Appendix 13.5-A IDZ Assessment Memo

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Final Memorandum

Tenas Project Initial Dilution Zone Assessment

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Project	1CT027.003

Executive Summary

An initial dilution zone (IDZ) assessment has been prepared to support Environmental Assessment (EA) application and address Joint Application Information Requirements (JAIR) for the proposed Tenas Project (the Project) in northwest British Columbia. This assessment was carried out following the Technical Guidance 11 (TG11) produced by the BC Ministry of Environment and Climate Change Strategy.

The IDZ is in Goathorn Creek below the confluence with a tributary that receives Project discharge from the Tenas Control Pond (TCP) and North Management Pond (NMP) during operation and post closure, respectively. This also includes discharge from the sewage treatment plant during operation. To characterize and delineate the IDZ, three credible and conservative cases were considered:

- a worst case (very worst case)
- a reasonable worst case (worst case that typically occurs)
- an expected case (case corresponding to average conditions)

The cases were defined based on conservative assumptions considering the in-stream flow and water quality of Goathorn Creek, and discharge rate and quality of Project effluent.

Parameters of potential concern (POPCs) were identified by screening the Project discharge water quality results relative to water quality guidelines (WQGs) for Goathorn Creek. Data were screened relative to the most stringent of:

- BC Approved Water Quality Guidelines (BC AWQG)
- BC Working Water Quality Guidelines (BC WWQG)
- Canadian Council of Ministers of the Environment (CCME) guidelines

The following parameters were identified as POPCs:

- dissolved and total aluminum
- arsenic
- dissolved cadmium
- chromium
- cobalt
- copper
- iron
- manganese
- nitrate-nitrogen
- nitrite-nitrogen
- selenium
- sulphate
- thallium
- uranium
- zinc

Site Performance Objectives (SPOs) were considered for selected parameters when case conditions exceed their respective WQGs.

To characterize the Goathorn Creek IDZ, cross-sectional channel morphology was surveyed at regularly spaced transects near the discharge location. Based on these surveys, a hydrodynamic model was developed using HEC-RAS. The estimated stream hydraulic properties were utilized in the mixing-dilution modeling. The water quality in the Goathorn Creek and its mixing and dilution characteristics were modeled using CORMIX. Estimates of the IDZ extent and corresponding plume features such as the flow occupied within the IDZ and its length and width were obtained considering the dilution required for each POPC to meet WQGs.

The reasonable worst case and the expected case are conservative but provide realistic scenarios for evaluation. These scenarios are summarized below.

During Operation:

- Reasonable worst case: Exceedance occurs for total aluminum, dissolved cadmium and selenium. These parameters meet the TG11 guidance when SPO limits are considered for in-stream water quality conditions.
- Expected case: Parameters meet TG11 guidance except total aluminum. The recommended guidelines are satisfied for total aluminum when the SPO limit is considered.

During Post Closure:

- Reasonable worst case: Exceedance occurs for total aluminum and iron. However, iron IDZ features are within 4% of the recommended values. Total aluminum meets TG11 guidance for the SPO limit, representing in-stream water quality.
- Expected case: Exceedance only occurs for total aluminum, but TG11 guidance is met when considering the SPO limit, representing in-stream water quality.

The end-of-pipe discharge criteria were developed for nitrate-nitrogen and total selenium. Based on the BC AWQG for nitrate-nitrogen and proposed Tier 1 SPO limit for selenium, the end-of-pipe targets were estimated to be 18.8 mg/L and 0.05 mg/L, respectively.

1 Introduction

The Tenas Project (the Project) is a proposed open pit coal mine, located approximately 25 km southwest of Smithers near the Town of Telkwa, British Columbia. All surface water in the Project footprint area will be collected through a series of management and sedimentation control ponds. Excess water will be discharged to the aquatic environment via a tributary of Goathorn Creek.

An initial dilution zone (IDZ) assessment has been prepared for the Project discharge to support the Discharge Management Plan for the Tenas Project as part of the Environmental Assessment (EA). IDZ characterization is required to address the Joint Application Information Requirements (JAIR) for the EA. This assessment is intended to delineate the extent of IDZ for the effluent discharge from the Project under a range of discharge and mixing conditions in the receiving stream.

Technical Guidance 11 (TG11), published by the Ministry of Environment and Climate Change Strategy (ENV 2019), specifies the presentation of worst, expected and best cases for an IDZ assessment. In this study, the IDZ delineation has been evaluated for 3 cases based on site-specific information. The cases presented include: a worst case (i.e., a very worst case), a reasonable worst case (i.e., worst case that typically occurs), and an expected case (i.e., case that corresponds to average conditions).

Table 1-1 lists the 3 cases and their corresponding flow and water quality conditions for Goathorn Creek and the discharge from the management ponds (i.e., Project Effluent). The flow and water quality conditions have been described in the hydrometeorological baseline report (SRK 2021a) and the water and load balance model results (SRK 2021b). Details of these cases are described in Sections 2.2 and 2.3.

Table 1-1: Definition of IDZ assessment cases

Cases	Goathorn Creek		Project Effluent	
	Flow condition	Water quality	Effluent discharge	Effluent quality
Worst case	7Q10 low-flow [(1)] of the lowest dilution month	50th percentile background concentration	Maximum discharge for lowest dilution month	95th percentile concentration with high source terms
Reasonable worst case	7Q10 low-flow relative to stream freshet	50th percentile background concentration	Average discharge for the freshet month	50th percentile concentration with high source terms
Expected case	Mean flow during critical period [(2)]	50th percentile background concentration	Average discharge during critical period	50th percentile concentration with expected source terms

Source: Prepared in the text

Notes:

[1] 7Q10 low-flow: 7-day minimum flow that is expected to occur once every 10 years

[2] Open water season (May-Oct) is the critical period for operation, while April-May is critical during post-closure

In the Canadian federal jurisdiction, end-of-pipe limits for discharge of excess water to the environment are not currently specified for the coal mining sector. The *Coal Mining Effluent Regulations (CMERs)* under the federal *Fisheries Act* are currently in development and expected to come into effect in future. Site-specific end-of-pipe discharge limits are presented in this study based on the in-stream water quality guidelines, site performance objectives and expected Project discharge rates.

The objectives of this memo are as follows:

- Present the IDZ delineation based on dispersion modeling
- Define end-of-pipe discharge criteria based on aquatic guidelines and Site Performance Objectives (SPOs)
- Provide end-of-pipe concentrations

1.1 Regulatory Context

The IDZ is a regulatory zone in the receiving aquatic environment where an effluent discharge is mixed and diluted. The BC Ministry of Environment and Climate Change Strategy (ENV) considers an IDZ for authorized project discharges based on the assessment of requested effluent releases according to Provincial guidance TG11 (ENV 2019).

The allowable extent of an IDZ depends on sensitivity and value of the receiving environment downstream of the discharge. TG11 provides some guidance on spatial dimensions for proposed IDZs. For rivers and streams (flowing water), the guidance recommends that an IDZ be limited within 25% of stream width, can occupy 25% of stream flow volume for low-flow conditions, and may extend up to 100 meters from the discharge point (ENV 2019). As outlined in TG11, these dimensions will vary on a case-by-case basis, depending on site-specific factors.

The release of parameters of potential concern (POPCs) should not cause acute toxicity in the receiving environment and the discharge at the end of the pipe released to the environment cannot exceed acute toxicity limits prior to mixing. In addition to acute toxicity limits, end-of-pipe limits are expected to come into effect based on *CMER*s under the federal *Fisheries Act* (ECCC 2018). Parameters are expected to include: pH, TSS, nitrate, and total dissolved selenium for new and existing coal mines.

The potential for chronic toxicity is limited to the IDZ extent, without significantly affecting aquatic life and integrity of the water body as a whole (ENV 2019). Appropriate selection of water quality guidelines (WQGs) is therefore critical in determining the extent of an IDZ. Selection of receiving WQGs is described in SRK (2021b), where the long-term average BC Approved Water Quality Guidelines or BC AWQG (ENV 2017) and the BC Working Water Quality Guidelines or BC WWQG (ENV 2015) for freshwater aquatic life and the BC Source Drinking Water Quality Guidelines (BC SDWQG 2020) were considered. Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (CCME WQG) are applied for those parameters for which no BC AWQG or BC WWQG have yet been established. Site Performance Objectives (SPOs) were developed for selected parameters for the Tenas Project. The SPOs are developed as in-stream site-specific receiving environment objectives, and for those parameters for which WQG exceedances were predicted, as part of water quality modeling.

2 Model Inputs

2.1 Site Description and Effluent Discharge

The management ponds (i.e., East, West and North Management Ponds) in the Project will collect all surface water from the mine area. The Tenas Control Pond (TCP) will be constructed downstream of all mining infrastructure and will collect water from the management ponds and all upstream mining activities prior to discharging excess water to the aquatic environment. Discharge will be directed towards a tributary of Goathorn Creek (Figure 2-1). Assessment of alternative discharge locations at a scoping level indicated that this location is beneficial in terms of water management and dilution capacity. A sewage treatment plant will operate onsite and will also discharge treated sewage effluent to the same tributary of Goathorn Creek during open-water season.

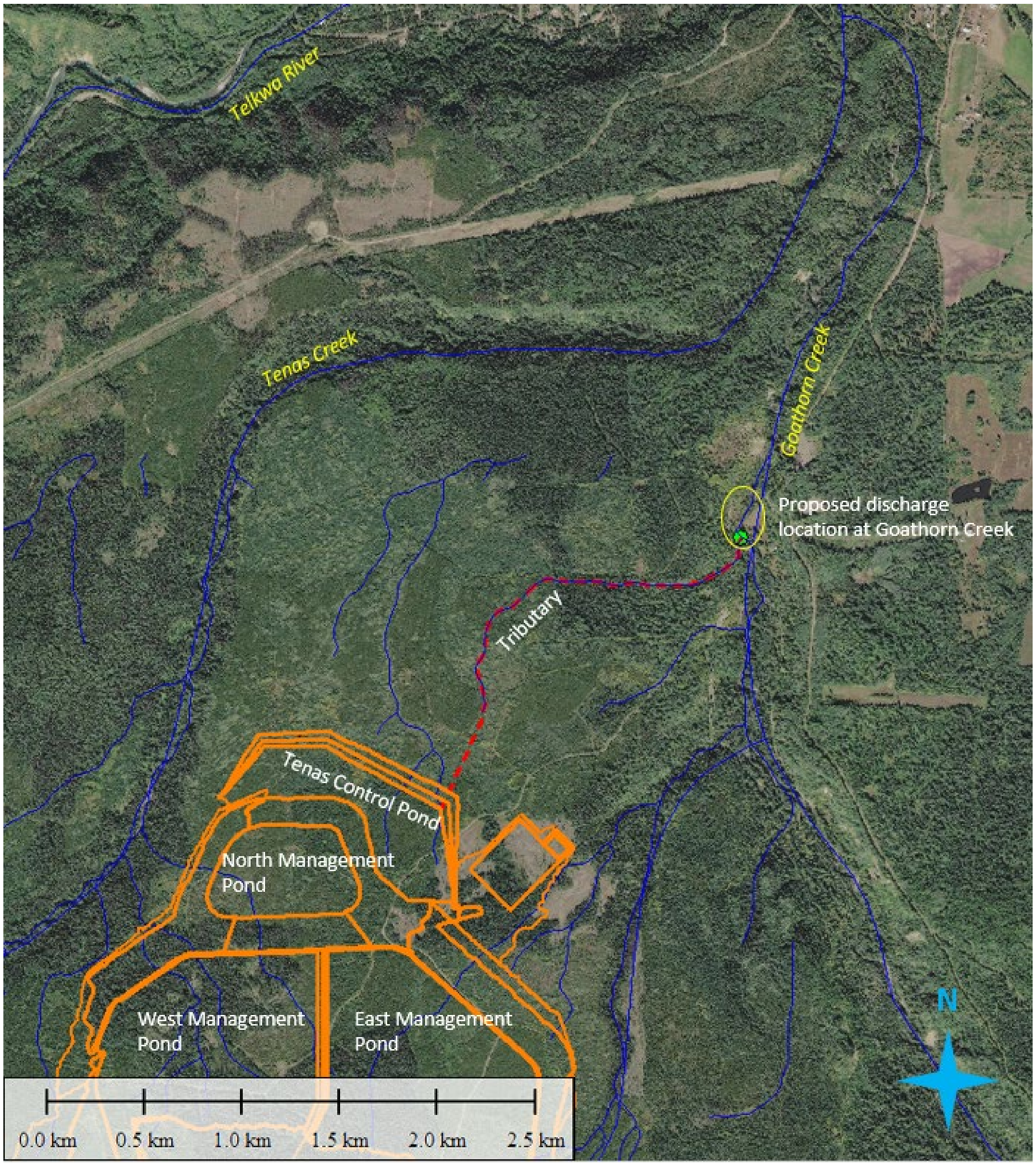

Figure 2-1: Location of proposed effluent discharge from the Tenas Project Management Ponds to Goathorn Creek

