Atlantic Gold

Appendix C.2

Evaluation of Potential for Aquatic Effects as a Result of Aquatic Releases Related to the Fifteen Mile Stream Gold Project, Intrinsik Corp.

EVALUATION OF POTENTIAL FOR AQUATIC EFFECTS AS A RESULT OF AQUATIC RELEASES RELATED TO THE FIFTEEN MILE STREAM GOLD PROJECT

Atlantic Mining NS Fifteen Mile Stream Gold Project

Technical Supporting Document

FINAL REPORT

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AQUATIC EFFECTS ASSESSMENT – FIFTEEN MILE STREAM MINE PROJECT

Table of Contents

List of Tables

List of Figures

List of Appendices

**EVALUATION OF POTENTIAL FOR AQUATIC EFFECTS RELATED TO
EMISSIONS FROM THE FIFTEEN MILE STREAM MINE PROJECT**

1   INTRODUCTION

The Fifteen Mile Stream (FMS) Gold Project will involve the construction, operation, closure
and reclamation of a surface gold mine near Trafalgar, Nova Scotia, if this project is approved.
The proposed mine will be a surface open pit mine, and will include milling facilities (e.g. a
primary crusher and concentrator), a Waste Rock Storage Area (WRSA), a Tailings Management
Facility (TMF), mine haul roads and associated mine infrastructure, including maintenance
facilities, local supply systems, explosive storage, fuel storage and mine offices (Atlantic Mining
Corp., 2018). Ore mined and milled at the FMS project site will be transported as concentrate to
the processing facilities at the Touquoy Mine, wherein gold dorée will be produced. Processing
at Touquoy Mine will involve the deposition of concentrate tails at the exhausted Touquoy Mine
pit. The total development area of the FMS Project is approximately 280 hectares (ha), which
includes the ore extraction area (surface mine) (20 ha), materials storage (waste rock,
overburden, low grade ore stockpile) (65 ha), crusher and concentrate facilities (10 ha) and site
infrastructure (5 ha), TMF (165 ha), mine site haul roads (10 ha), access roads (5 ha) and Seloam
Brook Realignment (Atlantic Mining Corp. 2018).

Once closed, all facilities will be removed from the landscape, and disturbed lands will be
rehabilitated and the property will be returned to a functional use according to the approved
reclamation plans and accepted practices at time of closure.

The main elements of the FMS Gold Project are as follows, with additional details being
provided in Atlantic Mining Corp. (2018):

- A surface mine from which 32.4 Mt of rock will be excavated, comprising 10.8 Mt of ore
  and 20.3 Mt of waste rock and 1.3 Mt of overburden;
- A Construction Phase (one year), an Operations Phase (7 years), and a Closure Phase,
  consisting of an Reclamation Stage (3 years) and a Post-Closure Stage;
- Construction of a realignment channel for Seloam Brook, to the north of the open pit.
  Surface and groundwater entering the open pit will be pumped to the TMF;
- Crushing and concentrate facilities to process 2.0 Mt/yr of ore, which will produce a gold
  concentrate which will be transported to the Touquoy facility for final processing;
- Waste rock storage with a capacity of 16.2 Mt of waste rock; over burden storage piles;
- A TMF with a design capacity of 8.3 Mm^3 of tailings solids;
- Administrative and maintenance buildings;
- Tailings storage within the exhausted open pit;

The hauling of concentrate from FMS Mine Site to Touquoy Mine Site will occur via two
possible routes, mainly on public roads. The distance is approximately 60 - 76 km between the
two sites. There are private dwellings along the proposed transportation route, in the community
of Sheet Harbour, with a lower density of dwellings between Sheet Harbour and Mooseland,
Tangier and Marinette.

With respect to project stages, the following is the anticipated operations and closure timings:

- Construction Phase (year 1)
- Operation Phase (years 2-8)
- Closure Phase (reclamation stage) (years 9-11)
- Closure Phase (post closure stage) (years 12+)

An Environmental Assessment commenced in July of 2018, and an Environmental Impact Statement (EIS) for the FMS Mine Site will be submitted for review to both the Canadian Environmental Assessment Agency (CEAA) and Nova Scotia Environment (NSE) in 2021. Guidelines were prepared for the EIS and were released in August of 2018. This technical report is prepared to support that EIS, related to the potential for aquatic effects as a result of mine releases to the receiving environments.

The FMS Study Area has two main aquatic receiving environments. The first receiving environment has been termed the FMS Receiving Environment for the purposes of this report and includes three main surface water receiving environmental components located within and directly downgradient/downstream of the Project footprint. These include the Anti-Dam Flowage outflow which will receive the discharged treated mine water effluent, the Seloam Brook located downstream of Seloam Lake which collects drainage from an area that is north and in part downgradient of the project area, and an unnamed stream located in a stream system that includes the collection of drainage from an area located immediately southeast and downgradient of the tailings (TMF)(known as watercourse 43). This stream drains into East Lake, which flows into East Brook. With the transfer of concentrate from the FMS Study Area to the Touquoy Mine Site, there is need for an additional assessment of potential for aquatic effects associated with the added process emissions related to FMS concentrate at the Touquoy facility. Currently, the active Touquoy pit is dewatered and all water is pumped to the Tailings Management Facility (TMF). Effluent passes from the TMF, through a polishing pond and a series of geobags to a constructed wetland and is released into Scraggy Lake (Final Discharge Point; FDP). The Touquoy Mine pit will eventually be exhausted and will be allowed to fill naturally with water. FMS concentrate process emissions generated as a result of processing of FMS concentrate at Touquoy Mine Site will be deposited in the exhausted Touquoy Mine pit. Once the Touquoy pit fills naturally, and once water quality within the pit meets MDMER discharge criteria, water surplus will be released at a new Effluent Final Discharge Point to the Moose River, via a spillway or channel (Stantec, 2021). Therefore, this report includes an assessment of both the FMS Study Area receiving environments, as well as the Moose River, associated with the FMS Gold Project. In addition to this, the Touquoy Mine exhausted pit is expected to also receive emissions related to the Beaver Dam Mine Project, the Cochrane Hill Gold Project, and additional input of tailings from the Touquoy Project. Therefore, the cumulative effects of Touquoy Mine pit discharges, in conjunction with both the FMS project contributions and the Beaver Dam Mine Project, Cochrane Hill Gold project, and Touquoy Project contributions merit consideration in this report.

As part of the mine planning process, Golder has predicted future releases related to the FMS Gold Project (Golder, 2019). This predictive modelling study provides future water quality during Operations (Ops) and Post Closure (PC) in the receiving environment at the Study Area.

An assimilative capacity study was conducted for the Moose River receiving environment at the Touquoy Mine Site (Stantec, 2021), to understand potential impacts associated with the processing of concentrate from FMS Gold Project, as well as the cumulative effects related to the Beaver Dam Mine Project, Cochrane Hill Gold Project and Touquoy Project deposition of tailings in the Touquoy Mine pit.

Therefore this aquatic effects assessment relies on the predicted receiving environment water quality into the FMS Receiving Environment (based on Golder, 2019), and the Moose River (Stantec, 2021).

The methods to conduct the aquatic effects assessment are presented in Section 2.0 of the report, whereas the assessment outcomes for the FMS Receiving Environment are presented in Section 3.0, and the assessment outcomes for the Moose River are in Section 4.0. Conclusions can be found in Section 5.0, with references in Section 6.0.

2   METHODS FOR CONDUCTING THE AQUATIC EFFECTS ASSESSMENT

2.1   Receiving Environment Characterization

To conduct the aquatic effects assessment, the receiving environment was characterized, based on available baseline data and descriptive text characterizing the receiving environments.

2.2   Exposure Assessment

To conduct the exposure assessment related to possible future concentrations of metals and other substances in the receiving environment, the predictive water quality modelling conducted by Golder (2019) and Stantec (2021) were used to characterize potential future receiving environment chemistry, as a result of mine-related emissions to either of the two environments, over various time frames.

2.3   Toxicity Assessment

Water quality guidelines used in the assessment are selected from the Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME, 2019) and the Nova Scotia Tier 1 surface water guidelines for use in freshwater (NSE, 2014; many of which are based on CCME). In addition, the Environment Canada Federal Environmental Quality Guidelines (FEQG, 2017) were considered for use relative to the water quality guidelines for cobalt. As stated in the FEQG website, the use of FEQGs is voluntary unless prescribed by regulation or binding agreements. These guidelines may be applied as intermediate values in calculations, but FEQGs are neither effluent limits, nor are they "never-to-be-exceeded" values (ECCC, 2017). For the selection of guidelines, the Nova Scotia Tier 1 surface water guidelines were given precedent over the CCME water quality guidelines with the exception of the following cases:

- the Nova Scotia Tier 1 guidelines have not accounted for site-specific toxicity modifying factors (*i.e.*, pH, hardness); or,
- the CCME or FEQG provides a more updated water quality guideline.

In these cases, the CCME or FEQG guideline was selected over the Nova Scotia Tier 1 guideline. Table 2-1 presents the CCME, Nova Scotia Tier 1, and FEQG water quality guidelines along with the selected guideline for each chemical. Where water quality varies between receiving environments, the modified guidelines for each site are presented. The chemicals presented in Table 2-1 are based on the metals or substances considered in the predictive modelling for the FMS Receiving Environment (Golder, 2019) or Moose River (Stantec, 2021). Not all chemicals are assessed in both receiving environments. Only those chemicals considered in each of the modelling efforts are carried into the assessment of potential for aquatic effects. For example, cyanide treatment is only conducted at the Touquoy Mine Site, and hence, cyanide did not merit assessment in the FMS Receiving Environment but was assessed in Moose River. For the specific compounds assessed in the different receiving environments, see Section 3.0 (FMS Receiving Environment) and Section 4.0 (Moose River).

Table 2-1   Selected Regulatory Water Quality Guidelines for Use in the Assessment

Chemical	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)	FEQG (mg/L)	Selected Guideline	Regulation
Aluminum	0.005/0.1[a]	0.005	-	0.005	Nova Scotia Tier 1
Antimony	NG	0.02	-	0.02	Nova Scotia Tier 1
Arsenic	0.005	0.005	-	0.005	Nova Scotia Tier 1
Boron	1.5	1.2	-	1.2	Nova Scotia Tier 1
Cadmium	0.00004/0.00009[b]	0.00001	-	0.00004	CCME
Chromium	0.0089[c]	0.001[d]	-	0.0089	CCME
Cobalt	NG	0.01	0.00078[e]	0.00078	FEQG
Copper	0.002/0.004[f]	0.002	-	0.002	Nova Scotia Tier 1
Iron	0.3	0.3	-	0.3	Nova Scotia Tier 1
Mercury	0.000026	0.000026	-	0.000026	Nova Scotia Tier 1
Manganese	NG	0.82	-	0.82	Nova Scotia Tier 1
Molybdenum	0.073	0.073	-	0.073	Nova Scotia Tier 1
Nickel	0.025/0.15[g]	0.025	-	0.025	Nova Scotia Tier 1
Lead	0.001/0.007[h]	0.001	-	0.001	Nova Scotia Tier 1
Selenium	0.001	0.001	-	0.001	Nova Scotia Tier 1
Silver	0.00025	0.0001	-	0.00025	CCME
Sulphate	NG	NG	-	128[i]	BC MOE
Thallium	0.0008	0.0008	-	0.0008	Nova Scotia Tier 1
Uranium	0.015	0.3	-	0.015	CCME
Zinc	0.007	0.03	-	0.007	CCME
WAD Cyanide	0.005	0.005	-	0.005	Nova Scotia Tier 1
Total Cyanide (based on Strong Acid Dissociated)	NG	NG	-	0.005[j]	CCME

Nitrite (as N)	0.06	NG	-	0.06	CCME
Nitrate	13	NG		13	CCME
Ammonia (total)	NG	Varies with pH and temperature	-	Varies with pH and temperature	CCME
Ammonia (un-ionized)	0.019	NG	-	0.019	CCME

