# *Appendix 7F: Mount Nansen Proposed Water Quality Objectives*

## *1 Overview and Background*

In support of the Mount Nansen Surface Water Quality and Aquatic Biota Effects Assessment, water quality data collected from 2012 to 2016 for the sites DC-R (in Dome Creek) and VC-UMN (in Victoria Creek) were screened against applicable long-term water quality guidelines (WQGs) for the protection of aquatic life as specified by the Canadian Council of Ministers of the Environment (CCME) for each parameter. The present memorandum describes the approaches used for the development of WQOs and, therefore, only relevant information to the derivation of WQOs is presented. Information on existing project conditions are summarized in the Mount Nansen Care and Maintenance Surface Water Quality Existing Conditions report (Appendix 6D); Sections 3.4 to 3.6 for Dome Creek and Section 3.7 for Victoria Creek.

The CCME guidelines are conservative and derived to be protective of all species of aquatic life under continuous exposure. Concentrations that are below WQGs indicate that the parameter is unlikely to cause a negative effect to aquatic life. Concentrations greater than a WQG do not necessarily imply impact, but warrant consideration of site specific conditions to derive benchmark concentrations (water quality objectives [WQOs]) that are above WQGs but still protective of aquatic biota in receiving aquatic environments. Parameters of potential concern were defined as measurable effects above a WQG that are attributable to Site activity and that extend beyond the PSA, as described in Section 3.8 of the Mount Nansen Care and Maintenance-Surface Water Quality Existing Conditions. These parameters include sulphate, total arsenic, iron, manganese, zinc and dissolved aluminum. Other parameters with exceedances limited to the PSA (e.g. dissolved cadmium) were not included in the effect assessment as their contribution to aquatic systems is expected to be negligible.

The methods used to derive WQOs that differ from generic water quality guidelines are described in this technical memorandum. The screening process for identifying parameters of concern is described in detail in Section 2.4 of the Surface Water Quality Existing Conditions Report (MN CMPPP Appendix 6D). WQOs were derived for four parameters of potential concern: arsenic (As), iron (Fe), manganese (Mn) and sulphate (SO4) for the Mount Nansen Site. Both Canadian Council of Ministers of Environment (CCME) guidelines (http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines) and British Columbia (BC) provincial guidelines (http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines) are considered. The

iron and manganese WQGs are based on toxicity tests. As such, these guidelines were applied as directed by CCME or BC. The remaining elements were primarily based on species sensitivity distributions. As such, the analysis was focused on species expected to occur in the project area.

# 2 Effects Benchmarks Derivation

## 2.1 Arsenic

The CCME and BC WQGs for arsenic (As) are both 0.005 mg/L. The CCME WQG is based on the sensitivity of a species of planktonic algae (*Scenedesmus obliquus*) which has been shown to exhibit reduced growth at an As concentration of 0.05 mg/L (CCME, 2001). A safety factor of 0.1 was applied to this lowest observable effect level to obtain the 0.005 mg/L aquatic life guideline.

Chronic toxicity end points for As were recently assessed for stream systems by Golder (2013) using a species sensitivity distribution (SSD) approach (Golder report provided in Appendix A). The Golder (2013) assessment is directly applicable to the Mt. Nansen project for several reasons. First, the assessment specifically addressed lotic (i.e., stream) systems, excluding data for lentic (i.e., lake) species that will not occur in Dome or Victoria Creeks. Second, the benchmark was developed for northern climates, and excluded toxicity data for temperate/tropical species that will not occur at Mt. Nansen. Third, the data set used to generate the SSD curve is robust, as it includes data for 24 species from various trophic levels, fully satisfying the data requirements of CCME (2007a). And finally, fourth, the Golder assessment considered more recent, and up-to-date, results from toxicity studies generated since the development of the original CCME (2001) As guideline (Table 2-1). Overall, the updated dataset agrees with the CCME dataset in showing that algae are more sensitive to As than invertebrates or fish.

Using the data provided in Table 2-1, Golder (2013) developed an SSD yielding a chronic effects benchmark of 0.025 mg/L (total As) (Figure 2-1). The planktonic alga, *S. obliquus*, is the most sensitive species applied in the SSD approach (Table 2-1). However, *S. obliquus* is a planktonic (lentic) species that is not predicted to be present in the creek systems at Mt. Nansen. Given the expected absence of this species from Dome and Victoria Creeks, the 0.025 mg/L benchmark is specifically considered to be protective of the most sensitive organisms in the system (benthic diatoms), and is therefore inherently protective of less sensitive taxa (benthic invertebrates, fish and amphibians). In this regard, a concentration of 0.025 mg/L total As is expected to afford a protective limit for aquatic life in both Dome and Victoria Creeks.

