Appendix 13.5-I Sulphate SPO Recommendation Memo

TELKWA COAL
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TECHNICAL MEMORANDUM

To: Dan Farmer (Chief Operating Officer, Allegiance Coal)

From: David DeForest (Windward Environmental) and Guy Gilron (Borealis Environmental)

Subject: Development of a Potential Site Performance Objective (SPO) for Sulphate for the Tenas Metallurgical Coal Mine Project

Date: April 27, 2022

INTRODUCTION

Allegiance Coal (Allegiance) is currently in the process of developing the Tenas Metallurgical Coal Mine Project (the Project) near Telkwa, British Columbia (BC). The aquatic effects assessment is a key component of the mine's comprehensive Environmental Assessment (EA), and includes the establishment of a site-wide water balance and various water management plans, support for effluent permitting efforts, and initial water quality modelling results developed by SRK Consulting. These modelling results indicate that effluent (i.e., end-of-pipe) discharges from the mining operation, under several post-closure scenarios, may result in downstream concentrations of sulphate that could have the potential to exceed approved provincial Aquatic Life Guidelines (ALGs).[1]

The objective of the current work is to develop a potential Site Performance Objective (SPO) for downstream receiving water bodies in which exceedances of sulphate ALGs are predicted to occur. The SPO can be used as a risk-based benchmark in the development of both final discharge point (FDP) limits and in-stream environmental compliance point (ECP) monitoring values for sulphate, should they be required.

[1] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines

Site and Baseline Information

The proposed Tenas Mine site is located in north-west British Columbia, 7 km southwest of the village of Telkwa. There are four streams potentially affected by the proposed Project: Tenas Creek, Four Creek, Goathorn Creek, and Helps Creek. Four Creek lies to the east of the main project site and flows northward into Goathorn Creek. Tenas Creek lies to the west of the project site and joins Goathorn downstream from where Four and Goathorn meet, and just over 1 km from where Goathorn then flows into Telkwa River. The Telkwa River is a tributary of the Bulkley River; Helps Creek – over which the proposed Tenas by-pass road crosses – flows into the Bulkley River, downstream of its confluence with Telkwa River. The Bulkley River is a tributary of the Skeena River, which flows into the Pacific Ocean.

A comprehensive baseline monitoring effort was conducted between 2017 and 2019 around the proposed Tenas Mine site. Sampling was undertaken in all four creeks, and the Telkwa and Bulkley rivers. Sampling data were also supported by historic, publicly-available data, where available and relevant.

Baseline Receiving Surface Water Quality Conditions

Temperatures recorded in the water bodies downstream of the proposed mine site during baseline monitoring ranged from -0.2 °C to 16.7 °C; dissolved organic carbon (DOC) concentrations ranged from below the detection limit of 0.5 mg/L to 20.5 mg/L (ERM 2019). Other water quality parameters in receiving waters vary seasonally; the seasonal patterns are driven largely by changes to stream flow associated with rains occurring during the May/June freshet and early autumn: hardness (ranging from 22.8 to 203 mg $CaCO_3$/L); pH (ranging from 6.9 to 8.5), and sulphate (ranging from <0.30 to 59.1 mg/L) are generally high during periods of low flow in the summer and winter, and low during the freshet and autumn rains; the opposite relationship occurs for TSS and turbidity (ERM 2019).

Resident Aquatic Biota

Periphyton communities in receiving waters downstream of the proposed mine site are dominated either by diatoms (Bacillariophyceae) or blue-green algae (Cyanophyceae). Frequently-sampled genera include: *Achnanthidium, Chamaesiphon, Fragilaria, Heteroleibeinia,* and *Leptolyngbya*. Less frequently-observed genera are *Phormidium, Pseudanabaena*, and *Tapinothrix* (ERM 2019).

Up to 75% of benthic macroinvertebrates (BMI) found in receiving waters downstream of the proposed mine site are mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (also known as “EPT” groups). Representative mayfly genera include *Baetis, Rithrogena, and Drinella* and Plecoptera genera include *Zapada* and *Taenionema*. True flies (Diptera) – particularly non-biting midges (family Chironomidae) – are dominant at some sites.

