

Appendix 4.1-C

Tenas Project 2017 to 2019 Baseline Report



Prepared for:



TENAS PROJECT 2017 to 2019 Baseline Report

November 2020

Telkwa Coal Limited, a subsidiary of Allegiance Coal Limited

TENAS PROJECT

2017 to 2019 Baseline Report

November 2020

Project #0403488

EXECUTIVE SUMMARY

A baseline program was established for the proposed Tenas Project in 2017. This report covers the program and information collected from spring 2017 to January 2020 for the following programs:

- meteorology;
- air quality;
- noise;
- hydrogeology;
- groundwater quality;
- surface water quality;
- sediment quality;
- aquatic resources;
- fish and fish habitat; and
- visual quality.

These programs will provide data required to characterize site-specific existing conditions; contribute to engineering analysis and the mine design; support future development of predictive models, effects assessments, management plans, and closure planning; support permitting; and monitor changes in the local environment.

Meteorology

A meteorological monitoring program was initiated with the installation of one meteorological station to monitor on-site representative meteorological conditions in the proposed mine area. The Tenas Deposit station was installed on September 29, 2017 and continuously measures air temperature, relative humidity, precipitation, snow depth, wind speed and direction, solar radiation, and barometric pressure.

Existing data used to supplement the baseline summary include data from regional Environment and Climate Change Canada and British Columbia Ministry of Environment and Climate Change meteorological and climate datasets.

A synthetic daily temperature and daily precipitation dataset was developed for January 1, 2017 to September 29, 2017 at the Tenas Deposit station location. Any data gaps from October 2017 to December 2018 were filled in using a similar methodology.

During the January 1, 2017 to December 9, 2019 period, air temperatures ranged from -26 to 32 °C. The annual 2017 precipitation was estimated to be 739 mm, with 32% as snowfall and 68% as rainfall. The 2018 annual precipitation at the Tenas Deposit station was measured to be 672 mm, with 71% falling as snowfall and 29% falling as rainfall, and the 2019 total precipitation (up to December 9, 2019) was

500 mm, with 69% snowfall and 31% rainfall. A large precipitation event occurred on October 24, 2017, with 73 mm of precipitation measured at the Tenas station and similar amounts measured at the Smithers airport stations. This was the largest amount of daily precipitation on record at the Smithers airport, with data spanning back to 1942.

During the period of record, wind speeds at the Tenas Deposit were generally low and predominately came from the southwest, hourly mean solar radiation ranged from 0 to 956 W/m², and hourly mean station-level barometric pressure ranged from 87 to 92 kPa. During the monitoring period, the snowpack began accumulating from mid to late October and melted in early May. The snowpack depth in the valley bottoms was unusually deep in 2017/2018 winter, and was the deepest on record at the Smithers airport station (103 cm in February 2018, with data spanning back to 1942). The snowpack's snow-water-equivalent measured at the Hudson Bay Mtn. snow course survey station peaked at 585 mm in April 2018.

Air Quality

A baseline air quality monitoring program was initiated with the installation of four dust and metal deposition (dustfall) stations, and one particulate matter station (Partisol 2025i-D) to monitor on-site representative dustfall and particulate matter conditions in different areas of the Project. Dustfall stations were installed in September 2017 at the proposed mine site (DF-TenasDep), along a proposed haul route near rural farm land (DF-Kerr) and within Telkwa (DF-Telkwa), and at the Rail Infrastructure area (DF-Rail). The particulate matter station was installed along a proposed haul route near rural farm land (PM-Kerr) to monitor particulate matter less than 2.5 microns in diameter (PM_{2.5}) and particulate matter less than 10 microns in diameter (PM₁₀).

The existing 2014 to 2019 nitrogen dioxide (NO₂), ozone (O₃), PM₁₀, and PM_{2.5} data from regional British Columbia Ministry of Environment and Climate Change (BC ENV) air quality monitoring stations were used to inform the baseline. The Davidson project was the only historical project in the region with publically available data (1996 – 2006).

There are no federal or BC dustfall benchmarks currently in use for comparing the dustfall results. Dustfall rates in the Project area ranged from less than 0.10 mg/dm²/day at various stations during the December/January 2018 and January/February 2018 monitoring periods, to 4.43 mg/dm²/day at DF-Kerr during the August/October 2018 monitoring period. Dustfall rates were generally higher at DF-Kerr, which was located adjacent to a public unpaved road. Dustfall was generally lower in the winter than the fall due to snow cover on the ground.

The November 2018 to January 2020 PM₁₀ and PM_{2.5} results from the PM-Kerr station were all below the applicable BC AQO. For comparison during the same period, the BC ENV-Smithers station had 19 24-hour exceedances of the PM₁₀ BC AQO (50 µg/m³), while the BC ENV-Houston station had 12 24-hour exceedances. The BC ENV-Smithers and BC ENV-Houston stations had four (out of 375) and 33 (out of 434) 24-hour exceedances, respectively, of the PM_{2.5} BC AQO (25 µg/m³; using 100th percentile instead of 98th percentile over one year).

NO₂ measurements at BC ENV-Smithers station (2014 to 2019) were all below the applicable BC AQO. O₃ measurements at BC ENV-Smithers station (2014 to 2019) were all below the applicable BC AQO.

PM₁₀ measurements at BC ENV-Smithers and Houston stations (2014 to 2019) had between one and 19 exceedances of the 24-hour BC AQO at each station in each year. PM_{2.5} measurements at BC ENV-Smithers, BC ENV-Houston and BC ENV-Telkwa (2014 to 2019) had only three of the twelve station-years of 98th percentile 24-hour average observations that were below the 24-hour BC AQO (25 µg/m³). All stations exceeded the annual PM_{2.5} BC AQO each year except for the BC ENV-Smithers station in 2016. The Bulkley Valley is known to have periods of poor air quality, primarily due to smoke and road dust emission sources.

Noise

A baseline ambient noise monitoring program was initiated in October 2017 to monitor on-site noise in different areas of the Project. Stations were established near the proposed open pit (S-TenasDep), near the proposed plant and water treatment area (S-Plant), and in the proposed rail infrastructure area (S-Rail). Each station measured approximately 24 hours of seasonal noise during one day in October, December, and March, except S-Rail, which was first established in December 2017.

Twenty-four hour noise levels at S-TenasDep and S-Plant were similar and ranged seasonally on average from 20 - 36 dBA. These stations were away from most sources of anthropogenic noise except for aircraft and train horns. Twenty-four hour noise levels for the S-Rail station ranged from 39 to 42 dBA. This station was 340 m away from existing train tracks and 900 m away from Highway 16. Aircraft were the loudest common noises sources recorded at S-TenasDep and S-Plant, and aircraft and passing trains were the loudest recorded at S-Rail.

Hydrogeology

During the 2017 to 2019 baseline program (July 2017 through November 2019), manual groundwater level measurements were recorded from 13 of the existing monitoring wells, nine new (2018) monitoring wells, and nine new (2019) geotechnical wells (PAG cell wells). Manual groundwater elevations were also measured at two geotechnical wells on the east side of Goathorn Creek.

Solinst Levellogger transducers were installed in September 2017 in five existing wells (three bedrock, two overburden) to record continuous groundwater level measurements every 12 hours. In the fall of 2019, additional transducers were installed in four of the new wells (one bedrock, two overburden and one along the bedrock/overburden interface), and at two geotechnical wells on the east side of Goathorn Creek. One Solinst Barologger was also used to compensate the pressure data from the transducers and placed in T95R-64, which is located at the mid-point elevation of the Project to capture average barometric pressure.

A 20-hour pump test was conducted at ARD 2 during early March 2019 to determine the physical properties (transmissivity) of the sandstone aquifer beneath the mineable coal seams. The hydraulic conductivity value, derived from the transmissivity for this pump test, is marginally lower than the hydraulic conductivity values documented for the historical slug tests performed at the mineable coal seams.

In general, the existing bedrock wells screened in deeper sections of the coal seams had the lowest manually measured water levels in the late spring/summer months and the highest manually measured water levels during the fall through spring months. The existing bedrock wells screened in

the shallower sections of the coal seams had the lowest manually measured water levels during September 2018 and the highest manually measured water levels during June 2019.

The new bedrock wells screened in the Hazelton Group volcanics up-gradient of the proposed pit area (W1 Deep and W1 Shallow) had the lowest manually measured water levels during the spring months and the highest manually measured water levels during the summer months. The other new bedrock well screened in the volcanics down-gradient of the proposed pit area (W3 Deep) had the lowest manually measured water level during November 2019 and the highest manually measured water level during August 2019. The new bedrock well screened in the Skeena Group sedimentary rocks below the mineable coal seams (ARD 2) had the lowest manually measured water level in August 2019 and the highest manually measured water level in February 2019.

Two of the existing bedrock monitoring wells (T95R-15C and T96R-34-87) and two of the new bedrock monitoring wells (W1 Deep and W1 Shallow) had groundwater elevations above the ground surface (flowing artesian) during each of the monitoring events. The two existing monitoring wells were observed to have flowing artesian conditions during previous monitoring events in late summer/early autumn of 1996 and 1997.

The majority of the shallow overburden wells were dry during the 2017 to 2019 baseline program, which correlates with historical data. Higher groundwater level seasonal fluctuations occurred in the shallow overburden wells in relation to the bedrock wells. Groundwater levels at two of the new deeper overburden wells (W3 Shallow and W2) showed minor seasonal fluctuations in comparison to the shallower overburden wells.

The groundwater level fluctuations observed at the two geotechnical wells (T18-14S and T18-15S) were relatively minor from November 2018 to November 2019. During the monitoring period, the groundwater level declined throughout the winter months (November to March), began to rise in April after the snowmelt, and then declined once again during the summer (May to September).

Two of the PAG cell wells were consistently dry during monitoring events from January to November 2019, while the other seven wells had water levels generally deeper than 23.5 m bgs. The groundwater level for each well was relatively stable from March to November 2019.

A total of 11 slug tests were conducted at five of the new baseline wells installed in 2018 (two in bedrock, two in overburden, and one along the bedrock/overburden interface). The hydraulic conductivity (K) values were generally consistent between each test at each of the wells. Packer tests were also conducted at three new boreholes from the 2018 drill program, with the geometric mean estimated K value of the volcanics (1.8×10^{-7} m/s) being an order of magnitude higher than the geometric mean of the sedimentary sequence tested below the lowest coal seam (2.9×10^{-8} m/s). In general, there is a decrease in K with depth at each test location.

A total of 19 slug tests were conducted at seven of the new PAG cell wells installed in 2019 (four in bedrock and three in overburden). The three wells screened in the glacial overburden material have average K values which are in general an order of magnitude higher than the four wells screened in the shallow bedrock.

Bedrock wells screened in the coal seams show a north-northeast flow direction under a horizontal hydraulic gradient of approximately 0.09. A minor upward vertical hydraulic gradient between two of the coal seams suggests these two seams may be hydraulically connected. There is also an upward vertical hydraulic gradient within the volcanic rocks situated cross-gradient of the proposed pit, and a relatively strong downward vertical hydraulic gradient between the overburden and underlying volcanic rocks down-gradient of the pit.

Shallow overburden wells showed a northern groundwater flow (similar to the topography) and a horizontal gradient of 0.04. Though more data is required to calculate the vertical hydraulic gradient between the upper and lower water-bearing overburden deposits, new and historical data infers a strong downward hydraulic gradient between these units. The groundwater flow direction and horizontal hydraulic gradient within the overburden and coal seams are very similar on a seasonal and historical basis.

Groundwater Quality

The 2017 to 2019 groundwater quality baseline program was initiated in August 2017 with the sampling of a subset of historical monitoring wells and new monitoring wells in and around the Tenas Pit. Eleven quarterly sampling events were conducted from nine existing wells, and eight quarterly sampling events were conducted from five new wells.

With the exception of three new wells (two screened in the volcanic rocks and one in the deeper overburden), the field pH value for the wells sampled during each sampling event was within the range of 6.5 to 9.0, thereby not exceeding the BC WQG – FAL. Excluding the exceedances at these three new wells, the pH value for the bedrock wells ranged from 6.99 to 8.99, while the pH in the overburden wells ranged from 7.20 to 8.99. The field pH measurements for the current baseline program were similar to the field pH measurements for the historical baseline program.

Turbidity values for the wells sampled during the 2017 to 2019 sampling events were generally below the BC WQG – FAL value of 50 NTU, with the exception of 19 samples from eight monitoring wells. Excluding exceedances noted above, the average turbidity value was 10.2 NTU for bedrock wells and 10.3 NTU for overburden wells. The turbidity values from the baseline (2017 to 2019) sampling events were considerably lower in comparison to the turbidity values from the 2016 sampling event, and turbidity was not measured during any of the sampling events from 1995 to 1997.

The average conductivity value in the bedrock wells was 1329 $\mu\text{S}/\text{cm}$, while the average conductivity of the overburden wells was 530 $\mu\text{S}/\text{cm}$. Seasonally, conductivity values for both the bedrock and overburden wells reported low variability, while historically, the range of conductivity values was similar between the 2017 to 2019 sampling events and the 1995 to 1997 sampling events.

Fluoride was the only anion which exceeded the BC WQG – FAL guideline of 0.4 to 2.0 mg/L (hardness dependent) during the 2017 to 2019 sampling events. The average concentration of fluoride in the bedrock and overburden wells was 1.68 mg/L and 0.18 mg/L, respectively.

Groundwater concentrations in the bedrock and overburden wells measured greater than the BC WQG – FAL approved guidelines for the following metals: total and dissolved iron, total copper, total arsenic,

total manganese, total zinc and dissolved aluminum. Monitoring well T95R-40 had the most metal exceedances during the January 2018 sampling event, which can be attributed to abnormally high turbidity. Overall, there is a correlation with total metals exceedances and slightly elevated turbidity.

In general, the historical data for the existing bedrock and overburden wells measured more exceedances for total and dissolved metals than the current 2017 to 2019 baseline data. There is also some variability between the historical and current baseline data for the existing overburden wells, but concentrations for samples collected as part of the current baseline (2017 to 2019) are generally consistent.

There are distinct hydrochemical differences between the shallow overburden wells, the deeper overburden wells, and the bedrock wells. There are also minor hydrochemical differences between the bedrock wells screened in the Skeena Group sedimentary rocks and the Hazelton Group volcanic rocks. These hydrochemical differences are consistent on a seasonal timeframe. The groundwater from the shallow overburden wells can be classified as a calcium-magnesium-bicarbonate (Ca-Mg-HCO_3) type, while the groundwater from the deeper overburden wells and all the bedrock wells can be classified as a sodium-bicarbonate (Na-HCO_3) water type. Bedrock well water can generally be considered “soft”, while overburden well water can generally be considered “hard”.

Hydrology

A baseline hydrometric monitoring program was initiated in May 2017 to collect Project specific streamflow data. A network of three automated hydrometric monitoring stations was established and operated in and around the Project area as a part of the 2017 to 2019 baseline monitoring program. Stations were established on Tenas and Goathorn creeks downstream of the proposed pit, and one station on the Telkwa River upstream of the confluence with Goathorn Creek.

During the 2017 to 2019 monitoring period (May 2017 through November 2019), 24 site visits were completed and a total of 73 manual discharge measurements conducted across the hydrometric network. Discharge measurements, along with concurrent stage measurements during the open water season were used to develop rating curves for the three monitoring stations. Rating curves were used along with the continuous stage data collected at the stations to generate annual hydrographs and compute various hydrologic indices.

Similar seasonal stream flow patterns were observed across the monitored streams and rivers in the Project area. The timing of runoff was typical of the regional stream flow regime, with the majority of runoff resulting from snowmelt during the spring and early summer. Runoff was highest in 2017, with the majority occurring in May, June, and October. In 2018, it was lower than in 2017, and the majority of the annual runoff was generated in May. Runoff was lowest in 2019, again with the majority occurring in May and June. Annual peak flows in 2017 resulted from a high intensity rain event that occurred in late October. Peak flows that resulted from this event were of short duration but very high, ranging approximately 45% to 80% higher than the observed freshet driven peak flows that year. In 2018 and 2019, peak flows were lower than in 2017, and for both years they were driven by snowmelt occurring in May. Summer low flows were observed in August and September all three years, and were lowest in 2018. Annual low flows occurred in late March each year throughout the Project area.

Surface Water Quality

A surface water quality baseline monitoring program was initiated in the spring of 2017. Creeks and rivers near proposed Project infrastructure were sampled from May 2017 to November 2019. Twenty-two sites were sampled for varying periods of time (monthly or quarterly in most cases), and data were supplemented with publicly available water quality data from an additional six sites.

Project area streams displayed strong seasonal patterns, with elevated nutrient and the majority of metal parameter concentrations occurring during freshet (May) and fall rains (September), and were associated with elevated suspended solids. Peak concentrations typically occurred during freshet in all creeks, except the Telkwa River, where concentrations were also high in the fall. In contrast, alkalinity, conductivity, and hardness were generally higher in the smaller streams or creeks than in the larger rivers; these parameters were highest in the winter during the low flow period, and were lowest in the summer following freshet. Project area streams had neutral to slightly basic pH and low sensitivities to acid-inputs, with hard water in the smaller creeks and soft water in the larger rivers. Total suspended solids and turbidity were generally low in Project area streams, except the Telkwa and Bulkley rivers during freshet and fall rains. Sulphate was the dominant anion, and sulphate concentrations were generally highest during low flow. Fluoride concentrations were highest in the fall and winter. Chloride concentrations were below detection limits in the majority of samples from 2017 to 2019.

Generally, concentrations of total nitrogen peaked during spring freshet (May), with a second peak occurring in the winter. Nitrogen in the Project area streams was principally in the form of total Kjeldahl nitrogen and nitrate. Total phosphorus and total organic carbon concentrations peaked in the Project area streams in May, with Telkwa River exhibiting a second peak of total phosphorus in September.

Polycyclic aromatic hydrocarbons and benzene, toluene, ethylbenzene, and xylene concentrations were all below detection limits. Phenols were below analytical detection limits in most samples.

Total and dissolved aluminum, and total copper were elevated in the Project area, as concentrations in creeks and rivers were frequently above federal and provincial guidelines. Dissolved copper, total and dissolved iron, and total chromium were above BC and/or CCME guidelines in all creeks and rivers except for Helps Creek. Dissolved copper, however, did not exceed either guideline in Four Creek. Elevated metal concentrations above guidelines typically occurred during freshet (May/June), and frequently in September, especially in the Telkwa River. In the Telkwa River, concentrations of eight metals were above guidelines, which was the most of any Project area stream. Helps Creek demonstrated the best water quality, with only two metals above relevant guidelines.

All anions and nutrients were below BC and CCME guidelines, and the Bulkley River samples were below provisional objectives. The only exception was ammonia, with 9% of the samples greater than the 30-day average Bulkley River objective. Ammonia is not likely to be a concern, as the magnitude of exceedance is low, and no exceedance was found for the BC ENV long-term guidelines or the Bulkley River provisional short-term objective.

Sediment Quality

A sediment quality baseline program was conducted in 2017 to 2019, with samples collected from 14 sites. The data were supplemented by publicly available data from two sites in Tenas Creek sampled in 1986.

Project area streams sediments were principally composed of sand, followed by gravel and silt. Sediment total organic carbon concentrations were generally low in Project area streams, with a maximum mean of 2.26% at WQS05 in 2019. Goathorn Creek and Helps Creek both had elevated sediment cadmium, and zinc. Further, Goathorn Creek had elevated copper, and Helps Creek had elevated arsenic and lead. Tenas Creek samples had the highest chromium, iron, manganese, and nickel concentrations, with higher metal concentrations typically observed in the upper portion of the creek. Selenium concentrations were low in Project area streams, with a maximum of 0.31 mg/kg in Goathorn Creek.

Sediment arsenic, iron, manganese, and nickel appear to be elevated in the Project area, as all sites, including upstream of the Project, were above provincial sediment quality guidelines. Arsenic, iron, and manganese were particularly high, as concentrations were above upper guidelines. Sediment copper concentrations were also commonly above guidelines in Tenas Creek, Goathorn Creek, and the Telkwa River. Sediment cadmium and zinc in Goathorn and Helps creeks were above BC guidelines. Goathorn Creek sediment concentrations were above guidelines for seven metals, and this creek typically had the highest metal concentrations of all sampled sites, followed by Helps Creek and upper Tenas Creek.

Aquatic Resources

An aquatic resources baseline program was conducted in 2017 to 2019, with samples collected from 14 sites. Data were supplemented by publicly available data from six additional sites.

Periphyton biomass and density were generally higher in the Telkwa and Bulkley rivers compared to the smaller streams. The periphyton communities in Tenas and Goathorn creeks were mainly composed of blue-green algae, while diatoms were more predominant in other streams. Periphyton richness and diversity were highest in the Bulkley River.

Benthic invertebrate communities were dominated by the intolerant to moderately pollution-tolerant Ephemeroptera and Plecoptera, and abundances were generally highest in the Bulkley River. Lower Tenas Creek in 2000, Helps Creek, the Telkwa River, and 2019 samples from the Bulkley River also had a high abundance of Diptera, particularly Chironomidae, which have higher pollution-tolerance. The Telkwa and Bulkley rivers generally had the highest family richness; however, family diversity was comparable across sites.

Benthic invertebrate communities were compared to Canadian Aquatic Biomonitoring Network (CABIN) reference communities. The majority of streams had benthic invertebrate communities similar or mildly divergent from reference communities. A downstream station in Goathorn Creek in 2000 was divergent to highly divergent from the reference communities, which reflected the low abundance and highly variable proportions of Chironomidae, Ephemeroptera, and Plecoptera in these samples. A downstream site on the Bulkley River in 2017 was also divergent from the reference communities, likely due to the low abundance, high Ephemeroptera, and low Chironomidae at this site.

Tissue metal concentrations were typically highest in upper Goathorn Creek, particularly periphyton tissues. Within Tenas Creek, benthic invertebrate tissue chromium and nickel concentrations were elevated, particularly at the downstream site. The two upstream sites on Tenas Creek had the highest benthic invertebrate tissue selenium concentrations in the area. Benthic invertebrate tissue mercury was highest in Helps Creek, with elevated concentrations also found in Four Creek and Goathorn Creek. Benthic invertebrate tissues from the Bulkley River had comparatively high concentrations of copper, iron, lead, manganese, molybdenum, and uranium.

Benthic invertebrate tissue mercury concentrations were above the CCME methylmercury guideline in Four, Goathorn, and Helps creeks, and the Telkwa River. Guideline exceedances were most common and by the highest factor in Helps Creek. Tenas, Four, and Goathorn creeks, and the Telkwa River all had benthic invertebrate tissues above the BC selenium guideline, with the highest concentrations found in Tenas Creek.

Fish and Fish Habitat

A fish and fish habitat baseline program was initiated in October 2017 and continued through the summer of 2018. The baseline program collected information on fish habitat, community, biology, and tissue quality at seven locations along Tenas Creek, Goathorn Creek, Telkwa River, and the Bulkley River, with three locations as reference sites, and four as receiving environment sites. In 2018, surveys also focused on confirming the non-fish-bearing status of streams draining the mine site, identifying potential water withdrawal sites, and identifying potential salmon spawning habitat in lower Goathorn Creek.

Fish habitat in the Project area was generally higher quality in the lower reaches of the streams; however, fish are present throughout the Project area. Tenas Creek and Goathorn Creek are typified by low to moderate gradient, gravel and cobble substrates, and occasional pools. The Bulkley River and Telkwa River are large streams with diverse fish communities, and moderately complex habitat.

There were some differences in fish size between the four watersheds, but indicators of fish health such as weight, length, and liver size were similar. Tissue metal concentrations were similar among watersheds. Two rainbow trout captured in Tenas Creek in 2018 slightly exceeded the interim BC tissue quality guideline for selenium; however, the interim guideline applies to the mean concentration of selenium, which was lower than the guideline at all sites. No fish in 2017 or 2018 exceeded the Health Canada guideline for tissue mercury concentration.

Visual Quality

In 2017, the visual quality study developed a viewshed for the Project using a digital elevation model based on a subset of The Canadian Digital Surface Model (CDSM). Fifteen sites found in *The Bulkley Land and Resource Management Plan* (LRMP) and associated *Bulkley Landscape Unit Plans* were visited and subsequently scoped out of further study, as they did not have any view of the Project area.

Based on important corridors identified in these plans, an additional 19 sites were established. Of these 19 sites, four sites were found in subsequent field visits to have vegetative screening that obscured any view of the project site. The remaining 15 sites were photographed.

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GLOSSARY AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

°C	Degree Celsius
µg/m ³	Micrograms per cubic metre
µS/cm	Microsiemens/centimetre
7-day low flows	The minimum average 7-day flow that occurs over a specified period, such as a month, season, or year.
AIR	Application Information Requirements
ALS	ALS Laboratory Group
Ambient noise	The all-encompassing noise associated within a given environment. It is the composite of sounds from many sources, both near and far. This is described using the LA _{eq} descriptor.
AMS	Airshed Management Society
Annual runoff	A measure of the hydrologic response of a watershed. It is often presented as a depth of water, in mm, over an entire watershed allowing direct comparison with precipitation totals.
ANOVA	Analysis of Variance
ANSI	American National Standards Institute
AR	Adit road
ARD	Acid rock drainage
ASTM	American Society for Testing and Materials
Background noise	The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the LA ₉₀ descriptor.
Baseflow	The groundwater component of flow discharge that is attributed to soil moisture and groundwater drainage into a channel.
BACI	Before-After-Control-Impact
BC	British Columbia
BC AQO	British Columbia Air Quality Objectives

BC EAO	British Columbia Environmental Assessment Office
BC ENV	British Columbia Ministry of Environment and Climate Change Strategy
bgs	Below ground surface
BC MEM	British Columbia Ministry of Energy and Mines
BC MEMPR	British Columbia Ministry of Energy, Mines and Petroleum Resources
BC MOE	British Columbia Ministry of Environment
BC MOT	British Columbia Ministry of Transportation
BC WQG - FAL	Water quality guidelines - freshwater aquatic life
Benchmark	A point of reference against which data may be compared or assessed.
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BVLD	Bulkley Valley Lakes District
CAAQS	Canadian Ambient Air Quality Standards
CABIN	Canadian Aquatic Biomonitoring Network
CALA	Canadian Association for Laboratory Accreditation
Ca-Mg-HCO₃	Calcium-magnesium-bicarbonate
CCME	Canadian Council of Ministers of the Environment
CH	Chad's House
chl <i>a</i>	Chlorophyll <i>a</i>
CI	Confidence interval
cm	Centimetre
CN	Canadian National Railway Avenue
COC	Chain of custody
CPUE	Catch per unit effort
CRA	Commercial, recreational, or Aboriginal
CRM	Comparison with reference material

dB	Decibel. The unit used to describe sound levels and noise exposure. It is equivalent to 10 times the logarithm (to base 10) of the ratio of a given sound pressure to a reference pressure. Differences in noise levels of around 10 dB are generally perceived to be a doubling (or halving) of the perceived loudness of the noise. An increase of 10 dB is perceived as twice as loud, an increase of 20 dB is four times as loud, an increase of 30 dB is eight times as loud, etc.
dba	The unit used to measure 'A-weighted' sound pressure levels. A-weighting is an adjustment made to sound-level measurement to approximate the response of the human ear.
dbc	The unit used to measure 'C-weighted' sound pressure levels. C-weighting is an adjustment made to sound-level measurements which takes into account low-frequency components of noise within the audibility range of humans.
DELT	Deformities, erosions, lesions, and tumours
DF	Dustfall
DFO	Fisheries and Oceans Canada
DR	Davidson Road
dwt	Dry weight
EC	Environment Canada
ECCC	Environment and Climate Change Canada
EEM	<i>Metal Mining Environmental Effects Monitoring</i>
EMA	<i>Environmental Management Act</i>
EMS	Environmental Monitoring System
EPA	Environmental Protection Agency
ERM	ERM Consultants Canada Ltd.
Eutrophic	Trophic level (total phosphorus 0.035 to 0.1 mg/L)
F	F-value
Field blank	Samples of distilled water that are opened in the field and are analyzed using the same methods as a regular sample; used to identify sources of contamination.
Field duplicate	Two samples that are collected at the same time/location and analyzed separately with blind labels; used to identify variation from the environment, sampling or analytical methods.

FL	Fork length
FSZ	Fisheries sensitive zone
g	Gram(s)
Gauge datum	An offset applied to gauges. It is set to an elevation relative to the common datum, the point of 0.0 m stage-height for a gauge.
GC	Glacier Gulch site
GEO	Geotechnical well installed by SRK
GHG	Greenhouse gas
GLM	Generalized linear model
Gradient	An increase or decrease in the magnitude of a parameter (i.e., the degree of steepness along a streambed).
Groundwater	Water stored in soil or rock
ha	Hectare
HCO₃	Bicarbonate
HDPE	High density polyethylene
HG-AFS	Hydride generation-atomic fluorescence spectrometry
Holding time	Maximum amount of time that a sample may be held without significant degradation of the parameter
HSI	Hepatosomatic index
Hydrographs	A graphic presentation of the variation of a hydrologic parameter with elapsed time
Hz	Hertz
ICP-MS	Inductively coupled plasma mass spectrometry
ID	Identification
IEC	International Electrotechnical Commission
in.	inch
IPI	Inflatable Packers International
ISO	International Organization for Standardization
ISQG	Interim Sediment Quality Guideline

Joint AIR for MA/EMA AIR Permits	Joint Application Information Requirements for <i>Mines Act</i> and <i>Environmental Management Act</i> Permits
K	Hydraulic conductivity
kg	Kilogram(s)
KL	Kathlyn Lake Elementary School
km	Kilometre
km/h	Kilometres per hour
kPa	Kilopascal
L	Litre
L₁₀	The noise level exceeded for 10% of the time and is approximately the average of the maximum noise levels.
L₉₀	The noise level exceeded for 90% of the time and is approximately the average of the minimum noise levels. The L90 level is often referred to as the “background” noise level and is commonly used as a basis for determining noise criteria for assessment purposes.
LA₁₀	L10 with A-weighting
LA₉₀	L90 with A-weighting
LA_{eq}	Leq with A-weighting
LA_{max}	Lmax with A-weighting
LA_{min}	Lmin with A-weighting
LDPE	Low density polyethylene
Leq	The equivalent or average noise level during a measurement period. For example, the one hour Leq noise descriptor simply refers to the Leq noise level calculated over a one hour period. Any of the noise descriptors may be defined in this way, with an accompanying time period (e.g., one hour L10) as required.
L_{max}	The absolute maximum noise level in a noise sample.
L_{min}	The absolute minimum noise level in a noise sample.
LSA	Local Study Area
LWD	Large woody debris
M	Million or mega
m	Metres

mbtoc	Metres below top of casing
m/s	Metres per second
MA	<i>Mines Act</i>
MA/EMA Permit	<i>Mines Act/Environmental Management Act Permit</i>
m ags	Metres above ground surface
m asl	Metres above sea level
m bgs	Metres below ground surface
m btoc	Metres below top of casing
Matrix spikes	Field samples to which known concentrations of analytes are added and analyzed to determine the percent recovery; used to determine the analytical accuracy in a given matrix.
MB	Method blank
MAD	Mean annual discharge (computed as an average discharge over the course of a year)
Meso-eutrophic	Trophic level (total phosphorus 0.02 to 0.035 mg/L)
Method blank	Samples of analyte-free matrix (i.e., distilled water) that are prepared and analyzed using the same methods as a regular sample; used to assess laboratory contamination.
mg	Milligram(s)
mg/dm²/day	Milligrams per square decimetre per day (accumulation)
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
mm	Millimetre
MDMER	Mineral and Diamond Mining Regulations
Mt	Million tonnes
N	Nitrogen
NAAQO	National Ambient Air Quality Objectives
NAD	North American Datum. A datum is a reference system for computing or correlating the results of a survey. The NAD83 was used for this report and is based on spheroid (GRS80).
NAG	Non Acid Generating rock

Na-HCO₃	Sodium-bicarbonate
Nival	Relating to snow (i.e., Snowmelt-dominated seasonal stream flow pattern)
nm	Not measured
NO₂	Nitrogen dioxide
NR	Northern route site
Ns	Not sampled
NTU	Nephelometric turbidity unit
O₃	Ozone
Observation Interval	The interval surrounding a vertical that extends half way between the previous and latter verticals along a stream cross section in a manual discharge measurement.
OD	Outer diameter
ORP	Oxidation-reduction potential
OVB	Overburden
P	p-value
PAG	Potentially Acid Generating rock
PAH	Polycyclic aromatic hydrocarbons
PEL	Probable effects level
PM₁₀	Particulate matter smaller than 10 microns in diameter
PM_{2.5}	Particulate matter smaller than 2.5 microns in diameter
ppb	Parts per billion (concentration)
PQ	Drill hole diameter (4.83 inch drill bit outside diameter)
Project, the	The proposed Tenas Project
Proponent, the	Telkwa Coal Limited, as subsidiary of Allegiance Coal Limited
PVC	Polyvinyl chloride
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
R²	R squared

Rating curves	A curve derived from concurrently measure stage and discharge data that is used to estimate the discharge for any given observed stage. Often referred to as a stage-discharge relationship for a streamflow monitoring station.
RCA	Reference condition approach
Reference material	Standards with known concentrations that are analyzed using the same methods as a regular sample; used to determine methodological accuracy.
Replicates	Subsamples of field samples that are analyzed separately using the same analytical methods; used to determine the precision of analytical methods.
RGS	Regional geochemistry survey
RIC	Resource Inventory Committee (currently known as the Resource Information Standards Committee)
RISC	Resource Information Standards Committee (previously known as the Resource Inventory Committee)
RMS	Root mean square
RPD	Relative percent difference
s	Second(s)
SARA	<i>Species at Risk Act</i>
SBEB	Science-based environmental benchmarks
SD	Standard deviation
SE	Standard error
Simpson's D	Simpson's Diversity index
SL	Slack Road
SO₂	Sulphur dioxide
Specific Conductivity	A measure of a solution's ability to conduct electricity, report in Siemens per metre (S/m)
SPL	Sound Pressure Level. The level of received sound pressure, as measured at a distance by a standard sound level meter with a microphone.
SRK	SRK Consulting

Stage	The height of the water surface in a water course or a channel above a fixed datum.
SWE	Snow-water-equivalent
TKN	Total Kjeldahl nitrogen
TL	Tail length
TOC	Total organic carbon
Travel blank	Samples of distilled water that remain unopened in the field and are analyzed using the same methods as a regular sample; used to identify sources of contamination.
TSS	Total suspended solids
Ultra-oligotrophic	Trophic level (total phosphorus <0.004 mg/L)
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator. A mathematical transformation (map projection) of the earth's surface to create a flat map sheet.
V	Volt
Vertical	The vertical line along a stream cross section where depth and velocity measurements are made when conducting a manual discharge measurement using a current meter.
W/m²	Watts per square metre
Watershed	The geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet.
WDR	Waste discharge regulation
WQG	Water Quality Guideline
WQO	Water Quality Objective
WSA	<i>Water Sustainability Act</i>
WSC	Water Survey of Canada
wwt	Wet weight
YOY	Young-of-year

1. INTRODUCTION

1.1 PROJECT PROPONENT

Telkwa Coal Limited (Telkwa Coal; the Company) a Canadian company, is a wholly owned subsidiary of Allegiance Coal Limited, an Australian-based company listed on the ASX (ASX:AHQ). The Company focuses on metallurgical coal projects in Canada.

Telkwa Coal maintains an office local to the Project at:

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778-643-2843
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1.2 PROJECT DESCRIPTION

The proposed Tenas Project (the Project) is located approximately 25 km south of Smithers, 7 km southwest of the village of Telkwa, and is within the Regional District of Bulkley-Nechako (Figure 1.2-1). Coal mining has historically occurred in the region between 1918 and 1985.

The Project occurs within the Telkwa Coalfield, which contains three identified deposits: Tenas, Goathorn, and Telkwa North. The Tenas Project specifically concentrates on the Tenas deposit (Figure 1.2-2).

Annual production is estimated at 0.75 Mt clean coal annual rate for 20 years, projected to begin in Q3 of 2021. The estimated total area disturbed by the Project is 1,040 ha.

Major components associated with the Project include:

- surface mine pit excavations;
- a coal processing plant;
- storage piles for waste rock, overburden, coarse and fine rock separated from coal in processing plant, and topsoil;
- materials handling systems for raw coal, coarse and fine rock and washed product coal including plant conveyors, storage bins and stockpiles;
- administration, first aid, maintenance, bathhouse, warehouse, laboratory, and vehicle wash facilities;
- surface water management systems including ditches, sedimentation and storage ponds;
- water discharge pipeline;
- solid waste management systems including recycling and composting facilities;

Figure 1.2-1
Project Location

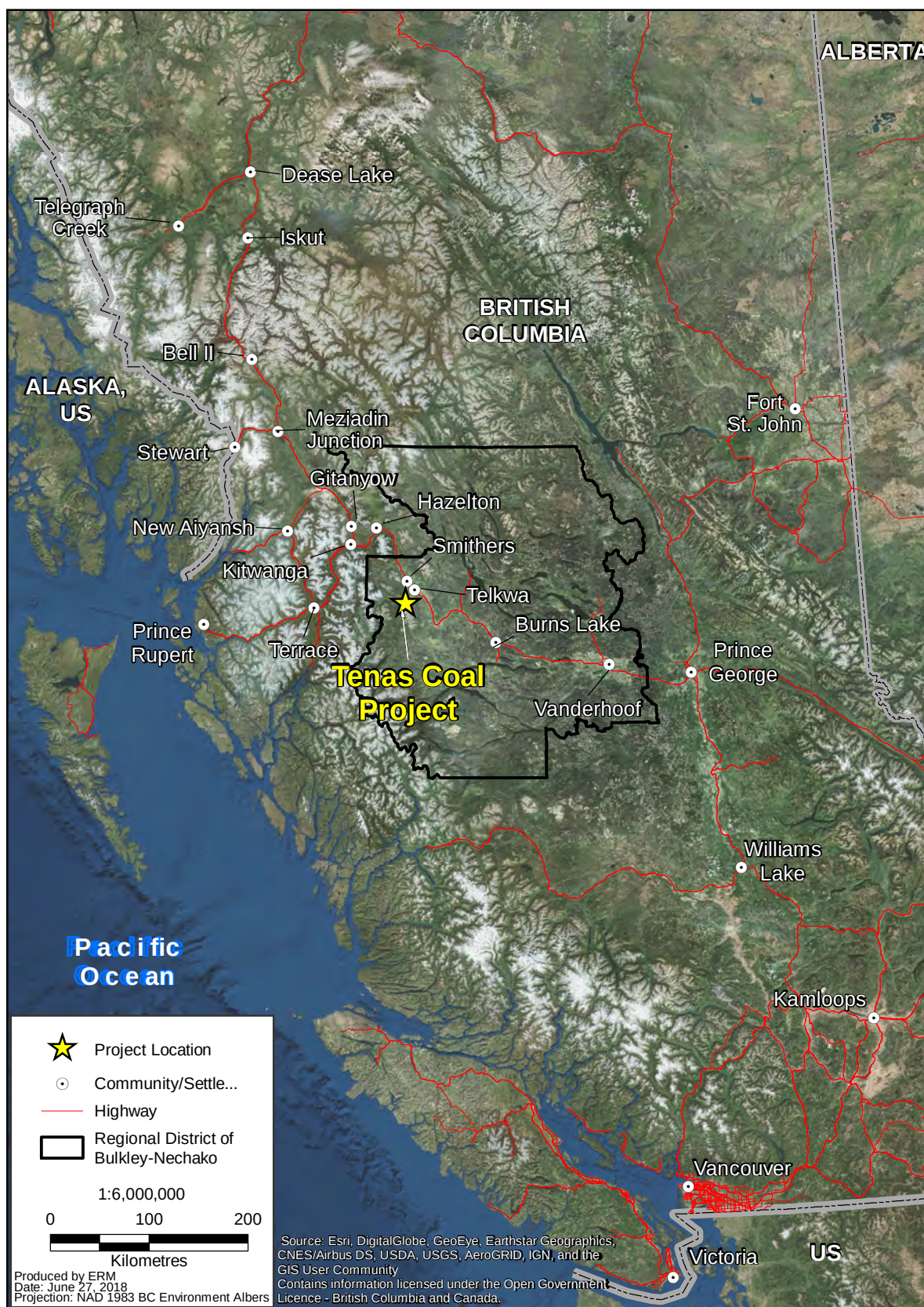
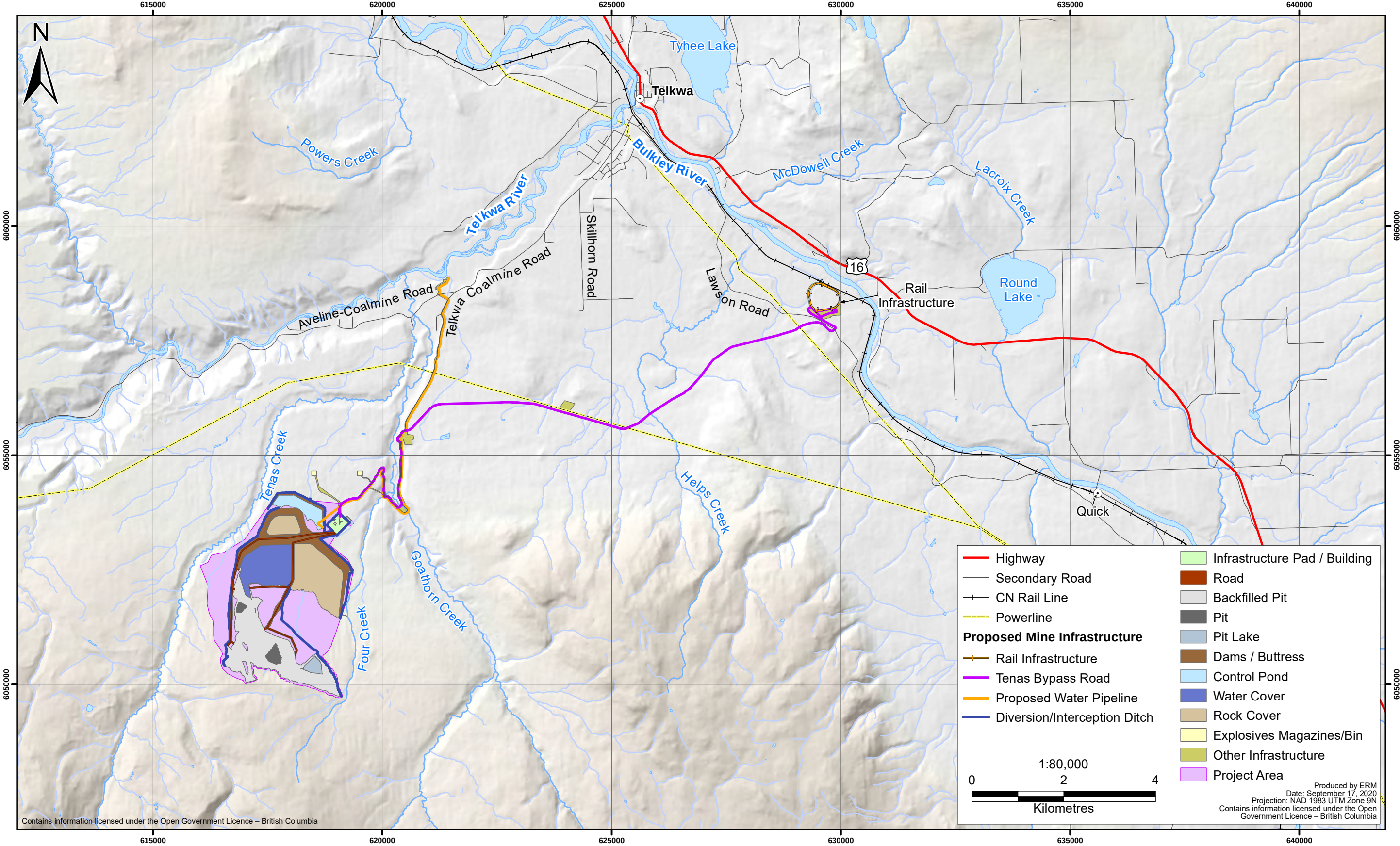


Figure 1.2-2
General Project Layout



- water supply wells, storage, and distribution system;
- fuel, lube and propane storage facilities;
- explosives magazine and storage facilities;
- mine haul roads within the mine site, including access roads;
- an approximately 3.5 kilometre (km) long, 25 kilovolt (kV) power line, and a 600 volt (V) substation adjacent to the processing plant;
- rail loadout facility and an approximately 2.5 km rail loop connecting to the existing main Canadian National Railway line;
- a permanent bridge over Goathorn Creek;
- improvements to approximately 6.5 km of existing roads; and
- an approximately 11 km dedicated bypass road from the mine site to the rail loop.

Construction activities will include site clearing, pre-stripping, building construction, road development, rail infrastructure construction, bridge construction, and development of onsite utilities and services.

The Project is planned to operate as a conventional truck and backhoe surface mine. In the early stage of operations, the pit and material storage piles will be developed. Topsoil and other material suitable for reclamation or construction uses will be stockpiled in designated areas. Coal processing, and the temporary stockpiling of raw coal prior to processing, and washed product coal prior to shipping, will occur. Aquatic effects monitoring, wildlife studies, and reclamation studies will also be ongoing during the operations period to monitor changes to the environment and develop or improve upon the approved mitigation measures provided during the regulatory process.

The timing and duration of closure and reclamation phase activities will be determined in more detail when a reclamation plan is submitted in the permitting process and updated in advance of projected mine closure. Post-closure reclamation activities are anticipated to require two to three years, with continued monitoring ongoing beyond this time frame to ensure successful reclamation.

1.3 ENVIRONMENTAL BASELINES

This consolidated baseline report provides information on field programs and their respective data summaries for the 2017 to 2019 programs (with data for particulate matter reported to January 2020). The data summaries are supplemented with existing information, where applicable.

Baseline programs covered by this report include:

- meteorology;
- air quality;
- noise;
- hydrogeology;
- groundwater water quality;

- hydrology;
- surface water quality;
- sediment quality;
- aquatics;
- fish and fish habitat; and
- visual quality.

2. METEOROLOGY

This chapter presents the methods and results of the meteorological monitoring program, initiated in September 2017. The purpose of the 2017 to 2019 program was to collect data on site specific meteorological conditions. This report summarizes meteorological monitoring from September 2017 to December 9, 2019. Maintenance up to December 2019 is also described. Project-specific meteorological and climate data will inform a wide variety of potential Project planning and future operational and closure activities, including mine design, water management planning, road maintenance, water resource studies, air emission permitting, air dispersion modelling, and air quality management.

The objectives of the program were to:

- install and maintain a new automated meteorological station; and
- monitor meteorological conditions representative of conditions in the project area including air temperature, relative humidity, precipitation, snow depth, wind speed and direction, solar radiation, and barometric pressure.

2.1 STUDY AREA

Meteorological conditions in the general area of the Tenas Project have moderate spatial variability due to topography and regional gradients of key climate parameters such as precipitation, temperature, and wind. There are no active regional meteorological stations (e.g., those operated by government agencies) in the immediate vicinity of the Project area, thus site-specific monitoring was deemed necessary to assess representative baseline conditions. The closest regional meteorological stations operated are at Telkwa, 14 km to the northeast of the Tenas Deposit, and the Smithers Airport, 26 km to the north of the Tenas Deposit.

2.2 REGULATORY AND POLICY FRAMEWORK

Guidance for Project-specific meteorological monitoring for the Tenas Project is provided by the Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators (BC MOE 2016) and the Joint Application Information Requirements for *Mines Act* and *Environmental Management Act* Permits (Joint AIR for MA/EMA Permits; BC MEM and MOE 2016). The site-specific monitoring is conducted to “describe how weather and climate will affect all aspects of the project” (BC MEMPR and MOE 2016).

2.3 EXISTING INFORMATION

Readily available sources of existing meteorological and climate information were reviewed and a summary of the review is provided in Table 2.3-1. The list of reviewed information is not exhaustive and additional potential sources of relevant public and private information may be available.

Table 2.3-1. Meteorological Data Information Table

Data Sources Reviewed	- ECCC historical meteorological and climate database. (ECCC. 2020a. <i>Historical Data – Climate</i>. http://climate.weather.gc.ca/historical_data/search_historic_data_e.html (accessed July 2020).) - ECCC <i>Climate Trends and Variations Bulletin</i>. (ECCC. 2020b. <i>Climate Trends and Variations Bulletin</i>. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html (accessed July 2020).) - ECCC Climate Normal database (ECCC. 2020c. <i>Canadian Climate Normals 1981 – 2010 Station Data</i> for Smithers A station. http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=smithers&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=487&dispBack=1 (accessed July 2020).) - BC ENV <i>BC Air Data Archive</i> database (BC ENV. 2020a. <i>Envista – Air Resources Manager</i>. https://envistaweb.env.gov.bc.ca/ (accessed July 2020).) - BC ENV snow survey data (BC ENV. 2020b. <i>Snow Survey Data</i>. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data and https://catalogue.data.gov.bc.ca/dataset/manual-snow-survey-observations-data-archive (accessed July 2020).) - BC MOT historical weather data (BC MOT. 2020. <i>Avalanche and Weather Programs</i>. https://prdoas3.pub-apps.th.gov.bc.ca/saw-paws/weatherstation (accessed July 2020).) - Pacific Climate Impacts Consortium BC station database (Pacific Climate Impacts Consortium. 2020. <i>BC Station Data</i>. http://tools.pacificclimate.org/dataportal/pcds/map/ (accessed July 2020).) <i>Davidson Project Application for Environmental Assessment Certificate</i> (2008) and supplemental information (BC EAO. 2018a. <i>EAO Project Information and Collaboration website for the Davidson project</i>. https://projects.eao.gov.bc.ca/p/davidson/docs?folder=75 (accessed April 2018).) <i>Telkwa Coal Project Application for a Project Approval Certificate</i> (1997; BC EAO. 2018b. <i>EAO Project Information and Collaboration website for the Telkwa Coal project</i>. https://projects.eao.gov.bc.ca/p/telkwa-coal/docs?folder=4 (accessed April 2018).)
General Remarks	Reviewed information included publicly available sources for data collected in the general regional area of the Tenas Project. Additional potential sources of relevant public and private information may be available.
Sampling Required for EA and by Joint AIR for MA/EMA Permits	EA-related meteorological monitoring is conducted according to guidance provided in <i>Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators</i> (BC MOE 2016). Recent project specific meteorological monitoring is a requirement of the Joint AIR in order to “demonstrate an understanding of how weather and climate will affect all aspects of the project”.
Existing Data	Data are available from over 117 meteorological stations that have operated at one time or another since 1922 within a 50 km radius of the Tenas Project.
Existing Data Issues	Most of these stations only measured specific meteorological parameters, do not have continuous datasets (e.g., seasonal operation), or were not operational in recent years.
Missing Data	There were no existing stations located in the general area of the Tenas Deposit with recent meteorological data.
2017–2019 Baseline Program	After reviewing the existing data, four stations were identified as being suitable for characterizing the recent regional meteorological conditions of the Project. One station was identified as being suitable for characterizing the long term Climate Normal conditions of the region. These stations are described in Section 2.4.1. The Tenas Project’s meteorological monitoring program was designed to address the lack of recent meteorological data in the Project area. The suitable regional data described above were also incorporated into the monitoring program.

2.4 METHODOLOGY

2.4.1 Automated Meteorological Station

The Tenas Deposit meteorological station was installed and became operational on September 29, 2017 (Photos 2.4-1 and 2.4-2). It is located in the Tenas coal deposit area, in a cutblock clearing. The Tenas Deposit station is located 14 km southwest of the closest British Columbia Ministry of Environment and Climate Change Strategy (BC ENV) meteorological station (Telkwa) and 26 km south of the Environment and Climate Change Canada (ECCC) meteorological stations at the Smithers Airport (Smithers A and Smithers AUTO). All station locations are listed in Table 2.4-1 and shown in Figure 2.4-1.



Photo 2.4-1. The Tenas Deposit meteorological station after installation. September 29, 2017. Looking west.



*Photo 2.4-2. The Tenas Deposit meteorological station on arrival. January 22, 2019.
Looking southeast.*

The Tenas Deposit station and sensors were installed according to sensor siting guidelines from ECCC (EC 2004, 2012) and the BC ENV (BC MOE 2016). These guidelines, wherever possible, follow standards set by the World Meteorological Organization which were established to promote standardization and describe practices, procedures, and specifications for proper siting of instruments, precision and accuracy of measurements, and archive formats.

The Project is located in a densely forested area, and finding a station location that fulfilled all sensor siting guidelines was challenging. The primary concerns when selecting an appropriate location for the meteorological station were to:

- monitor meteorological conditions representative of conditions in the Tenas Deposit area;
- avoid obstructions (e.g., existing and potential infrastructure and trees) that would bias wind speed and direction;
- avoid shaded areas that would bias solar radiation data and reduce exposure of the solar power panel to sunlight; and
- identify a suitable tower anchor foundation.

As the station is located in a remote region and unattended for long periods of time (months), consideration was also given to helicopter and vehicle accessibility.

Figure 2.4-1
Meteorological and Air Quality Monitoring Stations

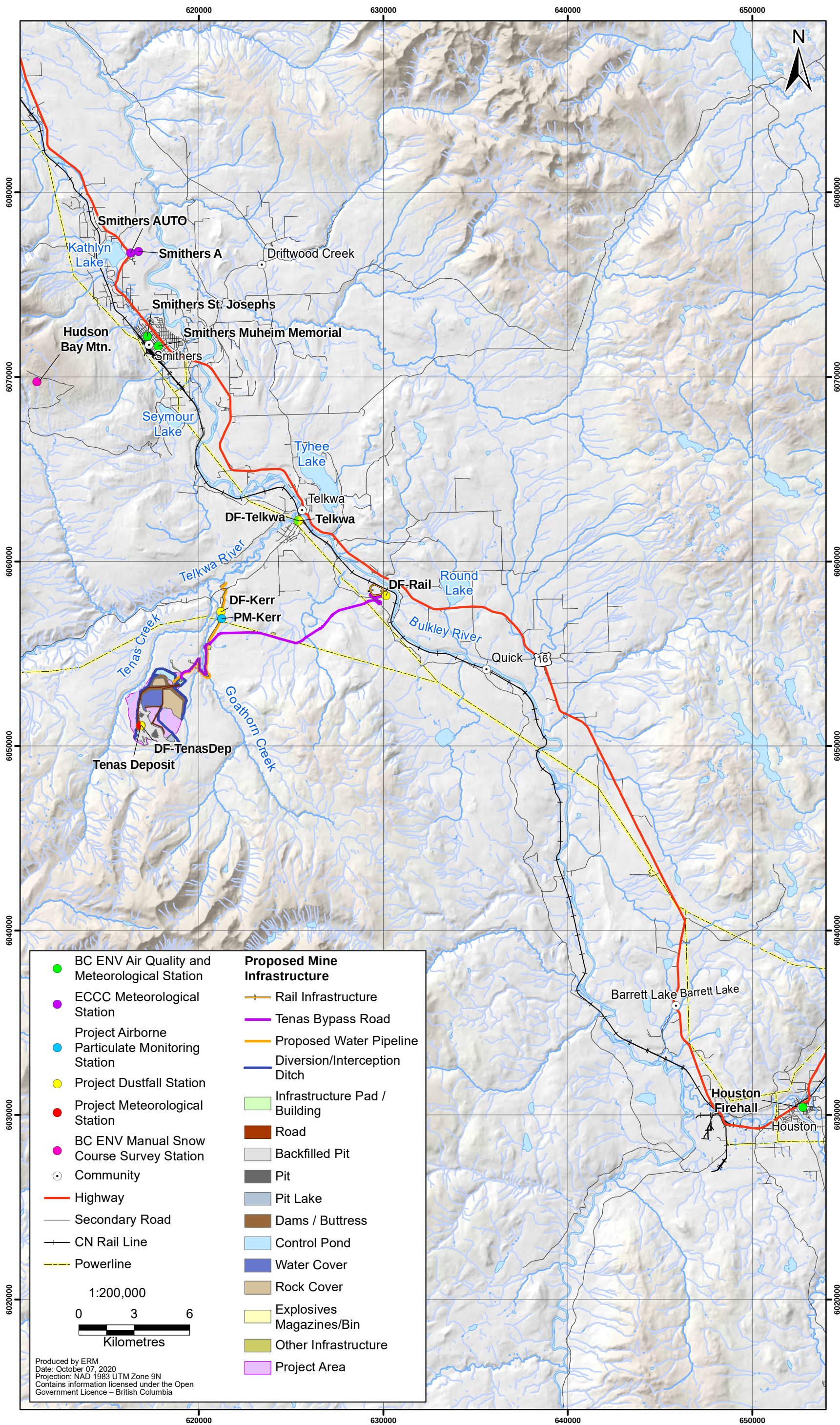


Table 2.4-1. Currently Active Project and Select Regional Meteorological Stations

Station Type	Station Name	Reporting Organization	Station Operating Period	UTM Coordinates (Zone 9U WGS84)		Elevation (masl) ^a	Data Source Reference
				Easting (m)	Northing (m)		
Standard meteorological station	Tenas Deposit	Telkwa Coal	Sep 29, 2017 - Present	616847	6051099	993	n/a
	Smithers AUTO	ECCC	Aug 19, 2013 - Present	616318	6076727	521	ECCC (2020a)
	Smithers A ^b	ECCC	Jun 1, 1942 - Present	616744 ^c	6076800 ^c	523	Time Series: ECCC (2020a) Climate Normals: ECCC (2020c)
	Smithers	ECCC	Apr 30, 2010 - Present	616744 ^d	6076800 ^d	523	Time Series: ECCC (2020a)
Air quality monitoring stations with limited meteorological monitoring	BC ENV-Telkwa	BC ENV	Jan 20, 1998 - Present	625405	6062198	515	BC ENV (2020a)
	BC ENV-Smithers St. Josephs ^e	BC ENV	Jun 3, 1997 – December 2018 ^f	617212	6072196	497	BC ENV (2020a)
	BC ENV-Smithers Muheim Memorial	BC ENV	January 2019 - Present	617795	6071677	497	BC ENV (2020a)
	BC ENV-Houston	BC ENV	No. 21, 1994 - Present	652757	6030420	603	BC ENV (2020a)
Manual snow course survey station	Hudson Bay Mtn	BC ENV	Feb 26, 1965 - Present	611242	6069734	1,363	BC ENV (2020b)

Notes:

n/a = not applicable

^a Some station elevations reported by ECCC and BC ENV are known to be inaccurate compared to established topography datasets; corrected elevations are used in this table.

^b Daily data are not available from Smithers A station after November 2018.

^c Coordinates provided by ECCC for the Smithers A station point to a location in the middle of the airport runway and are known to be inaccurate by about 500 m.

^d Coordinates provided by ECCC for Smithers station is the same as Smithers A station.

^e BC ENV-Smithers station was relocated from St. Josephs School to Muheim Memorial School in December 2018. BC ENV-Smithers Muheim Memorial station is operational beginning in January 2019.

^f Meteorological monitoring at BC ENV-Smithers St. Josephs station started on December 8, 2009.

The wind sensor is located over open and relatively level terrain, as far as possible from the edge of the forest (70 m away from the closest cutblock edges to the north and south of the station). The sensor is mounted 10 m above the ground, which is the standard reference height for wind measurements (EC 2004, 2012). Temperature and humidity sensors are shielded from solar radiation, and adequately ventilated. The precipitation gauge uses a single Alter wind screen to reduce precipitation undercatch due to wind turbulence.

The meteorological station is programmed according to the ECCC guidelines. The datalogger clock is set to Pacific Standard Time with no adjustment for daylight savings (as per meteorological monitoring standards). Automatically logged data include:

- hourly average wind speed, wind direction, and standard deviation of wind direction;
- hourly average air temperature;
- hourly average relative humidity;
- hourly average solar radiation;
- hourly sampled snow depth;
- hourly average barometric pressure;
- 5-minute and hourly total accumulated precipitation; and
- hourly average battery power supply voltage.

Each day at midnight, the following data are also automatically recorded:

- daily maximum and minimum air temperature;
- daily maximum wind speed, and the wind direction at maximum speed;
- total daily precipitation;
- total daily evaporation during snow free months; and
- diagnostic information.

A continuous record of these data is being maintained by ERM.

2.4.2 Station Sensors and Equipment

The sensors and equipment that were first installed on the Tenas Deposit station are summarized in Table 2.4-2. A meteorological sensor swap at the Tenas Deposit station was completed on December 9, 2019 (Table 2.4-2), and the removed sensors were sent to Campbell Scientific for recalibration.

The meteorological station consists of a 9 m high aluminum tower that is used to mount all sensors except for the precipitation gauge. The tower is anchored at the base and strengthened with guy wires. The tower base, most guy wires, and the Pluvio precipitation gauge pedestal are anchored into rock outcrops in the cutblock. One guy wire is anchored using a soil anchor.

Wind speed and direction are measured with an RM Young 05305 wind sensor, installed at a height of 10 m above the ground, extended above the tower frame. Wind speed is measured in metres per second (m/s) and wind direction in degrees from geographic north.

Air temperature and relative humidity are measured with sensors that are combined into a single Rotronic HC2-S3 probe. The probe is mounted on the tower, about two metres above the ground. The sensors are shaded from solar radiation by a multi-plate passive solar radiation shield (RM Young 41003-X). Air temperature is measured in degrees Celsius (°C) and relative humidity in percent (%).

Table 2.4-2. Tenas Deposit Station Sensors and Equipment Installed in September 2017

Description	Make	Model	Serial Number (Removed Sensor)	Serial Number (Installed Sensor)
Wind speed and direction sensor	RM Young	05305	WM154553	WM172289
Air temperature and relative humidity sensor	Rotronic	HC2-S3 (-50 to +50°C version)	20180200	20351539
Solar radiation shield for air temperature and humidity sensor	RM Young	41003-X	-	-
Solar radiation sensor	Kipp & Zonen	SP Lite2	173213	194375
Snow depth sensor	Campbell Scientific	SR50A	9103	12054
Barometric pressure sensor	Vaisala	CS106	N3030363	R4020454
Precipitation sensor (with single Alter wind screen)	OTT	Pluvio ² L (400 cm ² version)	417512 ^a	-
Evaporation gauge and evaporation pan	Novalynx	255-100 Class A 255-200 ^b	-	-
Datalogger	Campbell Scientific	CR1000-XT	85763	11580 ^c

*Notes:**Dash (-) = not available or not applicable.**^a Precipitation sensor was not swapped.**^b Model of the evaporation pan.**^c The model of the installed datalogger is CR1000X.*

Direct and diffuse incoming solar radiation (combined) are measured with a Kipp & Zonen SP Lite2 pyranometer. The sensor is mounted on the tower, about two metres above the ground. Solar radiation is reported in watts per square metre (W/m²).

Snow depth is measured with a Campbell Scientific SR50A sonic snow depth sensor that is mounted to the station tower with a cross arm about two metres above the ground. Snow depth is reported in centimetres (cm).

Barometric pressure is measured with a Vaisala CS106 barometer. The sensor is mounted inside the station's datalogger enclosure. The enclosure is vented with a hydrophobic filter and entry seal to equalize the pressure in the enclosure with the ambient pressure. Barometric pressure is reported as station-level pressure and sea-level corrected pressure, in units of kPa.

Precipitation is measured with an OTT Pluvio² L (400 cm² version) all-weather precipitation gauge. The larger 400 cm² orifice area was chosen to reduce the amount of snow buildup on the rim of the orifice that can lead to orifice blocking and a reduced catch efficiency. The station is located far away from an AC line power tie-in point, and therefore a heated precipitation gauge was not feasible. The precipitation gauge is mounted on a 1 m pedestal in order to keep the top of the gauge from being buried in snow. The precipitation gauge uses a single Alter wind screen to reduce precipitation undercatch caused by wind. During winter, the gauge is winterized with propylene glycol to prevent

freezing. The gauge automatically adjusts the data output to account for evaporation and does not require the addition of oil.

Evaporation rate is calculated using a Novalynx 255-100 evaporation gauge and Class A evaporation pan that was installed at the station site in 2019 during the snow free months when temperatures were above freezing (Photo 2.4-3). Daily evaporation totals are reported in mm and are calculated by taking the previous day's end-of-day evaporation water level, minus the current day's end-of-day water level and then adding the current day's total precipitation. Any negative daily evaporation values are set to zero.



Photo 2.4-3. The Tenas Deposit meteorological station Class A evaporation pan with evaporation gauge. July 18, 2019.

All station sensors are connected to a Campbell Scientific datalogger that controls the operation of the station. The datalogger's program monitors each sensor every 5 seconds, and generates hourly and daily data tables with instantaneous, average, maximum, minimum, total, and standard deviation values, depending on which meteorological variable is being measured. These tables are stored in internal memory. The station is powered with a solar panel, a 12 volt 75 amp hour deep cycle absorbent glass mat battery, and a solar controller. The station is grounded and has a lightning rod to help prevent lightning from damaging the electronics.

2.4.3 Quality Assurance/Quality Control

2.4.3.1 Station Maintenance

A maintenance program is in place for the Tenas Deposit meteorological station. A sensor swap was completed on December 9, 2019, and the removed sensors were sent to the supplier for calibration

because specialized equipment is required for most calibration procedures. The recommended recalibration interval for this station's application is every two years (BC MOE 2016).

Meteorological station maintenance site visits were conducted by experienced technicians to ensure the station continued to function correctly. Station maintenance fieldwork tasks are summarized in Table 2.4-3. Detailed trip reports were prepared to document field observations and completed tasks. During each station visit, sensors and equipment were checked to ensure they were operating normally.

Table 2.4-3. Tenas Deposit Station Visits and Sensor Maintenance, September 2017 to December 2019

Station Visit Dates	Tasks Performed
Aug 31, 2017	• Reconnaissance to identify suitable installation locations for a meteorological station
Sep 26-29, 2017 (Photo 2.4-1)	• Installed Tenas Deposit meteorological station
Oct 16, 2017	• Inspected station • Downloaded data • Winterized the precipitation gauge with propylene glycol and water • Cleared snow off the station
Nov 28, 2017	• Inspected station • Downloaded data • Updated datalogger program to correct a problem with the barometric pressure sensor measurements • Emptied and re-winterized the precipitation gauge
Dec 11, 2017	• Inspected station Downloaded data • Cleared rime ice off the station
Jan 17, 2017	• Inspected station • Downloaded data • Cleared snow off the station
Feb 19, 2018	• Inspected station • Downloaded data • Cleared snow off the station • Emptied and re-winterized the precipitation gauge
Mar 22, 2018 (Photo 2.4-2)	• Inspected station • Downloaded data • Cleared snow off the station
Apr 23, 2018	• Inspected station • Downloaded data • Cleared snow off the station
May 18, 2018	• Inspected station • Downloaded data • Emptied precipitation gauge
Oct 2, 2018	• Inspected station • Downloaded data • Winterized precipitation gauge

(continued)

Table 2.4-3. Tenas Deposit Station Visits and Sensor Maintenance, September 2017 to December 2019 (completed)

Station Visit Dates	Tasks Performed
Jan 22, 2019 (Photo 2.4-2)	• Inspected station • Downloaded data • Winterized precipitation gauge
Jun 5, 2019	• Inspected station • Downloaded data • De-winterized precipitation gauge • Surveyed a location for the evaporation pan installation nearby the station
Jul 18, 2019 (Photo 2.4-3)	• Inspected station • Downloaded data • Installed the evaporation pan and gauge • Installed a wire fence around the evaporation pan and gauge to prevent large animals from drinking the water
Nov 1, 2019	• Inspected station • Downloaded data • Winterized precipitation gauge • Emptied the evaporation pan and disconnected it from the evaporation gauge
Dec 10, 2019	• Inspected station • Downloaded data • Performed meteorological sensor swap

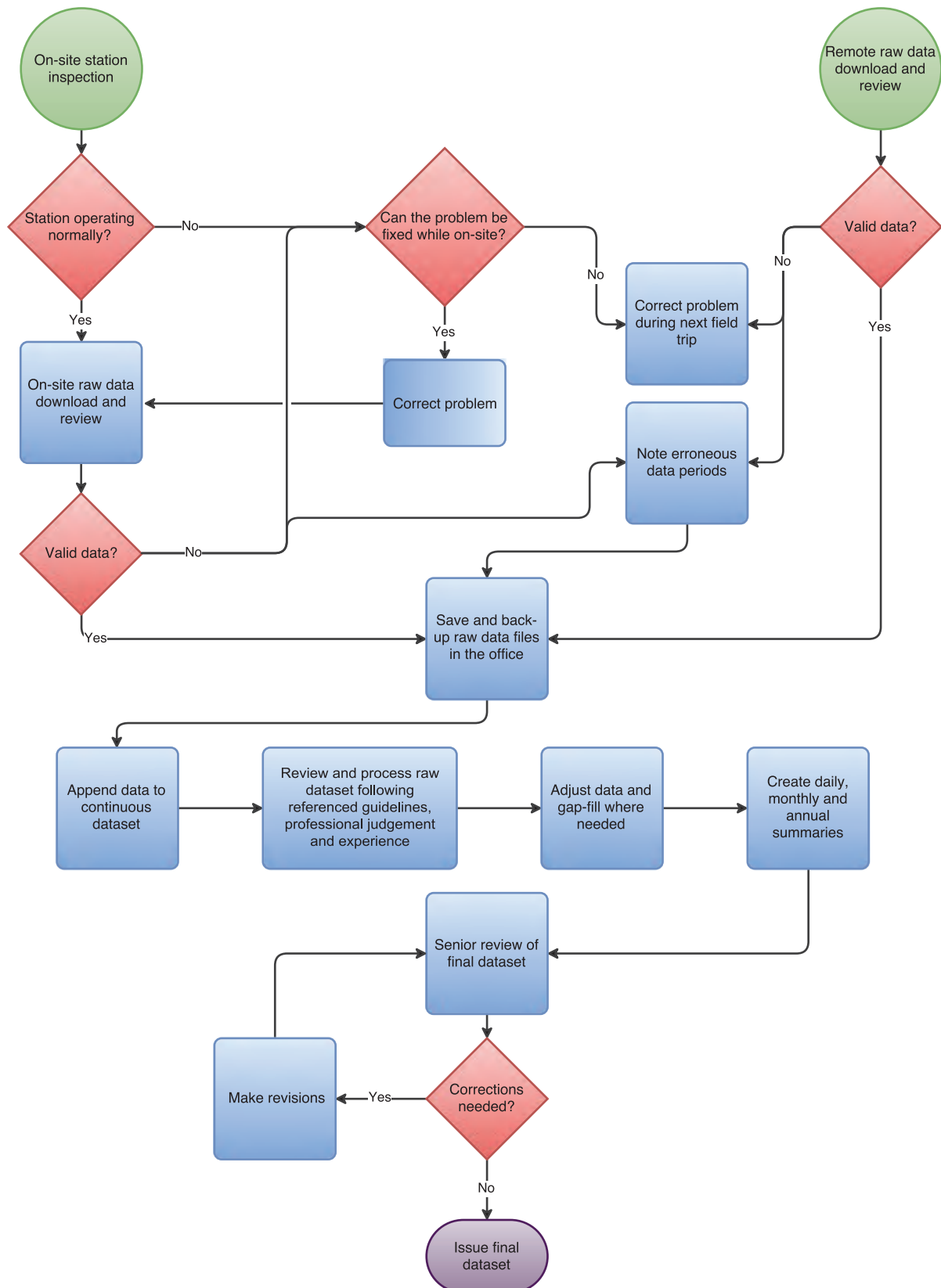
2.4.3.2 Data Review

All meteorological data were reviewed after collection to remove or correct any erroneous values. The screening process used by ERM draws on screening criteria used by the United States Environmental Protection Agency (US EPA 2000), ECCC (EC 2004), and the BC ENV (BC MOE 2016), as well as using professional judgement and experience (Figure 2.4-2). Any erroneous data were marked as missing and the periods of missing data are summarized in Section 2.5. After data were screened, the recorded hourly and daily values were analysed and processed into daily and monthly summaries.

As an example, during months with snowfall, the snow depth data were used to verify precipitation events. If snow depth increased but the precipitation gauge did not record any precipitation during the same time period, it was likely that there was a snow cap blocking the precipitation gauge orifice. In these cases, precipitation data were marked as missing. Large winter precipitation events recorded by the precipitation gauge were also verified by comparing the event with the snow depth change over the same period. Data were also compared against concurrent regional meteorological station data.

Figure 2.4-2

**Overview of Meteorological Monitoring Program
Quality Assurance and Quality Control Process**



2.4.3.3 Precipitation Classification

Total precipitation data were then separated into daily rainfall and snowfall based on daily air temperature data, and followed the methodology provided by Quick (1995). The algorithm is as follows:

$$\begin{aligned} \text{if } T > 2 \text{ then} \\ R &= P \\ SWE &= 0 \end{aligned}$$

$$\begin{aligned} \text{if } T < 0 \text{ then} \\ R &= 0 \\ SWE &= P \end{aligned}$$

$$\begin{aligned} \text{if } 0 < T < 2 \text{ then} \\ R &= P \times T/2 \\ SWE &= P \times (1 - (T/2)) \end{aligned}$$

where:

T = Mean Daily Air Temperature (°C)

P = Daily Precipitation (mm)

R = Daily Rainfall (mm)

SWE = Daily Snowfall Snow-Water-Equivalent (SWE; mm)

2.4.3.4 Estimating Missing Precipitation and Temperature Data

Where possible, any missing daily precipitation and temperature data from the Tenas Deposit station were estimated using the linear equations presented in Table 2.4-4 (January 1, 2017 to March 21, 2018) and Table 2.4-5 (March 22, 2018 to December 31, 2018). Daily precipitation and temperature data from January 1, 2019 to December 9, 2019 did not include any missing values.

Table 2.4-4. Daily Precipitation and Temperature Relationship Equations, Applied to January 1, 2017 to March 21, 2018 Missing Data.

Dependent Variable	Independent Variable	Equation	R ²	N (No. of Pairs ^a)
Daily Total Precipitation (mm)				
P _{TenasDeposit}	P _{SmithersA}	P _{TenasDeposit} = 1.098 * P _{SmithersA} + 0.857	0.773	173
P _{TenasDeposit}	P _{SmithersAUTO}	P _{TenasDeposit} = 1.183 * P _{SmithersAUTO} + 0.618	0.776	139
Daily Mean Air Temperature (°C)				
T _{TenasDeposit}	T _{SmithersA}	T _{TenasDeposit} = 0.864 * T _{SmithersA} - 1.886	0.878	173
T _{TenasDeposit}	T _{SmithersAUTO}	T _{TenasDeposit} = 0.838 * T _{SmithersAUTO} - 1.495	0.884	171

Notes:

Equations were developed using concurrent historical September 30, 2017 to March 21, 2018 data.

Equations were applied to any missing Tenas Deposit station data from January 1, 2017 to March 21, 2018.

When applying these equations, if the input precipitation value was zero then the output was set to zero. Any resulting negative precipitation values were also set to zero.

^a The number of concurrent data point pairs (dependent and independent variable pairs) used to develop the linear regression equations.

Table 2.4-5. Daily Precipitation and Temperature Relationship Equations, Applied to March 22 to December 31, 2018 Missing Data

Dependent Variable	Independent Variable	Equation	R ²	N (No. of Pairs ^a)
Daily Total Precipitation (mm)				
P _{TenasDeposit}	P _{SmithersA}	$P_{TenasDeposit} = 1.029 * P_{SmithersA} + 0.629$	0.711	389
P _{TenasDeposit}	P _{SmithersAUTO}	$P_{TenasDeposit} = 1.096 * P_{SmithersAUTO} + 0.307$	0.696	417
Daily Mean Air Temperature (°C)				
T _{TenasDeposit}	T _{SmithersA}	$T_{TenasDeposit} = 0.942 * T_{SmithersA} - 1.694$	0.955	389
T _{TenasDeposit}	T _{SmithersAUTO}	$T_{TenasDeposit} = 0.929 * T_{SmithersAUTO} - 1.405$	0.953	449

Notes:

Equations were developed using concurrent historical September 30, 2017 to December 31, 2018 data.