Goathorn Creek is a tributary of Telkwa River and flows along the eastern and northern extents of the Project. It is a braided creek with moderate width. Project discharge from the pond is conveyed to the creek through a tributary channel. This channel is typically steep, and the natural slope carries water downstream, ultimately discharging water along the left bank of Goathorn Creek. The tributary is not fish bearing, and erosion protection will be installed along the tributary to the confluence with Goathorn Creek (SRK 2021b). During operation, the TCP discharges only in open water season months and mixes with treated sewage effluent in the tributary of Goathorn Creek. The TCP will be decommissioned upon closure and, excess water will be released from the North Management Pond (NMP) through the same tributary channel towards Goathorn Creek.

Water quality in Goathorn Creek has the potential to be affected by mining operation. The primary pathways for impacting water quality, sources and receptors to the creek have been described in the Tenas Project Conceptual Site Model (SRK 2021c). The identified receptors including mammals, fish, amphibians, and human health were considered in the selection of the most appropriate water quality threshold criteria for the IDZ assessment described in Section 2.3.1.

2.2 Flow Characterization

Goathorn Creek is the receiving environment for the Project discharge from TCP in operation and NMP upon closure. Hydrologic estimates for the creek were estimated from the synthetic record of the Goathorn hydrologic station, which was developed based on scaling from the Goathorn Creek WSC station long-term data. The hydrology and detailed flow estimates for the creek are described in the Hydrometeorological Baseline Report (SRK 2021a).

The hydrograph of Goathorn Creek is dominated by meltwater in freshet (Figure 2-2), with a mean annual discharge of 1.7 m^3/s (SRK 2021a) at the Goathorn hydrologic station. Low flows typically occur in late fall and winter. The annual 7-day consecutive low flow during a 10-year return period (7Q10) is expected to be 0.22 m^3/s at the Goathorn hydrologic station. Monthly 7Q10 low-flow estimates range from 0.23 – 1.9 m^3/s. During the open water season (i.e., May – October), the monthly mean flow in the creek at Goathorn hydrologic ranges between 1.2 and 4.6 m^3/s, with an average of 2.68 m^3/s.

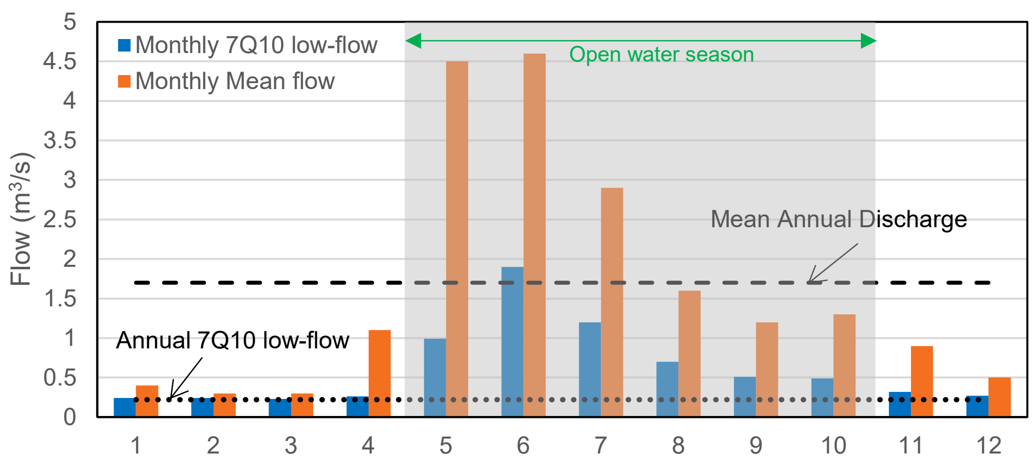

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Figure 2-2: Monthly flow at Goathorn hydrologic station in Goathorn Creek

The Project discharge from TCP (in operation) and NMP (after closure) into the Goathorn Creek tributary was obtained from the water and load balance modeling for the project footprint area (SRK 2021b). Long-term discharge estimates for the receiving environment were estimated using project-specific hydrology and considering the Project Case conditions with expected groundwater seepage, average hydrology (SRK 2022). Figure 2-3 illustrates the maximum monthly and average monthly discharges in operation and after closure. TCP discharge in operation primarily occur in the open water season. Discharge from TCP is highest in May, with maximum and average rate of 0.139 and 0.095 m^3/s respectively. The closure discharge from NMP will be highest in April.

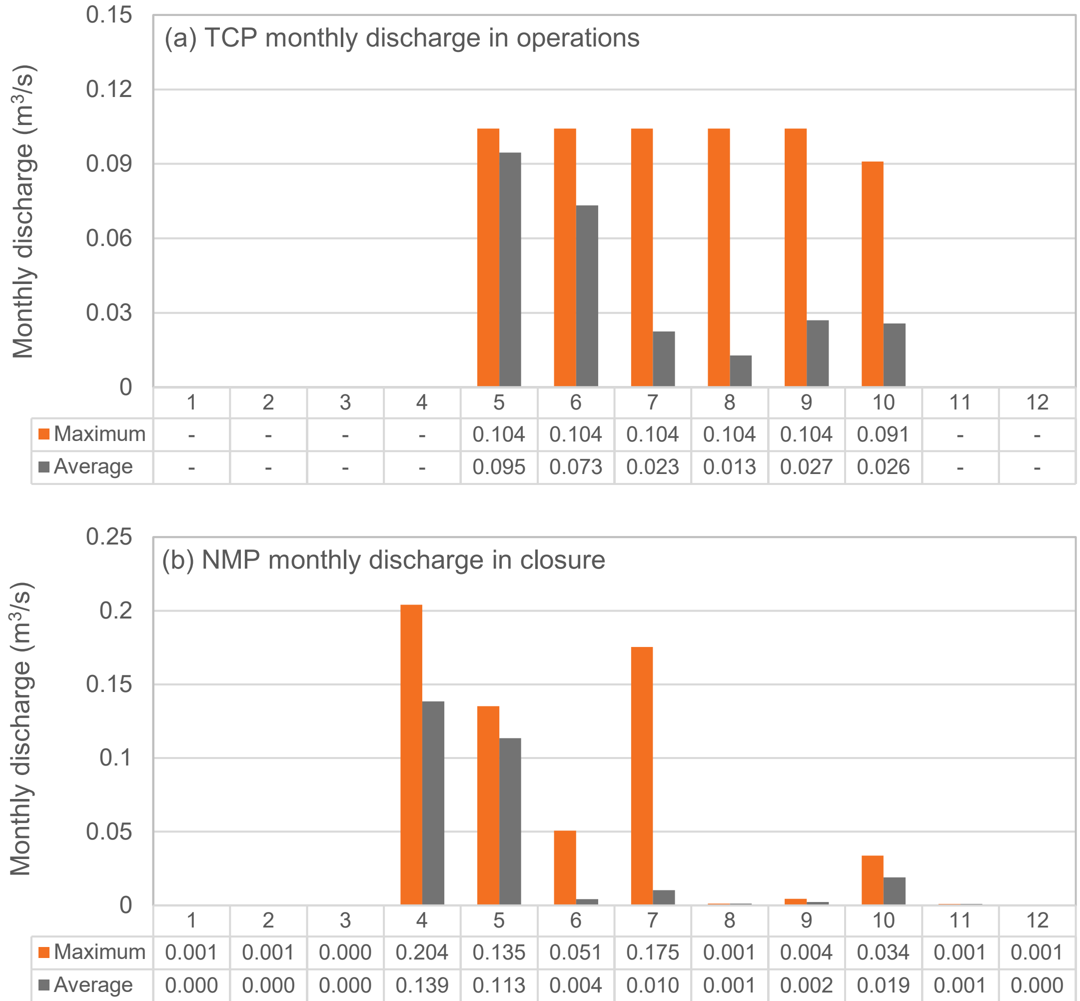

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Figure 2-3: Monthly Project discharge from (a) Tenas Control Pond (TCP) in operation, and (b) North Management Pond (NMP) upon closure

The lowest dilution capacity occurs when the low-flow condition prevails at Goathorn Creek with high Project discharge. Therefore, the IDZ case conditions were developed considering the low-dilution periods during operation and after closure (Table 2-1).

The summer open water season is critical for operation when the Project discharge rates are high (Figure 2-3a). The monthly average discharge is highest in May. However, the dilution capacity is lowest in September, which corresponds to relatively low monthly 7Q10 condition among the open-water season months (Figure 2-2) with maximum project discharge. Combinations of Project discharge rates with in-stream flow conditions were developed for operation as follows:

- Worst case: Monthly 7Q10 low-flow condition with maximum Project discharge rate during the same month (during open water season - October), representing lowest dilution condition
- Reasonable worst case: Monthly 7Q10 condition of a freshet month (May) and the corresponding monthly average discharge during this time (May)
- Expected case: Mean streamflow in open water season with average Project discharge over the same period

The dilution capacity after closure is low in April and May, when the Project discharge is higher. This period is critical since no operational controls are in-place to store water, and Goathorn Creek may still be experiencing lower flow pre-freshet. Combinations of Project discharge rates and in-stream flow conditions were developed for post closure as follows:

- Worst case: Maximum monthly Project discharge (April) with the April 7Q10 low-flow conditions, representing lowest dilution condition
- Reasonable worst case: Monthly 7Q10 condition of a freshet month (May) and the corresponding monthly average discharge for the same month (May)
- Expected case: Average of April and May Project discharge, which represents the average freshet discharge, and the average in-stream flow in Goathorn Creek over the same period (April and May)

Table 2-1: Case definition and flow summary

Cases	Goathorn Creek		Effluent Release		Flow ratio (1)
	Flow condition	***Flow***	***Discharge condition***	***Discharge***	
Operation (discharge from Tenas Control Pond)					
Worst case	7Q10 low-flow of the lowest dilution month (September)	0.51 m^3/s	Maximum discharge for the lowest dilution month (September)	0.104 m^3/s	4.9
Reasonable worst case	7Q10 low-flow relative to stream freshet (May)	0.99 m^3/s	Average discharge for the freshet month (May)	0.095 m^3/s	10.4
Expected case	Mean flow during critical period (May – October)	2.68 m^3/s	Average discharge during critical period (May – October)	0.043 m^3/s	62.3
Post Closure (discharge from North Management Pond)					
Worst case	7Q10 low-flow of the lowest dilution month (April)	0.26 m^3/s	Maximum discharge for the lowest dilution month (April)	0.204 m^3/s	1.3
Reasonable worst case	7Q10 low-flow relative to stream freshet (May)	0.99 m^3/s	Average discharge for the freshet month (May)	0.114 m^3/s	8.8
Expected case	Mean flow during critical period (April – May)	2.80 m^3/s	Average discharge during critical period (April – May)	0.126 m^3/s	22.2

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\InputDataAnalysis \TelkwaIDZ_InputSummary_rev08_rk.xlsm

Notes:

[1] Corresponds to ratio of Goathorn Creek flow over effluent discharge rate

2.3 Water Quality Characterization

Water quality characterization for each of the IDZ cases, including background water quality in Goathorn Creek, water quality guidelines, water chemistry of the effluent releases and corresponding POPCs, is discussed in the following sections.

