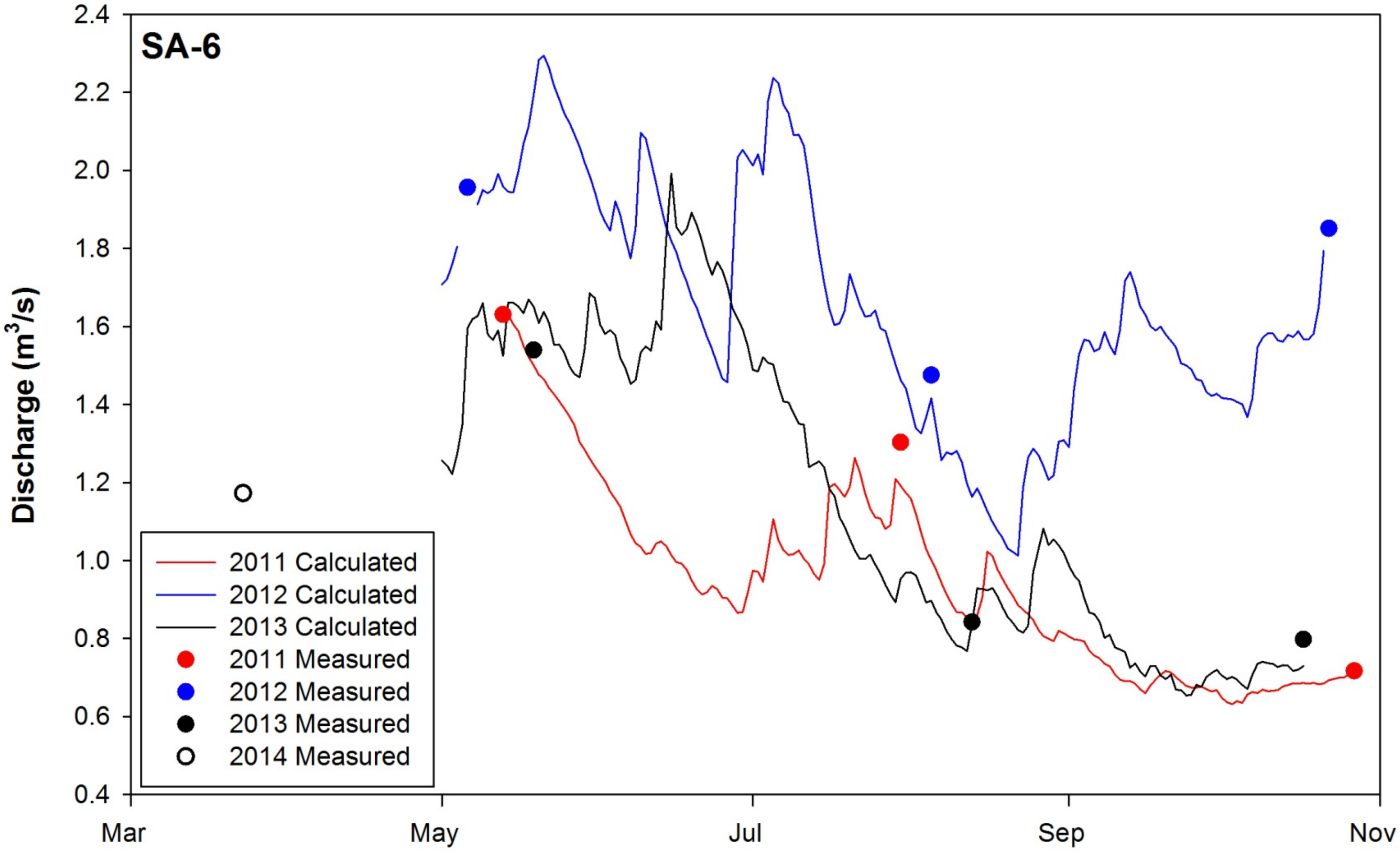

Figure D6: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SA-6.

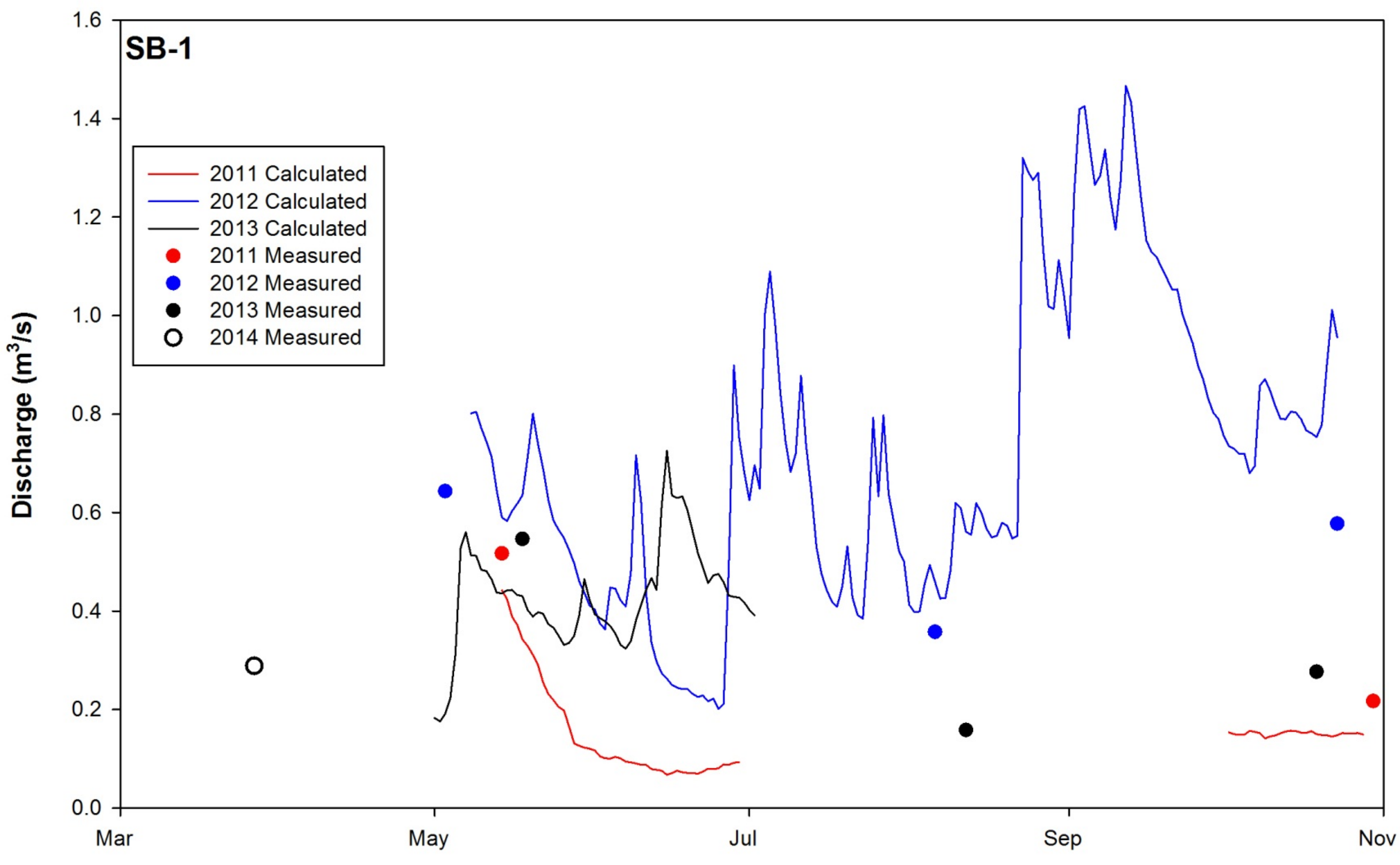

Figure D7: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SB-1.

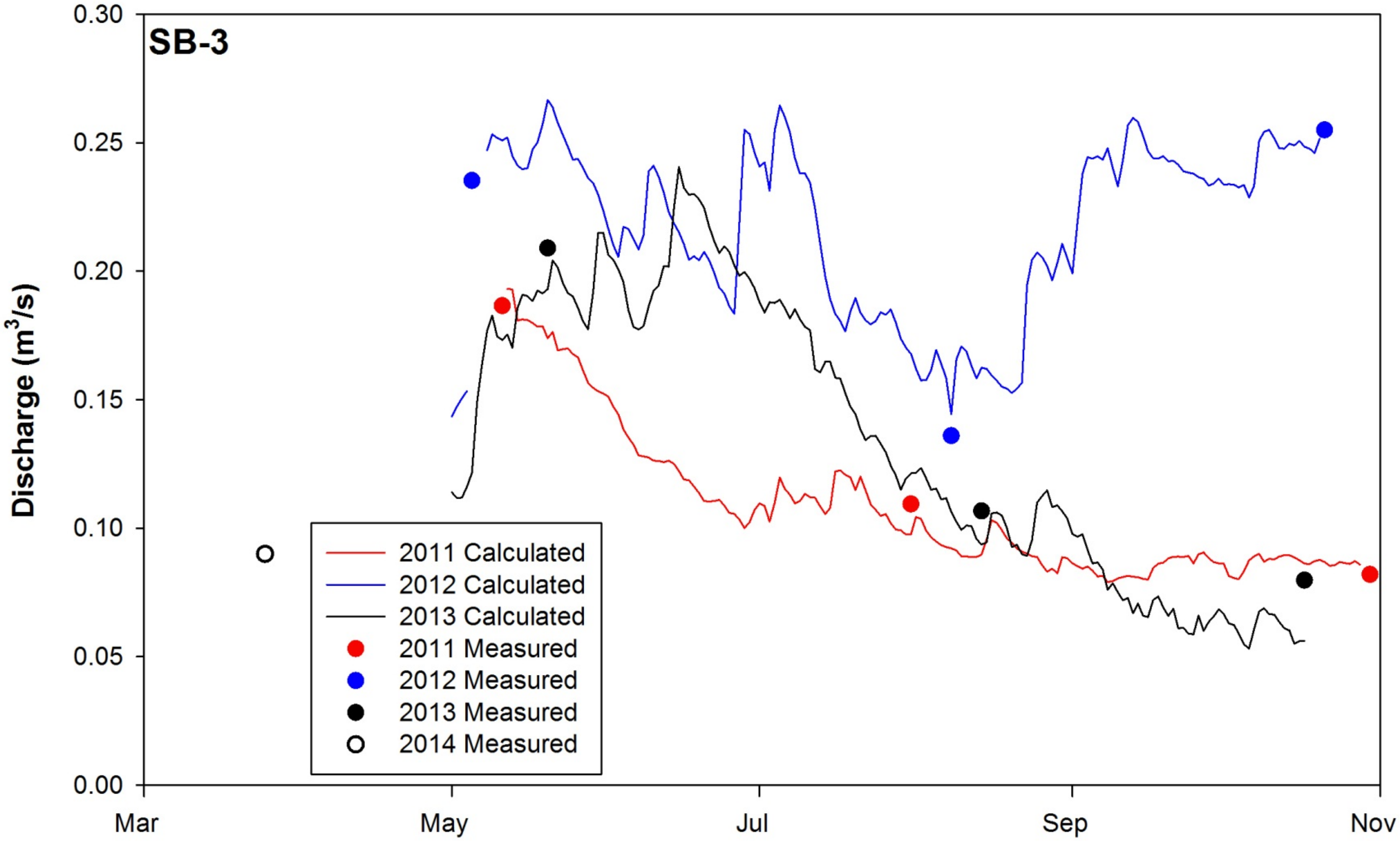

Figure D8: Measured and Calculated Discharge, Q (m^3/s), for Stream Monitoring Station SB-3.

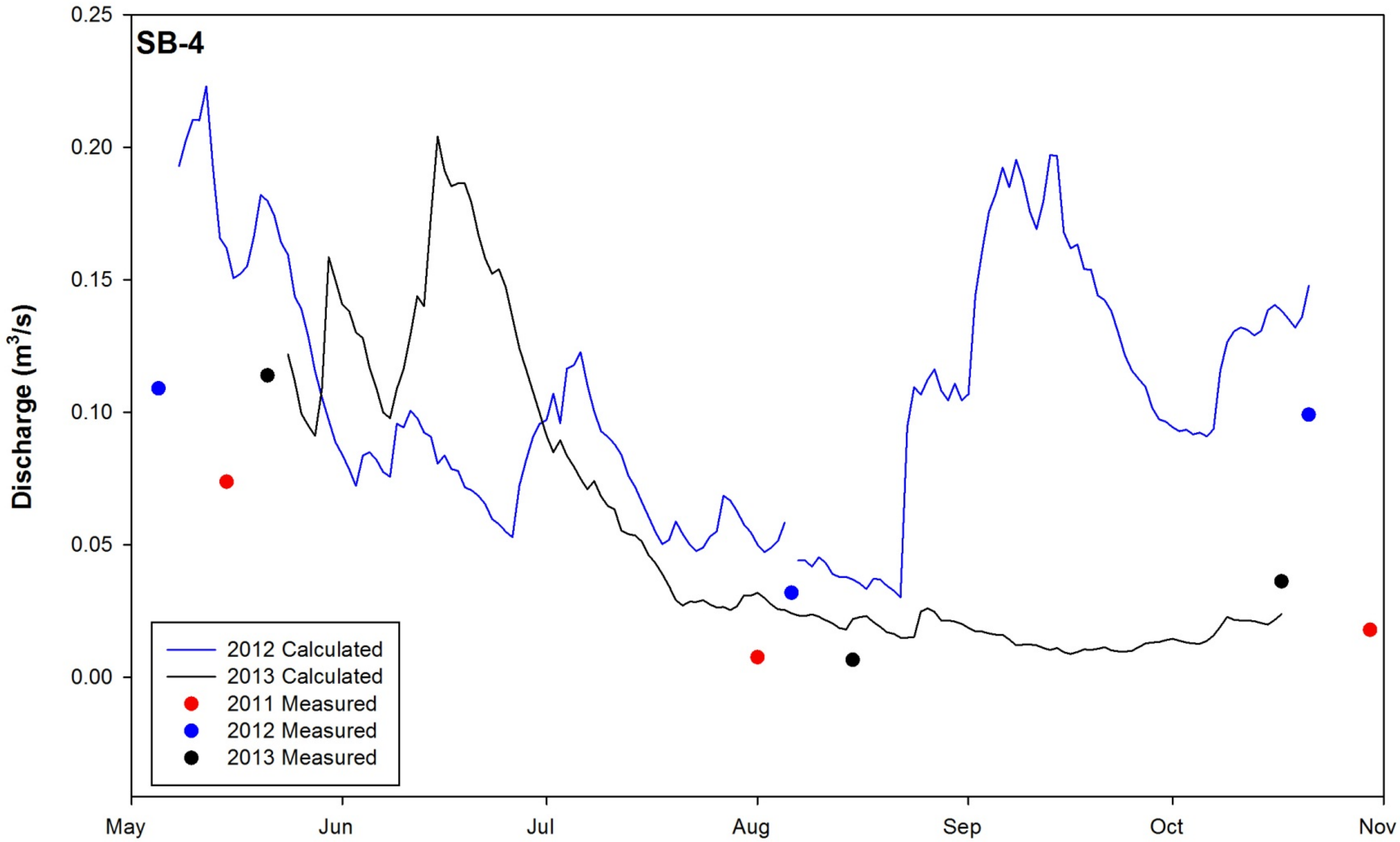

Figure D9: Measured and Calculated Discharge, Q (m^3/s),for Stream Monitoring Station SB-4.

APPENDIX E
Photos

Photo 1: SA-1 looking downstream. Photo taken May 14, 2011.

Photo 2: SA-2 looking downstream. Photo taken July 30, 2011.

Photo 3: SA-3 looking downstream. Photo taken May 13, 2011.

Photo 4: SA-4 looking downstream. Photo taken July 30, 2011.

Photo 5: SA-5 looking downstream. Photo taken July 31, 2011.

Photo 6: SA-6 looking upstream. Photo taken May 13, 2011.

Photo 7: SB-1 looking upstream. Photo taken May 14, 2011.

Photo 8: SB-3 looking upstream. Photo taken July 28, 2011.

Photo 9: SB-4 looking downstream. Photo taken July 31, 2011.

Photo 10: LA-1 looking west. Photo taken July 29, 2011.

Photo 11: LA-2 looking south. Photo taken July 29, 2011.

Photo 12: LA-3 looking northwest. Photo taken May 13, 2011.

Photo 13: LA-4 looking west. Photo taken July 29, 2011.

Photo 14: LA-5 looking south. Photo taken July 20, 2011.

Photo 15: LA-6 looking east. Photo taken July 30, 2011.

Photo 16: LA-7 looking north. Photo taken July 28. 2011.

Photo 17: LB-1 looking west. Photo taken July 31, 2011.

Photo 18: LB-2 looking southwest. Photo taken July 28, 2011.

Photo 19: LAB-1 looking east. Photo taken July 31, 2011.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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solutions@golder.com
www.golder.com

Golder Associates Ltd.
1721 8th Street East
Saskatoon, Saskatchewan, Canada S7H 0T4
Canada
T: +1 (306) 665 7989

Appendix E Wheeler River Lake Level Survey and 2016/2017 Streamflow Monitoring. Calder Engineering Ltd.

TECHNICAL MEMORANDUM

Project: **Wheeler River Lake Level Survey and 2016/2017 Streamflow Monitoring**
Wheeler Rive Mining Exploration, Key Lake, Saskatchewan
Calder Engineering Ltd. Project #16-190

To: **Janeen Tang**
EcoMetrix Incorporated

Date: **July 7th, 2017 revised August 2017**

INTRODUCTION

Provided in this Technical Memorandum is a summary of a lake level survey and streamflow monitoring program implemented in 2016/2017 at the Wheeler River Mine Exploration. The mine exploration is located in the Key Lake area of Saskatchewan. Surface water level elevations were surveyed at a number of lakes (13) and ponds (2) at the Wheeler River Mine Exploration Site. In addition, manual streamflow measurements were taken on 16 watercourses, continuous streamflow monitoring equipment was installed at 8 locations, and streamflow monitoring equipment was retrieved from 2 locations.

The respective pond/lake and streamflow locations are shown on **Figure 1(a and b)**.

LAKE AND POND LEVEL SURVEY

Surface water level elevations were surveyed for thirteen lakes and two ponds associated with the Wheeler River Mine Exploration near Key Lake, Saskatchewan. The water level elevation survey was performed by staff of Calder Engineering Ltd. and Ecometrix Incorporated between September 11 and September 22, 2016. Where possible, surface water elevations were referenced to geodetic benchmarks established by Golder Associates. New locations (LA8, LA9, PA2 and PA3) were initially referenced to temporary benchmarks. Geodetic elevations were assigned to the temporary benchmarks in June 2017 in conjunction with establishment of benchmarks by Webb Survey. An iron bar was installed at each of LA8, LA9, PA2 and PA3, and corrected static positions of each bar were determined from NRCAN. A copy of the report from Webb Survey is included as Attachment D.

A description of how the geodetic elevations of the Golder benchmarks were established is available in the 2012 – 2014 Baseline Hydrology Summary Report prepared by Golder Associates.

Summarized in Table 1 are surveyed pond and lake surface water level elevations. The pond and lake locations are shown on **Figure 1(a and b)**.

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TABLE 1
LAKE AND POND SURFACE WATER LEVEL ELEVATIONS

Lake/Pond	Date	Water Level Elevation (m)
LB1	September 11, 2016	503.66
LB2	September 11, 2016	510.54
LB3 (Williams Lake)	September 11, 2016	518.57
LAB1 (Russel Lake)	September 22, 2016	488.26
LA1	September 16, 2016	494.39
LA2	September 13, 2016	494.58
LA3	September 18, 2016	494.57
LA4	September 13, 2016	498.62
LA5	September 12, 2016	500.06
LA6	September 12, 2016	500.07
LA7 (Kratchowsky Lake)	September 12, 2016	520.53
	May 30, 2017	520.53
LA8	September 13, 2016	520.86
	June 1, 2017	520.80
LA9	September 13, 2016	514.25
	May 31, 2017	514.28
PA2	September 15, 2016	510.46
PA3	September 15, 2016	517.36

Note:
1. Units: m – metres.
2. Water level elevations are referenced to benchmarks with geodetic elevations established by Golder Associates, except for LA8, LA9, PA2 and PA3 which are referenced to geodetic elevations established as part of this report.
3. Water level elevations based on survey conducted by Calder Engineering Ltd. and Ecometrix Incorporated

Calder Engineering Ltd.

STREAMFLOW MONITORING

Stream Descriptions

Provided below are descriptions of each stream. Photographs are provided in **Attachment A**.

SA1

SA1 is located close to the outlet of Drainage Area A at Russel Lake. The stream bottom is comprised of boulders, cobble, gravel and sand. It is our understanding that a logger was left at this location; however, this logger was not located during the site visit and is presumed to be lost. The logger retrieved from SB1 was installed in a low gradient section immediately upstream of a high gradient section. SA1 is accessible by road.

SA2

SA2 flows into the northwest end of LA1. The stream at SA2 is generally steep with vertical banks and high velocities. No logger was installed at this location. SA2 is accessible by boat.

SA3

SA3 is shallow wide sandy bottom stream with vertical banks that connects LA2 to LA1. No logger was installed at this location. SA3 is accessible by boat.

SA4

SA4 is located upstream of LA6. The channel bottom is composed primarily of cobbles and boulders. A logger was installed at this location and was located in a pool upstream of a fast high gradient section. The barometric logger was located on the bank at this station. SA4 is accessible by road.

SA5

SA5 is located upstream of LA6. The channel bottom is primarily small boulders and cobbles overlain sand. A logger was installed on a straight run downstream of the removed bridge crossing. SA5 is accessible by road.

SA6

SA6 is a wide sandy bottom stream with vertical banks connecting lakes LA5 and LA6. Flow in the stream is deep and slow. The logger installed by Golder Associates was retrieved and reinstalled at the same location. The stream gauging equipment was located approximately halfway between the two lakes. SA6 is accessible by road.

SA7

SA7 is a narrow marshy stream with vertical banks. SA7 was identified for continuous water level monitoring, however no logger was installed at this location. While the water levels at this stream could be monitored, it is unlikely that a reliable rating curve could be developed for this location to convert levels to flows due to the site conditions. Flow in the stream is slow and deep, with significant undercut banks. The gradient from LA7 is shallow, allowing backwater from the lake to influence stream water levels. SA7 is accessible by boat.

SA8

SA8 is a meandering narrow sandy bottom stream with deep banks. Some areas of the bank were undercut. The monitoring station was installed in a relatively straight faster section immediately upstream of the lake. SA8 is accessible by boat.

SA9

SA9 was initially located at the outlet a small lake downstream of LA8. For access purposes, this station was relocated to the outlet of LA8 which is accessible by an existing ATV road. The stream in this section is shallow and relatively narrow. The stream bottom is comprised mainly of sand, gravel, cobbles. The monitoring station was located in a pool upstream of the road crossing. Stream banks are shallow and the surrounding land is relatively flat. The area has recently been impacted by a forest fire, so this station is at greater risk of trees/debris falling into the flow and impacting water levels. SA9 is accessible by road.

SA10

SA10 is a wide sandy bottom stream with vertical banks flowing into the northwest part of LA9. The water is deep and slow moving. The monitoring station was located in a relatively straight section with wadeable depths at the time of installation. The water depths downstream closer to the lake were too deep to wade at the time of installation. SA10 is accessible by boat.

SA11

SA11 is an additional station added to replace SA7. SA11 is located at the northern most inlet of LA7. The stream bottom is comprised primarily of gravel and cobbles. The stream channel is braided. The monitoring station was located in an unbraided section immediately upstream of the lake. SA11 is accessible by boat.

SB1

SB1 is located close to the outlet of Drainage Area B at Russel Lake. The monitoring station was located immediately upstream of the culverts at the McArthur River haul road. The stream in this area is marshy with a thick organic base. The stream base in the immediate vicinity of the monitoring station has been altered as result of the road crossing and consists sand, gravel and boulders. Signs of beaver activity were observed both upstream and downstream of the monitoring location. The logger installed by Golder Associates was retrieved from this location and redeployed at another station. SB1 is accessible by road.

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SB2

SB2 is located in a second channel immediately west of SB1. The characteristics of SB2 are similar to SB1 – marshy with a thick organic base impacted by the road construction with signs of beaver activity. At the time of the field visit, no flow was observed at this location. It is suspected that it either flows laterally towards SB1 or seeps under the road embankment. SB2 is accessible by road.

SB3

SB3 is located downstream of LB2. The stream bottom is comprised of organics, sand, cobbles and boulders. The banks are nearly vertical. No monitoring equipment was installed or retrieved from this location. SB3 is accessible by road.

SB4

SB4 is located at the southwest inlet of LB3. The stream banks are shallow and poorly defined. It is our understanding that monitoring equipment was left at this location; however the logger was not found and is assumed to be lost. The stream bottom is primarily boulders and large cobbles. SB4 is accessible by boat.

SB5

SB5 is located at the outlet of LB3. Gauging was conducted in a relatively straight section downstream of the camp road crossing and upstream of a low gradient pool and braid. The stream bottom was composed of sand, gravel and cobbles. SB5 is accessible by road.

Streamflow Monitoring Stations

Eight temporary streamflow monitoring stations were installed by Calder at the Wheeler River Mine Exploration. The streamflow monitoring stations were established to obtain information on local watercourse flow characteristics. Summarized in Table 2 and shown on Figure 1 are locations of the eight streamflow monitoring stations.

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TABLE 2
SUMMARY OF STREAMFLOW MONITORING STATION LOCATIONS

Station	Installation Date	Easting	Northing
SA1	September 22, 2016	480368	6371123
SA4	September 10, 2016	476926	6375868
SA5	September 9, 2016	477822	6375737
SA6	September 12, 2016	477863	6374742
SA8	September 15, 2016	471579	6378303
SA9	September 18, 2016	478226	6381589
SA10	September 18, 2016	479003	6380421
SA11	September 19, 2016	473026	6379260

Note:
1. Refer to Figure 1 for location of streamflow monitoring stations.
2. Eastings and northings referenced to the UTM Zone 17 grid and NAD83 datum.

The streamflow monitoring installations each comprised a Solinst Model 3001 LT F15/M5 Levelogger programmed to record water level at 15 minute intervals on a continuous basis. The Solinst Leveloggers were installed at the dates listed in Table 2. Leveloggers were programmed in June 2017 to collect data until the memory is full – around June 2018.

The Solinst Levelogger instrumentation measures absolute pressure and therefore compensation is required for atmospheric pressure fluctuations. Barometric pressure compensation is achieved using an additional device (e.g., Barologger) to measure barometric pressure. A barologger was installed and deployed adjacent the SA4 site. The data collected from the barologger will be used to apply barometric pressure compensation to data collected from the Solinst Levelogger instrumentation.

Streamflow Measurements

Streamflow measurements were conducted at 16 watercourses within the study area. For the sites with streamflow monitoring equipment installed, with enough manual flow measurements they can be used to develop site specific rating curves for each station. Results are shown in Table 3, detailed calculations sheets are provided in **Attachment B**.

Streamflow measurements were undertaken by wading using a portable velocity meter (Marsh-McBirney Model 2000 Flow-mate) and 1 metre staff gauge graduated in 2 millimetre increments. Streamflow measurements were conducted in accordance with ASTM Standard D 3868 – Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method, whereby flow velocity is measured at the 20% and 80% depth increments when water depths are greater than 1.0 meter, and at the 60% depth increment if water depth is less than 1.0 meter.

With respect to streamflow measurements, typically, a minimum of 10 segments across the stream were used to measure flow depth and flow velocity. Flow velocity was measured at each segment and applicable depth increment four times. Flow was computed by multiplication of measured mean flow velocities by the determined cross-sectional flow area (for each segment) and summing the respective values.

Water elevation was determined by referencing the water surface elevation to benchmarks at each location. Benchmarks for streams SA1, SA2, SA3, SA4, SA5, SA6, SB1, SB3, and SB4 were established by Golder Associates as part of the 2012 – 2014 Baseline Hydrology Summary Report. Elevations at SA8, SA9, SA10, SA11, Kratchowsky Creek were transferred across the lake surface from the lake benchmarks established by Golder Associates. The benchmark elevation at SB5 was established by Webb Survey and Calder Engineering in June 2017. An iron bar was installed at SB5 and the corrected static positions of the bar determined from NRCAN. A copy of the report from Webb Survey is included as Attachment D.

TABLE 3
SUMMARY OF MANUAL STREAMFLOW MEASUREMENTS

Station	Date	Water Elevation (mASL)	Flow (cms)
SA1*	September 17, 2016	492.71	2.34
	May 31, 2017	492.72	2.43
SA2	September 16, 2016	496.46	2.24
SA3	September 16, 2016	494.43	0.44
Kratchowsky Creek Outlet	September 14, 2016	520.30	0.58
SA4*	September 10, 2016	506.35	0.49
	May 30, 2017	506.37	0.58
SA5*	September 9, 2016	500.90	1.27
	September 21, 2016	500.91	1.58
	May 30, 2017	500.92	1.95
SA6*	September 11, 2016	500.07	1.98
	May 31, 2017	500.08	1.77
SA7	September 15, 2016	No BM set	0.04
SA8*	September 15, 2016	520.60	0.01
	September 19, 2016	520.62	0.04
	May 30, 2017	520.54	0.04

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SA9*	September 18, 2016	520.52	0.18
	June 1, 2017	520.49	0.16
SA10*	September 18, 2016	514.35	1.55
	May 31, 2017	514.31	1.22
SA11*	September 19, 2016	520.73	0.42
	May 30, 2017	520.71	0.31
SB1	September 17, 2016	488.55	0.64
SB2	September 17, 2016	No measurement taken	
SB3	September 11, 2016	510.47	0.20
SB4	September 11, 2016	519.21	0.12
SB5	September 14, 2016	518.33	0.14

Note:
1. Units: mASL = metres above sea leavel; cms = cubic metres per second
2. Refer to Figure 1 for location of streamflow monitoring stations.
3. Water level elevations are referenced to benchmarks with geodetic elevations established by Golder Associates, except for SA8, SA9, SA10, SA11, and SB5 which are referenced to geodetic elevations established as part of this report.
4. Water level elevations based on survey conducted by Calder Engineering Ltd. and Ecometrix Incorporated
5. * - indicates that continuous monitoring equipment was installed

RATING CURVES

Golder Associates Ltd. (2013) presented rating curves for SA1, SA4, SA5 and SA6. The manual flow measurements taken as part of the 2016-2017 field program were graphed along with the measurements and rating curves by Golder (2013) to review for suitability for use with the new installations.

Based on the data, the new station for SA5 was installed upstream of the Golder location. The stream bed in this area is of consistent width and slope. The rating curve for SA5 was shifted upstream based on the three manual flow measurements taken in 2016 and 2017.

Manual flow measurements taken at SA1, SA4, and SA6 appear to fit into the existing rating curve and the rating curve can be applied to the level data.

For streams SA8, SA9, SA10 and SA11 the manual flow measurements taken to date are not sufficient to develop a rating curve for conversion from level to flow.

Rating curves are presented in **Attachment B**.

CONTINUOUS WATER LEVEL DATA

It is our understanding that loggers installed by Golder in 2013 were left in place at the following locations: SB1, SB4, SA1, and SA6. Leveloggers were located and retrieved at SB1 and SA6 in the Fall of 2016; we were unable to locate equipment at SB4 and SA1. The logger at SA6 was redeployed at SA6 and the logger at SB1 was redeployed at SA1. Available on the instruments were level and temperature data from May 18, 2013 to August 30, 2015.

Recorded data from the leveloggers deployed in the Fall of 2016 at streams SA1, SA4, SA5, SA6, SA8, SA9 and SA10 and the site barologger was retrieved in the Spring of 2017.

Barometric Compensation

Barometric compensation for the 2016-2017 field program was completed using the site barologger with any gaps filled using transformed data from the Key Lake Climate Station (Climate ID = 4063757) at 57°15'23.000" N, 105°37'03.000" W. Barometric compensation for the retrieved 2013 to 2015 data at SB-1 and SA-6 was completed using transformed data from the Key Lake Climate Station.

The Key Lake Climate Station has an hourly barometric pressure record at 57°15'23.000" N, 105°37'03.000" W. The data was linearly interpolated to 15 minute and 30 minute intervals for use the levelogger data. A relationship between the barometric pressure at the site barologger and the Key Lake station was developed using the May 2017 data and applied to the Key Lake Climate Station data for use with the project Levelogger data.

Elevation Data

Calculated water elevation data for each of the locations is presented in **Attachment C**.

Calculated Flow

For stations SA1, SA4, SA6 and SB1 the water elevation data was converted to flow using rating curve relationships developed by Golder (May 2014). The modified rating curve was applied for SA5.

For streams SA8, SA9, SA10 and SA11 the manual flow measurements taken to date are not sufficient to develop a rating curve for conversion from level to flow.

Calculated flow data for each of SA1, SA4, SA5, SA6 and SB1 is presented in **Attachment C**.

Recommendations

- Additional manual flow measurements be taken at new monitoring locations: SA8, SA9, SA10, SA11 to establish a rating curve at each location
- Rating curves established by Golder Associates Ltd. for SA1, SA4, SA5 and SA6 be reviewed for suitability for use with the reinstallations, including additional manual flow measurements.

Yours Sincerely,

CALDER ENGINEERING LTD.

