Red Mountain Underground Gold Project – Baseline Climate and Hydrology Report

Prepared for

IDM Mining

Prepared by

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Executive Summary

This report presents methods and results of baseline meteorology and hydrology studies for the proposed Red Mountain Underground Gold Project (the Project) near Stewart, British Columbia. It was prepared by SRK Consulting (Canada) Inc. on behalf of IDM Mining Ltd. Related sampling activities from 2014 to 2016 were carried out by Avison Management Services Ltd. and contributed to the methods section.

The primary objective of these studies was to establish a baseline for evaluating potential changes that could occur as a result of the Project. The results were also used to establish hydrology inputs for the predictive water and load balance used to estimate potential changes in water quantity and quality resulting from mining activities, and as a reference for determining the size of civil structures associated with the water management plan.

The baseline program was designed to meet the requirements for an effects assessment and application for an Environmental Assessment Certificate.

Climate records are available for the Red Mountain area from local on-site meteorological monitoring stations, historical hydrology and meteorology reports, data provided by Environment and Climate Change Canada (ECCC), the Water Survey of Canada (WSC), the United States Geological Survey (USGS), and climatic models including reanalysis from the European Center for Medium-Range Weather Forecast (ECWMF) and the National Aeronautics and Space Administration (NASA).

Key Findings

Air Temperature. The mean annual air temperature (MAAT) at an elevation of 1514 metres is −0.8°C, with monthly variability ranging between −6.4°C in December and January and 6.9°C in August. MAAT is strongly correlated with elevation.

Precipitation. The regional meteorological station daily precipitation most representative with the site is Stewart A with a MAP of 1847 mm/yr.

Intensity duration frequency data for Stewart A provides an average intensity of 5.9 mm/hr for a 24-hour, 100-year return period event. The annual probable maximum precipitation of Stewart A was estimated to be 481 mm.

Snowmelt was estimated with a daily energy snowmelt model based on site and regional parameters. The values tend to be aligned with the site snow course data and differ from information provided for the Redmount meteorological station on site. The variation suggests problems with the instrument that measured snowpack height or specific wind speed issues relative to the station location that produced unreliable measurements locally.

Evaporation. The estimated annual actual evapotranspiration is 376 mm/yr, pan evaporation is 557 mm/yr, and the pan coefficient is 0.87.

Wind Speed and Direction. On-site wind measurements indicate that the prevailing wind direction is east and southeast during the winter, spring, and fall. During the summer, winds are generally the same direction, but are calmer.

Relative Humidity. Regional relative humidity is highly correlated with elevation. The mean annual relative humidity at the site is 70%.

Solar Radiation. The monthly average solar radiation at the site which ranges from 20 to 223 W/m².

Mean Annual Runoff. Two runoff models for areas with different glacier cover were developed: watersheds with less than 10% glacial cover have a mean annual runoff of 1555 mm/yr (i.e., Goldslide Creek) and watersheds with more than 10% glacial cover have a runoff of 2828 mm/yr (i.e., Otter and Bitter Creeks).

Base-Flows. The lower-flow conditions for base-flow are presented in January and are 1.6 l/s/km² for Bitter and Otter Creeks and 1.9 l/s/km² for Goldslide Creek.

Low-Flows. Bitter and Otter Creeks have an annual 7Q10 of 0.96 l/s/km². Goldslide Creek has an annual 7Q10 of 1.1 l/s/km². Bitter and Otter Creeks had lower values in January, while Goldslide Creek had lower values in March.

Peak Flows. Peak-flows were strongly correlated with glacier cover. To model this relationship, unit peak flows were estimated for every available regional gauge station for different return periods. As a reference, for a 50% glacial cover watershed, such as Bitter and Otter Creeks, and a 100-year return period, the unit flow rate is 1.94 $m^3/s/km^2$.

Climate Change. Climate change models predict an increase in the total mean annual precipitation to reach 2032 mm by 2100; and an increase in mean annual air temperature to reach 2.05°C by 2100.

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List of Abbreviations

AHCCD	adjusted and homogenized Canadian climate data
CRAE	complementary relationships for areal evapotranspiration
CRAN	Comprehensive R Archive Network
EA	environmental assessment
ECCC	Environment and Climate Change Canada
ECMWF	European Center for Medium-Range Weather Forecast
IDF	intensity duration frequency
LSA	local study area
MAAT	Mean annual air temperature
MAP	Mean annual precipitation
MAR	Mean annual runoff
masl	metres above sea level
MERRA	Modern-Era Retrospective Analysis for Research and applications
NASA	National Aeronautics and Space Administration
PMP	probable maximum precipitation
POWER	prediction of worldwide energy resource
RH	relative humidity
RSA	regional study area
SSE	sum of square error
SWE	snow water equivalent
USGS	United States Geological Survey
WSC	Water Survey of Canada

1 Introduction

This report presents methods and results of baseline meteorology and hydrology studies in support of the Environmental Assessment (EA) of the proposed Red Mountain Underground Gold Project (the Project) near Stewart, BC (Figure 1-1). The report was prepared by SRK Consulting (Canada) Inc. on behalf of IDM Mining Ltd. Avison Management Services Ltd. was responsible for all of the recent (i.e., 2014−2016) sampling activities, and contributed to the methods section of the report.

The primary objective of the baseline meteorology and hydrology studies was to establish a baseline against which to evaluate potential changes that could occur as a result of the Project. The results were also used (1) establish hydrology inputs for use in the predictive water and load balance used to estimate potential changes to water quantity and quality resulting from mining activities and, (2) as a reference for determining the size of civil structures associated with the water management plan.

The baseline water quality program for the Project was designed to meet the requirements for submission of an EA application, as described in the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2012, 2016). This report comprises:

- Section 2 – Background: Describes the physical, climate and hydrological local and regional study areas, meteorological stations and regional sources.
- Section 3 – Baseline Methods: Includes a compilation of the Project stations, and the data collected for meteorology and hydrology. This section also includes a general description of the methodologies used in collecting the baseline data, and the analyses conducted.
- Section 4 – Climatic Conditions: Comprises a description of the monthly variability and mean annual parameters associated with precipitation, snowmelt, evaporation, wind speed, wind direction, relative humidity, and solar radiation.
- Section 5 – Baseline Hydrology: Describes the site hydrology, including the mean annual runoff, monthly runoff variability, base-flow, low-flow and peak-flow conditions.
- Section 6 – Climate Change Projections: Provides an evaluation of potential changes in temperature and precipitation resulting from climate change.

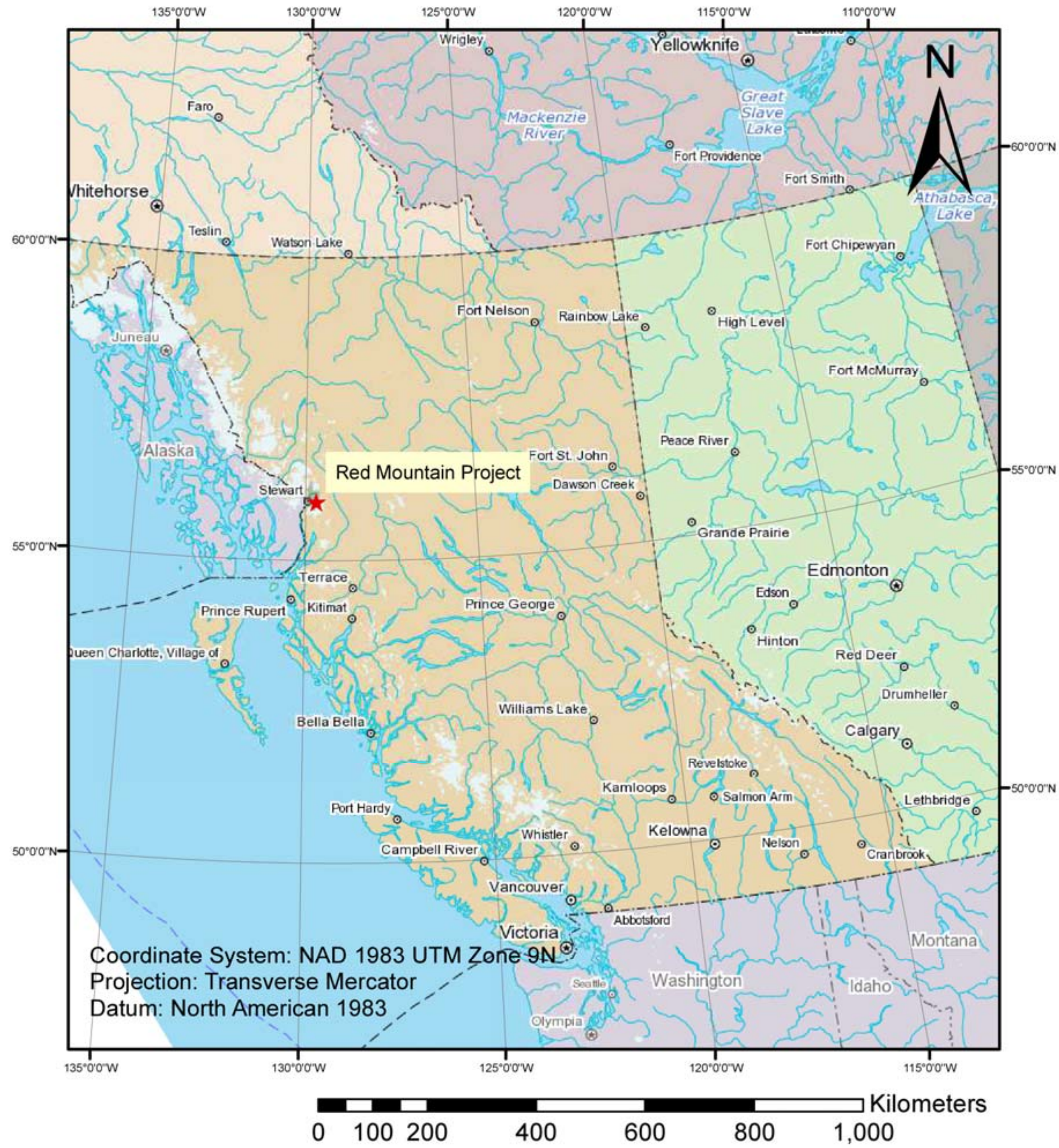


Figure 1-1: Project Location

2 Background

2.1 Physical, Climate, and Hydrological Setting

The Project is located in the Cambria Mountain Range, which is part of the Boundary Range (Alaska Boundary Range), and runs along the boundary of the state of Alaska and the province of British Columbia. The Project is located west of the Cambria Ice Field, and north of the Bromley Glacier (Figure 1-1) and is characterized by rugged, steep terrain with weather conditions typical of the northern coastal mountains. The elevation of the Project ranges from 1,500 to 2,100 metres above sea level (masl), with an average of approximately 1,800 masl. Two prominent peaks in the area are Otter Mountain at 2,700 masl, and Bromley Peak at 2,300 masl.

The Cambria Range and valley are heavily glaciated by the Bromley, Bear River, Kitsault and Sutton Glaciers, and the Cambria Icefield dominates the area. Large-scale atmospheric circulation, occurring over the Pacific Ocean and the Gulf of Alaska, is the driver of seasonal variations in precipitation and weather patterns in the region. Approximately two-thirds of precipitation occurs during half of the year (i.e., October to March) from the Pacific storm track, and much of this falls locally within the Cambria range.

The region has cold weather and warm summers, but no dry seasons, and has a Köppen-Geiger climate classification of Dfb. Regions with this classification are defined as having more than four months with an average temperature greater than 10°C, and an average temperature below 22°C during the hottest month (Peel, Finlayson, and McMahon 2007). The climate and hydrology are seasonally influenced by three factors: distance from the coast, site elevation, and glacial cover.

The proposed underground mine is in the Red Mountain cirque, a short, westerly-trending hanging valley above the Bitter Creek Valley. The cirque is drained by Goldslide Creek, which flows southwest to the side of Bromley Glacier close to its current extent, but is not glacially-influenced. Flows in Goldslide Creek peak during freshet (typically in June). Goldslide, Rio Blanco, Otter and Roosevelt Creeks are the main tributaries to Bitter Creek, which originates from the Bromley Glacier. Bitter Creek itself is a tributary to the Bear River, which flows into the Portland Canal near Stewart, BC. Bitter Creek and Otter Creek are glacially-influenced and with peak flows occurring during the summer (typically in July) as a result of glacial melt.

Climatic conditions at the Project site are influenced by high elevation and close proximity to the Pacific Ocean. The mine area is located in the upper part of the Red Mountain cirque, an area that is fully exposed to regional winds and precipitation. Climatic conditions at the site show some important similarities and differences from the closest Environment and Climate Change Canada (ECCC) meteorological station Stewart A (located 17 km west of the site), indicating that results from other regional stations should be considered in the review.

2.2 Description of Local and Regional Study Areas

The local study area (LSA) for meteorology and hydrology is the Bitter Creek watershed up to the glacial extent, including Goldslide and Otter Creeks. The regional study area (RSA) is the Bitter

Creek watershed, including the glacial extent and the Bear River watershed from American Creek to Stewart and the northern end of the Portland Canal.

It should be noted that analyses also included data from regional meteorological and gauge stations located as far away as 200 to 300 km from the mine site. The general extent of the regional stations used were Dease Lake to the north, Bella Bella to the south, Graham Island to the west, and 200 km to the east. Figure 2-1 illustrates the LSA, RSA and the meteorology and hydrology baseline study region.

2.3 Historical Baseline Monitoring

Historical meteorological and hydrological baseline monitoring was completed from 1990 to 1992 by Hallam Knight Piésold (HKP) for Bond Gold and then Lac Minerals (HKP 1992), and from 1993 to 1994 by Rescan for Lac Minerals (Rescan 1994, 1995).

Relevant results from historical baseline monitoring were compared to results from the more recent baseline monitoring program and regional analysis, and used to validate these results, and provide a far more robust basis for the analyses than is typically available at this stage of a project. The results of the validation for precipitation and hydrology are presented in Sections 4.3.8 and 5.4.6. Validation results for other parameters are presented along with both site-specific and regional data.

2.4 Regional Sources of Information

The meteorological information used in this baseline and analysis evaluation were obtained from the following sources/programs:

1. **Environment and Climate Change Canada (ECCC):** the ECCC databases (ECCC 2016) provide meteorological records with daily information for the following parameters: precipitation, maximum temperature, minimum temperature, relative humidity, wind speed, wind direction and solar radiation.
2. **Water Survey of Canada (WSC):** the WSC access database HYDAT, which is updated every 3 to 4 months with regional gauge records (including daily, monthly, annual and peak-flows records), was complemented with (1) available real-time information; and (2) direct information requests to receive draft information not available in the HYDAT database or the real-time webpage.
3. **United States Geological Survey (USGS):** the USGS flow database can be accessed through their webpage or through R packages called “waterData” and “dataRetrieval” (CRAN 2016). These packages, combined with SRK’s own R libraries, retrieve the historical records from their respective websites, combine the information from WSC and USGS seamlessly into one database to be analyzed into the regional hydrological analysis.
4. **Reanalysis (ERA-Interim & MERRA):** reanalysis combines satellite information, land records and numerical models that simulate the earth’s climatic conditions. Typically, reanalysis extends for several decades, and covers the entire planet. State-of-the-art,

publicly-available reanalysis data from ERA-Interim produced by the European Center for Medium-Range Weather Forecast (ECMWF) were used in this procedure (ECMWF 2016). ERA-Interim includes sub-daily data at 12-hour intervals from 1979 to present (2016) for the entire world, based on a 0.75 degree latitude by 0.75 degree longitude grid. MERRA from the National Aeronautics and Space Administration (NASA) produced another reanalysis source from NASA, prediction of worldwide energy resource (POWER) presents daily information from 1981 to present (2016) for the entire world, based on 0.5 degree latitude and 0.5 degree longitude grid.

All of these sources of meteorological and gauge information were processed using the specific statistical software, R (version: 3.3.1x86_64).

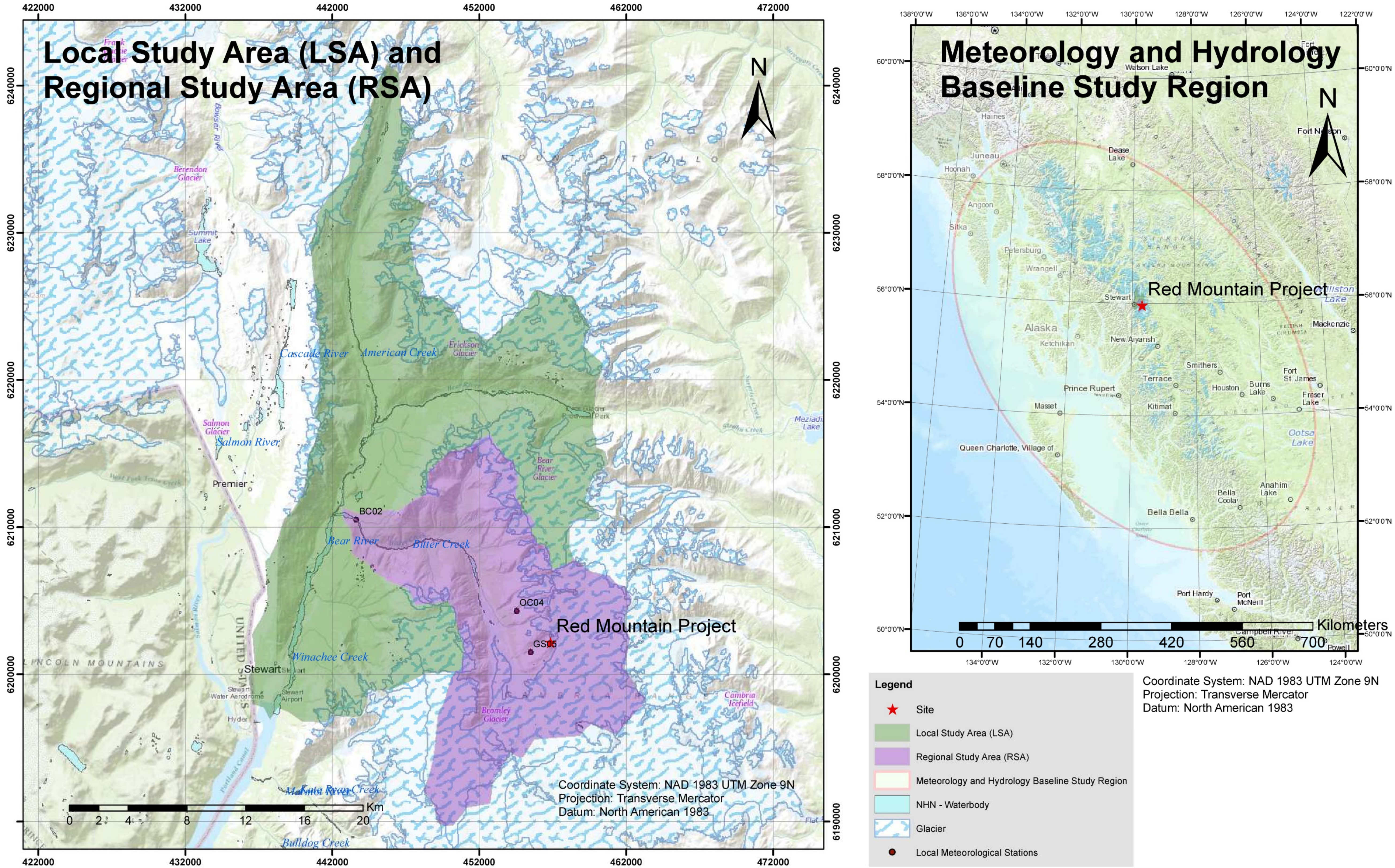


Figure 2-1: Extent of the Local Study Area (LSA), Regional Study Area (RSA) and other Regional Meteorology and Hydrology Stations Considered for this Evaluation

3 Baseline Study Methods

3.1 Meteorological Monitoring

3.1.1 Project Stations

Meteorological data were collected at an automated meteorological station referred to as the Redmount station. The station is located adjacent to the existing project camp in the Red Mountain cirque at UTM grid reference 9U 0454893N and 6201831E at an elevation of 1,498 masl on a ridge above the tree line. Instruments were installed in July 2014 on a pre-existing tower, one of several installed in the project area by Rescan Environmental Consultants (now ERM) in the early-1990s. The tower was a 10 m tall steel structure, supported by guy wires, which is standard for collecting wind speed and direction data. This location and tower height were ideal for monitoring wind speed and direction. However, this location was not ideal for collecting precipitation data, especially snow depth, as the site was observed to be completely wind-scoured during the winter.

Climate monitoring included daily measurements of the following parameters: barometric pressure, net radiation, total solar radiation, wind speed and direction, relative humidity, air temperature, and snow depth. A free-standing precipitation gauge was added to the station in August 2015. During each monthly visit, data were downloaded, instrumentation was inspected, and the precipitation gauge was emptied.

The 2MW snow course was located on the south side of Goldslide Creek, directly across the stream from the exploration camp. Snow sampling was conducted here historically and the course was found to be in good condition with the re-initiation of climate monitoring in 2014. The snow course consisted of 10 sampling posts (though one fell over in the winter of 2016) in an open, well-drained area with minimal vegetation and no brush. This is consistent with the standards for course design cited in the RISC *Standard Operating Procedures for Manual Snow Surveys* (BC MOE 2003). The snow course was sampled four times between January and May 2016. Like many of the higher-elevation sites in the project area, the snow course was subject to severe wind scour and resultant snow drifting.

Table 3-1 lists the Redmount climate station instrumentation. Table 3-2 details the methodologies implemented at the Redmount climate station and the 2MW snow course.

Table 3-1: Summary of Climate Monitoring Instruments Installed at Redmount Climate Station

Parameter, units	Manufacturer	Model
Barometric pressure, mbar	Vaisala	PTB110 Barometer
Net radiation, W/m²	Kipp and Zonen	NR Lite 2
Wind speed and direction, m/sec, degrees	RM Young	Alpine Version 05103-45-10A
Total solar radiation, W/m² Total solar density , MJ/m²	Kipp and Zonen	SP Lite 2
Relative humidity, % Air temperature, degrees C	Rotronic Instrument Crop.	HC-S3
Snow depth, mm	Sonic Ranger	SR50A
Data logger	Campbell Scientific	CR1000
Precipitation, mm	Ott	Pluvio²

Source: compiled in text.

Table 3-2: Summary of Site Climate Monitoring Stations

Site Name	Established	Location Description and Rationale	Methodology Implemented	Sampling Frequency	Measurements Undertaken
Redmount	July 30, 2014	Ridge above Goldslide Creek Elevation 1,498 m above sea level	Station design, installation and ongoing monitoring methodology follow standards outlined in BC MOE (1996)	Hourly	Air temperature, relative humidity, solar radiation, atmospheric pressure, precipitation
2MW Snow Course	January 20, 2016	Adjacent to Goldslide Creek, across the creek from the exploration camp	Manual snow measurements taken using a Federal Snow Sampler (Mt. Rose Sampler) in accordance with BC government standards (BC MOE, 2003)	Monthly when course is snow-covered	Average snow depth and snow-water equivalent

Source: compiled in text.

3.1.2 Data Collection

Air Temperature

Air temperature (in degrees Celsius) was recorded at the Redmount meteorological station using a Rotronic Instrument Corp. HC2-S3-L probe. This probe replaced the original HC-S3 temperature and relative humidity probe, which had malfunctioned in March 2015, and was reinstalled in August 2015. Average, maximum, and minimum temperature data were recorded hourly.

Precipitation

Precipitation data were collected by an Ott Pluvio² SDI-12 precipitation gauge. This weighing rain gauge measured the amount (in millimetres, mm) and intensity of rain, snow and hail. It was shielded by a stainless-steel Alter-shield in order to improve the efficiency of precipitation catch in windy conditions. However, precipitation gauge collection efficacy may have been affected by strong winds despite the wind shield. Studies have shown that the relative catch efficiencies for an Alter-shielded Geonor gauge (similar to the Pluvio^2) range between 36 and 95% and that this efficiency decreases exponentially with increased wind speed (Devine and Mekis 2008; Smith 2007). This underestimation is exacerbated by solid precipitation (i.e., snow) due to the typically slower fall speeds and thus can be affected to a greater degree by wind turbulence around the gauge. It should be noted that the precipitation data presented in this report have not been adjusted for this potential under-catch, so actual precipitation is likely higher than what was measured, and which is reported herein.

During the winter season, the automatically zeroing precipitation gauge was filled with 6 L of a 40% glycol/60% methanol mixture to melt solid precipitation and prevent freezing of accumulated liquid. Moreover, 500 mL of mineral oil was added to cover the liquid surface, preventing evaporation of this anti-freeze mixture.

Wind Speed and Direction

Wind speed (in m/s) and direction (in degrees) were recorded by an RM Young Alpine Version Wind Monitor.

Relative Humidity

Relative humidity (as a percentage value) was recorded by the Rotronic Instrument Corp. HC2-S3-L probe. Average, maximum, and minimum measurements were recorded hourly. Relative humidity was calculated from the ratio of the partial pressure of water vapor in a volume of air to the partial pressure of water vapor in that same volume when water-saturated.

Solar Radiation

Total solar energy and net radiation were recorded at the Redmount climate station using the Kipp & Zonen SP Lite2 pyranometer and the NR Lite2 net radiometer. The pyranometer measured all of the solar energy received from the hemisphere above it, and reported values in watts per square metre (W/m^2) and megajoules per square metre (MJ/m^2). The radiometer measured net radiation, also reported in W/m^2; this latter measurement is the difference between incoming solar radiation and reflected solar radiation.

Atmospheric Pressure

Atmospheric pressure data in millibars (mbar) was recorded using a Vaisala PTB110 barometer. This sensor was affected by a fault in its data channel in the CR1000 data logger and, as a result, did not collect data between November 11, 2015, and July 7, 2016. This data gap was addressed by using elevation-corrected data from another atmospheric pressure sensor located near the exploration camp on Goldslide Creek.

Snow Surveys

Snow data were collected at the 2MW snow course in accordance with the standards and methods outlined in the August 1981 *Snow Survey Sampling Guide* (BC MOE 1981). Sampling was conducted using a Federal Snow Sampler, which is a hollow aluminum tube marked in centimetres that was pushed down through the snow until it reached the ground. Snow depth was read and recorded, and the tube was then rotated using the driving wrench to cut out a dirt plug before being withdrawn along with the sampled snow core. The dirt plug was critical proof that the ground surface was indeed reached and prevented snow from falling out of the tube during withdrawal. After the dirt plug was measured (for subtraction from snow depth) and removed, the tube and core were weighed using a scale that reports snow water equivalent (SWE) in centimetres. The weight of the tube was subtracted from this value. Snow depth and SWE were reported as an average for all 10 stations of the snow course. Difficult sampling conditions, such as hard-packed snow drifts and deep snow, were approached using the recommendations in the *Snow Survey Sampling Guide*.

3.1.3 Data Management and Quality Assurance/Quality Control

During monthly visits to the station, all instruments were inspected visually to identify any evidence of mechanical damage that would impact instrument performance and data quality. Station inspections and snow surveys were both conducted by field technicians with significant relevant field experience. Reported climate station data were evaluated on site and compared to a visual confirmation of weather conditions such as approximate wind speed, wind direction and air temperature. Station data were also downloaded during each site visit. Both climate and snow observations were later reviewed as a quality control and assurance measure to confirm that the recorded values were reasonable and without anomalies, outliers, gaps or inconsistencies. Any questionable data was removed from the dataset.

3.2 Hydrometric Monitoring

Subsequent to the earlier historical data collection activities, hydrometric monitoring activities were reinitiated in June 2014, following recommendations in Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators (BC MOE 2012). Hydrometric station design, installation and ongoing monitoring methodology also followed standards outlined in the Manual of British Columbia Hydrometric Standards, March 12, 2009 (BC MOE 2009). This manual specifies the four criteria necessary to obtain high-quality water level and stream flow data as follows: the quality of instruments used, stream channel conditions, field procedures and data calculation and assessment (BC MOE 2009). To meet these criteria: (1) annually-calibrated equipment was used to record water levels within 2 mm; (2) sites with stable channel conditions were selected; (3) a minimum of three bench marks were installed at each station; (4) a minimum of five manual flow measurements were conducted per year; and (5) discharge measurements were performed with an accuracy rating of less than 10%.

Conditions for hydrometric monitoring in the Project area were challenging, with steep gradients, unstable and mobile beds, snow and ice accumulation, high sediment loads, and difficult and limited access. Detailed reconnaissance surveys were conducted on the catchments of interest, and stations were selected that were expected to provide good quality records.

The baseline study included four hydrometric monitoring stations. The hydrometric program included continuous monitoring of water level and, when possible, monthly flow measurements at each of the stream gauging stations. Weekly flow measurements were conducted during spring freshet in 2016. During a typical site visit to the monitoring stations, two discharge measurements were completed, as well as bench mark and stage surveys, logger data downloads and instrumentation inspections.

3.2.1 Project Hydrometric Monitoring Stations

Details pertaining to the hydrometric stations are provided in Table 3-3. All four hydrometric monitoring stations were located within the Bitter Creek watershed, the main drainage of the Project area. Hydrometric stations were established within the sub-watersheds of Goldslide and Otter Creeks, as well as on the main drainage of Bitter Creek. Hydrometric stations were installed to allow for accurate water level reading and discharge measurements at all stages where control was stable. Required station characteristics included straight and aligned banks where there was a single channel with minimal turbulence and backwater effects. Station location was also influenced by access and safety considerations. Access to Goldslide and Otter Creek stations (GSC05, OC04 and OC07, respectively) was by helicopter only, while the Bitter Creek station (BC02) was accessed by road.

Three of the stations (GSC05, OC04, and BC02) were established in June 2014. In April 2016, the Project footprint changed, with the proposed processing plant and tailings facility being relocated. In response, an additional hydrometric station was added to lower Otter Creek (OC07). This site was selected to augment the data collected from the existing hydrometric site (OC04) on the south arm of upper Otter Creek, with discharge measurements that represent the combined flows of both the north and south arms of this drainage.

Table 3-3: Summary of Instruments Installed at Red Mountain Hydrometric Stations

Station	Station Description	Zone	East	North	Instrument	Logging Interval
GSC05	Goldslide Creek before drop-off	9u	0455478	6201527	PT2X-21424045	5 Min
OC04	Otter Creek before drop-off	9u	0454534	6204347	PT2X-21424044	5 Min
BC02	Bitter Creek at HWY37A Bridge	9v	0443645	6210536	PT2X-21424043	15 Min
OC07	Lower Otter Creek	9u	0452679	6203839	PT2X-21634011 (Installed Sep,2016)	15 min

Each hydrometric monitoring station, with the exception of lower Otter Creek (OC07), had an Instrumentation Northwest (INW) PT2X integrated pressure/temperature sensor housed within an aluminum pipe, which was in turn fastened securely to either bedrock or to very large boulders.

Each pressure sensor were below the point of zero flow, or below the minimum expected stage, and sensors remained static for the entire open water field season. The pressure and temperature sensors were set to log data at 5-minute intervals at Goldslide Creek (GSC05) and upper Otter Creek (OC04) and 15-minute intervals at Bitter Creek (BC02). The longer logging interval at BC02 allowed for longer periods between site visits as this sensor remained installed and recorded data all year round, as Bitter Creek had sufficient flow during the winter to allow for continuous, year-round monitoring.

The PT2X pressure sensors recorded water levels through the open water season and were removed prior to freeze-up at the end of October of each year, with the exception of BC02. Anytime a pressure sensor was removed and reinstalled, a full bench mark survey was conducted so the new sensor depth was known relative to the gauge datum. Sensors were reinstalled each spring in the same locations to ensure consistency in the dataset. All stations were equipped with three permanent bench marks of known elevation relative to the arbitrary gauge datum. Bench marks were used so that gauge height could be confirmed and adjusted relative to gauge datum (station datum). These bench marks were anchor bolts placed into pre-drilled holes in exposed bedrock or unmovable boulders that were marked with metal tags and were accessible at all water levels.

Due to the dynamic nature and high variability in stage and discharge of these streams, no reference gauges (staff gauges) were installed at these stations. Full bench mark surveys were conducted during each field visit to determine an instantaneous direct water level. These surveys were completed using a surveyor’s rod and a Nikon AX-2s automatic level. All level notes were recorded and water levels were calculated in the field to confirm accuracy and precision prior to leaving the site. Due to dynamic hydraulic ramping and high fluctuation of stage height at higher flows, a large number (i.e., 10+) of measured water levels were recorded and then averaged to determine measured water level. This water level was then used to calibrate water levels recorded by the pressure transducer.

Table 3-4 below summarizes all site visits to the hydrometric and climate stations since June 2014.

Table 3-4: Summary of Site Visits to Hydrometric Stations and Climate Station

Site Visit Date	Goldslide Creek (GSC05/ GSC99)	Otter Creek (OC04)	Bitter Creek (BC02)	Otter Creek (OC07)	Redmount Climate Station	2MW Snow Course
June 23, 2014	X	X				
June 24, 2014	X	X	X			
July 29, 2014			X		X	
July 30, 2014	X	X				
August 26, 2014			X		X	
August 27, 2014	X	X				
September 15, 2014			X			
September 16, 2014	X	X			X	
September 30, 2014	X					
October 20, 2014			X		X	
October 21, 2014	X	X				
July 6, 2015			X			
July 7, 2015	X	X			X	
August 4, 2015			X			
August 5, 2015	X	X			X	
October 14, 2015			X			
October 15, 2015	X		X		X	
October 16, 2015		X				
January 19, 2016			X			
January 20, 2016	X	X			X	X
February 23, 2016	X	X	X			
February 24, 2016					X	X
April 12,2016			X			X
April 14, 2016					X	
May 10, 2016	X	X	X			X
May 11, 2016				X	X	
May 28, 2016			X			
May 29, 2016	X			X		
May 30, 2016		X				X
June 6, 2016			X			
June 7, 2016	X	X		X		X
June 8, 2016						
June 14, 2016	X	X	X	X		
June 15, 2016					X	
June 21, 2016		X				

Site Visit Date	Goldslide Creek (GSC05/ GSC99)	Otter Creek (OC04)	Bitter Creek (BC02)	Otter Creek (OC07)	Redmount Climate Station	2MW Snow Course
June 22, 2016	X		X	X		
June 27, 2016			X			
June 29, 2016	X	X		X		
July 19, 2016	X	X	X	X	X	
September 26, 2016			X			
September 29, 2016		X		X		
September 30, 2016	X					
November 1, 2016			X			
November 14, 2016			X			
November 15, 2016	X	X		X		
November 16, 2016						X

Source: compiled in text.

Note:

(1) X indicates a site visit.

3.2.2 Discharge Measurements

Discharge measurements were taken monthly over three time periods: June 2014 to October 2014, July 2015 to October 2015, and January 2016 to December 2016. Weekly freshet sampling was also conducted between May 29, 2016 and June 29, 2016. Sampling frequency was established to capture a wide range of discharges and stages throughout the year. Focused efforts were made to capture spring freshet and winter low-flows (i.e., the two extreme flow conditions).

When streams were safe to wade in at low-flows, current velocity measurements were obtained with a Hach FH950 electromagnetic current meter. This meter's range was 0−6.09 m/s, with a minimum water depth of 3.18 cm. Its accuracy was ±2% for readings in the range of 0.015 m/s to 3.04 m/s and ±4% of readings from 3.04 m/s to 4.87 m/s. The area-velocity method was used to calculate the mean discharge using the velocity and cross-sectional area of the stream. Ideally, 20 measurements of stream depth and velocity were taken at selected intervals across the stream. However, best practice was to ensure that each subsection between measurement stations was at least 10 cm in width, so fewer than 20 measurements were taken in the smaller stream sections (e.g., GSC05, OC04 and OC07), where wetted widths of less than 2.0 m could occur at low-flow conditions. If fewer than 20 measurements were taken, attempts were made to ensure that no single measurement accounted for more than 10% of the total discharge. In these small streams, distances between measurement points were generally less because water depth and flow velocities changed significantly within the cross-section in response to streambed features. In order to account for these changes, measurement points were selected at points of significant change in the streambed profile. In addition to these efforts, detailed notes were recorded on any morphological features of the streambed that could impact recorded depth or result in velocity values that are not representative of the natural condition. Streambed features could also deflect the flow so that it was not perpendicular to the cross-section. In these cases, the approximate angle of flow was recorded so the appropriate data correction could be made.

The measurement of velocity using a flow meter followed the *Manual of British Columbia Hydrometric Standards* prepared by the Ministry of Environment, Science and Information Branch for the Resource Information Standards Committee (BC MOE 2009). A top set wading rod was used to determine stream depth at each measurement point so average velocity could be measured. Velocity measurements were taken with the sensor positioned at 0.6 of the water depth (from the water's surface).

The quality of velocity measurements was improved by selecting the correct measurement cross-sections, where flow direction at each measurement point was parallel to the bank and perpendicular to the cross-section. Cross-sections were chosen and inspected prior to each discharge measurement to ensure they were free of debris, aquatic plants, and signs of human or animal activity. They also needed not to have had any significant changes in bed or channel morphology, overflow channels, and ice or snow jamming. There was a small side channel at OC04 that had flow at high stage. When these conditions were encountered, a separate discharge measurement was made in this channel to add to discharge values obtained from the main stream channel at the station installation.

During winter low-flows, stations at higher elevations (i.e., GSC05 and OC04) became buried in 1.5−2.5 m of snow pack and therefore access to these sites to take discharge measurements became difficult. On Goldslide Creek, an alternate snow-free site (i.e., GSC99) was located 300 m upstream from GSC05. This alternate site was found to be suitable for discharge measurements using the Hach FH950 current meter. Due to the low-flows, shallow water (< 4.0 cm), and greater pulsation effect at lower flows during winter months, the accuracy of these discharges was affected. These impacts were limited by increasing observation times of velocity measurements.

Though possible during winter low-flows, the use of the Hach FH950 in Bitter Creek (BC02) was not possible for most of the year due to safety concerns. These limitations were overcome by using tracer-dilution methodology. This mass balance method of determining discharges in high-flowing, turbulent, and steep streams is an accurate and reliable technique that involved injecting a known mass of tracer into the stream and measuring its concentration at a point downstream where the tracer has mixed evenly across the channel. The higher the flow was in the stream, the lower was the resultant tracer concentration (Hudson and Fraser 2005). Large quantities (typically 100 kg per injection) of dry table salt (sodium chloride) were injected into Bitter Creek at a site approximately 3.5 km upstream from BC02. Electrical conductivity at BC02 was then logged for a minimum of 45 minutes to verify that the salt pulse had passed and the conductivity of the stream water had returned to background levels. Salinity was measured indirectly using two YSI conductivity probes placed in the current directly opposite each other on both banks of Bitter Creek to verify complete mixing. Sensors were set to measure specific conductivity (in µs/cm), logged at 5s internals. Following data collection, probes were calibrated *in situ* to salt response and background conductivity levels using precise volumes of a known salt solution and water collected from the stream prior to the salt injections.

In order to calculate discharge, the logged conductivity data were plotted against time. Discharge was calculated from the area under the curve produced as conductivity rises from, and then returns to, background levels. Two discharge measurements were performed in this manner during each site visit and the average of the values was calculated. The agreement between the two discharge values is expressed as a percentage, and provided an ongoing indicator of the reliability of field measurements.