2.3.1 Water Quality Guidelines

Water quality guidelines (WQG) for the Goathorn Creek receiving environment were established based on the most stringent of the long-term average BC AWQG and the BC WWQG for freshwater aquatic life and the BC SDWQG (SRK 2022). CCME WQGs were applied for those parameters for which no BC AWQG or BC WWQG have been established (Table 2-2). WQG of some parameters depend on the water quality in the receiving environment itself, and are adjusted for temperature, pH, hardness and/or total organic carbon (TOC) based on average background concentrations (i.e., pre-mining conditions) in the Goathorn Creek.

The WQGs were applied to screen for POPCs in the model results for the receiving environment in Goathorn Creek. SPOs were considered for selected parameters when case conditions exceed their respective WQGs. SPOs were developed for total aluminum (Borealis, Windward 2021a), total selenium (Borealis, Windward 2021b), dissolved cadmium (Borealis, Windward 2021c), total cobalt (Borealis, Windward 2020), total thallium (Borealis, Windward 2021d) and nitrite (Nautilus Environmental 2020). For total selenium, a Tier 1 SPO of 0.0080 mg/L was developed. In addition, a sulphate-dependent guideline was identified as the Tier 2 SPO to account for the mitigating effect of sulphate on selenium bioaccumulation (Borealis, Windward 2021b).

2.3.2 Background Water Quality

The background water quality information for Goathorn Creek has been described in SRK (2022), which outlines 50th and 95th percentile concentrations of the water quality parameters. In processing the receiving water quality data, values less than the method detection limit (MDL) were assumed to be equal to the MDL to remain conservative. The assessment focuses on the median (50th percentile) water quality results, with the upper percentile (95th percentile) used for POPC screening and end-of-pipe discharge criteria assessment.

Baseline water quality monitoring indicated that exceedances of WQGs have occurred historically in Goathorn Creek for total and dissolved aluminum, total copper and total iron. The 95th percentile concentrations for these parameters are 0.13 mg/L, 0.75 mg/L, 0.0054 mg/L and 0.78 mg/L respectively, which exceed their respective WQGs described in Section 2.3.1. The 50th percentile concentration of each parameter was used as the background concentration for the IDZ cases.

Long-term WQGs of Goathorn Creek and the 50th percentile background concentration of each parameter are presented in Table 2-2. These are utilized in screening for POPCs and to estimate the extent of the IDZ for each case evaluated in the study.

Table 2-2: Background concentration and long-term water quality guidelines for Goathorn Creek

Parameter	Goathorn Creek Background Concentration (mg/L) 50th Percentile	Water Quality Guideline (WQG)		SPO (mg/L)
		Value (mg/L)	Source	
Ammonia*	0.003	1.5	BC AWQG	
Aluminum, dissolved*	0.014	0.05	BC AWQG	
Aluminum, total*	0.092	0.1	CCME WQG	0.236
Antimony, total	0.00005	0.009	BC WWQG	
Arsenic, total	0.00023	0.005	BC AWQG	
Barium, total	0.06	1	BC WWQG	
Beryllium, total	0.00005	0.00013	BC WWQG	
Boron, total	0.005	1.2	BC AWQG	
Cadmium, dissolved*	0.0000081	0.00016	BC AWQG	0.00019
Chloride	0.25	150	BC AWQG	
Chromium, total	0.0002	0.0089	CCME WQG	
Cobalt, total	0.00005	0.004	BC AWQG	0.0174
Copper, total*	0.0015	0.0028	BC AWQG	
Fluoride	0.03	0.12	BC AWQG	
Iron, total	0.085	0.3	CCME WQG	
Lead, total	0.00003	0.005	BC AWQG	
Manganese, total*	0.0059	0.12	BC SDWQG	
Mercury, total	0.000003	0.00002	BCAWQG	
Molybdenum, total	0.0005	0.088	CCME WQG	
Nickel, total*	0.0003	0.08	BC WWQG	
Nitrate-nitrogen	0.041	3	BC AWQG	
Nitrite-nitrogen	0.0005	0.02	BC AWQG	0.0524
Selenium, total	0.000086	0.002	BC AWQG	0.008 **
Strontium, total	0.076	7	BC SDWQG	
Silver, total*	0.00001	0.00005	BC AWQG	
Sulphate	24	218	BC AWQG	
Thallium, total	0.000005	0.0008	BC WWQG	0.0022
Uranium, total	0.000054	0.0085	BC WWQG	
Zinc, total*	0.0015	0.0075	BC AWQG	

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\InputDataAnalysis \TelkwaIDZ_InputSummary_rev08_rk.xlsm

Note: * Guideline dependent on hardness, pH, and temperature. Calculated based on the 50th percentile parameters from Goathorn Creek baseline monitoring. Note that a hardness value of 69 mg-$CaCO_3$/L (the 50th percentile concentration) from Goathorn Creek background concentration was used, when the guideline was adjusted for hardness.

** Tier 1 SPO for total selenium

2.3.3 Effluent Water Quality

Long-term estimates of effluent water quality were developed from water and load balance modeling results from pre-mining conditions, through operation and post closure (SRK 2022). These predictions incorporate variability in hydrologic conditions, groundwater conditions and geochemical source terms. Results are presented in terms of an expected source term and a worst-case high source term. Source terms are described in the water and load balance report (Appendix E, SRK 2022).

To represent the IDZ cases, statistics on the water quality time series were selected. The 50th and 95th percentiles were estimated from two 6-month periods, which reflect the open water period, denoted as summer in the result tables (i.e., May through October) and the winter period, where streamflow is dominated by groundwater recharge (i.e., November through April). Since project release from the TCP is discharged in open water season, statistics from this period were used to define the IDZ cases in operation. Concentrations of various water quality parameters for the worst case and the reasonable worst case were represented by the 95th and 50th percentiles, respectively, with the high source term. The expected case corresponds to 50th percentile summer concentration with expected source term (Table 2-3).

After operation, the TCP is decommissioned, and discharge controls are no longer available. Discharge from the Project is high in April and May, which have the least dilution capacity for the discharge from NMP after closure. Therefore, winter statistics were selected for IDZ post closure cases, since these provide conservative estimates compared to summer concentrations. The winter 95th percentile with high source term, 50th percentile with high source term and 50th percentile with expected source term were selected to represent the effluent discharge concentrations for the worst, reasonable worst and expected cases during after closure.

2.3.4 Parameters of Potential Concern

POPCs in the effluent releases were identified by screening the modelled Project discharge water quality results against the WQGs described in Section 2.3.1. This screening was carried out preferentially for parameters that have WQGs. The screening criteria were estimated using in stream water chemistry, as appropriate. Parameters that had 95th percentile concentrations above their respective WQGs were considered as POPCs.

Parameters identified as POPCs included: dissolved and total aluminum, arsenic, dissolved cadmium, chromium, cobalt, copper, iron, manganese, nitrate-nitrogen, nitrite-nitrogen, selenium, sulphate, thallium, uranium, and zinc.

Some constituents exceeded screening levels, but are not considered POPCs:

- In the TCP, the winter maximum and 95th percentile concentration of fluoride and total ammonia exceeded the BC AWQG, but there is no discharge from the pond during the winter
- There were only a few exceedances for antimony during operation, but the maximum concentration was very close to BC AWQG, and the 95th percentile concentration was below the WQG

Table 2-3 outlines the effluent concentration of each POPC for the worst, reasonable worst and expected cases evaluated in IDZ assessment.

Table 2-3: Effluent water quality characterization for the identified POPCs

Parameter	Effluent Concentration (mg/L)					
Project Stage	Operation			Post Closure		
IDZ Case	Worst case	Reasonable worst case	Expected case	Worst case	Reasonable worst case	Expected case
Water Balance Result Percentile	P95	P50	P50	P95	P50	P50
Source Term	High	High	Expected	High	High	Expected
Period Statistics	Summer	Summer	Summer	Winter	Winter	Winter
Aluminum, dissolved	0.16	0.046	0.029	0.01	0.0043	0.0042
Aluminum, total	0.53	0.42	0.4	0.38	0.37	0.37
Arsenic, total	0.0068	0.0029	0.0013	0.0014	0.001	0.00086
Cadmium, dissolved	0.0051	0.0013	0.00017	0.0002	0.000088	0.000036
Chromium, total	0.012	0.0073	0.0037	0.0051	0.0033	0.0023
Cobalt, total	0.01	0.0042	0.0017	0.0019	0.0013	0.00098
Copper, total	0.015	0.0091	0.0048	0.0061	0.004	0.0028
Iron, total	1.6	1.5	1.5	1.5	1.5	1.5
Manganese, total	0.32	0.15	0.075	0.081	0.055	0.042
Nitrate-nitrogen	6.4	2.1	2.1	0.18	0.01	0.01
Nitrite-nitrogen	0.15	0.048	0.048	0.0047	0.00092	0.00092
Selenium, total	0.027	0.017	0.0076	0.012	0.0062	0.0031
Sulphate	1500	980	430	680	340	170
Thallium, total	0.0052	0.0014	0.00018	0.00022	0.00011	0.000065
Uranium, total	0.012	0.0069	0.0028	0.0046	0.0024	0.0012
Zinc, total	0.037	0.02	0.011	0.013	0.0087	0.0067

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\InputDataAnalysis \TelkwaIDZ_InputSummary_rev08_rk.xlsm

Note:

P50 and P95 represent the 50^{th} percentile and 95^{th} percentile, respectively, of modelled monthly water quality from the discharging facility (SRK 2021b)

2.4 Sewage Effluent

The sewage treatment plant (STP) will discharge treated effluent into the tributary of Goathorn Creek. The treated effluent is held in a pond over winter and discharged during the open-water season from May through September. The average discharge rate from the STP is 41.5 m^3/day (0.0005 m^3/s). The effluent water quality was obtained from water and load balance modeling (SRK 2022) and is presented in Table 2-4. Considering TCP discharge rate (Table 2-1) and corresponding water quality (Table 2-3) for the 3 IDZ cases, concentrations in the tributary of Goathorn Creek were obtained based on mass balance approach assuming a fully mixed condition.