Fish communities in receiving waters downstream of the proposed mine site mainly comprise rainbow trout (*Oncorhynchus mykiss*) and Dolly Varden trout (*Salvelinus* *malma*). Other fish sampled include: coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), lampreys (*Lampetra* spp.), suckers (*Catostomus* spp.), minnows (Cyprinidae), and mountain whitefish (*Prosopium williamsoni*) (ERM 2019).

REGULATORY CONTEXT: BC AQUATIC LIFE GUIDELINE FOR SULPHATE

For proper context regarding the development of a sulphate SPO, we briefly review the history of the ALG derivation, revision and application in BC:

- Singleton (2000) derived the first sulphate ALG for BC, specifically, a maximum of 100 mg/L. The ALG was derived based primarily on four lines of evidence, demonstrating sulphate toxicity on freshwater organisms:
    - i. Acute (96-hour) toxicity tests with striped bass larvae (*Morone saxatilis*), which resulted in an LC50 (median lethal concentration) of 250 mg/L and LC0 (zero mortality) of 100 mg/L (Hughes 1973).
    - ii. Acute (96-hour) toxicity tests with the freshwater amphipod *Hyalella azteca* conducted by the Pacific Environmental Science Centre (PESC 1996, *unpublished*). *H. azteca* were more sensitive to sulphate in soft water than in hard water, with 96-hour LC50s of 205, 3,711 and 6,787 mg/L sulphate in waters with a hardness of 25, 100, and 250 mg/L as $CaCO_3$, respectively. The sulphate ALG of 100 mg/L, therefore, provided protection with a 2:1 uncertainty factor in soft water and greater protection in harder water.
    - iii. Frahm (1975) reported that a concentration of 100 mg/L sulphate was toxic to the freshwater aquatic moss, *Fontinalis antipyretica*, a common and ubiquitous species in BC. Toxicity of sulphate to four other species of aquatic moss ranged from 100 to >250 mg/L. The sulphate exposure durations and endpoints, however, were not noted.
    - iv. Evidence reported by Singleton (2000) that sulphate concentrations of 27.7 to 189 mg/L stimulate large sulphur bacteria growths that have the potential to cover creek beds, resulting in significant BMI community changes.
    - At the time the original guideline was established in 2000, there were not enough chronic toxicity data to develop a '30-day average' component to ALG.
- A review and update of the Singleton (2000) version of the ALG was conducted by the BC Ministry of Environment (ENV) to incorporate more recent chronic aquatic toxicity data for sulphate. This review included the recent scientific literature (Elphick et al. 2011) and additional laboratory toxicity testing

commissioned by (ENV) with a focus on chronic toxicity: the PESC and Dr. Chris Kennedy's (Simon Fraser University [SFU]) laboratories.[2]

- Toxicity data from the three studies (Elphick et al. 2011; PESC, *unpublished*; SFU, *unpublished*) were used to update BC's ALG. Statistical analyses determined that, while the concentration-response curves of many organisms were influenced by water hardness, a consistent relationship among the tested species could not be established.
- Over all tests and hardness concentrations in the three studies, rainbow trout (21-d exposure from embryo to alevin life stage) was identified as a sensitive species and endpoint. which demonstrated some reduction in sulphate toxicity with water hardness increasing from 6 mg/L to 250 mg/L.
- Based on this, the sulphate ALG was developed for different categories of water hardness based on the rainbow trout LC20 (lethal concentration to 20% of test organisms) data with the minimal uncertainty factor of 2 applied to the data.
- ENV's approved 30-day average (based on a minimum of 5 evenly-spaced samples collected in 30 days) ALG for sulphate are as follows:

Water hardness* (mg/L)	Sulphate guideline (mg/L)
Very Soft (0-30)	128
Soft to moderately soft (31-75)	218
Moderately soft/hard to hard (76-180)	309
Very hard (181-250)	429
>250	Need to determine based on site water**

*Water hardness categories adapted from the CCME.
** Toxicity tests on the early stage rainbow trout were only conducted up to a water hardness of 250 mg/L. Natural background concentrations of water hardness in BC are generally much lower than 250 mg/L. It is recommended that additional toxicity testing on several species is required if natural background water hardness is greater than 250 mg/L. Organisms exposed to higher concentrations of water hardness in combination with sulphate may experience osmotic stress.