Equations were applied to any missing Tenas Deposit station data from March 22, 2018 to December 31, 2018 data.

When applying these equations, if the input precipitation value was zero then the output was set to zero. Any resulting negative precipitation values were also set to zero.

^a The number of concurrent data point pairs (dependent and independent variable pairs) used to develop the linear regression equations.

Precipitation equations were derived using linear regressions on concurrent historical (September 30, 2017 to December 31, 2018) daily precipitation amounts between the stations. When applying these equations, if the input precipitation value was zero then the output was set to zero. Any resulting negative precipitation values were also set to zero. When possible, the station with the larger R² value was used to gap-fill the Tenas Deposit station data with synthetic data.

Temperature equations were derived using linear regressions on concurrent historical (September 30, 2017 to December 31, 2018) daily mean temperatures between the stations, and were applied to the daily dataset. When possible, the station with the larger R² value was used to gap-fill the Tenas Deposit station data with synthetic data.

The two tables (Table 2.4-4 and 2.4-5) are split on March 21, 2018 data as the linear regressions derived for the September 30, 2017 to March 21, 2018 were developed for the draft baseline report for data to March 2018 (Table 2.4-4). The new set of equations (Table 2.4-5) were developed using additional new data up to December 31, 2018. The new equations (Table 2.4-5) are not applied to the previously published gap filled synthetic temperature and precipitation datasets (January 1, 2017 to March 21, 2018) in order to avoid changing data that were previously reported in the earlier version of the baseline report.

The equations in Table 2.4-4 are applied to any daily precipitation or temperature unavailable data periods from January 1, 2017 to March 21, 2018 at the Tenas Deposit station. This includes the unavailable data period from January 1 to September 29, 2017, before the station was installed on September 29. The equations in Table 2.4-5 are applied to any unavailable data periods from March 22, 2018 to December 31, 2018.

2.5 DATA SUMMARY

The purpose of this section is to describe the on-site meteorological conditions measured by the Tenas Deposit station. Regional data are also incorporated to a limited extent. References to the full regional station datasets are listed in Table 2.4-1.

The Tenas Deposit meteorological station air temperature, relative humidity, precipitation, snow depth, wind speed and direction, solar radiation, barometric pressure, and evaporation data are briefly summarized in the sections below for the September 30, 2017 to December 9, 2019 period (last field visit to the station was on December 10, 2019). Synthetic air temperature and precipitation data from January 1, 2017 to September 29, 2017 are also included (see Section 2.4.3.4 for calculation methodology).

There were a number of days with unavailable data from the Tenas Deposit station during the January 1, 2017 to December 9, 2019 period. The unavailable data periods are summarized in Table 2.5-1.

Table 2.5-1. Tenas Deposit Station Unavailable Data Periods from January 2017 to December 2019

Parameter	Dates of Unavailable Data			Reason for Unavailable Data
	2017	2018	2019 ^a	
All Parameters	Jan 1 – Sep 29	-	-	Station was first installed on September 29, 2017. Temperature and precipitation were gap-filled with synthetic data.
Wind Speed and Direction	Oct 16, 17, 24; Nov 18, 19, 22, 23	Jan 29, 30; Sep 16; Oct 28, 31; Nov 1, 15; Dec 28 - 29	Jan 5, 6; Nov 23	Sensor frozen
Solar Radiation	Oct 21 – 24; Nov 6 – Dec 10, 21 – 31	Jan 1 – Feb 13, 28; Sep 15; Nov 1, 15 – 17; Dec 13 - 31	Jan 6 – 12;	Sensor covered in snow. Low wind speeds prevented natural snow clearing of the sensor.
Barometric Pressure	Sep 30 – Nov 28	-	-	Datalogger programming error. This period was gap-filled using adjusted regional data.
Snow Depth	Nov 29 – Dec 10	-	-	A large piece of snow fell from the tower, landing directly under the sensor, resulting in inaccurate data. The issue was resolved during the December 11 fieldtrip by levelling the snow surface.

Note:

This table only lists days that had less than 75% of valid hourly data. Missing temperature and precipitation data were gap-filled using the methods described in Section 2.4.3.4.

Daily evaporation totals are available only for the freeze free season in 2019 (the evaporation gauge/pan was installed on July 18, 2019).

^a Data are not available after December 9, 2019 as last field visit to the station was on December 10, 2019.

Tables 2.5-2, 2.5-3 and 2.5-4 summarize the monthly meteorological data at the Tenas Deposit station, and daily data records are included in Appendix 2-A. Hourly and five-minute datasets are available by request.

Table 2.5-2. Tenas Deposit Meteorological Data Summary, 2017

Month	Gap-filled or Synthetic ^a Air Temperature (°C)					Relative Humidity (%) Mean	Wind Speed (m/s)			Unadjusted Precipitation (mm) Total Precipitation	Gap-filled or Synthetic ^a Precipitation (mm)			Snow Depth (cm) Mean	Solar Radiation (W/m²) Mean	Station Elevation Barometric Pressure (kPa) Mean
	Mean	Mean Daily Max.	Mean Daily Min.	Absolute Max.	Absolute Min.		Mean	Absolute Max.	Gust		Total Precipitation	Total Rainfall	Total Snowfall SWE			
Jan ^a	-7.5	-4.3	-10.6	4.3	-26.0	-	-	-	-	-	44.4	6.8	37.6	-	-	-
Feb ^a	-6.8	-2.8	-10.8	6.3	-21.0	-	-	-	-	-	15.3	6.9	8.4	-	-	-
Mar ^a	-2.3	1.6	-6.2	8.5	-12.5	-	-	-	-	-	14.7	3.9	10.8	-	-	-
Apr ^a	3.1	8.2	-2.1	12.0	-5.4	-	-	-	-	-	19.4	16.2	3.2	-	-	-
May ^a	7.4	12.5	2.2	22.5	-4.3	-	-	-	-	-	109.8	107.9	1.9	-	-	-
Jun ^a	9.4	14.8	4.0	22.7	-2.4	-	-	-	-	-	72.0	72.0	0.0	-	-	-
Jul ^a	10.8	16.3	5.1	23.9	1.0	-	-	-	-	-	44.7	44.7	0.0	-	-	-
Aug ^a	12.3	18.3	6.4	25.4	2.5	-	-	-	-	-	26.0	26.0	0.0	-	-	-
Sep ^a	8.5	13.3	3.6	23.2	-2.1	-	-	-	-	-	101.6	101.6	0.0	-	-	-
Oct	1.9	6.7	-2.0	14.2	-5.9	83.2	1.2	13.3		147.2	147.2	114.5	32.7	4.1	79.8	89.8
Nov	-5.6	-3.0	-8.6	2.5	-15.9	90.0	1.1	11.5		133.8	133.8	0.0	133.8	28.2	-	89.3
Dec	-8.9	-6.0	-11.9	3.4	-24.9	88.3	0.9	11.2		9.6	9.6	0.0	9.6	46.9	-	90.7

Notes:

Dash (-) = not available. Less than 75% data availability for calculation of the mean or total. See Table 2.5-1 for a summary of missing data.

SWE = Snow-water-equivalent

^a The station was installed on September 29, 2017. The January to September 2017 temperature and precipitation data were synthesized using correlation to ECCC Smithers A and Smithers AUTO stations (see Section 2.4.3.4).

Table 2.5-3. Tenas Deposit Meteorological Data Summary, 2018

Month	Gap-filled ^a Air Temperature (°C)					Relative Humidity (%) Mean	Wind Speed (m/s)		Unadjusted Precipitation (mm) Total Precipitation	Gap-filled ^a Precipitation (mm)			Snow Depth (cm) Mean	Solar Radiation (W/m²) Mean	Station Elevation Barometric Pressure (kPa) Mean
	Mean	Mean Daily Max.	Mean Daily Min.	Absolute Max.	Absolute Min.		Mean	Absolute Max. Gust		Total Precipitation	Total Rainfall	Total Snowfall SWE			
Jan	-7.6	-5.0	-10.5	0.8	-24.7	92.0	0.7	8.3	50.2	50.2	0.0	50.2	63.0	-	89.5
Feb	-9.8	-5.6	-13.6	2.2	-21.0	83.2	1.2	10.5	150.4	150.4	0.0	150.4	101.4	-	90.0
Mar	-3.3	1.0	-7.3	8.3	-19.7	76.8	1.5	14.9	80.6	80.6	0.7	79.8	119.2	99.3	89.8
Apr	1.1	6.2	-4.0	19.8	-13.9	63.9	1.7	10.6	13.7	13.7	3.2	10.5	110.5	165.2	89.9
May	9.4	16.0	3.1	23.7	-1.1	59.6	1.7	11.0	14.4	14.4	14.4	0.0	11.7	233.0	90.3
Jun	10.6	16.6	5.1	30.1	-1.0	63.2	2.0	13.2	42.4	42.4	42.4	0.0	0.0	237.6	90.1
Jul	15.5	21.7	9.3	31.8	5.0	58.3	1.7	10.4	50.4	50.4	50.4	0.0	0.0	242.2	90.7
Aug	15.3	21.9	9.1	29.3	4.9	51.5	2.0	11.8	1.8	1.8	1.8	0.0	0.0	202.3	90.4
Sep	5.9	10.5	1.9	18.5	-5.2	78.3	1.4	10.3	49.9	49.9	30.3	19.6	0.6	112.5	90.3
Oct	3.0	7.6	-0.8	15.5	-6.3	75.5	1.1	14.7	54.0	54.0	42.5	11.5	0.2	73.1	90.2
Nov	-1.0	1.2	-3.3	6.2	-9.1	96.0	0.9	10.9	51.3	51.3	9.0	42.3	9.2	20.1	89.8
Dec	-6.1	-3.7	-8.6	0.6	-16.1	91.3	1.1	12.3	113.0	113.0	0.0	113.0	37.7	-	89.5

Notes:

Dash (-) = not available. Less than 75% data availability for calculation of the mean or total. See Table 2.5-1 for a summary of missing data.

SWE = Snow-water-equivalent

^a Any unavailable temperature and precipitation data were gap-filled using correlation to ECCC Smithers A and Smithers AUTO stations (see Section 2.4.3.4).

Table 2.5-4. Tenas Deposit Meteorological Data Summary, 2019

Month	Air Temperature ^a (°C)					Relative Humidity (%) Mean	Wind Speed (m/s)			Unadjusted Precipitation (mm) Total Precipitation	Precipitation ^a (mm)			Snow Depth (cm) Mean	Solar Radiation (W/m ²) Mean	Station Elevation Barometric Pressure (kPa) Mean	Total Pan Evaporation (mm)
	Mean	Mean Daily Max.	Mean Daily Min.	Absolute Max.	Absolute Min.		Mean	Max.	Gust		Total Precipitation	Total Rainfall	Total Snowfall SWE				
Jan	-3.8	-1.4	-6.5	6.2	-14.7	92.4	1.0	13.4		60.4	60.4	5.7	54.8	66.1	18.4	89.6	-
Feb	-12.7	-8.1	-17.2	2.7	-26.5	74.3	1.4	9.7		18.7	18.7	0.0	18.7	74.8	40.8	90.0	-
Mar	-1.3	4.6	-6.8	16.5	-20.7	58.6	1.3	9.4		8.1	8.1	0.0	8.1	73.7	137.3	90.4	-
Apr	2.4	8.0	-2.5	12.7	-6.2	61.6	1.6	13.1		13.4	13.4	7.3	6.1	32.2	181.4	89.8	-
May	10.5	16.8	4.1	25.6	-1.4	58.9	1.8	11.2		26.2	26.2	26.2	0.0	0.3	230.5	90.1	-
Jun	10.9	16.9	5.3	24.8	-1.3	69.2	1.7	11.8		56.6	56.6	56.6	0.0	0.0	219.5	90.3	-
Jul	12.9	18.3	8.3	25.9	3.8	77.0	1.4	12.7		82.7	82.7	82.7	0.0	0.0	182.3	90.3	- ^b
Aug	12.9	18.8	7.3	28.4	1.7	69.4	1.5	12.3		20.7	20.7	20.7	0.0	0.0	183.6	90.2	72.0
Sep	8.2	13.2	3.9	23.2	-4.8	78.9	1.3	11.1		47.1	47.1	46.6	0.6	0.0	108.5	90.1	25.0
Oct	0.7	4.5	-2.4	12.3	-9.5	89.7	1.1	11.8		92.9	92.9	68.9	24.0	5.0	58.4	90.1	-
Nov	-1.9	1.1	-4.7	9.1	-16.8	91.4	1.2	13.2		72.7	72.7	31.6	41.1	4.6	20.9	90.1	-
Dec ^c	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-

Notes:

Dash (-) = not available. Less than 75% data availability for calculation of the mean or total. See Table 2.5-1 for a summary of missing data.

SWE = Snow-water-equivalent

^a All temperature and precipitation data were available in 2019 (up to December 9); therefore no gap-filled correlations were applied to 2019 data.

^b There are only 13 days of total pan evaporation available for July as the evaporation pan was installed on July 18, 2019.

^c Data are not available after December 9 (the last field visit to the station was on December 10, 2019).

2.5.1 Air Temperature

The daily mean, maximum and minimum air temperatures calculated and monitored at the Tenas Deposit station in 2017, 2018 and 2019 are presented in Figures 2.5-1, 2.5-2 and 2.5-3, respectively, and in Appendix 2-A. Monthly data for the Tenas Deposit station are presented for the years 2017, 2018 and 2019 in Tables 2.5-2, 2.5-3 and 2.5-4, respectively. Figures 2.5-1, 2.5-2 and 2.5-3 also include the temperature data from the ECCC Smithers A and Smithers AUTO stations. Note that ECCC Smithers A station is replaced by ECCC Smithers station in 2019 as daily data from the Smithers A station are unavailable after November 2018. The data presented for January 1 to September 29, 2017 incorporates the synthetic dataset developed for the period before the station was installed (see Section 2.4.3.4 for the methodology).

In 2017, temperatures at the Tenas Deposit Station location, ranged from -26.0°C (January 11, 2017) to 25.4°C (August 6, 2017). This annual range incorporates the synthetic dataset developed for the January 1 to September 29, 2017 period before the station was installed. In 2018, temperatures at the Tenas Deposit Station ranged from -24.7°C (January 11, 2018) to 31.8°C (July 29, 2018), and in 2019, it ranged from -22.6°C (February 2, 2019) to 20.2°C (August 5, 2019). In all years, temperatures were generally cooler at this station (993 masl) compared to the lower valley elevation airport stations (525 masl), except during temperature inversion conditions.

The temperature gap-filling methodology used for January 1, 2017 to September 29, 2017 data does not accurately account for temperature inversions. Between September 30, 2017 and December 9, 2019, there were 83 days that experienced temperature inversions with a difference of more than 1°C between the Tenas Deposit and Smithers airport AUTO stations.

The ECCC *Climate Trends and Variations Bulletin* (ECCC 2020b) reported that the 2017 annual average temperature of Pacific Coast Region winter was slightly warmer than the climate normal with +0.4°C departure (Table 2.5-5). Both 2018 and 2019, recorded higher departures of +1.0°C and +0.7°C, respectively. 2018 was the 12th warmest year recorded in the Pacific Coast Region in the last 72 years. In the smaller region of the Tenas Project and Bulkley Valley area, 2017 annual temperature was similar to the climate normal, while both 2018 and 2019 recorded positive departures by +0.5°C and +1.0°C, respectively.

Table 2.5-5. Temperature Departures for the Pacific Coast and Project Region

Year	Temperature Departure		
	Pacific Coast Region		Tenas Project Region
	Rank (Warmest to Coldest, out of 72 years) ^a	Departure (°C) ^b	Departure (°C) ^{b,c}
2017	29	+0.4	0
2018	12	+1.0	+0.5
2019	17	+0.7	+1.0

Notes:

Dash (-) = data not available at the time of reporting

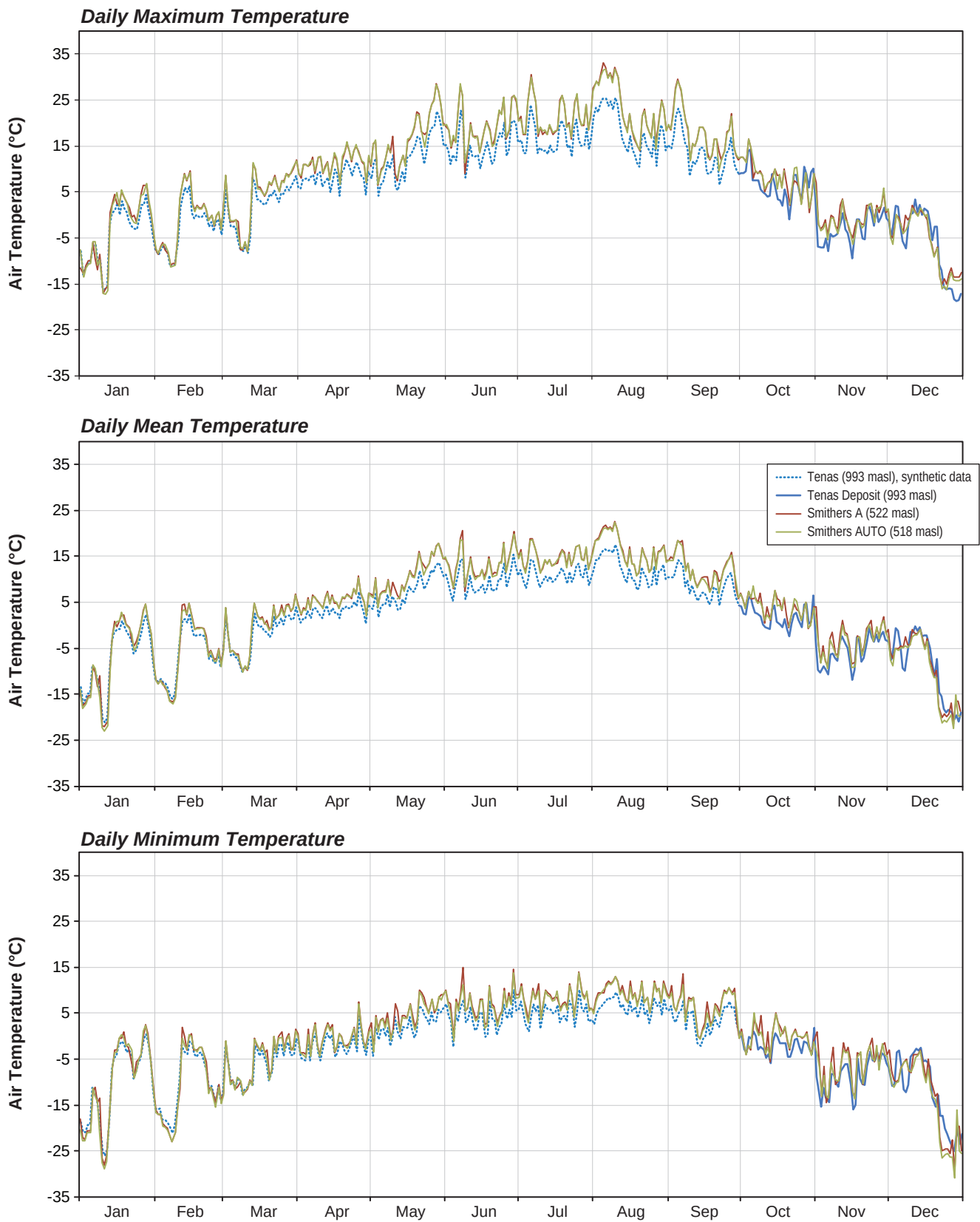
Data source: ECCC (2020b)

^a Ranked warmest to coldest. The rank is based on 72 years of data from 1948 to 2020.

^b The reference value used to calculate the departure is the mean value over the 1961 – 1990 reference period.

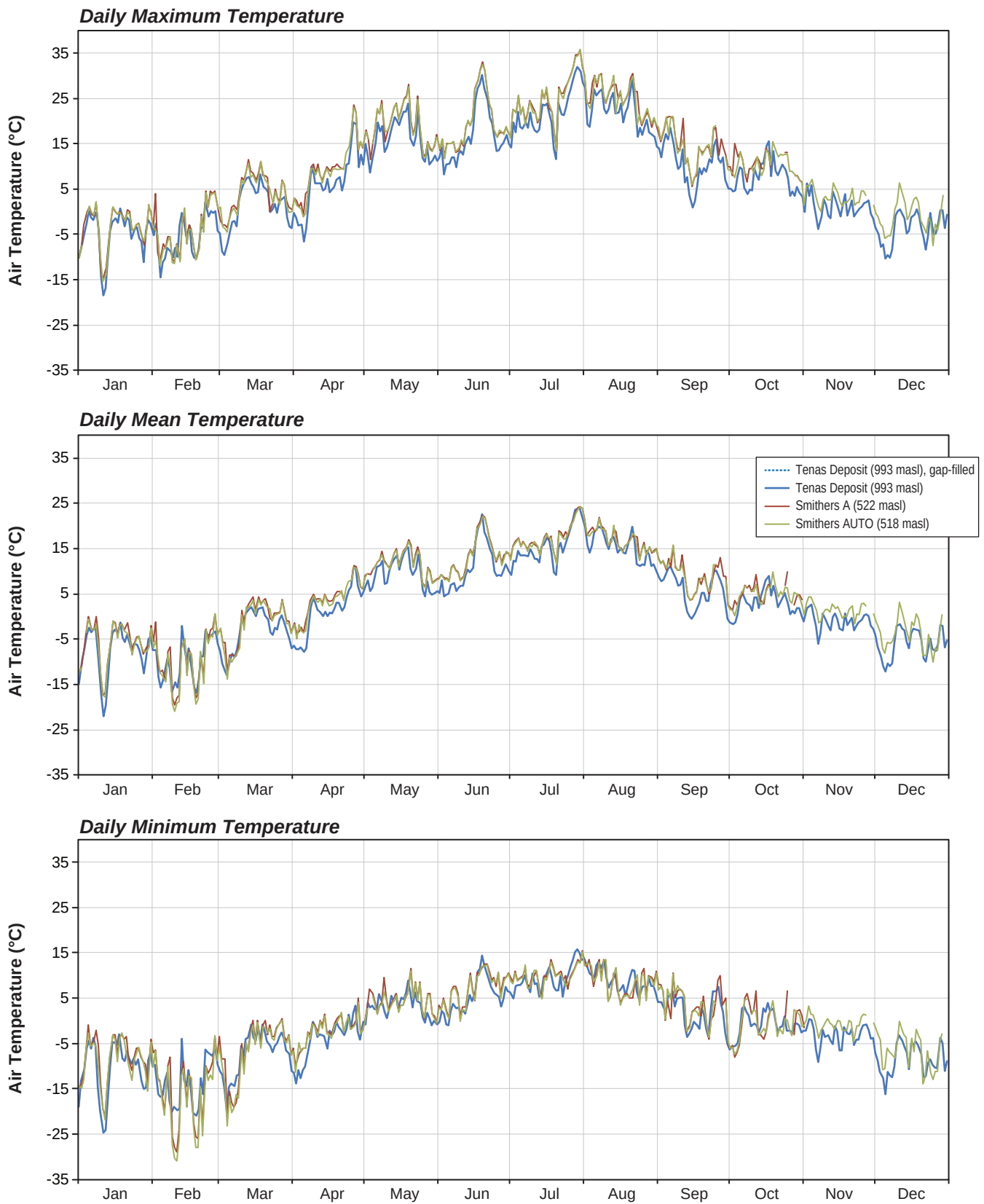
^c Interpreted from the bulletin's isotherm maps.

Figure 2.5-1
Daily Air Temperatures, 2017



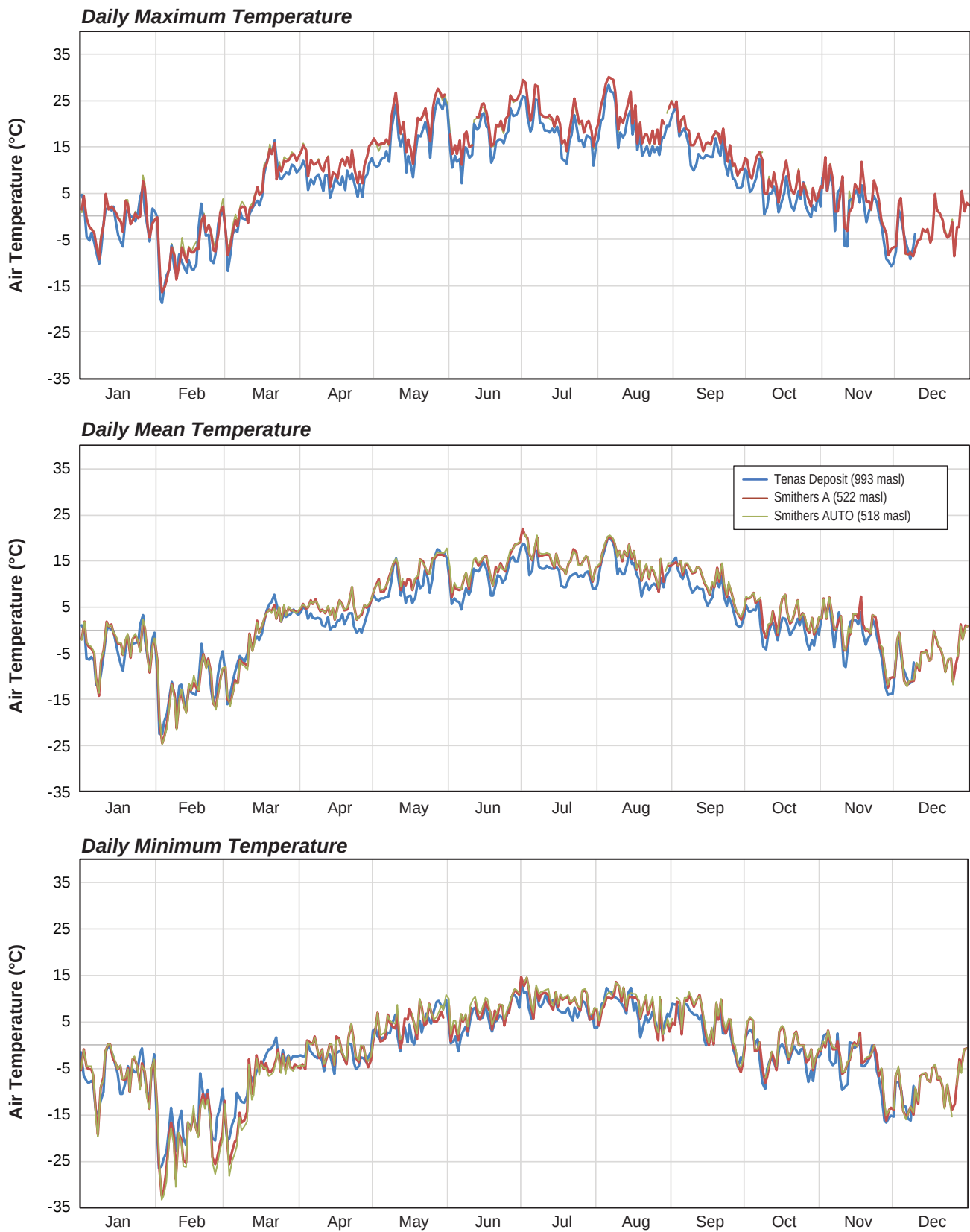
Note: See Table 2.5-1 for periods of unavailable data. Unavailable data have been gap-filled where possible using the methods described in Section 2.4.3.4.

Figure 2.5-2
Daily Air Temperatures, 2018



Note: See Table 2.5-1 for periods of missing data. Missing data have been gap-filled where possible using the methods described in Section 2.4.3.4.

Figure 2.5-3
Daily Air Temperatures, 2019



2.5.2 Precipitation

The daily gap-filled precipitation data for the Tenas Deposit station in 2017, 2018 and 2019 are presented in Figures 2.5-4, 2.5-5 and 2.5-6, respectively, and Appendix 2-A. The data presented for January 1 to September 29, 2017 incorporates the synthetic dataset developed for the period before the station was installed (see Section 2.4.3.4 for the methodology). Figures 2.5-4, 2.5-5 and 2.5-6 also include the daily precipitation data for the Smithers A and Smithers AUTO stations. Data from the ECCC Smithers station are used in 2019 since daily data from the Smithers A station are unavailable after November 2018. Monthly gap-filled precipitation data for the Tenas Deposit station in 2017, 2018 and 2019 are presented in Tables 2.5-2, 2.5-3 and 2.5-4, respectively. The top 10 daily precipitation intensities for all three stations in 2017, 2018 and 2019 are summarized in Tables 2.5-6, 2.5-7 and 2.5-8, respectively. The top 10 hourly and five-minute precipitation intensities for the Tenas Deposit station between September 30, 2017 and December 9, 2019 are summarized in Table 2.5-9.

Table 2.5-6. Top 10 Daily Precipitation Ranks, 2017

Rank	Tenas Deposit Station ^a		Smithers A Station		Smithers AUTO Station	
	Precipitation (mm)	Date	Precipitation (mm)	Date	Precipitation (mm)	Date
1	72.8	24-Oct-17	74.0	24-Oct-17	70.7	24-Oct-17
2	52.5	10-Sep-17	47.0	10-Sep-17	27.9	18-Nov-17
3	33.1	18-Nov-17	26.6	18-Nov-17	27.4	9-Jun-17
4	28.7	11-May-17	25.4	11-May-17	27.3	11-Sep-17
5	27.6	12-May-17	24.4	12-May-17	25.4	10-Sep-17
6	26.1	8-Jun-17	23.0	8-Jun-17	24.5	12-May-17
7	23.9	9-Jun-17	21.0	9-Jun-17	18.8	23-Oct-17
8	21.4	23-Oct-17	20.2	23-Oct-17	13.3	7-Nov-17
9	16.8	22-Nov-17	17.6	16-Oct-17	12.1	22-Nov-17
10	16.3	16-Oct-17	12.2	25-Nov-17	10.9	29-Sep-17

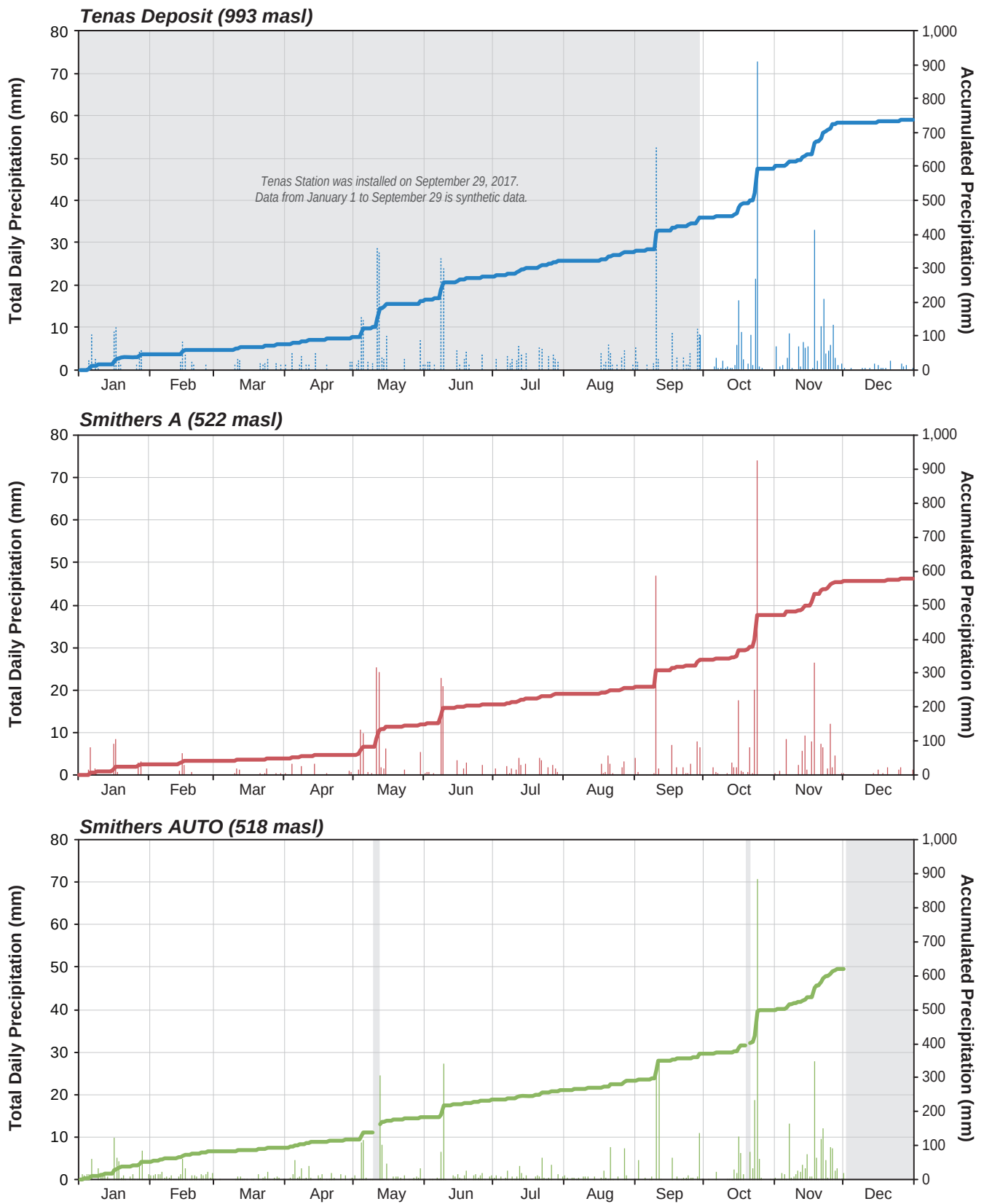
Note:

^a The Tenas Deposit daily precipitation data are gap-filled using the methodology described in Section 2.4.3.4. This includes the synthetic dataset developed for the period before the station was installed (January 1 to September 29, 2017).

Table 2.5-7. Top 10 Daily Precipitation Ranks, 2018

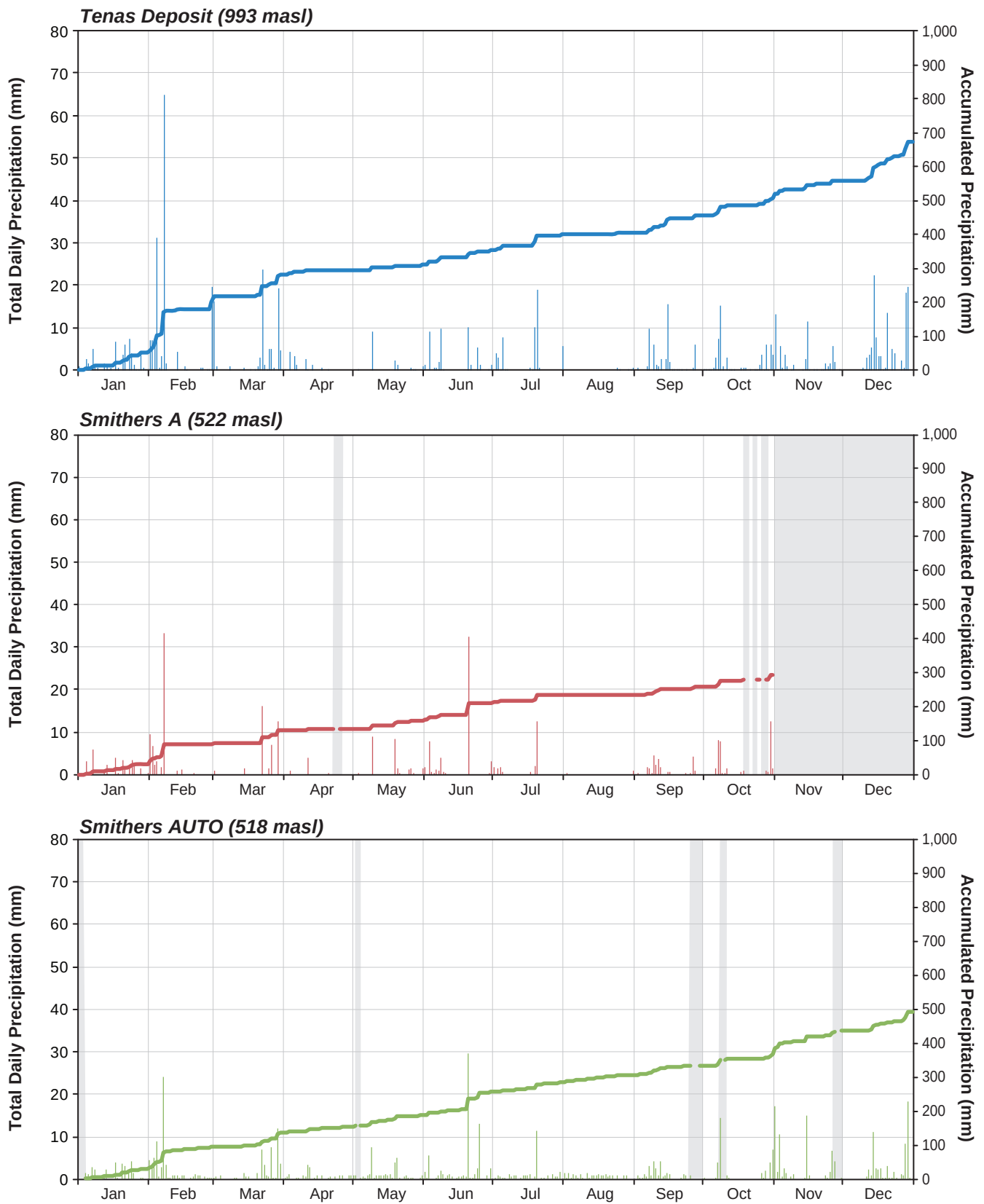
Rank	Tenas Deposit Station		Smithers A Station		Smithers AUTO Station	
	Precipitation (mm)	Date	Precipitation (mm)	Date	Precipitation (mm)	Date
1	65.0	7-Feb-18	17.4	1-Nov-18	29.7	20-Jun-18
2	31.2	4-Feb-18	16.3	15-Nov-18	24.0	7-Feb-18
3	23.6	22-Mar-18	16.1	8-Oct-18	18.2	29-Dec-18
4	22.4	14-Dec-18	15.2	25-Jun-18	17.3	1-Nov-18
5	19.7	29-Dec-18	12.5	20-Jul-18	15.0	15-Nov-18
6	19.6	28-Feb-18	11.2	3-Nov-18	14.3	8-Oct-18
7	19.2	29-Mar-18	10.3	23-Feb-18	13.1	25-Jun-18
8	19.0	20-Jul-18	9.9	29-Dec-18	11.9	29-Mar-18
9	18.3	28-Dec-18	9.4	17-Dec-18	11.3	20-Jul-18
10	16.2	1-Mar-18	8.2	9-May-18	11.1	14-Dec-18

Figure 2.5-4
Daily Precipitation, 2017



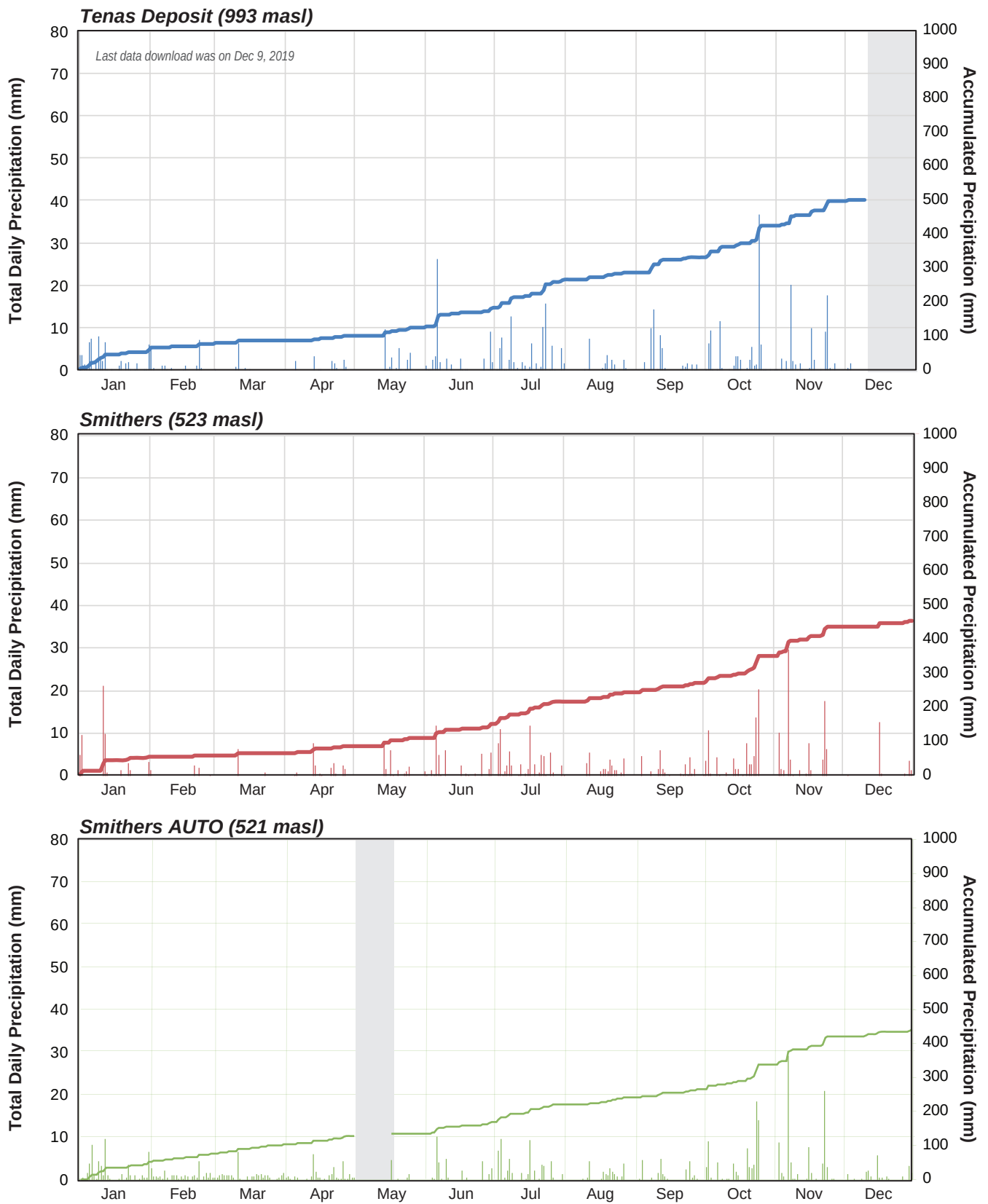
Note: Time periods in grey represent unavailable data. Unavailable data for the Tenas Deposit station have been gap-filled where possible with synthetic data using the methods described in Section 2.4.3.4. See Table 2.5-1 for periods of unavailable data.

Figure 2.5-5
Daily Precipitation, 2018



Note: Time periods in grey represent unavailable data.

Figure 2.5-6
Daily Precipitation, 2019



Note: Time periods in grey represent unavailable data.

Table 2.5-8. Top 10 Daily Precipitation Ranks, 2019^a

Rank	Tenas Deposit Station		Smithers Station ^b		Smithers AUTO Station	
	Precipitation (mm)	Date	Precipitation (mm)	Date	Precipitation (mm)	Date
1	36.7	24-Oct-19	29.6	7-Nov-19	29	7-Nov-19
2	26.1	6-Jun-19	21.1	11-Jan-19	20.8	23-Nov-19
3	20.1	7-Nov-19	20.3	25-Oct-19	18.5	24-Oct-19
4	17.8	23-Nov-19	17.6	23-Nov-19	14	25-Oct-19
5	15.7	23-Jul-19	13.7	24-Oct-19	10.2	6-Jun-19
6	14.2	8-Sep-19	12.7	17-Dec-19	9.6	4-Jul-19
7	12.6	8-Jul-19	11.9	6-Jun-19	9.5	12-Jan-19
8	11.7	7-Oct-19	11.7	17-Jul-19	9.2	17-Jul-19
9	10.3	22-Jul-19	11	4-Jul-19	9.1	3-Oct-19
10	10.0	7-Sep-19	10.6	3-Oct-19	8.6	3-Nov-19

Note:

^a The daily precipitation ranks include data up to December 9, 2019 as last field visit to the station was on December 10, 2019.

^b ECCC Smithers station is used in 2019 as daily data from Smithers A station are unavailable after November 2018.

Table 2.5-9. Top 10 Hourly and Five-Minute Precipitation Ranks, September 30, 2017 to December 9, 2019

Rank	Tenas Deposit Station ^a			
	Hourly Precipitation (mm)	Date and Time	Five-minute Precipitation (mm)	Date and Time
1	9.82	8-Jul-19 21:00	5.16	8-Jul-19 21:10
2	8.41	22-Jul-19 16:00	4.98	22-Jul-19 16:30
3	7.94	24-Oct-17 16:00	4.00	11-Sep-19 15:40
4	7.92	22-Nov-17 6:00	3.05	22-Jul-19 16:25
5	7.81	7-Feb-18 11:00	2.47	5-Jul-18 14:05
6	6.94	24-Oct-17 13:00	2.42	23-Jul-19 16:10
7	6.94	7-Sep-19 23:00	2.06	5-Jul-18 14:00
8	6.92	24-Oct-19 21:00	2.00	20-May-19 15:30
9	6.77	20-Jun-18 14:00	2.00	29-Jun-19 18:15
10	6.71	7-Feb-18 12:00	1.90	26-Jun-19 14:25

Notes:

All times are reported in Pacific Standard Time with no adjustment for daylight savings.

^a Tenas Deposit hourly and five-minute precipitation data are not gap-filled for data prior to October 1, 2017. Hourly and five-minute precipitation data are not available for the ECCC Smithers A, Smithers, and Smithers AUTO stations.

The 2017 annual precipitation at the Tenas Deposit station was estimated to be 739 mm, with 32% falling as snowfall and 68% falling as rainfall. This includes the synthetic dataset developed for the period before the station was installed. The highest observed monthly total precipitation was 147 mm during October 2017 and the lowest observed monthly total precipitation was 10 mm during December 2017.

In contrast, the 2018 annual precipitation at the Tenas Deposit station was measured to be 672 mm, with 71% falling as snowfall and 29% falling as rainfall. The highest observed monthly total

precipitation was 150 mm in February 2018 and the lowest observed monthly total precipitation was 1.8 mm in August 2018.

In 2019, the total precipitation up to December 9 was 500 mm, with 69% snowfall and 31% rainfall. The highest monthly total precipitation in 2019 (excluding December) was recorded in October (93 mm) and the lowest was recorded on March (8 mm).

In 2017, the highest observed daily precipitation at the Tenas Deposit station was 72.8 mm on October 24 (midnight to midnight). The Smithers A and Smithers AUTO stations both recorded record-breaking daily precipitation on this day (74.0 and 70.7 mm, respectively), and this event was the highest on record at the Smithers A station, with data spanning back to 1942. The previous record was 61 mm on January 16, 1947. This unusually high rainfall event had significant impacts on rivers (e.g., bank erosion) and infrastructure.

In 2018, the highest observed daily precipitation at the Tenas Deposit station was 65.0 mm on February 7 (midnight to midnight). The Smithers A and Smithers AUTO stations also received the greatest daily precipitation on February 7, 2018, with observed levels of 17.4 mm and 29.7 mm, respectively.

The highest daily precipitation in 2019 at the Tenas Deposit station was 36.7 mm recorded on October 24, while the ECCC Smithers and Smithers Auto stations received the highest daily precipitation in 2019 on November 7 (30 mm and 29 mm, respectively; Table 2.5-8).

Between September 30, 2017 and December 9, 2019, the highest observed hourly total precipitation at the Tenas Deposit station was recorded as 9.82 mm on July 8, 2019, and the highest five-minute total precipitation was recorded as 2.5 mm on the same day (July 8, 2019; Table 2.5-9).

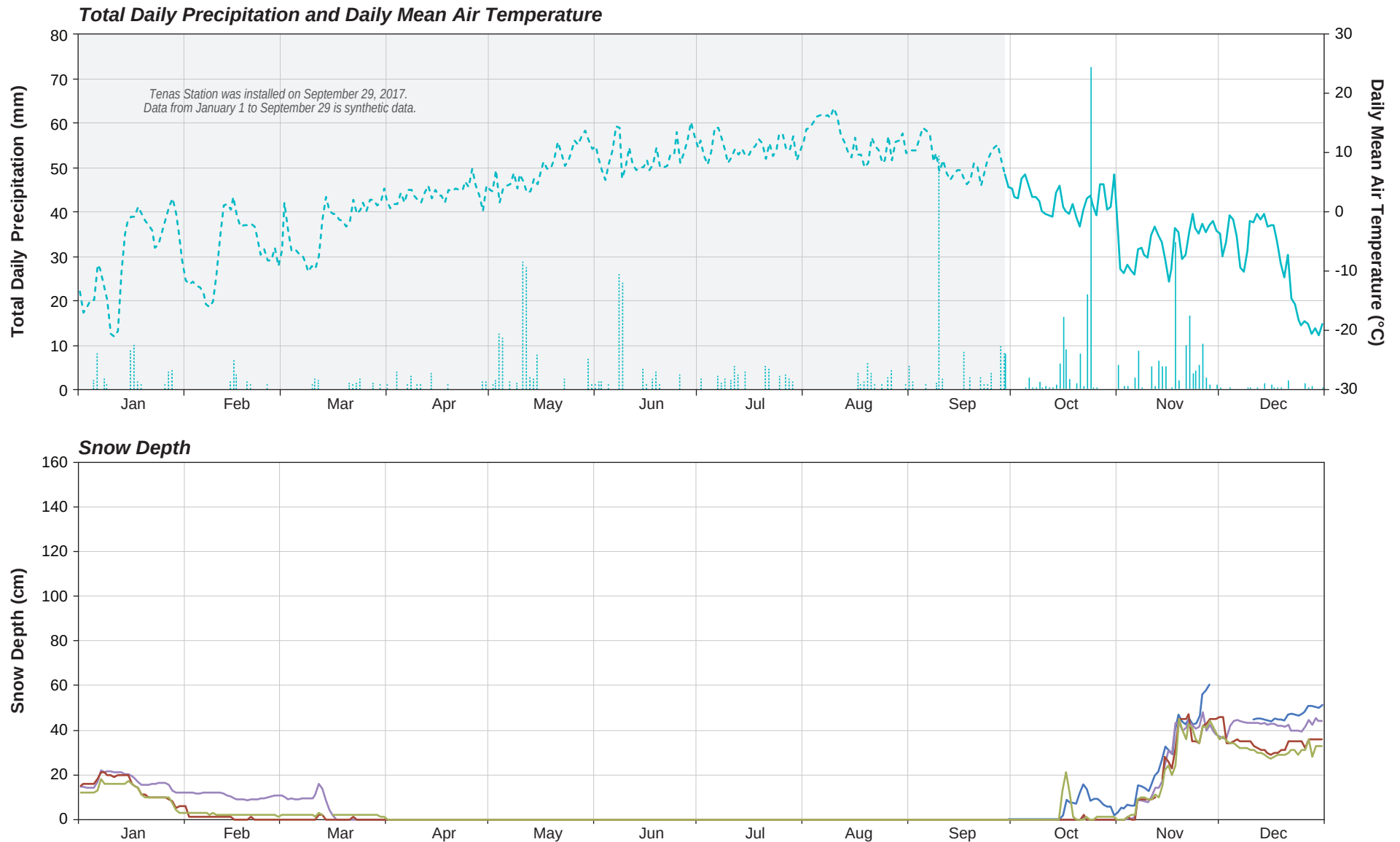
2.5.3 Snow Depth and Snow-Water-Equivalent

The daily mean snow depth data for the Tenas Deposit station in 2017, 2018 and 2019 are presented in Figures 2.5-7, 2.5-8, and 2.5-9 respectively. Monthly mean snow depths in 2017, 2018 and 2019 are presented in Tables 2.5-2, 2.5-3 and 2.5-4, respectively. Figures 2.5-7, 2.5-8, and 2.5-9 also include the daily mean snow depth data for the Smithers A and Smithers AUTO stations, and the daily temperature and precipitation data for the Tenas Deposit station.

At the Tenas Deposit station, the snowpack usually began to accumulate between mid to late October (October 16, 2017, October 28, 2018 and October 24, 2019) and melted in early May (May 10, 2018 and May 3, 2019). The snowpack peaked at 148.5 cm on March 30, 2018 in the 2017/2018 winter and at 82.6 cm on February 28, 2019 in the 2018/2019 winter.

The highest daily snowpack depth at the Smithers A station was 103 cm on February 8, 2017. This snowpack depth was the highest on record at the Smithers A station, with data spanning back to 1942. The previous record was 102 cm on March 3, 1972. The unusually deep snowpack in winter 2017/2018 resulted in numerous residential and commercial building roof collapses in Smithers and Telkwa.

Figure 2.5-7
Daily Mean Snow Depth, 2017



Note: Time periods in grey represent unavailable data. Unavailable data for the Tenas Deposit station have been gap-filled where possible with synthetic data (dashed lines) using the methods described in Section 2.4.3.4. See Table 2.5-1 for periods of unavailable data.

Figure 2.5-8
Daily Mean Snow Depth, 2018

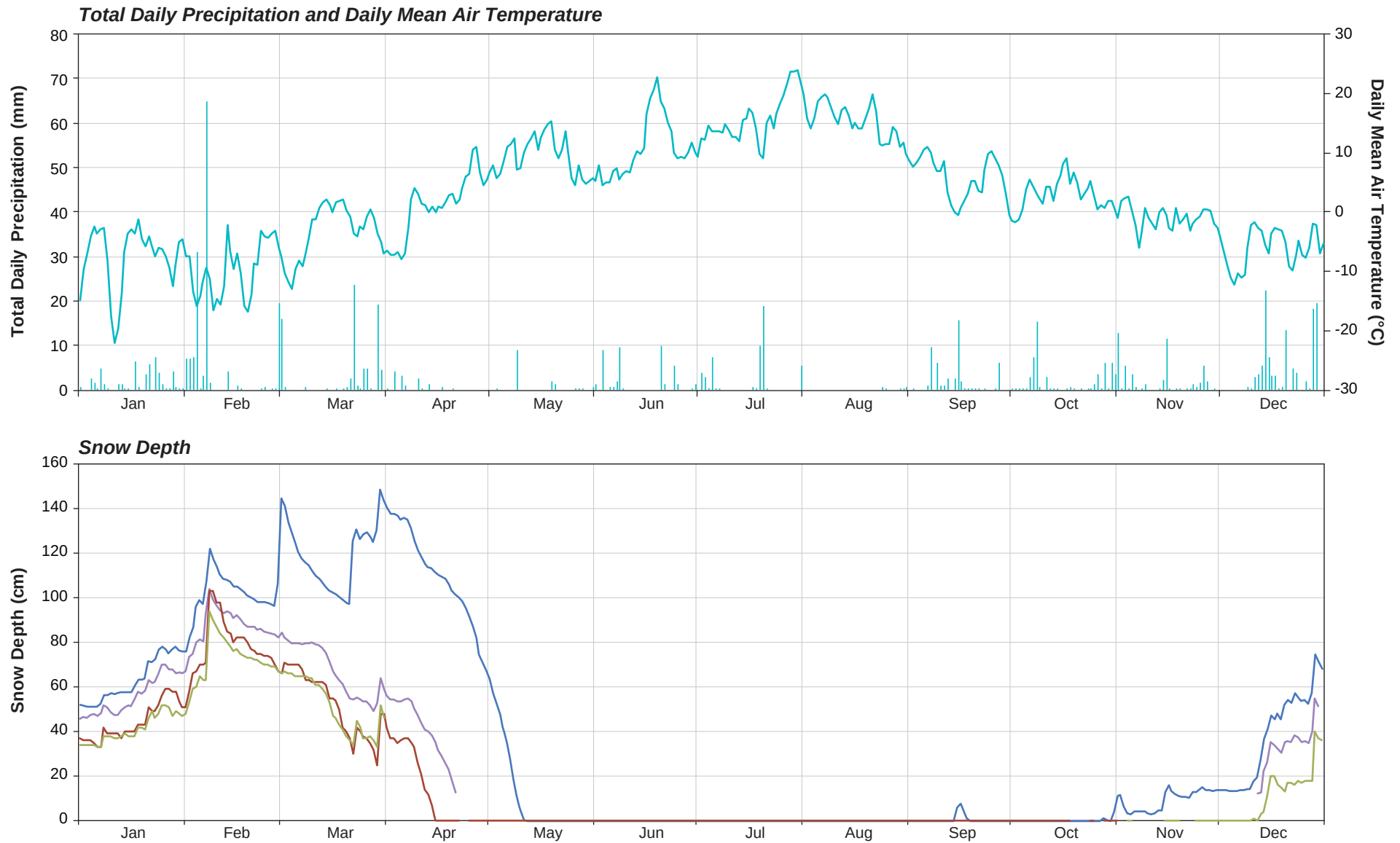
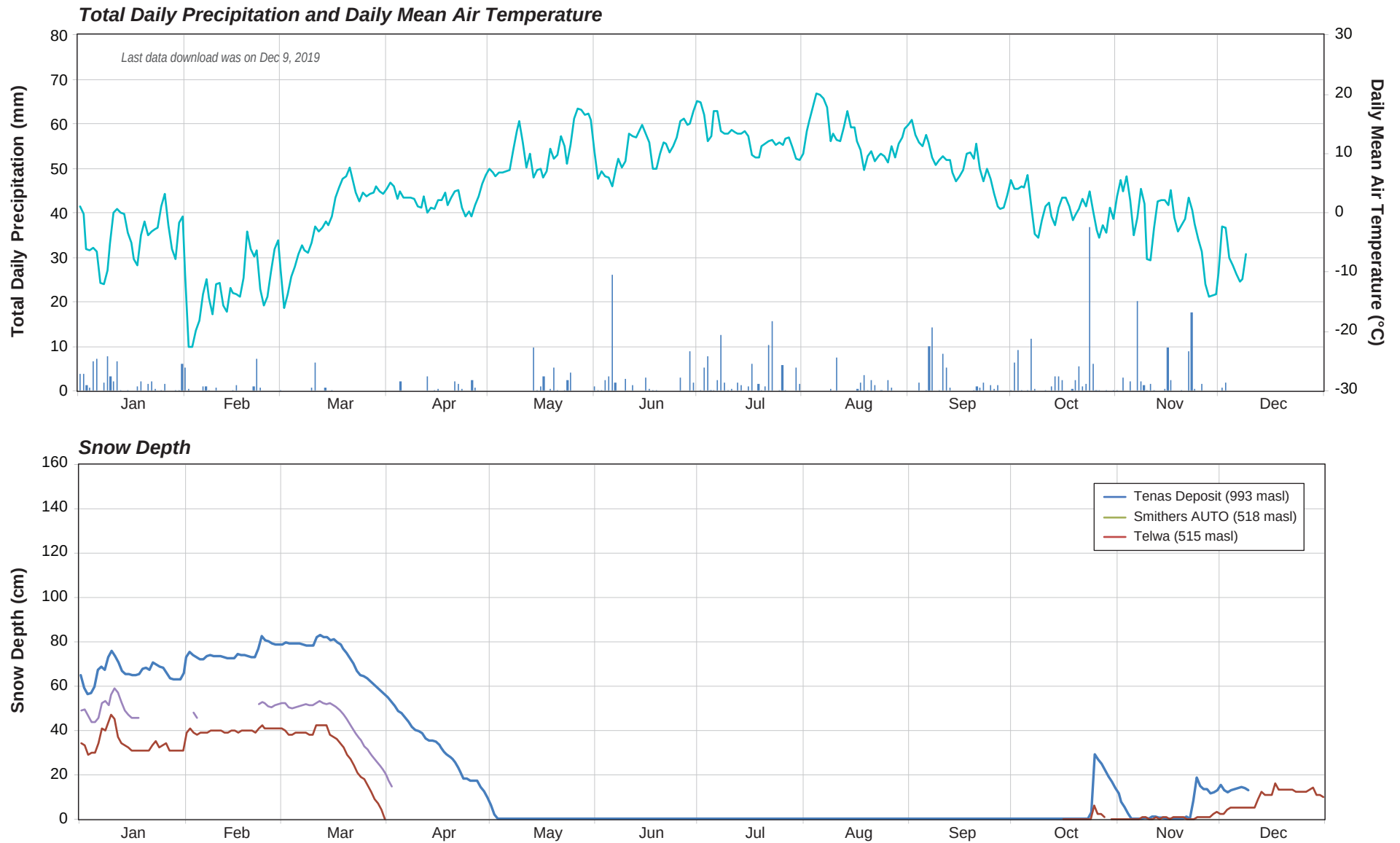


Figure 2.5-9
Daily Mean Snow Depth, 2019



The snowpack at the Tenas Deposit station does not have a large potential to be redistributed by the wind as the general surrounding area is forested and the recorded wind speeds are low. Therefore the snowpack depths are representative of the general Project area.

Manual snow course surveys are completed on a monthly basis at the BC ENV Hudson Bay Mtn. snow course survey station (Table 2.4-1, Figure 2.4-1). This station is located 20 km north-northwest of the Tenas Deposit station and 370 m higher in elevation. The 2017, 2018 and 2019 data from this snow course survey station are presented in Table 2.5-10. Based on the concurrent measurements recorded between January and June, the snow depth at the Hudson Bay Mtn. snow course station was approximately 51 cm and 66 cm deeper on average compared to the Tenas Deposit station in 2018 and 2019, respectively. In 2017, the snowpack's SWE peaked at 443 mm during the May 2, 2017 measurement. In 2018, the snowpack's SWE peaked at 585 mm during the April 25, 2018 measurement, and in 2019, the snowpack's SWE peaked at 478 mm during the May 1, 2019 measurement.

Table 2.5-10. Hudson Bay Mtn. Manual Snow Course Survey Data

Sampling Date	Snowpack Depth (cm)	Snowpack SWE (mm)	Snowpack Density (%)	Snowpack Snow Water Equivalent % of Normal	Snowpack Depth at Tenas Deposit Meteorological Station (cm)
January 4, 2017	82	218	27	83	-
January 30, 2017	128	326	25	90	-
March 1, 2017	120	369	31	83	-
March 30, 2017	134	408	30	82	-
May 2, 2017	126	443	35	87	-
June 1, 2017	25	76	30	29	-
January 4, 2018	93	286	31	108	51.1
January 29, 2018	123	364	30	101	78.0
February 28, 2018	149	478	32	108	106.5
March 28, 2018	174	530	30	106	124.9
April 25, 2018	162	585	36	115	91.5
May 11, 2018	92	398	43	94	0.13
June 1, 2018	23	106	46	41	0.00
January 3, 2019	104	274	26	104	56.3
February 4, 2019	133	363	27	101	72.8
February 28, 2019	135	419	31	95	78.4
March 27, 2019	119	425	36	85	61.8
May 1, 2019	117	478	41	94	6.4
May 16, 2019	62	279	45	66	0
May 29, 2019	0	0	-	-	0
June 19, 2019	0	0	-	-	0

Notes:

Dash (-) = data not available at time of reporting

SWE = Snow-water-equivalent

Snow Course Survey Data Source: BC ENV (2020b)

The Hudson Bay Mtn. snow course survey station is 20 km north-northwest of the Tenas Deposit meteorological station, and at 370 m higher elevation.

2.5.4 Wind Speed and Direction

The 2017 seasonal wind roses and wind speed frequency distributions at the Tenas Deposit (October to December), Smithers AUTO and Telkwa stations (January to December) are presented in Figures 2.5-10, 2.5-11 and 2.5-12, respectively. Similarly, Figures 2.5-13, 2.5-14, and 2.5-15 present the 2018 seasonal wind roses and wind speed frequency distributions at the Tenas Deposit, Smithers AUTO and Telkwa stations, respectively, and Figures 2.5-16, 2.5-17, and 2.5-18 present the 2019 seasonal wind roses and wind speed frequency distributions at the Tenas Deposit, Smithers AUTO and Telkwa stations, respectively. Concurrent wind roses from these stations are mapped on Figure 2.5-19 (2017 data), Figure 2.5-20 (2018 data) and 2.5-21 (2019 data). Daily wind speed data for the Tenas Deposit station are presented in Appendix 2-A, and monthly data are presented in Table 2.5-2 (2017 monthly data), Table 2.5-3 (2018 monthly data), and Table 2.5-4 (2019 monthly data).

Based on data from October 2017 to November 2019, winds at the Tenas Deposit station predominately came from the southwest (traveling down the Tenas Creek drainage basin). Wind speeds were mostly less than 2 m/s (winds under 2 m/s occurred ~73% of the time in 2019). During the same periods, the winds at the Smithers AUTO and Telkwa stations were predominantly travelling down the Bulkley Valley axis (from the southeast at Smithers AUTO and from the east-southeast at Telkwa). Wind speeds at these two stations were also predominantly low (less than 2 m/s).

The maximum hourly mean wind speed recorded at the Tenas Deposit station was 5.4 m/s in 2017, 6.3 m/s in 2018 and 5.3 m/s in 2019 (up to December 9, 2019). The maximum instantaneous wind gust speed was 13.3 m/s in 2017, 14.9 m/s in 2018 and 13.4 m/s in 2019.

The Telkwa station had a mean wind speed of 1.7 m/s in 2018 and 1.6 m/s in 2019, with a maximum hourly wind speed of 6.7 m/s in 2018 and 6.8 m/s in 2019. The Smithers AUTO station had an average wind speed of 1.7 (1.6) m/s in 2018 (2019), with a maximum hourly wind speed of 10.6 (8.3) m/s.

2.5.5 Solar Radiation

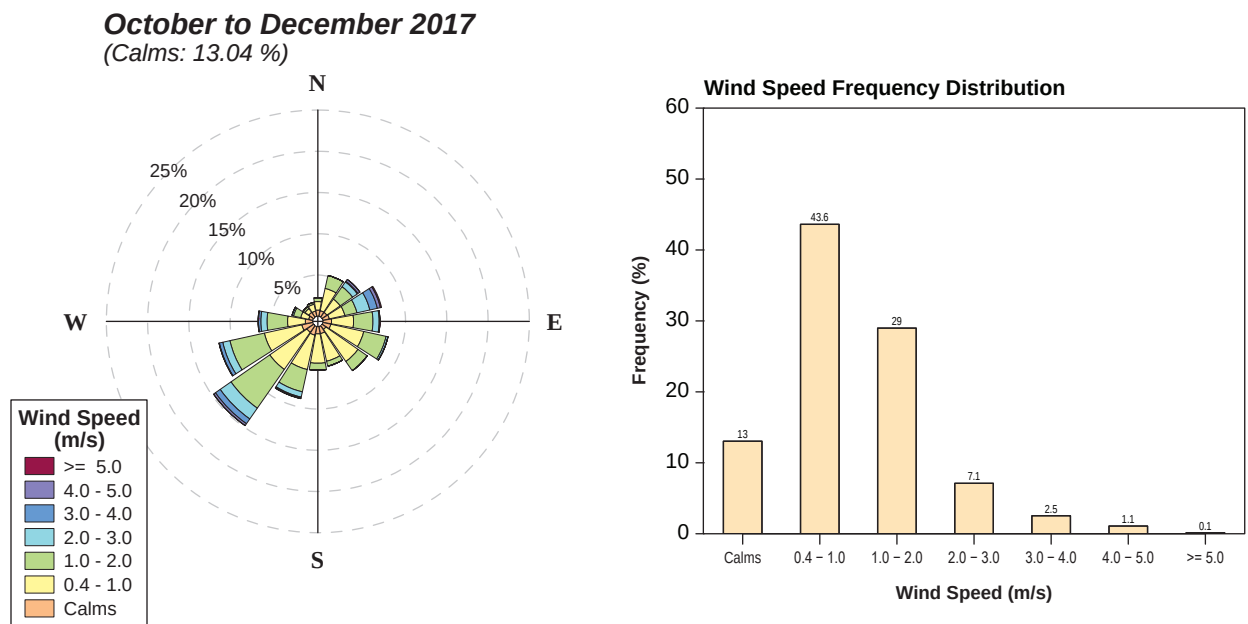
The daily mean solar radiation for the Tenas Deposit station between September 30, 2017 and December 9, 2019 is presented in Figures 2.5-22, 2.5-23, and 2.5-24, and Appendix 2-A. Monthly data for the Tenas Deposit station in 2017, 2018 and 2019 are presented in Tables 2.5-2, 2.5-3 and 2.5-4, respectively. As described in Table 2.5-1, there were many periods of erroneous solar radiation data removed from the dataset due to snow accumulation on top of the sensor, resulting in measurement values that were much lower than actual conditions. This is a common challenge in the winter for stations that rely on off-grid power, experience low wind speeds, and are unattended.

During the September 30, 2017 to December 9, 2019 reporting period, the maximum daily mean solar radiation was 351 W/m² (June 26, 2018) and the maximum hourly mean solar radiation was 956 W/m² (July 10, 2018).

Incoming solar radiation has diurnal and annual cycles and is primarily dependant on the sun's position in the sky, followed by cloud cover and the local horizon angle profile. Solar radiation is lowest at nighttime (zero W/m²) and highest during the daytime. It is lower during the winter, and mornings and evenings, and higher during the summer and at midday.

Figure 2.5-10

**Tenas Station Wind Rose and Wind Speed Frequency Distribution,
October to December 2017**



Note: See Table 2.5-1 for periods of unavailable data. Wind rose petals represent the direction the wind is coming from.