3.2.3 Data Management and Quality Assurance/Quality Control

The RISC hydrometric standards and methods outlined in the *Manual of British Columbia Hydrometric Standards* prepared by Ministry of Environment, Science and Information Branch for the Resource Information Standards Committee (BC MOE 2009) were used throughout the hydrology monitoring program. This manual outlines Data Grades and the four criteria used to define the grade. The five grades are Grade A National Standard, Grade B Provincial Standard, Grade C Manually-Operated Sites, Grade E Estimated, and Grade U Unknown. As indicated above, the four criteria used to assign data grades are instrumentation, stream channel conditions, field procedures, and data calculations and assessment. The goal in this study was to achieve the highest quality data grade while balancing budget and time constraints and the physical challenges of the Project area.

For the instrumentation criterion, the Grade A standard can be assigned as all sensors, data loggers, levels, current meters, and conductivity probes were calibrated according to the manufacturer’s instructions prior to each field season and/or site visit. The PT2X pressure sensors had an accuracy rating of 0.05% of the data range, which, for the observed water levels, was well below the maximum 2 mm standard for Grade A stage data.

The stream channel condition criterion met the Grade B standard as minor hydraulic issues, including some level of bed mobility at higher flows, occurred at all hydrometric monitoring stations across the Project area. To date, this erosion has not been significant enough to result in any shifts in the rating curves; however, it has been observed in the field and therefore a lower grade of data is more likely.

Field procedures followed the Grade A RISC standards in some areas, such as a minimum of three bench marks and 20 or more vertical sections in manual flow measurements when using a current meter if stream wetted width is greater than 2.0 m. However, some verticals were more than 10% of total discharge, particularly in low-flow conditions and when wetted width was less than 2.0 m. This merited a Grade B standard. Additionally, only four site visits were conducted in 2015; therefore, they only met the Grade B standard, which requires five or more site visits in a year prior to the rating curve being stabilized. Because the two high-elevation stations were deactivated in the winter months and limited discharge data and no stage data were available during this season, this data grade moved to C and E, estimated. Other than these exceptions, the field procedures met Grade B quality as a minimum, despite challenging site conditions.

Data calculation and assessment occurred at the field level with discharge rating accuracy based on the two discharge measurements being within 10% of each other. These data were used to develop site-specific rating curves and all subsequent data points served as a review for anomalies, further refining the curve. Site results were then compared to other adjacent stations to further verify that there were no anomalies. For this criterion, the overall data grade can be considered Grade A until rating curve extrapolation goes beyond twice the measured discharge levels, at which point it would become Grade E, estimated.

All field data checks were carried out using documented processes and procedures. All data were visualized and analyzed using Aquarius Time-Series software. If any anomalies were identified, the field crew and Project hydrologist met to discuss, assess, and rationalize any shortcomings and determined appropriate adjustments and field-level solutions.

All field technologists and hydrologists that conducted fieldwork for the Project were Qualified Professionals; specifically, they had a Bachelor's degree in Environmental Science, or a Master's degree in Environmental Engineering or Hydrology, in addition to significant relevant field experience.

3.3 Data Analysis

The typical methods used for the baseline analyses were as follows: correlation matrices, regional analysis, cluster analysis, frequency analysis and meteorological patching. These tools are standard methods often utilized within the field of hydrology. Due to the nature of the available site-specific data for the Project, it was preferable to use the more recent (i.e., 2014−2016) monitoring data to establish relationships between the site and regional data. However, historical data and previous data interpretations were used to validate the interpreted data record, and is presented in the Bench mark sections of the report (Sections 4.3.8 and 5.4.6 for precipitation and hydrology, respectively).

The following sections outline the methods used within the meteorology and hydrology baseline programs. Specific details for these methodologies are described in the associated parameters sub-sections.

3.3.1 Correlation Matrices

Correlation matrices are used to simultaneously evaluate the dependence of multiple variables with each other. The results of the matrix are a correlation factor, with the Pearson correlation coefficient (r) used as default for complete pairwise information. Depending on the specific methodology, the correlation values range from 0 to 1, or from -1 to 1.

Higher magnitude values suggest that the values can be used to represent one another. As an example, Figure 3-1 presents a correlation matrix in which the main parameter of interest is mean annual air temperature (MAAT), with latitude, longitude, elevation and distance of the meteorological station from the coast. The relationships and correlation coefficients for MAAT are shown along the bottom and right side of the graphic respectively. The stars at the cell's upper-right corner show a statistical significance of the correlation test results, where three stars is highly correlated (P-value < 0.001) and no stars demonstrates no correlation among variables (P-value > 0.1). The relationships along the bottom of the graphic illustrate Locally Weighted Scatterplot Smoothing (LOWESS) regressions. In this example, the strongest correlation was determined between MAAT and elevation (outlined in orange), with a Pearson correlation coefficient (r) of 0.91, and a high statistical significance (P value < 0.001).

This methodology allowed for the selection of the parameters with statistical significance to represent a meteorological/hydrological variable such as a MAAT, runoff or precipitation. Additionally, this methodology was used to find similarities between regional and local stations or to find appropriate stations to patch or fill the gaps between missing records (see also Section 3.3.5).

3.3.2 Regional Analysis

Regional analysis is used to investigate and establish relationships between regional parameters such as elevation, latitude, longitude, distance from the coast, slope, aspect, etc. and meteorological or hydrological parameters. This methodology is used to understand regional to local tendencies of regional parameters, and ultimately to predict site-specific conditions. As an example, Figure 3-2 presents the regional analysis of the MAAT versus elevation. In this example, the parameter elevation was selected from the correlation matrix as the best parameter to represent MAAT in the region. In contrast to Figure 3-2, a linear regression is shown.

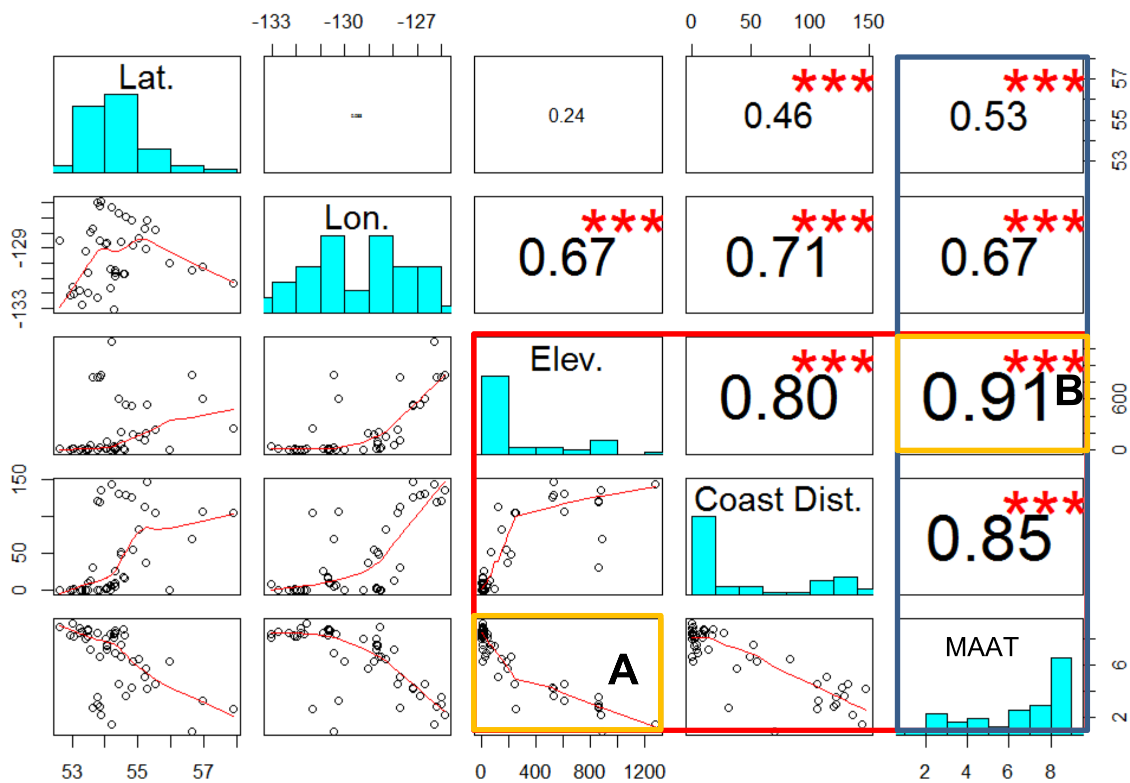


Figure 3-1: Example of Correlation Matrix for Regional Air Temperature (numbers represent the Pearson Correlation Coefficient (r), while *'s provide an indication of statistical significance)

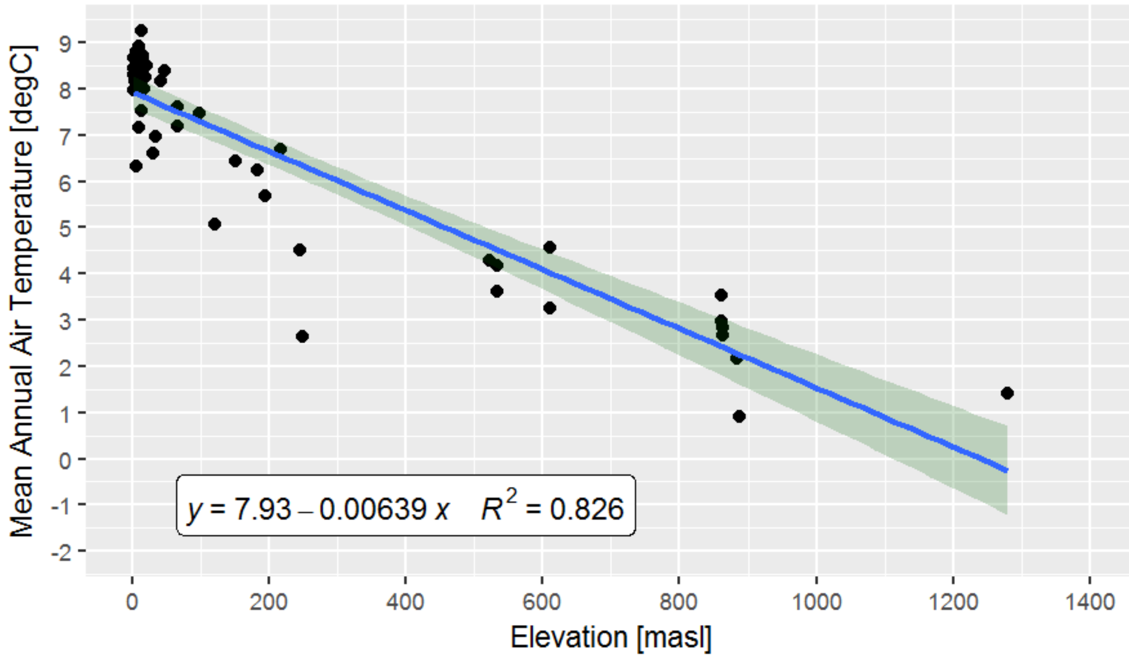


Figure 3-2: Regional Analysis of Mean Annual Air Temperature versus Elevation

3.3.3 Cluster Analysis

Cluster analysis is a commonly-used methodology for grouping objects with similar characteristics. Due to the number of regional stations that can be compiled, it is practical to divide the information into smaller groups with similar features. In the case of the hydrology, the regional gauge information was divided into clusters based on the following parameters:

- **Geometry parameters**: Watershed area, watershed perimeter, average elevation, centroid latitude and longitude, distance from the coast.
- **Watershed ratio**: Forest ratio, lake/pond ratio, glacial coverage ratio.
- **Flow parameters:** Mean annual runoff, ratio of the minimum average two-month runoff to the maximum average two-month runoff, beginning month of minimum average two-month runoff, beginning month of maximum average two-month runoff. These last three parameters are based on Guttman (1993), and are to represent the shape of the hydrograph.

Detail regarding the sources for these parameters is explained in Section 5.2.2. Prior to cluster analysis, the parameters above were normalized by removing the parameter means and then dividing by the standard deviation ($X_i scaled = \frac{X_i original - \overline{X}}{\sigma}$).

There is no standard procedure for defining the number of clusters in which to divide the data sets, so this was performed using three different methodologies: Sum of Squares Error (SSE) (Hothorn and Everitt 2009), Silhouette (Everitt et al. 2011), and Calinski-Harabasz methodology (Everitt et al. 2011). The most consistent result from these three methodologies was used to define the number of clusters. Then, the parameters listed above were used to partition the samples into clusters using the k-means methodology[1].

Figure 3-3 presents an example of the results of the cluster analysis for the regional hydrology. The data were grouped in to two clusters: coastal gauges without glacier cover (in red), and interior gauges with higher glacier cover (in blue).

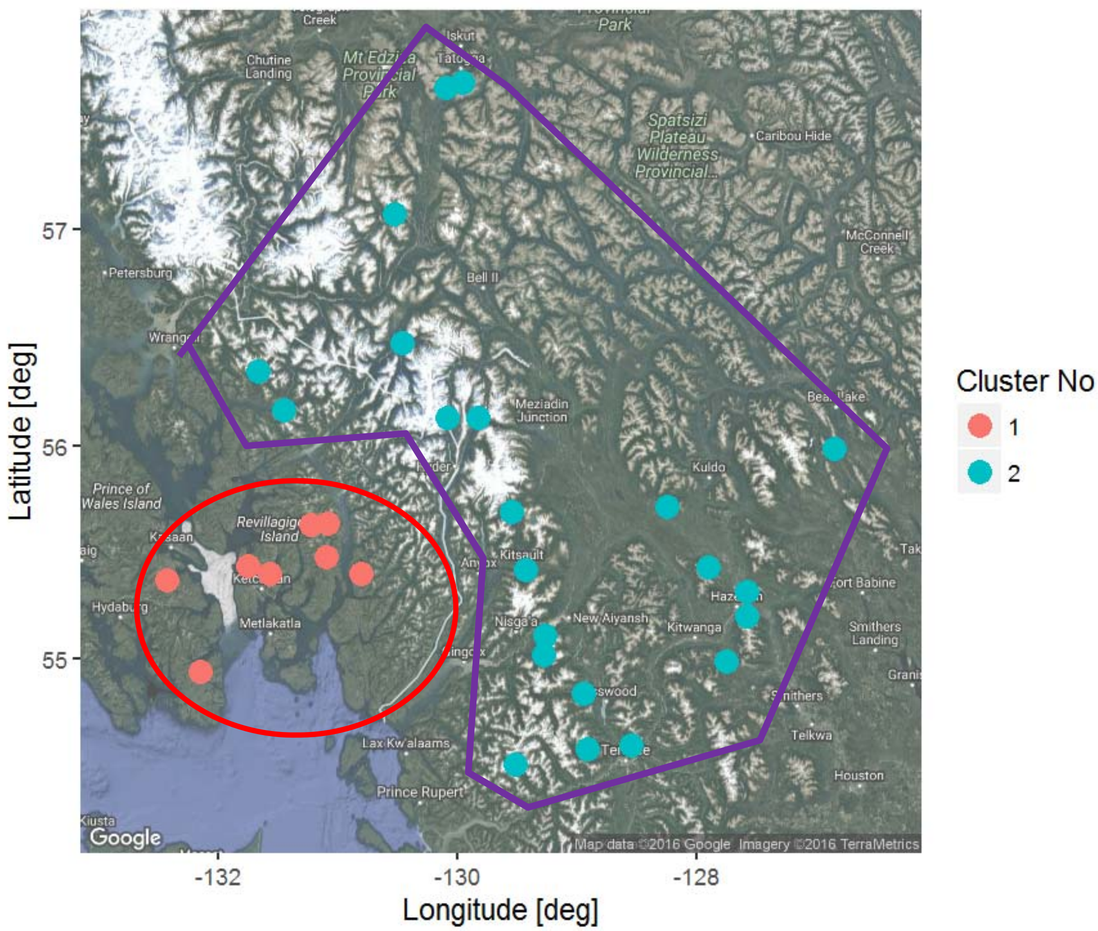


Figure 3-3: Cluster Analysis for the Regional Gauges

3.3.4 Frequency Analysis

Frequency analysis is a process used to estimate the frequency of occurrence of a value based on a long-term time series. The desired frequency is typically in months or years and the periods are called return periods. The historical information is adjusted into a probabilistic distribution, and the most suitable distribution is selected. In this case, the frequency analysis was prepared considering the following probabilistic distributions: Normal, Log-Normal, Generalized Extreme Value (GEV), Gumbel, Pearson III, and Log-Pearson III. The selection of the distribution parameters was prepared with the L-moments methodology. The L-moments approach provides

[1] k-means clustering is a statistical method used to partition a number of observations (data points) into a specified number of clusters in which each observation belongs to the cluster with the nearest mean.

a more resistant estimation to outliers when compared with typical moment estimations. The selection of the best-fit distribution was prepared based on three criteria: Akaike Information Criterion, Anderson-Darling Criterion, and Bayesian Information Criterion, as described by Liao et al. (2009) and implemented in the statistical software, R.

3.3.5 Meteorological Patching

Typically, meteorological records present in different degrees missing values; these missing values need to be completed to have a consistent long-term record. A normal procedure is to implement mathematical relationships between the missing-value station and similar meteorological stations. This process of replacing missing values in a time series is called patching.

In this baseline program, the patching process was implemented with a subroutine in the language R, where linear, polynomial and Locally Weighted Scatterplot Smoothing (LOWESS) regression with and without an intercept zero can be used. LOWESS is a non-parametric regression that combines multiple regression models. In simple terms, it is similar to hand-drawn regressions. For simplicity and accuracy, the patching process was conducted with a linear regression model. A correlation matrix was used to select the most appropriate station pairs to patch the data.

As an example, Figure 3-4 illustrates the patching process of Sandspit A (Climate ID: 1057050) with station Langara (Climate ID: 1054500) before the information was adjusted to the site. The original daily time series is represented in blue, with red representing the patched information, presented in normal and log scale. In the squares, the linear daily and logarithmical daily values and monthly relationships are compared before and after the patching process. Finally, to confirm similarities, the monthly non-dimensional distribution for these two stations is presented in the bottom-right corner. The methodology interpolates daily information; however, it does not support extrapolation.

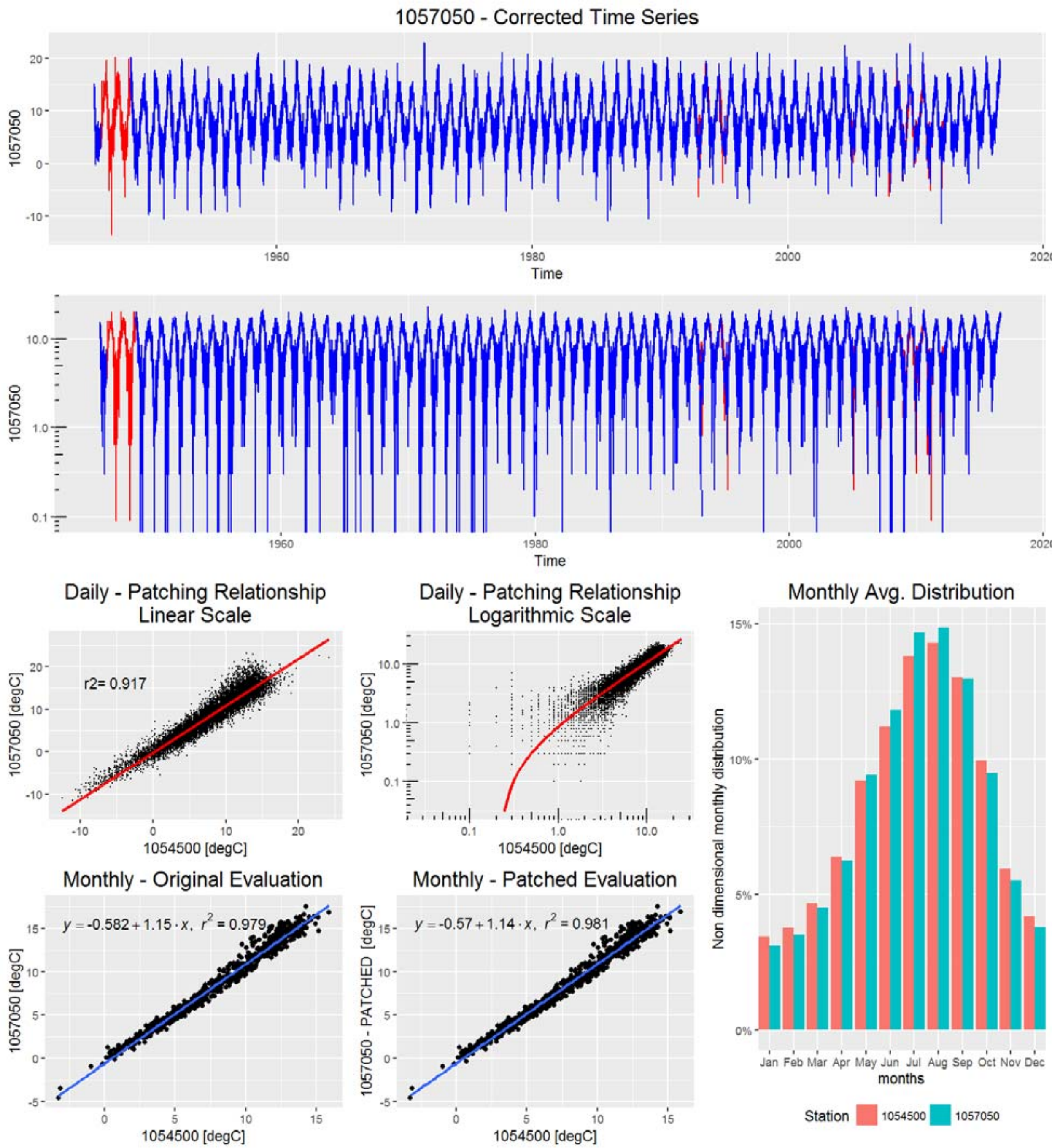


Figure 3-4: Example of Patching Process for Daily Air Temperature

4 Climatic Conditions

4.1 Overview

This section presents the results of site-specific data, and data analyses used to establish air temperature, precipitation, evaporation, wind speed and direction, relative humidity, and solar radiation at the site. The site-specific data include both historical and more recent monitoring data. In general, data from the more recent monitoring (i.e., July 2014 to July 2016) were used as the basis for establishing relationships with regional information, and then the historical data were used to validate these estimates.

4.2 Air Temperature

4.2.1 Available Data

Site Data

The site meteorological station, Redmount, was located at UTM grid reference 9U 0454893N and 6201831E, at an elevation of 1,498 masl. Hourly records of air temperature for the site were collected between July 2014 and July 2016[2]. For quality assurance purposes, a month of information was considered complete when fewer than five days were missing. Table 4-1 presents a summary of the available site information.

Table 4-1: Monthly Average Temperature Recorded at Red Mountain

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	-	-	-	-	-	-	-	8.7	6.2	0.7	-3.2	-4.2
2015	-4	-	-	-	-	-	-	6.4	2.3	1.6	-4.3	-6.2
2016	-3.2	-3.3	-2.4	0.3	3.3	5.5	-	-	-	-	-	-

Source: compiled in text.

Regional Data

The discontinuous site-specific temperature records from 2014 to 2016 were supplemented with regional data. The precipitation data from ECCC was available for the region as a daily time step for different meteorological stations for the period between 1886 and 2016.

The quality and quantity of data collected by ECCC was considered appropriate to characterize the region's climatic conditions due to the strict quality assurance system used by ECCC. Data from a total of 48 regional meteorological stations located within a 400 km radius from the site, and that have more than 10 years of information are summarized in Table B1 in Appendix B, and presented graphically in Figure 4-1 with MAAT from 0.91°C to 9.25°C.

[2] The cut-off for baseline climate data presented in this report was July 2016. The baseline hydrology data and analysis was updated to include data collected to December 2016.

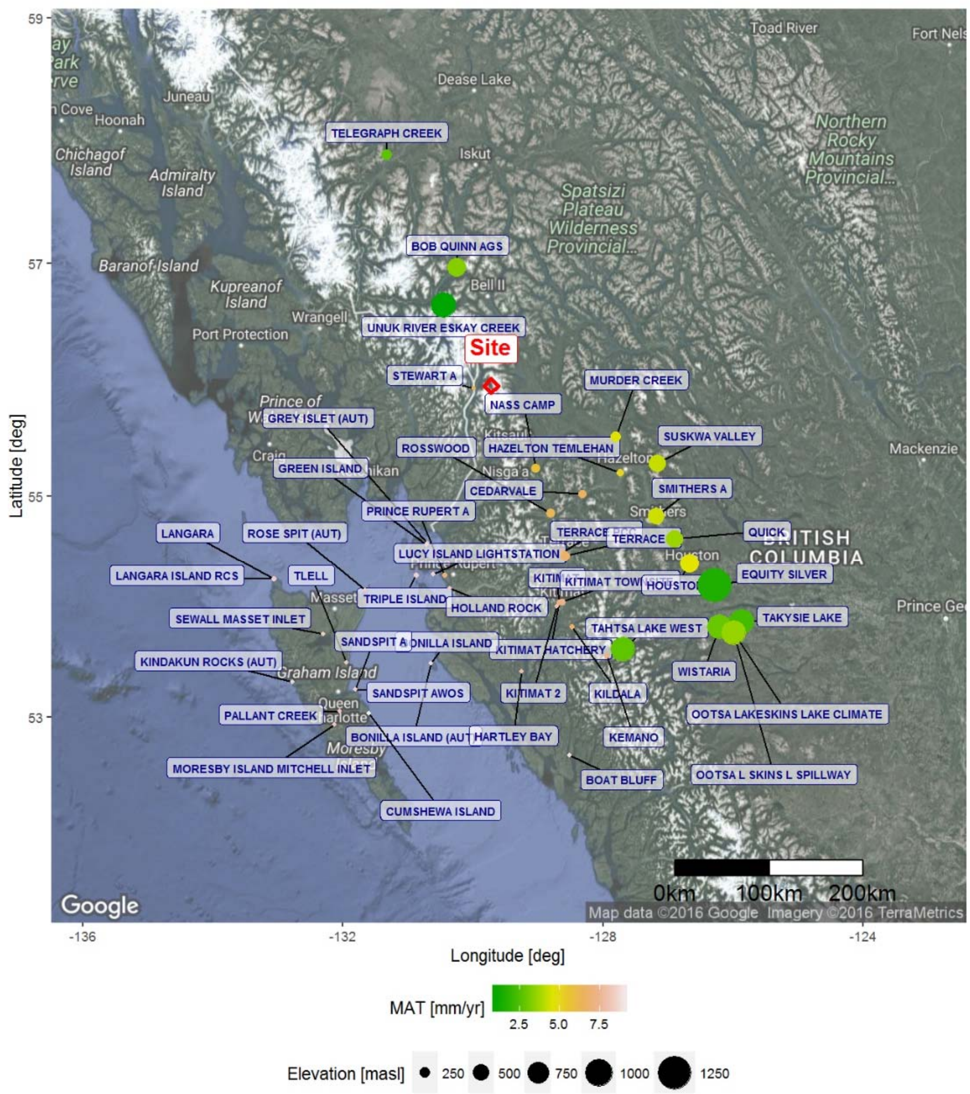


Figure 4-1: Mean Annual Air Temperature for the Regional Meteorological Stations

Reanalysis Data

The MAAT value at the site grid based on the reanalysis ERA-interim data set (ECMWF 2016) was 1.06°C. This value was estimated as an average of sub-daily information from 1979 to 2016.

4.2.2 Mean Annual Air Temperature Regional Trend

Figure 4-2 illustrates the MAAT recorded at the Stewart A, Sandspit A and Smithers A meteorological stations. At these three stations, the annual average temperatures increased at a constant rate from the 1940s (the beginning of the historical record for the stations Steward A, Sandspit A and Smithers A) to the present date, with a statistically-significant warming of 0.2°C per decade.

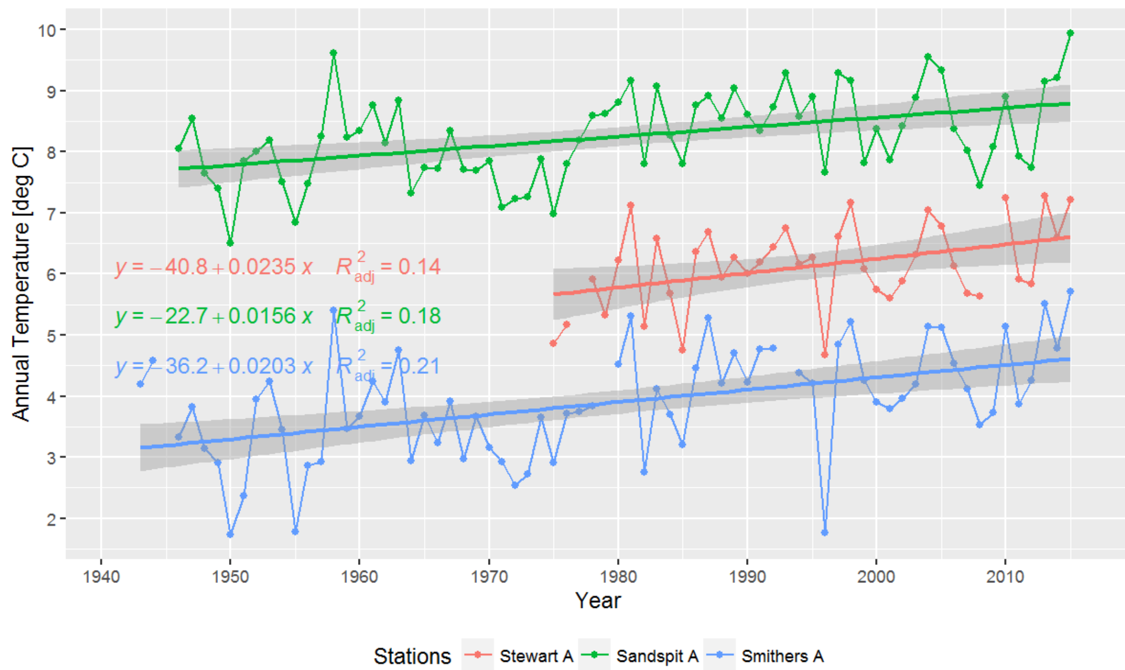


Figure 4-2: Historical Annual Trend for Regional Temperatures

4.2.3 Mean Annual and Monthly Air Temperature

Correlations between average daily temperatures at the site and average daily temperatures at various regional sites were used to establish trends in temperature over an extended timeline. Relationships between MAAT and elevation were then used to establish elevational differences and to estimate monthly air temperatures at the site.

The best correlations between daily regional temperatures with site temperatures were determined to be with stations on Haida Gwaii, and the coast (Pearson correlation coefficient, r, close to 0.9); these correlations were better than the values obtained with regional stations such as Stewart A, Smithers A and Terrace A. The strength of the correlation was likely due to the exposed nature of the Red Mountain site, which has temperature variability similar to other unprotected regions in the coastal area and at Graham Island. Figure 4-3 illustrates the daily temperature correlations between the site and regional stations, where the highest Pearson correlation coefficients with the site are in white tones, the lower values are in blue, and the size of the dot correlates with the amount of information available. The areas within a red circle have the highest regional correlations with the site.

The site information was estimated with daily information adjusted through a linear regression from the Sandspit A regional station to the site. This site had the highest correlation and one of the longest historical records, with 71 years of information.

Figure 4-4 presents the regional relationship between the MAAT and elevation. The color of the station identifier represents the distance from the site, with black indicating close proximity to the site, fading with increasing distance. The blue trend line represents a LOWESS relationship, a non-parametric regression that is a locally-moving regression (Cleveland et al. 1992), and the green line represents a linear regression. The bands around these lines represent the associated 95% confidence interval. Due to the continuous long-term regional warming trend, the presented information includes records from 1980 and beyond only. While this will not counteract the regional warming trend, it will produce a more homogenous record for comparison. The orange triangles represent historical results for the other site stations: Lower Tram, Upper Tram and Mount Dickie compiled in Rescan (1994), for the period between July 1993 and June 1994. The purple diamond and text is the MAAT determined for the area using reanalysis information with 1.06°C (Section 4.2.1), the red square and text is the MAAT average measured in the years 2014−2016 at the site station with 0.77°C, with the blue circle representing the estimated MAAT of the site data linearly extended with Sandspit A data with -0.86°C.

Figure 4-4 illustrates that the estimated value for the site, presented as a larger blue circle and text, follows the regional trend near the middle of the LOWESS and linear regression and is therefore considered to be an appropriate estimation for the site.

The MAAT for Red Mountain, measured at the site meteorological station and expanded with a linear regression from meteorological station Sandspit A from 1980 to 2016, is -0.86°C. The monthly air temperature is shown in Table A1 (Appendix A), and the mean monthly air temperature presented in Table 4-2. A boxplot with the monthly temperature ranges from 1980 to 2016 is presented in Figure 4-5, where the red line represents zero degrees.

All of the temperature relationships are prepared at reference elevation of 1,514 masl as this elevation was considered as representative for the site. However, these temperatures can be corrected for other elevations with the following relationship:

$$\mathrm{Tz} = (1514 - \mathrm{Z[masl]}) * 0.00634 + \mathrm{To}$$

where: To is the original temperature or time series of temperature presented in this report, Z is the elevation required for the new time series, and Tz is the temperature or time series associated with the elevation, Z. This relationship was derived from Figure 4-4.

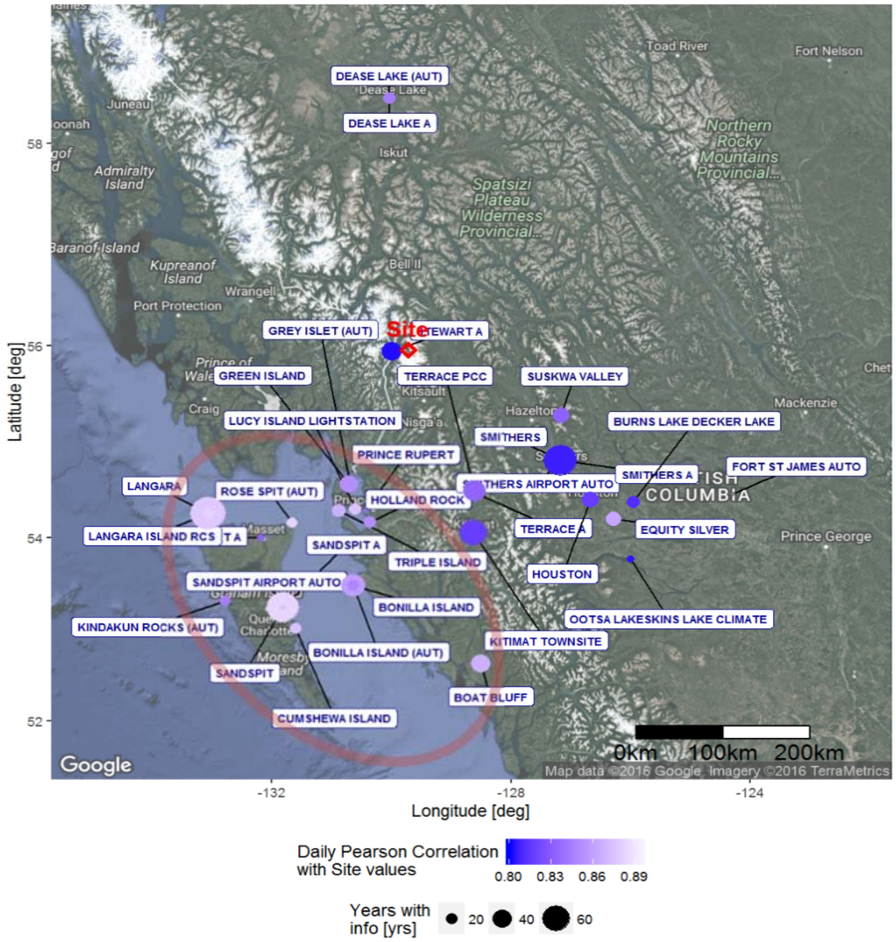


Figure 4-3: Correlations between Daily Temperature at the Site with the Regional Stations and Years of Information Available

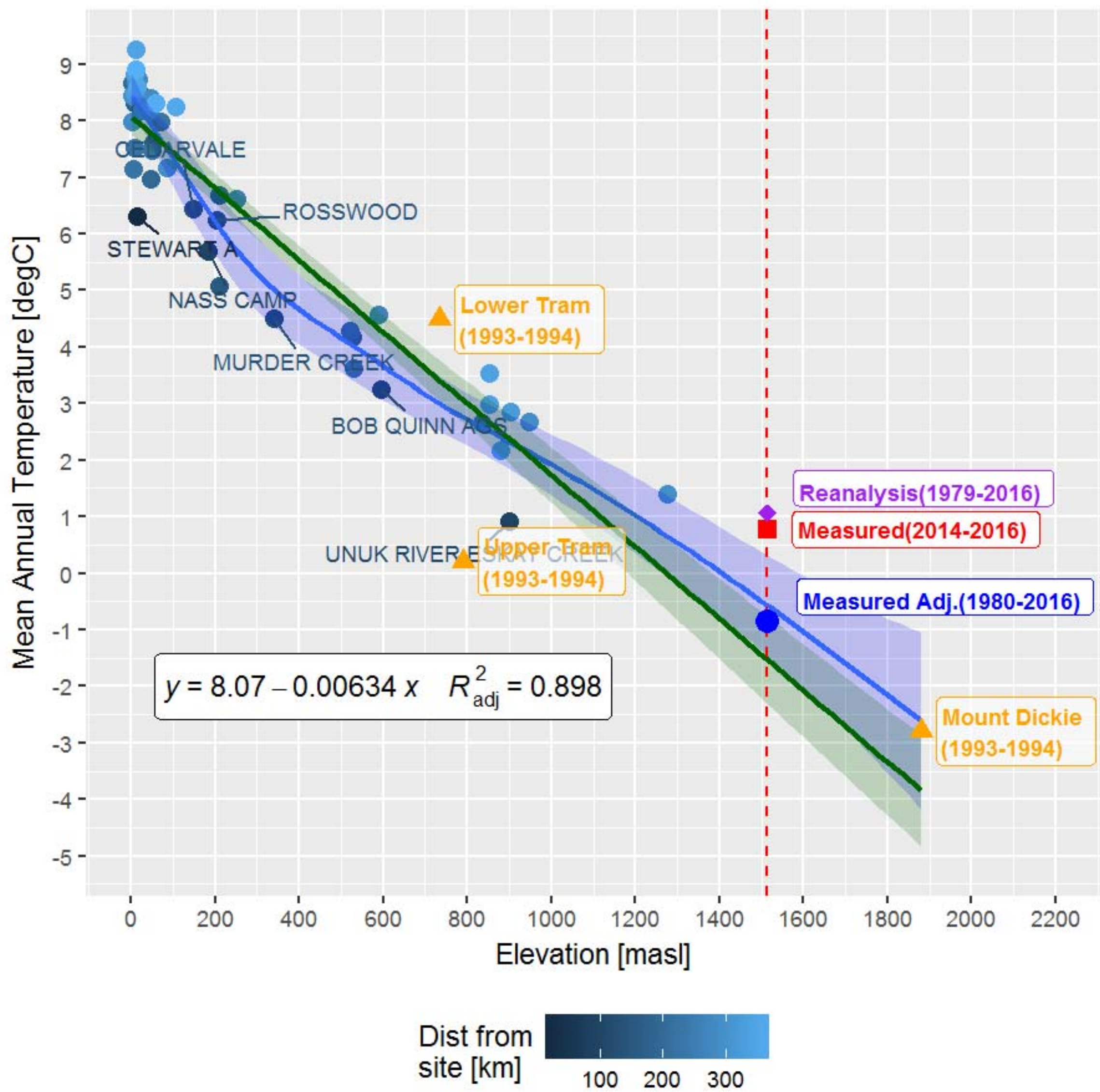


Figure 4-4: Regional Relationship between Elevation and MAAT

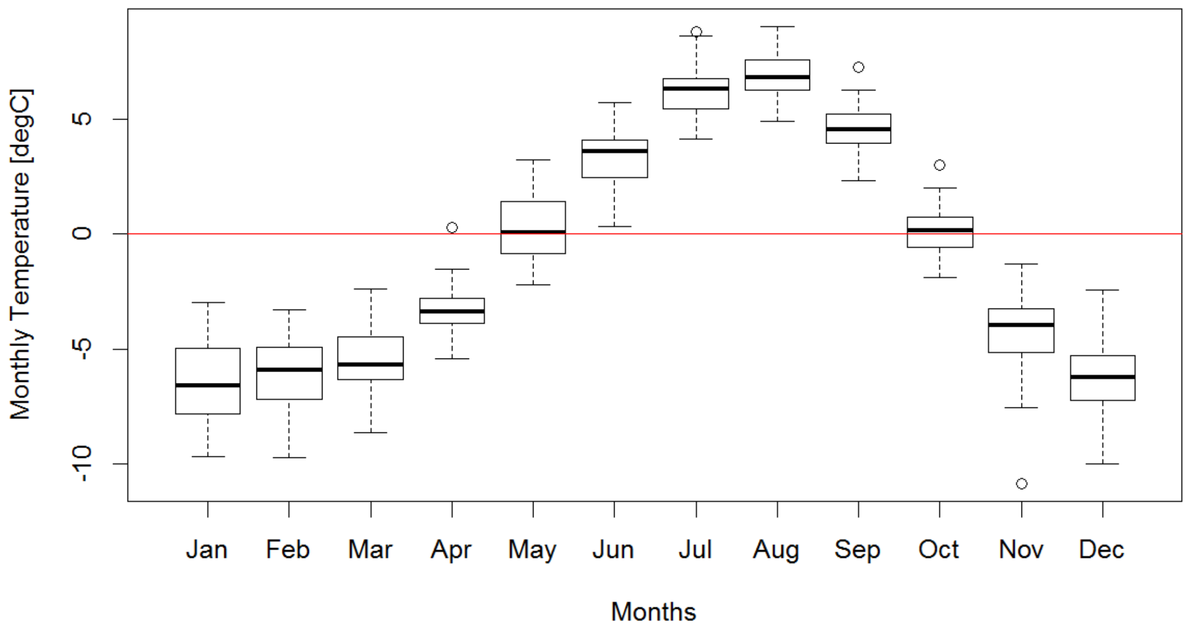


Figure 4-5: Monthly Boxplot for Temperature at Site in mm/month

Table 4-2: Monthly Statistics for Air Temperature for Red Mountain from 1980 to 2016

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	-9.7	-9.7	-8.7	-5.4	-2.2	0.3	4.2	4.9	2.3	-1.9	-10.9	-10
25%	-7.8	-7.2	-6.3	-3.9	-0.8	2.5	5.5	6.3	4	-0.5	-5.2	-7.2
50%	-6.6	-5.9	-5.7	-3.4	0.1	3.6	6.3	6.8	4.6	0.2	-4	-6.3
75%	-5	-4.9	-4.5	-2.8	1.4	4.1	6.8	7.6	5.2	0.7	-3.2	-5.4
100%	-3	-3.3	-2.4	0.3	3.3	5.7	8.8	9	7.3	3	-1.3	-2.5
-Mean	-6.4	-6.2	-5.5	-3.2	0.2	3.4	6.3	6.9	4.6	0.1	-4.4	-6.4
-Standard Deviation	1.9	1.8	1.5	1.1	1.4	1.3	1.1	1	1	1	1.8	1.6

Source: compiled in text.