FIGURE 1a: LAKE AND POND LOCATIONS

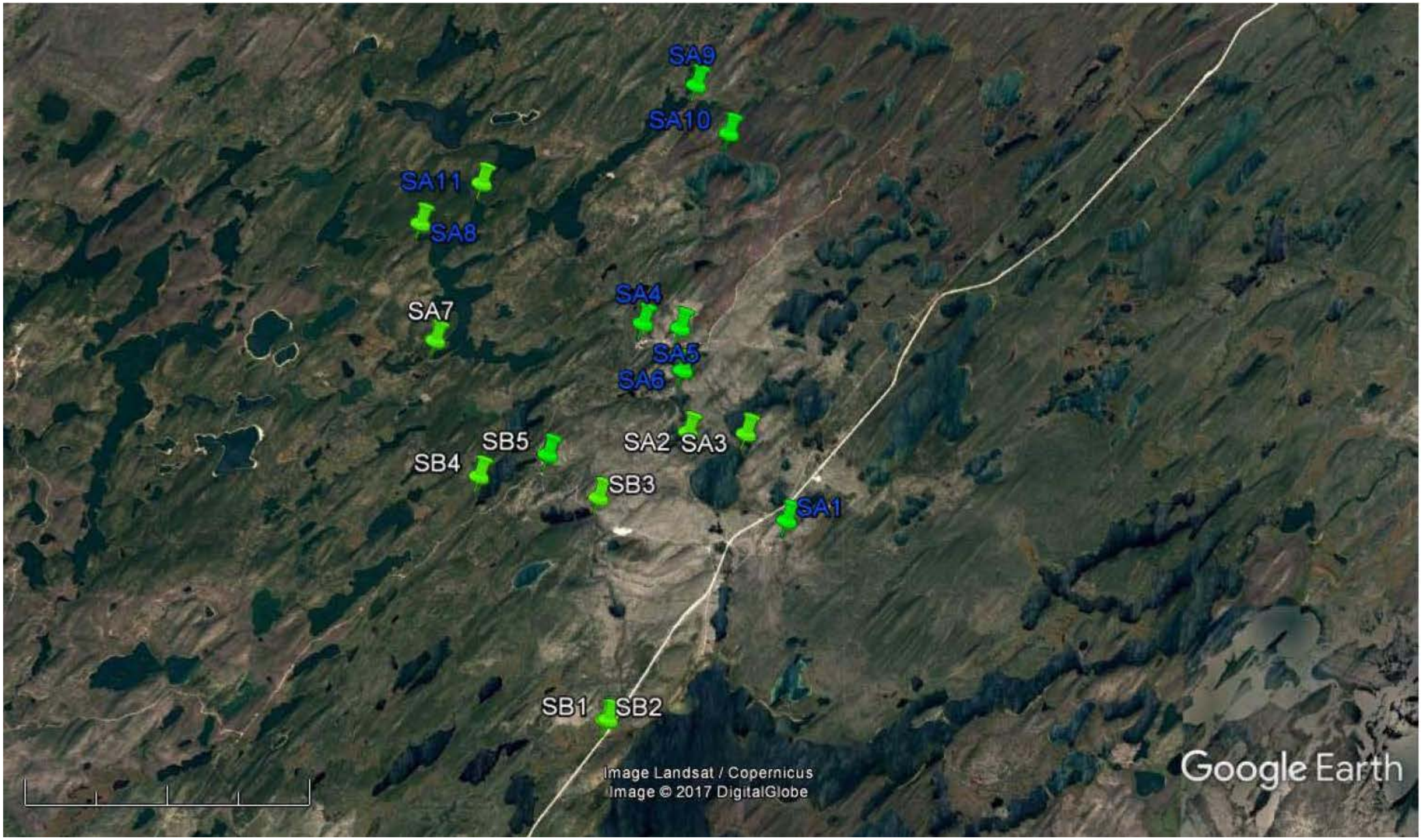


FIGURE 1b: STREAM LOCATIONS

ATTACHMENT A

PHOTOS

SA-1 facing upstream

SA-2 facing upstream

SA-1 facing downstream

SA-2 facing downstream

PHOTOS WHEELER RIVER	Calder Engeering Ltd.	SA1 and SA2	SEPT 2016 SHEET 1/9

SA-3 facing upstream

SA-4 facing upstream

SA-3 facing downstream

SA-4 facing downstream

PHOTOS WHEELER RIVER	Calder Engeering Ltd.	SA3 and SA4	SEPT 2016 SHEET 2/9

SA-5 facing upstream

SA-6 facing upstream

SA-5 facing downstream

SA-6 facing downstream

PHOTOS WHEELER RIVER	Calder Englneering Ltd.	SA5 and SA6	SEPT 2016 SHEET 3/9

SA-7 facing upstream

SA-8 facing upstream

SA-7 facing downstream

SA-8 facing downstream

PHOTOS WHEELER RIVER	Calder Engineering Ltd.	SA7 and SA8	SEPT 2016 SHEET 4/9

SA-9 facing upstream

SA-10 facing upstream

SA-9 facing downstream

SA-10 facing downstream

PHOTOS WHEELER RIVER	Calder Englneering Ltd.	SA9 and SA10	SEPT 2016 SHEET 5/9

SA-11 facing upstream


Kratchkowsky Lake Outlet facing upstream

SA-11 facing downstream

Kratchkowsky Lake Outlet facing downstream

PHOTOS WHEELER RIVER	Calder Englneering Ltd.	SA11 and Kractchowsky Lake Outlet	SEPT 2016 SHEET 6/9

SB-1 facing upstream

SB-2 facing upstream

SB-1 facing downstream

PHOTOS WHEELER RIVER	Calder Englneering Ltd.	SBI end SB2	SEPT 2016 SHEET 7/9

SB-4 facing upstream

SB-3 facing downstream

SB-4 facing downstream

PHOTOS WHEELER RIVER	Calder Engineering Ltd.	SB3 and S84	SEPT 2016 SHEET 8/9

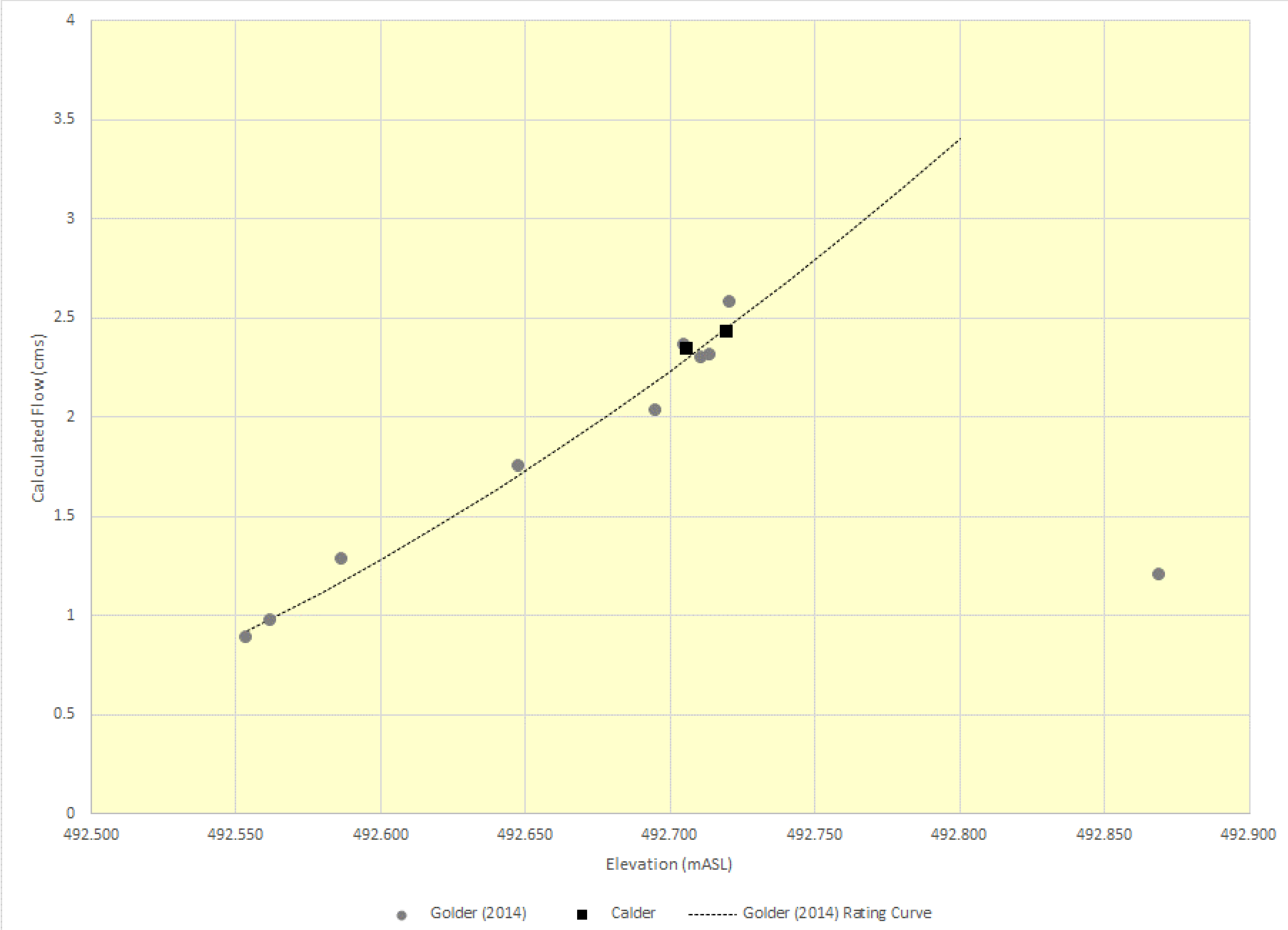
SB-5 facing upstream

SB-5 facing downstream

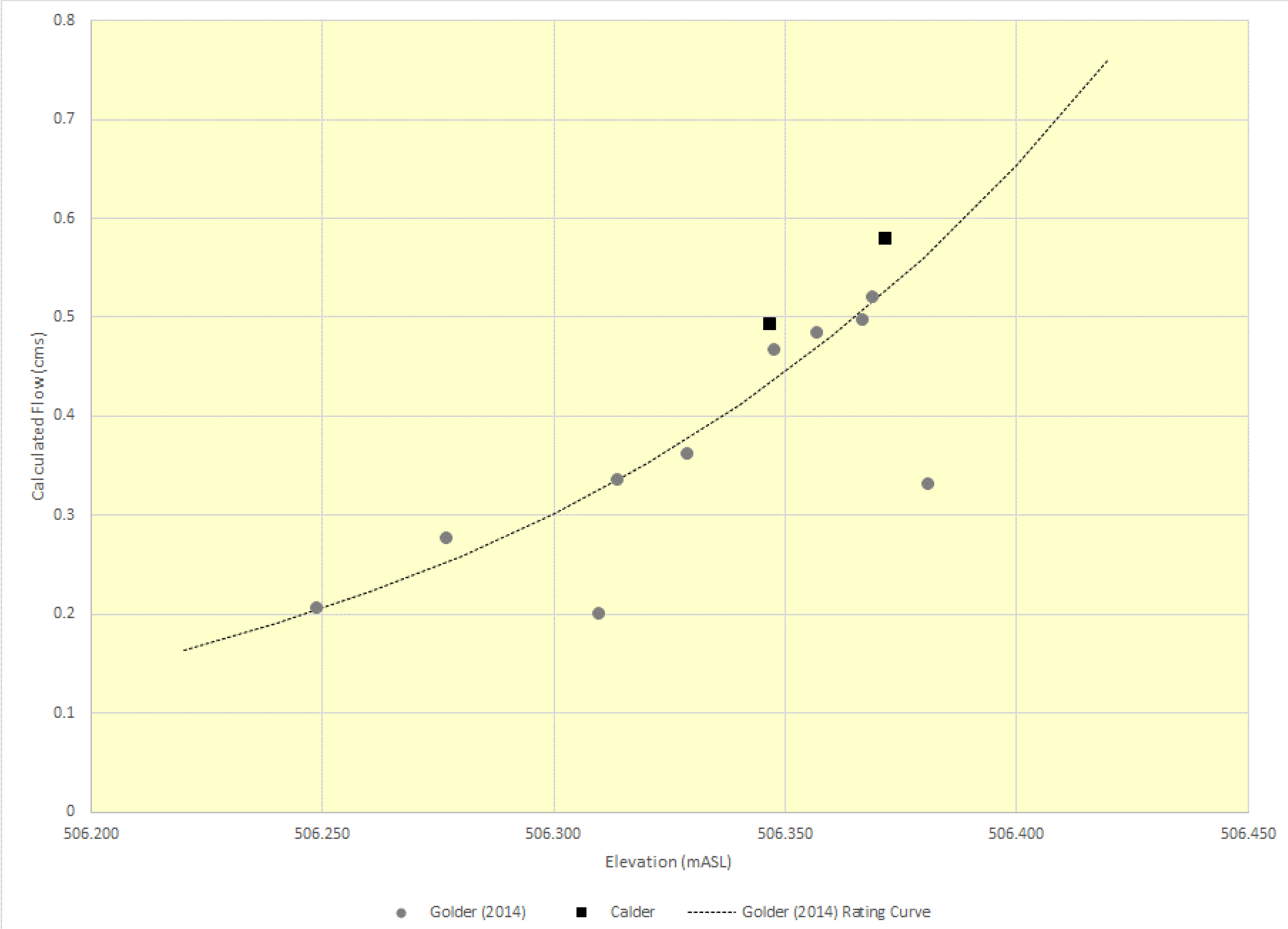
PHOTOS WHEELER RIVER	Calder Englneering Ltd.	SB5	SEPT 2016 SHEET 9/9

ATTACHMENT B

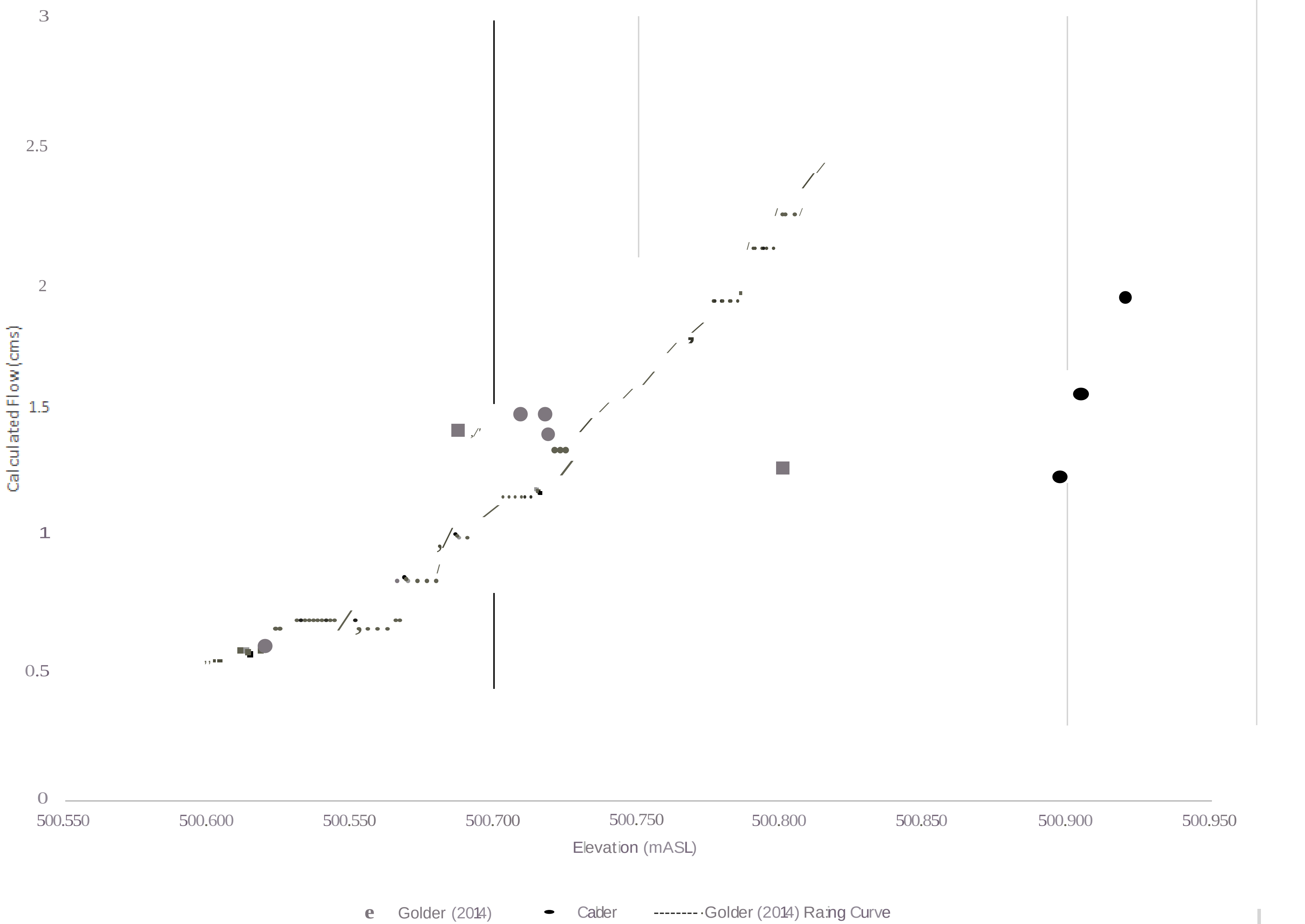
RATING CURVES AND MANUAL FLOW MEASUREMENTS



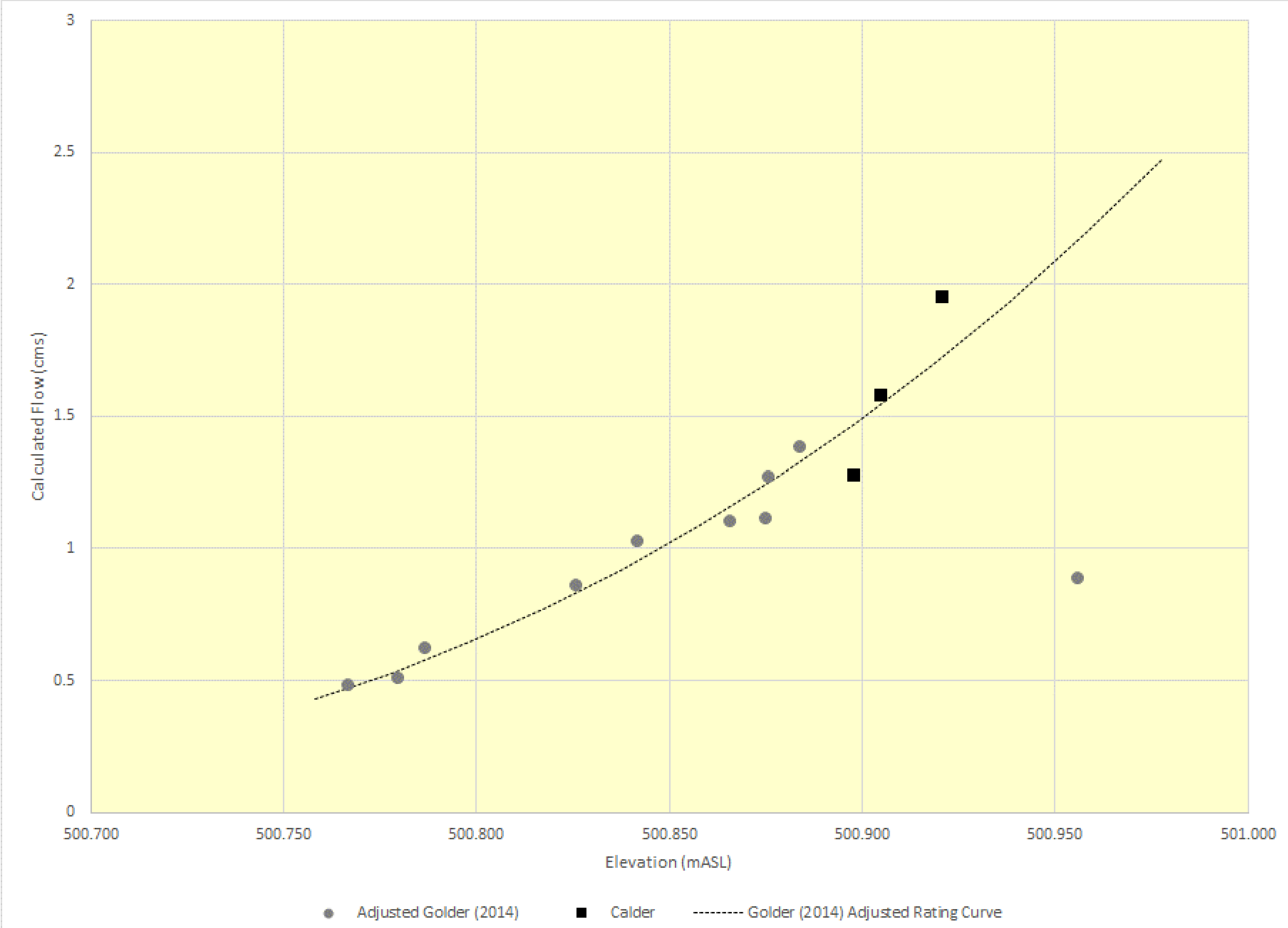
SA1 – MANUAL FLOW MEASUREMENTS AND RATING CURVE



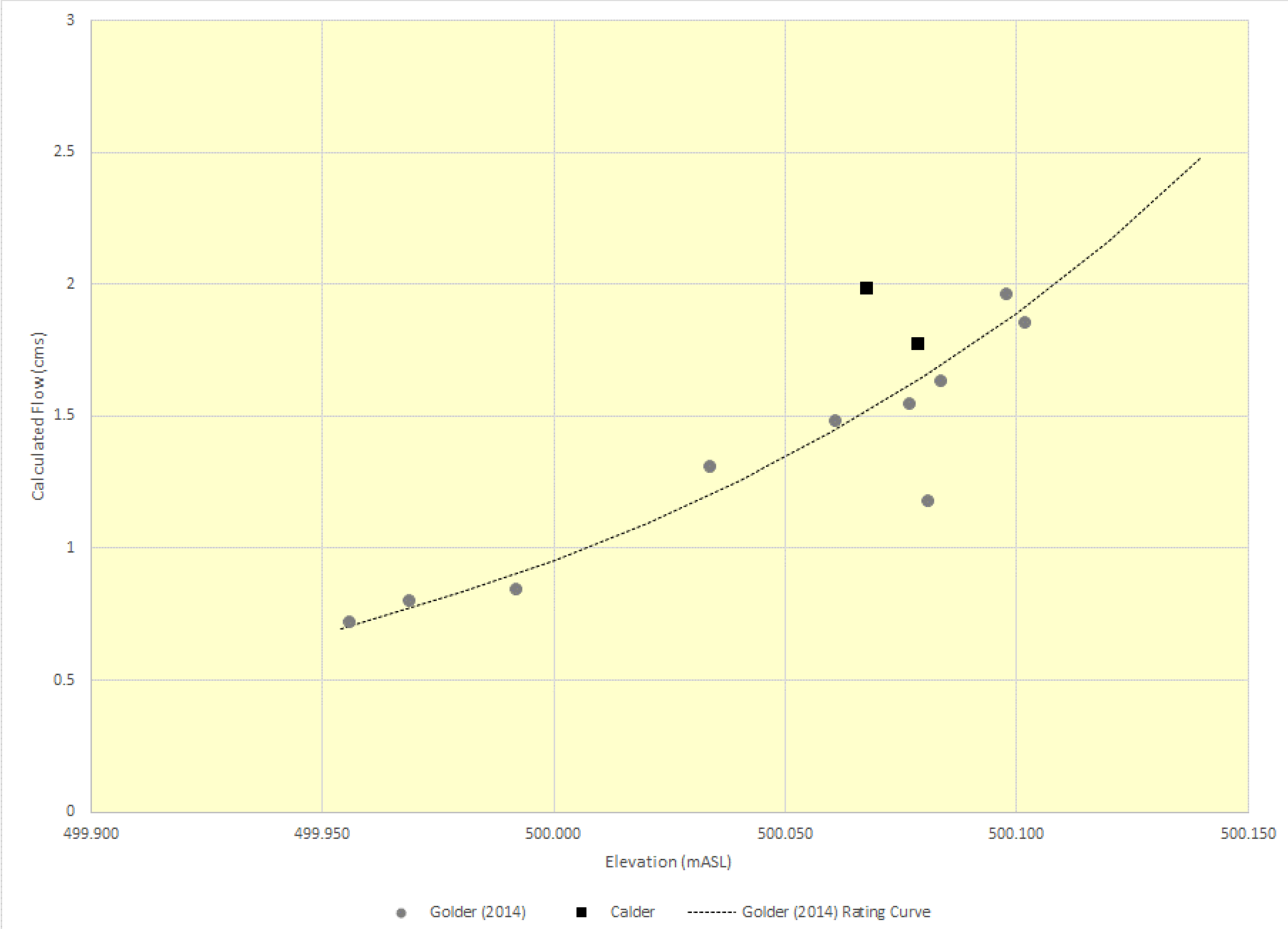
SA4 – MANUAL FLOW MEASUREMENTS AND RATING CURVE



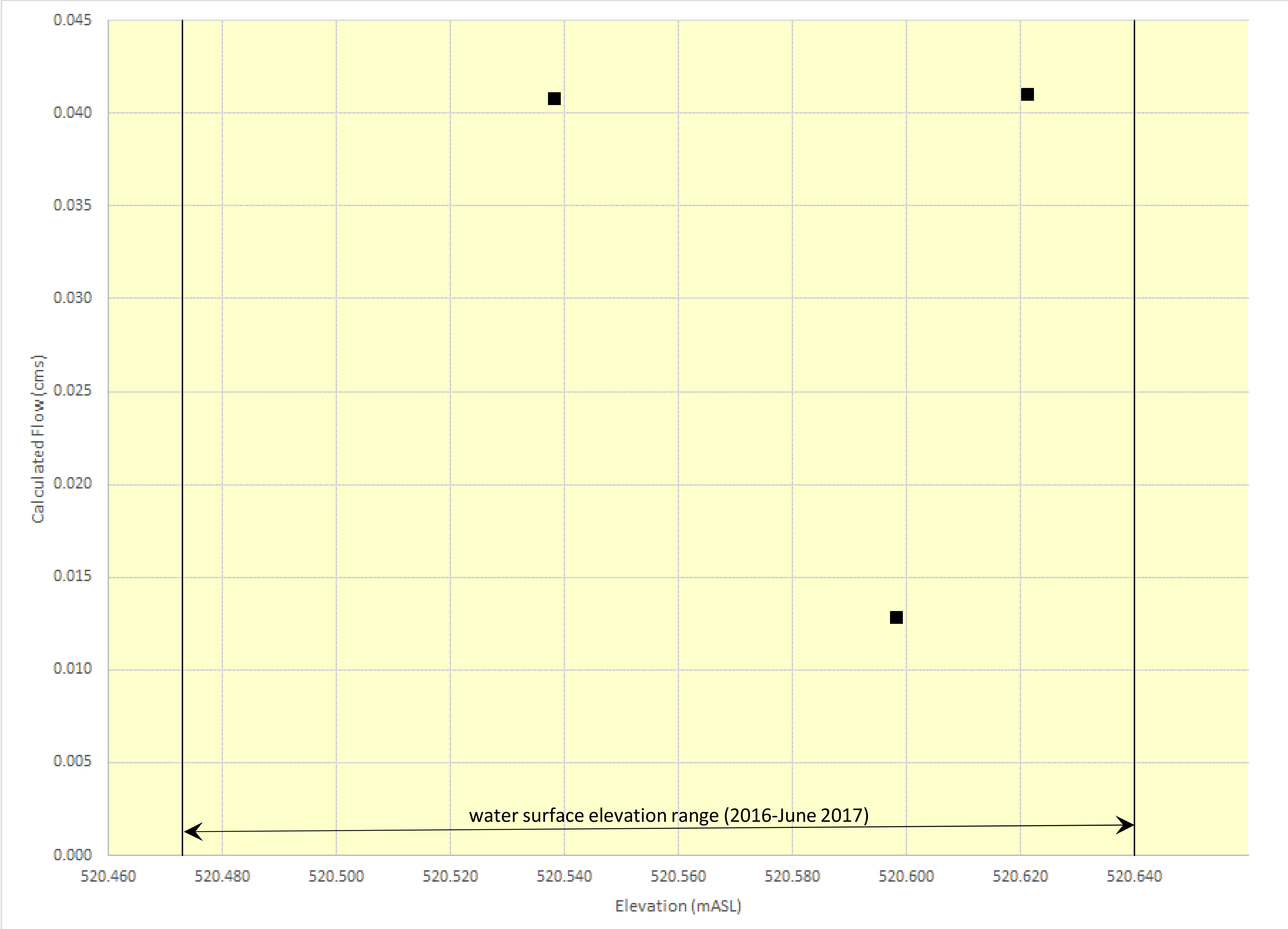
SA5 - MANUAL FLOW MEASUREMENTS AND RATING CURVE



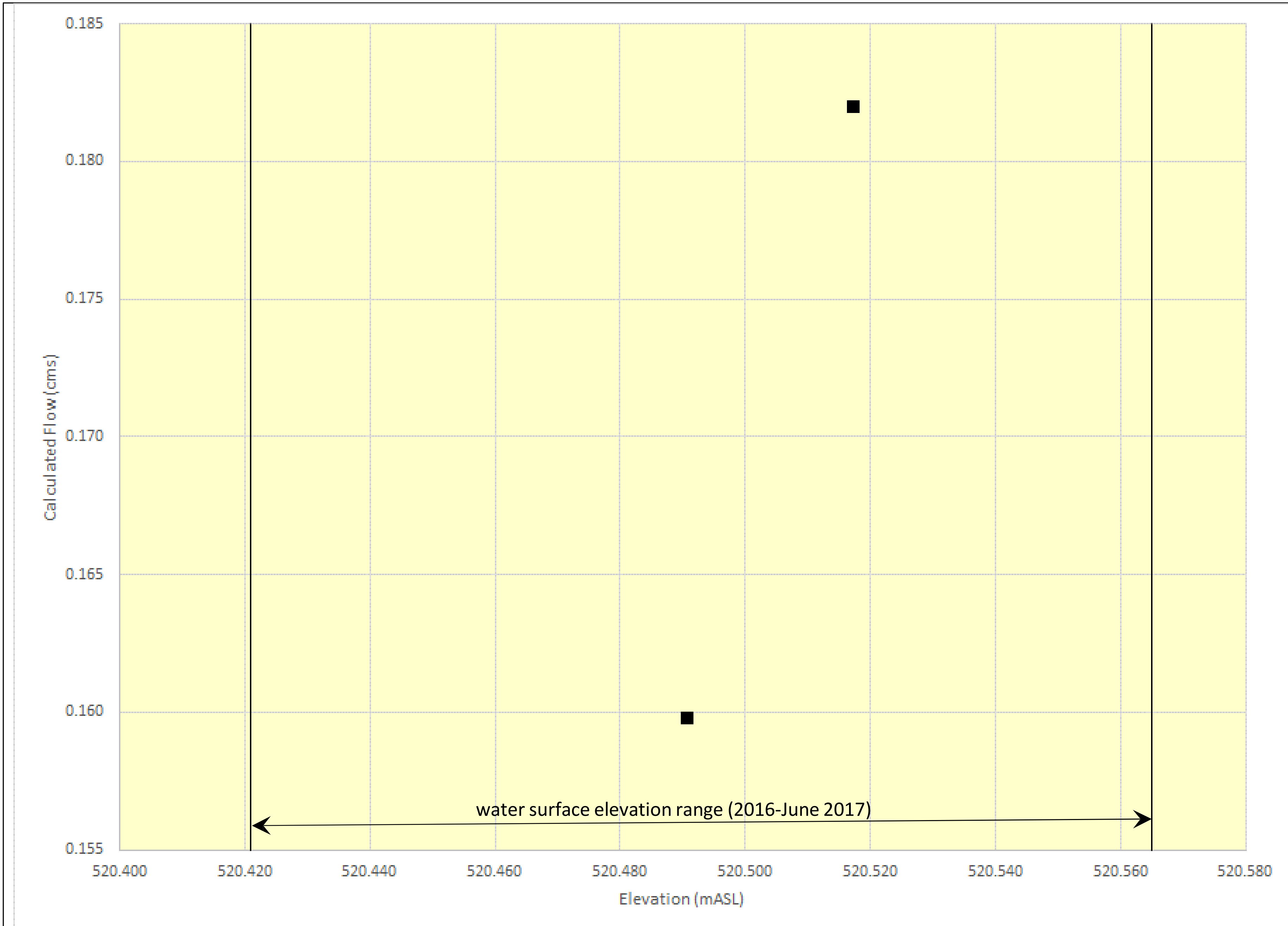
SA5 – ADJUSTED MANUAL FLOW MEASUREMENTS AND ADJUSTED RATING CURVE



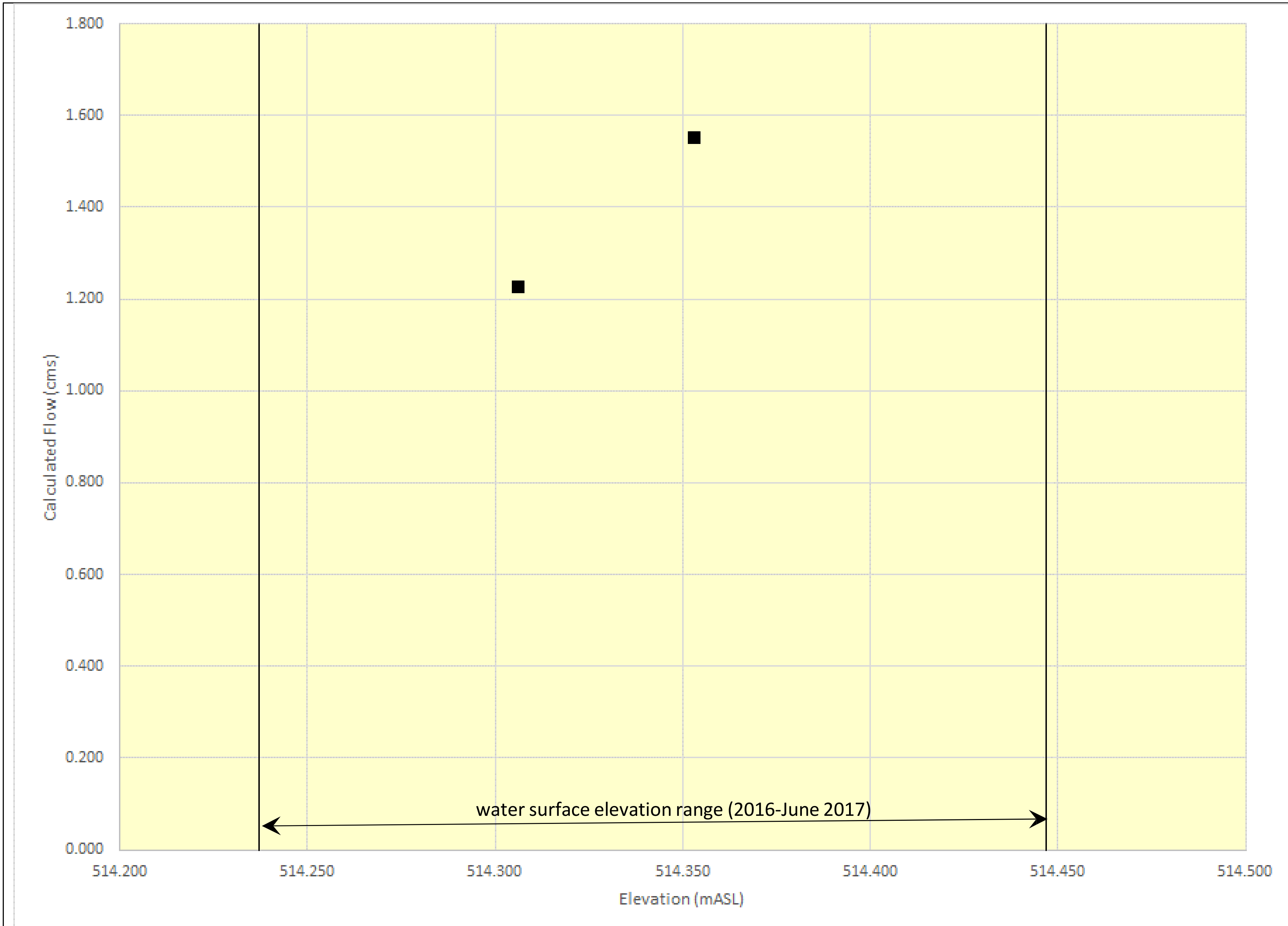
SA6 – MANUAL FLOW MEASUREMENTS AND RATING CURVE