Figure 2.5-11

Smithers AUTO Station Wind Rose and Wind Speed Frequency Distribution, 2017

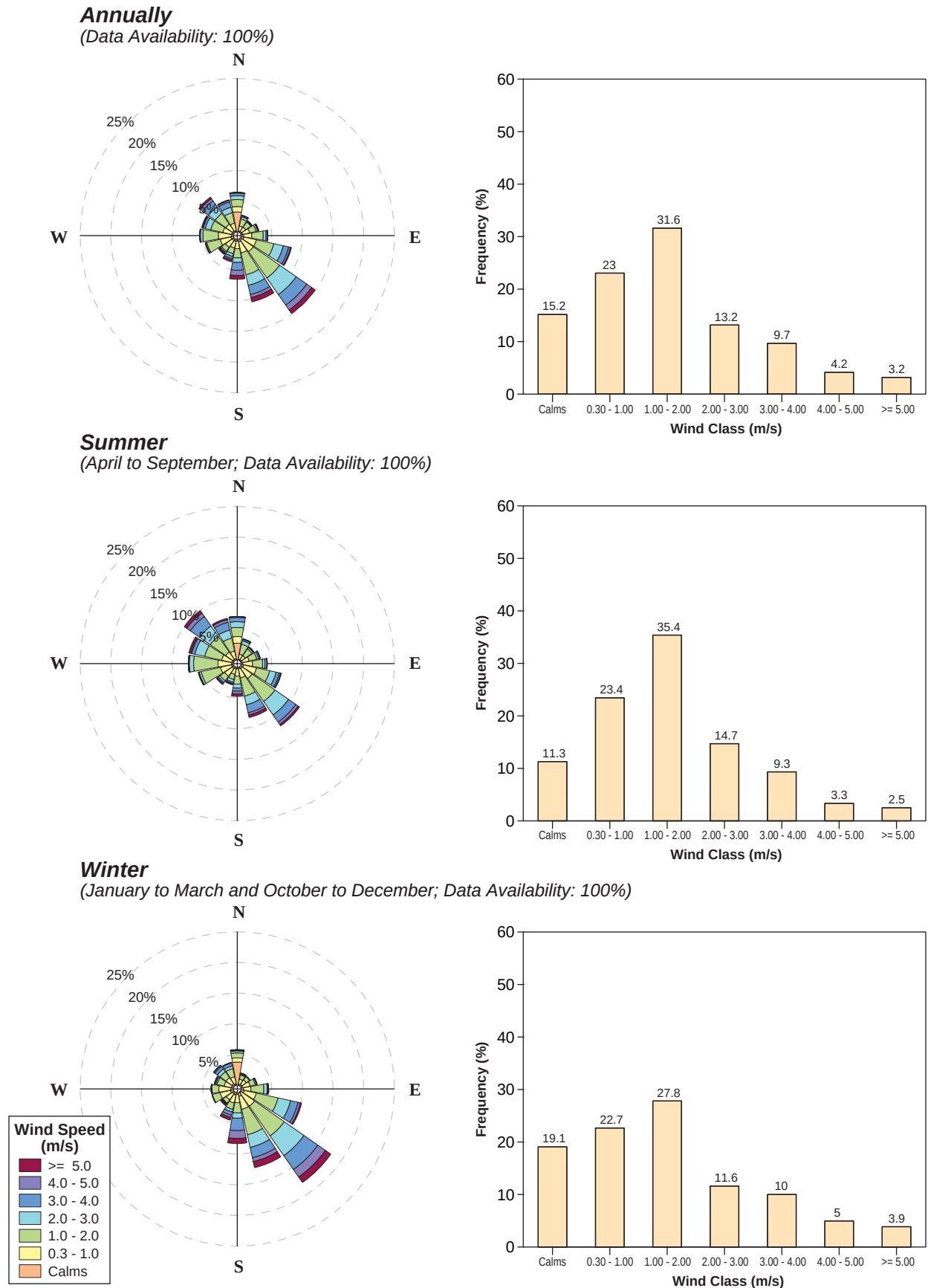


Figure 2.5-12

Telkwa Station Wind Rose and Wind Speed Frequency Distribution, 2018

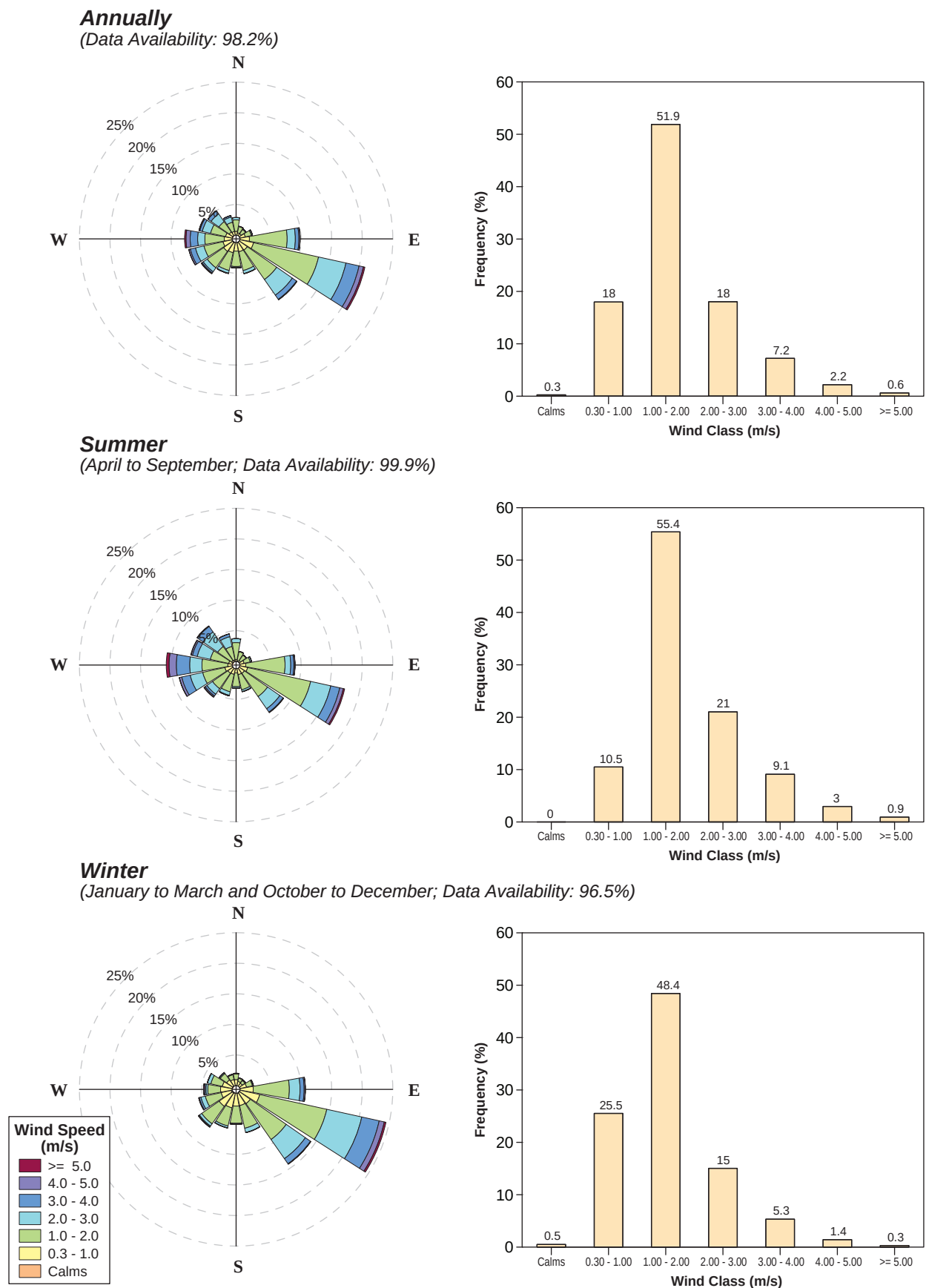
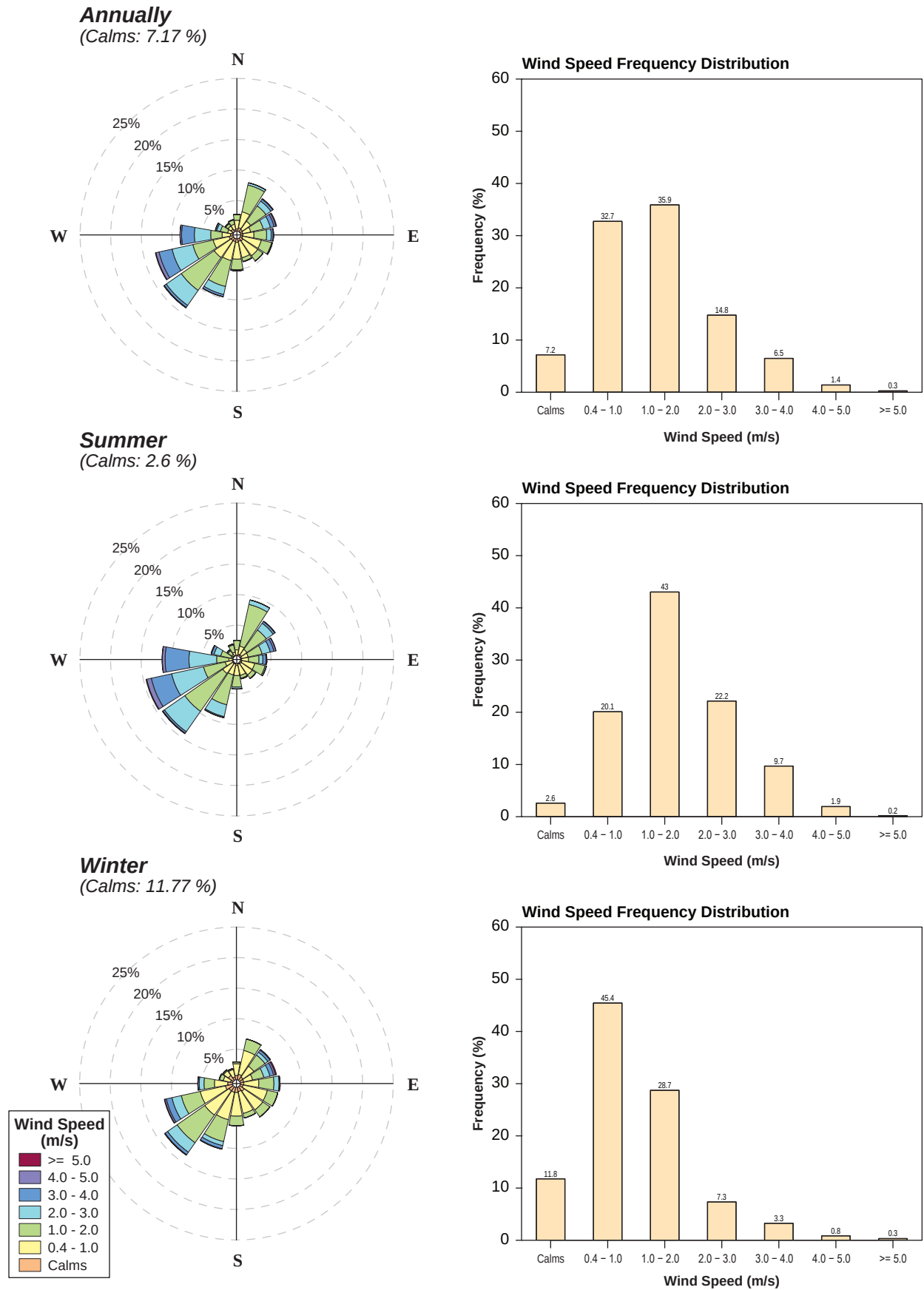


Figure 2.5-13

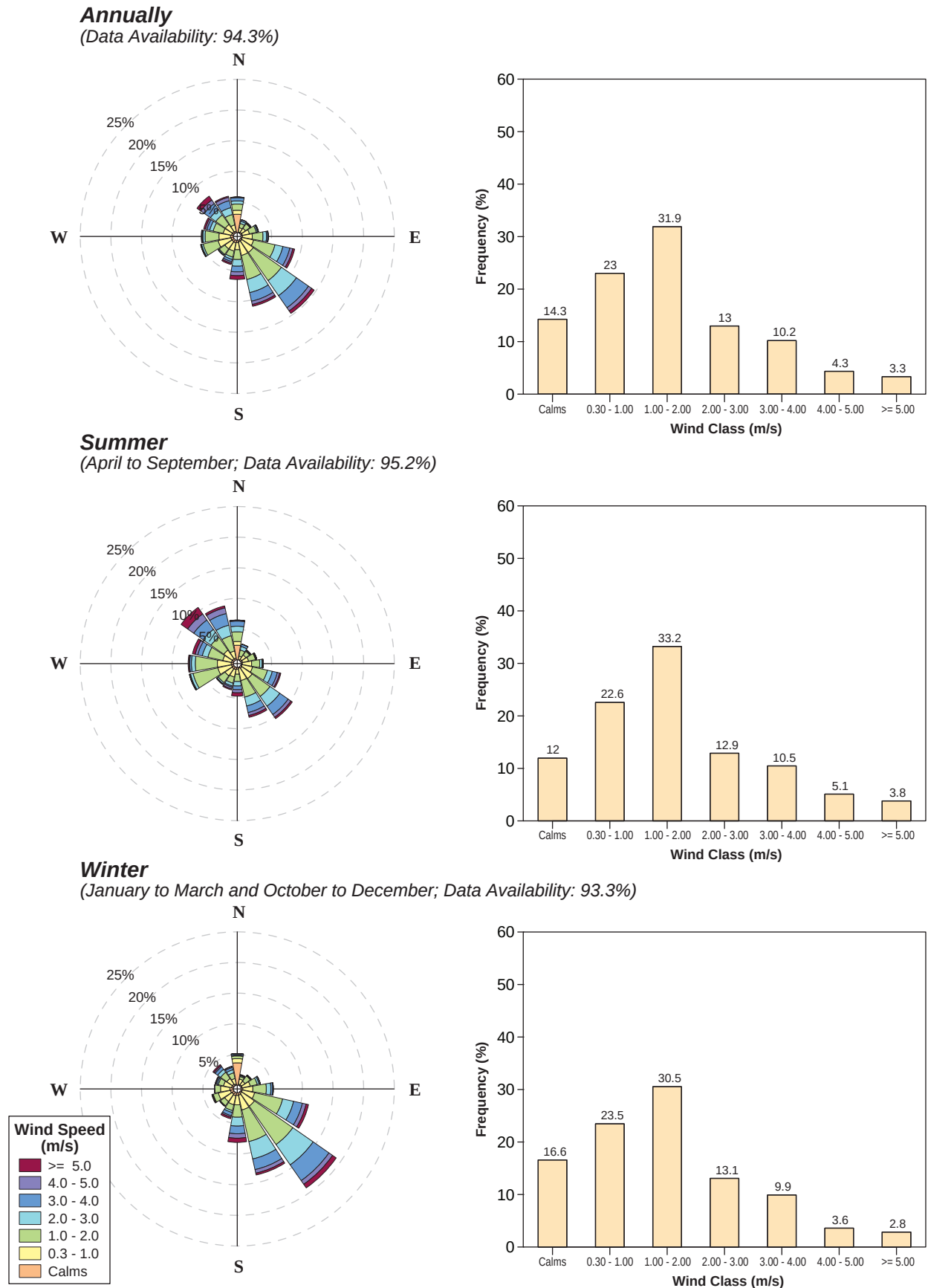
Tenas Station Wind Rose and Wind Speed Frequency Distribution, 2018



Note: See Table 2.5-1 for periods of unavailable data. Wind rose petals represent the direction the wind is coming from.

Figure 2.5-14

Smithers AUTO Station Wind Rose and Wind Speed Frequency Distribution, 2018



Note: Wind rose petals represent the direction the wind is coming from.

Figure 2.5-15

Telkwa Station Wind Rose and Wind Speed Frequency Distribution, 2018

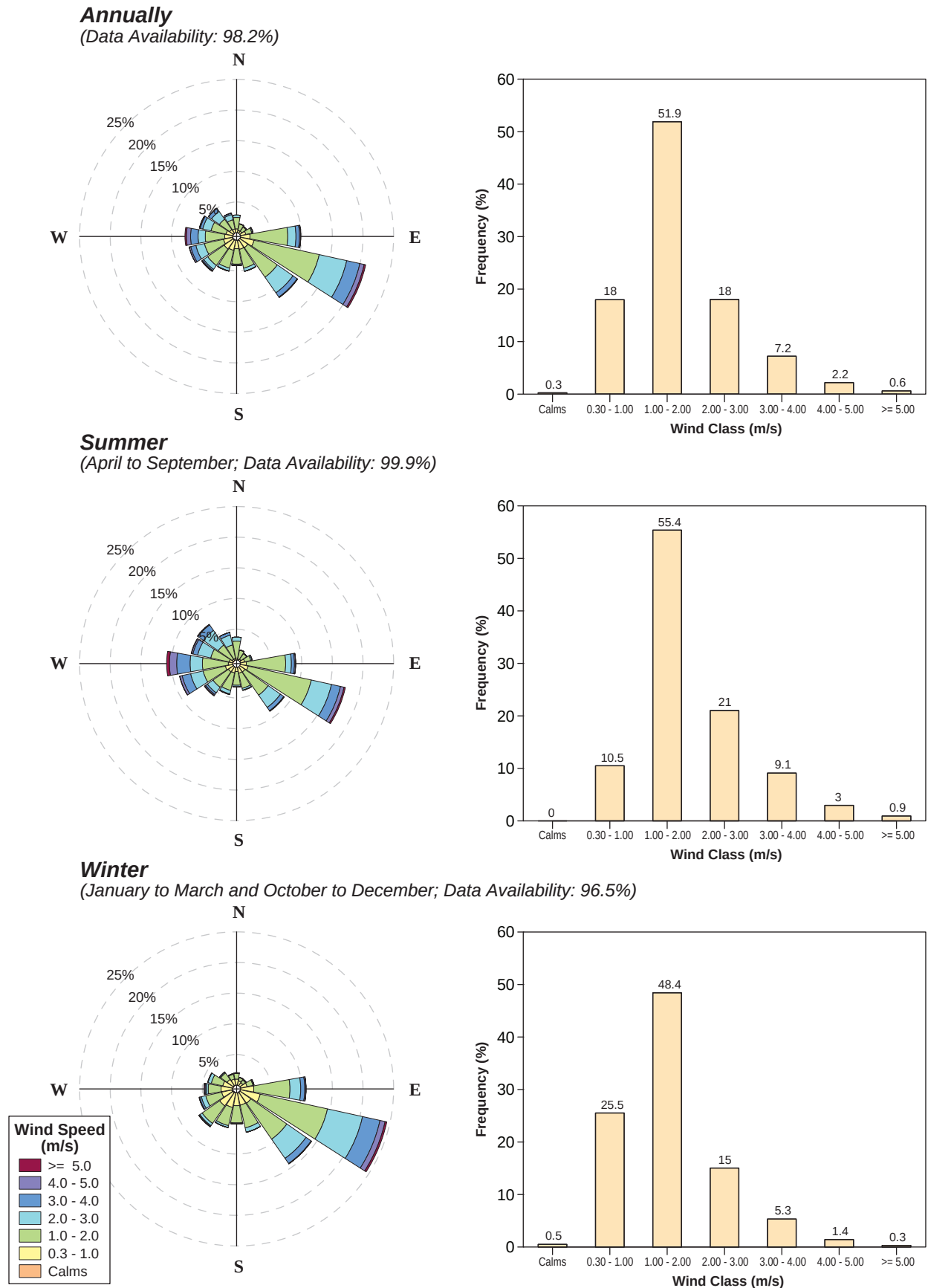


Figure 2.5-16

Tenas Station Wind Rose and Wind Speed Frequency Distribution, 2019

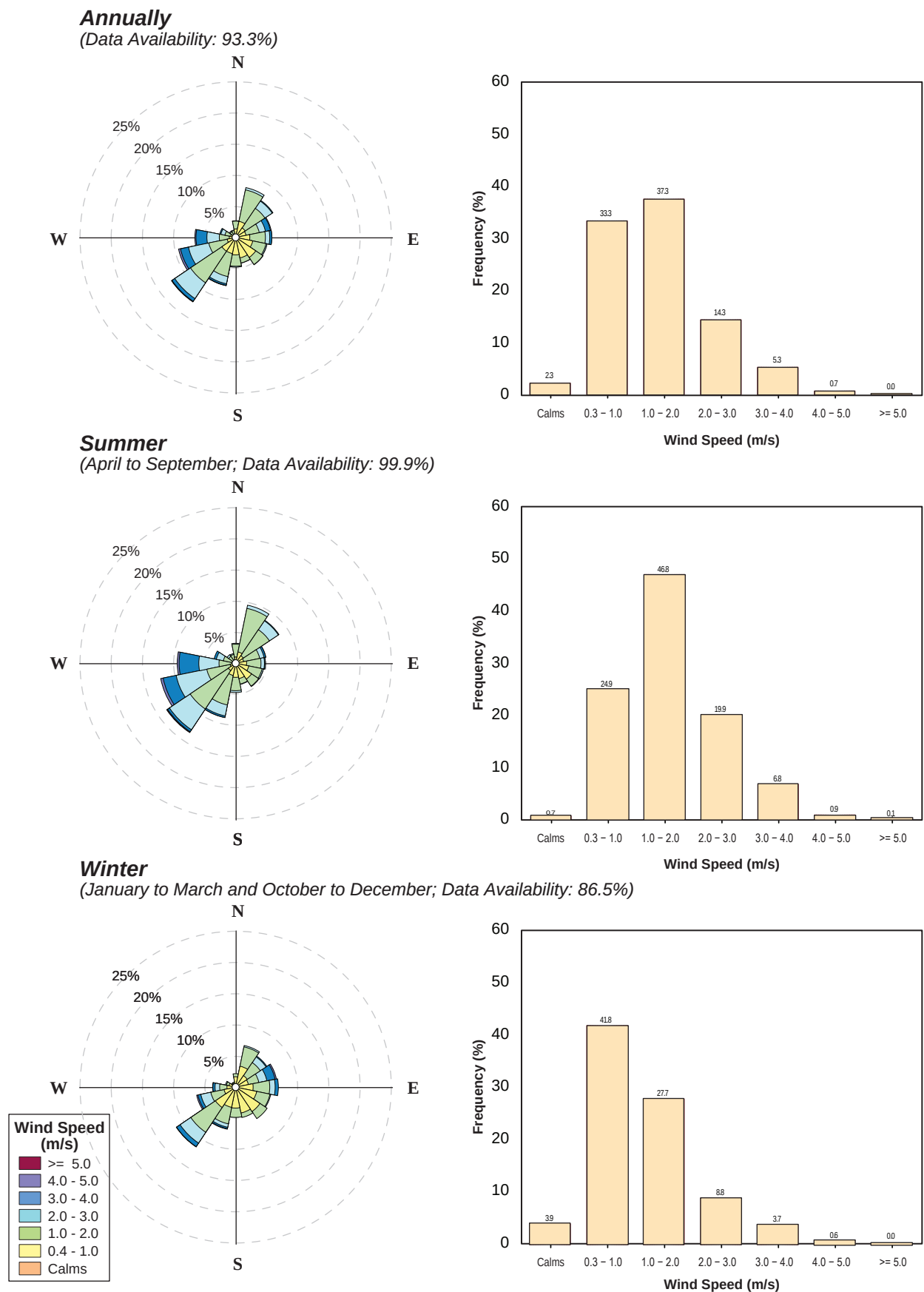


Figure 2.5-17

Smithers AUTO Station Wind Rose and Wind Speed Frequency Distribution, 2019

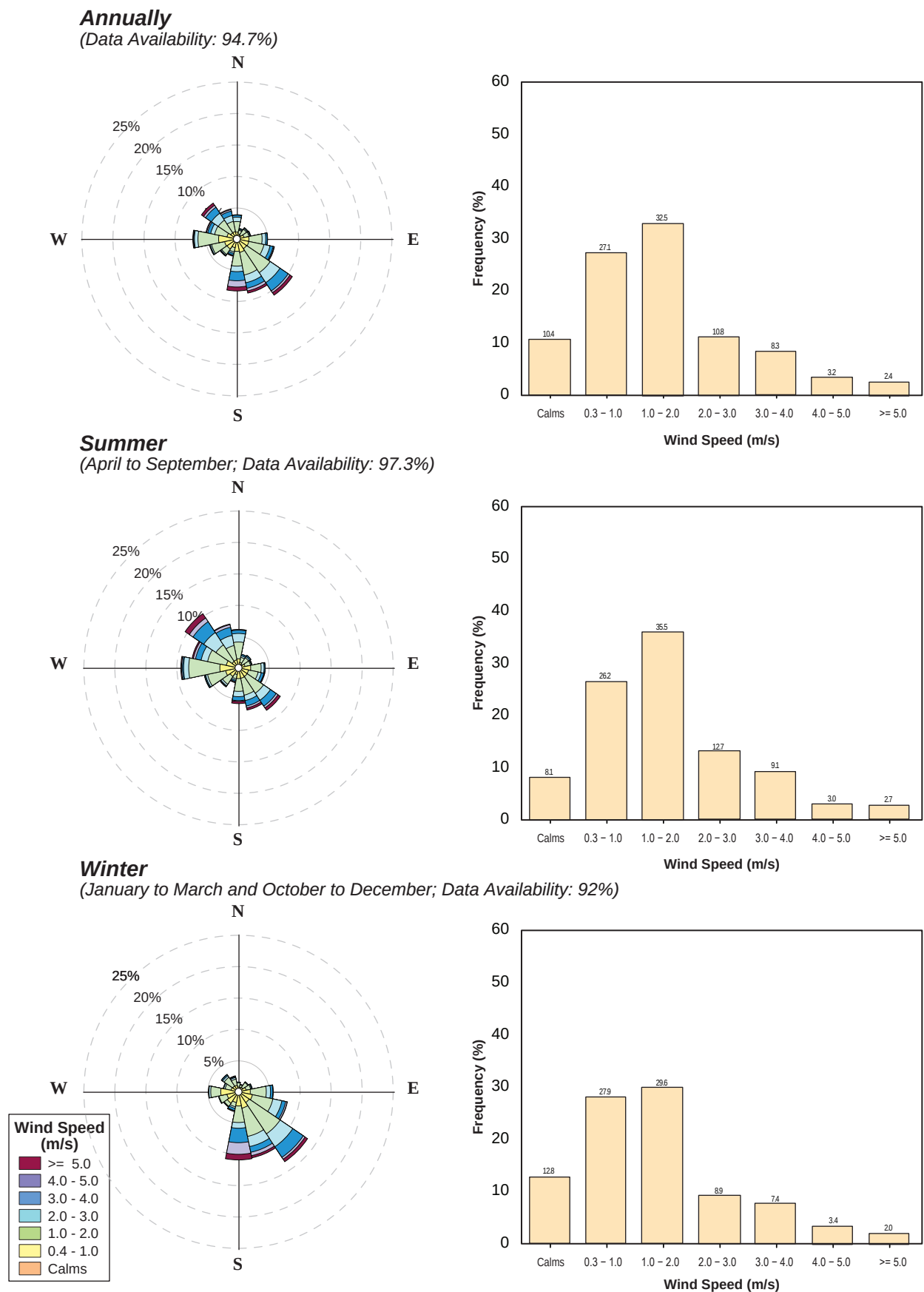
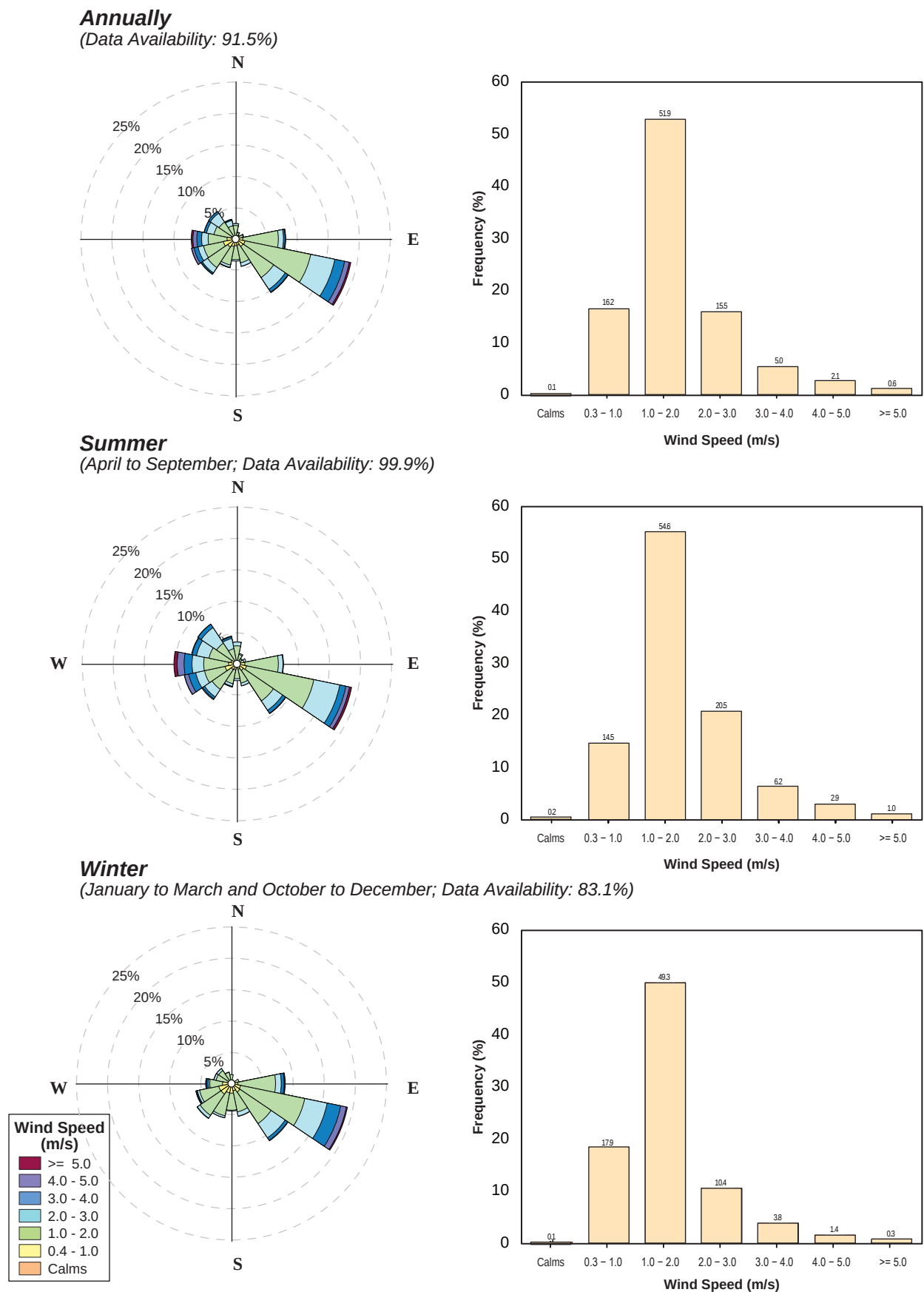


Figure 2.5-18

Telkwa Station Wind Rose and Wind Speed Frequency Distribution, 2019



2.5.6 Barometric Pressure

The daily mean station level barometric pressure for the Tenas Deposit station between September 30, 2017 and December 9, 2019 is presented in Figures 2.5-25, 2.5-26 and 2.5-27, and Appendix 2-A. Monthly data for the Tenas Deposit station in 2017, 2018 and 2019 are presented in Tables 2.5-2, 2.5-3 and 2.5-4, respectively. Figures 2.5-25, 2.5-26 and 2.5-27 also include data from the ECCC Smithers AUTO station.

During the September 30, 2017 to December 9, 2019 reporting period, the hourly mean station-level barometric pressure remained between 87 and 92 kPa at the Tenas Deposit station. Based on the Smithers AUTO station data, during the fall and winter months, pressure generally shows more fluctuations compared to the spring and summer, due to winter storms from the Pacific that are more frequent and intense during the fall and winter.

Generally, low and decreasing pressure indicates current or approaching adverse weather, and high and increasing pressure indicates current or approaching favorable weather. Because barometric pressure changes slowly over time and horizontal distance compared to other meteorological parameters, sea level barometric pressure in a region (i.e., tens of km, horizontally) is approximately the same at a given time. Absolute pressure (station-level pressure), however, is variable over the Project area because it is directly dependent on elevation differences.

Figure 2.5-19
Wind Roses for Tenas Deposit (October to December 2017) and
Smithers AUTO and Telkwa (January to December 2017)

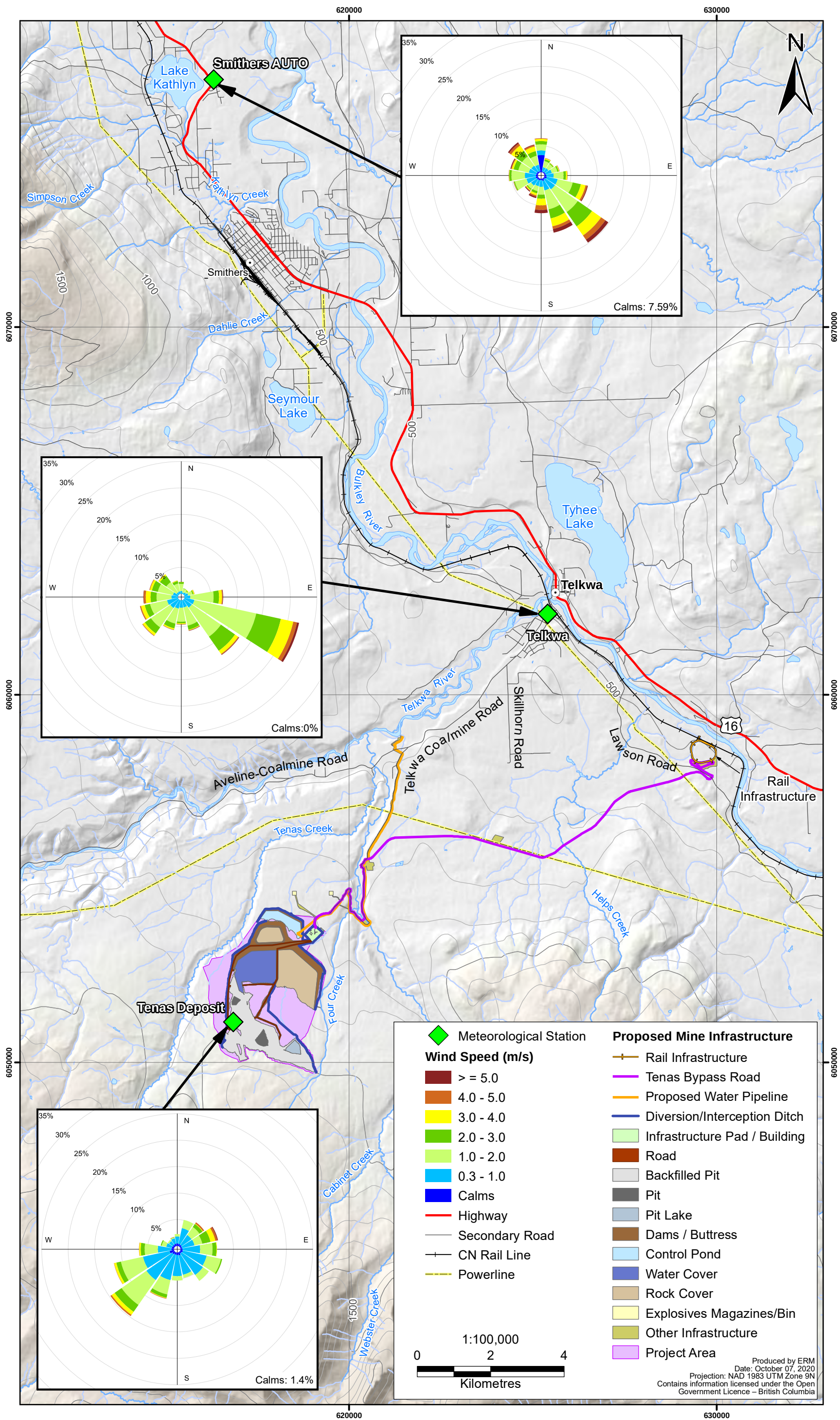


Figure 2.5-20

Wind Roses for Tenas Deposit, Smithers AUTO, and Telkwa, 2018

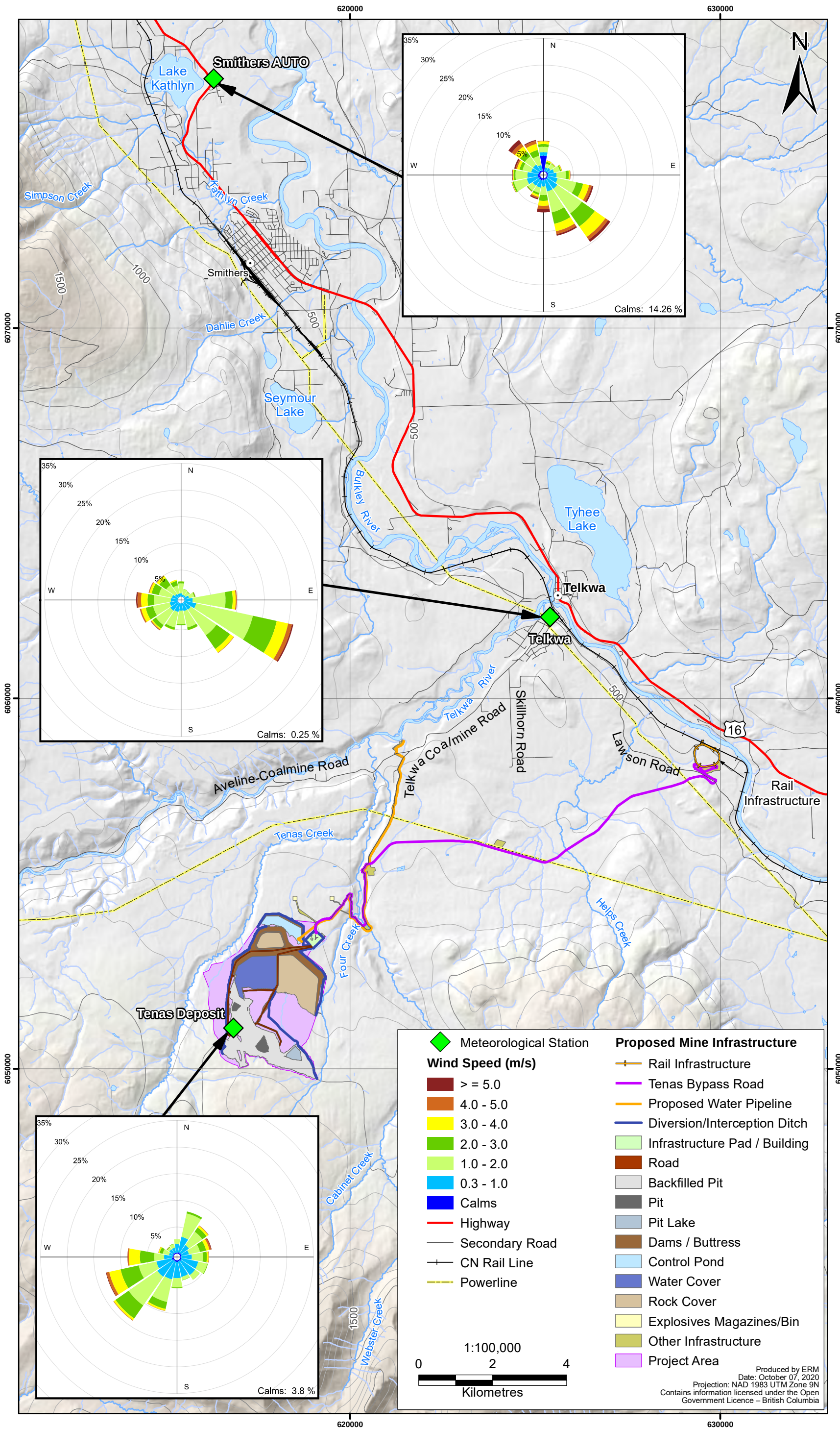


Figure 2.5-21
Wind Roses for Tenas Deposit, Smithers AUTO and Telkwa, 2019

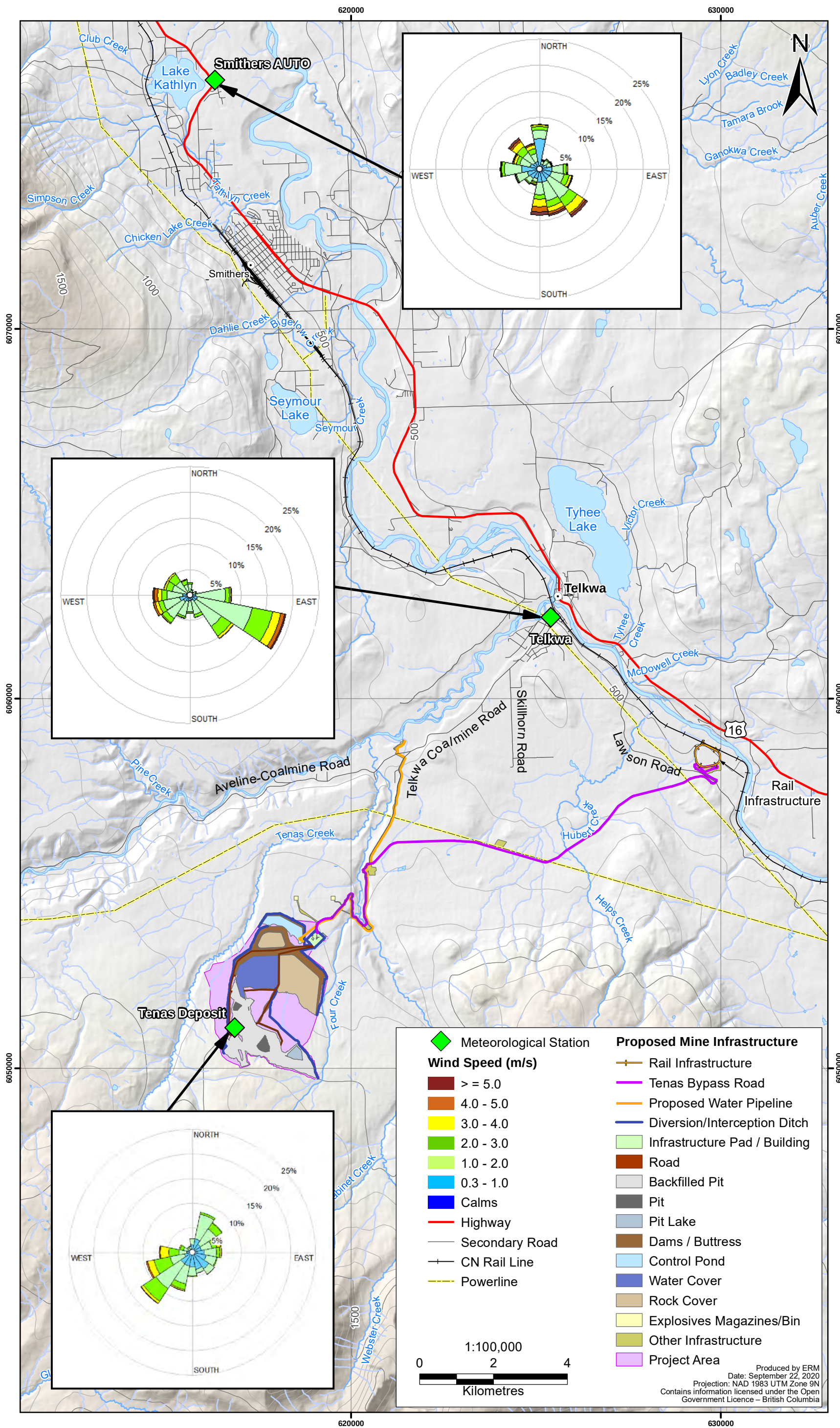


Figure 2.5-22
Daily Solar Radiation, 2017

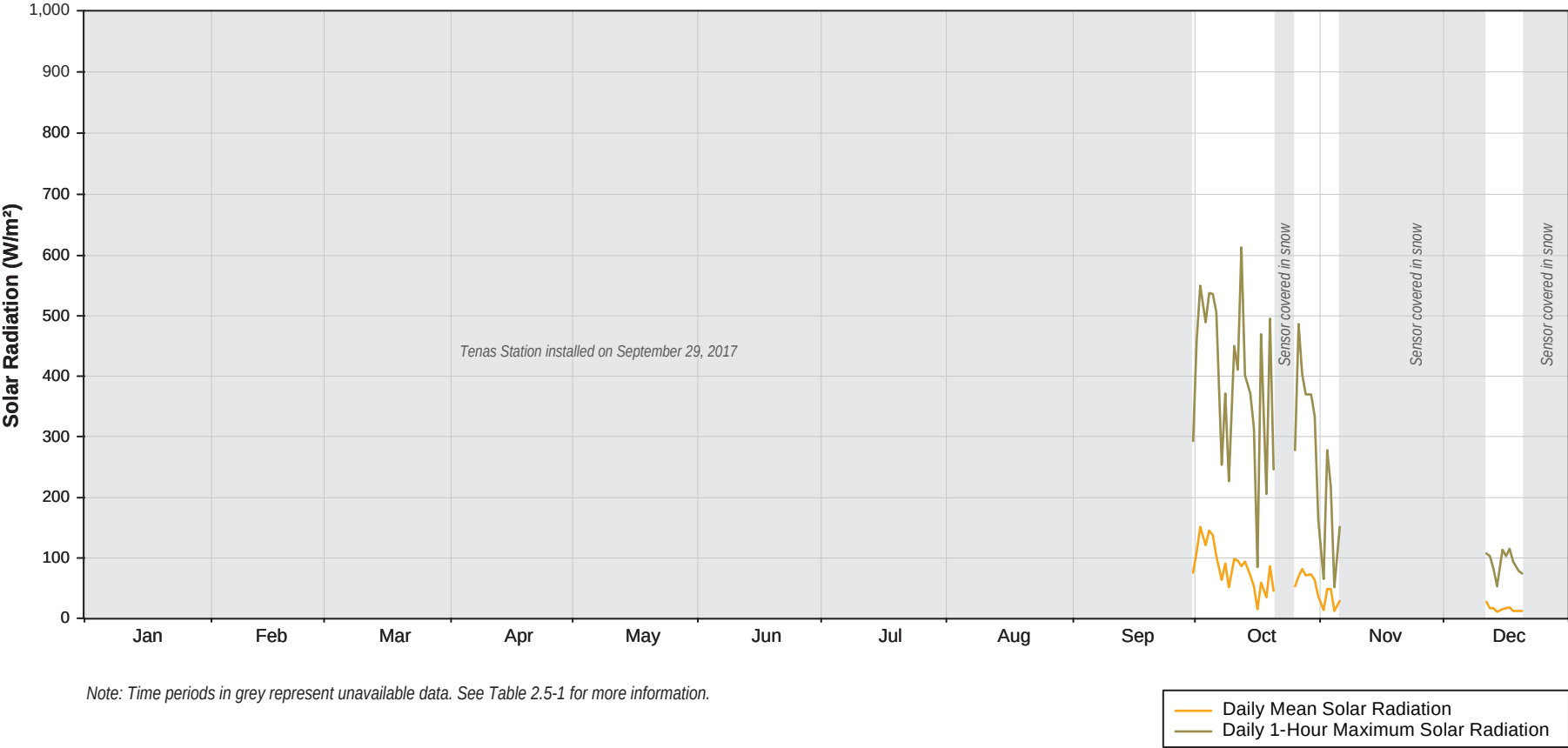


Figure 2.5-23
Daily Solar Radiation, 2018

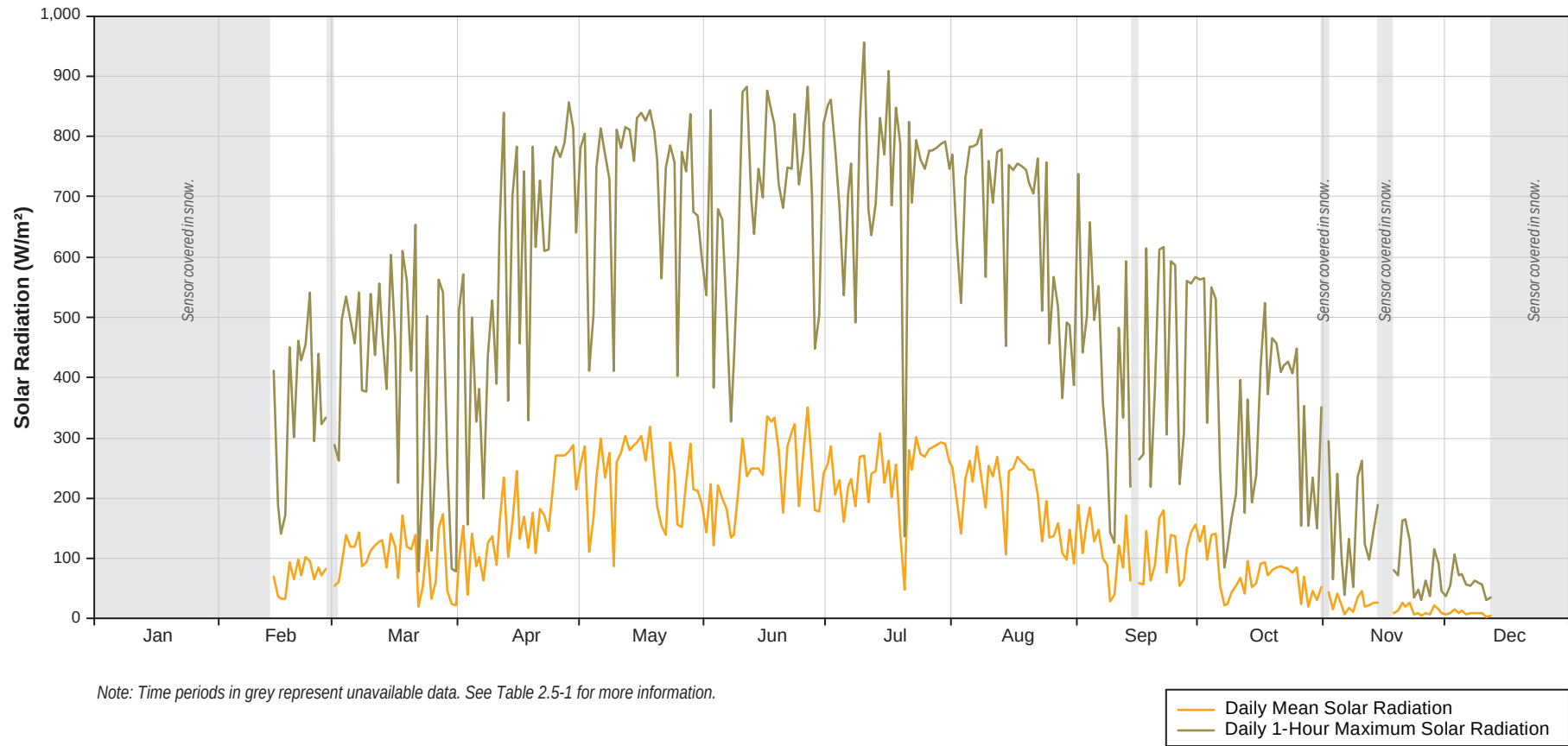


Figure 2.5-24
Daily Solar Radiation, 2019

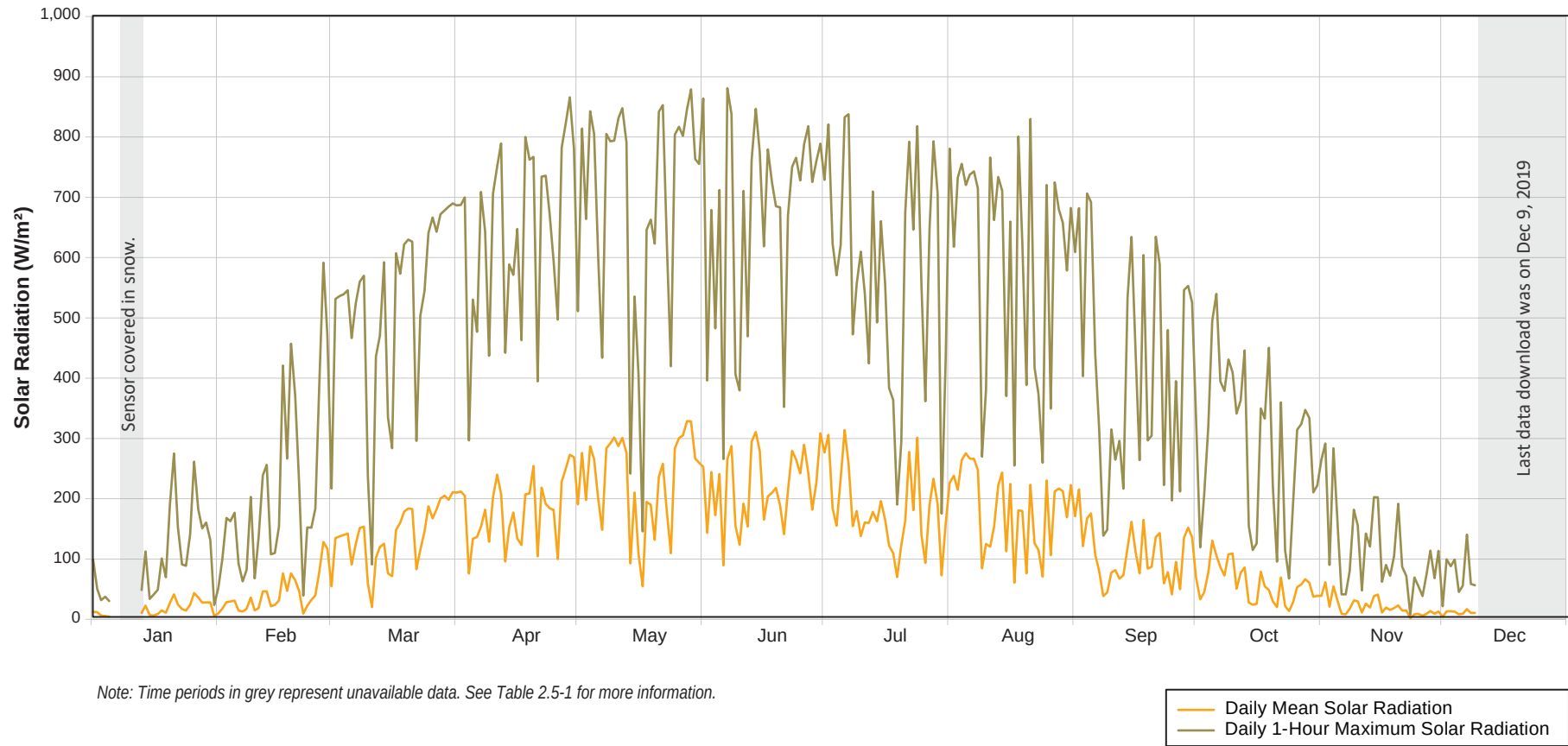


Figure 2.5-25

Daily Mean Barometric Pressure, 2017

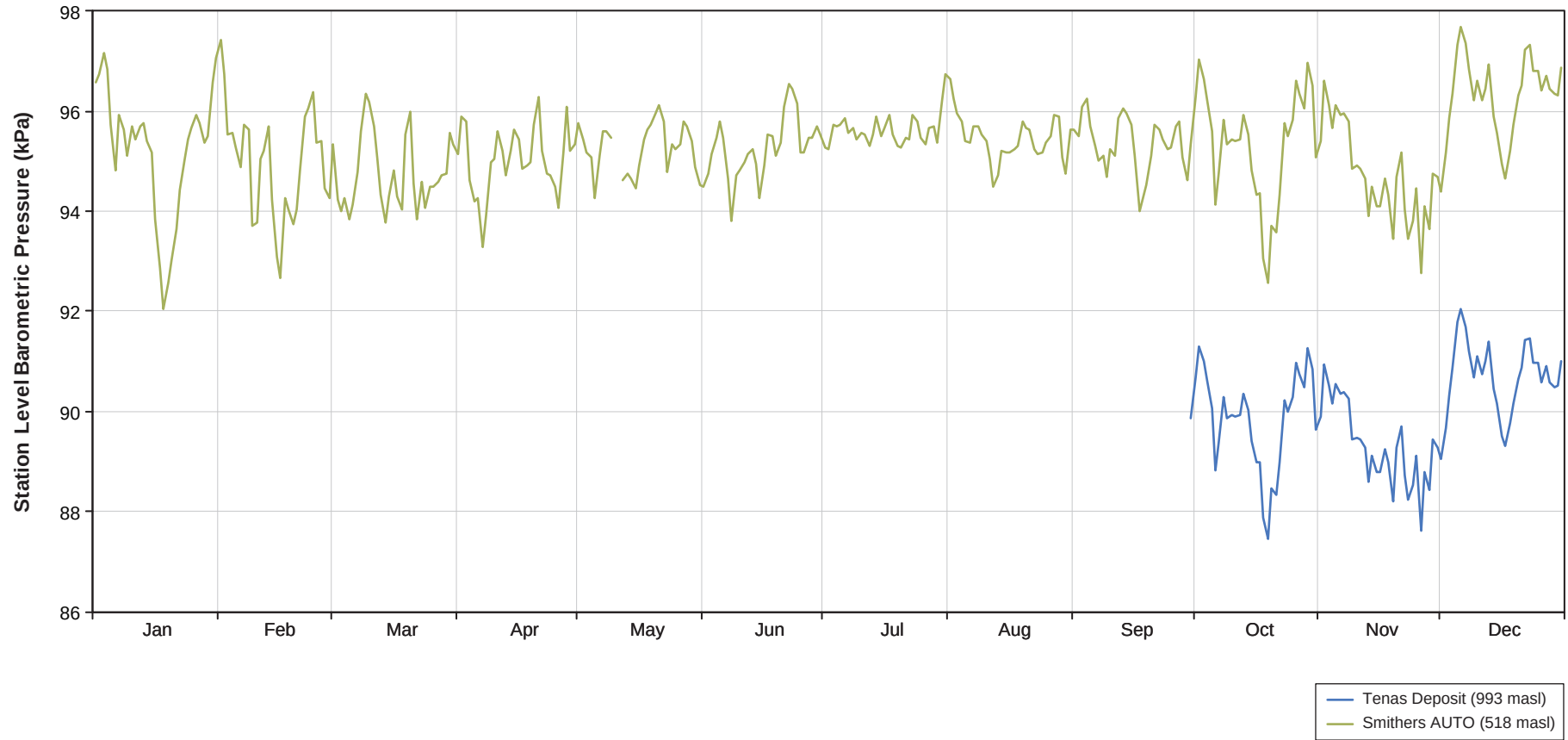


Figure 2.5-26

Daily Mean Barometric Pressure, 2018

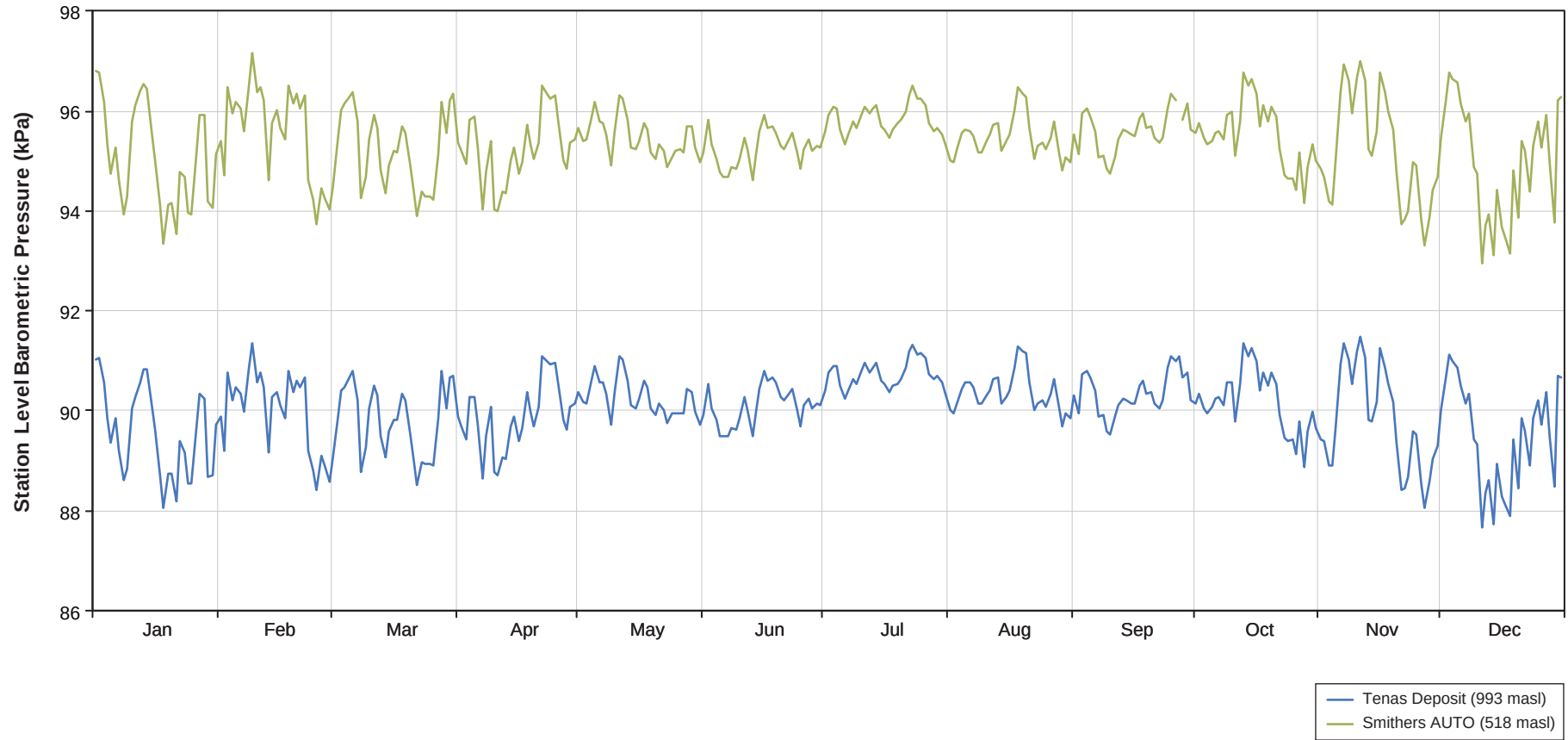
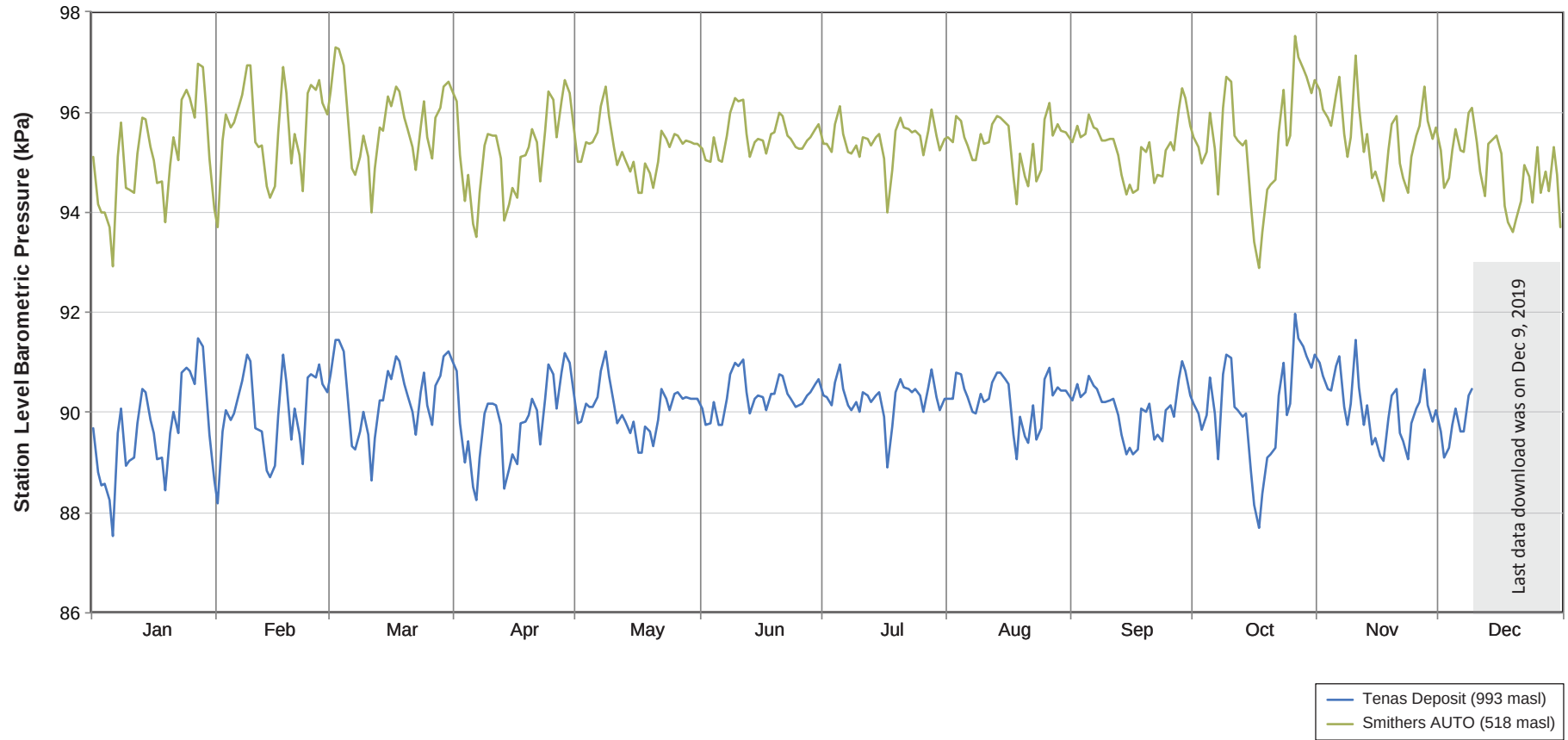


Figure 2.5-27

Daily Mean Barometric Pressure, 2019



3. AIR QUALITY

This chapter provides a summary of the available air quality monitoring data in the Project area and the surrounding southern Bulkley Valley region from Smithers to Houston. Data presented are current on-site Project data, and historical data for the region collected by the BC Ministry of Environment and Climate Change Strategy (BC ENV) and by other projects in the region.

An ambient air quality monitoring program was initiated for the Tenas Project in September 2017. Ambient air quality data are important for Project planning, including potential air emission permitting and air dispersion modelling, and future operational and closure activities relating to air quality management.

The objectives of the air quality baseline program were to:

- monitor local baseline dust deposition rates (dustfall) in the Project area, including the deposit, proposed haul routes along existing roads, and the proposed rail loadout area; and
- monitor local baseline ambient particulate matter concentrations (particulate matter smaller than 2.5 microns in diameter (PM_{2.5}), and particulate matter smaller than 10 microns in diameter (PM₁₀)) in the Project area.

Characterization of ambient air quality baseline pollutant concentrations (e.g., NO₂, O₃, PM₁₀, and PM_{2.5}) also relied on BC ENV ambient air quality monitoring stations in Telkwa, Smithers and Houston. SO₂ was characterized based on results from previous projects in the region.

3.1 STUDY AREA

The Project is located in west-central BC, in the Bulkley Valley Lakes District (BVLD), where the primary ambient air pollutants of concern are particulate matter (e.g., PM₁₀ and PM_{2.5}). The BVLD Airshed Management Society (AMS) has identified six primary categories of PM emissions in the region that affect the ambient air quality (BVLD AMS 2012):

- open burning;
- industrial sources;
- wood burning appliances (e.g., wood burning stoves are commonly used in the area for home heating);
- backyard burning;
- road dust; and
- vehicle emissions.

3.2 REGULATORY AND POLICY FRAMEWORK

Project specific ambient air quality monitoring for the Tenas Project is a component of the EA and Joint AIR for MA/EMA permit guidance (BC MEM and MOE 2016) and the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016a) in order to “characterize the current state of the substances in the atmosphere and develop an understanding of:

1. Potential incremental influences that a project can have on air quality, climate, and the hydrological environment; and
2. Potential cumulative influences that a project and existing emission sources in the area can have on air quality, climate and the hydrological environment.” (BC MOE 2016a)

Under the BC *Environmental Management Act* (EMA; 2003) *Waste Discharge Regulation* (WDR; 2004), coal mining is a Schedule 1 activity that requires a permit to authorize waste discharges, including air emissions (BC ENV 2018). Permit applications for air emissions often require an air quality dispersion modeling study, which incorporates ambient air quality baseline data.

Provincial and federal ambient air quality objectives and standards for numerous contaminants are in place for the protection of human health and the environment. Table 3.2-1 summarizes the BC Air Quality Objectives (BC AQO; BC ENV 2020a) and the Canadian Ambient Air Quality Standards (CAAQS) for select contaminants that are being reported as part of this report’s data summary (Section 3.5).

3.3 EXISTING INFORMATION

Readily available sources of existing air quality information were reviewed, and a summary of the review is provided in Table 3.3-1. The reviewed information included publicly available sources. The list of reviewed information is not exhaustive and additional potential sources of relevant public and private information may be available.

3.4 METHODOLOGY

3.4.1 Dustfall

Dustfall was monitored by the Project at four stations (Table 3.4-1; Figure 2.4-1; Photos 3.4-1 to 3.4-4): one in the Tenas deposit area where mining is proposed (DF-TenasDep), two along one of the routes proposed for trucks to haul mined material from the deposit to the Rail Infrastructure (DF-Kerr and DF-Telkwa), and one in the Rail Infrastructure area where the material would be transferred to railcars (DF-Rail).

Dustfall monitoring was completed in accordance with sampling method ASTM International D1739-98 (ASTM International 2017). Dustfall was monitored during consecutive periods of approximately 30 days each, as specified in Table 3.4-2, beginning in September/October 2017 and ending in October/November 2018. As part of the QA/QC program, fieldwork was conducted by or under the direction of a trained, experienced atmospheric scientist. Chain of custody (COC) forms were used for all samples collected, as part of the QA/QC program.

Table 3.2-1. Select BC and Federal Ambient Air Quality Objectives and Standards

Contaminant	Averaging Period	Units	Value	Calculation Metric	Effective Year	Source	Reference
SO ₂	1-hour	ppb	<u>75</u>	Achievement based on annual 97 th percentile of daily 1-hour maximum averaged over 2015-2017, annual 97.5 th percentile of daily 1-hour maximum averaged over 2016-2018, and annual 98 th percentile of daily 1-hour maximum averaged over 2017-2019, with one allowable excursion above 75 ppb to a maximum of 85 ppb over a three-year period prior to 2020. Superseded by CAAQS level and metric January 1, 2020.	Current	BC Interim AQO	(BC ENV 2020a)
	1-hour	ppb	70	Achievement based on annual 99 th percentile of daily 1-hour maximum, averaged over three consecutive years, effective January 1, 2020; used to inform new air management decisions beginning January 1, 2017 and all air management decisions beginning January 1, 2020.	2020	CAAQS	(Canada Gazette 2017b)
	1-hour	ppb	65	Achievement based on annual 99 th percentile of daily 1-hour maximum, averaged over three consecutive years.	2025	CAAQS	(Canada Gazette 2017b)
	Annual	ppb	<u>5.0</u>	Achievement based on annual average of 1-hour concentrations, over one year, effective January 1, 2020.	2020	CAAQS	(Canada Gazette 2017b)
	Annual	ppb	4.0	Achievement based on annual average of 1-hour concentrations, over one year.	2025	CAAQS	(Canada Gazette 2017b)
NO ₂	1-hour	ppb	<u>100</u>	Achievement based on annual 98 th percentile of daily 1-hour maximum over one year.	Current	BC Interim AQO	(BC ENV 2020a)
	1-hour	ppb	60	Achievement based on annual 98 th percentile of daily 1-hour maximum, averaged over three consecutive years.	2020	CAAQS	(Canada Gazette 2017)
	1-hour	ppb	42	Achievement based on annual 98 th percentile of daily 1-hour maximum, averaged over three consecutive years.	2025	CAAQS	(Canada Gazette 2017)
	Annual	ppb	<u>32</u>	Achievement based on annual average of 1-hour average concentrations, over one year.	Current	BC Interim AQO	(BC ENV 2020a)
	Annual	ppb	17	Achievement based on annual average of 1-hour average concentrations, over one year.	2020	CAAQS	(Canada Gazette 2017)
	Annual	ppb	12	Achievement based on annual average of 1-hour average concentrations, over one year.	2025	CAAQS	(Canada Gazette 2017)
O ₃	1-hour	ppb	<u>82^a</u>	-	Current	NAAQO	(BC ENV 2020a)
	8-hour	ppb	<u>63</u>	Achievement based on annual 4 th highest daily 8-hour maximum, averaged over three consecutive years.	Current	CAAQS	(Canada Gazette 2013)
	8-hour	ppb	62	Achievement based on annual 4 th highest daily 8-hour maximum, averaged over three consecutive years.	2020	CAAQS	(Canada Gazette 2013)
PM ₁₀	24-hour	µg/m ³	<u>50</u>	-	Current	BC AQO	(BC ENV 2020a)
PM _{2.5}	24-hour	µg/m ³	<u>25</u>	Achievement based on annual 98 th percentile of daily average, over one year.	Current	BC AQO	(BC ENV 2020a)
	24-hour	µg/m ³	28	Achievement based on annual 98 th percentile of daily average, over three consecutive years.	Current	CAAQS	(Canada Gazette 2013)
	24-hour	µg/m ³	27	Achievement based on annual 98 th percentile of daily average, over three consecutive years.	2020	CAAQS	(Canada Gazette 2013)
	Annual	µg/m ³	<u>8.0^b</u>	Achievement based on annual average, over one year.	Current	BC AQO	(BC ENV 2020a)
	Annual	µg/m ³	10.0	Achievement based on annual average, averaged over three consecutive years.	Current	CAAQS	(Canada Gazette 2013)
	Annual	µg/m ³	8.8	Achievement based on annual average, averaged over three consecutive years.	2020	CAAQS	(Canada Gazette 2013)

Notes:
Underlined values are the most stringent value currently in effect for the BC jurisdiction at the time of reporting.
^a The National Ambient Air Quality Objective (NAAQO) for ozone have been superseded by the CAAQS, but the 1-hour NAAQO of 82 ppb is retained for air quality advisories.
^b Planning goal of 6 µg/m³ provides voluntary target to guide airshed planning efforts and encourage communities to maintain good air quality in face of economic growth and development.

Table 3.3-1. Air Quality Data Information Table

Documents Reviewed	Davidson Project • <i>Davidson Project: Application for Environmental Assessment Certificate</i>. Submitted by Blue Pearl Mining Inc. (Rescan. 2008. <i>Davidson Project Application for Environment Assessment Certificate- Section 6.1 Air Quality and Climate</i>. Prepared for Blue Pearl Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.) • <i>Davidson Project Meteorology, Air Quality and Noise Baseline Study</i> (Rescan. 2007. <i>Davidson Project Meteorology, Air Quality and Noise Baseline Study</i>. Prepared for Blue Pearl Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.) Telkwa Coal Project • <i>Telkwa Coal Project: Application for a Project Approval Certificate – Volumes I-V</i>. Submitted by Manalta Coal Ltd. (Manalta Coal Ltd. 1997. <i>Telkwa Coal Project: Application for a Project Approval Certificate</i>. Prepared by Manalta Coal Ltd.: Vancouver, BC.) BC Ministry of Environment and Climate Change • <i>Air Quality Data from the BC Ministry of Environment and Climate Change BC Air Data Archive Website</i> (BC ENV. 2020b. <i>BC Air Data Archive Website</i>. https://envistaweb.env.gov.bc.ca/ (accessed April 2020).) BC Lung Association • <i>BC State of the Air Reports</i> (BC Lung Association. 2020. <i>BC State of the Air Reports</i>. https://bc.lung.ca/protect-your-lungs/air-quality-lung-health/bc-state-air-report (accessed July 2020).)
General Remarks	Reviewed information included publicly available sources for data collected in the general regional area surrounding the Tenas Project. The list of reviewed information is not exhaustive and additional potential sources of relevant public and private information may be available.
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (EA and Joint AIR for MA/EMA Permits)	EA-related air quality monitoring is conducted according to guidance provided in <i>Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators</i> (BC MOE 2016a). Project specific ambient air quality monitoring for the Tenas Project is a component of the EA and Joint AIR for MA/EMA Permits in order to “characterize the current state of the substances in the atmosphere and develop an understanding of: 1. Potential incremental influences that a project can have on air quality, climate, and the hydrological environment; and 2. Potential cumulative influences that a project and existing emission sources in the area can have on air quality, climate and the hydrological environment.” (BC MOE 2016a)

(continued)

Table 3.3-1. Air Quality Data Information Table (continued)

Existing Data	Davidson Project - Dustfall data summary statistics for various stations (August 2005 to September 2006.) Telkwa Coal Project - No relevant ambient air quality data were included in the application. Ambient air quality data from the BC ENV BC Air Data Archive Website (https://envistaweb.env.gov.bc.ca/). - Data were available for many monitoring stations throughout BC with many long periods of record. - There were three stations closest to the Project with more recent relevant raw data: - BC ENV-Houston Station: - PM_{2.5} raw data (January 2014 to January 2020); - PM₁₀ raw data (January 2014 to January 2020); - Smithers Station¹: <i>BC ENV-Smithers St. Josephs Station:</i> - PM_{2.5} raw data (January 2014 to December 2018); - PM₁₀ raw data (January 2014 to December 2018); - NO₂ raw data (January 2014 to December 2018); - O₃ raw data (January 2014 to December 2018); <i>BC ENV-Smithers Muheim Memorial Station:</i> - PM_{2.5} raw data (February 2019 to January 2020); - PM₁₀ raw data (January 2019 to January 2020); - NO₂ raw data (January 2019 to January 2020); - O₃ raw data (January 2019 to January 2020); - BC ENV-Telkwa Station: - PM_{2.5} raw data (January 2014 to May 2015).
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(continued)

Table 3.3-1. Air Quality Data Information Table (continued)

Existing Data (<i>cont'd</i>)	Ambient air quality data from the BC Lung Association annual BC State of the Air reports. - Reviewed and finalized statistical datasets were available for many monitoring stations throughout BC. - There were three stations closest to the Project with more recent relevant raw data: - BC ENV-Houston Station: - PM_{2.5} data summary statistics (2014 to 2018); - Smithers Station¹: - BC ENV-Smithers St. Josephs Station: - PM_{2.5} data summary statistics (2014 to 2018); - NO₂ data summary statistics (2014 to 2018); - O₃ data summary statistics (2015 to 2018); - BC ENV-Smithers Muheim Memorial Station: - PM_{2.5} data summary statistics (2019); - NO₂ data summary statistics (2019); - O₃ data summary statistics (2019); - BC ENV-Telkwa Station. - PM_{2.5} data summary statistics (2014). Ambient air quality data from PurpleAir Website (https://www.purpleair.com/) There are a few particulate matter sensors being operated in the Bulkley Valley area, including cleanairplan.ca-Telkwa-01, cleanairplan.ca-Telkwa-03, cleanairplan.ca-RailwaySouth, cleanairplan.ca-SmithersPL-02, and cleanairplan.ca-Smithers-DS. Overall, enough background air quality data for PM_{2.5}, PM₁₀, NO₂, and O₃ are available from various active and historical BC ENV ambient air quality monitoring stations to characterize the background air quality within the communities that are in proximity to the Project, with the exception of the Telkwa community that no longer has an active monitoring station. There are no BC ENV monitoring data in the Bulkley Valley that are representative of rural or remote air quality conditions outside the direct influence of close proximity community air emissions. A limited amount of historical background air quality data for dustfall, PM_{2.5}, PM₁₀, NO₂, SO₂ and ozone are available from the Davidson project in the region, outside of the Smithers and Telkwa communities.
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(continued)

Table 3.3-1. Air Quality Data Information Table (continued)

Existing Data Issues	The BC Ministry of Environment and Climate Change stations in Houston and Smithers are located within each of these communities and are within residential areas that are subject to nearby air emission sources (e.g., residential wood heating appliances, vehicle emissions and road dust). Because the Project's deposit area is located outside of these residential communities in an inactive forestry cut block and away from these emission sources, it is expected that the baseline ambient air quality in the deposit area is of better quality compared to within the residential communities. Therefore, using this data to inform baseline ambient air quality conditions in the deposit area may result in a more conservative baseline. The summary statistics provided from the <i>BC State of the Air</i> Reports are of reasonable quality; however, not all air quality parameters were monitored/reported for all stations. For example, although PM₁₀ is measured at some stations, the report does not provide PM₁₀ summaries for any of them. SO₂ was not monitored at any of the three stations during the more recent monitoring years (likely because overall SO₂ emissions have generally decreased over time and are becoming less of a concern). In addition, NO₂ and O₃ levels were not monitored at the Houston and Telkwa stations during the more recent monitoring years. Other than the dustfall data collected for the Project, the only source of background dustfall data are from the Davidson Project, monitored at various stations from August 2005 to September 2006. The data quality from the PurpleAir particulate matter sensors may not be reliable as it is not an approved monitoring method, and the monitoring citing locations may not be ideal for representative ambient air quality monitoring. Thus, the data from PurpleAir is not being used in this baseline report because it may not be of sufficient quality for incorporating into an ambient air quality baseline.
Missing Data	Prior to the 2017-2019 Baseline Program (with PM data up to January 16, 2020), the following represent missing data: • Background dustfall levels close to the Project area; • Background NO₂, SO₂, and O₃ concentrations close to the Project area; and • Background particulate matter monitoring in Telkwa after 2015.
2017-January 2020 Baseline Program	The primary air emissions of concern for the proposed Tenas Project are from direct and indirect particulate matter emissions (e.g., dust). These are common emissions from mining projects. The Bulkley Valley region already experiences poor ambient air quality events caused by particulate matter emissions from other sources (e.g., open burning, wood burning appliances, etc.) and meteorological and topographic conditions that can be unfavorable for pollutant dispersion and dilution. The Tenas Project is not expected to emit a large amount of gaseous contaminants (e.g., NO₂, SO₂, and ozone formation), and these contaminants are not much of a concern in the Bulkley Valley region (e.g., no poor ambient air quality events due to these contaminants), compared to particulate matter. In order to increase the amount of particle matter-related monitoring, four dustfall stations and one Partisol station were installed in various locations in the Project area to monitor baseline dust deposition, and particulate matter conditions (PM_{2.5} and PM₁₀) within the Project area.