4.3 Precipitation

4.3.1 Available Data

Site Data

The local Redmount station, described in Section 3.1.1, recorded hourly precipitation data for the site from August 2015 to June 2016. For quality assurance purposes, a month of information was considered complete when fewer than five days of data were missing. Table 4-3 presents a summary of the available site data.

Table 4-3: Monthly Precipitation (mm) Recorded at Redmount Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	-	-	-	-	-	-	-	155.4	179.3	349.6	-	-
2016	-	-	250.6	160.6	128.9	98.65	-	-	-	-	-	-

Source: compiled in text.

Regional Data

The discontinuous site-specific precipitation records from 2015 to 2016 were augmented with regional precipitation data. The regional precipitation data were available on a daily time step between 1886 and 2016 from ECCC.

The quantity and quality of the data were determined to be adequate to characterize the Project site's climatic conditions due to the strict quality assurance system operated by ECCC. The 200 stations closest to the site were selected, with a maximum distance of 100 km from the coast and a minimum of 10 years' worth of information to maintain the closest relationship to the site with a long-term record. This process resulted in the selection of 42 regional meteorological stations within a 400 km radius from the site (Table A2 and Table B2 in Appendix A and Appendix B, respectively); these are presented geographically in Figure 4-6. The amount of information available for each station is presented in Figure B2, in Appendix B.

Reanalysis Data

The mean annual precipitation (MAP) value determined at the site based on the reanalysis ERA-interim dataset (ECMWF 2016) is 2,027 mm/yr.

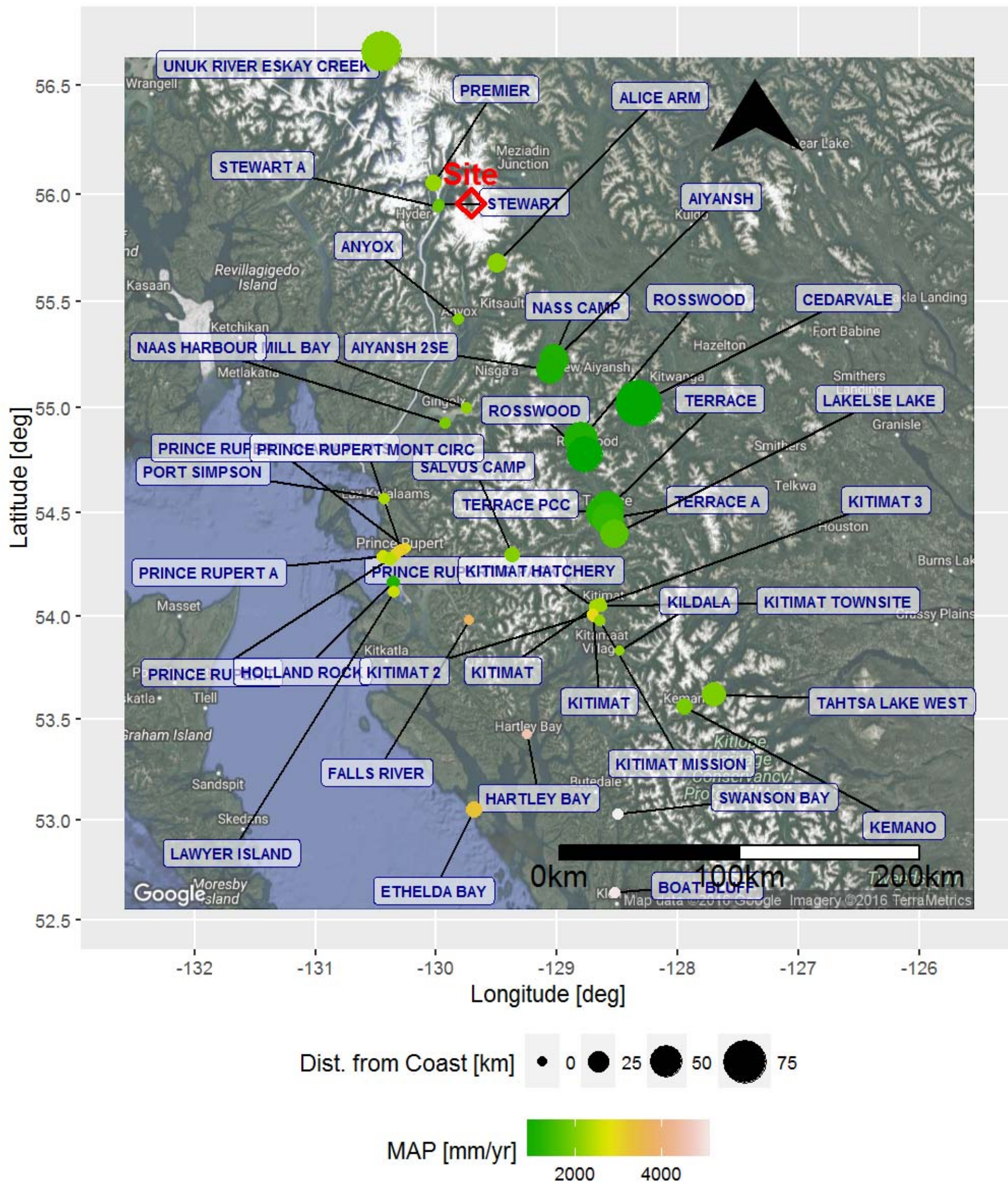


Figure 4-6: MAP for the Regional Meteorological Stations

4.3.2 Under-Catch

Local wind vortices around meteorological stations can produce a reduction in the amount of precipitation captured as rainfall or snowfall. The numerical factor to correct this loss is called the under-catch factor. The efficiency of each meteorological station depends on the station configuration.

ECCC publishes monthly under-catch factors for specific stations and parameters that are then described as adjusted and homogenized Canadian climate data (AHCCD) (Environment and Climate Change Canada 2016). The corrections are monthly values for parameters such as total precipitation, snowfall and rainfall.

The regional stations available and presented in Figure 4-7 were evaluated with and without under-catch corrections. In these regional stations, the under-catch correction changed mean annual precipitation by about 5%, which is considered within the range of precision of the study and therefore is not directly considered in the followed estimations. Further, there are no site-specific studies to corroborate this analysis; the presence of a value in the range of 5% suggests no important regional effect in the annual values associated with under-catch.

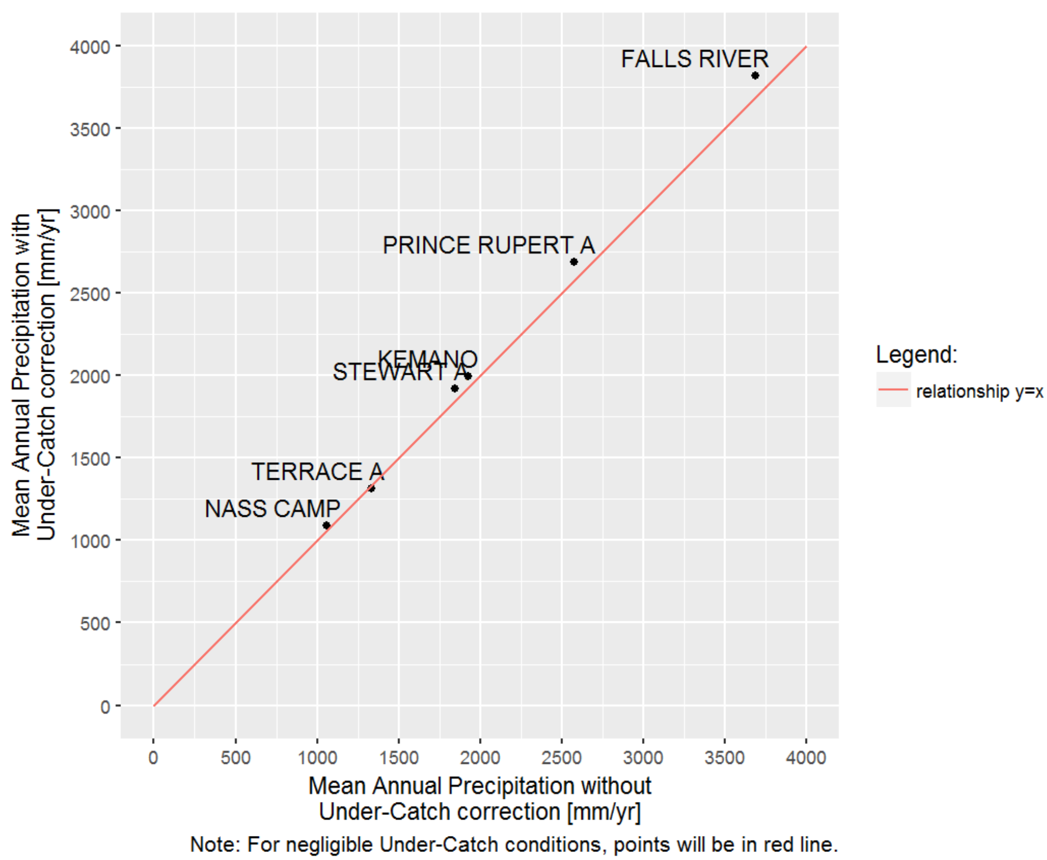


Figure 4-7: Comparison of Regional Mean Annual Precipitation with and without Under-catch Correction Factors

4.3.3 Mean Annual and Monthly Precipitation

Figure 4-8 presents a correlation matrix to select the most important parameters that affect the MAP for the regional meteorological stations. The parameters considered were latitude, longitude, elevation, and distance from the coast. The results suggest that distance from the coast and latitude are the most important factors that can be used to predict precipitation, with Pearson correlation coefficients (r) close to 0.6. Distance from the coast was selected as the parameter that most closely explained regional precipitation.

Theoretically, orographic effects should result in a relationship between elevation and MAP. However, the Pearson correlation coefficient (r) between these two parameters was 0.03, and the relationship had no statistical significance, with a P-value=0.83, when statistical significance is normally defined with P-value<0.05. This is likely due to the limited amount of elevation data in this area. However, in the absence of a numerical relationship with elevation, MAP estimates for the site were not adjusted for elevation.

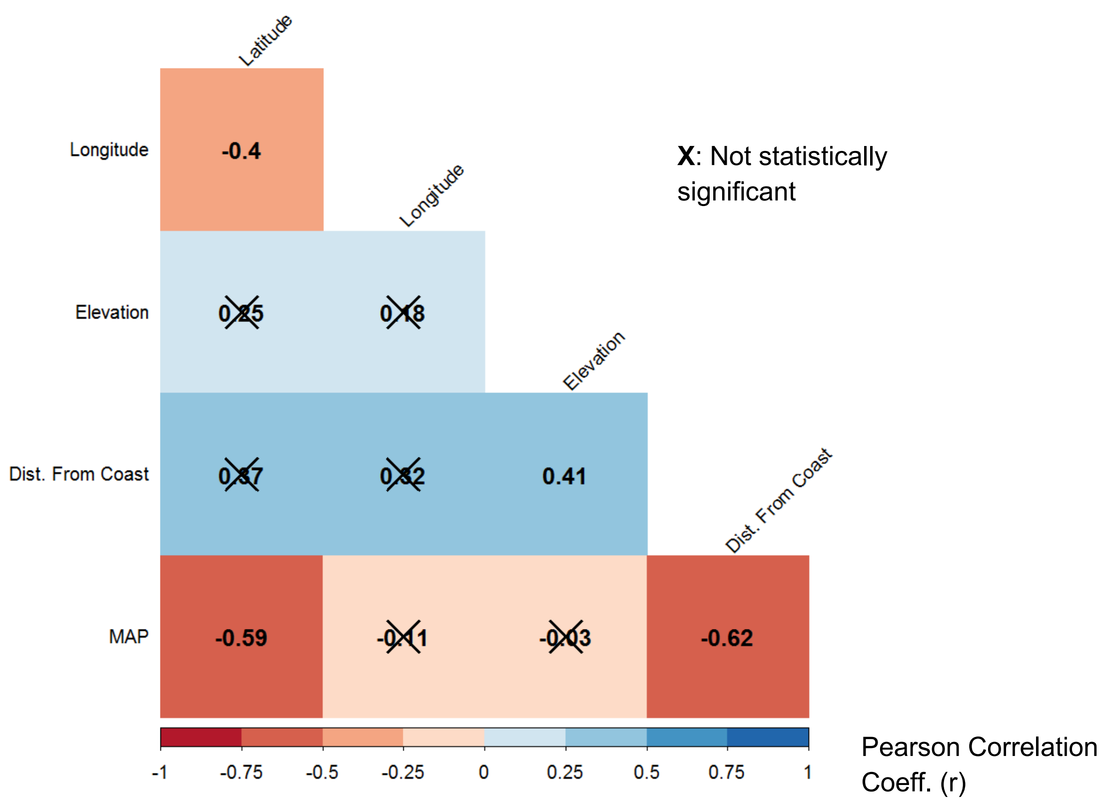


Figure 4-8: Pearson Correlation Coefficients between the Meteorological Parameters

Within the regional meteorological stations, Stewart A had the highest daily Pearson correlation coefficient with the site and it is the closest regional station to the site. The limited available site record suggests that: 1) daily precipitation at the site tends to be slightly higher than Stewart A where daily precipitation is over 20 mm and slightly lower than Stewart A where daily precipitation is less than 10 mm; however, 2) monthly precipitation at the site tends to be quite similar, with few monthly values slightly lower or higher than Stewart A. Since the amount of precipitation at Stewart is similar to the amount of precipitation at the site, the precipitation records from Stewart A were considered to be representative of the site without any corrections or adjustments.

Figure 4-9 illustrates a regional LOWESS regression relationship for distance from the coast and MAP, where the grey band represents the 95% confidence interval. The MAP for the site was estimated based on three methodologies: a regional analysis with 2,110 mm/yr (red dot), reanalysis information with 2,027 mm/yr (purple diamond), and the MAP from Stewart A meteorological station with 1,846 mm/yr (green triangle). The results yielded MAP values ranging from 1,846 mm/yr to 2,110 mm/yr, which were comparable to the estimates based on Stewart A data.

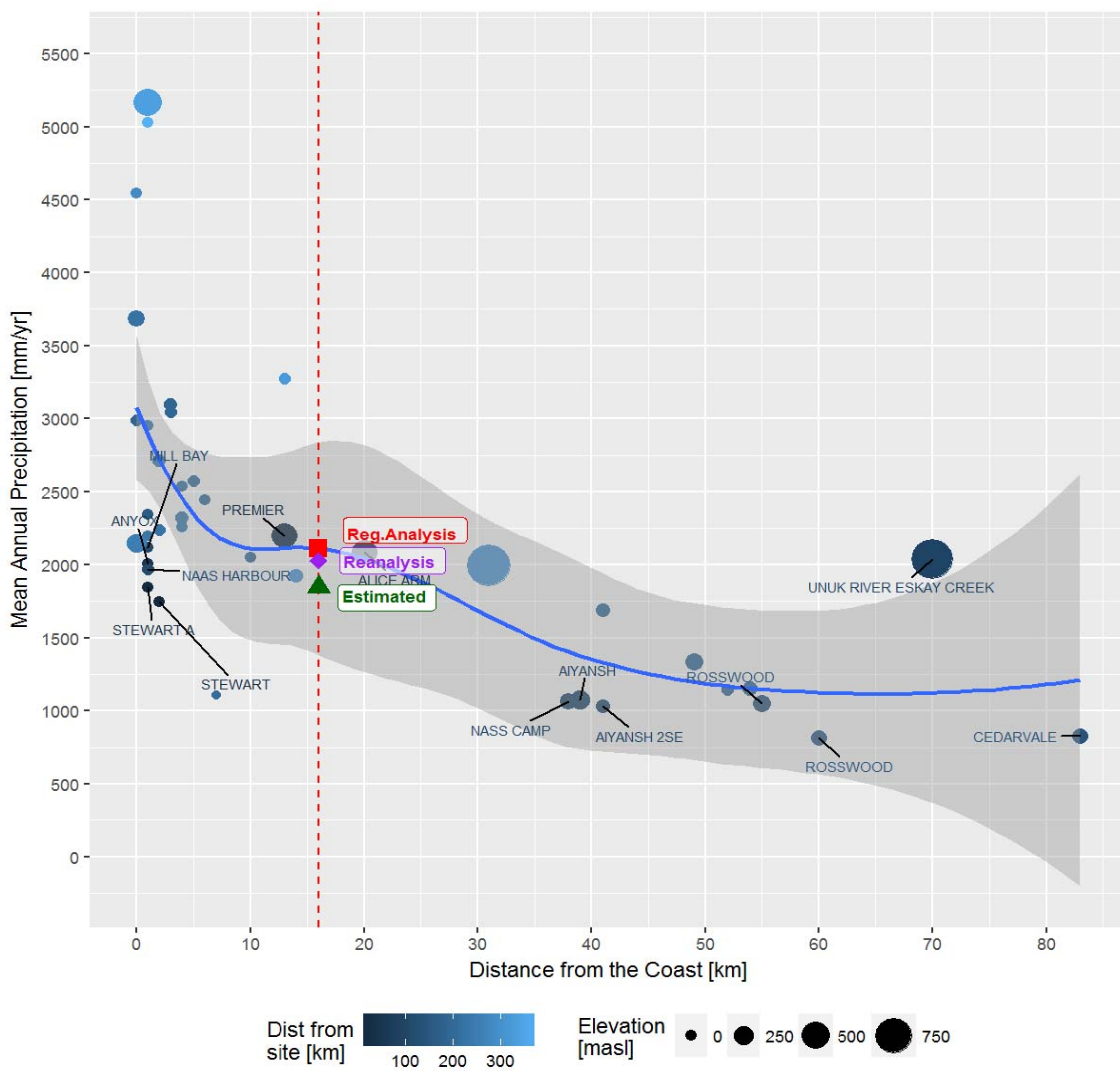


Figure 4-9: Regional Mean Annual Precipitation versus Distance from the Coast and the Mean Annual Precipitation at the Site

Because of the similarities in the results from these three methodologies, the limited amount of site information available, and the high daily correlations between the values measured at the site and Stewart A, the MAP of 1,847 mm/yr from the ECCC Stewart A meteorological station was used as the MAP estimate for the site.

The information from Stewart A was patched with Nass Camp and Terrace PCC to produce a continuous long-term precipitation record for Stewart A. The monthly precipitation for Red Mountain is shown in Table 4-4, while mean monthly precipitation and monthly statistics are presented in Table 4-4. A boxplot of the monthly variability is presented in Figure 4-10.

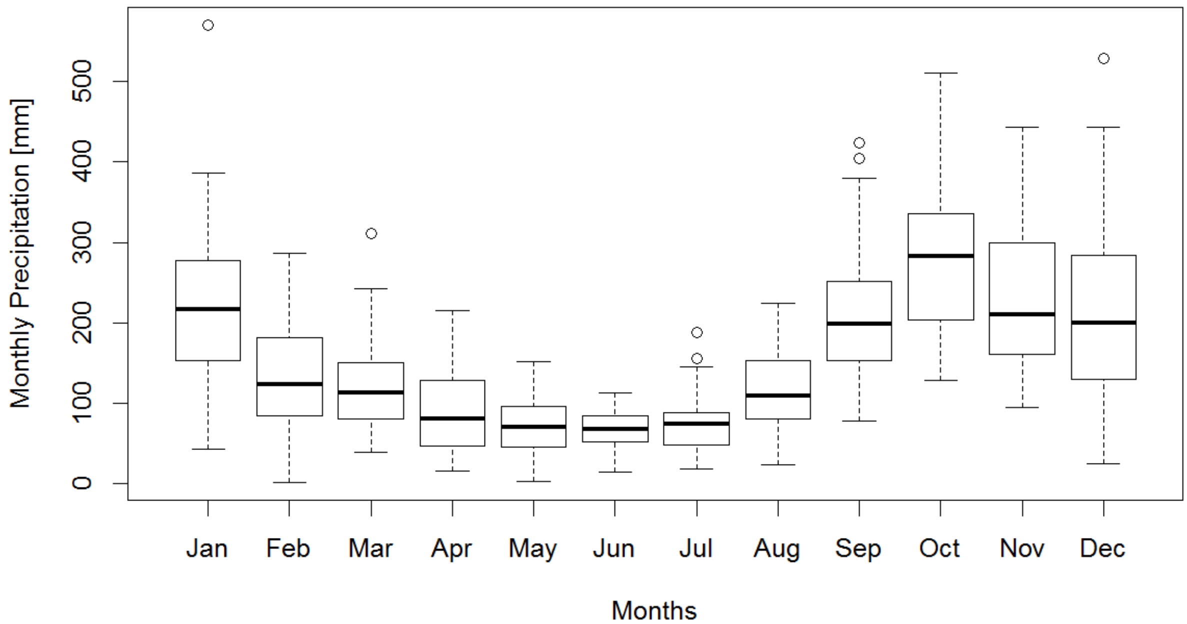


Figure 4-10: Monthly Boxplot for Precipitation at Site in mm/month

Table 4-4: Monthly and Annual Precipitation statistics at Red Mountain, Estimation directly from Stewart A Patched Records

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAP (mm/yr)
0%	43	2	39	17	3.7	16	18	24	78	128	95	25	-
25%	157	88	81	47	46	53	48	80	154	204	161	130	-
50%	217	124	113	82	70	68	75	109	199	283	210	200	-
75%	277	181	148	128	96	85	88	153	252	336	299	285	-
100%	570	287	311	215	152	113	189	225	424	510	443	528	-
Mean	219	137	121	90	72	66	77	121	211	291	227	214	1847
Standard Deviation	105	67	58	50	33	26	37	56	87	100	83	110	-

4.3.4 Annual Precipitation – Frequency Analysis

A frequency analysis was performed using the annual precipitation values for the Stewart A meteorological station. This frequency analysis was prepared considering the following probabilistic distributions: Normal, Log-Normal, GEV, Gumbel, Pearson III and Log-Pearson III. The distribution parameters were selected with the L-moments methodology. The L-moments approach suggests a more resistant estimation to outliers when compared with typical moment estimations.

The selection of the best-fit distribution was based on four criteria: Akaike Information Criterion, Akaike Information Criterion Corrected, Anderson-Darling Criterion and Bayesian Information Criterion as described by Liao et al. (2009) and implemented in the statistical software, R. A normal probability distribution was selected for this frequency analysis. Table 4-5 summarizes estimated annual precipitation at the Project for extreme conditions ranging from a 200-year dry return period (1,140 mm) to a 200-year wet return period (2,550 mm).

Table 4-5: Estimated Annual Precipitation for Extreme Conditions at Red Mountain

Hydrological Condition	Return Period	Estimated Annual Precipitation (mm)
Wet	200	2553
	100	2485
	50	2410
	20	2298
	10	2198
	5	2078
Median	2	1847
Dry	5	1616
	10	1496
	20	1396
	50	1284
	100	1209
	200	1141

Source: compiled in text.

4.3.5 Short Duration Rainfall

A precipitation-duration-frequency curve for the Stewart A station is available from ECCC, with return periods from 2 to 100 years (EC 2015). This information is presented in Table 4-6.

Table 4-6: Intensity-Duration-Frequency (IDF) Data for Red Mountain

Storm Duration		Average Intensity (mm/hr)					
		Return Period (yrs)					
min	hours	2	5	10	25	50	100
5	0.08	24.7	35.3	42.2	51	57.5	64
10	0.17	17.1	22.6	26.3	30.9	34.4	37.8
15	0.25	13.8	17.7	20.2	23.4	25.8	28.1
30	0.50	9.5	11.5	12.8	14.5	15.7	16.9
60	1	7.1	8.4	9.3	10.3	11.1	11.9
120	2	5.9	7.2	8	9.1	9.9	10.6
360	6	4.5	5.5	6.2	7.1	7.8	8.4
720	12	3.6	4.5	5.1	5.9	6.4	7
1440	24	2.8	3.7	4.2	4.9	5.4	5.9

Source: compiled in text.

4.3.6 Probable Maximum Precipitation

The probable maximum precipitation (PMP) was calculated using the Hershfield methodology (Hershfield 1965; WMO 2009), and the historical precipitation record from the Stewart A meteorological station (EC 2015). The Hershfield methodology requires the daily maximum 24-hour precipitation for at least 10 years of record. Station Stewart A consists of 41 complete years of recorded information. Using these data, the 24 hour-PMP was estimated to be 481 mm.

As further support through regional context, PMP was also estimated for the local region using the regional precipitation database (See Figure 4-6). Using a correlation matrix comparing the regional parameters: PMP, MAP, elevation, latitude, longitude and distance from the coast, the parameter that best correlated with PMP was found to be MAP. This relationship had a Pearson coefficient (r) of 0.68, R^2 adj. of 0.44 and statistical significance ($p < 0.001$). Figure 4-11 illustrates the regional relationship between MAP and PMP, with closer stations represented as black dots and further stations represented as lighter blue dots. In this relationship plot, Stewart A lies in the region within the grey band, which represents the 95% confidence interval and therefore a PMP of 0.48 m is considered appropriate for the site in a regional context.

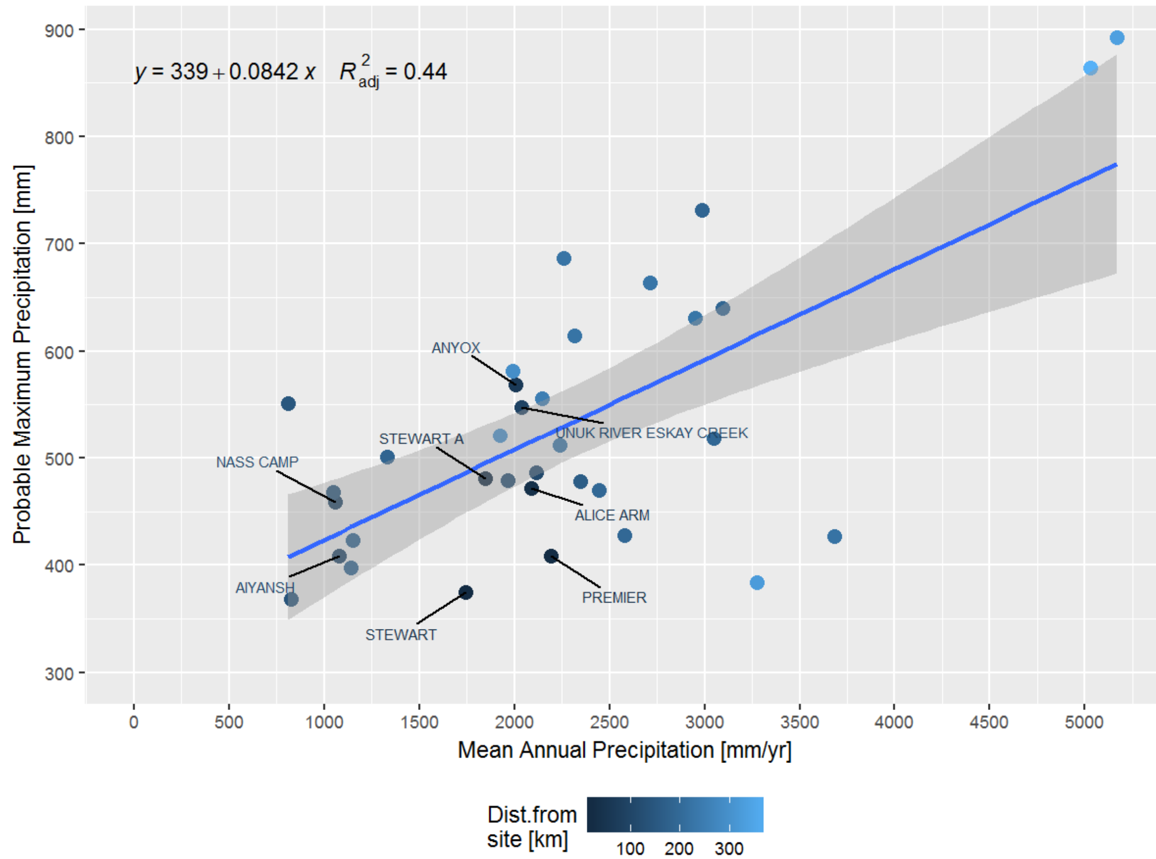


Figure 4-11: Regional Probable Maximum Precipitation around Red Mountain

4.3.7 Snowmelt

As described in Section 3.1.1, information associated with snowmelt and snow water equivalent (SWE) are from two recent site-specific sources: 1) the 2MW snow course, which started in 2016 and has four historical records; and, 2) the Redmount climate station with snow depth records from August 2015. Other regional sources of information were also used to derive the site values recommended for use in engineering design and analysis.

Snowmelt was estimated using a subroutine in R (CRAN 2016) called SnowMelt from the library EcoHydRology (Walter et al. 2005), which is a daily energy snowmelt model. This hydrological model is based on meteorological parameters, such as daily maximum and minimum air temperatures, wind speed and total precipitation.

For the maximum and minimum air temperature, the daily information from Sandspit A was patched with data from Langara and adjusted with a linear correction to be compatible with the site. The precipitation estimate was obtained from the daily patched information from Stewart A. Wind speed was obtained from reanalysis ERA-interim (ECMWF 2016). These sources produced daily information from September 1, 1979 to February 29, 2016. The model also required the latitude and longitude of the site and topographical slope and aspect of the terrain. These geological parameters were obtained from the USGS GTopo30, which provides worldwide topographical information with 30 arc-second spacing (USGS 2015).

Figure 4-12 illustrates the snowpack depth from September 2014 to 2016 based on different sources. Specifically, the snowpack depth measured at the Redmount station is presented in red, the spot measurements at 2MW snow course are shown in blue, and the results from the snowmelt model for snowpack are shown in green. The values for Redmount and the snowmelt model tend to have similar up and down shapes. However, the Redmount data show a higher peak in September and no important accumulations, with a reduction of snowpack in January 2016, which suggest values provided by the site instrument need to be reviewed. It is also possible that local wind characteristics in the area keep snowpack height locally at lower levels than the overall area.

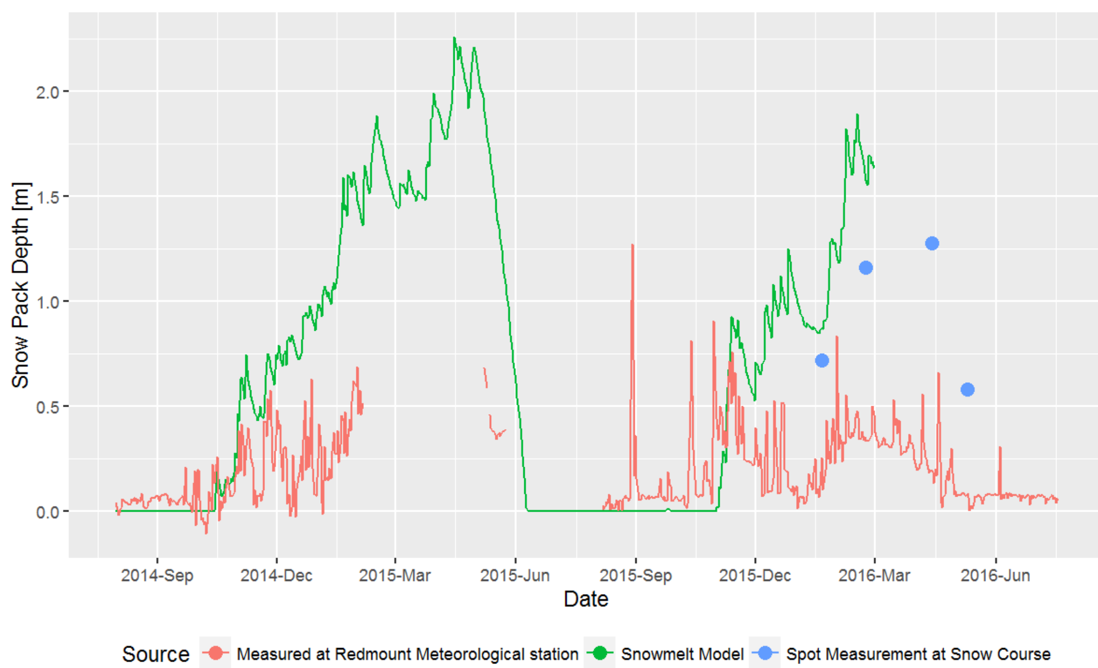


Figure 4-12: Snow Pack Depth at the Site Based on Redmount Station, 2MW Snow Course and Snowmelt Model

Figure 4-13 illustrates the SWE results, with model results in red and spot measurements in blue. Due to the similarities with the spot measurements at 2MW snow course, the energy balance snowmelt model based on Walter et al. (2005) is recommended for use in this study.

Based on the daily snowmelt model for the site, Table 4-7 presents the monthly average snowpack depth for the site of approximately 2 m from January to May, with maximum depths of 2.6 m in April. Table 4-8 shows the monthly SWE with maximum values in April and May of close to 1 m. The maximum daily snowmelt reported in an average year is 42 mm/day. Snowmelt is considered as effective reduction in height of the snowpack measured in mm/day.

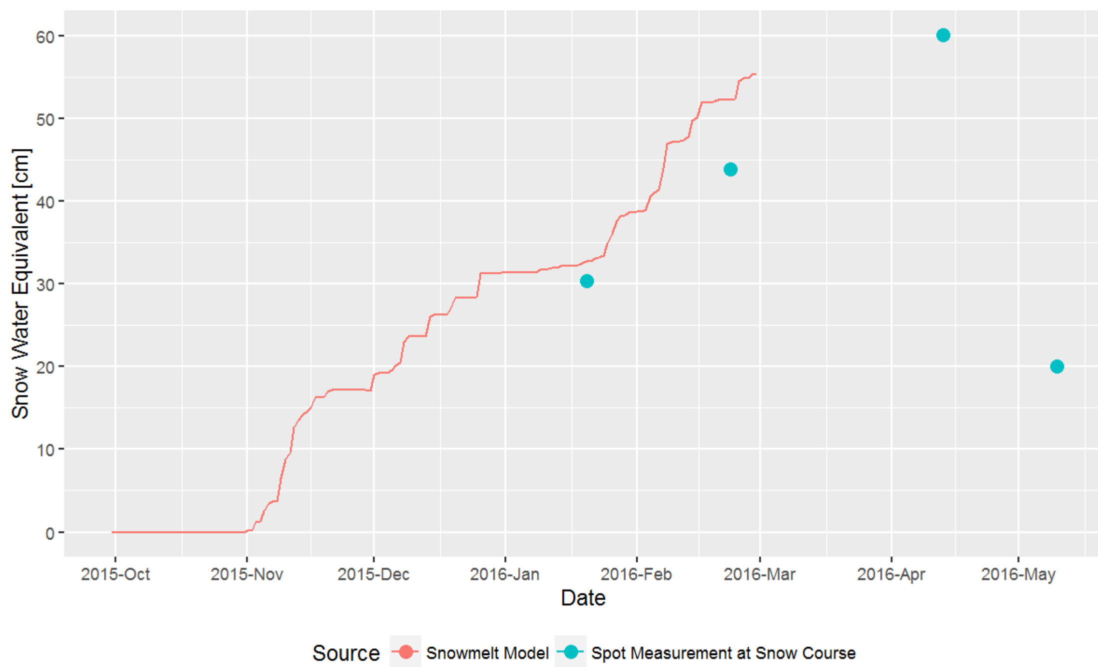


Figure 4-13: Snow Water Equivalent based on 2MW Snow Course and Snowmelt Model

Table 4-7: Monthly Average Snowpack Depth [cm]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
190	230	240	260	230	130	20	0	0	10	70	140

Table 4-8: Monthly Average Snow Water Equivalent [cm]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
57	75	88	98	97	58	11	0	0	2	16	36

4.3.8 Validation

Precipitation

Historical reports presented discontinuous precipitation results (Rescan 1994); however, there are no records or reports available from which this information can be recovered for further analysis or comparison with the analyses presented within this report. Previous reports and methodologies used Stewart A as a reference for the site precipitation, which is the same methodology selected for this report.