COMPARISON OF MODELLED SULPHATE CONCENTRATIONS TO THE SULPHATE AQUATIC LIFE GUIDELINE

Water quality modeling (conducted by SRK) was conducted to determine the expected surface water quality downstream of the Tenas Mine during various phases of the mine's life cycle. The model results included sulphate concentrations as well as calculated hardness. The BC hardness-dependent ALGs for sulphate were calculated throughout the modelled time series using the paired modelled hardness concentrations. The results show an exceedance of the BC hardness-dependent ALGs for sulphate in Four Creek but not in Tenas Creek. Guideline exceedance factors, calculated as the ratio of the modelled sulphate concentrations to its hardness-dependent ALG, reached a maximum of 0.8 in Tenas Creek (Figure 1A) and 1.2 in Four Creek (Figure 1B). In Four Creek, the hardness-dependent sulphate ALG was exceeded during 21 non-consecutive months over a 5-year period (Figure 1B). The hardness-

[2] All three studies evaluated the relationship between sulphate toxicity and water hardness.

based sulphate ALG applied to Four Creek was usually 309 mg/L, as the modelled hardness typically falls within the range of 76-180 mg/L).

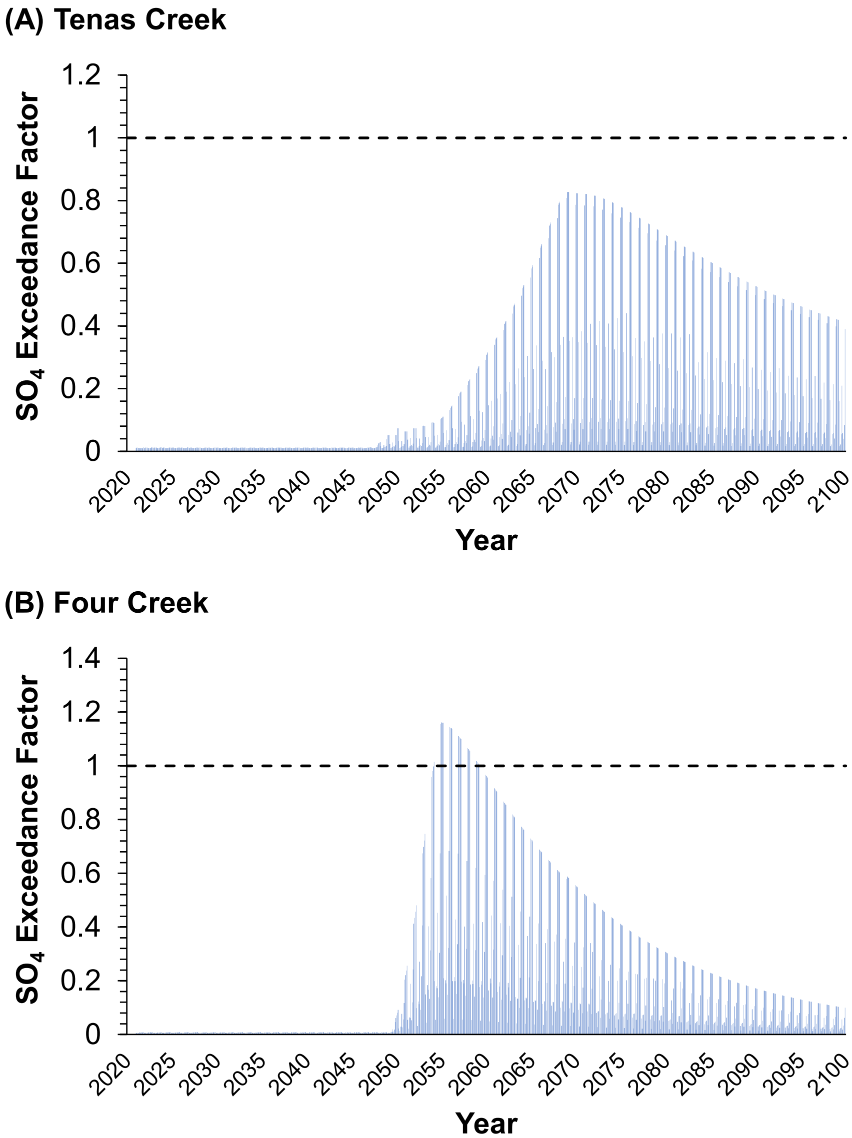

Figure 1. Sulphate (SO_4) exceedance factors in (A) Tenas Creek and (B) Four Creek; based on the ratio of modelled sulphate concentrations to their respective hardness-based sulphate aquatic life guidelines. Modelled data available for the years 2021-2099.

Proposed Sulphate SPO Development

