PE:7008 Quinsam Coal Annual Water Quality Monitoring Report 2021-2022

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GLOSSARY & ACRONYMS

B.C. British Columbia

CALA Calibration

CCR Coarse Coal Reject

COPC Contaminants of Potential Concern

CSR-AW B.C. Contaminated Sites Regulations for Freshwater Aquatic Life 2019

DL Detection Limit

DO Dissolved Oxygen

ENV Ministry of Environment and Climate Change Strategy

EMS Environmental Monitoring Station

MEMPR Ministry of Energy, Mines and Petroleum Resources

EPT Ephemeroptera, Plecoptera, and Trichoptera

Ha Hectares

Hp Horsepower

IDZ Initial Dilution Zone

km Kilometer

LLE Long Lake Entry

LLS Long Lake Seep

LLSM Long Lake Seep Middle

mASL Metres above sea level

MDL Mean Detection Limit

MOE Ministry of Environment and Climate Change Strategy

PTS Passive Treatment System

PAG-CCR Potentially Acid Generating Coarse Coal Reject

PAH Polyromantic Hydrocarbons

PEP Provincial Emergency Program

PNC Permit Non-compliance

QA/QC Quality Assurance/Quality Control

QCC Quinsam Coal Corporation

RPD Relative Percent Difference

TDS Total Dissolved Solids

TSS Total Suspended Solids

VIO Vancouver Island Objective for Phosphorus in Streams

WQG British Columbia Ambient Water Quality Guidelines for Protection of Aquatic Life

WQO Water Quality Objectives for Middle Quinsam Lake Sub-Basin

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EXECUTIVE SUMMARY

In accordance with the amended permit PE-7008 issued under the *Environmental Management Act*, Quinsam Coal Corporation (QCC) operates water management systems designed to mitigate effects of mining activities on the Middle Quinsam Sub-Basin and Iron River watershed(s). This effluent permit provides the framework for the comprehensive monitoring program along with allowable levels of Parameters of Interest (POI) within water released from the permitted management systems. In addition to surface water quality monitoring within management systems and receiving environments, local groundwater sediment and biological monitoring was conducted at numerous stations for a more comprehensive understanding of effects within and outside of the mine footprint.

The main objective of this report is to inform governing bodies and stakeholders on the effectiveness of the management systems and compliance with the effluent permit for the 2021-2022 monitoring year (April 1st through March 31st). These include:

- Description of mine-site operations and their respective environmental management systems
- Report on environmental performance and compliance with the Effluent Permit PE-7008
- Provide updates on surface, groundwater and receiving environment water quality including biological health
- Provide insight and recommendations for future monitoring and best environmental practices.

During the reporting period, QCC operated only in a care and maintenance mode with The Bowra Group Inc. appointed as the receiver of QCC. The mine has been in care and maintenance since May 29, 2019, ensuring the health and safety of the employees and environment while continuing to meet regulatory requirements.

Mine discharges released from the permitted locations were within permitted levels for the majority of samples obtained this monitoring period. The only parameter in excess of the permit limit was dissolved iron at Setting Pond #1. As explained below:

- A dissolved iron exceedance was observed Settling Pond #1 (SP1 / Environmental Management Site - EMS # E207409) applied to discharge limits at SPD of 0.5 mg/L) with a reported result of 1.19 mg/L. This exceedance was determined to be an isolated event with no additional exceedances observed in the year. Dangerous Goods Incident number (DGI-214321) was generated, and a non-compliance report was submitted on February 15, 2022.

Spill reports can be found in Appendix VII including description of the spill, follow up and mitigative techniques.

SP4 permitted annual average rate of discharge is (0.08 m^3/s or 2,522,880 m^3) measured over 365 days / year. The 2021-2022 annual average rate of discharge rate was 0.1081 m^3/s, above the authorized average rate of discharge by 4%. Appendix II, Graph 73 displays the cumulative year over year discharges at Settling Pond #4.

On January 3rd, 2022, the 5-South pump failed to restart after a power outage. The 5-South dewatering pump is a well pump located 80 meters below surface with its primary purpose being to transfer water from the 5-South mine into the 2-North mine (3 Mains) where it is discharged at Settling Pond #4. For Closure (Post Mine Period), the 5-South mine was expected to re-flood to pre-mine groundwater levels. Pumping perpetually from the 5-South mine is not part of the Closure plan. If it is determined that the 5-South mine pump is not required for any further use the mine will reflood back to pre-mine conditions. The Closure Plan for this mine was to allow it to flood to reduce oxidation of the mine walls and the potential for acid mine drainage and metal leaching. Mine water elevations are being monitored to ensure levels remain at safe conditions. A notification was sent to ENV on January 5, 2022, titled “Failure of Works Notice (PE:7008) (C-172)”.

The reader should note that concentrations for most parameters of interest were not elevated above BC Water Quality Guideline’s Freshwater Aquatic Life (WQG) levels in the receiving environment throughout the 5 in 30 sampling period. Those parameters that were above WQG’s include the following: dissolved aluminum (Al-D), total arsenic (As-T), dissolved copper (Cu-D), iron both total and dissolved (Fe-T / Fe-D) and total manganese (Mn-T). These parameters occurred at different locations with iron only observed at LLE and seep locations. The majority of the WQG observations were found with dissolved copper. Appendix I, Table 3 displays all WQG observations.

Elevated parameters are observed on the Iron River for arsenic (low flow) and aluminum (high flow). Both IR6 and IR8 experience elevated arsenic during all 5 weeks of sampling in summer low flow period.

WQG’s for dissolved copper are variable and calculated based on ambient site conditions such as pH, temperature, dissolved organic carbon and hardness. Appendix I, Table 3 displays those sites where copper was elevated. Throughout the monitoring period copper is elevated upstream of mine influence on the Quinsam river at WA, the Iron River, and No Name Lake. Highest concentrations are observed at WA for most periods. As a result, the downstream monitoring locations also display concentrations above their respective guidelines. These include Middle Quinsam and Long Lakes, downstream on the Quinsam river (QRDS1, 7SQR and IRQR), No Name Lake Outlet (NNO) and Lower Quinsam Lake (LQL). The guideline derived for dissolved copper uses a conservative approach.

Increases were observed for average dissolved sulphate in the Quinsam River compared to previous years. In spring, downstream locations measured marginal increases in dissolved sulphate compared to upstream at WB. This could indicate other sources of input from groundwater seepage areas (S and S2) discovered between WB and QRDS1. Results from WB, QRDS1 and 7SQR ranged from 40 mg/L to 44 mg/L to 45 mg/L, respectively. Average concentrations on the Quinsam River remained below 60 mg/L during all seasons with summer displaying the highest concentrations from WB to IRQR ranging from 55 mg/l to 55.8 mg/L, respectively. In fall WB had the highest concentrations with a decrease observed downstream at QRDS1 and 7SQR (47 mg/L to 43 mg/L) possibly due to the lower water levels in underground flooded mine voids ad decreased seepage rates.

Other than copper there were no other parameters observed to be above the WQG's or WQO's on the Quinsam River during this monitoring year. Increases in average concentrations of dissolved sulphate, iron and total manganese were observed compared to historical values during 2021. This could be attributed to increased groundwater discharge zones and continuous dewatering of mine voids during low flow. Potential seepage areas were discovered on the Quinsam River, and monitoring has been performed throughout the year. These sites have displayed elevated arsenic, iron and sulphate above WQG's. Monitoring has been performed to characterize seepage water quality and quantity and influences on the Quinsam River. The sediment and benthic invertebrate monitoring were used as a tools to identify impacts on the river downstream of seepage areas.

Sulphate concentrations at depth in Long Lake have continued to be a focal point for receiving environment water quality as elevated levels have persisted throughout past monitoring. In 2021, average concentrations during all seasons remained below average WQG's of 128 mg/L, using a background hardness concentration of 30 mg/L. The bottom depth ranges from 20 to 22 metres and is sampled at 1 metre above bottom (1MB). Average results for Long Lake 1MB during spring (102 mg/L), summer (105 mg/L), and fall (103 mg/L) were not elevated. In Middle Quinsam Lake dissolved sulphate remained well below average WQG's, with average results less than 55 mg/L throughout all seasons. Middle Quinsam Lake displayed the highest concentrations on surface during spring and summer (1 metre and 4 metre) with peak concentrations occurring in summer on surface averaging 50 mg/L. Increases were observed compared to 2020 due to increased discharge from Settling Pond 4 as a results of continuous underground dewatering efforts starting at the end of March 2021. Normally pumping would be reduced during summer months as mine void water elevations were lower.

Anoxic conditions (low dissolved oxygen) were observed in Long Lake during fall, with total manganese elevated above guidelines. Slightly acidic water quality was observed mostly in No Name Lake but also in Long Lake with pH values reported below the minimum WQO's of 6.5, which only applies to Long Lake.

The Passive Treatment System has been effective at reducing sulphate concentrations from mine pool water pumped to surface. The system was shut down August 11th to September 20th due to extreme electrical fire hazard under the power lines in the 2-South Area. Annual average concentrations of dissolved sulphate have been entering the system from the 2-South mine pool, measured at INF, resulting in 535 mg/L and leaving the system at the Sulphide Polishing Cell (SPCEFF) resulting in 397 mg/L with final discharge at measured at SPD averaging 147 mg/L. These results indicate dilution through the system is working to reduce sulphate concentrations below 300 mg/L as was intended for the Passive Treatment System.

Additional monitoring included in-situ and ex-situ groundwater wells, underground sumps and dewatering wells located in 2 / 3 North, 2 / 3 South, 4-South, 5-South and 7-South mine areas. Parameters of interest are compared to source terms derived for mine water within the mine footprint (in-situ) and British Columbia Contaminated Site Regulation (CSR) (BC reg.375/96. O.C. 1480/96), Schedule 6, Aquatic life (CSR-AW) are used to compare groundwater quality outside of the mine footprint (ex-situ). Certain parameters found in ex-situ groundwater continually result above the CSR-AL, these include the following dissolved parameters: arsenic, chloride, and sulphide as Hydrogen Sulphide (H^2S) and occasionally selenium. Selenium is observed periodically in the ex-situ deep groundwater of QU1105D situated to monitor water quality and vertical gradients downstream of the 2-North Mine and River Barrier Pillar. Currently, no inputs are known to have significant detrimental effects on receiving environments, but future monitoring will be an effective tool to identify and determine changes in the groundwater and observe long term trends.

Sediment quality and the benthic invertebrate community in the Iron River and Quinsam River were studied to meet conditions of amended Permit PE-7008, dated June 23, 2015. The permit requires sediment and benthic invertebrate monitoring in the Quinsam River every three to five years. Baseline monitoring is required once, prior to mine development, on the Iron River. Studies were conducted in 2020 (Iron River) and 2021 (Quinsam River) to meet these permit conditions. There were 2 locations on the Iron River and 4 locations on the Quinsam River upstream and downstream of mine influences. Additional sediment sampling was conducted at a potential seep location (S2) to investigate probable inputs from mine-affected groundwater to the Quinsam River. Results of the study are provided in Appendix X and summarized below.

In sediment, the following parameters of interest (POI), which exceeded ISQG or PEL in one or more samples, were identified: arsenic, copper, iron, naphthalene, 2-methylnaphthalene, acenaphthene and phenanthrene. The Iron River stations had low PAH levels (with some parameters exceeding the ISQG), arsenic concentrations higher than the PEL (reflecting the sedimentary stratum with elevated arsenic), and cadmium, chromium, copper, and zinc concentrations higher than the ISQG in some samples. The Quinsam River stations had low PAH levels (with some parameters higher than the ISQG at QRD-02 and QRD-03), arsenic concentrations higher than the ISQG, and isolated occurrences of copper and cadmium higher than ISQG. Arsenic concentrations were highest at QRD-02, with some values higher than the PEL. The seep sample S2 had notably elevated arsenic concentrations (more than 400 times the PEL), along with elevated iron and manganese concentrations compared to the river stations.

Elevated concentrations of arsenic, copper and iron were observed upstream of the mine influence on the Quinsam River at site WA. WA displayed the highest concentration of copper in sediment above the ISQG compared to downstream locations in the Quinsam River. Indicating either natural environmental condition or an upstream source of contaminant. Concentrations of arsenic copper, and iron declined compared to the 2016 monitoring program.

Benthic invertebrates and stream habitat data were collected following the procedures of the Canadian Aquatic Biomonitoring Network (CABIN), a biomonitoring program for assessing the health of freshwater ecosystems in Canada. Benthic invertebrate communities provide an indicator of the health of that water body. Taxonomic data were analyzed using the Reference Condition Approach (RCA) and for community metrics using the CABIN data analysis tools. The data were analyzed using the Preliminary BC Coastal RCA Model (2010) (the Model). Abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), known as the EPT group, is of particular interest as they are known as pollution-sensitive organisms, associated with clean water (coarse substrates, well oxygenated, low organic enrichment).

On the Iron River, the RCA model results and individual metrics (family richness, EPT richness, EPT predominance) indicate the river supports a variety of insect taxa that indicate good habitat conditions. The benthic invertebrate communities were similar to the Preliminary Coastal BC RCA model Reference Group 2 reference condition (invertebrate communities at undisturbed sites).

On the Quinsam River, the RCA model results at the four stations indicate the invertebrate communities differ from the Reference Condition for the assigned Reference Group 3. However, the communities are abundant, diverse, and dominated by EPT taxa. The difference from the assigned Reference Group may be associated with factors other than the mine. Potential influence of Quinsam Mine is detected in the invertebrate community metrics at QRD-02, but by station 7SQR, the community improves to conditions better than at station WA.

1.0 INTRODUCTION

The Quinsam Mine is located in the Quinsam River Watershed, approximately 28 kilometers (km) by road southwest of Campbell River. The Quinsam mining operation consists of approximately 283 hectares (ha) owned and operated by QCC. Coal production occurred from both 2-North and 7-South mining areas until May 2019 when the mine went into a temporary shutdown and then later suspended coal operations.

When in operation Quinsam Mine produces High Volatile “A” Bituminous thermal coal. Coal is processed at an onsite preparation plant and transported by B-train highway trucks to the Middle Point Barge Terminal north of Campbell River. Coal is then shipped via barge, to local customers and to Texada Island where it is then loaded onto a ship and sent to local companies or exported abroad.

Due to the mine’s location and sensitive habitat, adjacent to Middle Quinsam Lake, the Quinsam River, No Name Lake, and Long Lake, draining into Lower Quinsam Lake the operational permits issued by the Ministry of Environment (MOE) and Climate Change Strategy (ENV) as well as the Ministry of Energy, Mines and Low Carbon Innovation (MEMLCI) established stringent effluent quality standards. Accordingly, QCC has maintained an environmental management system defined by the requirements of Effluent Permit PE-7008 and the C-172 Mines Act permit. The mine has collaborated with regulators and stakeholders on key management aspects to minimize mine related effects in the receiving environment.

Sulphate concentrations in surface waters of the receiving environment (e.g., Long Lake) continued to be a focus for the QCC monitoring program. Although PE-7008 lists only one sulphate limit for effluent (500 mg/L at 7SSD), sulphate is routinely monitored at designated locations within the mine site and in the receiving environment. Quinsam continues to assess sources of sulphate and management options to mitigate concentrations in mine related discharge(s).

On-Site Water Quality and Activities

The North, South, and 7-South water management systems represent the cumulative mine related discharges to the Quinsam watershed. As such, strategic operation of management structures is designed for discharge waters to meet permit requirements and be of suitable quality for discharge into the receiving environment. Permit limits for parameters of interest have been established and are closely monitored to ensure environmental protection.

Acute and Chronic Bioassays and Toxicity Testing

Acute Rainbow trout bioassay (*Oncorhynchus mykiss*) are performed on water collected from the authorized discharge locations Settling Ponds #1, Settling Pond #4 and 7SSD during the first fall flush event. When discharge is occurring from 7SSD, samples are collected concurrently at 7SSD and the downstream site Stream 1, 7S during the first spring freshet and fall flush. Rainbow trout bioassays are performed on 7SSD discharge water and 7-day *Ceriodaphnia dubia* chronic toxicity testing is performed for water collected from Stream 1 ,7S. The acceptable criteria for a Rainbow trout bioassay test to pass includes no mortalities at 100% effluent concentration after 96 hours.

For the 7-day *Ceriodaphnia dubia* chronic toxicity testing the results are based on acute and chronic exposure levels. This toxicity test determines if the effluent causes death (acute toxicity) or reduction in the reproduction of the test organisms (chronic toxicity) during a 7- day period.

Receiving Water Quality

Water quality attainment in the Middle Quinsam Sub-Basin remains a key management objective at QCC. Comparison to provincial Water Quality Guidelines for Protection of Aquatic Life (WQG's) and Middle Quinsam Sub-Basin Water Quality Objectives (WQO's) are used to evaluate receiving water quality, aquatic health, and guide overall management operational performance. Although these guidelines do not have any legal standing, they are used to provide a basis for evaluating the health of the environment.

Monitoring sulphate concentrations provides an evaluation of mine influence on the receiving environment. Sulphate concentrations are compared to an average WQG of 128 mg/L, calculated using a background hardness of 30 mg/L for the Middle Quinsam Sub-Basin. Sulphate results averaged over five weekly samples collected over 30 days (5 in 30) were compared to the WQG. Other parameters of interest for the receiving environment include total arsenic, dissolved aluminum, dissolved copper, total and dissolved iron, total manganese, and dissolved zinc. Elevated dissolved aluminum, copper, and zinc concentrations are associated with rainfall events (elevated TSS) and may not be associated with mine related discharges; however, elevated concentrations are considered in the context of aquatic effects.

In 2019 the ENV updated the Copper (Cu) WQG from total to dissolved instead. The updated dissolved Cu WQG is calculated using a Biotic Ligand Model (BLM), which incorporates specific water chemistry data using specialized software. This model requires the input of site specific physical and chemical parameters (temperature, pH, alkalinity, dissolved copper, calcium, chloride, hardness, magnesium, sodium, potassium, sulphate, and organic carbon) where it then derives a site-specific guideline and normalizes the toxicity data to specific site conditions for specific aquatic receptors.

The BC BLM software allows the user to calculate either a chronic or acute guideline based on the underlying toxicity databases. Using the acute or chronic database, the BC BLM software first calculates a critical accumulation value and then normalizes this value to the water chemistry conditions specified in the input data. The normalized acute or chronic dataset of critical accumulations values is then used to identify the most sensitive endpoint of the most sensitive organism at the most sensitive life stage[1].

Quinsam is required to compare WQG to those sites outside of the Quinsam sub-basin. This includes the Iron River (IR6 and IR8), downstream Quinsam River 7SQR and IRQR, No Name Lake and the outlet and Lower Quinsam Lake. The new dissolved copper WQG is a more stringent and conservative guideline applied at all receiving environment locations. The WQO compared total copper at higher concentrations (acute (0.007 mg/L) and chronic (0.002 mg/L)) going forward QCC will apply the WQG to dissolved cooper at all receiving environment sites.

[1] B.C. Ministry of Environment and Climate Change Strategy 2019. Copper Water Quality Guideline for the Protection of Freshwater Aquatic Life-Technical Report. Water Quality Guideline Series, WQG-03-1. Prov. B.C., Victoria B.C.

Monitoring at sites upstream of mine influences (e.g., Iron River (IR6 and IR8)) indicates naturally elevated concentrations of dissolved aluminum during high flow and arsenic during low flow events. These metals and other parameters that are higher than WQGs or WQOs are discussed below.

Groundwater Quality

QCC maintains a comprehensive groundwater monitoring program to characterize water quality associated with mining development. There are numerous groundwater wells including underground sumps located in-situ (disturbance footprint) and ex-situ (outside of mine workings) that are monitored. In the absence of a groundwater well sample, underground sump samples are used for comparison. Results for ex-situ wells are compared to Contaminated Sites Regulations for Protection of Freshwater Aquatic Life (CSR-AW) and those for in-situ wells and sumps are compared to source terms derived for particular mining areas. Groundwater quality is influenced by bedrock chemistry, an example being the presence of realgar (arsenic sulphide) in the Dunsmuir Sandstone overlying the No. 4 coal zone, resulting in dissolved arsenic in the south area groundwater being naturally higher than the CSR-AW. Parameters of interest for groundwater are those with concentrations higher than the CSR-AW: arsenic, chloride, fluoride, sulphide as (H_2S) and sulphate. Overall, in-situ groundwater at Quinsam Coal is generally within the water quality prediction scenarios developed for specific mine waters and ex-situ groundwater typically trends below most CSR-AW. Two exceptions to this, is groundwater influenced by host geological formations (e.g., Dunsmuir Member sandstones, Cumberland Member No.1 Coal seam and mudstones) with naturally elevated concentrations of parameters of interest and by weathering processes (i.e., mine wall oxidation and flushing) of disturbed materials within the mine footprint.

Seepage Areas

There are two new areas discovered where possible mine water is seeping into the Quinsam River. These areas are located near groundwater wells QU1109 site name (S) and QU1105 site names (S2A and S2B). Investigation is underway for the potential mine water seepage areas. The main objective is to monitor seepage compared to underground flooded mine void water elevations including water quality and quantity. The Quinsam Coal Corporation: Mine Permit Amendment for 7-South Development May 30, 2011, resulted in a site wide hydrogeological investigation where seepage rates were predicted from mine areas into the Quinsam River. Currently seepage rates from mine voids are compared to predicted seepage rates. Parameters used for the cumulative effects assessment on the Quinsam River from mine areas are referred to as parameters of interest and include aluminum, arsenic, sulphate, boron, cadmium, copper, cobalt, iron manganese, nickel, selenium, and zinc.

Receiving Water Sediment and Biota

QCC conducted a comprehensive biological monitoring program in 2016, as stipulated in Section 4.2.4 and 4.2.7 of the effluent permit. The August through October program involved sediment and benthic invertebrate monitoring at 23 locations in the watershed (at five lakes, one wetland, and three locations on the Quinsam River). In the four lakes exposed to mine influences, samples were collected at inlets, deep sites, seeps, and outlets. Sediment results were compared to generic Canadian Council of Ministers of Environment (CCME) Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL) and to site-specific sediment quality objectives (SQOs) developed for Long Lake that reflect the naturally elevated background levels of some metals. The SQOs were derived from studies completed prior to mining influence in Long Lake (pre-1987). Where background levels are lower than ISQG's, the ISQGs are used for comparison. Primary parameters of interest for sediment are arsenic, iron, manganese, and total polycyclic aromatic hydrocarbons (PAH), identified based on concentrations, relative toxicity, and findings in previous reports. Most of the elevated concentrations are related to geology (host rock formations), although mining has contributed inputs.

In 2020 baseline monitoring for the Iron River was performed at IR6 and IR8. This included collection of sediment and benthic samples.

In 2021 only a partial program was performed on the Quinsam River that included the collection of sediment and benthic invertebrate samples at four locations.

Water quality in the Middle Quinsam Sub-Basin and Iron River largely meets WQGs and WQOs and is considered a healthy aquatic ecosystem. Throughout the monitoring period, Quinsam has demonstrated that mine water management system(s) and procedure(s) are an effective tool in reducing parameters of interest loading in the receiving environment.

Benthic invertebrate samples from lakes and the wetland were analyzed for community metrics (density, taxon richness, diversity, evenness, major taxonomic groups), and for ecologically relevant and statistically significant differences among sites. Quinsam River and Iron River sites were sampled and analyzed using the Canadian Aquatic Biomonitoring Network (CABIN) method. CABIN is an aquatic biomonitoring program for assessing the health of freshwater ecosystems in Canada. Benthic macroinvertebrates are collected at a site location and their counts are used as an indicator of the health of that water body.

Phytoplankton and zooplankton samples collected once per sampling event on all four lakes as a routine requirement of PE-7008s. Samples were analyzed for count, identification, and species abundance.

Long Lake Seep Passive Treatment System (PTS)

The Passive Treatment System (PTS) consists of a series of treatment cells designed to receive mine-water pumped from the 2-South underground workings to reduce POI's concentrations including dissolved sulphate and iron. This system was initiated as part of a remediation plan to limit localized mine-water seepage on the south-side of Long Lake as a result of subsidence caused by mining within close proximity and establishing an evident hydrologic connection.

The PTS continues to demonstrate reduction in sulphate concentrations throughout the system. Higher reduction is observed during warmer conditions, with reduction efficiencies upwards of 300 mg/L or 50% presented during optimal performance times. The addition of molasses (carbon source) has shown some capability to increase performance within the system but due to the viscosity of the molasses the injection system requires continuous replacement of pumps and as a result has been discontinued until a different system can be put in place.

2.0 WATER MANAGEMENT SYSTEMS AND MONITORING LOCATIONS

Settling ponds, sumps and ditches have been constructed to manage and treat mine contact water to help mitigate any negative effects on the receiving environment. Water management at the Quinsam Mine is divided into three discrete areas: North, South, and 7-South. Appendix IX, Site Maps, displays underground mine locations, groundwater wells and surface monitoring sites. Table 1 below describes the within-mine releases monitoring sites and associated initial dilution zones.

Table 1: Description of Monitoring Sites: In-Mine Releases & Initial Dilution Zones

EMS ID #	Monitoring Sites	Abbreviation (Station Code)	*Type of Water (MW, FW or GW)
	North Coal Mining Operation		
E207409	Settling Pond #4 Decant	WD	**Discharge (MW)**
E207411	Culvert, at Middle Quinsam Lake Road	WC	MW & FW
E283433	2-North Portal Sump (Adit Sump)	2NPS	MW
E207412	2-North Pit Sump CCR Cover	WP	PAG-CCR Water Cover - MW
E292126	South Dyke Sump	SDS	MW
	South Coal Mine		
E218582	Settling Pond #1 Decant	SPD	**Discharge (MW)**
E217014	Culvert, Downstream End at Access Road	SPC	MW & FW
E217015	South Pit Main Sump Water	3S	PAG-CCR Water Cover (MW & FW)
E292127	2-South Pit In Pit Water Cover (2-South Standpipe)	2S	PAG-CCR Water Cover (MW & FW)
E292128	1977 Bulk Sample Pit	3S77	MW & FW
E292129	Culvert Downstream of 4 South Access Road	4S-Lo	MW & FW
	7-South Mining Operation		
E292069	7-South Surface Decant	7SSD	**Discharge (MW & FW)**
E292110	7-South Adit Sump	7SPS	MW
	Seep Monitoring Sites		
E292131	Long Lake Seeps	LLS & LLSM	GW / MW
	Culvert that collects groundwater and Coal Main logging road water entering MQL (PDSR)	PDSR	GW / SW
	Receiving Environment Monitoring Sites - Near Initial Zone of Dilution (NIDZ)		
Near Initial Dilution Zone (NIDZ) Monitoring Sites			
E292130	Long Lake Entrance (South end water entering Long Lake)	LLE	NIDZ
E292109	Road Crossing Bridge on Stream 1 above the Lower Wetland (Downstream of 7SSD).The site name is Stream 1, 7S.	7S	NIDZ
	Receiving Water (Rivers & Lakes Monitoring Sites) 5 in 30 Monitoring Locations		
North Coal Mining Operation			
E0126402	Quinsam River at Argonaut Road	WA	FW
E206618	Middle Quinsam Lake Centre	MQL (1, 4, 9 & 1m from Bottom)	FW
E0900504	Outflow from Middle Quinsam Lake	WB	FW
South Coal Mine			
E217018	No Name Lake	NNL (1, 4, 9 & 1m from Bottom)	FW
E217017	No Name Lake Outlet	NNO	FW
E206619	Long Lake at Centre	LLM (1, 4, 9 & 1m from Bottom)	FW
E219412	Long Lake Outlet	LLO	FW
7-South Mining Operation (Areas 1 to 4)			
E286930	Quinsam River Upstream of 7-South Mining Operation	QRDS1	FW
E292113	Quinsam River Downstream of 7-South Mining Operation	7SQR	FW
E292112	Lower Wetland Outlet at the confluence of the Quinsam River	LWO	FW
E292118	Lower Quinsam Lake Centre	LQL (1, 4, 9 & 1m from Bottom)	FW
7-South (Proposed) Area 5 Mining Operation			
E297230	Iron River upstream of mining operations	IR1	FW
E297231	Iron River upstream of 7SA5	IR6	FW
E297232	Iron River downstream of 7SA5 and 242 inputs	IR8	FW
E299256	Quinsam River downstream of confluence with Iron River	IRQR	FW
E292118	Lower Quinsam Lake Centre	LQL (1, 4, 9 & 1m from Bottom)	FW
Block 242 Mining Operation (Reclaimed / Not Monitored)			
E225798	Iron River upstream of the 242 influence	Not Monitored	FW
E225808	Iron River downstream of the 242 influence	Not Monitored	FW
N/A	Old portal sump used for collection of water from underground	Reclaimed	FW / GW
Long Lake Seep Passive Treatment System			
N/A	Groundwater well (2-South Mine Pool) influent to the treatment system	QU11-11 (INF-EFF)	MW
N/A	Bio Cell Reactor	BCR-EFF	MW
N/A	Sulphide Polishing Cell	SPC-EFF	MW
N/A	2-South Inflow	2SI	MW
N/A	Aeration Lagoon	AL-EFF	Not in use
N/A	Settling Pond Effluent	SP-EFF	Not in use

*** MW= Mine Water, FW= Freshwater, GW =Groundwater NIDZ = Near Intial Dilution Zone**

2.1 Mine Related Discharge

2.1.1 *The North Water Management System*

The north water management system (NWMS) is designed to collect mine related runoff from the north disturbed surface areas and pumped water from the 2-North, 5-South and 7-South underground mine operations. This system includes catchment sumps and ditches, pipelines, a subaqueous storage facility for potentially acid generating (PAG) coarse coal reject (CCR) and Settling Pond # 4 (SP4/WD) EMS #E207409.