(continued)

Table 3.3-1. Air Quality Data Information Table (completed)

Key Issues	The BC Ministry of Environment and Climate Change recommended that the proponent conduct airborne particulate matter monitoring for PM₁₀ and PM_{2.5} within the Project area to better inform the baseline particulate matter conditions within the Project area. It is known that the available particulate matter data from the regional BC Ministry of Environment and Climate Change stations is conservative when applied to the Project area for baseline studies. If the project requires a permit application for air emissions and an air quality dispersion modeling study (see Section 3.2), in the absence of project specific data, the conservative particulate matter baseline data would be incorporated into the model. The conservative baseline data may make it more difficult for the Project's predicted emissions and resulting air quality to satisfy the ambient air quality objectives and standards (Table 3.2-1.). ERM has implemented a Tenas Project particulate matter station (Partisol 2025i-D) to monitor PM_{2.5} and PM₁₀ within the Project area.
Other Comments	No further comments.

Note:

¹ BC ENV-Smithers station was relocated from St. Josephs School to Muheim Memorial School in December 2018. BC ENV-Smithers Muheim Memorial station is operational beginning in January 2019.

Table 3.4-1. Dustfall and Particulate Matter Monitoring Station Locations

Station Identification	Station Location	Station Coordinates (UTM Zone 9U, WGS84)		Station Purpose
		Easting (m)	Northing (m)	
Dustfall				
DF-TenasDep	Within the proposed pit areas for the Tenas Deposit, 53 m northeast of the Tenas Deposit Meteorological Station.	616892	6051126	Pre-project Baseline
DF-Kerr	On the west side of the Kerr farm. Approximately 14 m from the edge of the Telkwa Coalmine Road.	621212	6057273	Pre-project Baseline
DF-Telkwa	Adjacent to the BC ENV-Telkwa meteorological station and historical air quality station. Within the fenced-in area, close to the intersection of Telkwa Coalmine Road and Birch Street.	625411	6062206	Pre-project Baseline
DF-Rail	Within the Rail Infrastructure area. 150 m east of farmland.	630156	6058144	Pre-project Baseline
Particulate Matter				
PM-Kerr	On the west side of the Kerr farm. Approximately 90 m from the edge of the Telkwa Coalmine Road.	621236	6056900	Pre-project Baseline



*Photo 3.4-1. Dustfall station DF-TenasDep after installation, looking east.
September 29, 2017.*

At the end of each sampling period, dustfall canisters were collected and sent to the ALS Laboratory Group (Canadian Association for Laboratory Accreditation [CALA] accreditation no. A1719) for analysis. Samples were analyzed for particulates (total, soluble, and insoluble), anions (sulphate, nitrate, chloride, and ammonia), various cations, and total metals. Laboratory analysis results from the 2017 to 2018 dustfall monitoring period can be found in Appendix 3-A. Following receipt of the results from the laboratory, values reported as being less than the detection limit were considered to be half the detection limit for calculation purposes.



Photo 3.4-2. Dustfall station DF-Kerr after installation, looking southwest. September 29, 2017.



Photo 3.4-3. Dustfall station DF-Telkwa after installation, looking southwest. The BC ENV-Telkwa meteorology and decommissioned air quality station can be seen in the background. September 25, 2017.



Photo 3.4-4. Dustfall station DF-Rail after installation, looking east. October 4, 2017.

Table 3.4-2. Dustfall Monitoring Station Deployment Dates

Monitoring Period	Station:	DF-Telkwa	DF-Kerr	DF-TenasDep ^a	DF-Rail
Sep/Oct 2017	Deployment Start Date:	25-Sep-17	29-Sep-17	29-Sep-17	4-Oct-17
	Deployment End Date:	18-Oct-17	18-Oct-17	16-Oct-17	18-Oct-17
	Deployment Duration (Days):	22.8	19.2	16.8	14.0
	Est. Snow-free Duration (Days):	22.8	19.2	16.8	14.0
Oct/Nov 2017	Deployment Start Date:	18-Oct-17	18-Oct-17	16-Oct-17	18-Oct-17
	Deployment End Date:	22-Nov-17	22-Nov-17	28-Nov-17	22-Nov-17
	Deployment Duration (Days):	35.0	34.9	43.0	34.9
	Est. Snow-free Duration (Days):	19.0	19.0	21.0	19.0
Nov/Dec 2017	Deployment Start Date:	22-Nov-17	22-Nov-17	28-Nov-17	22-Nov-17
	Deployment End Date:	15-Dec-17	15-Dec-17	14-Dec-17	15-Dec-17
	Deployment Duration (Days):	22.8	22.8	15.9	22.7
	Est. Snow-free Duration (Days):	22.8	22.8	15.9	22.7
Dec/Jan 2018	Deployment Start Date:	15-Dec-17	15-Dec-17	14-Dec-17	15-Dec-17
	Deployment End Date:	17-Jan-18	17-Jan-18	17-Jan-18	17-Jan-18
	Deployment Duration (Days):	33.1	33.1	34.0	33.1
	Est. Snow-free Duration (Days):	33.1	33.1	24.0	33.1

(continued)

Table 3.4-2. Dustfall Monitoring Station Deployment Dates (completed)

Monitoring Period	Station:	DF-Telkwa	DF-Kerr	DF-TenasDep ^a	DF-Rail
Jan/Feb 2018	Deployment Start Date:	17-Jan-18	17-Jan-18	17-Jan-18	17-Jan-18
	Deployment End Date:	19-Feb-18	19-Feb-18	19-Feb-18	19-Feb-18
	Deployment Duration (Days):	33.0	33.0	33.0	33.0
	Est. Snow-free Duration (Days):	9.8	3.2	3.3	3.2
Feb/Mar 2018	Deployment Start Date:	19-Feb-18	19-Feb-18	19-Feb-18	19-Feb-18
	Deployment End Date:	22-Mar-18	22-Mar-18	22-Mar-18	22-Mar-18
	Deployment Duration (Days):	31.0	31.0	31.0	31.0
	Est. Snow-free Duration (Days):	26.8	26.8	26.8	26.8
Mar/Apr 2018	Deployment Start Date:	22-Mar-18	22-Mar-18	n/a	22-Mar-18
	Deployment End Date:	23-Apr-18	23-Apr-18	n/a	23-Apr-18
	Deployment Duration (Days):	31.8	31.8	n/a	31.9
	Est. Snow-free Duration (Days):	31.8	31.8	n/a	31.9
Apr/May 2018	Deployment Start Date:	23-Apr-18	23-Apr-18	n/a	23-Apr-18
	Deployment End Date:	23-May-18	23-May-18	n/a	23-May-18
	Deployment Duration (Days):	30.2	30.2	n/a	30.3
	Est. Snow-free Duration (Days):	30.2	30.2	n/a	30.3
May/Jun 2018	Deployment Start Date:	23-May-18	23-May-18	n/a	23-May-18
	Deployment End Date:	18-Jun-18	18-Jun-18	n/a	18-Jun-18
	Deployment Duration (Days):	25.9	26.0	n/a	25.9
	Est. Snow-free Duration (Days):	25.9	26.0	n/a	25.9
Jun/Jul 2018	Deployment Start Date:	18-Jun-18	18-Jun-18	n/a	18-Jun-18
	Deployment End Date:	20-Jul-18	20-Jul-18	n/a	20-Jul-18
	Deployment Duration (Days):	31.9	31.8	n/a	31.9
	Est. Snow-free Duration (Days):	31.9	31.8	n/a	31.9
Jul/Aug 2018	Deployment Start Date:	20-Jul-18	20-Jul-18	n/a	20-Jul-18
	Deployment End Date:	22-Aug-18	22-Aug-18	n/a	22-Aug-18
	Deployment Duration (Days):	32.9	33.1	n/a	32.9
	Est. Snow-free Duration (Days):	32.9	33.1	n/a	32.9
Aug/Oct 2018	Deployment Start Date:	22-Aug-18	22-Aug-18	n/a	22-Aug-18
	Deployment End Date:	2-Oct-18	2-Oct-18	n/a	2-Oct-18
	Deployment Duration (Days):	41.1	41.5	n/a	40.7
	Est. Snow-free Duration (Days):	41.1	41.5	n/a	40.7
Oct/Nov 2018	Deployment Start Date:	2-Oct-18	2-Oct-18	n/a	2-Oct-18
	Deployment End Date:	5-Nov-18	5-Nov-18	n/a	5-Nov-18
	Deployment Duration (Days):	34.0	34.0	n/a	33.9
	Est. Snow-free Duration (Days):	34.0	34.0	n/a	33.9

Notes:

See Appendix 3-A for deployment start and end times. Deployment durations are calculated using both the date and time.

^a Dustfall monitoring at DF-TenasDep station was discontinued after the February/March 2018 monitoring period.

Starting with the February/March 2018 dustfall sample, the analysis parameters were changed to focus on total dustfall, volatile dustfall and non-volatile (fixed) dustfall. This was requested by Telkwa Coal. Volatile dustfall results were subjected to 550 °C. The volatile and fixed dustfall results are presented in Appendix 3-A. Section 3.5 only includes the total dustfall values.

There are currently no federal or BC dustfall air quality objectives in effect for comparing the dustfall results; therefore, dustfall levels were summarized for each deployment period and for each monitoring station.

During some monitoring periods, it was noted that snow had built up and blocked the opening of the dustfall sample canisters. To try and adjust the results to compensate for this blockage, dustfall results were calculated for each station during the entire deployment period as well as during the snow adjusted period. Dustfall results for the snow adjusted periods were calculated using Equation 1 below. The estimated number of snow free days was estimated using snow depth data from the Tenas Deposit Meteorological Station (see Section 2).

$$Dustfall_{Snow\ Adjusted\ Period} = Dustfall_{Deployment\ Period} \times \frac{\# of\ days\ used\ by\ the\ lab}{estimated\ \# of\ snow\ free\ days} \quad [Equation\ 1]$$

where:

<i>Dustfall_{Snow Adjusted Period}</i>	=	Dustfall results adjusted to exclude periods when the containers were potentially covered or blocked by snow
<i>Dustfall_{Deployment Period}</i>	=	Dustfall results for the entire period when dustfall monitoring equipment was deployed at a given station
<i># of days used by the lab</i>	=	Total number of days when dustfall monitoring equipment was deployed at a station
<i>estimated # of snow free days</i>	=	Number of days when the containers were estimated to be free of snow

3.4.2 Airborne Particulate Matter

Suspended particulate matter was monitored by the Project using a Thermo Scientific Partisol 2025i-D dichotomous sequential air sampler. This equipment is listed as a United States Environmental Protection Agency (USE EPA) PM_{coarse} and PM_{2.5} Equivalent Sampler (US EPA 2018). The station was installed on the west side of the Kerr farm, approximately 90 m from the edge of the Telkwa Coalmine Road (PM-Kerr; Figure 2.4-1; Table 3.4-1).

The Partisol station samples fine (PM_{2.5}) and coarse particles (PM_{coarse}) simultaneously. The dichotomous splitter installed in the sampler has a PM_{2.5}, high flow channel located at the rear of the sampling compartment, and a PM_{coarse}, low flow channel located in the front sampling compartment. The PM_{2.5} and PM_{coarse} actual flow rates were set to the default 15.0 L/min, and 1.67 L/min, respectively. The station was configured to sample default actual volume amounts per 24 hours (24 m³ total), and the datalogger reported out in actual volumes as per Canadian and BC air sampling and reporting guidelines (B. Weinstein, pers. comm., October 31, 2018b). During sampling, the sampler draws a particulate-laden ambient air stream through a PM₁₀ air inlet, and then through a US EPA dichotomous virtual impactor that separates the incoming PM₁₀ air stream into PM_{2.5} and PM_{coarse} (PM₁₀ minus PM_{2.5}) components. These two air components are collected onto separate filter

cassettes with pre-weighted Pallflex TX40 H120-WW 47-mm diameter filter provided by ALS Laboratory Group. A built-in pump provides the vacuum required to pull the air through the sample filter and a volume flow controller monitors and automatically adjusts the flow rate. A photo of the Partisol station installed at PM-Kerr location is shown in Photo 3.4-5.



Photo 3.4-5. Partisol station with access door open, looking toward the southeast. October 29, 2018.

PM_{2.5} and PM_{coarse} sampling commenced on November 1, 2018. For this baseline report, data are included up to January 16, 2020. The Partisol sampler was programmed to sample particulate matter for a 24-hour period (starting and ending at local midnight time) on a 3-day rotation following the Environment and Climate Change Canada's National Air Pollution Surveillance Program (NAPS) program schedule for particulate matter (ECCC 2019). Blank PM_{2.5} and PM_{coarse} samples were also used in the Partisol once per month as part of the QA/QC program.

All sampled and blank filters were sent to the ALS Laboratory Group in Burnaby, BC for analysis. The particulate matter was determined gravimetrically and the analysis was carried out in accordance with the Total Particulate – PM₁₀/PM₀₂ – 47mm – HiVol method of BC Ministry of Environment (BC MOE 2015). In this method, the weight change after the filter was exposed to a pre-determined volume of air determines the amount of particulate matter collected on the filter in µg/m³. During the analysis, concentrations of PM_{2.5} and PM_{coarse} were determined (Thermo Fisher Scientific 2015a). PM₁₀ concentration is calculated by adding the PM_{2.5} and PM_{coarse} concentrations. Following receipt of the results from the laboratory, values reported as being less than the detection limit were considered to be half the detection limit for calculation purposes.

The station was sited, installed and commissioned following the manufacturer's manual (Thermo Fisher Scientific 2015a), technical bulletins (Thermo Fisher Scientific 2012, 2016), audit and maintenance checklists (Thermo Fisher Scientific 2015b, 2015c), and regulatory guidelines (BC MOE 2016a; B. Weinstein, pers. comm., September 14, 2018a). All completed audit, calibration and maintenance documentation are presented in Appendix 3-B. As part of the QA/QC program, fieldwork was conducted by or under the direction of a trained, experienced atmospheric scientist. Chain of custody (COC) forms were used for all samples collected, as part of the QA/QC program.

3.4.3 BC ENV Nitrogen Dioxide, Ozone, and Particulate Matter

BC ENV raw monitoring data from the BC ENV-Smithers, BC ENV-Telkwa, and BC ENV-Houston ambient air quality monitoring stations were downloaded for the years 2014 to 2019, where available (BC ENV 2020b). The reviewed and published monitoring data from these stations were used from the BC Lung Association *BC State of the Air* reports, available up to the 2019 monitoring year (BC Lung Association 2015, 2016, 2017, 2018, 2019, 2020).

The contaminants being monitored were NO₂, O₃, PM₁₀, and PM_{2.5}. Not all stations monitored all of these contaminants in all years. The stations and their locations are listed in Table 3.4-3 and shown in Figure 2.4-1. BC ENV-Smithers station was relocated from St. Josephs School (BC ENV-Smithers St. Josephs) to Muheim Memorial School (BC ENV-Smithers Muheim Memorial) in December 2018. Data from 2014 to 2018 in Smithers were from St. Joseph station; BC ENV-Smithers Muheim Memorial station became operational beginning in January 2019.

Table 3.4-3. BC ENV Monitoring Stations – Locations

Station Identification	Station Location	Station Coordinates (UTM Zone 9U, WGS84)		Station Purpose
		Easting (m)	Northing (m)	
BC ENV-Smithers St. Josephs ¹	Approximately 70 m south-southeast of the intersection of Manitoba St and 1 Ave, on the property of St. Joseph's School.	617212	6072196	Pre-project Baseline
BC ENV-Smithers Muheim Memorial ¹	Approximately 100 m southeast of the intersection of King St and 3 Ave, on the property of Muheim Memorial School.	617795	6071677	Pre-project Baseline
BC ENV-Telkwa	Approximately 70 m south-southeast of the intersection of Telkwa Coalmine Rd and Birch St, in a fenced-in area.	625405	6062198	Pre-project Baseline
BC ENV-Houston	Approximately 35 m southwest of the intersection of 11 St and Poulton Ave, at the BC government building at 3400 11 St.	652757	6030420	Pre-project Baseline

Note:

¹BC ENV-Smithers station was relocated from St. Joseph's School to Muheim Memorial School in December 2018. BC ENV-Smithers Muheim Memorial station became operational beginning in January 2019.

Table 3.4-4 shows the raw, and the reviewed and published data availability by station, year, and contaminant at the time of reporting. The raw preliminary data are subject to future review and revisions.

Table 3.4-4. BC ENV Monitoring Stations – 2014 to 2019 Data Availability

Station Identification	Year	NO ₂ ¹		O ₃ ¹		PM ₁₀		PM _{2.5}	
		Raw Data, BC Air Data Archive	Published Data, BC State of the Air Report	Raw Data, BC Air Data Archive	Published Data, BC State of the Air Report	Raw Data, BC Air Data Archive	Published Data, BC State of the Air Report	Raw Data, BC Air Data Archive	Published Data, BC State of the Air Report
BC ENV-Smithers ²	2014	✓	✓	✓	-	✓	-	✓	✓
	2015	✓	✓	✓	✓	✓	-	✓	✓
	2016	✓	✓	✓	✓	✓	-	✓	✓
	2017	✓	✓	✓	✓	✓	-	✓	✓
	2018	✓	✓	✓	✓	✓	-	✓	✓
	2019	✓	✓	✓	✓	✓	-	✓	✓
BC ENV-Telkwa	2014	-	-	-	-	-	-	✓	✓
	2015	-	-	-	-	-	-	✓	-
	2016	-	-	-	-	-	-	-	-
	2017	-	-	-	-	-	-	-	-
	2018	-	-	-	-	-	-	-	-
	2019	-	-	-	-	-	-	-	-
BC ENV-Houston	2014	-	-	-	-	✓	-	✓	✓
	2015	-	-	-	-	✓	-	✓	✓
	2016	-	-	-	-	✓	-	✓	✓
	2017	-	-	-	-	✓	-	✓	✓
	2018	-	-	-	-	✓	-	✓	✓
	2019	-	-	-	-	✓	-	✓	✓

Notes:

Dash (-) = data not available

¹ NO₂ and O₃ data are available from BC ENV-Smithers St. Joseph station starting from 1997.

² Data from 2014 to 2018 in Smithers were from BC ENV-Smithers St. Joseph station; BC ENV-Smithers Muheim Memorial station is operational beginning in January 2019.

3.5 DATA SUMMARY

3.5.1 Dustfall

Total dustfall results and a statistical summary of the other parameters are presented in this section. The laboratory analysis results are found in Appendix 3-A, and include information on nitrate and sulphate deposition rates along with the metals content.

Starting with the February/March 2018 dustfall sample, the analysis parameters were changed to focus on total dustfall, volatile dustfall and non-volatile (fixed) dustfall. This was requested by Telkwa Coal. Volatile dustfall results were subjected to 550 °C. The volatile and fixed dustfall results are presented in Appendix 3-A. Only total dustfall values are presented in this section.

Table 3.5-1 and Figures 3.5-1 and 3.5-2 summarize the Project's dustfall monitoring station results sampled during the September 2017 to November 2018 monitoring period.

Table 3.5-1. Total Dustfall Results, September 2017 to November 2018 (mg/dm²/day)

Monitoring Period	Full Deployment Period					Snow Adjusted Period ^a				
	DF-Telkwa	DF-Kerr	DF-TenasDep ^b	DF-Rail	Monitoring Period Average	DF-Telkwa	DF-Kerr	DF-TenasDep	DF-Rail	Monitoring Period Average
September/October 2017	0.80	1.71	0.47	0.11*	0.77	0.80	1.71	0.47	0.11	0.77
October/November 2017	0.28	0.40	0.32	0.16	0.29	0.52	0.74	0.66	0.29	0.55
November/December 2017	0.27	0.19	0.07*	0.07*	0.15	0.27	0.19	0.07	0.07	0.15
December/January 2018	0.05*	0.11	0.05*	0.05*	0.07	0.05	0.11	0.07	0.05	0.07
January/February 2018	0.20	0.19	0.05*	0.05*	0.12	0.67	1.96	0.50	0.52	0.91
February/March 2018	0.28	0.25	0.11	0.11	0.19	0.32	0.29	0.13	0.13	0.22
March/April 2018	0.16	0.47	-	0.13	0.25	0.16	0.47	-	0.13	0.25
April/May 2018	1.37	1.18	-	2.54	1.70	1.37	1.18	-	2.54	1.70
May/June 2018	1.31	1.95	-	1.53	1.60	1.31	1.95	-	1.53	1.60
June/July 2018	0.91	2.20	-	0.45	1.19	0.91	2.20	-	0.45	1.19
July/August 2018	1.12	2.04	-	0.33	1.16	1.12	2.04	-	0.33	1.16
August/October 2018	1.16	4.43	-	2.17	2.59	1.16	4.43	-	2.17	2.59
October/November 2018	0.27	0.83	-	0.46	0.52	0.27	0.83	-	0.46	0.52
Dustfall Station Average	0.63	1.23	0.18	0.63		0.69	1.39	0.31	0.67	

Notes:

Dash (-) = data not available

Volatile and non-volatile (fixed) dustfall results are presented in Appendix 3-A.

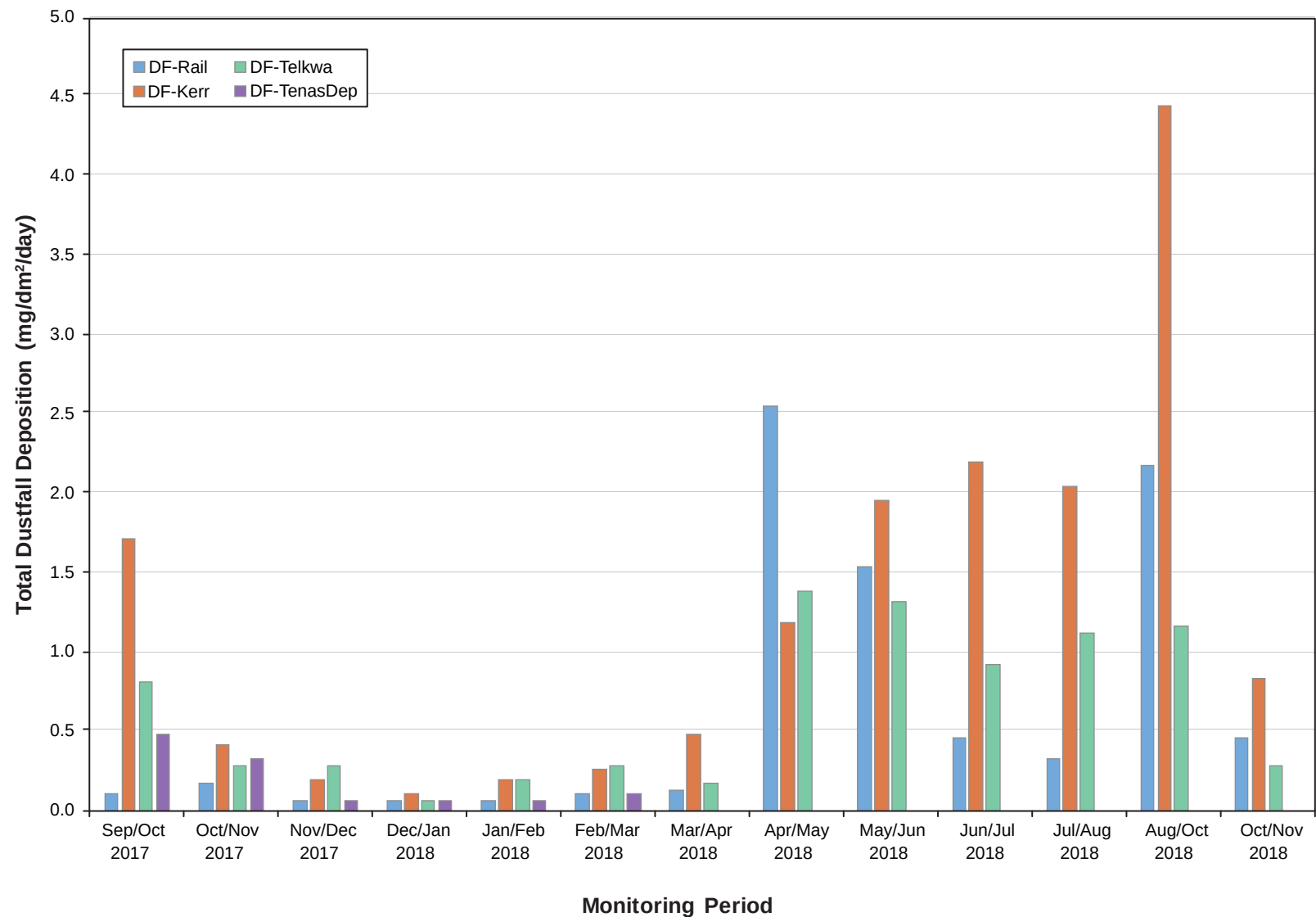
Values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

^a The snow adjusted period isolates the period of time when the container openings were not blocked by snow and dust accumulated without snow interference. Periods when the container openings were suspected to be blocked due to snow accumulation were not included for calculation of total dustfall based on field observations.

^b Dustfall monitoring at DF-TenasDep station was discontinued after the February/March 2018 monitoring period.

Figure 3.5-1

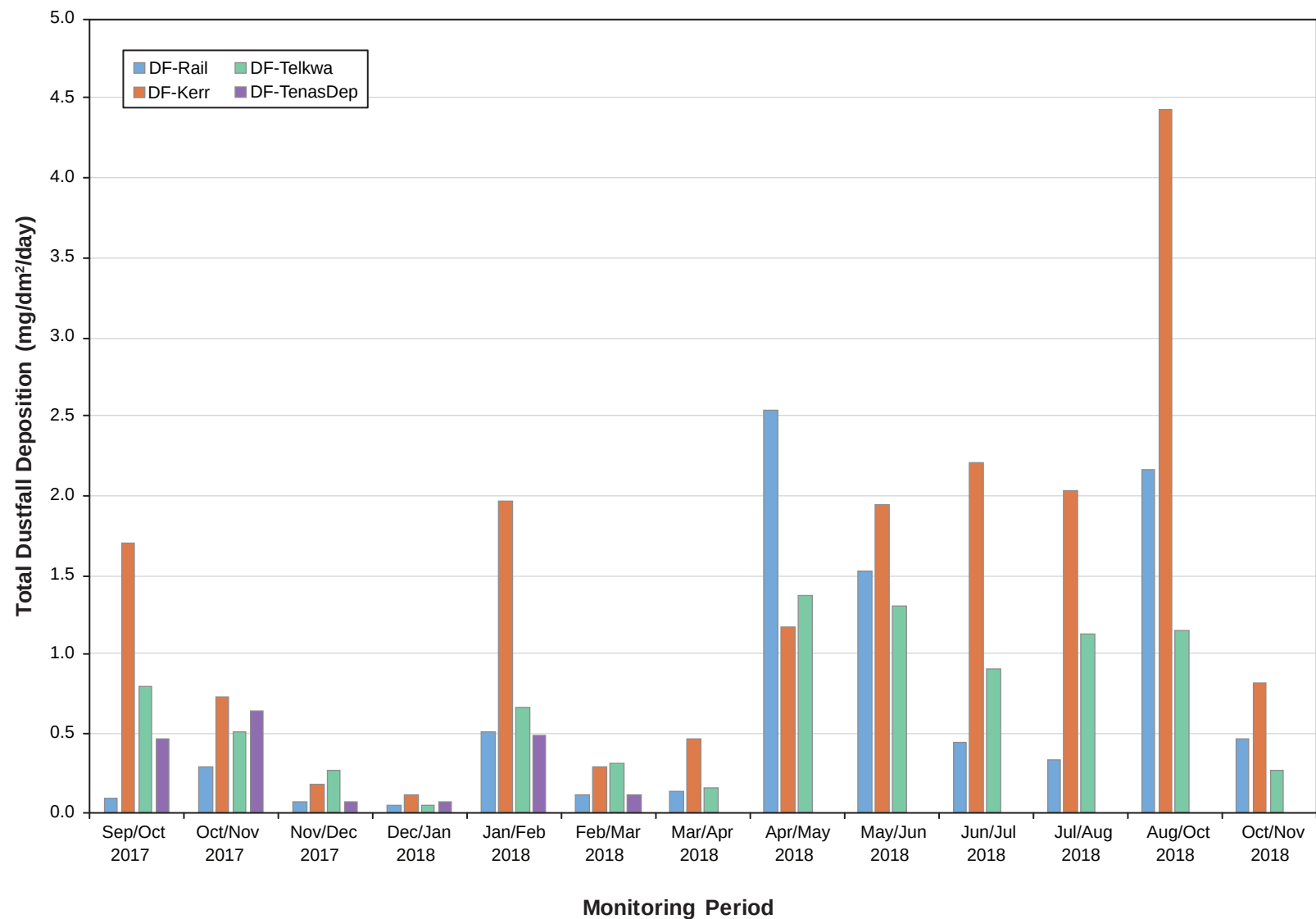
Total Dustfall Results, September 2017 to November 2018, Full Deployment Period



Note: Dustfall monitoring at DF-TenasDep station was discontinued after the February/March 2018 monitoring period. Values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

Figure 3.5-2

Total Dustfall Results, September 2017 to November 2018, Snow Adjusted Period



Notes: Dustfall monitoring at DF-Tenas Dep station was discontinued after the February/March 2018 monitoring period.
 The snow adjusted period isolates the period of time when the container openings were not blocked by snow and dust accumulated without snow interference.
 Periods when the container openings were suspected to be blocked due to snow accumulation were not included for calculation of total dustfall based on field observations.
 Values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

There are no federal or BC dustfall benchmarks currently in use for comparing the dustfall results. Dustfall rates in the Project area ranged from less than 0.10 mg/dm²/day at various stations during the December/January 2018 and January/February 2018 monitoring periods to 4.43 mg/dm²/day at DF-Kerr during the August/October 2018 monitoring period, without adjusting for potential blockage from snow (Table 3.5-1; Figure 3.5-1).

After adjusting for potential snow blockage, dustfall rates ranged from less than 0.10 mg/dm²/day at DF-Rail and DF-Telkwa stations during the December/January 2018 monitoring period to 4.43 mg/dm²/day at DF-Kerr during the August/October 2018 monitoring period (Table 3.5-1; Figure 3.5-2).

Dustfall rates were generally higher at DF-Kerr, likely because of the unpaved Telkwa Coalmine Road, located approximately 14 meters from the DF-Kerr station. Dustfall rates were generally lower at DF-Rail, which is on undeveloped land and is located over 300 m from the nearest road or rail line.

Tables 3.5-2 and 3.5-3 provide statistical summaries of the dustfall deposition data for nutrients and metals at the four stations during the September 2017 to November 2018 monitoring period. Results of the laboratory analysis are provided in Appendix 3-A. After excluding periods when the station gauge was potentially covered, the maximum observed metal deposition rate was 0.072 mg/dm²/day (sodium at the DF-Telkwa station). Without consideration of snow accumulation and dustfall gauge blockage, the maximum observed metal deposition rate was 0.022 mg/dm²/day (again, for sodium at the DF-Telkwa station).

Table 3.5-2. Summary of Dustfall (Nutrients and Metal Deposition), September 2017 to February 2018, Full Deployment Period

Parameter	No. of Obs. Below DL (out of 20 total obs.)	Dustfall Full Deployment Period (mg/dm²/day)					
		Mean	Median	Standard Deviation	Minimum	Maximum	Station of Maximum
Anions and Nutrients							
Total Ammonia (as N)	11	2.00E-03	1.00E-03	1.59E-03	4.50E-04	5.93E-03	DF-Telkwa
Chloride	20	1.22E-01	1.30E-01	3.85E-02	6.00E-02	1.80E-01	DF-TenasDep
Nitrate (as N)	11	8.65E-04	7.55E-04	4.76E-04	2.25E-04	1.87E-03	DF-TenasDep
Sulphate	19	9.86E-03	9.25E-03	5.89E-03	4.30E-03	3.20E-02	DF-Kerr
Metals							
Aluminum	9	1.14E-03	5.55E-04	1.21E-03	5.00E-05	3.91E-03	DF-Kerr
Antimony	20	2.49E-06	1.85E-06	1.53E-06	8.50E-07	6.00E-06	DF-TenasDep
Arsenic	19	2.94E-06	2.18E-06	3.21E-06	8.50E-07	1.52E-05	DF-Rail
Barium	4	3.37E-05	1.42E-05	5.25E-05	1.78E-06	2.31E-04	DF-Kerr
Beryllium	20	8.63E-06	8.75E-06	2.64E-06	4.15E-06	1.25E-05	DF-TenasDep
Bismuth	20	8.63E-06	8.75E-06	2.64E-06	4.15E-06	1.25E-05	DF-TenasDep
Boron	20	1.74E-04	1.75E-04	5.31E-05	8.50E-05	2.55E-04	DF-TenasDep
Cadmium	20	8.63E-07	8.75E-07	2.64E-07	4.15E-07	1.25E-06	DF-TenasDep
Calcium	16	4.58E-03	3.28E-03	4.92E-03	8.00E-04	1.83E-02	DF-Telkwa
Chromium	20	8.63E-06	8.75E-06	2.64E-06	4.15E-06	1.25E-05	DF-TenasDep

(continued)

Table 3.5-2. Summary of Dustfall (Nutrients and Metal Deposition), September 2017 to February 2018, Full Deployment Period (completed)

Parameter	No. of Obs. Below DL (out of 20 total obs.)	Dustfall Full Deployment Period (mg/dm ² /day)					
		Mean	Median	Standard Deviation	Minimum	Maximum	Station of Maximum
Metals (<i>cont'd</i>)							
Cobalt	20	1.74E-06	1.75E-06	5.31E-07	8.50E-07	2.55E-06	DF-TenasDep
Copper	10	8.58E-04	4.33E-04	9.57E-04	4.15E-06	2.74E-03	DF-Rail
Iron	12	1.35E-03	6.50E-04	1.36E-03	2.50E-04	4.70E-03	DF-Rail
Lead	9	3.13E-06	1.96E-06	3.33E-06	4.15E-07	1.44E-05	DF-Rail
Lithium	20	8.63E-05	8.75E-05	2.64E-05	4.15E-05	1.25E-04	DF-TenasDep
Magnesium	0	1.34E-03	1.01E-03	1.19E-03	9.30E-05	4.28E-03	DF-Telkwa
Manganese	5	1.21E-04	5.01E-05	2.22E-04	4.15E-06	1.02E-03	DF-Kerr
Mercury	20	8.63E-07	8.75E-07	2.64E-07	4.15E-07	1.25E-06	DF-TenasDep
Molybdenum	19	9.55E-07	9.25E-07	3.99E-07	4.15E-07	2.29E-06	DF-Rail
Nickel	18	9.76E-06	9.50E-06	3.99E-06	4.15E-06	2.30E-05	DF-TenasDep
Phosphorus	15	2.26E-03	9.50E-04	3.00E-03	4.15E-04	1.18E-02	DF-Kerr
Potassium	13	3.94E-03	9.75E-04	6.04E-03	4.15E-04	2.08E-02	DF-Kerr
Selenium	20	1.74E-05	1.75E-05	5.31E-06	8.50E-06	2.55E-05	DF-TenasDep
Silicon	12	2.30E-03	9.75E-04	2.28E-03	4.15E-04	7.40E-03	DF-Kerr
Silver	20	1.74E-07	1.75E-07	5.31E-08	8.50E-08	2.55E-07	DF-TenasDep
Sodium	12	3.48E-03	2.88E-03	4.40E-03	9.50E-04	2.15E-02	DF-Telkwa
Strontium	0	3.32E-05	1.56E-05	5.78E-05	2.40E-06	2.59E-04	DF-Telkwa
Thallium	20	1.74E-06	1.75E-06	5.31E-07	8.50E-07	2.55E-06	DF-TenasDep
Tin	20	1.74E-06	1.75E-06	5.31E-07	8.50E-07	2.55E-06	DF-TenasDep
Titanium	20	1.74E-04	1.75E-04	5.31E-05	8.50E-05	2.55E-04	DF-TenasDep
Uranium	14	3.72E-07	2.35E-07	4.05E-07	8.50E-08	1.60E-06	DF-Telkwa
Vanadium	20	1.74E-05	1.75E-05	5.31E-06	8.50E-06	2.55E-05	DF-Telkwa & DF-TenasDep
Zinc	16	1.32E-04	1.15E-04	8.85E-05	2.50E-05	4.00E-04	DF-Rail

Note:

Values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

Table 3.5-3. Summary of Dustfall (Nutrients and Metal Deposition), September 2017 to February 2018, Snow Adjusted Period

Parameter	Dustfall Snow Adjusted Period (mg/dm ² /day)					
	Mean	Median	Standard Deviation	Minimum	Maximum	Station of Maximum
Anions and Nutrients						
Total Ammonia (as N)	3.78E-03	3.20E-03	2.99E-03	4.50E-04	9.77E-03	DF-Telkwa
Chloride	3.58E-01	1.30E-01	4.61E-01	6.00E-02	1.44E+00	DF-Rail
Nitrate (as N)	2.81E-03	8.85E-04	3.91E-03	2.25E-04	1.32E-02	DF-Rail
Sulphate	2.70E-02	1.10E-02	3.35E-02	4.30E-03	1.03E-01	DF-Rail & DF-Kerr

(continued)

Table 3.5-3. Summary of Dustfall (Nutrients and Metal Deposition), September 2017 to February 2018, Snow Adjusted Period (completed)

Parameter	Dustfall Snow Adjusted Period (mg/dm ² /day)					
	Mean	Median	Standard Deviation	Minimum	Maximum	Station of Maximum
Metals						
Aluminum	2.39E-03	1.51E-03	2.58E-03	7.08E-05	9.18E-03	DF-Rail
Antimony	9.78E-06	1.85E-06	1.74E-05	1.10E-06	6.00E-05	DF-TenasDep
Arsenic	1.40E-05	2.73E-06	3.50E-05	8.50E-07	1.57E-04	DF-Rail
Barium	6.03E-05	2.76E-05	9.54E-05	2.52E-06	4.24E-04	DF-Kerr
Beryllium	2.52E-05	9.25E-06	3.25E-05	4.35E-06	1.00E-04	DF-TenasDep
Bismuth	2.52E-05	9.25E-06	3.25E-05	4.35E-06	1.00E-04	DF-TenasDep
Boron	5.08E-04	1.85E-04	6.56E-04	8.50E-05	2.05E-03	DF-TenasDep
Cadmium	2.52E-06	9.25E-07	3.25E-06	4.35E-07	1.00E-05	DF-TenasDep
Calcium	1.07E-02	4.43E-03	1.51E-02	8.00E-04	6.16E-02	DF-Telkwa
Chromium	2.52E-05	9.25E-06	3.25E-05	4.35E-06	1.00E-04	DF-TenasDep
Cobalt	5.08E-06	1.85E-06	6.56E-06	8.50E-07	2.05E-05	DF-TenasDep
Copper	3.63E-03	6.49E-04	7.73E-03	4.50E-06	2.83E-02	DF-Rail
Iron	2.73E-03	1.68E-03	2.62E-03	2.70E-04	8.63E-03	DF-Rail
Lead	7.02E-06	4.30E-06	8.41E-06	5.50E-07	2.89E-05	DF-Kerr
Lithium	2.52E-04	9.25E-05	3.25E-04	4.35E-05	1.00E-03	DF-TenasDep
Magnesium	3.66E-03	2.06E-03	5.08E-03	1.32E-04	1.88E-02	DF-Kerr
Manganese	2.30E-04	1.01E-04	4.08E-04	5.88E-06	1.87E-03	DF-Kerr
Mercury	2.52E-06	9.25E-07	3.25E-06	4.35E-07	1.00E-05	DF-TenasDep
Molybdenum	2.61E-06	1.05E-06	3.22E-06	4.35E-07	1.00E-05	DF-TenasDep
Nickel	2.64E-05	1.16E-05	3.20E-05	4.50E-06	1.00E-04	DF-TenasDep
Phosphorus	4.10E-03	2.38E-03	4.09E-03	4.35E-04	1.18E-02	DF-Kerr
Potassium	6.13E-03	3.43E-03	6.36E-03	4.35E-04	2.08E-02	DF-Kerr
Selenium	5.08E-05	1.85E-05	6.56E-05	8.50E-06	2.05E-04	DF-TenasDep
Silicon	5.47E-03	2.73E-03	6.21E-03	4.35E-04	2.06E-02	DF-Kerr
Silver	5.08E-07	1.85E-07	6.56E-07	8.50E-08	2.05E-06	DF-TenasDep
Sodium	8.64E-03	3.25E-03	1.61E-02	1.30E-03	7.24E-02	DF-Telkwa
Strontium	1.22E-04	1.56E-05	2.47E-04	3.40E-06	8.72E-04	DF-Telkwa
Thallium	5.08E-06	1.85E-06	6.56E-06	8.50E-07	2.05E-05	DF-TenasDep
Tin	5.08E-06	1.85E-06	6.56E-06	8.50E-07	2.05E-05	DF-TenasDep
Titanium	5.08E-04	1.85E-04	6.56E-04	8.50E-05	2.05E-03	DF-TenasDep
Uranium	1.70E-06	2.80E-07	3.28E-06	8.50E-08	1.30E-05	DF-Kerr
Vanadium	5.08E-05	1.85E-05	6.56E-05	8.50E-06	2.05E-04	DF-Telkwa
Zinc	3.76E-04	1.47E-04	4.85E-04	2.70E-05	1.75E-03	DF-Kerr

Note:

Values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

3.5.2 Airborne Particulate Matter

A summary of PM₁₀ and PM_{2.5} data from the Project's PM-Kerr location during the November 1, 2018 to January 16, 2020 monitoring period, and the data from the BC ENV-Smithers and BC ENV-Houston stations during the same period are presented in this section. Data from BC ENV-Houston and BC ENV-Smithers stations are raw preliminary data and are subject to future review and revisions by the reporting agency. The 24-hour PM₁₀ and PM_{2.5} data from the PM-Kerr and two BC ENV stations, and the laboratory analysis results from the PM-Kerr station are found in Appendices 3-C and 3-D, respectively.

Table 3.5-4 and Figure 3.5-3 present the PM₁₀ results from the PM-Kerr, BC ENV-Smithers and BC ENV-Houston stations. PM₁₀ concentrations were generally lower at PM-Kerr compared to BC ENV-Smithers and BC ENV-Houston stations. All PM₁₀ concentrations at the PM-Kerr station from November 1, 2018 to January 16, 2020 were below the 24-hour BC AQO of 50 µg/m³. The maximum 24-hour average PM₁₀ concentration was 12.8 µg/m³ in 2018, 21.0 µg/m³ in 2019, and 5.7 µg/m³ in 2020. However, the BC ENV-Smithers and BC ENV-Houston stations had 12 and 19 exceedances of the 24-hour BC AQO, respectively, in 2019. No exceedances were recorded from these two BC ENV stations during the November 1, 2018 to December 31, 2018, and January 1 to 16, 2020 monitoring periods. Most of these exceedances occurred towards the end of March 2019 (Figure 3.5-3). The maximum 24-hour average PM₁₀ concentrations at the BC ENV-Smithers and BC ENV-Houston stations during the entire monitoring period were 96.5 and 99.7 µg/m³, respectively.

Table 3.5-4. PM₁₀ Results, November 1, 2018 to January 16, 2020 (µg/m³)

Year	Partisol - Kerr Station			BC ENV-Houston Station			BC ENV-Smithers Station ^a		
	Period Average of 24-hour Values ^b	Maximum 24-hour Average	No. of Events >24-hour BC AQO (50 µg/m ³)	Period Average of 24-hour Values	Maximum 24-hour Average	No. of Events >24-hour BC AQO (50 µg/m ³)	Period Average of 24-hour Values	Maximum 24-hour Average	No. of Events >24-hour BC AQO (50 µg/m ³)
2018 ^c	4.0	12.8	0	12.6	46.3	0	15.5	49.1	0
2019 ^d	5.1	21.0	0	15.4	96.5	12	19.7	99.7	19
2020 ^e	2.7	5.7	0	10.0	23.8	0	15.2	25.5	0
Current BC AQO (µg/m ³)	-	50	n/a	-	50	n/a	-	50	n/a

Notes:

No data available from BC ENV-Telkwa station.

Data from BC ENV-Houston and BC ENV-Smithers-stations are raw preliminary data and are subject to future review and revisions by the reporting agency.

Dash (-) = data not available; n/a = not applicable

^a BC ENV-Smithers station: November 1, 2018 – December 6, 2018 data from St. Joseph's station, and January 26, 2019 – January 16, 2020 data from Muheim Memorial station; ; data between those periods are missing.

^b Period average value is the average of 24-hour values observed in each period.

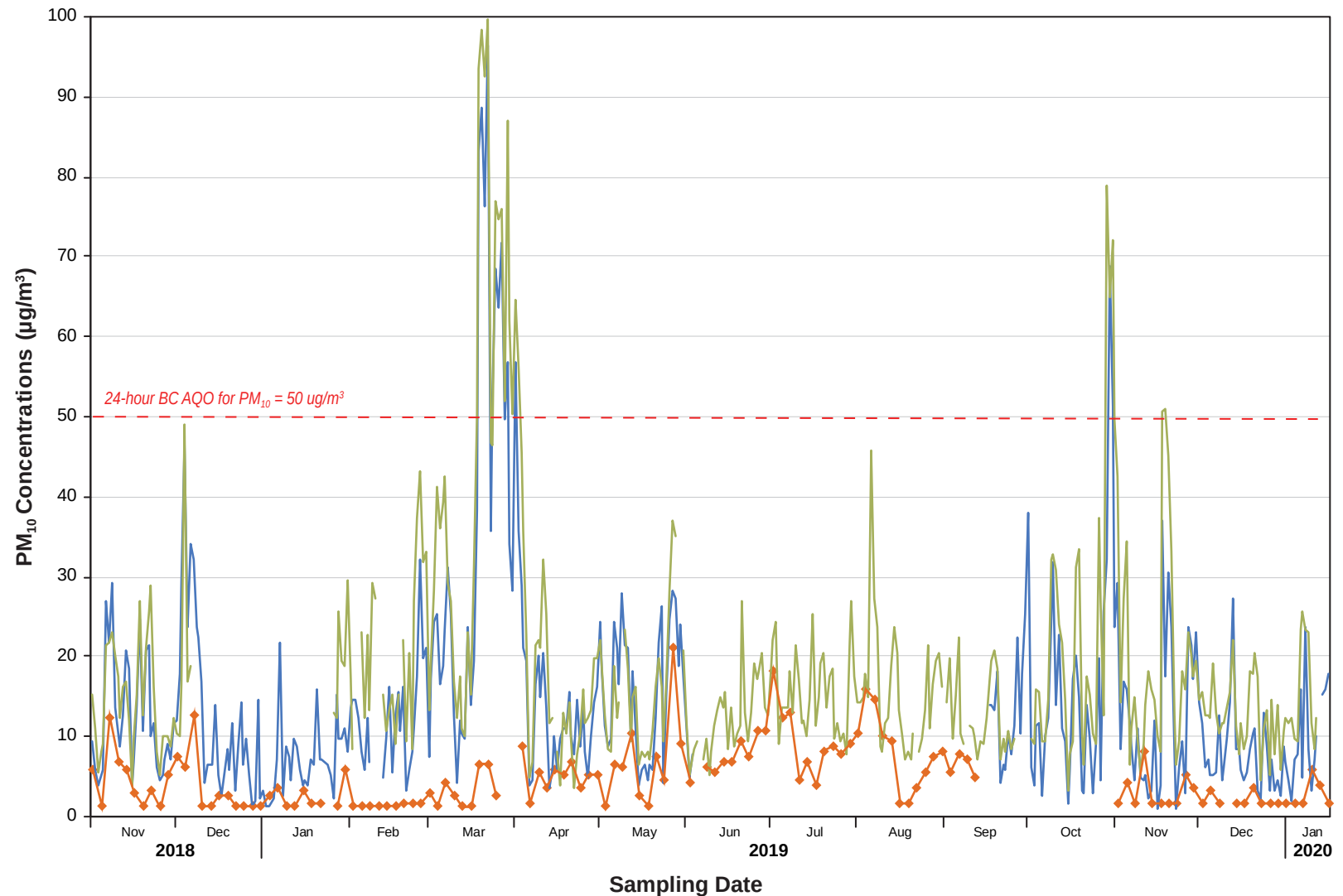
^c Year 2018 includes observed data from November 1, 2018 to December 31, 2018.

^d Year 2019 includes observed data from January 1, 2019 to December 31, 2019.

^e Year 2020 includes observed data from January 1 to 16, 2020.

Figure 3.5-3

PM₁₀ Results, November 1, 2018 to January 16, 2020



Notes: No available data from BC ENV-Telkwa Regional Station

Gaps indicate missing data.

PM-Kerr values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

Data from BC ENV-Houston and BC ENV-Smithers stations are raw preliminary data and are subject to future review and revisions by the reporting agency.

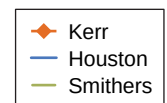


Table 3.5-5 and Figure 3.5-4 present the PM_{2.5} results from the PM-Kerr, BC ENV-Smithers and BC ENV-Houston stations. Similar to PM₁₀, PM_{2.5} concentrations were generally lower at PM-Kerr compared to BC ENV-Smithers and BC ENV-Houston stations. During the November 1, 2018 to January 16, 2020 monitoring period, the maximum 24-hour average PM_{2.5} concentration recorded at the PM-Kerr station was 14.7 µg/m³, while BC ENV-Smithers and BC ENV-Houston stations had 44.8 and 30.3 µg/m³, respectively.

Table 3.5-5. PM_{2.5} Results, November 1, 2018 to January 16, 2020 (µg/m³)

Year	Partisol - Kerr Station			BC ENV-Houston Station			BC ENV-Smithers Station ^a		
	Period Average of 24-hour Values ^b	Maximum 24-hour Average	No. of Events >24-hour BC AQO (25 µg/m ³) ^g	Period Average of 24-hour Values	Maximum 24-hour Average	No. of events >24-hour BC AQO (25 µg/m ³) ^g	Period Average of 24-hour Values	Maximum 24-hour Average	No. of Events >24-hour BC AQO (25 µg/m ³) ^g
2018 (Nov. 1 to Dec. 31) ^c	3.4	11.1	0	13.8	38.3	6	12.4	25.2	1
2019 ^d	2.8	14.7	0	10.6	44.8	24	8.5	30.3	3
2020 (Jan. 1 to 16) ^e	2.1	4.2	0	14.6	33.2	3	11.3	21.3	0
Current BC AQO (µg/m ³) ^f	8.0	25	n/a	8.0	25	n/a	8.0	25	n/a

Notes:

No data available from BC ENV-Telkwa station.

Data from BC ENV-Houston and BC ENV-Smithers-stations are raw preliminary data and are subject to future review and revisions by the reporting agency.

n/a = not applicable

^a BC ENV-Smithers station: November 1, 2018 – December 6, 2018 data from St. Joseph's station, and February 1, 2019 – January 16, 2020 data from Muheim Memorial station; ; data between those periods are missing.

^b Period average value is the average of 24-hour values observed in each period.

^c Year 2018 includes observed data from November 1, 2018 to December 31, 2018. Not enough data were available to do the full year calculation metric (see Table 3.2-1).

^d Year 2019 includes observed data from January 1, 2019 to December 31, 2019.

^e Year 2020 includes observed data from January 1 to 16, 2020. Not enough data were available to do the full year calculation metric (see Table 3.2-1).

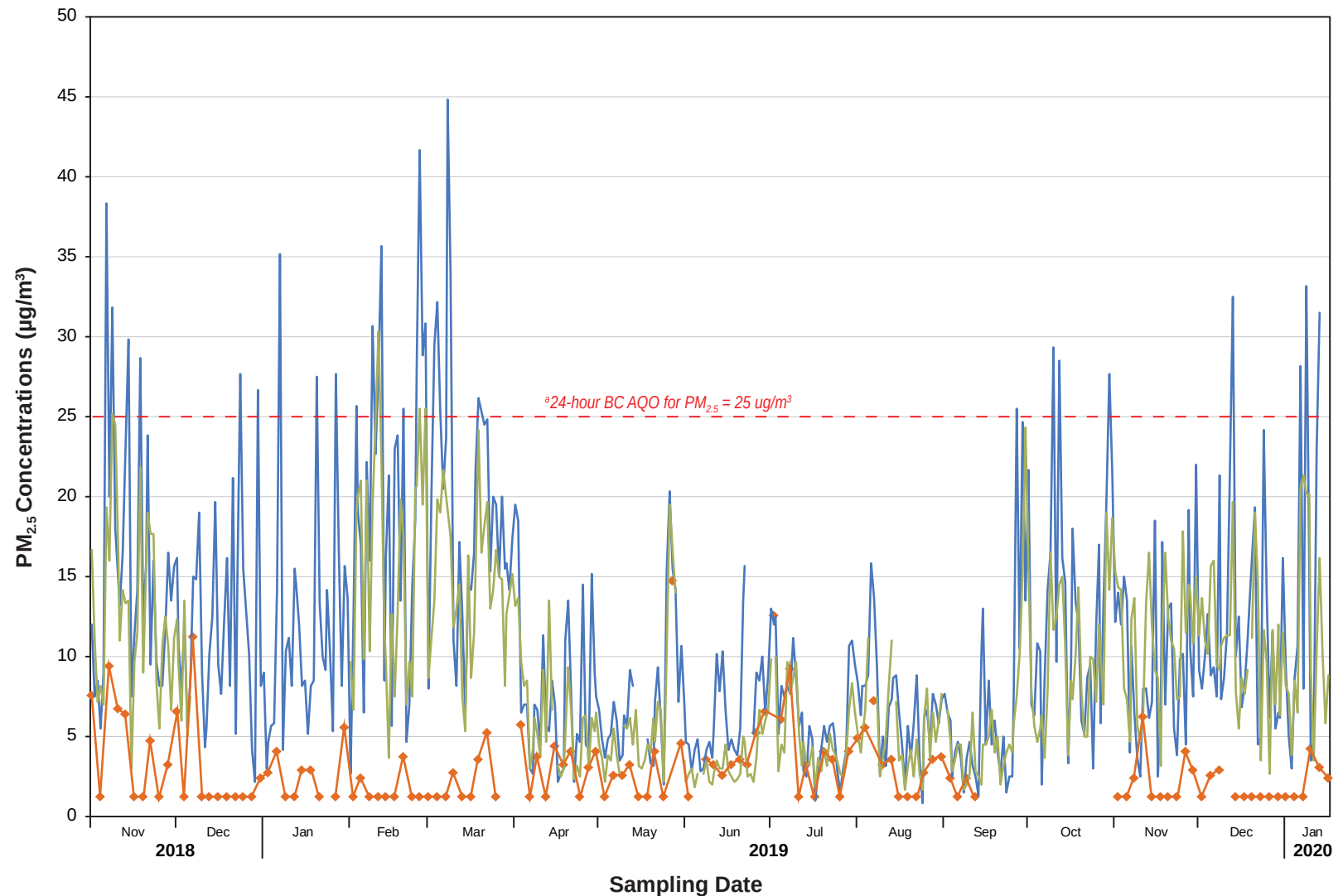
^f The 24-hour calculation metric is the annual 98th percentile of daily average, over one year. The annual calculation metric is the annual average, over one year. See Table 3.2-1 for more information.

^g The number of events represent the number days in the year when the daily average concentration was greater than 25 µg/m³, regardless of percentile.

The 24-hour PM_{2.5} BC AQO of 25 µg/m³ is based on the annual 98th percentile of daily average, over one year (BC ENV 2020a). This objective is applicable to 2019 PM_{2.5} results, and not to the 2018 and 2020 data presented in Table 3.5-5, since a minimum of one year of data are required for a true assessment. For 2019, the annual 98th percentile of daily average PM_{2.5} concentrations at BC ENV-Houston station was 30.8 µg/m³ and above the 24-hour BC AQO, while BC ENV-Smithers station had an annual 98th percentile of 22.2 µg/m³. From November 1, 2018 to January 16, 2020, all PM_{2.5} concentrations at the PM-Kerr station were below the 24-hour BC AQO. However, the 24-hour PM_{2.5} concentration was above the 25 µg/m³ benchmark about 8% of the time (33 out of 434 daily values) at the BC ENV-Houston station, and about 1% of the time (4 out of 375) at the BC ENV-Smithers station.

Figure 3.5-4

PM_{2.5} Results, November 1, 2018 to January 16, 2020



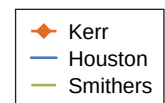
Notes: No available data from BC ENV-Telkwa Regional Station

Gaps indicate missing data.

PM-Kerr values below detection limit were considered to be half the detection limit (0.5 DL) for calculation purposes.

Data from BC ENV-Houston and BC ENV-Smithers stations are raw preliminary data and are subject to future review and revisions by the reporting agency.

^a The 24-hour calculation metric is the annual 98th percentile of daily average, over one year.



3.5.3 BC ENV Nitrogen Dioxide, Ozone, and Particulate Matter

Table 3.5-6 presents the NO₂ data from the BC ENV-Smithers station, the only one of the three stations with NO₂ data available. All observed 98th percentile of daily 1-hour maximum concentrations were below the 1-hour BC AQO of 100 ppb. From 2014 to 2019, the observed 98th percentile of daily 1-hour maximum concentration ranged from 23 to 34 ppb. All annual mean concentrations from 2016 to 2019 ranged from 5.0 to 6.2 ppb, and were below the annual BC AQO of 32 ppb.

Table 3.5-6. Air Quality Data Summary – BC ENV: NO₂

BC ENV-Smithers Station				
Year	98 th Percentile of Daily 1-hour Maximum (ppb)	No. of Exceedances of 1-hour BC AQO (100 ppb) ^a	Annual Mean (ppb)	No. of Exceedances of Annual BC AQO (32 ppb) ^b
2014	24	0	-	-
2015	-	0	-	-
2016	23	0	5.0	0
2017	29	0	5.4	0
2018	34	0	5.7	0
2019	34	0	6.2	0

Notes:

Dash (-) = data not available for this station and year

^a Based on annual 98th percentile of daily 1-hour maximum over one year.

^b Based on annual average of 1-hour average concentrations, over one year.

Table 3.5-7 presents the O₃ data from the BC ENV-Smithers station, the only one of the three stations with O₃ data available. All observed 1-hour maximum concentrations from 2014 to 2019 ranged from 52.3 to 60 ppb, and were below the 1-hour National Ambient Air Quality Objectives (NAAQO) of 82 ppb. The NAAQOs for ozone have been superseded by the CAAQS but the 1-hour NAAQO was retained for air quality advisories (BC ENV 2020a). All observed annual 4th highest daily 8-hour maximum concentrations from 2014 to 2019 were less than the 8-hour CAAQS of 63 ppb. The 8-hour CAAQS for ozone is based on annual 4th highest daily 8-hour maximum, averaged over three consecutive years.

Table 3.5-8 presents the PM₁₀ data from the BC ENV-Smithers and Houston stations (the BC ENV-Telkwa station did not monitor PM₁₀). All observed maximum daily concentrations from 2014 to 2019 from both BC ENV stations were above the 24-hour BC AQO of 50 µg/m³. Over 6 years of monitoring, there were between one and 19 daily exceedances of the 24-hour BC AQO. In the 1-hour average data from BC ENV-Smithers and Houston stations, of the twelve 75th percentile values, the maximum was 23.6 µg/m³, meaning that 75% of the time, at both stations during all five years, the 1-hour PM₁₀ concentration was at or below 23.6 µg/m³. Although both stations had episodes of high PM₁₀ concentrations during each year, the concentrations were not uniformly high throughout each year.

Table 3.5-7. Air Quality Data Summary – BC ENV: O₃

BC ENV-Smithers Station				
Year	Maximum Observed 1-hour Average (ppb)	No. of Exceedances of 1-hour NAAQO (82 ppb) ^a	Annual 4th Highest Daily 8-hour Maximum	No. of Exceedances of 8-hour CAAQS (63 ppb) ^b
2014	58.0	0	53.0 ^c	0
2015	58.0	0	47.0 ^c	0
2016	56.0	0	48.7 ^d	0
2017	55.0	0	47.7 ^d	0
2018	60.0	0	48.5 ^d	0
2019	52.3	0	48.2 ^d	0

Notes:

2014 data are raw preliminary data and is subject to future review and revisions by the reporting agency.

^a The NAAQOs for ozone have been superseded by the CAAQS, but the 1-hour NAAQO of 82 ppb is retained for air quality advisories.

^b The 8-hour CAAQS of 63 ppb for ozone is based on annual 4th highest daily 8-hour maximum, averaged over three consecutive years.

^c Annual 4th highest daily 8-hour maximum, averaged over one year. Not enough data were available to do the full three year calculation metric (see Table 3.2-1).

^d Annual 4th highest daily 8-hour maximum, averaged over three consecutive years.

Table 3.5-8. Air Quality Data Summary – BC ENV: PM₁₀

Year	BC ENV-Smithers Station		BC ENV-Houston Station	
	Maximum Observed 24-hour Average	No. of Exceedances of 24-hour BC AQO (50 µg/m ³)	Maximum Observed 24-hour Average	No. of Exceedances of 24-hour BC AQO (50 µg/m ³)
2014	78.1	4	55.0	3
2015	80.6	6	62.7	4
2016	70.7	4	61.3	1
2017	83.0	3	83.2	6
2018	120.6	2	240.4	18
2019	99.7	19	96.5	12

Note: All PM₁₀ data are raw preliminary data and are subject to future review and revisions by the reporting agency.

Table 3.5-9 presents the PM_{2.5} data from the BC ENV-Smithers, Telkwa, and Houston stations. Only three of the twelve station-years of 98th percentile 24-hour average observations were below the 24-hour BC AQO of 25 µg/m³. Only one of the twelve station-years of annual average observations was below the annual BC AQO of 8 µg/m³. The 24-hour and annual average concentrations together indicate that all three stations are subject to episodes of high PM_{2.5} concentrations during each year, and that relative to the BC AQO, the concentrations were uniformly high throughout each year. These consistent PM₁₀ and PM_{2.5} exceedances support the findings that smoke and road dust particulate matter emission sources have the largest impacts on local air quality in the Bulkley Valley (BVLDA AMS 2012) compared to other contaminant emissions and formation (e.g., SO₂, NO₂ and O₃).

Table 3.5-9. Air Quality Data Summary – BC ENV: PM_{2.5}

Year	BC ENV-Smithers Station		BC ENV-Telkwa Station		BC ENV-Houston Station	
	Annual 98 th Percentile of 24-hour Average (µg/m ³)	Annual Average (µg/m ³)	Annual 98 th Percentile of 24-Hour Average (µg/m ³)	Annual Average (µg/m ³)	Annual 98 th Percentile of 24-hour Average (µg/m ³)	Annual Average (µg/m ³)
2014	29	8.2	34	10.7	-	-
2015	24	8.3	34	12.6	31	9.7
2016	22	7.3	-	-	28	8.8
2017	35	8.3	-	-	30	9.3
2018	30	9.0	-	-	-	-
2019	22	8.5	-	-	31	10.6
Current BC AQO (µg/m ³) ^a	25	8.0	25	8.0	25	8.0

Notes:

2015 data from the Telkwa station are raw preliminary data and are subject to future review and revisions by the reporting agency.

Dash (-) = data not available for this station and year.

^a The 24-hour calculation metric is the annual 98th percentile of daily average, over one year. The annual calculation metric is the annual average, over one year. See Table 3.2-1 for more information.

3.5.4 Nearby Projects Data Summary – Dustfall, Nitrogen Dioxide, Ozone, Particulate Matter, and Sulphur Dioxide

This section presents air quality data as reported by nearby historical Projects. See Table 3.3-1 for the list of data sources.

Table 3.5-10 presents the dustfall data reported by nearby projects. The observed range of dustfall rates, from 0.3 to 0.6 mg/dm²/day, is comparable to the range observed for the Project (0.2 to 0.9 mg/dm²/day for the snow adjusted data).

Table 3.5-10. Nearby Projects – Dustfall (Davidson Project, 2005 to 2006)

Station	Averaging Period	Average Observed Dustfall Rate (mg/dm ² /day)
CN - Railway Ave (CN)	Annual	0.487
Chad's House (CH)	Annual	0.595
Slack Road (SL)	Annual	0.323
Kathlyn Lake Elementary School (KL)	Annual	0.328
Glacier Gulch Site (GG)	Annual	0.328
Adit Road (AR)	Annual	0.370
Northern Route Site (NR)	Annual	0.321
Davidson Road (DR)	Annual	0.482

Table 3.5-11 presents the SO₂ data reported by nearby projects. The maximum values were well below the current BC AQOs.

Table 3.5-11. Nearby Projects – SO₂ (Davidson Project)

Years	Station Identification	Averaging Period	Maximum Observed SO ₂ (ppb)	Current BC AQO (ppb)
1996-2006	Davidson-St Joseph	1-hour	10.3 ^{a,c}	75 ^b
		Annual	1.3 ^c	5

Notes:

There is no BC AQO for monthly SO₂.

^a 98th percentile.

^b Achievement based on annual 97th percentile of daily 1-hour maximum averaged over 2015-2017.

^c Data reported as µg/m³ in the source dataset and converted to ppb in this table using 25°C and 1 atmosphere.

Table 3.5-12 presents the NO₂ data reported by nearby projects. The observed maximum concentrations are significantly lower than the applicable BC AQOs.

Table 3.5-12. Nearby Projects – NO₂ (Davidson Project)

Years	Station Identification	Averaging Period	Maximum Observed NO ₂ (ppb)	Current BC AQO (ppb)
1997-2006	Davidson-St Joseph	1-hour	18.6 ^{a,b}	100 ^a
		Annual	5.9 ^b	32

Notes:

There is no BC AQO for monthly NO₂.

^a 98th percentile of daily 1-hour maximum (D1HM), over one year.

^b Data reported as µg/m³ in the source dataset and converted to ppb in this table using 25°C and 1 atmosphere.

Table 3.5-13 presents the PM₁₀ data reported by nearby projects. The maximum observed 24-hour average concentration was reported by the data source as a 98th percentile rather than a 100th percentile as used by the BC AQO. This 98th percentile is below the current BC AQO, but it is likely the 100th percentile would have been above the BC AQO.

Table 3.5-13. Nearby Projects – PM₁₀ (Davidson Project)

Years	Station Identification	Averaging Period	Maximum Observed PM ₁₀ (µg/m ³)	Current BC AQO (µg/m ³)
1997-2006	Davidson-St. Joseph	24-hour	43.6 ^a	50
		Annual	15.9	— ^b

Notes:

^a The data source document reports this value as the 98th percentile, while the current BC AQO uses the 100th percentile.

^b There is no BC AQO for annual PM₁₀.

Table 3.5-14 presents the PM_{2.5} data reported by nearby projects. Both the 24-hour and annual values from 2004 to 2006 are similar to the more recent 2014 to 2017 24-hour and annual values, respectively (Table 3.5-7).

Table 3.5-14. Nearby Projects – PM_{2.5} (Davidson Project)

Years	Station Identification	Averaging Period ^a	Maximum ^a Observed PM _{2.5} (µg/m ³)	Current BC AQO (µg/m ³)
2004-2006	Davidson-St. Joseph	24-hour	27.2	25
		Annual	9.8	8.0

Note:

^a: The 24-hour calculation metric is the annual 98th percentile of daily average, over one year. The annual calculation metric is the annual average, over one year. See Table 3.2-1 for more information.

4. NOISE

Elevated noise levels can have direct and indirect health effects on wildlife and human populations. Noise may affect wildlife populations by causing them to avoid important habitats and/or take time away from other key behaviors such as feeding, breeding, or watching for predators, which can ultimately lead to reduced reproductive productivity and/or increased mortality.

The objectives of the noise baseline monitoring program were to:

- establish noise monitoring locations in the vicinity of project infrastructure (mine site and rail loadout); and
- characterize existing ambient and background baseline noise levels prior to the generation of Project-related noise.

The baseline noise monitoring program will allow for comparison of measured ambient levels to measured or modelled noise levels that may be done in the future, associated with the proposed Tenas Project. Potential applications of noise monitoring may include supporting adaptive management, supporting the resolution of potential noise complaints, and informing other baseline and assessment programs (e.g., wildlife monitoring).

4.1 STUDY AREA

The Project is located in west-central BC, in the Bulkley Valley Lakes District (BVLD). The Tenas coal deposit is approximately 13 km from the community of Telkwa. The primary sources of ambient sound in the general project area include wildlife, traffic, aircraft, trains, other machinery, hunting, surface water, rain, and wind.

Figure 4.1-1 provides the noise monitoring stations.

4.2 REGULATORY AND POLICY FRAMEWORK

BC does not have any regulations or guidelines for mining or community noise. The following list of documents provide examples of noise guidelines published by other jurisdictions:

- The village of Telkwa has *Noise Control Bylaw No. 495, 2001* (2001) that describes noise restrictions within the community in order to prevent noise nuisance.
- BC oil and gas industry noise guidelines and noise limit calculation processes described in the BC Oil & Gas Commission *BC Noise Control Best Practices Guideline* (2009): “New facilities should meet a Permissible Sound Level of 40 dBA L_{eq} (nighttime) at the nearest dwelling, or at 1.5 km from the facility fence line, whichever is the lesser distance”. Also, low frequency noise from heavy equipment engines will be assessed by calculating a dBC – dBA to be less than 20 dB.
- Environment Canada *Environmental Code of Practice for Metal Mines* (2009): “In residential areas adjacent to mine sites, the equilibrium sound pressure level (L_{eq}) from mining activities should not

exceed 55 dBA during the day and 45 dBA at night. Ambient noise can also affect wildlife, so sites in remote locations should also work to meet these objectives for off-site ambient noise levels."

- World Health Organization (1999) has published guidelines on recommended noise levels to minimize sleep disturbance: *"If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise" and "For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dB L_{max} more than 10 to 15 times per night."*

4.3 EXISTING INFORMATION

Readily available sources of existing noise information were reviewed, and a summary of the review is provided in Table 4.3-1. The reviewed information included publicly available sources. The list of reviewed information is not exhaustive and additional potential sources of relevant public and private information may be available.

4.4 METHODOLOGY

The noise monitoring program was developed in accordance with *ASTM E1686-03 Standard Guide for Selection Environmental Noise Measurements & Criteria* (ASTM 2008) to monitor baseline noise levels in the Project area. Noise samples were collected using a Bruel & Kjaer Type 2250 (Class 1) sound level meter capable of logging data and audible noise.

The sound level meter was configured to sample in decibels using the "A and C" standardized frequency ratings (dBA, designed to match the frequency response of the human ear; dBC, designed to take into account low-frequency components of noise within the audibility range of humans), depending on the metric being recorded. The sound level meter was fitted with a microphone protected by a wind screen to help reduce the affects of the wind hitting the microphone and generating noise from the microphone itself. This windscreen reduces wind noise by approximately 15 dB for wind speeds up to 120 km/h and fulfils IEC 61672 class 1 and ANSI S1.4 Type 2 standards.

Noise measurements were logged once every minute at approximately 1.5 m above ground. Measurements were taken for approximately 24 hours at each sampling season and each location. For QA/QC purposes, the sound level meter was calibrated before and after each monitoring period. The hand held calibrator used for this purpose was a Bruel & Kjaer Type 4231 calibrator. At the time of use, both devices held manufacturers calibrations certificates within their recommended recalibration interval.

The software setup of the instrument and list of monitoring parameters were discussed with Ardea Biological Consulting before monitoring (L. Turney, pers. comm.) in order to ensure that the measurements were appropriate for informing wildlife baselines and assessments.

Figure 4.1-1
Noise Monitoring Locations

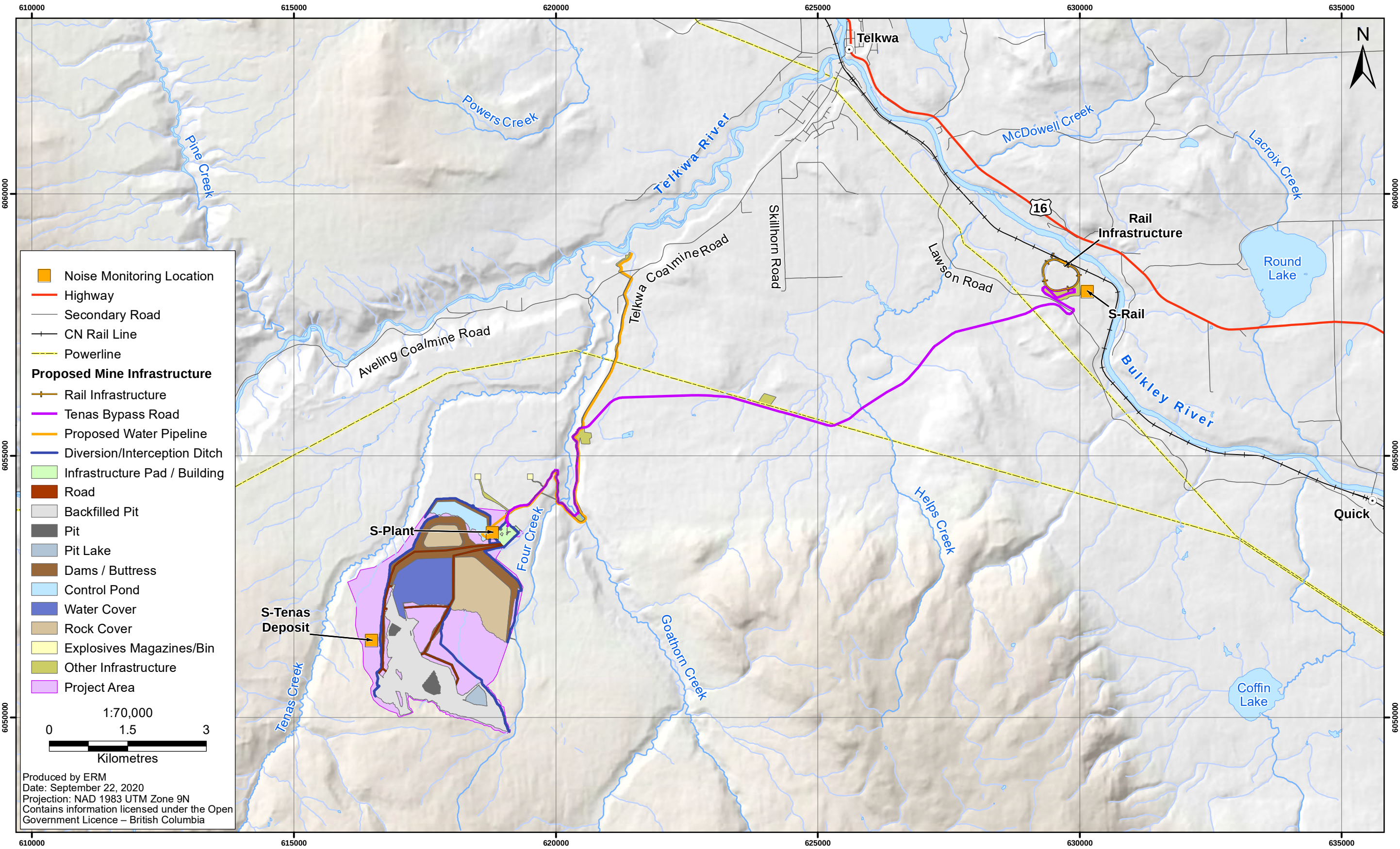


Table 4.3-1. Baseline Noise Monitoring Data Information Table

Documents Reviewed	Davidson Project • <i>Davidson Project: Application for Environmental Assessment Certificate.</i> Submitted by Blue Pearl Mining Inc. (Rescan. 2008. <i>Davidson Project Application for Environment Assessment Certificate - Section 6.15 Noise.</i> Prepared for Blue Pearl Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.) • <i>Davidson Project Meteorology, Air Quality and Noise baseline Study</i> (Rescan. 2007. <i>Davidson Project Meteorology, Air Quality and Noise Baseline Study.</i> Prepared for Blue Pearl Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.) Telkwa Coal Project • <i>Telkwa Coal Project: Application for a Project Approval Certificate – Volumes I-V.</i> Submitted by Manalta Coal Ltd. (Manalta Coal Ltd. 1997. <i>Telkwa Coal Project: Application for a Project Approval Certificate.</i> Prepared by Manalta Coal Ltd.: Vancouver, BC.)
General Remarks	Reviewed information included publicly available sources for data collected in the general regional area surrounding the Tenas Project. The list of reviewed information is not exhaustive and additional potential sources of relevant public and private information may be available.
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR for MA/EMA Permits)	There are no noise baseline sampling requirements described in the Joint AIR or for EAs.
Existing Monitoring Data	Davidson Project • Extensive baseline ambient noise data from eight monitoring stations close to the proposed Davidson Project and within the town of Smithers. 11,000 hours of noise data were recorded during four seasonal periods from September 2005 to August 2006. Telkwa Coal Project • No relevant ambient noise data were included in the application. The application only qualitatively described noise emission sources.
Existing Data Issues	Representative on-site noise monitoring data are required to inform wildlife studies and potential future human health and noise assessment studies. The eight Davidson Project noise monitoring stations were located close to the Davidson Project or within the town of Smithers. They are outside of and not representative of the Tenas Project area or the community of Telkwa. However the existing data may be useful for comparison to on-site noise monitoring.
Missing Data	Baseline ambient noise data for the Tenas Project area or for the community of Telkwa were not available.
2017–March 2018 Baseline Program	The primary noise emissions of concern for the proposed Tenas Project are from machinery and blasting. These are common noise emissions from mining projects. In order to determine baseline ambient noise levels for the Project, three noise monitoring stations were established to monitor baseline ambient noise in each season. The data are intended to be used to inform additional studies, including wildlife and potential future human health and noise assessments.
Key Issues	None
Other Comments	None

Noise was monitored at three stations (S-Plant, S-TenasDep, and S-Rail); their locations are summarized in Table 4.4-1 and mapped on Figure 4.1-1. The S-Plant and S-TenasDep station locations were chosen by Ardea Biological Consulting for the purpose of measuring baseline noise in the area of the proposed mine site to inform wildlife studies. S-Plant is near the proposed coal processing plant infrastructure, in a cutblock with young trees (Photo 4.4-1). S-TenasDep is near the edge of the proposed open pit, in a mature forest (Photo 4.4-2). The S-Rail station location was chosen for the purpose of measuring baseline noise in the area of the proposed rail load out to inform wildlife and human health studies. S-Rail is located within the proposed rail infrastructure, in a cutblock with young trees (Photo 4.4-3).