**Table 2-1:**
**Arsenic chronic toxicity data compiled by Golder (2013) in support of derivation of a chronic effects benchmark.**

| Species | Taxon | Species Mean Chronic Value (mg/L) |
|---|---|---|
| Algae | | |
| *Scenedesmus obliquus* | green algae | 0.010 |
| *Melorisa granulata* | diatom | 0.075 |
| *Ochromonas vallesiaca* | golden algae | 0.075 |
| *Ankistrodesmus falcatus* | green algae | 0.100 |
| *Lemna gibba* | inflated duckweed | 0.224 |
| *Cryptomonas erosa* | algae | 0.225 |
| *Chlamydomonas reinhardtii* | green algae | 2.25 |
| *Anabaena variabilis* | blue-green algae | 2.25 |
| *Scenedesmus quadricauda* | green algae | 5.49 |
| *Lemna minor* | duckweed | 8.71 |
| *Pseudokirchnerella subcapitata* | green algae | 25.0 |
| *Microcoleus vaginatus* | green algae | 100 |
| Invertebrates | | |
| *Daphnia pulex* | water flea | 0.100 |
| *Hyalella azteca* | amphipod | 0.581 |
| *Gammarus pseudolimnaeus* | amphipod | 0.973 |
| *Helisorna campanulata* | snail | 0.973 |
| *Stagnicola emarginata* | snail | 0.973 |
| *Daphnia magna* | water flea | 1.07 |
| *Cyclops vernalis* | copepod | 1.38 |
| *Ceriodaphnia dubia* | water flea | 1.42 |
| Fish | | |
| *Carassius auratus* | goldfish | 0.087 |
| *Anabas testudineus* | climbing perch | 0.500 |
| *Oncorhynchus mykiss* | rainbow trout | 1.76 |
| *Pimephales promelas* | fathead minnow | 2.59 |