The 21 months with modelled sulphate ALG exceedances in Four Creek had modelled hardness concentrations ranging from 166-177 mg/L. Because modelled sulphate and hardness concentrations tend to be correlated (i.e., conditions that result in higher modelled sulphate concentrations also result in higher modelled hardness concentrations), and given the hardness-dependent nature of sulphate toxicity, a proposed sulphate SPO relevant to hard waters was developed for the Project.

Specifically, a sulphate SPO of 593 mg/L was recommended based on sulphate toxicity tests conducted at a hardness of ≥100 mg/L. The following summarizes the basis for this guideline.

Chronic sulphate toxicity data, from tests with a hardness ≥100 mg/L, were compiled from Elphick et al. (2011), Meays and Nordin (2013), and Golder (2014). The data compiled from Meays and Nordin (2013) include the PESC and SFU studies previously discussed. A total of eight species were tested at hardness concentrations of ≥100 mg/L. For consistency with the BC sulphate guideline, which was based on LC20 data for rainbow trout, chronic EC20s were compiled as available. In some cases, only an EC25 or no-observed effect concentration (NOEC) were available, which were included in the dataset (Table 1).

The toxicity data were plotted to develop a species sensitivity distribution (SSD) (Figure 1). Rainbow trout was the most sensitive species, with a geometric mean EC20 of 580 µg/L. The 5th percentile of the SSD was 593 µg/L, which was defined as the proposed sulphate SPO for high hardness waters. This value is comparable to the species mean EC20 for rainbow trout.