Notes: NG = No guideline available from that agency

a The CCME water quality guideline for aluminum of 5 µg/L is for pH<6.5, and 100 µg/L is for pH ≥6.5. The background pH levels of the FMS Receiving Environment were <6.5; and mean pH of Moose River is 6.05; therefore, the guideline of 5 µg/L is appropriate for use at all sites.

b The CCME water quality guideline for cadmium of 0.04 µg/L is for water hardness >0 to <17 mg/L, and 0.09 µg/L is for water of 50 mg/L hardness. The background water hardness of the FMS Receiving Environment ranges between 2.8 and 5.1 mg/L $CaCO_3$; and the mean hardness of Moose River is 5.0 mg/L; therefore, the guideline of 0.04 µg/L is appropriate for use at all sites.

c Based on Cr^{3+}; this value was selected as Cr^{6+} is unlikely to be present in the receiving environment

d Based on Cr^{6+}

e Guideline varies with hardness, and the lowest hardness range was selected in this case.

f The CCME water quality guideline for copper of 2 µg/L is for water hardness of 0 to <82 mg/L or when the hardness is unknown. When the hardness is >82 to ≤180 mg/L, the following equation is used to calculate the guideline: CWQG (µg/L) = $0.2 * e^{(0.8545[ln(hardness)]-1.465)}$, and at a hardness >180 mg/L, the guideline is 4 µg/L. The background water hardness of the FMS Receiving Environment ranges between 2.8 and 5.1 mg/L $CaCO_3$ and the mean hardness of Moose River is 5.0 mg/L; therefore, the guideline of 2 µg/L is appropriate for use at all sites.

g The CCME water quality guideline for nickel of 25 µg/L is for water hardness of 0 to ≤60 mg/L or when the hardness is unknown. When the hardness is >60 to ≤180 mg/L, the following equation is used to calculate the guideline: CWQG (µg/L) = $e^{\{0.76[ln(hardness)]+1.06\}}$, and at a hardness >180 mg/L, the guideline is 150 µg/L. The background water hardness of the FMS Receiving Environment ranges between 2.8 and 5.1 mg/L $CaCO_3$ and the mean hardness in Moose River is 5.0 mg/L; therefore, the guideline of 25 µg/L is appropriate for use at all sites.

h The CCME water quality guideline for lead of 1 µg/L is for water hardness of 0 to ≤60 mg/L or when the hardness is unknown. When the hardness is >60 to ≤180 mg/L, the following equation is used to calculate the guideline: CWQG (µg/L) = $e^{\{1.273[ln(hardness)]-4.705\}}$, and at a hardness >180 mg/L, the guideline is 7 µg/L. The background water hardness of the FMS Receiving Environment ranges between 2.8 and 5.1 mg/L $CaCO_3$ and the mean hardness in Moose River is 5.0 mg/L; therefore, the guideline of 1 µg/L is appropriate for use at all sites.

i No CCME or NS Tier 1 guideline is available; therefore a guideline from BC MOE was used (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf)

j This guideline is for free CN, and hence does not apply to Total CN. It is used to provide perspective only in the effects assessment.

Where substances were found to exceed the selected guideline consideration was given to developing a Site Specific Water Quality Objective (SSWQO), following CCME guidance (CCME, 2007). The typical starting points for assessment of surface water data are the Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (WQGl - FWAL), established by the CCME. These guidelines are generic, national recommendations which reflect the most current scientific data at the time they were developed. They are intended to provide protection to all forms of aquatic life and aquatic life cycles, including the most sensitive life stages, at all locations across Canada (CCME, 2007). Since they are generic and do not always account for site-specific factors that can alter toxicity, these national guidelines can be modified using widely accepted procedures, to derive site-adapted or SSWQOs for a given project or location (CCME, 2003). Modifications to the generic guidelines allow for protection of aquatic species accounting for specific conditions in the receiving environment, primarily due to the following reasons (CCME, 2003):

- There may be naturally-occurring levels of substances that are above the generic guidelines. This is commonplace for metals and metalloids near areas of natural enrichment, such as mines.

- There may be certain characteristics of the water at a specific location or site which modify the toxicity of the substance, such that the generic guideline is unnecessarily conservative (protective). These characteristics are known as exposure and toxicity modifying factors (ETMFs), and can include parameters such as pH, temperature, hardness, and organic matter, amongst others (CCME, 2007).

- There may be certain sensitive species considered in the development of the generic guideline which are not present in the area under assessment (e.g., warm water species which are absent from northern environments), and removal of these data allows for a more site-specific guideline to be developed, without compromising protection. In addition, information on toxicity of the substance in question to resident species in the area of interest may be lacking in the existing database, and therefore, there may be interest in expanding the database to include site-specific toxicity data.

- The existing CCME guideline may be dated and hence, application of more advanced protocols and available data can result in a revised guideline, which is more representative of current scientific practice and available toxicity data.

To determine the need for the development of a SSWQO, predicted future concentrations of substances which were estimated to be elevated over guidelines were evaluated against natural background concentration ranges from the receiving environment. The 75th percentile was used to represent an upper bound of natural baseline conditions, which was considered conservative, as federal guidance suggests that a 90th percentile can be used (CCME, 2003). In the instance that the 75th percentile of baseline exceeded the guideline, the baseline was used as the benchmark for comparison. This occurred for aluminium and iron, which are commonly above guidelines in Nova Scotia waters. Other considerations were also evaluated prior to determining the need for development of SSWQO. These considerations included the frequency and degree of predicted exceedances for a given substance, the potential role of *in situ* modifying factors, such as hardness, on toxicity of the substance, and how recently the existing guideline was developed (e.g., CCME recently released guidelines for zinc (2018) and a recent guideline was developed by ECCC for cobalt (2017); hence, the most recent scientific literature was considered in these efforts, which suggest that further efforts to evaluate the literature would be unlikely to yield a vastly different guideline value).

Based on consideration of these factors and all the available information, a SSWQO was derived for arsenic, following CCME protocols (CCME, 2007). A SSWQO consistent with CCME (2007) guidance, using a species sensitivity distribution (SSD) approach was used to derive the SSWQO. The SSD approach was comprised of identifying chronic toxicity data for species, analyzing the data using a regression approach and selecting the final chronic effects benchmark. The HC5 (i.e., the concentration that is hazardous to no more than 5% of a species in the community) was selected as the final chronic effects benchmark as per CCME (2007) guidance. The resultant guideline using the protocol is 30 µg/L. The details related to the derivation of the SSWQO for arsenic are provided in Appendix A.

2.4 Characterization of Potential for Adverse Effects

The resulting future conditions in the receiving environments were compared to either CCME (2018) freshwater aquatic life guidelines (FWAL), Nova Scotia Tier 1 surface water guidelines (NSE, 2014), and/or FEQG (2017), or SSWQO, as well as to an upper percentile of baseline (75th percentile concentrations of existing near-field baseline water quality stations), to characterize potential risks to aquatic life.

Each aspect of the assessment is provided in Chapter 3 (FMS receiving environment assessment), and Chapter 4 (Moose River assessment).

3 FMS RECEIVING ENVIRONMENT ASSESSMENT

3.1 Description of Receiving Environment and Baseline Data

Surface water quality baseline work was conducted to establish the surface water quality conditions within the FMS Study Area, including the FMS Receiving Environment, prior to the development of the FMS Gold Project. The surface water quality observed in the FMS Study Area is typical of lakes and watercourses that are present within the geological terrain of the southern mainland of Nova Scotia. The geology within this region is dominated by Cambrian-aged bedrock and the hydrology is strongly controlled by bedrock outcrops that create irregular flow patterns. As drainage moves through the watersheds within this region, the surface water is subjected to water-rock interactions and weathering processes associated with the bedrock and overburden – these natural processes influence the baseline water quality (See Chapter 6.6, EIS).

The FMS Receiving Environment included key surface water features within and directly downgradient/downstream of the project footprint. These included a) the Seloam Brook (i.e., SW5) located downstream of Seloam Lake which collects drainage from an area that is north and in part downgradient of the project area; b) an unnamed stream (known as Watercourse 43) (i.e., SW15) located in a stream system that includes the collection of drainage from an area located immediately southeast and downgradient of the Tailings Management Facility (TMF), which drains to East Lake, and on to East Brook; and c) the Anti Dam Flowage which includes both the Anti-Dam Flowage outlet (i.e., SW6) and a location 100 m downstream of the discharge location for treated effluent (i.e., EMZ-2) (Golder, 2019). Figure 3-1 provides an overview of the mine site, and Figure 3-2 presents the various water quality assessment locations.
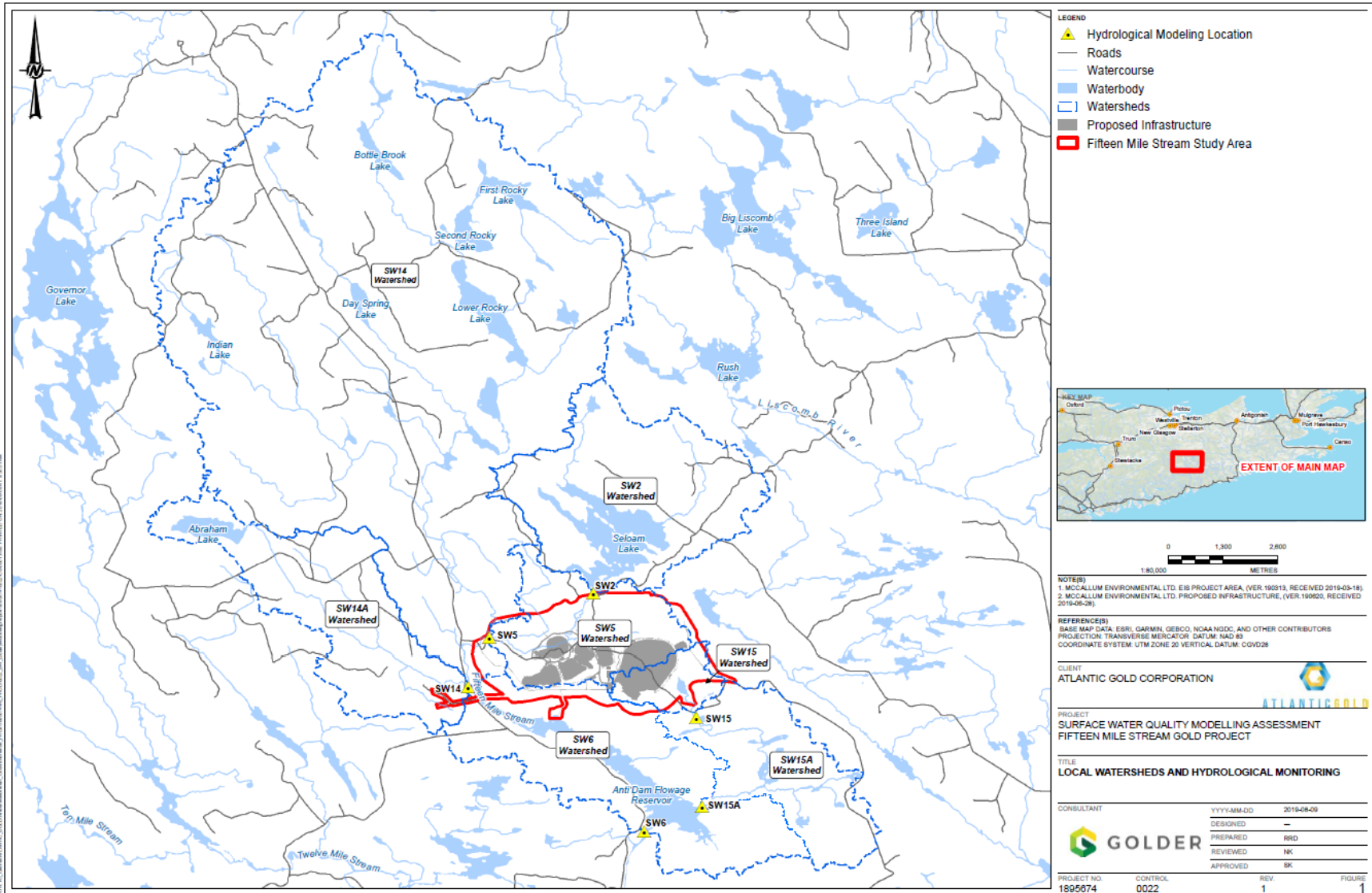
Figure 3-1   Local Watersheds and Hydrological Monitoring Locations
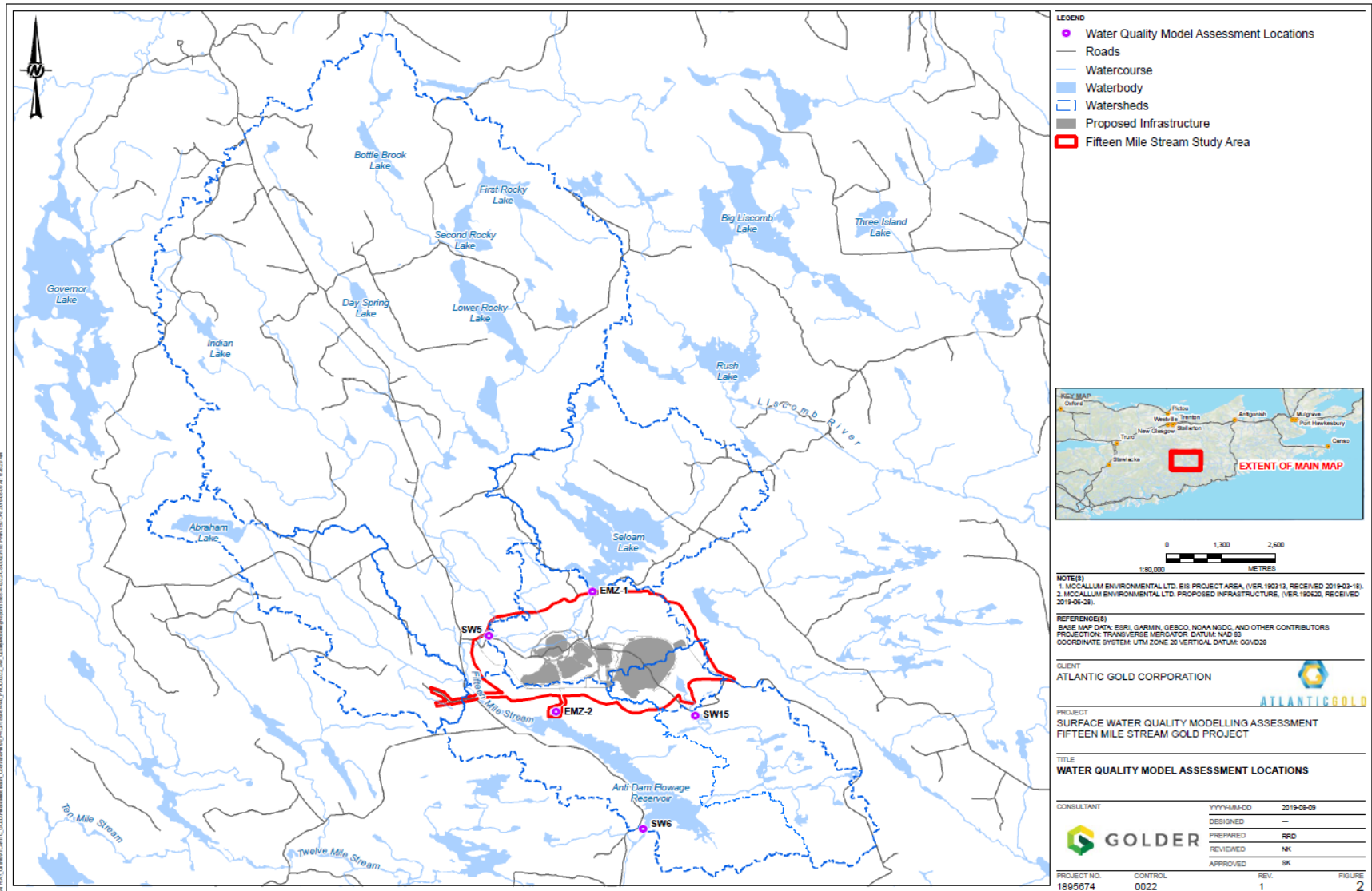
Figure 3-2   Water Quality Model Assessment Locations