Probable Maximum Precipitation

The site information was compared with the information reported by NOAA (1963), which provides the probable maximum 24-hour precipitation for various locations in Alaska. The closest point with available NOAA reported information is located less than 30 km west from the site, with an average PMP value of 0.57 m, which is comparable to the PMP of 0.48 m estimated for Stewart A. Therefore, a site PMP of 0.48 m is reasonable based on support by other PMP values in the region.

Snowmelt

Rescan (1995) presented a compiled record of snow depth, SWE, and density for the Red Mountain Camp, as well as other snow courses in the area (e.g., Bear Pass and Granduc Mine), which were measured in 1994. This information was compared with the snowmelt model evaluation for the year 1994 derived by SRK in this report. Figure 4-14 illustrates the snow depth of the snowpack measured in 1994, Figure 4-15 illustrates the SWE for the snowpack measured in 1994, and Figure 4-16 illustrates the snow density of snowpack. In all cases, the results yield strong similarities – specifically, with respect to the SWE and snow densities.

The SRK-modeled snow depth tends to be higher than that measured on site, which can be the consequence of small differences in the snow-pack density estimations; however, in terms of snow water equivalent (SWE), the most important parameter of concern, the model tends to be accurate. This can be explained by the snow-pack density and snow depth values which, while being slightly inaccurate compared to what is evident on site, are compensating for one another. These overall results suggest that the snowmelt model is compatible with previous on-site measurements, and thereby validates the use of this tool for the project.

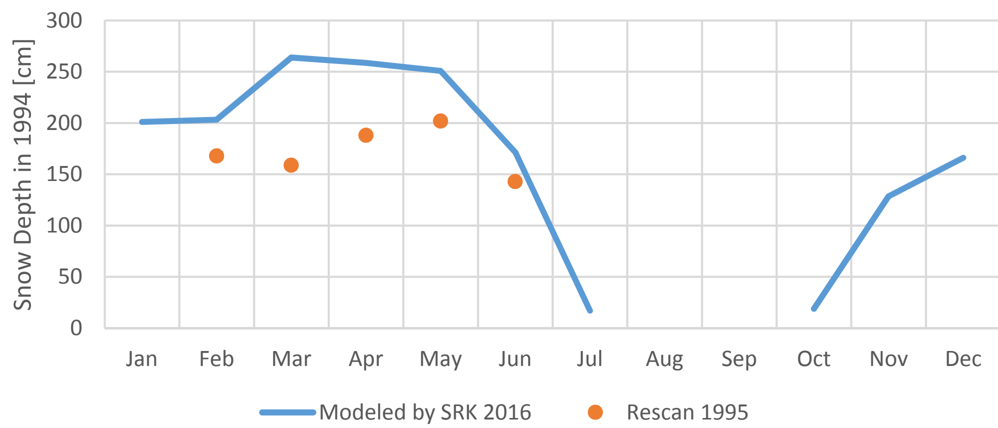


Figure 4-14: Snow Depth in 1994, Measured by Rescan (1995) and Modeled by SRK (2016)

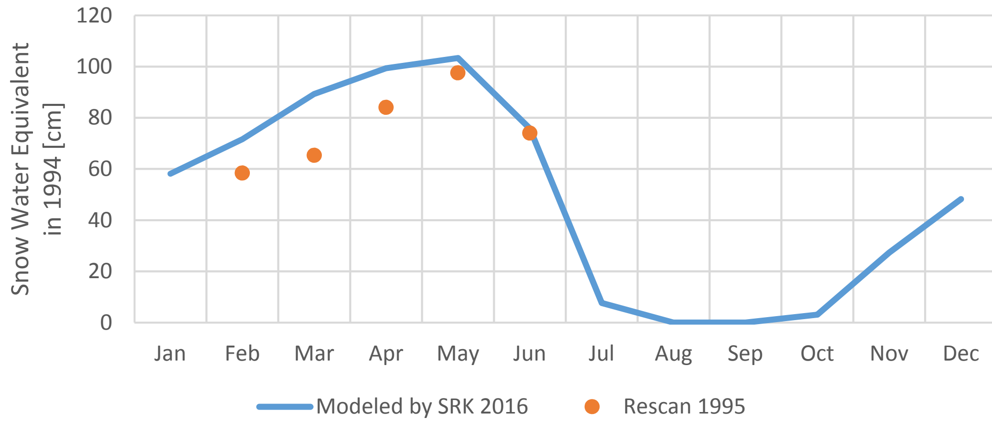


Figure 4-15: Snow Water Equivalent SWE) in 1995, Measured by Rescan (1995) and Modeled by SRK (2016)

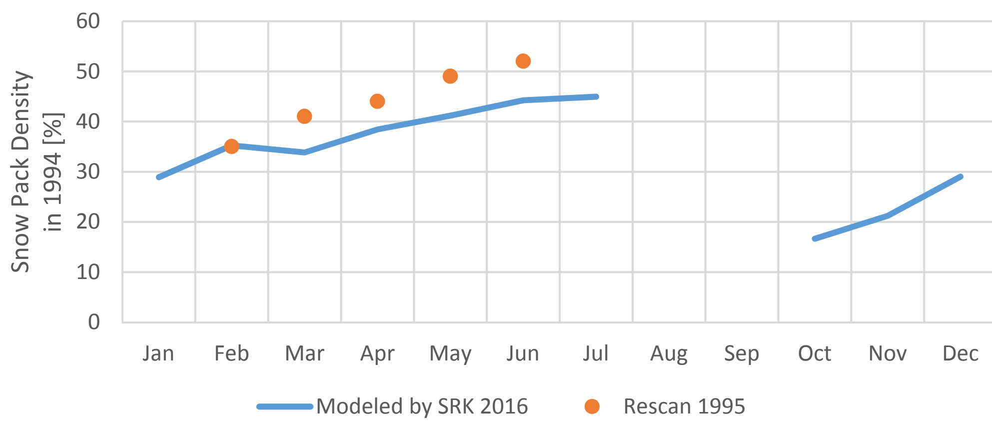


Figure 4-16: Snow Pack Density in 1994, Measured by Rescan (1995) and Modeled by SRK (2016)

4.4 Evaporation

Lake evaporation refers to evaporation from a free-water surface, while actual evapotranspiration refers to evaporation from land surfaces, including transpiration from vegetation. Both rates were estimated using the evapotranspiration computer model library in R, developed by the University of Adelaide, Australia (Guo & Westra 2014). The complementary relationships for areal evapotranspiration (CRAE) and wet-surface evaporation (CRWE) methodologies (Morton 1983) were used to estimate potential evapotranspiration and lake evaporation, respectively.

The model uses different routines to estimate lake evaporation and land evapotranspiration. The lake evaporation routine was tested against the results of detailed water-budget estimates of 11 lakes in North America and Africa. The evapotranspiration routine was tested against long-term water budget estimates of 143 experimental river watersheds in North America, Ireland, Australia, and New Zealand (Morton 1983).

Based on this, Morton's (1983) methodologies were applied to eight regional meteorological stations in British Columbia and Alberta, with latitudes similar to those of the Project site. Evaporation parameters, including air temperature, dew point temperature, and daylight hours were obtained from the 1981 to 2010 climate normal from ECCC (EC 2015). When any parameter was missing, the information was patched from two sources: 1) hourly information at the same station from ECCC (2016); or, 2) information from the closest regional station. The selected meteorological stations and the location with respect to the site is displayed in Figure 4-17.

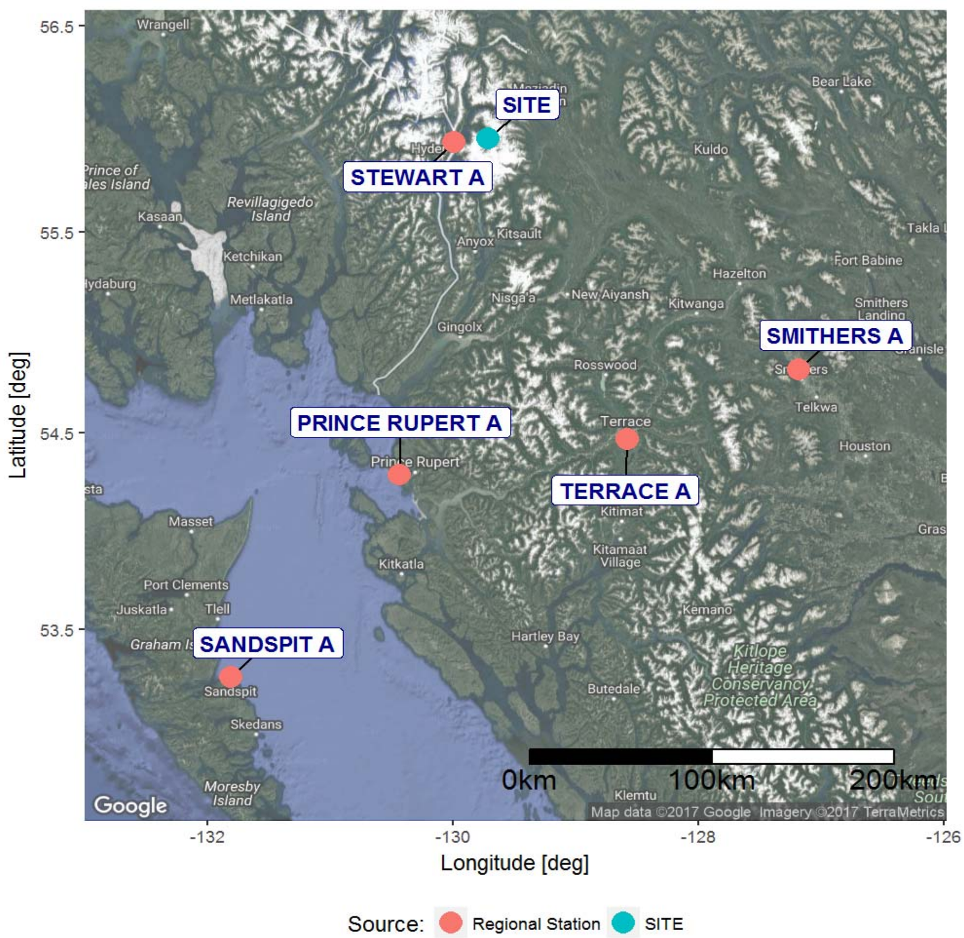
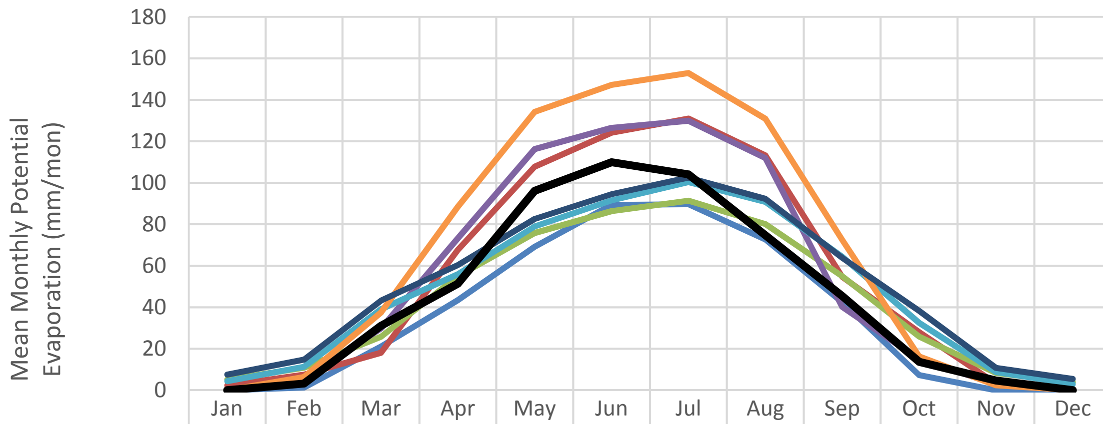


Figure 4-17: Regional Meteorological Station for Evaporation Estimations

The evaporation at the site was also calculated using Morton's (1983) methodology. The relative humidity was obtained from the monthly averages at Redmount station. Solar radiation was obtained from reanalysis MERRA (Section 4.7). Monthly temperature was obtained from the Sandspit A record, adjusted to the site (Section 4.2). The dew point temperature was estimated from the relative humidity and temperature records.

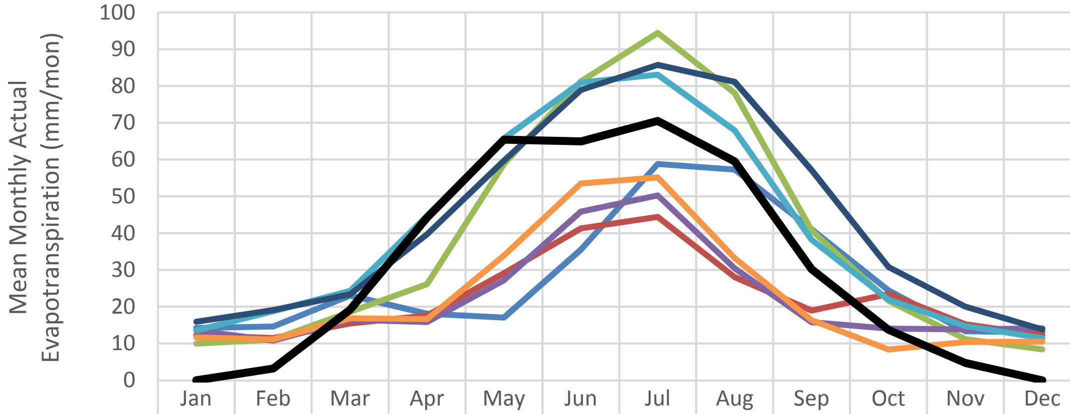
Figure 4-18 illustrates the mean monthly potential evaporation in the region and the sites where regional data exhibit similar trends. Figure 4-19 illustrates the actual evapotranspiration in the area and the site, which considers the effect of precipitation. Similarly, the regional data follow a similar trend, with the exception of the values estimated for Stewart A and Sandspit A, which have a delay in the peak to July. Figure 4-20 and Figure 4-21 illustrate the monthly average pan and lake evaporation in which all the values show similar trends.

Table 4-9 presents the overall monthly average evaporation for the site, as well as the annual values. The annual pan coefficient, defined as the quotient between annual lake evaporation and annual pan evaporation is 0.87.



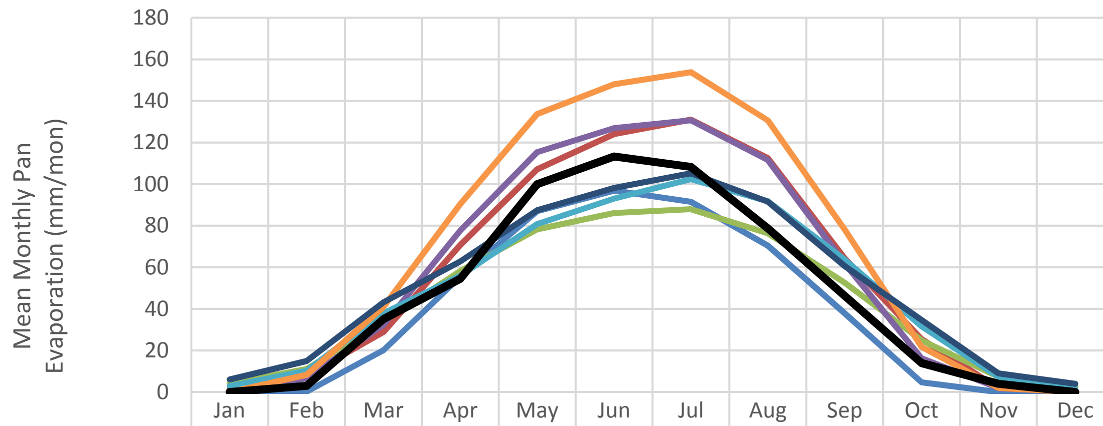
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STEWART A	0	1	21	43	69	89	90	73	42	7	0	0
TERRACE A	2	8	18	68	108	124	131	113	55	28	3	0
PRINCE RUPERT A	5	11	26	55	76	86	91	80	55	26	8	4
SMITHERS A	0	6	30	73	116	127	130	112	40	15	3	0
SANDSPIT A	4	11	39	56	79	91	100	91	64	32	9	3
PRINCE GEORGE A	0	6	37	88	134	147	153	131	72	16	2	0
PORT HARDY A	8	15	43	60	83	95	103	92	64	38	11	5
SITE	0	3	31	51	96	110	104	75	45	14	5	0

Figure 4-18: Mean Monthly Potential Evaporation in the Region and at the Site



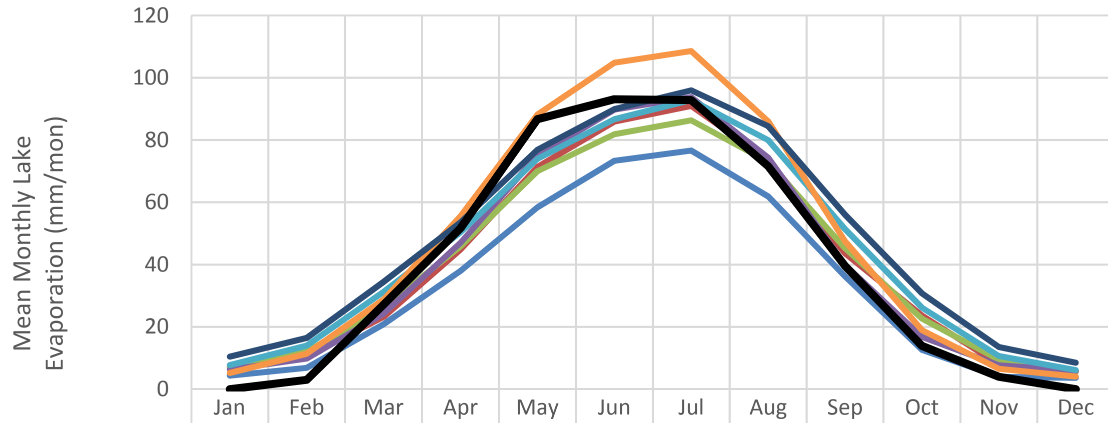
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STEWART A	14	15	23	18	17	36	59	57	41	24	13	13
TERRACE A	12	11	15	18	29	41	44	28	19	23	15	12
PRINCE RUPERT A	10	11	19	26	59	81	94	78	41	22	11	8
SMITHERS A	14	11	16	16	27	46	50	30	16	14	14	14
SANDSPIT A	14	19	24	45	66	81	83	68	38	22	15	11
PRINCE GEORGE A	12	11	17	17	34	54	55	33	16	8	10	11
PORT HARDY A	16	19	23	40	60	79	86	81	57	31	20	14
SITE	0	3	19	44	65	65	71	60	30	14	5	0

Figure 4-19: Mean Monthly Evapotranspiration in the Region and at the Site



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STEWART A	0	0	20	55	87	97	92	70	38	5	0	0
TERRACE A	2	8	29	71	107	124	131	113	64	25	2	0
PRINCE RUPERT A	4	11	34	58	78	86	88	76	53	25	7	3
SMITHERS A	0	7	32	78	115	127	131	112	62	16	2	0
SANDSPIT A	3	10	38	56	81	93	102	92	64	32	7	1
PRINCE GEORGE A	0	8	41	90	134	148	154	131	78	22	2	0
PORT HARDY A	6	15	43	63	87	98	105	92	61	35	9	4
SITE	0	3	35	55	100	113	108	79	46	14	4	0

Figure 4-20: Mean Monthly Pan Evaporation in the Region and at the Site



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STEWART A	4	7	21	38	58	73	77	62	36	13	4	4
TERRACE A	7	11	23	45	71	86	91	74	44	24	8	6
PRINCE RUPERT A	7	12	26	46	70	82	86	73	45	23	9	6
SMITHERS A	6	10	24	47	75	90	94	74	40	17	8	6
SANDSPIT A	8	14	31	50	74	87	93	80	51	26	11	6
PRINCE GEORGE A	5	11	29	56	88	105	109	86	47	19	7	4
PORT HARDY A	10	16	34	54	77	90	96	84	56	31	14	8
SITE	0	3	27	52	87	93	93	72	40	14	4	0

Figure 4-21: Mean Monthly Lake Evaporation in the Region and at the Site

Table 4-9: Mean Monthly Evaporation at the Site

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Potential Evapotranspiration	0	3	31	51	96	110	104	75	45	14	5	0	**534**
Actual Evapotranspiration	0	3	19	44	65	65	71	60	30	14	5	0	**376**
Pan Evaporation	0	3	35	55	100	113	108	79	46	14	4	0	**557**
Lake Evaporation	0	3	27	52	87	93	93	72	40	14	4	0	**484**

4.5 Wind Speed and Direction

Site Data

The local data include hourly wind speed direction and magnitude from July 30, 2014 to July 19, 2016. The record contains data gaps and has an average of 214 days of information per year. Table 4-10 presents the monthly measured wind speed and Table 4-11 presents the monthly measured wind direction at the Redmount meteorological station. In these two tables, a complete month was considered when a maximum of 5 days was missing.

Table 4-10: Mean Monthly Measured Wind Speed at Redmount Meteorological Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	-	-	-	-	-	-	-	2.4	3.4	6	4.3	6
2015	5.6	-	-	-	-	-	-	3.2	3.4	4.5	5	4.5
2016	6.1	5.7	6.1	4.5	3.5	2.3	-	-	-	-	-	-

Table 4-11: Mean Monthly Measured Wind Direction at Redmount Meteorological Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	-	-	-	-	-	-	-	SW	SSW	ESE	E	E
2015	SE	-	-	-	-	-	-	SSW	SSE	SE	SSE	E
2016	ESE	ESE	E	SE	WSW	WSW	-	-	-	-	-	-

The available local stations are illustrated by season in Figure 4-22. The predominant wind direction is east (E) and southeast (SE) during the winter, spring and fall. Summer winds tend to be calmer.

Regional Data

Regional data for hourly wind speed and daily wind gust speed were obtained from EC. However, the information available is scarce with a weak regional relationship between these stations and the site record. Furthermore, only a few stations recorded information between 2014 and 2016. Consequently, regional relationships were not used to supplement or expand site information.

Figure 4-22: Seasonal Wind Roses for the Redmount Meteorological Station

4.6 Relative Humidity

Site Data

Site data include relative humidity and magnitude from July 30, 2014 to July 19, 2016. There are some gaps in the information from February to July of 2015. Table 4-12 presents the historical information available at the site. In this table, a complete month was considered when less than five days were missing. With the limited information available, Table 4-13 presents the mean monthly relative humidity measured, which results in a mean annual relative humidity of 70% over this period of time.

Table 4-12: Measured Relative Humidity at the Redmount Meteorological Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	-	-	-	-	-	-	-	74.5	76.4	80	64.5	72.3
2015	80.4	-	-	-	-	-	-	82.5	84.3	70.4	68.4	68.3
2016	66	72.5	64.7	70.2	62	60	-	-	-	-	-	-

Table 4-13: Mean Monthly Relative Humidity Measured at the Redmount Meteorological Station

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
73.2	72.5	64.7	70.2	62	60	69.2	78.5	80.3	75.2	66.5	70.3

Regional Data

Regional data for hourly relative humidity are available from EC. The information is scarce, with only a limited number of stations for which data are available between 2014 and 2016. However, the regional information tends to be correlated among regional stations on a monthly scale. Figure B4 in Appendix B illustrates the available regional information.

Relative humidity is dependent on dew point temperature and air temperature; both parameters are intrinsically related to elevation. The mean annual relative humidity in the region was demonstrated to be strongly correlated with elevation, followed by distance from the coast. Figure 4-23 illustrates this regional relationship with the value estimated for the site. Unfortunately, in a radius of more than 500 km around the site, there are no public meteorological stations measuring relative humidity over 1,000 masl; however, the graph shows the site values within the magnitude expected for the elevation.

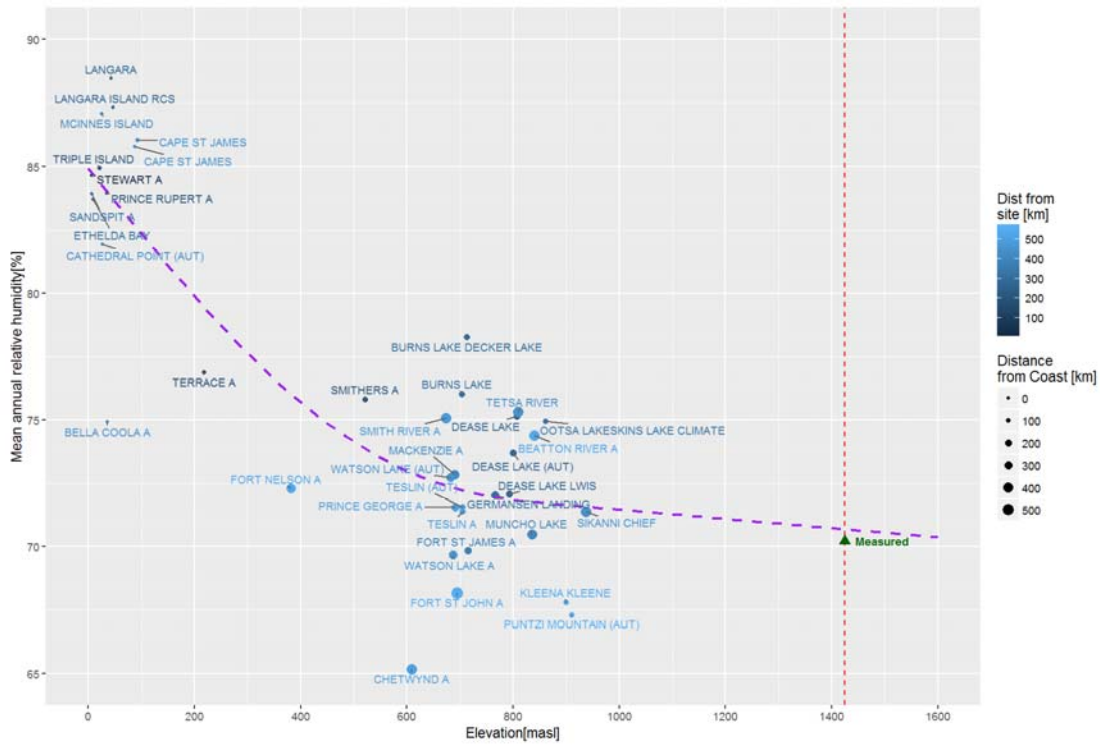


Figure 4-23: Regional Relationship between Elevation and Mean Annual Relative Humidity

4.7 Solar Radiation

Site Data

Site data include direct solar radiation from July 31, 2014 to July 18, 2016, with some gaps in the information from February to July 2015. Table 4-14 presents the historical information available at the site. In this table, and as mentioned above, a complete month was considered when fewer than five days were missing. Due to the limited information, the values should only be considered as a reference for the site. Future site meteorological records should complement and improve these presented estimations.

Table 4-14: Monthly Average Solar Radiation (W/m²)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	-	-	-	-	-	-	-	173.2	112.8	54.4	38.45	18.12
2015	24.83	-	-	-	-	-	-	140.9	103.9	67.66	37.24	22.69
2016	28.51	60.22	125.4	174.7	220.5	222.4	-	-	-	-	-	-

Regional Data and Reanalysis Data

Regional data for solar radiation are quite limited in the region and are mostly available through Canadian climate normals from ECCC (EC 2015). Daily reanalysis from MERRA (NASA 2016) information was preferable to using the climate normals, because reanalysis provides daily information over a period of more than 30 years, whereas Canadian climate normals are twelve monthly values from January to December calculated over less than 30 year time span. Consequently, the daily site information was compared with daily reanalysis from MERRA. Figure 4-24 illustrates the daily relationship between the daily solar radiation from reanalysis MERRA and the site (the red line represents the regression line). The relationship is quite close to a 1:1 relationship. Based on this similarity, the solar radiation from MERRA, which compiles information from 1983 to 2015, is an appropriate basis for extending the record over time. Table 4-15 shows the mean monthly average solar radiation at the site, based on reanalysis MERRA. Figure 4-25 illustrates a monthly boxplot of the solar radiation expected in the site based on reanalysis MERRA.

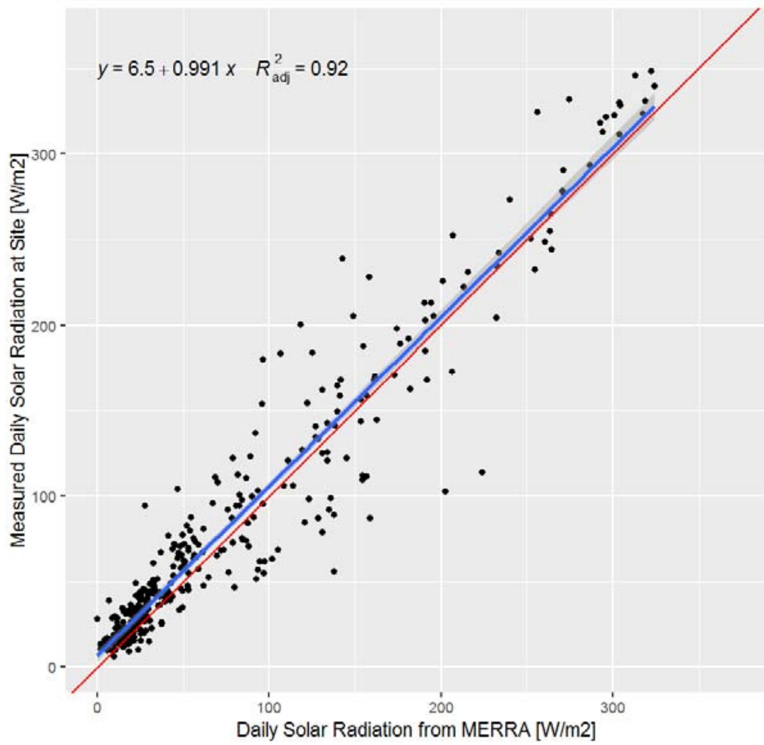


Figure 4-24: Daily Relationship between Daily Solar Radiation from Reanalysis MERRA and Measured at the Redmount Meteorological Station

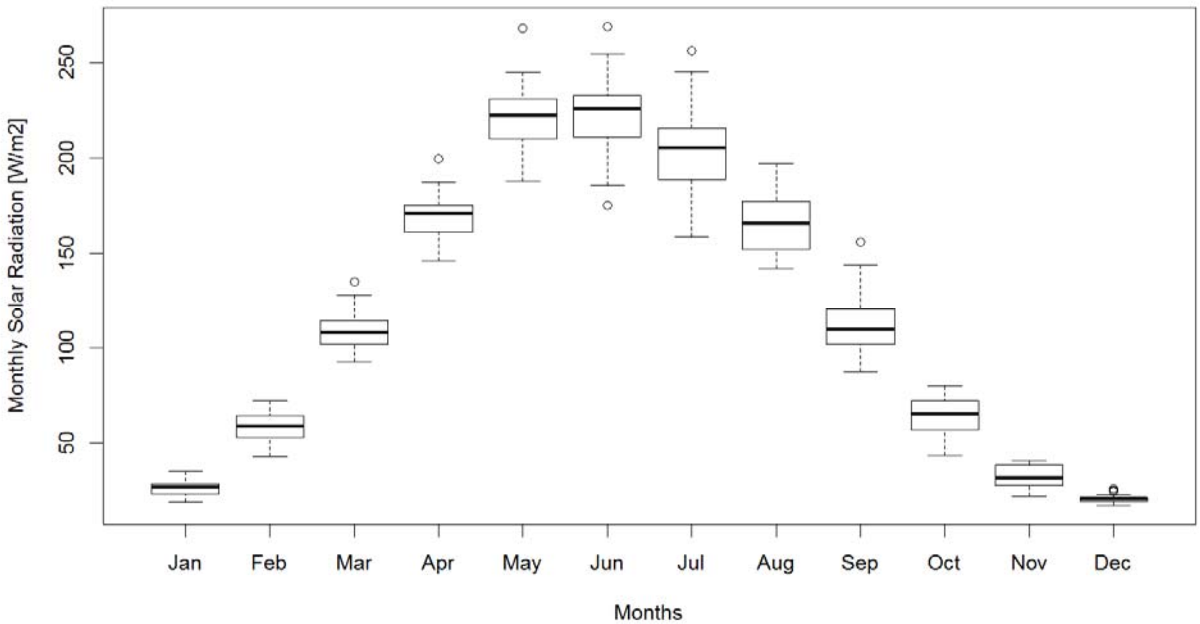


Figure 4-25: Monthly Boxplot for Solar Radiation in W/m²

Table 4-15: Monthly and Annual Solar Radiation statistics based on Reanalysis MERRA [W/m²]

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	19	43	93	146	188	175	158	142	87	43	22	17
25%	23	53	102	161	210	211	189	152	102	57	28	20
50%	27	59	108	171	222	226	205	165	110	65	32	21
75%	28	64	114	175	230	232	216	177	120	72	38	21
100%	35	72	135	200	268	269	256	197	156	80	41	26
Mean	26	59	110	169	222	223	204	165	112	64	32	21
Standard Deviation	4	7.1	9.7	12	16	21	24	15	16	9.7	6.2	1.9

5 Baseline Hydrology

5.1 Overview

This section presents results of the local and regional hydrology data, estimated hydrological parameters, including the mean annual runoff, seasonal runoff distribution, base-flow seasonal distribution, low-flow analysis, peak-flow analysis, and results of data validation for select parameters. The site-specific data includes both historical and more recent monitoring data from the baseline program. In general, data from the more recent monitoring (i.e., July 2014 to December 2016) were used as the basis for establishing relationships with regional information, and then the historical data were used to validate these estimates.

5.2 Local Data

5.2.1 Stage Discharge Relationships

The relationship between stage (i.e., height of the water surface above an arbitrary gauge datum) to discharge was determined for stations BC02, OC04 and GSC05 by measuring these qualities and their relationship over the past two field seasons including results up to December 2016. Station OC07, up to December 2016, has limited amount of information, which does not allow the preparation of a representative and accurate rating curve and; therefore, these records will not be used in these analyses and relationships.

Once there were sufficient data points for these two criteria, they were plotted to create a smooth curve representing this relationship.

This relationship is represented by a series of equations all following the form:

$$Q=C\ (Stage\text{-}a)^n$$

Where:

Q is discharge in cubic meters per second (m^3/sec)
C is a coefficient determined by discharge when depth of flow (Stage – a) is equal to 1
Stage is the height of the water surface above the gauge datum
a is an offset constant for the zero discharge gauge reading
n is the curve exponent

Corrected time series data from station level loggers were correlated to actual surveyed water levels conducted during each field visit. These corrected stage heights were then correlated to the corresponding discharge data. These were completed within the Aquarius software package, and follow the methods specified in the *Manual of British Columbia Hydrometric Standards* prepared by Ministry of Environment, Science and Information Branch for the Resource Information Standards Committee (BC MOE 2009).

The quality of these rating curves is dependent on the number and distribution of data points and the accuracy of the data collected in the field. The field measurements collected at high-flows and, to a lesser extent, low-flows, are especially important, as they define the shape of the upper and lower ends of the curve. It is important that these high- and low-flow data be as accurate as possible, as the shape of the resultant curve is used to extrapolate beyond actual recorded field data points. This extrapolation follows the general shape of the curve to a maximum of two times the largest measured discharge and stage.

The information with the manual gauging data for OC04 (Otter Creek) and BC02 (Bitter Creek) is presented in Table C1 and Table C2 in Appendix C, respectively. At the BC02 hydrometric station, two sensor locations were used due to the dewatering of the monitoring equipment at Location 1 during the 2014-2015 winter low-flow season (presented in Table C3 in Appendix C). The sensor was moved to Location 2 in October 2015 (Table C4 in Appendix C).

5.2.2 Watershed Parameters

The following auxiliary parameters were identified for the local and regional watersheds. In addition to the more conventional parameters, the local region includes variable amounts of forest cover and glaciers, and was therefore augmented by data on the percentage of forest cover and glaciation:

- Geometry: the geometrical parameters watershed area, watershed perimeter, average elevation, average slope, average aspect, latitude of the centroid watershed, and longitude of the centroid watershed were defined for the regional watersheds. All of these parameters were estimated with the software ARCGIS and Global Mapper.
- Distances: the distance from the site to the centroid of the regional gauge and distance from the centroid watershed to the closest shoreline were measured with the statistical software, R.
- Watershed ratio: the percentage of the total area covered by forest, lakes/ponds, and glaciers was identified. Forest and lake areas were identified from the information from the ECCC CANVEC database (NRC 2016). Glacial extent was defined from the information available from the project Global Land Ice Measurements from Space. This project monitors the world's glaciers primarily via optical satellite, with data obtained from the worldwide database archive filed in July 28, 2015.

The most important parameters associated with the local gauge are presented in Table 5-1.

Table 5-1: Auxiliary Parameters for Local Gauge Station at Red Mountain Underground Gold Project

ID	Station Name	Status	Area (km²)	Watershed Centroid Latitude (°)	Watershed Centroid Longitude (°)	Avg. Watershed Elevation (masl)	Avg. Watershed Slope	Forest Rate (%)	Glacier Rate (%)
H1	Bitter Creek	Inactive	0.02	56.13	-129.83	1193.08	26.47	100.00	0.00
H2	Goldslide Creek	Inactive	0.02	55.96	-129.72	1616.63	26.19	100.00	0.00
H4	Kitsault River	Inactive	17.13	55.77	-129.48	942.91	13.09	100.00	0.00

ID	Station Name	Status	Area (km²)	Watershed Centroid Latitude (°)	Watershed Centroid Longitude (°)	Avg. Watershed Elevation (masl)	Avg. Watershed Slope	Forest Rate (%)	Glacier Rate (%)
H3	Upper Roosevelt Creek	Inactive	0.16	56.04	-129.78	949.13	37.30	100.00	0.00
GSC05	Goldslide Creek before drop-off	Active	1.61	55.96	-129.70	1756.13	26.31	100.00	0.00
OC04	Otter Creek before drop-off	Active	2.15	55.99	-129.71	1849.90	28.32	100.00	45.84
BC02	Bitter Creek at HWY37A Bridge	Active	267.10	55.97	-129.74	1483.84	20.87	89.55	57.82
OC7	Lower Otter Creek	Active	6.64	55.99	-129.72	1709.61	23.55	93.31	38.70

5.3 Regional Data

A regional analysis was developed using empirical relationships based on regional streamflow data that provides flow estimates for ungauged locations. The WSC database and USGS database were used to identify the 100 closest regional gauging stations (WSC 2014). Twenty-eight stations were selected that correspond to unregulated watersheds (i.e., flow not controlled by human intervention) with areas less than 2500 km^2 and with a minimum of 10 years of information. Two additional stations, 08CG001- ISKUT RIVER BELOW JOHNSON RIVER (from EC) and 15024800- STIKINE R NR WRANGELL AK (from USGS), were identified during the scoping stage as demonstrating a strong relationship with the local gauges. Despite having watersheds larger than the defined criteria (close to 9,500 and 50,841 km^2, respectively), these stations were added to the dataset, providing a total of 30 regional stations in Canada and the US. Figure B3 in Appendix B illustrates the available information in each of the selected gauge stations after 1960. The blue tones represent more than 360 days with information, and a white square represents a year without information for the respective watershed. The compilation was updated to include all of the results available as of December 2016 (ECCC 2017a, ECCC 2017b).

Table B5 in Appendix B shows a synthesis of the regional stations selected for the regional analysis with the most important parameters. Figure 4-6 illustrates the location of the regional watersheds (centroid) and mean annual runoff (MAR) for the region. Figure 5-2 and Figure 5-3 illustrate the historical flow records for the two closest stations to the site: Bear River Above Bitter Creek, and Salmon River near Hyder, Alaska.

The mean monthly runoff in unit flow of l/s/km² is presented in Table B4 in Appendix B.