Table 4.4-1. Baseline Noise Monitoring Stations

Monitoring Station ID	UTM Zone 9U Coordinates		Station Description	Monitoring Dates
	Easting	Northing		
S-Plant	618794	6053543	Located in a forest cut block within the proposed location of the plant/water treatment area. Station surrounded by small young trees on gentle mountain slope.	October 16 – 17, 2017 December 12 – 13, 2017 March 20 – 21, 2018
S-TenasDep	616490	6051477	Located in mature forest adjacent to the proposed location of the Tenas deposit open pit. Station is on a gentle mountain slope.	October 17 – 18, 2017 December 11 – 12, 2017 March 21 – 22, 2018
S-Rail	630146	6058143	Located in a forest cut block within the proposed rail load out loop. A small 10 m high steep hill is 40 m south of the station, farm land is 140 m west, existing active train tracks are 340 m northeast, and Highway 16 is 900 m northeast.	December 15 – 18, 2017 March 22 – 23, 2018



Photo 4.4-1. Noise monitoring station location S-Plant after deployment. October 16, 2017. Looking south.



Photo 4.4-2. Noise monitoring station location S-TenasDep after deployment. October 17, 2017. Looking east.



Photo 4.4-3. Noise monitoring at new station S-Rail after deployment. December 15, 2017. Looking west.

Monitoring took place at S-Plant and S-TenasDep in October and December 2017, and March 2018. The S-Rail station was added in December 2017 and was monitored in December 2017 and March 2018. All stations measured one 24 hour period in each of these months, except for S-Rail in December when three consecutive days were measured to take advantage of favorable fieldwork schedule logistics. See Table 4.4-1 for monitoring dates.

Detailed field notes were recorded for each monitoring event and are presented in Appendix 4-A.

4.5 DATA SUMMARY

4.5.1 Noise Monitoring

Tenas Project baseline ambient noise data are summarized in the sections below. One-minute LA_{eq} data graphs with noise source descriptions are presented in Appendix 4-B. Hourly noise data and weather conditions are tabulated in Appendix 4-C.

Noise metrics used in this report (e.g., LA_{eq} , LA_{max} , LA_{10} , LA_{90} , LA_{min}) are defined in the Glossary and Abbreviations section and described below:

- LA_{eq} : The equivalent or average noise level during a measurement period, in dBA.
- LA_{max} : The absolute maximum noise level in a noise measurement period, in dBA.
- LA_{10} : The noise level exceeded for 10% of the time and is approximately the average of the maximum noise levels, in dBA.
- LA_{90} : The noise level exceeded for 90% of the time and is approximately the average of the minimum noise levels, in dBA.
- LA_{min} : The absolute minimum noise level in a noise measurement period, in dBA.

4.5.1.1 S-Plant Baseline Noise Results

Table 4.5-1 presents the overall (day, night, and day + night) noise metrics for each monitoring season at the S-Plant location.

Noise levels at the S-Plant monitoring location are generally consistent with a quiet, forested area away from most anthropogenic noise sources. Natural sources of noise identified during the fall, winter, and spring monitoring periods include rainfall, wildlife, bird calls, and wind. Relative to the fall and spring monitoring periods, lower noise levels (LA_{eq}) recorded during the winter monitoring period (December 12 and 13, 2017) are attributed to lower levels of audible wind gusts. Anthropogenic sources of noise were identified as occasional aircraft noise (e.g., helicopters, planes), and distant train horns.

4.5.1.2 S-TenasDep Baseline Noise Results

Table 4.5-2 presents the overall (day, night, and day + night) noise metrics for each monitoring season at the S-TenasDep location.

Table 4.5-1. S-Plant Baseline Noise Results (dBA) for Fall 2017, Winter 2017, and Spring 2018

Season	Period	Start time	End time	Duration (hh:mm)	LA _{eq}	LA _{max}	LA ₁₀	LA ₉₀	LA _{min}
Fall 2017	Day and Night	Oct. 16 12:18	Oct. 17 12:48	24:30	35.9	71.1	33.9	20.7	17.5
	Day only	Oct. 16 12:18	Oct. 17 12:48	15:30	37.7	71.1	35.8	21.5	19.2
	Night only	Oct. 16 22:00	Oct. 17 07:00	9:00	26.1	47.6	28.4	20.0	17.5
Winter 2017	Day and Night	Dec. 12 12:18	Dec. 13 12:55	24:37	21.3	53.0	20.4	17.4	16.5
	Day only	Dec. 12 12:18	Dec. 13 12:55	15:37	21.3	50.3	20.8	17.3	16.6
	Night only	Dec. 12 22:00	Dec. 13 07:00	9:00	21.4	53.0	19.5	17.4	16.5
Spring 2018	Day and Night	Mar. 20 10:13	Mar. 21 09:28	23:15	35.0	73.3	35.5	16.8	16.4
	Day only	Mar. 20 10:13	Mar. 21 09:28	14:15	37.1	73.3	38.2	17.7	16.5
	Night only	Mar. 20 22:00	Mar. 21 07:00	9:00	17.8	45.9	17.5	16.7	16.4

Notes:

Daytime noise occurs between 7:00 and 22:00; Nighttime noise occurs between 22:00 and 7:00.

Metrics are defined in the Glossary and Abbreviations section of this report.

Table 4.5-2. S-TenasDep Baseline Noise Results (dBA) for Fall 2017, Winter 2017, and Spring 2018

Season	Period	Start time	End time	Duration (hh:mm)	LA _{eq}	LA _{max}	LA ₁₀	LA ₉₀	LA _{min}
Fall 2017	Day and Night	Oct. 17 17:40	Oct. 18 18:18	24:38	27.3	64.3	28.4	17.1	16.3
	Day only	Oct. 17 17:40	Oct. 18 18:18	15:38	28.6	64.3	29.5	17.0	16.3
	Night only	Oct. 17 22:00	Oct. 18 07:00	9:00	22.9	48.0	25.3	17.1	16.6
Winter 2017	Day and Night	Dec. 11 10:54	Dec. 12 10:03	23:09	20.0	55.4	18.1	16.4	16.1
	Day only	Dec. 11 10:54	Dec. 12 10:03	14:09	20.5	55.4	18.7	16.5	16.1
	Night only	Dec. 11 21:59	Dec. 12 07:00	9:00	19.1	49.9	17.1	16.4	16.1
Spring 2018	Day and Night	Mar. 21 11:42	Mar. 22 09:14	21:32	36.4	68.8	39.5	17.8	17.1
	Day only	Mar. 21 11:42	Mar. 22 09:14	12:32	37.8	68.8	40.9	18.9	17.2
	Night only	Mar. 21 22:00	Mar. 22 07:00	9:00	33.1	68.0	36.6	17.6	17.1

Notes:

Daytime noise occurs between 7:00 and 22:00; Nighttime noise occurs between 22:00 and 7:00.

Metrics are defined in the Glossary and Abbreviations section of this report.

Noise levels at the S-TenasDep monitoring location are generally consistent with a quiet, forested area away from most anthropogenic noise sources. Natural sources of noise identified during the fall, winter, and spring monitoring periods include rainfall, wildlife, bird calls, and wind. Relative to the fall and winter monitoring periods in 2017, higher noise levels (LA_{eq}) recorded during the spring monitoring period (March 21 and 22, 2018) are attributed to frequent and strong gusts of wind, and tree and leaf movement/rustling (see Appendix 4-B and 4-C). Anthropogenic sources of noise were identified as aircraft noise, and distant train horns.

4.5.1.3 S-Rail Baseline Noise Results

Table 4.5-3 presents the overall (day, night, and day + night) noise metrics for each monitoring season at the S-Rail location.

Table 4.5-3. S-Rail Baseline Noise Results (dBA) for Winter 2017 and Spring 2018

Season	Period	Start time	End time	Duration (hh:mm)	LA _{eq}	LA _{max}	LA ₁₀	LA ₉₀	LA _{min}
Winter 2017	Day and Night	Dec. 15 10:37	Dec. 16 11:17	24:40	41.9	70.9	44.7	24.9	19.9
	Day only	Dec. 15 10:37	Dec. 16 11:17	15:40	42.7	70.9	45.3	32.4	21.6
	Night only	Dec. 15 22:00	Dec. 16 07:00	9:00	40.1	63.8	43.0	22.5	19.9
	Day and Night	Dec. 16 11:46	Dec. 17 12:45	24:59	41.1	65.0	42.3	27.2	20.3
	Day only	Dec. 16 11:46	Dec. 17 12:45	15:59	41.4	65.0	43.0	30.4	22.4
	Night only	Dec. 16 22:00	Dec. 17 07:00	9:00	40.5	62.2	39.6	25.7	20.3
	Day and Night	Dec. 17 13:00	Dec. 18 10:02	21:01	40.3	67.3	43.2	25.1	18.8
	Day only	Dec. 17 14:00	Dec. 18 10:02	11:02	40.8	67.3	43.3	30.3	21.9
	Night only	Dec. 17 22:00	Dec. 18 07:00	9:00	39.9	58.4	43.3	22.2	18.8
Spring 2018	Day and Night	Mar. 22 13:10	Mar. 23 14:04	24:54	39.4	80.4	40.0	19.1	17.1
	Day only	Mar. 22 13:10	Mar. 23 14:04	15:54	40.9	80.4	41.0	21.9	17.1
	Night only	Mar. 22 22:00	Mar. 23 07:00	9:00	33.5	52.2	35.3	18.4	17.1

*Notes:**Daytime noise occurs between 7:00 and 22:00; Nighttime noise occurs between 22:00 and 7:00.**Metrics are defined in the Glossary and Abbreviations section of this report.*

The S-Rail location was not monitored in the fall of 2017. In contrast to the S-Plant and S-TenasDep monitoring locations, noise levels at the S-Rail monitoring location were substantially influenced by nearby highway (900 m away) and rail activity (340 m away) noises. As a result, natural sources of noise are generally blended with or drained out by anthropogenic noise originating from the highway (vehicular traffic), railway (train cars, engines, and horns), or by occasional overflying aircraft. Noise spikes attributed to close proximity natural noise are limited and are associated with bird calls and wind.

5. HYDROGEOLOGY

This chapter presents the methods and results of the hydrogeology baseline monitoring program. The purpose of the 2017 to 2019 program was to collect Project specific baseline hydrogeology data. An understanding of this information will contribute to engineering analysis and water management feature design; support future development of predictive models, effects assessments, management plans, and closure planning; support permitting; and monitor changes in the local hydrogeology.

The objective of the 2017 to 2019 program was to:

- characterize the baseline groundwater quality and quantity of the Project area; the new information will be compared to the historical data.

5.1 STUDY AREA

The local study area (LSA) for the August 2017 – November 2019 baseline program is defined as the area where the Project may have a direct influence on the groundwater system and or groundwater users. The LSA is based on watershed boundaries and includes the Project footprint and private domestic wells located down-gradient of the Project (Figure 5.1-1).

5.2 REGULATORY AND POLICY FRAMEWORK

Groundwater is an important component of the biological and physical environment and is protected under the Groundwater Protection Regulation of the British Columbia (BC) *Water Sustainability Act* (2016). Groundwater baseline studies for the Project were designed to meet the requirements of the BC *Environmental Assessment Act* [SC 2002, c.43], and the *Mines Act* and *Environmental Management Act* Permits Joint Application Information Requirements (BC MEM and BC MOE 2016).

5.3 EXISTING INFORMATION

Exploration was conducted on the Telkwa Coal Property in the 1980's and 1990's, and extensive environmental baseline work was also collected over the decades. Table 5.3-1 below summarizes the existing hydrogeology data for the project, as well as the baseline work conducted in 2017 to 2019.

5.4 METHODOLOGY

The objective of the 2017 to 2019 baseline hydrogeology monitoring program was to expand the existing baseline database in areas that could potentially be affected by the development of the Tenas Project, and to capture seasonal and annual variability in groundwater levels.

The following sub-sections describe the field methodologies for the baseline hydrogeology monitoring program from July 2017 to November 2019.

Telkwa Coal Limited

Local Study Area

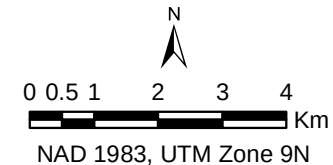
Figure 5.1-1

Legend

- GW LSA
- Mine Footprint
- Offsite Footprint

Map Features

- Road
- Highway
- Rail Line
- River/Stream
- Lake
- Wetland
- 20m Contour Line
- Municipal Area



Sources

Field Data: Cassiar Geoscience Consulting Ltd., Telkwa BC
Mine Features: ERM Consultants Canada Ltd., Smithers BC
Basedata: Government of BC
Mapping: Terraniche Environmental Solutions Ltd., Smithers BC
Date: November 17, 2020

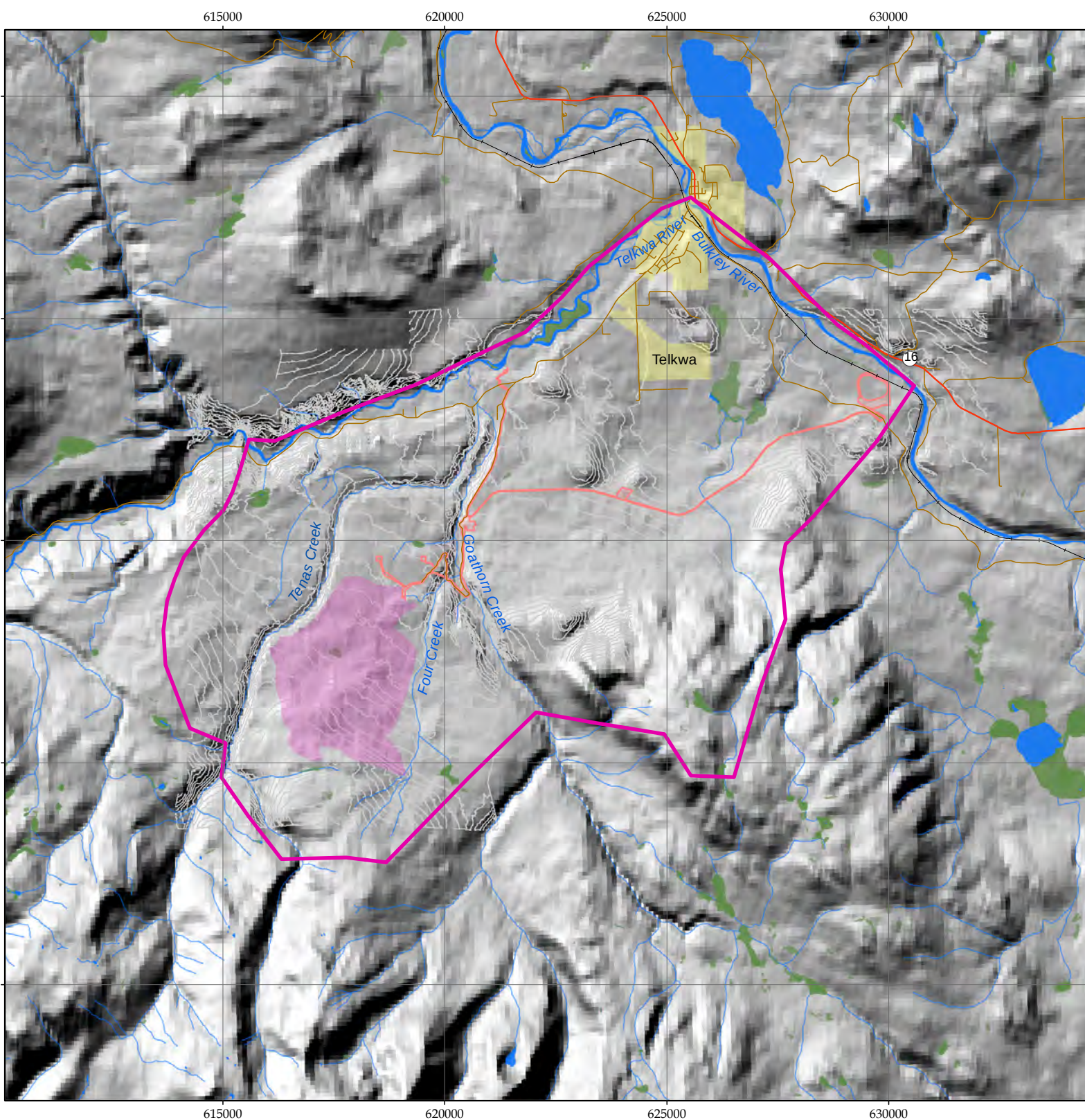


Table 5.3-1. Hydrogeology Data Information Table

Documents Reviewed	• <i>Baseline Data – Surface Water and Groundwater, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. (1994). • <i>Preliminary Assessment of Potential Groundwater Inflows and Dewatering Requirements in the Tenas Creek Region, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. (1996). • <i>Baseline Hydrogeological Investigations in the Tenas Pit, Waste Dumps, and Mine Pit 3, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. (1997). • <i>Baseline Hydrogeological Conditions in the Telkwa Coal Project Area – Volumes I and II.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. (1998).
General Remarks	• Insufficient seasonal measurement data acquired during the historical sampling events. Measurements were only collected during the late summer/early fall of 1995, 1996, and 1997. • Installing transducers in monitoring wells, which provide adequate spatial coverage of the proposed pit area (including up-gradient and down-gradient of the pit). The transducers will record water levels twice daily for a minimum of one year.
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR)	• One year of monthly groundwater levels and a credible database of low-flow streamflow measurements over two years is recommended. • Minimum one year of continuous water level measurements (i.e., daily measurements for key monitoring wells) using water level sensors (BC Ministry of Environment 2016).
Existing Data	• 1995: Tenas Pit - Rising head permeability tests. • 1996: Tenas Pit - Preliminary assessment of potential groundwater inflows and dewatering requirements for the Tenas Pit. Borehole drilling and installation of 5 piezometers within bedrock and 6 within surficial sediments. Rising head permeability tests.
Existing Data Issues	• Prior to initiating the 2017 to 2019 baseline field work there was uncertainty on the usability of the existing monitoring wells. • Historical data (i.e., well locations) did not support the configuration of the Tenas Project and new locations were recommended as part of the 2017 to 2019 baseline study. • Existing hydraulic conductivity (K) dataset provided a reasonable estimation of the range associated with coal seams, but it was not suitable to characterize properties of the rocks below the main coal-bearing sequence and differentiate low permeability layers that may limit groundwater flows down-gradient of the mine pit.
Missing Data	• No baseline hydrogeology work was conducted between 1997 and 2016. • Nine monitoring wells were inspected by Stantec in November 2016 within the northern portion the Tenas pit area. Three wells were damaged (blockage below surface or damaged casing), and three were dry.

(continued)

Table 5.3-1. Hydrogeology Data Information Table (completed)

2017 to 2019 Baseline Program	• 22 existing monitoring wells were inspected to determine their usability on July 25 and 26, 2017. • Quarterly groundwater monitoring at 13 existing wells initiated in July 2017. • Continuous water level monitoring (recorded at 12-hour intervals) at five wells initiated in September 2017. • Installation of five new hydrogeology monitoring wells took place in February 2018 to support the Tenas Project configuration. In addition, one pumping test well (ARD 2) and three new geotechnical wells (GEO 11, GEO 13, and GEO 22) were also installed. The water level for these wells were measured in conjunction with the other five new wells. • Packer injection tests were performed on one of the newly installed groundwater wells (W1) and two of the ARD boreholes (ARD 1 and ARD 6) during the February 2018 drilling program. • Well development was performed on the five newly installed wells during the March/April 2018 baseline groundwater program. Well development was also performed at the newly installed pump test well ARD 2. • Hydraulic conductivity tests (slug tests) were performed on five of the nine newly installed wells during the 2017 to 2019 baseline groundwater program (W1 Shallow, W2, W3 Shallow, W3 Deep, and ARD 2). • A pump test was conducted at ARD 2 from March 5 to 7, 2019 to estimate the physical properties of the sandstone aquifer and to determine if there is a hydraulic connection with the overlying coal seam units. • Potential Acid Generating (PAG) Cell Wells: ▪ Nine monitoring wells were installed during the 2019 winter drilling program in the area of the proposed PAG cell. ▪ Slug tests were completed at seven of these wells in March and May 2019. ▪ Continuous water level monitoring (recorded at 12-hour intervals) in one well (19-27S (R)) was initiated in November 2019. • Geotechnical Wells (East of Goathorn Creek): ▪ Two geotechnical wells (T18-14S and T18-15S) were installed on the east side of Goathorn Creek between September 24 and 29, 2018 as part of preliminary road design feasibility study. ▪ Continuous water level monitoring (recorded at 12-hour intervals) at T18-14S and T18-15S initiated in September 2019.
Key Issues	<i>n/a</i>
Other Comments	<i>n/a</i>

5.4.1 Inspection of Existing Monitoring Wells

On July 2017, 22 existing monitoring wells in the Tenas Pit Area of the Telkwa coal field were inspected to evaluate the suitability of the existing monitoring wells for use in the groundwater baseline program (Table 5.4-1; see Figure 5.5-1). Nine of the wells were previously inspected by Stantec in November 2016 and were included in the 2017 program to record water level measurements and to confirm the 2016 observations.

Table 5.4-1. Monitoring Wells Inspected, July 2017

Area	Well ID
Within Tenas Pit	T96TP-01-10
	T96TP-02-07
	T96R-16-19 and T96R-16-28 (nested pair)
	T97R-108C-70
	T93R-17
	T95R-15C
	T96R-34-67 and T96R-34-87 (nested pair)
	T95R-40
	T95R-39C
	T95R-64
	T96R-56C-83
Outside of Tenas Pit	TOB96-01-05
	TOB96-02-06 and TOB96-02-20 (nested pair)
	TOB96-11-04 and TOB96-11-19 (nested pair)
	TOB97-07-24
	TOB97-06-21
	TOB96-12-04
	T93R-18

The following data were recorded at each well that was inspected:

- date of inspection;
- depth to water (metres below top of casing [m btoc]);
- depth to bottom (m btoc);
- stick up (metres above ground surface [m ags]);
- diameter of well casing (inches [in.]);
- damage (yes/no); and
- dry (yes/no).

Field notes and photographs were also taken at each well location (Appendix 5-A).

5.4.2 Groundwater Level Monitoring

Manual groundwater levels and total well depth were measured from a consistent location at each monitoring well using a Solinst water level tape to monitor seasonal groundwater elevations. Well stick-up height was measured using a measuring tape. Water level measurements were not always possible in flowing artesian wells during the winter months due to frozen water columns.

Five Solinst Levellogger transducers (M10) and one Solinst barologger were installed in September 2017 in five baseline monitoring wells (Table 5.42) and programmed to collect continuous water level measurements at 12-hour time intervals. Three of the transducers were deployed in monitoring wells

screened in bedrock coal seams and two were deployed in glacial overburden soils (Table 5.4-2). These wells were selected for continuous monitoring as they provide adequate spatial coverage for a more detailed understanding of groundwater flow patterns within the proposed pit area. The barologger was deployed at T95R-64 at the mid-point elevation of the Project to capture average barometric pressure.

Table 5.4-2. Summary of Data Loggers Deployed, 2017 to 2019

Well ID	Logger Serial Number	Lithology	Monitoring Period
T95R-15C	2065041	Bedrock coal seam	September 2017 - Present
T96R-16-19	2060396	Bedrock coal seam	September 2017 - Present
T95R-64	2065044	Bedrock coal seam	September 2017 - Present
TOB96-02-06	2065063	Glacial overburden	September 2017 - Present
TOB96-02-20	2077546	Glacial overburden	September 2017 - Present
T95R-64	2077834 (barologger)	n/a	September 2017 - Present
W1 Shallow	2106507	Interface between Hazelton Group Volcanics and Glacial overburden	August 2019 - Present
W1 Deep	2104636	Hazelton Group Volcanics	August 2019 - Present
W2	2110536	Glacial overburden	August 2019 - Present
W3 Shallow	2110531	Glacial overburden	August 2019 - Present
W3 Deep	2110535	Hazelton Group Volcanics	August 2019 - Present
T18-14S	2111314	Glacial overburden	September 2019 - Present
T18-15S	2111310	Glacial overburden	September 2019 - Present
19-27(S)	2112090	Glacial overburden	November 2019 - Present

Eight additional Solinst Levellogger transducers (M5 and M10) were installed in 2019 (Table 5.42) and programmed to collect continuous water level measurements at 12-hour time intervals.

The data loggers were downloaded during each quarterly sampling/monitoring event. The data obtained from the data loggers were compensated for changes in atmospheric pressure using measurements from dedicated on-site barometric pressure recorder located within T95R-64.

5.4.3 Installation and Development of New Wells

5.4.3.1 Well Installation 2018

Nine new monitoring wells were installed during the January/February 2018 hydrogeology drilling program (five groundwater monitoring/sampling wells, three geotechnical wells and one pumping test/monitoring well). The locations for the installation of the monitoring wells were selected based on the following considerations:

- enhancing the hydrogeological database by collecting additional hydraulic conductivity information which can be used to improve predictions of pit inflow, potential dewatering requirements and slope pore pressures;

- improve the spatial coverage in the area of Tenas Creek in regard to the hydrogeology baseline quality and quantity data; and
- monitor groundwater elevations below proposed waste rock piles.

Seven of the new groundwater monitoring/sampling wells are comprised of 2-in. (53 millimetre [mm]) diameter, schedule 40 PVC (polyvinyl chloride) with a 0.01 in. (0.25 mm) slot-size screen, while the other groundwater monitoring/sampling well are comprised of a 1.5-in. (38 mm) diameter schedule 40 PVC with a 0.01 in. (0.25 mm) slot-size screen. The 3-in. (76 mm) well (ARD2) was installed for a future pumping testing and has been included in the baseline monitoring program. ARD2 is comprised of schedule 40 PVC with a 0.01 in. (0.25 mm) slot-size screen. Each of the new monitoring wells has a screen length of 3.05 meters (m).

A sand filter pack was placed a minimum of 0.3 m above the top of the screen in each well, and each borehole was backfilled with bentonite pellets or chips to provide a surface seal as required by the Groundwater Protection Regulation of the BC *Water Sustainability Act* (2016). ARD2 was grouted above the bentonite pellet seal after allowing the bentonite pellets to hydrate for over an hour.

Each PVC well was capped with a J-plug and a steel well monument was constructed to protect the PVC stickup. Sub-frost artesian plugs were installed at two of the new wells (W1 Shallow and W1 Deep) during the September 2018 sampling/monitoring event as these wells exhibited flowing artesian conditions. Well logs and drill hole details for the new groundwater monitoring wells are provided in *Telkwa 2018 Winter Hydro Field Program Memo*, prepared by SRK (attached as Appendix 5-B). The locations of the monitoring wells are shown on Figure 5.5-2 (see Section 5.5 of this report).

Following installation, the new wells were developed to remove stagnant water/drilling fluids and fine-grained materials from outside the well screen to obtain representative water for sampling with the goal of achieving the lowest possible turbidity. Groundwater was removed from the wells using a combination of inertial lifting with a surge block, pumping with a submersible pump and bailing. Well development was considered to be sufficient once the field parameters stabilized and there was no further visual improvement in water quality. Appendix 5-C provides 2018 well development details.

5.4.3.2 Geotechnical Wells (East Side of Goathorn Creek) 2018

Two geotechnical wells (T18-14S and T18-15S) were installed on the east side of Goathorn Creek between September 24 and 29, 2018 as part of the preliminary road design pre-feasibility study. Well installation details and borehole logs can be found in the report titled "*Geotechnical Investigation- Tenas Haul Road, Tenas Project Feasibility Study, Telkwa, BC*", dated April 29th, 2019, prepared by Westrek Geotechnical Services Ltd. (Westrek). The location of T18-14S and T18-15S are shown in Appendix B (Drawing 02) of the Westrek report, and on Figure 5.5-2 (see Section 5.5 of this report).

5.4.3.3 Well Installation 2019

Nine monitoring wells were installed during the 2019 winter drilling program in the area of the proposed PAG cell to determine the water level in the glacial overburden and shallow bedrock and to estimate the hydraulic conductivity (K) of these lithological units. Four wells were screened in Skeena

Group sedimentary bedrock (19-21S(AA), 19-22S(Z), 19-34S(Y) and 1935S(Y)), and five were screened in glacial overburden (19-18S(AB), 19-19S(W), 19-20S(AC), 19-26S(AD) and 19-27S(R)). Well locations are illustrated on Figure 5.5-2 (see Section 5.5 of this report).

The screen length for each well is 1.52 m (5 feet). The screen and blank sections of the monitoring wells consist of 50 mm diameter PVC. The well depths range from 29.3 m (19-22S) to 58.2 m (19-21S). Well installation details and borehole logs can be found in the report titled *“Tenas Project – Factual Data Report for 2019 Field Investigation”*, dated May 2019, prepared by SRK.

Seven of the nine newly installed wells were developed from March 3 to March 6, 2019 using a combination of water/air with a truck-mounted Ingersoll Rand air compressor (air lifting). Two of the wells (19-19S(W) and 19-20S(AC)) were dry after they were installed and did not require development. Each of the wells were filled with potable water from a support vehicle and then followed by a pulse of air to create a surging effect within the screened section of the well. The air was conveyed down the interior of the monitoring well through a tremie tube set above the screened section of the well. The development process was considered to be complete when the return water was visually observed to have a low turbidity.

5.4.4 Hydraulic Conductivity (K) Testing

5.4.4.1 Packer Tests

A total of 13 pneumatic constant head packer injection tests were completed at three locations (W1, ARD 1 and ARD 6 [see Figure 5.5-2]) during the January/February 2018 hydrogeology drilling program. The packer tests were conducted using 1-m length P-sized (designed for a PQ borehole) pneumatic straddle packers purchased from RST Instruments Ltd.

The packer tests were conducted in the open borehole after the final drilling depth was reached and the geophysics was completed. The borehole was flushed with clean water for a minimum of one hour before commencing the packer tests. Nitrogen gas was used to inflate the packers and fresh water was injected downhole to create a pressure response. The injection rate and pressure response were recorded using an Inflatable Packers International (IPI) flow meter, which was provided by SRK. An In-Situ Level TROLL 700 data logger was used to record the pressure within the packer test zones which provides additional pressure measurements along with the surface measurements. The data logger was placed within a specially designed capsule below the upper packer within the test zone. The data were downloaded onto Winsitu software once the packer tests were completed at each borehole.

The packer test zones were chosen based on core logging (lithology, fractures, bedding planes, etc.) conducted by the field geologist and correlated with the geophysical data. The geophysical data were used to confirm the competency of the borehole wall for proper packer placement and to confirm changes in lithology.

5.4.4.2 *Slug Tests*

2018 Wells

During April and June 2018, and January 2019, a total of eleven slug tests (eight falling head tests and three rising head tests) were conducted at five new well locations (W1 Shallow, W2, W3 Shallow, W3 Deep, and ARD 2). The falling head tests were conducted by rapidly pouring a known quantity of water down the well and then measuring the rate at which the water descends back to the static level. The rising head tests were conducted by removing a known volume of water out of the well with a bailer and then measuring the rate at which the water recovers back to the static level. A Solinst Levelogger transducer was temporarily installed inside the well to record the water levels at one second intervals. The slug tests were conducted after the wells were sufficiently developed and were not initiated until the groundwater had reached its static elevation.

A traditional slug test has not yet been completed at W1 Deep due to the relatively high static water level (>2.5 m above ground elevation). At a future date (to be determined) a pressure test/flow test will be conducted to determine hydraulic conductivity.

Aqtesolv software was used to analyze the slug test data, and the Hvorslev (straight-line method) solution was used for the analysis.

PAG Cell Wells

From March 8-12 and May 23-28, 2019, 19 hydraulic conductivity (slug) tests (17 falling head and two rising head tests) were completed at seven of the nine PAG cell monitoring wells:

- 19-18S(AB);
- 19-21S(AA);
- 19-22S(Z);
- 19-26S(AD);
- 19-27S(R);
- 19-34S(Y); and
- 19-35S(V).

Slug tests were not completed at 19-19S(W) and 19-20S(AC) as both were dry at the time of testing. The slug tests were completed after the wells were sufficiently developed and were not initiated until the groundwater had reached its static elevation.

The majority of the falling head tests were conducted by rapidly pouring a known quantity of water (2 - 4 litres [L]) down the well and measuring the rate at which the water recovered back to its static level. Three falling head tests were completed at five of the wells with two of these tests meant to have similar displacements (4 L of water) and one of the tests meant to have a displacement approximately half of the other two (2 L of water).

Only one falling head test was completed at 19-22S(AA) due to time constraints. The falling head test at this well was completed by rapidly inserting a solid slug (Midwest GeoSciences) below the static water level to displace a known volume of water and then monitor the rate of water level recovery.

Two rising head tests and one falling head test were conducted at 19-18S(AB). The rising head tests were completed by using a standard 4.1 cm (1.6 in.) diameter bailer to rapidly pull a known quantity of water out of the well. The falling head test was completed with a solid slug (Midwest Geosciences).

TD-Diver (vanEssen Instruments) and Solinst Levellogger dataloggers were used to record the change in water pressure at specified time intervals for each individual slug test. The time interval used to monitor the water level recovery varied for each well and was dependent on the expected recovery. A barologger was used to compensate the atmospheric data in the wells with the slowest recoveries (19-21(AA) and 19-22S(Z)).

A Heron 60 m water level tape was used to manually measure the static groundwater elevation and spot check the groundwater elevation as it returned back to the static elevation.

Aqtesolv software was used to analyze the slug test results. For data comparison two solution methods were employed in the analysis – Hvorslev (straight-line method) and Cooper, Bredehoeft and Papadopoulos (type curve method).

5.4.4.3 Pump Test

A pumping test was conducted at ARD 2 from March 5 to 7, 2019 to determine the physical properties (transmissivity) of the sandstone aquifer beneath the mineable coal seams. Baseline monitoring well T95R-64, which is screened in the coal seam above the sandstone unit, was used as an observation well during the pumping test. Although T95R-64 is approximately 440 m away from ARD 2, it is the closest well available for determining if there is a possible hydraulic connection between the sandstone and the overlying coal seam. The location of ARD 2 and T95R-64 are shown on Figure 5.5-2 (see Section 5.5 of this report).

Based on the diameter of the well (76 mm [3 in.]) and the depth of the screen (69.8 to 72.9 m below ground surface [bgs]), the use of a Grundfos Redi-Flo 2 electrical submersible pump (46 mm (1.8 in.) diameter) was the most feasible option for constant pumping and achieving a maximum drawdown. A Honda 3,000 watt 120 volt inverter generator was used as the power supply for the Redi-Flo 2 pump. The groundwater was conveyed from the pump through ½ in. inner diameter (ID) x 5/8 in. outer diameter (OD) HDPE tubing to the surface.

A Mini-Diver datalogger (M50) was used to monitor water level changes at ARD 2 during the pump test. The datalogger was set at a depth of 56.7 m below the top of the casing (btoc)¹ and recorded a pressure reading every 20 seconds. A Mini-Diver barologger recorded barometric pressure every 20 seconds and was synchronized with the Mini-Diver datalogger. A Mini-Diver datalogger (M10) was used to monitor water level changes at T95R-64 and was synchronized with the datalogger in ARD 2 and the barologger.

¹ 56.7 m btoc is equivalent to 55.7 m bgs

Water quality parameters² were measured *in situ* using a YSI Professional Plus multi-parameter meter and a LaMotte 2020 turbidity meter to determine water chemistry stability and/or changes during the test. A Solinst 60 m water level tape was used to manually measure the groundwater elevation during the pumping and recovery phases of the pump test.

The flow rate was controlled via the Grundfos variable frequency drive controller and rate was measured using a stopwatch and a 1-L bucket. Groundwater was discharged through the HDPE tubing approximately 6 m down-gradient from ARD 2. There was approximately 1 m of snow and over 65 m of relatively impermeable soil/rock at the pumping location, therefore it was not expected that discharged groundwater was reintroduced into the sandstone aquifer during the pumping and recovery phases of the test.

5.4.5 Quality Assurance / Quality Control

The monitoring program design and quality assurance/quality control (QA/QC) standards were developed in conformance with the *British Columbia Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC Ministry of Environment 2016).

QA/QC procedures specific to water level measurements include correcting pressure measurements from atmospheric pressure using records from the barometric pressure transducer (barologger), and conducting manual groundwater level measurements before and after every transducer download to calibrate and verify the automatic measurement data.

5.5 DATA SUMMARY

5.5.1 Inspection of Existing Monitoring Wells

Eleven of the 22 existing monitoring wells were considered to be useable at the time of the well inspection on July 25 and 26, 2017. An additional five monitoring wells were considered to be potentially useable or useable but possibly dry (Figure 5.5-1). All 16 of these monitoring wells appeared to be in good condition and the casings were not obstructed.

Four of the 22 monitoring wells were too damaged to be used for baseline monitoring, and two wells could not be located at the coordinates provided from the historical data.

After further consideration and field observations, an additional three existing monitoring wells (T96TP-01-10, TP96TP-02-07, and T96R-34-67) were deemed unusable for the hydrogeology baseline monitoring program. T96TP-01-10 and TP96TP-02-07 were installed in 1996 as test pit wells, therefore they may not be representative of natural groundwater conditions due to historical ground disturbance. Also, during groundwater sampling in August 2017, the inside of the well casing at T96R-34-67 was noted to be cracked approximately 14 to 15 m below the ground surface, making it unusable for monitoring (and sampling).

² pH, specific conductivity, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO) and turbidity.

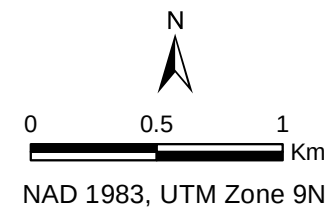
Telkwa Coal Limited

Existing Well Status July 2017

Figure 5.5-1

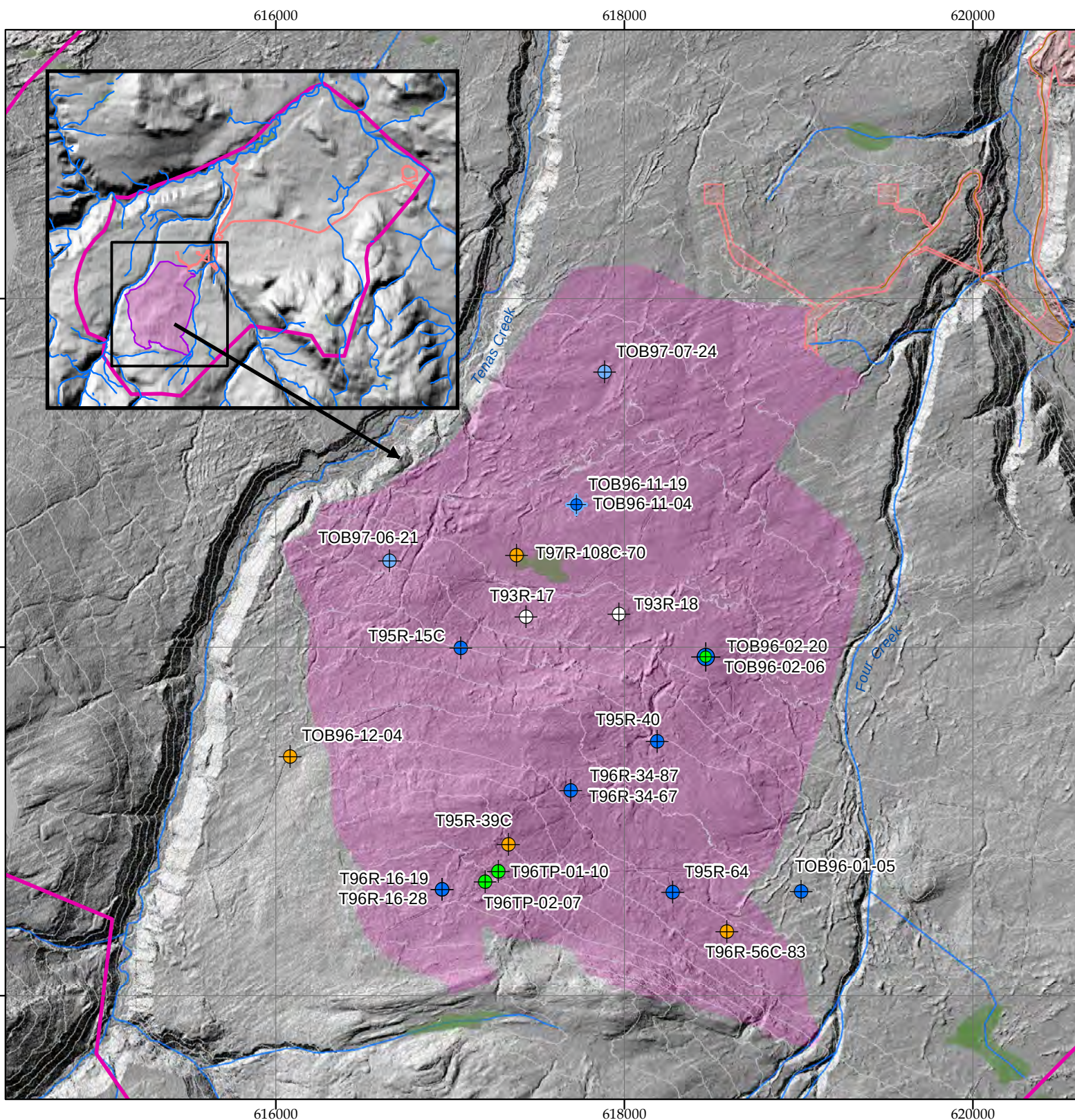
Legend

- GW LSA
- Mine Footprint
- Offsite Footprint
- Well Status
 - Damaged
 - Potentially Useable
 - Unknown
 - Useable
 - Useable/Dry
- Map Features
 - River/Stream
 - Lake
 - Wetland
 - 20m Contour Line
 - Road



Sources

Field Data: Cassiar Geoscience Consulting Ltd., Telkwa BC
Mine Features: ERM Consultants Canada Ltd., Smithers BC
Basedata: Government of BC
Mapping: Terraniche Environmental Solutions Ltd., Smithers BC
Date: November 17, 2020



In total, 13 of the 22 existing monitoring wells were deemed as useable for the hydrogeology baseline program. Figure 5.5-1 shows the status of existing monitoring wells and Appendix 5-D provides details for each of the wells inspected.

5.5.2 Groundwater Monitoring

5.5.2.1 Manual Groundwater Level Measurements – Baseline Wells

Groundwater level measurements were manually recorded in the new and existing wells (Figure 5.5-2) to monitor seasonal groundwater elevations. The monitoring wells have been subdivided into two groups based on the geologic unit within which the monitoring well is screened: bedrock and overburden. Of the 13 existing wells, six are located in bedrock and seven are located in overburden, and of the nine wells installed in 2018, four are located in bedrock and five are located in overburden (Table 5.5-1). Of the four new (2018) wells screened in bedrock, one (W1 Shallow) straddles the interface between the overburden and bedrock.

Manual groundwater levels were recorded in all the bedrock wells during the 2017 to 2019 monitoring events, with the exception of the flowing artesian wells, which were either frozen during January 2018 (T95R-15C and T96R-34-87) or had sub-frost artesian plugs installed (T95R-15C, T96R-34-87, and W1 Shallow and Deep) prior to winter 2019 (Table 5.5-1).

Manual groundwater levels were recorded in three of the seven existing overburden wells during the 2017 to 2019 monitoring events. The other four existing wells were dry during all monitoring events (with the exception of TOB96-02-20 which was not dry during the June 2018 program). Water levels were recorded in the two new overburden wells (W2 and W3 Shallow) during the 2018 and 2019 monitoring events, with the exception of June 2018 when W2 could not be measured due to an equipment malfunction (Table 5.5-1).

The three geotechnical wells installed in 2018 (GEO 11, GEO 13, and GEO 22) were dry during the 2018 and 2019 monitoring events (Table 5.5-1).

Manual groundwater elevations for the 2017 to 2019 and available historical measurement, are provided in Appendix 5-E, and graphs for each well are provided in Figures 5.5-3 and 5.5-4 in the following sub-sections.

Bedrock Monitoring Wells

In general, the existing bedrock wells screened in deeper sections of the coal seams (T95R-15C, T95R-40, T95R-64 and T96R-34-87) had the lowest measured water levels in the late spring/summer months (June 2018, August 2019, July 2017 and April 2019, respectively) and the highest measured water levels during the fall through spring months (T95R-15C (September 2017/January 2018/November 2019), T96R-34-87 (January 2018), T95R-64 (March 2018) and T95R-40 (April 2018); Figure 5.5-3).

The existing bedrock wells screened in the shallower sections of the coal seams (T96R-16-19 and T96R-16-28) had the lowest measured water levels during the September 2018 monitoring event and the highest measured water levels during the June 2019 monitoring program (Figure 5.5-3).

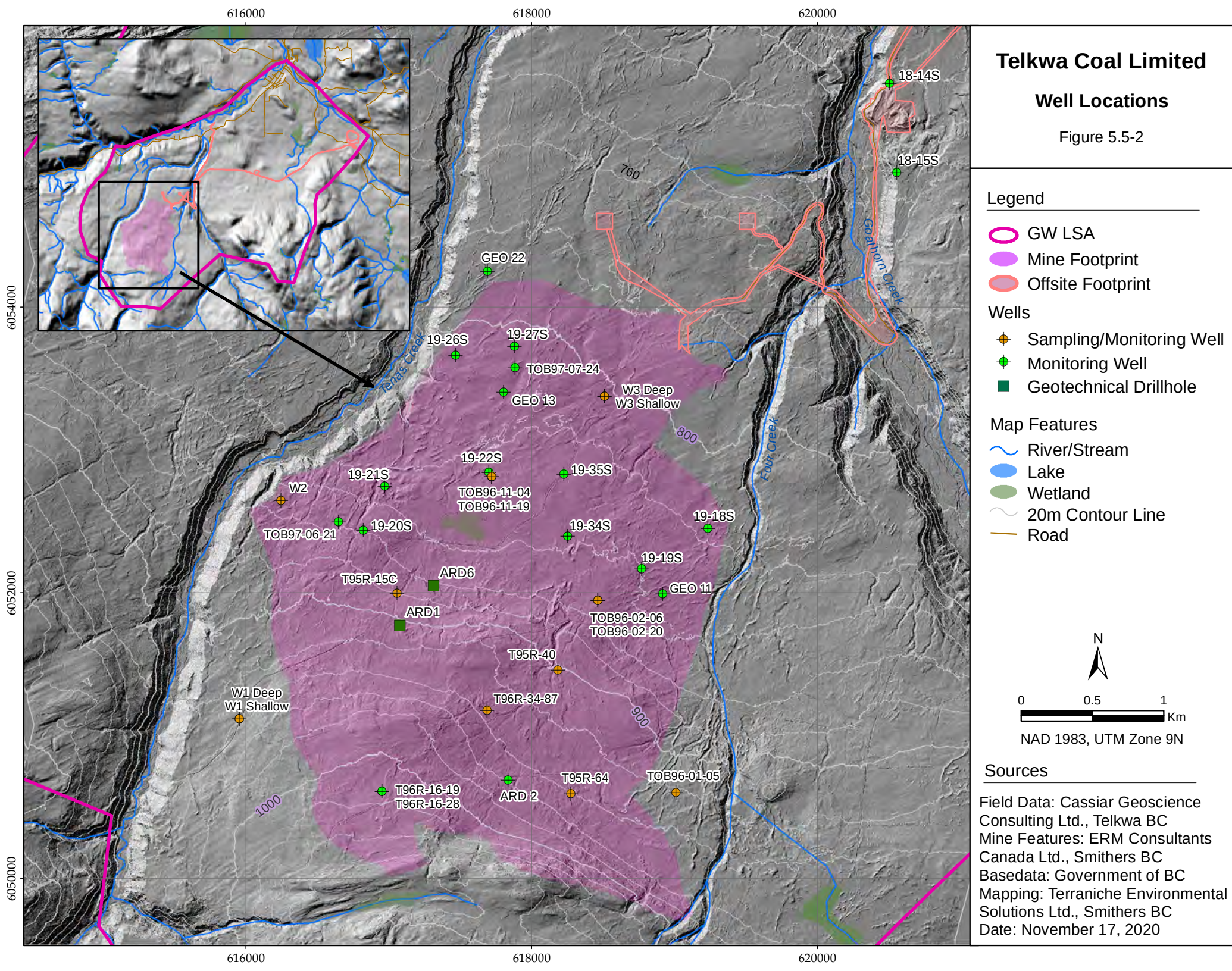


Table 5.5-1. Summary of Groundwater Monitoring Events, July 2017 to November 2019

Well ID	Well Installation Date	2017			2018				2019				
		Jul	Aug ¹	Sep	Jan	Mar/Apr	Jun	Sept	Jan	Mar/Apr	May/Jun	Aug	Nov
Bedrock													
T95R-15C	1995	x	nm	x	frozen	x	x	x	*	x	x	x	x
T95R-40	1995	x	x	x	x	x	x	x	x	x	x	x	x
T95R-64	1995	x	x	x	x	x	x	x	x	x	x	x	x
T96R-16-19	1996	x	nm	x	x	x	x	x	x	x	x	x	x
T96R-16-28	1996	x	nm	x	x	x	x	x	x	x	x	x	x
T96R-34-87	1996	x	x	x	frozen	x	x	x	*	x	nm	x	x
W1 Shallow	2018	-	-	-	-	x	x	x	*	x	x	x	*
W1 Deep	2018	-	-	-	-	x	x	x	*	x	x	x	x
W3 Deep	2018	-	-	-	-	x	x	x	x	x	x	x	x
ARD 2	2018	-	-	-	-	x	x	x	x	x	x	x	x
Overburden													
TOB96-01-05	1996	x	nm	x	x	x	x	x	x	x	x	x	x
TOB96-02-06	1996	x	nm	x	x	x	x	x	x	x	x	x	x
TOB96-02-20	1996	nm	nm	dry	dry	dry	x	dry	dry	dry	dry	dry	dry
TOB96-11-04	1996	x	nm	x	x	x	x	x	x	x	x	x	x
TOB96-11-19	1996	dry	nm	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
TOB97-06-21	1997	dry	nm	nm	dry	nm	dry	dry	dry	dry	dry	dry	dry
TOB97-07-24	1997	dry	nm	nm	nm	dry	dry	dry	dry	dry	dry	dry	dry
W3 Shallow	2018	-	-	-	-	x	x	x	x	x	x	x	x
W2	2018	-	-	-	-	x	nm	x	x	x	x	x	x
GEO 11	2018	-	-	-	-	dry	dry	dry	dry	dry	dry	dry	dry
GEO 13	2018	-	-	-	-	dry	dry	dry	dry	dry	dry	dry	dry
GEO 22	2018	-	-	-	-	dry	dry	dry	dry	dry	dry	dry	dry

Notes:

¹ August 2017 was not a scheduled monitoring event as three wells were sampled for water quality.

x = measured; nm = not measured

* Artesian well with sub-frost plug in well to prevent freezing; was not measured.

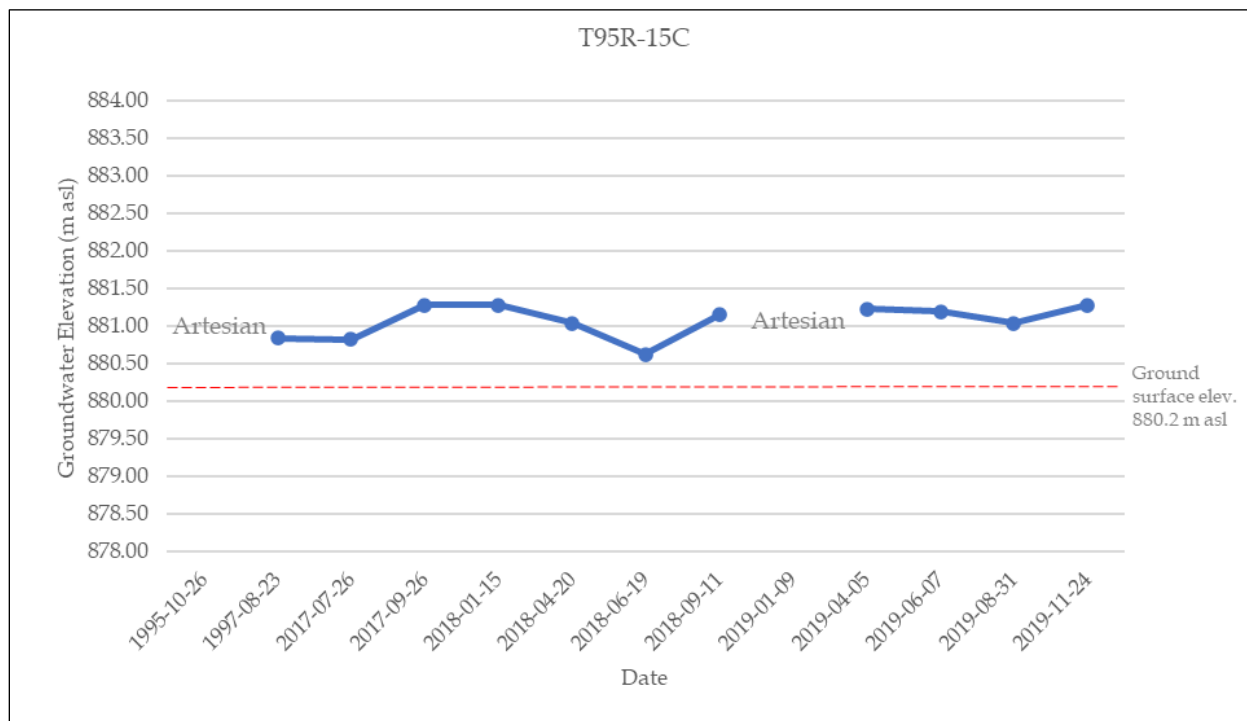
The new bedrock wells screened in the Hazelton Group volcanics, up-gradient of the proposed pit area (W1 Shallow and W1 Deep) had the lowest measured water levels during spring (May 2019 and April 2018, respectively) and the highest measured water levels during summer (W1 Shallow (September 2018) and W1 Deep (August 2019)).

The other new bedrock well screened in the volcanics down-gradient of the proposed pit area (W3 Deep) had the lowest measured water level during November 2019 and the highest measured water level during August 2019.

The new bedrock well screened in the Skeena Group sedimentary rocks below the coal seams (ARD 2) had the lowest measured water level in August 2019 and the highest measured water level in February 2019 (Figure 5.5-3).

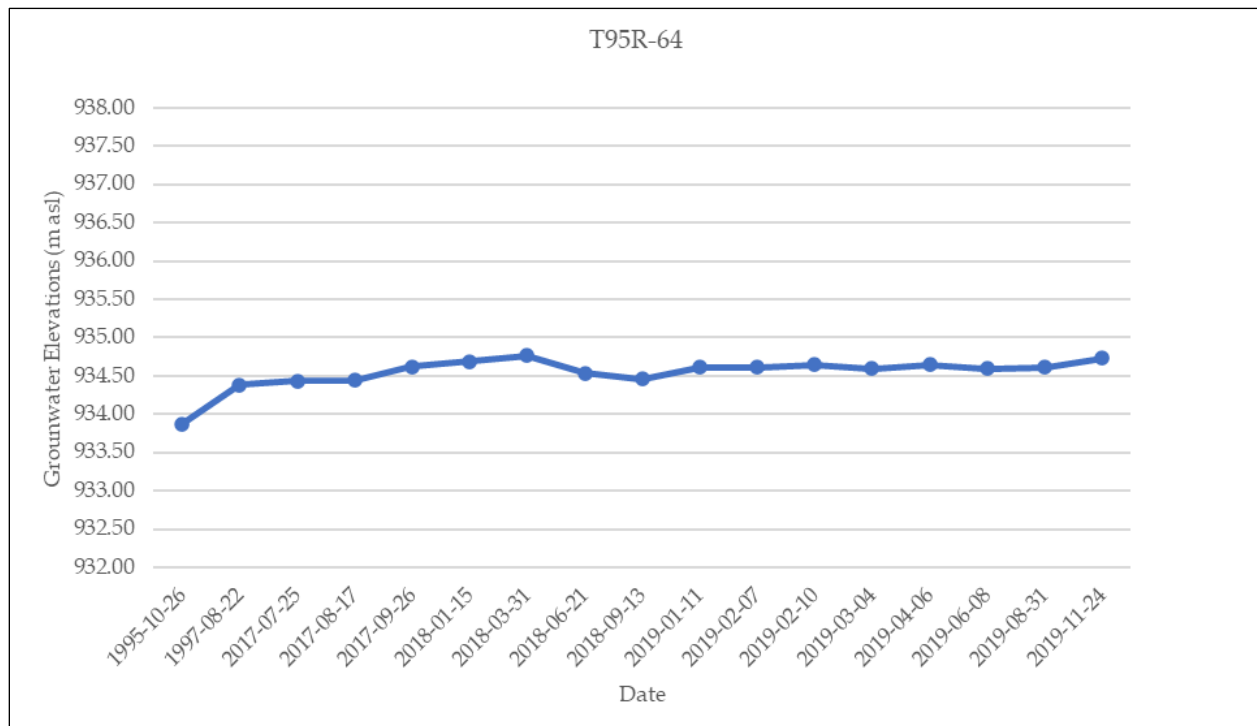
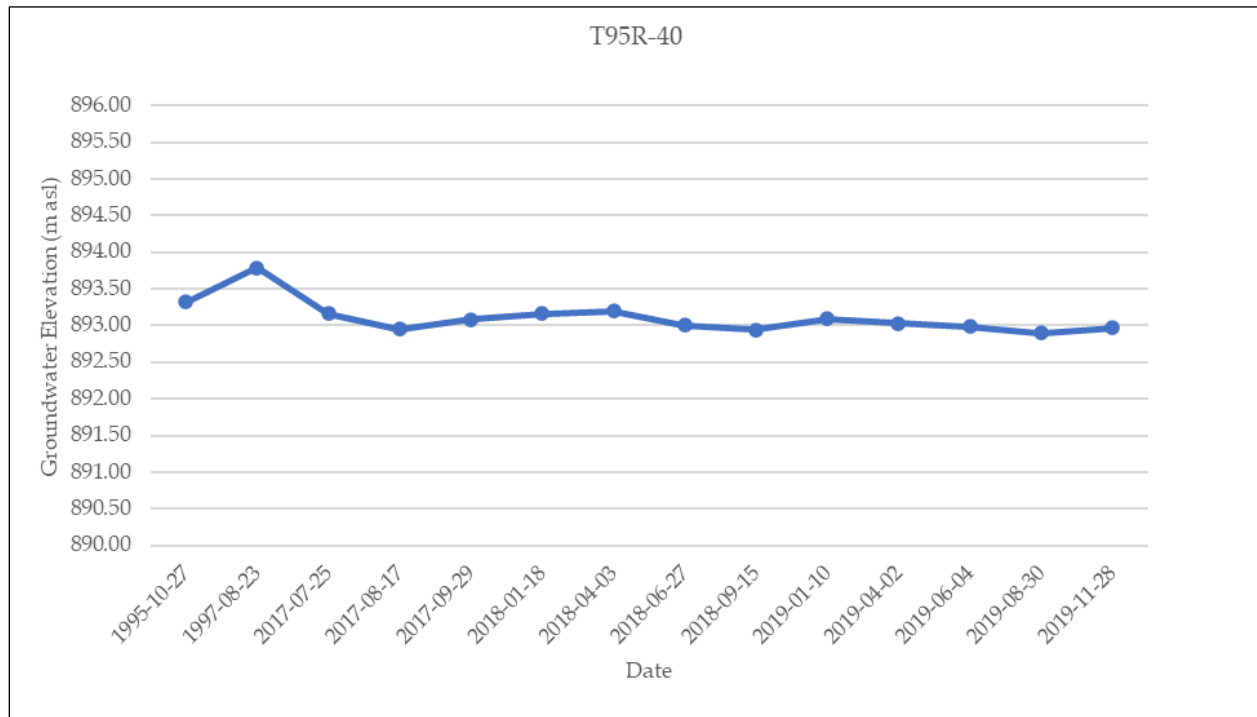
Two of the existing bedrock monitoring wells (T95R-15C and T96R-34-87) and two of the new bedrock monitoring wells (W1 Shallow and W1 Deep) had groundwater elevations above the ground surface (flowing artesian) during each of the monitoring events. T95R-15C and T96R-34-87 were observed to be frozen above the ground within the PVC casing during the January and March 2018 groundwater monitoring events (W1 Shallow and W1 Deep were installed during the February 2018 drilling program and were not measured until April 2018). T95R-15C and T96R-34-87 were observed to have flowing artesian conditions during previous monitoring events in late summer/early fall of 1996 and 1997 (Piteau Engineering Ltd. 1998).

Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



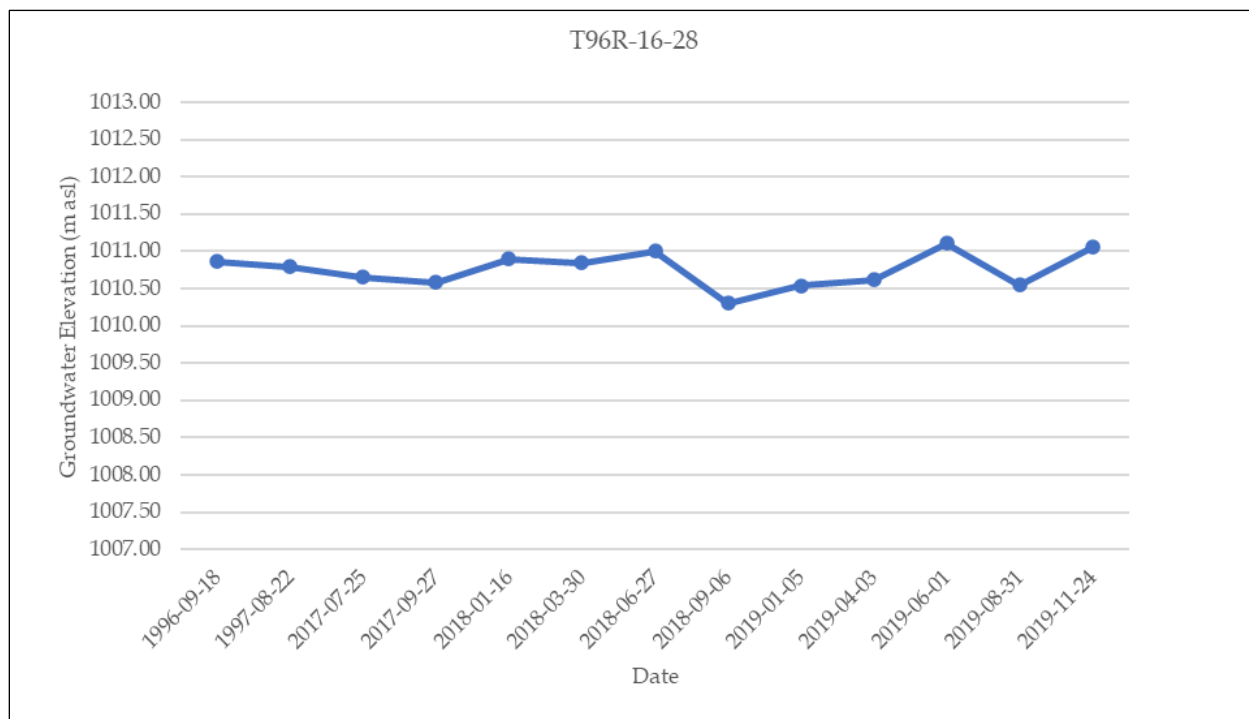
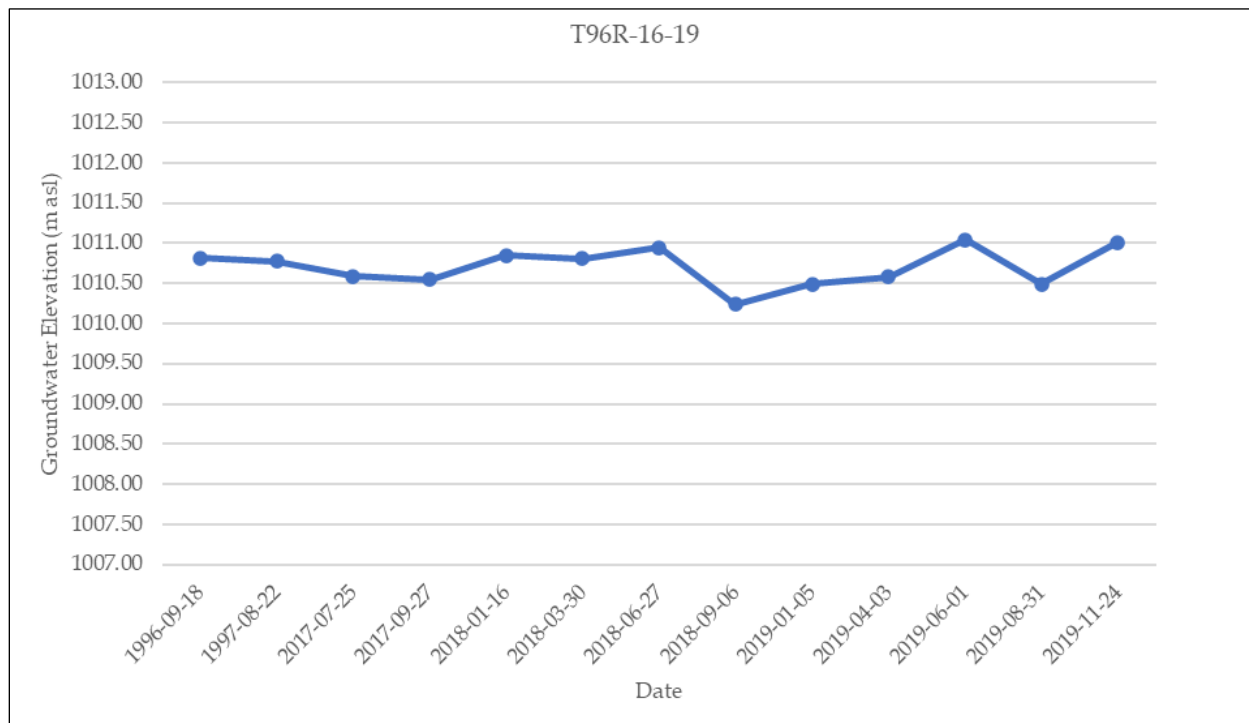
(continued)

Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data (continued)



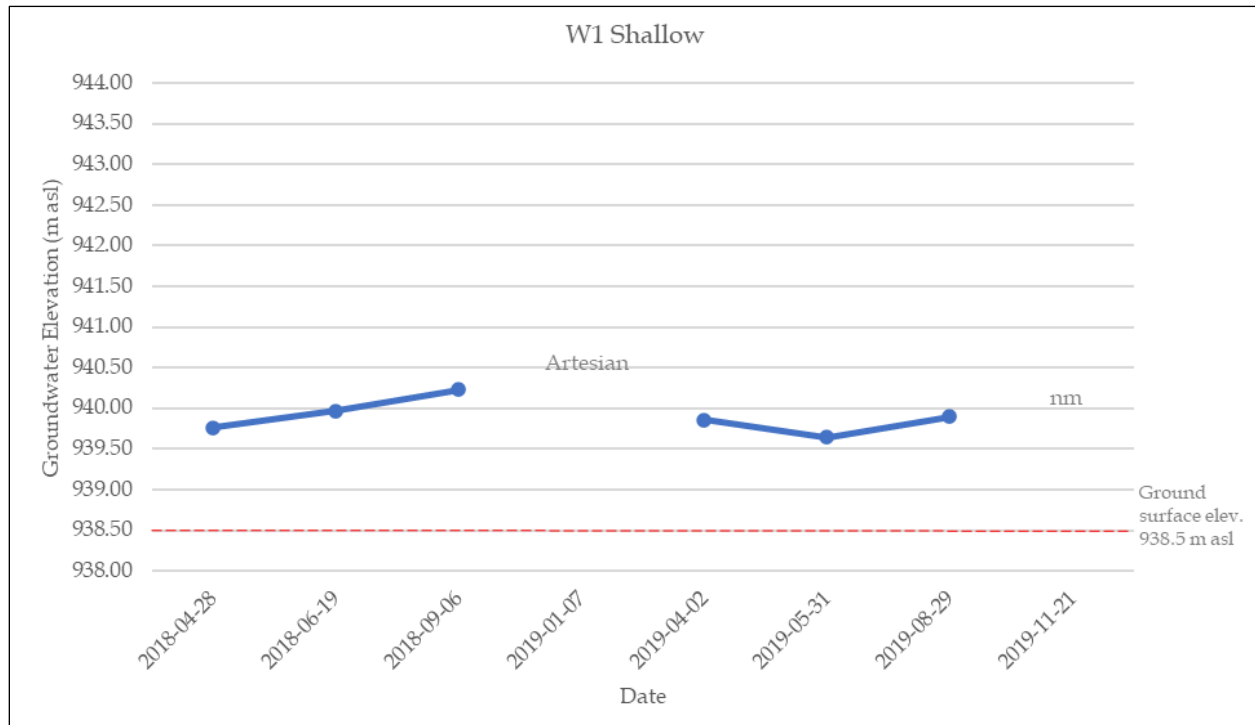
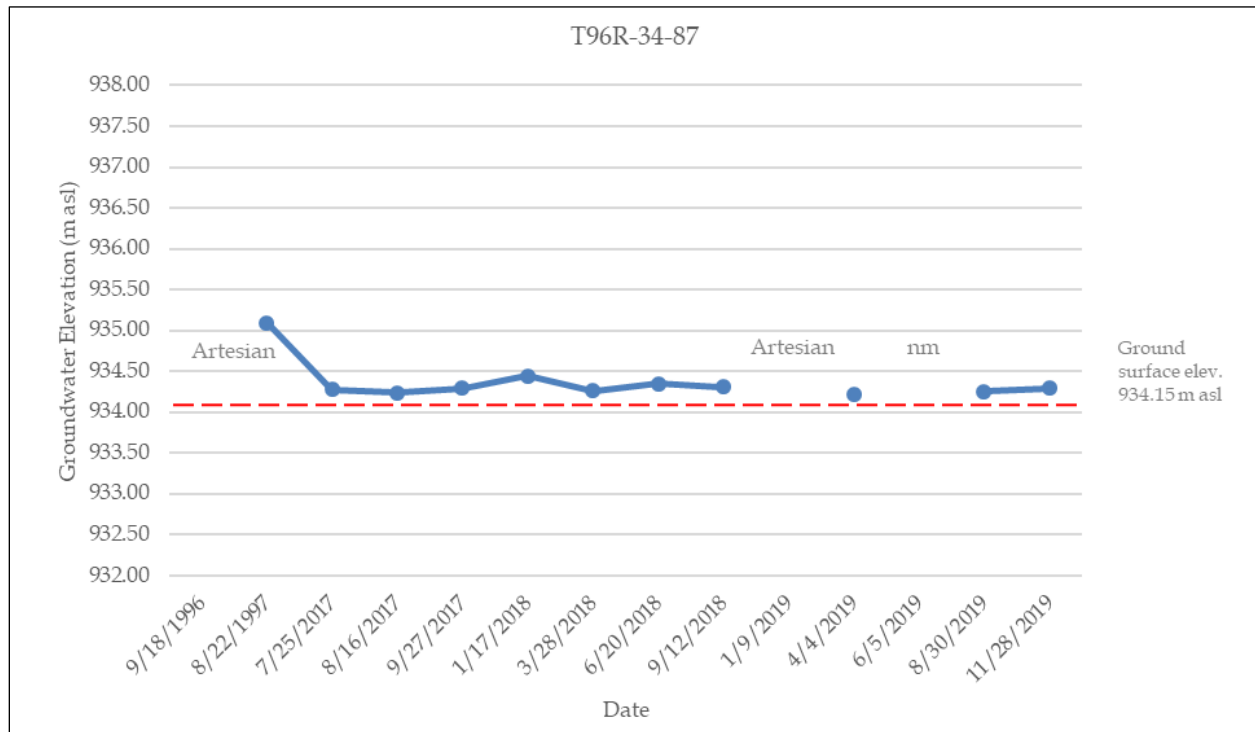
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Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data (continued)



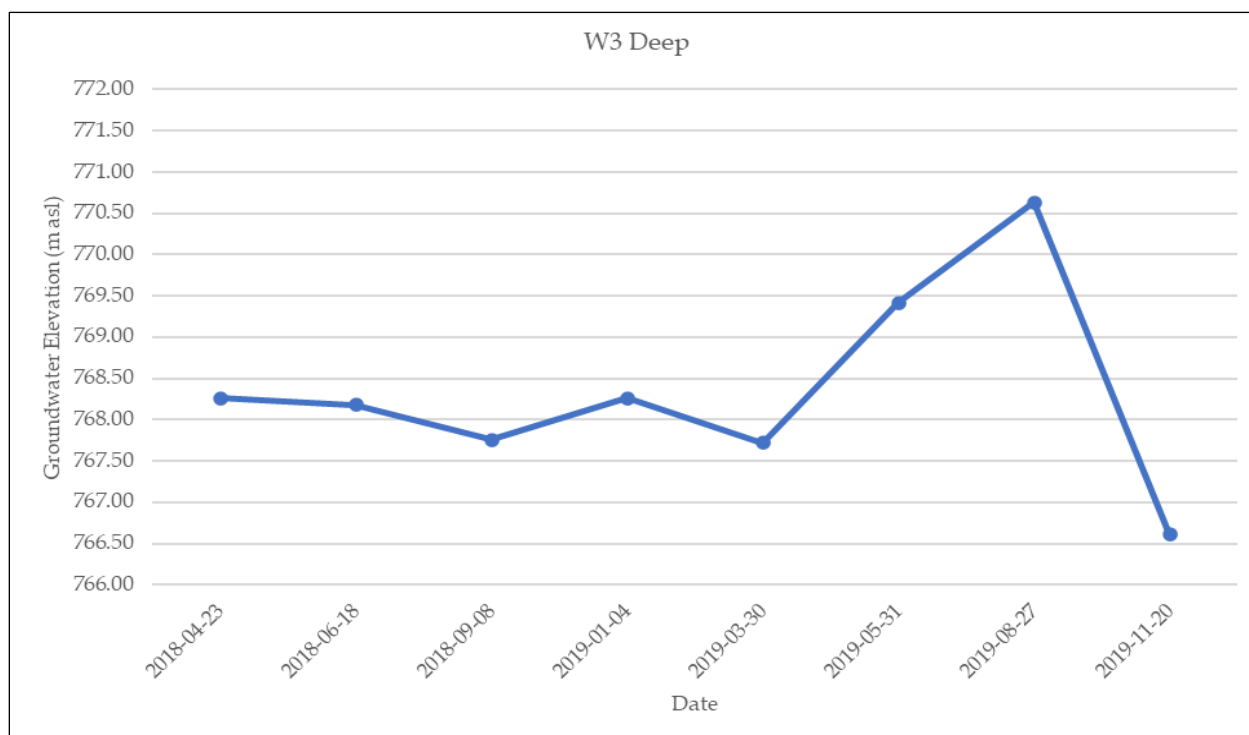
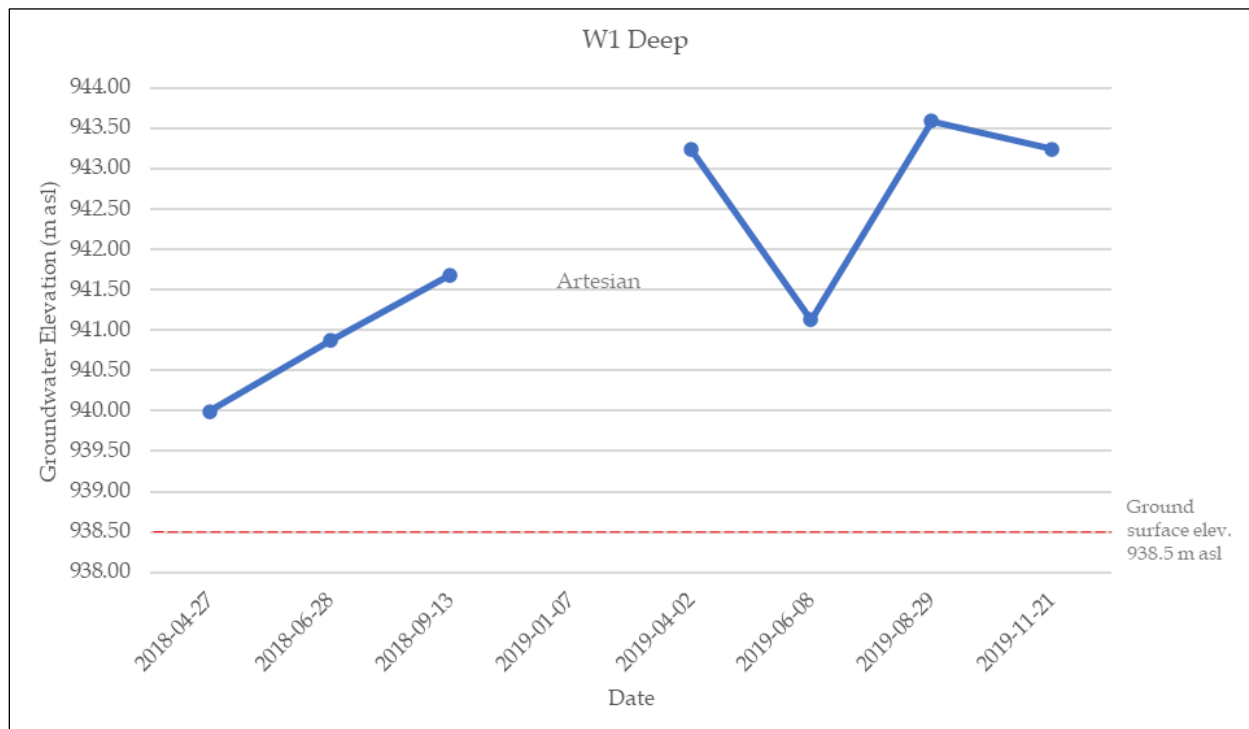
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Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data (continued)



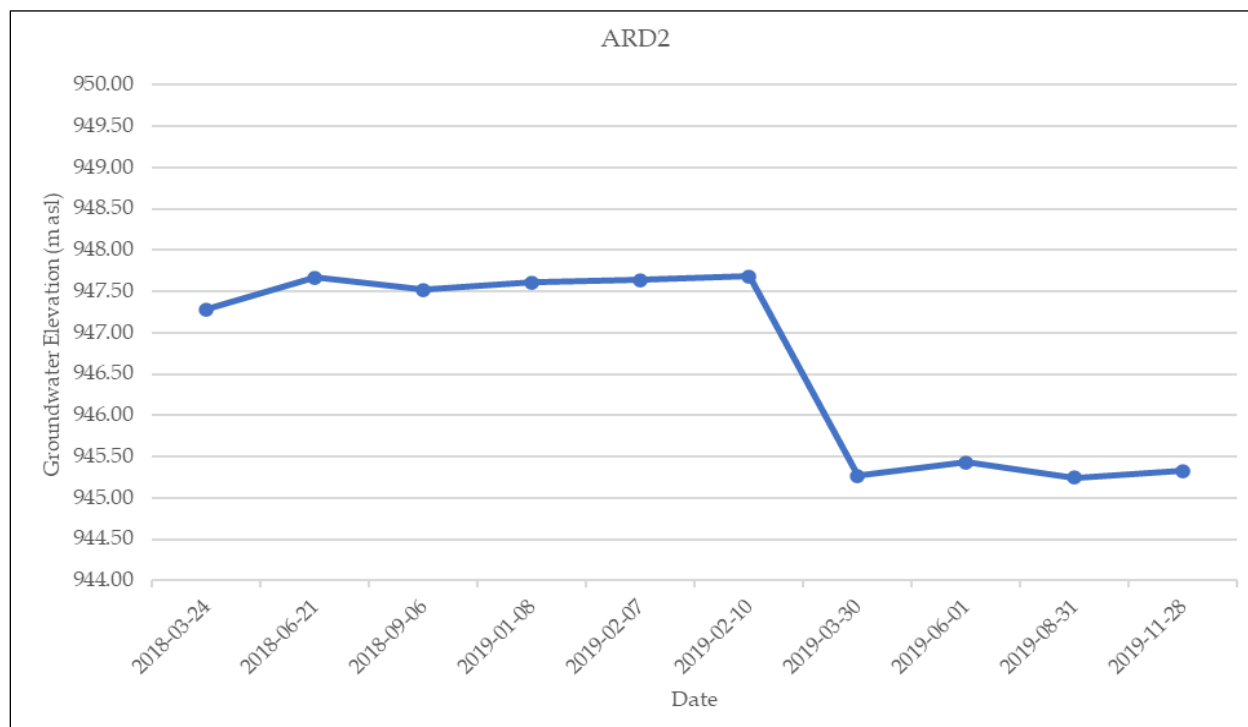
(continued)

Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data (continued)



(continued)

Figure 5.5-3. Manual Groundwater Elevations in Bedrock Wells, Historical and 2017 to 2019 Baseline Data (completed)



In order to prevent freezing within the upper casing during the winter months and to comply with the Groundwater Protection Regulations of the BC WSA, sub-frost artesian plugs were installed in the flowing artesian monitoring wells during the September 2018 monitoring/sampling event. Artesian water levels could not be measured in these four wells during the January 2019 monitoring events as sufficient time is required to reach static water levels, which would have resulted in the water freezing. The sub-frost artesian plugs were pulled in January 2019 to collect a groundwater sample from these wells (see Chapter 6) and were only out of the well for the short period of time required for the purging/sampling process.