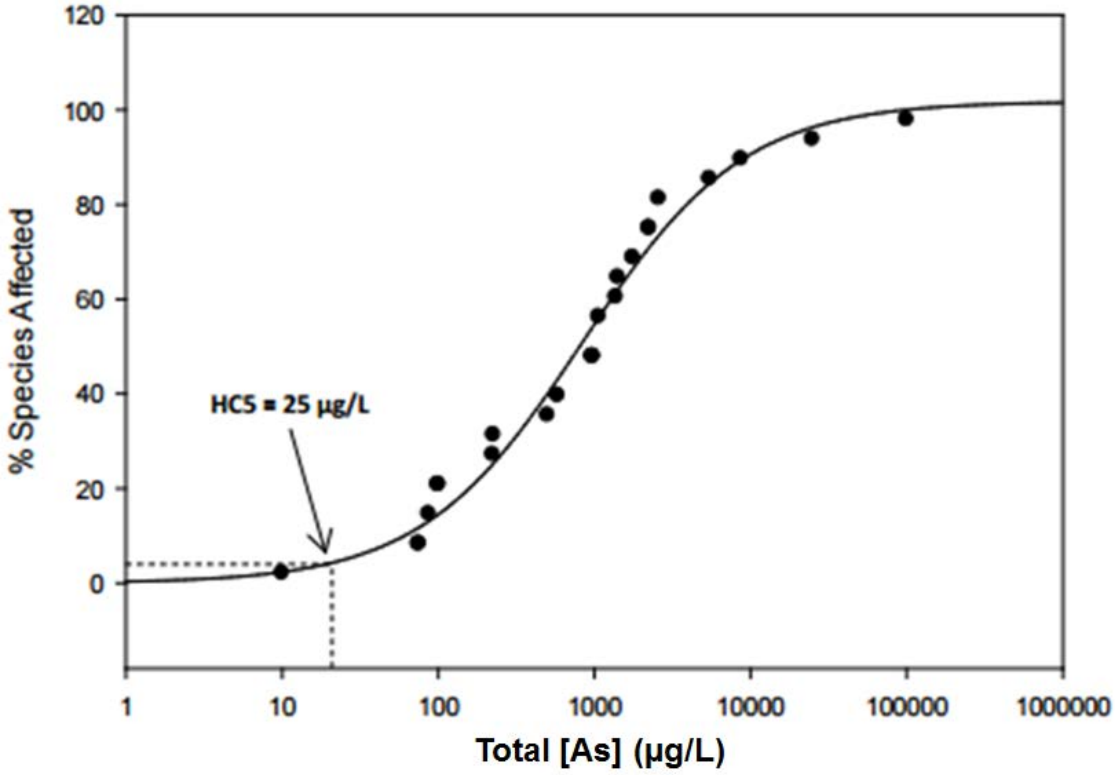


**Figure 2-1: Species sensitivity distribution for affects to freshwater aquatic life from arsenic (from Golder, 2013).**

Comparison of the CCME and site-specific effects benchmarks to measured concentrations of total As in Dome and Victoria creeks is presented in Figure 2-2. The data for Dome Creek show pervasive exceedances of both the CCME and effects benchmarks. In contrast, the data for Victoria Creek show only infrequent exceedances of the CCME guideline, and only a single exceedance of the 0.025 mg/L effects benchmark. Exceedances of the CCME guideline in Victoria Creek can be linked to elevated levels of particulate As associated with naturally-occurring high flow events during freshet, as illustrated by the correlation between TSS and As (Figure 2-3).

Based on the water quality observations, it is proposed that a water quality objective of 0.025 mg/L total As be applied to Dome Creek. Given that the bulk of the total As measurements in Victoria Creek remain below the CCME guideline, and given that CCME exceedances can be linked to natural processes, it is proposed that the CCME guideline be adopted as the water quality objective for Victoria Creek. However, the latter recommendation must also accommodate TSS-related exceedances of total As during high flow periods.