After mixing of sewage effluent and TCP discharge, total ammonia concentration in the tributary was below the WQG (1.5 mg/L). Ammonia was not considered a POPC. Nitrate-nitrogen and nitrite-nitrogen was identified as POPCs (refer to Section 2.3.4), and the mixed concentrations in the tributary were used for IDZ modeling at the Goathorn Creek.

According to BC Municipal Wastewater Regulation, a dilution ratio of 10:1 is required for sewage effluent (Radloff 2021), which will be supplied by the discharge from the Tenas Control Pond during operation. The dilution for the IDZ cases is high (> 90), and the required water to mix with sewage effluent will be met throughout operations based on available water in the TCP.

Table 2-4: Water quality of treated sewage effluent

Parameter	Cases	Effluent concentration (mg/L)		Concentration in tributary [(1)] (mg/L)	Dilution [(2)]
		STP	TCP		
Nitrate-nitrogen	Worst	36.9	6.4	6.5	218
	Reasonable worst	36.9	2.1	2.3	199
	Expected	36.9	2.1	2.5	91
Nitrite-nitrogen	Worst	0.1	0.15	0.15	218
	Reasonable worst	0.1	0.048	0.048	199
	Expected	0.1	0.048	0.049	91
Total ammonia (as nitrogen)	Worst	1.9	0.83	0.83	218
	Reasonable worst	1.9	0.27	0.28	199
	Expected	1.9	0.27	0.29	91

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\InputDataAnalysis \TelkwaIDZ_InputSummary_rev08_rk.xlsm

Notes:

[1] Obtained from mass-balance considering discharge rate from sewage treatment plant (STP) and Tenas Control Pond (TCP)

[2] Considering TCP discharge rate and sewage effluent discharge rate

2.5 Stream Survey

A field survey was carried out on October 30, 2020, in Goathorn Creek by DWB (2020). During the survey, the average streamflow in the creek was 1.2 m^3/s, based on the real-time hydrometric monitoring at Water Survey of Canada station 08EE008 (WSC 2020). This is comparable to the flow rate used in the reasonable worst case (i.e., 0.99 m^3/s) which corresponds to the 7Q10 flow during freshet (May).

To obtain a detailed description of the Goathorn Creek IDZ, cross-sectional measurements were carried out at 5 locations upstream and downstream of the proposed discharge point (Figure 2-4). The tributary discharges from the left bank at the creek, and a section (denoted by section C) was measured at this discharge location. Four more sections upstream (sections A and B) and downstream (sections D and E) were surveyed, covering about a 220 m reach near the discharge location. In each section, measurements were taken at close interval to capture the local variation of channel depth. Locations of the overbank points and water levels were also noted. The presence of boulders and cobbles in the creek makes the cross-sectional shapes highly irregular (Figure 2-4). The bed profile and the channel slope were obtained from these cross-sectional measurements. The estimated bed slope for the surveyed reach is about 2.3% (DWB 2020).

Figure 2-4: Surveyed cross sections near the Goathorn Creek discharge point

2.6 Hydraulic Properties

Assessment of stream hydraulic properties is crucial for the development of a mixing-dilution model, as these govern the dispersion characteristics in the receiving environment. Therefore, HEC-RAS (USACE 2016), a widely used tool for environmental applications, was utilized to develop a hydrodynamic model of the Goathorn Creek. Given the low-flow scenarios and the resolution of input data, this model is representative for the level of detail required in this study.

2.6.1 Methodology and Model Development

The model domain was constructed using the surveyed cross sections measured upstream and downstream of the discharge point, covering about 220 m long reach of the Goathorn Creek. Because of the highly irregular geometry, cross sections were interpolated to be 2 m spaced apart for better representation of hydraulic features. During the cross-section survey, average flow at the Goathorn Creek was 1.2 m^3/s, which was applied as the upstream boundary condition. The model was set to a normal depth boundary condition at the downstream model extent.

Since the IDZ assessment typically uses low-flow conditions, the variation in roughness between the channel and overbank locations is not very important, and a single channel roughness value was assigned for the entire reach. The model was calibrated by adjusting Manning's roughness coefficient 'n' to maintain observed water depths in the upstream sections. The estimated roughness coefficient was 0.14, typical of the large cobbles and boulders observed at the site. This also falls within the range of acceptable roughness values found in literature (USACE 2016). The measured and simulated water surface elevation agreed very well, with a correlation coefficient, R^2 = 0.999 (Figure 2-5), indicating appropriate selection of the model parameters.

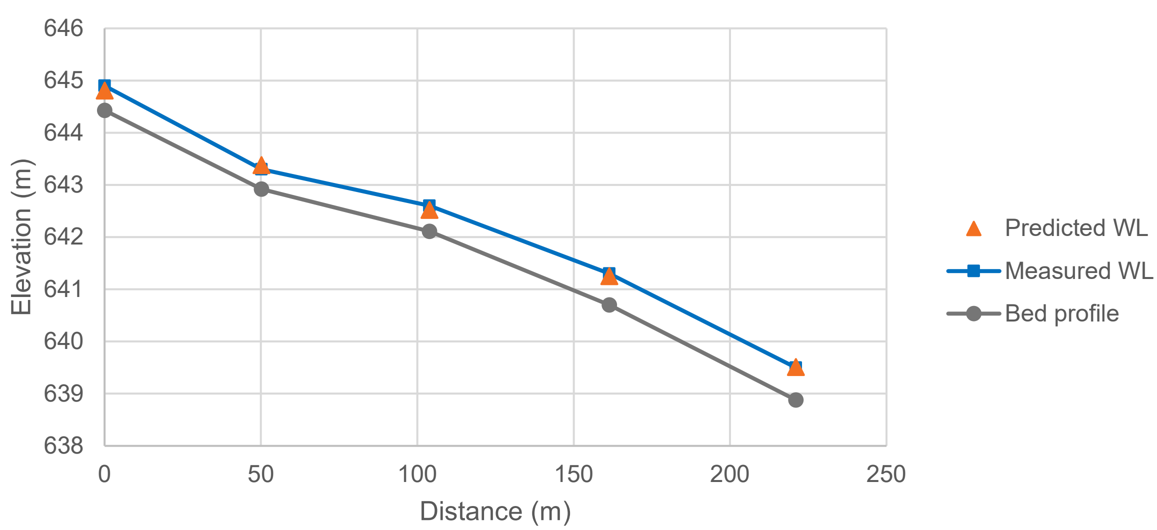

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Figure 2-5: Comparison between the measured and simulated water surface elevation

2.6.2 Hydraulic Characterization Results

The calibrated model was utilized to simulate the Goathorn Creek flow conditions for the three cases – worst, reasonable worst and expected conditions, during operation and post closure. For each case, the creek flow, and the corresponding effluent discharge rate (Table 2-1) were considered in the total flow. Various hydraulic parameters, such as depth, velocity, and width, were averaged over the IDZ reach downstream of the discharge location. Table 2-5 highlights the hydraulic characteristics for each case, which were utilized in the mixing-dilution modeling described in Section 3.

Table 2-5: Hydraulic features of Goathorn Creek for different cases

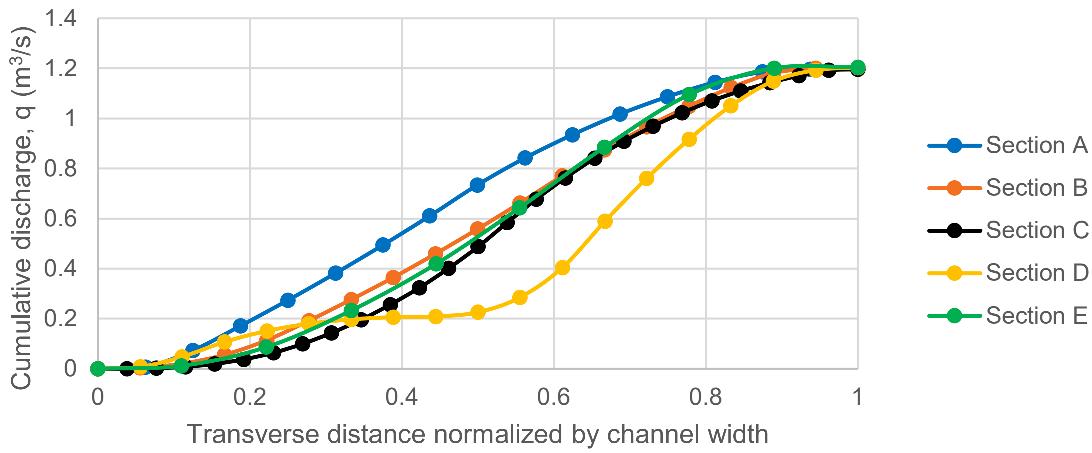
Parameter	Calibration	Operation			Post Closure		
		Worst case	Reasonable worst case	Expected case	Worst case	Reasonable worst case	Expected case
Total flow (m^3/s)	1.2	0.614	1.085	2.723	0.464	1.103	2.926
Slope (m/m) [(1)]	0.0231	0.0239	0.0231	0.0229	0.0244	0.0231	0.0229
Average Depth (m)	0.31	0.23	0.30	0.42	0.20	0.30	0.43
Average Velocity (m/s)	0.49	0.40	0.47	0.59	0.38	0.47	0.61
Average Width (m)	9.1	7.5	8.9	11.5	6.9	9.0	11.8

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\Hydraulic Analysis\HEC-RAS Modeling \TelkwaIDZ_GHC_hecras_modeling_rev04_nst

Notes:

[1] Slope of the energy grade line

Using the calibrated hydrodynamic model, velocity distribution and corresponding cumulative discharge were analyzed for the Goathorn Creek. The cumulative discharge, q, represents the volumetric flow rate which occurs between the bank and a given position within the channel, and is equal to zero on one bank and equal to the total discharge (Q) on the other bank. The cumulative discharge distribution at the surveyed sections of the Goathorn Creek is illustrated in Figure 2-6 where q = 0 at the left bank and q = 1.2 m^3/s at the right bank of the creek. The distribution is similar for most cases, except for section A (which is narrow) and section D (with divided flow).



Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

Figure 2-6: Cumulative discharge distribution at Goathorn Creek sections

The distribution of cumulative discharge lines in a channel provides an indication of the overall flow pattern that is important for constituent transport. The closely-spaced discharge lines, as shown in Figure 2-7, represent areas of large depth and higher velocities in the Goathorn Creek. Also, the sections are typically shallow towards the left bank, so wider plume widths are expected for effluent discharge, which exceeds that provided in the TG11 guidance. For example, section C (discharge location) and downstream sections occupy 37-56% channel width for 25% flow. As a result of this site-specific shallow-flow configuration, wider plume width criterion (40% of channel width) was used for IDZ delineation (see Table 3-2).