The four existing non-flowing artesian bedrock wells screened in the coal seams had measured groundwater depths ranging from 1.42 m bgs (T96R-16-28 – June 2019) to 7.95 m bgs (T95R-40 – August 2019). When comparing the average manual groundwater elevation data from the current program (2017, 2018, and 2019) with the average of the historical data (1995, 1996 and 1997) from similar seasons (late summer/early fall), there has been a slight decline (<0.8 m) in water elevations from four of the existing wells (T95R-40, T96R-16-19, T96R-16-28, and T96R-34-87) over the past 20 years (Piteau Engineering Ltd. 1998). Two of the existing monitoring wells (T95R-15C and T95R-64) showed a slight increase (0.24 m and 0.38 m, respectively) in groundwater elevation in comparison to the historical data for the same seasonal period (late summer/early fall; Appendix 5-E).

The two new non-flowing artesian bedrock wells had measured groundwater depths ranging from 9.61 m bgs (ARD 2 – February 2019) to 41.39 m bgs (W3 Deep – March 2019; Appendix 5-E).

The seasonal groundwater level fluctuations within all of the existing bedrock wells and one of the newly installed wells (W1 Shallow) ranged from 0.22 m to 0.81 m. The least amount of fluctuation (0.22 m) was observed at T96R3487 while the largest fluctuation (0.81 m) was observed at the nested well pair T96R-16-19/28.

Groundwater level fluctuations of 3.60 m have been measured at W1 Deep from April 2018 to November 2019. An accurate static water level was likely not obtained during the first monitoring event (April 2018) due to the well development and purging process which did not allow enough time for static levels to be reached. Static water levels were too high to safely measure at W1 Deep and a pressure gauge was used during the September 2018 monitoring event and all subsequent events. Difficulties in acquiring a perfect seal at the base of the pressure gauge have resulted in artesian water pressures which may be slightly conservative. The artesian pressures collected from the pressure gauge during the April, August and November 2019 monitoring events are believed to be the most accurate. The measured artesian water levels at W1 Deep were 4.74 m ags during the April and November 2019 monitoring events and 5.09 m ags during the August 2019 monitoring event.

The measured groundwater levels at W3 Deep were relatively stable between the April 2018 and March 2019 monitoring events with the largest fluctuation of 0.54 m measured between January and March 2019. The measured water level then increased 2.91 m from March to August 2019 and then declined 4.02 m between August and November 2019.

The measured groundwater levels at ARD2 were relatively stable between the March 2018 and February 2019 monitoring events with the largest fluctuation of 0.39 m measured between March and June 2018. A pump test was conducted at this well during early March 2019 which resulted in the water levels never recovering back to the original static water level. The new static water level after the pump test was 2.41 m lower than before the pump test with the subsequent measured water levels remaining relatively stable from March to November 2019 (largest fluctuation of 0.16 m from March to June 2019).

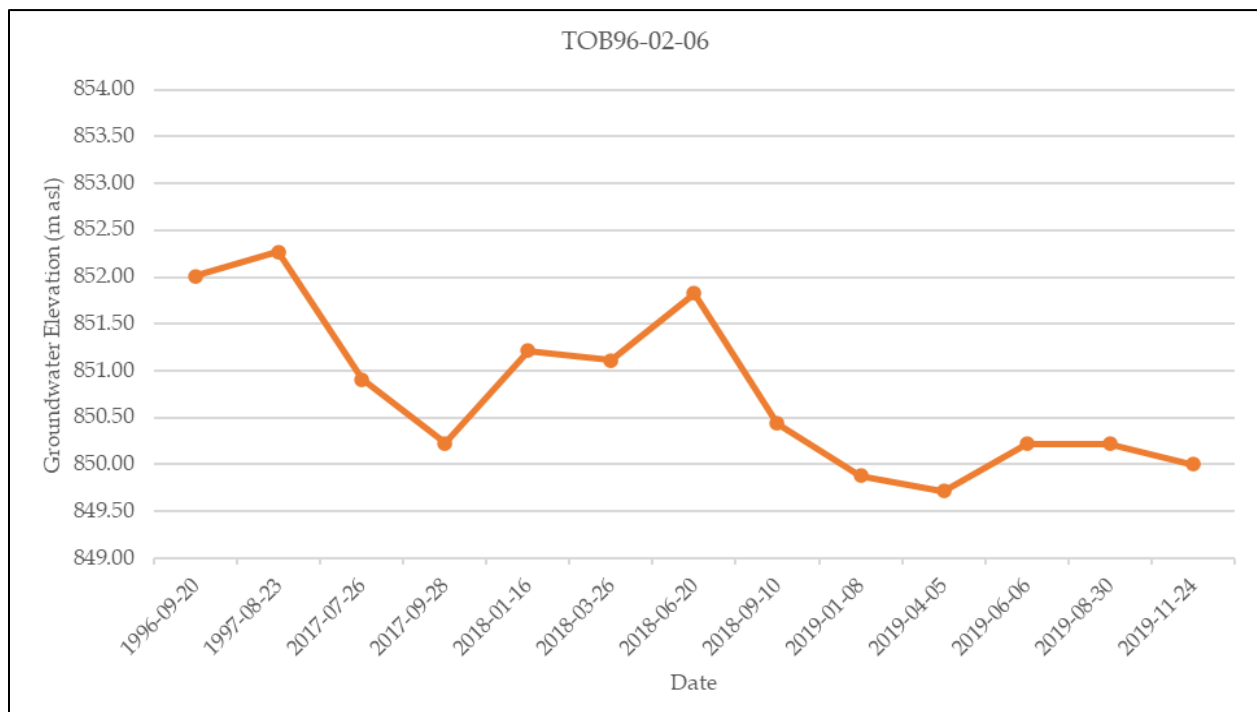
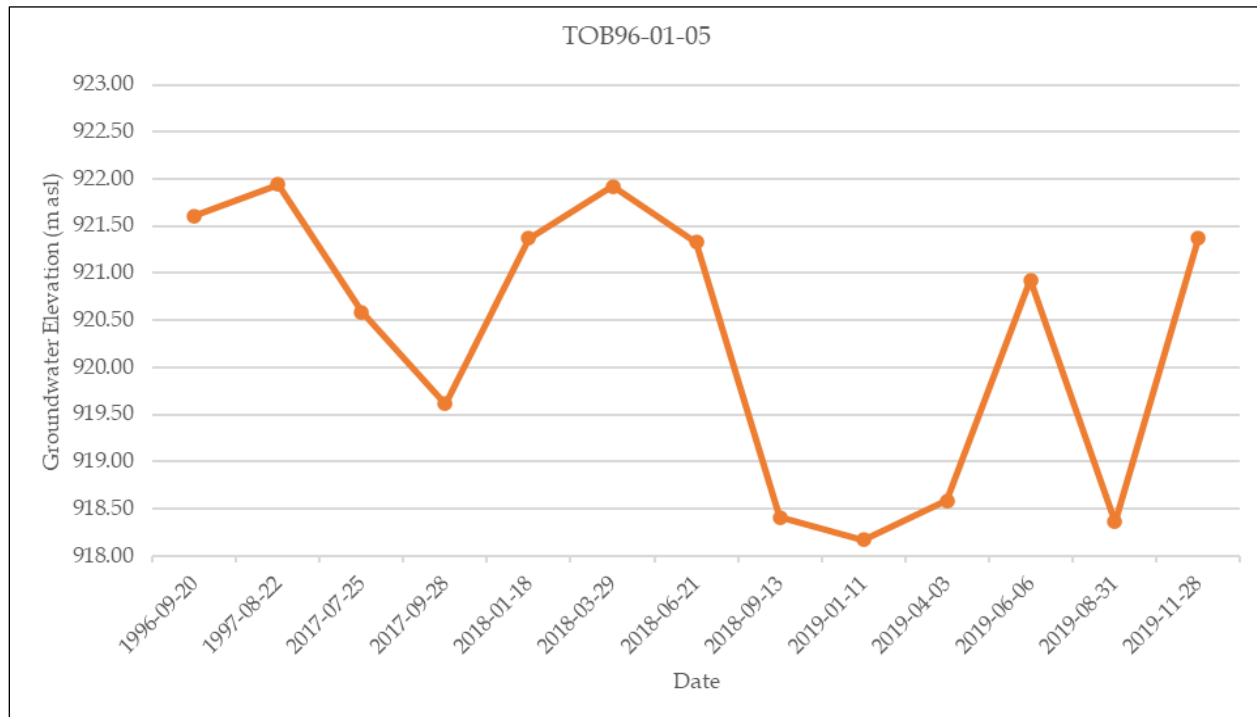
It is not possible to make seasonal fluctuation comparisons with the historical data as measurements were only recorded once a year during the fall and were not always recorded over consecutive years. For completeness, the historical measurements are included in Figure 5.5-3 and in Appendix 5-E.

Overburden Monitoring Wells

Three of the seven existing overburden wells (TOB96-11-19, TOB97-07-24, and TOB970621) were measured as dry during all 2017 to 2019 monitoring events (Figure 5.5-4). This correlates with the historical data from 1996 and 1997, where each of these wells were dry (Appendix 5-E). TOB96-02-20 was also dry during all 2017 to 2019 baseline monitoring events, except in June 2018 when 0.60 m of water was measured. This is similar to the historical data from 1996 (approximately 1.6 m of standing water) and 1997 (0.3 m of standing water) (Piteau Engineering Ltd 1997, Piteau Engineering Ltd. 1998).

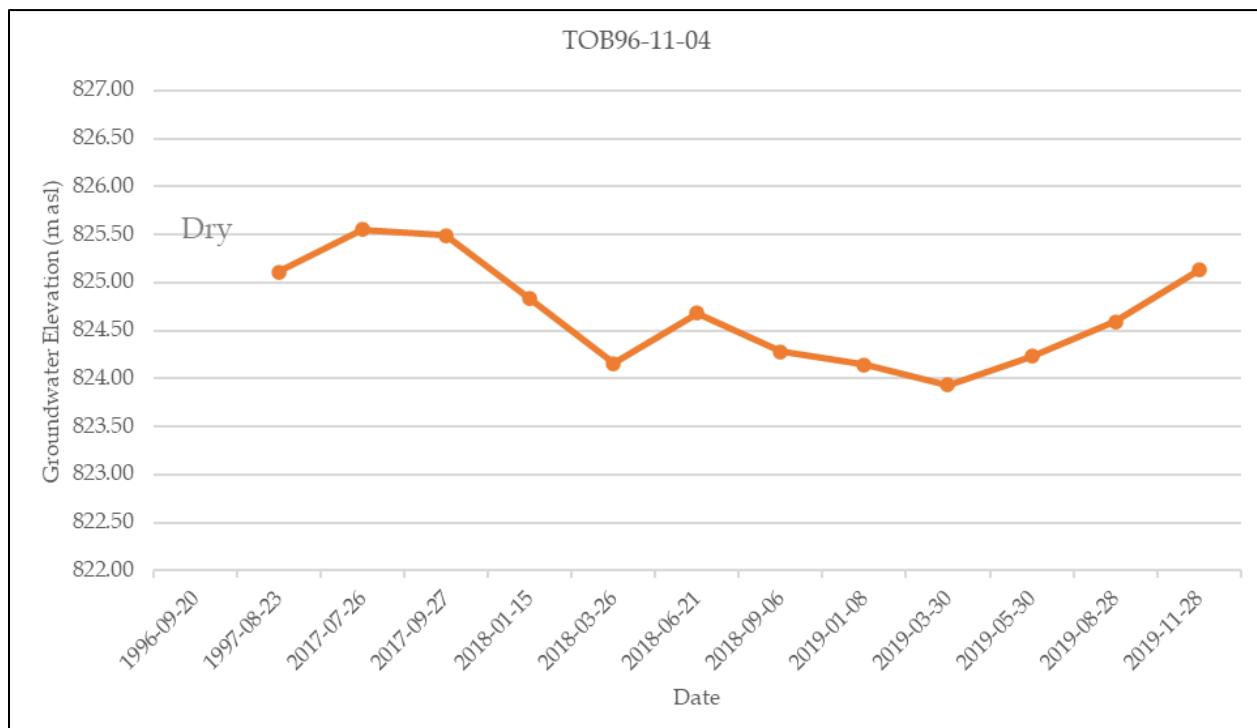
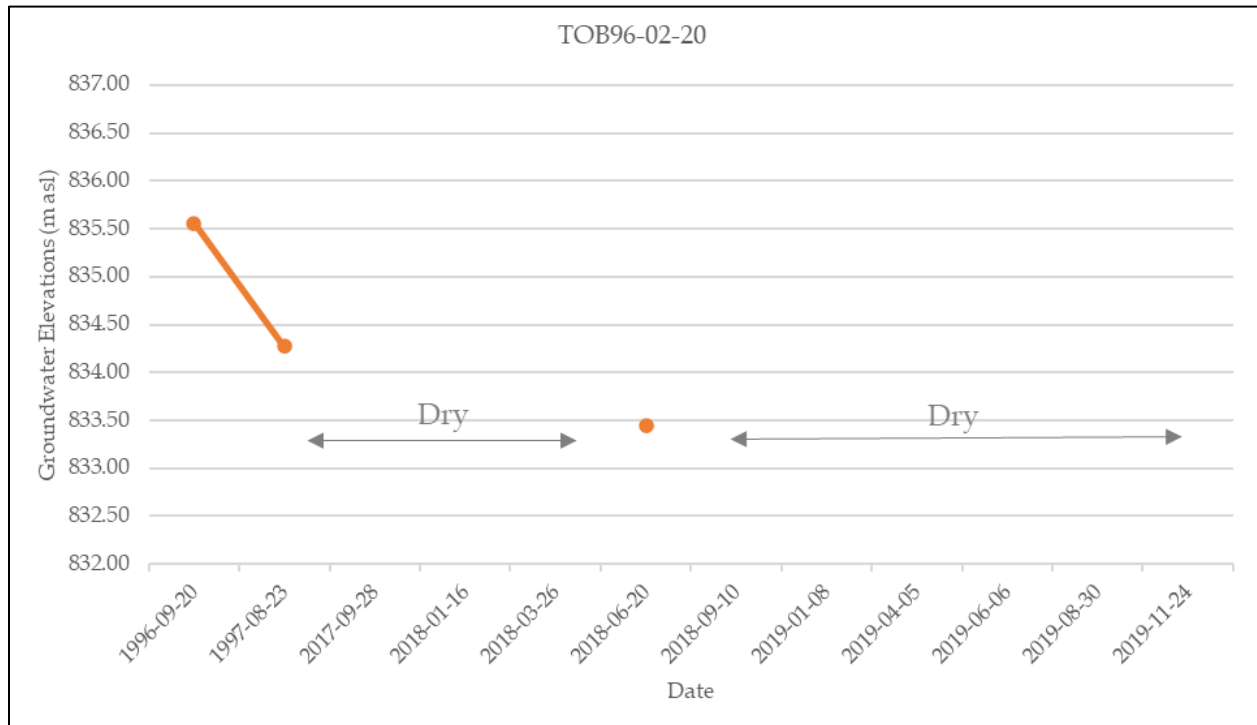
Of the three existing overburden wells that were not dry (TOB96-01-05, TOB96-02-06, and TOB96-11-04), TOB96-01-05 and TOB96-02-06 showed similar seasonal variation in groundwater elevation, although the seasonal fluctuations for both wells differed between 2017/2018 and 2018/2019 (Figure 5.5-4). The magnitude of the seasonal fluctuations was also greater at TOB96-01-05 in relation to TOB96-02-06. TOB96-11-04 seasonal water levels were more consistent on a yearly basis compared to TOB96-01-05 and TOB96-02-06 with a general decrease throughout the summer to winter months and then an increase during the spring months (Figure 5.5-4).

Figure 5.5-4. Manual Groundwater Elevations in Overburden Wells, Historical and 2017 to 2019 Baseline Data



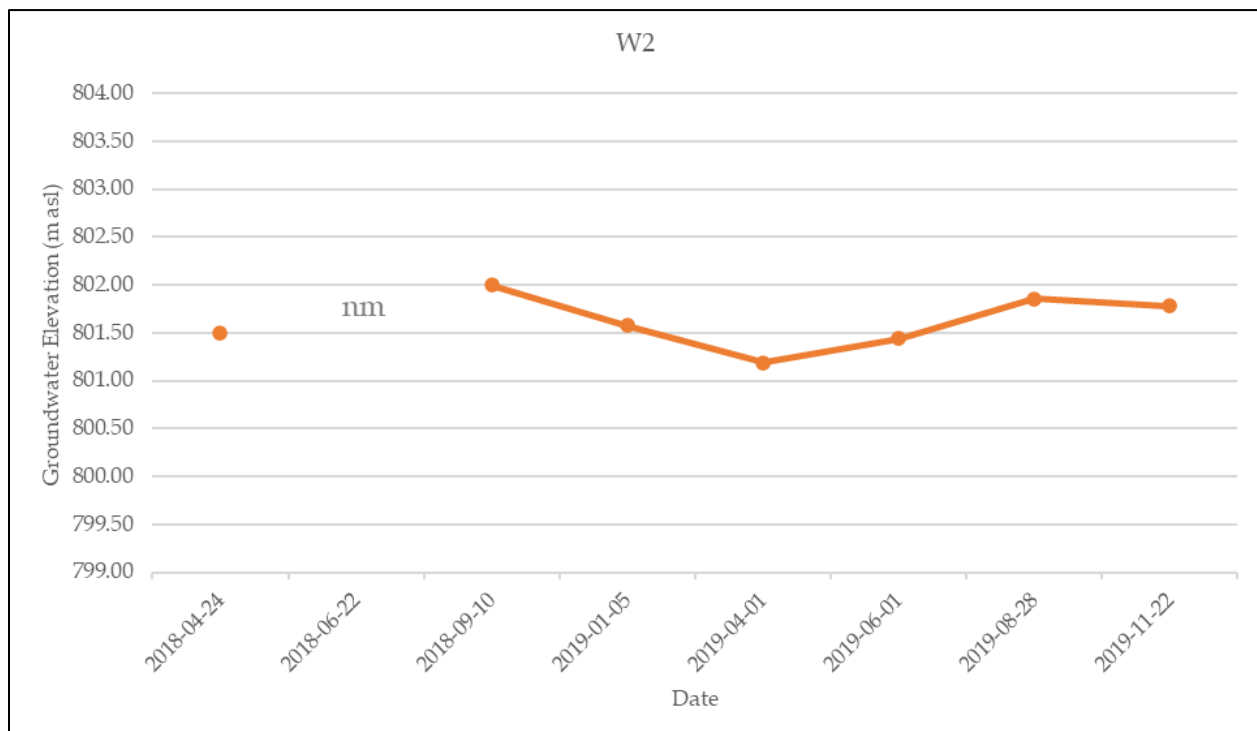
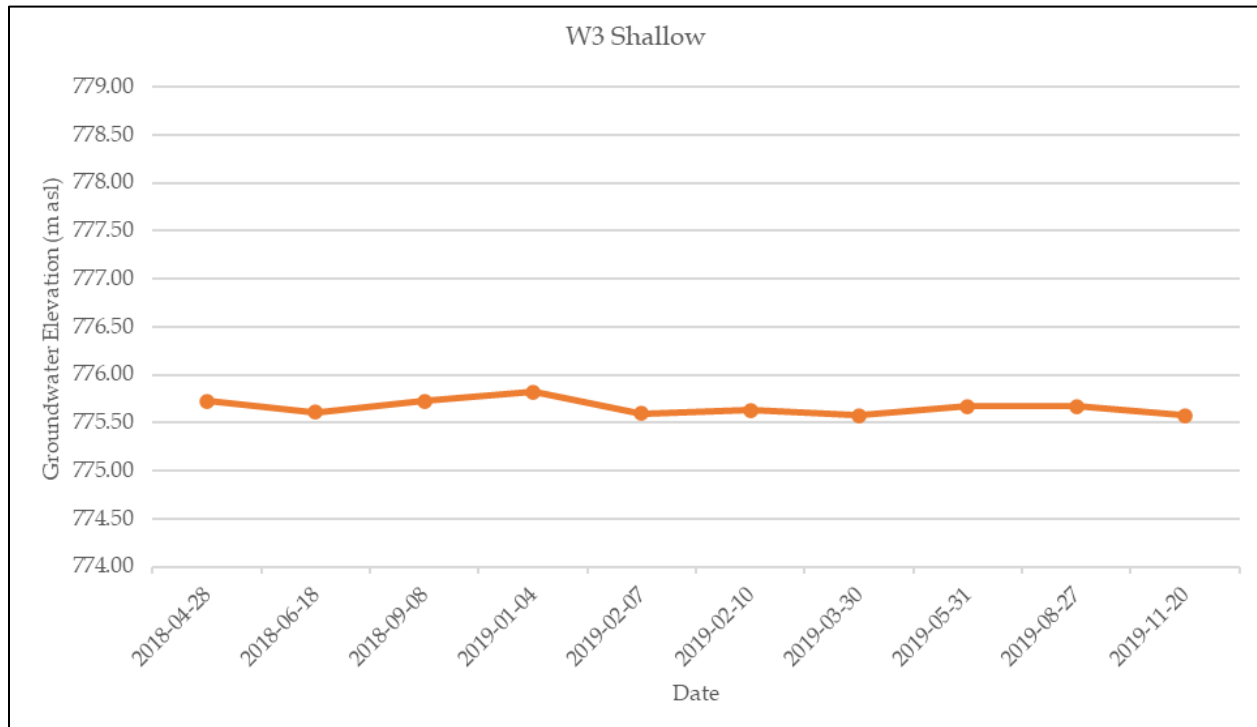
(continued)

Figure 5.5-4. Manual Groundwater Elevations in Overburden Wells, Historical and 2017 to 2019 Baseline Data (continued)



(continued)

Figure 5.5-4. Manual Groundwater Elevations in Overburden Wells, Historical and 2017 to 2019 Baseline Data (completed)



In 2018 and 2019, the water level in TOB96-01-05 dropped 2.92 m and 2.57 m, respectively from summer to fall. TOB96-02-06 had measured summer to fall water level decreases of 1.39 m in 2018 and 0.22 m in 2019. TOB96-11-04 had a measured summer to fall water level decrease of 0.40 m in 2018 and a measured summer to fall water level increase of 0.90 m in 2019 (Figure 5.5-4). The lowest measured water level at TOB96-01-05 was recorded during the January 2019 monitoring event while the lowest measured water levels at TOB96-02-06 and TOB96-11-04 were recorded during the March/April 2019 monitoring event.

Groundwater level fluctuations from July 2017 to November 2019 within TOB96-01-05, TOB960206, and TOB96-11-04 ranged from 1.62 m to 3.75 m. The least amount of fluctuation (1.62 m) was observed at TOB96-11-04, while the largest fluctuation (3.75 m) was observed at TOB96-01-05 (Figure 5.5-4).

When comparing the average manual groundwater elevation data from the current program (2017 - 2019) with the historical data (1995, 1996 and 1997) from similar seasons (late summer/early fall), there is an overall decline in water levels in each of the three existing overburden wells (TOB96-01-05, TOB96-02-06, and TOB96-11-04) which are not typically dry. The decline in average water levels ranged from 0.47 m (TOB96-11-04) to 3.21 m (TOB96-01-05).

It is not possible to make seasonal fluctuation comparisons with the historical data, as measurements were only recorded once per year in 1996 and 1997. For completeness, the historical measurements are included in Figure 5.5-4 and in Appendix 5-E.

Groundwater levels at two of the new overburden wells (W3 Shallow and W2) showed minor seasonal fluctuations with approximately 0.24 m and 0.81 m of change, respectively (Figure 5.5-4). The seasonal high and low groundwater levels were not as consistent or distinct at W3 Shallow as W2. In general, the seasonal high groundwater level at W2 was observed during the fall months while the seasonal low groundwater level was observed during the spring months. The other three new overburden geotechnical wells (GEO 11, GEO 13, and GEO 22) were dry during every monitoring event (Appendix 5-E).

The minimum and maximum manually measured groundwater depths for the shallow overburden wells (TOB96-01-05, TOB96-11-04, and TOB96-02-06) were both measured at TOB96-01-05 (minimum of 0.62 m bgs - March 2018 and maximum of 4.37 m bgs - January 2019). The manually measured groundwater depths for the deeper overburden wells (TOB96-02-20, W2 and W3 Shallow) ranged from 20.02 m bgs (TOB96-02-20 - June 2018) to 50.81 m bgs (W2 - April 2019) during the current monitoring program (Appendix 5-E).

Geotechnical Wells (East side of Goathorn Creek)

Manual groundwater elevations were measured with a Solinst 30 m water level tape at T18-14S and T1815S a total of 10 times from November 2018 to November 2019 (Figure 5.5-5). The shallowest manual depth to water measurements were recorded during early to mid-spring which corresponds with the spring freshet (T18-14S - 5.37 m bgs on April 18, 2019 and T18-15S - 12.43 m bgs on May 29, 2019; Appendix 5-F). The deepest manual depth to water measurement at T18-14S (5.89 m bgs) was recorded on September 26, 2019 and during the February and March monitoring event at T1815S (12.66 m bgs; Appendix 5-F).

Figure 5.5-5. Manual Groundwater Measurements at Geotechnical Wells (Converted to m above sea level [asl]) at T18-14S and T18-15S, November 2018 to November 2019



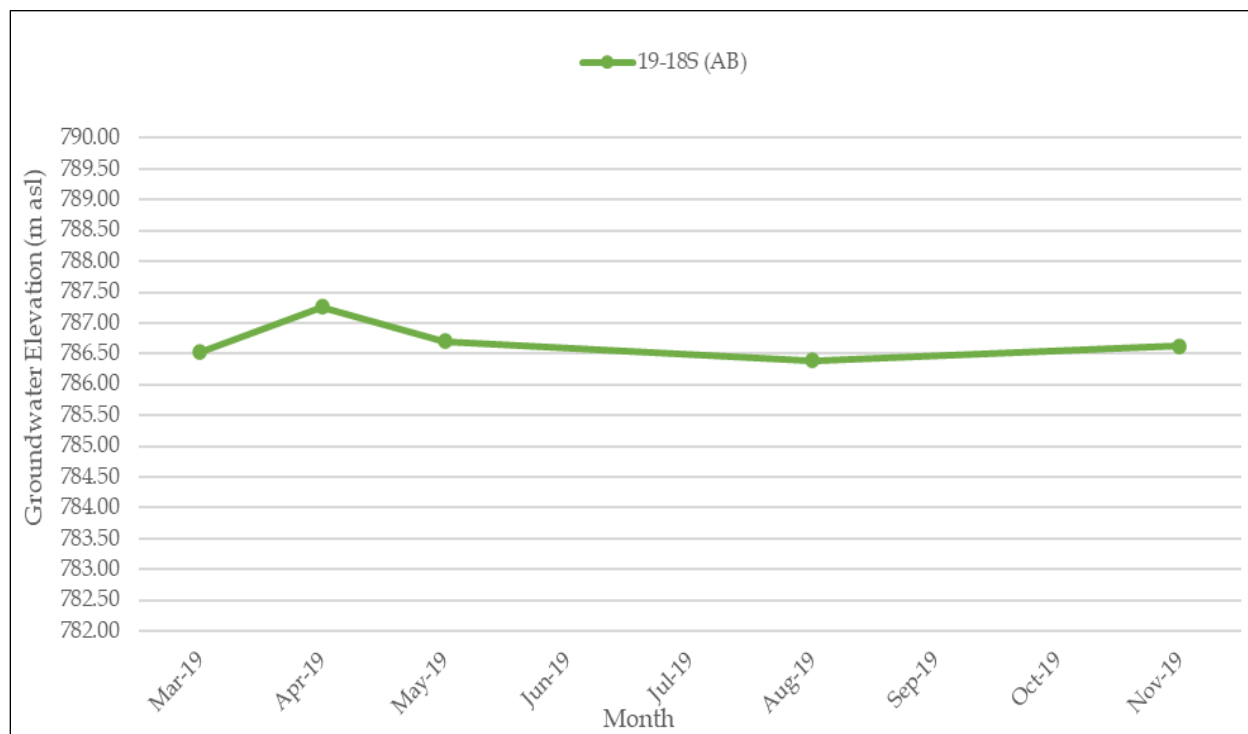
The groundwater fluctuations observed at each well were relatively minor from November 2018 to November 2019 (0.52 m at T18-14S and 0.23 m at T18-15S; Appendix 5-F and Figure 5.5-5). During the monitoring period, the groundwater level declined throughout the winter months (November to March), began to rise in April after the snowmelt and then declined once again during the summer (May to September). The groundwater level at T18-15S increased slightly (0.07 m) from September to November while holding relatively steady at T18-14S.

PAG Cell Wells

Manual groundwater elevations were measured with a Heron 60 m water level tape at each of the nine PAG cell wells monthly from the time of well installation (January to March 2019) until May 2019, and then in August and November of 2019 (minimum of five manual measurements per well in 2019). Two of the wells were consistently dry (19-19S (W) and 19-20S (AC)) during monitoring events from January to November 2019, while the other seven wells had water levels generally deeper than 23.5 m bgs (Appendix 5-G). The shallowest water level (23.96 m bgs) was measured at 19-22S (Z) and 19-35S (V) while the deepest water level (40.78 m bgs) was measured at 19-27S (R) (Appendix 5-G).

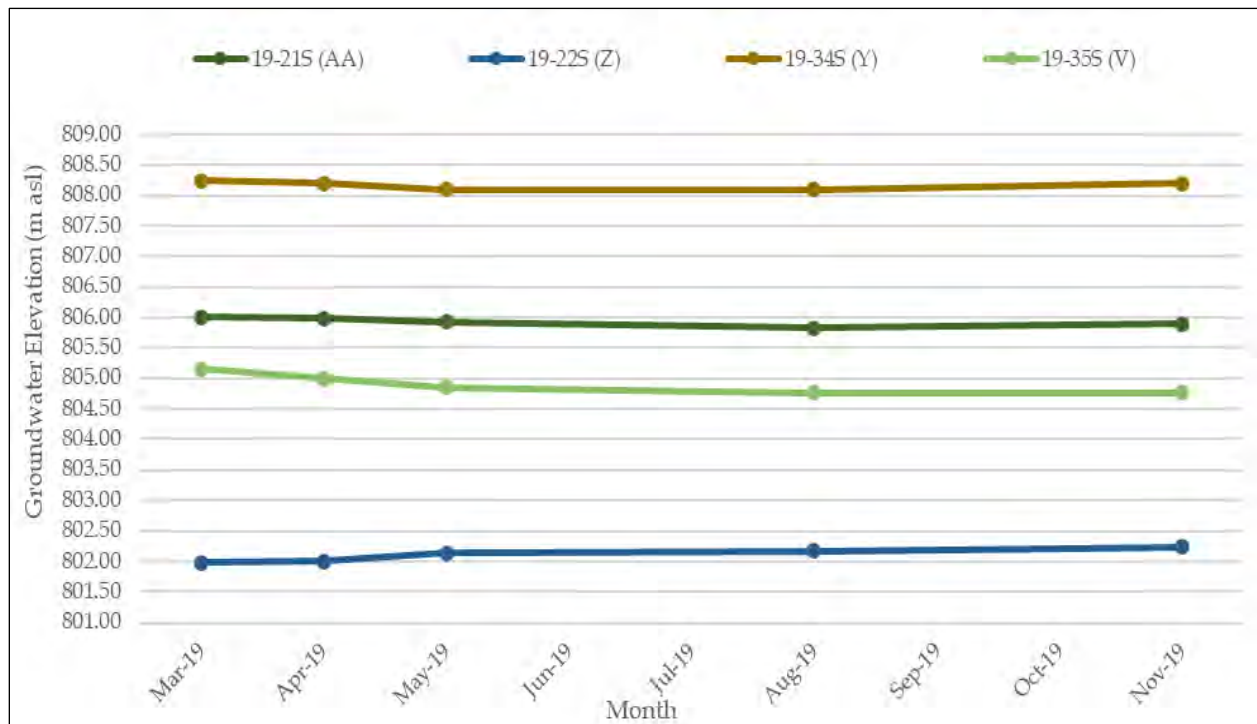
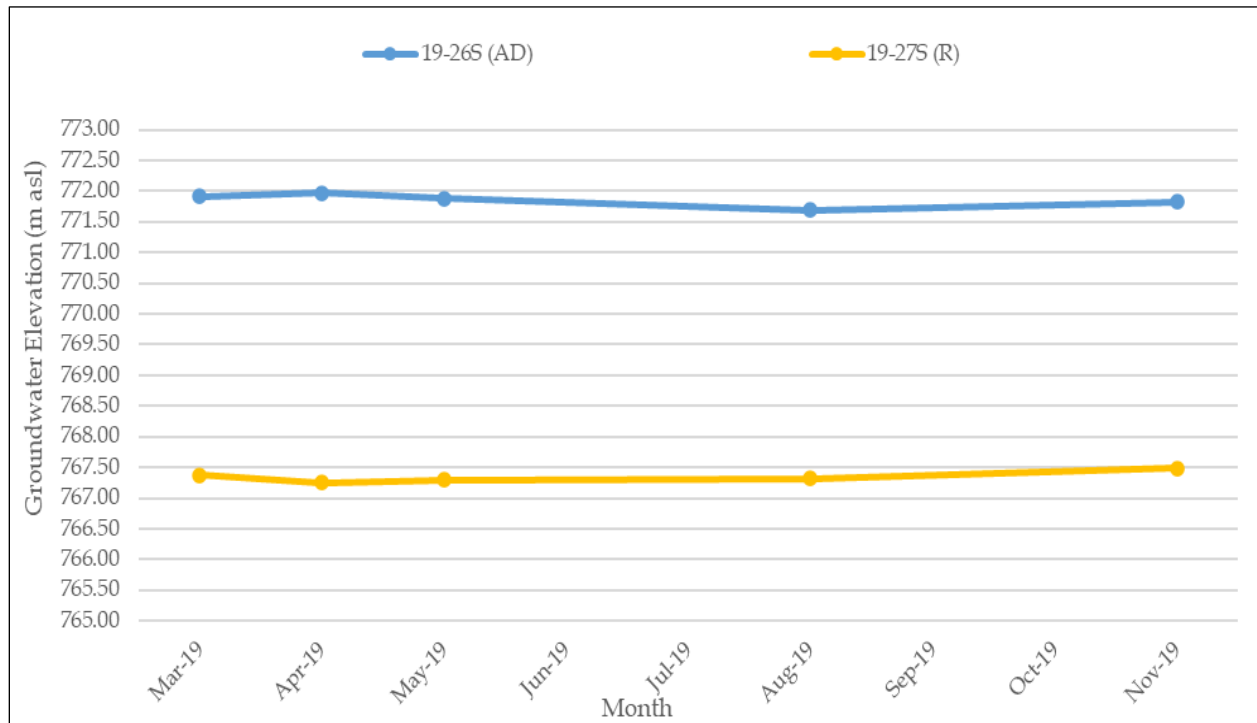
The groundwater level for each well was relatively stable from March to November. The least amount of water level fluctuation (0.14 m) was observed at 19-34S (Y) while the largest water level fluctuation (0.87 m) was observed at 19-18S (AB; Figure 5.5-6). The measurements from January and February were not included on Figure 5.5-6 as the water levels were still stabilizing after the drilling and well development. 19-19S (W) and 19-20S (AC) were also not included as the wells were consistently dry.

Figure 5.5-6. Groundwater Elevations (m asl) Derived from Manual Water Level Measurements at the PAG Cell Wells, March to November 2019



(continued)

Figure 5.5-6. Groundwater Elevations (m asl) Derived from Manual Water Level Measurements at the PAG Cell Wells, March to November 2019 (completed)



Based on the groundwater elevations for each of these wells it can be inferred that the groundwater flows from 19-18S (AB) towards 19-27S (R) in the overburden and from 19-34S (Y) towards 19-22S (Z) in the bedrock.

5.5.2.2 *Continuous Groundwater Level Measurements*

Baseline Wells

Groundwater level measurements were recorded twice daily (every 12 hours) with Solinst Levellogger transducers in five of the existing wells from late September 2017 to November 2019 and in four of the new wells from late August/early September 2019 to November 2019. Of these five existing wells, three are located in bedrock (T95R-64, T95R-15C, and T96R-16-19) and two are located in overburden (TOB96-02-06 and TOB96-02-20). Of the four new wells, one is located in bedrock (W1 Deep), one is located along the overburden/bedrock interface (W1 Shallow) and two are located in the deeper overburden (W2 and W3 Shallow). An additional Solinst Levellogger transducer was installed in another of the new wells (W3 Deep) in November 2019 and had not yet been downloaded at the time of this report.

One Solinst Barologger was also used to compensate the pressure data from the transducers and placed in T95R-64, which is located at the mid-point elevation of the Project to capture average barometric pressure.

Bedrock Wells

In general, continuous water level measurement data from the shallowest existing bedrock well (T96R-16-19) show that the groundwater levels increased during the fall months of 2017, 2018, and 2019 and the spring months of 2018 and 2019. Groundwater levels declined during the winter months of 2018 and the summer months of 2018 and 2019. The groundwater levels were relatively steady throughout the winter months of 2019 (Figure 5.5-7).

The continuous water level measurement data from the two deeper existing bedrock wells (T95R-15C and T95R-64) differs from T96R-16-19 in that the seasonal fluctuations were not as pronounced, although both of these wells showed increasing groundwater levels during the fall months of 2017, 2018 and 2019 (similar to T96R-16-19) (Figure 5.5-7). T95R-15C and T95R-64 both showed decreasing groundwater levels during the spring months of 2018 and 2019 which is opposite of the groundwater level data from T96R-16-19. The groundwater levels are relatively steady at T95R-64 during the winter months of 2018 and 2019 and the summer months of 2019 while the groundwater levels were steady at T95R-15C during the late fall/early winter of 2017/2018 and the winter months of 2019 (Figure 5.5-7). The data gap at T95R-15C from April 20 to June 28, 2018 was the result of an animal disturbance that caused the transducer to be lost down the well (Figure 5.5-7). A new transducer was installed in T95R-15C in June 2018.

The three existing bedrock wells had seasonal groundwater level fluctuations ranging from 0.52 m (T95R-64) to 1.00 m (T96R-16-19). T95R-15C had a seasonal groundwater level fluctuation of 0.53 m during this time span. The highest groundwater elevation for each of these three wells occurred at different times of the year:

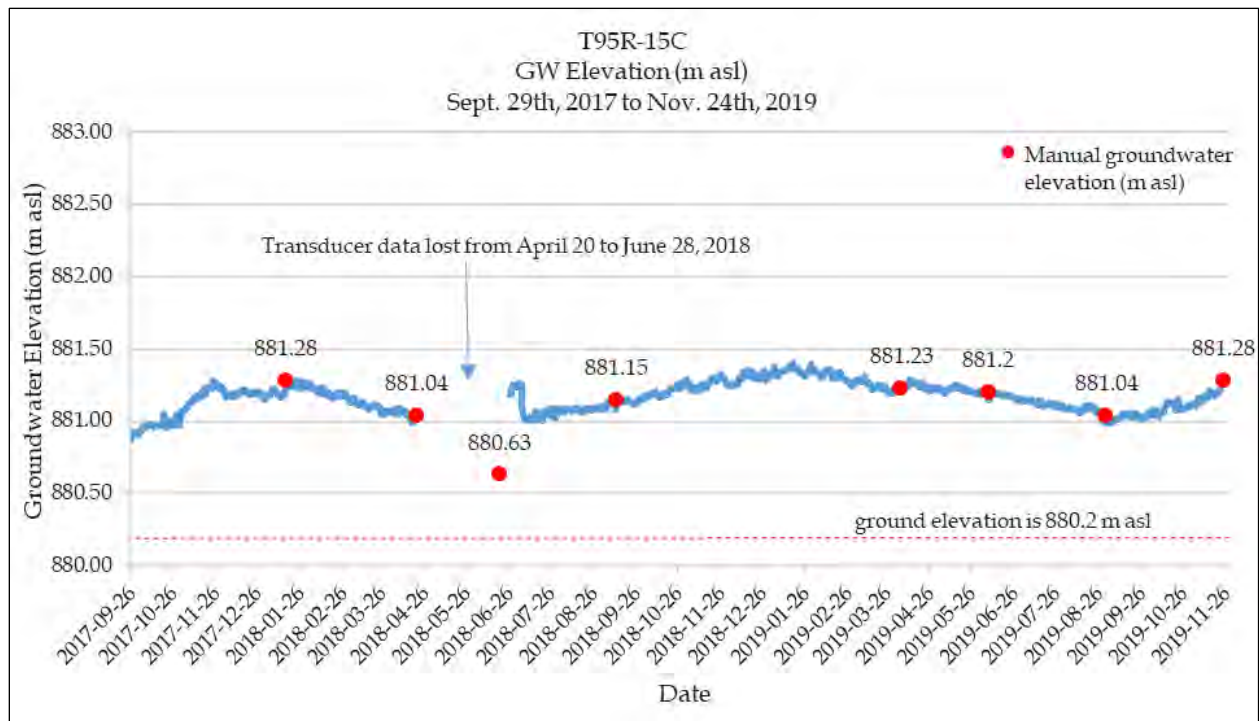
- T95R-15C (881.41 m asl) – January 19, 2019;
- T95R-64 (934.81 m asl) – November 26, 2017; and
- T96R-16-19 (1,011.24 m asl) – May 20, 2018.

The lowest groundwater elevation for all three bedrock wells was observed during the month of September during various years:

- T95R-15C (880.88 m asl) – September 29, 2017;
- T95R-64 (934.29 m asl) – September 15, 2018; and
- T96R-16-19 (1,010.24 m asl) – September 8, 2018.

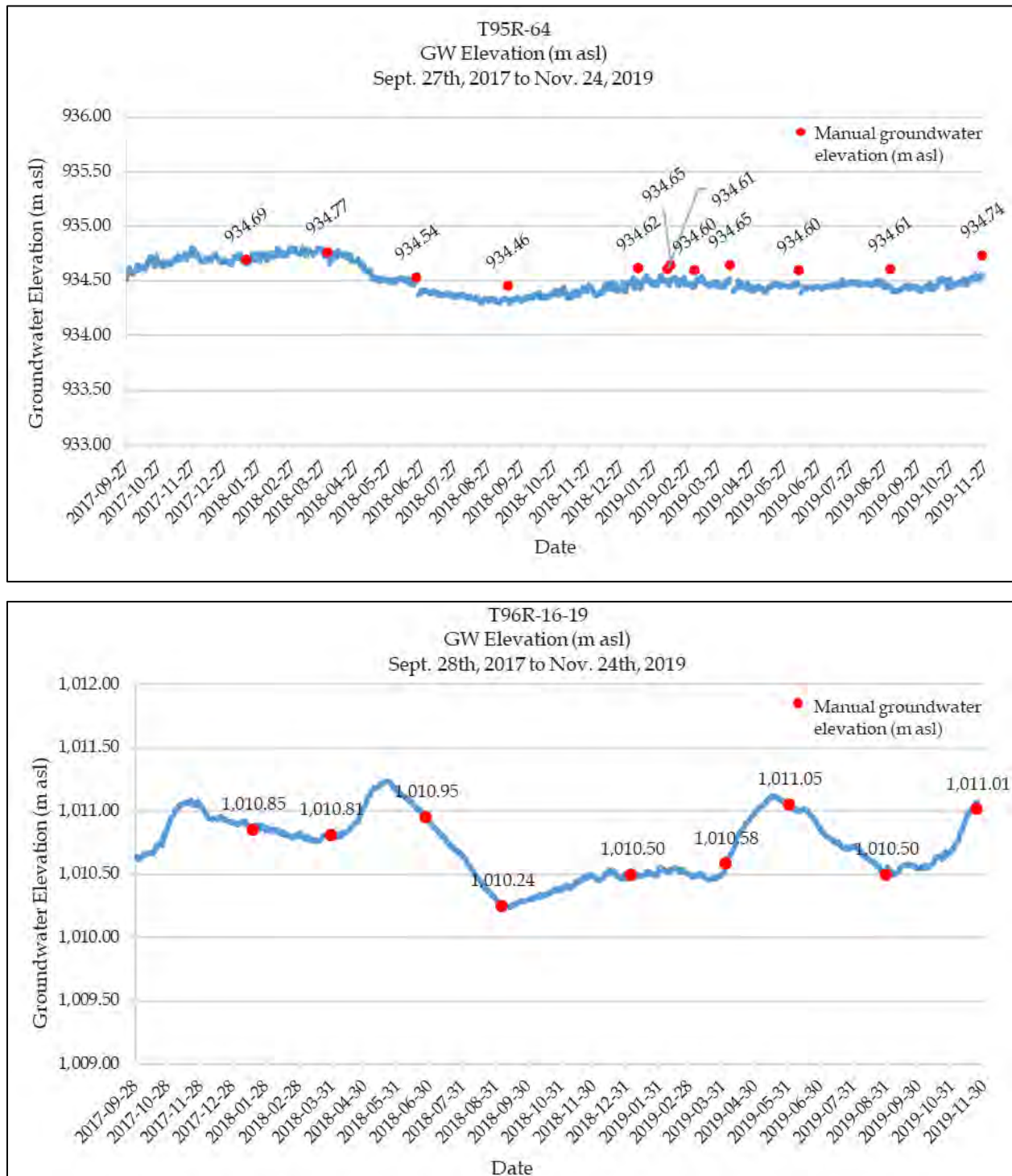
The continuous water level measurement data for the two new bedrock wells (W1 Shallow and W1 Deep) were collected during the late summer/fall months of 2019; therefore seasonal and yearly changes cannot be discussed at this time. The water level at W1 Shallow steadily decreased by 1.40 m from late August to late November 2019 while the water level at W1 Deep increased by 0.66 m from early September to late November of 2019 (Figure 5.5-7).

Figure 5.5-7. Continuous Groundwater Level Measurements – Bedrock Wells

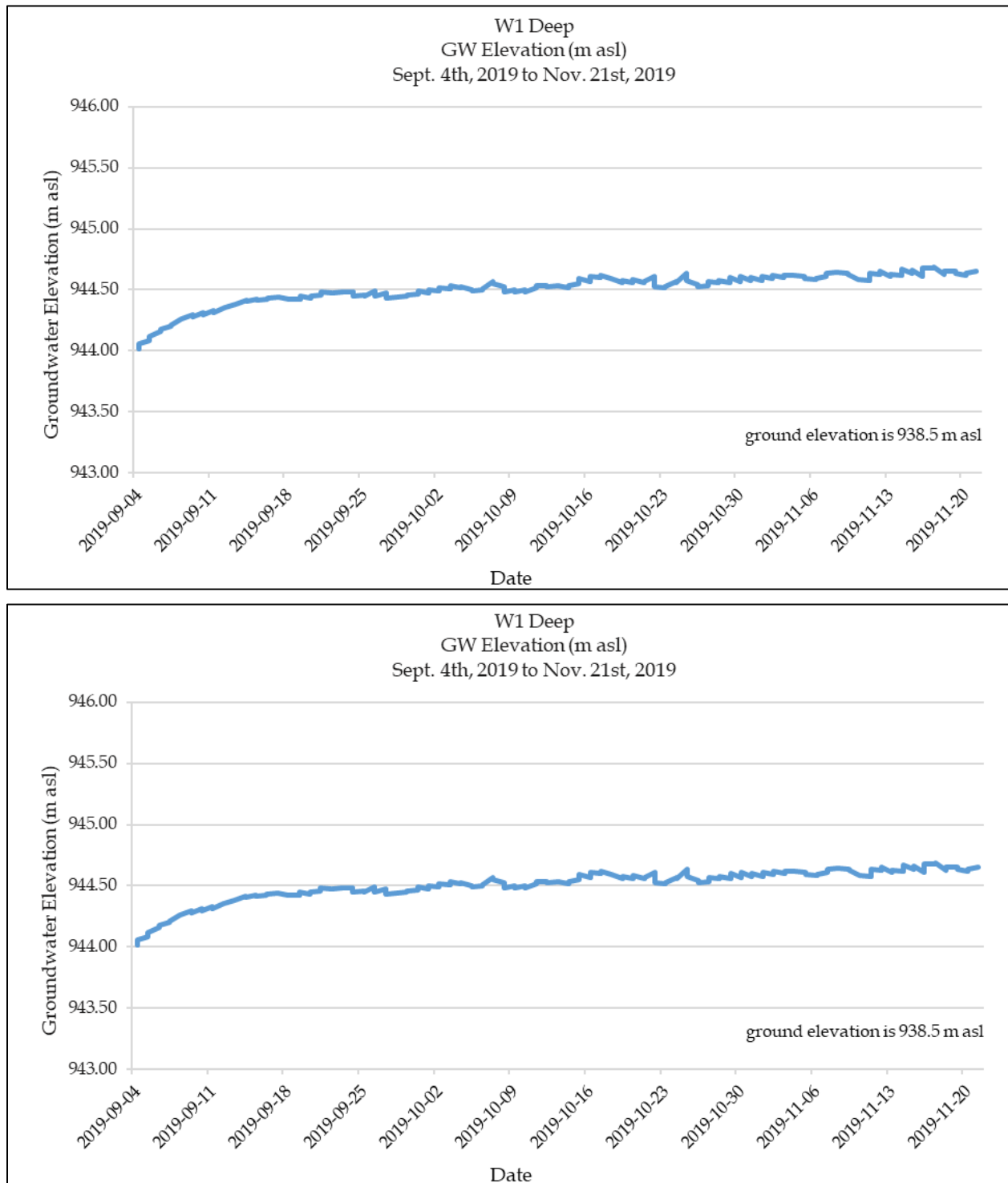


(continued)

Figure 5.5-7. Continuous Groundwater Level Measurements – Bedrock Wells (continued)



(continued)

Figure 5.5-7. Continuous Groundwater Level Measurements – Bedrock Wells (completed)

Overburden Wells

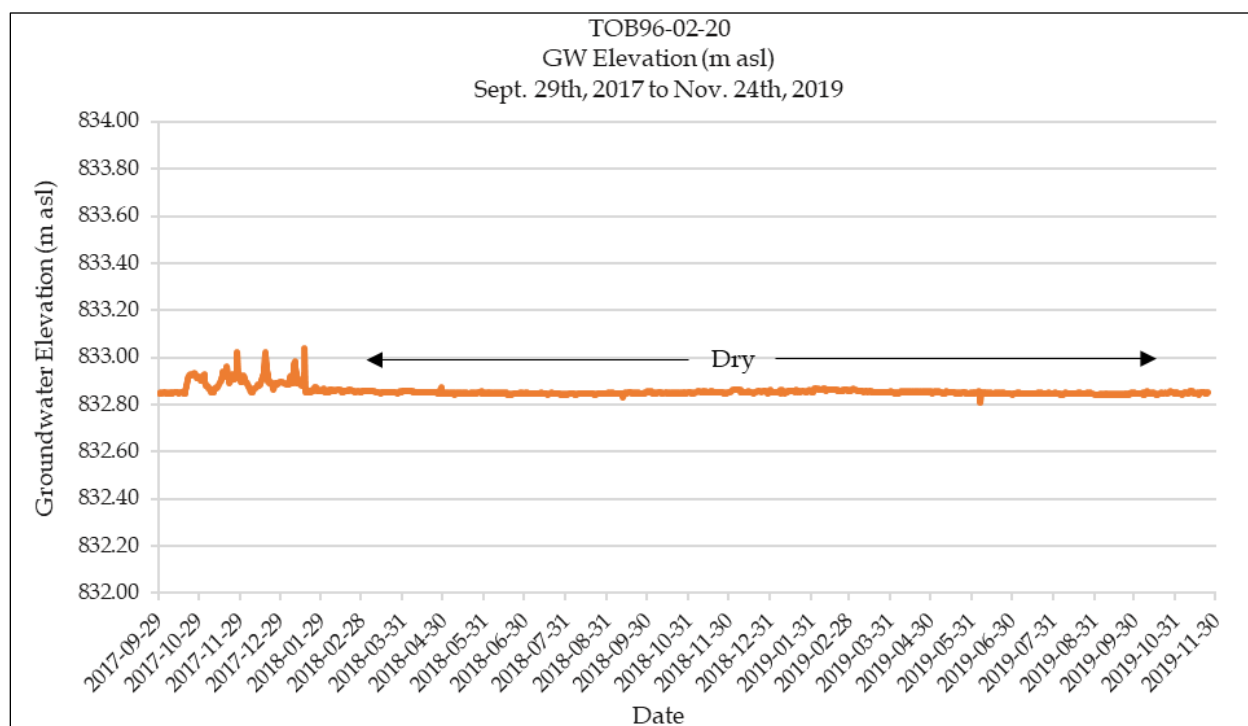
In general, continuous water level measurement data from the shallow overburden well TOB96-02-06 show that the groundwater levels increased during late fall of 2017, the spring of 2018 and the spring/summer 2019. The increase in the spring 2018 water levels were over double in magnitude in relation to the spring 2019 groundwater level increases. The groundwater level peaked in mid May during 2018 and mid July during 2019. The groundwater levels declined throughout the winter months of 2018 and 2019 and throughout the summer and fall of 2018 and 2019 (Figure 5.5-8).

The groundwater elevation fluctuated a maximum of 3.07 m at TOB96-02-06 from late September 2017 to November 2019, with the highest groundwater elevation on May 9, 2018 (852.67 m asl) and the lowest groundwater elevation on April 6, 2019 (849.6 m asl; Figure 5.5-8).

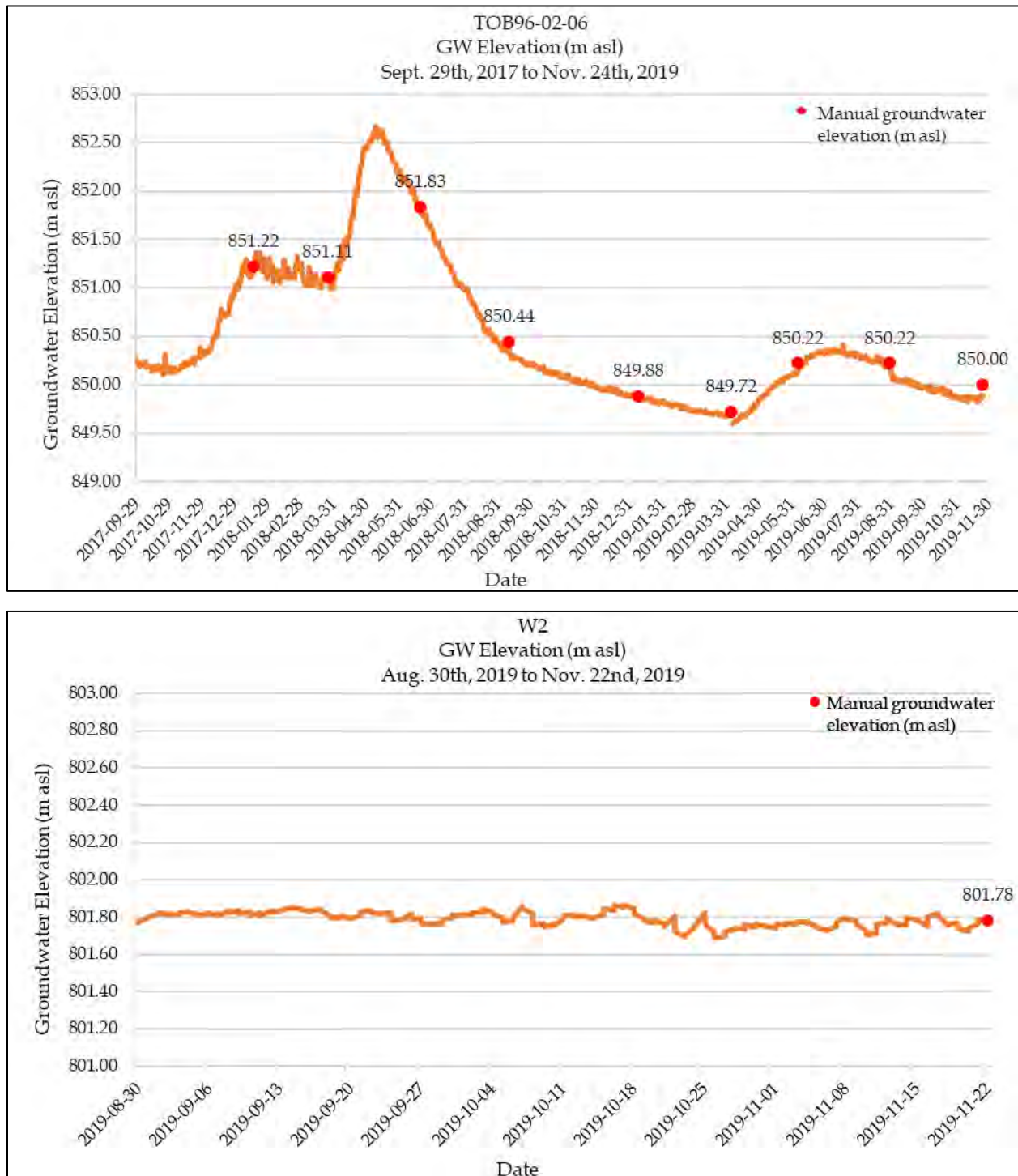
The continuous water level measurement data from overburden well TOB96-02-20 show that the well was predominantly dry from late September 2017 to late November 2019 with the exception of brief groundwater inputs from mid October 2017 to mid-January 2018. The highest groundwater level at TOB96-02-20 was on January 16, 2018 (833.02 m asl; Figure 5.5-8).

The continuous water level measurement data for the two new deeper overburden wells (W2 and W3 Shallow) were only collected during the late summer/fall months of 2019, therefore seasonal and yearly changes cannot be discussed at this time. Both of these wells showed minor water level fluctuations during this time period (0.17 m for W2 and 0.43 m for W3 Shallow) and had generally steady water levels.

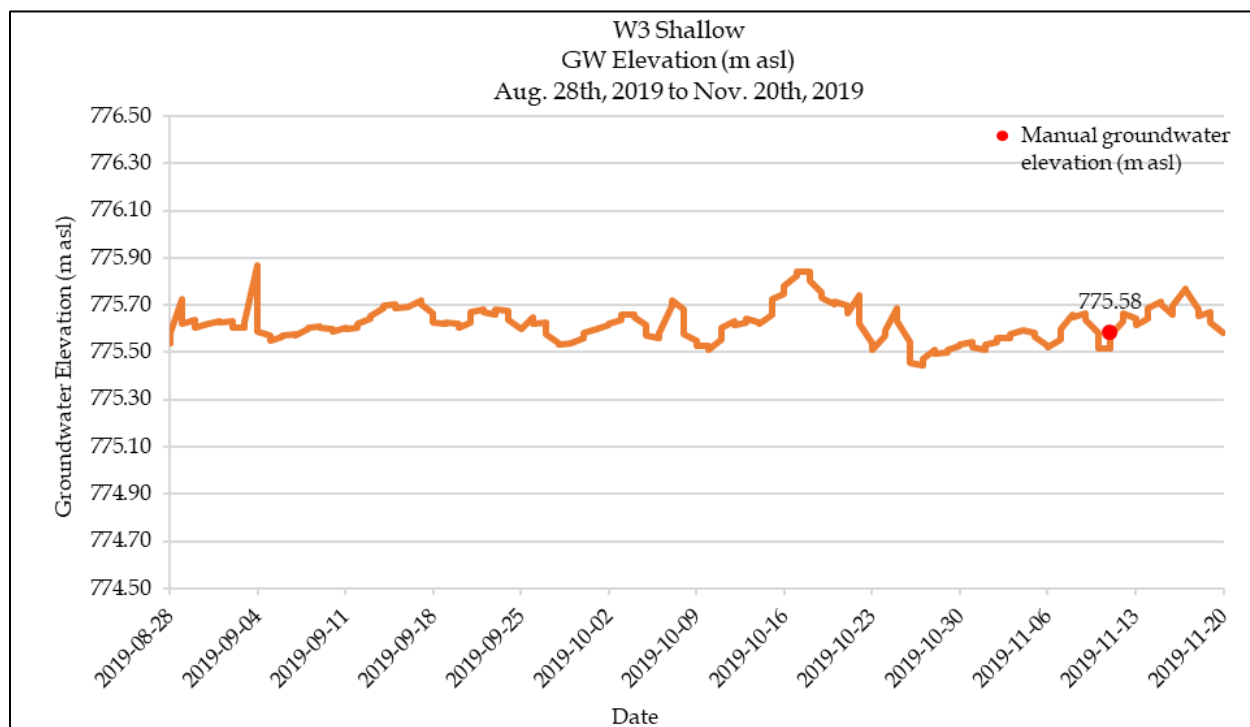
Figure 5.5-8. Continuous Groundwater Level Measurements – Overburden Wells



(continued)

Figure 5.5-8. Continuous Groundwater Level Measurements – Overburden Wells (continued)

(continued)

Figure 5.5-8. Continuous Groundwater Level Measurements – Overburden Wells (completed)

Geotechnical Wells (East side of Goathorn Creek)

Continuous groundwater pressure data was collected from T18-14S and T18-15S every 12 hours from September 27, 2019 to November 19, 2019 with Solinst Levellogger dataloggers and compensated barometrically with a Solinst Barologger. The groundwater elevation was relatively stable from September 27 to November 19, 2019 with the groundwater elevation fluctuating 0.09 m at T18-14S and 0.11 m at T18-15S (Figure 5.5-9).

In general, the lowest groundwater elevation for both of these wells was recorded during mid-October while the highest groundwater elevation was recorded during mid-November as the groundwater level was beginning to trend upwards at the start of November (Figure 5.5-9).

5.5.3 Hydraulic Conductivity

5.5.3.1 Slug Tests (Existing and New Wells)

Hydraulic conductivity (K) values were measured during the baseline work conducted in the 1990s, and the K values for the existing wells that are included in the 2017 to 2019 baseline program are summarized below (Table 5.5-2).

Figure 5.5-9. Continuous Groundwater Level Measurements, Geotechnical Wells, East Side of Goathorn Creek, September 27 to November 19, 2019

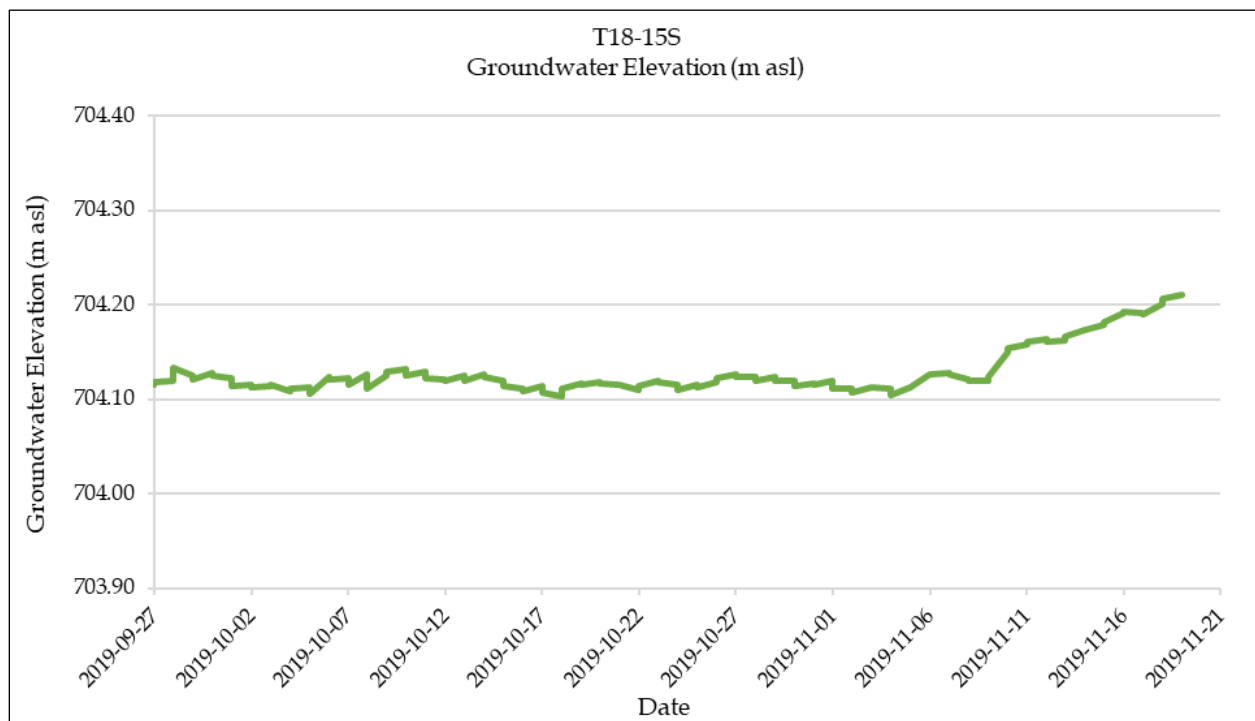
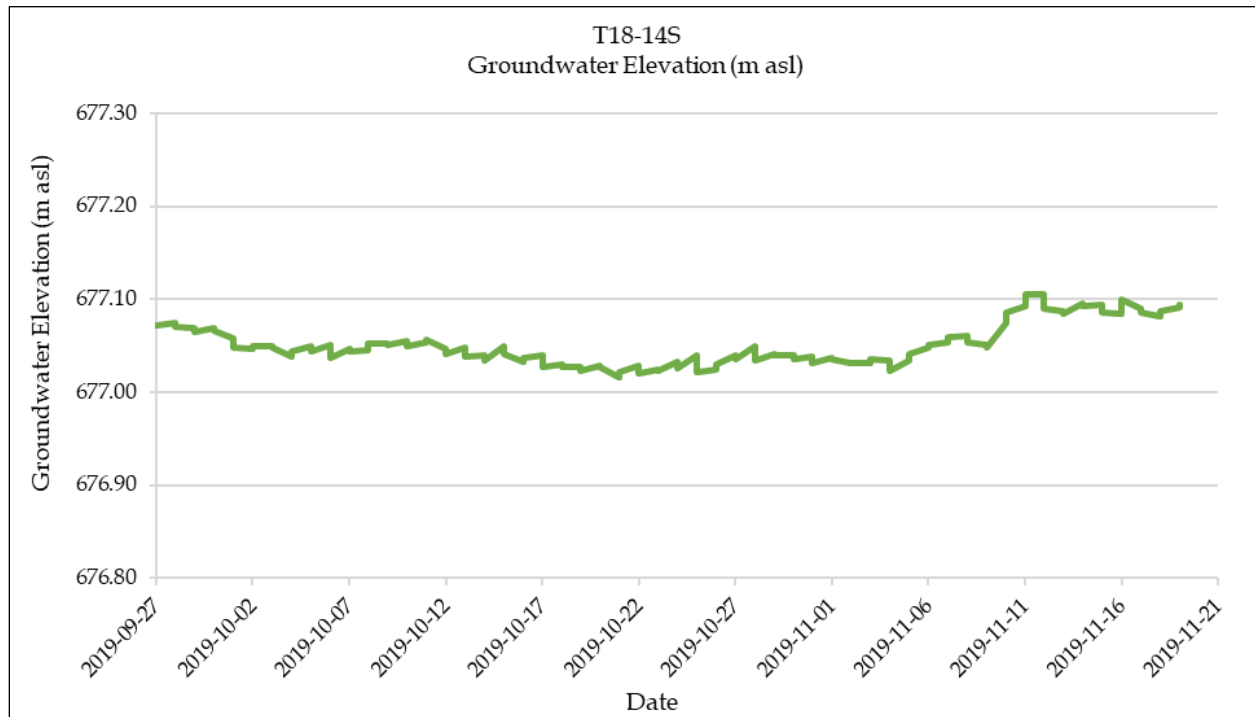


Table 5.5-2. Historical Hydraulic Conductivities by Material Type

Monitoring Location	Material Type	Hydraulic Conductivity (m/s)
T95R-15C	Coal (seam #1)	6.0×10^{-6}
T95R-40	Coal (seam #1)	1.4×10^{-6}
T95R-64	Coal (seam #1)	5.5×10^{-7}
T96R-16-19	Coal (seam #1)	1.6×10^{-7}
T96R-16-28	Unnamed lower coal seam	3.2×10^{-8}
T96R-34-87	Coal (seam #1)	1.2×10^{-7}
TOB96-01-05	Till	7.2×10^{-7}
TOB96-02-06	Till	1.4×10^{-7}
TOB96-02-20	Sand & gravel	1.3×10^{-8}
TOB96-11-04	Clay	1.4×10^{-10}
TOB96-11-19	Fine sand	nm (well dry)
TOB97-06-21	Sand	nm (well dry)
TOB97-07-24	Sand	nm (well dry)

Source: Baseline Hydrogeological Investigations in the Tenas Pit, Waste Dumps, and Mine Pit 3, Telkwa Coal Project, Table 1.
Prepared by Piteau Engineering Ltd., 1997

A total of 11 slug tests were conducted in five new wells (two in bedrock, two in overburden and one along the bedrock/overburden interface). The results of the rising and falling head slug test analyses are provided in Appendix 5-H and are summarized below (Table 5.5-3). The measured K values were highest in the overburden unit at W2 and lowest in the volcanic unit at W3 Deep. The K values were generally consistent between each test at each of the wells with the exception of W3 Deep, where the K value differed by an order of magnitude between the two tests. An artesian pressure test/flow test is planned at W1 Deep in the near future in order to acquire the K value at this well.