The baseline surface water quality program was initiated in July 2017 and was later expanded in the following quarter. The program included the analysis of routine field parameters (temperature, pH, conductivity, total dissolved solids, turbidity, dissolved oxygen, and salinity), general chemistry, total metals, and total mercury, and now includes dissolved mercury. The monitoring program was revised in September 2018 to include a supplementary monitoring station (SW14) and more comprehensive list of analytical parameters applicable to baseline studies. Overall, the baseline surface water quality program comprised of a total of fifteen stations, thirteen of which were monitored per quarter, and two stations (SW13-S and SW13-D) that targeted water quality profiling in the deep water of the Anti-Dam Flowage (reservoir) (Golder, 2018). Although baseline water quality monitoring was conducted at multiple sites in the FMS study area, only baseline data for the FMS Receiving Environment (i.e., SW5, SW15, EMZ-2, and SW6) are discussed below. Baseline data from July 2017 to June of 2019 were included in the statistical analysis.

The baseline surface water quality in the FMS Receiving Environment was generally characterized as having acidic to near-neutral pH ($p<6.5$), low alkalinity and hardness, and low concentrations of nutrients. Concentrations of most parameters were observed to be consistently below the Nova Scotia Tier 1, and FEQG water quality guidelines. However, concentrations of aluminum, arsenic, and iron were observed to be greater than surface water quality guideline criteria (Golder, 2018). Background environmental baseline concentrations of some parameters exceeding surface water quality criteria are not uncommon, including within areas that are relatively pristine and not disturbed. Table 3-1 outlines the available baseline data (75th percentile) from the environmental components making up the FMS Receiving Environment (SW5, SW15, EMZ-2, and SW6). Values below the detection limit were assumed to equal ½ of the detection limit, for statistical calculations (see Golder, 2019). Refer to Appendix B for the results of all summary statistics for the environmental components.

Table 3-1   Baseline Surface Water Concentrations Collected from SW5, SW6, EMZ-2, and SW15 (Total Metals mg/L)[a]

Parameter	75th Percentile (mg/L)[c]					CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
	SW5	SW6	EMZ-2	SW15	Range		
Aluminum	0.20	0.25	0.25	0.32	0.2 – 0.32	0.005	0.005
Antimony	0.00050	0.00050	0.00050	0.00050	0.00050	NV	0.02
Arsenic	0.037	0.0045	0.0048	0.0005	0.0005 – 0.037	0.005	0.005
Boron	0.025	0.025	0.025	0.025	0.025	1.5	1.2
Cadmium	0.000014	0.000020	0.000022	0.000021	0.000014 – 0.000022	0.00004	0.00001
Chromium	0.00050	0.00050	0.00050	0.00050	0.00050	0.0089	0.001
Cobalt	0.00020	0.00020	0.00020	0.00046	0.00020 – 0.00046	NV	0.01
Copper	0.0010	0.0010	0.0010	0.0010	0.0010	0.002	0.002
Iron	0.59	0.33	0.33	0.86	0.33 – 0.86	0.3	0.3
Lead	0.00025	0.00025	0.00025	0.00057	0.00025 – 0.00057	0.001	0.001
Manganese	0.082	0.068	0.072	0.078	0.068 – 0.082	NV	0.82

Mercury	0.0000091	0.0000065	0.0000065	0.0000065	0.0000065 – 0.0000091	0.000026	0.0000026
Molybdenum	0.0010	0.0010	0.0010	0.0010	0.0010	0.073	0.073
Nickel	0.0010	0.0010	0.0010	0.0010	0.0010	0.025	0.025
Selenium	0.00050	0.00050	0.00050	0.00050	0.00050	0.001	0.001
Silver	0.000050	0.000050	0.000050	0.000050	0.000050	0.00025	0.0001
Thallium	0.00005	0.00005	0.00005	0.00005	0.00005	0.0008	0.0008
Uranium	0.00005	0.00005	0.00005	0.00005	0.00005	0.015	0.3
Zinc	0.0025	0.0025	0.0025	0.0025	0.0025	0.007	0.03
WAD Cyanide	0.0000015	0.0000015	0.0000015	0.0000015	0.0000015	0.005	0.005
Total Cyanide (based on Strong Acid Dissociated)	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	0.005	NV
Nitrite (as N)	0.0050	0.0050	0.0050	0.0050	0.0050	0.06	NG
Nitrate	0.025	0.025	0.025	0.025	0.025	13	NG
Ammonia (total; ammonia nitrogen)	0.025	0.025	0.025	0.033	0.025 – 0.033	NV	Varies with pH and temperature
Ammonia (un-ionized)	0.0000020	0.0000013	0.0000018	0.00000063	0.00000063 – 0.0000020	0.019	NV
Sulphate	1.0	1.0	1.0	1.0	1.0	NV	NV

Notes:

[a] Summary statistics were calculated using half the detection limit value when a chemical was not detected in a sample.

[b] Surface water concentrations are not available for SW15; therefore, surface water concentrations from SW12 (upstream of SW15) were used as a surrogate (Golder, 2019)

[c] Refer to Appendix B for the results of all summary statistics for SW5, SW6, EMZ-2 and SW15.

NV indicates no value available

Water quality stations in the FMS Receiving Environment were found to have elevated concentrations of aluminum and in some cases, iron and arsenic [above the CCME FWAL and Nova Scotia Tier 1 surface water guidelines]. Aluminium is commonly above guidelines in Nova Scotia waters, as is iron. Golder (2018) indicate that approximately 100% of the aluminum results, and 49% of the iron results in the overall sampling program exceeded the chronic environmental quality guidelines. In addition, arsenic exceedances occurred at stations SW4, SW5, SW6 and SW13 and SW14. Historic tailings from previous gold mining activities are likely influencing arsenic concentrations at SW4 (data not shown) and SW5 (see Table 3-1). The relative soft waters in the area also present a challenge for mitigation of metals toxicity in the environment.

As a result of naturally occurring elevated concentrations of iron and aluminium (relative to CCME or NS Tier 1 standards), the benchmark used for comparison of future receiving environment concentrations for these two elements was the 75th percentile of baseline at the relevant surface water quality monitoring stations, rather than the NS Tier 1 or CCME guidelines. This is an accepted practice for inorganics. With respect to arsenic, the SSWQO of 0.03 mg/L was used in all cases, with the exception of SW5, which exhibited elevated baseline concentrations of arsenic.

3.2 Description of Water Quality Modelling Conducted

The surface water quality effects predictions were completed by Golder (2019), and detailed modelling approach, methods and assumptions and limitations are provided in the Surface Water Quality Modelling report (Golder, 2019). The numerical model was developed using GoldSim Version 12.1, which is a graphical, object-oriented mathematical model designed to facilitate understanding of the various factors that influence an engineered or natural system, which allows for forecasting the potential changes to surface water quality.

The objective of the water quality modelling is to predict the combined-net effect that the Project components and activities may have on the quality of the surface water environment. The modelling approach used for the surface water quality predictions is a mass-balance mixing cell model with a number of site-specific components, consisting of both natural components (e.g., natural runoff, rainfall) and site components (e.g., treated effluent discharge, seepage), that are linked together to form a series of mixing cells, or combined water quality. The model uses a 40-year climate record and considers precipitation records for the hydrology (flow) simulations using a stochastic (Monte Carlo) method. This approach provides a framework for the range of probabilistic climate conditions that the site and receiving surface water environment are likely to experience over the period of the Project. Using this approach, a range of resultant flows and water quality were available for the operations (EOM) and post-closure (PC) phase. In addition to the annual average statistical summary, predicted monthly concentrations for key parameters (average, 5th percentile and 95th percentile) were determined for the EOM and PC phases and are presented graphically in the report on the Surface Water Quality Modelling (Golder, 2019b).