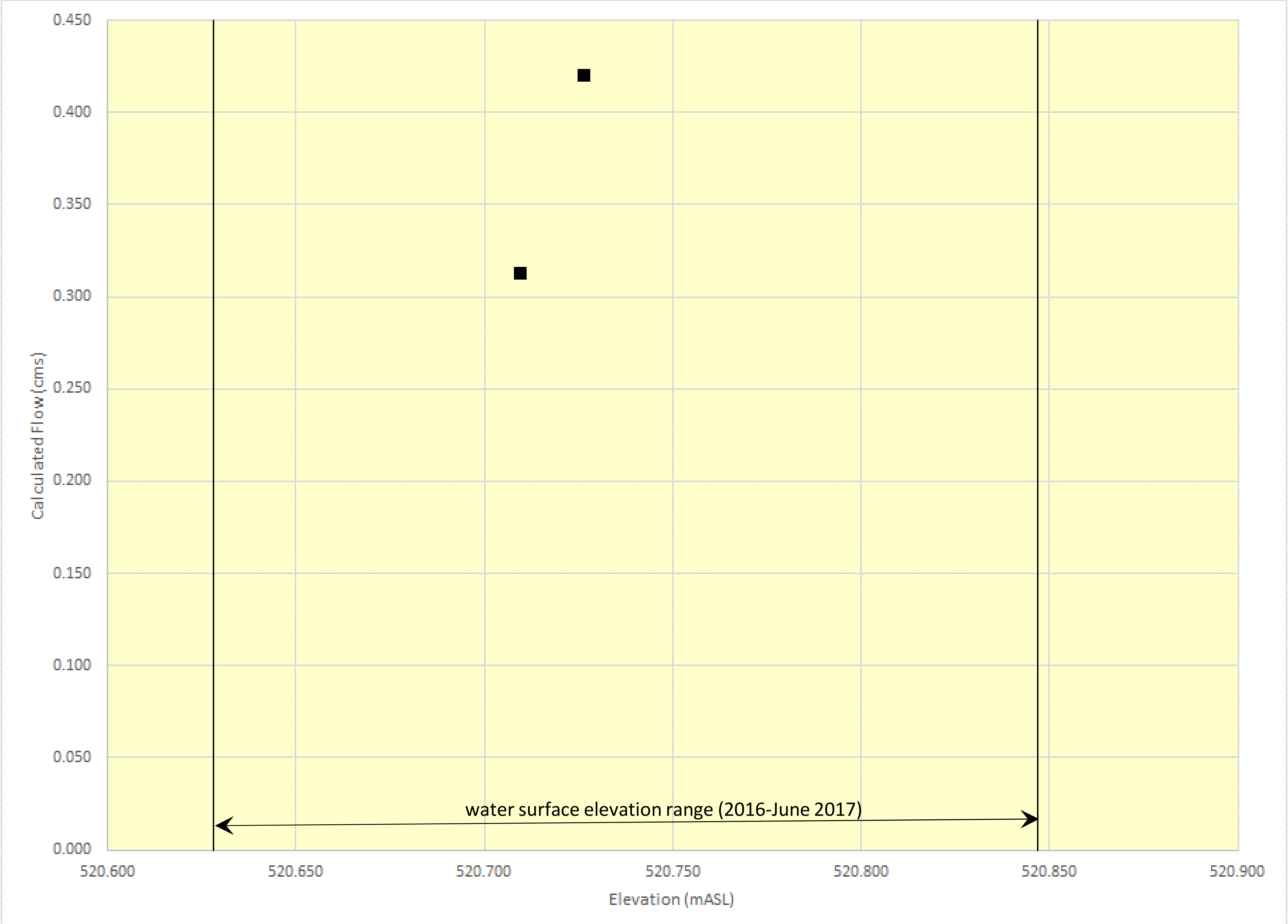
SA8 – MANUAL FLOW MEASUREMENTS



SA9 – MANUAL FLOW MEASUREMENTS



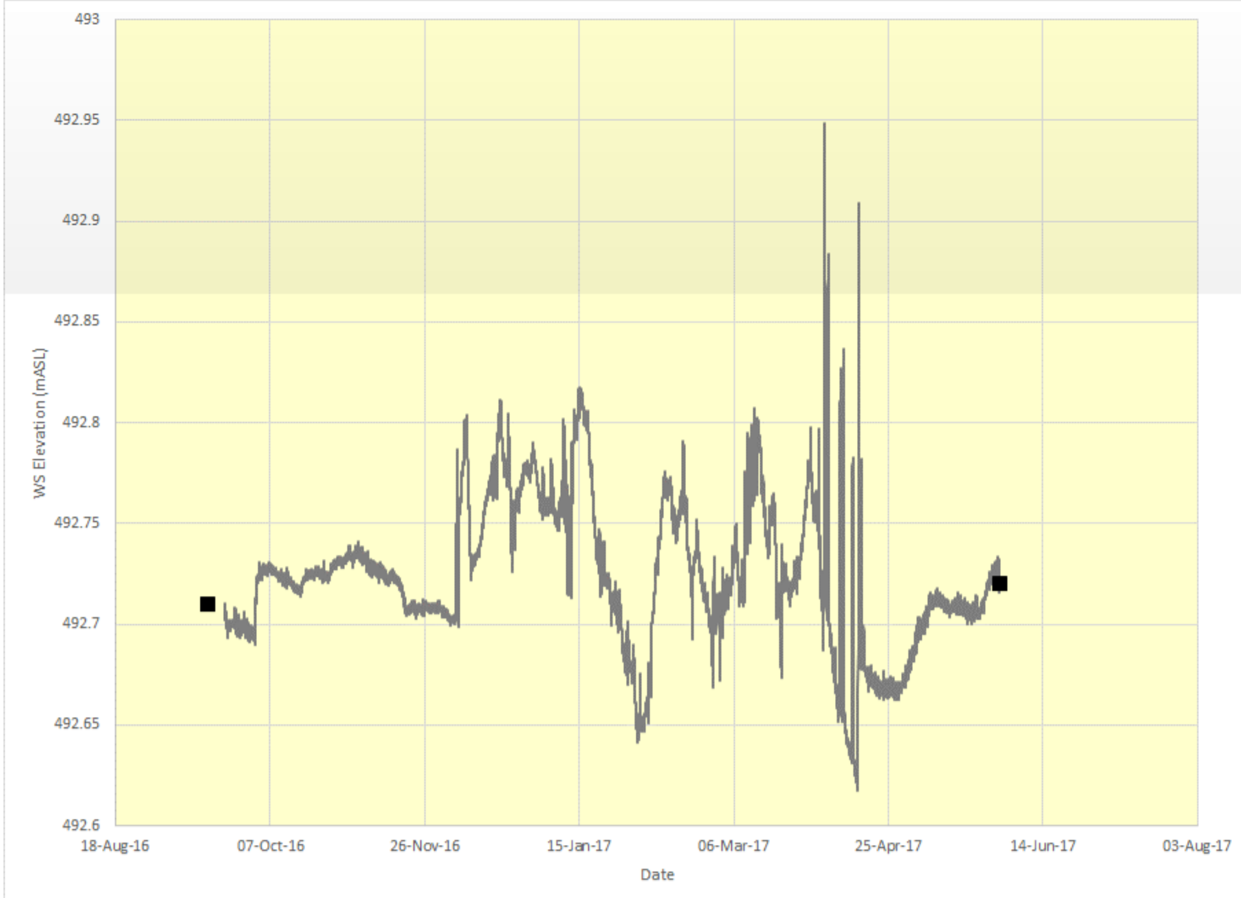
SA10 – MANUAL FLOW MEASUREMENTS

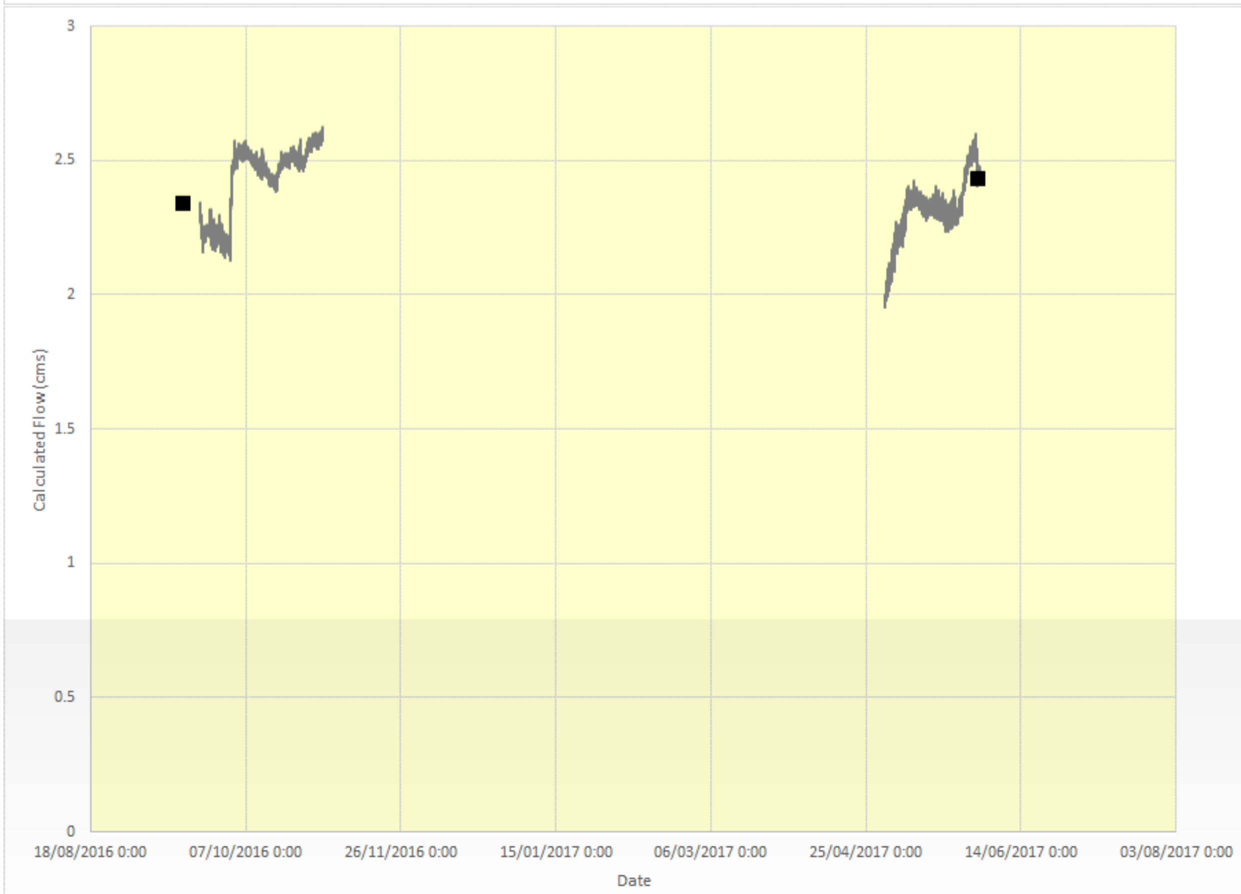


SA11 – MANUAL FLOW MEASUREMENTS

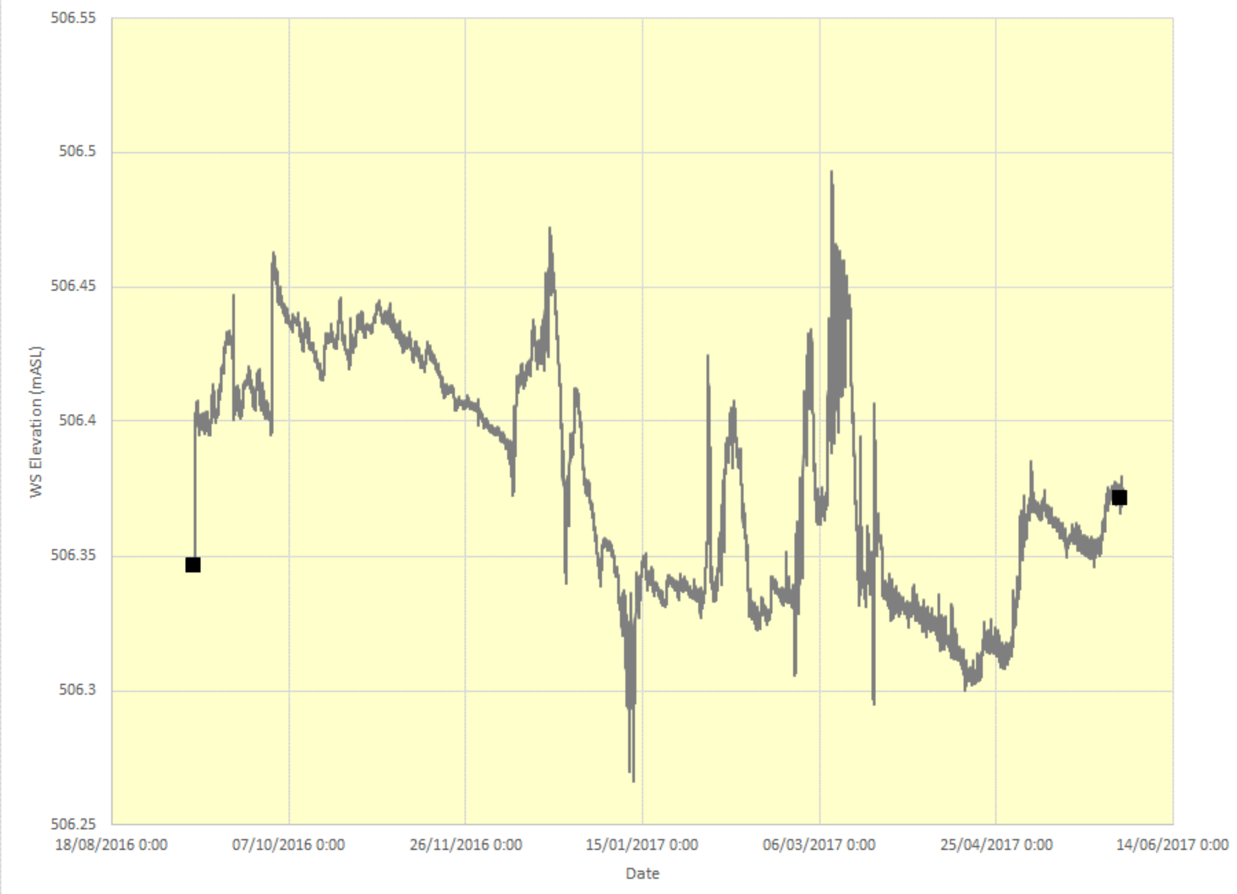
ATTACHMENT C

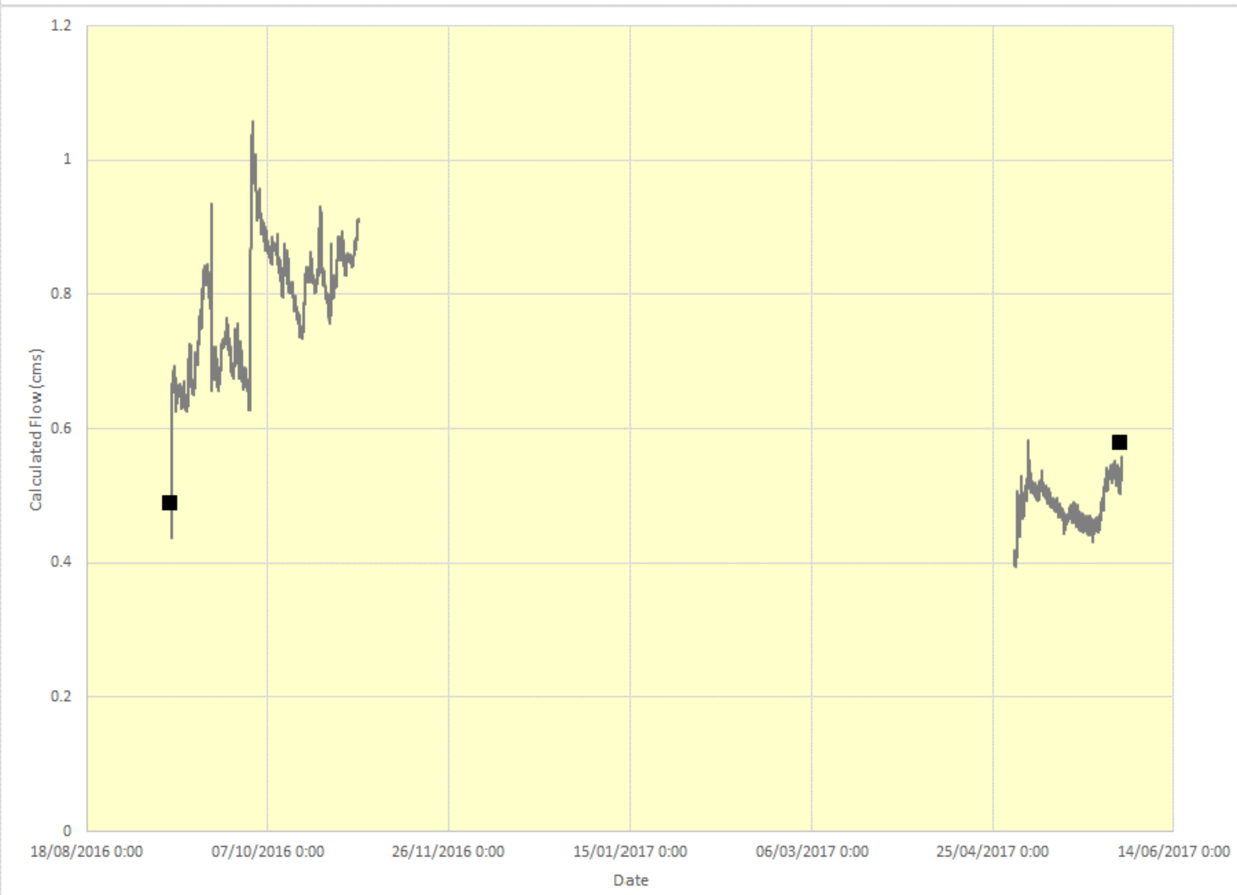
LEVEL LOGGER DATA



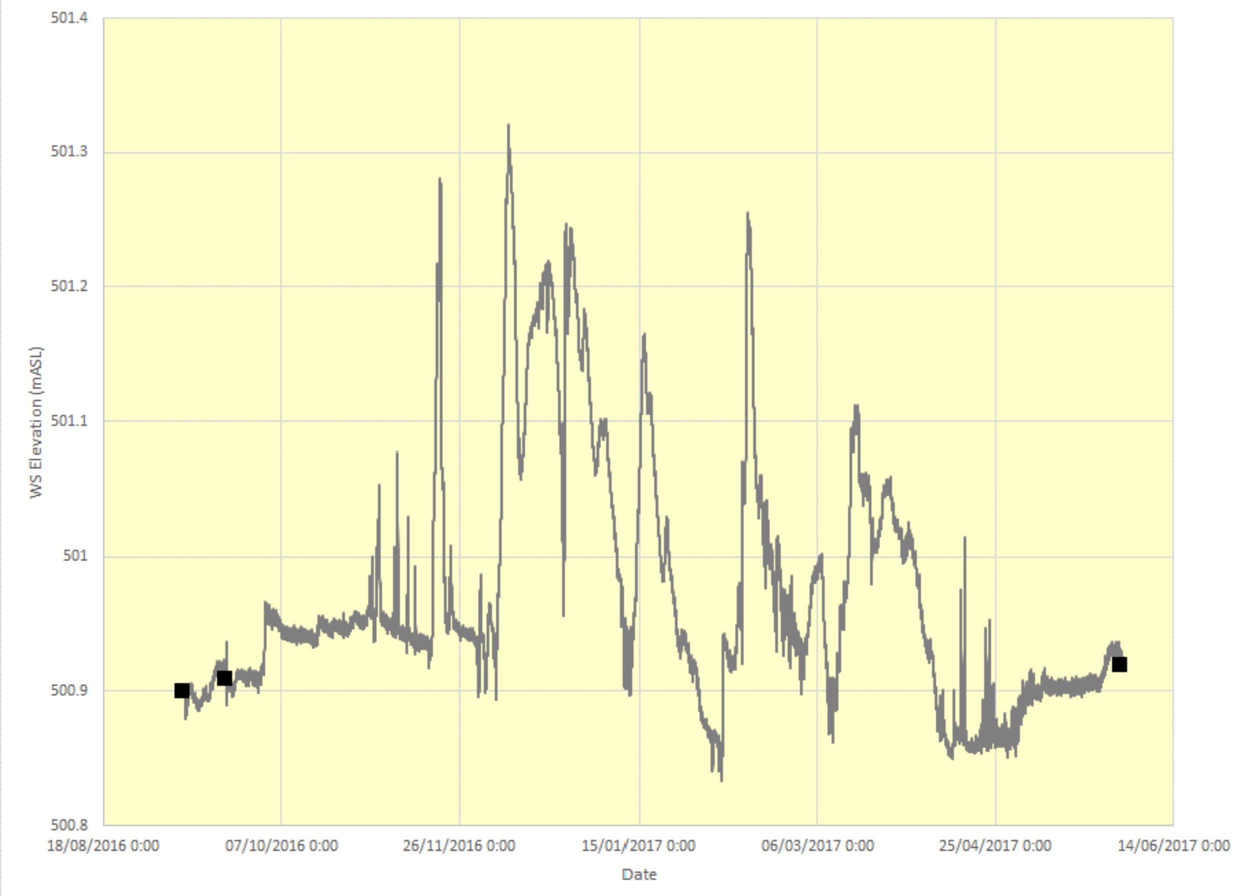


SA1 – Elevation and Discharge (September 2016 to June 2017)



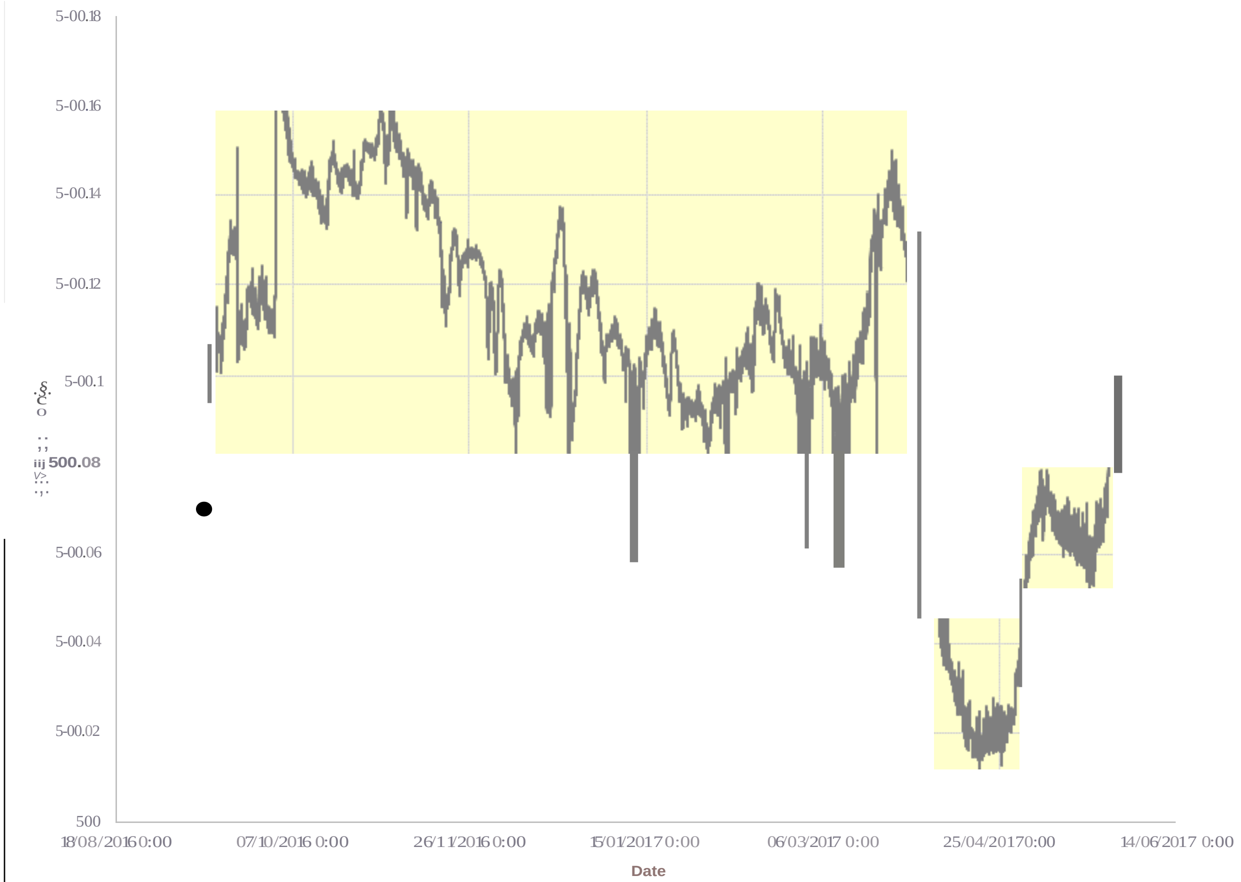


SA4 – Elevation and Discharge (September 2016 to June 2017)

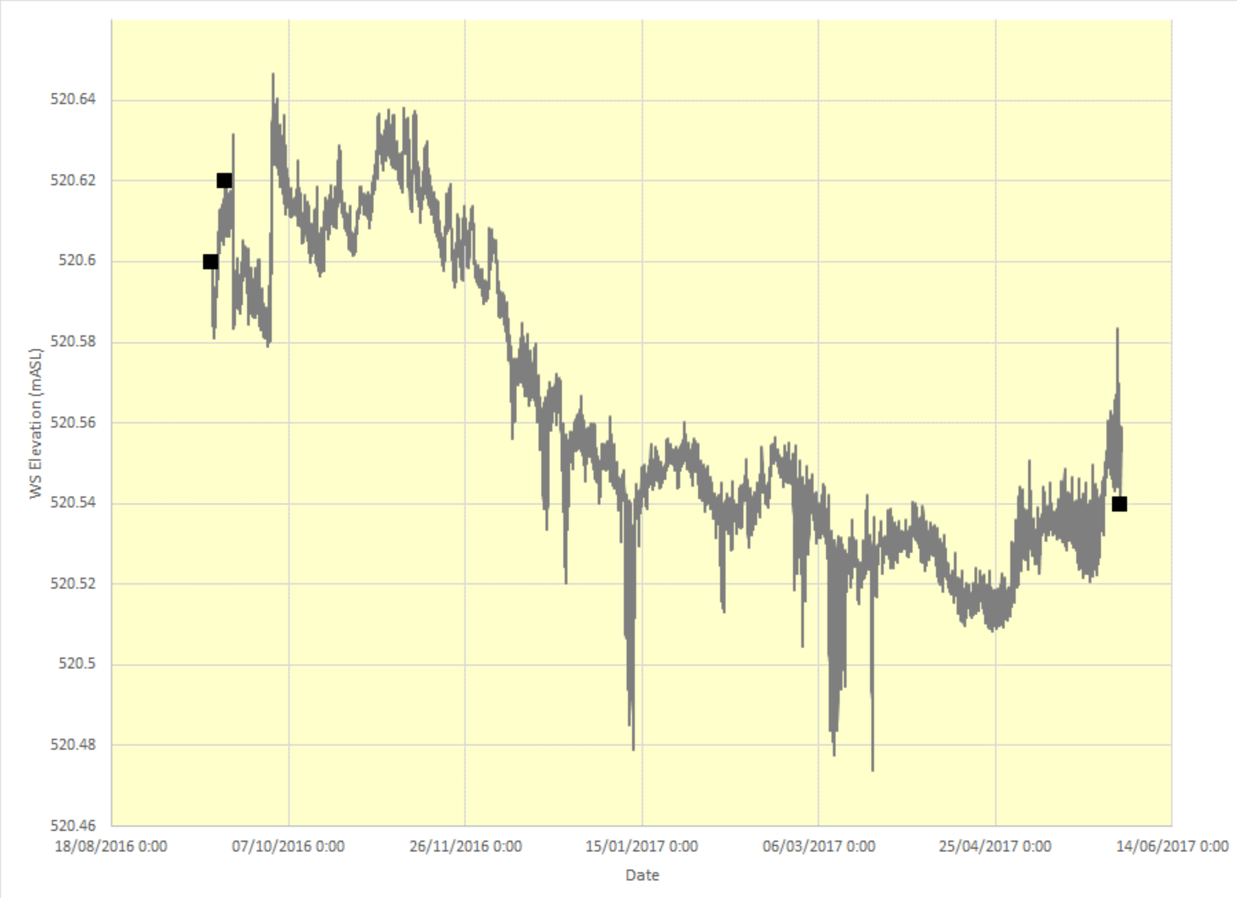


SA5 – Elevation and Discharge (September 2016 to June 2017)

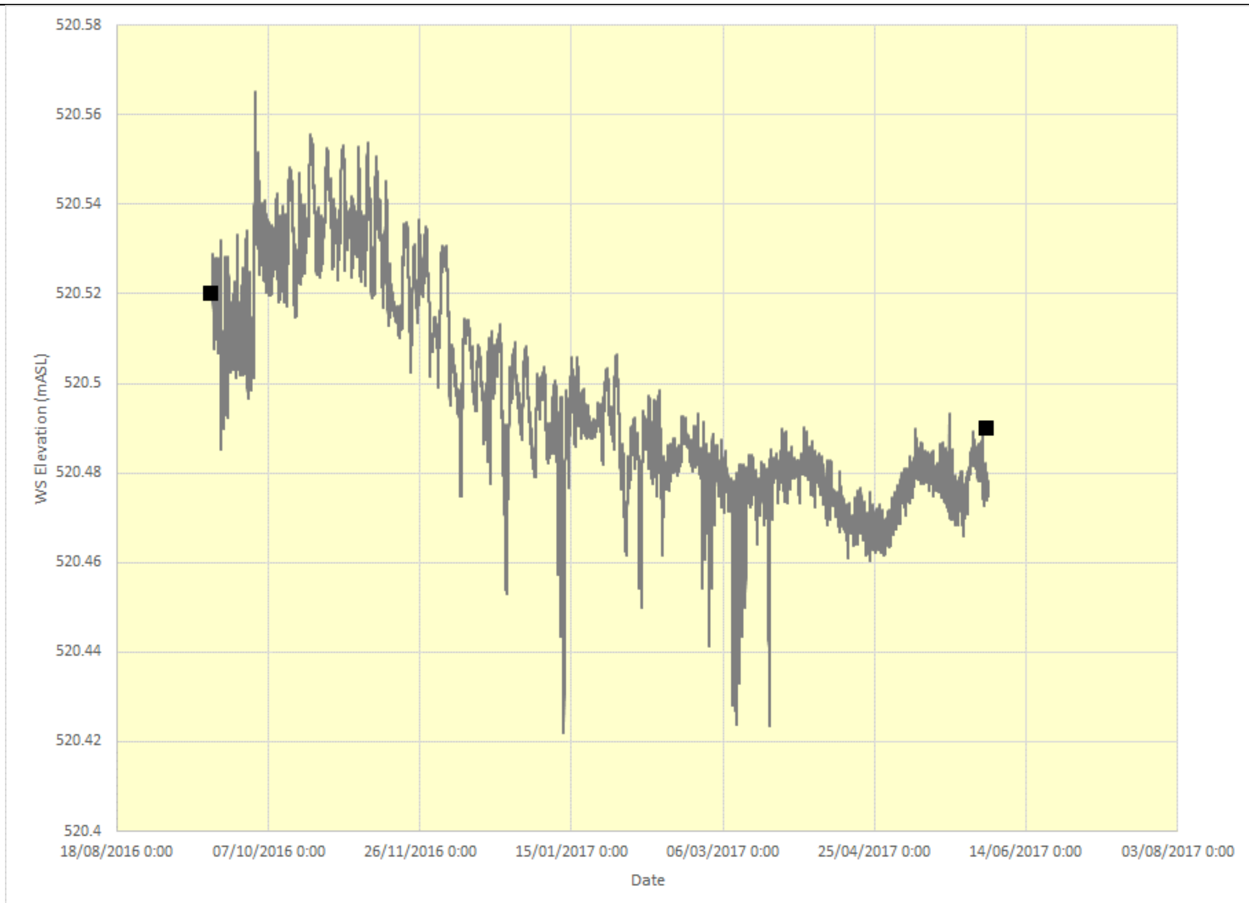
SA6 – Elevation and Discharge (March 2014 to August 2015)



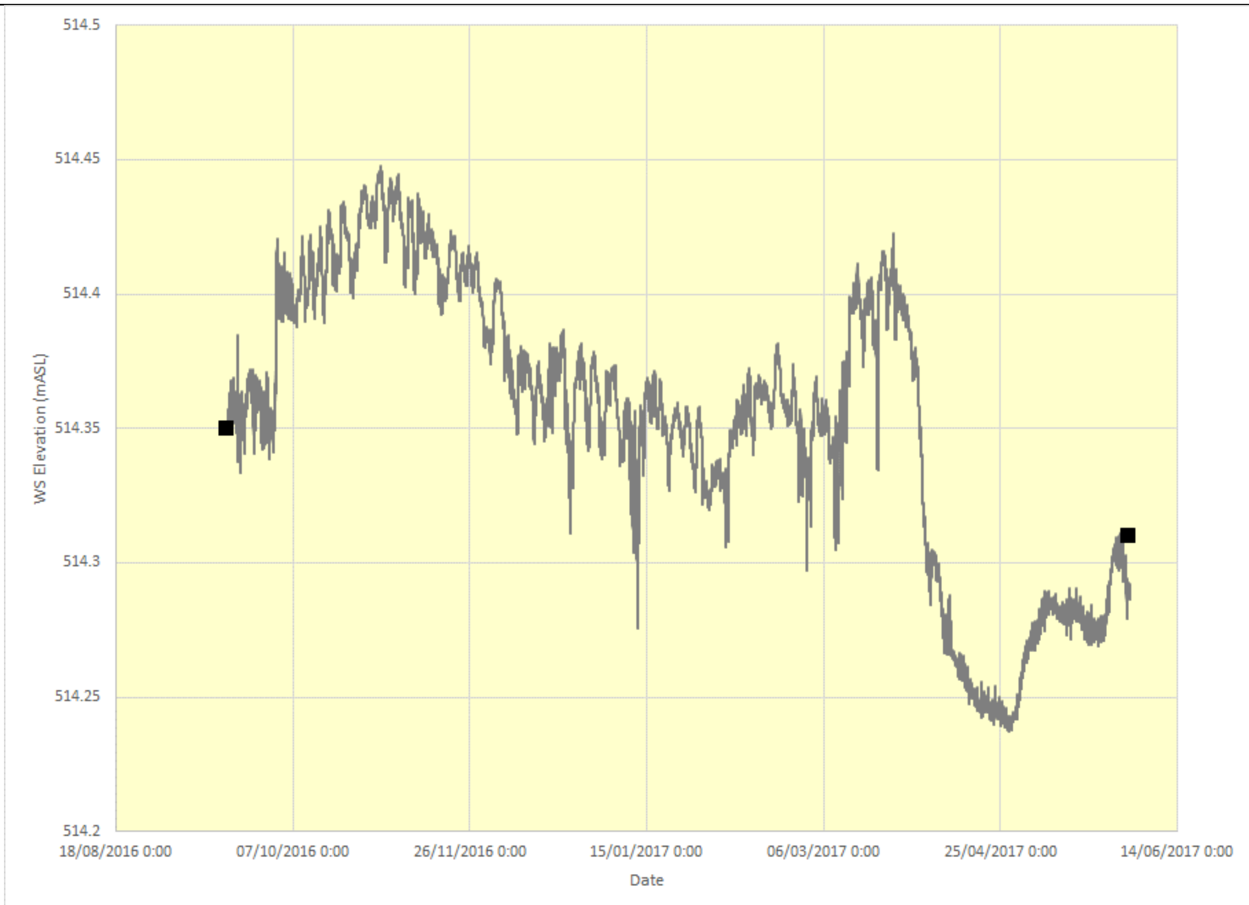
SA6 - Elevation and Discharge (September 2016 to June 2017)



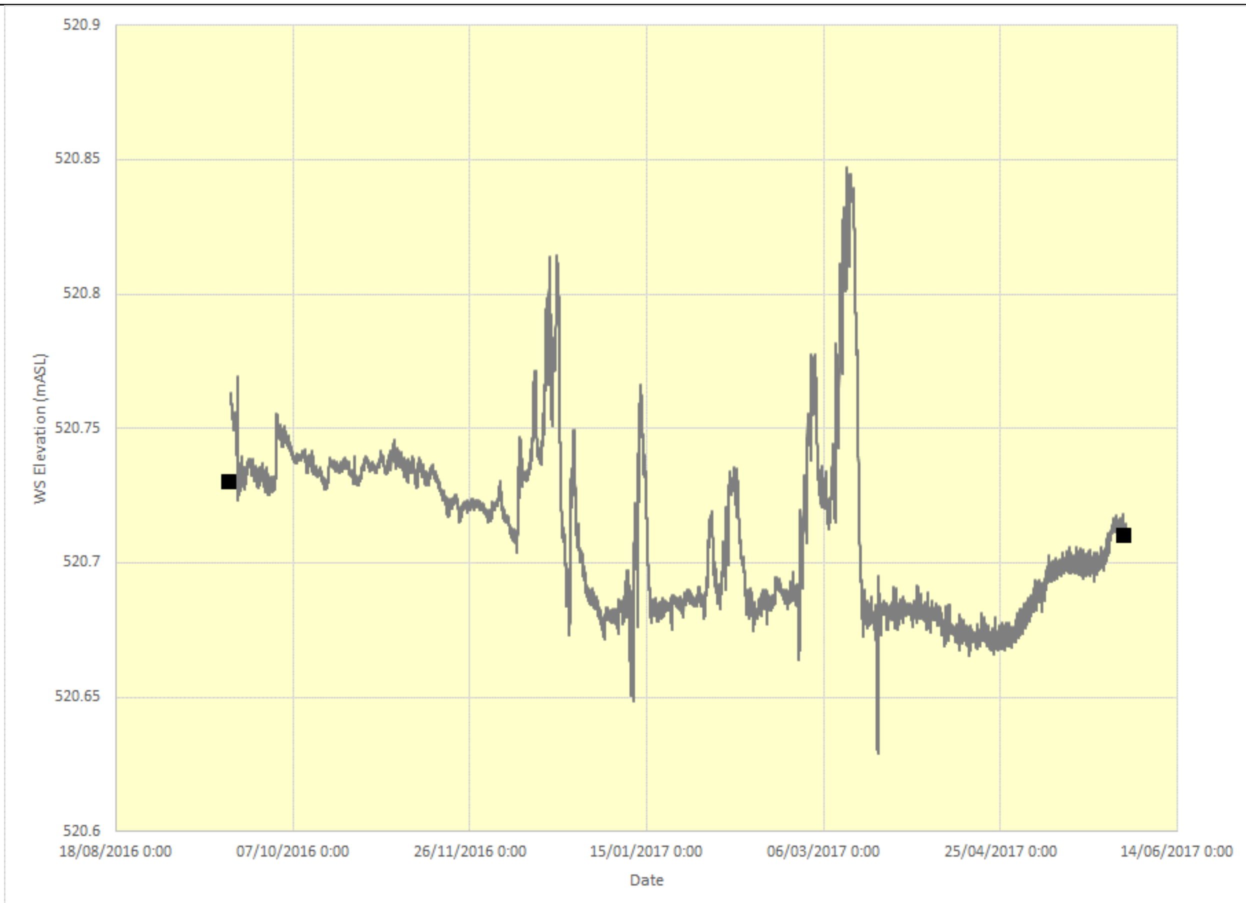
SA8 – Elevation (September 2016 to June 2017)



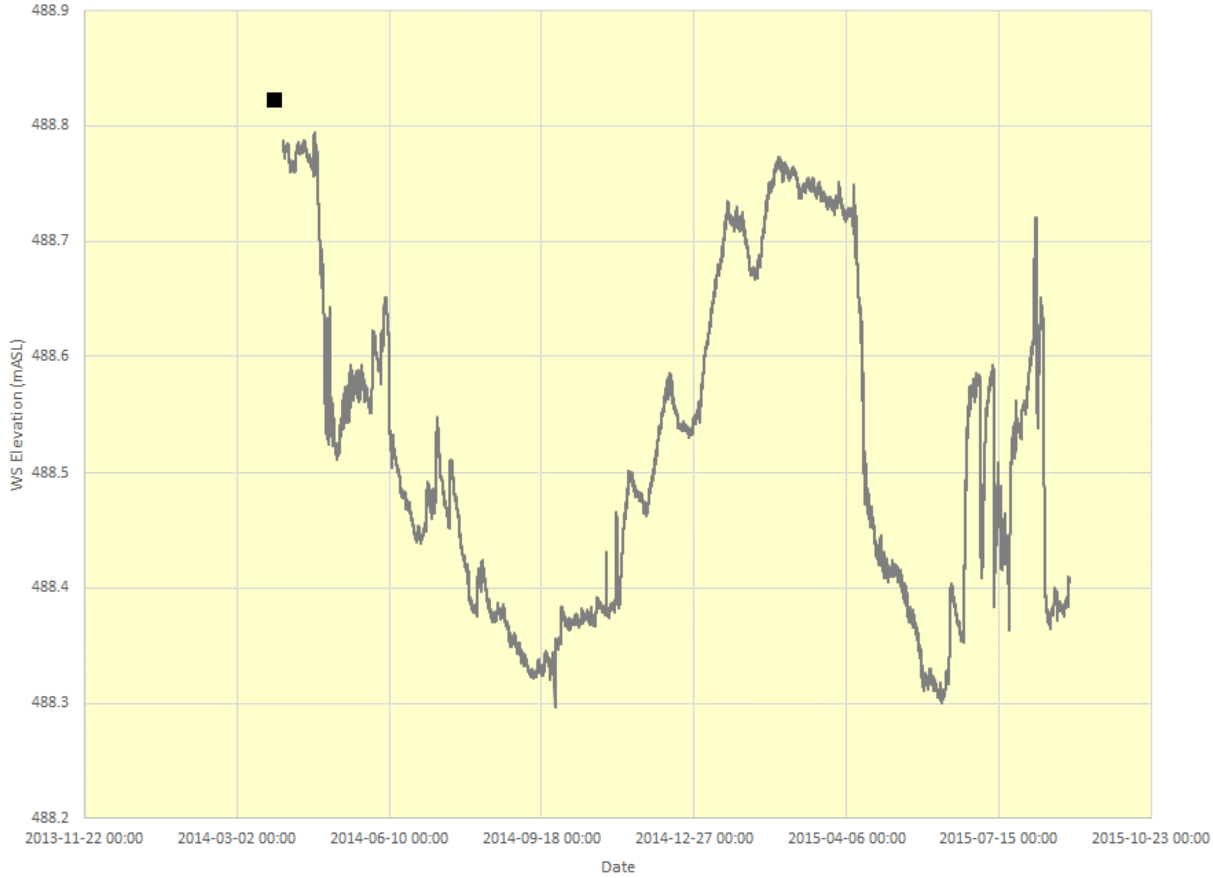
SA9 – Elevation (September 2016 to June 2017)

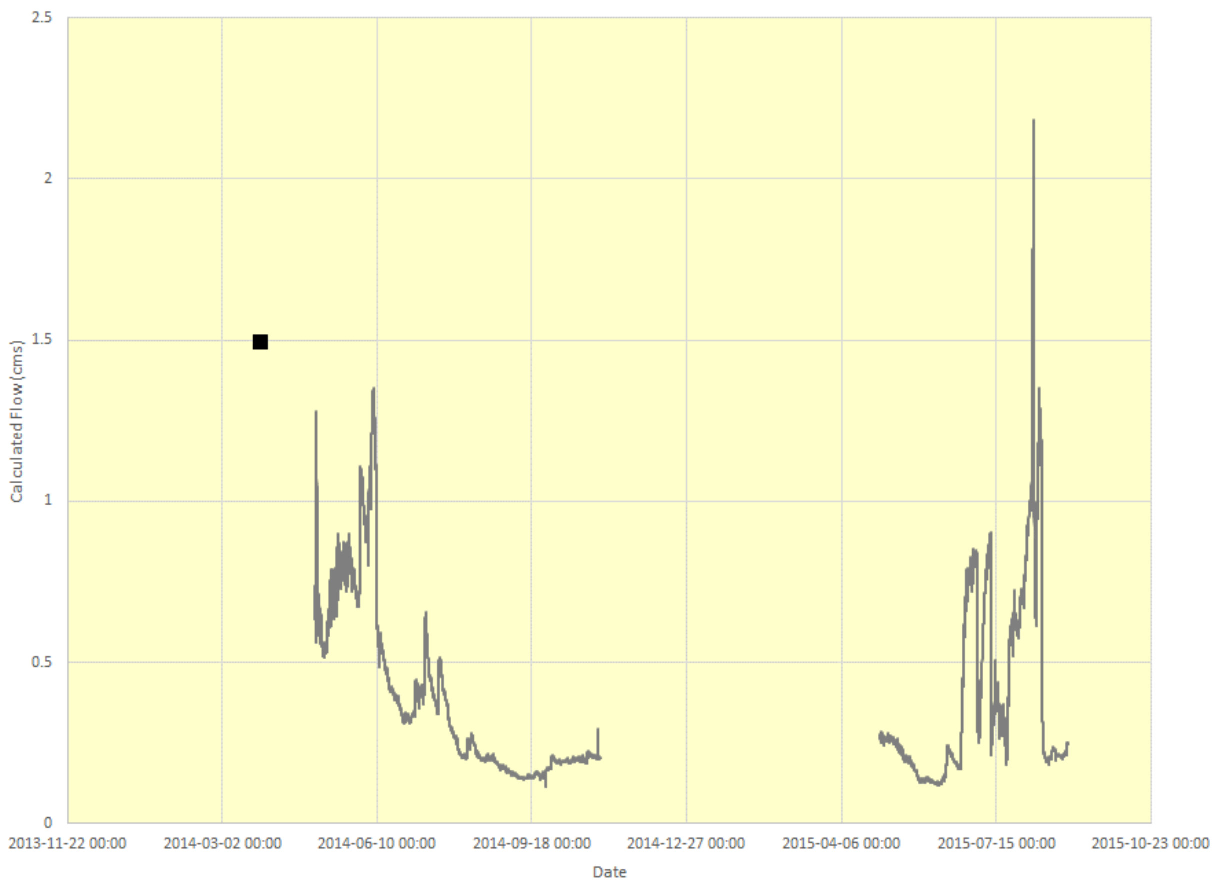


SA10 – Elevation (September 2016 to June 2017)



SA11 – Elevation (September 2016 to June 2017)





SB1 – Elevation and Discharge (March 2014 to August 2015)

ATTACHMENT D

WEBB SURVEY REPORT

Webb Surveys
REGISTERED LAND SURVEYORS
LAND DEVELOPMENT CONSULTANTS

June 6, 2017 WO# 17-246

Calder Engineering Ltd.
6440 King Street
Caledon, ON
L7C 0S1

Attn: Robert Whyte

Robert,

Please find attached the static reports from NRCAN showing the corrected static positions of the points that I surveyed between May 29 and June 1, 2017.