Table 5.5-3. Hydraulic Conductivities Values for the 2018 Wells

Monitoring Location	Material Type	Hydraulic Conductivity (m/s)
W2 (Test #1)	Overburden (Sand)	2.0×10^{-6}
W2 (Test #2)	Overburden (Sand)	1.9×10^{-6}
W2 (Test #3)	Overburden (Sand)	1.9×10^{-6}
ARD 2 (Test #1)	Bedrock (Sandstone)	8.3×10^{-7}
ARD 2 (Test #2)	Bedrock (Sandstone)	3.2×10^{-7}
W1 Shallow (Test #1)	Bedrock Interface (Volcanics and Till)	4.2×10^{-7}
W1 Shallow (Test #2)	Bedrock Interface (Volcanics and Till)	5.1×10^{-7}
W3 Shallow (Test #1)	Overburden (Sand)	4.7×10^{-7}
W3 Shallow (Test #2)	Overburden (Sand)	4.7×10^{-7}
W3 Deep (Test #1)	Bedrock (Volcanics)	3.4×10^{-9}
W3 Deep (Test #2)	Bedrock (Volcanics)	6.2×10^{-10}

5.5.3.2 PAG Cell Wells

The three wells screened in the glacial overburden material have average K values ranging from 5.08E 10⁻⁵ m/s (19-27S(R)) to 5.90E 10⁻⁷ m/s (19-18S(AB)) while the four wells screened in the shallow bedrock have average K values ranging from 5.30E 10⁻⁶ m/s (19-35S(V)) to 3.03E 10⁻⁸ m/s (19-21S(AA)) (using values derived from the Hvorslev method; Table 5.5-4). It is recommended to conduct a minimum of one more slug test at 19-22S(Z) in order to confirm the validity of the first test. The individual slug test results with the parameters used for the analysis are presented in Appendix 5-I.

Table 5.5-4. Hydraulic Conductivity Test Results (PAG Cell Monitoring Wells)

Well ID	Test #	Test Analysis	Hydraulic Conductivity (m/s)	Average Hydraulic Conductivity (m/s)
Overburden Wells				
19-18(AB)	1	Hvorslev	3.26E-07	5.90E-07
	2	Hvorlsev	7.46E-07	
	3	Hvorlsev	6.97E-07	
19-26S(AD)	1	Hvorslev	3.16E-06	3.29E-06
	2	Hvorlsev	3.21E-06	
	3	Hvorlsev	3.51E-06	
19-27S(R)	1	Hvorslev	4.82E-05	5.08E-05
	2	Hvorlsev	4.11E-05	
	3	Hvorlsev	6.31E-05	
Shallow Bedrock Wells				
19-21S(AA)	1	Hvorslev	2.89E-08	3.03E-08
	2	Hvorlsev	2.79E-08	
	3	Hvorlsev	3.41E-08	
19-22S(Z)	1	Hvorslev	6.59E-08	n/a
19-34S(Y)	1	Hvorslev	8.61E-08	1.35E-07
	2	Hvorlsev	1.91E-07	
	3	Hvorlsev	1.28E-07	
19-35S(V)	1	Hvorslev	5.15E-06	5.30E-06
	2	Hvorlsev	4.86E-06	
	3	Hvorlsev	5.89E-06	

5.5.3.3 Packer Tests (Winter 2018 Drill Program)

While the existing K dataset provided a reasonable estimation of the range associated with coal seams, it was not suitable to characterize properties of the rocks below the main coal-bearing sequence and differentiate low permeability layers that may limit groundwater flows down-gradient of the mine pit. SRK conducted packer test analysis for hydraulic conductivity at three new boreholes (W1, ARD01, and ARD06) to enhance the hydrogeological database and improve predictions of the slope pore pressures, pit inflow, and potential dewatering requirements (SRK Consulting 2018). The results of the SRK analysis are summarized below (Table 5.5-5), and provided in Appendix 5-B. Well logs are also provided in Appendix 5-B.

Table 5.5-5. Packer Test Analysis Summary

Hole ID	Test Number	Test Interval		Lithology	Estimated Hydraulic Conductivity (m/s)	Notes
		Top (m bgs)	Bottom (m bgs)			
BW01	1	63.2	68.0	Volcanics	4.6×10^{-8}	
	2	54.2	59.0		7.6×10^{-8}	No downhole pressure measurement
	3	45.2	50.0		1.0×10^{-8}	No downhole pressure measurement
	4	33.2	38.0		8.9×10^{-7}	No downhole pressure measurement
	5	21.2	26.0		5.4×10^{-7}	No downhole pressure measurement
ARD01	1	90.2	97.0	Mudstone/Siltstone	8.0×10^{-9}	
	2	81.2	88.0	Conglomerate	6.5×10^{-9}	
	3	63.2	71.5	Siltstone	1.2×10^{-8}	Fractures noted
	4	42.2	48.5	Mudstone	1.7×10^{-8}	
ARD06	1	200.2	207.0	Conglomerate	6.4×10^{-8}	
	2	176.2	183.0	Siltstone	9.7×10^{-8}	Steady stated drawdown not reached
	3	170.2	174.0	Sandstone	3.7×10^{-8}	
	4	149.2	156.0	Siltstone	2.2×10^{-7}	

Source: SRK (2018)

The measured K values are consistent with literature values (e.g. Heath 1983). The geometric mean estimated K value of the volcanics (1.8×10^{-7} m/s) is an order of magnitude higher than the geometric mean of the sedimentary sequence tested below the lowest coal seam (2.9×10^{-8} m/s). There is moderate to little variation in the estimated K values, the log standard deviation of K values for both the volcanics and sedimentary sequence is ~0.5 (half an order of magnitude). In general, there is a decrease in K with depth at each test location (SRK Consulting 2018).

5.5.3.4 Pump Test

During the pump test, a total of approximately 5,850 L of groundwater was removed over 20 hours, which results in an overall average pumping rate of 4.9 L/min. After the pumping portion of the test was completed, the recovery phase was monitored for approximately 23 hours before the pump was removed. The water level recovered to 90% of the pre-pumping static water level before the pump was pulled out of the well.

The Theis step-drawdown test solution was used to estimate the transmissivity of the aquifer based on the combined pumping and recovery data, and the Theis (recovery) solution was used for the transmissivity estimation based on the recovery data. The transmissivity and the hydraulic conductivity values derived from these two solutions are shown on Table 5.5-6. The Aqtesolv test analysis results and the pumping test field notes can be found in Appendix 5-J.

Table 5.5-6. Pumping Test Results – Transmissivity Derived from Theis Solutions

Well ID	Data Type	Test Analysis	Transmissivity (m ² /day)	Aquifer Thickness (m)	Hydraulic Conductivity (m/s)	Storativity
18-01D	Pumping and recovery	Theis step-drawdown	0.0622	6.2	1.2E-07	0.00012
	Recovery	Theis (recovery)	0.208	6.2	3.9E-07	-

During the pump test the water level within monitoring well T95R-64 was relatively stable and actually rose 4 cm during the test. Because of the distance between 18-01D and T95R-64 (~440 m), the water level data from T95R-64 could not be used to verify if there is hydraulic connectivity between the coal seam and the underlying sandstone, therefore it was not used in the estimation of transmissivity.

5.5.4 Groundwater Flow Direction and Horizontal/Vertical Hydraulic Gradients

5.5.4.1 Horizontal Hydraulic Gradients

Groundwater levels from two monitoring events (June and September 2018) were used to map the general direction of groundwater flow within the bedrock and the overburden. The bedrock flow directions were derived from five of the historical wells screened in coal seam #1 (T95R-15C, T95R-40, T95R-64, T96R-16-19, and T96R-34-87), while the overburden flow directions were derived from three of the historical wells screened at similar depths in the shallow overburden units (TOB96-02-06, TOB96-11-04, and TOB96-01-05).

Bedrock Wells

For the wells screened in coal seam #1 (bedrock), the groundwater elevations during late June 2018 and early September 2018 ranged from 1,010.95 m asl and 1,010.24 m asl, respectively (T96R-16-19) to 880.63 m asl and 881.15 m asl, respectively (T95R-15C).

The general direction of groundwater flow is towards the north-northeast under a horizontal hydraulic gradient of approximately 0.09 (Figures 5.5-10 and 5.5-11). The groundwater flow direction and horizontal hydraulic gradient from June and September 2018 are very similar in comparison to the historical information from August 1997 (Piteau Engineering Ltd. 1998).

Overburden Wells

For the wells screened in the shallow overburden, the groundwater elevations during late June 2018 and early September 2018 ranged from 921.33 m asl and 918.41 m asl, respectively (TOB96-01-05) to 824.68 m asl and 824.28 m asl, respectively (TOB96-11-04).

The general direction of groundwater flow is towards the north (similar to the topography) under a horizontal hydraulic gradient of approximately 0.04 (Figures 5.5-12 and 5.5-13). The groundwater flow direction and horizontal hydraulic gradient from June and September 2018 are very similar in comparison to the historical information from August 1997 for these same wells (Piteau Engineering Ltd. 1998).

616000

618000

620000

6054000

6052000

6050000

616000

618000

620000

Telkwa Coal Limited

Bedrock (Coal Seam) Potentiometric Elevation Diagram June 2018

Figure 5.5-10

Legend

-  GW LSA
-  Mine Footprint
-  Offsite Footprint
-  Bedrock Well
-  Inferred Groundwater Flow Direction
-  Inferred Potentiometric Elevation Contour Line (20m intervals)

Map Features

-  River/Stream
-  Lake
-  Wetland
-  20m Contour Line
-  Road

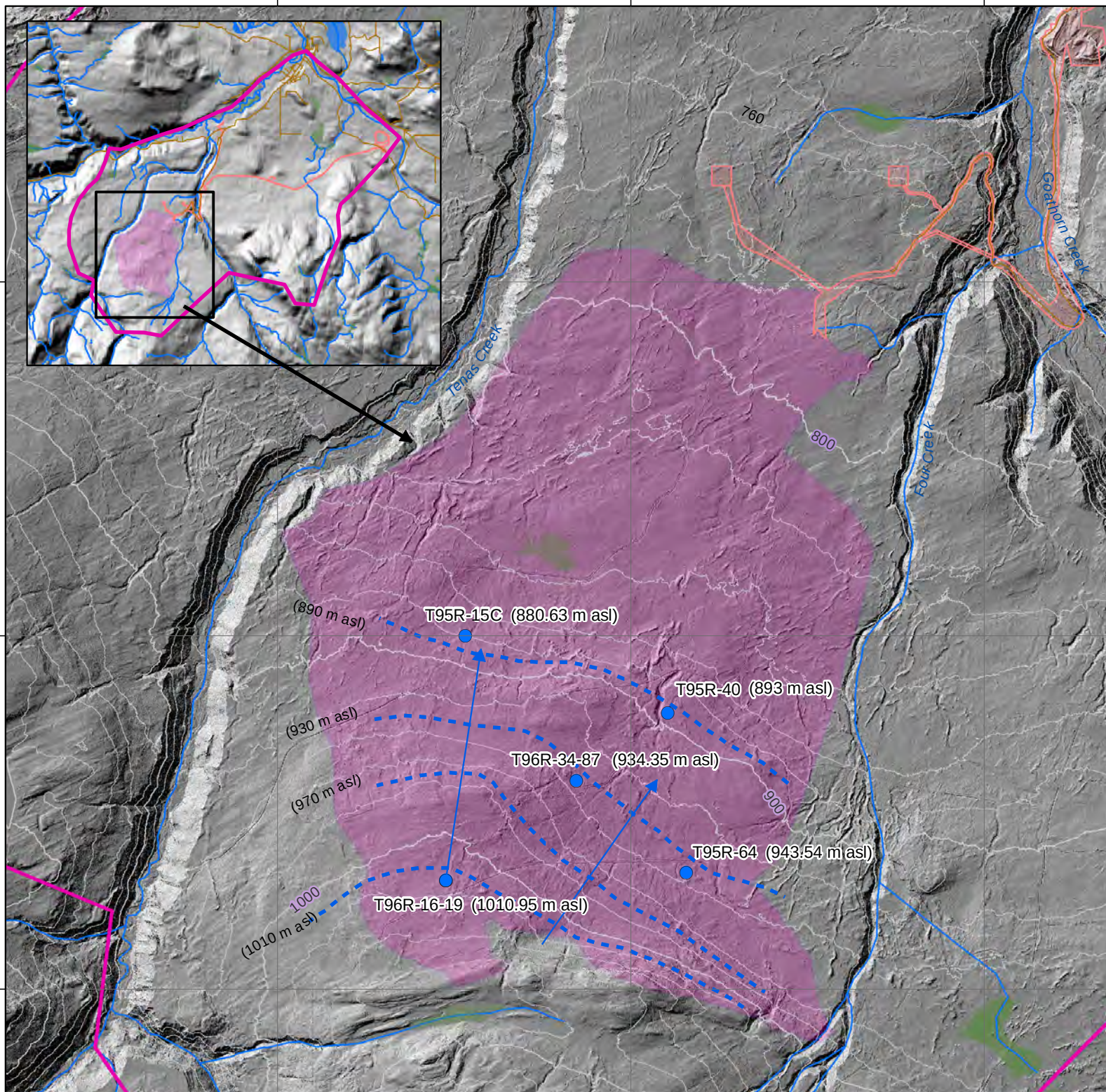
N

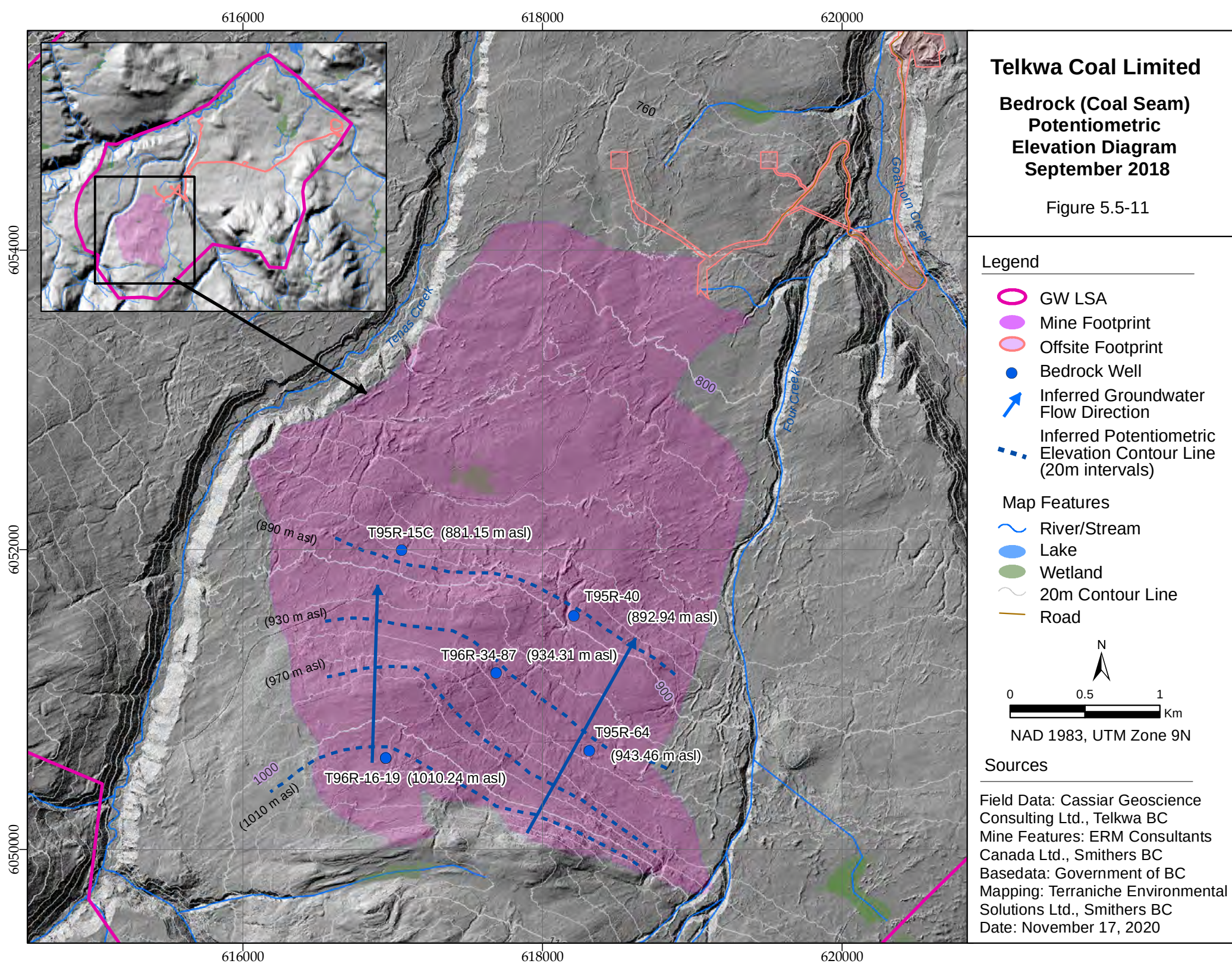
0 0.5 1
Km

NAD 1983, UTM Zone 9N

Sources

Field Data: Cassiar Geoscience Consulting Ltd., Telkwa BC
 Mine Features: ERM Consultants Canada Ltd., Smithers BC
 Basedata: Government of BC
 Mapping: Terraniche Environmental Solutions Ltd., Smithers BC
 Date: November 17, 2020





Telkwa Coal Limited

Shallow Overburden Groundwater Elevation Diagram June 2018

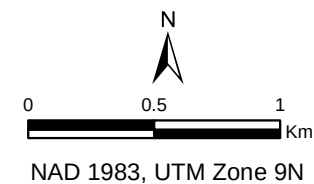
Figure 5.5-12

Legend

- GW LSA
- Mine Footprint
- Offsite Footprint
- Overburden Well
- Inferred Groundwater Flow Direction
- Inferred GW Elevation Contour (20m intervals)

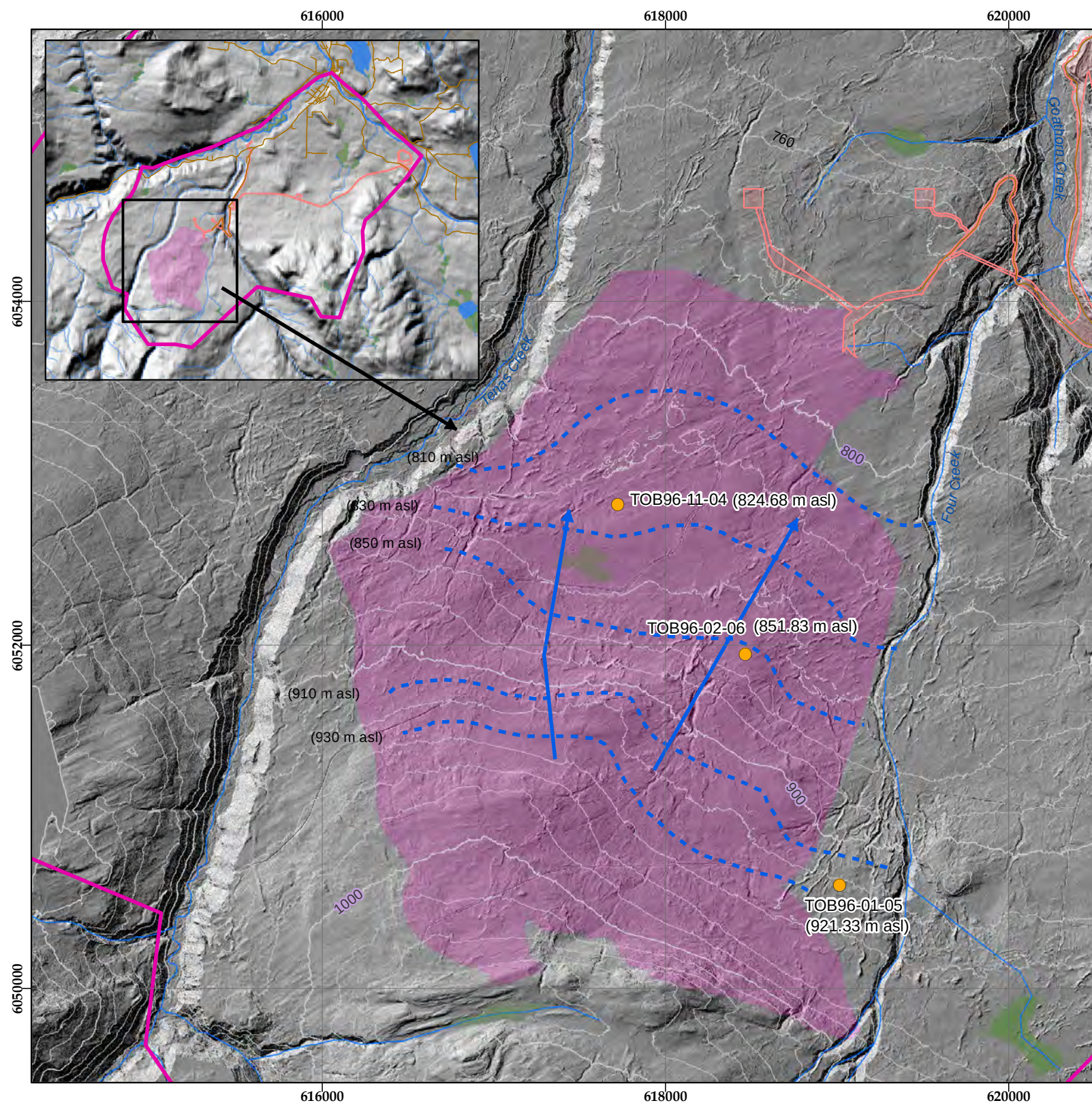
Map Features

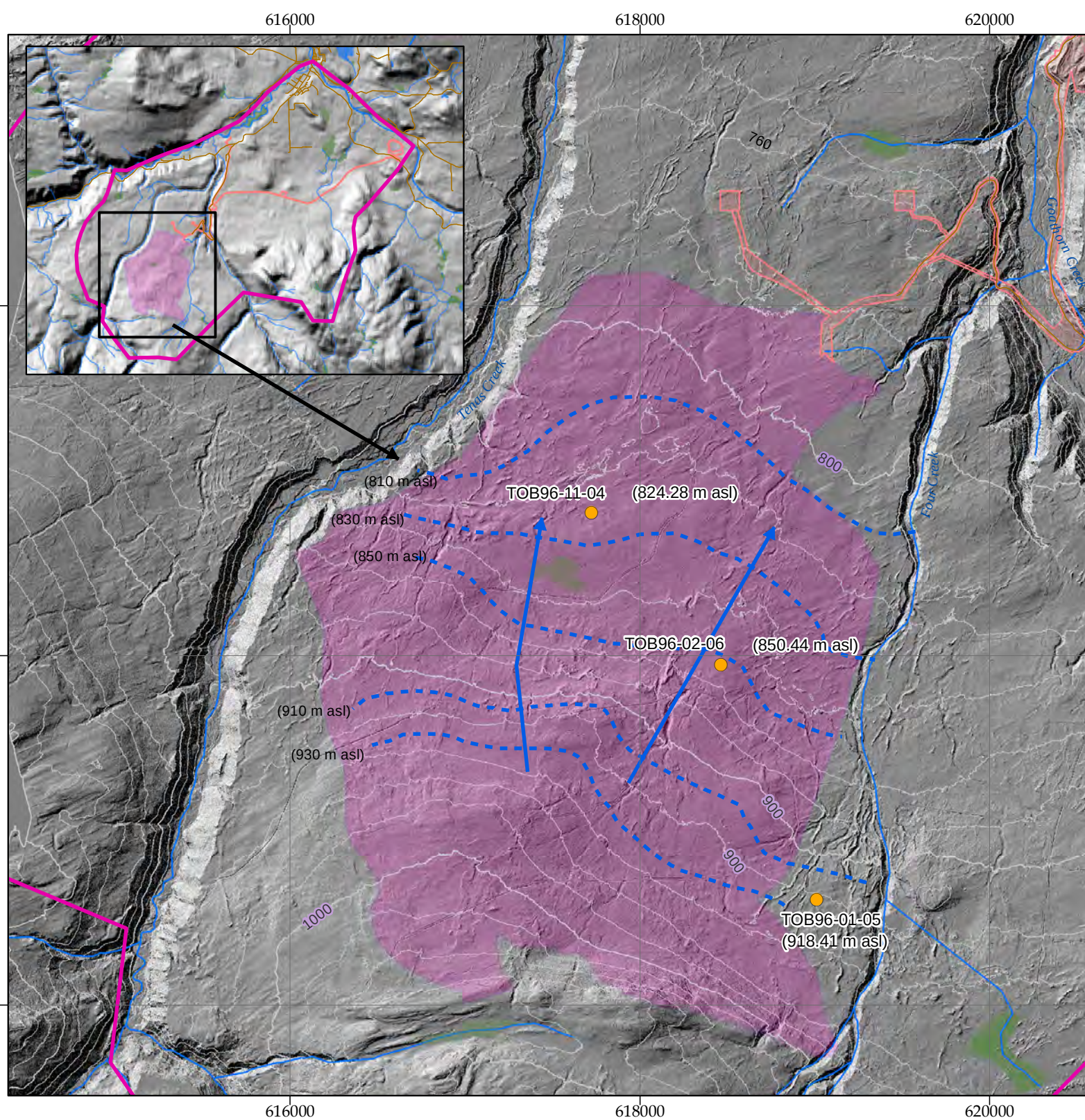
- River/Stream
- Lake
- Wetland
- 20m Contour Line
- Road



Sources

Field Data: Cassiar Geoscience Consulting Ltd., Telkwa BC
Mine Features: ERM Consultants Canada Ltd., Smithers BC
Basedata: Government of BC
Mapping: Terraniche Environmental Solutions Ltd., Smithers BC
Date: November 17, 2020





Telkwa Coal Limited

Shallow Overburden Groundwater Elevation Diagram September 2018

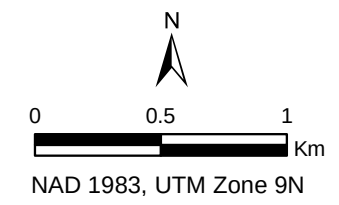
Figure 5.5-13

Legend

- GW LSA
- Mine Footprint
- Offsite Footprint
- Overburden Well
- Inferred Groundwater Flow Direction
- Inferred GW Elevation Contour (20m intervals)

Map Features

- River/Stream
- Lake
- Wetland
- 20m Contour Line
- Road



Sources

Field Data: Cassiar Geoscience Consulting Ltd., Telkwa BC
Mine Features: ERM Consultants Canada Ltd., Smithers BC
Basedata: Government of BC
Mapping: Terraniche Environmental Solutions Ltd., Smithers BC
Date: November 17, 2020

As there are only two monitoring wells screened in a deeper confined overburden unit (W2 and W3 Shallow), an accurate estimate of groundwater flow direction and horizontal hydraulic gradient could not be made between these wells at this time.

5.5.4.2 *Vertical Hydraulic Gradients*

Bedrock Wells

Nested monitoring wells T96R-16-19 and T96R-16-28 were used for determining the vertical hydraulic gradient between coal seam #1 and a deeper unnamed coal seam in the upper portions of the proposed pit. Based on 11 sets of monitoring data (July 2017, September 2017, January 2018, March 2018, June 2018, September 2018, January 2019, April 2019, June 2019, August 2019, and November 2019), the deeper well (T96R-16-28) had a slightly higher groundwater elevation than the shallower well (T96R-16-19) for each measurement; this infers a minor upward vertical hydraulic gradient (0.004 to 0.007) at this location.

Nested monitoring wells W1 Shallow and W1 Deep (cross-gradient to the west of the proposed pit) were used for determining the vertical hydraulic gradient within the Hazelton Group volcanics. W1 Shallow is screened across the interface of the shallow weathered volcanic bedrock and the overlying overburden. Based on the artesian conditions in this well and the similar chemistry to W1 Deep, it is inferred the majority of the groundwater within W1 Shallow arises from the weathered volcanic bedrock. Based on two sets of monitoring data (April 2019 and August 2019) the deeper well (W1 Deep) had a higher groundwater elevation than the shallower well (W1 Shallow) for each measurement; this infers an upward vertical hydraulic gradient (0.07 to 0.08) at this location.

Nested monitoring wells W3 Shallow and W3 Deep were used for determining the vertical hydraulic gradient between the Hazelton Group volcanics (W3 Deep) and the overlying overburden unit (W3 Shallow) down-gradient of the proposed pit. Based on eight sets of monitoring data (April 2018, June 2018, September 2018, January 2019, March 2019, May 2019, August 2019 and November 2019) the shallow well (W3 Shallow) had a higher groundwater elevation than the deep well (W3 Deep) for each measurement, which infers a relatively strong downward vertical hydraulic gradient (-1.05 to -1.92) at this location.

Overburden Wells

Nested monitoring wells TOB96-02-06 and TOB96-02-20 were used for determining the vertical hydraulic gradient between the upper and lower water-bearing overburden deposits down-gradient of the proposed pit. Only one set of monitoring data (June 2018) could be used for determining the vertical hydraulic gradient between these two wells, because the deeper well (TOB96-02-20), screened in a coarser-grained material below the finer-grained unit, was dry during the majority of the monitoring events. Based on this one monitoring event, the shallow well (TOB96-02-06) had a higher groundwater elevation than the deep well (TOB96-02-20), which infers a relatively strong downward vertical hydraulic gradient (-1.31) at this location. This data is consistent with historical data, as there has been recorded water levels in the deeper well during previous monitoring events in 1996 and 1997 (Piteau Engineering Ltd. 1998).

The vertical hydraulic gradient results for the bedrock and overburden units can be found in Appendix 5-E.

6. GROUNDWATER QUALITY

The 2017 to 2019 baseline groundwater quality program was initiated in August 2017 with the sampling of a subset of historical monitoring wells in and around the Tenas Pit. An understanding of this information will contribute to engineering analysis and design of water management features; support development of water quality and water balance models, effects assessments, management plans, closure planning, support permitting, and monitor changes in groundwater quality.

This chapter describes the baseline groundwater quality data collected to the end of November 2019, during which time 11 quarterly sampling events were conducted. The historical groundwater quality data from 1995 to 1997 and 2016 is also discussed in comparison to the current data.

The objective of the groundwater quality baseline is to:

- expand the existing baseline data in areas that could potentially be affected by the development of the mine;
- capture the seasonal and annual variability in groundwater quality to assess the existing (baseline) groundwater quality before the proposed mine occurs; and
- identify any existing exceedances of relevant water quality guidelines.

6.1 STUDY AREA

The local study area (LSA) for the August 2017 to November 2019 baseline program is defined as the area where the Project may have a direct influence on the groundwater system and or groundwater users. The LSA is based on watershed boundaries and includes the Project footprint and private domestic wells located down-gradient of the Project (Figure 5.1-1).

6.2 REGULATORY AND POLICY FRAMEWORK

Groundwater quality is an important component of the biological and physical environment and is protected under the Groundwater Protection Regulation of the British Columbia (BC) *Water Sustainability Act* (2016). Groundwater baseline studies for the Project were designed to meet the requirements of the BC *Environmental Assessment Act* [SC 2002, c.43], and the *Mines Act* and *Environmental Management Act* Permits Joint Application Information Requirements (BC MEM and BC MOE 2016).

6.3 EXISTING INFORMATION

Groundwater quality data collection in the area of the Tenas Pit occurred concurrently with exploration investigations during the mid 1990's. No data were collected from 1997 to 2015 and in 2016 only nine monitoring wells were inspected in the Tenas Pit area. Of these nine, three were suitable for sampling, three were damaged (blockage below surface or damaged casing), and three were dry or did not have enough water to allow sampling (Stantec undated). Table 6.3-1 below summarizes the historical groundwater quality data information for the Project, as well as the baseline work conducted from 2017 to 2019.

Table 6.3-1. Groundwater Quality Data Information Table

Documents Reviewed	• <i>Baseline Data – Surface Water and Groundwater, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. June 1994. • <i>Preliminary Assessment of Potential Groundwater Inflows and Dewatering Requirements in the Tenas Creek Region, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. January 1996. • <i>Baseline Hydrogeological Investigations in the Tenas Pit, Waste Dumps, and Mine Pit 3, Telkwa Coal Project.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. January 1997. • <i>Baseline Hydrogeological Conditions in the Telkwa Coal Project Area – Volumes I and II.</i> Prepared by Piteau Engineering Ltd. Prepared for Manalta Coal Ltd. June 1998. • Stantec lab data, 2016. No report available.
General Remarks	• The historical groundwater quality data is lacking in seasonal data as samples were only collected during the late summer/early fall of 1995, 1996, and 1997. Similarly, the 2016 sampling was only conducted once (November).
Sampling Required for EA and by <i>Joint AIR for Mines Act and Environmental Management Act Permits</i> (Joint AIR)	• Collect eight samples quarterly (i.e., within each of the four seasons) over two years is recommended.
Existing Data	• 1995: Tenas Pit - Groundwater sampling. • 1996: Tenas Pit - Groundwater sampling. • 1997: Pit 3, Tenas Pit, Pit 7 & 8 - A 7h aquifer test in the northern portion of Pit 3. Domestic well survey in area extending three to five km north of Pit 3. Borehole drilling and installation of 27 piezometers in Reclamation Pit (test pit originally excavated in 1983). Groundwater sampling from nearby domestic wells and from all piezometers, where possible. • 2016: Tenas Pit – Groundwater sampling at three monitoring wells by Stantec in November 2016.
Existing Data Issues	• Prior to initiating the 2017 to 2019 baseline field work there was uncertainty on the usability of the existing monitoring wells. • Historical data (i.e., well locations) did not support the configuration of the Tenas Project and new locations were recommended as part of the 2017 to 2019 baseline study. • Historical data were lacking seasonal data as samples were collected annually (not seasonally) in 1995, 1996, 1997 and 2016. • General age of historical groundwater quality data.
Missing Data	• No baseline groundwater quality work was conducted between 1997 and 2016. • In 2016, only nine monitoring wells were inspected by Stantec in November 2016 within the Tenas area. Of these nine, three were suitable for sampling; three were damaged (blockage below surface or damaged casing), and three were dry or did not have enough water to allow sampling (Stantec undated).

(continued)

Table 6.3-1. Groundwater Quality Data Information Table (completed)

2017 to 2019 Baseline Program	• 22 existing monitoring wells were inspected to determine usability. • Quarterly groundwater monitoring was initiated in August 2017. • Five new monitoring wells were installed in January 2018 to support the Tenas Project configuration. • One sample was collected from 18-01D (ARD 2) during the pump test (refer to Section 5.5) in March 2019. • Samples were collected from seven of the nine new monitoring wells in the area of the proposed PAG cell in May 2019. • Four quarterly samples were collected from one residential well, outside of the LSA, from June 2018 to April 2019. Four additional residential wells were each sampled once during winter 2019.
Key Issues	None
Other Comments	None

6.4 METHODOLOGY

The following sections describe the field methodologies for the August 2017 to November 2019 baseline groundwater quality monitoring program, during which time 11 groundwater sampling events were conducted (Table 6.5-1). Additional sampling, using the same methods, were conducted at 18-01D (ARD2) on March 6, 2019 prior to completion of the pump test, and one round of groundwater samples was collected from seven of the PAG cell wells (19-18S, 19-21S, 19-22S, 19-26S, 19-27S, 19-34S and 19-35S) between May 23 and June 5, 2019. Results for 18-01D (ARD2) and the PAG cell wells are provided in separate subsections in section 6.5 Data Summary below.

6.4.1 Groundwater Sampling

Groundwater sampling procedures were followed in general accordance, per the protocols in the British Columbia Field Sampling Manual (BC MOE 2013). Groundwater was purged from each well prior to sampling so that a representative sample could be obtained. Field parameters (pH, specific conductivity, temperature, dissolved oxygen, and oxidation-reduction potential) were measured in situ during the purging process using a YSI 556 multi-parameter reader and/or Oakton multi-parameter probes. Turbidity was measured qualitatively in the field, and periodic turbidity measurements were taken with a LaMotte 2020 turbidity reader. Purging was considered complete when the field parameters stabilized, indicating natural groundwater. All of the field parameter instruments were checked each day with buffer solutions, and recalibrated if the readings were off by more than 5 percent.

Purging and sampling methods differed based on the depth and location of the well:

- Bedrock wells – Waterra foot valve with 5/8-inch outer diameter (OD) high density polyethylene (HDPE) tubing (inertial pump system) combined with a Hydrolift pump, Grundfos submersible pump with 5/8-inch OD HDPE tubing or a Waterra Mini-Monsoon submersible pump with 1/2-inch OD low density polyethylene (LDPE) tubing.
- Overburden wells – 1.6-inch diameter, standard-weighted bailer or a Geotech peristaltic low-flow pump.

After purging was considered complete, groundwater samples were collected by pumping directly into the appropriate bottles supplied by ALS Environmental Laboratory (ALS). Groundwater samples were collected for the analysis of:

- general parameters (pH, specific conductivity, total dissolved solids, total suspended solids, turbidity, color, total hardness);
- major anions and nutrients (nitrate, nitrite, total nitrogen, ammonia, total and dissolved phosphorus);
- alkalinity and acidity;
- total and dissolved organic carbon;
- total metals (including total mercury);
- dissolved metals (including dissolved mercury); and
- polycyclic aromatic hydrocarbons (PAH) (March/ April 2018 event and all following events).

The listed analytes were chosen based on the requirements set out in the BC Ministry of Environment (BC MOE) document *Technical Guidance 6: Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016).

The parameters to be analyzed for dissolved constituents were filtered in the field and all of the required preservatives were added in the field after the sample was collected. Samples were stored in coolers with ice and/or frozen ice packs to minimize the potential for chemical alteration. Coolers were transported to ALS in Burnaby, BC by Air Canada Cargo from Smithers, BC, with the accompanying chain-of-custody forms.

The analytical results for the groundwater samples were compared to the BC MOE approved and working water quality guidelines - freshwater aquatic life (BC WQG - FAL). Some BC WQG-FAL are dependent on hardness, temperature, and pH. The pH and hardness-dependent guidelines were calculated using the pH recorded in the field and lab-reported hardness (as CaCO_3) in each sample. The temperature-dependent guidelines were based on temperatures recorded in the field.

6.4.2 Quality Assurance / Quality Control

The monitoring program design and quality assurance/quality control (QA/QC) standards were developed in conformance with *Technical Guidance 6: Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators* (BC MOE 2016).

During each sampling event, one duplicate sample was collected for QA/QC from the same location and time as the original sample and using the same sampling procedures. Duplicate samples were submitted as 'blind' samples to provide a QA/QC check on the field sampling and laboratory precision. The relative percent difference (RPD) between the original sample and their respective duplicate sample was calculated using the equation below.

$$RPD = \text{absolute value} \left(\frac{\text{sample 1} - \text{sample 2}}{\frac{\text{sample 1} + \text{sample 2}}{2}} \right) \times 100$$

A duplicate sample with an RPD of less than 20% of the original sample is considered an accepted level of precision, if at least one of the values is greater than five times the detection limit (BC Ministry of Water, Land and Air Protection 2013). A travel blank and a field blank were also taken during each sampling event.

Ionic charge balance was calculated for each of the 2017 to 2019 baseline groundwater samples. Ion charge balance is expressed in percent as the difference using the calculation below. Ion balance percent difference is a relative error (rather than an absolute one), as low-concentrated waters are especially sensitive to small deviations between total cations and anions.

$$\text{percent difference} = 100 \times \left(\frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \right)$$

6.5 DATA SUMMARY

The following section summarizes the groundwater quality results for the monitoring wells in the LSA that were sampled during 2017 to 2019 sampling events and includes historical data. Results for 18-01D (ARD2; pump test well) and the PAG cell wells are provided in Section 6.5.2 and 6.5.3 respectively. A data summary for the residential wells sampled in 2018 to 2019 are also included (Section 6.5.4).

6.5.1 Baseline Monitoring Wells

The monitoring wells in the LSA have been subdivided into two groups based on the geologic unit within which the monitoring well is screened: bedrock and overburden.

A total of nine existing monitoring wells (four bedrock wells and five overburden wells) have been included as part of the baseline groundwater quality program. Samples could not be collected from all the wells during each sampling event, as some of the wells were dry or frozen (Table 6.5-1). Of the nine existing monitoring wells, one overburden well has been consistently dry (TOB96-11-19), and another overburden well (TOB96-02-20) was dry during every sampling event except June 2018 (Table 6.5-1).

Five new monitoring wells were added to the baseline program in the spring of 2018 – one along the bedrock/overburden interface (W1 Shallow³), two in the bedrock (W1 Deep and W3 Deep) and two in the overburden (W2 and W3 Shallow). Samples were collected from these new wells during eight sampling events (Table 6.5-1).

³ Based on the water chemistry and artesian conditions at W1 Shallow, the groundwater within this well is considered to be predominantly coming from the bedrock (Hazelton Group volcanics) even though the well is screened along the bedrock/overburden interface.

Table 6.5-1. Groundwater Quality Sampling Schedule (2017 to 2019)

Well ID	August 2017	September 2017	January 2018	March/ April 2018	June 2018	September 2018	January 2019	March/ April 2019	May/ June 2019	August 2019	November 2019
Bedrock											
T95R-15C	Ns	x	frozen	x	x	x	x	x	x	ns	ns
T95R-40	X	x	x	x	x	x	x	x	x	ns	ns
T95R-64	X	x	x	x	x	x	x	x	x	ns	ns
T96R-34-87	X	x	frozen	x	x	x	x	x	x	ns	ns
W1 Shallow	-	-	-	x	x	x	x	x	x	x	x
W1 Deep	-	-	-	x	x	x	x	x	x	x	x
W3 Deep	-	-	-	x	x	x	x	x	x	x	x
Overburden											
TOB96-01-05	Ns	dry	x	x	x	*	*	x	*	ns	ns
TOB96-02-06	Ns	x	x	x	x	x	x	x	x	ns	ns
TOB96-02-20	Ns	dry	dry	dry	x	dry	dry	dry	dry	ns	ns
TOB96-11-04	Ns	x	x	x	x	x	x	x	x	ns	ns
TOB96-11-19	Ns	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
W2	-	-	-	x	x	x	x	x	x	x	x
W3 Shallow	-	-	-	x	x	x	x	x	x	x	x

Notes:

*x = sampled; ns = not sampled*** not enough water to sample*

The laboratory results for each of the wells sampled from 2017 to 2019 have been tabulated and compared to the BC Ministry of Environment Water Quality Guidelines (WQG) for Freshwater Aquatic Life (FAL), and are presented in Appendix 6-A. Historical data are also included in Appendix 6-A.

The results of the duplicate sample analyses as well as the RPD for each laboratory parameter are provided in Appendix 6-B.

Appendix 6-C presents the field measurements that were collected at the end of the purging process at each monitoring well for the events in 2017 to 2019. This table also includes the other parameters that were recorded during the purging process, such as oxidation-reduction potential (ORP), dissolved oxygen, specific conductivity, and temperature.

Laboratory certificate of analysis for the 11 monitoring events is provided in Appendix 6-D. Copies of field notes and field data sheets are also provided in Appendix 6-E.

6.5.1.1 *Physical Parameters*

Turbidity and pH are the only two physical parameters that have guidelines under the BC WQG – FAL and are discussed below. Other parameters such as conductivity and hardness are briefly discussed in this section, as well.

pH

With the exception of W1 Deep, W1 Shallow, and W3 Shallow, the field pH value for the wells sampled during each sampling event was within the range of the BC WQG – FAL for pH of 6.5 to 9.0 (Appendix 6-A).

The measured field pH of W1 Deep was greater than 9.0 during six of the eight sampling events and ranged from 9.10 (April 2018) to 9.64 (January 2019), with an average pH of 8.30 (SD = 0.56). W1 Shallow field pH exceeded 9.0 during three of the eight sampling events and ranged from 9.08 (June 2019) to 9.60 (January 2019), with an average pH of 8.73 (SD = 0.35). The measured field pH of W3 Shallow was greater than 9.0 during one sampling event (March 2019 – 9.15). High turbidity values were also measured at W1 Shallow and W1 Deep (see below), which suggests that the groundwater may require a longer period to be developed, and/or could be a product of the natural lithology in which the wells are screened.

Excluding the exceedances at W1 Deep, W1 Shallow and W3 Shallow, the pH value for the bedrock wells ranged from 6.99 to 8.99; in the overburden wells pH ranged from 7.20 to 8.99. The field pH measurements for the current baseline program were similar to the field pH measurements for the historical baseline program (Appendix 6-A).

Turbidity

Turbidity value for the wells sampled during the 2017 to 2019 sampling events did not exceed the BC WQG – FAL value of 50 NTU (Nephelometric Turbidity Unit), with the exception of 19 samples from eight monitoring wells (Table 6.5-2; Appendix 6-A).

Table 6.5-2. Summary of Turbidity Exceedances of BC Water Quality Guidelines for Freshwater Aquatic Life, August 2017 to November 2019

Well ID	Sample Date	Field Turbidity (Qualitative)	Field Turbidity (NTU) ¹	Lab Turbidity (NTU) ¹	Comment
Bedrock					
T95R-40	January 2018	Turbid	1718	489	Purged and sampled using the inertial lift pump instead of the submersible pump.
T95R-15C	January 2019	Clear	39	53.5	Minor exceedance. Field measurement did not exceed 50 NTU.
T96R-34-87	April 2019	Clear	42	75.1	Minor exceedance. Field measurement did not exceed 50 NTU.
W1 Shallow	April 2018	Semi-turbid	nm	173	Sampled after well development.
W1 Shallow	January 2019	Semi-turbid	138	164	Well is screened across the interface between the fine-grained overburden unit and the underlying volcanic rock (see Chapter 5), and turbidity may occur as a result of the natural lithology.
W1 Shallow	April 2019	Clear	nm	62.5	"
W1 Shallow	June 2019	Semi-turbid	108	160	"
W1 Shallow	August 2019	Turbid	nm	166	"
W1 Shallow	November 2019	Turbid	79.0	89.7	"
W1 Deep	April 2018	Semi-turbid	nm	730	Sampled after well development.
W1 Deep	January 2019	Clear to semi-turbid	17	56.2	Minor exceedance. Field measurement did not exceed 50 NTU.
W1 Deep	April 2019	Clear	78	106	Turbidity may occur as a result of the natural lithology (fractured volcanic bedrock) as the well was sufficiently developed and is artesian.
W1 Deep	June 2019	Semi-turbid	67	77.3	"
W1 Deep	August 2019	Turbid	nm	858	"
W1 Deep	November 2019	Turbid	nm	254	"
Overburden					
TOB96-02-20	June 2018	Turbid	nm	229	Historically dry. Very little water in well. Bailer used to collect sample.
TOB96-01-05	April 2019	Clear	nm	76.3	Very little water in the well for sampling and well is screened in a finer-grained lithological unit. Water was qualitatively non-turbid before collecting the sample.
W2	April 2018	Semi-turbid	nm	76.3	Sampled after well development.
W2	June 2019	Clear	28	415	Field measurement did not exceed 50 NTU.

¹ BCWQG - FWAL approved guideline for turbidity is 50 NTU.

Excluding exceedances noted above, the average turbidity value was 10.2 NTU (SD = 11.6 NTU) for bedrock wells, and 10.3 NTU (SD = 12.3 NTU) for overburden wells. Turbidity values are generally expected to be slightly higher in the overburden wells in comparison to the bedrock wells due to the fine-grained nature of the glacially deposited material.

The turbidity values from the baseline sampling events (2017 to 2019) were considerably lower in comparison to the turbidity values from the 2016 sampling event; turbidity was not measured during any of the sampling events from 1995 to 1997 (Appendix 6-A).

Conductivity

The average conductivity value in the bedrock wells was 1329 $\mu\text{S}/\text{cm}$ (SD = 650 $\mu\text{S}/\text{cm}$) and ranged from 567 $\mu\text{S}/\text{cm}$ (W3 Deep) to 2,790 $\mu\text{S}/\text{cm}$ (T95R-40). The conductivity range of the existing wells (1,200 $\mu\text{S}/\text{cm}$ to 2,790 $\mu\text{S}/\text{cm}$) was similar to the range recorded in the historical data (1,305 to 2,883 $\mu\text{S}/\text{cm}$).

The average conductivity of the overburden wells was 530 $\mu\text{S}/\text{cm}$ (SD = 102 $\mu\text{S}/\text{cm}$). Conductivity values ranged from 225 $\mu\text{S}/\text{cm}$ (TOB96-01-05) to 697 $\mu\text{S}/\text{cm}$ (TOB96-11-04) and were similar to historical measurements from the existing overburden wells (range of 373 to 760 $\mu\text{S}/\text{cm}$; average of 567 $\mu\text{S}/\text{cm}$) (Appendix 6-A).

Hardness

Hardness (CaCO_3) in the bedrock wells ranged from 3.9 mg/L (W1 Deep) to 138.0 mg/L (W3 Deep), with an average concentration of 49.0 mg/L (SD = 40.1 mg/L) (considered soft water⁴). Hardness in the overburden wells ranged from 57.9 mg/L (W2) to 405.0 mg/L (TOB96-11-04), with an average concentration of 204.3 mg/L (SD = 123.2 mg/L) (very hard water²). The current (2017 to 2019) hardness values for the existing bedrock and overburden wells are slightly lower than the values from the historical sampling events (Figure 6.5-1, Figure 6.5-2, Appendix 6-A).

6.5.1.2 *Alkalinity*

Alkalinity (bicarbonate) in the bedrock wells ranged from 238 mg/L (W3 Deep) to 1690 mg/L (T95R-40), with an average concentration of 715.9 mg/L (SD = 442.3 mg/L). Alkalinity in the overburden wells ranged from 127 mg/L (TOB96-01-05) to 407.0 mg/L (TOB96-11-04), with an average concentration of 280.2 mg/L (SD = 62.6 mg/L). The current (2017 to 2019) alkalinity values for the existing bedrock and overburden wells are slightly lower than the values from the historical sampling events (Figure 6.5-3, Figure 6.5-4, Appendix 6-A).

⁴ Hardness categories in equivalent concentration of CaCO_3 – Soft: <60mg/L; Medium hard: 60 to <120 mg/L; Hard: 120 to <180 mg/L; Very hard: >180gm/L (Government of BC 2007).

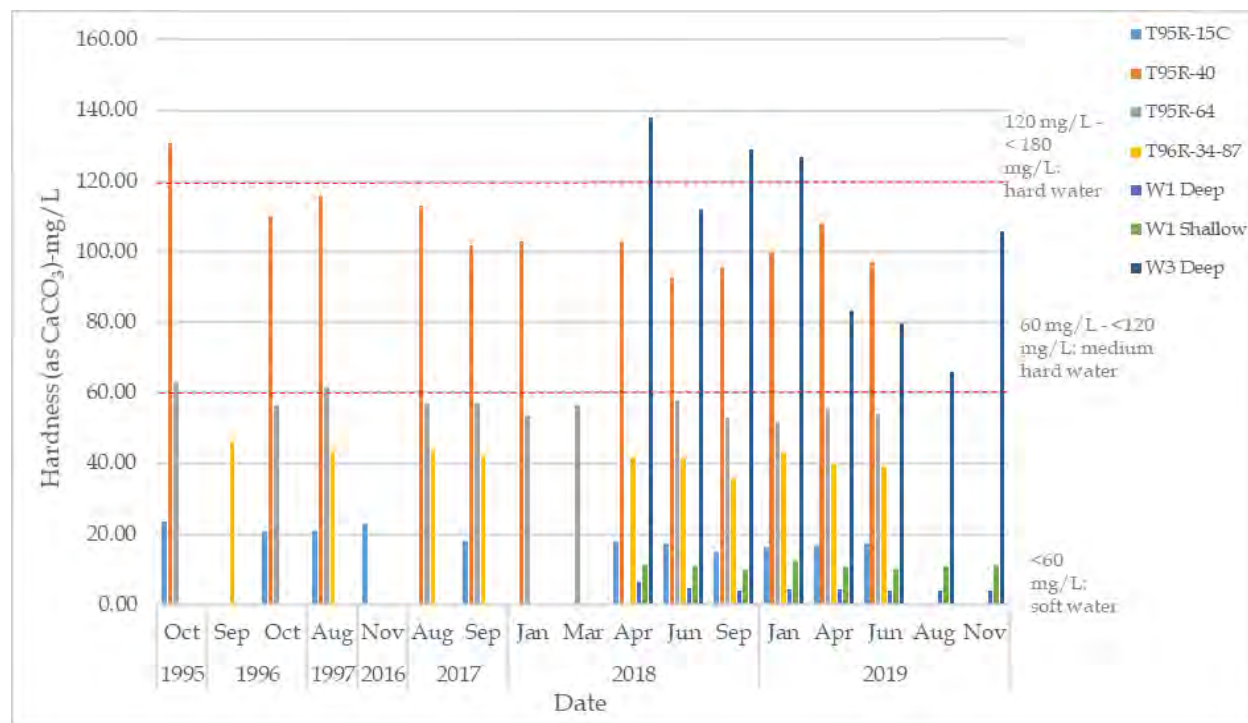
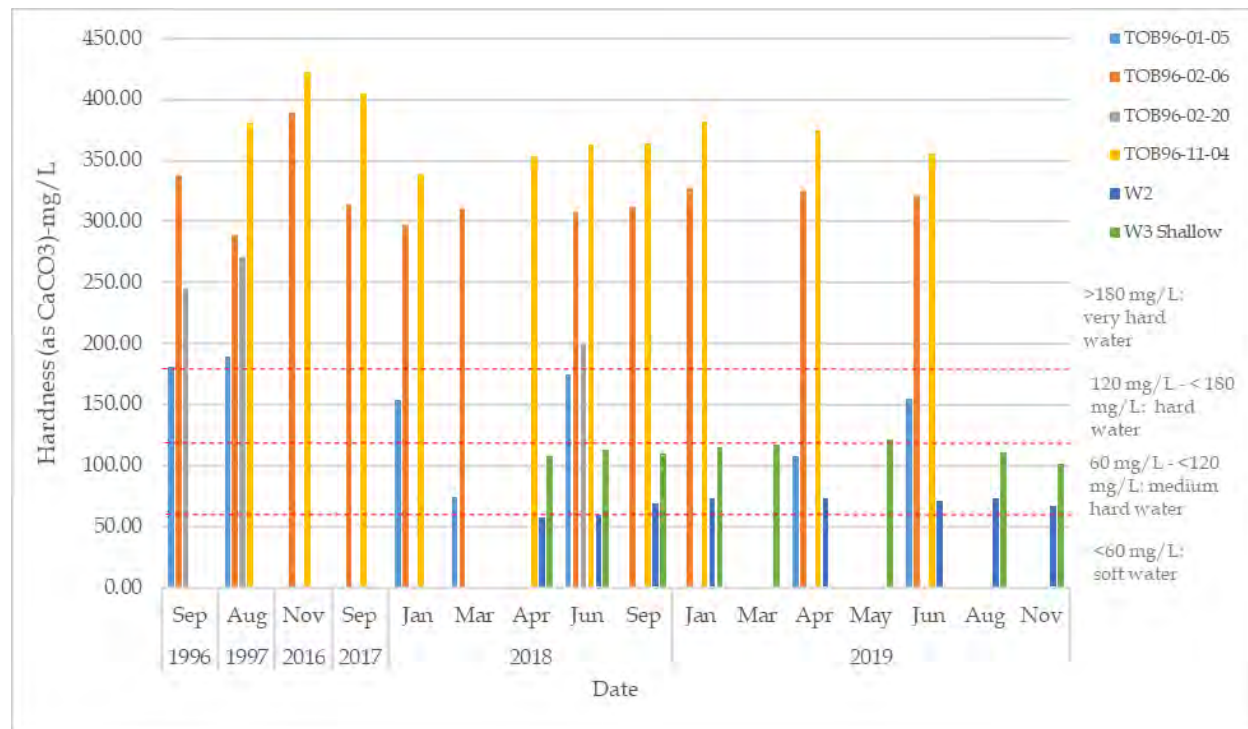
Figure 6.5-1. Hardness (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data**Figure 6.5-2. Hardness (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data**

Figure 6.5-3. Alkalinity (bicarbonate) Concentration (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data

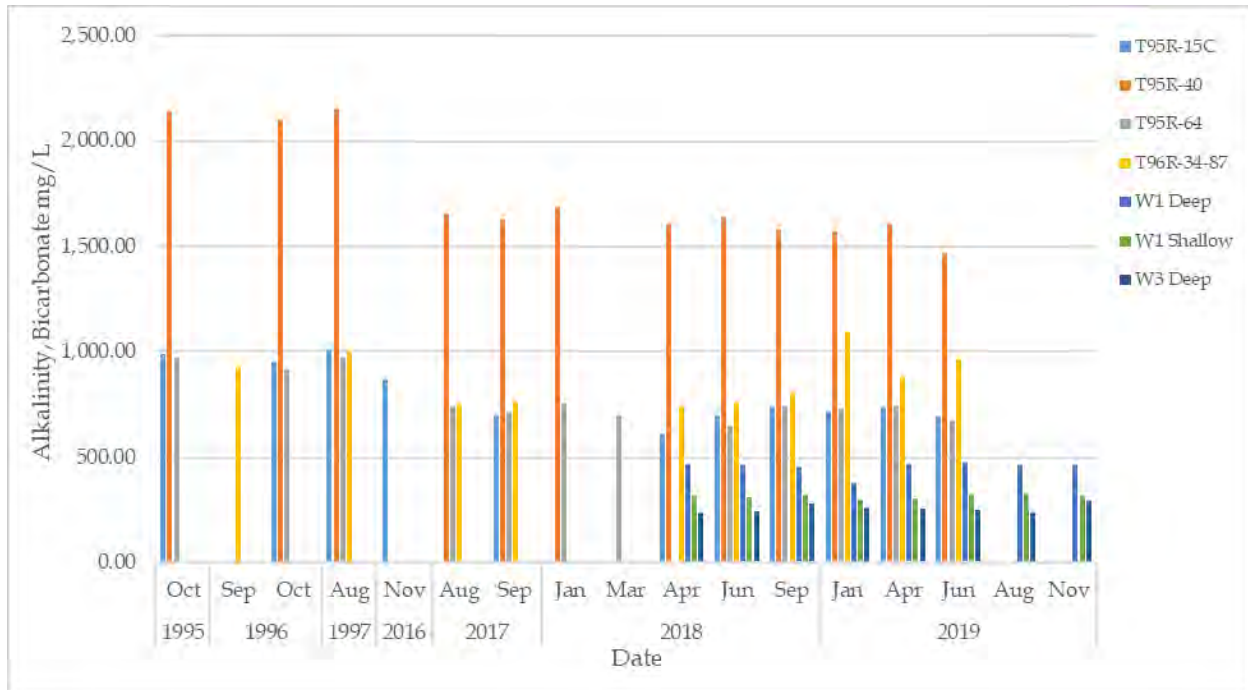
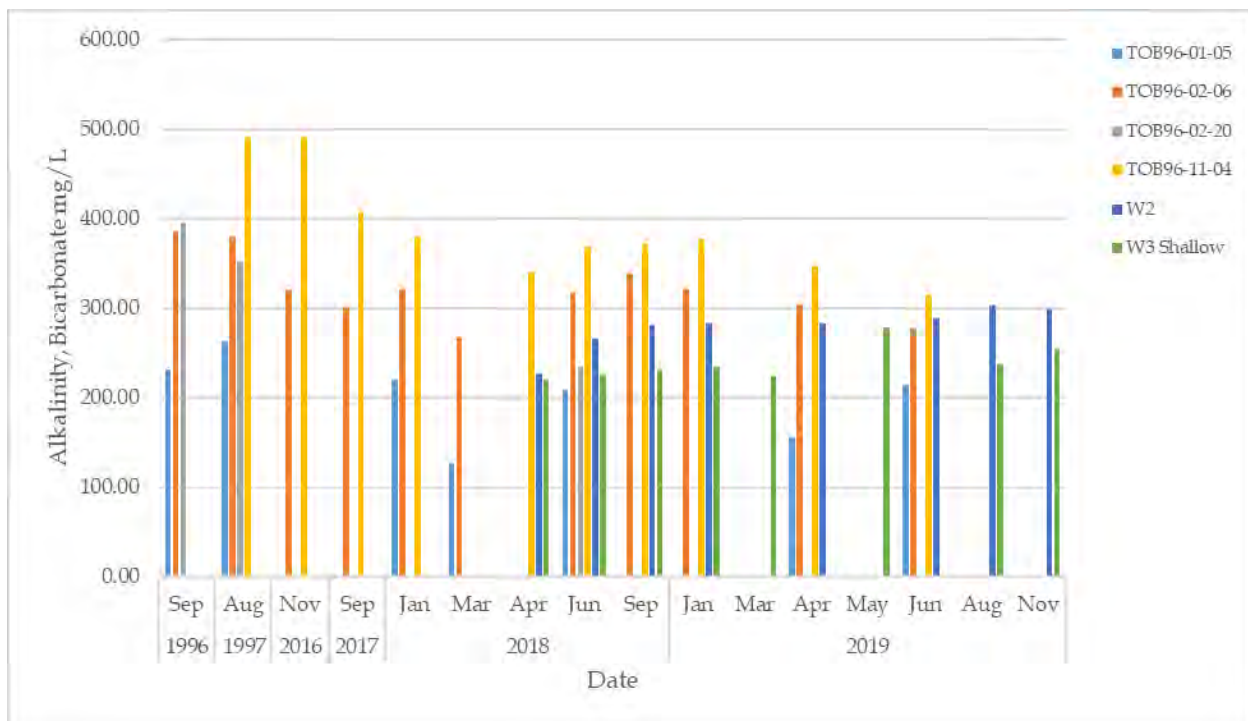


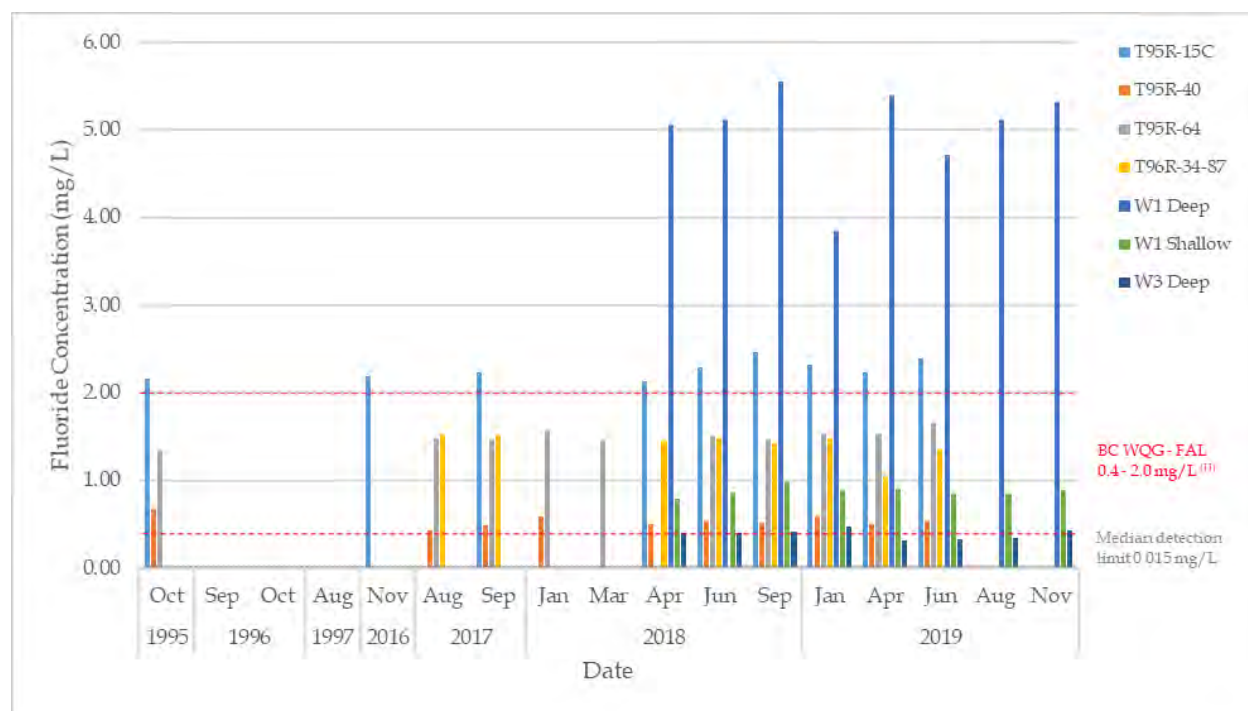
Figure 6.5-4. Alkalinity (bicarbonate) Concentration (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data



6.5.1.3 Anions and Nutrients

Fluoride was the only anion which exceeded the BC WQG - FAL guideline of 0.4 to 2.0 mg/L (hardness dependent) during the 2017 to 2019 sampling events (Figure 6.5-5; Appendix 6-A). In bedrock wells, fluoride ranged from 0.32 mg/L (W3 Deep) to 5.55 mg/L (W1 Deep), with an average concentration of 1.68 mg/L (SD = 1.45 mg/L). In the overburden wells, fluoride concentrations ranged from 0.086 mg/L (TOB96-01-05) to 0.383 mg/L (W2), with an average concentration of 0.18 mg/L (SD = 0.09 mg/L; Appendix 6-A).

Figure 6.5-5. Fluoride Concentrations (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



There is limited historical data for fluoride in the existing wells (Appendix 6-A). T95R-15C is the only existing well to have fluoride analyzed twice in the historical data (1995 and 2016), and the historical concentrations are consistent with the concentrations from the current baseline program (Figure 6.5-5; Appendix 6-A).

Nitrate concentrations were below detection limits, except for two bedrock wells (W1 Deep and W3 Deep) and three overburden wells (TOB96-01-05, TOB96-02-06 and TOB-11-04). Low concentrations of nitrite were detected in one bedrock well (W3 Deep) and four overburden wells (TOB96-02-06, TOB96-11-04, TOB96-02-20, and W3 Shallow; Appendix 6-A). Nitrate and nitrite were not analyzed in 1995, 1996 or 1997. In 2016, the three samples analyzed (TOB96-02-20, TOB96-01-05, and T95R-15C) were below detection limits for both nitrate and nitrite. Ammonia concentrations exceeded the BC FWQ-FAL guidelines in two overburden wells: W3 Shallow (March 2019) and W2 (September 2018, and April, June, August and November 2019; Appendix 6-A).

6.5.1.4 *Total and Dissolved Organic Carbon*

In the bedrock wells, total organic carbon (TOC) concentrations ranged from 0.54 mg/L (T95R-64) to 64.80 mg/L (T95R-40). Comparisons to historical data could not be made as T95R-15 is the only well with any historical data and it was only sampled once for TOC (November 2016); the concentration was less than the detection limit of 0.5 mg/L (Appendix 6-A).

Dissolved organic carbon (DOC) concentrations ranged from 0.50 mg/L to 38.7 mg/L (Appendix 6-A). TOC concentrations in the overburden wells ranged from 1.05 mg/L (TOB96-02-06) to 26.7 mg/L (W3 Shallow), and the concentrations in the existing wells are similar to the limited historical data. DOC ranged from 1.30 mg/L (TOB96-02-06) to 22.80 mg/L (W3 Shallow; Appendix 6-A).

6.5.1.5 *Polycyclic Aromatic Hydrocarbons (PAH)*

PAH values were less than the laboratory detection limits in all samples, except for T95R-15C and W2 (Appendix 6-A). T95R-15C had measurable concentrations of 10 PAH and one exceedance of benzo(a)pyrene (0.0000596 mg/L) in the September 2018 sample. During the next sampling event, only one PAH (phenanthrene; 0.000022 mg/L) was detected in T95R-15C, which was just above the detection limit. W2 had a hit of naphthalene (0.000053 mg/L), just above the detection limit in the April 2018 sample. All subsequent samples at W2 did not have detectable concentrations of any PAH.

PAH were not analyzed during the historical sampling programs (1995, 1996, 1997, and 2016).

6.5.1.6 *Total and Dissolved Metals*

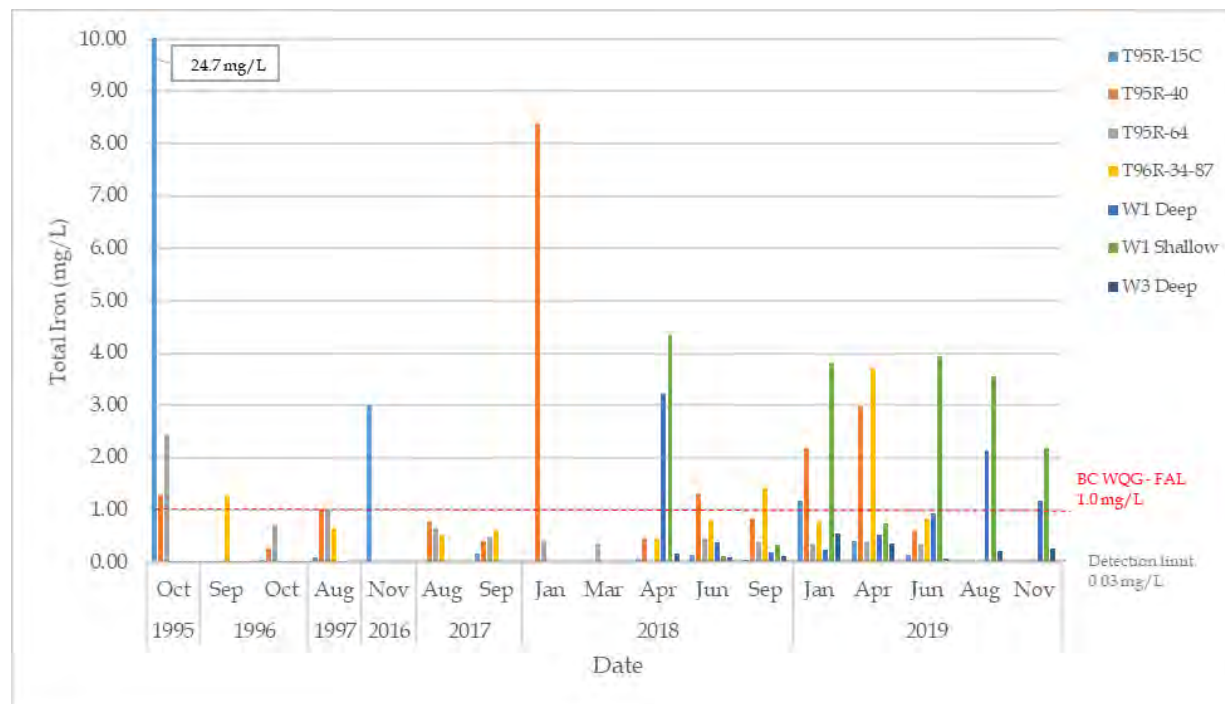
Groundwater concentrations in the bedrock wells exceeded the BC WQG – FAL approved guidelines for the following metals during the 2017 to 2019 baseline program: total and dissolved iron, total copper, total arsenic, total zinc, and dissolved aluminum. BC WQG – FAL working guidelines were also exceeded for total barium and total chromium (Appendix 6-A).

Groundwater concentrations in the overburden wells exceeded the BC WQG – FAL approved guidelines for the following metals: total iron, total arsenic, total copper, total manganese and total zinc. Total chromium exceeded the BC WQG – FAL working guideline. No dissolved metals concentrations exceeded approved or working guidelines (Appendix 6-A). In general, the historical data for the existing wells measured more exceedances for total and dissolved metals than the current 2017 to 2019 baseline data (Appendix 6-A, trend graphs below).

Iron

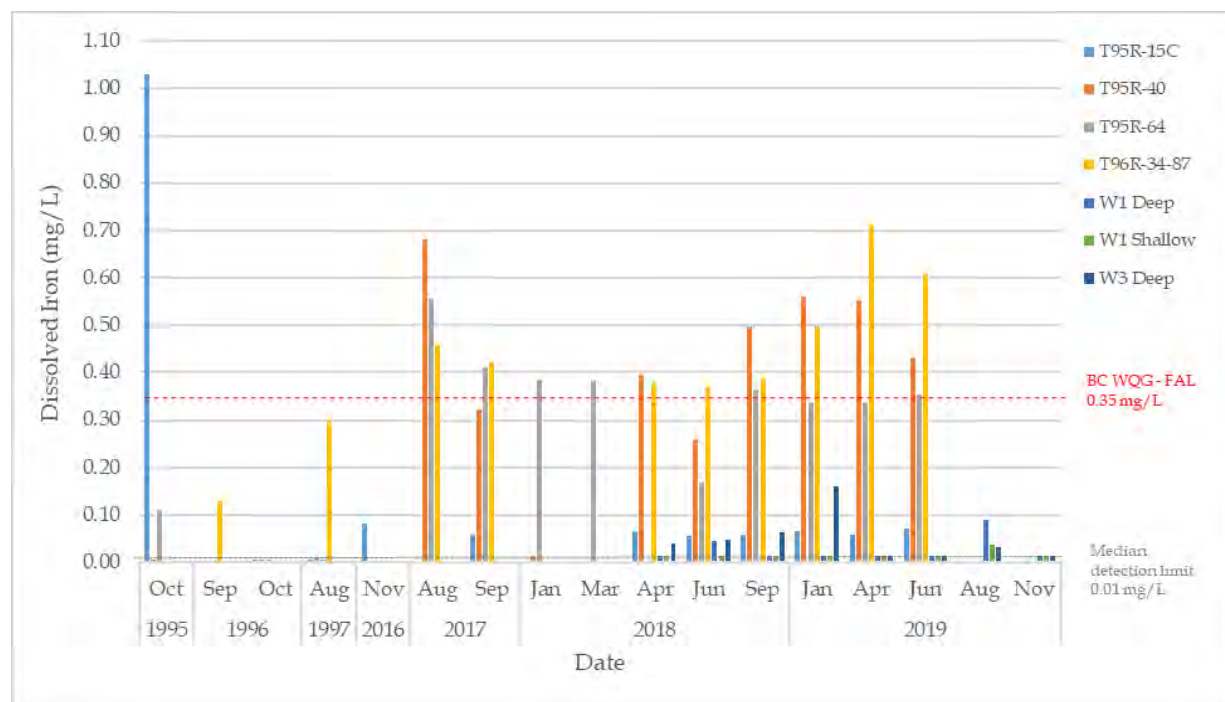
Total iron concentrations exceeded the BC WQG – FAL approved guideline of 1.0 mg/L in three existing and two new bedrock wells (T95R-40, T96R-34-87, T95R-15C, W1 Shallow, and W1 Deep; Figure 6.5-6). Total iron concentrations ranged from 0.061 mg/L (T95R-15C) to 8.39 mg/L (T95R-40), with an average concentration of 1.10 mg/L (SD = 1.50 mg/L). The concentration of dissolved iron exceeded the BC WQG – FAL approved guideline of 0.35 mg/L in three existing bedrock wells (T95R-64, T95R-40, and T96R-34-87; Appendix 6-A; Figure 6.5-7). With a couple of exceptions related to high turbidity samples, iron concentrations (total and dissolved) were consistent, and were similar to the historical data.

Figure 6.5-6. Total Iron Concentration (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



Note: T95R-15C concentration in October 1995 is greater than graphed extent at 24.7 mg/L.