The 2-North Mine is dewatered through a network of pump systems. These include 1 Mains 2-North (1M2N), 5 Mains 2-North (5M2N) and 3 Mains 2-North (3M2N). Table 2 below describes the underground pumps systems and Figure 1 describes the 2-North pumping network.

Table 2: 2-North Pump System

Area	Type of Pump	Pumping capacity gallons /min (GPM)	Total Pumping Capacity
1M2N #1	1 x 125 hp	750 (Failed November 30, 2020 replaced April 10, 2021)	750
5M2N	1 x 125 hp	750 (Failed February 2020 replaced March 25, 2021)	750
3M2N	2 x 250 hp	1000	2000
Contingency			
3M2N	1 x 250 hp & 3 x 58 hp	4000 (requires testing)	4000

Based on the hydrogeology of the area and depth of mine workings, the 2-North mine requires dewatering. The 1M2N and 5M2N pumps operate at dewatering the 1 Mains and 5 Mains areas of the 2-North flooded mine voids in order to:

- protect underground electrical equipment
- mitigate potential seepage from subsidence features
- control underground water levels for a future restart

In February 2020, the 5M2N dewatering pump failed and on November 30, 2020 the 1M2N dewatering pump failed. 1M2N and 5M2N were equipped with 200-hp, 600-volt, 3-phase submersible deep well pumps capable of pumping 750 gallons per minute each. Both 200 Hp pumps in 5M2N and 1M2N were replaced with 125 Hp pumps at the end of March early April 2021.

The 3M2N pumping network was used as the backup system for dewatering the mine pool until the failed pumps could be replaced. Additional systems in 3M2N were installed as contingency to dewater portions of the mine that are hosting operations and are used intermittently as required.

There were 3 x 58 Hp and 1 x 250 Hp pumps installed for contingency purposes to convey water from the old 3-Mains areas and overflow from 1-Mains and 5-Mains out of the mine. Collectively these pumps can dewater that section of the mine at a rate of approximately 6000 GPM.

In December 2017, the combined 5-South and 7-South mine water and the South Dyke Sump (SDS) was redirected into two boreholes in 3M2N mine area. On January 3, 2022, the 5-South Mine pump failed and has not been replaced. The mine will be allowed to flood to near pre-mine groundwater conditions. 3M2N water is dewatered to surface and received at Settling Pond #4 or 2-North subaqueous PAG-CCR facility. SDS collects seepage water from the south side of the tailings dam and pumps it back 3M2N (the seepage does not report to the Quinsam River or Middle Quinsam Lake from this location).

The 2-North subaqueous PAG-CCR facility (WP) EMS #E207412 contains waste rock from 5-South mine coal processing and is stored with at least 1.50 m of water cover to inhibit the onset of acid generation from the stowed material. This water cover is sourced from underground at either / or a combination of 1M2N, 5M2N, 3M2N or the 2-North Portal Sump (2NPS) EMS #E283433. Water is directed into the pond by opening gate values directing water into WP, maintained by QCC personnel. A permanent water cover of 1.5m is required until final reclamation of the site occurs.

Settling Pond # 4 collects gravity fed water from Brinco Brook, which includes disturbed surface runoff, tailings dam seepage, and underground water collected at 2NPS. When the gate values to Brinco Brook are open, all underground dewatering wells 1M2N and 5M2N discharges are directed into Brinco Brook mixing with the water from 2NPS and 3M2N. Settling Pond # 4 acts as the final collection point before discharge into a meadow/biomass system where it flows into a culvert at Middle Quinsam Lake road sampling location (WC) EMS #E207411, prior to entering another extensive wetland that flows into the inlet of Middle Quinsam Lake.

Settling Pond #4 encompasses approximately 2.4 ha of marshland with an average depth of 1.5 m and a storage capacity of approximately 30,000 m^3. It has been designed to receive a 1 in 10-year flood event and has an emergency spillway to prevent structure failure during extreme flood events. Water from Settling Pond #4 is pumped to the wash plant for use in coal processing. When processing 2-North coal the used wash plant water is pumped to the tailings dam at the pump site CPP collection ditch. From the tailings dam the water filters through the north and south sides of the structure into 2NPS and SDS EMS #E292126, respectively.

When processing 7-South coal, wash plant water and fine tailings are pumped directly underground to 1-Mains 2-North. Water in the 2NPS is used for underground equipment, dust suppression and emergency firefighting. Excess water in the 2NPS is conveyed with a 65 HP pump that ties into a 12-inch pipeline from 3-Mains 2-North, this pipeline extends along the 2-North high wall where it is discharged into Brinco Brook.

Below the wash plant is a natural drainage where groundwater surfaces and flows towards Middle Quinsam Lake. This area has two nested (deep and shallow) groundwater wells. This water flows towards Middle Quinsam Lake near the inlet end. Deep and shallow nested groundwater wells MW00-1 (S and D) and MW00-6 (S and D) represent the groundwater below the collection ditch, processing plant and coal pad. These wells were installed to monitor seepage from the plant site collection ditch. Historically, the plant site collection ditch was used to transport fine tailings from the processing of coal to WP, which was used as a fine-tailings settling pond, with excess water pumped into Brinco Brook and gravity feed into Settling Pond # 4. Figure 1 provides a flow chart describing the flow paths of water in the 2-North Water Management System.

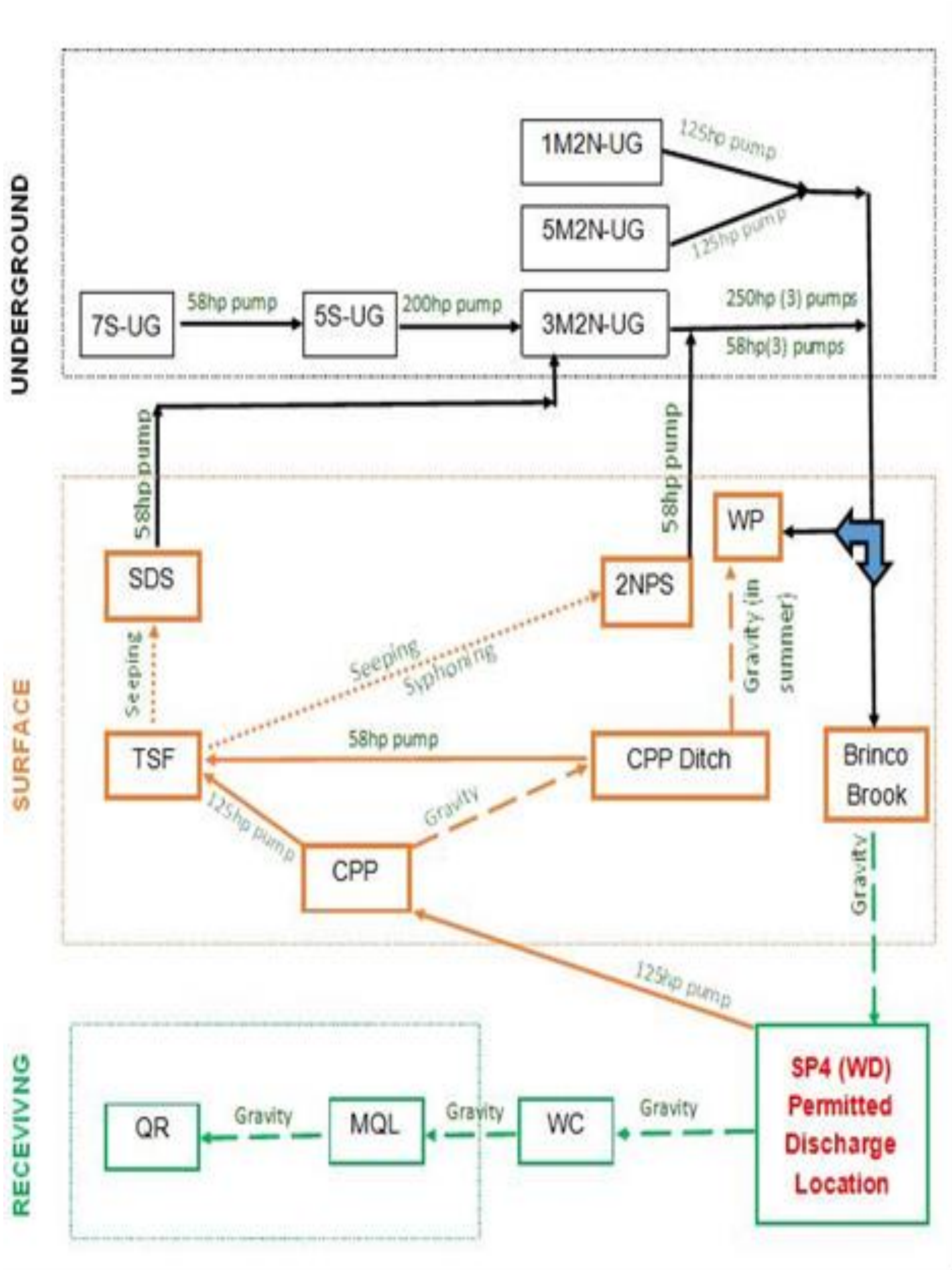

Figure 1: Water Movement and Flow Path in the North Management System

2.1.2 *The South Water Management System*

The South Water Management System (SWMS) is designed to collect mine related runoff from the south disturbed surface areas and manage water in the 2-South (2S) EMS #E292127 and 3-South (3S) EMS #E217015 PAG-CCR containment pits and Passive Treatment System (PTS).

These two permanent PAG-CCR pits have been completed as part of the SWMS. Construction of the 2S pit was completed in 2014. It includes a clay-bentonite liner to retain water within the pit and a water cover fed by a series of ditches and pipes that collect local catchment water. Surface personnel control valves to direct fresh non-mine impacted water into the PAG-CCR facility or to No Name Lake. Source water for the 2-South pit is from local catchment and the PTS. Recently (2018) the PTS discharge has been permanently diverted into the 2S pit to maintain a water cover. This maintains a water cover and inflow rate of approximately 4.5 L/s. Flow rates are recorded at the well head INF of the PTS and at the inflow and outflow of the 2-South pit. The inflow of 2-South is equipped with a V-notch weir, pressure transducer and staff gauge where weekly measurements are recorded. A minimum of 1.0 m water cover is required in the 2S pit and excess water cover overflows down a spillway (built in 2015) into a large channel that leads to the 3S PAG-CCR storage pit. Seepage from under the liner of the 2S pit is directed down the channel to 3-South pit. The 2S water cover and seepage maintains a 1.0 m water cover over the 3S pit. Continuous outflow from 2S pit is recorded at the H-Flume before water enters 3S pit.

In late January 2021 a submersible 58 horsepower pump (Hp) was installed in 2S pit. The discharge from the 2-South 58 Hp pump leads into a pipeline that ties into the existing 3-South pipeline that discharges into a roadside ditch leading to Settling Pond # 1. By reducing water levels in 2S pit below the 1.88 m outlet structure, water levels are restricted in 3S pit, mitigating any future unauthorized discharge during heavy rain events. Appendix I, Table 31 and Appendix II, Graphs 68 through 69 display the recorded inflow and outflow of the 2S and 3S areas.

Excess water in 3S is pumped via an 88 HP pump capable of pumping 500 gallons per minute directly into the roadside collection ditch that flows into Settling Pond #1 or during the summer (if required), a gate valve is opened on the highwall above the 2S pit, directing water back into the 2S pit making it a closed loop system.

Settling Pond #1 (SPD/ SP1) EMS #E218582 is the authorized discharge location and compliance point before water enters Long Lake. Settling Pond #1 encompasses 1.8 ha of wetland with an average depth of 1.5 m. An emergency overflow ditch built into the impoundment dam is located on the north end of the pond. A siphon pipeline from SP1 to the 3S pit provides an emergency source of water to maintain the 1 m cover over the 3S Pit or can be used to pump water out of the 3S pit to SP1.

The PTS is designed to inhibit flow at the Long Lake Seep by lowering the 2-South mine-pool through pumping from monitoring well QU11-11 (INF), where it is treated on surface. Previously four ponds were used. These include the Biochemical Reactor (BCR), Sulphide Polishing Cell (SPCEFF), Aeration Lagoon (AL) & Settling Pond (SP) where water passively flowed through processing. Since 2018 only the ponds BCR and SPCEFF have been operating, with the other two ponds decommissioned. Since May 2018, the treatment system discharge was directed into the 2S pit from the SPCEFF. The sample location before it enters the pit, is referred to as 2-South Inflow

(2SI). The reason for decommissioning the last two ponds was to keep the water within the authorized works and aid in maintaining a water cover over the 2S pit during the dry season.

SP1 channel leads into a series of meadow/biomass systems and combines with the surface and subsurface groundwater where it discharges at LLE near the outlet of Long lake.

Monitoring location SPC, EMS #E217014, located downstream of the 4-South pad and 4S-Lo, (does not interact with effluent from 4-South); captures SP1 discharge. The final collection point LLE (EMS #E292130) located at the downstream end of a culvert leading into Long Lake, draining a wetland that discharges approximately 50 m upstream of Long Lake near the outlet. This site is considered the edge of the initial dilution zone (IDZ) for Long Lake.

The figures below provide a flow chart describing the SWMS.

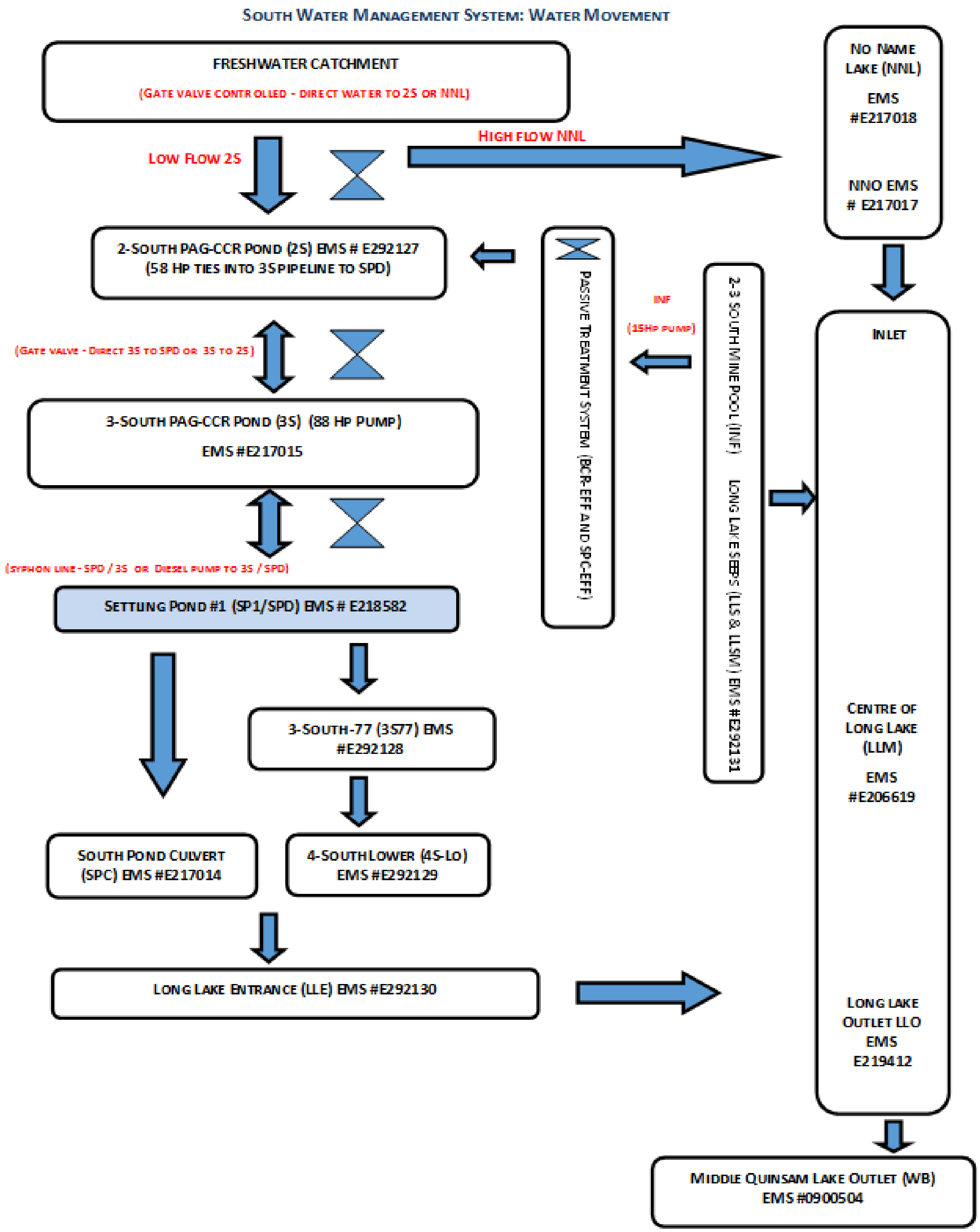

Figure 2: Water Movement & Flow Path in the South Water Management System

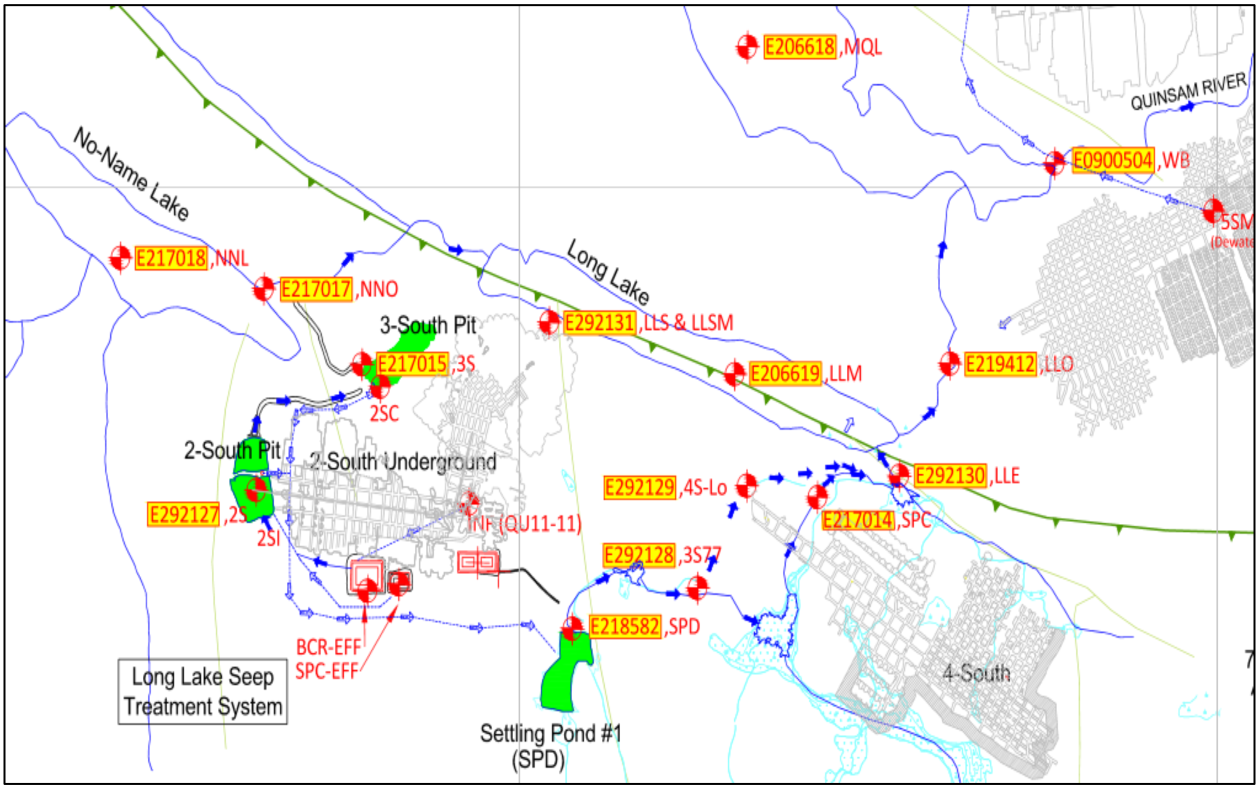

Figure 3: South Water Management System with Underground Workings

2.1.3 *7-South Water Management System*

The 7-South Water Management System includes permitted locations, 7-South Surface Decant Settling Pond (7SSD) EMS #E292069, 7-South-Adit Sump (7SPS) EMS #E292110, 7-South Containment Pond (7SCP), and receiving environment sites downstream at Stream 1 (7S) EMS #E292109, which flows into the lower wetland and monitoring location Lower Wetland Outlet (LWO) EMS #E292112 at the confluence of the Quinsam River. This system is designed to manage excess water from the 7-South catchment area and mitigate environmental impacts from disturbed surface locations affected by mining and underground activity. Water is collected and stored in three main ponds in the 7-South Mine catchment area: 7SPS, 7SCP, and 7SSD.

7SPS contains water that is collected from dewatering processes during mining activity while most of surface water from the coal storage pad is directed into the adit sump (7SPS). Water is pumped from active mining areas, 7-South Area 5 (7SA5) and 1-Mains 7-South (1M7S) and either stored in 7SPS adjacent to the portal entrance to use for dust suppression on mining equipment / fire suppression or pipelined directly into 5-South flooded mine pool at borehole QU05-13. Water levels at 7SPS are set up on an automated float system, when water levels rise beyond a desired storage capacity, excess water is pumped into the 5-South mine pool. From there water mixes with the 5-South water where it is pumped periodically into the 2-North mine at 3-Mains. 3-Mains discharges into Brinco brook which is gravity fed to Settling Pond #4 and discharges into Middle Quinsam Lake.

7SCP collects surface runoff from the 7-South surface disturbance area, local groundwater, and infiltration water from the coal pad. This pond allows suspended solids in surface water to settle before the water enters 7SSD. When this pond reaches a certain capacity, it discharges through a culvert into 7SSD. In 2015, the 7SCP was enlarged to accommodate more water. Additional pumps were placed at 7SSD and 7SCP to decrease 7SSD discharge and assist with water management. The revised system pumps water from 7SSD and 7SCP to 7SPS which pumps into 5-South Mine Pool. The pump at 7SCP runs on an automated float system where water levels are kept below the overflow channel into 7SSD.

During high precipitation events, a secondary pump can be activated to assist in pumping water to 7SPS. This pump can also be relocated to 7SSD where accumulated water can be diverted into 7SCP. This system has helped reduce discharge from this location.

7SSD is the permitted discharge location and main water collection pond for the 7-South Mine area, with a cumulative catchment of 3.14 ha. 7SSD is a settling pond that receives water from groundwater infiltrated from the surrounding hillsides and the coal storage pad. This water is monitored for quality and quantity during discharge events. Water is discharged from the pond via a 2-inch discharge line equipped with a valve to allow environmental personal to set the discharge rate based on flow rates measured at the downstream site 7S in Stream 1. An 8:1 ratio (7S:7SSD) was calculated from previous water quality data and modelling conservatively to protect the Stream 1 receiving environment. Water quality downstream in Stream 1 meets applicable guidelines with dilution ratios greater than 8:1.

Discharge from 7SSD forms the headwaters of Stream 1, monitoring location 7S is located on Stream 1 below the confluence with Stream 2 and, for the purposes of the effluent permit, is compared to British Columbia water quality guidelines (WQGs) for protection of aquatic life to evaluate potential effects on aquatic receptors at this location.

Figure 4 provides a flow chart describing the flow paths of water in the 7-South Water Management System.

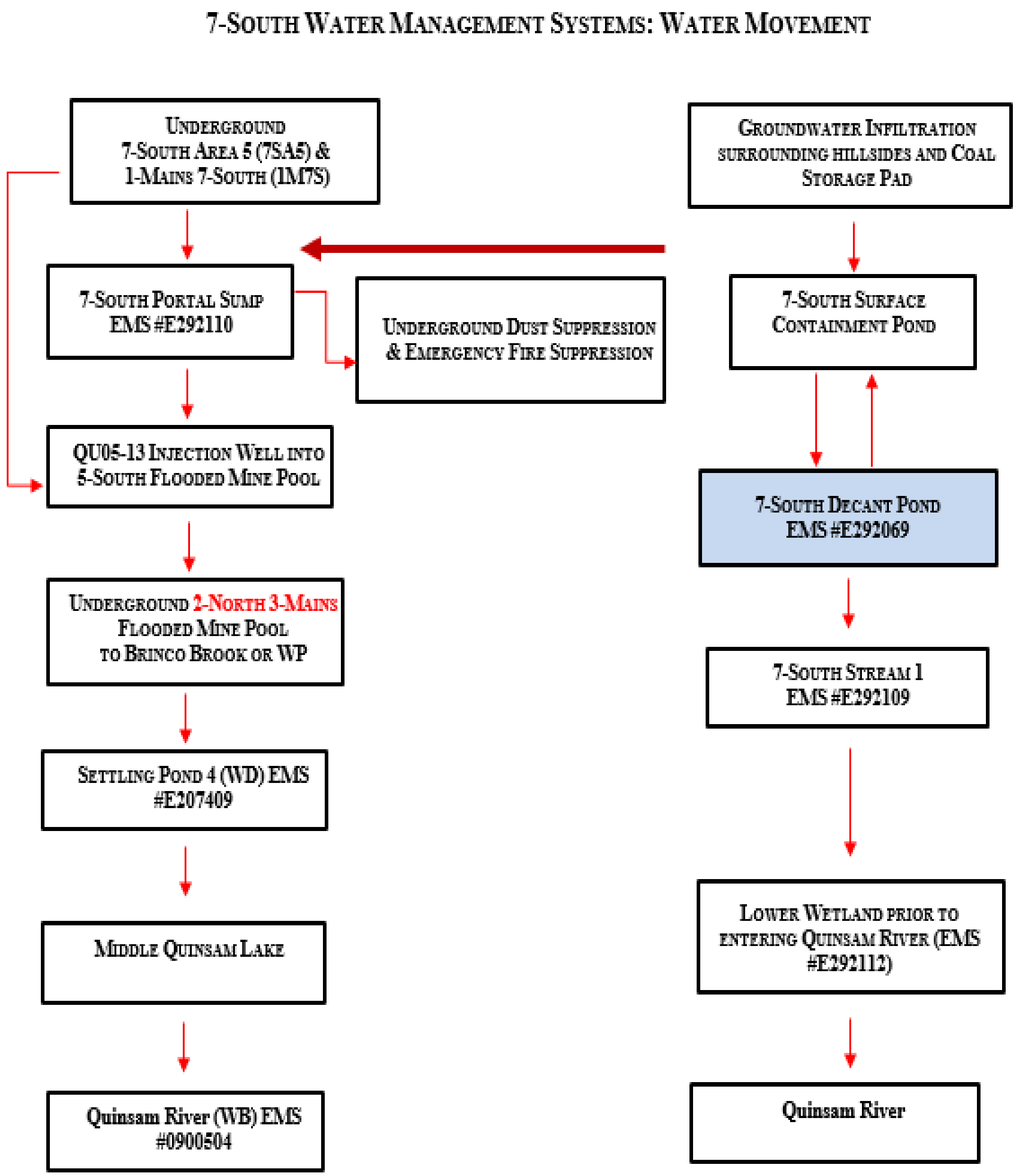

Figure 4: Water Movement and Flow Path at the 7-South Operation

2.2 Receiving Environment Sites

2.2.1 *River, Stream & Lake Monitoring Sites*

Effluent Permit PE-7008 Section 4.2.3 identifies river, stream, and lake monitoring sites that represent the receiving environment for various mine related discharge(s). Most of these sites are monitored on a 5 in 30 sampling frequency (5 events in 30 days) during the spring, summer and fall seasons. Table 3 lists the receiving water monitoring sites.