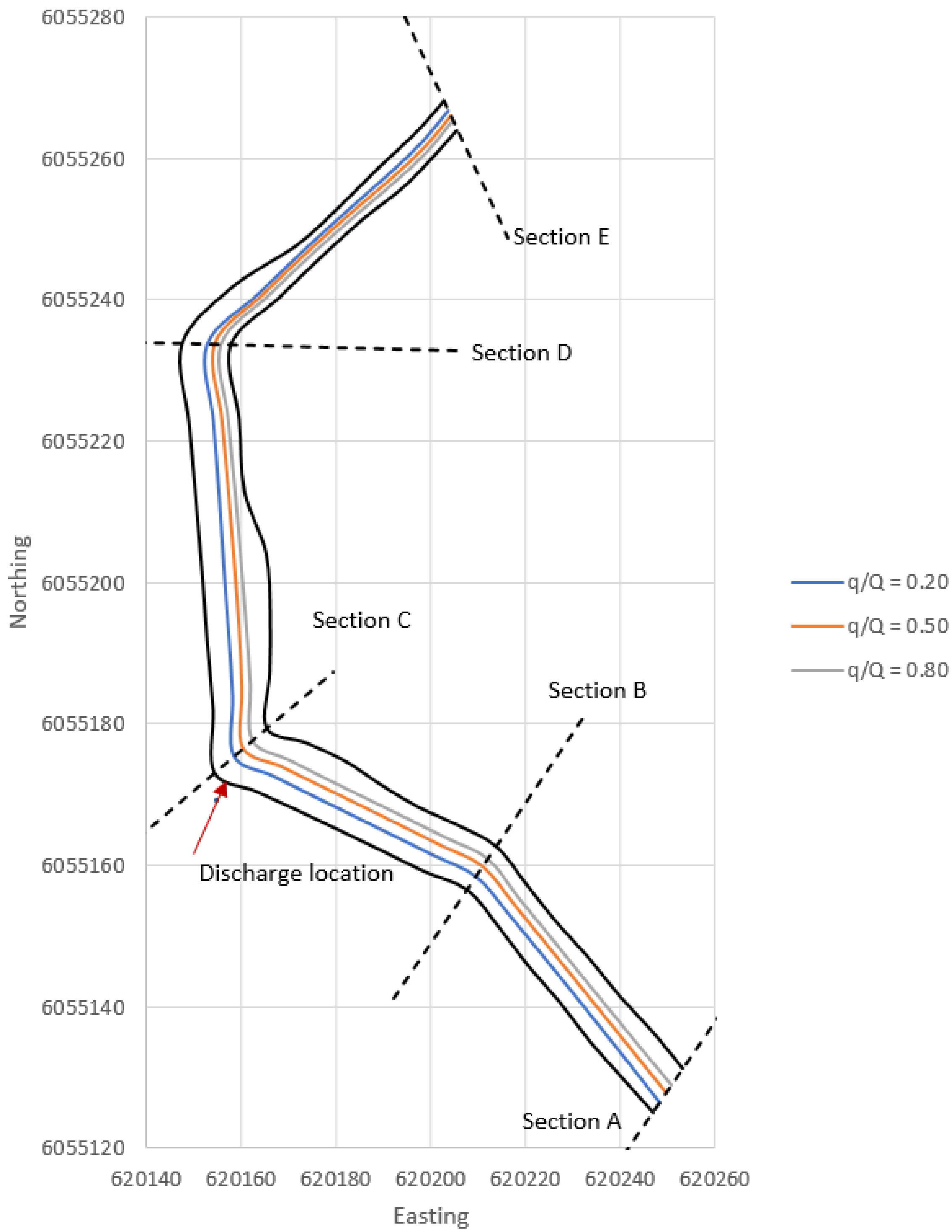


Figure 2-7: Illustration of cumulative discharge near the Goathorn Creek IDZ

3 Mixing and Dilution Modeling

The water quality in the Goathorn Creek and its mixing and dilution characteristics were modeled using CORMIX (Doneker and Jirka, 2007), which is a computer-aided system for the analysis, prediction, and design of regulatory mixing zones, and is supported by the US Environmental Protection Agency.

3.1 Mixing Model Description

CORMIX employs jet integral model for near-field and cumulative discharge method (Yotsukura and Sayre, 1976) for far-field mixing processes (Doneker and Jirka, 2007). The program requires input on flow and discharge rate, hydraulic condition, simplified geometry of ambient and discharge channel, and water quality descriptions, among others. For the IDZ cases evaluated in this study, the model was configured as a slightly meandering channel (conservative assumption) to represent the Goathorn Creek, with Manning's roughness coefficient obtained from the hydraulic modeling (Section 2.6). The model geometry for each IDZ case was schematized as a rectangular cross-section keeping the depth-velocity conditions consistent with hydraulics of the creek (refer to Table 2-5). For the tributary (discharging channel), it was assumed that the velocity is the same as the creek, and the depth at the discharge location is similar to the mean depth of creek flow. The model domain was extended up to 1.5 km downstream of the discharge location.

For water quality prediction, parameter concentrations were specified for the effluent discharge with consideration of background water quality in the creek. With the mixing models set for the worst, reasonable worst and expected cases, in-stream water quality was evaluated for each POPC. Estimates of the effluent plume were obtained at various distances downstream of the discharge location, and across the transverse direction of the creek.

3.2 Dilution Model Results

The developed CORMIX model was used to predict water quality in the Goathorn Creek as a result of effluent discharge from the TCP (during operation) and North Management Pond (during post closure). The model provided estimates of concentration change and corresponding dilution of the effluent plumes at downstream locations. Figure 3-1 and Figure 3-2 illustrate dilution contours for the IDZ cases during operation and during post closure, respectively. The dilution (denoted as *S*) is defined as the effluent concentration (or initial concentration) over the concentration at a point resulting from mixing. Since CORMIX utilizes the 'cumulative discharge method', the transverse dimension illustrated in the figures represents relative width in terms of cumulative discharge across the creek. The actual width was obtained using the cumulative discharge distribution of the surveyed cross sections described in Section 2.6.2.

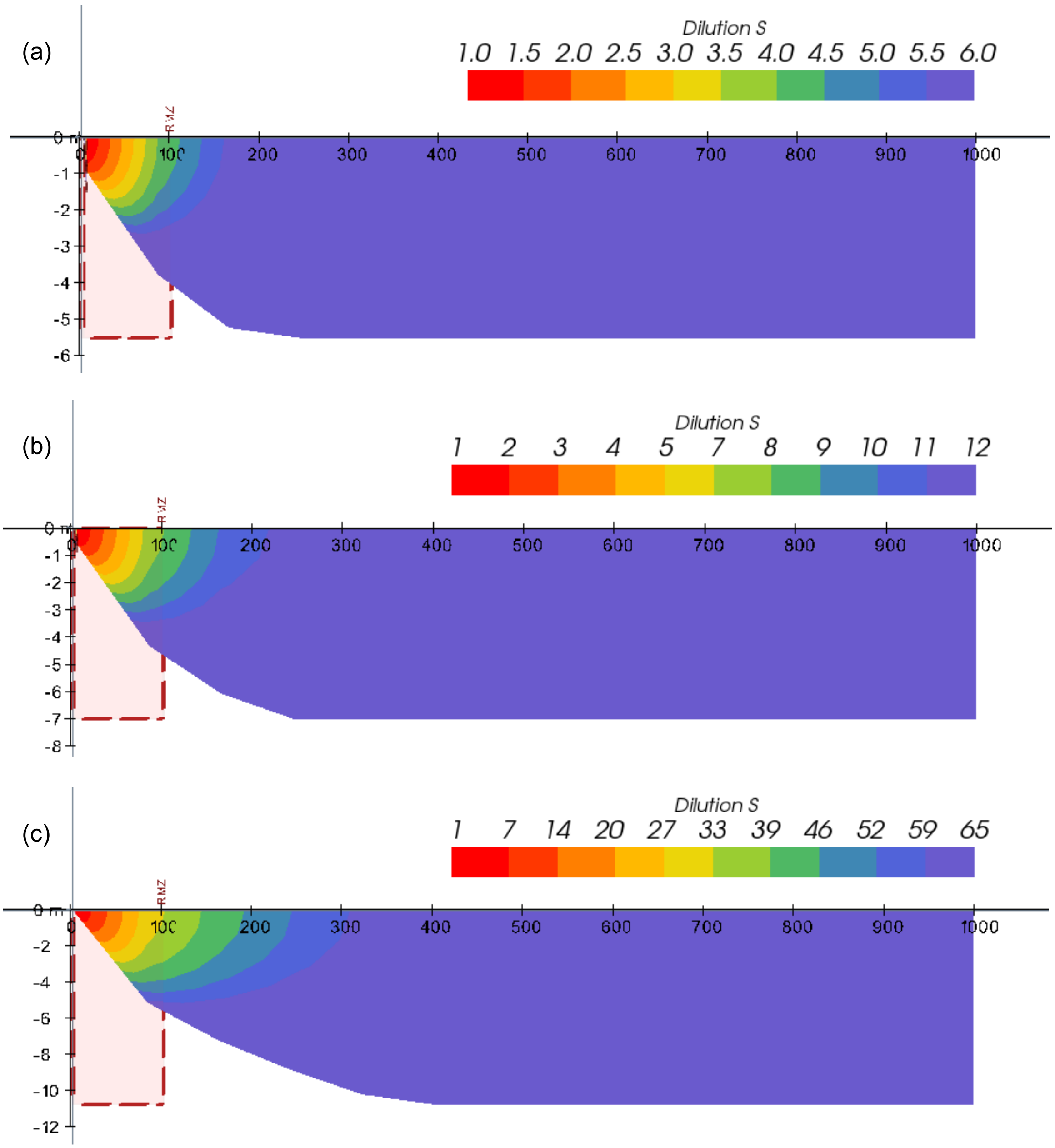


Figure 3-1: Model results showing dilution for the IDZ cases during operation – (a) worst case (S_{max} = 5.7), (b) reasonable worst case (S_{max} = 11.6), and (c) expected case (S_{max} = 55.7)