As a brief summary here is a list of the points and elevations:

LA8	523.991
LA9	515.312
PA2	511.303
PA3	517.851
SB5	518.673

Feel free to contact me if you have any questions.

Thank you,

D.L. (Dan) Codling, SLS, P.Surv

222 Jessop Avenue • Saskatoon SK • S7N 1Y4 • Phone: (306) 955-5330 • Fax: (306) 955-0292 • Email: admin@webbsurveys.ca

CSRS-PPP (V 1.05 11216)

LA8

Data Start	Data End	Duration of Observations
2017-06-01 15:47:00.000	2017-06-01 21:11:30.000	5h 24m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.010m		2.0m / 2.092m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	15.00 sec / 15.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TPSGR5 NONE	L1= 0.221 m L2= 0.218 m	1.459 m

(APC = antenna phase center; ARP = antenna reference point)

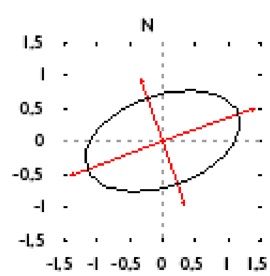
Estimated Position for LA8152p.17O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997)	57º 33’ 39.2611’’	-105º 23’ 48.9852’’	492.933 m
Sigmas(95%)	0.006 m	0.009 m	0.021 m
Apriori	57º 33’ 39.262’’	-105º 23’ 49.066’’	494.022 m
Estimated - Apriori	-0.042 m	1.352 m	-1.089 m

Orthometric Height
CGVD28 (HTv2.0)

523.991 m
(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.219cm
semi-minor: 0.688cm
semi-major azimuth: 71º 1’ 7.79’’



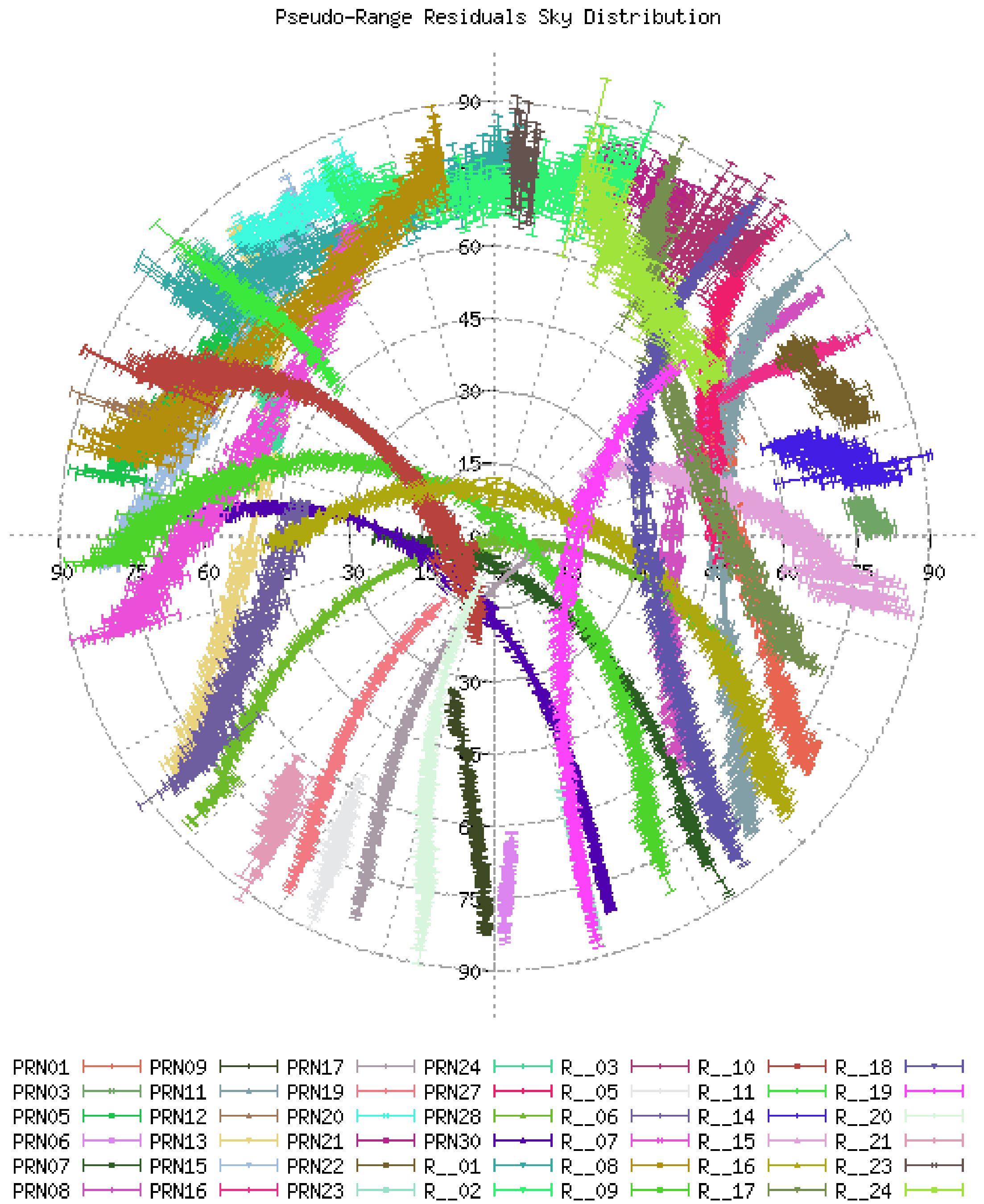
UTM (North) Zone 13

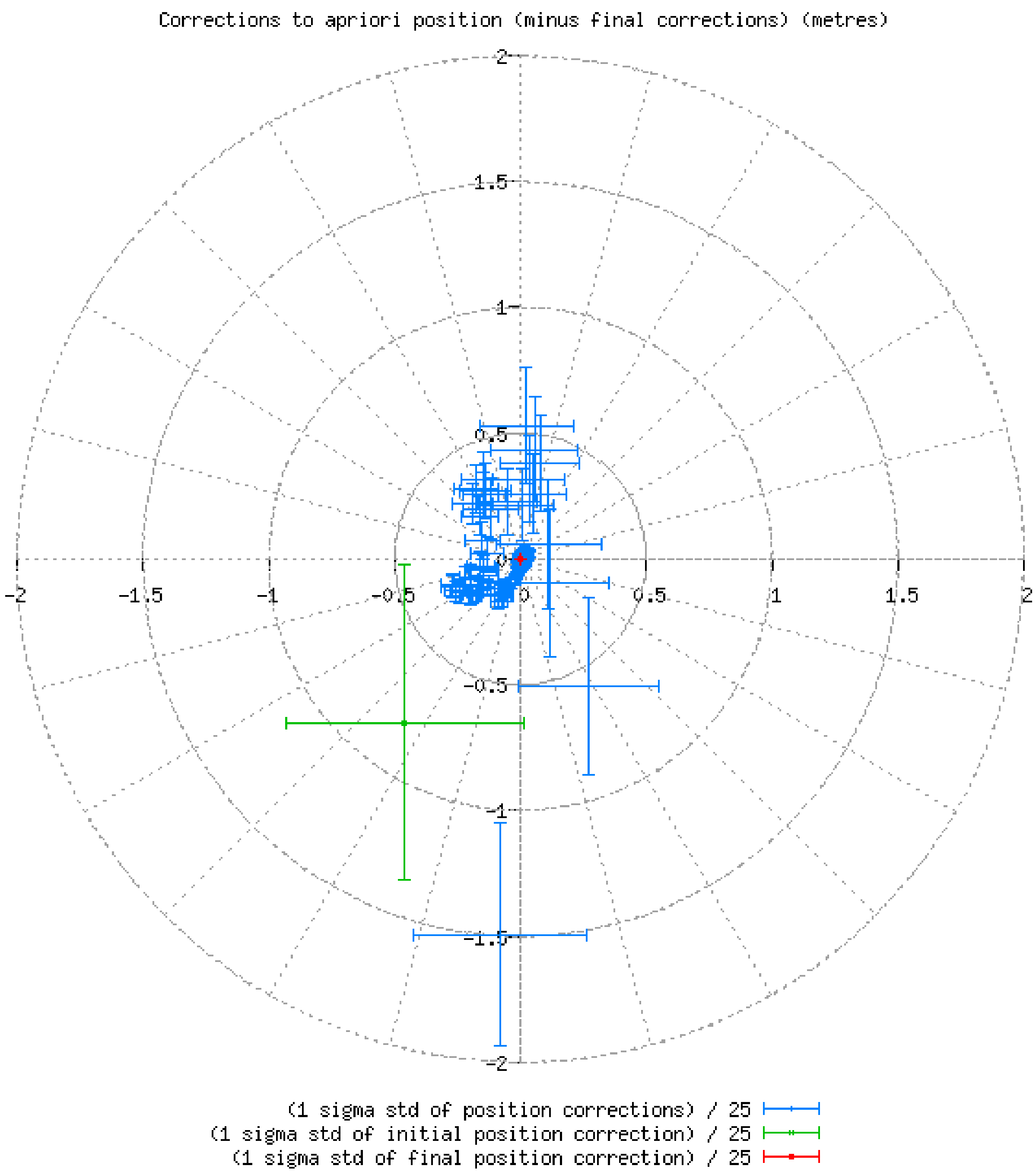
6379895.581m (N) 476250.738m (E)

Scale Factors
0.99960692 (point)
0.99952959 (combined)

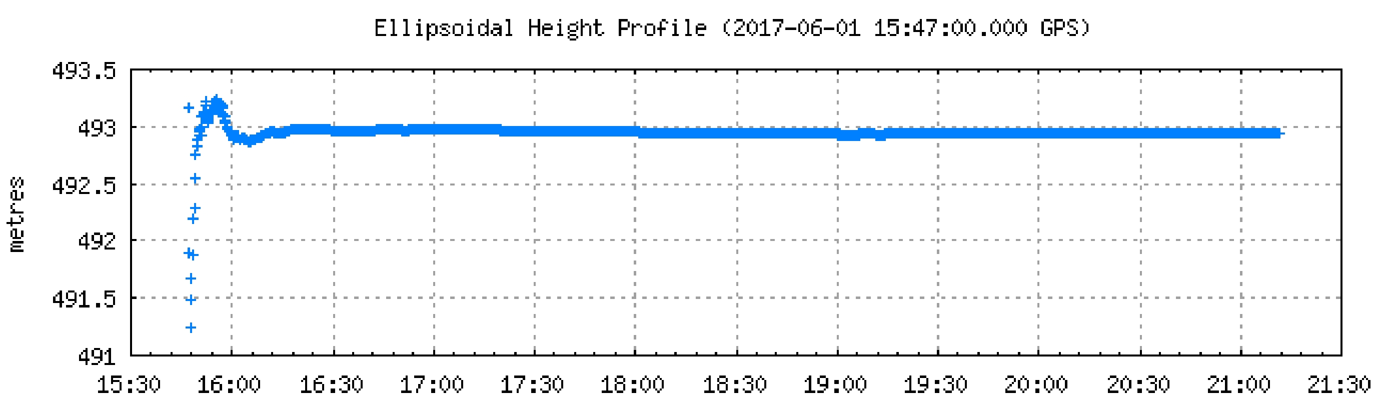
(Coordinates from RINEX file used as apriori position)

Estimated Parameters & Observations Statistics





Corrections to apriori position (minus final corrections) (metres)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
(1 sigma std of position corrections) / 25
(1 sigma std of initial position correction) / 25
(1 sigma std of final position correction) / 25



Ellipsoidal Height Profile (2017-06-01 15:47:00.000 GPS)
metres
493.5
493
492.5
492
491.5
491
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
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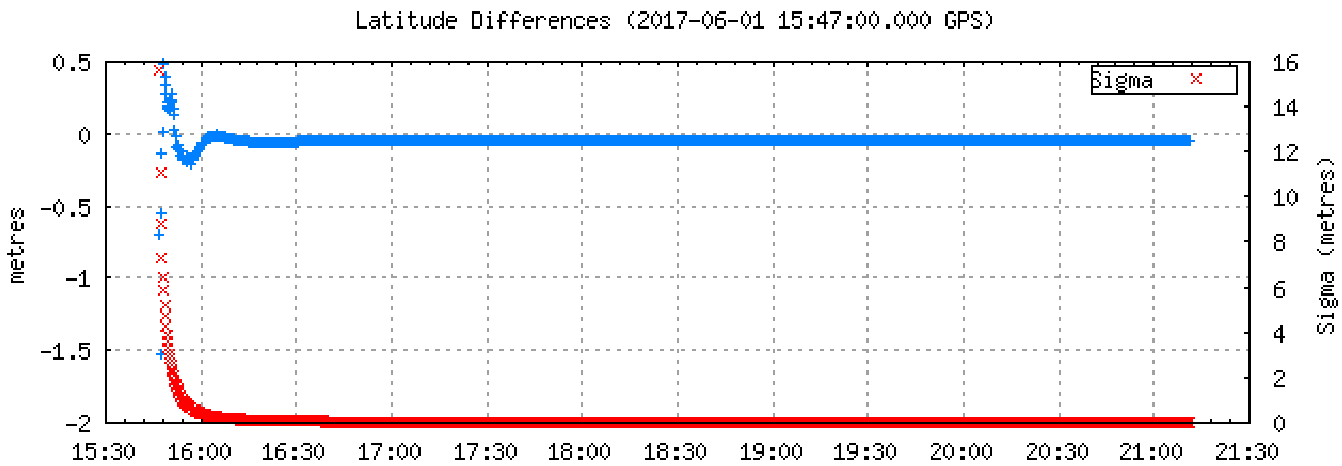
20:30
21:00
21:30


Latitude Differences (2017-06-01 15:47:00.000 GPS)
metres
Sigma (metres)
Sigma
0.5
0
-0.5
-1
-1.5
-2
16
14
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
17:30
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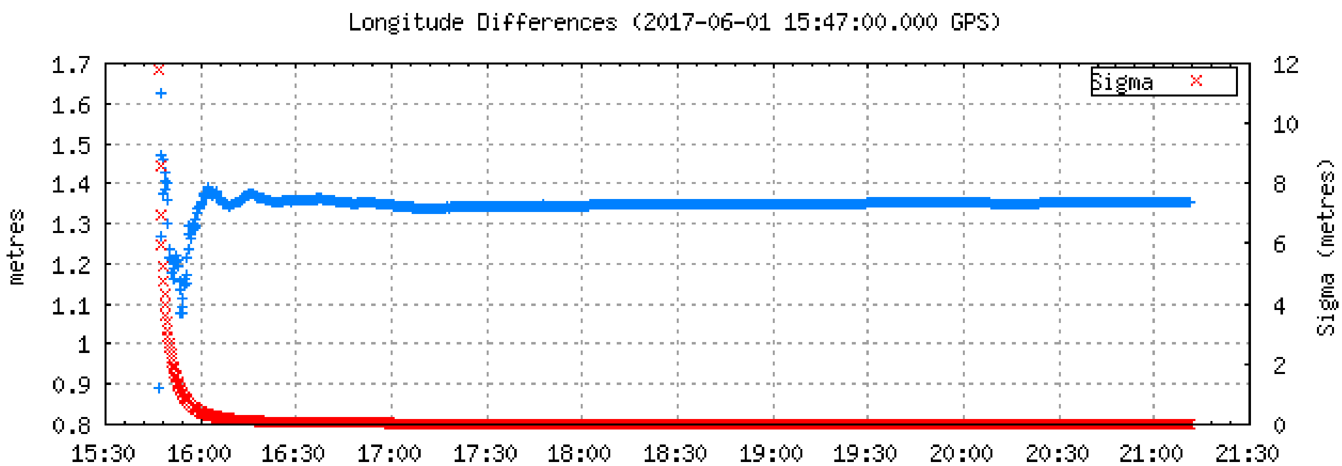
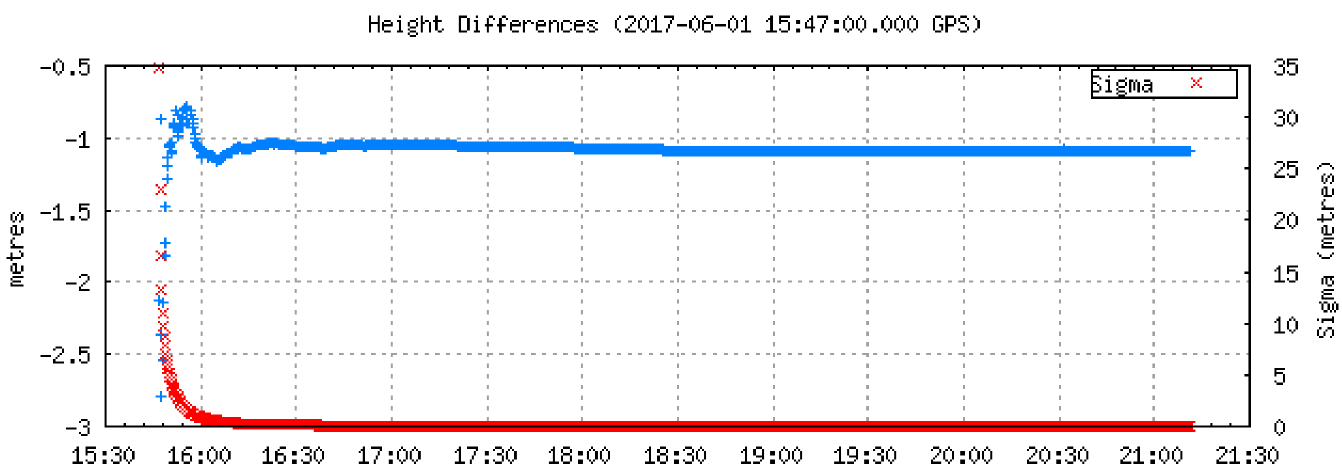
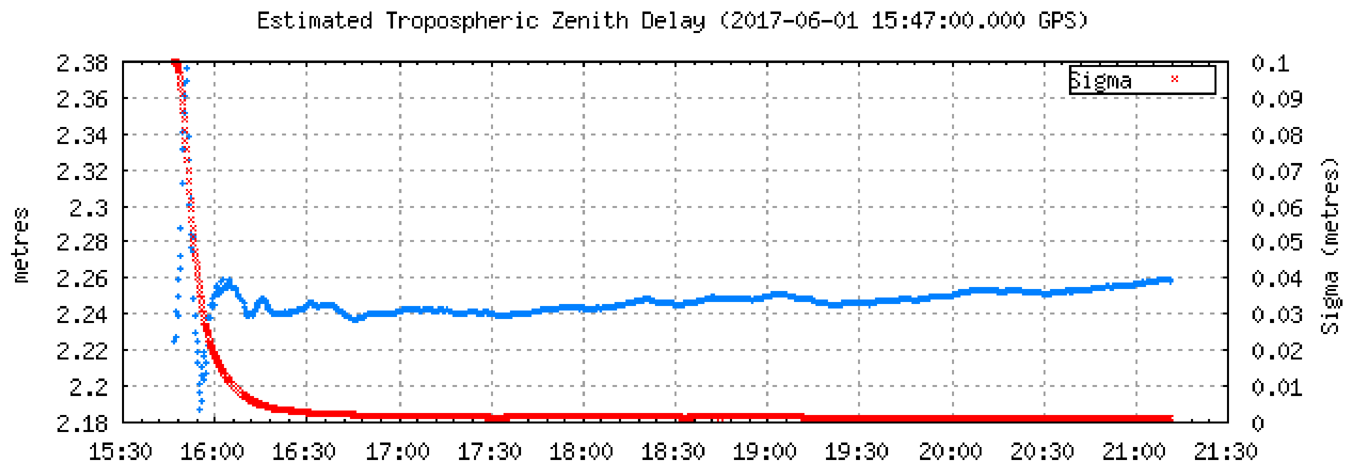
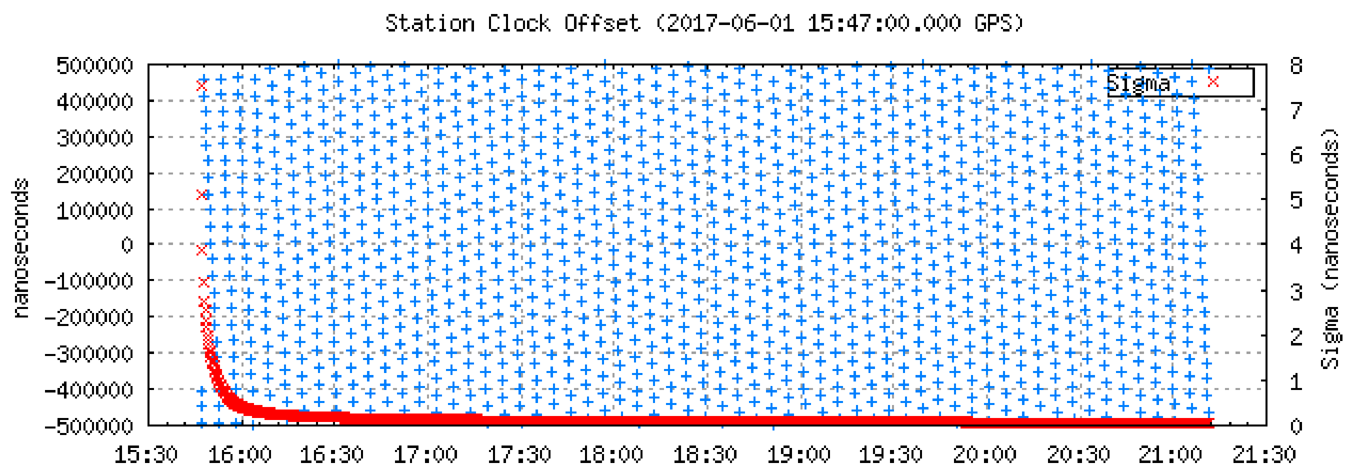
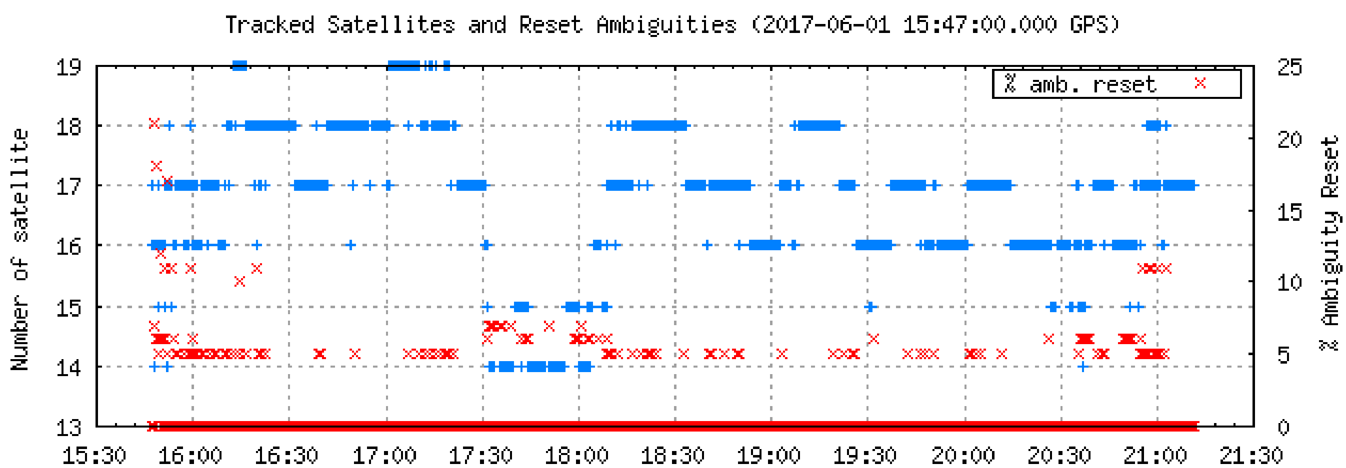
20:30
21:00
21:30

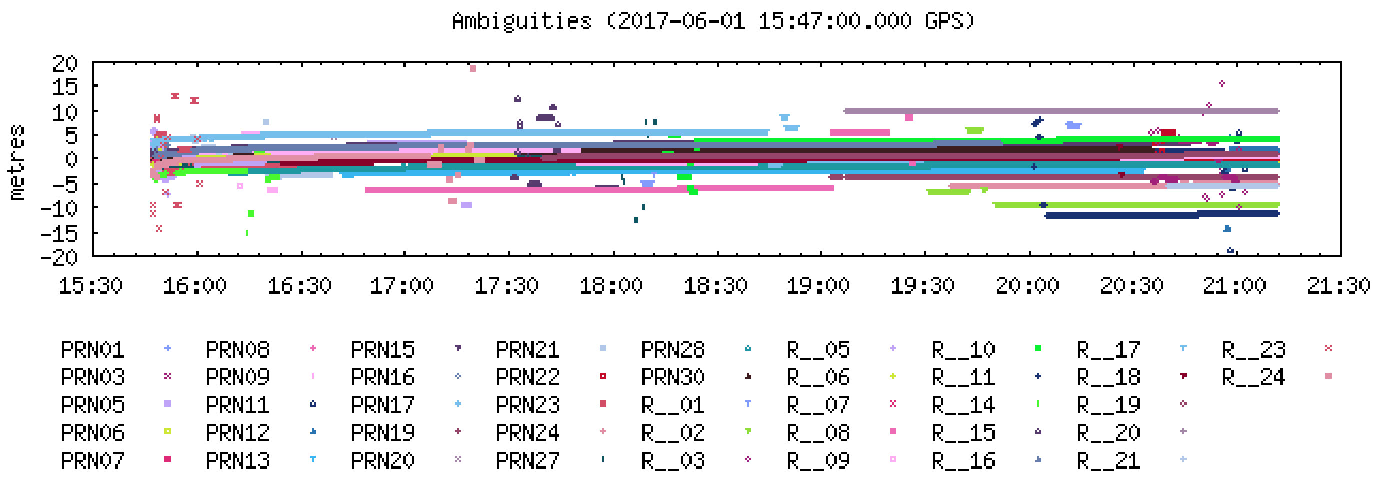

Longitude Differences (2017-06-01 15:47:00.000 GPS)
metres
Sigma (metres)
Sigma
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30


Height Differences (2017-06-01 15:47:00.000 GPS)
metres
Sigma (metres)
Sigma
-0.5
-1
-1.5
-2
-2.5
-3
35
30
25
20
15
10
5
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30

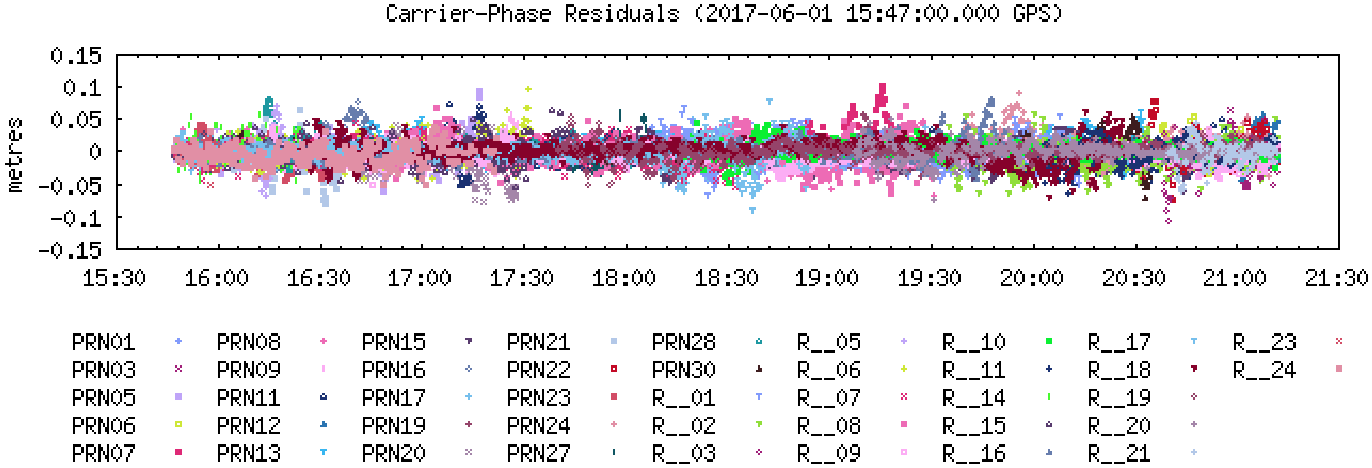

Estimated Tropospheric Zenith Delay (2017-06-01 15:47:00.000 GPS)
metres
Sigma (metres)
Sigma
2.38
2.36
2.34
2.32
2.3
2.28
2.26
2.24
2.22
2.2
2.18
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30


Station Clock Offset (2017-06-01 15:47:00.000 GPS)
nanoseconds
Sigma (nanoseconds)
Sigma
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
8
7
6
5
4
3
2
1
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30

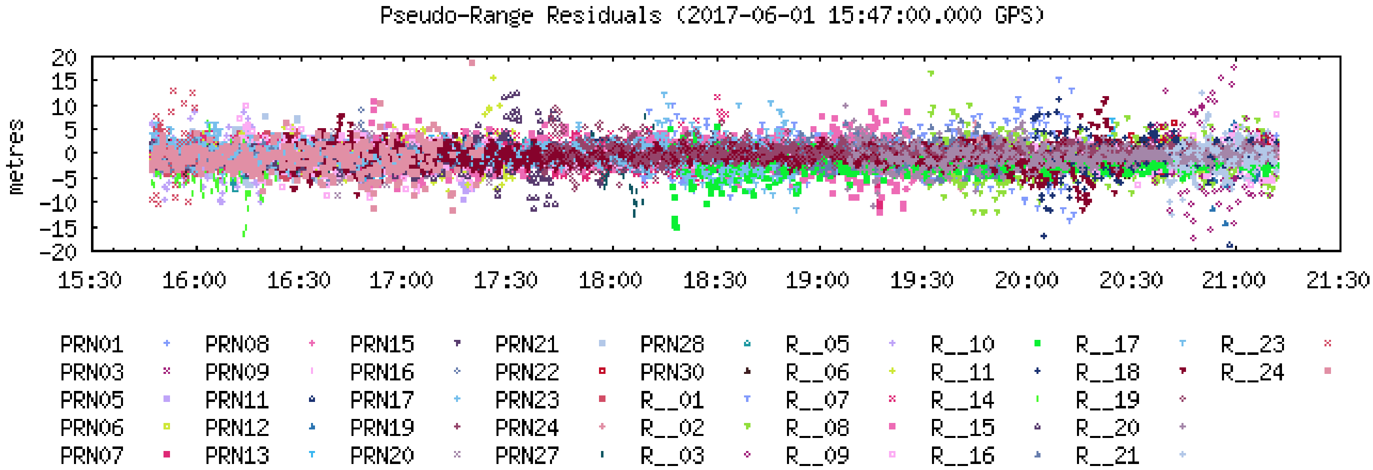

Tracked Satellites and Reset Ambiguities (2017-06-01 15:47:00.000 GPS)
Number of satellite
% Ambiguity Reset
% amb. reset
19
18
17
16
15
14
13
25
20
15
10
5
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30



Ambiguities (2017-06-01 15:47:00.000 GPS)
metres
20
15
10
5
0
-5
-10
-15
-20
15:30 16:00 16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00 20:30 21:00 21:30
PRN01 PRN08 PRN15 PRN21 PRN28 R__05 R__10 R__17 R__23
PRN03 PRN09 PRN16 PRN22 PRN30 R__06 R__11 R__18 R__24
PRN05 PRN11 PRN17 PRN23 R__01 R__07 R__14 R__19
PRN06 PRN12 PRN19 PRN24 R__02 R__08 R__15 R__20
PRN07 PRN13 PRN20 PRN27 R__03 R__09 R__16 R__21



Carrier-Phase Residuals (2017-06-01 15:47:00.000 GPS)
metres
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
15:30 16:00 16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00 20:30 21:00 21:30
PRN01 PRN08 PRN15 PRN21 PRN28 R__05 R__10 R__17 R__23
PRN03 PRN09 PRN16 PRN22 PRN30 R__06 R__11 R__18 R__24
PRN05 PRN11 PRN17 PRN23 R__01 R__07 R__14 R__19
PRN06 PRN12 PRN19 PRN24 R__02 R__08 R__15 R__20
PRN07 PRN13 PRN20 PRN27 R__03 R__09 R__16 R__21



Pseudo-Range Residuals (2017-06-01 15:47:00.000 GPS)
metres
20
15
10
5
0
-5
-10
-15
-20
15:30 16:00 16:30 17:00 17:30 18:00 18:30 19:00 19:30 20:00 20:30 21:00 21:30
PRN01 PRN08 PRN15 PRN21 PRN28 R__05 R__10 R__17 R__23
PRN03 PRN09 PRN16 PRN22 PRN30 R__06 R__11 R__18 R__24
PRN05 PRN11 PRN17 PRN23 R__01 R__07 R__14 R__19
PRN06 PRN12 PRN19 PRN24 R__02 R__08 R__15 R__20
PRN07 PRN13 PRN20 PRN27 R__03 R__09 R__16 R__21

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EMail: nrcan.geodeticinformationservices.rncan@canada.ca
Phone:343-292-6617

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CSRS-PPP (V 1.05 11216)

LA9

Data Start	Data End	Duration of Observations
2017-05-31 15:37:30.000	2017-05-31 20:08:15.000	4h 30m 45.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.010m		2.0m / 1.435m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	15.00 sec / 15.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TPSGR5 NONE	L1= 0.221 m L2= 0.218 m	1.440 m

(APC = antenna phase center; ARP = antenna reference point)

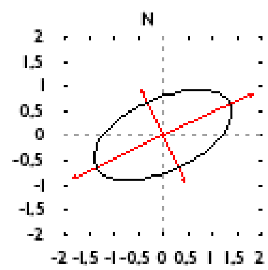
Estimated Position for LA9151p.17O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997)	57º 33’ 18.1971’’	-105º 20’ 19.7196’’	484.198 m
Sigmas(95%)	0.007 m	0.011 m	0.022 m
Apriori	57º 33’ 18.204’’	-105º 20’ 19.803’’	484.162 m
Estimated - Apriori	-0.207 m	1.393 m	0.036 m

Orthometric Height
CGVD28 (HTv2.0)

515.312 m
(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.502cm
semi-minor: 0.730cm
semi-major azimuth: 65º 23’ 47.07’’



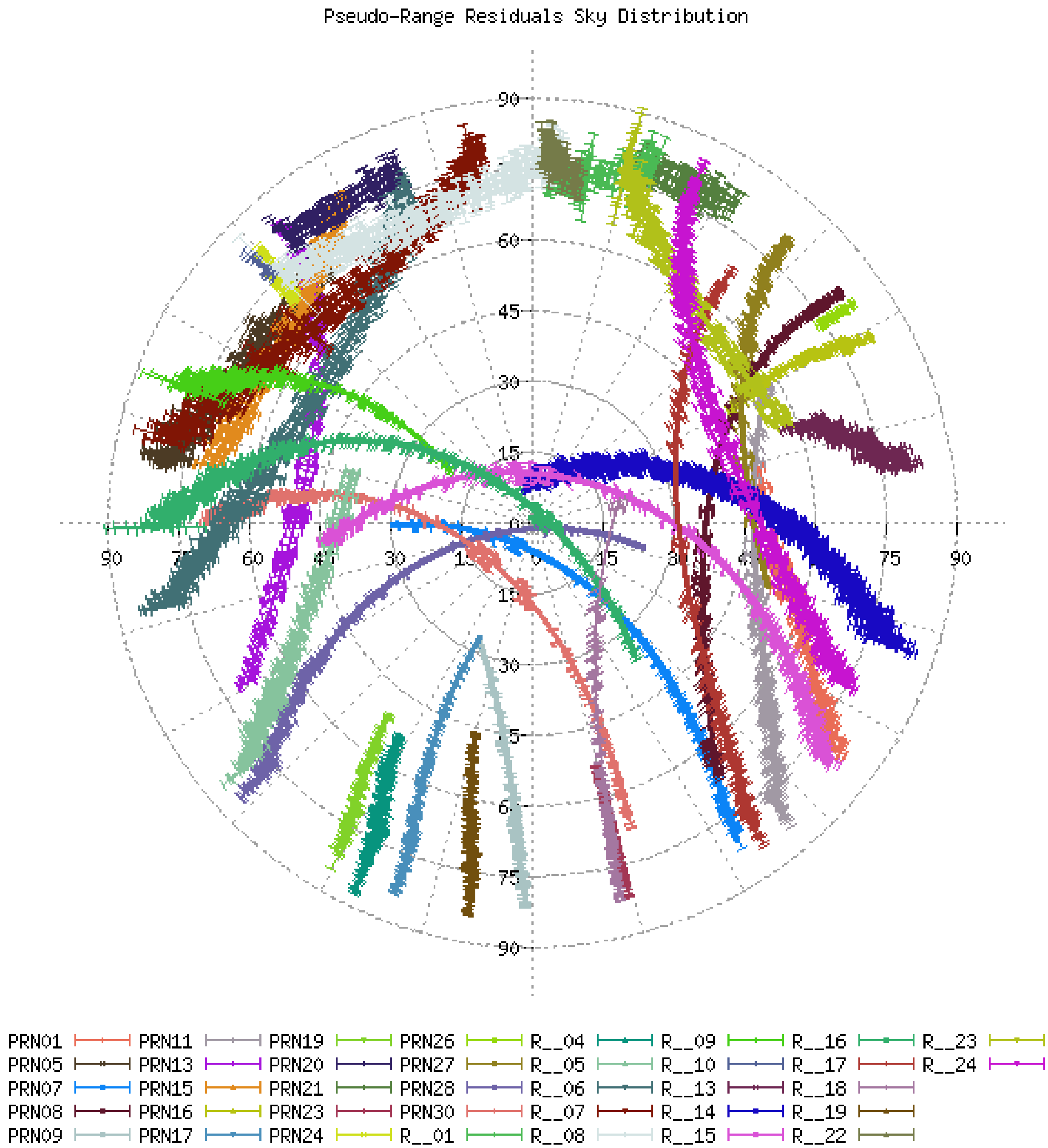
UTM (North) Zone 13

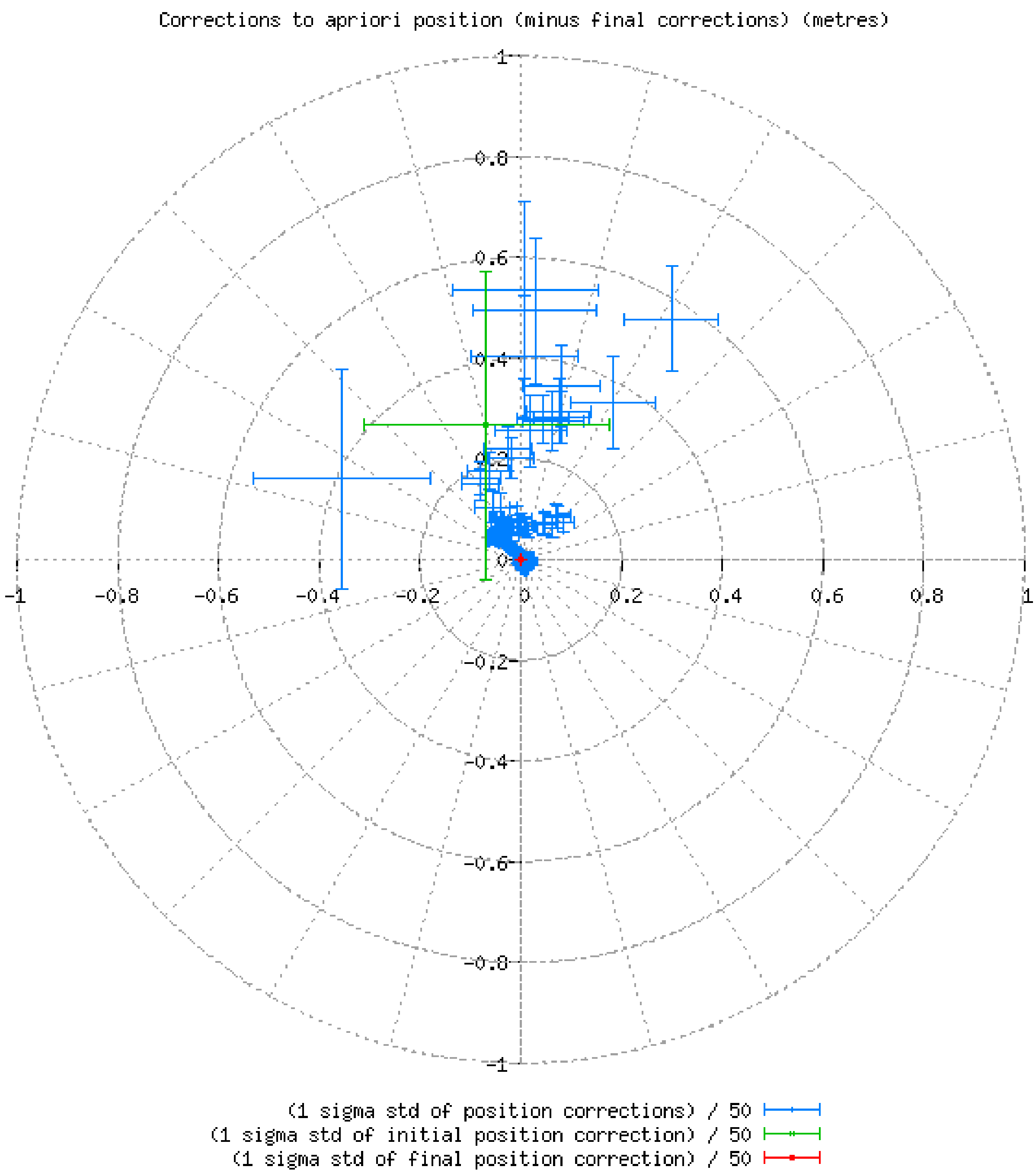
6379225.363m (N) 479725.394m (E)