Table 3: Receiving Water (Stream and Lake) Monitoring Sites

Streams	Lakes
North Mining Operation	
Quinsam River at Argonaut Road (WA) (EMS # 0126402) Outflow from Middle Quinsam Lake (WB) (EMS # 0900504)	Middle Quinsam Lake Centre (EMS # 206618)
South Mining Operation	
Long Lake Outlet (LLO) (EMS # E219412) No Name Lake Outlet (NNO) (EMS # E217017)	Long Lake at Centre (LLM) (EMS #E206619) No Name Lake (NNL) (EMS # E217018)
7-South Mining Operation (Areas 1 to 4)	
Quinsam River upstream of 7 South Mining Operation (QRDS1) (EMS # E286930) Quinsam River downstream of 7 South Mining Operation (7SQR) (EMS # E292113) Lower Wetland Outlet at the confluence of Quinsam River (LWO) (EMS # E292112)	Lower Quinsam Lake (LQL) (EMS #E292118)
7-South Area 5 Mining Operation	
Iron River upstream of 7SA5 (IR6) (EMS # E297231) Iron River downstream of 7SA5 and 242 inputs (IR8) (EMS # E297232) Quinsam River downstream of confluence with Iron River (IRQR) (EMS # E299256)	Lower Quinsam Lake (LQL) (EMS # E292118)

River and Stream Sites in the Quinsam River Sub-Basin

- Quinsam River at Argonaut Road (WA) EMS #0126402 – Located upstream of all mine related discharges; represents background (baseline) conditions for water quality comparisons.
- Outflow from Middle Quinsam Lake (WB) EMS #0900504 – Located at the outflow of Middle Quinsam lake; represents combined discharge from North and South water management systems.
- No Name Lake Outlet (NNO) EMS #E217017 – Located at the outflow of No Name Lake; not presently influenced by surface mine related discharge in the South.
- Long Lake Outlet (LLO) EMS #E219412 – Located at the outflow to Long Lake; captures all South mine related inputs on surface and a percentage of groundwater (i.e. LLE and Long Lake Seep).
- Quinsam River Downstream Site 1 (QRDS1) EMS #E286930 – This site is located downstream of Middle Quinsam Lake Outflow (WB), the North Mining Operation and upstream of the 7-South Mining Operation; captures changes in water quality before the 7-South Mine and groundwater inputs related to mining.
- Lower Wetland Outlet at the confluence of the Quinsam River (LWO) EMS #E292112 – This site is located downstream of Stream 1 (7S); represents final surface discharge quality prior to combining with the Quinsam River.
- 7-South Quinsam River (7SQR) EMS #E292113 – Quinsam River downstream of QRDS1, LWO, and 7-South Mining Operation; captures incremental changes in water quality that may be attributed to 7-South PAG-CCR storage and flooded mine pool.

Iron River – Proposed 7-South Area 5 (7SA5) Mining Operation

- Iron River Upstream of 7SA5 (IR6) EMS #E297231 – Located upstream of any mine related activity (currently); reflects baseline conditions in an area of different geologic formation(s) and baseline water quality influences (mainly arsenic concentrations).
- Iron River downstream of 7SA5 and 242 inputs (IR8) EMS #E297232 – Downstream monitoring site on the Iron River; will be used to monitor potential influence of 7SA5.
- Quinsam River downstream of the confluence with the Iron River (IRQR) EMS #E299256 –Located downstream of all current and planned (7-South, Area 5) activities; represents the cumulative mine related discharge.

Lake Monitoring Sites

- No Name Lake (NNL) EMS #E217018– Located within the South mine development area.
- Long Lake (LLM) EMS #E206619 – Located within the South mine development area and receives water from No Name Lake, 2and 3 South flooded mine pool and 3-South Pit as groundwater and surface water (Long Lake Seep). The outlet end receives seepage from 4-South flooded mine pool, estimated at 0.14 m^3/day and south water management discharge (LLE).
- Middle Quinsam Lake (MQL) EMS #E206618 – Located adjacent to the North mine development area and receives all discharge from the North water management system and upstream (non-mine related) inputs. Long Lake flows into Middle Quinsam Lake at the south end near the outlet (WB) via a small tributary stream (LLO).

- Lower Quinsam Lake (LQL) EMS #E292118 – Located well below mine related discharge(s); reflects the combined influences of Quinsam River and Iron River water quality.

On November 1, 2019 authorization was approved from ENV for a minor permit amendment to PE:7008 to remove monitoring at certain locations and reduced the frequency of monitoring at others.

Receiving environment sites that were removed include:

- Iron River upstream of mining operations (IR1) (EMS #E297230)
- Quinsam River upstream of 7 South Mining Operation (QRDS1) (EMS # E286930) **(QCC added this site back in 2021**)
- Lower Wetland Outlet at the confluence of Quinsam River (LWO) (EMS # E292112)

Sites with the frequency of monitoring reduced included:

- Long Lake Outlet (LLO) (EMS # E219412) - reduced to 5 in 30 spring, summer and fall, only removed weekly SO_4
- Quinsam River downstream of 7 South Mining Operation (7SQR) (EMS # E292113) - reduced to 5 in 30 spring, summer and fall, removed monthly
- Quinsam River downstream of confluence with Iron River (IRQR) (EMS # E299256) - reduced to 5 in 30 spring, summer and fall, removed monthly
- Iron River upstream of 7SA5 (IR6) (EMS # E297231) - reduced to 5 in 30 summer and fall only, removed monthly and spring monitoring
- Iron River downstream of 7SA5 and 242 inputs (IR8) (EMS # E297232) - reduced to 5 in 30 summer and fall only, removed monthly and spring monitoring
- No Name Lake (NNL) EMS #E217018 – reduced to spring 5 in 30 only, removed summer and fall
- Lower Quinsam Lake (LQL) EMS #E292118 - reduced to spring 5 in 30 only, removed summer and fall

2.2.2 *GROUNDWATER MONITORING SITES*

Numerous groundwater observation wells in the vicinity of pits 2N, 1S, 2S, 3S, 4S, Block 242, and 7S are monitored. Appendix I, Table 31 lists groundwater wells, location, and geological setting of these wells. For further information refer to Appendix I, Tables 32 to 39 for water chemistry and Appendix VI, *2021-2022 Annual Groundwater Monitoring Report*. As an alternative to the 2N, 1S, 2S, 3S, 4S and 7S wells, QCC established monitoring sites at underground sumps.

2.3 ADDITIONAL MONITORING PROGRAMS

QCC conducts a diverse environmental monitoring program governed largely by the effluent permit PE: 7008. There are also additional baseline water quality monitoring programs, and in 2016, and 2020 and 2021 sediment and benthic invertebrate monitoring programs were conducted. Details are included below.

2.3.1 *BASELINE MONITORING PROGRAMS*

Quinsam conducts additional monitoring to support permit amendment efforts and to provide additional insight into water quality trends and observations. Although this information is not specifically included in this report, the data may be used in future submissions to ENV.

On August 9, 2020, an application titled "*Iron River Baseline Benthic Sampling (CABIN)*" was submitted for approval to Ministry of Environment and Climate Change Strategy (ENV) for approval addressing the permit clause 4.2.4 (i) of PE: 7008:

> *Section 4.2.4 Sediment and Benthic Monitoring Sites i) The permittee shall propose sediment monitoring locations in the 7-South Area 5 receiving environment to the Director by October 1, 2014, for approval.*

The application was approved on September 4, 2020, for the purpose of performing sediment and benthic invertebrate sampling on the Iron River using the Canadian Aquatic Biomonitoring Network approach. While the submission of proposed locations for sediment and benthic monitoring was due October 1, 2014, limited mining occurred in 7 South Area 5. The data collected represents baseline conditions relative to any impacts from mining in 7-South Area 5.

Sediment and benthic invertebrate sampling were conducted early September 2020 as per the requirements and parameters listed in permit clause 4.2.7, and at the following sites:

- EMS ID E297231 (IR6) - upstream of 7-South Area 5 potential impact(s), downstream of 4-South potential impact (s)

- EMS ID E297232 (IR8) - New "Lower Iron River" site downstream of the IRT6 and the expected inflow of the mine impacted water.

Taxonomical analysis and results are presented in Appendix IV.

2.3.2 *SEDIMENT AND BENTHIC MONITORING PROGRAM ON THE QUINSAM WATERSHED FOR EFFLUENT PERMIT PE:7008*

In September 2021 sediment and benthic invertebrate monitoring was performed at four locations on the Quinsam River in to meet condition 4.2.7 (iii) of the amended Permit PE-7008 (dated June 24, 2015). This monitoring program was designed to supplement existing sediment and benthic monitoring performed in 2016 including continues water quality monitoring. These results evaluate historical sediment and chemistry with benthic biota in the Quinsam River that receive mine impacted discharges and reference sites with similar characteristics.

In 2016 a full program was carried out as described in Appendix VI of the *2016-2017 Annual Water Quality Monitoring Report*, the sampling sites included five lakes, one wetland, and one river system (Quinsam River) for a total of twenty-three sites. Table 4 below lists the waterbody type, waterbody name and site outlined in the study.

Table 4: Sediment and Benthic Monitoring Sites

Waterbody Type	Waterbody Name	Site
Lakes	No Name Lake (NNL)	No Name Lake Inlet, NNLI (EMS # E224246) No Name Lake Deep, NNLD (EMS # E217018) No Name Lake Near Seep (EMS # E292114) No Name Lake Outlet (EMS # E217017)
	Middle Quinsam Lake (MQL)	Middle Quinsam Lake Inlet (EMS # E206901) Middle Quinsam Lake Deep (EMS # E292115) Middle Quinsam Lake Near Seep (EMS # E292116) Middle Quinsam Lake Outlet (EMS # 0900504)
	Lower Quinsam Lake (LQL)	Lower Quinsam Lake Inlet (EMS # E292117) Lower Quinsam Lake Deep 1 (EMS # E29118) Lower Quinsam Lake Deep 2 (EMS # E292119) Lower Quinsam Lake Outlet (EMS # E292120)
	Long Lake (LL)	Long Lake Inlet (EMS # E292121) Long Lake Deep (EMS # E292122) Long Lake Near Seep (EMS # E292123) Long Lake Outlet (EMS # E219412)
	Gooseneck Lake (GNL)	Middle Gooseneck Lake (EMS # 1132502)
Wetland	Lower Wetland	Lower Wetland Inlet (EMS # E292124) Lower Wetland Middle (EMS # E292125) Lower Wetland Outlet (EMS # E292112)
Quinsam River	At Argonaut Road (WA)	(EMS # 0126402)
	Upstream of 7 South Mining Operation (QRDS1)	(EMS # E286930)
	Downstream of 7 South Mining Operation (7SQR)	(EMS # E292113)

In 2021 only a partial assessment was performed on the Quinsam River due to financial restraints with the mine in care and maintenance after bankruptcy. This included a habitat assessment, collection of benthic invertebrate organisms, water, and sediment chemistry. Table 5 below lists the waterbody type, waterbody name and site outlined in the 2020 and 2021 monitoring program conducted on the Iron and Quinsam Rivers.

Sediment quality and the benthic invertebrate community in the Iron River and Quinsam River were studied to meet conditions of amended Permit PE-7008, dated June 23, 2015. The permit requires sediment and benthic invertebrate monitoring in the Quinsam River every three to five years. Baseline monitoring is required once, prior to mine development, on the Iron River. Studies were conducted in 2020 (Iron River) and 2021 (Quinsam River) to meet these permit conditions. Additional sediment sampling was conducted at a potential seep location to investigate probable inputs from mine-affected groundwater to the Quinsam River.

Results of the study are provided in Appendix X and summarized below.

Table 5: 2020 and 2021 Sediment and Benthic Monitoring Sites

Waterbody Type	Station Name	Site
Iron River	Iron River Upstream of 7SA5 (IRN-06)	IR6 (EMS # E297231)
	Iron River downstream of 7SA5 and 242 inputs (IRN-08)	IR8 (EMS # E297232)
Quinsam River	Argonaut Road (WA)	WA (EMS # 0126402)
	Upstream of 7 South Mining Operation (QRD-02) and (QRD-03)	QRDS2 and QRDS3
	Downstream of 7 South Mining Operation (7SQR)	7SQR (EMS # E292113)

In the Iron River, baseline sediment, water quality, and benthic invertebrates were monitored in September 2020 at locations upstream (IR-06) and downstream (IR-08) of the proposed mining to meet condition 4.2.7 (i) of the amended permit. Mining at the proposed mine 7-South Area 5 has since been suspended.

In the Quinsam River, sediment, water quality, and benthic invertebrates were monitored in September 2021 at four locations to meet condition 4.2.7 (iii) of the amended permit. This program was designed to supplement data collected at three of the locations in 2016. The 2021 program was conducted to evaluate conditions in the Quinsam River in areas that receive mine impacted discharges and compare results with reference locations with similar characteristics. Sampling station WA is located upstream of mine related inputs at Argonaut Bridge on the Quinsam River. Stations WRD-02 and QRD-03 are located downstream of mine related discharge from mining operations (2-North, 2-South, 4-South and 5-South). Station 7SQR is located further downstream of mine related inputs from 7-South Mining Operation. Sediment samples were also collected at a seepage area identified near the Quinsam River (station S2) that was assumed to contain mine-affected groundwater. The seepage area is located near QRD-02, downstream of Middle Quinsam Lake and upstream of 7 South Mining Operation.

Sediment

Sediment samples were collected using a spoon to remove fine sediment from around boulders and other slow flowing areas, within the surface 10 cm of sediment. Typically, five replicate samples were taken at each station, with additional split samples collected for quality assurance/quality control. Samples were analyzed for total moisture, particle size, total organic carbon, paste pH, total sulphur, total metals, and polycyclic aromatic hydrocarbons (PAH). Results for metals and PAH were compared to Canadian Council of Ministers of Environment (CCME) sediment quality guidelines: the interim sediment quality guidelines (ISQG) and probable effects levels (PEL) (CCME 2017). “The ISQG reflects the concentration below which adverse biological effects are expected to occur rarely. The PEL defines the level above which adverse effects are expected to occur frequently” (CCME 2001).

In sediment, the following parameters of interest (POI), which exceeded ISQG or PEL in one or more samples, were identified: arsenic, copper, iron, naphthalene, 2-methylnaphthalene, acenaphthene and phenanthrene. The Iron River stations had low PAH levels (with some parameters exceeding the ISQG), arsenic concentrations higher than the PEL (reflecting the sedimentary stratum with elevated arsenic), and cadmium, chromium, copper, and zinc concentrations higher than the ISQG in some samples. The Quinsam River stations had low PAH levels (with some parameters higher than the ISQG at QRD-02 and QRD-03), arsenic concentrations higher than the ISQG, and isolated occurrences of copper and cadmium higher than ISQG. Arsenic concentrations were highest at QRD-02, with some values higher than the PEL. The seep sample S2 had notably elevated arsenic concentrations (more than 400 times the PEL), along with elevated iron and manganese concentrations compared to the river stations.

Benthic Invertebrate Community

Benthic invertebrates and stream habitat data were collected following the procedures of the Canadian Aquatic Biomonitoring Network (CABIN), a biomonitoring program for assessing the health of freshwater ecosystems in Canada. Benthic invertebrate communities provide an indicator of the health of that water body. Taxonomic data were analyzed using the Reference Condition Approach (RCA) and for community metrics using the CABIN data analysis tools. The data were analyzed using the Preliminary BC Coastal RCA Model (2010) (the Model). Abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), known as the EPT group, is of particular interest as they are known as pollution-sensitive organisms, associated with clean water (coarse substrates, well oxygenated, low organic enrichment).

On the Iron River, the RCA model results and individual metrics (family richness, EPT richness, EPT predominance) indicate the river supports a variety of insect taxa that indicate good habitat conditions. The benthic invertebrate communities were similar to the Preliminary Coastal BC RCA model Reference Group 2 reference condition (invertebrate communities at undisturbed sites).

On the Quinsam River, the RCA model results at the four stations indicate the invertebrate communities differ from the Reference Condition for the assigned Reference Group 3. However, the communities are abundant, diverse, and dominated by EPT taxa. The difference from the assigned Reference Group may be associated with factors other than the mine. Potential influence of Quinsam Mine is detected in the invertebrate community metrics at QRD-02, but by station 7SQR, the community improves to conditions better than at station WA.

2.3.3 *Passive Treatment System (PTS)*

The Passive Treatment System (PTS) consists of a series of treatment cells designed to receive mine-water pumped from the 2-South underground workings to reduce POI's concentrations including dissolved sulphate and iron. This system was initiated as part of a remediation plan to limit localized mine-water seepage on the south-side of Long Lake as a result of subsidence caused by mining within close proximity and establishing an evident hydrologic connection.

The PTS continues to demonstrate reduction in sulphate concentrations throughout the system. Higher reduction is observed during warmer conditions, with reduction efficiencies upwards of 300 mg/L or 50% presented during optimal performance times. The addition of molasses (carbon source) has shown some capability to increase performance within the system but due to the viscosity of the molasses the injection system requires continuous replacement of pumps. As a result, has been discontinued until a different system in designed.

2.4 Maintenance & Reclamation Activities

To ensure proper functioning of site wide water management systems, haul roads, roadside ditches, catchment ditches, ponds, culverts, pumps, and water lines are maintained on a routine basis. Regular maintenance activities include removal of debris from culverts, replacement of silt fences and straw bales, and removal of sediment build-up from catchment ditches and ponds. Pumps and water lines are inspected daily and maintained as part of the surface inspection. Maintenance and repair occurred within the water management systems of the North and South Water Management Areas.

2-North Underground Water Management

Both the 5M2N and 1M2N well pumps were replaced. The 5M2N was installed on March 25, 2021 and 1M2N was replaced April 13, 2021. Trees were removed from under the powerlines in August through September.

South Water Management

Trees were removed from under the powerlines in August through September. Due to extreme fire hazard in 2-South area next to the power lines power was isolated and shut off in 2-South resulting in the 15-horsepower pump in borehole QU11-11 (INF) powered off from August 11 to September 20 (41 days).

Reclamation

There were no reclamation activates completed during 2021 (see the *Annual Reclamation Report for 2021, Mines Act Permit Number C-172* for further details).

3.0 CHEMICAL REAGENTS AND WASTE STORAGE

Waste oil and solvents are stored in sealed containers or tidy tanks at secure locations and removed from site for recycling by Terrapure Nanaimo. Scrap metal at the mine site is collected in designated containers and recycled. There were no waste oil / solvents removed from site or metal recycled in 2021-2022.

4.0 INCIDENTS - PERMIT LIMIT EXCEEDANCES & PERMIT NON-COMPLIANCES

Please refer to Appendix 1, Table 2 for a summary of all permit limit exceedances (P) and permit non-compliances (PNC) specific to missed samples, parameter analysis, and missing flow data. Appendix VII provides the non-compliance reports. All spill and excursion reports were submitted to the Environmental Compliance website at: environmentalcompliance@gov.bc.ca. Spill reports are available in Appendix VII.

4.1 POTENTIAL SEEPAGE AREAS

In 2021 January to March the water table in 2-North Mine (aquifer recharge zone) increased to an elevation approximately 243.7 masl. The ground elevation at well QU11-09 is 226.3 masl. This caused the well which is an open borehole to underground flooded mine void in the River Barrier Pillar to become artesian and discharge mine water into the Quinsam river. It is estimated that this occurred from January 2021, until March 19th, 2021, when discovered. The well was capped, and remaining discharge was directed into a sump where water was collected and discharge to river was stopped. The underground dewatering well pumps (1M2N and 5M2N) were both replaced by the beginning of April 2021. Water levels decreased daily and by April 30th, 2021, the mine pool was reduced below 226.63 masl from 243.7 masl.

When the water table declined a potential seepage area (S) was discovered along a natural flow path leading into the river. It has been suspected that the seepage is mine impacted shallow groundwater. This area has been monitored intermittently since it was discovered in 2021 for water quality and quantity.

In September 2021 potential seepage area S2 was observed from a flow path containing iron precipitate. This was observed while preforming sediment and benthic invertebrate sampling on the Quinsam River at sampling location QRD-02 near groundwater well QU11-05. Sediment and water chemistry samples were collected.

In March another visit to the site found the flow path had increased to two flow paths referred to as (S2A and S2B) and further monitoring was initiated. During September only one small flow path existed.

The potential seepage areas (S and S2) were investigated in 2021 - 2022, to evaluate sources of seepage and potential effects on the river. Water quality and quantity was monitored throughout 2021-2022 at S and only September 2021 and March 2022 for S2.

Water quality for both potential seepage locations is summarized below and available in Appendix I, Tables 40 and 41. Table 5 displays the parameters of interest compared to BC Acute Water Quality Guidelines Freshwater Aquatic Life (WQG). Table 6 presents flow estimates for S and S2, estimated using timed bucket tests.

Monitoring results at the potential seepage area (S) display neutral pH, elevated arsenic, conductivity, and sulphate. Iron was elevated initially but has since declined to below WQG's. Total arsenic ranged from 0.0138 mg/L to 0.0748 mg/L and averaged 0.036 mg/L. Dissolved sulphate ranged from 110 mg/L to 360 mg/L averaging 210 mg/L. Annual average flow rates were 0.00164 m^3/s. Monitoring will continue to occur until the seepage stops.

At S2 water quality was found to be elevated in arsenic, conductivity, iron and sulphate. In the sediment results were elevated in arsenic and iron (refer to Appendix X).

Weirs were established at S in 2021 and S2 in March 2022 with timed measured bucket tests used to calculate water quantity. Increased monitoring on the Quinsam river was also initiated upstream and downstream at sites WB and QRDS1, respectively. In 2021-2022 monitoring year water quality in the Quinsam river has remaining below WQG's except for dissolved copper. Dissolved copper was found at highest concentrations in water quality upstream of mine influence (WA) and decreasing concentrations were observed downstream. Modeling results[2] indicate that under expected case conditions the predicted monthly contaminant concentrations in the Quinsam River remain below both chronic and acute Water Quality Guidelines.

Measured flow rates at S2 were 0.01 m^3/s and 0.0075 m^3/s collected on two occasions, March 22, and March 28, 2021. An investigation continues to be underway to determine the source of the potential seepage areas. Groundwater in these areas interacts with the No. 3 coal seam and No. 4 coal seam that sub crops at the river in both locations. The source is yet to be determined and further investigation is warranted.

[2] *2-North/3-North and 5-South Groundwater Evaluation by Lorax Environmental and Enterprise Geoscience Ltd 2011.*

Table 6: Summary Table for Potential Seepage Areas

Site Description	**Potential Seepage near QU11-09**					
Site Name	**S**	**WQG-Acute**	**Average**	**Min**	**Max**	**Count of Samples**
pH	pH Units		7.95	7.27	8.42	24
Cond-F	uS/cm		1347.78	430.3	2220	24
SO4-D*	mg/L		**209.62**	110	360	26
As-T	mg/L	0.005	**0.03562**	0.0138	**0.0748**	26
Fe-T	mg/L	1	0.4295	0.131	**1.71**	26
Mn-T	mg/L	0.8706	0.1549	0.0153	0.521	26
As-D	mg/L		0.0315	0.0117	0.0715	26
Cu-D	mg/L	≤ 0.0054	0.00063	0.0002	0.00138	19
Fe-D	mg/L	0.35	0.12859	0.0276	0.243	26
Mn-D	mg/L		0.12175	0.0061	0.516	26

Site Description	**Potential Seepage on QR near QU11-05**					
Site Name	**S2**	**WQG-Acute**	**2021/Sep/13**	**2022/Mar/08**	**2022/Mar/22**	**2022/Mar/28**
pH	pH Units		6.90	7.62	7.42	7.22
Cond	uS/cm		387	1575	1537	1309.9
SO4-D*	mg/L		160	300	380	360
As-T	mg/L	0.005	**0.0908**	**0.0402**	**0.051**	**0.051**
Fe-T	mg/L	1	**1.85**	**1.06**	**1.51**	**1.39**
Mn-T	mg/L	0.8706	0.498	0.202	0.262	0.264
As-D	mg/L		0.0375	0.0414	0.0424	0.0368
Fe-D	mg/L	0.35	0.342	**1.01**	**1.21**	**0.977**
Mn-D	mg/L		0.387	0.2	0.263	0.262

Bold indicates result is above WQG-Acute
***Dissolved Sulphate is a 30-day average**

The potential seepage areas are located near groundwater wells QU11-09 and QU11-05. The wells monitor water quality and vertical gradients downstream of the River Barrier Pillar and 2 North workings. The cross section shown in Figure 5 displays the well QU11-09 in the River Barrier Pillar. Groundwater in this area has an upward vertical seepage toward the river. The monitoring wells QU11-09 and QU11-05 are in the River Barrier Pillar area. QU11-05 (228.4 masl) is located downstream and at a similar elevation as QU1109 (226.3 masl). The seepage is not coming from the groundwater wells.

The potential seepage areas S located near QU11-09 water is percolating from the ground and follows a natural flow path entering the river. The potential seepage areas S2 discovered near

QU11-05 (at QRD-02) is at a lower elevation by the river and is also percolating from the bank and following a natural flow path into the river.

Predictions for seepage rates, expected parameter loading and water chemistry were modeled for groundwater quality, flow pathways to surface water, and projected concentrations in the Quinsam River[3]. Geochemical source terms were developed from the materials and water chemistry in flooded mine voids and groundwater quality.

Each mine area has geochemical source terms developed and predicted seepage rates expected once the mine voids have been flooded and either backfilled with PAG-CCR or Tailings. All seepage was expected to enter the Quinsam River from 2-North/3-North, 4-South, 5-South and 7-South flooded mine voids. Section 4 of the 7-South Mine Permit Amendment Application Document provides further seepage information.

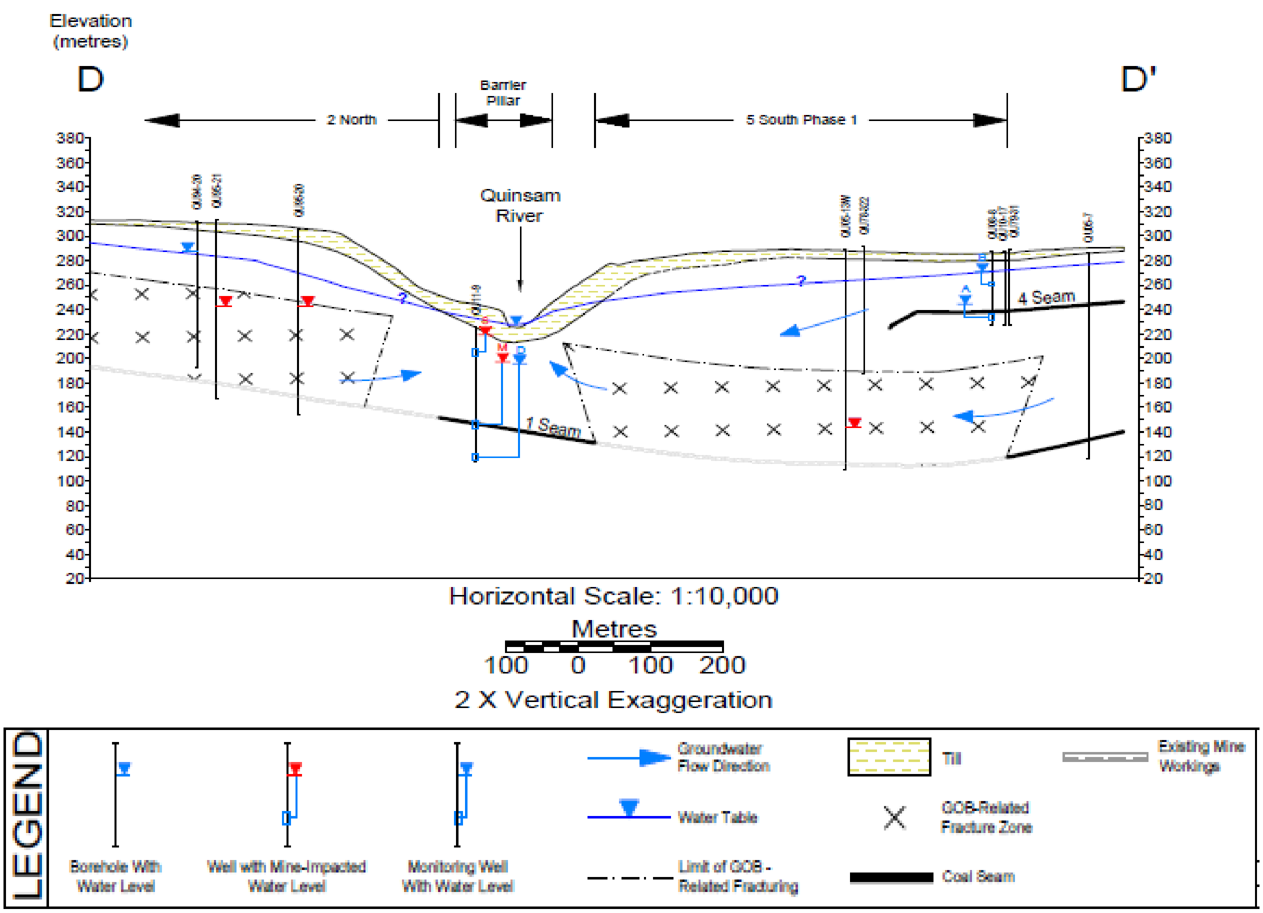

Figure 5: Cross section of QU11-09

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[3] *The influence of the geochemical characteristics of these materials (PAG tailings and PAG-CCR, primarily from 7-South) combined with the water chemistry of the mine water pools and the geochemistry of the formation rock (No. 1 Coal Zone and over-lying rock) provide the source terms for the water that will evolve and seep to the receiving environment. 2-North/3-North and 5-South Groundwater Evaluation by Lorax Environmental and Enterprise Geoscience Ltd-2011.*

Table 7 provides a summary of the seepage pathways considered for each area and the seepage rates expected Table 8 displays the actual water quantity from the seepage areas recorded in 2021-2022.