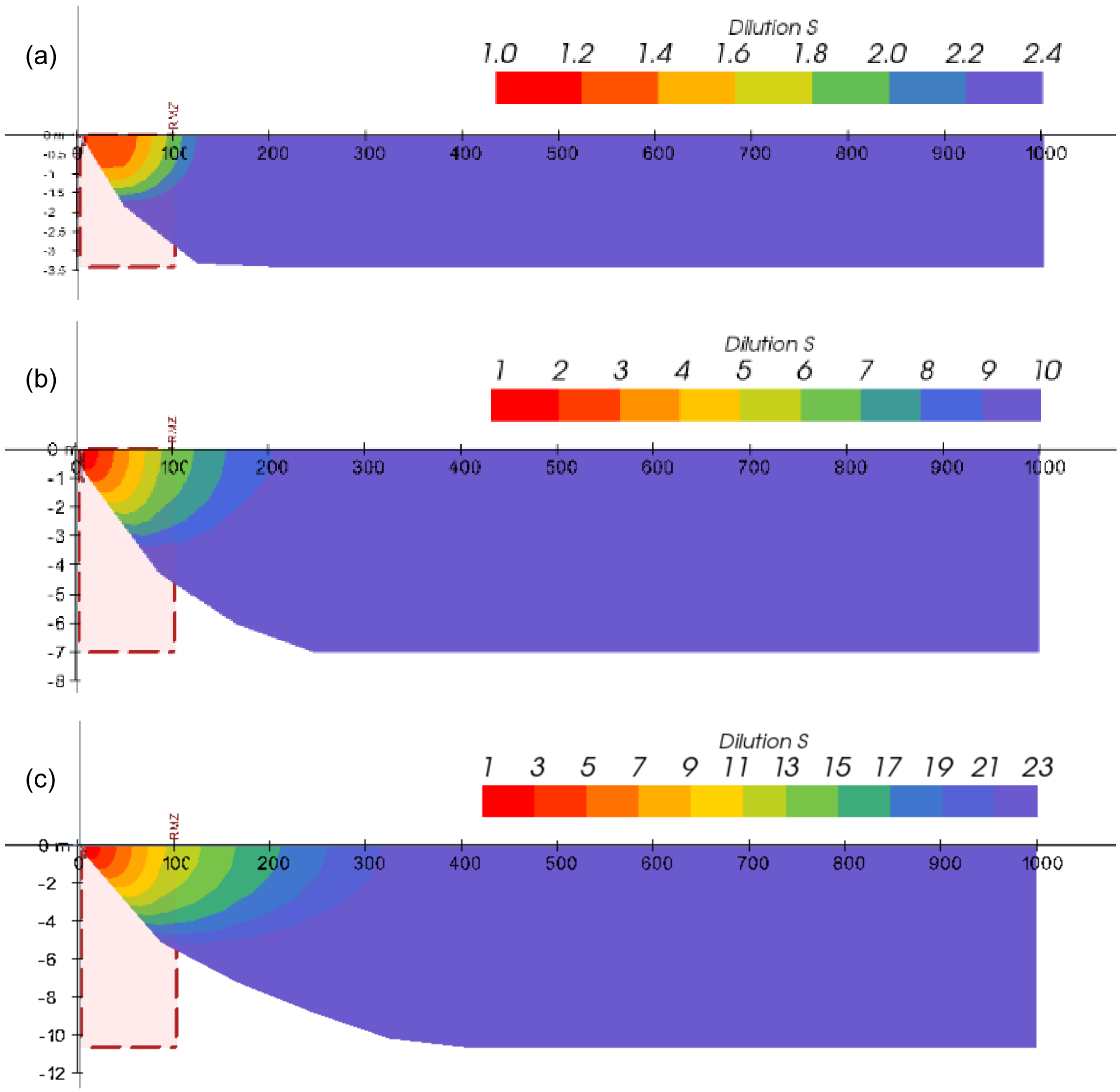


Figure 3-2: Model results showing dilution for the IDZ cases during post closure – (a) worst case (S_{max} = 2.3), (b) reasonable worst case (S_{max} = 9.7), and (c) expected case (S_{max} = 23.2)

As a result of turbulent mixing, the effluent plume is diluted downstream beyond the discharge location. The maximum dilution depends on the creek flow and the effluent discharge rate. For the worst, reasonable worst and expected cases, the maximum dilutions were 5.7, 11.6 and 55.7 during operation and 2.3, 9.7 and 23.2 during Post Closure, respectively (Table 3-1). Due to shallow depths, plumes become vertically well-mixed within shorter distances, and the dilution is governed by transverse mixing across channel width. The mixing coefficient for different cases varied from 0.022 – 0.066 m^2/s, where the dimensionless mixing coefficient was about 0.5. This is a conservative estimate and falls within literature values. The dimensionless transverse mixing coefficients can vary from 0.3-0.6 for regular channels and 0.6-0.9 for gently-meandering channels (Fischer et al. 1979; Rutherford 1994).

Table 3-1: Mixing model results for various cases

Parameter	Operation			Post Closure		
	Worst case	Reasonable worst case	Expected case	Worst case	Reasonable worst case	Expected case
Goathorn Creek Flow (m^3/s)	0.51	0.99	2.68	0.26	0.99	2.80
Effluent Discharge Rate (m^3/s)	0.104	0.095	0.043	0.204	0.113	0.126
Total Flow (m^3/s)	0.614	1.085	2.723	0.464	1.103	2.926
Transverse Mixing Coefficient (m^2/s)	0.026	0.038	0.063	0.022	0.038	0.066
Limiting Dilution, S_{max} (1)	5.9	11.4	63.3	2.3	9.8	23.2
Complete Mixing Length (m)	183	217	359	130	221	354

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

Notes:

[1] Maximum possible dilution for a given flow condition.

Table 3-1 shows the model predicts that complete mixing during operation will be achieved at 183 m, 217 m and 359 m downstream from the effluent source for the worst case, reasonable worst case and expected case, respectively. It remains similar for the reasonable worst case, and expected case in post closure, but reduces to 130 m for the worst case. These results suggested that complete mixing is not achieved within the TG11 IDZ length guidance of 100 m.

3.3 IDZ Delineation

The effluent and Goathorn Creek background water chemistries described in Sections 2.3.2 and 2.3.3, respectively, were applied to the mixing model for each POPC, considering the dilution required to meet the corresponding WQGs. Plume features such as the flow occupied within the IDZ and its length and width were estimated for the three case scenarios. As outlined in TG11, these dimensions can vary depending on site-specific factors. Because of the shallow configuration near the left banks of Goathorn Creek (Section 2.6.2), plume widths are typically higher for a given flow condition, and 40% of channel width was considered for IDZ delineation. This width corresponds to 25% of total flow at the discharge location (section C, Figure 2-6). Emphasis was placed upon the IDZ length and flow criteria for evaluation. Table 3-2 outlines the evaluation criteria for the Goathorn Creek IDZ.

Table 3-2: Evaluation criteria for IDZ delineation

IDZ Feature	Criterion	Reference / Remark
Length	100 m	TG11 (ENV 2019)
Flow	25% of total flow	TG11 (ENV 2019)
Width	40% of channel width	Based on site-specific condition guided by TG11 (Section 3.5.2)

Source: Compiled in text

3.3.1 IDZ Results for Operation

The modeled water quality of each POPC and corresponding plume features in the Goathorn Creek was compared with the IDZ evaluation criteria (Table 3-2) based on TG11 guidance. Considering BC ENV and/or CCME WQGs, guidance values are exceeded in operations for the following parameters:

- Worst case: Dissolved and total aluminum, dissolved cadmium, copper, iron, nitrite-nitrogen, selenium, sulphate, thallium and zinc
- Reasonable worst case: Total aluminum, dissolved cadmium and selenium
- Expected case: Total aluminum

Table 3-3 compares the results of the IDZ model for each POPC against the TG11 guidance criteria. Figure 3-3 presents the delineated plumes for the POPCs during discharge from TCP during operation.

Table 3-3: Results of the IDZ cases from Tenas Control Pond discharge in operation

Parameter	Scenario	WQG (mg/L)	Background concentration (mg/L)	Effluent concentration (mg/L)	IDZ length (m)	IDZ flow (% of stream)	IDZ width (% of stream)
Aluminum, dissolved	Worst case	0.05	0.014	0.16	88.8	29.6	43.8
	Reasonable worst	0.05	0.014	0.046	n.a.	n.a.	n.a.
	Expected case	0.05	0.014	0.029	n.a.	n.a.	n.a.
Aluminum, total	Worst case	0.1	0.092	0.53	Fully mixed concentration > WQG		
	Reasonable worst	0.1	0.092	0.42	Fully mixed concentration > WQG		
	Expected case	0.1	0.092	0.4	132.8	26.1	41.7
Arsenic, total	Worst case	0.005	0.00023	0.0068	11.5	9.8	28.6
	Reasonable worst	0.005	0.00023	0.0029	n.a.	n.a.	n.a.
	Expected case	0.005	0.00023	0.0013	n.a.	n.a.	n.a.
Cadmium, dissolved	Worst case	0.00016	0.0000081	0.0051	Fully mixed concentration > WQG		
	Reasonable worst	0.00016	0.0000081	0.0013	122.2	32.1	45.3
	Expected case	0.00016	0.0000081	0.00017	3.2	0.5	10.2
Chromium, total	Worst case	0.0089	0.0002	0.012	11.5	9.8	28.6
	Reasonable worst	0.0089	0.0002	0.0073	n.a.	n.a.	n.a.
	Expected case	0.0089	0.0002	0.0037	n.a.	n.a.	n.a.
Cobalt, total	Worst case	0.004	0.00005	0.01	33.2	17.9	35.9
	Reasonable worst	0.004	0.00005	0.0042	5.7	2.7	18.1
	Expected case	0.004	0.00005	0.0017	n.a.	n.a.	n.a.
Copper, total	Worst case	0.0028	0.0015	0.015	Fully mixed concentration > WQG		
	Reasonable worst	0.0028	0.0015	0.0091	58.9	21.9	38.9
	Expected case	0.0028	0.0015	0.0048	4.6	1.5	15.0

Parameter	Scenario	WQG (mg/L)	Background concentration (mg/L)	Effluent concentration (mg/L)	IDZ length (m)	IDZ flow (% of stream)	IDZ width (% of stream)
Iron, total	Worst case	0.3	0.085	1.6	Fully mixed concentration > WQG		
	Reasonable worst	0.3	0.085	1.5	74.9	24.7	40.7
	Expected case	0.3	0.085	1.5	8.8	2.2	16.8
Manganese, total	Worst case	0.12	0.0059	0.32	42.3	20.4	37.7
	Reasonable worst	0.12	0.0059	0.15	6.8	4.5	21.6
	Expected case	0.12	0.0059	0.075	n.a.	n.a.	n.a.
Nitrate-nitrogen *	Worst case	3	0.041	6.5	25.7	15.1	33.5
	Reasonable worst	3	0.041	2.3	n.a.	n.a.	n.a.
	Expected case	3	0.041	2.5	n.a.	n.a.	n.a.
Nitrite-nitrogen *	Worst case	0.02	0.0005	0.15	Fully mixed concentration > WQG		
	Reasonable worst	0.02	0.0005	0.048	13.3	8.1	26.7
	Expected case	0.02	0.0005	0.049	4.6	1.5	15.0
Selenium, total	Worst case	0.002	0.000086	0.027	Fully mixed concentration > WQG		
	Reasonable worst	0.002	0.000086	0.017	131.3	33.1	45.9
	Expected case	0.002	0.000086	0.0076	6.0	1.8	16.0
Sulphate	Worst case	218	24	1500	Fully mixed concentration > WQG		
	Reasonable worst	218	24	980	43.3	18.0	35.9
	Expected case	218	24	430	4.2	1.4	14.4
Thallium, total	Worst case	0.0008	0.000005	0.0052	Fully mixed concentration > WQG		
	Reasonable worst	0.0008	0.000005	0.0014	9.8	6.7	24.9
	Expected case	0.0008	0.000005	0.00018	n.a.	n.a.	n.a.
Uranium, total	Worst case	0.0085	0.000054	0.012	11.5	9.8	28.6
	Reasonable worst	0.0085	0.000054	0.0069	n.a.	n.a.	n.a.
	Expected case	0.0085	0.000054	0.0028	n.a.	n.a.	n.a.
Zinc, total	Worst case	0.0075	0.0015	0.037	185.1	43.2	51.2
	Reasonable worst	0.0075	0.0015	0.02	19.5	9.2	27.9
	Expected case	0.0075	0.0015	0.011	3.7	1.1	13.3

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

Notes: n.a. refers to not applicable when effluent concentration is below WQG
* Effluent concentration considers discharge from sewage treatment plant