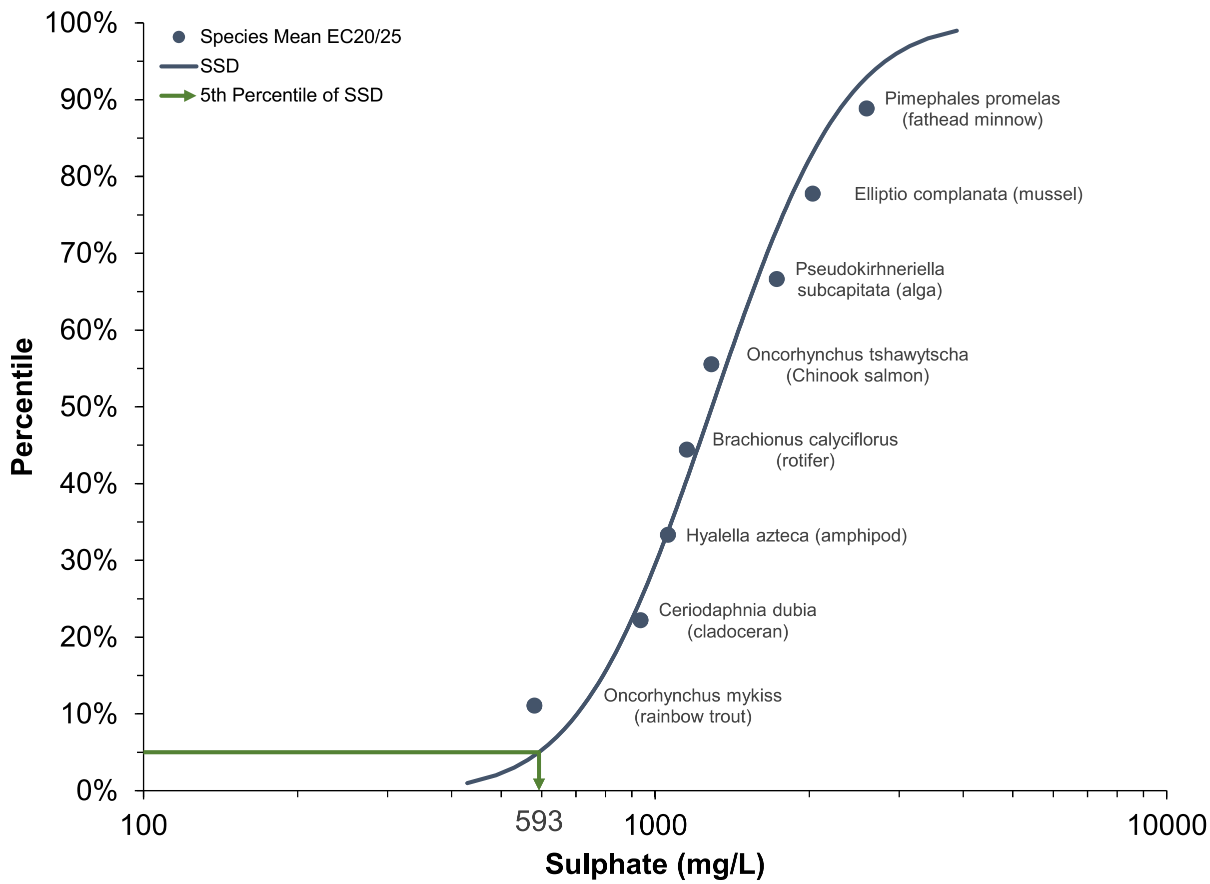

Figure 2. Species sensitivity distribution for sulphate from tests conducted at a hardness of ≥100 mg/L. Toxicity thresholds are based on EC20s/EC25s and unbounded NOECs when necessary.

Table 1. Sulphate toxicity data for tests conducted at a hardness of ≥100 mg/L.