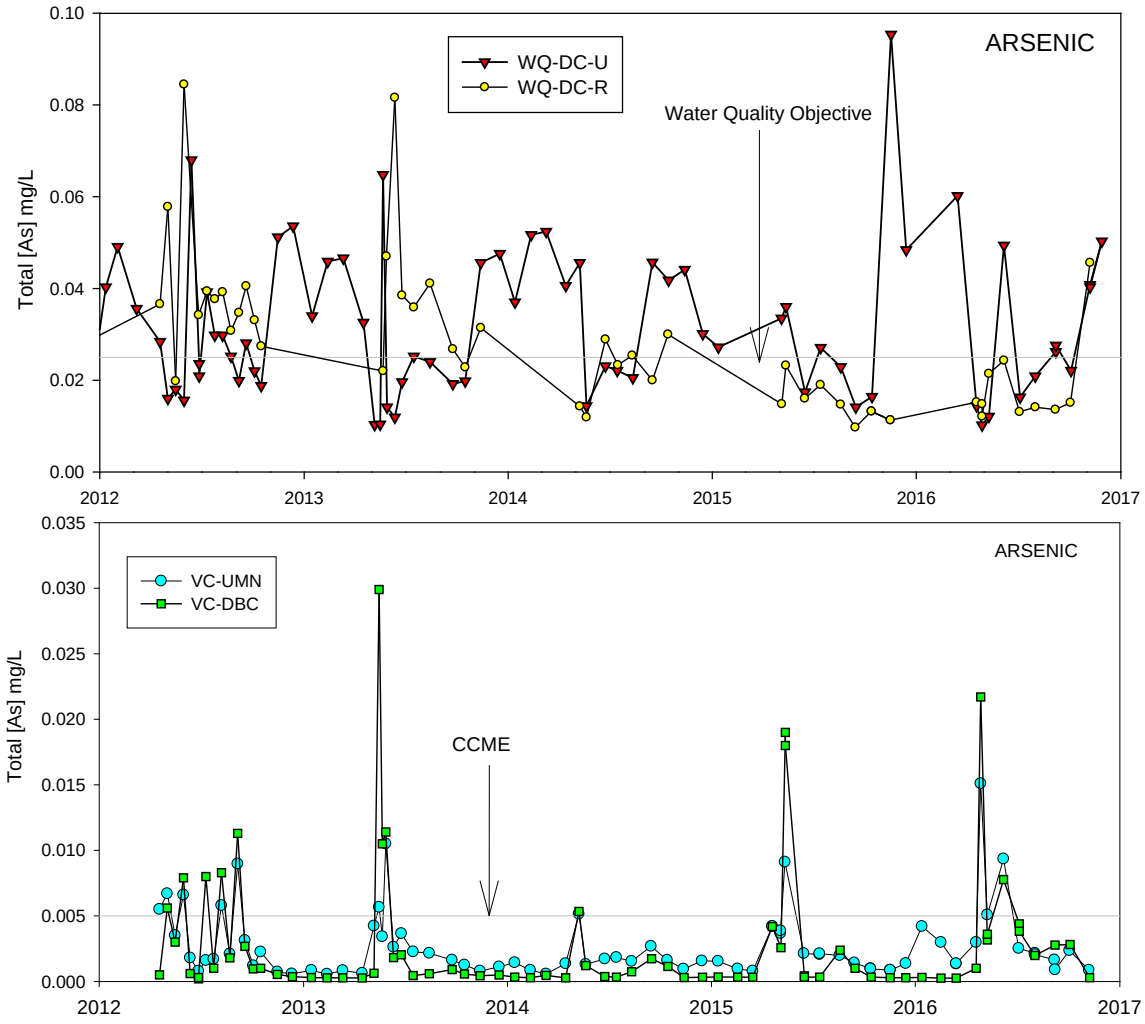


**Figure 2-2: 2012-2016 total arsenic concentrations for Dome Creek water quality stations DC-U (Upstream) and DC-R (Road) (upper plot) and Victoria Creek water quality stations VC-UMN (Upstream of Minnesota Creek) and VC-DBC (Downstream of Back Creek) (lower plot). Data compared to relevant water quality objectives for total arsenic.**

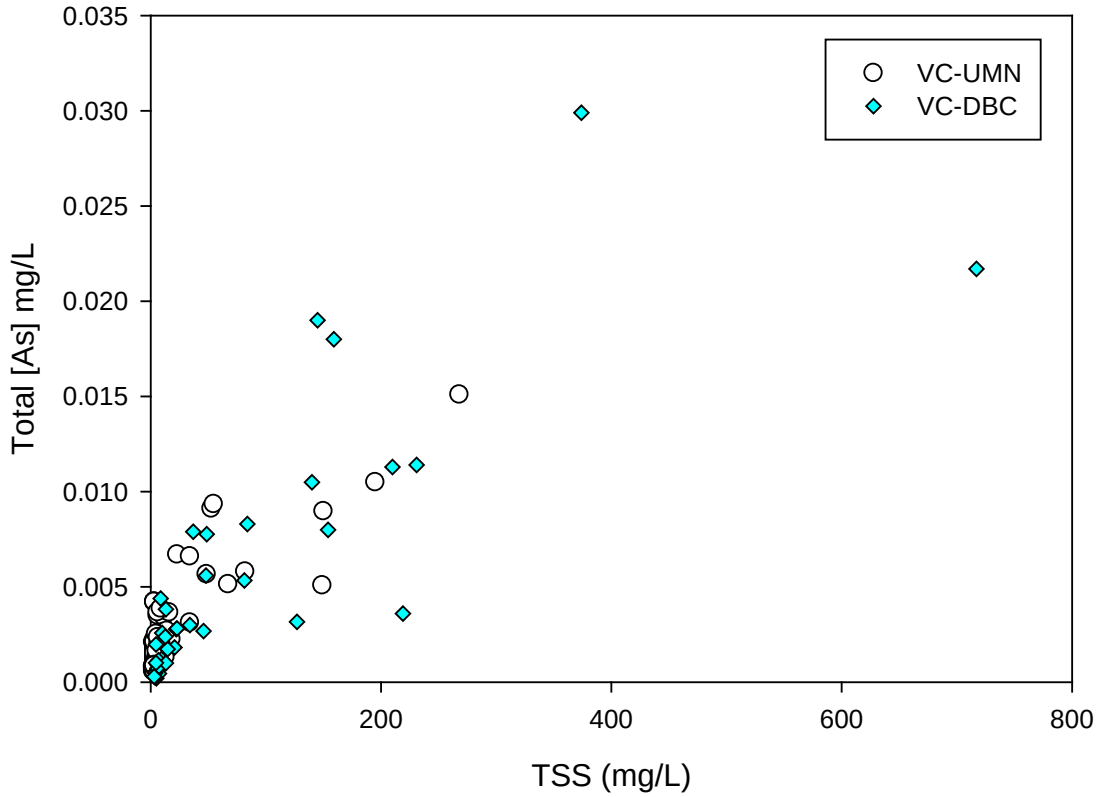


**Figure 2-3: Scatter gram comparing total arsenic concentration as a function of total suspended solids (TSS) for Victoria Creek water quality stations VC-UMN (Upstream of Minnesota Creek) and VC-DBC (Downstream of Back Creek). Data shown for period 2012-2016.**