Source-term effluent quality predictions were included for operational components that have the potential to affect the overall site water quality. Atlantic Mining NS Corp. (2019) indicates that the Open pit wall runoff; non-acid generating Waste Rock Storage Area (WRSA) drainage; potentially acid generating WRSA drainage; LGO stockpile drainage; Topsoil stockpile drainage; Till stockpile drainage; Process water (water associated with the tailings from the plant site); TMF tailings beach and embankment runoff; and Tailings seepage, were all included in the modelling effort, based on source terms provided by Lorax (2019). Effluent discharge from TMF pond via the water treatment plant will meet the federal MDMER requirements as per the Fisheries Act. Greater detail on the modelling approach, methods, assumptions and limitations are discussed in the report on the Surface Water Quality Modelling (Golder, 2019), as well as the EIS (Chapter 6.6).

3.3 Discharge Points and Receiving Environment Prediction Points

The potential effects of the FMS mine on surface water quality was simulated at key surface water features that are within and directly downgradient/downstream of the Project footprint. The main discharge point identified in Chapter 6.6 (Atlantic Mining NS Corp, 2019) with potential for discharge of impacted mine effluent into the FMS system is the Anti-Dam Flowage outflow (see Figure 3-1 for identified discharge location; also called EMZ-2) in both operational (OPs) and post closure (PC) scenarios. Additionally, the Seloam Brook (i.e., SW5) and an unnamed stream (i.e., SW15) which collect drainage from areas north and downgradient of the project area and areas southeast and downgradient of the TMF, respectively, were considered to be other important receiving environmental components.

Water quality was predicted at 100 m downstream of the discharge location into Anti-Dam Flowage (EMZ-2), a far field location within Anti-Dam Flowage (SW6), the Seloam Brook (SW5), and unnamed stream (i.e., SW15). Based on the water flow characteristics of the receiving environment, full mixing was assumed to occur at the near field prediction node.

3.4   Selected Benchmarks

Benchmark concentrations used for comparison against predicted water concentrations are presented in Table 3-2. Selection of these benchmark concentrations is described in Section 2.3. These benchmark concentrations were based on the greater of either the water quality guideline selected for use in the assessment (see Table 2-1), or the 75th percentile of the baseline surface water concentrations collected from the FMS Receiving Environment (Table 3-1), except for arsenic for which a site-specific water quality objective was calculated and adopted (see Section 2.3 and Appendix A). With respect to arsenic, the SSWQO of 0.030 mg/L was selected as the benchmarks for all nodes. The increased baseline at SW5 (due to presence of historic tailings) will also be discussed for that prediction node.

Table 3-2   Selected Benchmark Concentrations for Use in the Assessment (mg/L)

Parameter	Selected Guideline[a]	75th Percentile of Baseline[d]	Site-Specific Water Quality Objective	Selected Benchmark Concentration
Aluminium	0.005	0.2/0.25/0.25/0.32	-	0.2/0.25/0.25/0.32
Antimony	0.02	0.0005/0.0005/0.0005/0.0005	-	0.02
Arsenic	0.005	0.037/0.0045/0.0048/0.0005	0.030	0.037[e]/0.030
Boron	1.2	0.025/0.025/0.025/0.025	-	1.2
Cadmium	0.00004[b]	0.000014/0.00002/0.000022/0.000021	-	0.00004
Chromium	0.0089[b]	0.0005/0.0005/0.0005/0.0005	-	0.0089
Cobalt	0.00078[b]	0.0002/0.0002/0.0002/0.00046	-	0.00078
Copper	0.002	0.001/0.001/0.001/0.001	-	0.002
Iron	0.3	0.59/0.33/0.33/0.86	-	0.59/0.33/0.33/0.86
Lead	0.001	0.00025/0.00025/0.00025/0.00057	-	0.001
Manganese	0.82	0.082/0.068/0.072/0.078	-	0.82
Mercury	0.000026	0.0000091/0.0000065/0.0000065/0.0000065	-	0.000026
Molybdenum	0.073	0.001/0.001/0.001/0.001	-	0.073
Nickel	0.025	0.001/0.001/0.001/0.001	-	0.025
Selenium	0.001	0.0005/0.0005/0.0005/0.0005	-	0.001
Silver	0.00025[b]	0.00005/0.00005/0.00005/0.00005	-	0.00025
Thallium	0.0008	0.00005/0.00005/0.00005/0.00005	-	0.0008
Uranium	0.015[b]	0.00005/0.00005/0.00005/0.00005	-	0.015
Zinc	0.007[b]	0.0025/0.0025/0.0025/0.0025	-	0.007
WAD Cyanide	0.005	0.0000015/0.0000015/0.00000015/0.0000015	-	0.005
Total Cyanide (based on Strong Acid Dissociated)	0.005[b]	0.0000025/0.0000025/0.00000025/0.0000025	-	0.005
Nitrite (as N)	0.06	0.005/0.005/0.005/0.005	-	0.06
Nitrate	13	0.025/0.025/0.025/0.025	-	13
Ammonia (total)	Varies with pH and temperature	0.025/0.025/0.025/0.033	-	Varies with pH and temperature
Ammonia (un-ionized)	0.019	0.000002/0.0000013/0.0000018/0.00000063	-	0.019
Sulphate	128[c]	1/1/1/1	-	128

Notes:

- not calculated; NDA: no data available

[a]   Selected guidelines represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b]   Selected guideline adopted from CCME, or in the case of cobalt, ECCC (2017).

[c]   Selected guideline adopted from BC MOE.

[d]   Baseline concentrations from prediction nodes presented as follows: SW5 / SW6 / EMZ-2 / SW15

[e]   For node SW5, baseline arsenic concentrations exceed the SSWQO, and hence, for that node, the baseline 75th percentile represents the benchmark, whereas all other nodes, the benchmark is the SSWQO

3.5   Predicted Water Quality – Operations

Only receiving environment predictions are assessed herein, and discharge predictions relative to MDMER limits are provided in Golder (2019). The predictions provided by Golder (2019) include the Project increment + mean Baseline. Mean baseline metrics are provided in Golder (2019). With naturally occurring dilution within the Fifteen Mile Stream receiving environment, some metals are predicted to be less than mean baseline at some of the prediction nodes.

The Golder (2019) predicted chemical concentrations assume the upper case of source terms from Lorax (2019), and hence, represent a conservative modeling scenario. Table 3-3 provides the annual average and 95th percentile predicted baseline + operational future concentrations at the 4 prediction nodes (SW5; EMZ-2; SW15 and SW6), as well as the 75th percentile of baseline and relevant guidelines. Metals or other substances which are predicted to exceed either the baseline metric (where baseline exceeds the guideline), or the relevant guideline are identified by bolding and underlining.

Table 3-3 Comparison of Predicted Annual Average Water Concentrations in Receiving Environment to Selected Guidelines (mg/L) – Operations (Upper Case)

Parameter	Selected Guideline (mg/L)	75th Percentile Baseline Concentrations (mg/L) [a]				Predicted Annual Average Concentration in Receiving Environment (mg/L) [b]							
		SW5	SW6	EMZ-2 [c]	SW15 [d]	SW5		SW6		EMZ-2		SW15	
						average	95%	average	95%	average	95%	average	95%
Aluminum	0.2/0.25/0.25/0.32[e]	0.20	0.25	0.25	0.32	0.18	0.18	0.22	0.22	0.22	0.22	0.24	0.24
Antimony	0.02	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00049	0.00050	0.00050	0.00050
Arsenic	0.037[f]/0.030	0.037	0.0045	0.0048	0.0005	0.025	0.025	0.0057	0.0059	0.0063	0.0065	0.00070	0.00074
Boron	1.2	0.025	0.025	0.025	0.025	0.025	0.025	0.026	0.027	0.027	0.028	0.025	0.025
Cadmium	0.00004	0.000014	0.000020	0.000022	0.000021	0.000012	0.000012	0.000017	0.000017	0.000017	0.000018	0.000017	0.000017
Chromium	0.0089	0.00050	0.00050	0.00050	0.00050	0.00056	0.00056	0.00054	0.00054	0.00055	0.00055	0.00050	0.00050
Cobalt	0.00078	0.00020	0.00020	0.00020	0.00046	0.00026	0.00026	0.00024	0.00025	0.00023	0.00026	0.00034	0.00034
Copper	0.002	0.0010	0.0010	0.0010	0.0010	0.00086	0.00087	0.00078	0.00079	0.00077	0.00078	0.00084	0.00084
Iron	0.59/0.33/0.33/0.86[e]	0.59	0.33	0.33	0.86	0.39	0.39	0.37	0.38	0.35	0.36	0.58	0.59
Lead	0.001	0.00025	0.00025	0.00025	0.00057	0.00025	0.00025	0.00030	0.00030	0.0002904	0.0002921	0.00037	0.00037
Manganese	0.82	0.082	0.068	0.072	0.078	0.073	0.073	0.068	0.069	0.069	0.071	0.056	0.057
Mercury	0.000026	0.0000091	0.0000065	0.0000065	0.0000065	0.0000095	0.0000095	0.0000070	0.0000070	0.0000070	0.0000070	0.0000065	0.0000065
Molybdenum	0.073	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0013	0.0015	0.0014	0.0017	0.0011	0.0011
Nickel	0.025	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0014	0.0017	0.0015	0.0020	0.0010	0.0010
Selenium	0.001	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00051	0.00051	0.00051	0.00052	0.00050	0.00050
Silver	0.00025	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000049	0.000050	0.000049	0.000050	0.000050	0.000050
Thallium	0.0008	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.000050	0.000050	0.000049	0.000050	0.000050	0.000050
Uranium	0.015	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.00014	0.00021	0.00018	0.00028	0.000051	0.000051
Zinc	0.007	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0027	0.0028	0.0027	0.0028	0.0030	0.0030
Nitrite	0.06	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0090	0.012	0.010	0.015	0.0050	0.0050
Nitrate	13	0.025	0.025	0.025	0.025	0.0050	0.0050	0.16	0.28	0.22	0.40	0.0050	0.0050
Ammonia (un-ionized)	0.019	0.0000020	0.0000013	0.0000018	0.00000063	0.00000056	0.00000056	0.0000014	0.0000018	0.0000016	0.0000022	0.00000078	0.00000079
Sulphate	128	1.0	1.0	1.0	1.0	1.3	1.4	11	18	14	25	1.9	2.3

Notes:
Shaded values indicate and exceedance of the selected guideline

[a] Statistics calculated from the available surface water quality baseline dataset (June 2017 to December 2018).

[b] Predicted annual concentration calculated from the GoldSim stochastic model; statistics presented are the mean and 95th percentile.

[c] Baseline water quality for EMZ-2 is derived from the available dataset for SW14 and SW6 (see Golder, 2019).

[d] Baseline water quality for SW15 is derived from the available dataset for SW12 (see Golder, 2019).

[e] Baseline concentrations from prediction nodes presented as follows: SW5 / SW6 / EMZ-2 / SW15

[f] For node SW5, baseline arsenic concentrations exceed the SSWQO, and hence, for that node, the baseline 75th percentile represents the benchmark, whereas all other nodes, the benchmark is the SSWQO

In the Operations scenario, all predicted constituent concentrations based on annual average concentrations in the upper case were consistently below selected water quality benchmarks or baseline, with the exception of iron, which marginally exceeds the respective 75th percentile baseline at SW6 and EMZ-2.

Additional modelling was conducted for all parameters to examine the potential for exceedances on a monthly basis. All parameters, when examined on a monthly basis (5th percentile; average and 95th percentile), were less than the receiving environmental quality guidelines (see Golder, 2019). Predicted monthly iron results for the upper case source terms during operations are provided in Figure B-31 (Golder, 2019). The annualized exceedances over baseline identified in Table 3-3 above for EMZ-2 and SW6, remain fairly consistent when considered on a monthly basis (see Figure B-31, Golder, 2019). While the predicted levels slightly exceed the 75th percentile of baseline, they remain within the range of baseline and are unlikely to pose a risk to aquatic life.