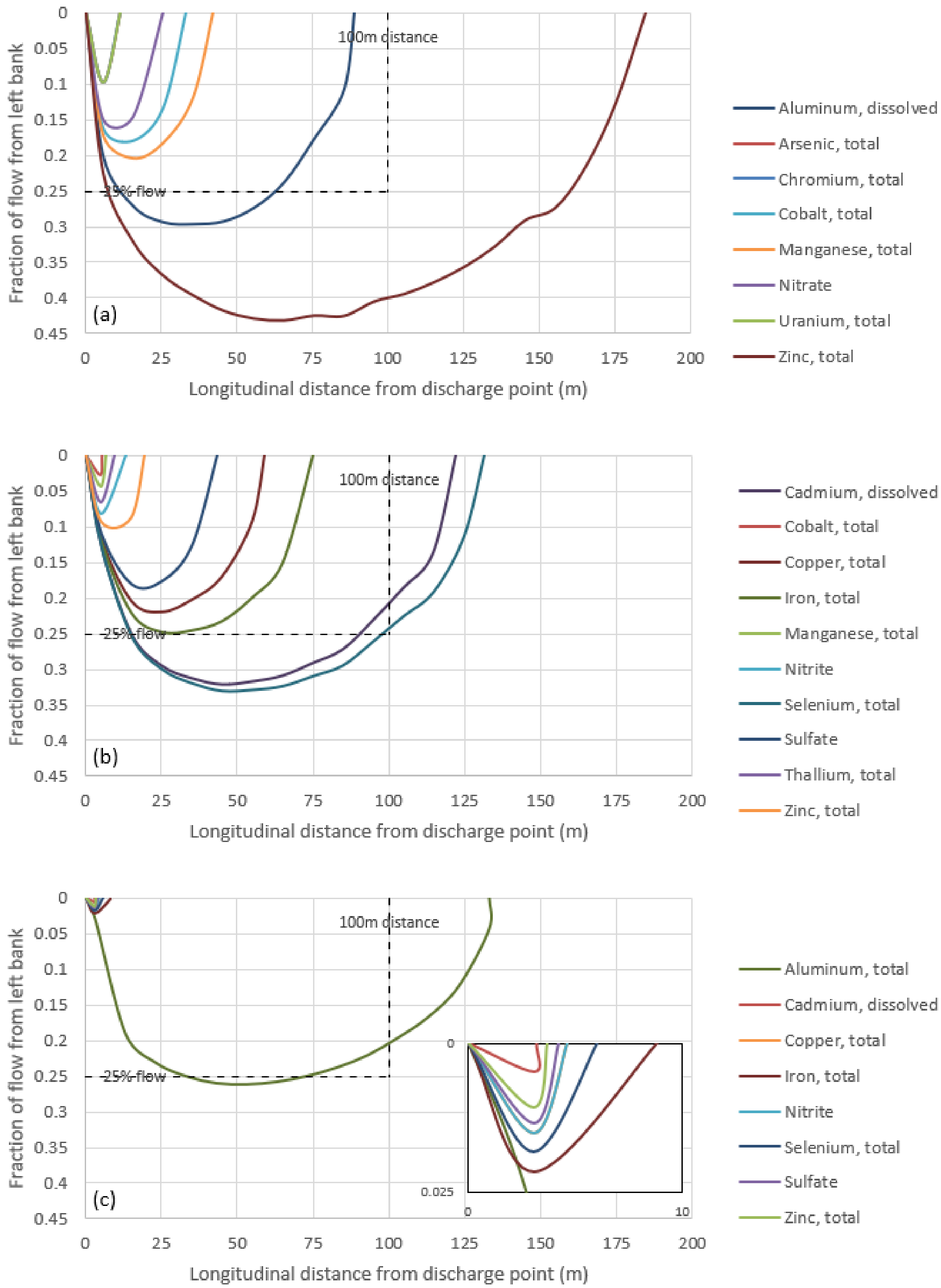


Figure 3-3: Plume delineation of POPCs during operation – (a) worst case, (b) reasonable worst case, and (c) expected case

3.3.2 IDZ Results for Post Closure

For discharge from the North Management Pond during/after closure, water quality parameters including dissolved aluminum, total arsenic, chromium, cobalt, manganese, nitrate-nitrogen, nitrite-nitrogen, thallium, and uranium do not register an IDZ, as the effluent concentrations are below the corresponding WQGs for the IDZ cases (Table 3-4). POPCs with IDZ in closure, along with plume delineation, are illustrated in Figure 3-4.

Considering BC ENV and/or CCME WQGs, parameters that exceeded the IDZ evaluation criteria based on TG11 guidance are summarized below:

- Worst case: Total aluminum, copper, iron, selenium, sulphate and zinc
- Reasonable worst case: Total aluminum and iron
- Expected case: Total aluminum

Table 3-4: Results of the IDZ cases from North Management Pond discharge after closure

Parameter	Scenario	WQG (mg/L)	Background concentration (mg/L)	Effluent concentration (mg/L)	IDZ length (m)	IDZ flow (% of stream)	IDZ width (% of stream)
Aluminum, dissolved	Worst case	0.05	0.014	0.01	n.a.	n.a.	n.a.
	Reasonable worst	0.05	0.014	0.0043	n.a.	n.a.	n.a.
	Expected case	0.05	0.014	0.0042	n.a.	n.a.	n.a.
Aluminum, total	Worst case	0.1	0.092	0.38	Fully mixed concentration > WQG		
	Reasonable worst	0.1	0.092	0.37	Fully mixed concentration > WQG		
	Expected case	0.1	0.092	0.37	Fully mixed concentration > WQG		
Arsenic, total	Worst case	0.005	0.00023	0.0014	n.a.	n.a.	n.a.
	Reasonable worst	0.005	0.00023	0.001	n.a.	n.a.	n.a.
	Expected case	0.005	0.00023	0.00086	n.a.	n.a.	n.a.
Cadmium, dissolved	Worst case	0.00016	0.0000081	0.0002	51.0	22.5	39.2
	Reasonable worst	0.00016	0.0000081	0.000088	n.a.	n.a.	n.a.
	Expected case	0.00016	0.0000081	0.000036	n.a.	n.a.	n.a.
Chromium, total	Worst case	0.0089	0.0002	0.0051	n.a.	n.a.	n.a.
	Reasonable worst	0.0089	0.0002	0.0033	n.a.	n.a.	n.a.
	Expected case	0.0089	0.0002	0.0023	n.a.	n.a.	n.a.
Cobalt, total	Worst case	0.004	0.00005	0.0019	n.a.	n.a.	n.a.
	Reasonable worst	0.004	0.00005	0.0013	n.a.	n.a.	n.a.
	Expected case	0.004	0.00005	0.00098	n.a.	n.a.	n.a.
Copper, total	Worst case	0.0028	0.0015	0.0061	Fully mixed concentration > WQG		
	Reasonable worst	0.0028	0.0015	0.004	12.4	8.2	26.9
	Expected case	0.0028	0.0015	0.0028	n.a.	n.a.	n.a.

Parameter	Scenario	WQG (mg/L)	Background concentration (mg/L)	Effluent concentration (mg/L)	IDZ length (m)	IDZ flow (% of stream)	IDZ width (% of stream)
Iron, total	Worst case	0.3	0.085	1.5	Fully mixed concentration > WQG		
	Reasonable worst	0.3	0.085	1.5	102.7	28.8	43.4
	Expected case	0.3	0.085	1.5	32.7	12.3	31.1
Manganese, total	Worst case	0.12	0.0059	0.081	n.a.	n.a.	n.a.
	Reasonable worst	0.12	0.0059	0.055	n.a.	n.a.	n.a.
	Expected case	0.12	0.0059	0.042	n.a.	n.a.	n.a.
Nitrate-nitrogen	Worst case	3	0.041	0.18	n.a.	n.a.	n.a.
	Reasonable worst	3	0.041	0.01	n.a.	n.a.	n.a.
	Expected case	3	0.041	0.01	n.a.	n.a.	n.a.
Nitrite-nitrogen	Worst case	0.02	0.0005	0.0047	n.a.	n.a.	n.a.
	Reasonable worst	0.02	0.0005	0.00092	n.a.	n.a.	n.a.
	Expected case	0.02	0.0005	0.00092	n.a.	n.a.	n.a.
Selenium, total	Worst case	0.002	0.000086	0.012	Fully mixed concentration > WQG		
	Reasonable worst	0.002	0.000086	0.0062	26.9	13.7	32.3
	Expected case	0.002	0.000086	0.0031	7.1	3.0	18.8
Sulphate	Worst case	218	24	680	Fully mixed concentration > WQG		
	Reasonable worst	218	24	340	10.1	7.0	25.3
	Expected case	218	24	170	n.a.	n.a.	n.a.
Thallium, total	Worst case	0.0008	0.000005	0.00022	n.a.	n.a.	n.a.
	Reasonable worst	0.0008	0.000005	0.00011	n.a.	n.a.	n.a.
	Expected case	0.0008	0.000005	0.000065	n.a.	n.a.	n.a.
Uranium, total	Worst case	0.0085	0.000054	0.0046	n.a.	n.a.	n.a.
	Reasonable worst	0.0085	0.000054	0.0024	n.a.	n.a.	n.a.
	Expected case	0.0085	0.000054	0.0012	n.a.	n.a.	n.a.
Zinc, total	Worst case	0.0075	0.0015	0.013	94.6	35.9	47.4
	Reasonable worst	0.0075	0.0015	0.0087	7.1	4.4	21.5
	Expected case	0.0075	0.0015	0.0067	n.a.	n.a.	n.a.

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

Note:

n.a. refers to not applicable when effluent concentration is below WQG

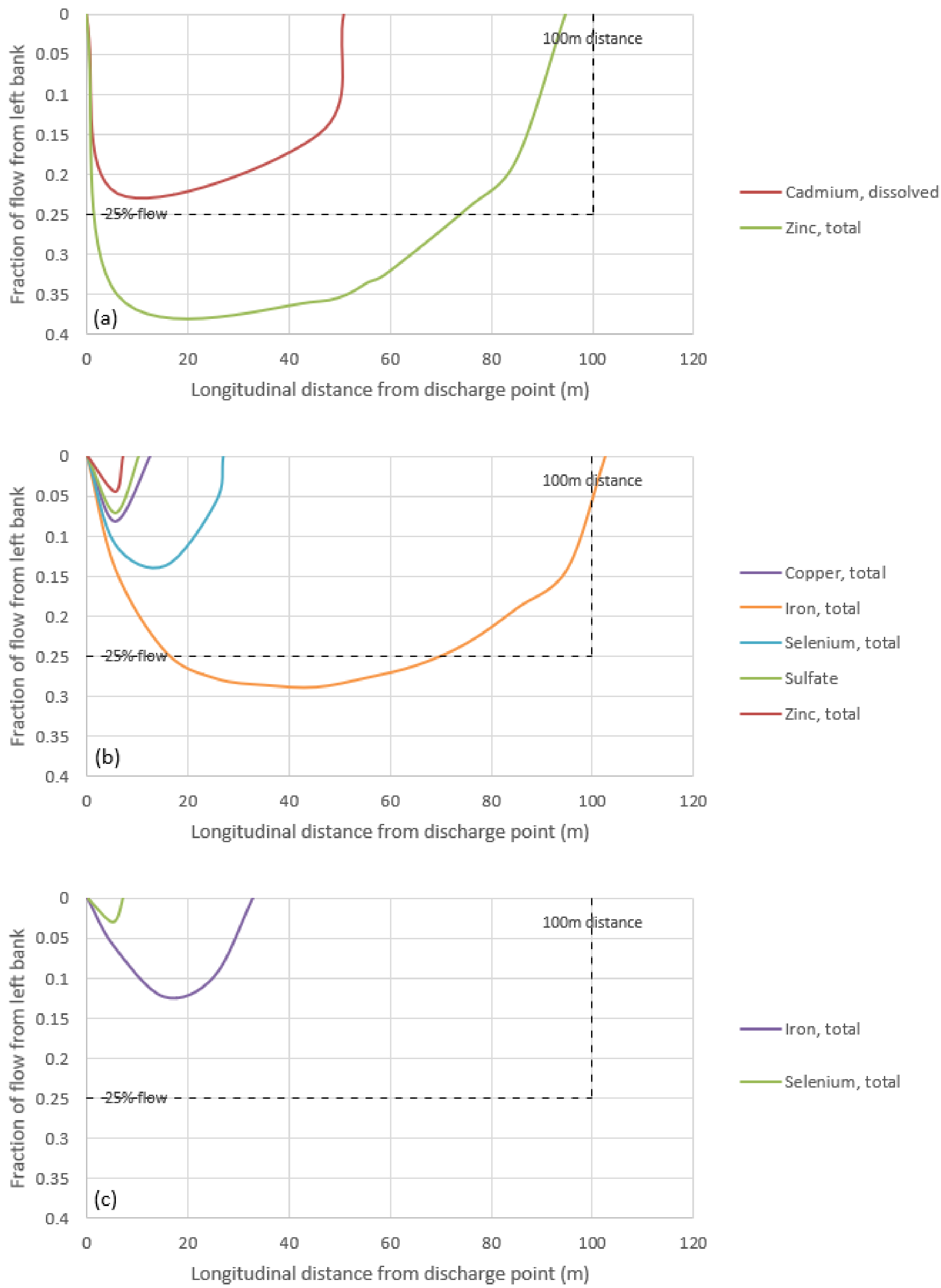


Figure 3-4: Plume delineation of POPCs during post closure – (a) worst case, (b) reasonable worst case, and (c) expected case