Species	Common Name	Duration	Effect	Mean Hardness (mg/L)	Endpoint	Sulphate Toxicity Value (mg SO_4/L)	Species Mean Toxicity Value (mg SO_4/L)	Reference
Elliptio complanata	Mussel	28-d	survival	250	LC20	>2030	>2030	Meays and Nordin 2013
Hyalella azteca	Amphipod	28-d	growth	100	EC25	1030	1058	Meays and Nordin 2013
Hyalella azteca	Amphipod	28-d	growth	250	EC25	1198		Meays and Nordin 2013
Hyalella azteca	Amphipod	14-d	growth	245	NOEC	950		Golder 2014
Hyalella azteca	Amphipod	14-d	growth	161	NOEC	947		Golder 2014
Hyalella azteca	Amphipod	14-d	growth	485	NOEC	1150		Golder 2014
Hyalella azteca	Amphipod	14-d	growth	378	NOEC	1100		Golder 2014
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	160	EC25	1212	935	Elphick et al. 2011
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	320	EC25	542		Elphick et al. 2011
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	245	NOEC	894		Golder 2014
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	161	NOEC	951		Golder 2014
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	485	NOEC	1165		Golder 2014
Ceriodaphnia dubia	Cladoceran	7-d	reproduction	378	NOEC	1030		Golder 2014
Brachionus calyciflorus	Rotifer	48-h	reproduction	160	EC25	1292	1152	Elphick et al. 2011
Brachionus calyciflorus	Rotifer	48-h	reproduction	320	EC25	1027		Elphick et al. 2011
Oncorhynchus mykiss	Rainbow trout	21-d	survival	100	EC20	618	580	Meays and Nordin 2013
Oncorhynchus mykiss	Rainbow trout	21-d	survival	250	EC20	857		Meays and Nordin 2013
Oncorhynchus mykiss	Rainbow trout	21-d	survival	100	EC20	427		Meays and Nordin 2013
Oncorhynchus mykiss	Rainbow trout	21-d	survival	250	EC20	502		Meays and Nordin 2013
Oncorhynchus tshawytscha	Chinook salmon	28-d	survival	250	EC10	1287	>1287	Meays and Nordin 2013
Pimephales promelas	Fathead minnow	7-d	biomass	250	EC25	2999	2590	Meays and Nordin 2013
Pimephales promelas	Fathead minnow	7-d	growth	160	EC25	3077		Elphick et al. 2011
Pimephales promelas	Fathead minnow	7-d	growth	320	EC25	3463		Elphick et al. 2011
Pimephales promelas	Fathead minnow	7-d	survival	100	EC25	1408		Meays and Nordin 2013
Pimephales promelas	Fathead minnow	7-d	survival	245	NOEC	948*		Golder 2014
Pimephales promelas	Fathead minnow	7-d	survival	161	NOEC	973*		Golder 2014
Pimephales promelas	Fathead minnow	7-d	survival	485	NOEC	1170*		Golder 2014
Pimephales promelas	Fathead minnow	7-d	survival	378	NOEC	1085*		Golder 2014
Pseudokirchneriella subcapitata	Algae	72-h	growth	320	EC25	1727	1727	Elphick et al. 2011

* Excluded from species mean because NOEC values are less than EC25 values.
EC20 = 20% effect concentration
EC25 = 25% effect concentration
NOEC = no-observed-effect concentration

SUPPLEMENTAL EVALUATION

Because no modelled sulphate concentrations in Four Creek exceed the proposed SPO of 593 mg/L, the following provides a supplemental evaluation to demonstrate that modelled sulphate and hardness concentrations in Four Creek are not expected to result in chronic toxicity to rainbow trout. The highest sulphate guideline exceedance factor for Four Creek, a value of 1.2, was based on a sulphate concentration of 359 mg/L and a corresponding hardness of 173 mg/L. This combination of sulphate and hardness concentrations was compared to chronic sulphate toxicity thresholds (EC20s and NOECs) that were plotted as a function of hardness. As shown in Figure 3, this "worst-case" combination of sulphate and hardness concentrations in Four Creek falls below all of the sulphate toxicity thresholds for rainbow trout, indicating that sulphate is not expected to be toxic to rainbow trout, which is consistent with the conclusion that would be reached through application of the proposed SPO.