3.6   Predicted Water Quality – Post Closure

Golder (2019) also predicted chemical concentrations for the PC scenario, at the 4 prediction nodes receiving releases to the environment. As per the operational scenario, these predictions assume the upper case of source terms from Lorax (2019), and hence, represent a conservative model scenario. Table 3-4 provides the annual average and 95th percentile predicted baseline + future concentrations for Post Closure at the 4 prediction nodes (SW5; EMZ-2; SW15 and SW6), as well as the 75th percentile of baseline and relevant guidelines. Metals or other substances which are predicted to exceed the either the baseline metric (where baseline exceeds the guideline), or the relevant guideline are identified by shading.

Table 3-4   Comparison of Predicted Annual Average Water Concentrations in Receiving Environment to Selected Guidelines (mg/L) – Post Closure (Upper Case)

Parameter	Selected Guideline (mg/L)	75th Percentile Baseline Concentrations (mg/L) [a]				Predicted Concentration (mg/L) [b]							
		SW5	SW6	EMZ-2 [c]	SW15 [d]	SW5		SW6		EMZ-2		SW15	
						mean	95%	mean	95%	mean	95%	mean	95%
Aluminum	0.2/0.25/0.25/0.32 [e]	0.20	0.25	0.25	0.32	0.18	0.18	0.21	0.21	0.21	0.21	0.24	0.24
Antimony	0.02	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Arsenic	0.037[f]/0.030	0.037	0.0045	0.0048	0.0005	0.025	0.025	0.0058	0.0060	0.0065	0.0067	0.0013	0.0017
Boron	1.2	0.025	0.025	0.025	0.025	0.025	0.025	0.026	0.026	0.026	0.026	0.025	0.025
Cadmium	0.00004	0.000014	0.000020	0.000022	0.000021	0.000012	0.000012	0.000024	0.000030	0.000027	0.000035	0.000017	0.000017
Chromium	0.0089	0.00050	0.00050	0.00050	0.00050	0.00056	0.00056	0.00056	0.00057	0.00057	0.00058	0.00050	0.00050
Cobalt	0.00078	0.00020	0.00020	0.00020	0.00046	0.00026	0.00026	0.00045	0.00062	0.00052	0.00079	0.00034	0.00034
Copper	0.002	0.0010	0.0010	0.0010	0.0010	0.00087	0.00087	0.00094	0.0011	0.0010	0.0012	0.00084	0.00084
Iron	0.59/0.33/0.33/0.86 [e]	0.59	0.33	0.33	0.86	0.39	0.39	0.39	0.41	0.38	0.39	0.58	0.59
Lead	0.001	0.00025	0.00025	0.00025	0.00057	0.00025	0.00025	0.00045	0.00056	0.00050	0.00067	0.00037	0.00037
Manganese	0.82	0.082	0.068	0.072	0.078	0.074	0.074	0.074	0.080	0.078	0.087	0.059	0.060
Mercury	0.000026	0.0000091	0.0000065	0.0000065	0.0000065	0.0000095	0.0000095	0.0000073	0.0000075	0.0000074	0.0000077	0.0000065	0.0000065
Molybdenum	0.073	0.0010	0.0010	0.0010	0.0010	0.0011	0.0012	0.0012	0.0013	0.0012	0.0014	0.0014	0.0015
Nickel	0.025	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0024	0.0034	0.0029	0.0045	0.0010	0.0010
Selenium	0.001	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00051	0.00051	0.00051	0.00052	0.00050	0.00050
Silver	0.00025	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050
Thallium	0.0008	0.00005	0.00005	0.00005	0.00005	0.000050	0.000050	0.000051	0.000052	0.000052	0.000053	0.000050	0.000050
Uranium	0.015	0.00005	0.00005	0.00005	0.00005	0.000050	0.000051	0.00010	0.000144	0.00012	0.00019	0.000051	0.000052
Zinc	0.007	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0037	0.0046	0.0041	0.0055	0.0029	0.0030
Nitrite	0.06	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0054	0.0057	0.0055	0.0060	0.0050	0.0050
Nitrate	13	0.025	0.025	0.025	0.025	0.0050	0.0051	0.026	0.041	0.033	0.056	0.005	0.005
Ammonia (un-ionized)	0.019	0.00000020	0.00000013	0.00000018	0.0000063	0.00000056	0.00000056	0.00000081	0.00000085	0.00000084	0.00000089	0.00000079	0.00000079
Sulphate	128	1.0	1.0	1.0	1.0	1.5	1.8	6.8	11	8.9	15	2.6	3.4

Notes:

Shaded values indicate and exceedance of the selected guideline

[a] Statistics calculated from the available surface water quality baseline dataset (June 2017 to June 2019).

[b] Predicted annual concentration calculated from the GoldSim stochastic model; statistics presented are the mean and 95th percentile.

[c] Baseline water quality for EMZ-2 is derived from the available dataset for SW14 and SW6.

[d] Baseline water quality for SW15 is derived from the available dataset for SW12.

[e] Baseline concentrations from prediction nodes presented as follows: SW5 / SW6 / EMZ-2 / SW15

[f] For node SW5, baseline arsenic concentrations exceed the SSWQO, and hence, for that node, the baseline 75th percentile represents the benchmark, whereas all other nodes, the benchmark is the SSWQO

In the Post Closure scenario, all predicted constituent concentrations were consistently below selected water quality benchmarks or baseline, when considered on an annual average basis with the exceptions of cobalt, which marginally exceeded the FEQG at EMZ-2, and iron, which marginally exceeded the respective 75th percentile baseline at SW6 and EMZ-2.

Additional modelling was conducted for all parameters to examine the potential for exceedances on a monthly average basis. When examined on a monthly basis, cadmium is predicted to be greater than the CCME water quality guideline at EMZ-2 in the months of May, October and November, based on the 95th percentile predictions (Table 3-5). In addition, cobalt exceeds the FEQG in January, February, April, October, November and December at EMZ, and in October and November at SW6 (see Table 3-6). Zinc also exceeds the CCME water quality guideline at EMZ in the month of November (Tables 3-7), but no exceedances are predicted in any other month. These exceedances are discussed further as follows:

- **Cadmium:** The predicted 95th percentile concentrations of cadmium at EMZ-2 in the months of May, October, and November (0.000041 – 0.000049 mg/L) exceeded the CCME water quality guideline of 0.00004 mg/L. The 95th percentile results represent an upper bound scenario, which would only result in the instance that low flow events occur in conjunction with upper case source term conditions, which is unlikely. Hence, the likelihood of toxicity is considered to be low.
- **Cobalt**: Predicted concentrations of cobalt do not exceed the NSEQS of 0.01 mg/L in any of the prediction nodes. Only the predicted 95th percentile cobalt concentration at EMZ-2 in the months of January, February, April, October, November and December (0.00080 – 0.00125 mg/L) and at SW6 in the months of October and November (0.00084 – 0.00096 mg/L) exceeded the FEQG of 0.00078 mg/L. The 95th percentile concentrations are up to 1.6 times the FEQG of 0.00078 mg/L. The 95th percentile results represent an upper bound scenario, which would only result in the instance that low flow events occur in conjunction with upper case source term conditions, which is unlikely. The FEQG considers hardness as a modifying factor, but the SSD model developed by Environment Canada in this guideline setting approach is very conservative, and the data used in the assessment do not fit the selected model of the SSD in the lower quartile of the dataset well (see Figure 1; ECCC, 2017). This results in the estimated HC5 value being considerably lower than it should be, relative to the toxicity dataset. This indicates that the selected guideline is over predicting toxicity of cobalt, and hence, the marginal exceedances indicated in Table 3-6 are considered to represent a low risk potential, with respect to toxicity to aquatic species, particularly considering that the upper case source terms and low flow events would have to co-occur in the 95th percentile calculations outlined below in Table 3-6.
- **Zinc:** Predicted concentrations of zinc do not exceed the NS Tier 1 standard of 0.030 mg/L in any of the prediction nodes. Only the predicted 95th percentile concentration at EMZ-2 in the month of November (0.0078 mg/L) exceeds the CCME CWQG of 0.007 mg/L. The lowest observed effect concentration (LOEC) listed in the CCME (2018) fact sheet is 0.00989 mg/L (11 week study; development; Chironomid sp.; normalized to 50 mg/L $CaCO_3$ and Dissolved Organic Carbon (DOC) of 0.5 mg/L). Since the predicted exceedance is marginal, relative to the guideline, and only occurs in the month of

November, the likelihood of toxicity occurring in the Baseline + Project scenario is considered to be low.

- **Iron:** Figure B-75 (Golder, 2019) provides the monthly predictions for iron in the Post closure, upper case scenario. The exceedances noted in EMZ-2 and SW6 in Table 3-4 remain fairly constant over the monthly intervals, and only marginally exceed the 75th percentile of baseline, and remain within the range of baseline. As per the discussion related to the operations upper case scenario related to iron, these predicted concentrations are unlikely to result in aquatic effects.

Table 3-5   Cadmium (mg/L) Predicted Baseline + Project Receiving Environment Monthly Concentrations – Post Closure

Receiving Environment Station/Month	EMZ			SW6		
	Average	5%	95%	Average	5%	95%
January	0.000026	0.000020	0.000035	0.000023	0.000020	0.000028
February	0.000026	0.000020	0.000036	0.000023	0.000020	0.000028
March	0.000024	0.000021	0.000030	0.000023	0.000020	0.000026
April	0.000026	0.000020	0.000037	0.000023	0.000020	0.000027
May	0.000030	0.000019	0.000043	0.000024	0.000020	0.000030
June	0.000028	0.000019	0.000031	0.000025	0.000019	0.000029
July	0.000025	0.000020	0.000026	0.000024	0.000020	0.000025
August	0.000027	0.000020	0.000028	0.000025	0.000019	0.000026
September	0.000027	0.000020	0.000029	0.000025	0.000019	0.000027
October	0.000030	0.000019	0.000041	0.000027	0.000019	0.000036
November	0.000028	0.000020	0.000049	0.000025	0.000020	0.000040
December	0.000026	0.000020	0.000036	0.000023	0.000020	0.000031

Modelling outcomes provided by Golder (2019); shaded cells exceed CCME water quality guideline of 0.00004 mg/L

Table 3-6   Cobalt (mg/L) Predicted Baseline + Project Receiving Environment Monthly Concentrations – Post Closure

Receiving Environment Station/Month	EMZ			SW6		
	Average	5%	95%	Average	5%	95%
January	0.00048	0.00030	0.00080	0.00041	0.00030	0.00056
February	0.00049	0.00030	0.00083	0.00042	0.00030	0.00059
March	0.00044	0.00033	0.00062	0.00040	0.00032	0.00050
April	0.00049	0.00031	0.00085	0.00041	0.00031	0.00055
May	0.00062	0.00028	0.0010	0.00045	0.00030	0.00064
June	0.00055	0.00027	0.00065	0.00047	0.00028	0.00061
July	0.00047	0.00031	0.00050	0.00044	0.00029	0.00047
August	0.00052	0.00032	0.00056	0.00047	0.00029	0.00051
September	0.00052	0.00029	0.00060	0.00047	0.00027	0.00055
October	0.00063	0.00028	0.00098	0.00053	0.00027	0.00084

November	0.00058	0.00031	0.00125	0.00048	0.00029	0.00096
December	0.00048	0.00031	0.00084	0.00042	0.00030	0.00067

Modelling outcomes provided by Golder (2019); shaded cells exceed FEQG of 0.00078 mg/L

Table 3-7   Zinc (mg/L) Predicted Baseline + Project Receiving Environment Monthly Concentrations – Post Closure

Receiving Environment Station/Month	EMZ			SW6		
	Average	5%	95%	Average	5%	95%
January	0.0039	0.0030	0.0055	0.0036	0.0030	0.0043
February	0.0040	0.0030	0.0057	0.0036	0.0030	0.0044
March	0.0037	0.0031	0.0046	0.0035	0.0031	0.0040
April	0.0039	0.0030	0.0057	0.0035	0.0030	0.0042
May	0.0046	0.0029	0.0067	0.0038	0.0030	0.0047
June	0.0043	0.0029	0.0048	0.0038	0.0029	0.0046
July	0.0039	0.0031	0.0040	0.0037	0.0030	0.0039
August	0.0041	0.0031	0.0043	0.0039	0.0030	0.0041
September	0.0041	0.0030	0.0045	0.0038	0.0028	0.0042
October	0.0047	0.0029	0.0064	0.0041	0.0028	0.0057
November	0.0044	0.0031	0.0078	0.0039	0.0030	0.0063
December	0.0039	0.0030	0.0057	0.0036	0.0030	0.0048

Modelling outcomes provided by Golder (2019); shaded cells exceed CCME CWQG of 0.007 mg/L

3.7   Summary – FMS Receiving Environment

Under the Operations scenario (upper case), predicted annual water concentrations for the Baseline + Project scenario were consistently below selected water quality guidelines or benchmarks, with the exception of iron which marginally exceeded the 75th percentile baseline concentrations at SW6 and EMZ-2. Additional modelling was conducted on a monthly basis for the Operations scenario to which there were no exceedances of water quality guidelines for any metal. Iron remains above the 75th percentile of baseline in the monthly predictions, but is within the baseline range which suggest that toxicity is unlikely within the predicted range of concentrations.