3.4 Evaluation of Results

BC provincial regulations recognize that dilution can play a role in mitigating the effects of effluents, and that an accepted area of higher concentrations of parameters can be present in an IDZ prior to full mixing. Evaluation of the IDZ cases based on BC's TG11 guidance indicated that, during the worst case scenario, Goathorn Creek exceeds WQG for: dissolved and total aluminum, dissolved cadmium, copper, iron, nitrite-nitrogen, selenium, sulphate, thallium and zinc in operation, and for total aluminum, copper, iron, selenium, sulphate and zinc during post closure. It is important to note that the worst case is very conservative, as it considers the 7Q10 low flow combined with maximum discharge from the facility. It is unlikely water would need to be discharged from the facility during such a dry period. Water could be stored during these periods or the discharge could be reduced to avoid WQG exceedances during this period.

A more realistic case is the reasonable worst case for which total aluminum, dissolved cadmium and selenium exceed WQGs during operation, and total aluminum and iron exceed WQGs after closure. The reasonable worst-case scenario combines conservative conditions in both effluent quality (50th percentile value with high source terms) and Goathorn Creek flows (low-flow conditions). POPCs with exceedances for this case are discussed below.

Total aluminum: Total aluminum exceeds the WQG of 0.01 mg/L during operation and post closure (Table 3-3 and Table 3-4). The background concentration in the Goathorn Creek is historically high, with 95th percentile concentration (i.e., 0.75 mg/L) exceeding the WQG, while the 50th percentile concentration (i.e., 0.092 mg/L) is very close to it. The exceedances are associated with limited dilution capacity in the creek, and further dilution only occurs in the Telkwa River. This evaluation is based on the stringent WQG of 0.1 mg/L. When the SPO of 0.236 mg/L is considered, the IDZ would become much smaller, therefore meeting the TG11 guidance. For the reasonable worst case, the IDZ length reduces to 12.7 m and 12.4 m during in operation and during post closure, respectively (Table 3-5). The operation and post closure expected cases also meet the TG11 guidance when considering the SPO limit.

Dissolved cadmium: Based on WQG of 0.00016 mg/L, dissolved cadmium develops an IDZ exceeding the TG11 guidance for the reasonable worst case in operation (Table 3-3). The IDZ becomes shorter when the SPO of 0.00019 mg/L is considered for in-stream water quality. Modeling results suggested that a mixing length of 86.8 (Table 3-5) would meet the SPO during operation. The TG11 guidance is met for the expected case in operation considering the WQG (Table 3-4). No IDZ is present for the reasonable worst case and the expected case after closure, as the effluent concentration would be below the WQG.

Total iron: The background concentration of total iron in Goathorn Creek is typically high, with 50th percentile and 95th percentile concentrations of 0.085 and 0.78 mg/L, respectively. After closure, iron exceeds the WQG of 0.3 mg/L for the reasonable worst case. The IDZ length and percentage of flow slightly exceeds the TG11 guidance but are within 4% of the recommended values. The guidance is met for the reasonable worst case in operation, as well as for the expected case during operation and post closure (Table 3-3 and Table 3-4).

Total selenium: The TG11 guidance is exceeded for total selenium with the WQG of 0.002 mg/L for the reasonable worst case during operation (Table 3-3). The IDZ meets the TG11 guidance when Tier 1 SPO of 0.008 mg/L is considered, with plume length of 11.5 m occupying 7.5% flow (Table 3-5). The guidance is met for the reasonable worst case after closure and the expected case during operation and post closure considering the WQG (Table 3-3 and Table 3-4). The effluent discharge concentration corresponding to these cases is below the SPO limit.

Table 3-5: IDZ evaluation based on SPO limits for POPCs with WQG exceedance for reasonable worst case

Parameter	Project stage	SPO (mg/L)	Background concentration P50 (mg/L)	Effluent concentration (mg/L)	IDZ length (m)	IDZ flow (%)	IDZ width (%)
Aluminum, total	Operation	0.236	0.092	0.42	12.7	7.9	26.5
	Post Closure			0.37	12.4	8.2	26.9
Cadmium, dissolved	Operation	0.00019	0.0000081	0.0013	86.8	26.6	42.0
	Post Closure			0.000088	n.a.	n.a.	n.a.
Selenium, total	Operation	0.008	0.000086	0.017	11.5	7.5	25.9
	Post Closure			0.0062	n.a.	n.a.	n.a.

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

Note:

n.a. refers to not applicable when effluent concentration is below SPO

4 Determination of End of Pipe Targets

The end-of-pipe discharge criteria for nitrate-nitrogen and selenium was developed considering BC AWQG and Tier 1 SPO respectively, which are representative of in-stream receiving water quality in Goathorn Creek. For selenium, the sulphate-dependent Tier 2 SPO was also evaluated considering 50th and 95th percentile background sulphate concentration in Goathorn Creek, as well as the long-term modelled sulphate concentrations during operation and closure (SRK 2021b). In all cases, the sulphate concentrations are comparatively lower and the Tier 2 SPO was lower than Tier 1 SPO in Goathorn Creek. Therefore, Tier 1 SPO was used to calculate the end-of-pipe target.

The end-of-pipe targets were estimated based on plume modeling to meet TG11 guidance for flow conditions representing the reasonable worst case and the expected case during operation and Post closure (Table 2-1). For these estimates, Goathorn Creek background concentration corresponding to the 95th percentile value was used. Table 4-1 summarizes the end of pipe targets for selenium and nitrate-nitrogen which are currently the only two items that are under consideration by regulatory agencies.

The estimated end-of-pipe targets are most conservative for the reasonable worst case during closure, as the long-term closure discharge for this case is higher than in operation. The case also considers 7Q10 low-flow in Goathorn Creek during spring freshet and 95th percentile background concentration. The resultant end-of-pipe concentrations under these conditions are conservative, and the recommended targets for nitrate-nitrogen and total selenium were estimated to be 18.8 mg/L and 0.05 mg/L, respectively.

Table 4-1: End-of-pipe targets for nitrate-nitrogen and total selenium

Parameter	Project Stage	Background concentration P95 (mg/L)	In-stream water quality limit (mg/L)		End-of-pipe target (mg/L)	
			Source	***Value***	***Reasonable worst case***	***Expected case***
Nitrate-nitrogen	Operation	0.076	BC AWQG	3.0	22.6	96.6
	Post Closure				18.8	35.5
Total selenium	Operation	0.0002	Tier 1 SPO	0.008	0.06	0.26
	Post Closure				0.05	0.095

Source: Z: \1CT027.003 Telkwa/2020 EA Water Management Support\900_Discharge_Mgmt\IDZ_study\ CORMIX_Modeling\ TelkwaIDZ_CORMIX_ModelResults_rev04_nst.xlsm

5 Conclusions

The Goathorn Creek IDZ assessment was carried out following the TG11 document, produced by the BC Ministry of Environment and Climate Change Strategy. The assessment considers Tenas Project discharge during operation and after closure, with discharge from TCP and NMP, respectively. To characterize and delineate the extent of IDZ, three credible and conservative cases were considered, based on site-specific information:

- a worst case (very worst case)
- a reasonable worst case (worst case that typically occurs)
- an expected case (case corresponding to average conditions)

POPCs in the effluent were identified by screening effluent water quality data relative to WQGs for Goathorn Creek. The following parameters were identified as POPCs: dissolved and total aluminum, arsenic, dissolved cadmium, chromium, cobalt, copper, iron, manganese, nitrate-nitrogen, nitrite-nitrogen, selenium, sulphate, thallium, uranium, and zinc.

Mixing and dilution modeling was conducted to evaluate the IDZ extent for POPCs for the worst, reasonable worst and expected cases and compared against TG11 guidance. For the worst case scenario, Goathorn Creek exceeds WQG for dissolved and total aluminum, dissolved cadmium, copper, iron, nitrite-nitrogen, selenium, sulphate, thallium and zinc in operations, and for total aluminum, copper, iron, selenium, sulphate and zinc in closure. This case is very conservative. Emphasis was placed upon the reasonable worst case and the expected case, which are conservative but provides realistic evaluation scenario. The results are summarized below.

During Operation:

- <u>Reasonable worst case:</u> Exceedance occurs for total aluminum, dissolved cadmium and selenium. These parameters meet the TG11 guidance when SPO limits are considered for in-stream water quality conditions.
- <u>Expected case:</u> Parameters meet TG11 guidance except total aluminum. The recommended guidelines are satisfied for total aluminum when the SPO limit is considered.

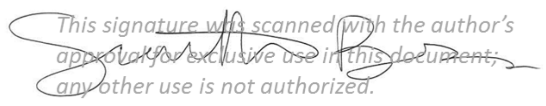
During Post Closure:

- <u>Reasonable worst case:</u> Exceedance occurs for total aluminum and iron. However, iron IDZ features are within 4% of the recommended values. Total aluminum meets TG11 guidance for the SPO limit, representing in-stream water quality.
- <u>Expected case:</u> Exceedance only occurs for total aluminum, but TG11 guidance is met when considering the SPO limit, representing in-stream water quality.

As part of the assessment, the end-of-pipe target discharge criteria for nitrate-nitrogen and selenium were developed considering a conservative worst case that can typically occur (i.e., reasonable worst case). Based on the BC AWQG for nitrate-nitrogen and proposed Tier 1 SPO limit for selenium, the end-of-pipe targets were estimated to be 18.8 mg/L and 0.05 mg/L, respectively.

Regards,

SRK Consulting (Canada) Inc.



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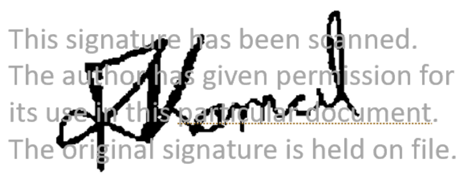

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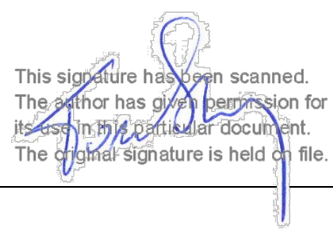

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