## 2.2 Iron

The BC WQG for iron (Fe) is proposed as the WQO. The BC Fe guideline was updated in 2008 and was derived using more up to date toxicity information in comparison to the CCME guideline (derived in 1987). Separate BC guidelines are provided for total Fe (1 mg/L) and dissolved Fe (0.35 mg/L) and are adopted as WQOs for Dome and Victoria Creeks. Dissolved forms of iron are considered the main form of direct toxicity to aquatic biota.

Although iron solubility is significantly influenced by pH, WQGs are derived using the most sensitive species, and over a wide range of water quality parameters (e.g., hardness) to be applied across Canada. A level of conservativeness is incorporated into WQGs to address uncertainties, which makes WQGs for the protection of aquatic life one of the most stringent and protective guidelines. Therefore, there is a high degree of confidence that BC WQGs for iron will be protective of the aquatic biota in the Mount Nansen project.

The Fe WQO was developed to represent relevant site-specific water quality conditions, and hence is expected to also be applicable for the pH ranges generally occurring in the project area.

## 2.3 Manganese

The CCME has not derived a water quality guideline for manganese and therefore, the BC guideline was applied to calculate WQOs for the Site. Similar to many other metals, hardness is known to ameliorate the toxicity of manganese (Stubblefield et. al. 1997, Lasier et.al. 2000). Thus, the derived BC manganese guidelines are hardness dependent and based on the lowest manganese toxicity values with an applied factor of 0.25 (4:1 safety factor).

The WQO for T-Mn is derived using the same equation as the BC long-term water quality guidelines as follows:

0.0044 x hardness (mg/L CaCO3) + 0.605 (Equation 1)

The guideline for manganese ranges from approximately 0.7 to 3.9 mg/L for hardness values ranging from 0.25 to 300 mg/L (as CaCO3) and expected to represent natural ("unaffected") background conditions for the Province of BC. This is clearly the case for Victoria Creek were hardness values are well below 300 mg/L CaCO3 (average of 119 and 76 mg/L CaCO3 for the pre-treatment and post-treatment scenario, respectively). However, hardness in Dome Creek average of 500 and 727 mg/L CaCO3 for the pre-treatment and post-treatment scenario, respectively. When hardness values fall out of range (i.e., > 300 mg/L CaCO3) a site-specific WQO may be derived to adapt the recommended guidelines to given site conditions such as, high hardness (BC-MOE 2001).

Hardness ranges for Victoria (Vic-UMN hardness ranged from 36 to 248 mg/L ($CaCO_3$) and Dome Creeks (DC-U hardness ranged from 76 to 776 mg/L ($CaCO_3$)) were used then to derive site-specific WQOs for manganese based on Equation 1 above.

## 2.3 Sulphate

British Columbia is one of the few jurisdictions to have a WQG for $SO_4$ (BC-MOE, 2013) and CCME has not derived a SO4 guideline. The BC SO4 guideline is hardness-dependent, based on studies showing decreasing toxicity with increasing hardness (Table 2-2). No guideline for SO4 has been recommended for hardness values greater than 250 mg/L due to a lack toxicological data at higher hardness levels. For the assessment of potential SO4 toxicity in Dome Creek and Victoria Creek, it was assumed that the modifying effect of hardness plateaus at 250 mg/L, and that the WQG for the highest hardness range applies to water with hardness >250 mg/L.