Under the Post Closure scenario (upper case), predicted annual water concentrations for the baseline + future scenario were consistently below selected water quality guidelines or benchmarks with the exceptions of cobalt which marginally exceeded the new FEQG guideline at EMZ-2 and iron which marginally exceeded the 75th percentile baseline concentrations at SW6 and EMZ-2. Additional modelling was also conducted on a monthly basis for the Post Closure scenario. Predicted 95th percentile cadmium, cobalt and zinc exceeded their respective guidelines at SW6 and/or EMZ-2 over select months. However, based on further investigation, adverse effects to aquatic life are not anticipated from the predicted concentrations, as these predictions are based on an upper bound scenario, which would only result in the instance that low flow events occur in conjunction with upper case source term conditions, which is unlikely. Note that source terms will continue to be developed and revised, as will water quality modelling, and it is likely that these exceedances predicted in post closure will reduce as refined modelling inputs become available.

4   MOOSE RIVER ASSESSMENT

4.1   Description of Receiving Environment and Baseline Data

As summarized by GHD (2017), Moose River is the largest watercourse at the Touquoy Mine Site, and it flows along the western border of the property. As discussed in Chapter 6.6 of the EIS (Surface Water Quality and Quantity; Atlantic Mining NS Corp, 2019; GDH, 2017), where Moose River is adjacent to the Mine Pit (at surface water monitoring station SW-2, which is the most relevant surface water monitoring station for the assessment of potential aquatic effects associated with discharge from the Touquoy Pit), it is a 3rd order watercourse with an approximately 12.5 m bankfull width as measured in the 2017 hydrometric program. The substrate was noted in the 2017 hydrometric monitoring report as characteristically muddy consisting predominantly of cobbles and small boulders, silt/sand with gravel. An unnamed tributary to Moose River (known as watercourse 4) flows south through the Touquoy property, between the open pit and tailings management area. A first order unnamed tributary to the latter, south of the proposed pit, flows southward. Fish River drains Square Lake, northeast of the property, to Scraggy Lake. Fish River then flows west and then south into Lake Charlotte, eventually emptying into Ship Harbour. The Fish River Watershed river system is significant for trout, gaspereau and Atlantic salmon populations. A study area and site map is presented in Figure 4-1.

As discussed in GHD (2017), the tributary to Moose River is very small, north of the Mooseland Road and was dry for much of 2005 and 2006. Fish habitat is marginal, dependent on surface flow, and at flow levels observed in 2005 and 2006, is expected to be limited to fish excursions during high flows. The culvert at the Mooseland Road was installed incorrectly and is hung, thus preventing fish passage during average and low flow conditions. From the wetland area, downstream there is limited potential for seasonal brook trout habitat. Two small juvenile brook trout were captured just downstream of the woods road (south of the wetland). Moose River may host a small salmon population. Some years, however, Moose River dries up into a series of pools.
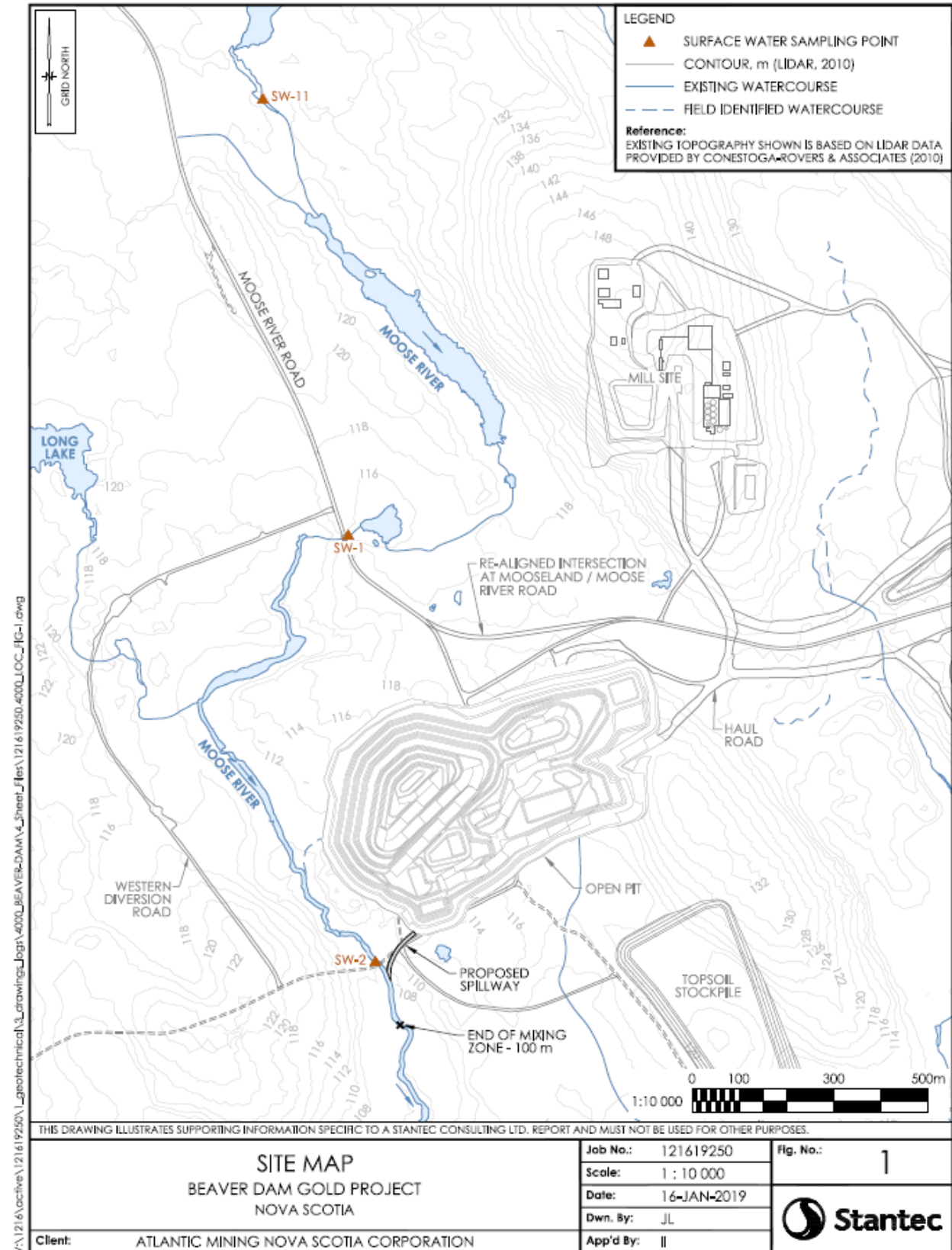
Figure 4-1   Site Map of Fifteen Mile Stream Gold Project – Touquoy Mine Site Releases

Baseline data for surface waters in the area is presented in Table 4-1. The data in Table 4-1 are for surface water monitoring station SW-2, which is where discharge from the Mine Pit at Touquoy will be released, once the pit fills (see Figure 4-1). This station is the most representative of the receiving environment conditions for the assessment of aquatic effects. As discussed in Section 6.6 of the EIS (Surface Water), dissolved ions are low and the water is very soft, indicating little mineral content and influence from weathered rock. Alkalinity is low at all sampling locations throughout the FMS Study Area. This is anticipated due to the surficial geology being resistant to weathering and containing little carbonate. pH was generally low in all sampling locations and outside the range identified in the CCME. In addition, as discussed in Chapter 6.6 of the EIS (Surface Water), arsenic was noted to consistently exceed the Tier 1 EQS at SW-2 downstream of the open pit in both 2016 and 2017. These elevated arsenic concentrations are not attributed to operation and may be from historical tailing piles and/or the Touquoy ore body itself. A remedial action plan is currently underway by AMNS that involves the delineation, removal, and management of these historical tailings piles around the open pit area. In general, water quality exceedances for aluminum, iron, arsenic, cadmium are commonplace in the environment, even at surface water quality monitoring stations upgradient of the mine ("background" stations) (Stantec, 2018).

Table 4-1   Baseline Surface Water Concentrations Collected from Moose River (Total Metals mg/L; Station SW-2)

Chemical	Min	Max	Mean	75th Percentile	# of Non-Detects	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
Aluminium	0.073	0.35	0.169	0.187	0/22	0.005	0.005
Arsenic	0.004	0.03	0.012	0.018	0/22	0.005	0.005
Calcium	0.84	1.7	1.2	1.3	0/22	NV	NV
Cadmium	<0.00001	0.00004	0.000014	0.000019	7/22	0.00004	0.00001
Cobalt	<0.0004	0.00071	<0.0004	<0.0004	21/22	NV	0.01
Chromium	<0.001	0.0017	<0.001	<0.001	20/22	8.9	NV
Copper	<0.002	<0.002	<0.002	<0.002	22/22	0.002	0.002
Iron	0.19	0.85	0.48	0.62	0/22	0.3	0.3
Lead	<0.0005	0.00086	<0.0005	<0.0005	20/22	0.001	0.001
Mercury	<0.000013	0.00002	<0.000013	<0.000013	20/22	0.000026	0.000026
Magnesium	0.35	0.75	0.488	0.52	0/22	NV	NV
Manganese	0.029	0.18	0.06	0.07	0/22	NV	0.82
Molybdenum	<0.002	<0.002	<0.002	<0.002	22/22	0.073	0.073
Nickel	<0.002	<0.002	<0.002	<0.002	22/22	0.025	0.025
Tin	<0.002	<0.002	<0.001	<0.001	22/22	NV	NV
Selenium	<0.001	<0.001	<0.001	<0.001	22/22	0.001	0.001
Silver	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.00025	0.0001
Dissolved Sulphate	<2	2.6	<2	<2	19/22	NV	NV
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.0008	0.0008
Uranium	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.015	0.3
Zinc	<0.005	0.0061	<0.005	<0.005	19/22	0.007	0.03

WAD Cyanide	<0.003	0.004	<0.003	<0.003	21/22	NV	0.005
Total Cyanide (based on Strong Acid Dissociated)	<0.001	0.002	<0.005	<0.005	19/22	NV	0.005
Nitrate (as N)	<0.05	0.18	<0.05	0.054	15/22	13	NV
Nitrite (as N)	<0.01	<0.01	<0.01	<0.01	22/22	0.06	NV
Ammonia	<0.05	0.14	<0.05	0.062	13/21	23.7	NV
pH	4.9	6.89	6.05	6.24	22/22	6-9	NV
Hardness (mg/L CaCO₃)	3.5	7.3	5.0	5.25	22/22	NV	NV

Notes:

NV indicates no value provided

As discussed in Stantec (2021), arsenic concentrations varied throughout the stations in the surface water monitoring program near the mine. Moose River experiences levels above the CCME guideline in the summer (lower water flow). This is likely due to arsenopyrite, an iron arsenic sulfide compound, which is common in the surficial and bedrock geology of the area. Other exceedances over freshwater aquatic life guidelines occurred with lead, cadmium, copper, selenium, and zinc, which fluctuated throughout the year at most sampling locations and sometimes slightly exceed the guidelines. Alkalinity is low at all sampling locations throughout the study area, again due to naturally occurring surficial geology being resistant to weathering and containing little carbonate. Similarly, pH was generally low in all sampling locations and outside the range identified in the CCME guidelines; however, this a common feature of surface water in Nova Scotia being influenced by acidic precipitation originating in the northeast United States. At the Touquoy Mine Site, pH measures were highly variable, in particular on Moose River, where on several sampling events at two sampling stations, the pH varies by two orders of magnitude.