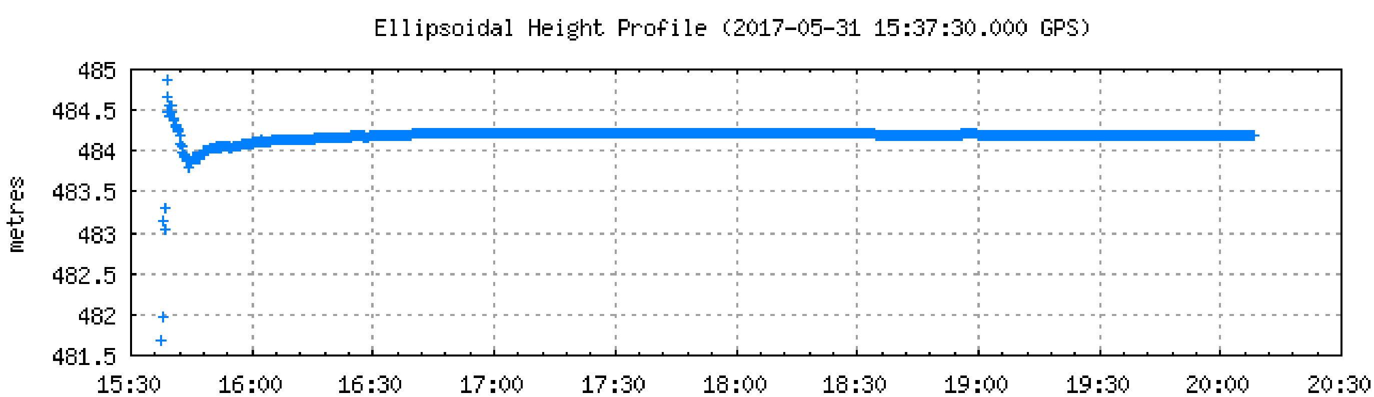
Scale Factors
0.99960504 (point)
0.99952908 (combined)

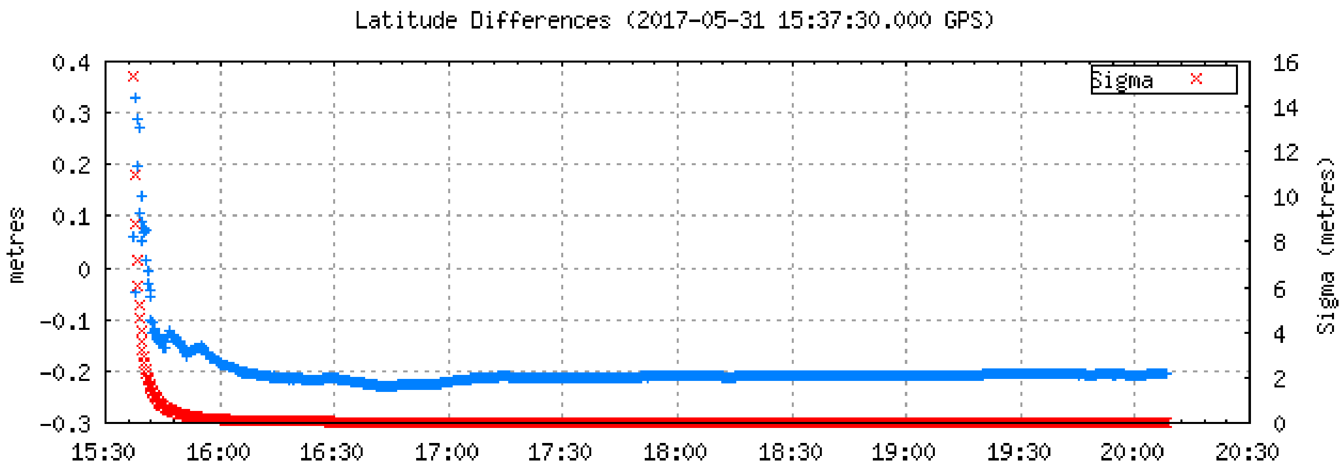
(Coordinates from RINEX file used as apriori position)

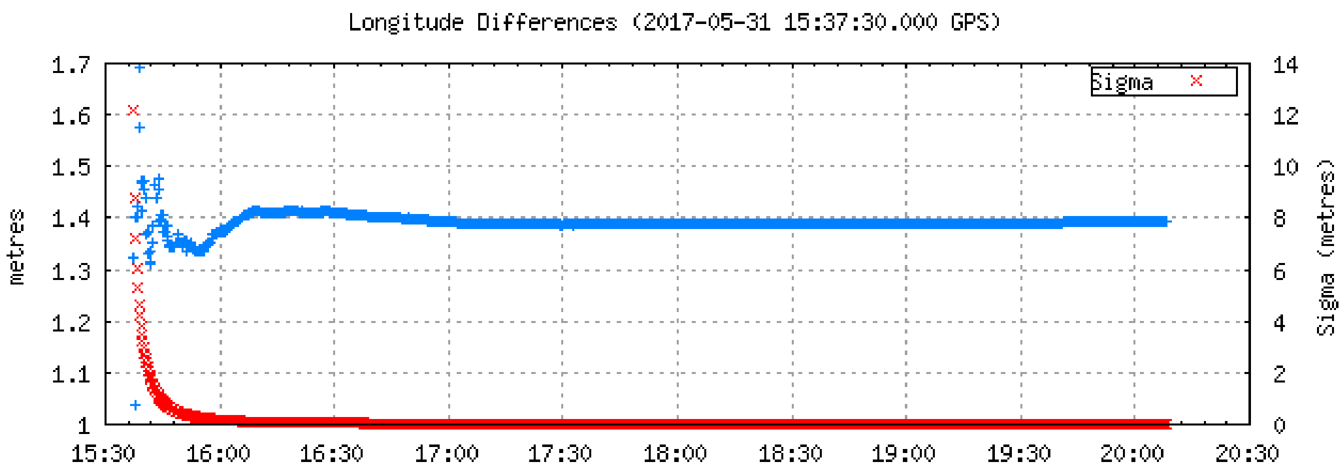
Estimated Parameters & Observations Statistics

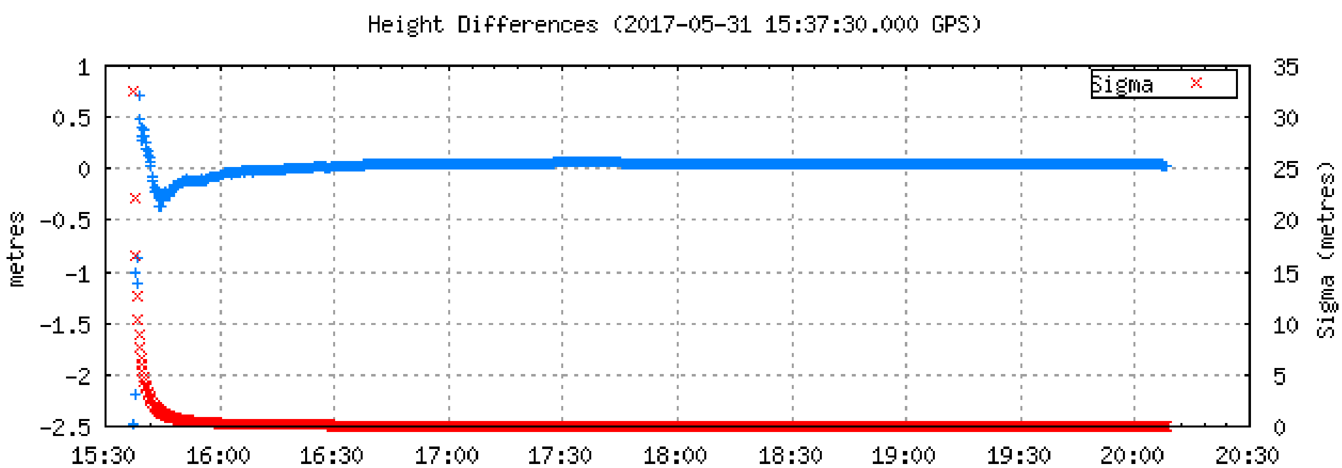


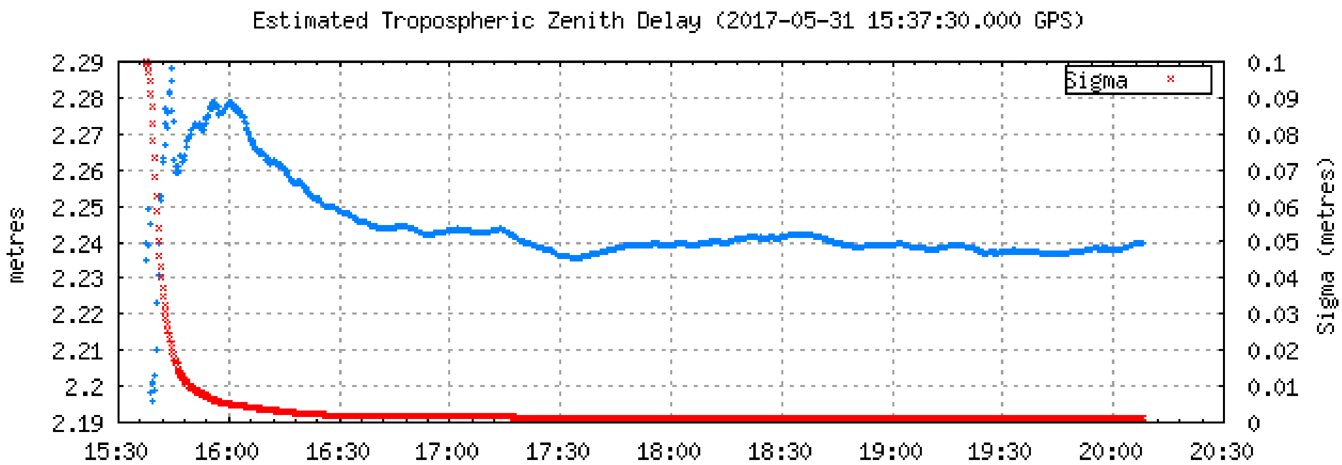

Corrections to apriori position (minus final corrections) (metres)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
(1 sigma std of position corrections) / 50
(1 sigma std of initial position correction) / 50
(1 sigma std of final position correction) / 50

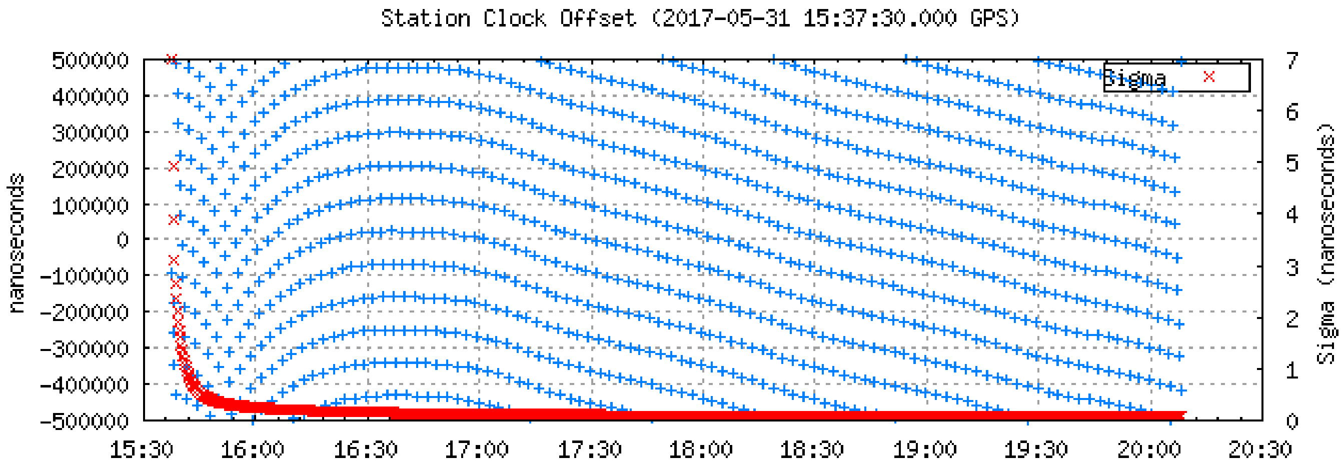

Ellipsoidal Height Profile (2017-05-31 15:37:30.000 GPS)
metres
485
484.5
484
483.5
483
482.5
482
481.5
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30

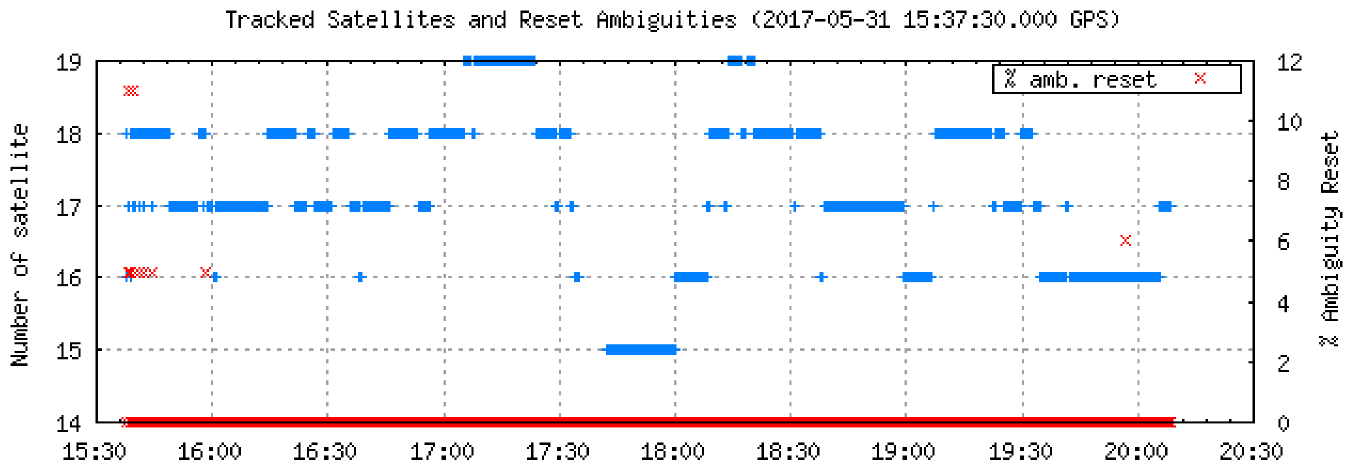

Latitude Differences (2017-05-31 15:37:30.000 GPS)
metres
Sigma (metres)
Sigma
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
16
14
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30


Longitude Differences (2017-05-31 15:37:30.000 GPS)
metres
Sigma (metres)
Sigma
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
14
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30

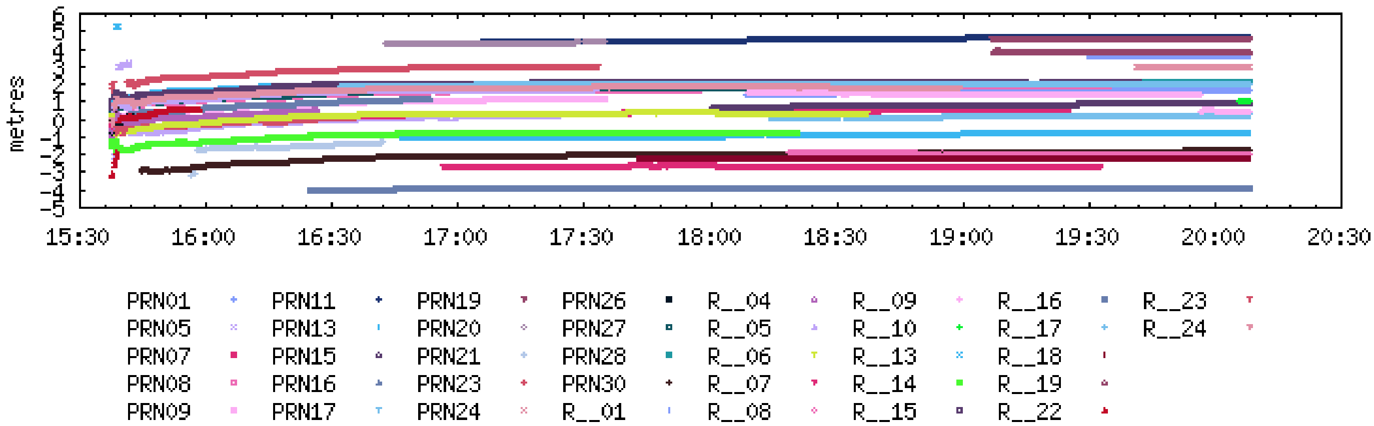

Height Differences (2017-05-31 15:37:30.000 GPS)
metres
Sigma (metres)
Sigma
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
35
30
25
20
15
10
5
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30


Estimated Tropospheric Zenith Delay (2017-05-31 15:37:30.000 GPS)
metres
Sigma (metres)
Sigma
2.29
2.28
2.27
2.26
2.25
2.24
2.23
2.22
2.21
2.2
2.19
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30

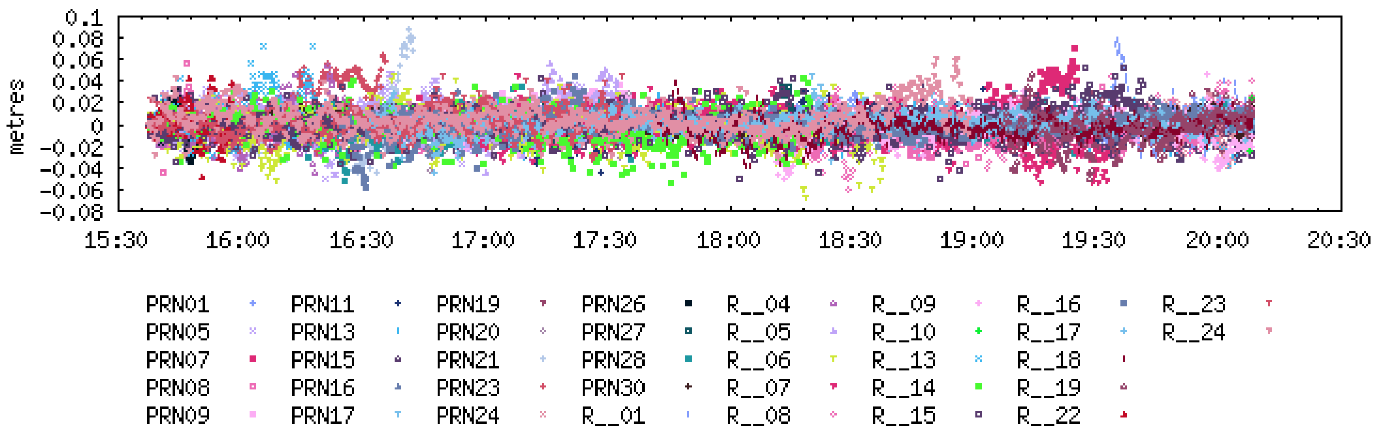

Station Clock Offset (2017-05-31 15:37:30.000 GPS)
nanoseconds
Sigma (nanoseconds)
Sigma
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
7
6
5
4
3
2
1
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30


Tracked Satellites and Reset Ambiguities (2017-05-31 15:37:30.000 GPS)
Number of satellite
% Ambiguity Reset
% amb. reset
19
18
17
16
15
14
12
10
8
6
4
2
0
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30

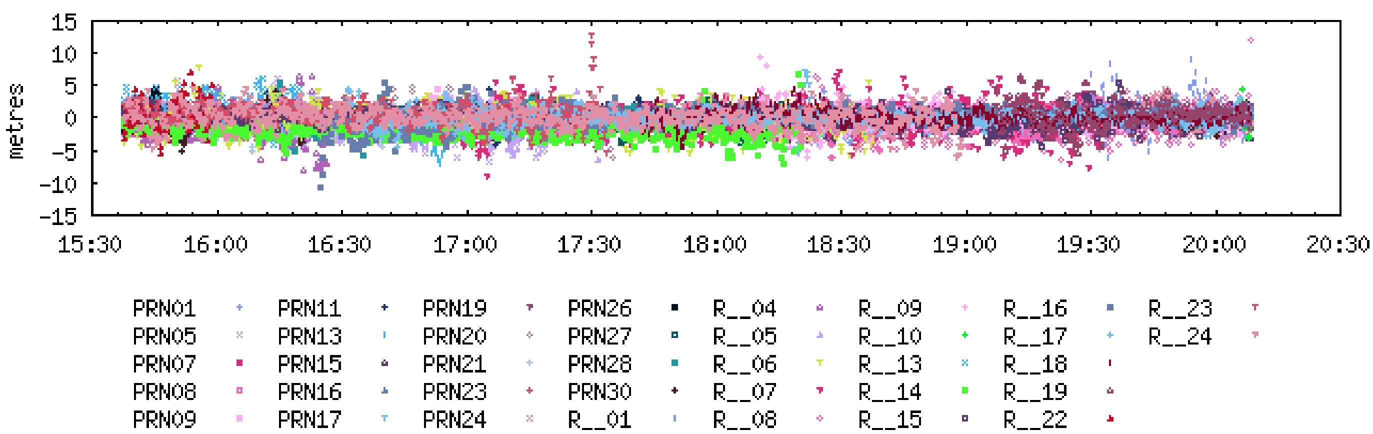
Ambiguities (2017-05-31 15:37:30.000 GPS)



Carrier-Phase Residuals (2017-05-31 15:37:30.000 GPS)



Pseudo-Range Residuals (2017-05-31 15:37:30.000 GPS)



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Phone:343-292-6617

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Canada

CSRS-PPP (V 1.05 11216)

PA2

Data Start	Data End	Duration of Observations
2017-05-30 15:19:45.000	2017-05-30 23:52:00.000	8h 32m 15.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.014m		2.0m / 2.594m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	15.00 sec / 15.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TPSGR5 NONE	L1= 0.221 m L2= 0.218 m	1.303 m

(APC = antenna phase center; ARP = antenna reference point)

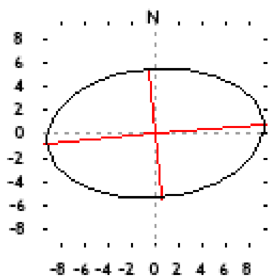
Estimated Position for PA2150p.17O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997)	57º 32’ 12.2526’’	-105º 22’ 56.6452’’	480.270 m
Sigmas(95%)	0.004 m	0.007 m	0.017 m
Apriori	57º 32’ 12.253’’	-105º 22’ 56.731’’	480.126 m
Estimated - Apriori	-0.019 m	1.422 m	0.144 m

Orthometric Height
CGVD28 (HTv2.0)

511.303 m
(click for height reference information)

95% Error Ellipse (mm)
semi-major: 9.266mm
semi-minor: 5.453mm
semi-major azimuth: 84º 48’ 31.47’’



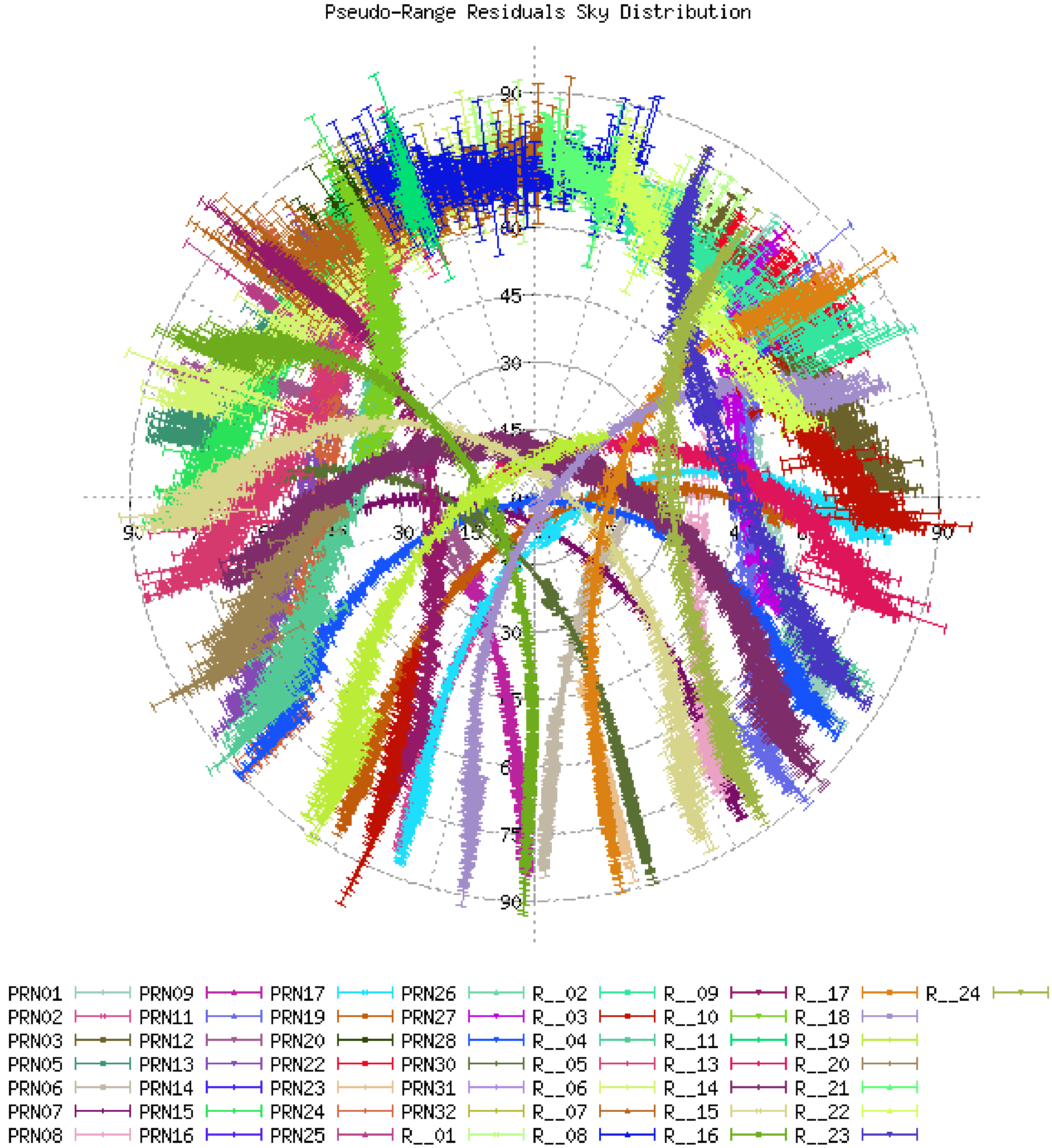
UTM (North) Zone 13

6377199.994m (N) 477105.453m (E)

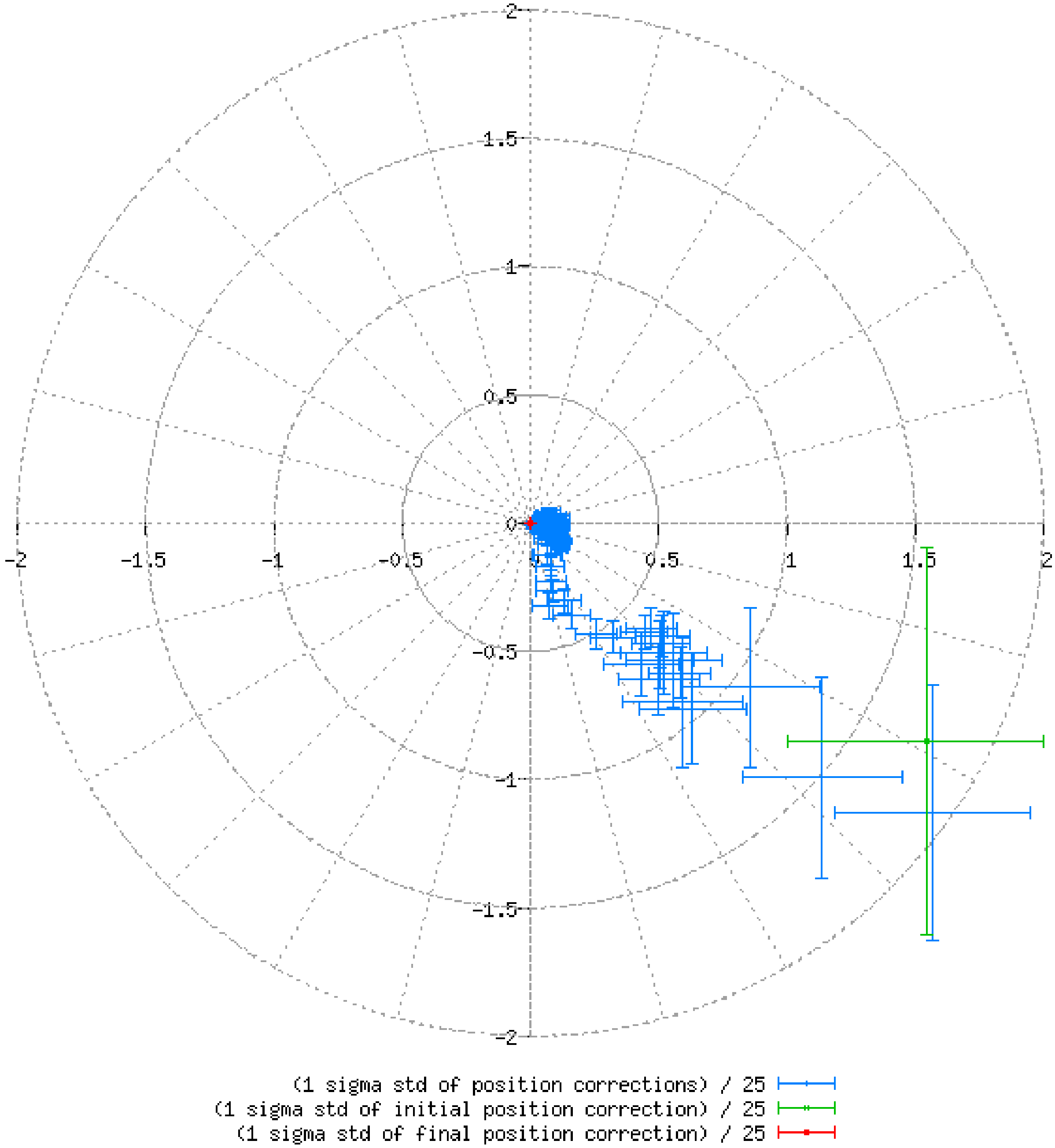
Scale Factors
0.99960643 (point)
0.99953108 (combined)

(Coordinates from RINEX file used as apriori position)

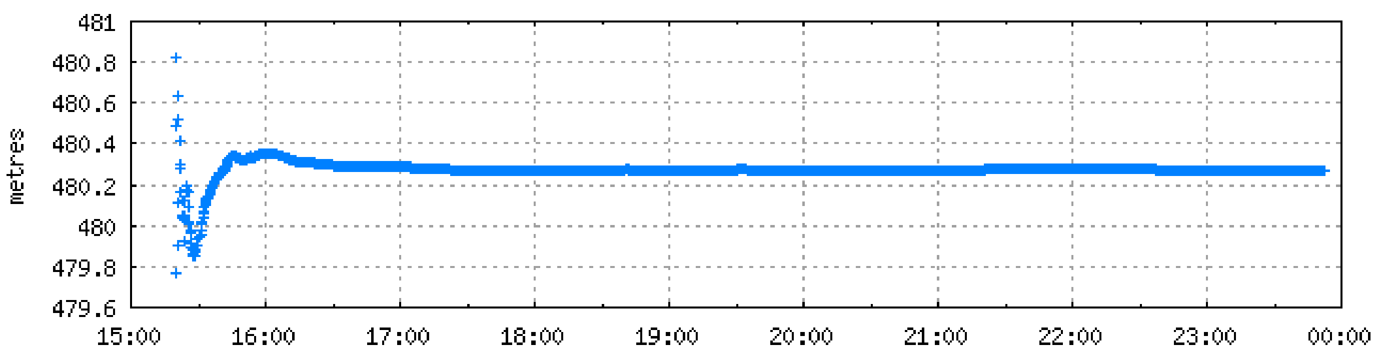
Estimated Parameters & Observations Statistics



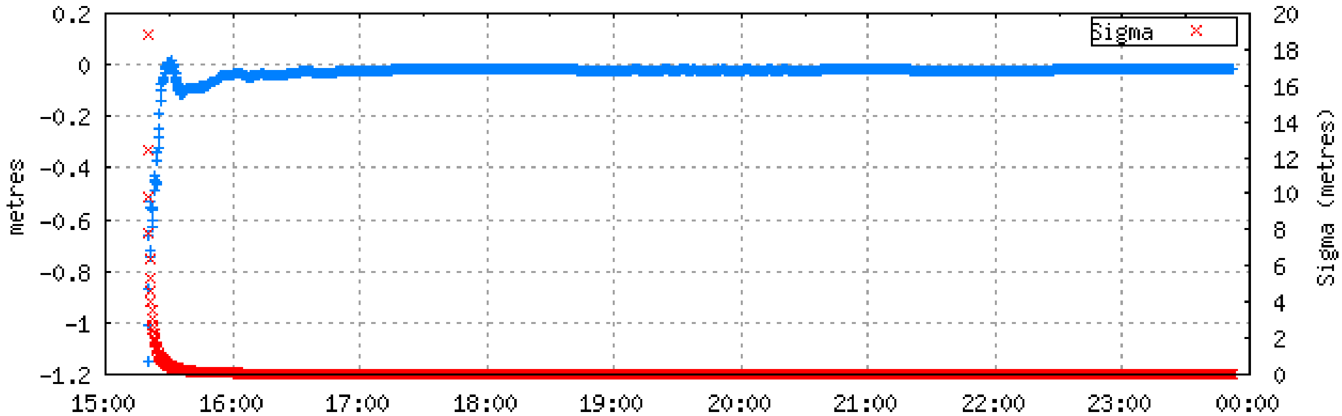
Corrections to apriori position (minus final corrections) (metres)



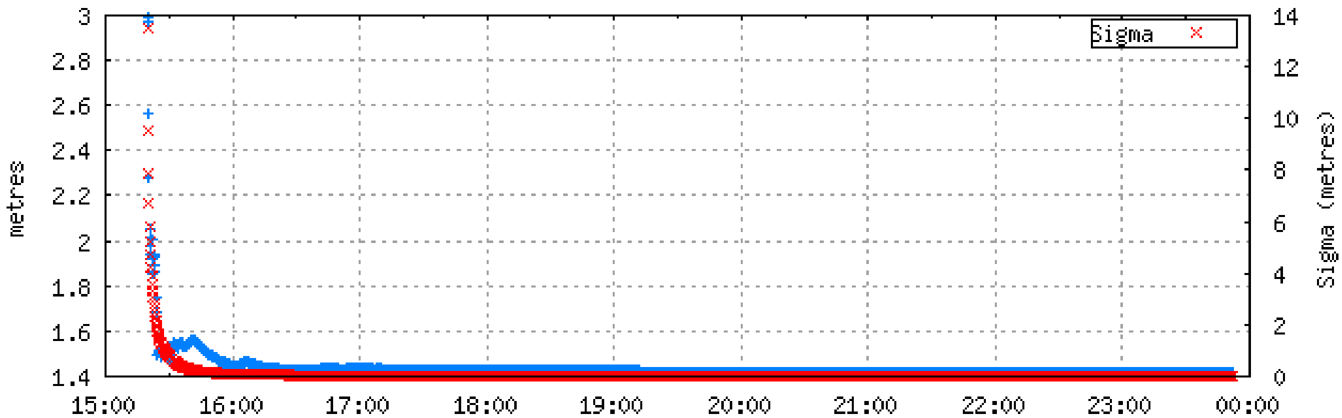
Ellipsoidal Height Profile (2017-05-30 15:19:45.000 GPS)