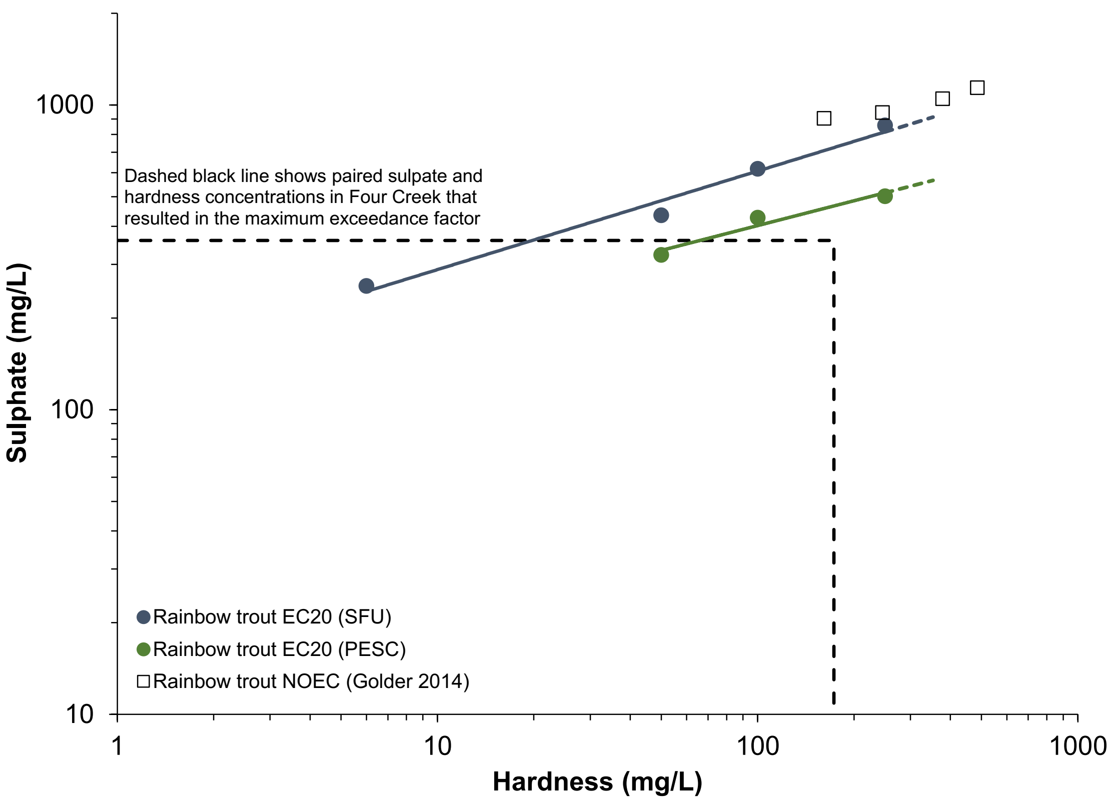

Figure 3. Comparison of "worst-case" modelled sulphate and hardness concentrations in Four Creek to sulphate toxicity and hardness relationships for rainbow trout.

CONCLUSION

Water quality modelling indicates that the sulphate concentration in Four Creek has the potential to infrequently exceed the hardness-based ALG. All exceedances occur when the modelled sulphate concentration is greater than 309 mg/L and the modelled hardness ranges from 166-177 mg/L (under these hardness conditions, the ALG is 309 mg/L). Accordingly, a proposed sulphate SPO based on toxicity data for higher hardness waters (≥100 mg/L) was developed. The resulting SPO was 593 mg/L, which is driven by rainbow trout, a sensitive species that occurs in Project receiving waters. The proposed SPO was developed based on sulphate toxicity data previously evaluated by Meays and Nordin (2013) in developing the BC guideline, along with supplemental data from Golder (2014), to specifically be appropriate for evaluating sulphate toxicity in higher hardness waters (i.e., ≥100 mg/L).

CLOSURE

We trust that this technical memorandum meets your needs. Please do not hesitate to let either of the undersigned know if you have any questions or require additional information.

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References

Elphick JR, Davies ME, Gilron G, Canaria EC, Lo B, Bailey HC. 2011. An aquatic toxicological evaluation of sulphate: the case for considering hardness as a modifying factor in setting water quality benchmarks. EnvironToxicol Chem 30:247–253.

ERM. 2019. Tenas project 2017 to 2019 baseline report. Prepared for Telkwa Coal Limited.

Frahm JP. 1975. Toxicity tolerance studies utilizing periphyton. (Toxitoleranzversuche an Wassermoosen). Gewasser Und Abwasser 57/58:59-66.

Golder. 2014. Elk Valley Water Quality Plan. Benchmark derivation report for nitrate and sulphate. Golder Associates Ltd.

Hughes JS. 1973. Acute toxicity of thirty chemicals to striped bass (*Morone saxatilis*). La Dep Wildl Fish 318-343-2417. 15 pp.

Meays C, Nordin R. 2013. Ambient water quality guidelines for sulphate: Technical Appendix. Update.

Singleton H. 2000. British Columbia ambient water quality guidelines for sulphate: Technical Appendix. Ministry of the Environment, Lands and Parks, Water Quality Section. Water Management Branch. Victoria, BC, Canada. 33 pp.