4.2   Description of Water Quality Modelling Conducted

Stantec (2021) conducted an assimilative capacity modelling exercise, to predict future water quality in the receiving environment, Moose River. The methodology used followed CCME (2003), which is a framework established for assessing assimilative capacity of receiving environments. As outlined by Stantec (2021), this approach involved identifying parameters of potential concern within the proposed discharge (such as those that may exceed applicable regulatory limits within the open pit effluent); establishing water quality objectives for the receiving environment (in this case, CCME and NS Tier 1 standards); establishing background parameter concentrations, in the instance that some compounds may be naturally elevated above regulatory objectives; determination of the initial mixing zone; and, development of end of pipe effluent discharge limits which will meet ambient water quality objectives at the edge of the mixing zone.

The specific details of the hydrology of the receiving environment are presented in Stantec (2021). A water balance model was developed to predict the Open pit effluent overflow to Moose River at mine closure. Effluent water quality was predicted using the water quality and quantity model and groundwater flow model (see Stantec 2021). Water quality modelling considered pore water within the tailings, as well as groundwater inflow quality in the pit floor

and walls, and dilution from surface runoff, as well as direct precipitation and process water surplus, etc (Stantec, 2021). Both an average concentration within the open pit and a maximum concentration were predicted, for both a base scenario, which included only FMS deposits, as well as a cumulative scenario, involving FMS releases combined with Beaver Dam releases, Cochrane Hill releases and Touquoy releases (tailings from each deposit deposited in the exhausted Touquoy pit).

Concentrations at end of the 100 m mixing zone in the receiving environment of Moose River, predicted using the FMS Only and cumulative scenarios, were compared to selected benchmark concentrations representing the greater of either the water quality guideline selected for use in the assessment (see Table 2-1), or the 75th percentile of the baseline surface water concentrations collected from the Moose River. These comparisons are described further in the sections 4.4 and 4.5 below.

4.3   Selected Benchmarks

Benchmark concentrations used for comparison against predicted water concentrations are presented in Table 4-2. Selection of these benchmark concentrations is described in Section 2.3. These benchmark concentrations were based on the greater of either the water quality guideline selected for use in the assessment (see Table 2-1), or the 75th percentile of the baseline surface water concentrations collected from the Moose River (Table 4-2), except for arsenic for which a site-specific water quality objective was calculated and adopted (see Section 2.3 and Appendix A). Chemicals determined to merit further evaluation in the receiving environment by Stantec (2021) are listed in Table 4-2.

Table 4-2   Selected Benchmark Concentrations for Use in the Moose River Assessment (mg/L)

Parameter	Selected Guideline[a]	75th Percentile Baseline Concentration	Site-Specific Water Quality Objective	Selected Benchmark Concentration
Aluminum	0.005	0.187	-	0.187
Antimony	0.02	NDA	-	0.02
Arsenic	0.005	0.018	0.030	0.030
Cadmium	0.00004[b]	0.000019	-	0.00004
Chromium	0.0089[b,c]	<0.001		0.0089
Cobalt	0.00078[d]	<0.0004	-	0.00078
Copper	0.002	<0.002	-	0.002
Iron	0.3	0.62	-	0.62
Mercury	0.000026	<0.000013	-	0.000026
Manganese	0.82	0.07	-	0.82
Molybdenum	0.073	<0.002	-	0.073
Nickel	0.025	<0.002	-	0.025
Lead	0.001	<0.0005	-	0.001
Selenium	0.001	<0.001	-	0.001
Silver	0.00025[b]	<0.0001	-	0.00025

Sulphate	128[e]	<2	-	128
Thallium	0.0008	<0.0001	-	0.0008
Uranium	0.015[b]	<0.0001	-	0.015
Zinc	0.007[b]	<0.005	-	0.007
WAD Cyanide	0.005[b,f]	<0.003	-	0.005[b,f]
Total Cyanide (based on Strong Acid Dissociated)	0.005[b,f]	<0.005	-	0.005[b,f]
Nitrite (as N)	0.06[b]	<0.01	-	0.06
Nitrate (as N)	13[b]	0.054	-	13
Ammonia (total)	126[b,g]	0.062	-	126

Notes:

- not calculated; NDA: no data available

[a]   Selected guidelines represent Nova Scotia Tier 1 guidelines unless specified otherwise; see Table 2-1

[b]   Selected guideline adopted from CCME

[c]   Based on Cr^{3+}; this value was selected as Cr^{6+} is unlikely to be present in the receiving environment

[d]   Selected guideline from FEQG (ECCC, 2017)

[e]   No CCME or NS Tier 1 guideline is available; therefore a guideline from BC MOE was used (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf)

[f]   Based on free cyanide; the application of this guideline for Total Cyanide is overly conservative, and is applied for discussion purposes

[g]   In the month of April, the average field pH at SW-2 was 5.6 (lab pH of 5.9) and the discharge temperature was conservatively assumed to be 5ºC. The derived guideline of 126 mg/L represents the CCME guideline for total ammonia-N at a pH of 6.0 and temperature of 5ºC.

4.4   Predicted Water Quality – FMS Only Scenario

Based on the modelling conducted for the FMS Only scenario, predicted concentrations at end of the 100 m mixing zone in the receiving environment of Moose River are provided in Table 4-3 (from Stantec, 2021).

Where predicted concentrations exceed regulatory guidelines, they are further discussed relative to background concentrations in the receiving environment, and available site specific water quality objectives (arsenic) or other toxicity data and information. For the purposes of predicting receiving environment concentrations at the end of the 100 m mixing zone, arsenic was assumed to meet the MDMER limits (Stantec, 2021). The predicted water quality concentrations at the edge of a 100 m mixing zone in the receiver are presented in Table 4-3, relative to the selected benchmarks in Table 4-2.

Table 4-3   Water Quality Modelling Results for Predicted Concentrations at end of 100 m Mixing Zone in Receiving Environment of Moose River, relative to Selected Benchmarks - FMS Only Scenario

WQ Parameter[a]	Selected Benchmarks (mg/L)	Concentration at end of 100 m mixing zone[a] (mg/L)
Aluminum	0.187	0.184
Antimony	0.02	0.0005
Arsenic	0.030	0.024
Cadmium	0.00004	0.00002
Chromium	0.0089	0.0005
Cobalt	0.00078	0.00077
Copper	0.002	0.0013
Iron	0.62	0.61
Mercury	0.000026	6.8E-06
Manganese	0.82	0.070
Molybdenum	0.073	0.0011
Nickel	0.025	0.0012
Lead	0.001	0.00025
Selenium	0.001	0.0005
Silver	0.00025	0.00005
Sulphate	128	3.6
Thallium	0.0008	0.00005
Uranium	0.015	0.0001
Zinc	0.007	0.0025
WAD Cyanide	0.005*	0.0024
Total Cyanide[b]	0.005[*]	0.0052
Nitrite (as N)	0.06	0.018
Nitrate (as N)	13	0.074
Ammonia (total)	126	0.061

Notes:

Values highlighted in grey indicate that the concentration at end of 100 m mixing zone exceeded the selected benchmarks.

*   Free form of cyanide;

[a]   From Stantec (2021)

[b]   Total cyanide receiver concentrations are based on Strong Acid Dissociated concentrations

Based on the predicted future concentrations, relative to available water quality guidelines, total cyanide merits further evaluation. A discussion is also provided for arsenic, as the CCME guideline of 5 µg/L is superseded in this project by a SSQWO of 30 µg/L, to provide additional context.

Arsenic:

While predicted receiving environment concentrations of arsenic at the end of the 100 m mixing zone within Moose River (0.024 mg/L) exceeds the CCME FWAL guideline of 0.005 mg/L, this guideline was derived some time ago using a safety factor applied to the Lowest Observed Effect Level [the 14-day EC50 (growth) of 50 µg/L for the algae *Scenedesmus obliquus* (Vocke et al., 1980), with a safety factor of 0.1 (CCME, 2001)]. The Vocke et al. (1980) study was the most sensitive freshwater organism to arsenic identified by the CCME, following consideration of data from 21 different species of fish, 14 species of invertebrates and 14 species of plants. Other regulatory guidelines are also available from other jurisdictions, such as the National recommended water quality criterion known as the Criterion Continuous Concentration (CCC) from the US EPA (US EPA, 2018; arsenic criteria developed in 1995). The CCC is "an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect". The CCC for arsenic are based on the amount of dissolved metal in the water column and is 150 µg/L (0.150 mg/L) and was derived in 1995.

Using the CCME protocol for development of water quality guidelines (CCME, 2007), a Species Sensitivity Distribution approach was used to develop a site specific water quality objective (SSWQO), as discussed in Section 2.3. Details are presented in Appendix A. The value developed is 0.030 mg/L (30 µg/L) and concentrations predicted in receiving environment of Moose River are below this value. The predicted receiving environment concentration of 0.024 mg/L is below any of the no observed effect concentration (NOEC) or low observed effect concentration (LOEC) data for arsenic provided in Table A-2 for chronic studies. Hence, risks to aquatic life are anticipated to be low.

Total Cyanide:

The chemistry of cyanide is complex, and the toxicity of various cyanide complexes varies widely. So, the form of cyanide in the environment greatly affects the toxicity of the compound. The most toxic form of cyanide is free cyanide, which includes the cyanide ion ($^-$CN) and HCN (ICMC, 2018). Cyanide is highly reactive, and readily forms simple salts with earth cations and ionic complexes. The strength of the bonds of these associations vary depending upon the salt, and the pH of the environment. Weak or moderately stable complexes are known as WAD (weak acid dissociable), and typically involve cations such as cadmium, copper and zinc. WAD cyanide is less toxic than free cyanide, but when they dissociate they release free cyanide and the metal cation. Typically, WAD complexes dissociate and release HCN under mildly acidic conditions such as those ranging from pH 3 – 6 (OI, 2009). Cyanide can also form very stable complexes with gold, mercury, cobalt and iron. The stability of these complexes in the environment depends on pH in the environment, but strong metals-cyanide complexes (SAD)

typically require strongly acidic conditions (pH<2) to dissociate and release HCN (OI, 2009). The term "total cyanide" typically refers to the sum of all cyanide species that are converted to HCN following digestion in a strong acid solution (Total cyanide = free cyanide + WAD + SAD). Other cyanide compounds, such as thiocyanate and cyanate, are markedly less toxic than free cyanide (ICMC, 2018).

With this in mind, a measured or estimated Total Cyanide concentration can range from including 100% SAD forms of cyanide, to 100% free cyanide, depending upon the chemistry of the effluent, and the receiving environment. Some SAD forms of cyanide (iron cyanide complexes) can dissociate in sunlight and release free CN (ICMC, 2018). Other environmental fate processes, such as volatilization, wherein the amount of cyanide lost increases with decreasing pH, and biodegradation, where aerobic conditions result in microbial degradation of cyanide to ammonia, and subsequently, nitrate (ICMC, 2018). Therefore, environmental fate of cyanides in the receiving environment is modified by a number of factors.

It is important to note that the NS Tier 1 guideline of 5 µg/L (which is based on the CCME guideline), is for free cyanide. This guideline is not a relevant guideline to compare Total cyanide, SAD or even WAD forms of cyanide to, as it is based on the free ion, as opposed to bound forms of cyanide, which have far lower toxic potential. Based on the receiving environment predictions in Table 4-3, WAD cyanide is approximately half of the Total Cyanide predicted concentration (0.0024 mg/L WAD, compared to 0.0052 mg/L Total). This implies that the half of the Total Cyanide prediction would be SAD, and hence, less likely to dissociate in the receiving environment (mean pH in receiving environment is 6.05; see Table 4-1). Predicted WAD concentrations in the receiving environment are below the NS Tier 1 guideline, indicating acceptable levels of risk to aquatic life. Based on this, risks to aquatic life are predicted to be low.