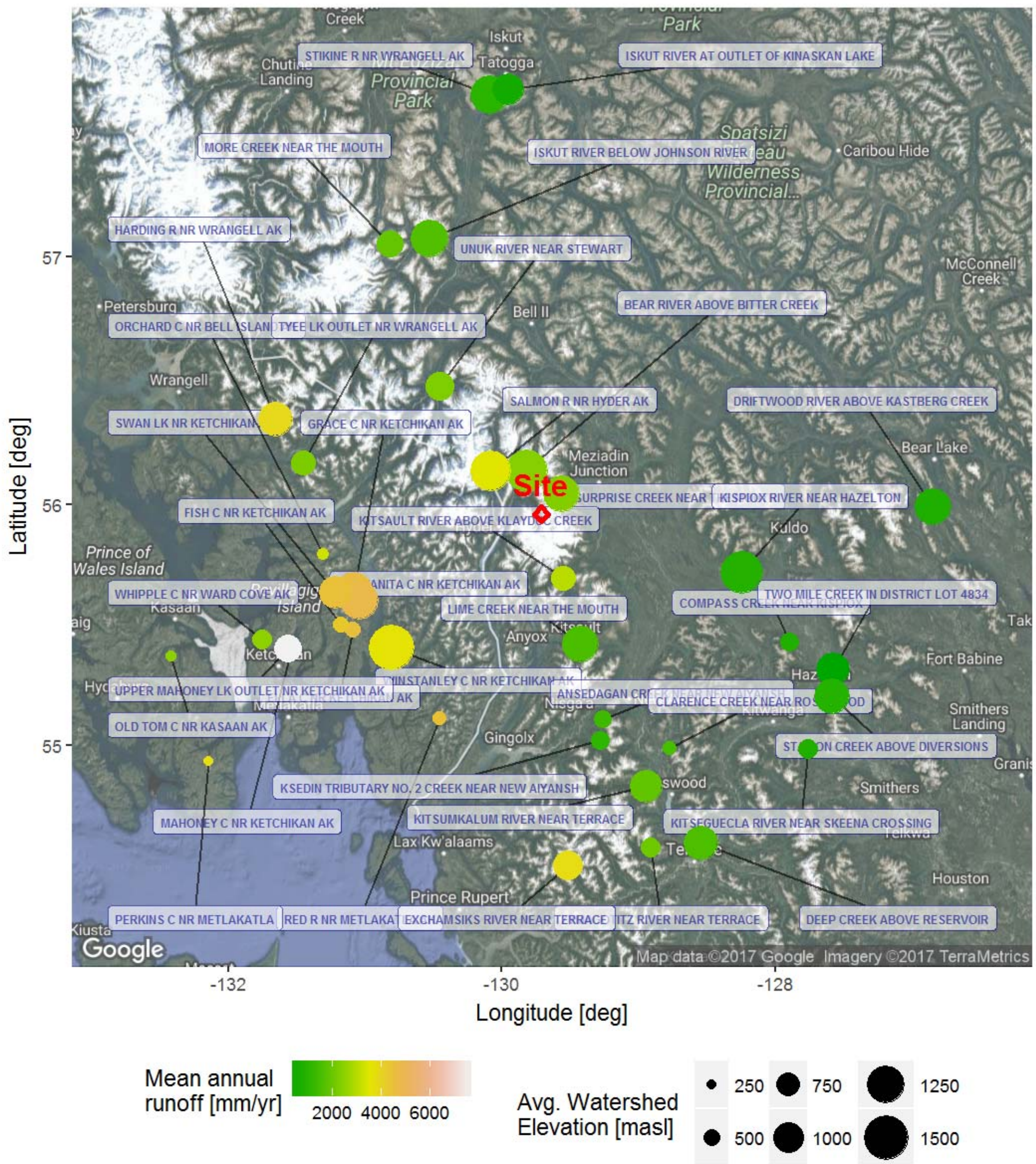


Figure 5-1: Regional Mean Annual Runoff in the Region

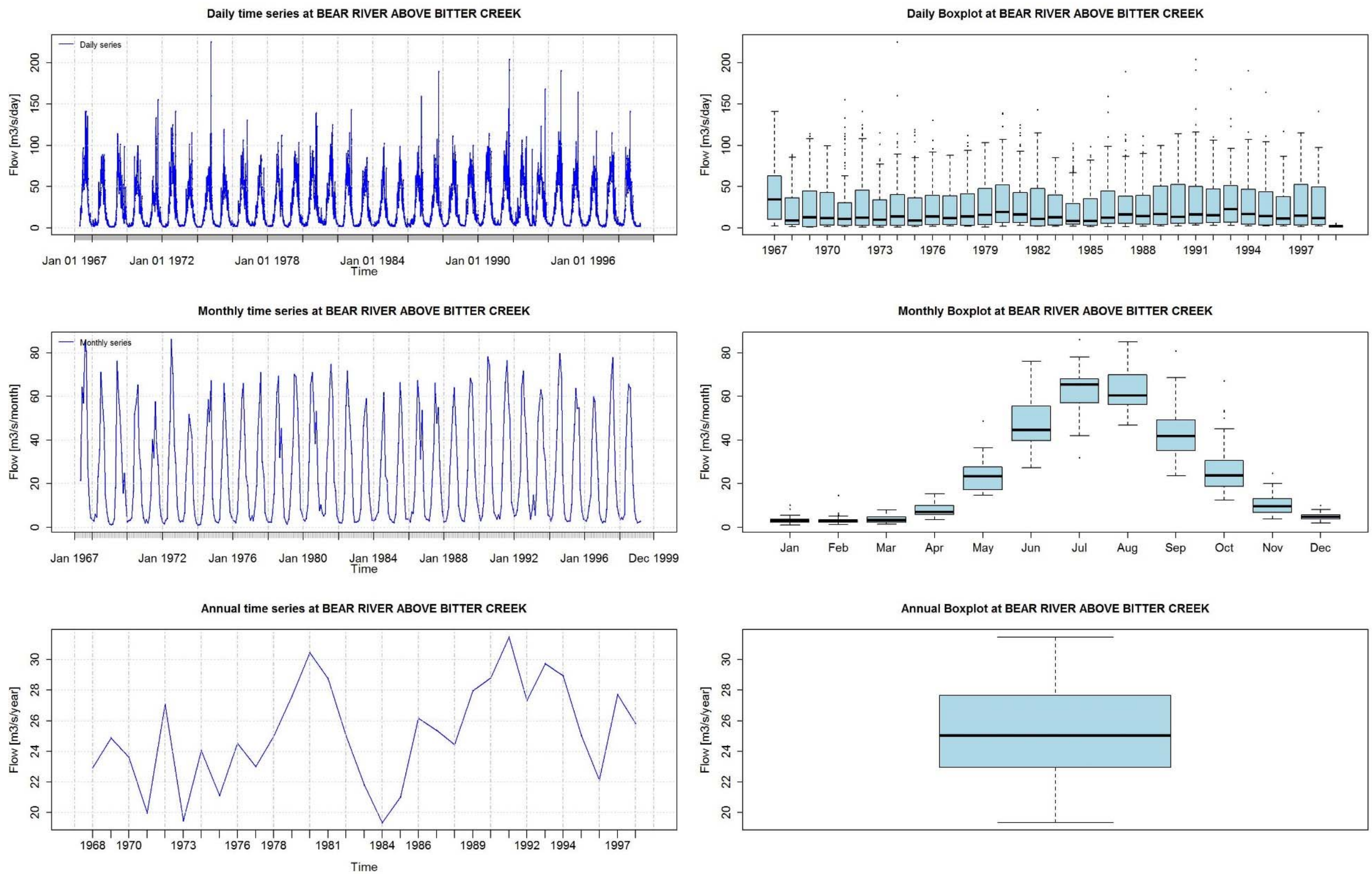


Figure 5-2: Hydrograph for the Regional Station Bear River Above Bitter Creek

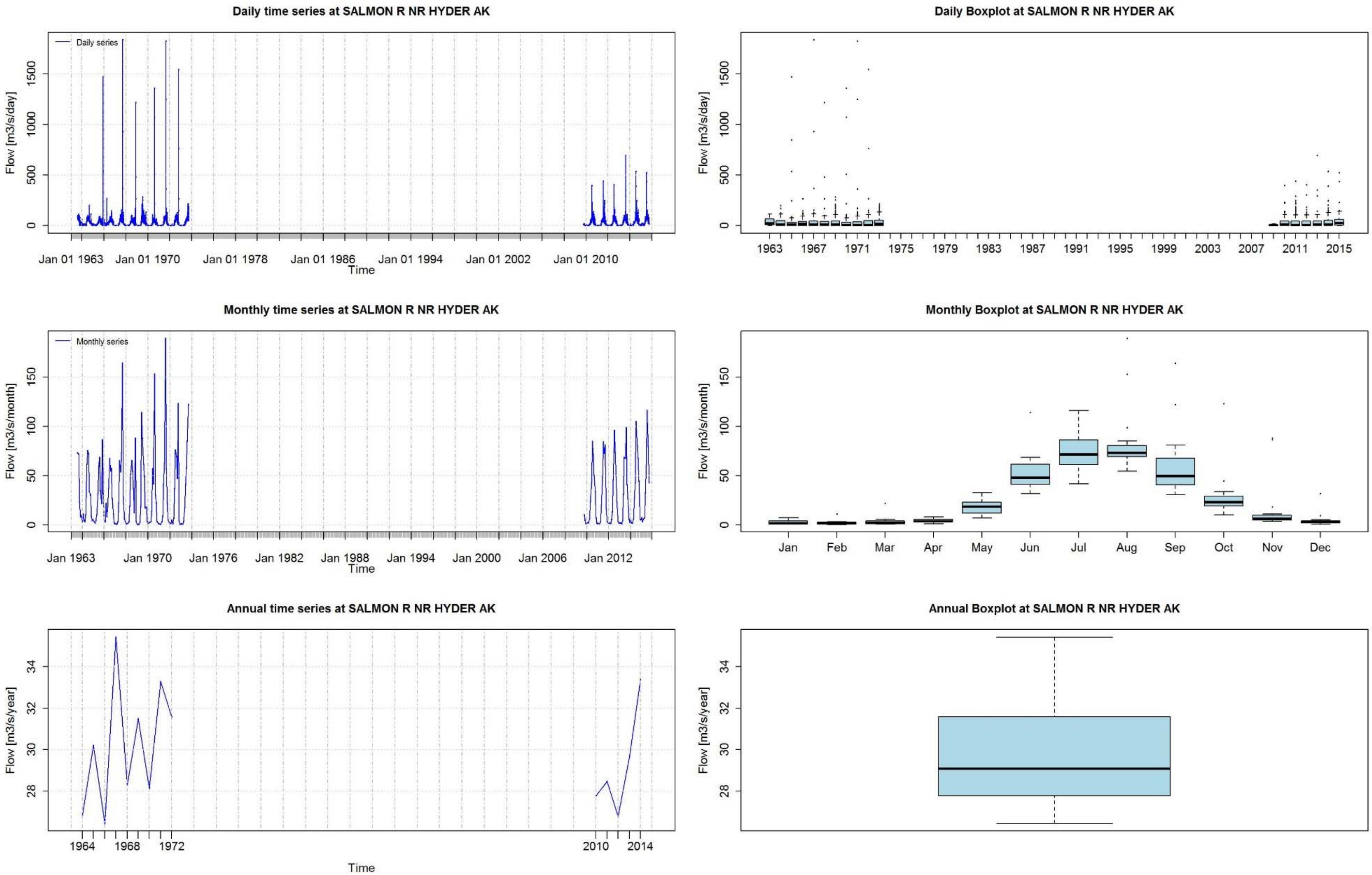


Figure 5-3: Hydrograph for the Regional Station Salmon R NR Hyder AK

5.4 Hydrologic Parameters/Indices

5.4.1 Mean Annual Runoff

NOTE: Mean annual runoff for the site was estimated based on regional station 08CG001- ISKUT RIVER BELOW JOHNSON RIVER. This gauge station with an upstream watershed of 9500 km², was used instead of smaller watersheds and closer-to-site stations such as: 08DA005 – SURPRISE CREEK NEAR THE MOUTH, 08DB014-KSEDIN TRIBUTARY No 2 CREEK NEAR NEW AIYANSH or 15008000 - SALMON R NR HYDER AK. Even though the selection of this regional watershed did not follow the typical practice of hydrology; the selected station produce the most relevant hydrograph similarities, and the highest Pearson correlations (including this analysis review of delay/lag time of the runoff).

These results were prepared separately for glaciated and un-glaciated watersheds with the strongest correlations in every case using 08CG001- ISKUT RIVER BELOW JOHNSON RIVER.

These relationships were established with the information available for ECCC (2017) and for the site gauges up to December 2016. These runoff relationships were compared with historical information (Rescan 1994) and confirmed as an appropriate runoff model in section 5.3.6.

Runoff is defined as the total amount of water discharged from a watershed, and is frequently presented as the depth of water distributed evenly throughout the watershed area. This amount of water is the result of a watershed water balance between: precipitation, snowmelt, evaporation, groundwater losses and glacial discharges. Runoff values presented in this section are the net result of all of the water gains and losses due to these factors.

From the original regional stations, the stations were grouped based on those closest to site with a similar glacial influence and annual hydrograph, utilising a k-means cluster analysis.

The partition with k-means defined two differentiated clusters: where the coastal gauges without glacier cover were selected as a group (in red) and the more interior gauges with higher glacier cover were selected as a different group (in blue). Details of this methodology are presented in Section 3.3.3. Figure 5-4 illustrates the cluster number two as the selected stations for the regional analysis with 22 gauge stations. Within this subset, the most relevant parameters to characterize MAR in this region are: distance from the coast (as precipitation influences runoff relationships), average slope, and glacier and forest ratios.

Due to the limited period of record for Goldslide, Otter and Bitter Creeks, particularly during winter months, the site information was correlated with regional information to find the most relevant stations to use as analogue stations. As indicated previously, the local and regional data included available results as of the end of December 2016. Although better correlations are typically found for smaller or closer watersheds, the best correlations between both glaciated and unglaciated site stations were found with gauges 08CG001 – ISKUT RIVER BELOW JOHNSON RIVER and 15024800- STIKINE R NR WRANGELL AK, which are 9,500 km^2 and 50,800 km^2 respectively. There were no meaningful correlations with smaller watersheds or watersheds located closer to the site such as: 08DA005 – SURPIRSE CREEK NEAR THE MOUTH, 08DB014 - KSEDIN TRIBUTARY No 2 CREEK NEAR NEW AIYANSH or 15008000 - SALMON R NR HYDER AK.

Modelled site flows were based on results from station 08CG001- ISKUT RIVER BELOW JOHNSON RIVER. This station was selected as an analogue station for the site, due to the high correlation with the recorded streamflow on site and because it is smaller than the 15024800- STIKINE R NR WRANGELL AK watershed. Although it would be considered standard practice to select a data from a smaller and closer watershed, the selected station produced the most relevant hydrograph similarities, and the highest Pearson correlations.

Monthly adjustments of 08CG001- ISKUT RIVER BELOW JOHNSON RIVER relative to the measured flows were prepared. The site adjustments were based on just one monthly factor multiplied by the flow values at 08CG001- ISKUT RIVER BELOW JOHNSON RIVER, to obtain the estimated site flows over a longer period of time.

These runoff relationships were compared with historical information (Rescan 1994) and confirmed as an appropriate runoff model in Section 5.4.6.

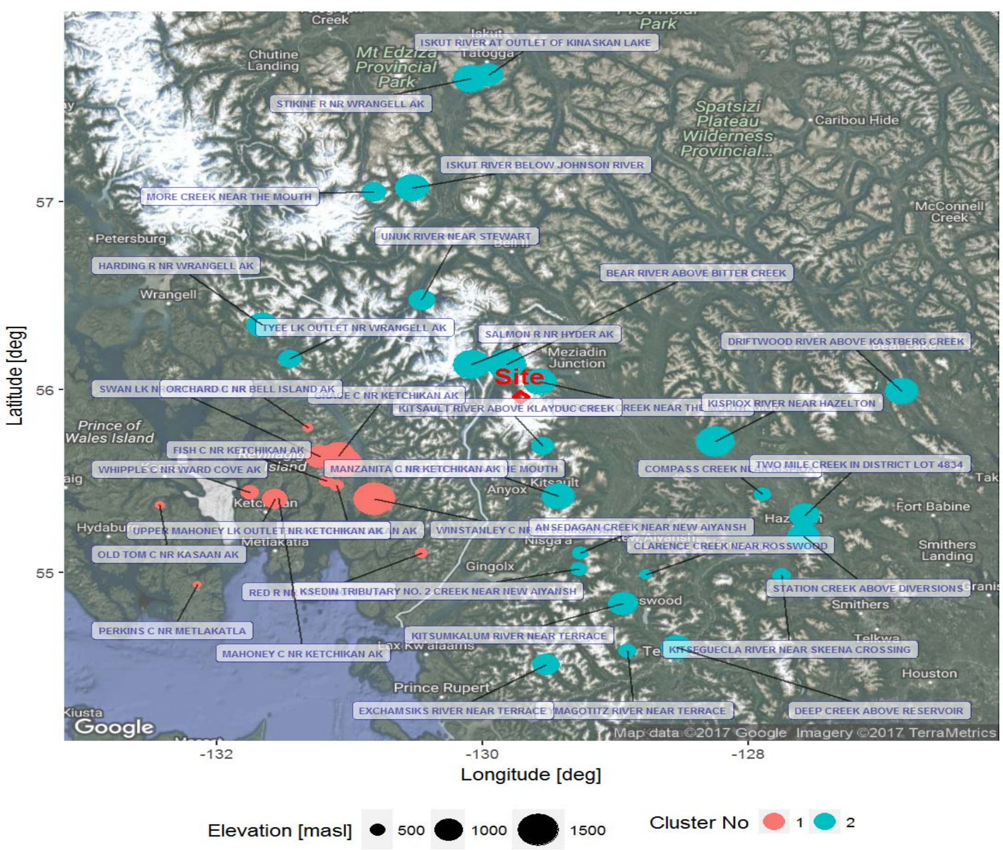


Figure 5-4: Regional Gauge Partition based on K-mean Cluster Analysis

It was determined that the runoff and hydrograph were strongly influenced by the glacier cover and therefore Bitter, Otter and Goldslide Creeks were grouped based on glacier cover similarities. Figure 5-5 displays the unit flows in $m^3/s/km^2$, which is the measured flow divided by the respective area. This figure presents the time series for:

1. Available regional stations during the period 2014 to 2016, with meaningful correlations with the site measurements (i.e., at meteorological stations 08DA005,08DB014, 08EB004, 08EC004, 08CG001, 15024800 and 08EG012);
2. Measured local information from Otter, Goldslide, and Bitter Creeks; and,
3. Modelled daily results for Bitter-Otter and Goldslide Creeks.

The defined monthly factors were smoothed and adjusted on a daily scale, to avoid jumps when the information is from different months.

Figure 5-6 and Figure 5-7 demonstrate the similarities between the measured flows and their respective models.

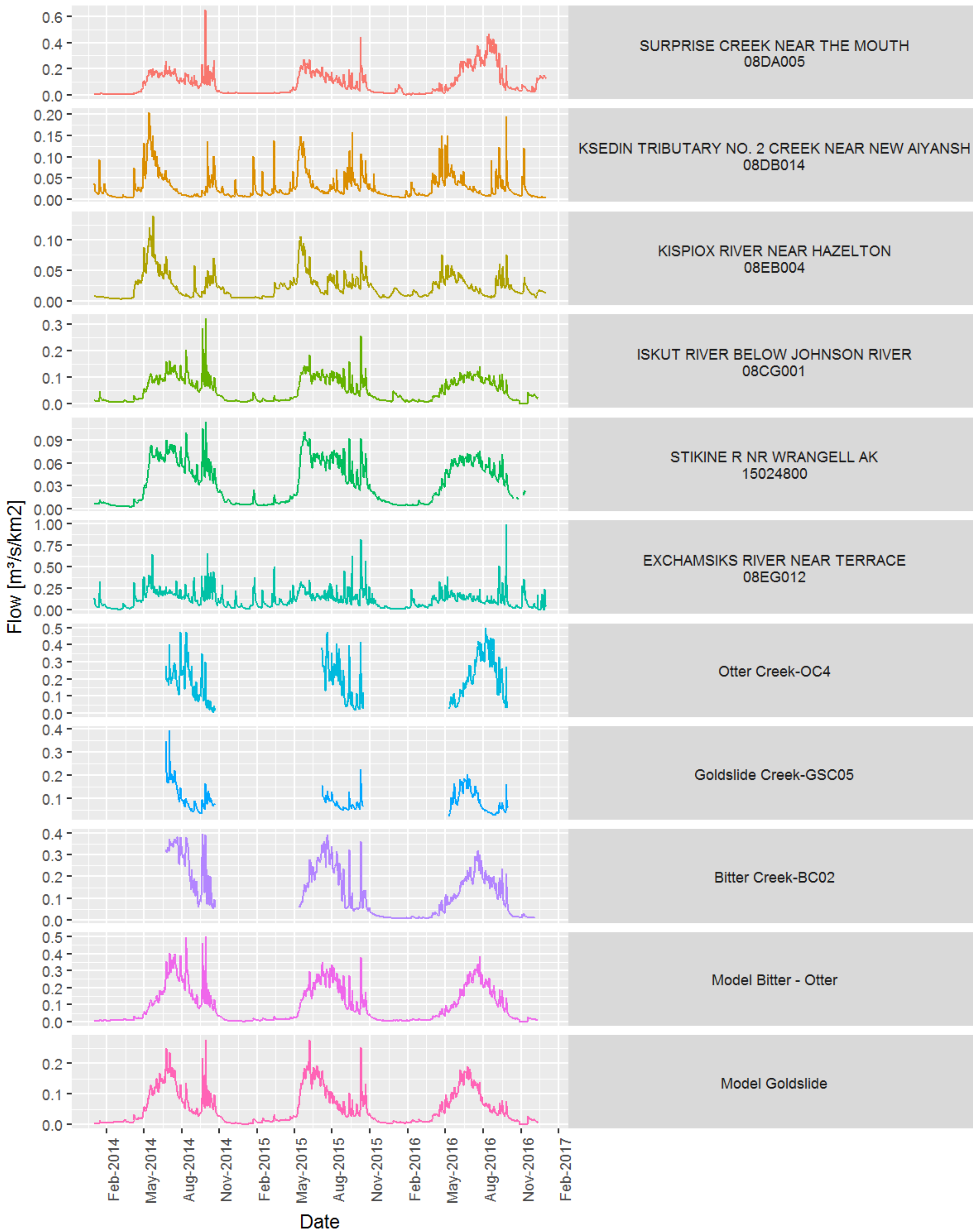


Figure 5-5: Unit Flow for the Regional Stations, Measured Values (Otter Creek – OC4, Goldslide Creek – GSC05, Bitter Creek – BC02) and Long-term Models for Bitter-Otter and Goldslide Creek

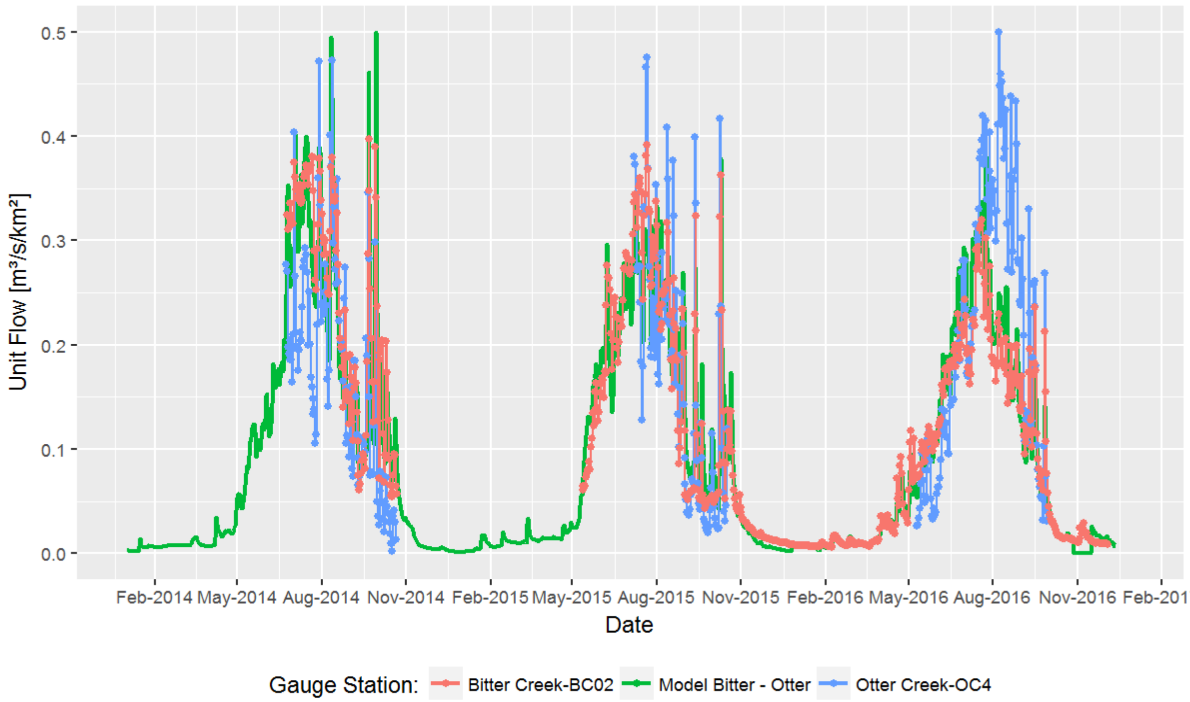


Figure 5-6: Time Series of the Measured Unit Flow and Long-term Model for Bitter and Otter Creeks, based on Monthly Adjusted Flows at Station 08GC001

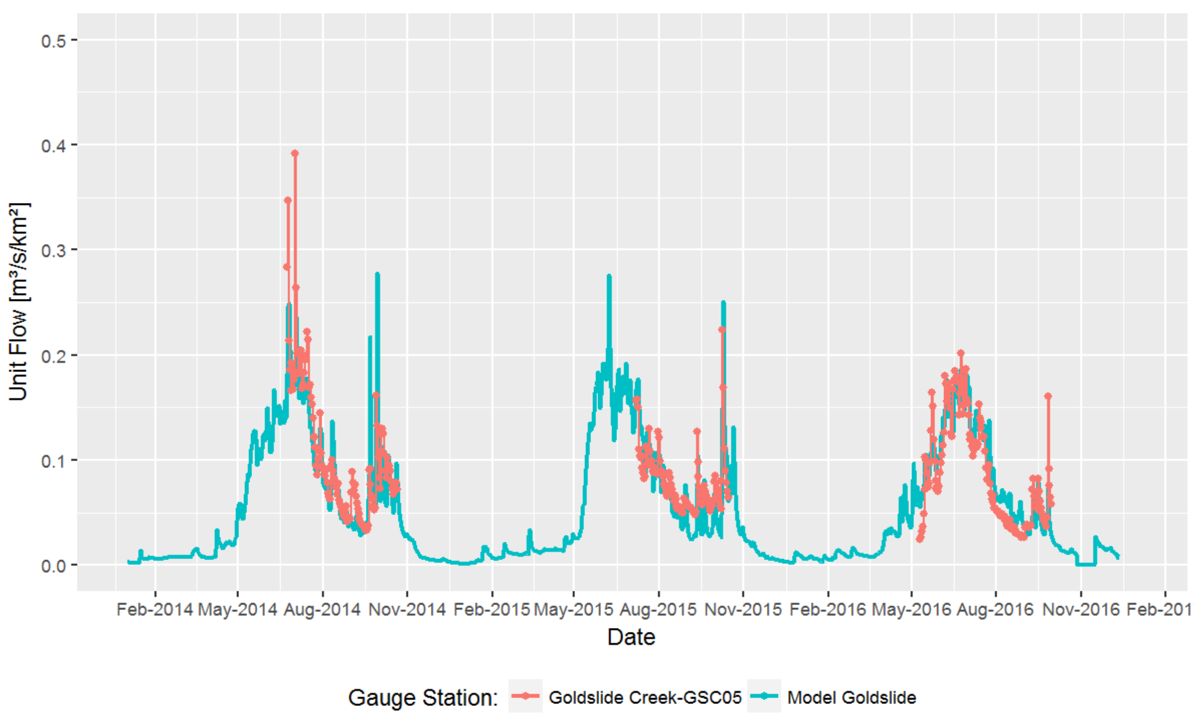


Figure 5-7: Time Series of the Measured Unit Flow and Long-term Model for Goldslide Creek, based on Monthly Adjusted Flow at Station 08CG001

Figure 5-8 and Figure 5-9 illustrate the regional relationships for the MAR. The x-axis is the distance from the coast, and the y-axis is the MAR. The blue line demonstrates a relationship based on a LOWESS regression, the grey band represents the 95% confidence interval, and the size of the dot represents the glacier cover. In Figure 5-8, the shade of blue represents the forest cover. In Figure 5-9, the shade of blue represents the distance from the site. Squares represent the model site information, with the MAR for Bitter and Otter Creeks being 2,981 mm/yr and the MAR for Goldslide Creek being 1,555 mm/yr. These annual runoff values were estimated directly from the respective runoff models.

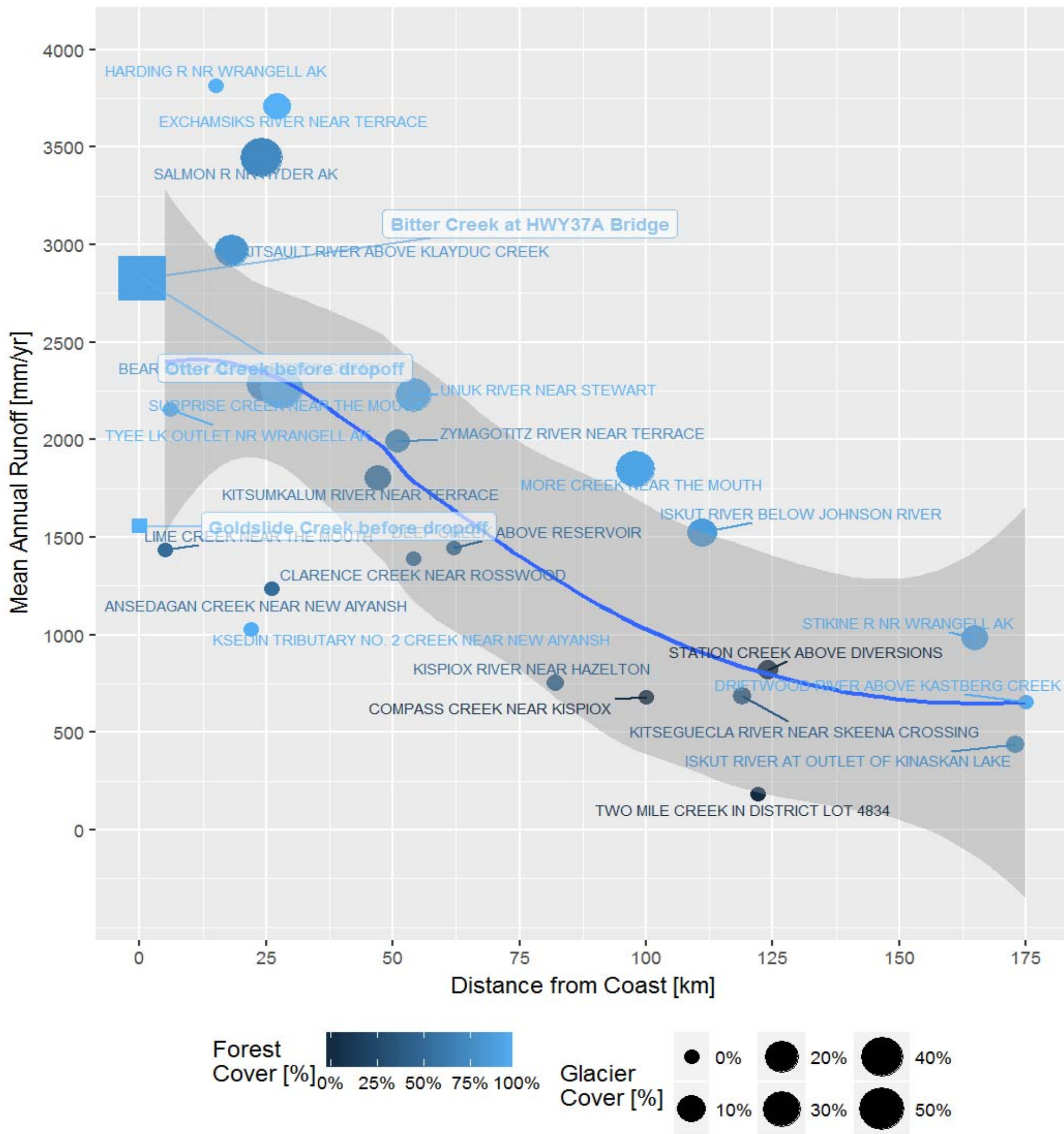


Figure 5-8: Regional Relationship of Runoff versus Distance from the Coast, Glacial Cover and Forest Cover

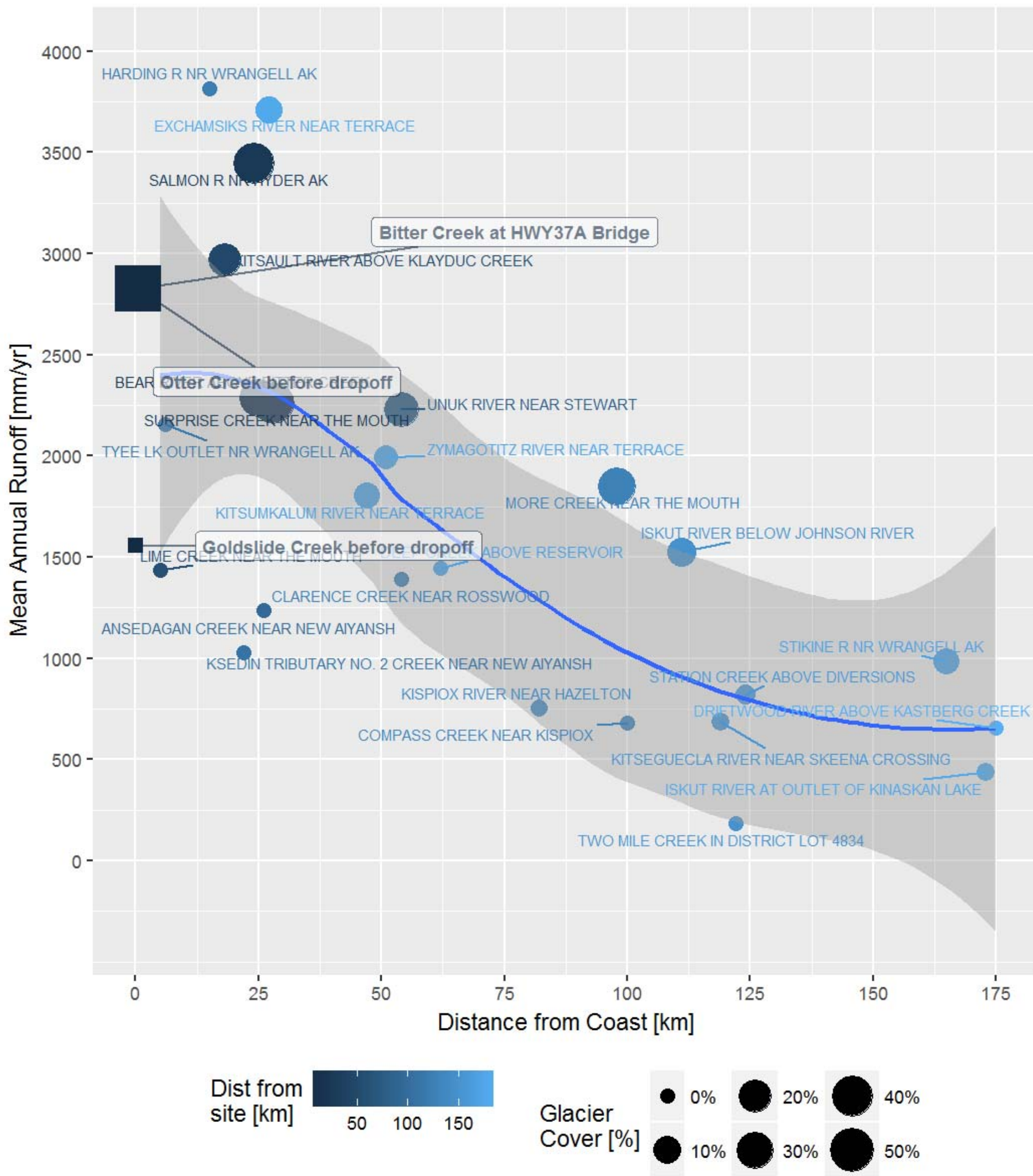


Figure 5-9: Regional Relationship of Runoff versus Distance from the Coast, Glacial Cover and Distance from Site

The MAR was further verified employing a simple water balance approach using the previously-estimated MAP, and the mean annual actual evapotranspiration. The difference between the two values (i.e., 1,847 mm/year for MAP and 376 mm/year for actual evapotranspiration) is 1,471 mm/year. This MAR estimation (MAR ≈ MAP – actual evapotranspiration) is comparable to the estimate using the regional analysis of 1,555 mm/year for the runoff in Goldslide Creek, which is unaffected by glacial cover.

These values are comparable with the regional data, where:

- gauges closer to the coast tend to have higher MAR; however, gauges farther than 100 km from the coast are not significantly affected by this coastal effect;
- gauges with higher forest cover tend to have a reduction in the MAR; however, this influence is not as strong as glacial cover;
- gauges with higher glacial cover are closer to the site. These gauges tend to have a reduced forest cover and are located closer to the coast, which leads to a combined effect resulting in the highest MAR in the area with a value over 3,000 mm/yr;
- based on the regional mean annual precipitation for the area of 1,800 mm/yr (Stewart A), the glacier cover is effectively decreasing (melting), providing a net contribution to the total runoff in the glaciated watersheds;
- increased glacial cover within a watershed increases the impermeable surface area of the drainage basin, resulting in a significantly reduced infiltration of precipitation to the subsurface, and an increased proportion of runoff translating to an elevated MAR in these regions; and
- based on monthly adjustments with station 08CG001, two models were prepared and compared with the region. The MAR of these models present the higher and lower ranges at both sides, within the confidence interval.

This analysis suggests that the whole site hydrology can be represented by two runoff models: (1) Bitter-Otter; and (2) Goldslide, where the Bitter-Otter model represents a watershed affected by glaciers and the Goldslide model represents a watershed without glacier cover.

It is recommended that for all subsequent analyses and general runoff applications, the Goldslide model be used for watersheds with less than 10% of glacial cover and the Bitter-Otter model be used for watersheds with more than 10% of glacial cover, where higher runoff can be expected. Table 5-2 synthesizes the recommended uses for these two runoff models.

Due to limited information, the runoff model should be used instead of the measured values, except when spot measurements are required.

Table 5-2: Runoff Models and their Recommended Uses

<table>
<tr><th>Runoff Model</th><th>Source</th><th>Glacier Cover (%)</th><th>Mean Annual Runoff (mm/yr)</th><th>Recommended Uses</th></tr>
<tr><td rowspan="2">Bitter-Otter Creek Model</td><td>Bitter Creek</td><td>58%</td><td rowspan="2">2,828</td><td rowspan="2">To predict local flows in watersheds with glacial cover over 10%</td></tr>
<tr><td>Otter Creek</td><td>46%</td></tr>
<tr><td>Goldslide Creek Model</td><td>Goldslide Creek</td><td>0%</td><td>1,555</td><td>To predict local flows in watersheds with glacial cover below 10%</td></tr>
</table>

Source: compiled in text.