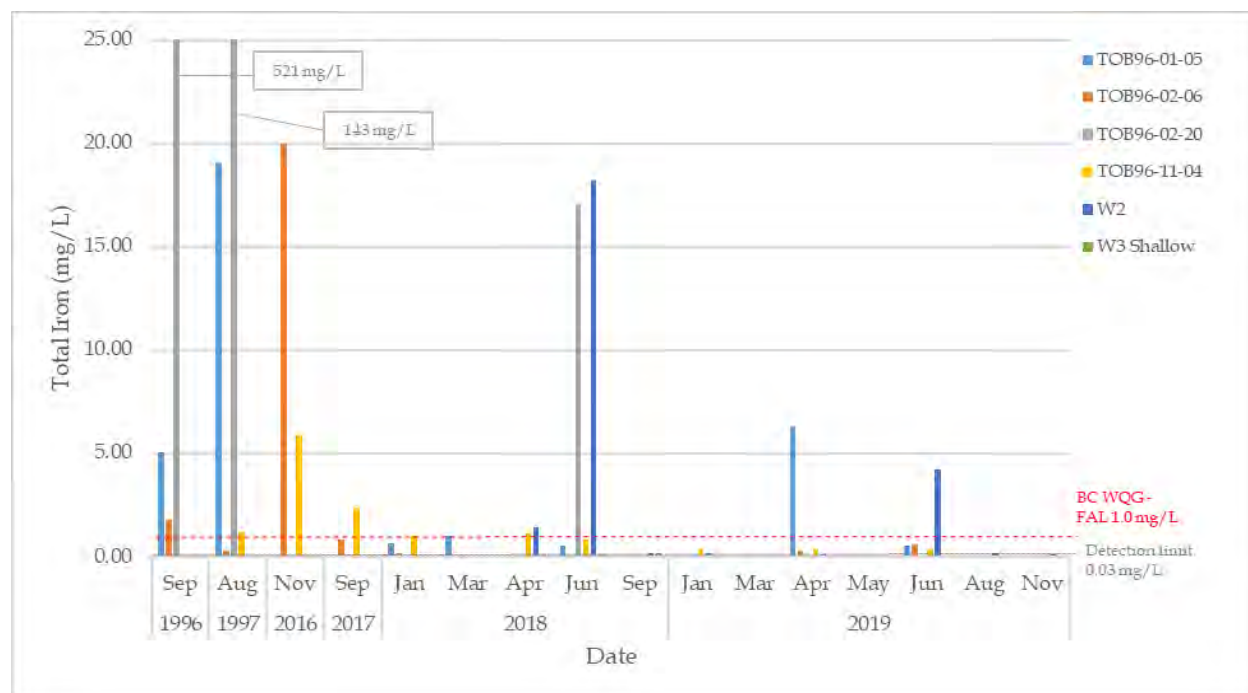
Figure 6.5-7. Dissolved Iron Concentrations (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



Notes: Values below the detection limit were plotted as half the detection limit.

Total iron concentrations in three existing overburden wells (TOB96-02-20, TOB96-11-04, TOB96-01-05) and one new overburden well (W2) exceeded the BC WQG - FAL approved guideline (Figure 6.5-8). Total iron concentrations ranged from 0.052 mg/L (W3 Shallow) to 18.2 mg/L (W2), with an average concentration 1.62 mg/L (SD = 4.07 mg/L). Dissolved iron concentrations ranged from 0.031 mg/L (W2) to 0.23 mg/L (TOB96-01-05), with an average concentration of 0.08 mg/L (SD = 0.06 mg/L) (Appendix 6-A). There is some variability between the historical and current baseline data for the existing overburden wells, but concentrations for samples collected as part of the current baseline (2017 - 2019) are generally consistent (Appendix 6-A).

Figure 6.5-8. Total Iron Concentration (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data

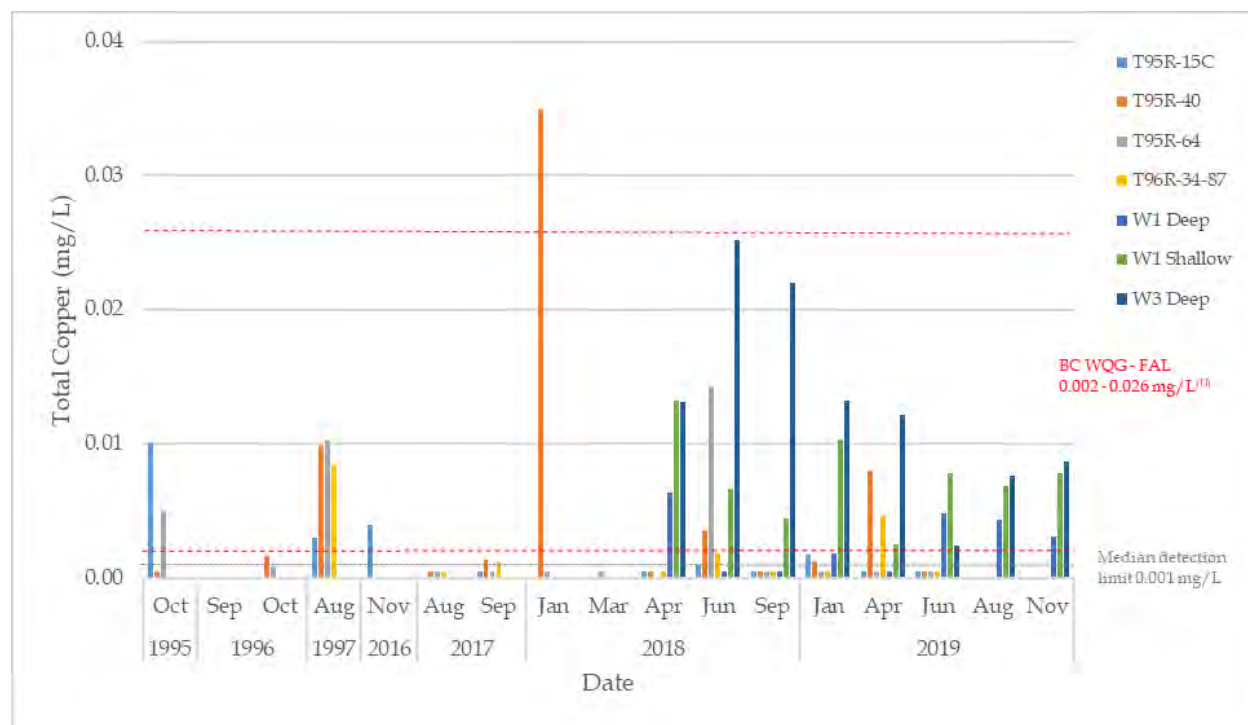


Note: TOB96-02-20 concentrations are greater than graphed extent at 521 mg/L (Sept 1996) and 143 mg/L (Aug 1997).

Copper

Total copper concentrations in bedrock wells ranged from 0.0010 mg/L (T95R-15C) to 0.0349 mg/L (T95R-40). Three new wells (W1 Shallow, W1 Deep and W3 Deep) and two existing wells (T95R-40 and T95R-64) exceeded the BC WQG - FAL approved guideline for total copper (0.002 - 0.026 mg/L [hardness dependent]). T95R-40 exceeded the guideline once in January 2018 and is likely related to a high turbidity sample (489 NTU), whereas T95R-64 did have a previous exceedance in August 1997. T95R-15C had one historical exceedance of copper in 1995 but did not exceed during the 2017 to 2019 baseline sampling (Figure 6.5-9).

Figure 6.5-9. Total Copper Concentrations (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



Notes: Values below the detection limit were plotted as half the detection limit.

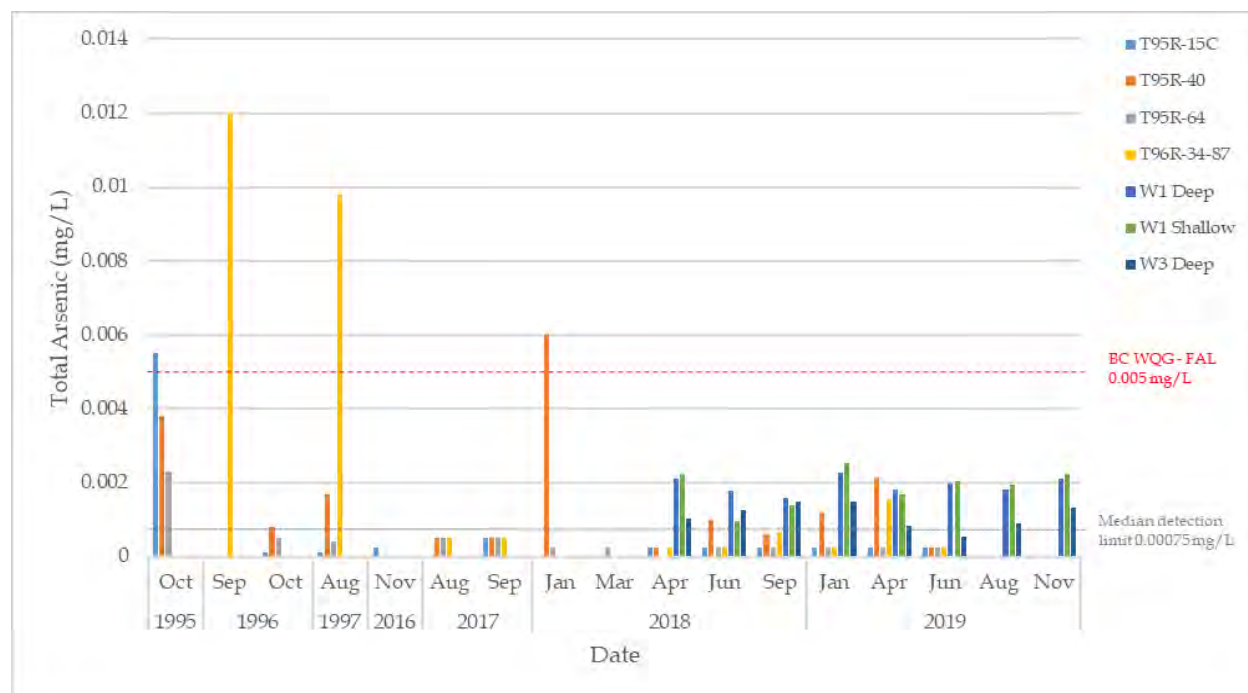
^H Copper guideline is hardness dependant.

Total copper concentrations in overburden wells ranged from 0.0011 mg/L (TOB96-02-06) to 0.0264 mg/L (TOB96-02-20). Two existing overburden wells (TOB96-02-20 and TOB96-01-05) and one new well (W2) had concentrations of total copper greater than the approved BC WQG - FAL guidelines (Figure 6.5-10; Appendix 6-A). TOB96-02-20 has exceeded the guideline each time it has been sampled (September 1996, August 1997, and June 2018; Figure 6.5-10). TOB96-01-05 exceeded the approved guideline once in April 2019 and is likely attributed to turbidity in the sample as none of the other samples (historical and 2017-2019 baseline) had exceedances. W2 exceeded in April and June 2018 and may not have been fully developed as five of the six subsequent samples had concentrations less than laboratory detection (0.001 mg/L).

Arsenic

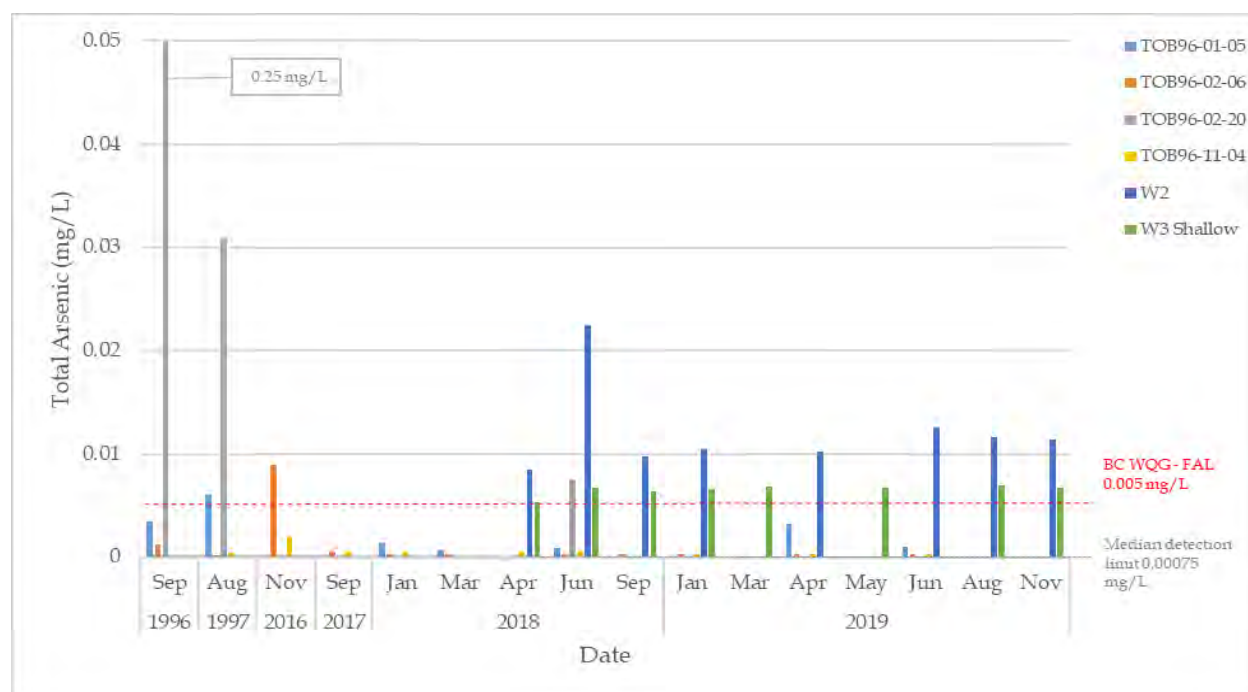
Total arsenic concentrations in the bedrock wells ranged from 0.00054mg/L (W3 Deep) to 0.0060 mg/L (T95R-40), with an average concentration of 0.0017 mg/L (SD = 0.0010 mg/L). T95R-40 had one exceedance of arsenic (0.006 mg/L), which is likely a by-product of the turbidity of the sample which was abnormally high (489 NTU). Two existing bedrock wells (T95R-15C and T95R-34-87) exceeded the guideline for arsenic in 1995, and 1996 and 1997 respectively, but most 2017 to 2019 samples were below the laboratory detection limit of 0.0005 mg/L (Figure 6.5-11, Appendix 6-A).

Figure 6.5-11. Total Arsenic Concentrations (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



Notes: Values below the detection limit were plotted as half the detection limit.

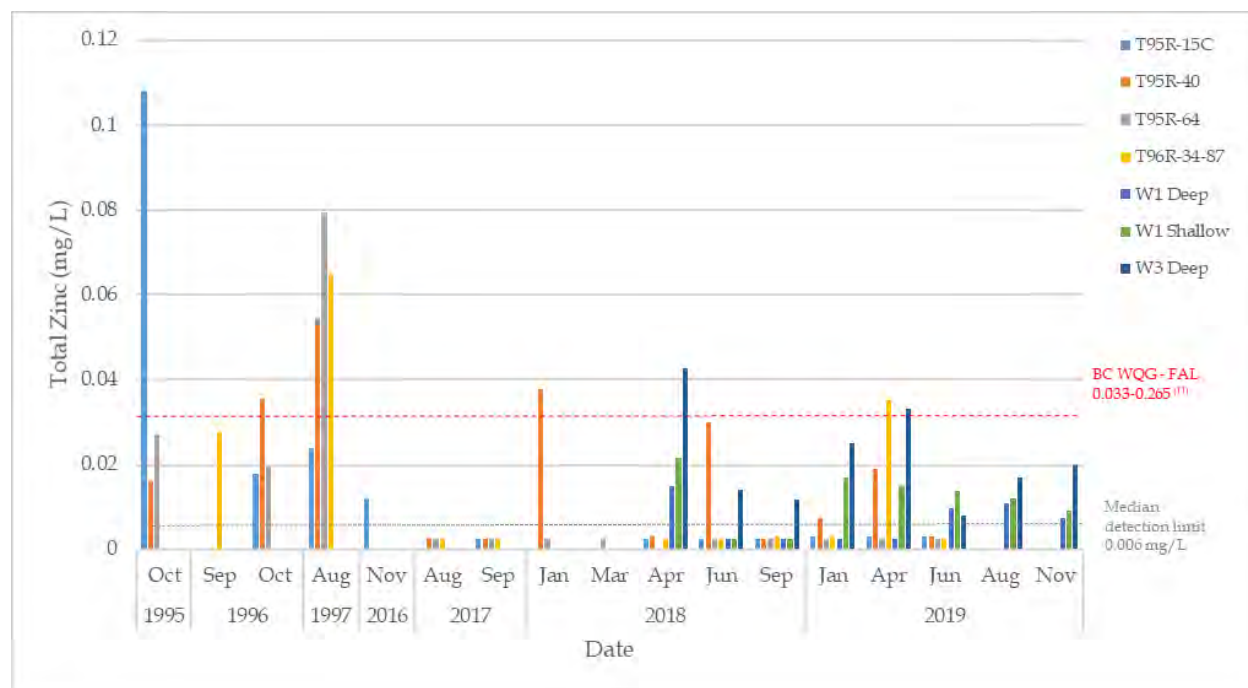
Figure 6.5-12. Total Arsenic Concentrations (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data



Notes: Values below the detection limit were plotted as half the detection limit.

TOB96-02-20 concentration in Sept 1996 is greater than the graphed extent at 0.25mg/L.

Figure 6.5-13. Total Zinc Concentrations (mg/L) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



Notes: Values below the detection limit were plotted as half the detection limit.

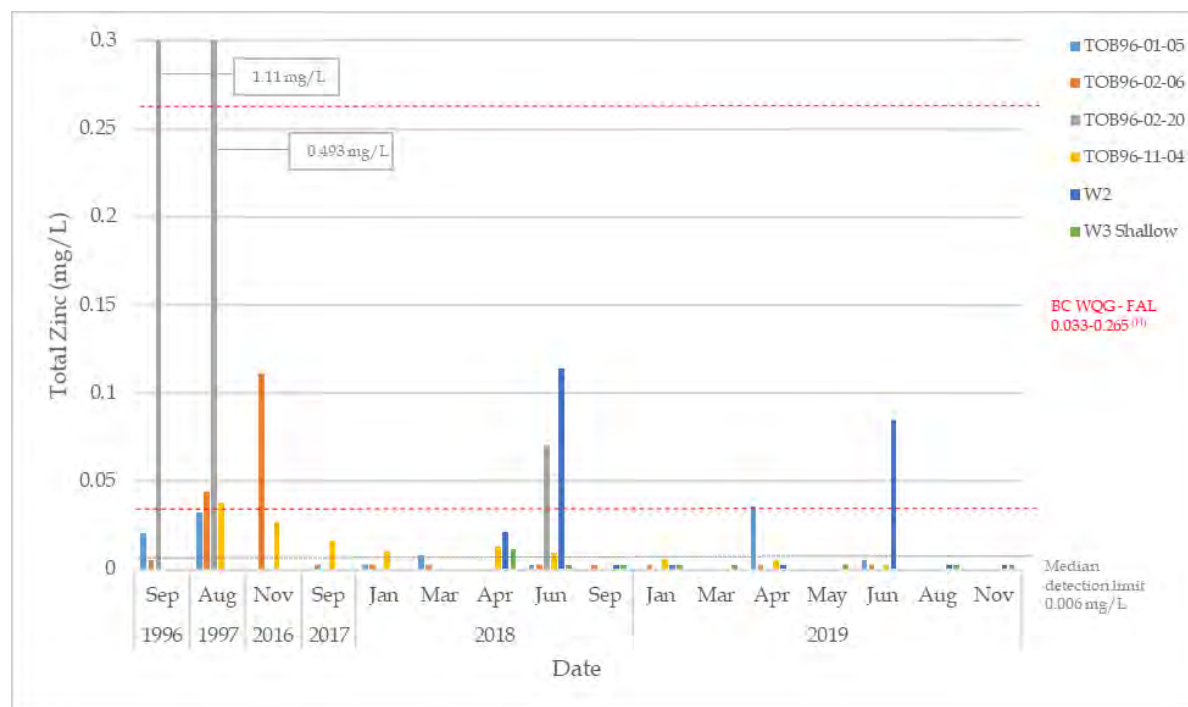
^H Zinc guideline is hardness dependant.

In the overburden wells, total zinc concentrations ranged from 0.0053 mg/L (TOB96-11-04) to 0.1140 mg/L (W2) with an average concentration of 0.0295 mg/L (SD = 0.0348 mg/L). One new well (W2) exceeded the BC WQG - FAL approved guideline for total zinc in June 2018 and 2019. There were no other exceedances of samples from the 2017 - 2019 baseline. In the historical data, TOB96-02-20 exceeded the approved guideline during sampling in 1996 and 1997 (Figure 6.5-14; Appendix 6-A).

Manganese

In the bedrock wells, total manganese concentrations ranged from 0.00245 mg/L (T95R-15C) to 0.275 mg/L (W3 Deep), with an average concentration of 0.063 mg/L (SD = 0.068 mg/L). In the overburden wells, total manganese concentrations ranged from 0.013 mg/L (TOB96-02-06) to 2.7 mg/L (W2), with an average concentration of 0.272 mg/L (SD = 0.514 mg/L). The total manganese concentration at W2 (2.7 mg/L) in June 2018 exceeded the BC WQG - FAL approved guideline; however this exceedance is likely an anomaly as all the other manganese concentrations at W2 were below 0.350 mg/L. There were no other exceedances in the historical or current baseline data (Figure 6.5-15; Appendix 6-A).

Figure 6.5-14. Total Zinc Concentrations (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data

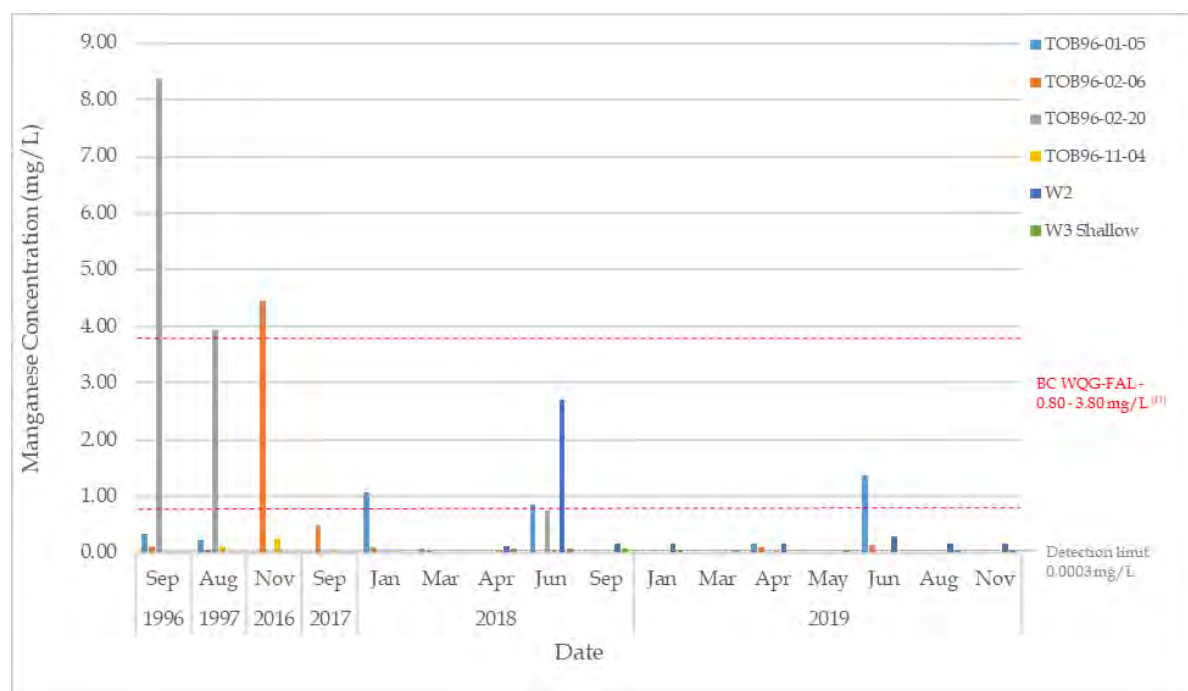


Notes: Values below the detection limit were plotted as half the detection limit.

^H Zinc guideline is hardness dependant.

TOB96-02-20 concentrations are greater than graphed extent at 1.11 mg/L (Sept 1996) and 0.493 mg/L (Aug 1997).

Figure 6.5-15. Total Manganese Concentrations (mg/L) in Overburden Wells, Historical and 2017 to 2019 Baseline Data



Chromium

Total chromium concentrations exceeded the BC WQG – FAL working guideline in two existing bedrock wells (T95R-40 and T95R-34-87) in April 2019. Further analysis was conducted to separate and quantify chromium IV (Cr(IV)) in the samples (chromium speciation), and the concentration of Cr(IV) was less than the laboratory detection limit of 0.0005 mg/L in both samples. T95R-34-87 also exceeded the working guideline in 1996 but chromium speciation was not conducted. Two other existing bedrock wells (T95R-64 and T95R-15C) also exceeded the working guideline in 1995, but again speciation was not conducted, and concentrations in these two wells did not exceed the working guideline during the 2017 to 2019 baseline sampling.

Total chromium concentrations in the overburden wells exceeded the working guideline in one existing well (TOB96-02-20; June 2018) and one new well (W2; June 2018). Chromium speciation analysis was not conducted on these samples; however, speciation was conducted on the next sample collected from W2 that had a detectable concentration of chromium, and the Cr(VI) concentration was less than the laboratory detection limit. TOB96-02-20 also exceeded the working guideline in 1996 and 1997, as did TOB96-02-06, but chromium speciation was not conducted on these samples.

6.5.1.7 Piper Plot and Groundwater Types

Piper plots of the major dissolved cations (calcium, magnesium, and sodium + potassium) and major anions (bicarbonate, sulfate, fluoride, and chloride), using percentages of total milliequivalents per liter (meq/L), were used to classify the groundwater. The piper plots contain all historical and current data from thirteen sample locations (seven bedrock wells and six overburden wells) and are shown below on Figures 6.5-16 to 6.5-18 by season.

In general, there are distinct hydrochemical differences between the deep confined overburden wells (W2 and W3 Shallow), the bedrock wells and the shallow overburden wells (TOB96-11-04, TOB96-02-06, TOB96-02-20, and TOB96-01-05). There are also minor hydrochemical differences between the bedrock wells screened in the Skeena Group sedimentary rocks and the Hazelton Group volcanic rocks. These hydrochemical differences are consistent on a seasonal timeframe.

The groundwater from the shallow overburden wells can be classified as a calcium-magnesium-bicarbonate (Ca-Mg-HCO₃) type. Of the shallow overburden wells, TOB96-02-20 and TOB96-01-05 show minor cation variability between sampling events/seasons, while the two other wells (TOB96-11-04 and TOB96-02-06) have very consistent hydrochemistry between sampling events/seasons.

The groundwater from one of the new deeper overburden wells (W2) and all the bedrock wells can be classified as a sodium-bicarbonate (Na-HCO₃) water type. There are minor ionic differences between the Skeena Group coal seam bedrock wells and the Hazelton Group volcanic bedrock wells with the volcanic rocks having a slightly higher percentage of sulfate than the coal seam bedrock wells. The coal seam bedrock wells have similar chemistry between each other, and the hydrochemistry is consistent between seasons. This is also the case between the nested well pair W1 Shallow and W1 Deep which are screened in the Hazelton Group volcanics.

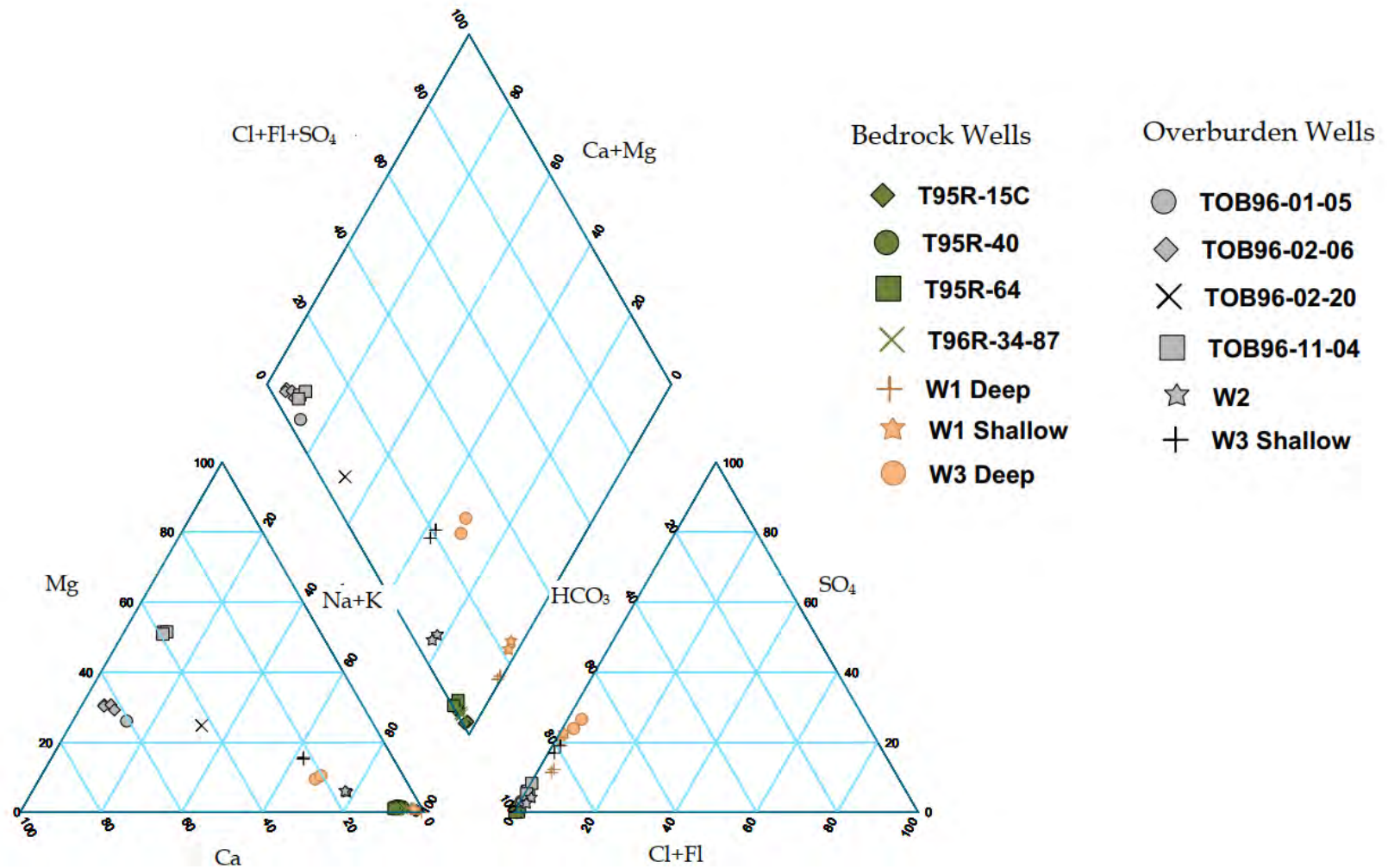
Figure 6.5-16. Piper Plot Diagram – September to November, Historical and 2017 to 2019 Baseline Data ⁵⁵ Data from October 1995, September and October 1996, November 2016, September 2017, September 2018, and November 2019.

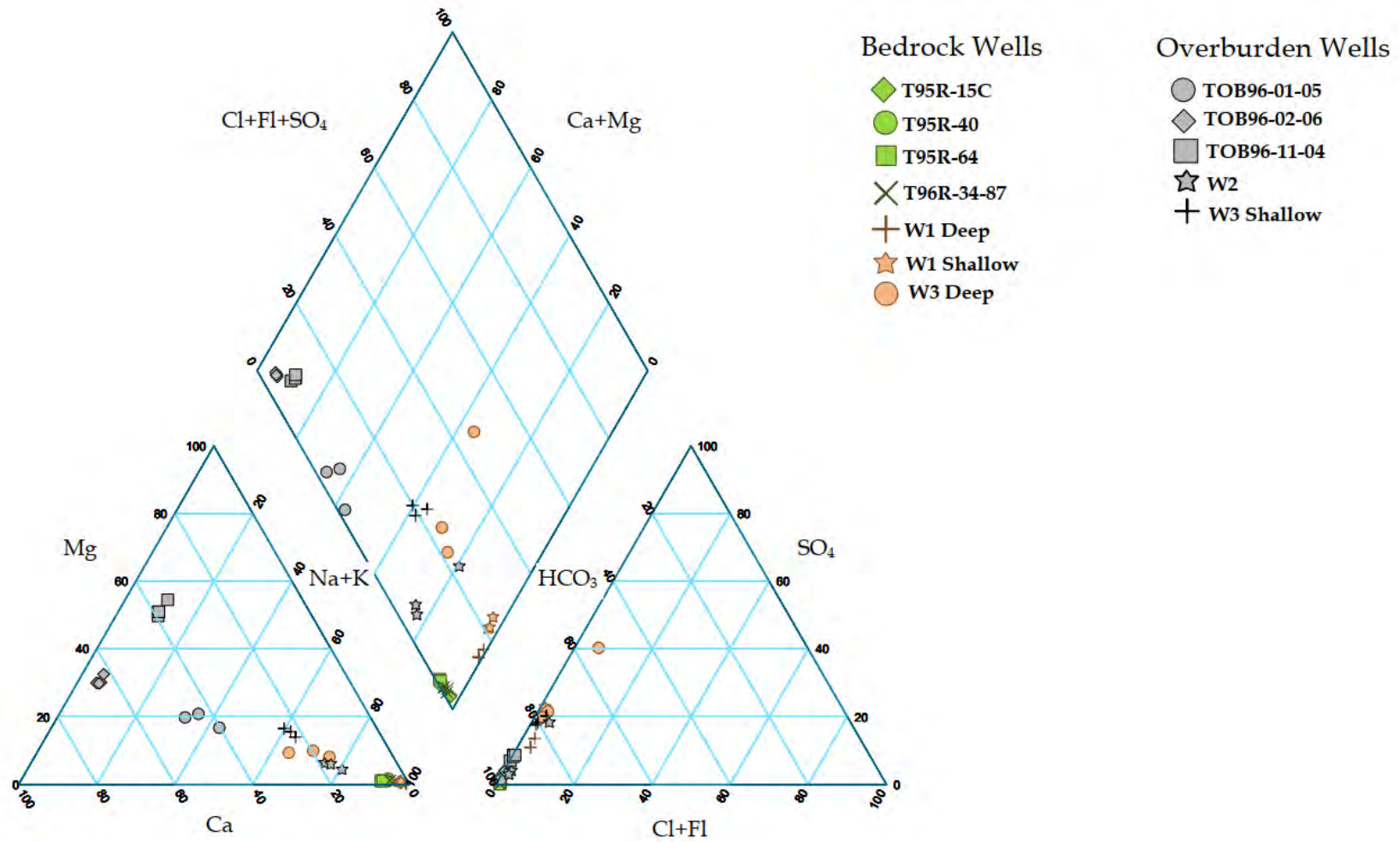
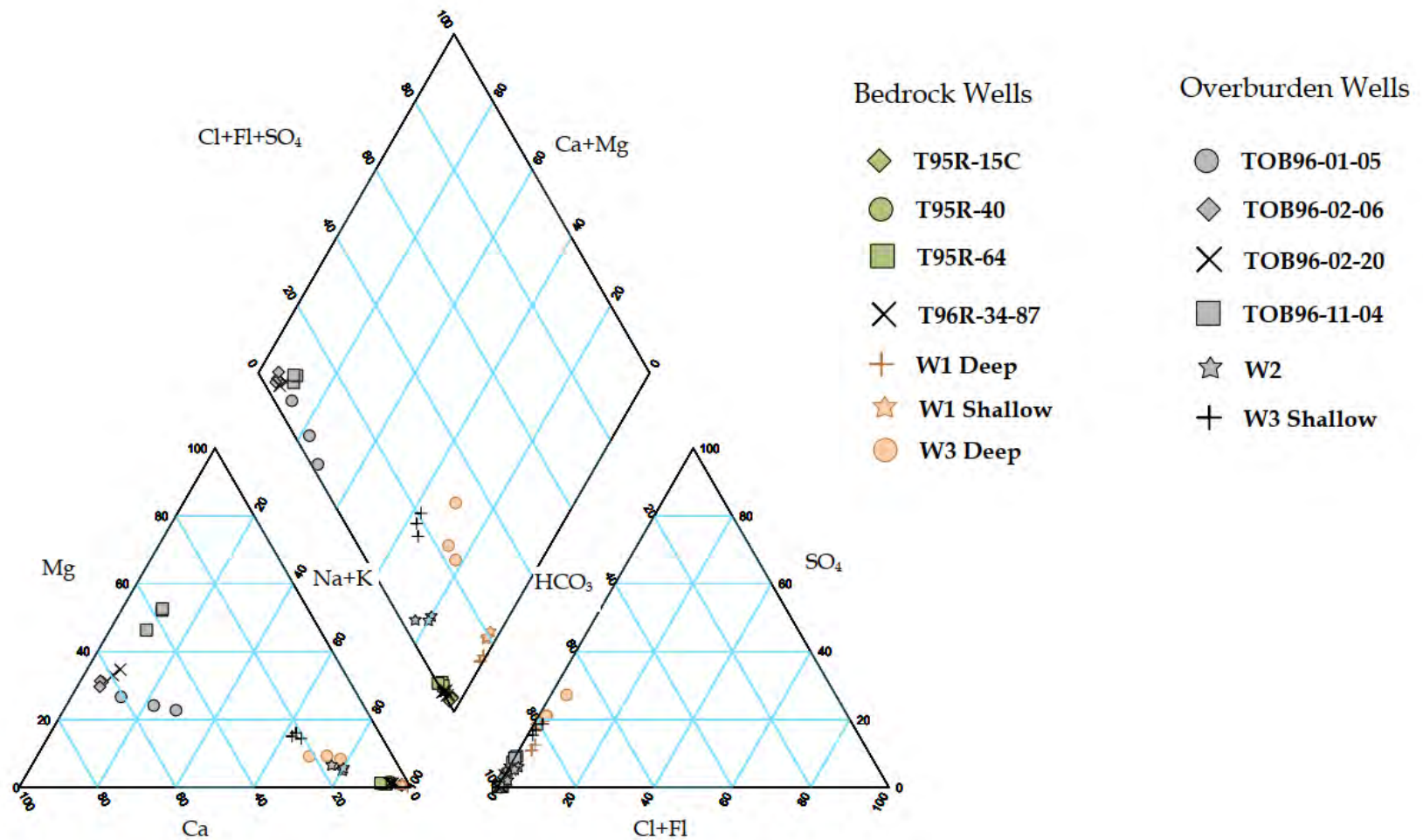
Figure 6.5-17. Piper Plot Diagram – January and March/April 2018 and 2019 Baseline Data⁶⁶ Date from January 2018, March/April 2018, January 2019, and March/April 2019.

Figure 6.5-18. Piper Plot Diagram – June to August, Historical and 2017 to 2019 Baseline Data ⁷⁷ Data from August 1997, August 2017, June 2018, June 2019, and August 2019.

The groundwater within the deep overburden well (W2) likely has some interaction with the underlying volcanic rock unit and shows hydrochemical consistency between sampling events/seasons except for the first sample from April 2018 just after well development.

The newly installed nested well group W3 Shallow/Deep can also be classified as a sodium bicarbonate- (Na-HCO_3) water type, although they differ slightly than the other bedrock wells and W2 as they contain a higher percentage of calcium + magnesium and sulfate. W3 Shallow/Deep are screened in different lithologic units (W3 Shallow is screened in a confined coarse-grained overburden unit just above the contact with the Hazelton Group volcanic rock which W3 Deep is screened), however they have relatively similar chemistry between each other and minor hydrochemical variability between sampling events/seasons. The similar chemistry between W3 Shallow and W3 Deep may imply a hydraulic connection between the two lithologic units which corresponds with the strong downward vertical hydraulic gradient observed between the two wells. The minor outlier in hydrochemistry observed at W3 Deep during the April 2018 sampling event can be attributed to the sample being collected after the well development process and may have had some drilling water residue. More representative groundwater was collected during subsequent sampling events from W3 Deep and W2.

Trend graphs showing the concentrations of the major cations over time are provided below in Figure 6.5-19 and Figure 6.5-20, and trend graphs showing the concentration of bicarbonate over time are provided in Section 6.5.1.2 above.

The distinct water types found during the current sampling program between the existing bedrock and existing shallow overburden wells is consistent with the historical hydrochemical analysis conducted by Piteau for the same wells (Piteau Engineering Ltd. 1998).

6.5.1.8 *Quality Assurance / Quality Control*

During the 2017- 2019 baseline, one duplicate sample was collected during each of the sampling events for a total of 11 duplicates.

For parameters where both samples had detectable concentrations, the RPD was calculated when the results for a given parameter were greater than five times the detection limit. Ten of the duplicate sample sets had an average RPD value less than 10%, indicating satisfactory laboratory analytical methods and reproducibility. The groundwater duplicate sample set collected from T95R-40 on April 3, 2018 had an average RPD of 26.7% (Appendix 6-B).

The average ion charge balance for the 2017 to 2019 samples was calculated to be 6.7%. Charge balance percentages are shown in Appendix 6-A.

Eleven trip blanks and 10 field blanks were analyzed during each of the sampling events. One trip blank (September 2017) contained measurable total ammonia (as N) at 0.0136 mg/L, and another trip blank (June 2018) contained measurable total cadmium that was just slightly above the detection limit (i.e., 0.0000050 mg/L). One field blank contained measurable total cadmium that was just slightly above the detection limit in November 2019. The trip and field blank results are presented in Appendix 6-F.

Figure 6.5-19. Major Cations Concentrations (Dissolved Calcium and Magnesium [mg/L]) in Overburden Wells, Historical and 2017 to 2019 Baseline Data

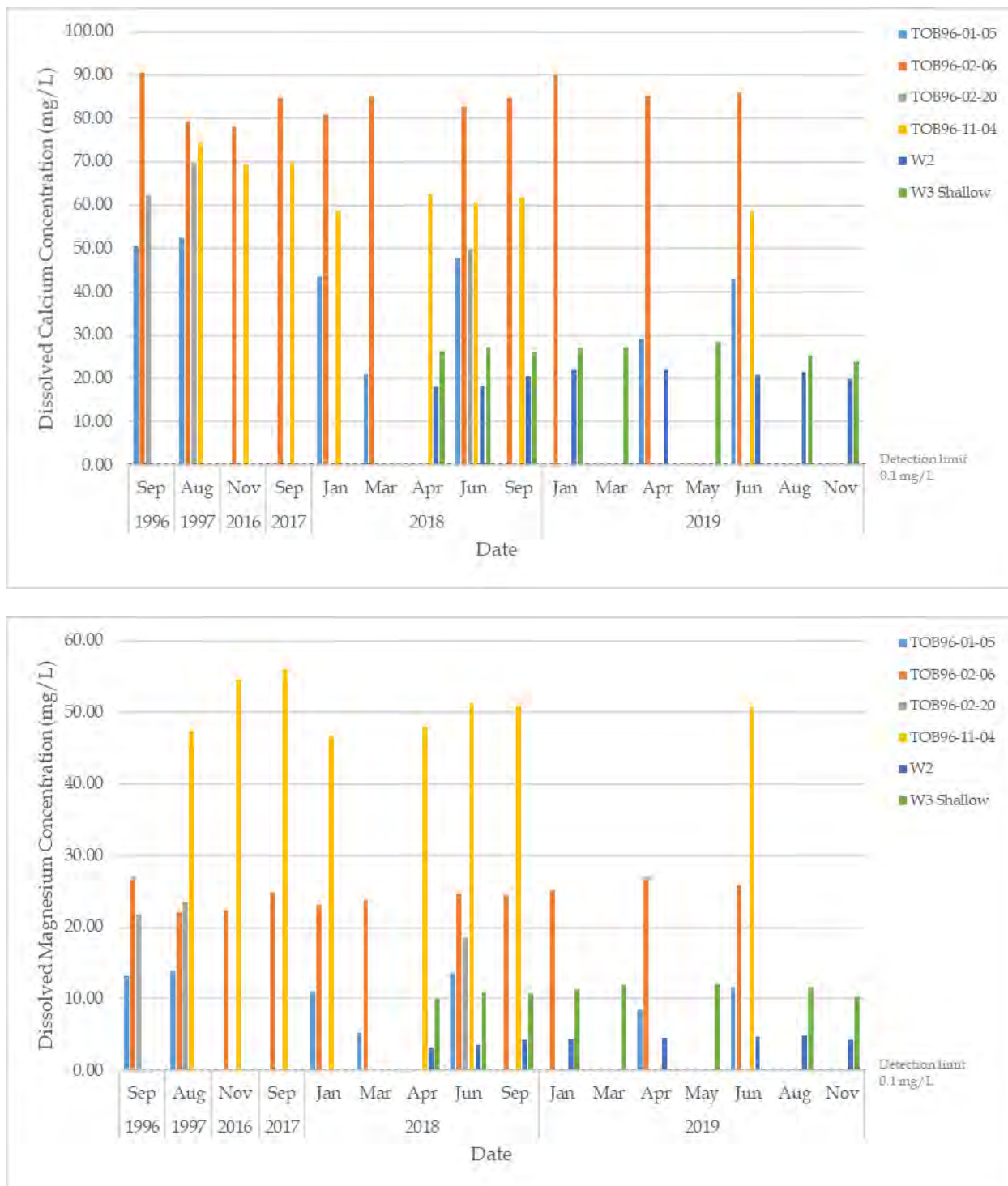
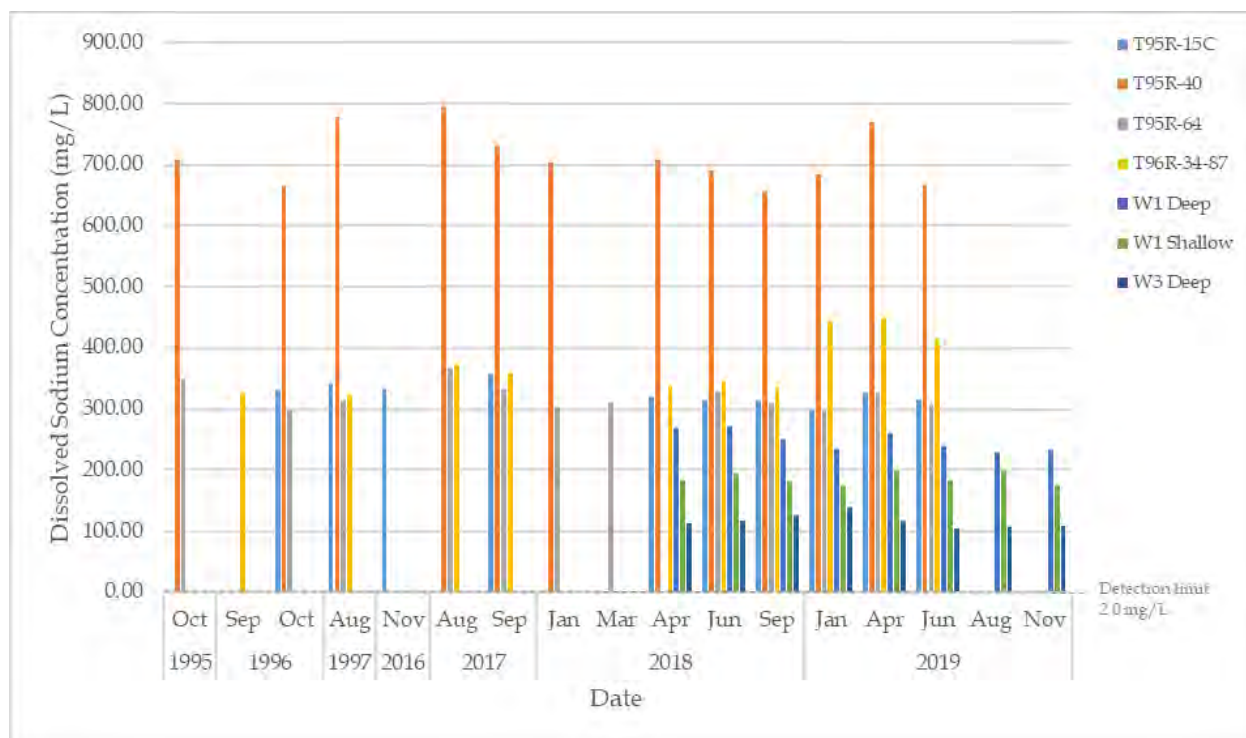


Figure 6.5-20. Major Cation Concentrations (Dissolved Sodium [mg/L]) in Bedrock Wells, Historical and 2017 to 2019 Baseline Data



The results of the laboratory's internal QA/QC testing are provided in the laboratory certificates of analysis found in Appendix 6-D. In general, the lab reported that percent recoveries for matrix spikes, spiked blanks, and method blanks were within acceptable ranges or were less than detection limits.

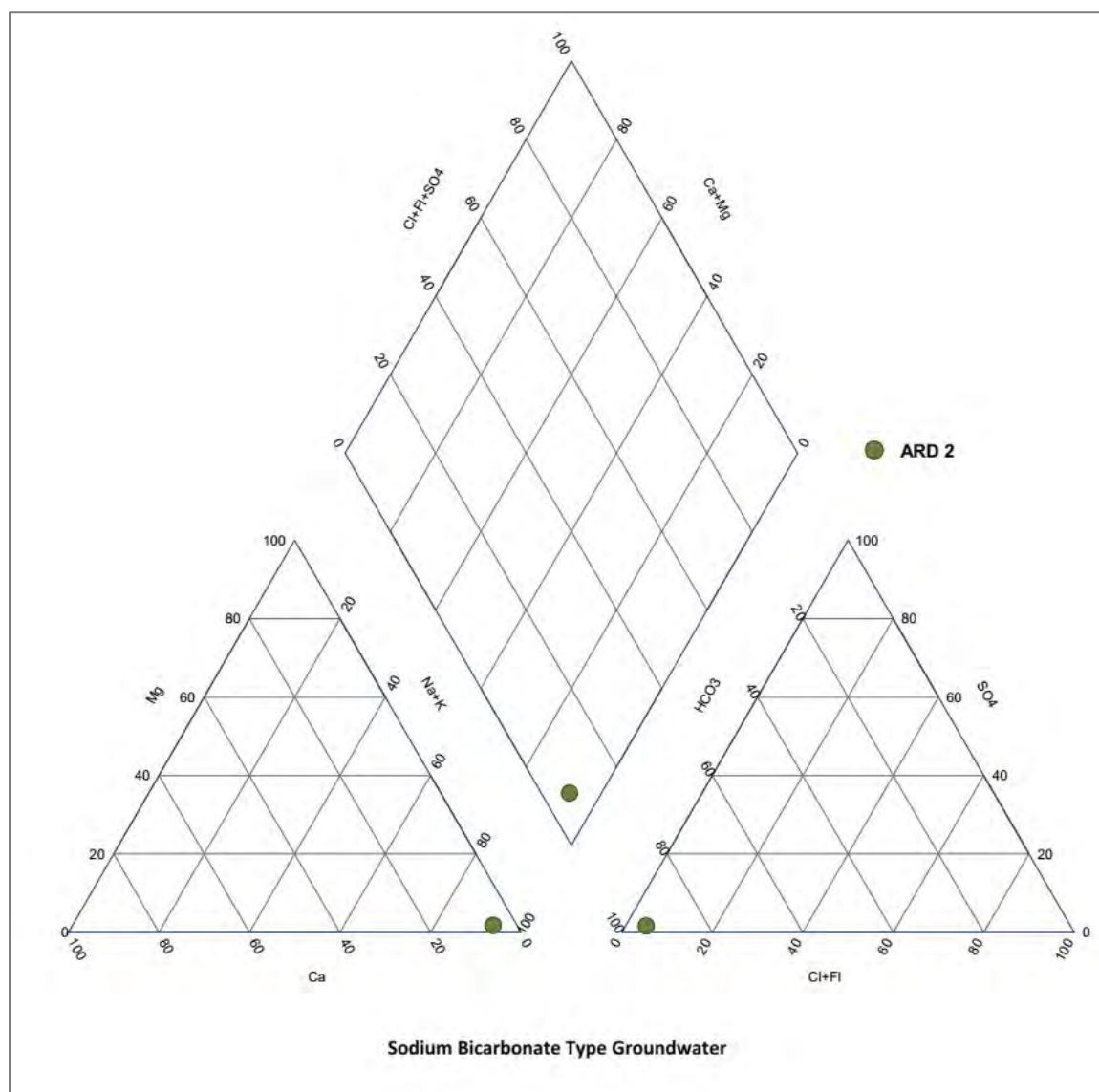
6.5.2 Well 18-01D (ARD 2) Results

Based on the analytical laboratory results for 18-01D (ARD 2), the groundwater type can be categorized as sodium bicarbonate (Figure 6.5-21), soft in terms of hardness and has a slightly basic pH. This water type is similar to the other wells screened in the Skeena Group sedimentary rocks located within the Tenas Project area.

The following parameters exceeded the BC water quality guidelines – freshwater aquatic life (BC WQG FAL):

- Total iron - 1.5 mg/L (BCWQG FAL = 1.0 mg/L)
- Fluoride - 1.35 mg/L (BCWQG FAL = 1.03 mg/L)
- Dissolved aluminum - 3.15 mg/L (BCWQG FAL = 0.10 mg/L)
- Dissolved iron - 0.848 mg/L (BCWQG FAL = 0.35 mg/L)

The analytical results for PAH were below laboratory detection limits. The analytical results compared to the BC WQG FAL for 18-01D are shown in Appendix 6-G and the laboratory Certificate of Analysis is provided in Appendix 6-H.

Figure 6.5-21. Trilinear Diagram for 18-01D (ARD2), March 2019

6.5.3 PAG Cell Wells

Seven out of nine new monitoring wells were sampled after the 2019 winter drilling program in the area of the proposed PAG cell (two wells were dry). Nine wells were installed for the purpose of determining the water level in the glacial overburden and shallow bedrock and for estimation of the hydraulic conductivity (K) of these lithological units (refer to Section 5.5). One round of sampling was conducted at these wells in May 2019. There was a total of 27 exceedances of the BC WQG FAL guidelines from six of the seven wells (no exceedances from 19-35S). Fourteen of the 27 exceedances are attributed to the total metal concentrations. Monitoring well 19-34S had the most exceedances (seven) while 19-27S had only one exceedance. Table 6.5-3 below summarizes the exceedances. Detailed analytical results are provided in Appendix 6-I and the laboratory Certificate of Analysis is provided in Appendix 6-J.

Table 6.5-3. Summary of Exceedances of the BC WQG FAL Guidelines in PAG Cell Wells, May 2019

BCWQG FAL – Approved/ Working Guideline		Well ID						
		19-18S	19-21S	19-22S	19-26S	19-27S	19-34S	19-35S
Turbidity	50 NTU	201	375	30.1	208	1.15	194	0.37
Fluoride	0.4-2.0 mg/L (hardness dependent)	0.275	0.34	0.49	0.30	0.17	1.14	0.382
Total Arsenic	0.005 mg/L	0.0070	0.00138	0.00163	0.0134	0.00539	0.00666	0.0027
Total Copper	0.002 - 0.026 mg/L (hardness dependent)	0.0243	0.0182	0.0042	0.0157	<0.0010	0.0066	0.0014
Total Iron	1 mg/L	10.9	4.81	3.29	8.81	0.046	6.37	0.12
Dissolved Iron	0.35 mg/L	0.12	0.109	0.047	0.207	<0.030	0.572	0.046
Total chromium	0.001 mg/L - 0.0089 mg/L*	0.0091	0.005	0.0012	0.0071	<0.0010	0.0027	<0.0010
Dissolved Aluminium	0.10 mg/L (pH dependent)	0.0059	<0.0050	0.0293	0.226	<0.0050	2.52	<0.0050
Benzo(a)pyrene	0.00001 mg/L	<0.0000050	0.0000122	<0.000020	<0.0000050	<0.0000050	<0.0000060	<0.0000050
Naphthalene	0.001 mg/L	<0.000050	0.00141	0.00188	<0.000050	<0.000050	0.000633	<0.000050
Phenanthrene	0.0003 mg/L	<0.000020	0.000882	0.000791	<0.000020	<0.000020	0.000298	<0.000020

Note: **Bold** values are exceedances of the applicable guideline. * - BCWQG FAL – Working Guideline Chromium III – 0.0089 mg/L, Chromium IV – 0.001mg/L.

The parameter concentration for metals which exceeded their total metal guideline is significantly below the guideline when looking at their dissolved concentration (which is more representative of natural groundwater). PAH compounds were detected in three of the seven wells (19-21S, 19-22S and 19-34S) with guideline exceedances in two of those three wells (19-21S and 19-22S; Table 6.5-3). The PAH compounds were only detected in wells screened in bedrock which may indicate that these compounds could be naturally occurring in these sedimentary units.

Total chromium concentrations exceeded the BC WQG - FAL working guideline in 19-18S. Further analysis was conducted to separate and quantify chromium IV (Cr(IV)) in all samples with detectable concentrations. The concentration of Cr(IV) was less than the laboratory detection limit of 0.0005 mg/L in all samples (Appendix 6-I).

Exceedances of approved and working BCWQG-FAL guidelines may be attributed to relatively high turbidity values seen in the majority of samples. The turbidity values encountered during sampling are not uncommon after a well is drilled either as a result of the natural lithology in which the well is screened (sand and silt in the overburden and weathered fine-grained sedimentary rocks in the bedrock) and/or residue from the development process. With only one round of sampling, it is difficult to confirm if the presence of these compounds is natural or derived from the drilling or sampling process.

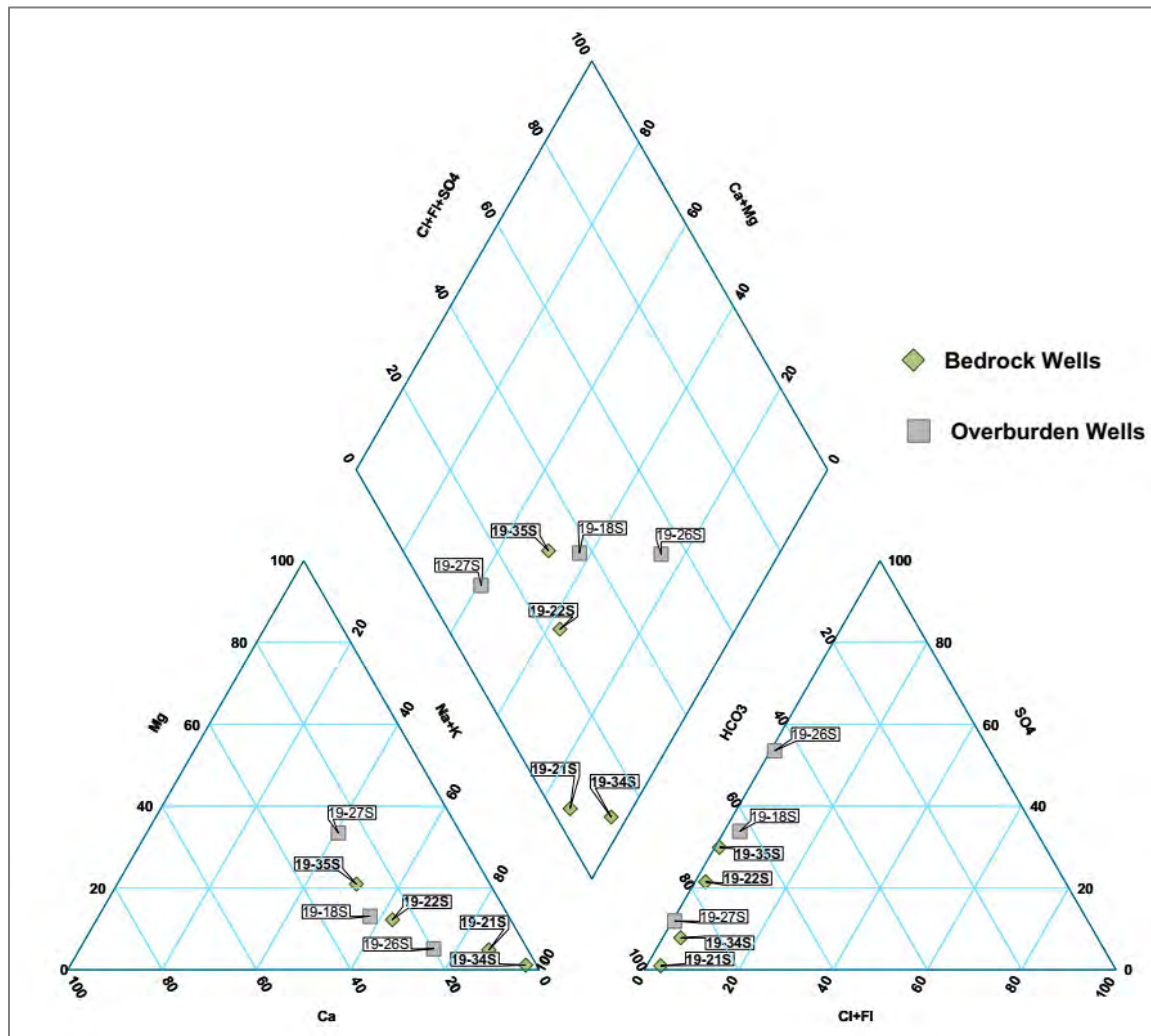
6.5.3.1 Piper Plot and Groundwater Type

Based on the analytical laboratory results for the PAG cell wells, the groundwater type generally differs between the overburden and bedrock wells. The corresponding water type has been plotted on a tri-linear diagram which shows the relative abundance (percent milliequivalents per liter) of cations and anions based on the dissolved constituents of the sample (Figure 6.5-22). The groundwater type differs between the bedrock and overburden wells with the exception of bedrock well 19-35S which has a major ion composition similar to the overburden wells (specifically 19-18S).

The four bedrock wells have the following hydrogeochemical characteristics:

- All four wells are bicarbonate rich.
- All four wells have over 50% sodium with 19-21S and 19-34S having over 85% sodium.
- In general, the groundwater in these bedrock wells can be considered a sodium bicarbonate type with 19-35S containing slightly more of a mix of cations in relation to the other three bedrock wells (Figure 6.5-22).
- 19-35S, 19-21S and 19-22S have moderately hard water ranging from 106 to 116 mg/L as CaCO_3 , while 19-34S has relatively soft water (17 mg/L as CaCO_3).
- All bedrock wells have a slightly basic pH value ranging from 7.73 to 8.76.
- The TDS values range from 243 mg/L to 1,100 mg/L.

Figure 6.5-22. Trilinear Diagram for PAG Cell Wells, May/June 2019



The three overburden wells have the following hydrogeochemical characteristics:

- 19-18S and 19-27S are bicarbonate rich while 19-26S is comprised of a mixture of sulfate and bicarbonate.
- 19-26S is sodium rich (75%), 19-18S has slightly more sodium than calcium + magnesium, and 19-27S has slightly more calcium + magnesium than sodium.
- In general, the groundwater in these overburden wells can be considered a mixture of calcium + magnesium and sodium bicarbonate (19-18S and 19-27S) and sodium bicarbonate and sulfate (19-26S; Figure 6.5-22).
- 19-18S and 19-27S have hard water (153 mg/L as CaCO_3 and 180 mg/L as CaCO_3 , respectively), while 19-26S has relatively moderate hard water (70 mg/L as CaCO_3).
- All three wells have a slightly basic pH value ranging from 8.07 to 8.86.
- The TDS values range from 295 mg/L to 433 mg/L.

6.5.3.2 *Quality Assurance / Quality Control*

One duplicate sample was collected from 19-18S during the May/June 2019 sampling event. For parameters where both samples had detectable concentrations, the RPD was calculated when the results for a given parameter were greater than five times the detection limit. In general, the average RPD value for all of the parameters analyzed, excluding total metals, was less than 10% (with the exception of dissolved iron which was 58%). The average RPD for the total metals parameters was 47% which can be attributed to the turbidity of the sample (201 NTU). The RPD results are shown in Appendix 6-I.

The average ion charge balance for the May/June 2019 samples was calculated to be 8.9% (Appendix 6-I).

One field blank was analyzed during the May/June 2019 sampling event. All of the analyzed parameters were below detection limits in the field blank with the exception of total aluminum and total sodium. The field blank results along with the laboratory's internal QA/QC testing are presented within the ALS certificate of analysis in Appendix 6-J. In general, the lab reported that percent recoveries for matrix spikes, spiked blanks, and method blanks were within acceptable ranges or were less than detection limits.

6.5.4 **Domestic Wells**

There are 48 private domestic wells with the LSA (Figure 6.5-23). As part of the baseline program, one private domestic water source (spring [Kerr]), was sampled quarterly during the groundwater sampling events from June 2018 to April 2019. Four additional private domestic wells (Shmike, Shearer, Ragula, and Buekema) were each sampled once during winter 2019. These water sources were selected for sampling as they are the closest drinking water sources down-gradient of the proposed mine site.

Total arsenic, iron, manganese, and dissolved iron exceeded BC WQG – FAL and the Maximum Acceptable Concentration for Drinking Water Sources in the Kerr spring. Total phosphorus and TOC also exceeded the drinking water guidelines (Appendix 6-K).

Total copper exceeded the BC WQG – FAL Approved Guideline in both the Schmike and Shearer wells. The Shearer well also had an exceedance of BC Approved WQG - Drinking Water Sources for total organic carbon. Total iron and manganese exceed the BC Approved WQG - Drinking Water Sources Guideline in the Ragula well. There were no exceedances in the Buekema well (Appendix 6-K).

The corresponding water type has been plotted on a tri-linear diagram which shows the relative abundance (percent milliequivalents per liter) of cations and anions based on the dissolved constituents of the sample. Based on the analytical laboratory results, the groundwater type for each of the private domestic water sources can be categorized as a Ca+Mg bicarbonate type, with the Schmike well containing a higher relative abundance of sulfate in relation to the other water sources tested (Figure 6.5-24).

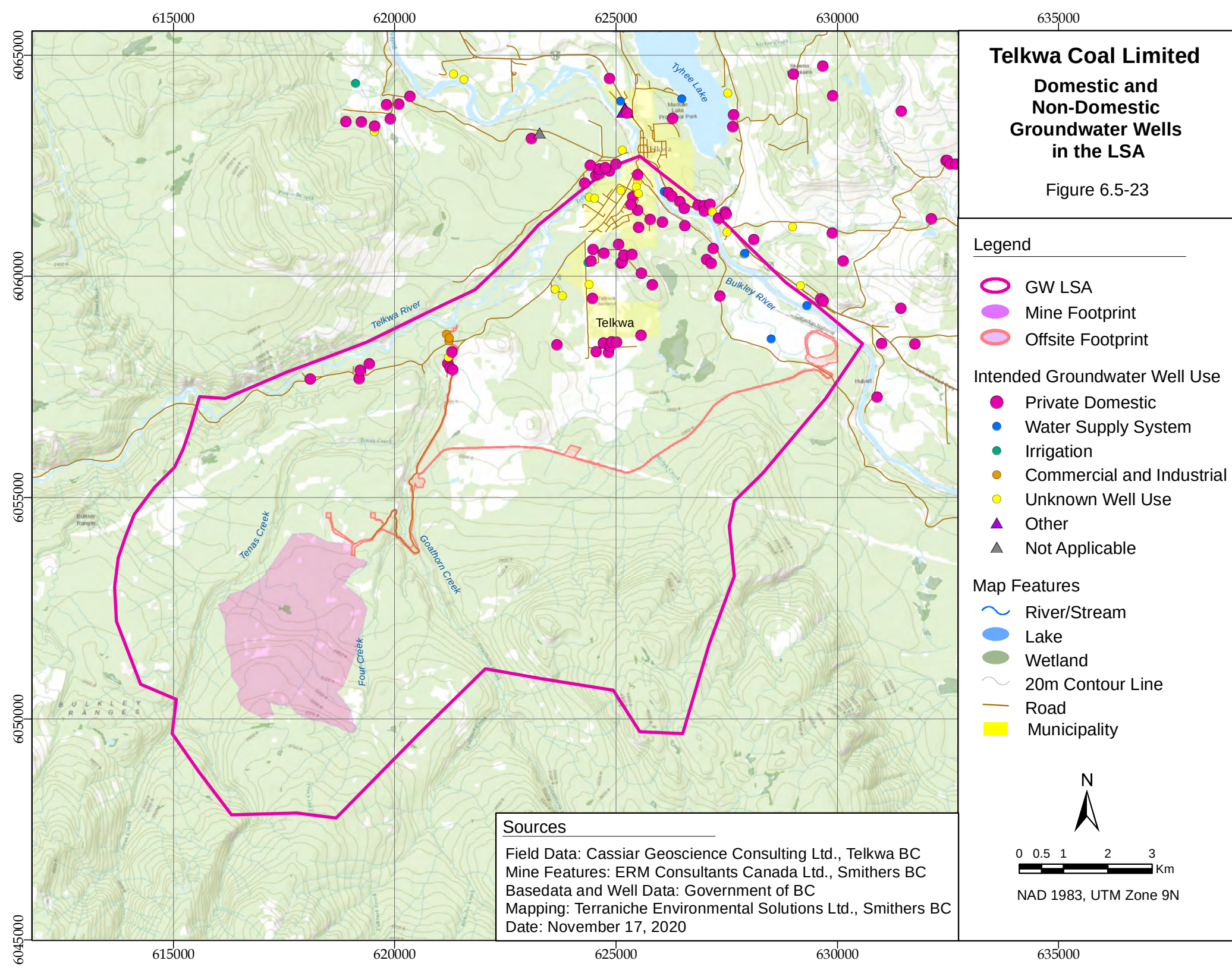
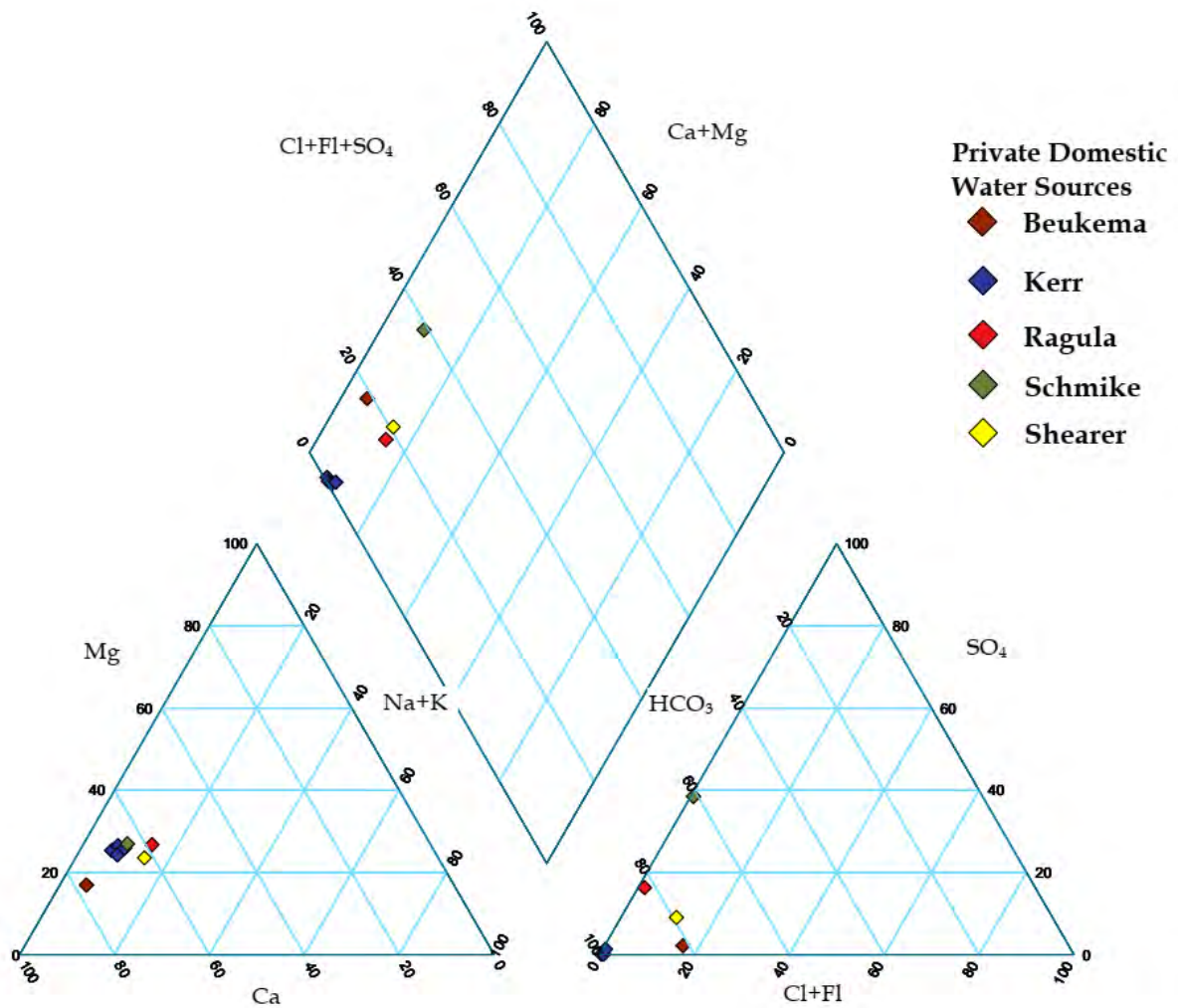


Figure 6.5-24. Trilinear Diagram for Private Domestic Water Sources, 2019



7. HYDROLOGY

This chapter presents the methods and results of the surface water hydrology baseline monitoring program. The purpose of the 2017 through 2019 (2017-2019) hydrometric monitoring program was to collect Project specific baseline surface water flow data. These site specific streamflow data, along with other existing regional data summarized in Section 7.3, can be used to understand the hydrologic characteristics within and downstream of the Project area. Hydrologic characteristics will contribute to engineering analysis and design of water management features; support the development of water balance and water quality models, effects assessments, management plans, and closure planning; support permitting; and support fisheries monitoring programs for the Project.

The objectives of the 2017-2019 program were to:

- establish three hydrometric monitoring stations within and near the Project area;
- develop the stage-discharge rating curves for each of the hydrometric monitoring stations;
- calculate flow discharge estimates and generate annual hydrographs for the hydrometric monitoring stations for 2017, 2018 and 2019; and
- generate hydrologic indices for 2017, 2018 and 2019.

7.1 STUDY AREA

The Project area is located within the Telkwa River watershed, approximately 180 km east of the Pacific Ocean. Telkwa River is a tributary of the Bulkley River that drains to the Skeena River, and ultimately discharges into the Pacific Ocean. Two main sub-watersheds that contain sites of potential Project infrastructure are Tenas Creek and Goathorn Creek (Figure 1.2-2) sub-watersheds. The Project is bound by Goathorn Creek to the east, and Tenas Creek to the north and west. Downstream of the Project, Tenas Creek joins Goathorn Creek, which flows into the Telkwa River. The Telkwa River flows northwest approximately six (6) km from the confluence with Goathorn Creek before discharging into the Bulkley River.

7.1.1 Hydrologic Setting

The Project is located in the transition zone between the wetter Coast Mountains and the drier Interior Plateau. The streamflow regime of the area is nival (snowmelt) with the majority of runoff occurring in the spring and early summer due to the melting winter snowpack. Following the snowmelt-driven high flow, there is typically a period of low flow throughout the late summer and early fall when inputs from snow have diminished. Throughout the fall period, short duration high intensity rain events may produce substantial high flow events. Annual low flows occur during the winter when air temperatures remain below freezing and snow falls to be stored in the snowpack until spring. During the winter low flow period, most streams retain baseflow from groundwater discharge. Some streams in the region have glacier inputs, but this is less prominent in the Project area, as most of the substantial glacier coverage is situated west of the Project.