Table 7: 2-North / 3-North and 5-South Seepage Rates[4]

Mine Area	Seepage Component	Seepage Flux (m^3/d)	Travel Time[2] (years)
2-North/3-North	Horizontal	53	1.4
	Vertical[1]	36	
	Fracture Flow	131	
	Subtotal	*220*	
5-South	Horizontal	42	1.5
	Vertical[1]	2	
	Subtotal	*44*	
River Barrier Pillar	Vertical (upward)	4	3.6
Study Area	**Total**	**268**	

NOTES:
1. The vertical component of mine seepage is inferred to occur only in areas where the No. 1 coal Zone is mined above the elevation of base drainage which is assumed to be 275m (the elevation of the Quinsam River at the outlet of Middle Quinsam Lake.
2. Fastest seepage pathway.

Table 8: Flow Rates Established by Timed Bucket Tests

Site	**Possible Seepage Area 1**	**Site**	**Possible Seepage Area 2**
Flow (m^3/s)		**Flow (m^3/s)**	
Weeks	**Estimate Flow**	**Weeks**	**Estimate Flow**
26-Apr-21	0.0010	22-Mar-22	0.0100
10-Jun-21	0.0002	28-Mar-22	0.0075
06-Jul-21	0.0001		
27-Sep-21	0.0001		
05-Oct-21	0.0001		
12-Oct-21	0.0000		
20-Oct-21	0.0043		
26-Oct-21	0.0040		
03-Nov-21	0.0100		
08-Dec-21	0.0010		
14-Feb-22	0.0013		
22-Feb-22	0.0010		
01-Mar-22	0.0010		
22-Mar-22	0.0012		
28-Mar-22	0.0016		

4 *2-North/3-North and 5-South Groundwater Evaluation by Lorax Environmental and Enterprise Geoscience Ltd*

As shown in Figure 6, the observed seepage area S2 sits in a lowland area, which is outside of the mine area surrounded by 2-North mine in the North, River Barrier Pillar PAG-CCR storage 87-panel and seam 4B (lower layer of coal seam 4) subcrops in the West, and Quinsam River in the South. The area is downstream of the 2-North mine groundwater flow, north bank of Quinsam River and close proximity to the sub-crops of the coal seam 4B (Figure 6). The complicity of the structure and hydrogeology in this area makes it difficult to define the point source of the seepage based on geology and water quality.

The increased seepage rate observed from September 2021 to present is coincident with the mine pool water level increase (see Figure 7). In September the mine pool was low (water level was below the seepage elevation). The quantity of water in the flow path was minimal with iron precipitate observed. This is indicative that the seepage could be from shallow groundwater (sandstone beddings hosting the No 3 and 4 coal seams). The increased and observed iron-stained seepage area during the higher (than the seepage elevation) mine pool level is indicative of certain inputs of mine impacted water from 2-North mine pool, where PAG-CCR is stored, and the dominant lithology is siltstone/mudstone. There is no direct influence from 5-South Mine, which is separated from the 2-North mine by the engineer-designed cement plugs at 8 Mains.

The 180m wide river barrier pillar (no mining zone, 90m on each side of the Quinsam River), where the borehole QU11-05 is located, was designed by an engineer to limit the mining impact on the receiving environment.

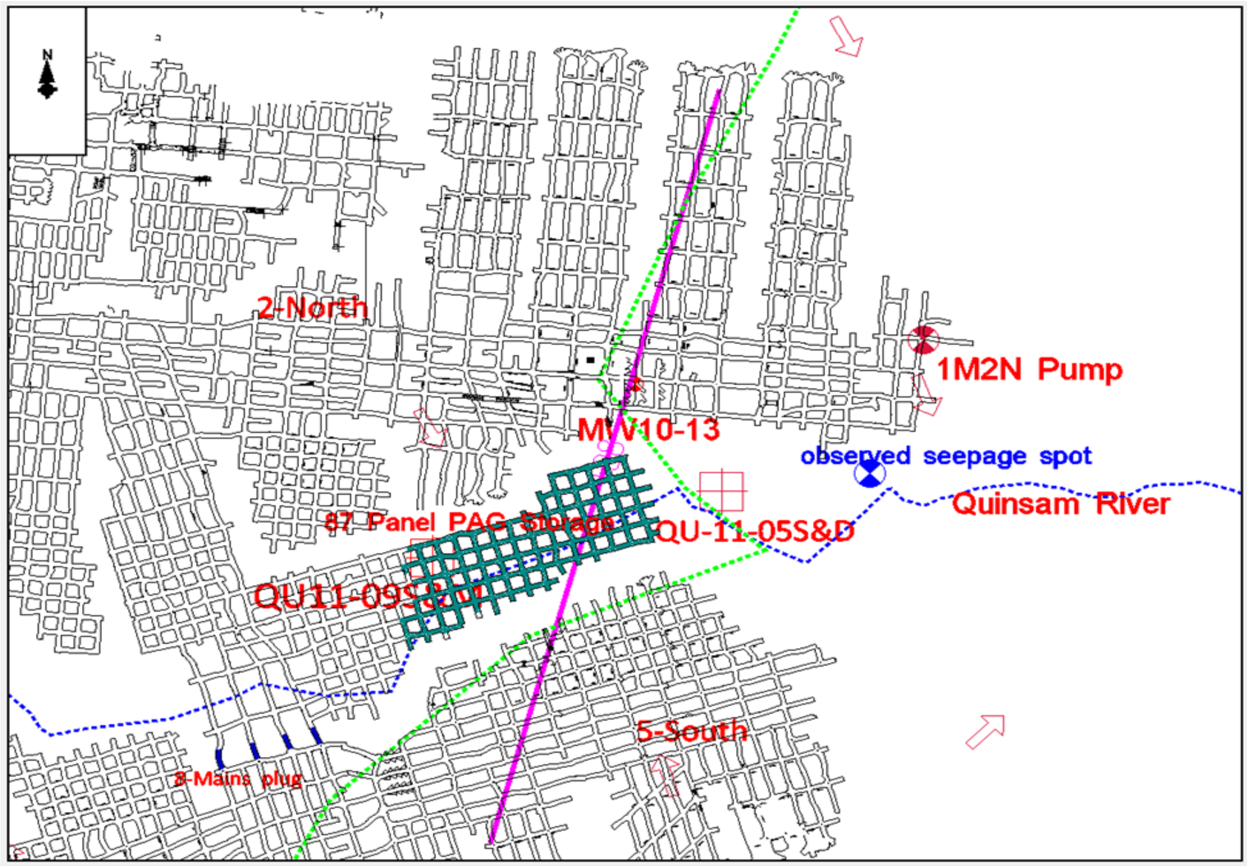

Figure 6: Plan View for QU11-05 and QU1109 Potential seepage areas (S and S2)

Figure 6 above, displays a plan view of the areas where the seepage is observed near well QU11-05 with cross section line (pink solid polyline), seam 4B subcrops (green dotted polyline), and groundwater flow (pink arrow).

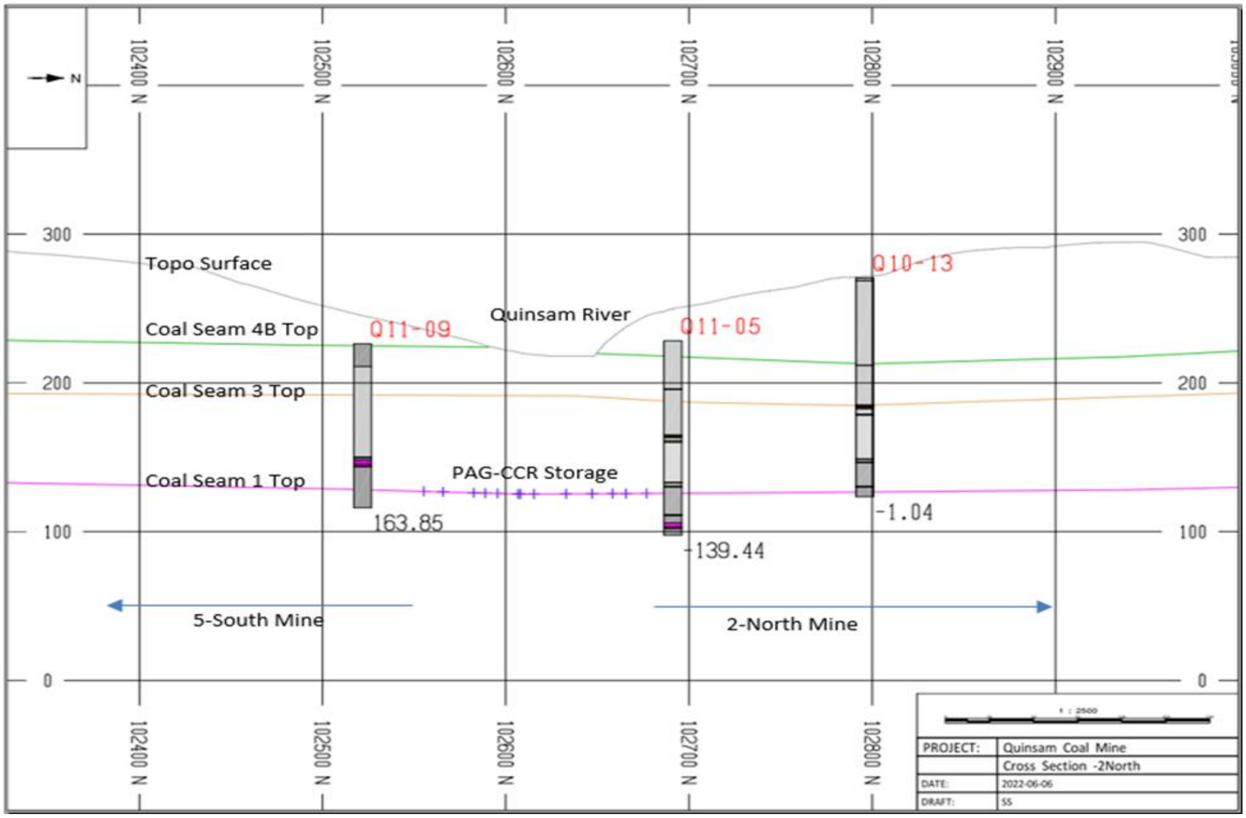

Figure 7: Cross section in North-South direction near the seepage area near QU11-09 and QU11-05

Figure 7 above displays a cross section in North-South direction near the seepage areas QU11-09 and QU11-05 at locations S and S2. The numbers at the bottom of each borehole are the distance offset from the cross-section line. Positive (negative) sign indicate borehole locates in the north (south) of the cross-section line. The PAG-CCR storage area (blue cross) is projected on the coal seam 1 top surface, where the coal was mined at 2-North. Non-arrowed polylines represent different surfaces.

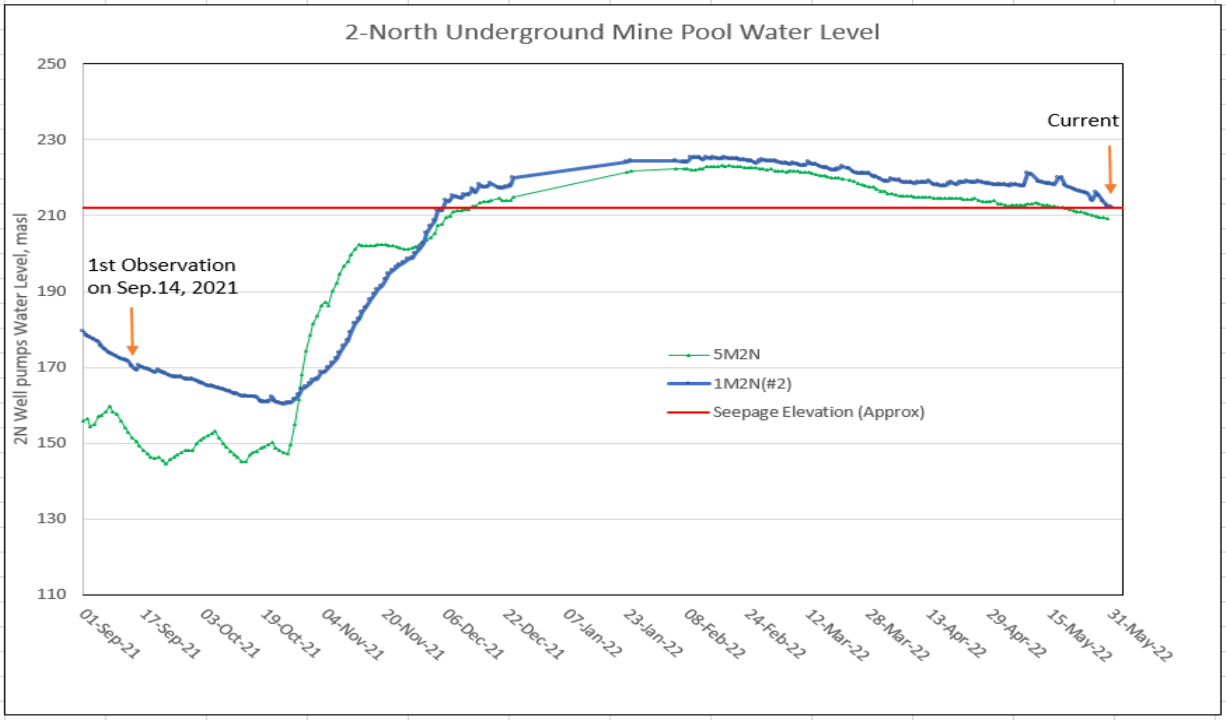

Figure 8: 2-North Underground Mine Pool Level During September 2021 to Current

Further monitoring and field investigation has been initiated by Quinsam and will continue. The seepage areas necessitate the requirement for an update to the previous model developed by Lorax 2011 with current site conditions. Refer to Section 9.2 for water quality results on the Quinsam river, Appendix II for graphs displaying trends for parameters of interest on the Quinsam River. Appendix V provides a report for the Sediment and Benthic Invertebrate monitoring program performed in 2021.

Reports submitted for this investigation include the following:

- Spill Report DGIR 204584 - March 19, 2021
- Annual Reclamation Report – March 31, 2021
- Q4 Report with follow up - April 30, 2021
- Annual Water Quality Monitoring Report - June 30, 2021
- Q1 2021 further follow up reported - July 31, 2021
- Final Report Unauthorized Discharge and seepage DGIR 204584 - September 8, 2021
- Q2 2021 further follow up reported - October 31, 2021
- Q3 2021 further follow up reported – January 31, 2022
- Q4 2022 further follow up reported – April 30, 2022
- Annual Water Quality Monitoring Report - 2021-2022

5.0 MATERIALS AND METHODS: ENVIRONMENTAL MONITORING PROGRAM

All water samples were collected in accordance with methods described in "*The British Columbia Field Sampling Manual for Continuous Monitoring of Air- Emissions, Water, Soil, Sediment, and Biological Samples*" (MOE 2013)[5]. This includes following of specified field protocols: use of field duplicates, split samples, and method blanks and checking for transcription errors.
Bureau Veritas Laboratories (BV labs) located in Burnaby B.C., a Canadian Association for Laboratory Accreditation (CALA) designated laboratory, conducted the analysis of surface, groundwater, and sediment samples. Phytoplankton samples were analyzed by Stantec Consulting Ltd. (Burnaby B.C.). Zooplankton samples were analyzed by Fraser Environmental (Surrey, B.C.). Benthic Invertebrate samples were sent to Cordillera Consulting Inc. (Summerland, B.C.).

5.1 WATER QUALITY ANALYSIS

PE-7008 identifies the parameters to be analyzed in effluent. Each site has specific requirements for parameters to be analyzed. The following parameters are generally monitored at each station:

- Total suspended solids (TSS) (mg/L)
- Total dissolved solids (TDS) (mg/L)
- pH-Field (standard units)
- Conductivity-Field (uS/cm)
- Alkalinity (mg/L as $CaCO_3$)
- Hardness (mg/L as $CaCO_3$)
- Sulphate (mg/L)
- Ammonia as nitrogen (mg/L)
- Nitrate/nitrite combined as nitrogen (mg/L)
- Dissolved Organic Carbon (mg/L)
- Total phosphorus and dissolved phosphate (mg/L)
- Total and dissolved metals (mg/L)
- Oil and grease (for sites SPD and WD only) (mg/L)
- Rainbow trout bioassays (for sites SPD, WD and 7SSD only)
- 7 Day *Ceriodaphinia dubia* chronic toxicity test (at site 7S only)

The following parameters are specific to lake sampling:

- Dissolved oxygen (mg/L)
- Temperature (Celsius)
- Oxidation reduction potential
- Biological
  - Phytoplankton (chlorophyll “a” and phaeopigment)
  - Phytoplankton (counts and identification to species)
  - Zooplankton (counts and identification to species)

[5] MOE. 2013. "The British Columbia Field Sampling Manual for Continuous Monitoring of Air- Emissions, Water, Soil, Sediment, and Biological Samples". Available at: http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/field_sample_man2013.pdf

All surface and groundwater samples were filtered through a 0.45 µm filter and most were preserved on site except for a few samples where preservation did not occur. BV Labs analyzed dissolved and total metals samples using the CCME/BC WQG analytical package to provide suitable detection limits for comparison with guidelines and as per ENV requirements. This included use of conventional and Inductively Coupled Plasma Mass Spectrometry (ICPMS) equipment.

On March 9, 2021 Quinsam removed total and dissolved mercury from all analytical requests going forward.

5.2 Environmental Monitoring Equipment

The following equipment was used to conduct the surface monitoring program at Quinsam Coal:

- ISCO 4210 flow metres equipped with a paper chart plotter and datalogger, which are connected to a sonic depth sensor to measure water height above decant (Settling Pond #1) and an ISCO signature flow metre with an ultrasonic sensor (Settling Pond #4). Both instruments use water height to determine discharge by using provided weir/orifice equations. Continuous monitoring is achieved using a datalogger and downloaded using a computer with Flow link software.
- A maidlabs technology, Flowmaid with an ultra-sonic depth sensor replaced the ISCO 4210 at Settling Pond #1
- A Sitrans F M MAG 8000 CT electromagnetic flow metre to record discharge at 7SSD.
- ISCO 12-volt automatic samplers programmed to collect daily composite samples for analysis of TSS deployed at all permitted discharge locations.
- A YSI Exo 1 multiparameter sonde and YSI Pro-Plus, to obtain physical water quality parameters, and calibrated prior to each sampling event following manufacturer specifications for maintenance and handling.
- Two handheld sondes (Oakton PC Tester 35), for routine monitoring of pH and conductivity.
- Level logger pressure transducers, used to obtain continuous water level measurements at Long Lake Outlet, Middle Quinsam Lake Outlet and the Iron River, with data used to create daily hydrographs.
- A 4-litre Beta sampler, to collect lake water samples; the sampler is constructed with materials to minimize interference cross contamination of metals and the 4 litre volume provides sufficient water for all required analyses in one deployment per depth.
- A Campbell Scientific weather site, to record temperature, precipitation, wind, humidity, solar intensity, and snow accumulation data (installed next to the 2-South pit in August 2015, became operational in October 2015).
- An Eckman grab sampler, for collection of sediment and benthic invertebrate samples.
- Hydro-lift used for collection of groundwater samples
- Portable Bladder pump used for collection of groundwater samples
- Peristaltic pump used for collection of groundwater samples

Although this list is not exhaustive, it provides an overview of the equipment used for environmental monitoring.

5.3 Quality Assurance / Quality Control

Quality Assurance / Quality Control (QA/QC) sampling followed protocols described in MOE (2016). QA/QC practices were integrated into the water sampling program to maintain the integrity, consistency, and reproducibility of sampling techniques and results of environmental monitoring. Various samples, including field blanks, trip blanks, equipment blanks, and replicates, are used to evaluate methods and identify potential issues related to sampling techniques and equipment. Each sample type serves a specific purpose:

- Field Blanks – Samples of laboratory-grade, reverse osmosis, deionized water deposited into sample containers in the same location in which a field sample is collected. These samples are carried and treated in the same manner as a field sample to assess any potential cross-contamination that may occur due to sampler technique.
- Trip Blanks – Samples of laboratory-grade, reverse osmosis, deionized water deposited into sample containers in a laboratory setting are transported into field locations with samplers to determine if any cross-contamination occurs due to the handling or storage of sample bottles.
- Equipment Blanks – Samples of laboratory-grade, reverse osmosis, deionized water placed into a piece of equipment at a sampling station to identify potential cross-contamination associated with equipment (e.g., Beta sampler), sampling procedures, or general cleanliness.
- Replicates – Samples collected at the same location and time by the same sampler using the same techniques and equipment. Replicates samples are used to assess precision for each analyte analyzed. Observed variance between replicates identifies uncertainty in sampling, environmental heterogeneity, and laboratory analysis.

Field replicate samples are collected during every sampling event, accounting for approximately 10% of analyses requested from the laboratory. One sampling event may span two or more days. The primary sampling events are:

- Weekly, monthly, and quarterly sampling for all permitted monitoring locations
- 5 in 30-day programs, three times per year for receiving environment sampling for lakes, rivers, and streams
- Groundwater wells

For all replicates collected Relative Percent Difference (RPD) values were calculated for the analytical results from the sample and its respective replicate. In accordance with the British Columbia Field-Sampling Manual, the calculation was applied as stated below:

$$RPD = Absolute\,\frac{(Sample\ Concentration - Replicate\ Concentration)}{\left(\frac{Sample\ Concentration + Replicate\ Concentration}{2}\right)}\ x\ 100\%$$

RPD calculations were only practical for results where concentrations were found at or greater than five times the reported detection limit (RDL) as there is considerable uncertainty at low levels. In addition, mathematical calculations for RPD appear exaggerated with low values where absolute differences may be relatively low. It is expected to see variation between a sample and its respective field replicate for several reasons. Some considerations include redox reactive parameters, inconsistent sample stream at sampling locations; heterogeneity of water at sampling location; the possibility of minor contaminations; laboratory sample preparation and accuracy of analytical instrument and the lab mean detection limits for the results are different to name a few. Taking these possibilities into consideration, RPD values less than 20% are deemed “acceptable” and indicate proper sampling methodology with representative results. It has been acknowledged that RPD values greater than 20% indicate a potential problem with sampling integrity whereas values greater than 50% indicate a definite problem.

Appendix I, Tables 51 to 55 display the results of the RPD calculations.

During the 2021/2022 monitoring year, there were a total of 4820 parameters analyized for replicate samples. Of the analyzed 4820 parameters in these parent samples and their replicate samples, 33 were outside the RPD limit. With 16 out of 4820 (0.33%) having a RPD greater than 20% and 17 out of 4820 (0.35%) having an RPD greater than 50%. Duplicate analyses for acidity, hydrogen sulphide and sulphide were the most common accounting for the most frequent instances of RPD greater than 20%.

The parameters that were found with an RPD greater than 50% do not seem to be displaying enough RPD magnitude to identify any issues requiring attention. Only 0.33 % of the parameters displayed an RPD greater than 50%.

Issues were raised when the parent sample and replicates were found to have two different laboratory mean detection limits reported. This occurred 5 different samples and 79 parameters. The analytical laboratories process is to report the lowest detection limit possible and only do dilution as necessary. It is recognized that having two different detection limits especially for replicated samples can reflect poor sampling techniques and/or laboratory analysis. As a response to this issue additional steps were introduced at the analytical laboratory in order to notify the lab of replicate samples for all future submissions. This will assist on ensuring that parent samples and their replicates are run at the same detection limits.

The RPD for field blank sample concentrations should not be significantly greater nor occur more frequently than for laboratory method blanks (MOE 2016). Results greater than two times the laboratory MDL are identified and investigated to determine potential contamination.

Field blank and trip blank and equipment blank results of laboratory grade deionized water were within the acceptable range for samples analyzed in 2021/2022. All results met the RPD, indicating acceptable sampling collection and handling.

Results of QA/QC review indicate confidence in the ability of QCC to collect and analyze samples that meet required accuracy and precision requirements. Internal performance audits will continue, and any identified deficiencies will be investigated to adjust sampling protocol. All employees will be kept up to date with sampling procedures and provided with any training and equipment necessary. QCC will continue to adhere to sampling practices identified in MOE (2016) and promote best practices at all locations.

A variance analyses to identify outliers is performed prior to uploading analytical data into the database. Any results outside 95% confidence intervals (within 4 standard deviations) of previous results are investigated, and if needed BV's is contacted and the results are rerun, with a new report issued that include a review of BV's internal investigation.

BV laboratory performs internal QA/QC on all sample sets that are analyzed. This is included in the laboratory report provided by BV and reviewed by QCC. The internal QA/QC performed by BV meets laboratory standards. BV internal QA/QC involves the following procedures with every sample set analyzed:

- Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
- Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
- Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Field Filtering

Since the initiation of field filtering and preserving dissolved metal samples, dissolved iron displays an increase in concentrations signifying the importance of field filtering. Mine water high in iron concentrations has the highest observed effect from the transition of laboratory filtering compared to field filtering. This is most noticeable at the Long lake seeps and other mine discharge water like 1M2N and 5M2N. These areas were perceived to have less than detection limits in most samples for dissolved iron. Once field filtering was introduced dissolved iron resulted in elevated concentrations.

6.0 HYDROLOGY

6.1 NORTH WATER MANAGEMENT SYSTEM

6.1.1 *AUTHORIZED DISCHARGE RATES AT SETTLING POND #4 (SP4/WD) E207409*

Maximum authorized rates of discharge at SP4 are 0.32m^3/s (instantaneous) and 0.08m^3/s (annual average) or 2,522,880 m^3 over a period of 365 days. Maximum discharge rates were below 0.32 m^3/s throughout the entire monitoring period. This year the cumulative discharge was calculated as 3,363,034 m^3 higher compared to last year 2,343 ,773 m^3. This is equivalent to an annual average discharge rate of 0.107 m^3/s; higher than the authorized average rate of discharge by 4% (0.08 m^3/s or 2,522,880 m^3).

Appendix I, Table 25 displays discharge rates and Appendix II, Graph 73 displays cumulative and daily discharge rates compared to the cumulative annual authorized rate of discharge. Discharge did not occur for 5 out of 365 days this reporting year (September 9 through 12 and 15).

6.2 SOUTH WATER MANAGEMENT SYSTEM

6.2.1 *AUTHORIZED DISCHARGE RATES AT SETTLING POND #1 (SP1/ SPD) E218582*

Maximum authorized rates of discharge at SP1 are 0.46 m^3/s (instantaneous) and 0.10 m^3/s (annual average) or 3,153,600m^3 over a period of 365 days. Both annual maximum flow (0.197 m^3/s) and annual average flow (0.021 m^3/s) were well below the permitted rates with the cumulative flow rate recorded as 671,751 m^3.

Discharge did not occur for 86 consecutive days June 28th through September 21, 2021, days this reporting year due to low flow rates. Daily discharge peaked in November and January due to heavy precipitation and pumping from 3-South pit and more recently 2-South pit (January 2020).

Appendix I, Table 26 displays discharge rates and Appendix II Graph 72 displays cumulative and daily discharge rates compared to the cumulative annual authorized rate of discharge. Discharge did not occur for 5 out of 365 days this reporting year (September 9 through 12 and 15).

6.2.2 *SOUTH WATER MANAGEMENT SYSTEM ENTRANCE INTO LONG LAKE (LLE) E292130*

Flow monitoring is required weekly at LLE, which discharges near the outlet of Long Lake. Discharge at LLE represents the combined flow from the South water management systems along with groundwater from the 4-South coal pad area and non-mine related surface water from the upstream wetland and drainage features. As such, this site provides cumulative flow data representing all discharges from the South water management system prior to entering Long Lake near the outlet.

Flow at LLE is well correlated with precipitation events and, historically, experiences a seasonal dry period during summer. Beaver activity occurs at the culvert in this wetland from spring to fall and as a result flow rates are sporadic when the dam is removed. Appendix I, Table 29 displays flow rates and Appendix II, Graph 68 discharge versus precipitation at LLE.

6.2.3 *SEEP MONITORING SITES, LONG LAKE SEEP (LLS/ LLSM) – E292131*

Manual flow measurements are obtained weekly at the two sites LLS and LLSM. At LLS a staff gauge is used to obtain a level at the weir. LLSM is equipped with an H-Flume, flow meter and sensor providing more accurate monitoring of seep discharge. Staff gauge measurements are obtained weekly and compared to the meter flow rates. The flow information is available in Appendix I, Table 29 and Appendix II, Graph 67. The flow recorded at Long Lake Seep's indicates a dependency on mine pool (void) water levels. As mine pool levels decrease in late spring, flow at the seep decreases substantially and temporarily ceases during summer to fall.

6.3 7-South Mining Operation Decant (7SSD) - E292069

The maximum authorized discharge from settling pond 7SSD is 0.005m^3/s (5 L/s). However, discharge is dependent on assimilative capacity of Stream 1 (7S) and, therefore, dynamic in nature. To facilitate determination of the appropriate discharge level at 7SSD, a flow rating curve was developed for monitoring site 7S (Figure 9) to allow instantaneous flow levels at 7S to be measured by reading the installed staff gauge.