Table A3 of Appendix A provides the monthly unit runoff for Goldslide and Otter Creeks, with the monthly average presented in Table 5-3. Table A4 in Appendix A displays the monthly unit runoff for Bitter Creek, with the monthly average presented in Table 5-4.

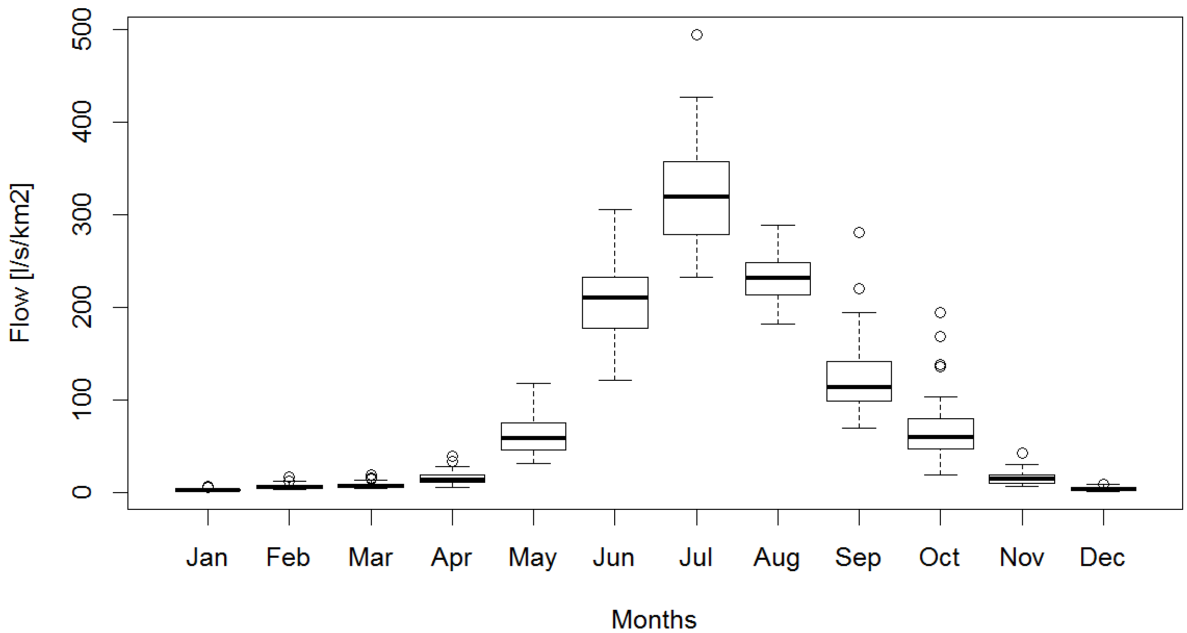


Figure 5-10: Monthly Boxplot for Flows for Bitter and Otter Creeks in l/s/km²

Table 5-3: Monthly Flow Statistics for Bitter and Otter Creeks in l/s/km²

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	1.4	3.4	4.3	6	32	121	233	182	70	20	7.1	1.5
25%	2.1	4.8	5.9	12	47	178	279	214	100	48	10	2.7
50%	2.8	5.9	7.2	14	59	211	319	232	113	59	14	3.4
75%	3.4	7.7	9.3	19	75	233	357	248	141	78	20	5.3
100%	6.7	17	19	39	118	306	495	289	282	195	43	9.7
Mean	3	6.6	8.1	16	62	208	323	231	122	68	16	4
Standard Deviation	1.3	2.6	3	6.5	19	41	50	28	37	32	7.3	1.9

Source: compiled in text.

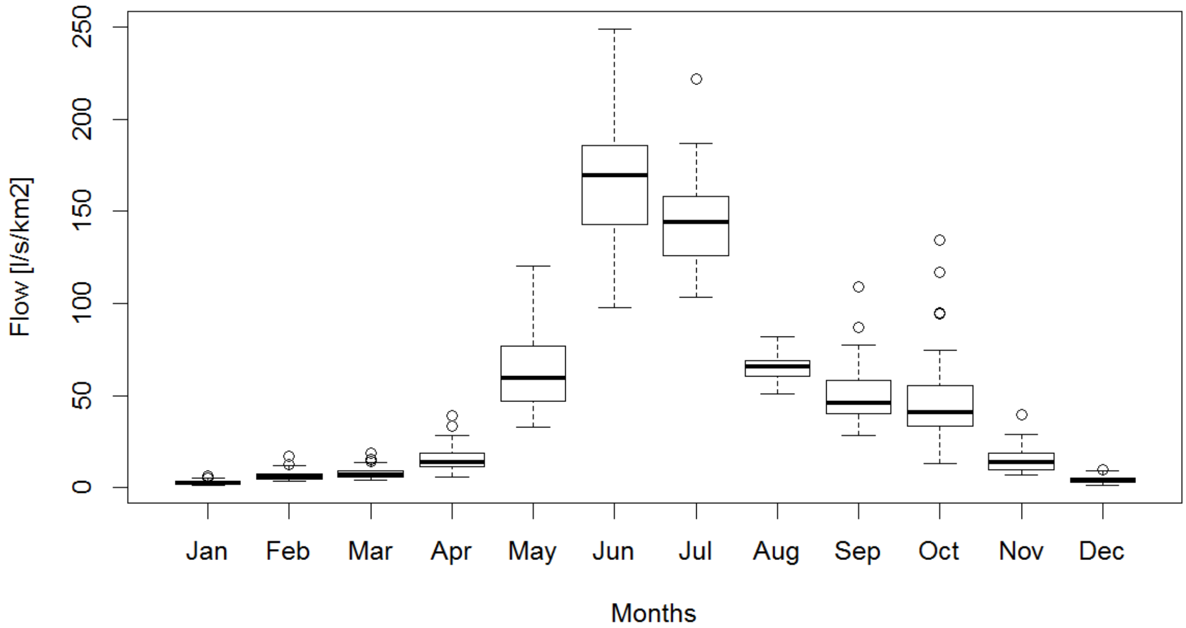


Figure 5-11: Monthly Boxplot for flows at Goldslide Creek in l/s/km²

Table 5-4: Monthly Flow Statistics for Goldslide Creek in l/s/km²

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0%	1.4	3.4	4.3	6.1	33	98	104	51	29	14	6.8	1.6
25%	2.1	4.8	5.9	12	48	143	126	61	41	34	9.7	2.8
50%	2.8	5.9	7.2	14	60	169	144	66	46	41	14	3.5
75%	3.4	7.7	9.3	19	77	186	158	69	58	54	19	5.6
100%	6.6	17	19	39	120	249	222	82	109	135	40	10
Mean	3	6.6	8.1	16	63	166	144	65	50	47	15	4.2
Standard Deviation	1.3	2.7	3	6.5	19	33	23	7.9	15	22	6.8	1.9

Source: compiled in text.

5.4.2 Seasonal Runoff Distribution

The seasonal runoff distribution associated with the different return period was calculated using the Bitter-Otter Creek and Goldslide Creek models.

Table 5-5 presents the seasonal runoff distribution, in units of l/s/km², for return periods ranging from the 100-year dry to 100-year wet. To estimate the seasonal runoff distribution for site catchments, the upstream catchment areas should be multiplied by the values presented in Table 5-5.

Under both hydrological conditions, the annual hydrograph presents a freshet peak-flow during the months of June and July. For Bitter and Otter Creeks, the peak-flow is observed in July. For Goldslide Creek, the freshet can be delayed until July for the dry hydrological years, and a continual reduction of the flow thereafter. Throughout the winter, when precipitation is stored as snow, base-flow contributes primarily to stream flow.

Table 5-5: Average Monthly Flow for Different Return Periods for Red Mountain

Loc.	Return Period (years)	Monthly Flow (l/s/km²)												Annual Runoff (mm)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Bitter and Otter Creeks	100 Wet	7.5	14.4	17	30.4	115	265	369	262	148	59.6	11.2	5.5	3420
	50 Wet	6.69	13.1	15.3	28	106	261	361	255	147	61.7	13.2	5.98	3350
	25 Wet	5.87	11.7	13.7	25.7	96.7	255	353	249	145	63.7	15	6.37	3260
	20 Wet	5.61	11.2	13.2	24.9	93.8	253	350	247	145	64.2	15.5	6.48	3230
	10 Wet	4.77	9.8	11.5	22.5	84.4	245	342	240	142	65.7	16.9	6.69	3130
	5 Wet	3.91	8.29	9.77	20	74.5	233	332	235	137	66.7	17.8	6.69	3010
	2 Wet	2.69	6.09	7.41	15.8	59.7	209	317	228	126	66.6	17.6	5.95	2790
	5 Dry	1.95	4.67	6.06	11.8	48.7	183	305	226	112	64.2	14.9	4.33	2590
	10 Dry	1.73	4.19	5.68	9.74	44	169	300	226	105	62.1	12.7	3.16	2480
	20 Dry	1.6	3.91	5.48	8.03	40.6	158	296	226	98.1	60.2	10.5	2.05	2400
	25 Dry	1.57	3.84	5.44	7.53	39.7	154	295	227	96.1	59.5	9.81	1.7	2380
	50 Dry	1.51	3.68	5.35	6.12	37.1	145	292	228	90.5	57.6	7.66	0.64	2310
	100 Dry	1.47	3.58	5.31	4.87	35	137	290	229	85.4	55.8	5.56	0.383	2250
Goldslide Creek	100 Wet	7.48	14.4	17	30.6	118	206	159	67.4	39.5	63.9	1.69	9.06	1930
	50 Wet	6.67	13.1	15.3	28.2	108	204	156	66.9	44.6	59.4	5.49	8.53	1880
	25 Wet	5.86	11.7	13.7	25.8	98.8	201	153	66.4	49.3	55.1	9.1	7.95	1830
	20 Wet	5.59	11.2	13.1	25	95.7	200	152	66.2	50.6	53.8	10.2	7.75	1820
	10 Wet	4.76	9.8	11.5	22.6	86.1	194	148	65.7	54.2	49.7	13.4	7.05	1760
	5 Wet	3.9	8.3	9.76	20.1	76	186	145	65.3	56.6	46	16.2	6.2	1680
	2 Wet	2.68	6.09	7.4	15.8	60.9	168	141	65	55.7	42.2	18	4.58	1570
	5 Dry	1.95	4.67	6.06	11.9	49.6	147	138	65	48.4	42.6	15.7	2.96	1540
	10 Dry	1.72	4.19	5.67	9.79	44.8	136	137	65.2	42.3	44.3	12.9	2.11	1470
	20 Dry	1.6	3.91	5.48	8.07	41.3	127	137	65.4	36.2	46.5	9.87	1.41	1400
	25 Dry	1.57	3.84	5.44	7.57	40.3	124	137	65.5	34.2	47.3	8.86	1.21	1330
	50 Dry	1.51	3.68	5.35	6.15	37.7	116	137	65.7	28.2	49.8	5.66	0.621	1270
	100 Dry	1.47	3.58	5.3	4.9	35.6	109	137	65.9	22.3	52.4	2.4	0.0961	1250

Source: compiled in text.

5.4.3 Base-Flow Seasonal Distribution

A base-flow separation analysis was prepared in order to estimate the proportion of groundwater contributing to creek flows. Stream discharge was separated into two components, specifically, quick-flow and base-flow. *Quick-flow* is defined as the portion of streamflow that comes from either surface runoff or interflow. *Base-flow* is the portion of streamflow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow. The runoff separation was conducted with the Nathan and McMahon (1990) technique, an automated digital filter method constrained by the following two parameters:

- Alpha (α): Nathan and McMahon (1990) suggests a value between 0.90 and 0.95; and
- N: this parameter is the number of times that the digital filter passes over the runoff time series. Higher N numbers make the base-flow time series smoother and less dependent on peak-flows within the runoff time series.

For this scenario, the coefficient α was set at 0.95 and the N was set at 3. Table 5-6 presents the results of the base-flow analysis for Bitter-Otter and Goldslide Creeks. Figure 5-12 and Figure 5-13 illustrate the base-flow separation for Bitter-Otter and Goldslide Creeks respectively from 2012 to 2016.

Table 5-6: Unit Base-Flow for Bitter, Otter and Goldslide Creeks

Location	Base-Flow (l/s/km²)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bitter and Otter Creeks	1.6	3	5.3	7.7	18	69	165	135	62	28	7.2	2.2
Goldslide Creek	1.9	3.2	5.3	7.7	19	64	82	41	28	21	7.2	2.6

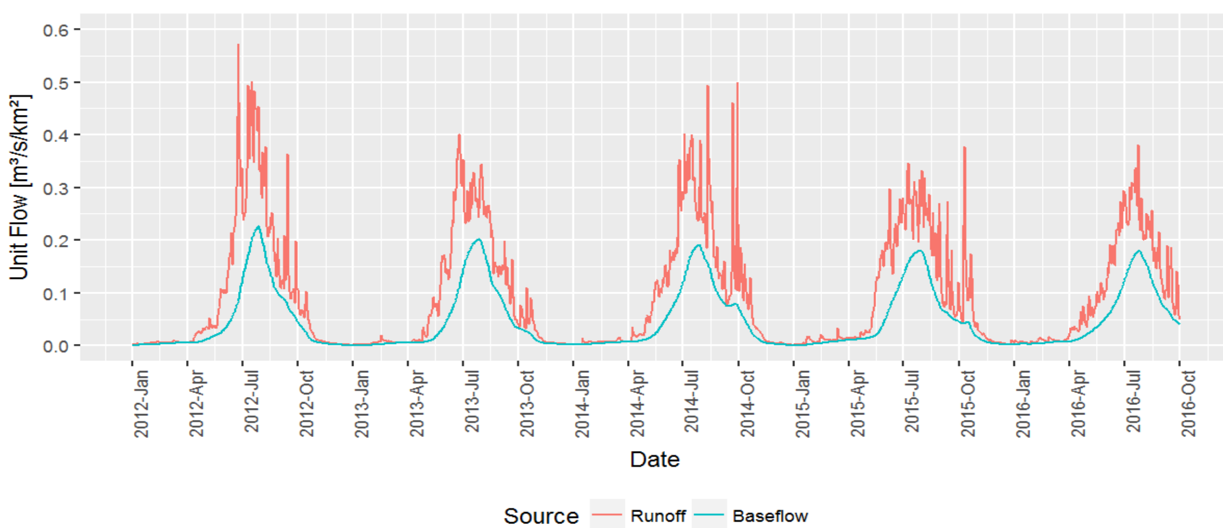


Figure 5-12: Base-Flow Separation for Bitter-Otter Creek for 2012 to 2016

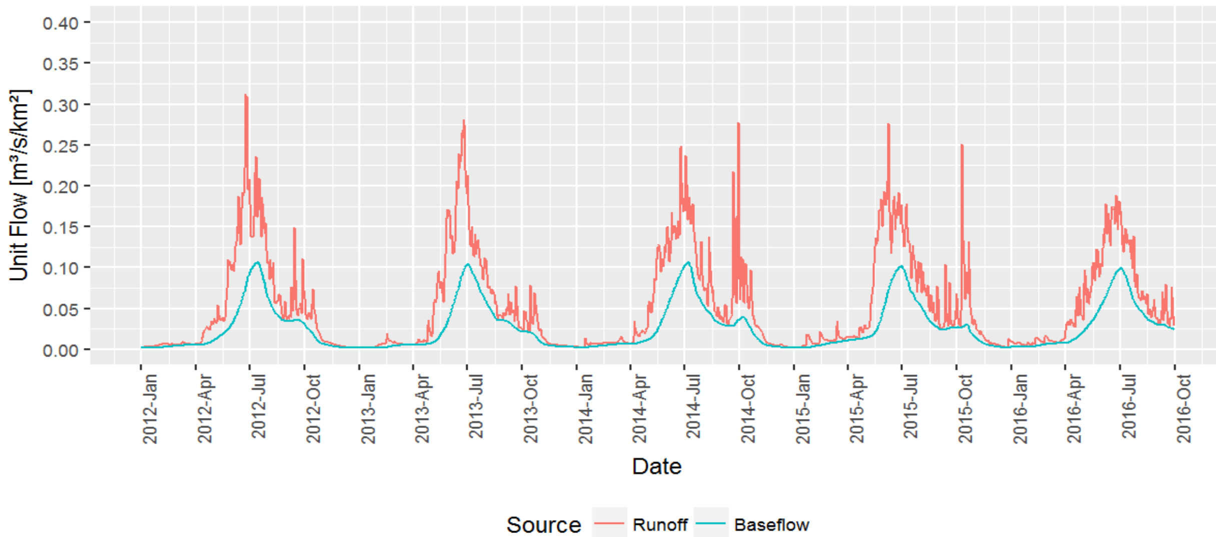


Figure 5-13: Base-Flow Separation for Goldslide Creek for 2012 to 2016

5.4.4 Low-Flow Analysis

Low-flow estimates include seven-day period low-flows for a 10-year return period (7Q10) by month and year (i.e., 2-, 5-, 10-, 50-, and 100-year return periods). The catchments in and around the site should be estimated using the Bitter-Otter Creek model results for watersheds with glacial cover higher than 10% and Goldslide Creek model results for watersheds with glacial cover less than 10%. This methodology resulted in a 7Q10 of 2.7 l/s/km² for Bitter and Otter Creeks and 2.9 l/s/km² for Goldslide Creek. Table 5-7 summarizes the results of the low-flow analyses. The annual 7Q10 values were prepared with the available modeled information for complete years. Bitter and Otter Creeks' 7Q10 results tend to have the lowest values in January, whereas Goldslide Creek has slightly lower values in March.

Table 5-7: Seven Day Low-Flow by Month and Year under the Return Periods of 2, 5, 10, 50 and 100 Years for the Red Mountain Underground Gold Project

Location	Return Period (years)	7-day Low-Flow (l/s/km²)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bitter and Otter Creeks	2	1.6	4.4	6.2	8.2	25	120	243	141	67	27	6.2	1.7	1.3
	5	1.2	3.2	4.8	6	18	91	213	121	51	20	4.3	1.2	1
	10	1.1	2.9	4.2	5.2	14	76	197	112	45	17	3.5	1	0.96
	25	0.97	2.7	3.6	4.6	11	59	180	103	39	14	2.8	0.87	0.9
	50	0.93	2.6	3.2	4.2	9.8	49	169	98	35	13	2.4	0.8	0.88
	100	0.9	2.6	2.9	4	8.5	40	159	93	32	11	2.1	0.74	0.87
	200	0.89	2.5	2.7	3.8	7.5	31	150	89	29	10	1.8	0.7	0.86
Goldslide Creek	2	1.7	4.4	6.2	8.1	26	112	94	40	30	22	6.4	2	1.5
	5	1.3	3.2	4.8	6	18	87	81	35	24	17	4.4	1.5	1.2
	10	1.1	2.9	4.2	5.2	15	74	75	32	22	14	3.6	1.2	1.1
	25	1	2.7	3.6	4.6	12	60	68	30	20	12	2.8	1.1	0.93
	50	0.99	2.6	3.2	4.2	10	51	64	28	19	11	2.4	0.98	0.85
	100	0.96	2.6	2.9	4	8.7	43	61	27	18	10	2.1	0.91	0.79
	200	0.94	2.5	2.7	3.8	7.6	36	58	25	18	9.2	1.8	0.86	0.74

5.4.5 Peak-Flow Analysis

The peak-flow analysis was performed using the regional gauging stations. This analysis was not supplemented with site-specific information due to the short duration of available site data. Normally, smaller watersheds (i.e., <1 km²) produce higher unit peak-flows than larger watersheds. Those stations with a minimum of 20 years of recorded instantaneous peak-flows were selected. In this analysis, the regional peak-flows were highly sensitive to MAR, which is also affected by the glacial cover (Section 5.3).

The regional analysis includes information for a MAR from 250 mm to 3,750 mm. Because no site information was used for this analysis, this regional peak-flow analysis should be considered to be a reference. During the design and construction phase, this analysis should be complemented with site-specific hydrological information or watershed specific hydrological models (i.e. HEC-HMS, UBC Watershed model).

The unit peak-flows were estimated through a frequency analysis to fit a probability distribution to the peak data at every available regional gauging station. The relationship between the MAR and maximum instantaneous peak-flows for the region is illustrated as an average trend in Figure 5-14. The results of the linear relationship equations presented in Figure 5-14 are the unit peak-flow in m³/s/km².

The unit peak-flows associated with the runoff models of Goldslide and Bitter-Otter Creeks are presented in Table 5-8.

Table 5-8: Unit Peak-Flows for Goldslide and Bitter – Otter Creek Runoff Models

Return Period [yrs]	Unit Peak-Flow [m³/s/km²]	
	Goldslide Creek	Bitter-Otter Creeks
200	1.23	2.21
100	1.04	1.94
50	0.89	1.71
25	0.76	1.49
20	0.72	1.43
10	0.61	1.23
5	0.5	1.03
2	0.36	0.76

5.4.6 Validation

Historical reports present baseline hydrology information from the early 1990s (HKP (1992), Rescan (1994), Rescan (1995)). This earlier work used a completely different set of information to estimate the flow values and calibrations compared with the current analyses. For example, there was a focus on the information from the Bear River Above Bitter Creek (08DC006) gauge station, which is an inactive station with daily records from 1967 to 1999. As this station is no longer in operation, it was not possible to compare the local information with this former regional station.

To provide additional confidence in the updated results presented in this report, validation against the historical information was conducted. These values were not used for calibration or in the preparation of the runoff models.

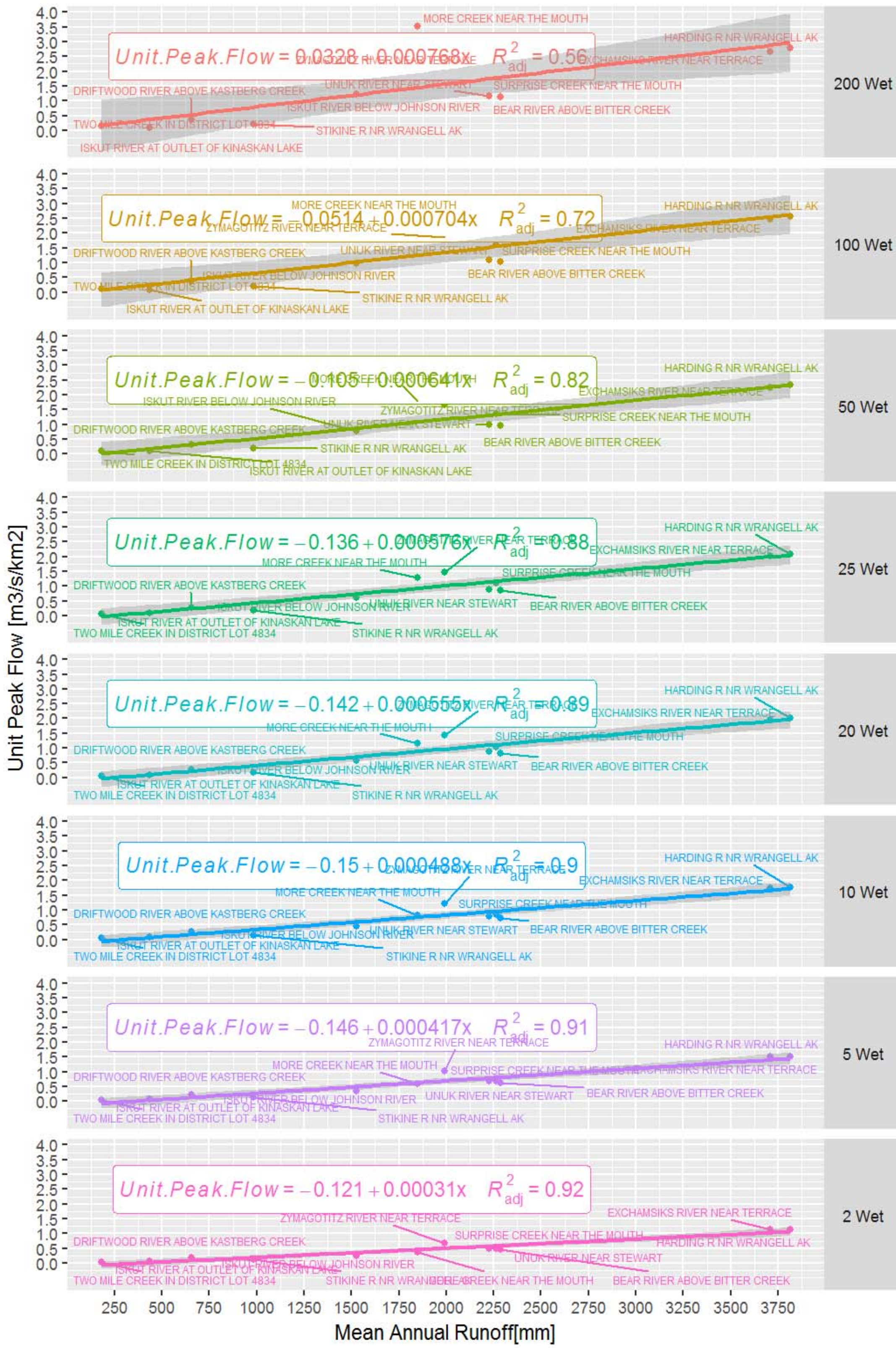


Figure 5-14: Regional Relationships between Mean Annual Runoff and Unit Peak-Flow for the Return Periods from 2 to 100 Years

Monthly Time Series of Flows

Rescan (1994) presented the recorded monthly information with gauge stations, H1 and Goldslide. These monthly records are illustrated for Bitter Creek H1 in Figure 5-15 and Goldslide in Figure 5-17. In these two figures, there are quite strong similarities between the measured values in red by Rescan (1994) with the modeled values in blue by SRK (this study). In the case of Bitter Creek, H1 was used with the Bitter–Otter model for glaciated watershed. Based on Rescan (1994), H1 included 33% glaciation. For Goldslide Creek, the Goldslide model results were used. In these two cases, Figure 5-16 and Figure 5-18 compare SRK runoff models vs actual measured values, where the red line represents an ideal relationship y=x. These figures demonstrate a linear correlation with R^2 adj. values of 0.83 to 0.85 and a statistical significance (P-value<0.05). These estimated regressions present similarities with the equation y=x (in red line); which suggests monthly likenesses between the measured and model flows.

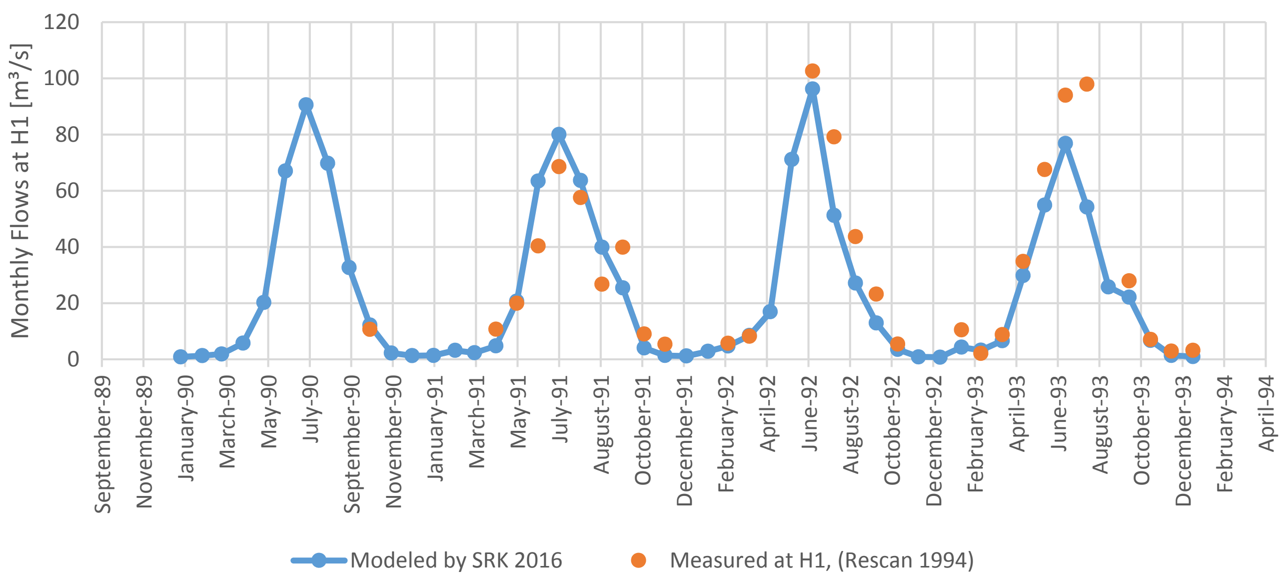


Figure 5-15: Time Series Flow Comparison between Measured (Bitter Creek H1; Rescan, 1994) and Modeled (SRK, 2016) Flows

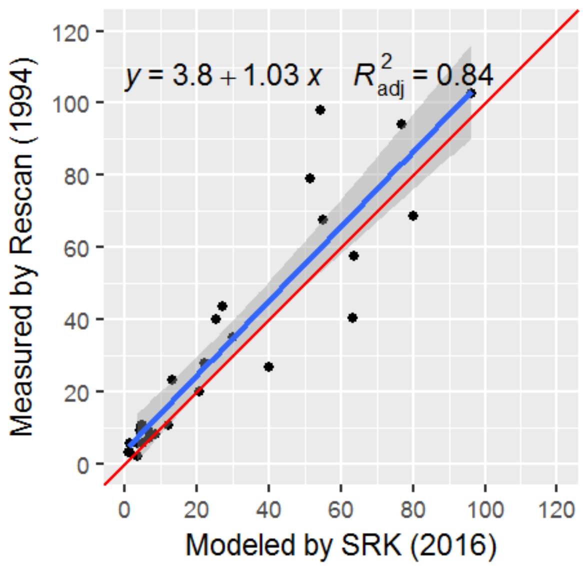


Figure 5-16: Pairwise Flow Comparison between Measured (Bitter Creek H1; Rescan, 1994) and Modeled (SRK, 2016) Flows

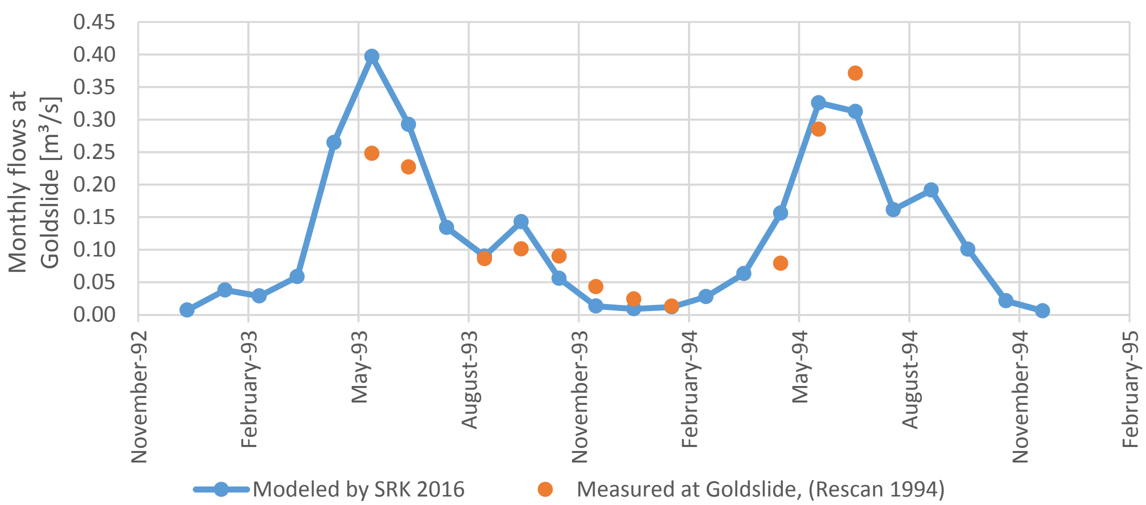


Figure 5-17: Time Series Flow Comparison between Measured (Goldslide Creek; Rescan, 1994) and Modeled (SRK, 2016) Flows

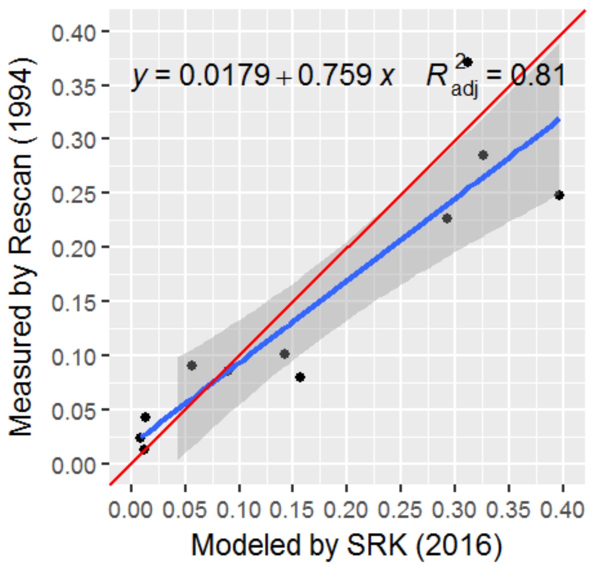


Figure 5-18: Pairwise Series Flow Comparison between Measured (Goldslide Creek; Rescan, 1994) and Modeled (SRK, 2016) Flows

Monthly Average Flows

Rescan (1994) presented mean monthly flows based on Bear River, for H1, Hartley Gulch and Goldslide Creek, and these flows are compared with the results obtained by SRK in the same watersheds. These are illustrated in Figure 5-19 for H1, Figure 5-20 for Hartley Gulch and Figure 5-21 for Goldslide Creek. In every case, the results tend to present similar seasonality and magnitude between the high-flows close to July and low-flows from November to April.

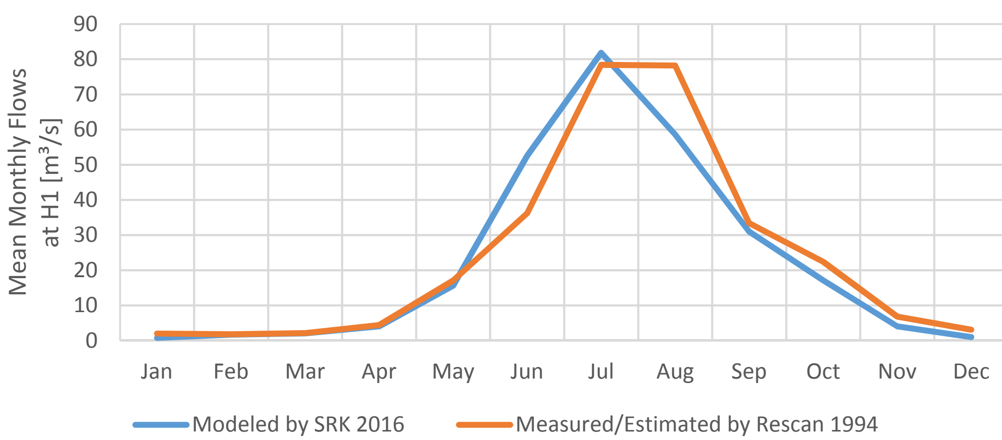


Figure 5-19: Mean Month Flows at H1 (Comparison of SRK (2016) and Rescan (1994)

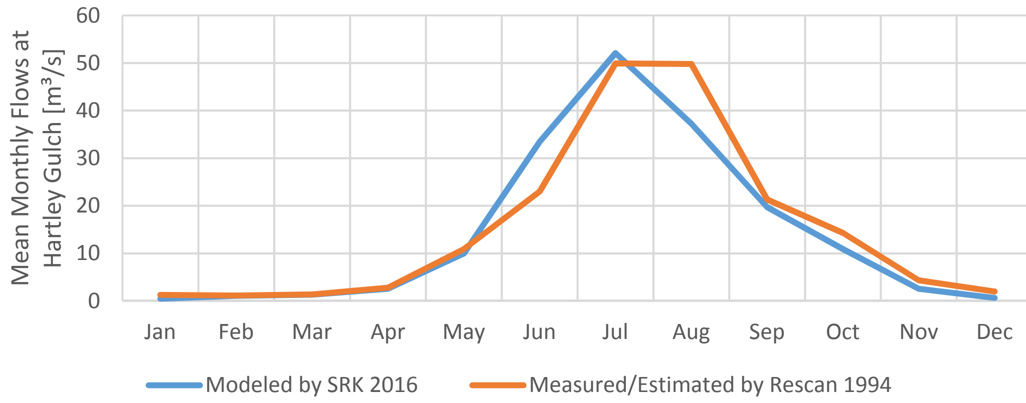


Figure 5-20: Mean Month Flows at Hartley Gulch (Comparison of SRK (2016) and Rescan (1994))

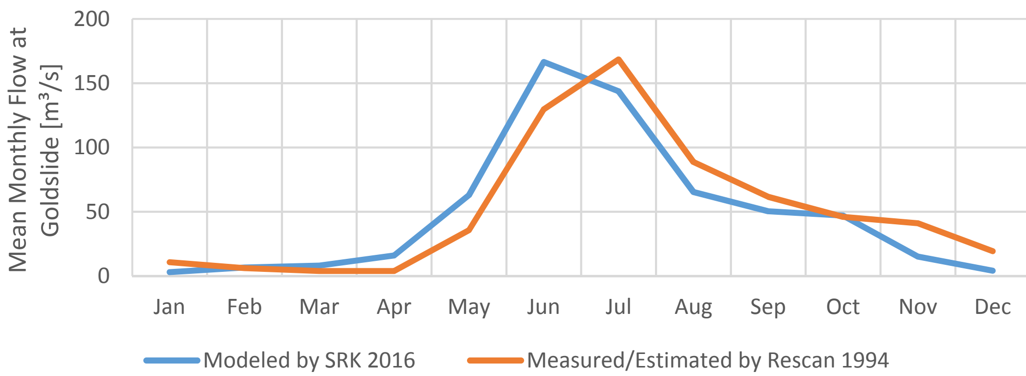


Figure 5-21: Mean Month Flows at Goldslide Creek (Comparison of SRK (2016) and Rescan (1994)

Low-Flow Conditions

Rescan (1994) presented the values for 7Q10 for Bitter and Goldslide Creeks; these values were compared with the SRK estimates, presented in Table 5-9. Although the overall methodologies used to obtain these runoff values are completely different, the results tend to be quite consistent lower for both stations, these low values can be the resultant of limited measures for low flow conditions.

Peak-Flows

In this study (SRK 2016), peak-flows were determined based on a regional analysis and the estimated MAR (See Section 5.4.5). Rescan (1994) prepared a regional analysis based on five small watershed gauges, but that analysis did not include a relationship with MAR or glacier rate, as presented herein.

Table 5-10 presents the comparison of results between Rescan (1994) and this study. In this case, there are differences in the peak-flow estimates. Compared to the estimates from Rescan (1994), the SRK results are more conservative. However, due to the limited information available for this analysis, SRK believes that these values are the most appropriate at this time.

Table 5-9: 7Q10 in the region – Comparison of Rescan (1994) and SRK (2016) Estimates

Location	7Q10 [l/s/km²]	
	Rescan (1994)	SRK (2016)
Bitter Creek	2.69	0.96
Goldslide Creek	3.90	1.1

Table 5-10: Maximum Instantaneous Peak-Flow – Comparison of Rescan (1994) and SRK (2016)

Source	Return Period [m³/s]	
	20 yrs - Goldslide Creek	100 yrs - Bitter Creek
Rescan (1994)	0.88	329
SRK (2016)	1.58	491

6 Climate Change Projections

The section below addresses climate change trends and effects that may occur at the Red Mountain site in the future. This analysis includes the evaluation of the mean annual air temperature (MAAT) and mean annual precipitation (MAP).