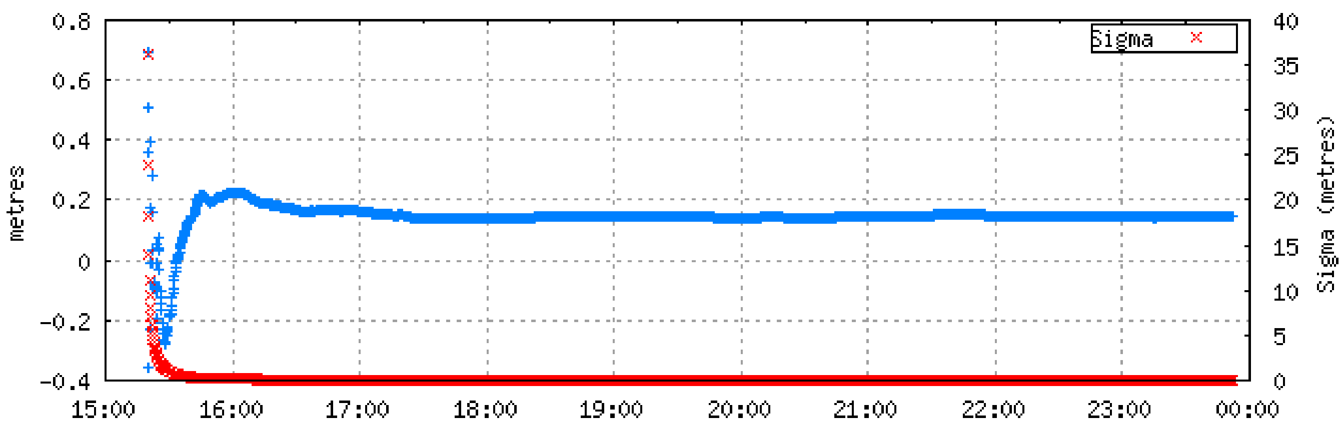
Latitude Differences (2017-05-30 15:19:45.000 GPS)

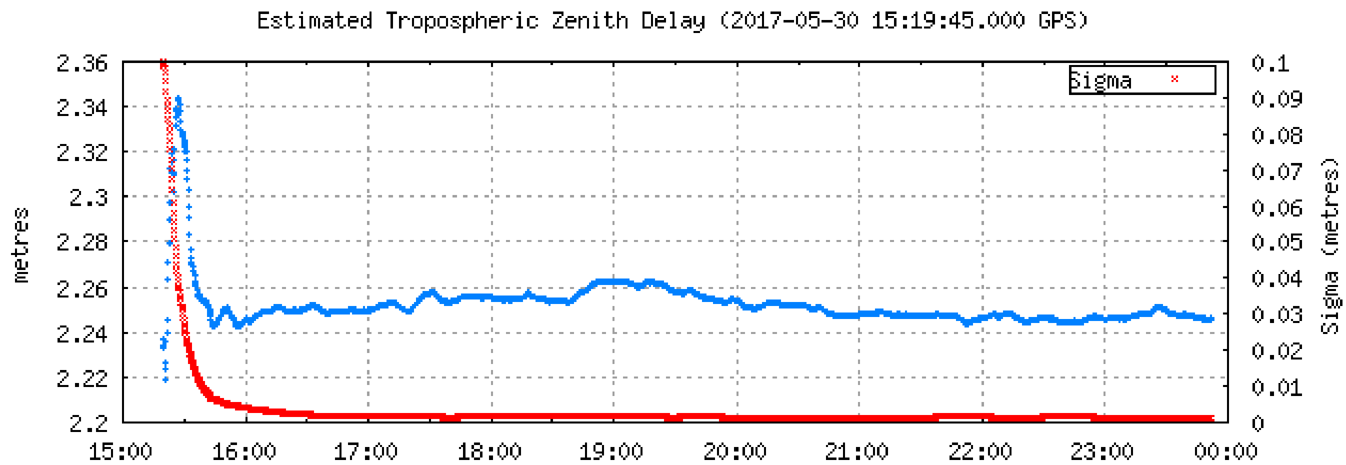


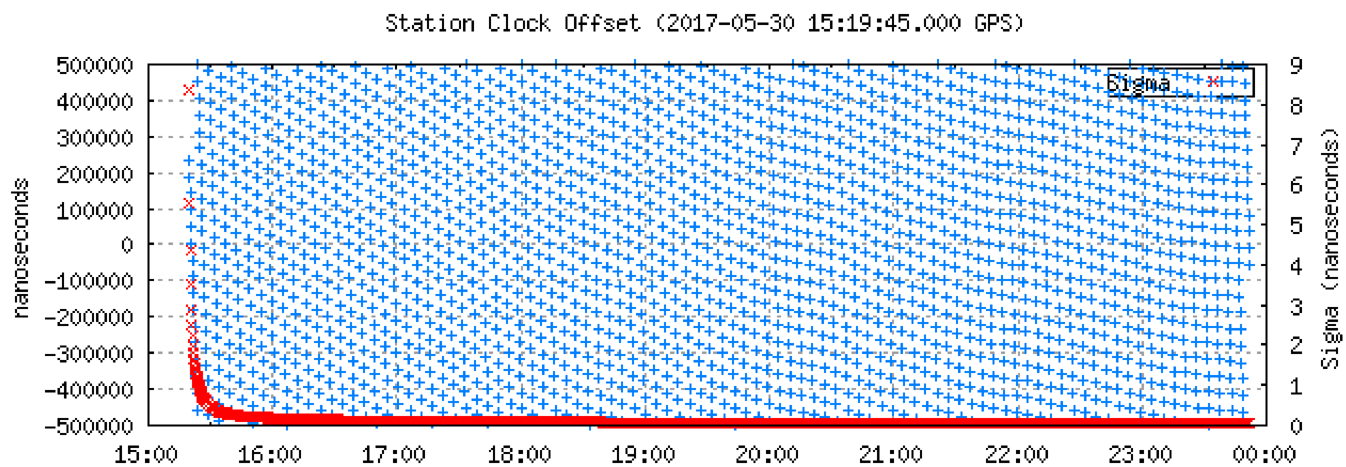
Longitude Differences (2017-05-30 15:19:45.000 GPS)

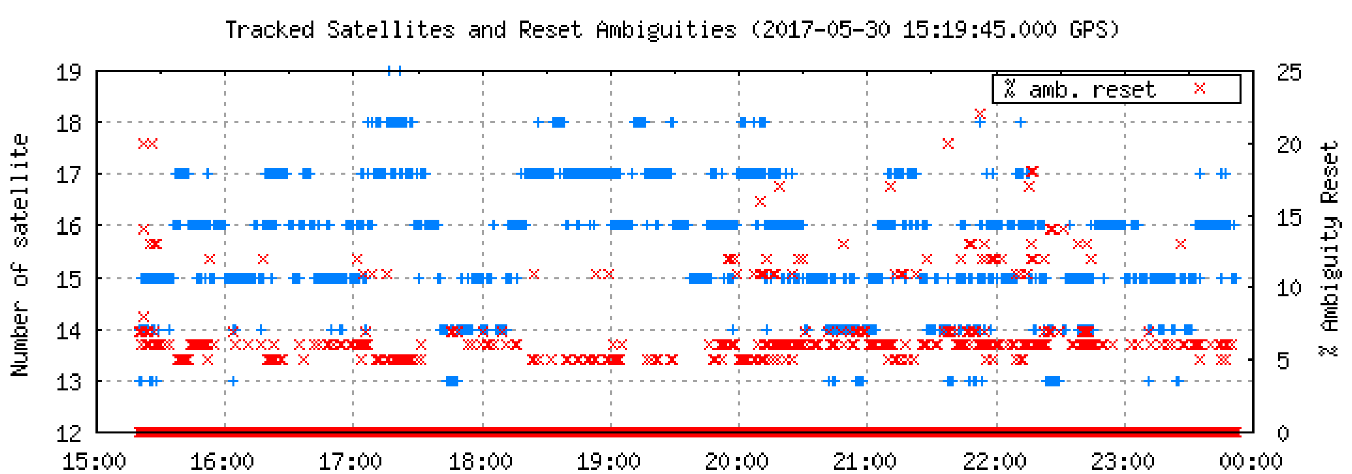


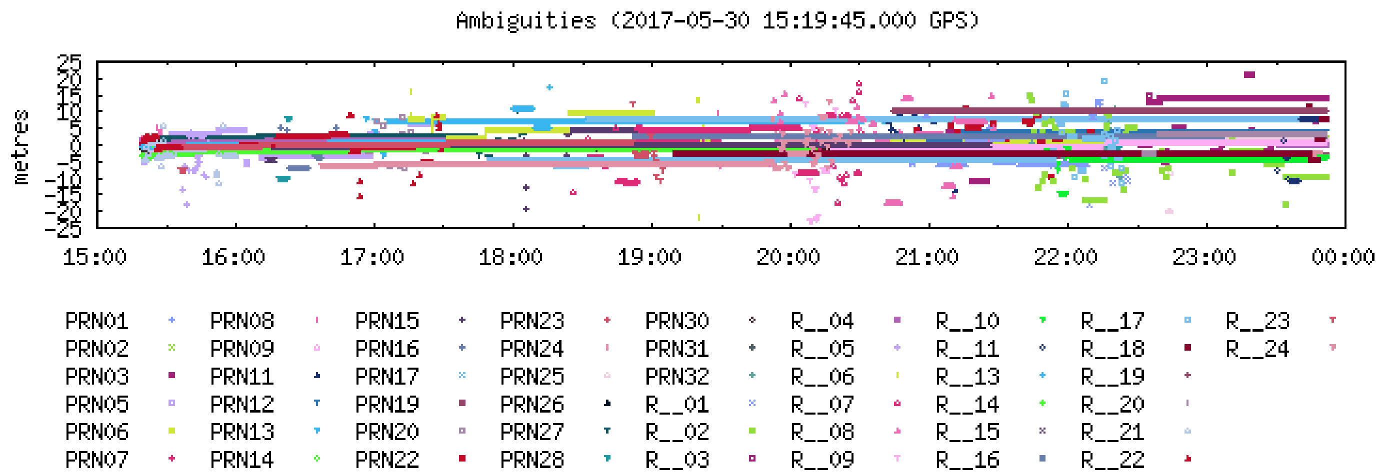
Height Differences (2017-05-30 15:19:45.000 GPS)

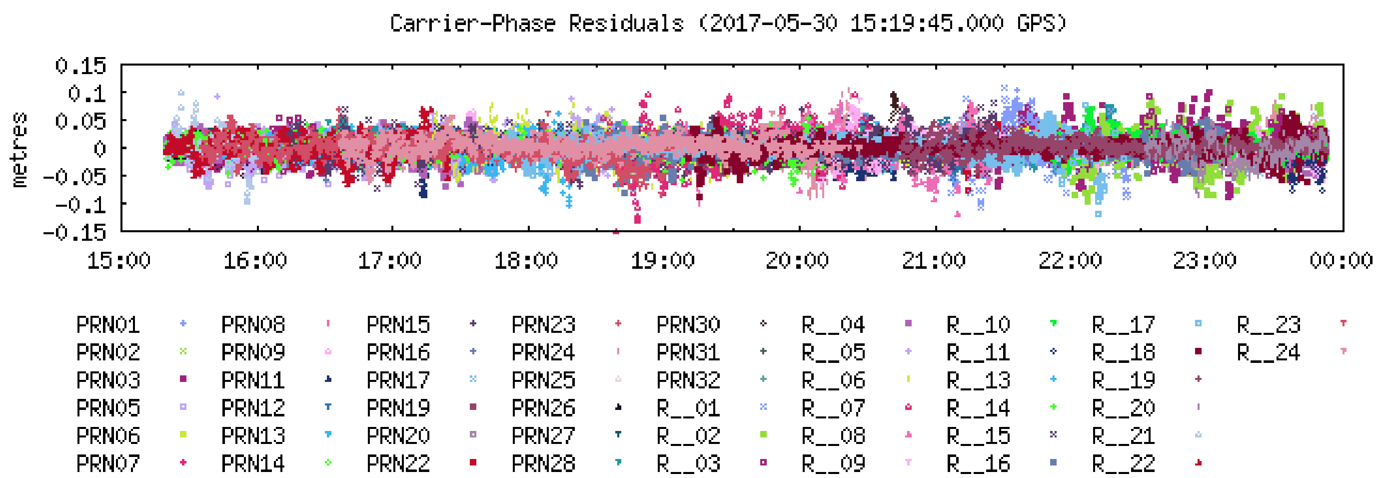


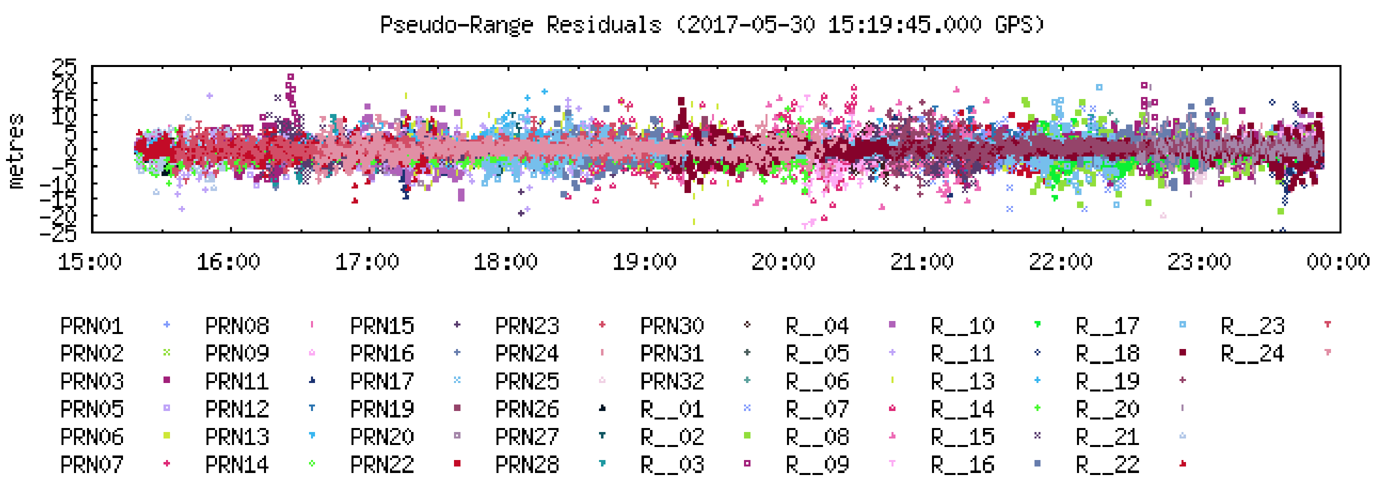

Estimated Tropospheric Zenith Delay (2017-05-30 15:19:45.000 GPS)
metres
Sigma (metres)
Sigma
2.36
2.34
2.32
2.3
2.28
2.26
2.24
2.22
2.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Station Clock Offset (2017-05-30 15:19:45.000 GPS)
nanoseconds
Sigma (nanoseconds)
Sigma
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
9
8
7
6
5
4
3
2
1
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Tracked Satellites and Reset Ambiguities (2017-05-30 15:19:45.000 GPS)
Number of satellite
% Ambiguity Reset
% amb. reset
19
18
17
16
15
14
13
12
25
20
15
10
5
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Ambiguities (2017-05-30 15:19:45.000 GPS)
metres
25 20 15 10 5 0 -5 -10 -15 -20 -25
15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00
PRN01 PRN02 PRN03 PRN05 PRN06 PRN07
PRN08 PRN09 PRN11 PRN12 PRN13 PRN14
PRN15 PRN16 PRN17 PRN19 PRN20 PRN22
PRN23 PRN24 PRN25 PRN26 PRN27 PRN28
PRN30 PRN31 PRN32 R__01 R__02 R__03
R__04 R__05 R__06 R__07 R__08 R__09
R__10 R__11 R__13 R__14 R__15 R__16
R__17 R__18 R__19 R__20 R__21 R__22
R__23 R__24


Carrier-Phase Residuals (2017-05-30 15:19:45.000 GPS)
metres
0.15 0.1 0.05 0 -0.05 -0.1 -0.15
15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00
PRN01 PRN02 PRN03 PRN05 PRN06 PRN07
PRN08 PRN09 PRN11 PRN12 PRN13 PRN14
PRN15 PRN16 PRN17 PRN19 PRN20 PRN22
PRN23 PRN24 PRN25 PRN26 PRN27 PRN28
PRN30 PRN31 PRN32 R__01 R__02 R__03
R__04 R__05 R__06 R__07 R__08 R__09
R__10 R__11 R__13 R__14 R__15 R__16
R__17 R__18 R__19 R__20 R__21 R__22
R__23 R__24


Pseudo-Range Residuals (2017-05-30 15:19:45.000 GPS)
metres
25 20 15 10 5 0 -5 -10 -15 -20 -25
15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00
PRN01 PRN02 PRN03 PRN05 PRN06 PRN07
PRN08 PRN09 PRN11 PRN12 PRN13 PRN14
PRN15 PRN16 PRN17 PRN19 PRN20 PRN22
PRN23 PRN24 PRN25 PRN26 PRN27 PRN28
PRN30 PRN31 PRN32 R__01 R__02 R__03
R__04 R__05 R__06 R__07 R__08 R__09
R__10 R__11 R__13 R__14 R__15 R__16
R__17 R__18 R__19 R__20 R__21 R__22
R__23 R__24

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Phone:343-292-6617

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CSRS-PPP (V 1.05 11216)

PA3

Data Start	Data End	Duration of Observations
2017-05-30 15:57:00.000	2017-05-30 23:34:00.000	7h 36m 60.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.012m		2.0m / 2.020m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	15.00 sec / 15.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TPSGR5 NONE	L1= 0.221 m L2= 0.218 m	1.327 m

(APC = antenna phase center; ARP = antenna reference point)

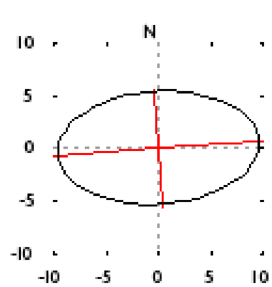
Estimated Position for PA3150p.17O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997)	57º 32’ 26.9749’’	-105º 23’ 36.1688’’	486.823 m
Sigmas(95%)	0.004 m	0.008 m	0.016 m
Apriori	57º 32’ 26.976’’	-105º 23’ 36.263’’	486.523 m
Estimated - Apriori	-0.039 m	1.567 m	0.299 m

Orthometric Height
CGVD28 (HTv2.0)

517.851 m
(click for height reference information)

95% Error Ellipse (mm)
semi-major: 9.630mm
semi-minor: 5.345mm
semi-major azimuth: 86º 16’ 41.17’’



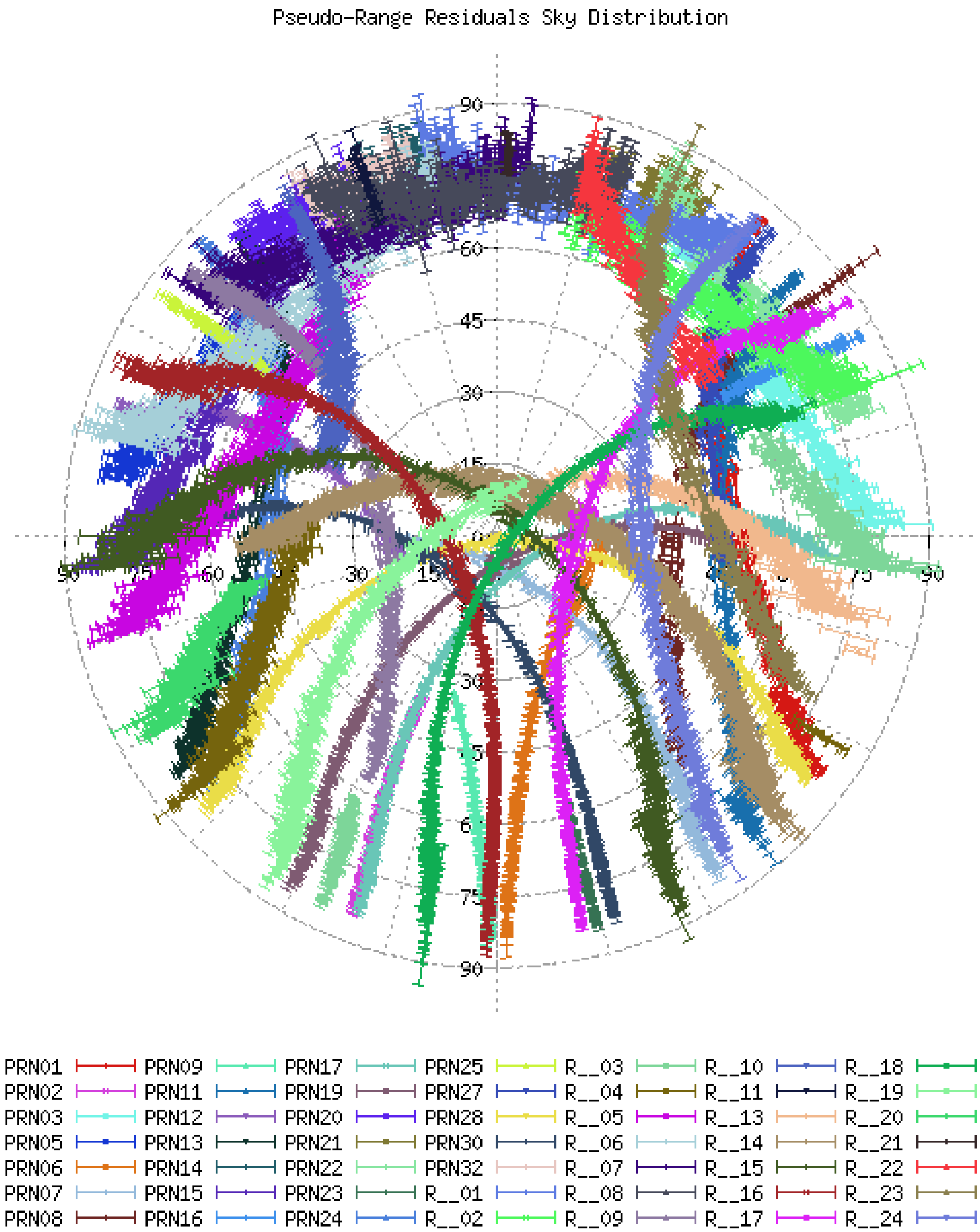
UTM (North) Zone 13

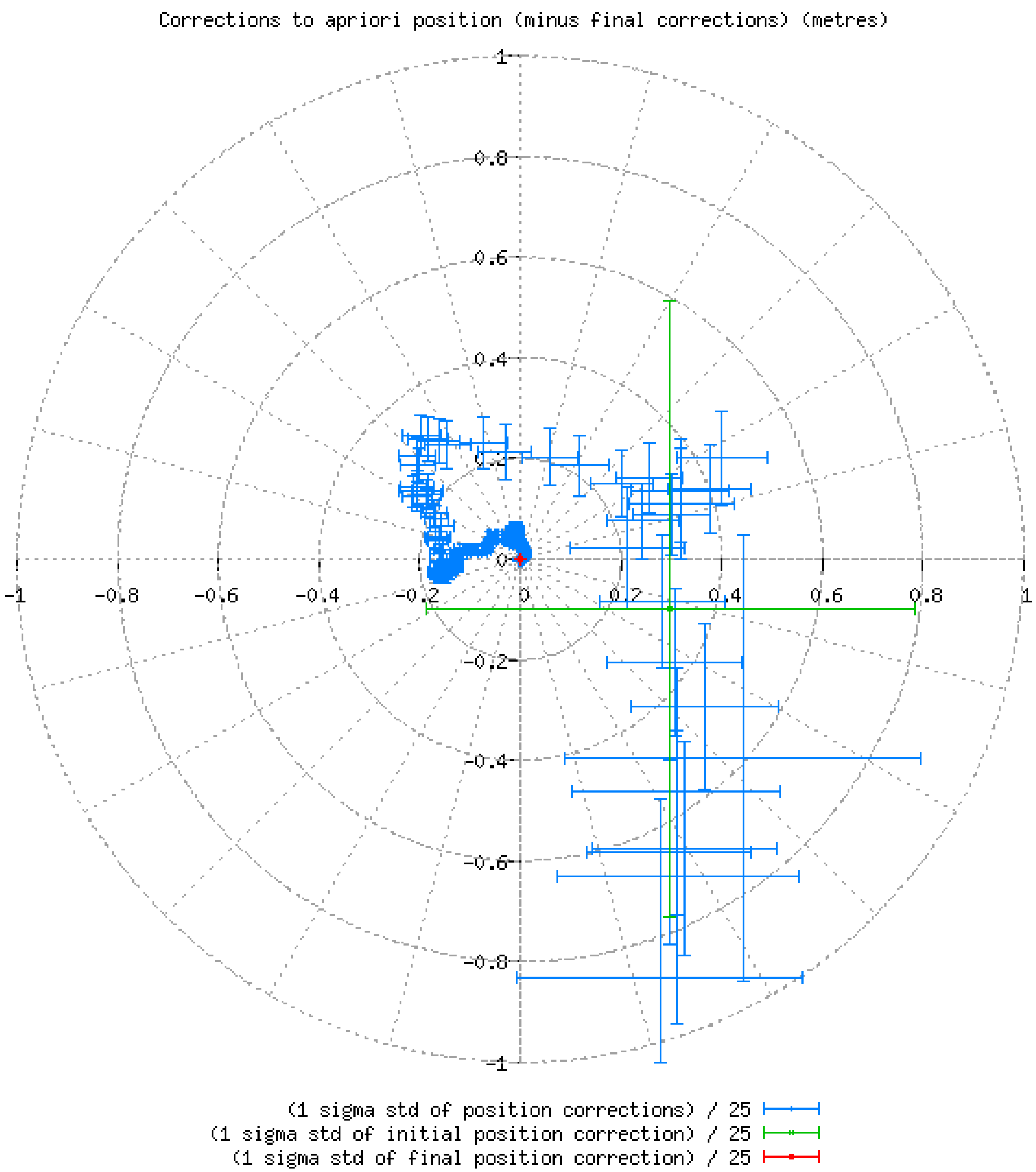
6377659.010m (N) 476450.790m (E)

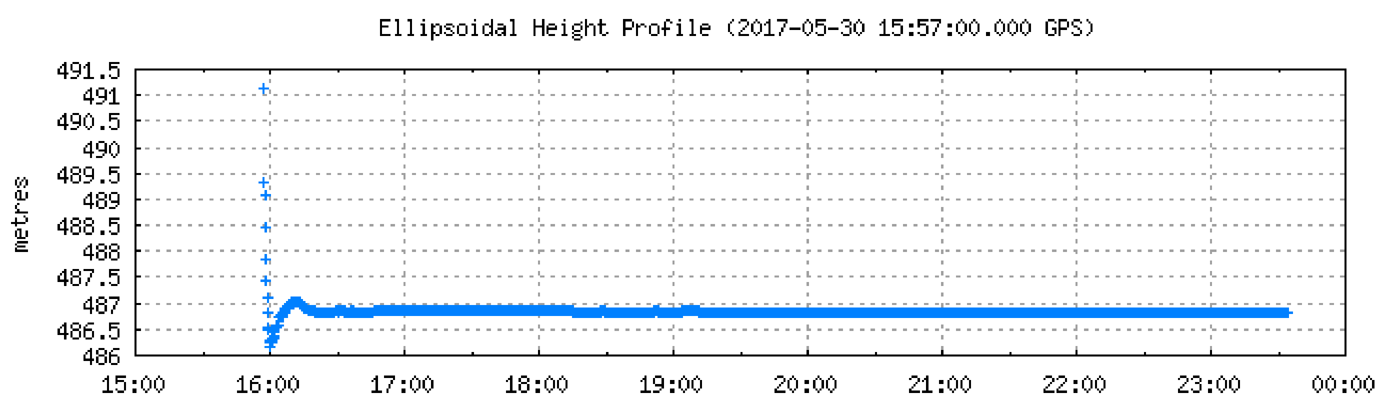
Scale Factors
0.99960680 (point)
0.99953042 (combined)

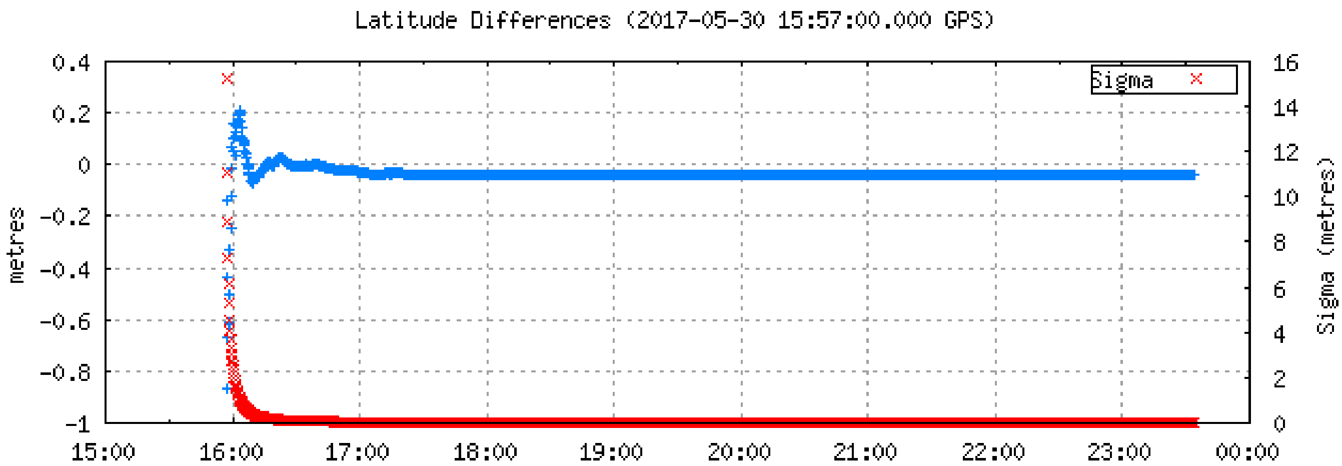
(Coordinates from RINEX file used as apriori position)

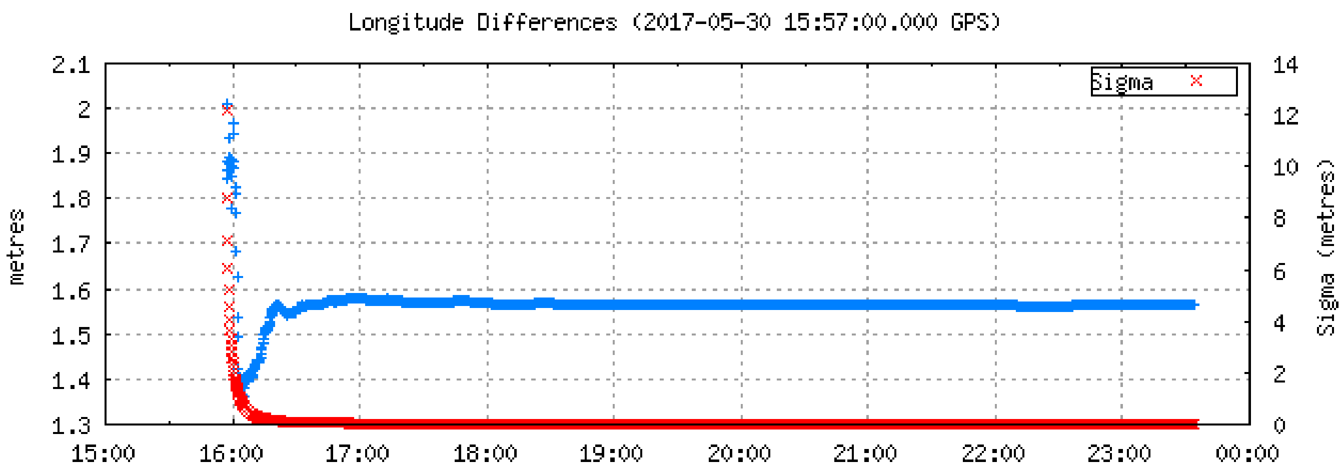
Estimated Parameters & Observations Statistics

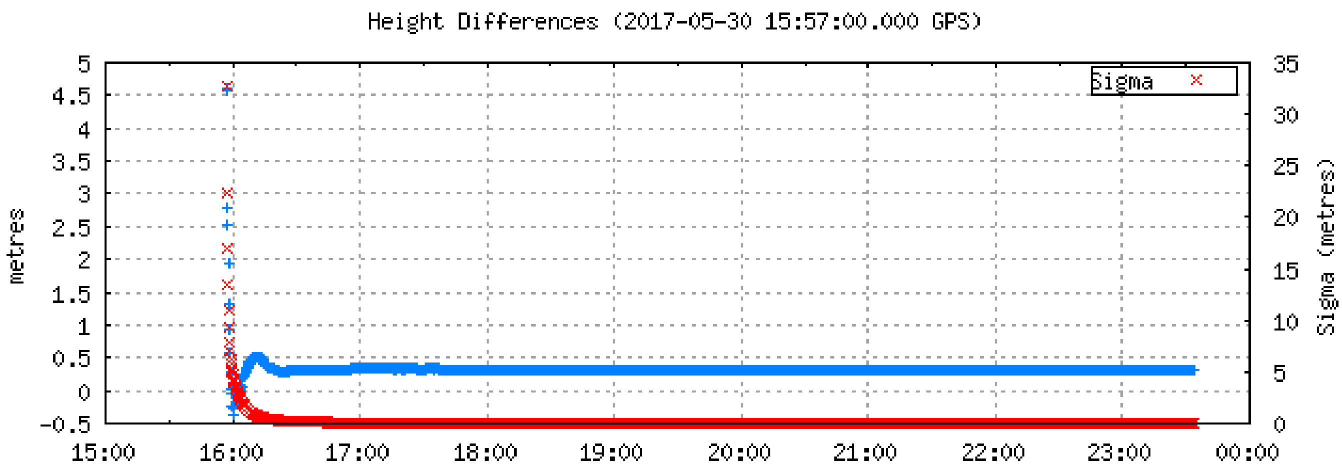


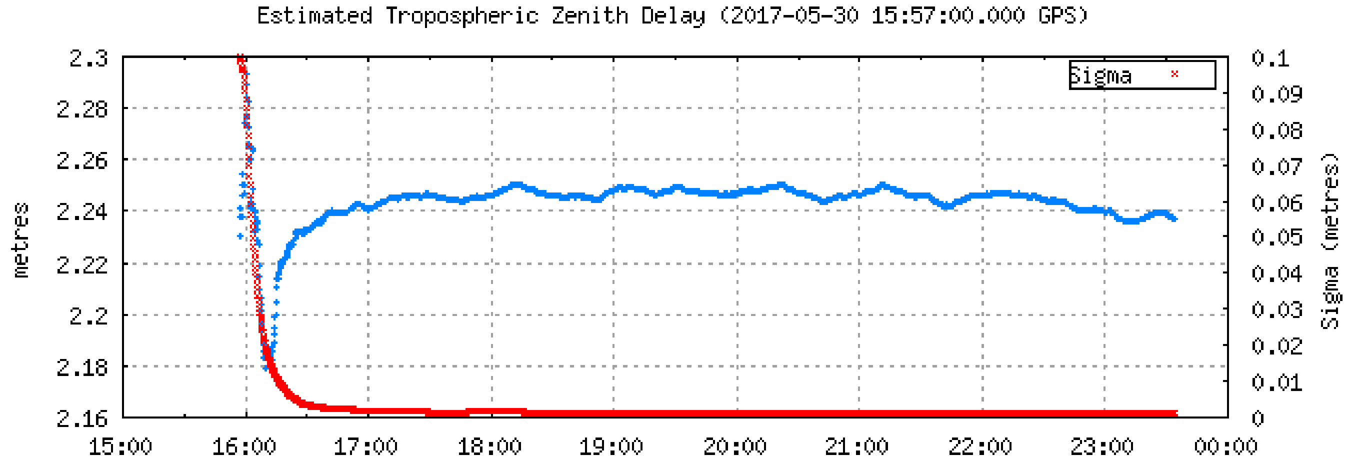

Corrections to apriori position (minus final corrections) (metres)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
(1 sigma std of position corrections) / 25
(1 sigma std of initial position correction) / 25
(1 sigma std of final position correction) / 25

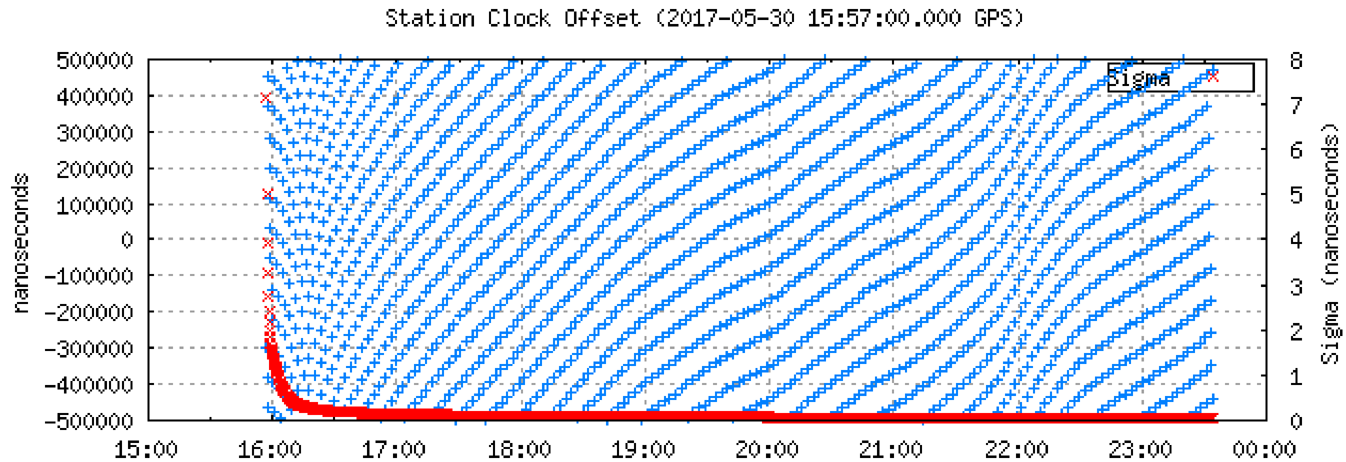

Ellipsoidal Height Profile (2017-05-30 15:57:00.000 GPS)
metres
491.5
491
490.5
490
489.5
489
488.5
488
487.5
487
486.5
486
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