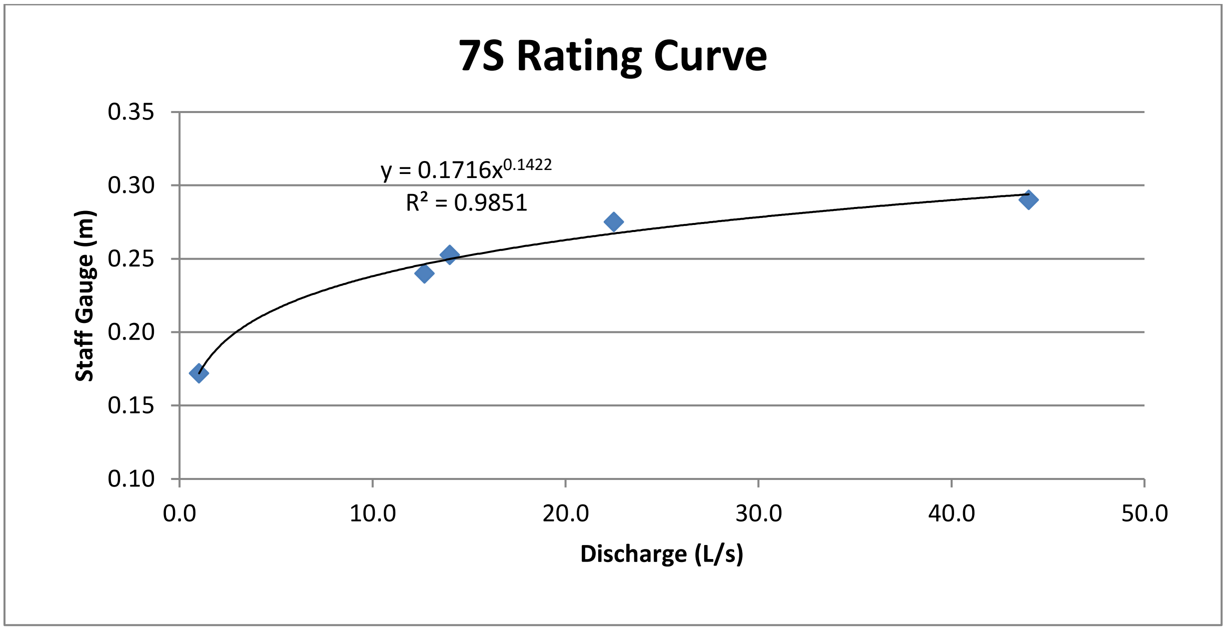

Figure 9: Monitoring Site 7S Stage Discharge Curve

Initially, an 8:1 dilution ratio was identified to maintain desirable water quality in the receiving environment, monitored at downstream site Stream 1 (7S). However, throughout the 7-South operational period, a lower dilution ratio has been shown to allow WQG's to be met in the receiving environment (site 7S). The dynamics of this system are still being monitored and measured; as a longer-term dataset is developed, the information will be evaluated to optimize discharge rates, while continuing to protect aquatic life.

In 2015, modifications were made to minimize discharge from 7SSD. The containment pond (7SCP) that delivers water into 7SSD was enlarged to accommodate more water. Additional pumps were placed at 7SSD and 7SCP to decrease 7SSD discharge and assist environmental personnel in water management. The revised system pumps water from 7SSD and 7SCP to 7SPS. The pump at 7SCP runs on an automated float system where water levels are kept below the overflow channel into 7SSD. During high precipitation events, a secondary pump can be activated to assist in pumping water to 7SPS. This pump can also be relocated to 7SSD, where any accumulated water can be diverted into 7SCP. This system does not eliminate all discharge from 7SSD but substantially reduces discharge frequency and aids in management during times of heavy precipitation.
No discharge occurred during 2021-2022, Appendix I, Table 27.

7.0 RECEIVING ENVIRONMENT HYDROLOGY

Hydrometric stations in the receiving environment monitor hydrological conditions at key locations affected by QCC operations. Stage discharge curves for these stations have been developed using various methods (e.g. staff gauge, pressure transducer, manual measurements) and are periodically updated to ensure that the full range of flow is captured. The information is used to evaluate water quality and, in turn, determine assimilative capacity of the receiving environment with respect to mine related discharge. Moreover, flow is well correlated with lake flushing and turnover events, which directly influence concentrations of certain parameters (e.g. sulphate).

Flow data for WA is obtained from the Environment Canada monitoring station "Quinsam River at the Argonaut Bridge"; the data is currently subject to revision and has not been approved. The flow for WA is controlled upstream by the BC Hydro diversion dam to Gooseneck Lake; therefore, the volume of water diverted for hydro generating purposes influences flows at WA and WB. Accordingly, water levels at these two stations are not as closely correlated with precipitation as they are for other receiving environment stations.

Flow monitoring stations on the Iron River, Stream 1, and Long Lake system(s) are directly influenced by precipitation and the hydrographs typically show a pronounced peak following a precipitation event. This increase generally represents additional dilution and, therefore, assimilative capacity (for most parameters) in the receiving environment.

Appendix I, Table 29 Appendix II, Graphs (65 to 71) display flows compared to water level measurements and precipitation for the receiving environment hydrometric stations (WA, WB, LLO, 7S and IR8).

8.0 WATER QUALITY: IN-SITU MINE RELEASES & WATER MANAGEMENT SYSTEMS

This section presents results of the 2021/2022 water quality monitoring program for the North, South, and 7-South in-situ (within) mine releases and water management systems for the major monitoring locations (e.g. settling ponds, discharges), permitted parameters and parameters of interest, to provide context for evaluating receiving environment water quality. The data for all in-situ mine monitoring stations are presented throughout Appendix I of the Tables section.

Appendix I, Table 50 provides a five-year statistical summary (year over year, minimum, maximum, average, median, geometric mean, count, count < detection limit (DL), standard deviation, first quartile, third quartile and standard error) for 27 parameters measured in the settling ponds, applicable receiving environment monitoring stations, and ex-situ groundwater wells. Monitoring years 2017 to 2021 are presented, where data is available. Table 7 below lists the monitoring stations, parameters, and statistics included in this evaluation.

For a summary of permit limit exceedances please refer to Appendix I, Table 2 and Appendix VIII to review the Annual Status Form prepared for PE-7008.

Table 9: List of Monitoring Stations, Parameters and Statistics

Monitoring Stations		
WA	LLS	
WD	LLSM	QU0813A
MW001D	MW002	QU0813B
MW001S	QU1009D	QU0821GD
MW006D	QU1009S	QU0821GS
MW006S	SPD	QU1010D
WC	LLE	QU1010S
MQL1	LLM1	QU1011D
MQLB	LLMB	QU1011S
NNL1	LLO	QU1105S
NNLB	WB	QU1109S
NNO	7SSD	7SQR
Parameters		
Arsenic (As-T)	Iron (Fe-T)	Lead (Pb-T)
Arsenic (As-D)	Iron (Fe-D)	Lead (Pb-D)
Aluminum (Al-T)	Manganese (Mn-T)	Sulphate (SO4-D)
Aluminum (Al-D)	Manganese (Mn-D)	Zinc (Zn-T)
Alkalinity (Alk-T)	Mercury (Hg-T)	Zinc (Zn-D)
Cadmium (Cd-T)	Mercury (Hg-D)	Phosphorous (P-T)
Cadmium (Cd-D)	Hardness (Hard-T)	Phosphorous (P-D)
Copper (Cu-T)	Nickel (Ni-T)	Nitrate & Nitrite combined (N-NO2,3)
Copper (Cu-D)	Nickel (Ni-D)	Ammonia Nitrate (N-NH3)
Statistics		
Count	Geometric Mean	1st Quartile
Minimum	Count <DL	Median
Maximum	Standard Deviation	3rd Quartile

8.1 North Water Monitoring Sites

The 2-North mine pool could be considered a large reservoir with different chambers hosting a variety of geochemical water quality. The 2-North mine system holds fresh water from perched water tables above the mine that interact with exposed mine walls at 5-Mains. 1-Mains 2-North holds 7-South tailings from processing of 7-South coal and 3-Mains holds a mixture of water from flooded 5-South mine pool (5SMW), dewatering of the 7-South mine and tailings dam seepage collected at SDS.

Mine water from 7-South Area 5 (7SA5) is directed into the underground sump 1-Mains 7-South (1M7S). From here water is pumped into the 7-South portal sump (7SPS) where it mixes with surface water in the sump or is pumped directly into the flooded 5-South mine pool at borehole (QU0513). From the 5-South mine, water is pumped via a 6-inch pipeline directly into 3-Mains 2-North mine and includes water from the SDS. Water collected in the 2NPS is a mixture of 1-Mains 2-North and tailings dam seepage. 2NPS discharge line ties into the 3-Mains pipeline and discharges into Brinco brook.

Brinco brook also collects discharge water from underground dewatering wells 1-Mains, 2-North (1M2N) where 7-South tailings are injected and 5-Mains #2 (5M#2) where flooded workings are dewatered. Both wells dewater the flooded mine pool of the 2-North mine.

All discharge water pumped into Brinco brook is sampled on a monthly or quarterly basis from the well heads and portal sumps. These sites include: 2NPS, 1M2N, 5M#2, 5SMW, 7SA5, 1M7SA5 and 7SPS (Appendix I, Tables 32 to 35). Geochemical source terms were derived for specific areas and modeled with different scenarios where mine water interacts with tailings or flooded mine pools. This is discussed in more detail in Appendix (VI) Annual Groundwater Monitoring Report.

Discharge water quality from Brinco brook forms the headwaters for Settling Pond # 4 where water quality is compared to permit limits and source terms derived for this site. The two primary permitted monitoring locations in the North water management system are located at Settling Pond #4, (SP4) sedimentation pond decant (WD) EMS #E207409 and the final discharge point above Middle Quinsam Lake, (WC) EMS #E207411. Results for WD and WC including additional monitoring locations in the North mine area are provided in Appendix I, Tables (6 - 9).

8.1.1 *Settling Pond #4 (WD) EMS #E207409*

Results for the 2021/2022 monitoring program demonstrated that water quality for all permitted parameters were within permit limits listed in Table 8. Appendix I, Tables 5 and Appendix II Graphs 1 through 10 provide water quality results for Settling Pond #4. On November 1, 2019, authorization was received from ENV to reduce daily composite TSS sampling to weekly and incorporate dissolved metals monthly. Table 9 displays the list of permitted parameters and the limits applied.

Table 10: Permit Limits Applied to Settling Pond #4

Parameters	Limit	Unit
Total Suspended Solids (daily composite)	25	mg/L
Total Suspended Solids (hourly composite)	35	mg/L
pH	6.0-8.5	mg/L
Ammonia (as N)	1.0	mg/L
Phosphorus (as P)	0.03	mg/L
Oil and Grease (total)	10	mg/L
Aluminum, dissolved	0.5	mg/L
Copper, dissolved	0.02	mg/L
Iron, dissolved	0.3	mg/L
Lead, dissolved	0.05	mg/L
Zinc, dissolved	0.1	mg/L
Rainbow Trout Bioassay (*Oncorhynchus mykiss*)	No mortalities at 100% effluent concentration after 96 hour	96LC50

8.1.2 *General Parameters*

pH

Field pH values displayed little variance, ranging and remained within permit limits. The water is pH neutral to alkaline. Appendix II, Graph 3 displays the pH values.

Total Suspended Solids (TSS)

Observations with respect to precipitation, dewatering system operations, pond turbidity in Brinco brook and WD, concentrations of TSS and metals will continue to refine best practices and minimize TSS concentrations in WD. TSS was below permit limits the monitoring period.

Hardness and Dissolved Sulphate

Total hardness ranged from 375 mg/L to 647 mg/L (averaging 539 mg/L), while weekly sulphate ranged from 340 mg/L to 1000 mg/L (averaging 706 mg/L). Sulphate concentrations were variable throughout the year with peak concentrations occurring in June associated with the pumping from underground and lowest concentrations were observed in February through March when surface discharge and dilution is greatest. Sulphate continues to be the primary parameter of interest from mine related discharges, as it is a common and traceable parameter associated with coal mining. See Appendix II, Graphs 1 and 2.

8.1.2.1 *Metals and Geochemical Source Terms*

Since commencement of underground mining in 1992, dissolved aluminum, copper, lead and zinc concentrations have remained below permit limits, with minor, irregular fluctuations noted. Iron is the only permitted metal that displays elevated concentrations related to mine void dewatering areas.

This year dissolved metal parameters remained well below permit limits. Refer to Table 9 below for summary statistics.

Parameters of interest such as dissolved arsenic, copper, total and dissolved iron, and total manganese are displayed graphically in Appendix II, Graphs 4 through 10.

Table 11: Summary Statistics for Parameters of Interest at WD

	Statistic	As-D	Al-D	Alk-T	Cd-D	Cu-D	Fe-D	Mn-D	Hard-T	Ni-D	Pb-D	SO4-D	Zn-D
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WD	Average	0.00082	0.00402	466	8.2E-06	0.000301	0.0119	0.349	539	0.00132	0.00015	706	0.00935
E207409	Minimum	0.00036	<0.0030	390	<0.000010	<0.00020	<0.010	0.105	375	<0.0010	<0.00020	340	<0.0050
	Maximum	0.00144	0.018	510	0.00002	0.00095	0.0322	0.591	647	0.0035	<0.00040	1000	0.033
	Geometric Mean	0.00077	0.00308	465	7.5E-06	0.000242	0.0106	0.304	532	0.00114	0.000141	679	0.00628
	Count <DL	0	16	0	21	13	4	0	0	13	22	0	14
	Standard Deviation	0.00028	0.00406	31	3.6E-06	0.00023	0.0062	0.169	84	0.00082	0.000051	195	0.00931
	1st Quartile	0.00059	0.00187	440	0.000005	0.0002	0.0082	0.205	510	0.001	0.0001	560	0.0025
	Median	0.00079	0.003	470	0.00001	0.0002	0.011	0.339	564	0.001	0.00015	630	0.005
	3rd Quartile	0.00098	0.00353	490	0.00001	0.000322	0.0148	0.509	592	0.0012	0.0002	912	0.01185

8.1.3 *Culvert into Middle Quinsam Lake (WC) EMS #E207411*

Monitoring station WC represents the cumulative surface water discharge from WD prior to entering Middle Quinsam Lake. Concentrations for parameters of interest are typically slightly lower at WC than at WD, likely attributed to the attenuation that occurs along the WD-WC flow path that includes an expansive wetland. The exception observed is sulphate concentration during summer when discharge and dilution are lowest, and evapo-concentration is thought to occur. Dissolved sulphate ranged from 330 mg/L to 1000 mg/L averaging 693 mg/L at WC. Refer to Table 9 below for summary statistics. It is important to remember that after passing WC, the discharge water enters another large wetland before entering near the inlet of Middle Quinsam Lake approximately 350 m downstream of WC. Refer to Table 10 below for summary statistics for parameters of interest.

Table 12: Summary Statistics for Parameters of Interest WC

	Statistic	As-D	Al-D	Alk-T	Cd-D	Cu-D	Fe-D	Mn-D	Hard-T	Ni-D	Pb-D	SO4-D	Zn-D
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Average	0.00036	0.00584	400	6.9E-06	0.000276	0.0098	0.0221	412	0.0011	0.000138	693	0.00344
WC	Minimum	0.00027	<0.0060	400	<0.000010	<0.00020	<0.010	0.0084	285	<0.0010	<0.00020	330	<0.0050
E207411	Maximum	0.00044	0.0117	400	<0.000020	0.00059	0.0153	0.0379	520	0.0031	<0.00040	1000	<0.010
	Geometric Mean	0.00036	0.00508	400	6.5E-06	0.000245	0.0092	0.0196	402	0.00091	0.00013	650	0.00324
	Count <DL	0	3	0	8	4	2	0	0	6	8	0	8
	Standard Deviation	0.00006	0.00335	0	2.6E-06	0.000151	0.0036	0.0109	92	0.00086	0.000052	238	0.00129
	1st Quartile	0.00033	0.003	400	0.000005	0.0002	0.0074	0.0155	342	0.0005	0.0001	547	0.0025
	Median	0.00036	0.00445	400	0.000005	0.000225	0.0104	0.0197	405	0.001	0.0001	700	0.0025
	3rd Quartile	0.00038	0.00853	400	0.00001	0.000313	0.0118	0.0316	494	0.00105	0.0002	892	0.005

8.2 South Water Monitoring Sites

The primary monitoring locations in the South water management system are stations that directly influence water quality in Long Lake: Settling Pond #1 decant (SP1/SPD) EMS #E218582, Long Lake Entrance (LLE) EMS #E292130, and Long Lake Seeps (LLS & LLSM) EMS #E292131.

SP1 captures the combined discharge of the Long Lake Seep Passive Treatment System (PTS) from the Biochemical reactor cell (BCREFF) and the Sulphide polishing cell (SPCEFF). The treated discharge water from SPCEFF has been redirected to 2-South pit EMS #E292127, where (when overflowing from 2-South), flows to 3-South pit and is pumped to SP1. During the dry season, 3-South pit (EMS # E217015) water is directed back into 2-South pit for a closed loop circuit. The PTS discharge aids in maintaining the required 1.5 m water cover over 2-South pit during times of low precipitation. All discharge is contained within the authorized works and meeting permit limits when discharging from SP1.

Water quality results for the monitoring locations in the South mine area are provided in Appendix I, Tables (10 - 21).

8.2.1 *Settling Pond #1 (SP1/SPD) EMS #E218582*

Settling Pond #1 represents the cumulative mine related discharge from the South water management system. Permit limits applied to SPD are shown in the table below. All parameters except dissolved iron remained within permit limits at SPD during 2021/2022.

Table **13** below represents the permit limits applied to the discharge waters at SPD. Refer to Appendix I, Table 10 for water chemistry results at SPD. Appendix II, Graphs (11 through 17) display the parameters of interest for SPD.

Table 13: Permit Limits Applied to SPD

Parameters	**Limit**	**Unit**
Total Suspended Solids (daily composite)	25	mg/L
Total Suspended Solids (hourly composite)	35	mg/L
pH	6.0-8.5	mg/L
Ammonia (as N)	1.0	mg/L
Phosphorus (as P)	0.03	mg/L
Oil and Grease (total)	10	mg/L
Aluminum, dissolved	0.5	mg/L
Copper, dissolved	0.02	mg/L
Iron, dissolved	0.5	mg/L
Lead, dissolved	0.05	mg/L
Zinc, dissolved	0.2	mg/L
Rainbow Trout Bioassay (*Oncorhynchus mykiss*)	mortalities at 100% effluent concentration after 96 hour	96LC50

8.2.1.1 *General Parameters*

pH

All pH readings were within the permit limits in 2021/2021. Appendix II, Graph 13 displays historical to present pH at SPD. Discharge water at SPD in the fall and winter can be described as having circumneutral pH (6.5 to 7.5) related to discharge conditions *i.e. pumping from 3-South pit*. Slightly acidic conditions are observed in fall and winter with more neutral to alkaline conditions in spring and summer.

Total Suspended Solids (TSS)

Grab samples for TSS analysis were collected on a weekly basis depending on discharge rates. TSS ranged from <1.0 mg/L to 5.2 mg/L, averaging 1.61 mg/L. Most results were less than the detection limits of 1.0 mg/L.

Hardness and Dissolved Sulphate

Hardness concentrations ranged from 23 mg/L to 490 mg/l, averaging 324 mg/L. Increased concentrations are observed with lower flow rates. Sulphate concentrations in Settling Pond #1 have varied, depending on pumping rates from 3-South Pit and historically 5-South underground during high flow. Since the 5-South Mine pool water was redirected to 2-North mine at the end of 2017, the main contributor to sulphate is water pumped from 3-South pit. This year weekly sulphate at SPD ranged from 26 mg/L to 490 mg//L and averaged 271 mg/L. Concentrations were highest from summer through fall (low dilution) and lowest during winter (higher flow and high dilution) as shown in Appendix II, Graph 12. Typically, there is zero flow at SPD from late spring to early fall as there is limited pumping from 3-South Pit.

8.2.1.2 *Dissolved Metals*

Most permitted dissolved metals (Al-D, Cu-D, Pb-D and Zn-D) concentrations at SPD remained below SPD permit limits. Dissolved iron was elevated above permit limits of 0.5 mg/L on January 4th, 2022, resulting in 1.19 mg/L. The trend for D-Fe is concentration highs in winter and lows in summer as displayed in Appendix II. This year concentrations ranged from 0.0241 mg/L to 1.19 mg/L averaging 0.231 mg/L.

Appendix II, Graphs (13 and 14) display Fe-D and Mn-T for SPD.

Besides slightly elevated sulphate and occasionally elevated iron, the water quality at SPD has remained in good condition. It is expected this trend will continue in the future.

Table 14: Summary Statistics for Parameters of Interest SPD

	Statistic	As-D	Al-D	Alk-T	Cd-D	Cu-D	Fe-D	Mn-D	Hard-T	Ni-D	Pb-D	SO4-D	Zn-D
SPD	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E218582	Average	0.00093	0.01304	90.8	0.0000061	0.000265	0.2313	0.0606	324.1	0.0005	0.0001	271.2	0.01012
	Minimum	0.0002	<0.0030	26	<0.000010	<0.00020	0.0241	0.005	23	<0.0010	<0.00020	26	<0.0050
	Maximum	0.00172	0.0421	110	0.00002	0.00054	1.19	0.386	490	<0.0010	<0.00020	490	0.0633
	Geometric Mean	0.00081	0.00573	85	0.0000055	0.000242	0.1486	0.0309	248.8	0.0005	0.0001	218.1	0.00565
	Count <DL	0	6	0	13	2	0	0	0	14	14	0	7
	1st Quartile	0.00066	0.0015	82	0.000005	0.00022	0.0895	0.0149	213	0.0005	0.0001	130	0.0025
	Median	0.00092	0.00415	110	0.000005	0.000245	0.1255	0.0244	392	0.0005	0.0001	270	0.0047
	3rd Quartile	0.00102	0.02683	110	0.000005	0.000302	0.2045	0.0693	463	0.0005	0.0001	410	0.0112

8.2.2 *Long Lake Entrance (LLE) EMS #E2922130*

Appendix I, Tables (19) provide the full set of data collected at LLE and Appendix II, Graphs 18 through 22 display parameters of interest. LLE is the most downstream monitoring station in the South Water Management System and represents cumulative mine water discharge into Long Lake (excluding the seeps and groundwater inputs). This station is located at the outflow of a culvert discharging from a wetland, where discharge water flows through an approximately 50 m long channel before entering Long Lake. LLE is not defined as a receiving environment station but rather constitutes the upstream segment of a mixing zone defined as the IDZ in the permit. For observation purposes, results for LLE are compared to WQGs to assess overall water management system performance and influence on Long Lake.

Sulphate and iron are two main parameters of interest at LLE, both are frequently above WQGs as displayed in Appendix II, Graphs 18 to 20. Peak concentrations are observed in summer during low flow periods. Dissolve sulphate ranged from 43 mg/L to 660 mg/L and averaged 209 mg/L. Annual average hardness concentration at LLE was 264 mg/L.

It should also be noted that during the summer low flow period LLE discharge may not be flowing into the lake before it is evaporated. This year there has also been beaver activity at LLE which blocked the culvert and stirred up the bottom sediment. The culvert was cleaned out many times during fall. Discharge at LLE is extremely low to zero during summer and early fall.

Both total (1.00 mg/L) and dissolved (0.35 mg/L) iron exceeded the WQG in monthly sampling events. Total iron had 2 out of 13 results above WQG in June and July resulting in 1.04 mg/L and 1.24 mg/L, respectively. Dissolved iron had 3 out of 13 results above WQG in May, June and January, ranging from 0.402 mg/L, 0.641 mg/L and 0.855 mg/L, respectively. Beaver activity occurred from September to November this year.

Elevated iron is observed during low flow periods when anoxic conditions occur in the wetland and during high flow conditions causing the mixing of iron-rich bottom waters to be discharged at LLE.

High flows may inhibit the typical redox reactions and iron precipitation processes that reduce dissolved iron to particulate iron.

8.2.3 *LONG LAKE SEEP*

The seeps into Long Lake are bedrock groundwater seeps flowing from the 2 and 3 South mine pool. The two seep sites are monitored for water quality and quantity on a monthly basis to assess overall loading into Long Lake. The water chemistry is influenced by groundwater levels in the 2-3 South mining area(s) and is subject to seasonal 'flushing' events due to local precipitation and infiltration.

LLS is the smaller seep and LLSM is the middle seep. LLSM is considered the primary seep, as flows at this site are much higher and more variable compared to LLS; as such, the hydrology monitoring station is located on this seep. Due to lower flow rates at LLS concentrations of most parameters are higher than LLSM. Normally at LLSM a pattern of high flow during winter and no flow through late summer and early fall when the mine pool is recharged with groundwater are observed. Flows cease when the mine pool water level falls below the elevation of approximately 303.5 - 304 mASL (between 9 m and 10 m above pump measured at INF). LLSM flowed for 8 months (no flow August 16 through October 23), and LLS flowed for 12 months. There was a 4-day period in September (12-15) when flows occurred, but water did not reach the lake as conditions were so dry.

All monthly water quality samples collected from the seeps are included in Appendix I, Tables 21 and 22 and flow data is included in Table 32. Overall, water chemistry at both seeps remained consistent with that observed during previous reporting periods. Sulphate concentrations at the seeps displayed peak concentrations in summer when flow is low and fall when the mine voids fill back up and flows resume. Results remained consistent throughout the monitoring year ranging from 530 mg/L to 660 mg/L averaging 615 mg/L at LLS and 370 mg/L to 540 mg/L and averaging 451 mg/L at LLSM, Appendix II, Graph 22.

Other parameters of interest include arsenic, iron, and total manganese. Metals display seasonal trends, with peak concentrations related to low flow rates summer and fall. Appendix II, Graphs 23 through 25 display concentrations of total arsenic, manganese and both total and dissolved iron since 2016.

This year concentrations of arsenic remained below WQG-Max (0.005 mg/L) at both seeps ranging from 0.00217 mg/L to 0.0046 mg/L and averaging 0.00358 mg/L at LLS. At LLSM arsenic ranged from 0.00024 mg/L to 0.0018 mg/L and averaging 0.0009 mg/L at LLSM.

All 12 monthly results for total iron at LLS were observed above the WQG-Max (1.00 mg/L) at LLS. Results ranged from 1.20 mg/L to 2.23 mg/L and averaged 1.71 mg/L at LLS. There were no elevated total iron results at LLSM where results ranged from 0.097 mg/L to 0.952 mg/L and averaged 0.529 mg/L. Dissolved iron results were above WQG-Max (0.35 mg/L) at LLS on all monthly samples collected and 8 out of 11 samples collected at LLSM. Results ranged from 1.01 mg/L to 2.09 mg/L and averaged 1.59 mg/L at LLS. Results ranged from 0.0509 mg/L to 0.869 mg/L and averaged 0.477 mg/L at LLS.

The increase in concentrations observed in spring is attributed to oxidation (and leaching) of the mine void walls. The mine void is recharged with the infiltration of groundwater after it is depleted during summer. These sites have elevated concentrations of iron, which is evident by the iron rich sediment deposited as it changes state from ferrous iron to its oxidized state ferric iron, when it interacts with oxygen. Iron occurs naturally in water in soluble form as the ferrous iron (bivalent iron in dissolved form Fe2+ or Fe (OH)+) or complexed form like the ferric iron (trivalent iron: Fe3+ or precipitated as Fe (OH)3). The iron rich sediment deposited from the water makes sample collection extremely difficult at these locations and insurances are made so the flow path is not disturbed prior to sampling (as is routine everywhere). If any of the sediment is disturbed due to higher flow conditions or extremely low flow conditions the results will display elevated levels of iron. As a result, iron has a higher percentage of exceedances occurring here due to the flow path the water is taking over the iron rich sediment, sample collection and nature of the water.

Iron rich sediment will also draw arsenic out of water where it is adsorbed by iron. All the natural iron oxide minerals (magnetite, hematite and goethite) as well as an iron rich lateritic soil are effective in adsorbing arsenic from solution[6]. Iron nanoparticles, which bind easily to arsenic and have high surface areas, have been recognized and used as an effective means to sequester, or neutralize, the contaminant[7].

8.2.4 *Passive Treatment System (PTS)*

The PTS was operational throughout the year except for a one-month period from August to September due to extreme fire hazard in the 2-South area. The treatment system was operating at an annual average of 4.23 L/s. The mine pool water level was measured at 15.4 m above the pump in April 2021 and decreased to 8.0 m above the pump on August 8th, 2021, when the LLSM had stopped flowing. Underground mine pool water levels increased to 9.3 m in September when the pump was off and once powered up seepage stopped. Seepage was observed at LLSM but not reaching the lake.

Once operating the seepage stopped until late fall coinciding with precipitation. LLSM started flowing on October 25th after a heavy rain event where the underground water levels rose from 8.9 m to 10.6 m in a week. Peak underground water levels of 18.5 m were reached in January 2021 as displayed in Figure 11 below. Previous observations for LLSM suggest it stops flowing when the mine pool water level is 8.30 m above the pump and the smaller seep stops at 7.80 m above the pump this could be associated with pumping rates as well. A more precise level for when the seeps stop flowing is currently being developed.