**Table 2-2:**
**BC Sulfate Water Quality Guideline for Protection of Freshwater Aquatic Life.**

| Water hardness (mg/L) | Sulphate guideline (mg/L) |
|---|---|
| Very soft (0-30) | 128 |

| | |
|---|---|
| Soft to moderately soft (31-75) | 218 |
| Moderately soft to hard (76-180) | 309 |
| Very hard (181-250) | 429 |
| >250 | Need to determine based on site water |

The BC SO4 guideline is based on toxicity to early life stage rainbow trout, which likely has relevance to salmonids present to Victoria Creek (Arctic Grayling). Other organisms are less sensitive to SO4, and therefore the WQG may be overprotective for Dome Creek since post-mining fish sampling in Dome Creek has not confirmed fish presence (EDI, 2009). Thus, applicable toxicity benchmarks for this element in non-fish bearing streams such as Dome Creek should be based on invertebrates and algae species. Sulphate has shown no lethal toxicity to widely distributed aquatic invertebrates and algae species at concentrations higher than 429 mg/L and with an associated hardness of 80 to 250 mg/L CaCO3 (Table 2-3). For example, *Ceriodpahnia dubia* (water flea) showed mortality (LC10) and reproductive (IC10) effects due to sulphate exposure at 857 mg/L and 1,184 mg/L, respectively (BC MOE 2013). The invertebrate displayed a slight reproductive effect of sulphate at hardness of 320 mg/L CaCO3, however this is primarily related to osmotic challenges faced by *C. dubia* at elevated hardness conditions as opposed to responses to sulphate exposure (BC MOE 2013). Given the presence of these confounding factors, toxicity values associated with hardness values of 320 mg/L were not included in the derivation of the sulphate WQO for *C. dubia*. For algae, including *Pseudokirchneriella subcapitata* and *Lemna minor*, sulphate concentrations up to 2,300 mg/L showed no adverse effects in cell growth and proliferation (Table 2-3; BC MOE, 2013).

The proposed sulphate WQO for non-fish bearing streams (i.e., Dome Creek) is 857 mg/L, based on the lowest toxicity value for *C. dubia* at hardness of 160 mg/L CaCO3. The BC WQG for sulphate of 218 mg/L, based on the minimum hardness value for Victoria Creek upstream of Minnesota Creek (VC-UMN), from 36 to 248 mg/L (CaCO3)) is applicable for fish bearing water bodies (i.e., Victoria Creek). The derived value is highly conservative and expected to be protective of fish in Victoria Creek as LC10 concentrations for the most sensitive species, rainbow trout exposed to sulphate, ranged from 444 mg/L to 654 mg/L (BC MOE, 2013).

**Table 2-3:**
**Sulphate toxicity Data for Algae, Invertebrates and Fish (adapted from BC MOE, 2013)**

| Species | Endpoint | Hardness (mg/L CaCO3) | LC10/ EC10/IC10 | LC25/EC25/IC25 (CI) | LC50/EC50/IC50 (CI) |
|---|---|---|---|---|---|
| *P. subcapitata* | Cell yield | 10 | 441 | 696 | 1,101 |
| | | 80 | 2,487 | 2,165 | 2,749 |
| | | 320 | 2,548 | 2,660 | 2,777 |
| *L. minor* | Frond Increase | 50 | 2,143 | - | - |
| | | 100 | 2,243 | - | - |
| | | 250 | 2,314 | - | - |
| *Ceriodaphnia dubia* | Survival | 40 | 402 | 570 | 809 |
| | | 80 | 593 | 871 | 1,282 |
| | | 160 | 857 | 1,145 | 1,531 |
| | | 320 | 816 | 1.135 | 1,580 |
| | Reproduction | 40 | 158 | 272 | 463 |
| | | 80 | 708 | 890 | 1,119 |
| | | 160 | 1,184 | 1,223 | 1,263 |
| | | 320 | 253 | 425 | 717 |

Notes: LC- Lethal Concentration; EC – Effective Concentration; IC – Inhibitory Concentration; - not available

## 3 Summary

A summary of the proposed WQO for the Site is provided in Table 3-1. Where applicable, WQO that equate to an associated water quality guideline are denoted.

**Table 3-1:**
**Proposed Water Quality Objectives (WQOs) for the Mount Nansen Project Site.**

| Parameter | Victoria Creek | Dome Creek |
|---|---|---|
| Sulphate | 218* | 857 |
| Dissolved Aluminum | 0.05* | |
| Total Arsenic | 0.005* | 0.025 |
| Total Iron | 1* | |
| Dissolved Iron | 0.35* | |
| Total Manganese | 1.0 to 1.3* | 2.3 to 4.8 |
| Total Zinc | 0.03+ | |

Notes: Values in mg/L; * denotes British Columbia Water Quality Guidelines; + denotes Canadian Council of Ministers of Environment Water Quality Guidelines.

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