6.1 Model

Climate change modeling for the Project was conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and by completing a probability analysis on the multiple climatic models using a purpose-built script developed by SRK using R Software (CRAN 2016). The results of the analysis provide an estimate of the expected change of different climatic parameters for a specific longitude and latitude with respect to baseline conditions.

There are five Assessment Reports from the IPCC that present monthly climate change modelling predictions for any location globally:

- First Assessment Report (FAR) (IPCC 1990)
- Second Assessment Report (SAR) (IPCC 1995)
- Third Assessment Report (TAR) (IPCC 2001)
- Fourth Assessment Report (AR4) (IPCC 2007)
- Fifth Assessment Report (AR5) (IPCC 2014)

The Assessment Reports incorporate 58 global climate models with an average of three climatic scenarios for more than 160 climate change predictions. Climate change models presented in these reports assume the application of radiative forces (energy flux) from different anthropogenic sources that results in discharge of varying concentrations of atmospheric greenhouse gases. These radiative forces are not constant through time, as they are based on global anthropogenic behavior. To eliminate bias when choosing a specific climate scenario, all of the available climate change models are weighted equally during analyses and present a single climate change design parameter based on a rational statistical evaluation of the overall cumulative results. The goal of the climate change analysis is to obtain one engineering design value which includes the variability of all the different global circulation model (GCM) scenarios available and combines a simple understanding of actual historical conditions with the use of reanalysis data.

IPCC-TGICA (2007) suggests that the best correlated models with present day measurements may not necessarily be the GCM models providing the most reliable predictions. Further, sources of uncertainty (not including bias) are incorporated from estimations for future greenhouse gas and aerosol emissions, global climate sensitivity, and regional climate changes and these cannot be accurately predicted. These are actual sources of uncertainty inherent in the models. To best manage these uncertainties and model variability, SRK has included as many models as possible which allows a quick exploration of the range of consequences based on these scenarios using a concept of a "one-model-one-vote", where every climate change model-scenario is considered to be equally as likely to occur as the others.

SRK's analysis was done on an annual time scale and the annual projected values from reanalysis were validated by SRK in order to be comparable to the site's precipitation data. The climate predictions are presented up to the year 2100, which is deemed the maximum reasonable timeframe in which to extend predictions. Within the projected timeframe, three 30-year periods are applied: (1) from 2011 to 2040, (2) from 2041 to 2070, and (3) from 2071 to 2100; these time periods will be referred to as 2020s, 2050s and 2080s, respectively.

The analysis produces a series of figures that summarize climatic prediction models and the statistical analysis of the climatic baseline data (available from 1976 to 2005). The first analysis summarizes the number of models and predicted change with respect to the set baseline condition. The second analysis is the change in baseline conditions for each individual Assessment Report. Thirdly, a trend analysis is applied using reanalysis (ECMWF 2015), which combines satellite information, land records, and numerical models that simulate the earth's climatic conditions. State-of-the-art publicly available reanalysis data for the record period of 1979 to 2015 from reanalysis ERA-interim data produced by the ECMWF (ECMWF 2015) was used in this trend analysis. The methods of trend analyses were Ordinary Least Squares (Maidment 1993), Quantile Regression (Koenker and Bassett 1978), Mann-Kendall (1945) and Sen (1968), Zhang (2000), and Yue and Pilon (2002). The last analysis is of a cumulative probabilistic curve that is created from the combined data available from the Assessment Reports.

In each of the five trend analysis cases, a statistical significance value is produced. If it is greater than 95%, the case with the maximum climate change design parameter is used. If there is no trend with a statistical significance value greater than 95%, then the climate change design parameter is the 50% cumulative probability value. This is also the case if the 50% cumulative probability value is greater than the climate change design parameter values produced through the trend analyses. To determine the climate change design parameter, the following equation is applied:

$$\begin{aligned} &Recommended\ Climate\ Change\ Design\ Parameter \\ &= MAX(50\%\ Cumulative\ Probability, Mean\ \{Regression_{stat.sign \geq 95\%}\}) \end{aligned}$$

6.2 Long-Term Temperature Trends

The MAAT baseline condition, defined from the period of 1976 to 2005, is calculated from Table A1 (Appendix A).

For temperature change with respect to baseline values, the climate change design parameter is presented as a percent change in degrees Kelvin. Converting baseline values in degrees Celsius to degrees Kelvin is necessary before applying the climate change design parameter.

Table 6.1 presents the change in the MAAT with respect to the baseline value of -0.88°C, which corresponds to the site value of -0.86°C from Section 4.2.3 but evaluated for the period between 1976 and 2005. The MAAT is predicted to increase to 2.11°C by the year 2100, representing a change of +2.99°C over the baseline conditions. As climate change progresses, the change in MAAT with respect to baseline conditions follows a near-linear trend.

Table 6.1: Mean Annual Air Temperature under Climate Change Conditions for Red Mountain

Timeline	Source	Name	Value (°C)	Change with Respect to Climate Change Baseline (1976-2005)	
				(°C)	(%)[°K]
-	SRK	Baseline	-0.86	-	-
1976-2005	SRK	Climate Change Baseline	-0.88[3]	-	-
2011-2040	SRK based on ECCC and ERA-Interim	2020s	0.24	+1.12	+0.41%
2041-2070	SRK based on ECCC and ERA-Interim	2050s	1.19	+2.07	+0.76%
2071-2100	SRK based on ECCC and ERA-Interim	2080s	2.11	+2.99	+1.10%

6.3 Long-Term Precipitation Trends

The total annual precipitation baseline condition, defined from the period 1976 to 2005, is calculated from Table A2 (Appendix A).

Table 6.2 presents the change in the total MAP with respect to the baseline value of 1852 mm, which corresponds to the site value of 1847 mm from Section 4.3.3, but evaluated for the period between 1976 and 2005. The total precipitation at Red Mountain is forecasted to increase +185mm (+10%) by the year 2100. As climate change progresses, the change in annual precipitation with respect to baseline conditions follows a near-linear trend.

[3] Mean annual air temperature between 1976 to 2005 estimated from Table A1 (Appendix A)

Table 6.2: Total Precipitation under Climate Change Conditions for Red Mountain

Timeline	Source	Name	Value (mm)	Change with respect Climate Change Baseline (1976-2005)	
				(mm)	(%)[mm]
-	SRK	Baseline	1847	-	-
1976-2005	SRK	Climate Change Baseline	1852[4]	-	-
2011-2040	SRK based on ECCC and ERA-Interim	2020s	1907	+56	+3.0%
2041-2070	SRK based on ECCC and ERA-Interim	2050s	1982	+130	+7.0%
2071-2100	SRK based on ECCC and ERA-Interim	2080s	2037	+185	+10.0%

6.4 Summary of Trends and Implications for Long-Term Hydrology

Climate change effects at Red Mountain area may develop over long timescales. For this analysis, potential effects up to year 2100 are considered. The potential climate trends, as listed in Table 6.3, may manifest as small but continuous increases in temperature and total precipitation.

It is not possible to quantify the effects of changing precipitation and temperature on the hydrology due to the uncertainties associated with quantifying melt rate, the inventory of glacial ice over time, and the available hydrological data. However, some qualitative trends can be anticipated. The increase in precipitation of 10% could be expected to translate to an approximately 10% increase in MAR for unglaciated catchments. The increase in precipitation would have the same effect on glaciated catchments, but over the short to medium term, there would also be an unquantifiable increase in flows associated with glacial meltwater due to rising temperatures and increased melting rates. Over the much longer term, as the inventory of ice is depleted, there would be an unquantifiable decrease in the glacial meltwater. If the glacial ice is fully depleted, the MAR would eventually reach values equivalent to that of an unglaciated catchment.

Table 6.3: Summary of Climate Change Factors

Climate Factor	Trend	Justification
Average Temperature	Increasing	Increase in mean annual air temperature with respect to baseline (1976-2005) of 3.0°C (+1.10%[K]) by 2100.
Total Rainfall	Increasing	Increase in total precipitation with respect to baseline (1976-2005) of 185 mm (+10%[mm]) by 2100.

[4] Mean annual precipitation between 1976 to 2005 estimated from Table A2 (Appendix A)

7 Conclusions

This report presented methods and results for the baseline meteorology and hydrology studies for the proposed Red Mountain Underground Gold Project near Stewart, BC. The report was prepared by SRK Consulting (Canada) Inc., on behalf of IDM Mining Ltd. Avison Management Services Ltd. was responsible for all of the recent sampling and monitoring activities, and contributed to the methods section of the report.

Key results from the frequency analyses are presented in Table 7-1. Climate change trends are shown in Table 7.2. Key meteorological and hydrological parameters are summarized in Table 7-3.

Table 7-1: Summary of Unit Peak-Flow and Low-Flow Conditions – 7Q10 for Red Mountain

Section	5.3.5		5.3.4	
Return Period [yrs]	Unit Peak-Flow [m³/s/km²]		7Q10 [l/s/km²]	
	Glacier Cover <10%[2]	Glacier Cover >10%[1]	Glacier Cover <10%[2]	Glacier Cover >10%[1]
2	0.36	0.76	1.5	1.3
5	0.5	1.03	1.2	1
10	0.61	1.23	1.1	0.96
25	0.72	1.43	0.93	0.9
50	0.89	1.71	0.85	0.88
100	1.04	1.94	0.79	0.87
200	1.23	2.21	0.74	0.86

Notes:

[1]: Runoff model Bitter-Otter Creek

[2]: Runoff model Goldslide Creek

Table 7.2: Summary of Climate Change Factors

Climate Factor	Trend	Justification
Average Temperature	Increasing	Increase in mean annual air temperature with respect to baseline (1976-2005) of 3.0°C (+1.10%[K]) by 2100.
Total Rainfall	Increasing	Increase in total precipitation with respect to baseline (1976-2005) of 185 mm (+10%[mm]) by 2100.

Table 7-3: Summary of Mean Monthly Meteorological and Hydrological Parameters for Red Mountain

Section	Parameter	Unit	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Meteorology															
4.2	Air Temperature	[°C]	-0.86	-6.4	-6.2	-5.5	-3	0.2	3.4	6.3	6.9	4.6	0.1	-4	-6
4.7	Precipitation	[mm]	1847	219	137	121	90	72	66	77	121	211	291	227	214
4.3.7	Snowpack	[cm]	-	190	230	240	260	230	130	20	0	0	10	70	140
4.3.7	Snow Water Equivalent	[cm]	-	57	75	88	98	97	58	11	0	0	2	16	36
4.4	Potential Evapotranspiration	[mm]	534	0	3	31	51	96	110	104	75	45	14	5	0
4.4	Actual Evapotranspiration	[mm]	376	0	3	19	44	65	65	71	60	30	14	5	0
4.4	Pan Evaporation	[mm]	557	0	3	35	55	100	113	108	79	46	14	4	0
4.4	Lake Evaporation	[mm]	484	0	3	27	52	87	93	93	72	40	14	4	0
4.6	Relative Humidity	[%]	70	73	73	65	70	62	60	69	79	80	75	67	70
4.7	Solar Radiation	[W/m²]	-	26	59	110	169	222	223	204	165	113	64	32	21
Hydrology															
5.3.1	Runoff (Glacier Cover >10%)[1]	[l/s/km²]	2828 [mm]	3	6.6	8.1	16	62	208	323	231	122	68	16	4
5.3.1	Runoff (Glacier Cover <10%)[2]	[l/s/km²]	1555 [mm]	3	6.6	8.1	16	63	166	144	65	50	47	15	4.2
5.3.3	Baseflow (Glacier Cover >10%)[1]	[l/s/km²]	-	1.6	3	5.3	7.7	18	69	165	135	62	28	7.2	2.2
5.3.3	Baseflow (Glacier Cover <10%)[2]	[l/s/km²]	-	1.9	3.2	5.3	7.7	19	64	82	41	28	21	7.2	2.6

Notes:

[1]: Runoff model Bitter-Otter Creek

[2]: Runoff model Goldslide Creek

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendix A – Monthly Results from Regional Analysis

Table A1: Monthly Air Temperature for Red Mountain

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1945	-	-	-	-	-	-	-	-	-	-0.1	-6.7	-7.2
1946	-6.5	-7.2	-5.7	-4.8	0.5	3	5.4	6.6	4.2	-0.3	-5.9	-8.4
1947	-10.4	-6.7	-4.5	-2.9	0.3	2.9	5.8	6.4	5	0.3	-2.8	-5
1948	-6.3	-9.6	-6.7	-5.1	0.4	3.6	5.7	7.3	3.1	-1.7	-5.6	-10
1949	-8.6	-10.5	-6.4	-4.3	-0.6	1.6	4.3	4.2	4.7	-0.3	-2.6	-10
1950	-16.7	-9.3	-7.5	-5.4	-1.8	3.4	4.3	5.2	3.4	-2.6	-7.8	-6.3
1951	-9.8	-8	-9.5	-4.1	-0.8	4.6	6.8	7.2	4.9	-1.2	-4.1	-8.1
1952	-10.6	-7.7	-6.9	-5	-1.4	1.5	5.9	7.7	4.5	1.4	-3.4	-5.9
1953	-10.7	-6.3	-5.9	-3.9	-0.1	3	6.1	6.4	3.4	0	-3.8	-5.2
1954	-11.7	-8.6	-7.6	-6	-0.5	1.4	2.9	7	5.1	-0.5	-1.9	-6.5
1955	-5.2	-7.1	-8.4	-5.5	-2.9	1.8	4.7	4.7	3.1	-1.8	-8.6	-11.1
1956	-9.6	-9.6	-8.2	-4.1	0.6	1.5	5.3	6.8	4	-2.9	-4.5	-6.6
1957	-10.6	-9.1	-6.5	-4	1	3	5.1	6.4	6.9	0.6	-2	-7
1958	-4.3	-4.2	-5	-1.7	1.9	7.1	9.8	7.4	3.9	0.2	-5.7	-5.7
1959	-7.6	-7.2	-5.9	-3.8	-0.3	3.1	5.9	5.5	3	0.8	-4.3	-5.6
1960	-6.7	-6.2	-6.5	-3.3	-0.8	1.7	4.8	6.2	4.1	1	-4.1	-4.8
1961	-5.4	-5.7	-5.5	-2.5	0.4	2.9	7.3	8.4	4.8	-0.3	-5.9	-7.3
1962	-6	-6.9	-8.1	-4.3	-1.7	2	6	6.2	4.3	0.1	-4.3	-4.9
1963	-6.3	-3	-5.7	-3.2	-0.1	2.7	6.2	8.4	5.9	-0.5	-6.6	-5.3
1964	-7.4	-5.6	-6.1	-4.6	-1.9	3.1	4.3	5	3.2	-1.2	-6	-12
1965	-9.8	-7.2	-5.7	-3.9	-2.1	2	5.1	6.5	6.4	-0.7	-5.2	-8.7
1966	-9.8	-7	-5.9	-3.9	-1.9	1.9	6.4	5.7	3.5	-1.8	-4.8	-6
1967	-8.3	-5.9	-8	-4	0	4.6	5.5	7.9	4.2	-0.5	-3.5	-6.5
1968	-10	-7.2	-5.1	-4.6	0.8	2.2	6.3	6.9	3.4	-1.4	-4	-11.1
1969	-15.3	-10	-6.8	-4.5	0.2	5.5	5.6	4.5	3.3	0.2	-2.7	-4
1970	-8.5	-4	-4.1	-4.1	-1.2	2.6	4	5.5	3.3	-0.3	-5.4	-9.4
1971	-11.1	-7.9	-7.7	-5	-2.3	1.3	6.8	6.3	3	-1.7	-4.3	-9.9
1972	-12.3	-10.7	-7.1	-6.7	-0.7	1.7	5.8	6.9	3.6	-0.4	-3.4	-7.6
1973	-8.2	-6.5	-6.1	-3.7	-1.6	0.8	4	5.1	3.4	-2	-8.9	-6.5
1974	-10.2	-7.6	-6.7	-3.9	-1.5	0.9	4.1	7.1	5.7	0.4	-4.5	-5.5
1975	-9.2	-10.4	-8	-5.1	-1.9	1.1	4.6	4.2	4.5	-1.5	-6.2	-6.7
1976	-5.9	-8.4	-7.6	-4.4	-2.1	1.4	3.8	4.7	3.6	-0.1	-3.1	-4.4
1977	-6.1	-3.6	-5.7	-3.5	-1.1	3	4.9	8.4	4.6	-0.6	-6.6	-10.4
1978	-8.3	-5	-5.1	-2.8	-0.6	4.8	6.9	6.7	3.4	0.7	-4.5	-7.3
1979	-9.1	-9.2	-4.6	-3	-0.1	2.6	6.5	7.9	5.3	1.2	-2.9	-5.5
1980	-9.4	-4.9	-5.3	-2.9	0.2	4.4	6.5	7.4	5.5	1.1	-2.9	-7.6
1981	-3	-4.9	-4.1	-3.5	0.5	2.4	7.3	7.8	4.8	-0.3	-2.5	-7.2
1982	-9.4	-8.8	-6.2	-5.4	-1.4	4.1	5.6	5.6	4.8	0.1	-5.5	-6.2
1983	-5.1	-3.5	-3.6	-1.6	1.6	3.8	6	6.3	3.7	0.2	-3.6	-8.2
1984	-5	-5.1	-3.3	-3.3	-0.9	2.6	4.9	5.8	3.2	-1.1	-5.4	-8.1

Appendix A – Monthly Results from Regional Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	-3.8	-6.7	-6	-4.6	-0.8	1.5	6.4	6.7	4.5	-1.9	-10.9	-7.2
1986	-5.8	-9	-4	-4.5	-1.4	2.6	5.2	7.5	5.4	3	-3.2	-4.7
1987	-5.3	-4.5	-5.7	-3.6	-0.3	2.9	5.7	7.6	4.8	0.6	-2.3	-6.2
1988	-6.6	-5.3	-4.5	-3.5	-0.6	2.3	5	6.6	4.3	0.8	-3.8	-6.3
1989	-8	-9.7	-7	-2.3	1.2	5	6.5	7.7	7.3	0.3	-3.5	-2.5
1990	-6.6	-8.7	-4.2	-2	1.4	4	7.6	8.4	5.2	-1.5	-6.8	-8.1
1991	-9.2	-5.3	-7.3	-4.3	-0.3	2.7	5.5	6.4	4.8	-0.3	-2.7	-4.4
1992	-5.4	-5	-4.5	-3.2	0.4	4.1	6.4	6.7	3.2	-0.6	-3.1	-7.9
1993	-8.2	-5.7	-5.7	-2.3	2	3.6	6.4	8.1	6.3	2	-3	-4.5
1994	-3.8	-8.9	-4.8	-2.2	0.2	2.9	6.8	7.5	4.6	-0.2	-6.4	-7.3
1995	-5.5	-6.8	-5.9	-2.1	1.8	4	7.4	5.6	5.6	-0.5	-4	-6.3
1996	-9.7	-7	-5.5	-2.9	-0.4	2.5	5.6	6.8	3.3	-0.9	-6.2	-10
1997	-7.1	-4.5	-6.4	-3	1.9	3.8	6.3	8.5	5.7	0.4	-2.5	-4.1
1998	-6.8	-3.8	-3.4	-2.9	1	5.4	7.5	6.6	4	0.6	-4	-6.9
1999	-6.9	-7.3	-6.6	-3.9	-2.2	1.8	5.2	5.4	3.1	-0.2	-4.8	-6
2000	-8.9	-7	-4.8	-3.8	-1	3.2	6	6.8	4.5	0.1	-3.5	-5.9
2001	-4.9	-6.6	-5.6	-3.8	-1.9	1.8	5	5.7	2.7	-1.6	-5.1	-7.2
2002	-6.4	-7.2	-8.7	-4.6	-1.1	2.7	4.9	7.5	4.3	1.4	-1.3	-4.9
2003	-3.7	-5.9	-6.1	-3.4	-0.2	4	6.3	6.9	5.1	1.3	-5.1	-6
2004	-6.7	-4.5	-4.7	-1.5	2	5.6	7.6	9	4.5	0.3	-3.6	-5.5
2005	-7	-6.3	-4.1	-2.1	2.4	5.1	6.8	7.9	5.3	-0.2	-4.5	-4
2006	-5.7	-6.3	-7.7	-4	0.1	4.1	6.3	6.3	5.1	0.8	-7.6	-5.7
2007	-7.3	-5.8	-6.9	-3.4	-1	2.5	5.9	6.3	4.5	-0.4	-4.7	-8.8
2008	-9.1	-6.9	-5.9	-4.9	-0.4	0.3	4.2	4.9	4	-0.9	-3.7	-9.1
2009	-7.8	-8.4	-8.3	-3.9	-0.5	3.7	7.3	7.6	3.6	0.2	-5.2	-7
2010	-4.7	-4.2	-5	-3.2	0.2	2	6.7	7.4	5.3	0.3	-4.4	-6.9
2011	-6.8	-7.9	-6.3	-4.7	-0.8	3.6	5	5.8	4.1	-0.8	-5.9	-6.2
2012	-9	-5.7	-7.3	-3.9	-1.8	1.6	4.6	6	4.5	-1	-4.1	-7.1
2013	-5.5	-5.1	-6	-3.4	1	4.1	7.3	7.4	4.9	0.9	-3.7	-5
2014	-4.5	-8.8	-6.3	-2.8	1.4	3.7	6.6	8.7	6.2	0.7	-3.2	-4.2
2015	-4	-3.4	-2.6	-2.8	2.1	5.7	8.6	6.5	2.3	1.6	-4.3	-6.2
2016	-3.2	-3.3	-2.4	0.3	3.3	5.5	8.8	-	-	-	-	-

Source: compiled in text.

Table A2: Monthly Precipitation at Red Mountain, Estimation Directly from Stewart A Patched Records

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	-	-	-	-	-	-	-	-	-	-	-	-
1975	275	242	66	37	49	68	85	98	161	204	203	317
1976	379	198	115	46	127	91	113	85	182	305	236	200
1977	99	167	109	90	45	112	42	36	78	203	195	82
1978	46	71	78	64	44	16	18	152	148	510	355	333
1979	154	126	82	17	94	89	40	24	282	190	135	330
1980	149	121	132	144	70	16	116	109	223	484	353	342
1981	121	167	130	159	58	87	40	133	380	173	246	197
1982	278	102	94	129	107	16	58	46	157	345	145	129
1983	238	101	40	42	94	86	85	174	212	294	95	68
1984	322	199	70	38	45	71	88	138	146	183	117	285
1985	190	287	176	110	56	63	40	80	107	272	167	163
1986	166	130	185	138	71	72	46	73	92	422	240	182
1987	249	85	119	187	108	85	21	103	333	248	330	165
1988	182	176	160	68	97	68	156	101	195	286	231	217
1989	570	2	61	28	34	25	53	65	145	252	443	313
1990	246	214	131	51	58	106	64	126	166	276	316	443
1991	177	228	91	57	57	64	93	166	214	455	353	528
1992	295	118	136	117	152	53	37	44	405	233	199	218
1993	248	264	93	45	70	63	80	55	101	312	332	203
1994	235	102	158	123	108	58	74	88	363	235	331	130
1995	43	111	91	52	45	50	62	128	99	336	210	129
1996	264	100	92	90	44	105	40	138	154	258	130	117
1997	186	190	150	153	58	113	91	61	164	315	155	347
1998	61	51	81	59	27	35	73	215	182	209	118	226
1999	290	99	49	105	139	73	48	161	215	469	192	209
2000	225	57	222	73	46	53	146	225	323	193	259	166
2001	284	78	136	104	122	81	75	170	280	256	161	203
2002	184	178	55	27	87	65	77	218	274	128	200	122
2003	361	63	140	31	70	77	65	96	283	288	257	145
2004	195	64	194	124	25	35	81	104	234	303	307	277
2005	247	241	202	73	45	39	126	153	230	283	299	221
2006	184	111	111	132	57	59	80	120	199	202	152	373
2007	386	179	311	138	74	55	136	77	196	475	105	104
2008	103	192	98	126	104	85	103	221	95	411	232	184
2009	316	164	133	55	71	40	45	95	180	183	249	25
2010	96	42	166	47	30	106	51	89	252	391	205	48
2011	209	182	55	47	67	39	82	216	424	326	317	263
2012	351	68	94	41	93	79	87	68	222	129	143	131
2013	119	143	39	98	96	64	60	143	111	176	216	379

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	176	51	130	215	72	79	78	150	250	319	187	108
2015	225	105	242	142	3.7	75	189	218	217	390	173	144
2016	73	169	62	164	96	-	-	-	-	-	-	-

Source: compiled in text.

Table A3: Monthly Unit Flow for Bitter and Otter Creek in l/s/km²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959	-	-	-	-	52	228	374	185	86	63	15	8.9
1960	-	-	-	-	-	-	427	272	97	83	16	3.1
1961	2.5	5.7	7.2	-	-	217	360	257	86	195	23	4.4
1962	2.7	7.8	7.2	22	58	195	370	243	110	46	29	-
1963	-	-	-	-	60	148	337	240	178	80	-	-
1964	-	-	8.3	13	38	254	334	222	72	62	13	2.5
1965	2.4	5.9	7.6	12	39	144	342	256	88	34	12	3.4
1966	2.1	4.2	8.4	15	38	173	357	215	127	58	17	3.2
1967	2.2	4.4	4.3	7.8	57	300	260	282	187	74	15	3.3
1968	2.7	5.9	16	13	58	154	355	194	133	45	13	2.9
1969	1.5	3.4	5.4	13	56	306	258	186	108	46	43	9.7
1970	3.3	10	12	14	42	213	273	243	101	60	17	3
1971	1.6	4.2	6.6	9.3	39	223	350	289	112	56	10	2.6
1972	1.7	3.6	5.8	7.9	55	215	375	269	103	73	13	3.1
1973	2.4	5.8	6.5	14	54	176	297	232	117	34	8.3	1.7
1974	1.4	3.4	5	10	42	121	233	232	143	169	23	6.3
1975	2.9	5.3	5.5	11	47	152	387	182	89	42	7.3	1.5
1976	2.5	6.1	5.9	9.7	46	171	330	269	119	65	28	3.9
1977	3.3	8.8	7.9	20	47	180	298	287	81	48	9.9	2.3
1978	1.9	5.2	5.9	13	36	171	262	235	75	104	24	2.6
1979	1.8	4.3	8.3	17	61	172	343	232	125	85	11	3.8
1980	2.7	4.4	5.9	18	65	233	294	211	98	139	28	8.7
1981	6.6	12	11	13	81	180	331	267	221	62	30	4.4
1982	2.8	5.3	4.7	6	32	243	309	197	118	75	9.2	2.3
1983	2.5	5.7	6.9	17	69	211	273	221	103	39	12	2.2
1984	1.9	8.8	10	13	40	152	269	237	70	53	8.4	2.6
1985	3.4	6.4	7.3	11	57	167	397	217	95	35	7.3	1.7
1986	2.1	3.8	11	14	43	184	355	212	86	136	25	2.9
1987	3	5.8	5.9	16	56	172	381	187	146	103	26	6.5
1988	2.1	4.7	7.1	17	63	183	270	240	132	69	11	3.4
1989	3	6.6	4.6	16	75	226	349	263	127	61	22	5.3
1990	3.6	5.3	7.6	23	80	265	358	276	129	48	9	5.3
1991	5.6	13	9.3	19	82	251	316	252	158	101	16	5.5
1992	4.8	11	19	34	67	281	380	203	107	51	14	3.6
1993	3.2	17	13	26	118	217	304	214	102	87	27	5.7
1994	4.1	5.4	13	29	69	186	319	260	195	66	10	2.6
1995	1.6	5.5	7.7	21	86	185	279	185	142	39	9.5	2.7

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	1.7	4.9	7.9	18	45	183	280	199	88	46	8.8	2.9
1997	2	4.5	5.3	16	76	227	316	228	146	48	15	5.4
1998	3.1	7.1	7.2	13	92	224	282	214	103	56	11	2.8
1999	2.1	4.6	5.7	14	57	223	312	240	113	68	18	3.5
2000	3.1	7.6	9	13	42	192	363	237	145	57	16	5.3
2001	3.7	5.8	7.1	9.9	34	188	314	224	129	36	8.4	2.1
2002	1.7	4.7	4.8	7.2	59	233	279	269	126	55	15	6.2
2003	4.8	6.5	6.4	18	59	195	326	192	144	82	20	5.7
2004	3.7	7.8	10	22	83	294	347	232	106	70	15	8.1
2005	4.4	8.4	15	26	97	222	292	245	109	48	24	5.4
2006	3.5	6.8	5.5	12	54	242	343	189	154	61	9.6	3.3
2007	3.2	7.7	9.3	19	66	272	495	226	110	50	12	2.7
2008	2.1	4.2	4.7	9.4	83	166	279	248	92	57	14	4.1
2009	2.9	7.4	7.2	9.7	61	253	380	236	158	43	14	3.1
2010	2.7	5.9	11	21	70	178	264	226	117	81	21	3.5
2011	2.8	6.4	7.8	9.4	64	211	251	247	282	59	16	4.2
2012	3.3	6.1	6.6	19	55	241	380	238	138	53	7.1	2.1
2013	2	8.5	6.1	12	82	247	282	216	113	53	9.6	3.4
2014	5.1	7.3	9.3	19	90	195	318	230	159	95	13	3.2
2015	6.6	10	14	18	100	215	271	225	99	101	16	4.9
2016	6.7	10	10	39	85	197	278	197	105	20	8.5	-
2017	-	-	-	-	-	-	-	-	-	-	-	-

Source: compiled in text.

Table A4: Monthly Unit Flow for Goldslide Creek in l/s/km²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959	-	-	-	-	53	177	168	53	36	44	14	9.1
1960	-	-	-	-	-	-	187	77	40	59	15	3.3
1961	2.5	5.7	7.2	-	-	178	160	73	34	135	22	4.6
1962	2.6	7.8	7.2	22	59	153	162	69	46	33	27	-
1963	-	-	-	-	61	118	155	68	71	56	-	-
1964	-	-	8.3	13	38	208	146	63	29	45	12	2.6
1965	2.4	5.9	7.6	12	39	120	154	73	36	24	11	3.5
1966	2.1	4.2	8.4	15	39	141	155	61	51	40	15	3.4
1967	2.2	4.4	4.3	7.8	59	236	115	80	77	51	15	3.4
1968	2.7	5.9	16	13	59	121	158	55	54	31	13	3
1969	1.4	3.4	5.4	13	57	249	118	53	43	31	40	10
1970	3.3	10	12	14	43	175	122	69	42	41	16	3.2
1971	1.6	4.2	6.6	9.3	40	177	152	82	43	38	10	2.7
1972	1.7	3.6	5.8	7.9	56	171	164	76	42	50	13	3.3
1973	2.4	5.9	6.5	14	55	139	131	66	46	24	7.7	1.8
1974	1.4	3.4	5	10	43	98	104	66	58	117	21	6.6
1975	2.9	5.3	5.5	11	48	120	181	51	36	28	6.9	1.6
1976	2.5	6.1	5.9	9.7	47	133	148	76	54	45	27	4.1

Appendix A – Monthly Results from Regional Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977	3.3	8.8	7.9	20	48	145	131	81	33	34	9.4	2.4
1978	1.9	5.2	5.9	13	37	139	116	67	30	75	22	2.7
1979	1.8	4.3	8.3	17	62	138	151	66	51	58	11	4
1980	2.7	4.4	5.9	18	66	187	128	60	42	94	27	9
1981	6.6	12	11	13	82	146	143	76	87	44	29	4.6
1982	2.8	5.3	4.7	6.1	33	193	139	56	46	52	8.7	2.4
1983	2.5	5.7	6.9	17	70	169	122	63	40	27	11	2.3
1984	1.9	8.8	10	13	41	118	115	67	29	37	8.1	2.7
1985	3.4	6.4	7.3	11	58	135	178	62	39	24	7	1.7
1986	2.1	3.8	11	14	44	147	159	60	35	95	23	3.1
1987	3	5.8	5.9	16	57	136	175	53	59	68	25	6.7
1988	2.1	4.7	7.1	17	65	146	115	68	51	48	11	3.5
1989	3	6.6	4.6	16	76	184	154	74	53	41	22	5.6
1990	3.6	5.3	7.6	23	82	214	162	77	56	33	8.6	5.6
1991	5.6	13	9.3	19	84	196	144	71	66	70	16	5.9
1992	4.8	11	19	34	68	221	174	57	48	35	14	3.8
1993	3.2	17	13	27	120	180	133	61	41	65	25	6
1994	4.1	5.4	13	29	71	148	142	73	87	46	9.7	2.7
1995	1.6	5.5	7.7	21	87	150	126	52	56	27	9.1	2.8
1996	1.7	4.9	7.9	18	46	143	120	56	36	32	8.4	3
1997	2	4.5	5.3	16	78	180	144	64	61	34	14	5.7
1998	3.1	7.1	7.2	13	93	186	128	60	40	40	10	2.9
1999	2	4.6	5.7	14	58	179	140	68	48	50	17	3.7
2000	3.1	7.6	9	13	43	150	157	67	62	40	15	5.5
2001	3.6	5.8	7.1	10	34	149	138	63	54	25	8	2.2
2002	1.7	4.7	4.8	7.2	60	187	123	75	51	38	14	6.4
2003	4.7	6.5	6.4	18	60	160	146	54	58	59	19	6
2004	3.7	7.8	10	22	85	226	154	65	46	48	14	8.6
2005	4.4	8.4	15	26	99	180	133	68	44	34	24	5.7
2006	3.5	6.8	5.5	12	55	198	151	54	66	42	9.1	3.5
2007	3.2	7.7	9.3	19	68	225	222	64	45	35	12	2.9
2008	2.1	4.2	4.7	9.4	84	132	127	69	40	40	14	4.3
2009	2.9	7.4	7.2	9.8	62	210	167	67	67	30	13	3.2
2010	2.7	5.9	10	21	71	144	116	64	47	55	20	3.7
2011	2.8	6.4	7.8	9.4	66	171	111	69	109	41	15	4.4
2012	3.3	6.1	6.6	19	56	184	163	67	59	37	6.8	2.2
2013	2	8.5	6.1	12	83	195	126	61	45	38	9	3.6
2014	5.1	7.3	9.2	19	92	155	144	65	71	65	13	3.4
2015	6.6	11	14	18	102	176	121	64	41	71	15	5.5
2016	6.6	10	10	39	87	156	122	55	44	14	8.8	-
2017	-	-	-	-	-	-	-	-	-	-	-	-

Source: compiled in text.

Appendix B – Supplementary Tables and Figures

Table B1: Regional Meteorological Stations with Temperature Data

Station Name	Station ID	Longitude (°)	Latitude (°)	Elevation (masl)	Distance from Site (km)	Distance from Coast (km)	Mean Annual Air Temperature (°C)
STEWART A	1067742	-129.99	55.94	7	17	1	6.32
UNUK RIVER ESKAY CREEK	1078L3D	-130.45	56.65	887	89	70	0.91
NASS CAMP	1075384	-129.03	55.24	195	91	38	5.69
BOB QUINN AGS	1200R0J	-130.25	56.97	610	117	107	3.25
MURDER CREEK	1075253	-127.80	55.52	245	130	106	4.51
ROSSWOOD	1076886	-128.80	54.85	183	137	55	6.24
CEDARVALE	107ADFE	-128.32	55.02	152	137	83	6.44
HAZELTON TEMLEHAN	1073347	-127.73	55.20	122	151	114	5.07
GREY ISLET (AUT)	1063303	-130.70	54.58	10	166	17	8.32
GREEN ISLAND	1063298	-130.71	54.57	12	167	18	8.71
SUSKWA VALLEY	107G879	-127.17	55.29	534	177	147	4.18
TERRACE PCC	1068131	-128.62	54.50	67	177	52	7.60
TERRACE A	1068130	-128.58	54.47	217	181	49	6.68
PRINCE RUPERT A	1066481	-130.44	54.29	35	191	5	6.97
LUCY ISLAND LIGHTSTATION	1064728	-130.61	54.30	2	193	11	8.66
TRIPLE ISLAND	1068250	-130.88	54.29	21	200	27	8.50
HOLLAND ROCK	1063496	-130.36	54.17	6	203	7	8.43
SMITHERS A	1077500	-127.18	54.82	522	205	127	4.28
KITIMAT	1064288	-128.68	54.05	13	223	4	7.53
KITIMAT TOWNSITE	1064320	-128.63	54.05	98	224	2	7.47
KITIMAT HATCHERY	106D289	-128.68	54.04	11	224	4	7.15
KITIMAT 2	1064321	-128.71	54.01	17	226	2	7.99
QUICK	1076638	-126.90	54.62	533	233	129	3.61
ROSE SPIT (AUT)	1056869	-131.66	54.16	7	235	0	8.40
TELEGRAPH CREEK	1208040	-131.33	57.90	250	237	106	2.65
KILDALA	1064138	-128.48	53.83	30	250	0	6.61
HOUSTON	1073612	-126.67	54.40	610	260	132	4.58
BONILLA ISLAND	1060902	-130.64	53.49	16	281	10	8.73
BONILLA ISLAND (AUT)	1060R0K	-130.64	53.49	13	281	10	8.68
HARTLEY BAY	1063339	-129.25	53.42	2	284	0	7.98
LANGARA	1054500	-133.06	54.26	43	284	9	8.16
LANGARA ISLAND RCS	1054503	-133.06	54.26	47	284	9	8.39
KEMANO	1064020	-127.94	53.56	66	291	14	7.18
TAHTSA LAKE WEST	1087950	-127.70	53.62	863	291	31	2.68
EQUITY SILVER	1072692	-126.28	54.20	1280	294	144	1.41
SEWALL MASSET INLET	105PA91	-132.30	53.76	3	295	0	8.43
TLELL	1058190	-131.95	53.50	5	309	1	8.18
WISTARIA	1088970	-126.21	53.83	863	327	120	2.85
SANDSPIT A	1057050	-131.81	53.25	6	330	0	8.82
SANDSPIT AWOS	1057055	-131.81	53.25	6	330	0	8.49
TAKYSIE LAKE	1087974	-125.87	53.87	884	339	136	2.17
OOTSA L SKINS L SPILLWAY	1085835	-126.00	53.77	861	341	122	2.97
OOTSA LAKESKINS LAKE CLIMATE	1085836	-126.00	53.77	861	341	122	3.54
CUMSHEWA ISLAND	1062251	-131.60	53.03	13	348	0	9.25
KINDAKUN ROCKS (AUT)	1054222	-132.77	53.32	15	353	1	8.61

Station Name	Station ID	Longitude (°)	Latitude (°)	Elevation (masl)	Distance from Site (km)	Distance from Coast (km)	Mean Annual Air Temperature (°C)
PALLANT CREEK	1055950	-132.05	53.05	20	357	3	8.24
MORESBY ISLAND MITCHELL INLET	10551R8	-132.13	52.93	3	371	1	8.31
BOAT BLUFF	1060901	-128.52	52.64	11	378	1	8.91

Source: compiled in text.