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[6] Sonia Aredes, Bern Klein, Marek Pawlik,
The removal of arsenic from water using natural iron oxide minerals, Journal of Cleaner Production, Volumes 29–30, 2012, Pages 208-213, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2012.01.029.
(https://www.sciencedirect.com/science/article/pii/S0959652612000492)

[7] W. Zhang et al. Arsenic removal from contaminated water by natural iron ores Miner. Eng.
(2004)

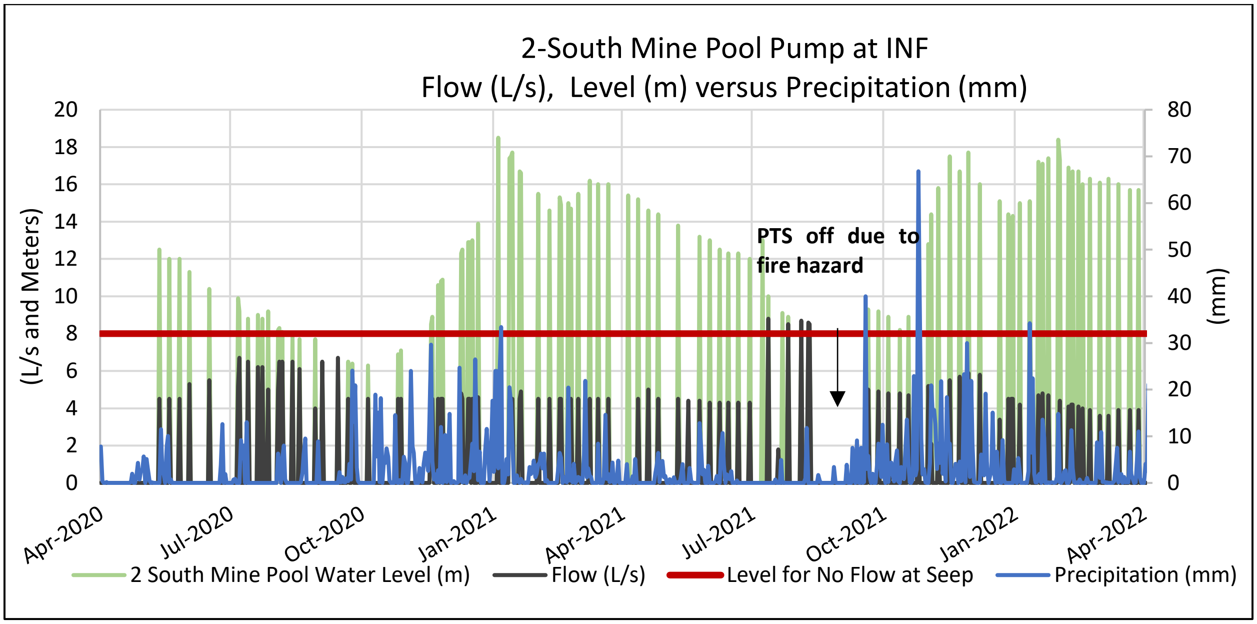

Figure 10: 2-South Mine Pool Flow Rate and Water Level versus Precipitation

Annual average concentrations of dissolved sulphate have been entering the system from the 2-South mine pool, measured at INF, resulting in 535 mg/L and leaving the system at the Sulphide Polishing Cell (SPCEFF) resulting in 397 mg/L with final discharge at measured at SPD averaging 147 mg/L (Figure 10).

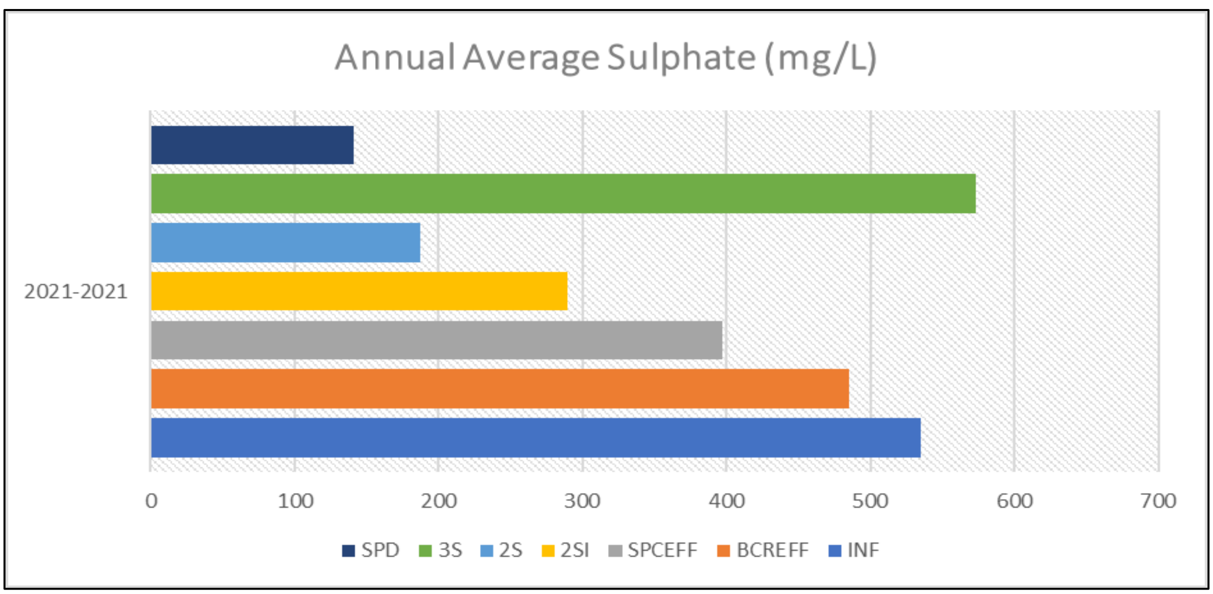

Figure 11: Annual Average Sulphate in the South Mine Area (mg/L)

Figure 12 below displays annual average sulphate reductions through the PTS including the sites 2-South Inflow (2SI) (receives discharge from the PTS) and SPD. As displayed the greatest reduction is observed between INF to SPD. This indicates that the water management system is working at reducing the concentrations of sulphate pumped from the mine pool into the treatment system and discharged at SPD.

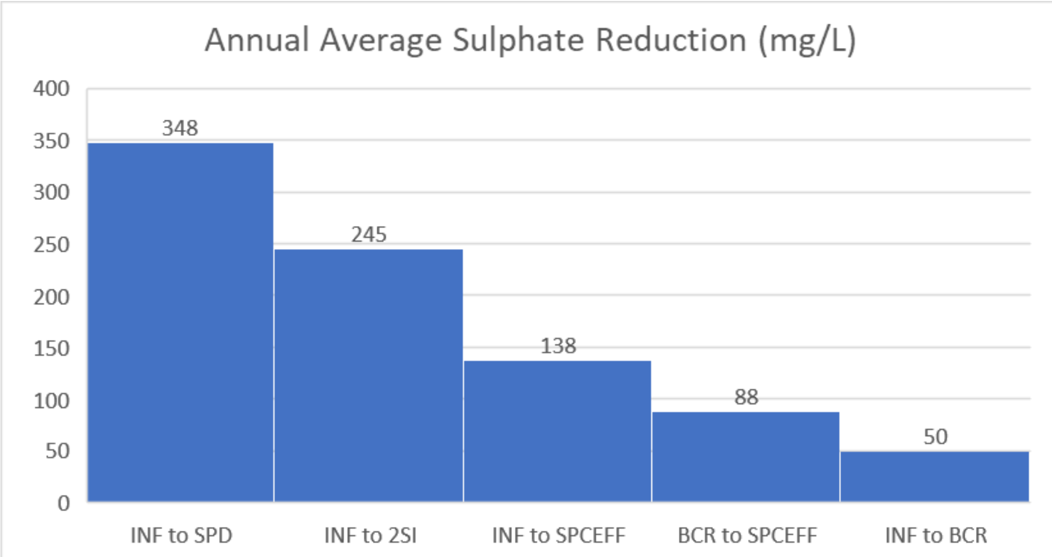

Figure 12: Quarterly Sulphate Reduction through the Water Management System

The PTS displays the greatest reduction in sulphate within the cells between INF and SPCEFF resulting in 138 mg/L. Between INF and Biochemical Reactor (BCR) mg/L reduction was low resulting in 88 mg/L. Warmer ambient temperatures normally increase microbial metabolic activity within the BCR and SPC during summer and early fall. The low average reduction rate between INF and BCR in summer could indicate that the substrate requires replacement, or the retention time is not long enough in the BCR. In winter the cooler ambient temperatures decreased microbial activities and sulphate reduction rates are low. Overall, an annual average sulphate reduction of 348 mg/L was attained between INF and SPD. The original reduction goal has been achieved for the PTS, which was to reduce sulphate concentrations to 300 mg/L. Table 15 displays a summary for 2021-2022.

Table 15: Summary of Sites Sulphate Concentrations and Reduction Rates

2021-2022	INF	BCR	SPCEFF	2SI	SPD	2S	3S
Ave	535	485	397	290	187	573	141
Count	12	12	10	12	3	3	12
Min	450	410	270	220	23	490	26
Max	640	560	510	390	340	650	290
	INF to BCR	BCR to SPCEFF	INF to SPCEFF	INF to 2SI	INF to SPD		
Sulphate reduction	50	88	138	245	348		

The PTS is effective at maintaining water cover over the PAG-CCR in the 2-South pit and reducing discharge at the Seep into Long Lake during low flow periods. This is accomplished by decreasing the elevation of the mine pool below the elevation of the seep. The period of "no flow" at the Middle Seep into Long Lake (LLSM) has been observed to be extended by pumping down the mine pool.

Further monitoring of the PTS continues and includes the 2-South and 3-South systems and groundwater well MW004. A relationship between MW004, Seep flow and the elevation of the mine pool at the INF location continues to be developed with observations noted every quarter.

8.3 7-South Water Monitoring Sites

The 7-South water management system is comprised of several structures (Section 2.1.3) to manage local water in and around the disturbed area, with the most substantial structure being the 7-South settling pond (7SSD). This structure represents the point of discharge for 7-South operations and is regulated under PE-7008. Table 16 outlines the applicable permit limits at 7SSD for each controlled parameter.

Table 16: Permit Limits Applied to 7SSD EMS #E292069

Parameters	Limit	Unit
Total Suspended Solids (daily composite)	25	mg/L
Total Suspended Solids (hourly composite)	35	mg/L
pH	6.0-8.0	mg/L
Sulphate	500	mg/L
Aluminum dissolved	0.1	mg/L
Cadmium dissolved	0.000045	mg/L
Copper dissolved	0.014	mg/L
Iron dissolved	0.35	mg/L
Selenium dissolved	0.016	mg/L
Rainbow Trout Bioassay (*Oncorhynchus mykiss*)	No mortalities at 100% effluent concentration after 96 hour	-

8.3.1 *7-South Settling Pond (7SSD) EMS #E292069 and Steam 1, (7S) EMS #E292109*

There was no discharge from this location in 2021-2022. Complete water chemistry of the supernatant can be found in Appendix I, Table (22).

Water quality has improved from previous years, resultant of adopted water management practices that are effective at reducing impacts downstream at 7S. These methods include pumping all mine related discharged from the 7-South area into 5-South mine pool and then into 2-North mine pool where it is discharged at SP4. In Appendix I, Table 24 provides water quality at 7S and Appendix II, Graph 70 provides flow vs precipitation at Stream 1, 7S.

8.4 Bioassays

An LC50 (median lethal concentration) is the concentration of material (in this case, effluent) in water that is estimated to be lethal to 50% of the test organisms. The LC_{50} and its 95% confidence limits are usually derived by statistical analysis of percent mortalities in several test concentrations, after a fixed period of exposure. The duration of exposure must be specified (e.g., 96-h LC50).

PE-7008 indicates that rainbow trout (*Oncorhynchus mykiss*) LC_{50} bioassays are required once per year (fall flush) at Settling Pond #1, EMS# E218582 and at Settling Pond #4, EMS# E207409. The bioassays are performed using 100% (non-diluted) discharge water to assess the potential survival of rainbow trout over a period of 96-hours. A successful test sees no mortalities throughout the 96-hour period. Discharge was collected from Settling Pond #1 and Settling Pond #4 on October 14 and 15, 2021 respectively.

If discharging, section permit requires a 96-hour LC_{50} test on rainbow trout to be completed using 7SSD EMS# E292069 effluent and, concurrently, a 7-day *Ceriodaphnia dubia* test from water obtained from 7S, EMS# E292109. This is required twice per year; once during the spring freshet and once during the fall flush, when discharging is occurring from 7SSD. The discharge from 7SSD pond did not occur this resulted in omitting the spring freshet and fall flush samples.

All rainbow trout bioassays had 100% survival (Appendix III). This indicated that mine related discharges at Settling Pond #1 and Settling Pond #4, are compliant, and not acutely toxicity.

9.0 WATER QUALITY IN THE RECEIVING ENVIRONMENT

Preamble – Water Hardness

For the purposes of this report, water quality in the receiving environment is compared to Acute and Chronic BC Water Quality Guidelines for Freshwater Aquatic Life (WQG). For those parameters that are hardness dependent the guideline has been derived using background (i.e., monitoring location WA) hardness (~30mg/L) at all stations. Quinsam Coal has adopted this approach for the Iron River to provide a conservative comparison of receiving environment water quality except for dissolved copper.

To obtain the dissolved copper guideline ambient water quality from the receiving environment sites has been uploaded into the British Columbia Copper Biotic Ligand Model Database. The database uses ambient hardness, pH, temperature and dissolved organic carbon from each sampling event and derive a site specific acute and chronic WQG for dissolved copper. Appendix II, Graphs 49 to 55 display the acute and chronic Aquatic Life – WQG's derived for copper compared to individual results from receiving environment sites during spring, summer and fall.

Guidelines and Objectives: Receiving environment water quality is compared to the British Columbia Ambient WQG for Protection of Aquatic Life for most parameters. The exceptions are hypolimnetic DO (using a WQO based on a site-specific conditions), total cobalt and total lead (using more recently established site-specific Water Quality Objectives (WQO)[8]), and total phosphorus in streams (using the Vancouver Island objective[9]). Table 17 lists the WQG, WQO and VIO used to screen receiving water quality. Water quality at locations outside of the Middle Quinsam Lake Sub-basin, such as the No Name Lake, Iron River and 7-South (7SQR / IRQR), Lower Quinsam lake are compared exclusively to the WQG.

[8] Campbell River Area Middle Quinsam Lake Sub-Basin Water Quality Assessment and Objectives. Ministry of Environment. 1989

[9] Guidance Document for Phosphorous Management in Vancouver Island Streams. Ministry of Environment. 2012

Table 17: Water Quality Guidelines and Objectives Applied to Receiving Environment Stations

Parameter				
	Lakes (mg/L)		Streams (mg/L)	
	Maximum	5 in 30-day Avg	Maximum	5 in 30-day Avg
Phosphorus - total	0.007 summer avg - Long Lake		0.01	0.005**
	0.006 summer avg - Middle Quinsam Lake		(May-September)	
Turbidity	n/a	n/a	5.0 NTU	1.0 NTU
Non-filterable residue or TSS	25	5	n/a	n/a
Hypolimnetic DO	3 mg/L minimum during June-August		n/a	n/a
pH	6.5 – 9	n/a	6.5 – 9	n/a
Aluminum (dissolved)	0.1	0.05	0.1	0.05
Arsenic (total)	0.005	n/a	0.005	n/a
Cadmium (dissolved)*	0.00017	0.000088	0.00017	0.000088
Cobalt (total)	0.05	0.004	0.05	0.004
Copper (total)***	0.007	0.002	0.007	0.002
Iron (total)	1.0	n/a	1.0	n/a
Iron (dissolved)	0.35	n/a	0.35	n/a
Lead (total)	0.005	0.003	0.005	0.003
Manganese (total)	0.8	0.7	0.8	0.7
Mercury (total)	0.0001	n/a	0.0001	n/a
Nickel (total)	0.025	n/a	0.025	n/a
Silver (total)	0.0001	n/a	0.0001	n/a
Zinc (total)	0.03	n/a	0.03	n/a
*Sulphate dissolved	n/a	128	n/a	128

* Values represent Middle Quinsam sub-basin water quality using WA hardness.
** Average based on monthly samples from May to Sept
***Using WQG for dissolved copper.

9.1 LAKES

The monitoring program for the Middle Quinsam Lake Sub-basin employed a 5 in 30 sampling approach at No Name Lake (NNL), Long Lake (LLM), Middle Quinsam Lake (MQL), and Lower Quinsam Lake (LQL). There are four depths monitored at each lake:

- 1 metre below surface (1m)
- 4 metres below surface (4m)
- 9 metres below surface (9m)
- 1 metre above bottom (1mb)

Monitoring occurred during three separate periods:

- Spring – April / May 2021 at NNL, LLM, MQL and LQL
- Summer – July / August 2021 at LLM and MQL
- Fall – October / November 2021 at LLM and MQL

A summary table is provided in Appendix I, Table 3 and Tables 42 - 47 displaying the depth profiles and water chemistry results compared to guidelines with Table 50 providing a statistical summary for parameters of interest. Appendix II, Graphs (26 through 51) illustrate parameter trends at each lake.

9.1.1 *SEASONAL TRENDS*

Spring and fall sampling events are timed to cover lake turnover, when water circulates freely in the water column and nutrients become more available for phytoplankton growth (Wetzel 2001)[10]. Water is most dense at 4ºC, and during winter, the surface water (epilimnion) is typically colder than 4ºC and the deeper water (hypolimnion) is at about 4ºC (displaying inverse stratification). Spring turnover occurs when the surface water warms to 4ºC and begins to mix with the deeper water. The lake circulates freely throughout the water column for several days (Wetzel 2001). Through the spring and summer, surface temperatures increase, establishing a thermocline (region of rapid temperature change), with warmer water above and cooler water below. Temperatures cool in late summer, and eventually the thermal stratification breaks down, leading to fall overturn and to mixing of the water column. As surface waters continue to cool, a colder layer overlies the dense bottom water (4ºC), and inverse stratification persists from late fall to spring. During periods with distinct stratification, it has been observed that water chemistry often displays variable concentrations throughout the water column. During overturn, nutrients associated with decomposition of organic matter that has sunk to the bottom are brought into surface waters, where they are available for phytoplankton growth. The timing and duration of spring and fall turnover depend on the size and depth of the lake.

9.1.1.1 Spring

The spring sampling program is scheduled to capture the lake turnover that typically occurs in conjunction with warmer temperatures, snowmelt, and increased precipitation. Spring sampling was

[10]Wetzel, R.G. 2001. Limnology, Third Edition. Academic Press, San Diego CA.

performed from April 7th through May 4th. The sampling regime commenced during the spring turnover event with warming ambient temperatures of greater than 4 ºC. From March 1st through to May 4th, 110.3 mm of precipitation was received.

Noteworthy observations resulting from the spring lake monitoring program include the following:

- Average sulphate concentrations were measured below the water quality guideline (130 mg/L) in all lakes.

- Average sulphate concentrations resulted in 97 mg/L at 9 m and 102 mg/L from the 1 metre from bottom (1MB), on Long Lake during spring sampling.

- Sulphate in Middle Quinsam lake remained well below average guideline levels throughout the lake, averaging 36 mg/L on surface (1m and 4m) to 28 mg/L at depth (9m and 1MB).

  Long Lake was below WQO for pH (6.5) at 2 depths (20 m - 21 m) in the hypolimnion during spring, measuring 6.46 and 6.45.

- Chronic dissolved copper was above the guideline in No Name, Middle Quinsam and Lower Quinsam Lakes (1m, 4m, 9m, 1MB) and Long Lake at 9M depth during spring. These guidelines provide a conservative comparison.

- Acute dissolved copper was above the guideline in No Name Lake at 4m, 9m, and 1MB in spring.

9.1.1.2 *Summer*

The summer sampling program is scheduled to capture the period of low flow and lake stratification. The summer program spanned July 12th through August 10th. The summer program represents the lake's seasonal thermal stratification and a time when deeper lakes naturally develop anoxia in deeper waters. Results from this sampling period represent low dilution conditions when the lakes display minimum assimilative capacity and mine related surface discharges and groundwater infiltration have the greatest influence.

During the summer sampling program, there were high ambient temperatures and low precipitation. There was 49 mm of accumulated precipitation for June 1st through August 10th.

Noteworthy observations resulting from the summer lake monitoring program include:

- Average sulphate concentrations were measured at or below the chronic water quality guideline (128 mg/L) at all depths sampled (1m, 4m, 9m and 1MB) in both lakes.

- In Long Lake sulphate accumulates at depth with average sulphate resulting in 67 mg/L at 1m, 71 mg/L at 4m and 104 mg/L at 9m and 105 mg/L at 1MB.

- During summer stratification period there are limited surface contributions to Long Lake.

- Long Lake displayed pH values < 6.50 at depths 1 to 21 metres in 2 out of 5 weeks of sampling. The minimum pH was observed to be 6.43.

- Dissolved oxygen in Long Lake's hypolimnion (18 to 21 metres) resulted in < 3 mg/L in 9 depths profiled during 4 out of 5 weeks of sampling, indicating anoxic conditions at depth.

- Total manganese was elevated and neared acute WQG at 1MB in Long lake on week 2 as a result of anoxic conditions.

- Average sulphate in Middle Quinsam lake (MQL) remained well below chronic guideline (128 mg/L) throughout the lake averaging 50 mg/L at 1 and 4 meters and 44 mg/L to 24 mg/L, at the 9m and 1MB, respectively from surface to bottom depths (1m, 4m, 9m and 1MB).

9.1.1.3 *Fall*

The fall sampling program is scheduled to capture the period of elevated precipitation following the summer dry season, representing fall overturn and a 'fall flushing' event that is correlated with elevated surface water metal concentrations resulting from localized weathering and mobilization. The lakes turn over in the fall as the water temperatures decrease and high inflows return. In 2021, the fall monitoring program spanned October 6th through November 2nd during a time of light precipitation (332.4 mm from September 1st through November 2nd).

During the fall turn over the deeper portions (hypolimnion) have been replenished with dissolved oxygen. This was evident in MQL as it is a long, shallow lake (14m to 15m) with inputs controlled by the upstream dam on the Quinsam River. Long Lake is deeper (19m to 22m) and shorter in length with inputs received from No Name Lake and groundwater inputs including Long Lake seeps and mine related discharge at the outlet (LLE).

When there is limited inflow at the inlet (from No Name Lake) and ambient temperatures remain warm, lake stratification is extended compared to MQL. In Long Lake turn over occurs late in the fall, with stratification remaining late into November and dissolved oxygen levels depleted at depth, referred to as anoxic conditions. Anoxic conditions at depth causes manganese concentrations to increase at the sediment / water interface. Anoxic conditions were observed during the fall sampling events in the hypolimnion zone (16 m to 22 m) and as a results manganese was elevated at the 1 metre from bottom depth (1MB).

In MQL in the fall remained consistent from surface to bottom depths ranging from 9.35 to 10.32 over the 5 weeks.

Noteworthy observations resulting from the fall monitoring program include the following:

- Average dissolved sulphate in MQL was below the chronic WQG (128 mg/L) at all depths resulting in 44 mg/L at 1M and 4M depths, and 45 mg/L at 9M and 1MB depths.

- Average dissolved sulphate in LL was below the chronic WQG (128 mg/L) at all depths averaging 62 mg/L at 1M and 63 mg/L 4M, and 79 mg/L at 9M and 103 mg/L at 1MB depths.

- Stratification was still apparent during the first three weeks in LLM, again observed through temperature gradients. Turnover was starting to occur during the last two weeks.

- Dissolved oxygen (DO) was below 3 mg/L in Long Lake in the hypolimnion zone resulting in anoxic conditions at depth where Mn-T was observed to be elevated above WQG's.

- Low DO is correlated with lake stratification depleting DO where manganese is released at the sediment / water interface.

- LL displayed slightly acidic conditions during week one (four depths) in the hypolimnion.

- LL displays elevated conductivity, increasing with depth ranging from 6.45 to 6.49.

- The Long Lake Middle Seep stopped flowing mid-August until mid-October, indicating LL had some surface influence from the seeps.

- Average results for dissolved copper were elevated at MQL 1M and at depth in both lakes (LLMB and MQL9)

9.1.1.4 *General Parameters*

pH

Lakes that are deeper and thermally stratified normally have pH that ranges from alkaline on the surface (epilimnion) to slightly acidic at bottom depths (hypolimnion). This trend is typically more pronounced during summer, when the lake is stratified, and surface temperatures are elevated.

The four lakes (NNL, LL, MQL and LQL) have occurrences of slightly acidic conditions at depth in the hypolimnion portion. NNL normally has slightly acidic conditions year-round at a range of depths due to the natural features of the water body.

For all lakes, pH remained mostly circumneutral (having a pH between 6.5 and 7.5), with NNL and LLM having lows of 6.13 and 6.45, respectively.

Middle Quinsam Lake is generally neutral to slightly alkaline throughout the spring, summer, and fall and this trend continued for 2021. Both WA and WC, which enter Middle Quinsam Lake, exhibit neutral pH.

HARDNESS

The WQG for sulphate and several metals varies with hardness. The simple definition of water hardness is the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, largely calcium and magnesium.

Water hardness (mg/L CaCO3) is defined as:

- very soft if hardness ranges from 0 - 30 mg/L

- soft to moderately soft at 31- 75 mg/L
- moderately soft/hard to hard at 76-180 mg/L and
- very hard at 181-250 mg/L

No Name Lake is considered to have very soft water (average concentration of ~13 mg/L at all depths). Lower Quinsam Lake is characterized as soft to moderately soft (average concentration of ~34 mg/L at all depths). Since summer of 2014, Middle Quinsam Lake has had soft to moderately soft water throughout the water column. In 2021 the average of all depths was 40 mg/L for all seasons.

Long Lake generally has moderate to hard water with the greatest variation between depths 1m and 9m and highest hardness in deep water. The range varies with season and depth. Spring averages from surface to bottom ranged from 55 mg/L to 116 mg/L, summer ranged from 84 mg/L to 111 mg/L with fall averages ranging from 103 mg/L to 118 mg/L from surface to bottom. The spring and summer surface depths have the most variability compared to the deeper waters. The influence of freshwater inflow, lake turnover and stratification are most evident at surface 1m and 4m depths. Due to its depth (19-21 m), Long Lake has very little turnover or flushing in the hypolimnion zone.

SULPHATE

As noted previously, the sulphate WQG is hardness dependent, but for QCC, it is set at 128 mg/L (applying a background hardness of 30 mg/L from monitoring station WA, upstream of mine influences).

Dissolved sulphate concentrations were lower than the WQG of 128 mg/L in all lakes at all depths, during all seasons. In Long Lake at 1 m, 4 m depths during spring, summer, and fall. The 1MB remained below 128 mg/L during spring, summer and fall averaging 110 mg/L during spring and summer and 102 mg/L in fall, respectively. Sulphate concentrations increased with depth in LLM, NNL where the opposite trend exists for MQL and LQL. Results appeared to be correlated with thermal stratification

Average sulphate results showed little variation between seasons at the 9M and 1MB depths in Long Lake. This vertical pattern through the seasons suggests that the deeper water (15 to 20 m depth) does not turn over.

Recognizing that hardness and sulphate concentrations in Long Lake reflect the influence of mining discharges, and not baseline conditions, a higher hardness defined WQG would still be protective of aquatic life, given the protective mechanism provided by hardness (MOE 2013)[11].

Higher concentrations at depth are related to sulphate sinking through the water column and accumulating, or groundwater influence. In Long Lake during summer and early fall there was limited surface contributions from the seeps from mid-July to mid-November with limited to no surface discharge from Settling Pond #1 or LLE. In addition, limited to no inflow and outflow from the inlet and outlet.

[11] Ministry of Environment. 2013. Ambient water quality guidelines for sulphate. Technical Appendix Update. Available at:http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/bc_moe_wqg_sulphate.pd

In Middle Quinsam Lake, since 2016 all sulphate concentrations have remained below 60 mg/L since with one an average 1MB in spring 2017 above this. In 2021, the average sulphate concentrations remained similar throughout the year (<54 mg/L) with the spring displaying the lowest concentrations at 1m and 4m depths (28 mg/L) compared to summer and fall. Middle Quinsam Lake has a fast flushing and turnover rate as is demonstrated by the low concentrations of sulphate in the water column. This lake receives discharge water from Settling Pond #4, where permit limits are applied.

No Name Lake and Lower Quinsam lakes continued to have sulphate concentrations well below the WQG. In Lower Quinsam Lake, concentrations remain low (<31 mg/L) reported during spring suggesting some influence of mine related discharges with limited accumulation. In No Name Lake, the average sulphate concentration was <5.1 mg/L for all depths.