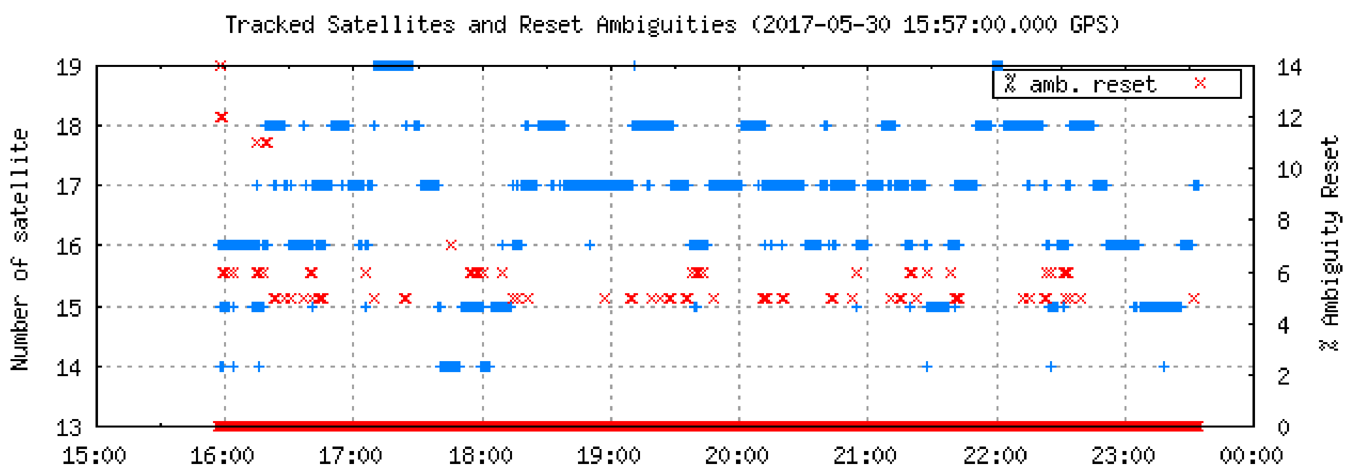

Latitude Differences (2017-05-30 15:57:00.000 GPS)
metres
Sigma (metres)
Sigma
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
16
14
12
10
8
6
4
2
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Longitude Differences (2017-05-30 15:57:00.000 GPS)
metres
Sigma (metres)
Sigma
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
14
12
10
8
6
4
2
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

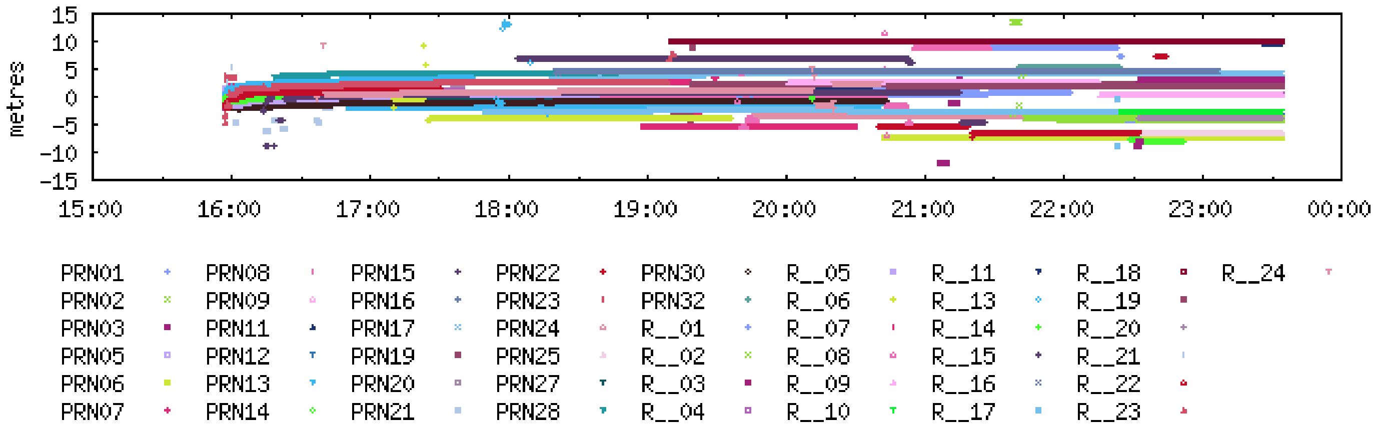

Height Differences (2017-05-30 15:57:00.000 GPS)
metres
Sigma (metres)
Sigma
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
35
30
25
20
15
10
5
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Estimated Tropospheric Zenith Delay (2017-05-30 15:57:00.000 GPS)
Sigma
metres
Sigma (metres)
2.3
2.28
2.26
2.24
2.22
2.2
2.18
2.16
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

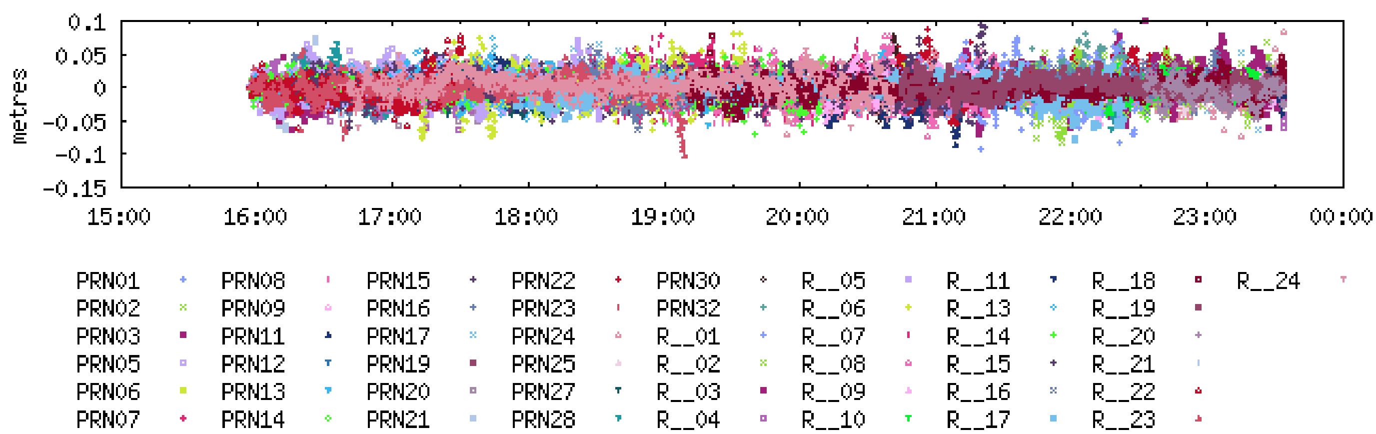

Station Clock Offset (2017-05-30 15:57:00.000 GPS)
Sigma
nanoseconds
Sigma (nanoseconds)
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
8
7
6
5
4
3
2
1
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00


Tracked Satellites and Reset Ambiguities (2017-05-30 15:57:00.000 GPS)
% amb. reset
Number of satellite
% Ambiguity Reset
19
18
17
16
15
14
13
14
12
10
8
6
4
2
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00

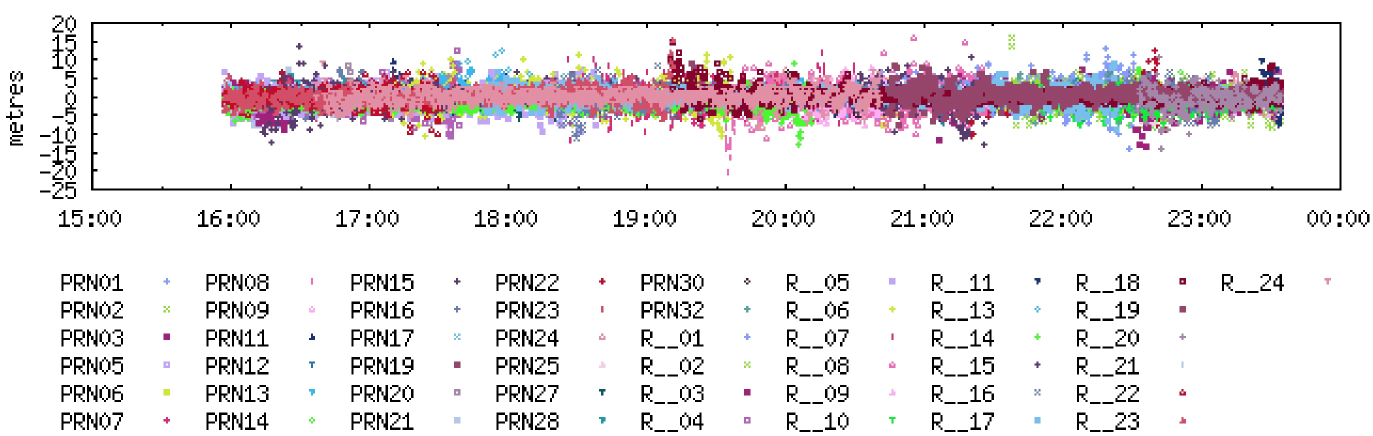
Ambiguities (2017-05-30 15:57:00.000 GPS)



Carrier-Phase Residuals (2017-05-30 15:57:00.000 GPS)



Pseudo-Range Residuals (2017-05-30 15:57:00.000 GPS)



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Phone:343-292-6617

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CSRS-PPP (V 1.05 11216)

SB5

Data Start	Data End	Duration of Observations
2017-05-29 23:07:00.000	2017-05-30 01:49:00.000	2h 42m 0.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.010m		2.0m / 1.887m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TPSGR5 NONE	L1= 0.221 m L2= 0.218 m	1.242 m

(APC = antenna phase center; ARP = antenna reference point)

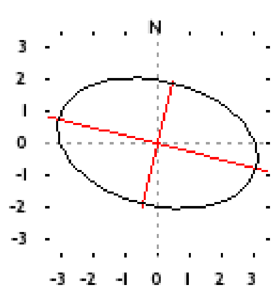
Estimated Position for SB5149x.17O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (1997)	57º 29’ 47.4940’’	-105º 25’ 23.7269’’	487.757 m
Sigmas(95%)	0.016 m	0.025 m	0.044 m
Apriori	57º 29’ 47.490’’	-105º 25’ 23.821’’	487.571 m
Estimated - Apriori	0.126 m	1.575 m	0.186 m

Orthometric Height
CGVD28 (HTv2.0)

518.673 m
(click for height reference information)

95% Error Ellipse (cm)
semi-major: 3.203cm
semi-minor: 1.946cm
semi-major azimuth: 103º 35’ 31.03’’



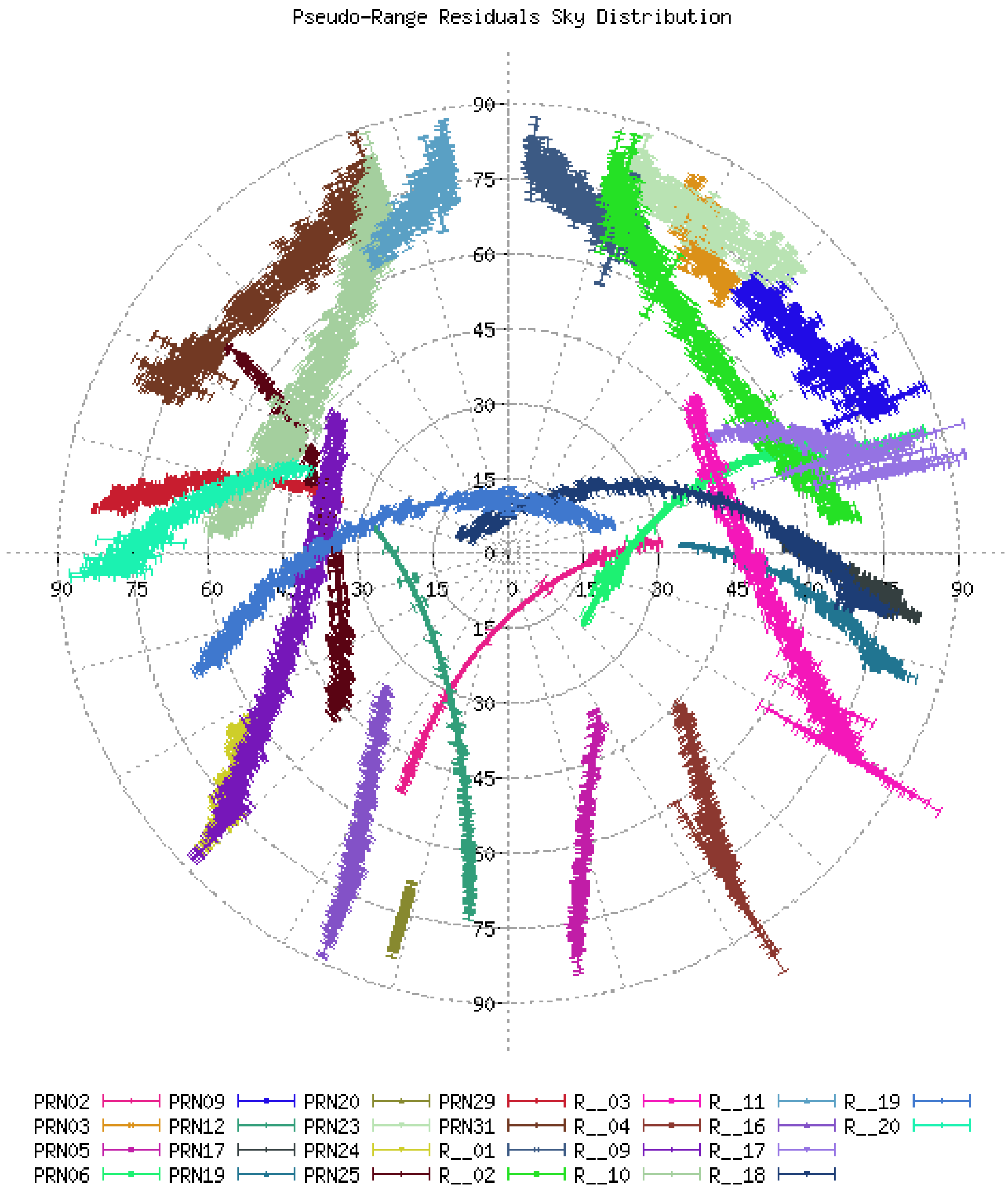
UTM (North) Zone 13

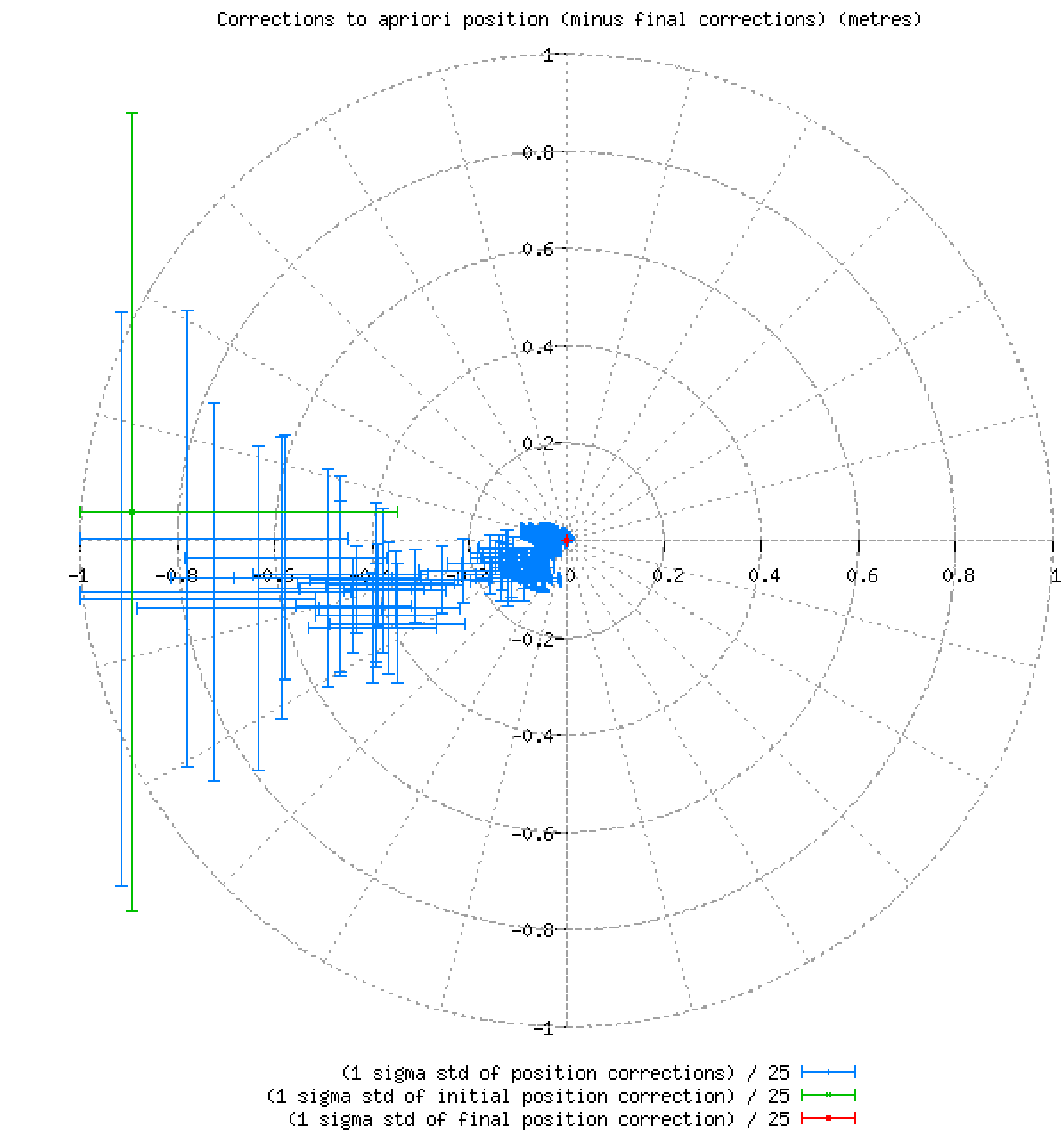
6372738.116m (N) 474631.507m (E)

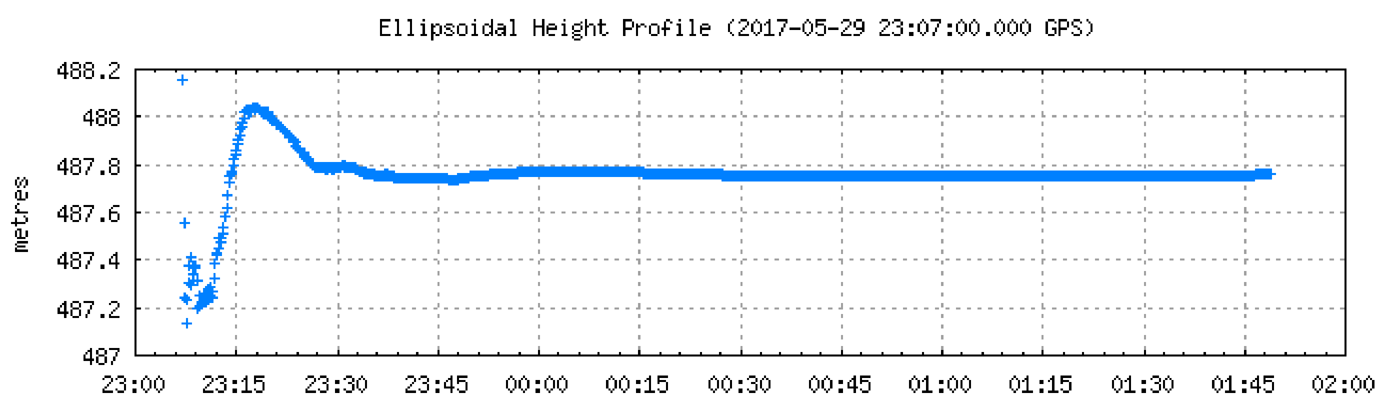
Scale Factors
0.99960789 (point)
0.99953137 (combined)

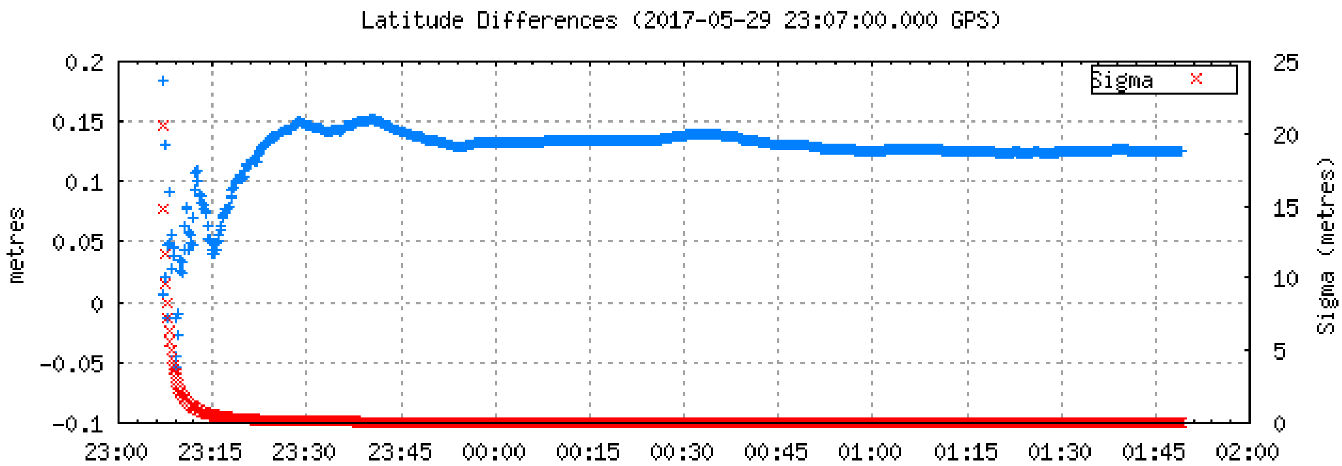
(Coordinates from RINEX file used as apriori position)

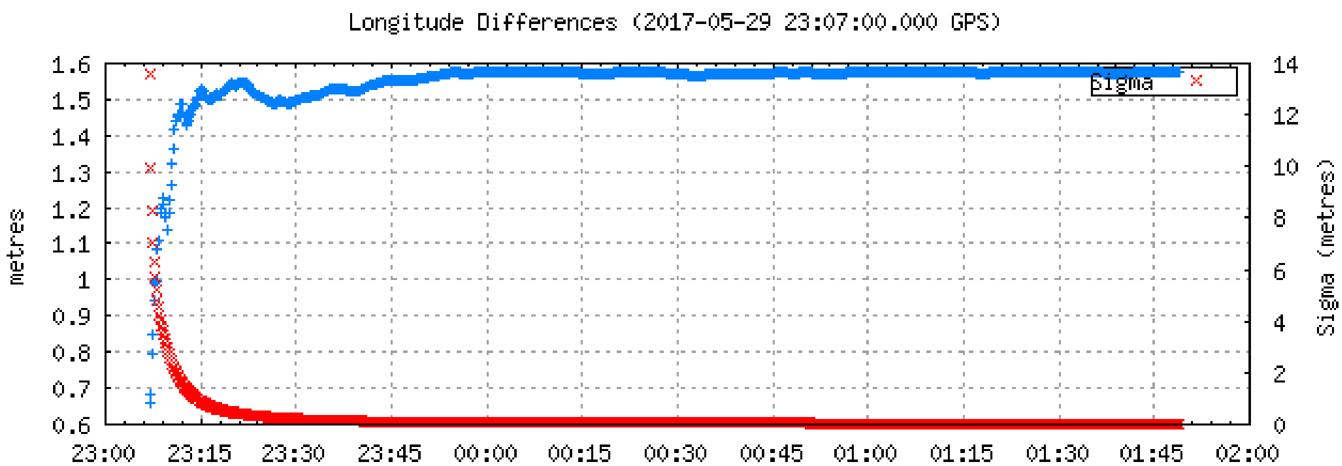
Estimated Parameters & Observations Statistics

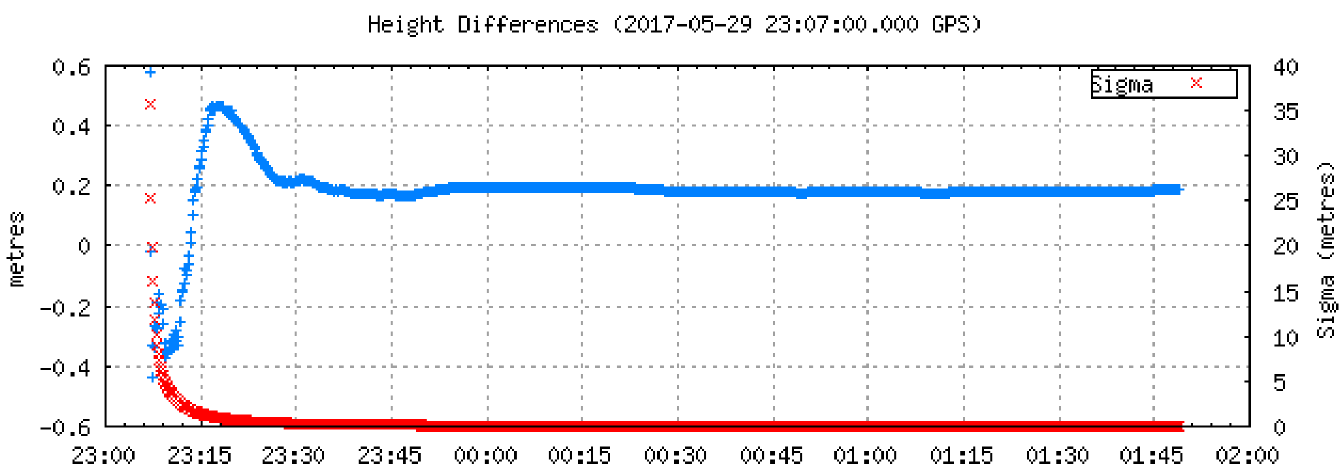



Corrections to apriori position (minus final corrections) (metres)
(1 sigma std of position corrections) / 25
(1 sigma std of initial position correction) / 25
(1 sigma std of final position correction) / 25

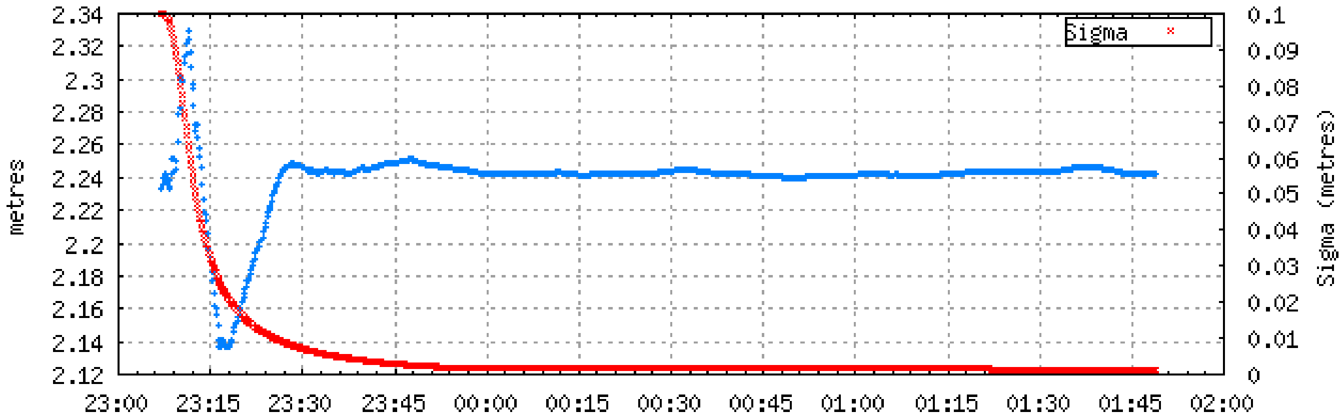

Ellipsoidal Height Profile (2017-05-29 23:07:00.000 GPS)
metres


Latitude Differences (2017-05-29 23:07:00.000 GPS)
metres
Sigma (metres)
Sigma
0.2
0.15
0.1
0.05
0
-0.05
-0.1
25
20
15
10
5
0
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00

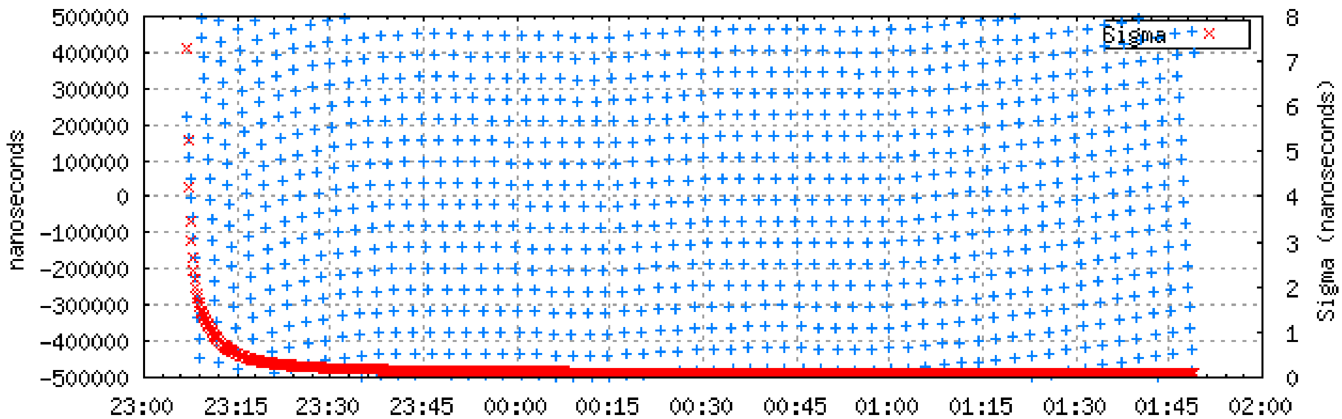

Longitude Differences (2017-05-29 23:07:00.000 GPS)
metres
Sigma (metres)
Sigma
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
14
12
10
8
6
4
2
0
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00


Height Differences (2017-05-29 23:07:00.000 GPS)
metres
Sigma (metres)
Sigma
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
40
35
30
25
20
15
10
5
0
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00

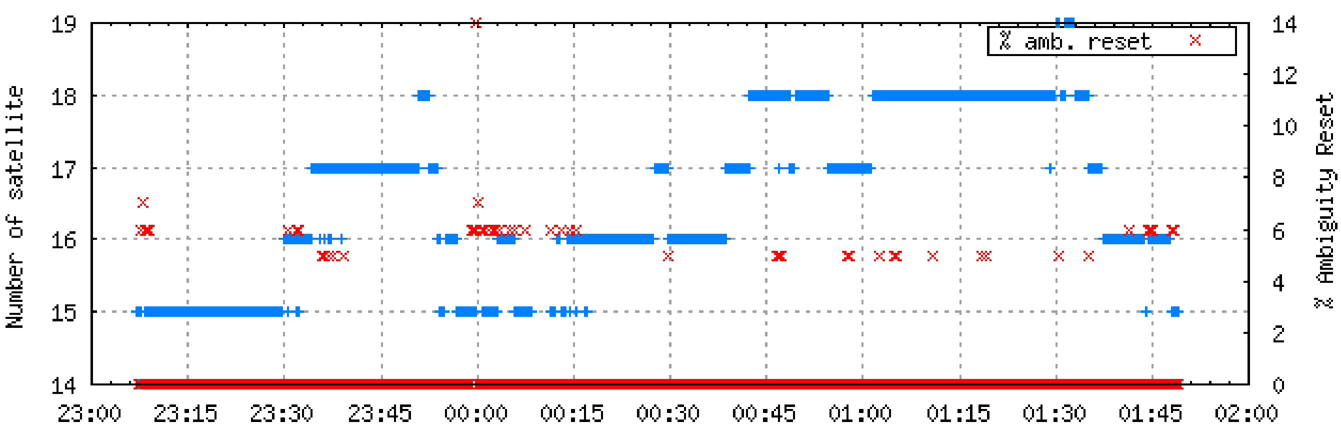
Estimated Tropospheric Zenith Delay (2017-05-29 23:07:00.000 GPS)

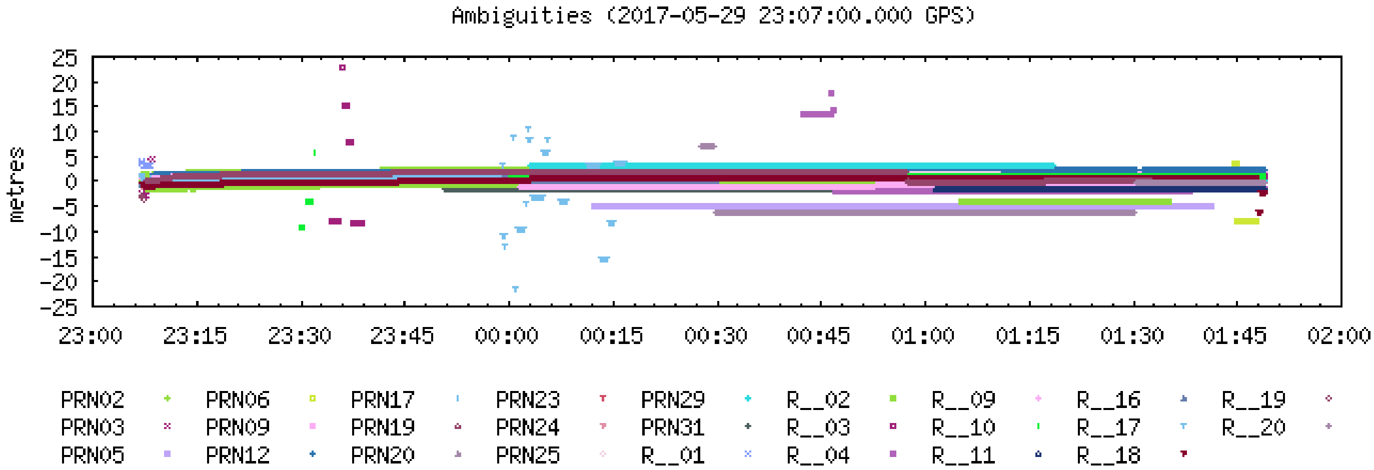


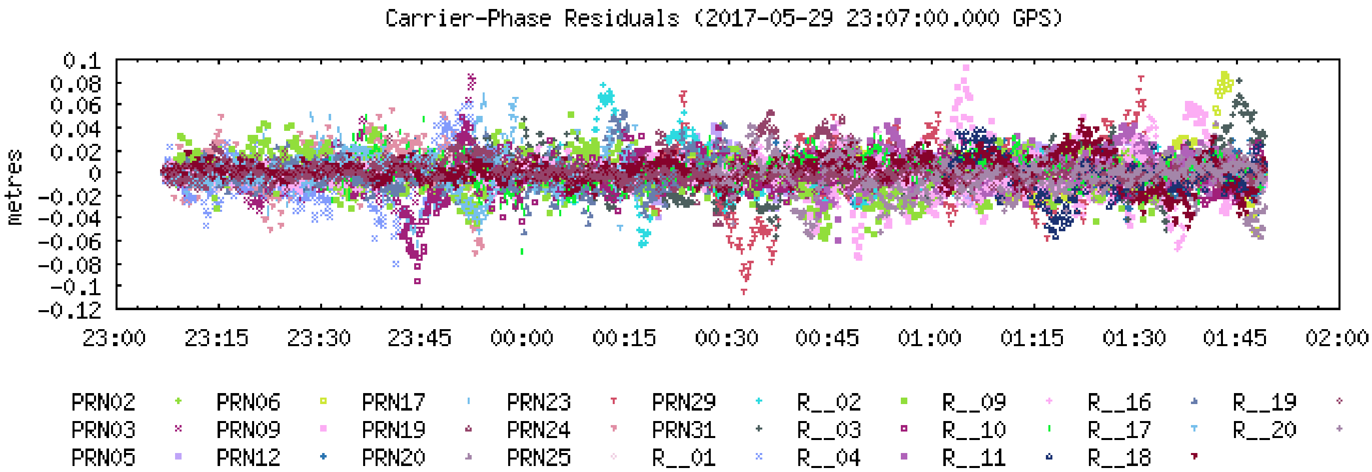
Station Clock Offset (2017-05-29 23:07:00.000 GPS)

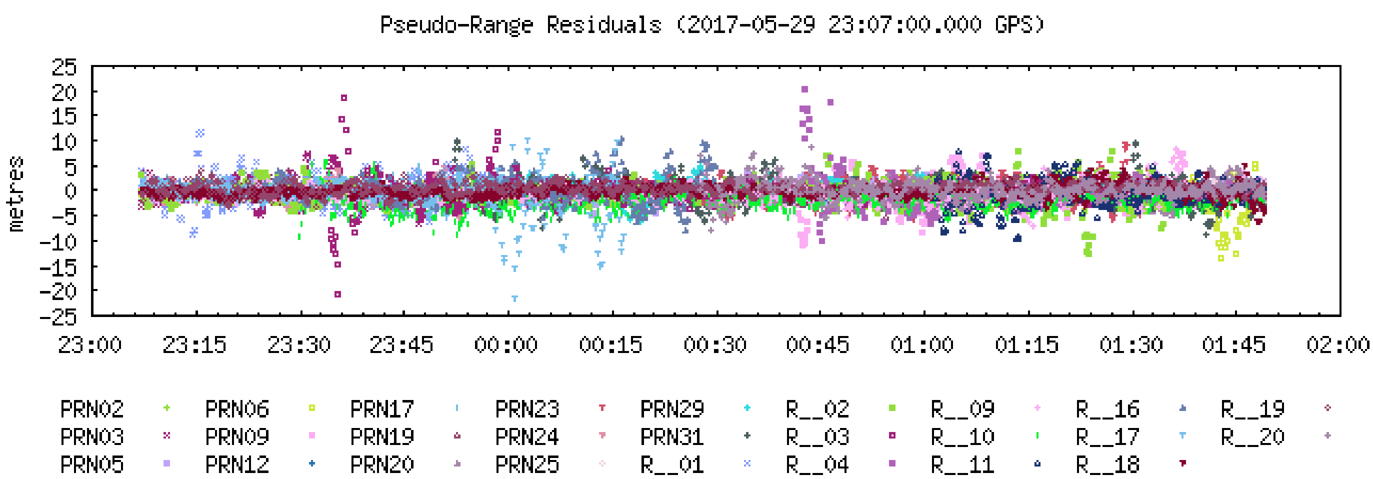


Tracked Satellites and Reset Ambiguities (2017-05-29 23:07:00.000 GPS)




Ambiguities (2017-05-29 23:07:00.000 GPS)
metres
25
20
15
10
5
0
-5
-10
-15
-20
-25
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00
PRN02 PRN06 PRN17 PRN23 PRN29 R__02 R__09 R__16 R__19
PRN03 PRN09 PRN19 PRN24 PRN31 R__03 R__10 R__17 R__20
PRN05 PRN12 PRN20 PRN25 R__01 R__04 R__11 R__18


Carrier-Phase Residuals (2017-05-29 23:07:00.000 GPS)
metres
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00
PRN02 PRN06 PRN17 PRN23 PRN29 R__02 R__09 R__16 R__19
PRN03 PRN09 PRN19 PRN24 PRN31 R__03 R__10 R__17 R__20
PRN05 PRN12 PRN20 PRN25 R__01 R__04 R__11 R__18


Pseudo-Range Residuals (2017-05-29 23:07:00.000 GPS)
metres
25
20
15
10
5
0
-5
-10
-15
-20
-25
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45
01:00
01:15
01:30
01:45
02:00
PRN02 PRN06 PRN17 PRN23 PRN29 R__02 R__09 R__16 R__19
PRN03 PRN09 PRN19 PRN24 PRN31 R__03 R__10 R__17 R__20
PRN05 PRN12 PRN20 PRN25 R__01 R__04 R__11 R__18

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Phone:343-292-6617

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Appendix F Wheeler River Hydrometric Monitoring Activity Summary 2019. Missinipi Water Solutions.