Table B2: Regional Meteorological Stations with Precipitation Data

Station Name	Station ID	Longitude (°)	Latitude (°)	Elevation (masl)	Distance from Site (km)	Distance from Coast (km)	Mean Annual Precipitation (MAP) (mm/yr)
STEWART	1067740	-130	55.95	4.6	16.7	2	1745
STEWART A	1067742	-130	55.94	7.3	17.4	1	1847
PREMIER	1066420	-130	56.05	410	21.7	13	2195
ALICE ARM	1060330	-129.5	55.68	314.2	33.6	20	2087
ANYOX	1060446	-129.8	55.42	112.8	60.2	1	2008
UNUK RIVER ESKAY CREEK	1078L3D	-130.4	56.65	887	89.6	70	2036
NASS CAMP	1075384	-129	55.24	195	90.7	38	1061
AIYANSH	1070150	-129	55.23	228.6	91.9	39	1077
AIYANSH 2SE	1070154	-129.1	55.18	213.4	96	41	1032
MILL BAY	1065130	-129.8	55	3	106.6	1	2116
NAAS HARBOUR	1065275	-129.9	54.93	6.1	115.2	1	1967
ROSSWOOD	1076886	-128.8	54.85	182.9	136.1	55	1050
CEDARVALE	107ADFE	-128.3	55.02	152	136.4	83	825.2
ROSSWOOD	1066885	-128.8	54.78	146.3	144	60	812.7
PORT SIMPSON	1066336	-130.4	54.57	7.9	161	1	2349
TERRACE	1068100	-128.6	54.52	NA	175.4	54	1150
TERRACE PCC	1068131	-128.6	54.5	67	176.4	52	1141
TERRACE A	1068130	-128.6	54.47	217.3	180.5	49	1334
PRINCE RUPERT SHAWATLANS	1066493	-130.2	54.33	11	184.3	0	2988
SALVUS CAMP	1067005	-129.4	54.3	15.2	185.8	10	2046
PRINCE RUPERT MONT CIRC	1066488	-130.3	54.32	60	185.9	3	3097
PRINCE RUPERT R PARK	1066492	-130.3	54.3	90.8	188.6	3	3049
LAKELSE LAKE	1064497	-128.5	54.4	76	189.2	41	1688
PRINCE RUPERT A	1066481	-130.4	54.29	35.4	191.3	5	2577
PRINCE RUPERT	1066480	-130.4	54.28	51.8	191.5	6	2443
HOLLAND ROCK	1063496	-130.4	54.17	5.5	203.2	7	1108
LAWYER ISLAND	1064591	-130.3	54.12	6.1	208.5	4	2540
FALLS RIVER	1062790	-129.7	53.98	18	220.1	0	3683
KITIMAT 3	1064322	-128.6	54.06	137	222	4	2318
KITIMAT	1064288	-128.7	54.05	12.8	222.3	4	2260
KITIMAT TOWNSITE	1064320	-128.6	54.05	98	223.3	2	2242
KITIMAT HATCHERY	106D289	-128.7	54.04	11	223.4	4	2307
KITIMAT 2	1064321	-128.7	54.01	16.8	226	2	2712
KITIMAT	1064289	-128.7	54	16.8	227.3	1	2951
KITIMAT MISSION	1064290	-128.7	53.98	6.1	230.3	1	2198

Station Name	Station ID	Longitude (°)	Latitude (°)	Elevation (masl)	Distance from Site (km)	Distance from Coast (km)	Mean Annual Precipitation (MAP) (mm/yr)
KILDALA	1064138	-128.5	53.83	30.5	249.6	0	2148
HARTLEY BAY	1063339	-129.2	53.42	2	284	0	4546
KEMANO	1064020	-127.9	53.56	66	290.1	14	1927
TAHTSA LAKE WEST	1087950	-127.7	53.62	862.6	290.4	31	1990
ETHELDA BAY	1062745	-129.7	53.05	9.6	323.6	13	3274
SWANSON BAY	1067880	-128.5	53.03	4.6	335.1	1	5168
BOAT BLUFF	1060901	-128.5	52.64	10.7	377.3	1	5030

Source: compiled in text.

Table B3: Regional Average Monthly Precipitation and Mean Annual Precipitation

Station Name	Monthly Average (mm)												MAP (mm/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
STEWART	190	141	110	90	60	67	77	120	168	303	209	209	1745
STEWART A	219	137	121	90	72	66	77	121	212	293	226	214	1847
PREMIER	289	200	171	110	74	67	76	105	183	318	304	298	2195
ALICE ARM	196	194	150	131	69	75	74	119	196	357	245	282	2087
ANYOX	245	180	150	82	61	55	66	107	150	300	335	276	2008
UNUK RIVER ESKAY CREEK	248	210	185	95	87	70	83	134	214	247	221	240	2036
NASS CAMP	131	67	47	43	50	58	58	78	112	162	127	127	1061
AIYANSH	144	101	65	43	37	45	49	63	97	150	136	149	1077
AIYANSH 2SE	140	86	36	36	47	52	54	58	106	167	119	131	1032
MILL BAY	229	182	175	119	86	75	88	126	174	302	278	282	2116
NAAS HARBOUR	206	137	155	115	73	62	73	129	196	307	268	245	1967
ROSSWOOD	124	78	46	38	47	53	56	58	107	175	137	132	1050
CEDARVALE	113	60	40	32	39	48	39	47	81	127	92	109	825
ROSSWOOD	103	61	51	33	28	33	43	43	64	127	120	107	813
PORT SIMPSON	221	182	147	177	111	109	119	174	242	321	287	259	2349
TERRACE	123	95	81	63	43	47	52	53	82	166	179	167	1150
TERRACE PCC	136	88	77	60	48	46	46	59	101	176	156	149	1141
TERRACE A	171	115	88	67	51	47	54	62	107	200	185	187	1334
PRINCE RUPERT SHAWATLANS	293	230	215	211	158	133	137	184	280	430	354	362	2988
SALVUS CAMP	229	186	144	114	77	65	72	91	194	310	277	287	2046
PRINCE RUPERT MONT CIRC	314	243	242	230	164	133	129	188	288	448	354	364	3097
PRINCE RUPERT R PARK	306	258	252	247	164	139	120	172	258	429	357	348	3049
LAKELSE LAKE	274	170	111	81	59	50	53	68	116	216	235	252	1688
PRINCE RUPERT A	257	204	195	176	139	117	116	170	255	371	294	281	2577
PRINCE RUPERT	235	188	210	177	129	106	117	145	217	335	303	281	2443
HOLLAND ROCK	110	76	92	68	65	58	62	91	113	134	110	128	1108
LAWYER ISLAND	257	224	199	211	148	104	93	117	241	335	334	277	2540
FALLS RIVER	430	338	316	283	158	117	107	147	295	550	479	464	3683
KITIMAT 3	328	175	181	116	85	69	69	104	193	349	341	308	2318
KITIMAT	313	231	154	120	75	72	50	70	191	326	340	319	2260
KITIMAT TOWNSITE	290	211	173	124	81	68	65	100	189	345	305	291	2242
KITIMAT HATCHERY	307	153	189	148	86	71	70	108	167	354	323	332	2307
KITIMAT 2	349	243	225	165	105	79	71	109	220	411	382	353	2712
KITIMAT	335	316	227	187	92	77	64	107	201	513	399	434	2951

Station Name	Monthly Average (mm)												MAP (mm/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
KITIMAT MISSION	276	141	138	126	82	87	64	114	178	377	339	277	2198
KILDALA	262	194	148	133	88	82	81	104	187	316	280	273	2148
HARTLEY BAY	449	408	322	311	241	205	174	193	402	679	624	538	4546
KEMANO	236	173	140	100	60	57	57	81	168	319	273	263	1927
TAHTSA LAKE WEST	261	203	150	104	63	59	54	73	156	290	281	294	1990
ETHELDA BAY	362	299	285	258	194	139	123	162	255	418	416	365	3274
SWANSON BAY	590	371	452	333	283	235	195	218	350	708	781	652	5168
BOAT BLUFF	584	431	457	376	244	214	182	230	384	616	673	641	5030

Source: compiled in text.

Table B4: Mean Monthly Runoff per Station in l/s/km²

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BEAR RIVER ABOVE BITTER CREEK	9.8	9.8	10	23	68	135	179	179	125	79	31	14
SURPRISE CREEK NEAR THE MOUTH	6.1	5.3	5.6	21	106	207	190	132	91	59	22	9.4
SALMON R NR HYDER AK	10	9.1	13	16	67	192	271	304	221	109	62	18
KITSAULT RIVER ABOVE KLAYDUC CREEK	22	25	24	54	155	218	183	133	131	98	52	32
LIME CREEK NEAR THE MOUTH	14	16	17	47	111	99	47	25	44	70	38	17
UNUK RIVER NEAR STEWART	15	13	12	23	75	144	166	150	109	79	37	20
GRACE C NR KETCHIKAN AK	105	90	82	116	210	193	135	124	134	242	186	132
MANZANITA C NR KETCHIKAN AK	116	109	85	119	190	189	132	118	144	254	203	156
WINSTANLEY C NR KETCHIKAN AK	73	69	54	82	146	159	110	98	129	197	134	96
ANSEDAGAN CREEK NEAR NEW AIYANSH	14	10	11	26	67	96	66	36	45	51	29	17
ELLA C NR KETCHIKAN AK	129	112	102	139	191	137	88	96	126	231	207	167
RED R NR METLAKATLA AK	69	79	66	106	208	215	150	120	159	254	152	91
KSEDIN TRIBUTARY NO. 2 CREEK NEAR NEW AIYANSH	12	7.4	7.4	18	74	89	44	23	32	43	23	15
SWAN LK NR KETCHIKAN AK	87	76	62	104	206	203	140	123	157	228	203	118
ORCHARD C NR BELL ISLAND AK	60	55	42	85	158	145	91	83	103	157	152	91
FISH C NR KETCHIKAN AK	117	102	84	112	157	144	105	105	146	219	176	133
TYEE LK OUTLET NR WRANGELL AK	15	3.6	1.7	4.8	70	174	139	89	137	132	44	13
CLARENCE CREEK NEAR ROSSWOOD	10	6.2	10	38	122	131	53	28	36	59	19	13
HARDING R NR WRANGELL AK	43	38	33	59	148	224	217	184	188	174	81	56
FORREST KERR CREEK ABOVE 460 M CONTOUR	5.3	4.1	3.8	8.3	52	165	289	284	168	87	22	7.9
MORE CREEK NEAR THE MOUTH	7.8	6.9	6.8	13	58	135	167	133	82	58	21	10
MAHONEY C NR KETCHIKAN AK	110	104	87	128	251	290	235	203	215	323	240	158
COMPASS CREEK NEAR KISPIOX	2.1	2.3	1.8	15	63	80	33	14	16	18	8.2	4.4
UPPER MAHONEY LK OUTLET NR KETCHIKAN AK	167	133	93	135	334	450	334	242	287	381	243	98
KISPIOX RIVER NEAR HAZELTON	4.5	4	5.2	21	56	66	38	20	21	27	15	6.7
WHIPPLE C NR WARD COVE AK	53	75	67	108	82	47	39	49	77	125	120	81
ISKUT RIVER BELOW JOHNSON RIVER	8.4	7.3	7.2	15	53	109	123	100	72	50	22	12
TWO MILE CREEK IN DISTRICT LOT 4834	3.6	3.1	3.7	7.9	7.2	5.7	8.1	7.5	6.1	6	5.9	4.3
KITSEGUECLA RIVER NEAR SKEENA CROSSING	4.7	4.5	5.1	10	46	74	38	17	15	23	15	7.3
STATION CREEK ABOVE DIVERSIONS	4.2	3.2	3.4	6.9	42	77	65	39	30	23	10	5.8
KITSUMKALUM RIVER NEAR TERRACE	17	13	12	25	81	131	109	85	68	66	46	29

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DEEP CREEK ABOVE RESERVOIR	43	31	32	54	73	62	30	19	35	65	62	41
STIKINE R NR WRANGELL AK	6.3	5	5.4	9.3	39	76	73	59	46	32	13	7.8
ZYMAGOTITZ RIVER NEAR TERRACE	17	17	18	43	102	148	117	77	66	80	46	23
ISKUT RIVER AT OUTLET OF KINASKAN LAKE	3.6	3.1	2.9	3.3	9.9	35	38	25	17	14	8	4.8
EXCHAMSIKS RIVER NEAR TERRACE	37	30	33	74	160	220	209	175	175	165	83	43
OLD TOM C NR KASAAN AK	94	81	73	88	73	44	23	28	62	128	118	109
DRIFTWOOD RIVER ABOVE KASTBERG CREEK	3.1	2.4	2.2	8.3	71	83	29	10	12	15	8.9	4.7
PERKINS C NR METLAKATLA	167	135	128	112	76	45	36	50	109	178	212	159

Table B5: Auxiliary Parameters for Regional Gauge Stations at Red Mountain Underground Gold Project

Gauge ID	Regional Gauge Station	Area (km²)	Distance Between Site and Gauge (km)	Watershed Centroid Latitude(°)	Watershed Centroid Longitude (°)	Avg. Watershed Slope	Avg. Watershed Elevation (masl)	Glacier Rate (%)	Forest Rate (%)	Distance from Coast (km)	Mean Annual Runoff (mm/yr)
08DC006	BEAR RIVER ABOVE BITTER CREEK	350	16.23	56.13	-129.8	22.91	1421	32.5	83.2	25	2285
08DA005	SURPRISE CREEK NEAR THE MOUTH	218	22.14	56.04	-129.6	24.81	1192	44.2	100	28	2262
15008000	SALMON R NR HYDER AK	277	23.36	56.14	-130.1	18.59	1349	41.4	72.6	24	3420
08DB011	KITSAULT RIVER ABOVE KLAYDUC CREEK	242	46.21	55.7	-129.6	19.27	770.5	19.1	81.7	18	2971
08DB010	LIME CREEK NEAR THE MOUTH	39.4	57.99	55.42	-129.4	14.27	1218	0	52.1	5	1434
08DD001	UNUK RIVER NEAR STEWART	1480	74.83	56.48	-130.4	20.8	903.9	24	99	54	2228
15078000	GRACE C NR KETCHIKAN AK	81	85.75	55.64	-131.1	18.28	1240	0	98.4	8	4606
15076000	MANZANITA C NR KETCHIKAN AK	89	89.24	55.6	-131	19.78	1258	0	100	5	4778
15012000	WINSTANLEY C NR KETCHIKAN AK	40	94.54	55.41	-130.8	23.7	1522	0	100	4	3547
08DB013	ANSEDAGAN CREEK NEAR NEW AIYANSH	26	95.03	55.11	-129.3	22.23	530.2	0	52	26	1237
15074000	ELLA C NR KETCHIKAN AK	48	96.65	55.48	-131.1	15.71	451.9	0	99.8	7	4542
15011500	RED R NR METLAKATLA AK	117	104.7	55.11	-130.4	26.34	395.1	0	97.7	13	4401
08DB014	KSEDIN TRIBUTARY NO. 2 CREEK NEAR NEW AIYANSH	18	107.3	55.02	-129.3	21.43	556.2	0	98.3	22	1026
15070000	SWAN LK NR KETCHIKAN AK	92	108.9	55.64	-131.2	25.17	1059	0	97.2	7	4493
15080000	ORCHARD C NR BELL ISLAND AK	158	109.5	55.79	-131.3	22.09	322	0	85	9	3216
15072000	FISH C NR KETCHIKAN AK	90	112.6	55.5	-131.2	19.12	442.6	0	97.5	7	4207
15019990	TYEE LK OUTLET NR WRANGELL AK	38	114.8	56.17	-131.4	25.05	787.5	0	100	6	2171
08EG018	CLARENCE CREEK NEAR ROSSWOOD	7.16	121.8	54.99	-128.8	15.42	401.1	0	52.9	54	1391
15022000	HARDING R NR WRANGELL AK	175	123	56.35	-131.7	25.27	1123	0	100	15	3814
08CG005	MORE CREEK NEAR THE MOUTH	844	127.6	57.05	-130.8	15.95	836.2	32.8	90.8	98	1848
15068000	MAHONEY C NR KETCHIKAN AK	15	127.7	55.41	-131.5	24.07	287.8	0	0	2	6181
08EB006	COMPASS CREEK NEAR KISPIOX	19.1	129.2	55.43	-127.9	17.19	567.5	0	0	100	681.3
15067900	UPPER MAHONEY LK OUTLET NR KETCHIKAN AK	5	130.8	55.4	-131.6	14.45	866.9	0	0	5	7634
08EB004	KISPIOX RIVER NEAR HAZELTON	1880	138.2	55.72	-128.2	10.57	1411	0.2	44.3	82	753.5
15059500	WHIPPLE C NR WARD COVE AK	13	142.9	55.44	-131.8	14.59	611.6	0	0	3	2423
08CG001	ISKUT RIVER BELOW JOHNSON RIVER	9500	148.4	57.07	-130.5	17.91	1228	12.5	86.5	111	1526
08EE025	TWO MILE CREEK IN DISTRICT LOT 4834	21.2	150.7	55.31	-127.6	13.13	1104	0	0	122	182.3
08EF004	KITSEGUECLA RIVER NEAR SKEENA CROSSING	728	153.9	54.98	-127.8	16.07	595.6	0.4	39.2	119	687
08EE028	STATION CREEK ABOVE DIVERSIONS	10.8	157.4	55.2	-127.6	23.81	1154	1.6	0	124	817.6
08EG006	KITSUMKALUM RIVER NEAR TERRACE	2180	167.2	54.83	-128.9	20.71	1048	7.2	59.6	47	1802
08EG017	DEEP CREEK ABOVE RESERVOIR	12.5	168.8	54.58	-128.5	12.93	1119	0	49	62	1443
15024800	STIKINE R NR WRANGELL AK	50841	171	57.64	-130.1	14.56	1288	7.1	93.1	165	983
08EG011	ZYMAGOTITZ RIVER NEAR TERRACE	376	172.1	54.56	-128.9	24.16	609.1	5.5	72.8	51	1991
08CG003	ISKUT RIVER AT OUTLET OF KINASKAN LAKE	1250	177.2	57.66	-129.9	15.1	1011	0.6	73.9	173	434.9
08EG012	EXCHAMSIKS RIVER NEAR TERRACE	370	179.6	54.49	-129.5	29.66	965.3	8.7	100	27	3705
15085100	OLD TOM C NR KASAAN AK	16	180.6	55.37	-132.4	14.64	281.8	0	0	2	2423
08JD006	DRIFTWOOD RIVER ABOVE KASTBERG CREEK	403	189	55.99	-126.8	11.66	1199	0	97.1	175	659.2
15083500	PERKINS C NR METLAKATLA	9	192	54.93	-132.1	16.93	234.9	0	93.6	3	3692

Source: compiled in text.

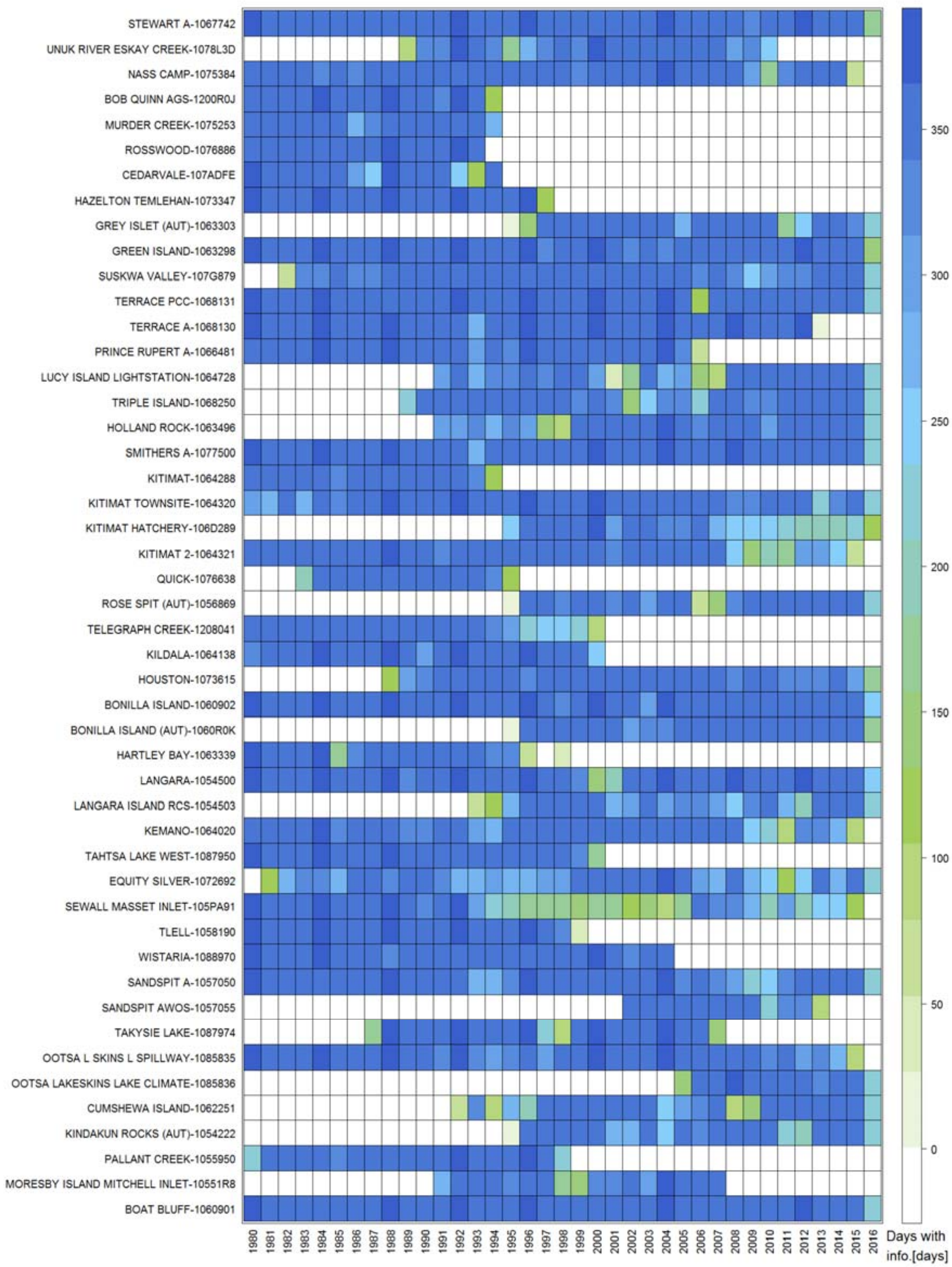

Figure B1: Regional Temperature Records Available since 1980

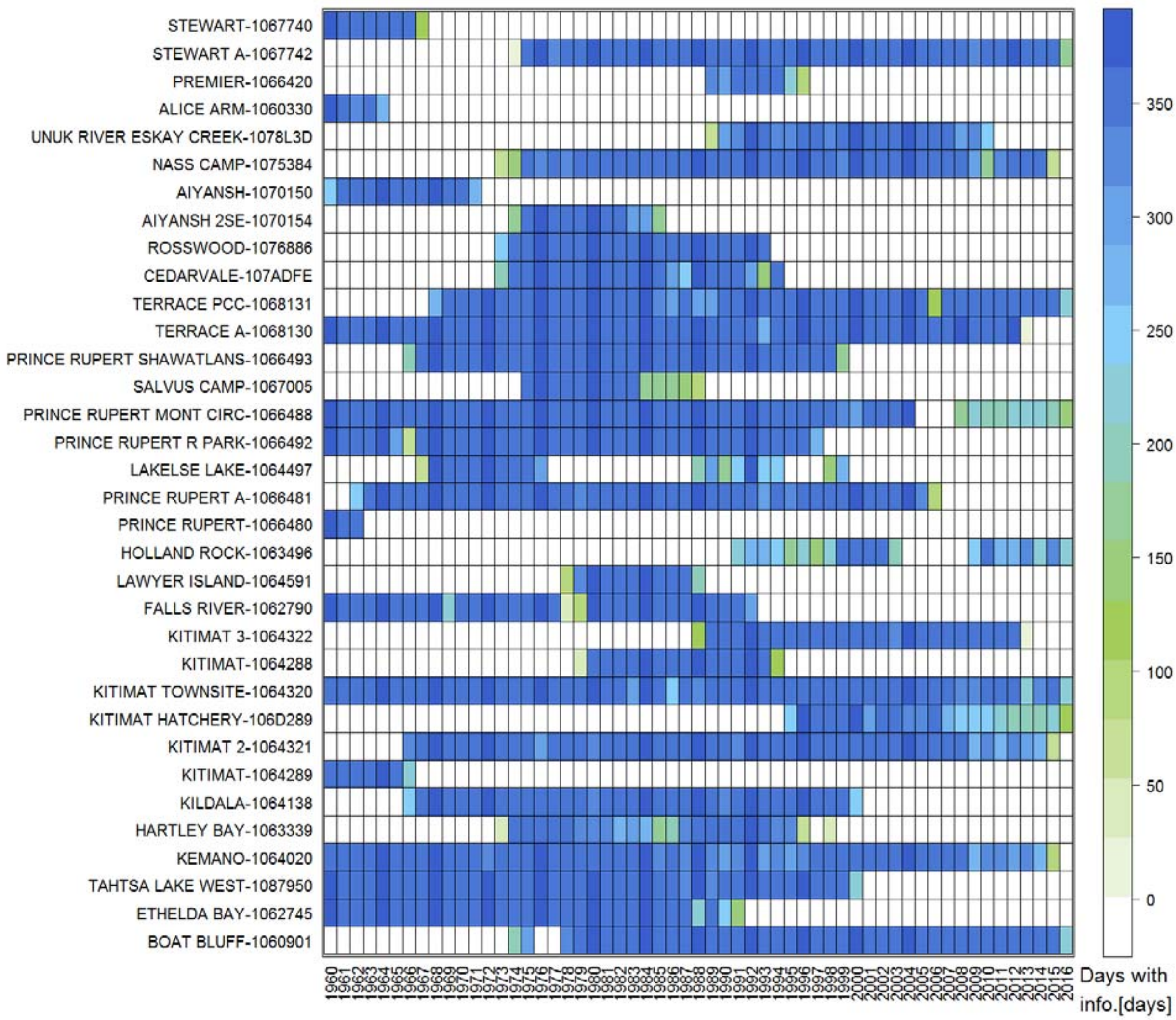

Figure B2: Regional Precipitation Records Available since 1960

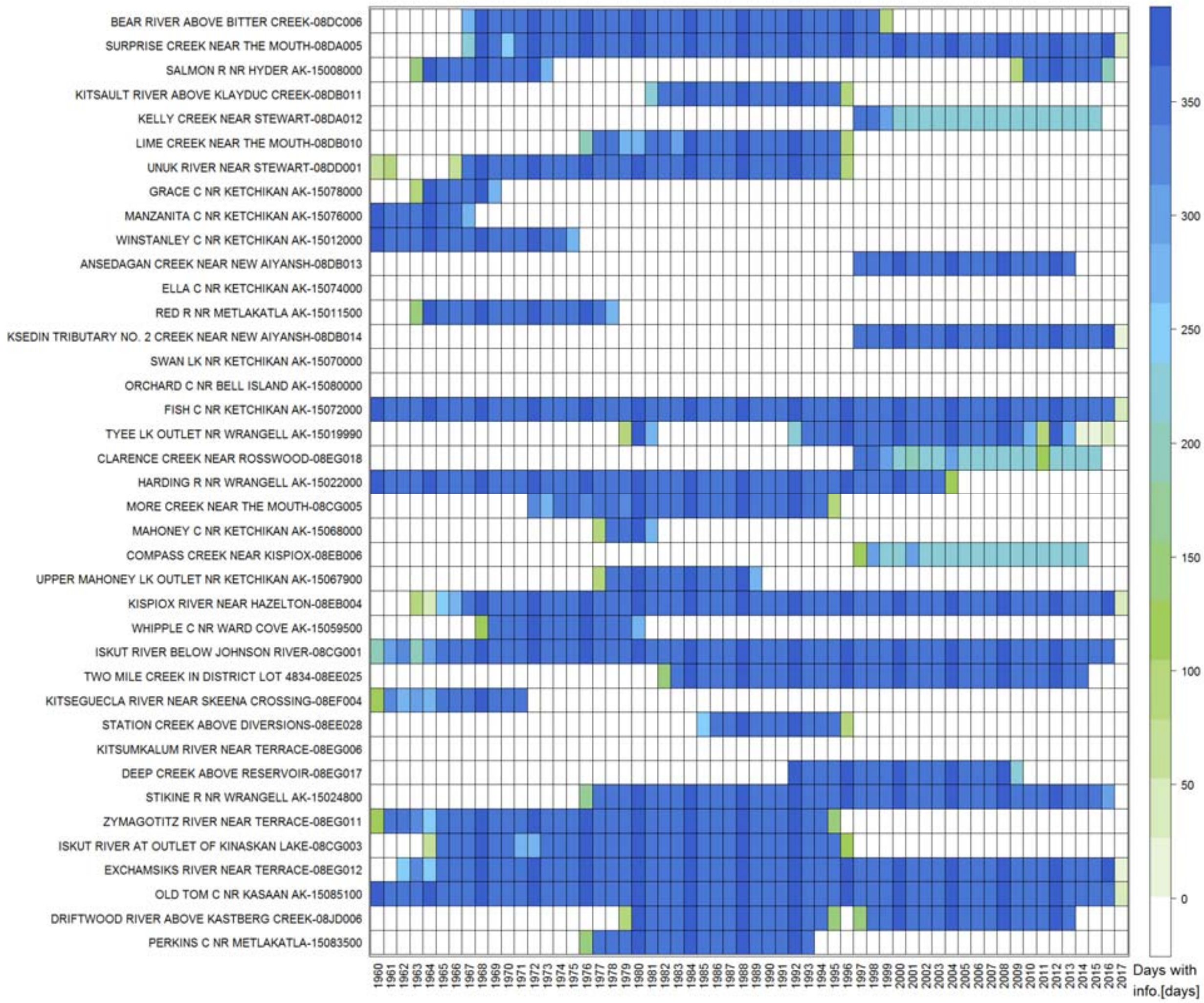

Figure B3: Graphical Information available for Runoff (in Days/Year) for Regional Meteorological Stations since 1960

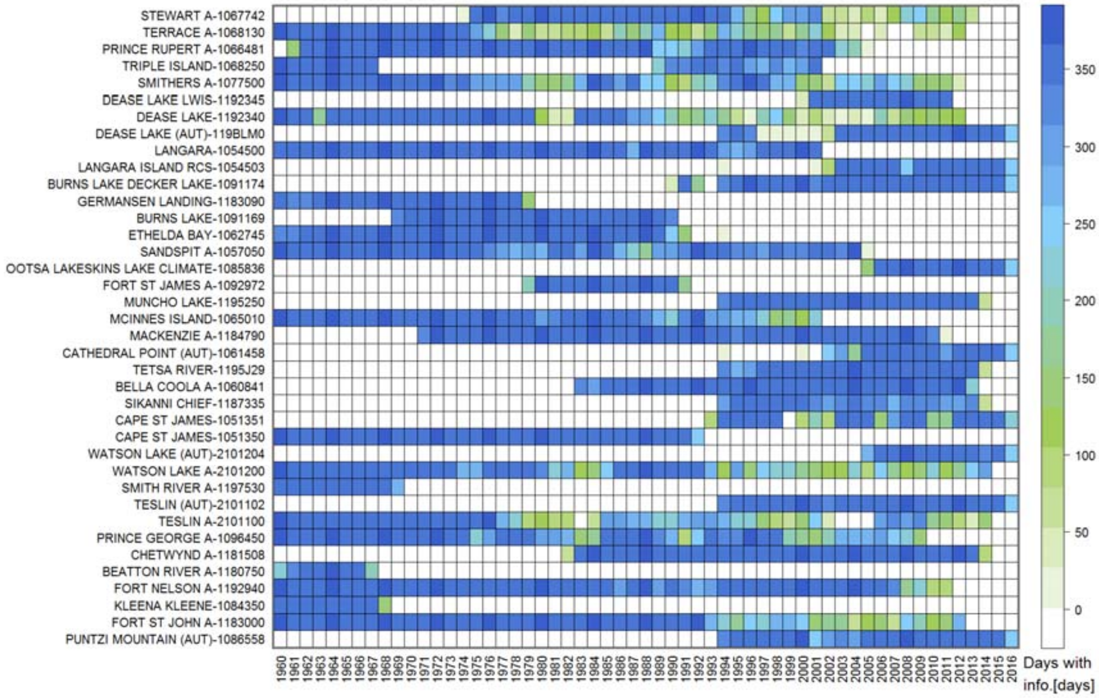

Figure B4: Regional Relative Humidity Available from 1960

Appendix C – Gauging Data

Table C1: Manual Gauging Data, OC04 (Otter Creek)

Date/Time	Stage (m)	Discharge (m^3/s)
6/23/2014 13:25	0.938	0.4731
6/23/2014 13:25	0.939	0.4754
7/30/2014 15:00	0.934	0.6604
7/30/2014 15:00	0.931	0.6541
8/27/2014 12:34	0.874	0.3771
8/27/2014 12:34	0.873	0.3761
9/16/2014 11:10	0.837	0.1753
9/16/2014 11:10	0.839	0.1905
10/21/2014 10:57	0.785	0.075
10/21/2014 10:57	0.785	0.0675
7/7/2015 12:30	0.92	0.777
7/7/2015 12:30	0.92	0.821
8/5/2015 12:55	0.895	0.5
8/5/2015 12:55	0.904	0.5844
10/16/2015 8:05	0.852	0.2644
10/16/2015 8:05	0.852	0.281
5/10/2016 9:20	0.79	0.058
5/10/2016 9:20	0.79	0.0518
5/30/2016 12:00	0.792	0.0631
5/30/2016 12:00	0.792	0.0621
6/7/2016 7:28	0.848	0.2205
6/7/2016 7:48	0.848	0.2387
6/14/2016 12:22	0.833	0.1626
6/14/2016 12:41	0.833	0.1673
6/21/2016 15:35	0.873	0.399
6/21/2016 16:25	0.874	0.359
6/29/2016 14:28	0.907	0.619
6/29/2016 14:54	0.91	0.6123
7/19/2016 11:52	0.886	0.7606
7/19/2016 12:15	0.886	0.7281
9/29/2016 13:30	0.776	0.0722
9/29/2016 13:30	0.776	0.0635

Table C2: Manual Gauging Data, GSC05 (Goldslide Creek)

Date/Time	Stage (m)	Discharge (m^3/s)
6/23/2014 8:45	1.093	0.3631
6/23/2014 8:45	1.093	0.3143
7/30/2014 15:30	1.059	0.1649
7/30/2014 15:30	1.059	0.173
8/27/2014 13:00	1.015	0.0736
8/27/2014 13:00	1.015	0.0737
9/16/2014 9:03	0.993	0.0542
9/16/2014 9:03	0.993	0.054
9/30/2014 11:44	1.049	0.1838
9/30/2014 11:44	1.049	0.1744
10/21/2014 8:46	1.026	0.1154
10/21/2014 8:57	1.026	0.1185
7/7/2015 10:41	1.067	0.198
7/7/2015 10:41	1.068	0.2173
8/5/2015 10:26	1.039	0.1212
8/5/2015 10:26	1.04	0.1342
10/15/2015 9:26	1.026	0.1118
10/15/2015 9:26	1.026	0.1031
6/29/2016 16:00	1.08	0.3
6/29/2016 16:00	1.08	0.301
7/19/2016 10:52	1.044	0.2
7/19/2016 10:58	1.044	0.201
9/30/2016 8:15	1.009	0.094
9/30/2016 8:40	1.009	0.0902

Table C3: Manual Gauging Data, BC02 Location 1 (Bitter Creek)

Date/Time	Stage (m)	Discharge (m^3/s)
2014-08-26 12:45:00 [UTC-08:00]	6.308	63.048
2014-08-26 12:45:00 [UTC-08:00]	6.308	62.468
2014-09-15 16:00:00 [UTC-08:00]	6.145	32.96
2014-09-15 16:00:00 [UTC-08:00]	6.145	35.169
2014-10-20 15:07:30 [UTC-08:00]	6.105	27.226
2014-10-20 15:07:30 [UTC-08:00]	6.105	29.912
2015-07-06 17:00:00 [UTC-08:00]	6.56	96.296
2015-07-06 17:00:00 [UTC-08:00]	6.557	94.183
2015-08-04 17:00:00 [UTC-08:00]	6.344	66.785
2015-08-04 17:00:00 [UTC-08:00]	6.344	60.857
2015-10-14 16:44:00 [UTC-08:00]	5.91	28.313
2015-10-14 16:44:00 [UTC-08:00]	5.91	23.353

Table C4: Manual Gauging Data, BC02 Location 2 (Bitter Creek)

Date/Time	Stage (m)	Discharge (m^3/s)
1/19/2016 14:04	5.284	1.842
1/19/2016 14:25	5.286	1.935
2/23/2016 13:31	5.307	2.017
2/23/2016 13:57	5.311	2.041
4/12/2016 14:24	5.495	5.975
4/12/2016 14:24	5.497	5.389
5/10/2016 13:12	5.666	12.952
5/10/2016 13:12	5.666	13.074
5/28/2016 16:12	5.825	25.84
5/28/2016 16:12	5.825	26.628
6/6/2016 16:08	5.956	46.175
6/6/2016 16:55	5.956	45.179
6/14/2016 15:00	5.953	40.6
6/14/2016 16:20	5.953	40.639
6/22/2016 9:02	5.986	48.459
6/22/2016 9:30	5.986	45.785
6/27/2016 15:10	6.08	61.519
6/27/2016 15:52	6.08	65.716
7/19/2016 14:49	6.193	90.932
7/19/2016 15:59	6.193	87.235

Appendix D – Electronic Time Series of Processed Records for Meteorology and Hydrology

In this appendix the complete daily time series is presented as an excel file. This information is accessible by internet through the following weblink:

https://van.files.srk.com/owncloud/index.php/s/qQPNZS1DCVKV4xp

Figure D1 presents the daily information available. Most of the information does not present any gaps or missing values; the only exception is runoff between 1959 and 1964, where there are some missing values. After this period the information extends without any missing values.

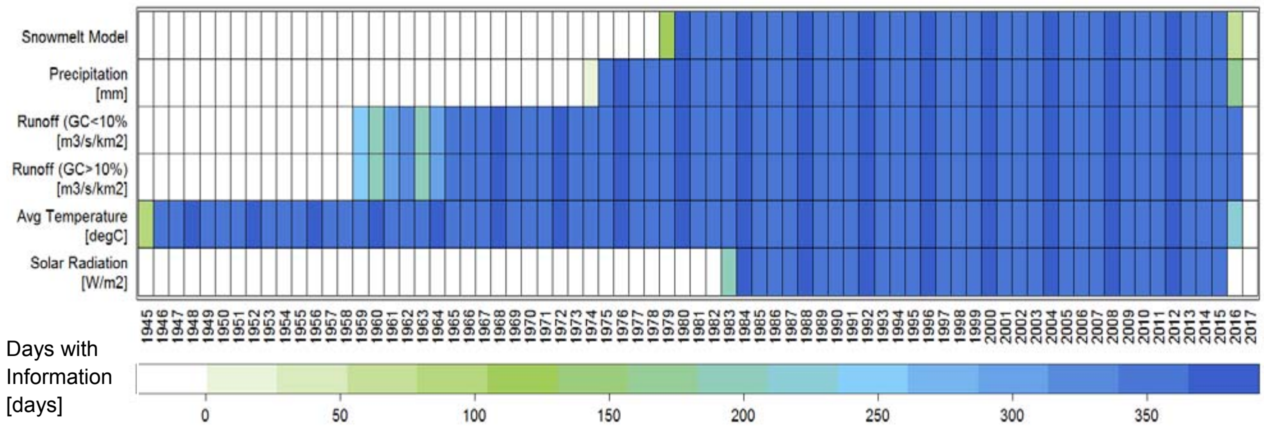

Figure D1: Graphical Representation of the Daily Information Available for the Site