HYPOLIMNETIC DISSOLVED OXYGEN AND MANGANESE

The hypolimnetic dissolved oxygen (DO) Water Quality Objective of 3 mg/L minimum in June through August was developed for the Water Quality Objectives for Middle Quinsam Lake Sub-basin (MQL and LL); however, Quinsam also applies this objective to NNL and LQL. The hypolimnion is the dense, cold bottom layer below the thermocline in a thermally stratified lake. Typically, the hypolimnion is the coldest layer in summer and the warmest layer during winter. Anoxic conditions may develop naturally in deep waters over the summer due to the lack of circulation with upper, oxic water during stratification and the consumption of DO by microorganisms that decompose organic matter and by chemical reactions. The reducing environment can cause lake sediments to release iron, manganese, sulfide, and arsenic, all of which could have potential toxicological effects on aquatic receptors.

In 2021, hypolimnetic DO in Long Lake was below 3 mg/L during the summer and fall sampling period below the 14m depths. The low DO was observed during summer and fall sampling. Long Lake has a deep basin (21 - 22 m) and experiences anoxic conditions during summer and fall. An inverse relationship between manganese (Mn-T) and DO is observed in lakes. Mn-T concentrations are highest when DO falls below 3 mg/L. Elevated manganese is associated with low DO. This year manganese was only elevated during fall in Long lake at 1MB. DO was low in the hypolimnion and as a result manganese was elevated at IMB above the acute and chronic WQG of 0.87 mg/L and 0.0737 mg/L, respectively (Appendix 1, Table 3).

Lower Quinsam Lake has exhibited anoxic conditions in the hypolimnion during the summer and fall, sampling events. The November 1st permit amendment does not require summer and fall sampling in Lower Quinsam Lake. This lake has a deep basin (17 – 19 m) and typically experiences low DO (anoxic conditions) at depth when stratification is pronounced normally associated with elevated iron.

In Middle Quinsam Lake concentrations of DO remain high throughout the year.

A similar trend of elevated Mn-T with low DO has been identified for Lower Quinsam Lake at 1mb during the summer monitoring period historically.

The Ambient Water Quality Guidelines for Manganese[12] state:

> "*Mn is only slightly to moderately toxic to aquatic organisms in excessive amounts. It is present in almost all organisms and often ameliorates the hazard posed by other metals. Hence jurisdictions in the international arena have not disseminated Mn guidelines to protect freshwater and marine life. Mn availability and, hence its toxicity in the aquatic environment, can be influenced by many factors including water hardness.*"

In deeper lakes, stratification may result in anoxic conditions in the hypolimnion and the dissolution of the iron and manganese from sediment. Casey (2009)[13] noted:

> "*Iron and manganese are commonly found in groundwater and some surface water such as lakes that have a significant groundwater input. The existence of Fe and or Mn in groundwater generally infers prior anaerobic conditions with the result that the water is likely to be devoid of oxygen and may also have a high carbon dioxide (CO_2) concentration. As well as being associated with groundwater input the existence of Fe and Mn in some deep lakes and reservoirs may be due to stratification, resulting in the development of anaerobic conditions in the bottom water zone and the dissolution of the iron and manganese from floor deposits*."

Long Lake has historically been characterized as having very low DO at depth, with levels in September to October below 4 mg/L at depths greater than 15 m (Kangasniemi,1989)[14]. Nordin (2006)[15] reported that Long Lake stratifies into hyperlimnion and hypolimnion sections in April and May and remains stratified until October through November.

Appendix II, Graph 31, displays the inverse relationship between historical DO vs Mn-T reported at 1MB since 2016 that occurs during late summer and fall when DO levels decline to below 3 mg/L.

SLR (2015)[16] suggested these findings have potential implications for the means by which sediments and Contaminants of Potential Concern (COPC) are distributed in Long Lake. They suggested that the deepest portion of the lake has the greatest potential to accumulate and retain COPCs whose mobility in aquatic systems is affected by oxygen availability in overlying waters and sediments.

It is conceivable that manganese has a greater loading rate from the parent rock and substrate materials, with mobility accelerated by anoxic conditions at depth (SLR, 2015); The regional geology of Long Lake is divided in half with the Nanaimo group in the southern half and the Island Plutonic Suite (IPS) in the northern half (SLR, 2015); this could have implications for different loading of arsenic and possibly manganese and other metals from parent material (SLR, 2015).

The Mn-T concentrations in deep waters of the lakes do not appear to be mine related, as concentrations at most discharge locations remains low; however, the WQO exceedances are of

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12 Ministry of Environment.2013. Ambient Water Quality Guidelines for Manganese

13 Casey,T.J. 2009. Iron and Manganese in Water Occurrence, Drinking Water Standards and Treatment Options through the Aquavarra Research LMT Water Engineering Papers. Paper 3..

14 Kangasniemi, B.J.1989.Campbell River Area Middle Quinsam Lake Sub-Basin Water Quality Assessment and Objectives. Ministry of Environment, Lands and Parks. Summary.

15 Nordin, R.N.2006.An Evaluation of the sediment quality and invertebrate benthic communities of Long and Middle Quinsam Lakes with regards to local coal mining activity.

16 SLR.2015. Sediment Quality, Toxicity, and Bioavailability Review with Background Assessment Based on Current Knowledge of Sediment Dynamics and interpretation or Pre and Post Mining Sediment Concentrations and Distribution.

concerns for assessing potential effects in the receiving environment and trends will continue to be monitored in subsequent years.

9.1.1.5 *Total and Dissolved Metals*

Concentrations of most metals at the four lake monitoring stations were low and below WQGs throughout the spring, summer, and fall sampling periods. Concentrations of total manganese (discussed above) and dissolved copper were elevated compared to WQG's.

Copper (Cu)

Water chemistry (e.g. pH, DOC and hardness) is needed to calculate Cu WQGs using BC BLM[17]. All water quality was input into the Biotic Ligand Models (BLM). Both acute and chronic WQG's vary between each site and result which are dependent on individual parameters. Refer to Appendix I, Table 3, page 2 for dissolved copper results above guidelines.

Dissolved copper was elevated above Chronic -WQG that ranged from (0.0002 mg/L to 0.0004 mg/L) during spring in all lakes at all depths except LL where only 9m was elevated. Average spring dissolved copper results above the Chronic-WQG ranged from 0.000314 mg/L to 0.000486 mg/L throughout all lakes. Appendix II, Graph 49.

Results for NNL 4m, 9m and 1MB were above the Acute-WQG's that ranged from 0.00034 mg/L to 0.00088 mg/L, Appendix II, Graph 49.

In summer averaged results at LL 1MB (0.0003 mg/L) and MQL 1MB (0.00046 mg/L) were above the Chronic-WQG of 0.0002 mg/L and 0.0003 mg/L, respectively, Appendix II, Graph 50.

In Fall averaged results at LL 1MB (0.0003 mg/L), MQL 1m (0.00041mg/L) and 1MB (0.000420 mg/L) were above the Chronic-WQG of 0.0002 mg/L and 0.0004 mg/L, respectively. Appendix II, Graph 51.

Water quality remained below Acute-WQG's in both lakes for fall, Appendix II, Graph 51.

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[17] B.C. Ministry of Environment and Climate Change Strategy 2019. Copper Water Quality Guideline for the Protection of Freshwater Aquatic Life-Technical Report. Water Quality Guideline Series, WQG-03-1. Prov. B.C., Victoria B.C

9.2 River and Stream Sites

A summary table is provided in Appendix I, Table 3 and Tables 48-49 displaying water chemistry results compared to guidelines. Appendix I, Table 50 provides a statistical summary for parameters of interest. Appendix II, Graphs (52 through 64) illustrate parameter trends for the rivers (dissolved sulphate, arsenic, iron, copper and manganese) in the Quinsam Sub-basin.

9.2.1 *Middle Quinsam Lake Inflow (WA) EMS #0126402 and Outflow (WB) EMS #0900504*

Comparing Middle Quinsam Lake's upstream river site, sampled at the Argonaut bridge *(*WA) EMS # 0126402 as the "*inlet"* and outlet (WB) EMS #0900504 offers an opportunity to assess potential mine-related effects on Middle Quinsam Lake water quality. Additionally, water quality results from WA are considered "baseline" for the Middle Quinsam sub-basin receiving environment stations as the site is situated upstream of any mine related discharge. Data obtained from WB (outlet of Middle Quinsam Lake) provides information on lake water quality after the addition of discharges from the South water management system, shallow and deep groundwater, Long Lake Outlet (LLO), mine related discharge from Settling Pond #4, and other anthropogenic sources (e.g., logging and historical Argonaut mine).

Appendix II, Graphs (52 through 54) display the parameters of interest or those found elevated above WQGs (dissolved sulphate, arsenic, iron, copper and manganese) in the Quinsam Sub-basin. Appendix II, Graph (65) displays Middle Quinsam Lake daily inflow obtained at the Argonaut bridge hydrometric station and Graph (66) compares water levels for discharge at WB.

TSS results at WA and WB remained at or just above detection limits (1.0 - 2.8 mg/L) throughout all sampling events, as reported in previous years, and are expected to continue at low concentrations. Samples for WB are collected below the Coal Main Road crossing on the Quinsam River and the low TSS results reflect the efforts made in reducing sediment and erosion at this location.

The pH values were similar at WA and WB, pH at WA and WB was weakly alkaline and within the WQG range of 6.5-9.0; pH values averaged 7.35 at WA and 7.60 at WB. Conductivity at WB reflected the mine influences (elevated conductivity and sulphate are considered signatures of mine influence). For example, average conductivity values were 60 µs/cm at WA and 187 µs/cm at WB.

Significant increases of average sulphate, hardness and sulphate concentrations are observed between WA and WB. With average dissolved sulphate results at WA (3.43 mg/L) and WB (47 mg/L), remain below the WQG of 128 mg/L at both stations (Appendix II, Graph 57). Like sulphate, annual average hardness concentrations display a significant increase from WA to WB with average concentrations of 20 mg/L and 44 mg/L, respectively. Concentrations of sulfur are also notably significant between the two stations with WA averaging (<3 mg/L) and WB averaging (14 mg/L). Dissolved copper was more elevated at WA than WB average concentrations of 0.00056 mg/L and 0.00047 mg/L, respectively. WA has displayed the highest concentrations for copper throughout all sites on the Quinsam River exceeding Chronic-WQG throughout spring, summer and fall, Appendix II, 52 through 54.

Dissolved metals displaying an observable increase in annual average concentrations between WA and WB include iron and manganese likely attributed to mine related discharge. All total and dissolved metals (except dissolved copper at WA) remained below WQGs. Deceases in parameters are observed between WA and WB for aluminum and copper as expressed in bold below.

		pH-F	Cond-F	SO4-D	TSS	As-T	Fe-T	Al-D	As-D	Cu-D	Hard-D	Fe-D	Mn-D	S-D	Zn-D
Station Code		pH Units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WA	Ave	7.35	60	3.43	1.00	0.00013	0.028	0.022	0.000115	0.0006	20.3	0.013	0.001	3	0.005
WB	Ave	7.60	186	46.67	1.23	0.00018	0.042	0.013	0.000166	0.0005	43.6	0.025	0.004	14	0.005
Increase / Decrease		0.24	127	43.233	0.23	0.000043	0.014	**-0.009**	0.000051	**-0.0001**	23.3	0.012	0.003	11	0.000

9.2.2 *No Name Outlet (NNO) EMS # E217017 and Long Lake Outlet (LLO) EMS # E219412*

Flow from No Name Lake (NNO) enters the west end of Long Lake and exits Long Lake at the site known as LLO. LLO discharges to Middle Quinsam Lake upstream of Middle Quinsam Lake outlet (WB). Water quality monitoring at NNO and LLO provides information on changes in water chemistry in both Long Lake and the channel connecting the two lakes. The sampling location on No Name Lake is considered to be outside of direct mine discharge but could be influenced by groundwater. Therefore, changes in water chemistry between NNO and LLO represent the incremental mine loading into Long Lake from various inputs, including shallow and deep groundwater (e.g. emanating from 2S/3S), Long Lake Seep discharge, mine related discharge from the South water management system, and other anthropogenic sources (e.g., logging).

Average TSS concentrations for LLO and NNO remained below 4 mg/L during the three monitoring periods. Both NNO and LLO exhibited similar pH, averaging 7.23 at NNO and 7.28 at LLO.

Conductivity, sulphate and hardness levels increase between NNO and LLO, reflecting mine related influences on Long Lake. Annual average conductivity was 66 µs/cm at NNO and 186 µs/cm at LLO. Annual average sulphate was 3 mg/L at NNO and 61 mg/L at LLO. Sulphate concentrations at LLO are cyclic, normally highest during summer and decreasing during fall along with higher flow rates and increased dilution, in 2020 and 2021 concentrations were highest during fall, Appendix II, Graph (56). Sulphate was monitored weekly at LLO (until November 1st) to assess water quality exiting Long Lake. Appendix II, Graph 57, displays the average dissolved sulphate results from NNO compared to LLO. Like sulphate, water hardness increases from NNO (average of 15 mg/L) to LLO (average of 72 mg/L). Concentrations of sulfur also display a significant increase between the two sites related to mine discharges with averages of 3.00 mg/L at NNO and 19 mg/L at LLO.

Average concentrations of metals observed between NNO and LLO remained low, with many below laboratory DLs. Increases between the sites (NNO to LLO) are observed for all parameters except aluminum, copper, iron and manganese expressed in bold below. All total and dissolved metals were below their WQGs except dissolved copper at NNO. Dissolved copper was elevated above the Chronic-WQG's during summer and fall of 0.0002 mg/L and 0.0003 mg/L averaging 0.000376 mg/L and 0.00045 mg/L, respectively. In summer NNO was above the Acute-WQG of 0.0005 mg/L with a result of 0.00052 mg/L.

Station Code		pH-F	Cond-F	SO4-D	TSS	As-T	Fe-T	Al-D	As-D	Cu-D	Hard-D	Fe-D	Mn-D	S-D	Zn-D
		pH Units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
NNO	Average	7.23	66	3	1.34	0.00030	0.0864	0.0222	0.0003	0.0004	15.33	0.053	0.024	3.0	0.0050
LLO	Average	7.28	186.23	61	1.16	0.00038	0.0550	0.0123	0.0003	0.0003	71.57	0.023	0.009	18.8	0.0050
Increase / Decrease		0.05	119.80	58	**-0.18**	0.00008	**-0.0314**	**-0.0099**	0.0001	**-0.0001**	56.24	**-0.030**	**-0.015**	15.8	0.0000

Water quality data for sites LLO and NNO are presented in Appendix I, Tables (48 to 49) with comparison to WQGs. Appendix II, Graph 52 to 56 displays NNO and LLO for sulphate and copper and Graph 69 compares discharge with precipitation at LLO.

9.2.3 *Stream 1 – (7S) EMS # E292109*

Results are displayed in Appendix I, Table 24 and Appendix II, Graph 70 displays water level for discharge at 7S.
The headwaters of Stream 1 are formed by the discharge of 7SSD, which combines with Stream 2 above sampling location 7S. Downstream of site 7S, Stream 1 enters the Lower Wetland then flows into the Quinsam River. Given the aquatic values (fish habitat) in the Quinsam River, the 7S station has been defined as the initial dilution zone for 7-South discharge water. This receiving environment site is used to evaluate the influence of 7-South operations on aquatic receptors. The Lower Wetland Outlet (LWO) station was established to monitor the cumulative water quality in Stream 1, and to understand overall contributions to the Quinsam River. The Lower Wetland Outlet station has not been representative of water quality from 7SSD nor from 7S. The November 1, 2019, permit amendment removed this site from the monitoring program.

There has been zero discharge from 7SSD since 2017, with only 24 hours and 12 days in 2016/2017; indicating the limited amount of surface loading from 7SSD discharge to the Lower Wetland.

Average sulphate was 4.1 mg/L and TSS was 1.1 mg/L at 7S, well below the WQG (128 mg/L), reflecting the water management measures employed at 7SSD sedimentation pond and surrounding 7-South operations are working. All total and dissolved metals were below WQGs at 7S.

9.2.4 *Quinsam River Downstream Site 1 (QRDS1) EMS # E286930, 7-South Quinsam River (7SQR) EMS # E292113, Outflow (WB) EMS #0900504 & Quinsam River Downstream of the Confluence with Iron River (IRQR) EMS # E299256*

Appendix I, Tables (48 through 49) and Appendix II, Graphs (52 to 54 and 57 to 61) display relevant parameters of interest for these sites.

Quinsam River Downstream Site 1 (QRDS1) is located approximately 2 km downstream from the Middle Quinsam Lake outlet (sampling site WB) and upstream of any inputs associated with 7-South operations. QRDS1 was established to monitor groundwater inputs from the underground disposal of 7-South tailings into the 2-North mine and the underground sub-aqueously stored PAG-CCR material from processing of 5-South coal stored in the river barrier pillar.

Any incremental loading or seepage associated with stored PAG - tailings from 2-North mine and PAG -CCR RBP was observed between WB and QRDS1 this monitoring year.

7-South Quinsam River monitoring station (7SQR) is on the Quinsam River approximately 4 km downstream of QRDS1. 7SQR water quality is used to evaluate the influence of 7-South mine related discharge to the Quinsam River downstream of the LWO, and groundwater inputs to the Quinsam River from sub-aqueously stored PAG-CCR in the 7-South mine. This site captures cumulative mine related discharge from all mine areas.

On November 1st, 2019, authorization was received through ENV to remove the monitoring location QRDS1 from the permit 7008. In 2021 potential mine related groundwater seepage areas were observed between WB and QRDS1 (S and S2). QRDS1 and an additional site (QRDS) upstream of QRDS1 were included into the monitoring program in order to identify contamination loading from the site S.

Marginal concentration increases on the Quinsam River were observed between WB and 7SQR for arsenic (T and D) and iron (T and D). The incremental loading of contributions from the potential seepage sites (S and S2) were observed between each site (QRDS, QRDS1 and 7SQR). Average dissolved arsenic at WB to 7SQR ranged from 0.00017 mg/L to 0.00055 mg/L, respectively. Average dissolved iron at WB to 7SQR ranged from 0.0246 mg/L to 0.0562 mg/L, respectively.

Most average metals increased slightly between the sites with decreases (expressed in bold below) observed for hardness and pH. There was minimal increase in dissolved copper between sites. Indicting limited loading from mine impacted water. Average dissolved copper was above the Chronic -WQG (0.0003 mg/L and 0.0004 mg/L) during summer at QRDS1(0.000478 mg/L) and 7SQR (0.00044 mg/L) and in fall at 7SQR (0.00053 mg/L), chronic-WQG (0.0005 mg/L).

Station Code		pH-F	Cond-F	SO4-D	TSS	As-T	Fe-T	Al-D	As-D	Cu-D	Hard-D	Fe-D	Mn-D	S-D	Zn-D
		pH Units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WB	Average	7.60	186	47	1.23	0.000178	0.042	0.013	0.00017	0.000466	44	0.0246	0.00369	14	0.005
QRDS	Average	7.65	188	49	1.28	0.000384	0.069	0.012	0.00031	0.000442	43	0.0212	0.00268	15	0.005
QRD1		7.54	193	47	1.20	0.000538	0.055	0.014	0.00049	0.000460	43	0.0279	0.00389	15	0.005
7SQR		7.35	214	48	1.71	0.000621	0.106	0.014	0.00055	0.000467	43	0.0562	0.00642	14	0.005
7SQR - WB Increase / **Decrease**		**-0.25**	28.26	0.93	0.48	0.000443	0.064	0.0016	0.00039	0.000001	**-0.46**	0.0316	0.00273	0.07	0.00

Quinsam River Downstream of the confluence with Iron River (IRQR) is located about 5 km downstream of 7SQR and captures the full mixing of the Iron and Quinsam rivers.

At IRQR parameter concentrations remained below WQG's except for average dissolved copper (0.000486 mg/L and 0.00066 mg/L) above the Chronic -WQG of 0.003 mg/L and 0.0006 mg/L during summer and fall, respectively. Average concentrations for most parameters were higher upstream at 7SQR compared to downstream at IRQR. Decreases were observed for conductivity, hardness, iron (T and D), manganese, and sulphur, sulphate and TSS. Arsenic was higher at IRQR than upstream at 7SQR as a result of loading from the Iron River.

Station Code		pH-F	Cond-F	SO4-D	TSS	As-T	Fe-T	Al-D	As-D	Cu-D	Hard-D	Fe-D	Mn-D	S-D	Zn-D
	Unit	pH Units	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7SQR	Average	7.35	214	48	2	0.00062	0.1057	0.0143	0.0006	0.00047	43	0.0562	0.00642	14	0.005
IRQR	Average	7.39	148	36	1	0.00071	0.1012	0.0257	0.0006	0.00055	39	0.0500	0.00523	11	0.005
IRQR - 7SQR Increase / **Decrease**		0.04	**-66**	**-11**	**-1**	0.00009	**-0.0045**	0.0114	0.0001	0.00009	**-4**	**-0.0062**	**-0.00119**	**-4**	0.000

9.2.5 *Iron River*

The Iron River Baseline Summary Report was submitted to the ENV on March 31, 2016. The report reviewed the monitoring data at all sites in the Iron River, summarizing trends and parameters found to be naturally elevated due to the watershed geology and contact with the Benson/Dunsmuir members of the Comox Formation.

As part of the 7-South Area 5 permit application, baseline water quality data were collected at ten stations on the Iron River to gain an understanding of existing water quality and local influences. Additionally, six tributaries were monitored to identify incremental loading.

One year of monthly baseline samples was obtained at all sites to maximize interpretation of seasonal variations and trending on the Iron River. Post-baseline monitoring in 2019/2020 continued to consist of 5 in 30 and monthly sampling until November 1, 2020 at three stations on the Iron River (IR1, IR6 and IR8) and one station on the Quinsam River, downstream of the confluence of the Iron River (IRQR).

November 2019 permit amendment removed monitoring location IR1 and reduced the frequency of sampling at IR6 and IR8 to summer and fall 5 in 30 only. Monthly sampling has occurred at these sites since 2014 and a strong dataset is now available. The two seasons of worst water quality are summer and fall, so this reduction will provide the information necessary to compare to baseline data and to conditions at other sites.

Most general parameters (e.g., TSS and sulphate) had low concentrations at the two stations (IR6 and IR8) and remained well below WQGs. Hardness showed seasonal variability, with lower levels in spring and fall (higher flow) than in summer (low flow). A conservative approach was taken when calculating hardness dependent WQGs (using a background hardness of 30 mg/L).

Dissolved aluminum (Al-D) and total arsenic (As-T) are the two primary parameters displaying a trend related to flows in the Iron River. Al-D concentrations were higher than the acute-WQG (0.100 mg/L) during one event at IR6 and IR8 in fall resulting in 0.125 mg/L and 0.112 mg/L, respectively. Both sites were above the chronic-WQG of (0.05 mg/L) during fall. Average results were 0.0612 mg/L and 0.0564 mg/L respectively, for IR6 and IR8. Appendix II, Graphs 62 to 64.

As-T concentrations were elevated above WQGs (0.005 mg/L) during summer low flow at both IR6 and IR8 for 5 out of 5 weeks of sampling in summer with maximum results of 0.0117 mg/L and 0.020 mg/L, respectively. Concentrations increased from IR6 to IR8 (downstream) as displayed in Appendix II, Graph 64.

An inverse relationship between As-T and Al-D has been identified: Al-D is elevated during periods of higher flow while As-T is elevated at times of low flow. In 2021-22 for example, As-T displayed highest concentrations at IR6 and IR8 in samples collected during the summer while Al-D is elevated during spring and fall.

Average dissolved copper was elevated above the Chronic-WQG (0.0003 mg/L and 0.0004 mg/L) during summer at both IR6 and IR8, averaging 0.000456 mg/L and 0.000644 mg/L, respectively.

All other parameters of interest were below WQG's at IR6 and IR8 and there were no further parameters above WQGs observed IRQR. Therefore, mixing of the Quinsam and Iron Rivers continues to provide sufficient dilution to maintain water quality.

Appendix II, Graph 71 displays the flow on the Iron River measured at IR8.

9.3 Conclusion

Water quality within Quinsam subbasin is of good quality, meeting WQGs and WQOs on most sampling dates in 2021 in the Quinsam and Iron rivers and in the four lakes (No Name, Long, Middle Quinsam and Lower Quinsam Lakes).

Dissolved copper concentrations were above variable Chronic-WQG's (0.0002 mg/L to 0.0006 mg/L) throughout the watershed during spring, summer and fall. Notably upstream of mine influence on the Quinsam river at WA, NNL its outlet NNO and the Iron River. This resulted in multiple dissolved copper results above Chronic-WQG's throughout the lakes and rivers at various locations ranging from 0.000298 mg/L to 0.00066 mg/L. Sediment samples collected on the Quinsam River resulted in the highest concentrations of copper at WA that were above the ISQG (35.7 mg/kg). This indicates there is either naturally elevated copper in the environment or an upstream source of contamination (i.e., above WA the historical Argonaut mine). Refer to Appendix II, Graphs 49 to 55 and Appendix X for a report on the Sediment and Benthic Invertebrate Monitoring Program.

Average sulphate concentrations remained below the Chronic-WQG (128 mg/L) applying a background hardness of 30 mg/L in all lakes and river sites. Dissolved sulphate is moderately elevated in deep water (1MB) of Long Lake (105 mg/L) decreasing from previous years. Average dissolved sulphate concentrations in Middle Quinsam Lake remained in low concentrations (< 55 mg/L) throughout the water column during all sampling periods. Appendix II, Graphs 33 and 36 display average dissolved sulphate in the Long and Middle Quinsam Lakes.

Anoxic conditions represented by low DO levels in deep waters are common during summer and early fall in Long and (historically) Lower Quinsam lakes. Anoxic conditions result in mobilization of iron in Lower Quinsam Lake and manganese in Long Lake and occasionally Middle Quinsam Lake. Concentrations of manganese in deep water in LLM (1MB) were elevated above both chronic and acute WQG's of (0.737 mg/L and 0.8706 mg/L), respectively during periods of low dissolved oxygen in fall (Appendix II, Graph 31).

Increases were observed for average dissolved sulphate in the Quinsam River compared to previous years. In spring, downstream locations measured marginal increases in dissolved sulphate compared to upstream at WB. This could indicate other sources of input from groundwater seepage areas between WB, QRDS1 to 7SQR (40 mg/L to 44 mg/L to 45 mg/L). Average concentrations on the Quinsam River remained below 60 mg/L during all seasons with summer displaying the highest concentrations from WB to IRQR (55 mg/l to 55.8 mg/L). In fall WB had the highest concentrations with a decrease observed downstream at QRDS1 and 7SQR (47 mg/L to 43 mg/L) possibly due to the lower water levels in underground flooded mine voids. Marginal increases are observed on the Quinsam river between sites for POI (arsenic and iron) but no significant increases were measured. Sampling during high and low flow rates play a significant role in observations related to seasonal trends and concentration of POI. In order to clearly identify concentrations of sulphate throughout all season's weekly sampling has been implemented on the Quinsam River at WB and QRDS1. This information will provide water quality for predicted concentrations of dissolved sulphate at closure on Quinsam River (Appendix II, Graph 57 to 61).

On the Iron River dissolved aluminum was elevated during fall with increased flow rates and arsenic was elevated during summer with lower flow rates. The sediment and benthic invertebrate sampling results collected in 2020 demonstrated elevated arsenic and copper within the sediment Appendix X.

10.0 Biota Monitoring in the Receiving Environment

Phytoplankton and zooplankton are monitored every year at one station in each of No Name, Long, Middle Quinsam, and Lower Quinsam lakes. The sampling sites are shown in Appendix IX, Figure 1. This section of the report describes sampling objectives, methods, QA/QC, and results for phytoplankton and zooplankton. Refer to Appendix IV for all historical and present phytoplankton data.

10.1 Phytoplankton

Phytoplankton are photosynthetic microorganisms that live in lakes at depths to where adequate sunlight can penetrate. They are the main primary producers in lakes, converting sunlight, CO_2, and water into organic matter, and are the foundation for the aquatic food web (Wetzel 2001). Phytoplankton includes algae and cyanobacteria, both of which contain at least one form of chlorophyll (chlorophyll *a*), the major photosynthetic pigment. They are sensitive to changes in water quality (Wetzel 2001). Many lakes have a spring and fall phytoplankton bloom (peak growth period) following the seasonal "overturns" or mixing of the water column, which redistribute nutrients through the water column.

Phytoplankton are monitored annually at one station each in No Name, Long, Middle Quinsam, and Lower Quinsam lakes, in the deepest area of the lakes, where routine water quality monitoring is conducted. From 2013 to 2019, phytoplankton samples have been collected at the four lakes once each during the spring, summer and fall 5 in 30-day water sampling periods defined in amended Permit PE 7008. From the 1990s to 2012, Permit PE 7008 required sampling at 1, 4, and 9 m depth in April through September at Long Lake and Middle Quinsam Lake, with No Name Lake added in 2012 and Lower Quinsam Lake added in 2013. From November 2019 amended Permit PE 7008 removed No Name and Long Lake from the summer and fall 5 in 30-day sampling periods.