November 6, 2019 File Number: MWS-19-013

Dr. Fei Luo
Environmental Engineer
EcoMetrix Incorporated
6800 Campobello Road
Mississauga, ON L5N 2L8

RE: 2019 Wheeler River Hydrometric Monitoring Activity Summary

Dear Dr. Luo,

This letter is provided to you as a summary of field hydrometric monitoring activities during 2019 at Denison Mine's (Denison) Wheeler River Project (the Project). EcoMetrix Incorporated (EcoMetrix) is completing baseline monitoring for the Project on behalf of Denison and has retained Missinipi Water Solutions Inc. (MWSI) to provide hydrometric monitoring and water sampling at the Project.

Introduction

The Project is located approximately 750 km north of Saskatoon within Saskatchewan's Athabasca Basin. The Project is considered to be Denison's flagship project and Denison is currently proceeding with development of an Environmental Impact Statement (EIS) for the property. Data recorded during baseline monitoring are important to the development of an EIS in context of existing conditions and predicted impacts.

In coordination with EcoMetrix, MWSI completed two field programs at the project in 2019 from July 3 to 7 and August 28 to September 1. The purpose of each field program was as follows:

July Field Program

- Project introduction with EcoMetrix including guided access to all stations and identification of survey benchmarks;
- Discharge measurement and water level survey at SA-1, SA-2, SA-3, SA-4, SA-5, SA-6 and RC-1;
- Water level survey at LA-1; and,
- Water sampling at SA-1, SA-2, SA-3, SA-4, SA-5, SA-6 and RC-1.

August Field Program

- Discharge measurement and water level survey at SA-1, SA-2, SA-3, SA-4, SA-5, SA-6, SA-8, SA-9, SA-10, SA-11 and RC-1;
- Water level survey at LA-1 and LA-6; and,
- Water sampling at SA-1, SA-2, SA-3, SA-4, SA-5, SA-6 and RC-1.

PO Box 32089 Erindale
Saskatoon SK S7S 1N8
Tel: 306-242-4000
Email: info@missinipisolutions.ca

Some stations are equipped with water level dataloggers which were downloaded in 2019. Each station is discussed in detail below and notes any observations or changes to instrumentation. Discharge and water level data developed from installed dataloggers are being provided electronically to EcoMetrix as a part of, but not attached/appended to, this letter.

Methodology and Equipment

This monitoring program is a continuation of work completed by others and all relevant background data and previous measurements for each station are discussed by EcoMetrix (2019) in *Baseline Hydrology Summary Report – Wheeler River Project, Denison Mines*. Work completed by MWSI in 2019 included extension of the stage-discharge rating curves (rating curve) at each station and development of hydrographs.

A rating curve requires several measurements of water level (stage) and discharge measurement over a wide range of flow conditions. During 2019, discharge was measured at each station by in-stream velocity measurements via the Mid-Section Method (Terzi, 1981). A Sontek FlowTracker was used to record velocity measurements at all stations for the Project in 2019. Water levels were recorded by elevation surveys to previously installed benchmarks using an engineer's rod and level. At some locations (SA-1, SA-4, SA-5, SA-6, SA-8, SA-9, SA-10, SA-11 and LA-6) Solinst Leveloggers are installed to record water level.

The quality of the data collected and reported is directly related to the accuracy of the measurements collected in the field. MWSI regularly inspects and calibrates field equipment to provide quality data for analysis. As of the spring of 2019 there are no facilities in Canada to perform calibration of Sontek FlowTrackers; however, MWSI regularly calibrates the older mechanical flow meters and annual verification is completed to confirm that all flow meters have agreement under a range of velocities in a lab controlled hydraulic flume. Two Peg Test surveys are performed to verify the accuracy of survey equipment. During station monitoring additional survey collection and measurements are often completed to confirm and validate measurements prior to leaving the station.

Solinst Leveloggers installed in-stream record total pressure which is a combination of water level and barometric pressures. A Solinst Barologger is used to measure local barometric pressure and this data record can be confirmed and extended, if needed, using local climate station data. The barometric pressure record is subtracted from the total pressure record for all in-stream Leveloggers. This record is used to generate the hydrograph by correcting the record to the surveyed water level, referenced to local benchmarks, and applying the trendline equation from the rating curve at a given station. Any users of hydrograph data should exercise caution if a given hydrograph has data that are developed by extrapolation beyond the measured range of a rating curve.

Winter water level data records are often impacted by ice cover and encroachment of the channel by snow. All stations with dataloggers installed at the Project are similarly impacted. Winter flow data can be estimated from other regional stations, but this effort is not included as a part of this report.

During the 2019 field programs the dataloggers were observed to have a two hour time shift from Central Standard Time (CST). All dataloggers were reset to CST to ease future processing of logger data at a sampling frequency of 30 minutes.

Stream Discharge and Lake Level Monitoring

This section provides a summary of activities for each station as well as updated tables of measured stage and discharge. When possible the current stage-discharge rating curve is plotted including the equation for the fitted trendline and the coefficient of determination (R^2). In some cases, a measurement may be rejected from the trendline equation and R^2 assessment based upon the type of measurement (i.e. winter vs. open water) or professional judgment based on the perceived fit of the data point. Rejection of data points is based upon close scrutiny of the data set, consideration for the data and conditions associated with that measurement and the potential perceived influence of site conditions such as measurement location.

As previously discussed, this monitoring is a continuation of work completed by others. The measurements discussed below are a compilation of all work at each station where MWSI completed measurements made in 2019 and all other work is discussed by EcoMetrix (2019).

SA-1 (Icelander River)

Measurements were completed at SA-1 twice in 2019 (Table 1). A data logger is installed at this location and a new sensor housing was added during the August field program. The current data logger is an older model of the Solinst Levelogger product and will need replacement soon but was not believed to be required for 2019.

Some discrepancy was noted at this station regarding previously reported benchmark labels and elevations. For the 2019 data to fit with previously reported data in the rating curve (Figure 1) the benchmark elevation from BM3 (as previously reported by others) needed to be assigned to BM1. This is a somewhat arbitrary correction; however, it creates a proper fit to the rating curve based on the measured flow and stage data. Should other information regarding the benchmarks at SA-1 become available it could be used to provide any other correction which may be required.

Photo 1 and Photo 2 are photos of the cross-section at SA-1 taken in July and August, respectively.

Table 1: SA-1 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-14	492.714	2.3070
2011-07-29	492.648	1.7500
2011-10-28	492.562	0.9730
2012-05-05	492.711	2.2930
2012-08-06	492.695	2.0310
2012-10-23	492.721	2.5750
2013-05-20	492.705	2.3580
2013-08-14	492.587	1.2800
2013-10-18	492.554	0.8870
2014-03-30	492.869	1.2030
2016-09-17	492.710	2.3400
2017-05-31	492.720	2.4300
2018-07-02	494.043	2.4100
2019-07-05 9:00	492.744	3.0553
2019-08-30 9:30	492.733	2.7760

Figure 1: SA-1 Rating Curve

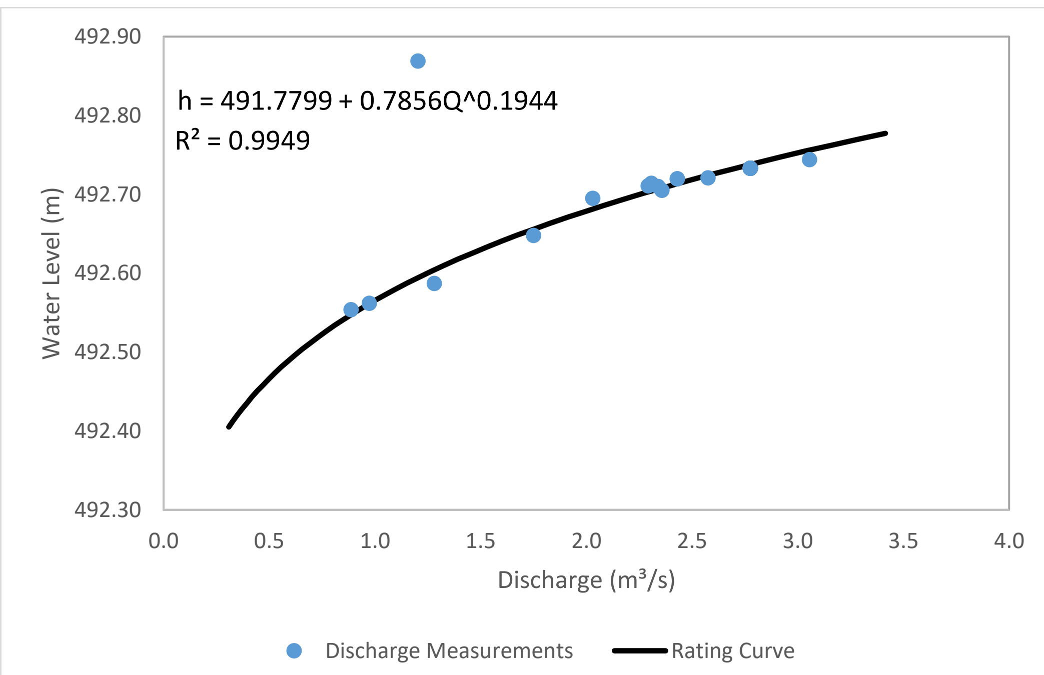

Photo 1: SA-1 - July Field Program

Photo 2: SA-1 - August Field Program

SA-2 (Northwest Flow into McGowan Lake)

Station SA-2 is located to the northwest of McGowan Lake. A datalogger is not installed at this location. During the 2019 monitoring program it was learned that the cross-section had been moved in 2016 creating a discrepancy in water levels. The old cross-section was identified during the August field program and sufficient data are available to correct the July 2019 measurement (Table 2 and Figure 2). The original cross-section will be used for measurements in future field monitoring programs. Photo 3 is taken of the cross-section used during the July field program while Photo 4 is the original cross-section used in August.

Table 2: SA-2 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-12	496.727	1.6490
2011-07-30	496.698	1.3870
2011-10-27	496.667	0.8090
2012-05-08	496.748	2.0080
2012-08-08	496.689	1.3050
2012-10-24	496.734	2.0300
2013-05-21	496.727	1.8420
2013-08-14	496.660	0.8630
2013-10-16	496.641	0.7410
2014-03-24	496.805	1.1800
2016-09-16	496.460	2.2400
2019-07-05 12:30	496.773	2.2095
2019-08-30 13:30	496.748	1.9537

Figure 2: SA-2 Rating Curve

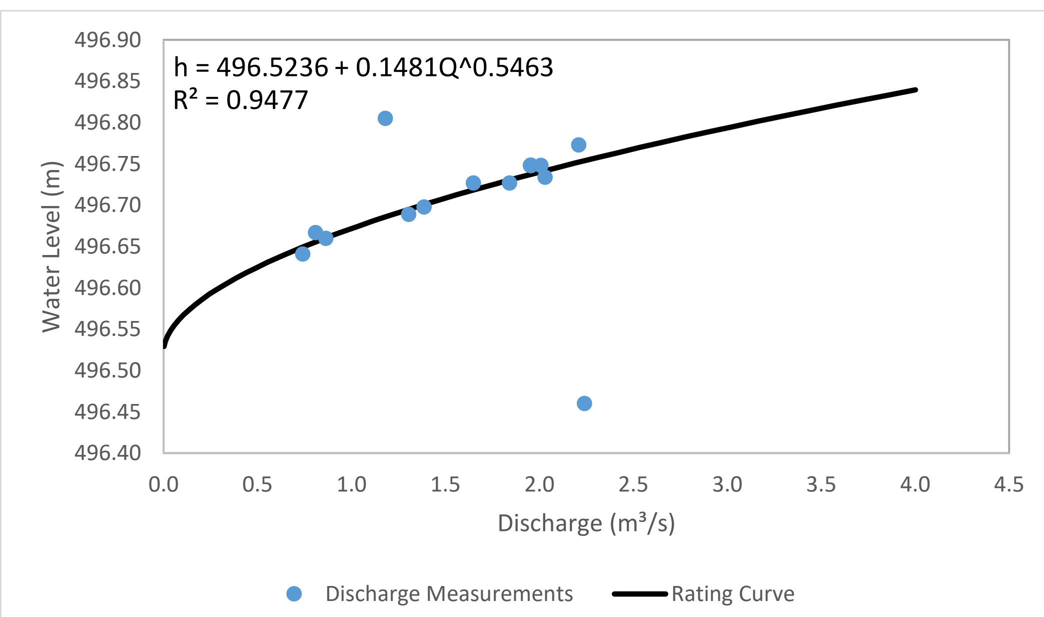

Photo 3: SA-2 - July Field Program

Photo 4: SA-2 - August Field Program

SA-3 (LA-2 to McGowan Lake)

SA-3 is located on an inflow stream to McGowan Lake from the northeast. The station does not have a datalogger. Stage and discharge measurement data are provided in Table 3 and plotted in Figure 3. Photo 5 and Photo 6 are taken during the July and August field programs, respectively. The stream at this location has a low gradient and, due to the proximity to the lake, is believed to have been slightly backwatered by McGowan Lake during 2019.

Table 3: SA-3 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-13	494.459	0.4760
2011-07-29	494.392	0.3700
2011-10-28	494.322	0.2390
2012-05-04	494.473	0.5280
2012-08-05	494.443	0.4780
2012-10-23	494.487	0.5780
2013-05-20	494.482	0.5640
2013-08-14	494.344	0.2550
2013-10-16	494.243	0.0510
2014-03-24	494.248	0.3620
2016-09-16	494.430	0.4400
2019-07-05 14:00	494.541	0.6219
2019-08-30 15:30	494.506	0.5474

Figure 3: SA-3 Rating Curve

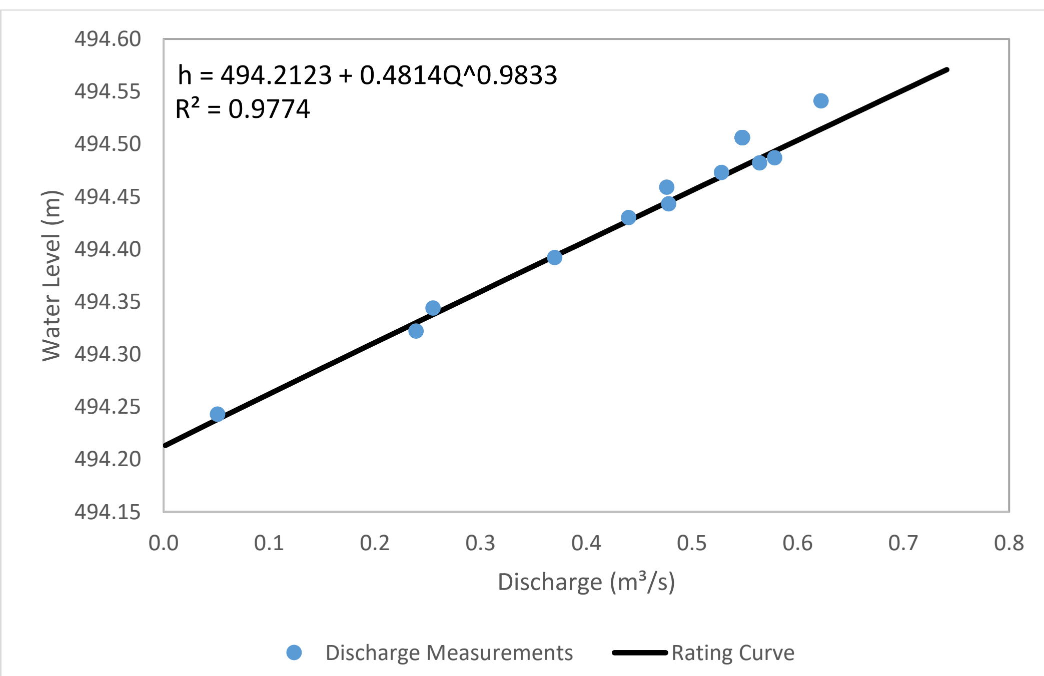

Photo 5: SA-3 - July Field Program

Photo 6: SA-3 - August Field Program

SA-4 (Downstream of Outflow from Kratchkowsky Lake)

SA-4 is located downstream of Kratchkowsky Lake and flows into LA-6 from the northwest. This station has a datalogger. The measured stage and discharge data are presented in Table 4 and Figure 4. Photo 7 was taken during the July field program while Photo 8 is from August.

Table 4: SA-4 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-11	506.357	0.4830
2011-07-30	506.314	0.3350
2011-10-31	506.310	0.1990
2012-05-04	506.348	0.4660
2012-08-05	506.329	0.3610
2012-10-22	506.367	0.4970
2013-05-19	506.369	0.5190
2013-08-13	506.277	0.2760
2013-10-17	506.249	0.2060
2014-03-23	506.381	0.3300
2016-09-10	506.350	0.4900
2017-05-30	506.370	0.5800
2018-06-29	506.357	0.4845
2019-07-04 12:00	506.387	0.6336
2019-08-29 13:00	506.374	0.5900

Figure 4: SA-4 Rating Curve

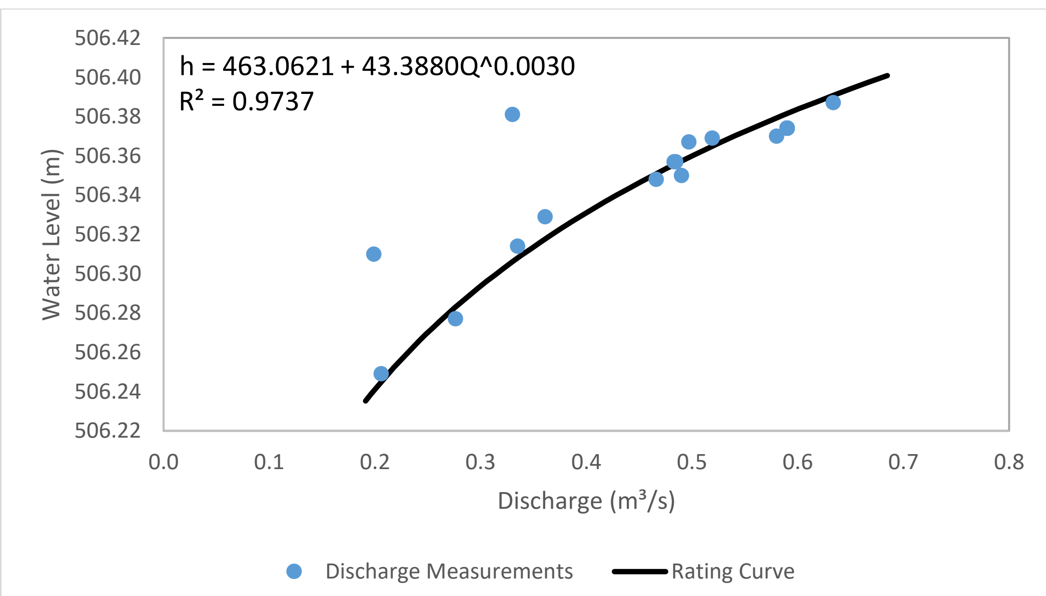

Photo 7: SA-4 - July Field Program

Photo 8: SA-4 - August Field Program

SA-5 (Northwest Inflow to LA-6)

A second northwest inflow to LA-6 is monitored at SA-5. This station is equipped with a datalogger and a new logger housing was installed during the August field program. Stage and discharge measurements are presented in Table 5 and the rating curve is shown in Figure 5. Photo 9 and Photo 10 show the cross-section during the July and August field programs, respectively.

This station has been measured at two cross-sections approximately 30 m apart. The reason for the change in cross-section is unknown at this time; however, efforts have been undertaken both in previous reporting and this document to shift all measurements to a common datum. This may not be justifiable in consideration of hydraulic characteristics but it will be possible in future measurements to confirm the shape of the rating curve and provide any additional shifts that may be required.

Table 5: SA-5 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-12	500.891	1.1000
2011-07-30	500.851	0.8580
2011-10-29	500.792	0.4760
2012-05-04	500.900	1.1110
2012-08-05	500.867	1.0260
2012-10-22	500.901	1.2690
2013-05-19	500.909	1.3810
2013-08-13	500.812	0.6160
2013-10-17	500.805	0.5070
2014-03-23	500.981	0.8860
2016-09-09	500.900	1.2700
2016-09-21	500.910	1.5800
2017-05-30	500.920	1.9500
2018-06-30	500.890	1.6567
2019-07-04 10:30	500.955	1.6137
2019-08-29 10:30	500.927	1.3589

Figure 5: SA-5 Rating Curve

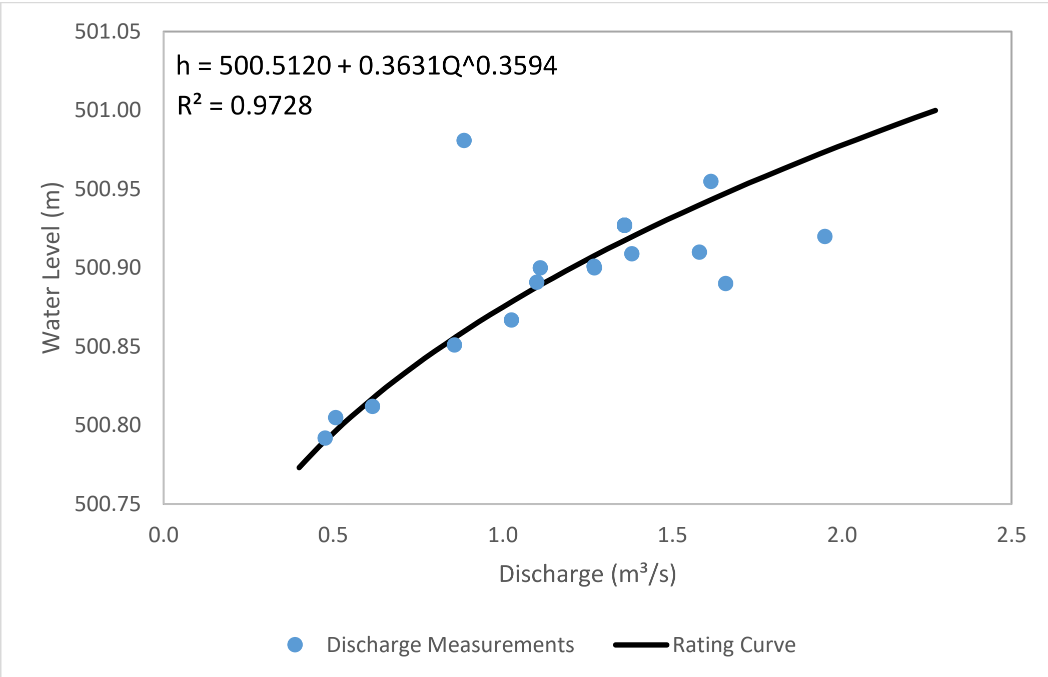

Photo 9: SA-5 - July Field Program

Photo 10: SA-5 - August Field Program

SA-6 (Outflow from LA-6)

SA-6 is the outflow from LA-6 and is equipped with a stage recording datalogger. The sensor and sensor housing at this location were replaced in August. Stage and discharge data for SA-6 are presented in Table 6 and the rating curve is shown as Figure 6. The cross-section is shown in Photo 11 for the July field program and Photo 12 is from the August field program.

Table 6: SA-6 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2011-05-13	500.084	1.6310
2011-07-30	500.034	1.3030
2011-10-27	499.956	0.7170
2012-05-06	500.098	1.9570
2012-08-05	500.061	1.4760
2012-10-22	500.102	1.8510
2013-05-19	500.077	1.5400
2013-08-13	499.992	0.8420
2013-10-17	499.969	0.7980
2014-03-23	500.081	1.1730
2016-09-11	500.070	1.9800
2017-05-31	500.080	1.7700
2018-06-30	500.125	1.5576
2019-07-04 14:30	500.125	2.2674
2019-08-29 16:00	500.110	2.0247

Figure 6: SA-6 Rating Curve

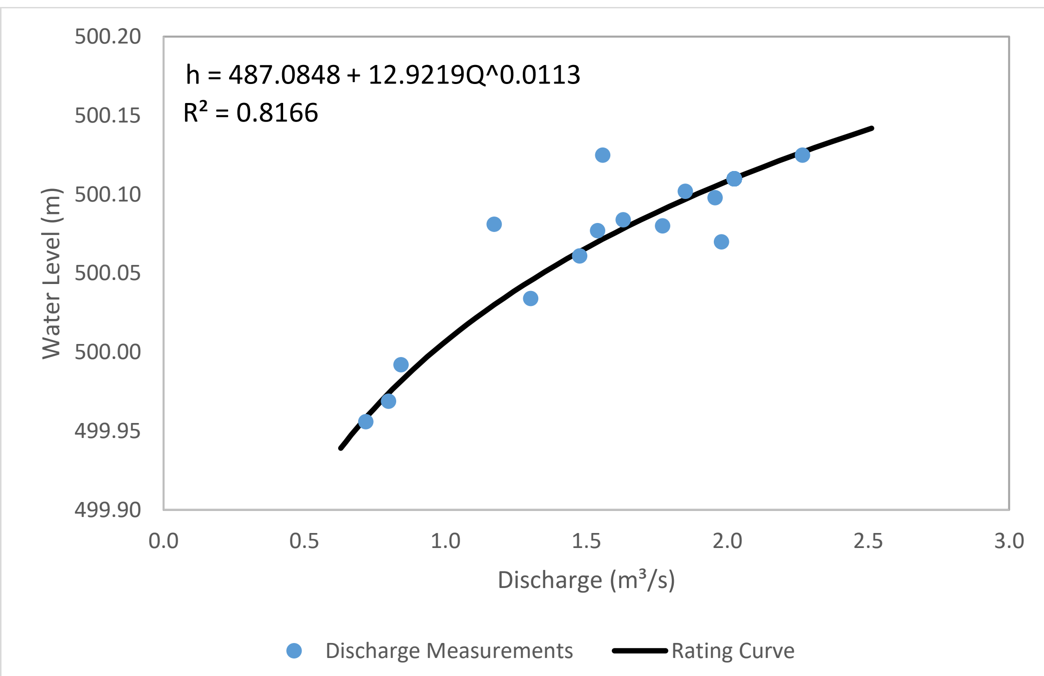

Photo 11: SA-6 - July Field Program

Photo 12: SA-6 - August Field Program

SA-8 (Inflow to Kratchkowsky Lake)

SA-8 is an inflow to Kratchkowsky Lake and was located immediately upstream of the shoreline. It is believed that stage measurements at that location were influenced by the lake level in Kratchkowsky Lake and not representative of the hydraulics of the inflow channel. The station was moved upstream and re-installed with a new sensor housing. The station was surveyed to new local benchmarks and not referenced to the old cross-section (Table 7). Photo 13 shows the old monitoring location during the July field program while Photo 14 was taken at the new upstream location in August.

Table 7: SA-8 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2016-09-15	520.600	0.0100
2016-09-19	520.620	0.0400
2017-05-30	520.540	0.0400
2018-07-03	520.570	0.0560
2019-08-31 10:00	99.455*	0.0443

* Referenced to local benchmark after moving measurement location.

Photo 13: SA-8 - July Field Program

Photo 14: SA-8 - August Field Program

SA-9 (Outflow from LA-8)

SA-9 is located downstream of LA-8 and is equipped with a datalogger. Insufficient stage and discharge measurement data (Table 8) are available to generate a rating curve at this time. Photo 15 was taken during the August field program.

Table 8: SA-9 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2016-09-18	520.520	0.1800
2017-06-01	520.490	0.1600
2019-08-31 14:10	520.547	0.1457

Photo 15: SA-9 - August Field Program

SA-10 (Northwest Inflow to LA-9)

SA-10 is an inflow to LA-9 and is equipped with a datalogger. Stage and discharge measurement data are presented in Table 9 but are insufficient to generate a rating curve. Photo 16 was taken during the August field program.

Table 9: SA-10 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2016-09-18	514.350	1.5500
2017-05-31	514.310	1.2200
2019-08-31 17:30	514.344	1.3127

Photo 16: SA-10 - August Field Program

SA-11 (North Inflow to Kratchkowsky Lake)

The north inflow to Kratchkowsky Lake is monitored at SA-11. This station is equipped with a datalogger. Stage and discharge measurement data are provided in Table 10 and the rating curve is shown in Figure 7. Due to the brevity of data, caution is advised when using this rating curve especially for extrapolation above the highest measured discharge. Photo 17 was taken of the cross-section during the August field program.

Table 10: SA-11 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2016-09-19	520.730	0.4200
2017-05-30	520.710	0.3100
2018-07-02	520.561	Not Measured
2019-08-31 11:00	520.713	0.3104

Figure 7: SA-11 Rating Curve

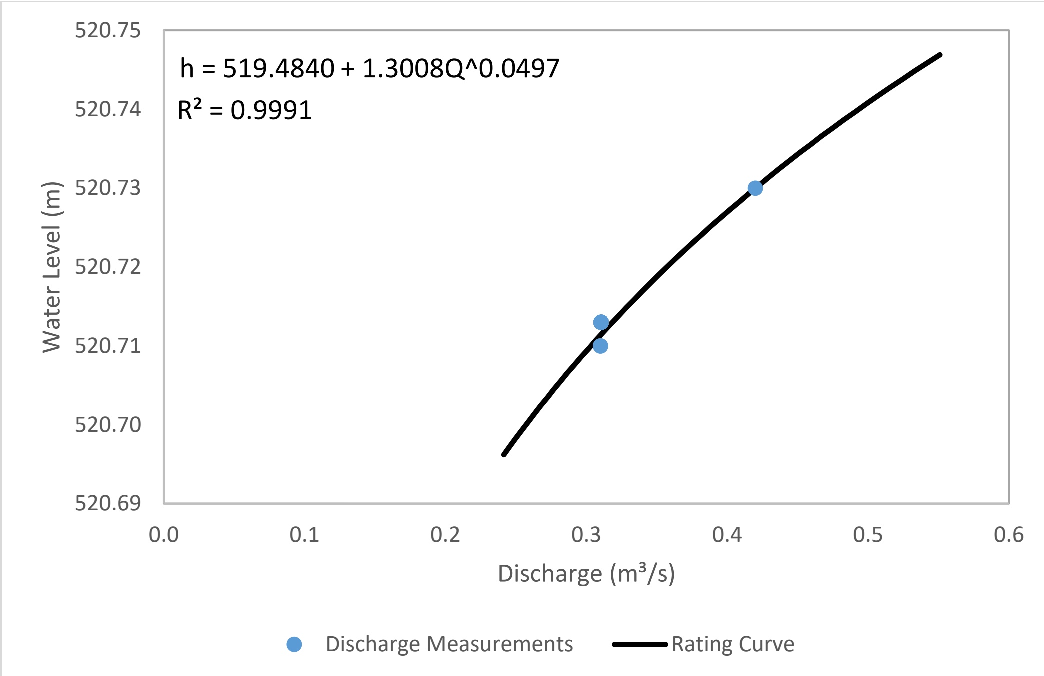

Photo 17: SA-11 - August Field Program

RC-1 (Outflow from Kratchkowsky Lake Upstream of SA-4)

RC-1 is measured near the outflow from Kratchkowsky Lake and upstream of SA-4. A datalogger is not installed at this location. Water level measurements in Table 11 are referenced to the lake water level measured at a different location on Kratchkowsky Lake. There are not enough data to generate a rating curve. Photo 18 and Photo 19 show the cross-section during the July and August field programs, respectively.

Table 11: RC-1 Stage and Discharge Measurements

Measurement Date & Time	Water Level (m)	Discharge (m^3/s)
2016-09-14	520.300	0.5800
2018-03-15	No WL Measured	0.2303
2019-07-06 9:00	No WL Measured	0.6041
2019-09-01 8:30	520.559	0.5514

Photo 18: RC-1 - July Field Program

Photo 19: RC-1 - August Field Program

LA-1 Water Level

Measurements of water level for LA-1 occur coincident with monitoring at SA-3. The stream and lake are separated by a long natural levy and survey benchmarks are located between the two stations and used for both water level surveys. Table 12 presents the survey data for LA-1. A new datalogger was installed at this location during the August field program.

Table 12: LA-1 - Water Level Measurements

Measurement Date & Time	Water Level (m)
2011-05-13	494.439
2011-07-29	494.327
2011-10-28	494.218
2012-05-04	494.423
2012-08-05	494.386
2012-10-23	494.448
2013-05-21	494.440
2013-08-14	494.265
2013-10-16	494.194
2014-03-24	494.298
2016-09-16	494.390
2018-07-02	494.344
2019-07-05 14:00	494.515
2019-08-30 15:30	494.476

LA-6 Water Level

LA-6 is upstream of SA-6. Water level survey (Table 13) was completed once during the August field program. A datalogger for LA-6 could not be found during the August field program; however, comparison of historical measurement between LA-6 and SA-6 (Figure 8) indicate that the water levels are similar enough to use water level data from the SA-6 datalogger to represent the water level of LA-6.

Table 13: LA-6 - Water Level Measurements

Measurement Date & Time	Water Level (m)
2011-05-13	500.063
2011-07-31	500.028
2011-10-27	499.943
2012-05-06	500.088
2012-08-05	500.058
2012-10-22	500.092
2013-05-19	500.088
2013-08-13	499.973
2013-10-17	499.947
2014-03-23	500.058
2016-09-12	500.070
2018-06-30	500.106
2019-08-29 14:25	500.118

Figure 8: Comparison of LA-6 and SA-6 Water Levels

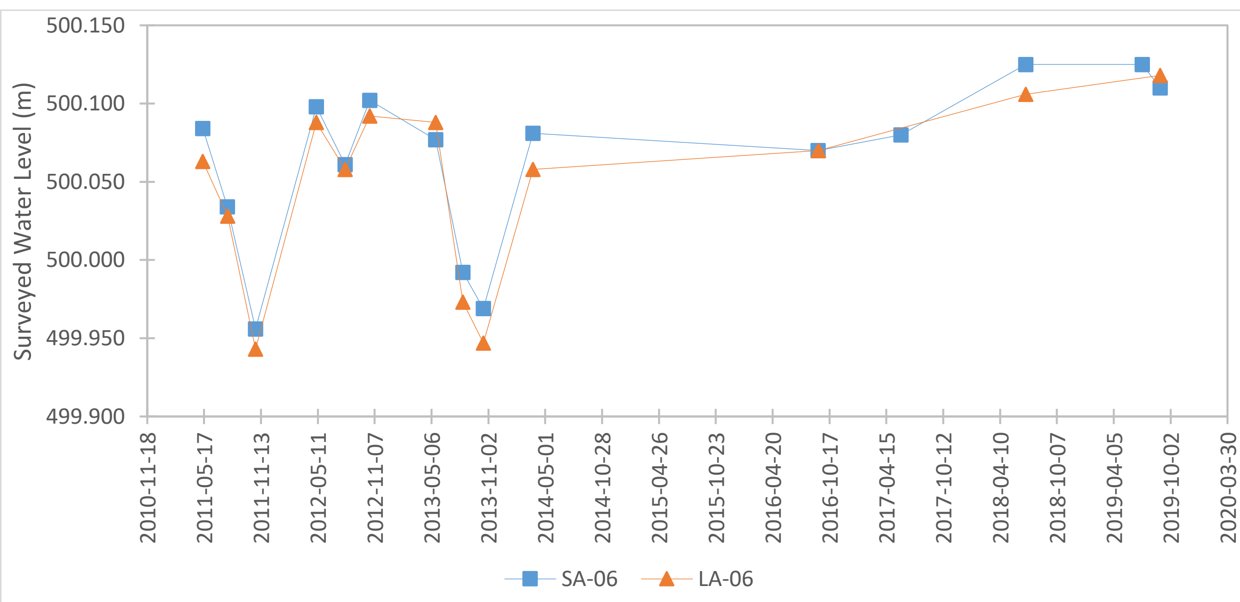

Photo 20: LA-6 - August Field Program

Water Quality Parameter Measurements

Water samples were collected during both 2019 field programs. Water quality parameters recorded during the August field program are presented in Table 14.

Table 14: August Water Quality Field Measurements

Station ID	SA-01	SA-02	SA-03	SA-04	SA-05	SA-06	RC-01
Water Depth (m):	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Water Temp (°C)	12.8	14	15.2	14.1	12.4	13.8	12.8
Conductivity (uS/cm):	14	13.7	16.7	15.8	12.3	13.7	15.4
Spec. Conductivity (uS/cm):	18.3	17.4	20.6	19.9	16.2	17.5	20.1
pH:	6.82	6.98	6.76	6.93	6.75	6.86	7.04
Dissolved Oxygen (mg/L):	8.91	9.11	9.21	7.15	7.81	7.33	9.09
DO Sat. (%):	84.1	88.2	92.3	70.2	73.2	71.1	86.1

Summary and Closure

On behalf of Denison, EcoMetrix has retained MWSI for monitoring and reporting of discharges in the vicinity of the Project. This reporting consists of the monitoring data and other pertinent observations recorded during two field programs in 2019.

This report has been prepared for the exclusive use of Denison and EcoMetrix. MWSI is not responsible for any unauthorized use or modification of this document. All third parties relying on information presented herein do so at their own risk.

MWSI appreciates the opportunity to work with Denison and EcoMetrix on this project. Should there be any questions regarding this document please contact the undersigned.

Respectfully submitted,

Missinipi Water Solutions Inc.

Tyrel J. Lloyd, M.Eng., P.Eng.

Senior Water Resources Engineer

References

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Terzi, R.A. 1981. Hydrometric Field Manual – Measurement of Streamflow. Inland Waters Directorate, Water Resources Branch, Environment Canada.