10.1.1 *METHODS*

10.1.1.1 *Field Methods*

In 2021, samples were collected from 1 m depth using a 4 L Beta sampler. Chlorophyll *a* sample were collected as 1 L raw water samples, shipped to BV laboratory (Burnaby B.C.) and laboratory filtered for analysis. A 250 mL sample was preserved with Lugol's in the field and analyzed for community composition, i.e., counts and identification to lowest practical level (Stantec Consulting Ltd., Burnaby B.C.). Field replicates were collected for QA/QC in May, July and October 2021, from Long Lake and Middle Quinsam Lake, respectively.

10.1.1.2 *Laboratory Methods*

Organisms were identified to lowest practical level (species where possible) using an inverted microscope. A 27 mL volume of lake water was settled in a chamber. Counts were made at 100X, 400X, and 1000X magnifications, to record the size range of phytoplankton.

10.1.2 *RESULTS*

10.1.2.1 *Chlorophyll a*

This year samples were collected and sent to the laboratory during spring for all four lakes, then summer and fall for Middle Quinsam and Long Lake.

Chlorophyll *a* concentrations provide an indication of overall phytoplankton biomass at any given time and provide a basis for comparing primary production among lakes. Table 18 provides data for samples collected from 1 m depth in 2021. Concentrations ranged from 0.50 µg/L (No Name Lake spring sample, and Middle Quinsam Lake spring and summer) to 1.1 µg/L (Middle Quinsam Lake, fall sample).

Table 18: Chlorophyll a Concentrations, 1 m Depth, Quinsam Lakes System, 2021

Lake	Chlorophyll *a* (µg/L)		
	Spring	Summer	Fall
No Name Lake (NNL)	0.5	N/A	N/A
Long Lake (LL)	0.69	0.63	0.82
Middle Quinsam (MQL)	0.50	0.50	1.1
Lower Quinsam (LQL)	0.86	N/A	N/A

Concentrations of Chlorophyll *a* was within the range previously reported for all four lakes (NNL, LL, MQL and LQL) during spring and fall. LQL had the highest results in spring (0.86 µg/L) with LLM displaying the highest results in summer and fall (0.63 µg/L and 0.82 µg/L).

Historically chlorophyll *a* concentrations reported for these lakes reflected oligotrophic conditions (mean of 1.7 µg/L, maximum of 4.5 µg/L), and low total phosphorous concentrations (mean of 8 µg/L, maximum of 18 µg/L), according to the trophic classification system for lakes developed by Vollenweider and Kerekes (1982; cited in Environment Canada 2004)[18].

Appendix IV and Figure 13 provide data for 2013 through 2021. Chlorophyll *a* results for 2021 spring, summer, and fall were within the range reported from 2013 to 2020 (0.48 µg/L to 2.68 µg/L).

[18] Vollenweider, R. and J. Kerekes. 1982. Eutrophication of Waters. Monitoring Assessment and Control. Organization for Economic Co-operation and Development (OECD) Paris. 55 pp. cited in Environment Canada 2004. Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems. Report No. 1-8. http://publications.gc.ca/collections/Collection/En1-34-8-2004E.pdf

Figure 13: Chlorophyll a (µg/L) at 1 m Depth, Quinsam Lakes System, 2013 – 2021

10.1.2.2 *Phytoplankton Communities*

Phytoplankton taxonomy reports are included in Appendix IV and results are summarized here. Duplicate samples collected for Long Lake in May and October, as well as Middle Quinsam in August showed good agreement for the paired samples (within 20% of duplicate samples).

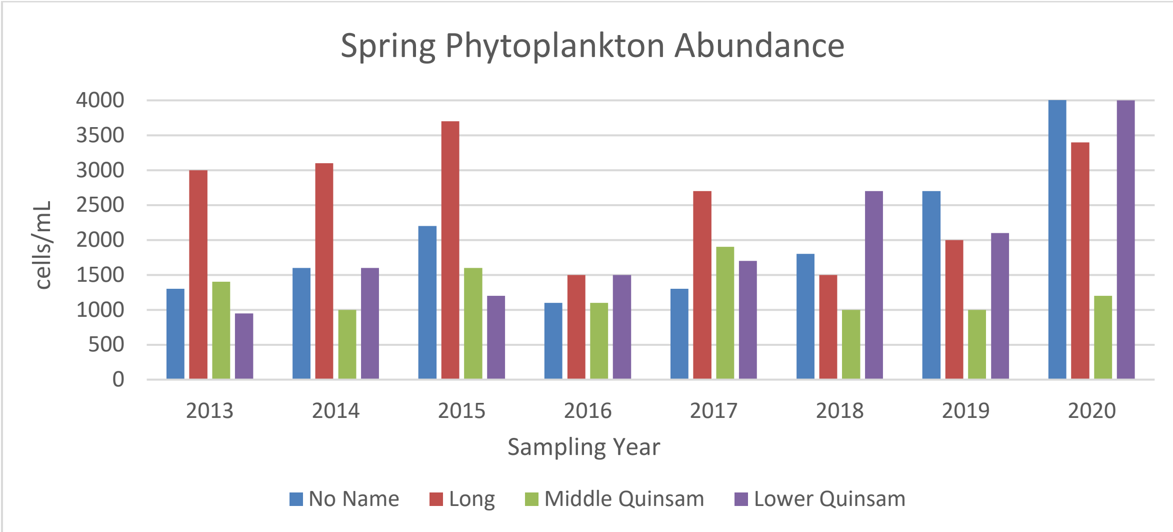
Abundance is summarized in Table 19 as total and by size fraction (identified at 1000X, 400X, and 100X magnifications). Total abundance ranged from 1,000 to 2,200 cells/mL in 2021. The smallest size fraction (less than 5 µm in size) comprised of 87 % of the total abundance.

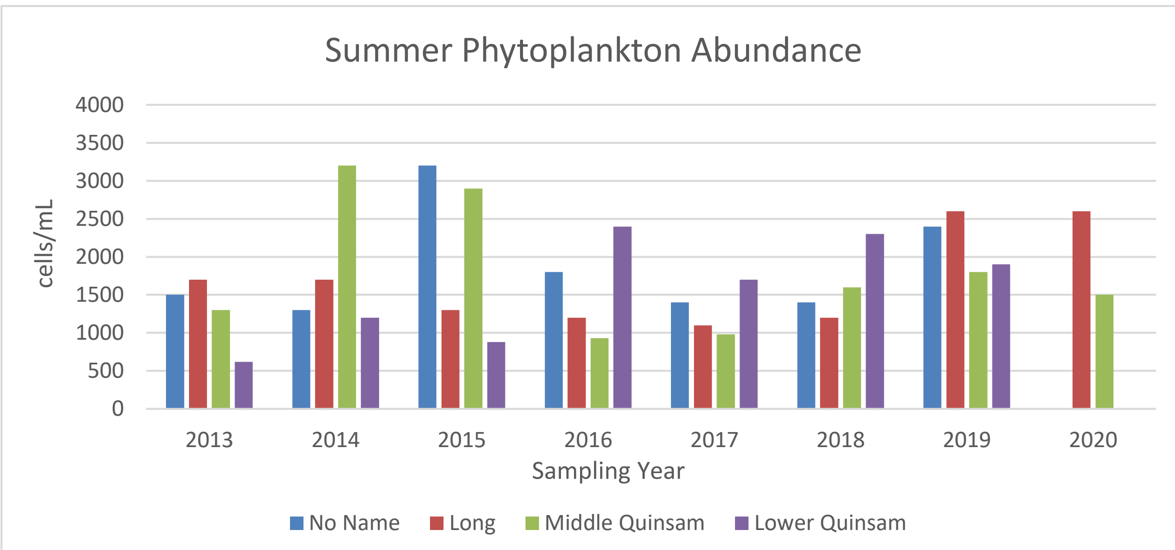
Table 19: Phytoplankton Abundance (cells/mL) in Quinsam Lake Systems, 2021

Lakes 2021	Date	Abundance (cells/mL) at 1 m depth			
		Total	<5 µm (1,000 X)	5 to 25 µm (400 X)	>25 µm (100 X)
Long	May	1,000	920	120	1.7
Long Rep.		1,200	1,100	120	0.7
Middle Quinsam		2,200	2,100	120	0.1
No Name		1,200	990	220	0.2
Lower Quinsam		1,300	1,100	180	1.8
Long	July	1,000	830	190	0.9
Long Rep.		1,000	810	190	0.4
Middle Quinsam		1,400	1000	390	0.2
Long	October	2,100	1,900	190	0.4
Middle Quinsam		2,200	2,000	200	12.6
Middle Quinsam Rep.		2,200	2,000	230	11.4

In 2021, abundance was greatest in spring and fall at Middle Quinsam Lake (2,200 cells/mL). Total abundance was lowest at Long Lake in spring and summer (1,000 cells/mL) which increased in abundance in the fall. Peak abundance and chlorophyll *a* concentration did not always coincide, likely related to changes in size of abundant taxa over the sampling periods. There were two sets of samples collected during spring 2019 (May 1st and May 8th) for graphing purposes only May 8th samples were used (See Spring Phytoplankton Abundance Figure 14, below).

Variation in total abundance among lakes and through the three seasonal sampling periods for 2013 through 2021 is shown in Figure 14. As noted for chlorophyll *a*, high variability among seasons, years, and lakes between 2013 and 2021 was likely related to variation in timing of spring and fall overturn and nutrient concentrations. Phytoplankton abundance data for spring 2021 at Middle Quinsam displayed greatest abundance since 2013, and highest of all four lakes. Summer and fall data illustrate similar abundance between Long Lake and Middle Quinsam Lake. Middle Quinsam and Long Lake are the only lakes sampled in fall and summer due to a permit amendment.





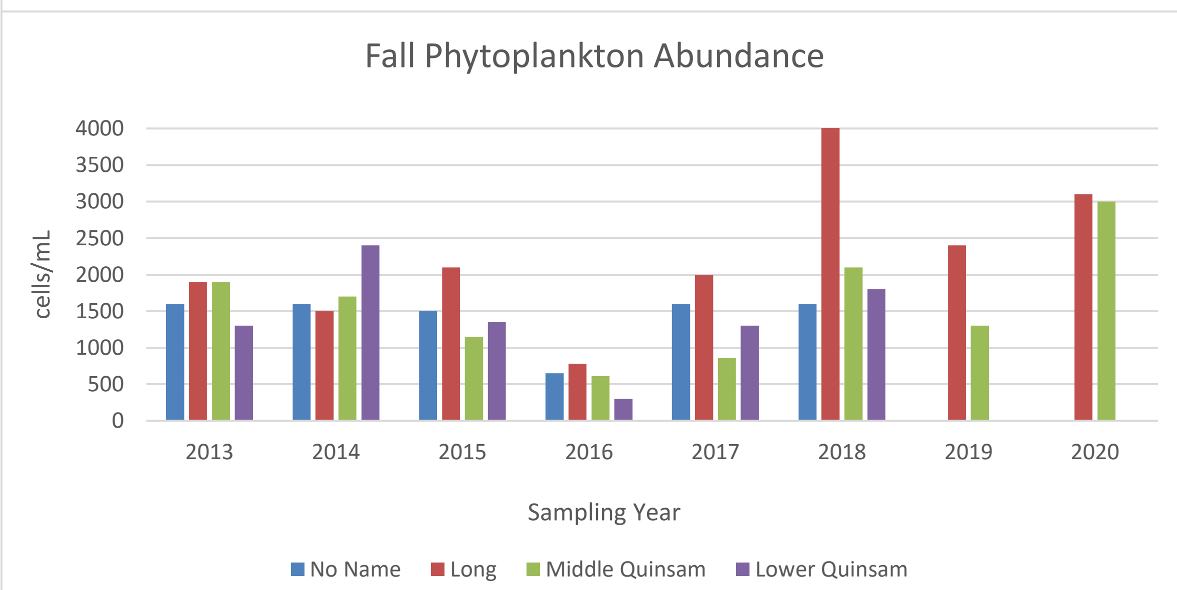


Figure 14: Total Phytoplankton Abundance, 1 m Depth, Quinsam Lakes System, 2013 – 2021

10.1.2.3 Species Composition

Spring

Species composition data for the May 2021 samples are contained in Appendix IV. The most abundant phytoplankton in Long, Middle Quinsam, No Name, and Lower Quinsam lakes were the very small (less than or equal to 5 µm) chrysoflagellates (Ochromonas spp. and Chromulina spp.). Although these ultra-nanoplankton species were very abundant numerically, they usually contribute little to algal biomass.

The most abundant of the larger algae were as follows:

- In Long Lake (both samples), larger Ochromonas spp. were predominant, with the cryptophyte Rhodomonas minuta common. The large dinoflagellate Ceratium hirudinella was also present; this species more typically occurs during the summer.
- In Middle Quinsam Lake, larger Ochromonas spp. were predominant, with other taxa not present in sufficient numbers to be considered common.
- In No Name Lake, larger Ochromonas spp. were predominant, with the cryptophytes Rhodomonas minuta and Cryptomonas spp. common.
- In Lower Quinsam Lake, larger Ochromonas spp. were predominant, with the cryptophytes Rhodomonas minuta and Cryptomonas common.

The May 2021 samples were similar in composition and abundance to samples collected during the spring in recent years.

Summer

Species composition data for the July 2021 samples are contained in Appendix IV. The most abundant phytoplankton in Long and Middle Quinsam lakes were the very small (less than or equal to 5 µm) chrysoflagellates (Ochromonas spp. and Chromulina spp.). Although these ultra-nanoplankton species were very abundant numerically, they usually contribute little to algal biomass.

The most abundant of the larger algae were as follows:

- In Long Lake (both samples), the colonial green alga Dictyosphaerium pulchellum was predominant and larger Ochromonas spp. were common.
- In Middle Quinsam Lake, the colonial green alga Dictyosphaerium pulchellum was predominant and larger Ochromonas spp. and colonial green alga Gloeocystis sp. were common.

The July 2021 samples were similar in composition to samples collected during the spring in recent years.

Fall

Species composition data for the October 2021 samples are contained in Appendix IV. The most abundant phytoplankton in Long and Middle Quinsam lakes were the very small (less than or equal to 5 µm) chrysoflagellates (Ochromonas spp. and Chromulina spp.). Although these ultra-nanoplankton species were very abundant numerically, they usually contribute little to algal biomass.

The most abundant of the larger algae were as follows:

- In Long Lake, the cryptophyte Rhodomonas minuta was predominant and larger Ochromonas spp. and Mallomonas spp. were common.
- In Middle Quinsam Lake (both samples), larger Ochromonas spp., and Rhodomonas minuta were predominant and the colonial chrysophyte Dinobryon cylindricum was common.

The replicate samples were similar in species composition and in abundance (2,200 cells/mL in both samples); this similarity indicates reasonable inter-sample reproducibility.

10.2 ZOOPLANKTON

Zooplankton form the second trophic level in the water column of lakes (secondary producers), grazing on phytoplankton, consuming organic matter, and providing a food source for juvenile fish (Wetzel 2001). Abundance and composition of the zooplankton community vary among lakes due to variation in water chemistry, lake characteristics, and grazing pressures from fish (Wetzel 2001[19]).

According to PE:7008, zooplankton are monitored in the Quinsam mine receiving environment three times per year at one station in Middle Quinsam and Long lake. Lower Quinsam and No Name Lakes are monitored once a year (spring) as of Permit amendment in November 2019. Since 2014, zooplankton samples have been collected once in the spring, summer, and fall during the 5 in 30 water quality sampling periods.

10.2.1.1 *Field Methods*

Zooplankton were collected from No Name, Long, Middle Quinsam, and Lower Quinsam lakes historically three times per year (once during each 5 in 30-day period). In 2019 there was an extra set of samples collected in spring at each lake. In the fall only Middle Quinsam and Long lakes were sampled pursuant to a permit amendment received on November 1st, 2019. Samples were collected using a Wisconsin Plankton Sampler (63 µm net) in a 10 m vertical tow, with one sample collected per lake. Samples were preserved with ethanol and sent to Fraser Environmental Services (Surrey B.C.) for taxonomic analyses.

[19] Wetzel R. 2001. Limnology: Lake and River Ecosystems 150 pp

10.2.1.2 Laboratory Methods

Organisms were counted and identified to lowest practical level.

10.2.2 RESULTS

Detailed zooplankton taxonomic composition results are provided in Appendix IV and are summarized below. Abundance is the relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample. Peak abundance ranged from 6,682 organisms/sample (Long Lake, May) to 2,125 organisms/sample (Lower Quinsam Lake, May). The lowest abundance among the four lakes was 620 organism/sample in fall at Long Lake. Middle Quinsam lake had 1,272 organisms/sample reported in spring and dropped to 766 organisms/sample in October. No Name Lake decreased in abundance from 1,336 organisms/sample (2021) from 2,651 organisms/sample (2020). Long Lake had the greatest change in abundance in 2021 from spring to fall.

Zooplankton organism abundance per sample collected in 2021 is displayed in Table 20, and Figure 15 below. For the two sample sets collected per lakes in May the results were summed. The most abundant of the Zooplankton were as follows:

- In No Name Lake spring samples *Cyclopoida* and *Cladocera* displayed similar results and *Calanoida* was most abundant.
- In Long Lake spring samples *Calanoida* and *Rotifera* were most abundant, while summer had higher abundance of *Cladocera*.
- In Middle Quinsam Lake, *Calanoida* were most abundant in spring, with *Cladocera* most abundant in the summer and fall. Lowest total count for Middle Quinsam (both samples) was *Cyclopoida* in fall.
- In Lower Quinsam Lake *Calanoida* were most abundant in spring samples, with *Cladocera, Cyclopoida* and *Rotifera* having similar results.

Table 20: Zooplankton Abundance (Organisms/sample)

Lakes 2021	Month	Abundance (organisms/sample)				
		Total	Cyclopoida	Calanoida	Cladocera	Rotifera
No Name	May	1,336	72	561	478	225
	August	N/A	N/A	N/A	N/A	N/A
	October	N/A	N/A	N/A	N/A	N/A
Long Lake	May	6,682	324	1,693	256	4,409
	May Rep.	3,585	144	907	199	2,335
	July	2,017	44	477	1,272	224
	October	620	28	99	370	123
Middle Quinsam	May	1,272	52	602	452	166
	July	1,714	189	516	961	48
	July Rep.	1,595	64	462	871	198
	October	766	3	195	494	74
	October Rep.	726	25	183	324	194
Lower Quinsam	May	2125	333	1442	204	146
	August	N/A	N/A	N/A	N/A	N/A
	October	N/A	N/A	N/A	N/A	N/A

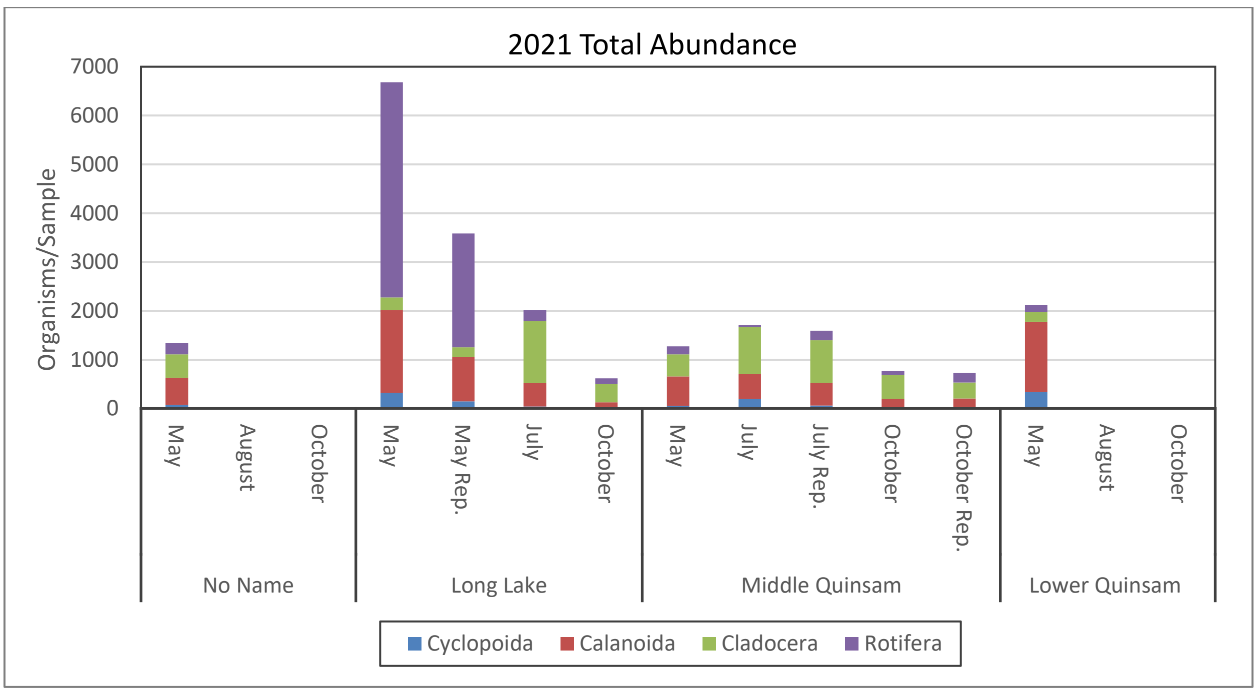


Figure 15: 2021 Total Abundance

Seasonal and spatial trends are displayed in Figure 16 below, for samples collected from 2014 through 2021. Results from the spring 2019 sampling had 2 sets submitted and displayed below in the Spring Zooplankton chart. There has been high variability among lakes, seasons, and years. In general, abundance is highest for the summer samples, following peaks in levels of phytoplankton and organic matter; however, there are exceptions, including low abundance in No Name Lake in summer 2014, 2017 - 2018 and peak abundance in Lower Quinsam Lake in fall 2015. Variations in total abundance when comparing lake phytoplankton abundance may be related to the month sampled and phytoplankton blooms. For example, spring, and summer sampling should occur during the last weeks of the 5 in 30 with fall sampling occurring during the first week of the 5 in 30 for a better representation. Some spring and fall samples were collected in either too early in the spring or too late in the fall late, when the water colder representing the lowest species abundance and counts. This is mainly observed in Middle Quinsam lake during fall sampling events (2016, 2018 and 2019).

Differences in taxonomic composition are related to seasonal conditions, including food supply (phytoplankton and organic matter) and grazing pressures from fish. The larger copepods and Cladocerans provide preferred food sources for fish. All four lakes are known to be fish bearing (e.g., salmon and trout species), but there is not enough information about fish populations to estimate grazing pressures on zooplankton.

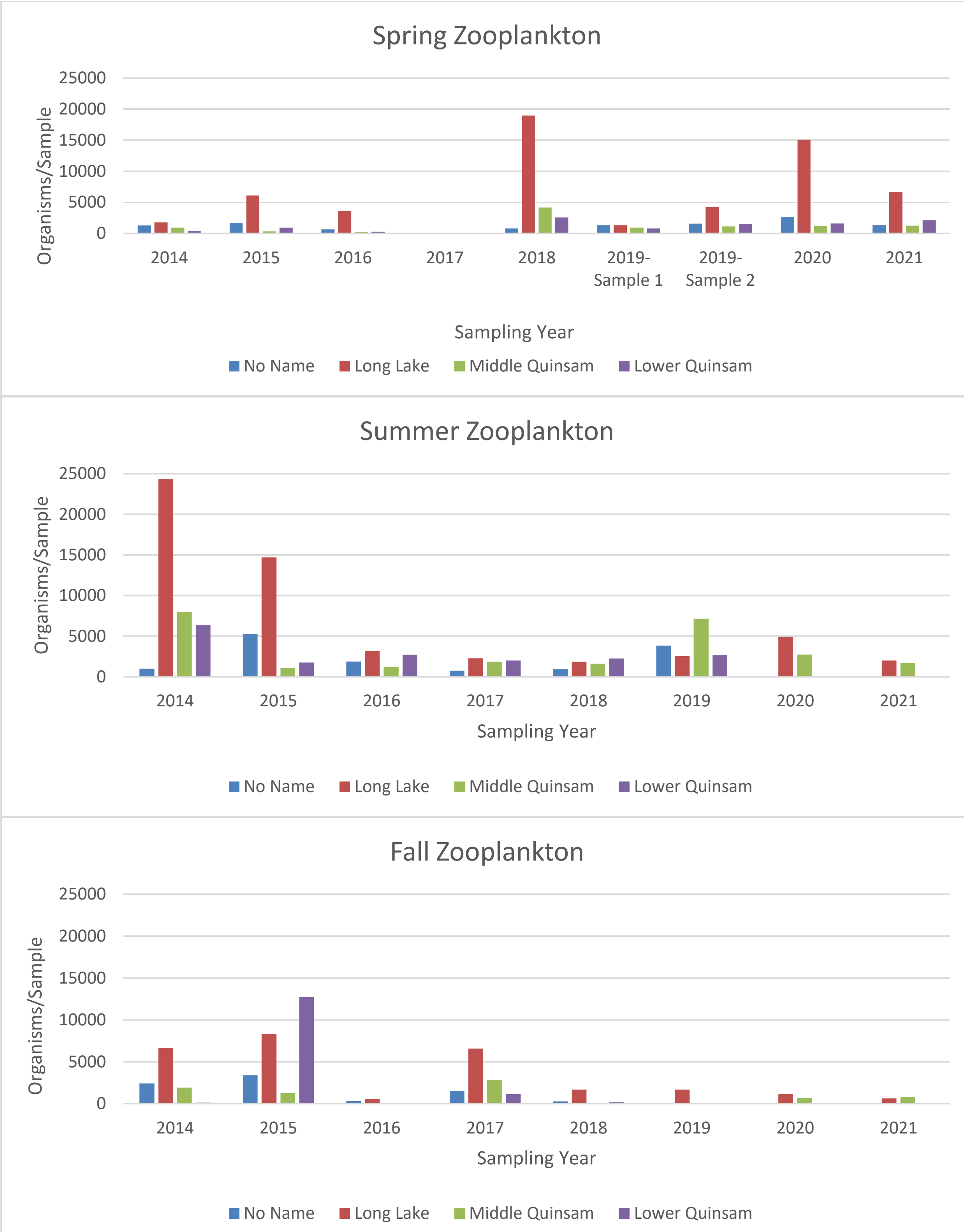


Figure 16: Total Zooplankton Abundance (0 to 10 m Vertical Tows), Quinsam Lakes System, 2014 – 2021

10.2.3 *Conclusion*

No Name, Long, Middle Quinsam, and Lower Quinsam lakes support phytoplankton communities typical of oligotrophic conditions and distinct zooplankton communities in each lake that provide typical prey for fish. There were no indications of adverse effects of mine discharges on the plankton communities of lakes (density, taxonomic richness, composition) in the spring, summer and fall samples. Middle Quinsam lake had the highest counts for phytoplankton abundance during all seasons but lower counts for zooplankton during all seasons. Future monitoring is required to determine if this is related to seasonal limnological conditions such as temperature or water quality.

11.0 CLOSING

Water quality in the Middle Quinsam Sub-Basin remained consistent with previous years and is in good condition with little appreciable impacts associated with coal mining. The majority of parameters of concern were below Provincial guideline and objective levels indicating minimal health risk to sensitive aquatic receptors. For example, sulphate concentrations were recorded below its respective guideline during all sampling events in all four lakes sampled; this trend signifies water management features and controls at the mine site are effective. Appendix II, Graphs 33 and 36 display average dissolved sulphate in the Long and Middle Quinsam Lakes.

Parameters of interest and those displaying slightly elevated concentrations in Long Lake include total manganese (LLM 1MB) associated with anoxic concentrations at depth. The relationship between low DO and elevated manganese in Long Lake 1MB and historically iron in Lower Quinsam Lake at 1MB has been demonstrated in Appendix II, Graphs (31, 47 and 48). This pattern of elevated manganese and iron at depth in these lakes has become more evident since the initiation of the 5 in 30 monitoring in 2013. Previously, there were occasional exceedances occurring during monthly sampling over summer and fall and all events were associated with low DO.

No Name and Long Lake displayed lower pH conditions > 6.5 mostly observed in No Name Lake during spring. However, there is little concern as the slightly acidic conditions are likely naturally occurring.

The Iron River system experiences naturally elevated concentrations (above water quality guidelines) of aluminum during high flow and arsenic during low flow. Aluminum is present throughout the system (i.e., from IR1 through IR8) whereas arsenic is primarily detected below the sandstone unit of the Dunsmuir member contact represented by monitoring location IR6.

Quinsam Coal will continue to focus on site wide water management with a target of mitigating parameter of interest concentrations in the receiving environment. To date, Quinsam has demonstrated that the existing mine related controls and features implemented have been effective at maintaining water quality below guidelines. This trend is expected to persist and will be highlighted by future monitoring programs.

In closing, Quinsam trusts the information herein addresses the environmental responsibilities and provisions applicable to effluent permit PE: 7008.

Should you have any questions or concerns please contact the undersigned at Quinsam Coal Environmental Department 250-286-3224 Ext 225.

Kathleen Russell, B.Sc. E.P. Environmental Coordinator - Quinsam Coal Corporation