4.5   Predicted Water Quality – Cumulative Scenario

Based on the modelling conducted for the cumulative scenario, predicted concentrations at end of the 100 m mixing zone in the receiving environment of Moose River are provided in Table 4-4. These predictions include FMS releases combined with Beaver Dam releases, Cochrane Hill releases and Touquoy releases (tailings from each deposit deposited in the exhausted Touquoy pit).

Where predicted concentrations exceed regulatory guidelines, they are further discussed relative to background concentrations in the receiving environment, and available site specific water quality objectives (arsenic) or other toxicity data and information. For the purposes of predicting receiving environment concentrations at the end of the 100 m mixing zone, arsenic was assumed to meet the MDMER limits (Stantec, 2021). The predicted water quality concentrations at the edge of a 100 m mixing zone in the receiver are presented in Table 4-4, relative to the selected benchmarks in Table 4-2.

Table 4-4 **Water Quality Modelling Results for Predicted concentrations at end of 100 m Mixing Zone in Receiving Environment of Moose River, relative to Selected Benchmarks – Cumulative Scenario**

WQ Parameter[a]	Selected Benchmarks (mg/L)	Concentration at end of 100 m mixing zone[a] (mg/L)
Aluminum	0.187	0.184
Antimony	0.02	0.0006
Arsenic	0.030	0.024
Cadmium	0.00004	0.00002
Chromium	0.0089	0.0005
Cobalt	0.00078	0.0016
Copper	0.002	0.0017
Iron	0.62	0.60
Mercury	0.000026	6.8E-06
Manganese	0.82	0.070
Molybdenum	0.073	0.0012
Nickel	0.025	0.0013
Lead	0.001	0.00025
Selenium	0.001	0.0005
Silver	0.00025	0.00005
Sulphate	128	5.8
Thallium	0.0008	0.00005
Uranium	0.015	0.0001
Zinc	0.007	0.0025
WAD Cyanide	0.005*	0.0040
Total Cyanide[b]	0.005[*]	0.0098
Nitrite (as N)	0.06	0.010
Nitrate (as N)	13	0.183
Ammonia (total)	126	0.071

Notes:
Values highlighted in grey indicate that the concentration at end of 100 m mixing zone exceeded the selected benchmarks.

* Free form of cyanide;
[c] From Stantec (2021)
[d] Total cyanide receiver concentrations are based on Strong Acid Dissociated concentrations

Based on the predicted future concentrations, relative to available water quality guidelines, total cyanide and cobalt merit further evaluation.

Total Cyanide:

The chemistry of cyanide is complex, and the toxicity of various cyanide complexes varies widely. So, the form of cyanide in the environment greatly affects the toxicity of the compound. The most toxic form of cyanide is free cyanide, which includes the cyanide ion ($^-$CN) and HCN (ICMC, 2018). Cyanide is highly reactive, and readily forms simple salts with earth cations and ionic complexes. The strength of the bonds of these associations vary depending upon the salt, and the pH of the environment. Weak or moderately stable complexes are known as WAD (weak acid dissociable), and typically involve cations such as cadmium, copper and zinc. WAD cyanide is less toxic than free cyanide, but when they dissociate they release free cyanide and the metal cation. Typically, WAD complexes dissociate and release HCN under mildly acidic conditions such as those ranging from pH 3 – 6 (OI, 2009). Cyanide can also form very stable complexes with gold, mercury, cobalt and iron. The stability of these complexes in the environment depends on pH in the environment, but strong metals-cyanide complexes (SAD) typically require strongly acidic conditions (pH<2) to dissociate and release HCN (OI, 2009). The term "total cyanide" typically refers to the sum of all cyanide species that are converted to HCN following digestion in a strong acid solution (Total cyanide = free cyanide + WAD + SAD). Other cyanide compounds, such as thiocyanate and cyanate, are markedly less toxic than free cyanide (ICMC, 2018).

With this in mind, a measured or estimated Total Cyanide concentration can range from including 100% SAD forms of cyanide, to 100% free cyanide, depending upon the chemistry of the effluent, and the receiving environment. Some SAD forms of cyanide (iron cyanide complexes) can dissociate in sunlight and release free CN (ICMC, 2018). Other environmental fate processes, such as volatilization, wherein the amount of cyanide lost increases with decreasing pH, and biodegradation, where aerobic conditions result in microbial degradation of cyanide to ammonia, and subsequently, nitrate (ICMC, 2018). Therefore, environmental fate of cyanides in the receiving environment is modified by a number of factors.

It is important to note that the NS Tier 1 guideline of 5 µg/L (which is based on the CCME guideline), is for free cyanide. This guideline is not a relevant guideline to compare Total cyanide, SAD or even WAD forms of cyanide to, as it is based on the free ion, as opposed to bound forms of cyanide, which have far lower toxic potential. Based on the receiving environment predictions in Table 4-4, WAD cyanide is approximately half of the Total Cyanide predicted concentration (0.0040 mg/L WAD, compared to 0.0098 mg/L Total). This implies that the half of the Total Cyanide prediction would be SAD, and hence, less likely to dissociate in the receiving environment (mean pH in receiving environment is 6.05; see Table 4-1). Predicted WAD concentrations in the receiving environment are below the NS Tier 1 guideline, indicating acceptable levels of risk to aquatic life. Based on this, risks to aquatic life are predicted to be low.

Cobalt:

Predicted cobalt levels in the receiving environment (0.0016 mg/L) were approximately 2-fold of the new FEQG for cobalt (0.00078 mg/L), but are less than the NS Tier 1 cobalt value of 0.01 mg/L. The FEQG considers hardness as a modifying factor, but the SSD model developed

by Environment Canada in this guideline setting approach is very conservative, and the data used in the assessment do not fit the selected model of the SSD in the lower quartile of the dataset well (see Figure 1; ECCC, 2017). This results in the estimated HC5 value being considerably lower than it should be, relative to the toxicity dataset. This indicates that the selected guideline is over predicting toxicity of cobalt, and hence, the marginal exceedance indicated in Table 4-4 is not considered to represent a concern, with respect to toxicity to aquatic species. Cobalt concentrations are predicted to decrease to 0.0014 mg/L by 120 m from the effluent discharge point (see Stantec, 2021; Table 11), which is above the guideline. Risks to aquatic life at this concentration are anticipated to be low, based on the conservative approach taken to establish the guideline, relative to the toxicity database.

4.6   Summary – FMS Only and Cumulative Scenarios

Based on the predictive modelling conducted, Total cyanide was predicted to exceed the selected benchmarks under the FMS Only and cumulative scenarios, and cobalt was predicted to exceed the selected benchmark under the cumulative scenario. For Total cyanide, the selected benchmark was the NS Tier 1 guideline, which is based on free cyanide, and hence not a relevant benchmark for comparison purposes. Based on the available toxicity data and predictions, Total cyanide is unlikely to be present in concentrations of concern to aquatic life. Predicted cobalt under the cumulative scenario marginally exceed the new FEQG for cobalt (ECCC, 2017), but did not exceed the NS Tier 1 guideline. The conservative nature of the SSD calculation within the FEQG for cobalt is potentially resulting in a biased low guideline, and based on comparisons to available toxicity data, cobalt at the predicted concentration under the cumulative scenario is not expected to result in adverse effects in aquatic life in the receiving environment.

5   UNCERTAINTIES AND LIMITATIONS

As inherent in any risk assessment study, there are limitations, uncertainties and conservative assumptions applicable to this screening level risk assessment, as follows:

- Modelling was conducted to predict surface water concentrations in Anti Dam flowage (FMS Project site) and Moose River (Touquoy Mine Site). Assumptions and uncertainties associated with the modelling studies are provided in Golder (2019) and Stantec (2021).
- Baseline data to characterize existing metals concentrations in The Fifteen Mile Stream project area are limited (N = 6 to 9 samples). Since mean baseline concentrations were added to the predicted increment from the Project, in situations where the mean baseline metric is based on non-detect data and half of the detection limit was used to represent baseline, this characterization is uncertain. Gathering additional baseline data, with improved detection limits will reduce uncertainties in these predictions and assist in identifying water treatment needs.
- The water quality in both Moose River and Fifteen Mile Stream receiving environment is soft, with reasonable low pH. Some mine effluents have increased hardness which can assist in ameliorating receiving environment conditions.

- Toxicity data were assessed to derive the arsenic SSWQO, as per standard methods provided by CCME (2007). Speciation of arsenic in the receiving environments could vary, depending upon various water quality parameters. In all cases, where toxicity data for both arsenic V and arsenic III were available, the data with the greatest toxicity were selected irrespective of receiving environment conditions. In addition, chronic test time frames were selected over those of shorter durations.
- Toxicity data for certain receptor groups are limited, including amphibians and reptiles. Specific targeted literature searches were conducted to identify any available data for these receptor groups. The standard CCME (2007) protocol was used to derive the SSWQO, and where amphibian and reptile data were available, they were included.

6   CONCLUSIONS

For the Fifteen Mile Stream receiving environment, predicted near-field (SW5, EMZ-2, SW15) and far-field (SW-6) chemical concentrations in the Operations scenario (upper case) were consistently below selected water quality benchmarks, with the exception of iron which marginally exceeded the 75th percentile baseline at EMZ-2 and SW6. In the Post Closure scenario, the annual average predictions for the upper case scenario were all within the selected benchmarks, with the exceptions of cobalt which marginally exceeded the FEQG at EMZ-2 and iron which marginally exceeded the 75th percentile baseline at EMZ-2 and SW6. A number of monthly averages exceeded guidelines at EMZ-2 (cadmium, cobalt and zinc), and at SW6 (cobalt). These marginal exceedances were considered to represent a low risk potential to aquatic life, as the predictions are based on upper case source terms and low flow events co-occurring, and are within 1.6 fold the guideline (cadmium, cobalt and zinc). Source terms and water quality predictions will continue to be refined as more data becomes available.

Based on predictive modelling conducted for the FMS Only and cumulative scenarios in the Moose River assessment, Total cyanide is predicted to be above a free cyanide guideline in the receiving environment. The free cyanide guideline is not an appropriate benchmark for Total cyanide, and examination of the possible concentrations of WAD and SAD cyanide within the predictions indicate that Total cyanide in the receiving environment is unlikely to pose a risk to aquatic life. Similarly, a marginal exceedance of the new FEQG guideline for cobalt was predicted in the receiving environment under the cumulative scenario. Risks associated with this for aquatic life are considered to be low.

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APPENDIX A
ARSENIC SITE-SPECIFIC WATER QUALITY OBJECTIVE

1.0   INTRODUCTION

The typical starting point for assessment of surface water data in an aquatic effects assessment are the Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (WQGl - FWAL), established by the Canadian Council of Ministers of the Environment (CCME). These guidelines are generic, national recommendations which reflect the most current scientific data at the time they were developed. They are intended to provide protection to all forms of aquatic life and aquatic life cycles, including the most sensitive life stages, at all locations across Canada (CCME, 2007). Since they are generic and do not account for site-specific factors that can alter toxicity, these national guidelines can be modified using widely accepted procedures, to derive site-adapted or site-specific water quality objectives (SSWQOs) for a given project or location (CCME, 2003). Modifications to the generic guidelines allow for protection of aquatic species accounting for specific conditions in the receiving environment, primarily due to the following reasons (CCME, 2003):

- There may be naturally-occurring levels of substances that are above the generic guidelines. This is commonplace for metals and metalloids near areas of natural enrichment, such as mines.

- There may be certain characteristics of the water at a specific location or site which modify the toxicity of the substance, such that the generic guideline is unnecessarily conservative (protective). These characteristics are known as exposure and toxicity modifying factors (ETMFs), and can include parameters such as pH, temperature, hardness, and organic matter, amongst others (CCME, 2007).

- There may be certain sensitive species considered in the development of the generic guideline which are not present in the area under assessment (e.g., warm water species which are absent from Canadian environments), and removal of these data allows for a more site-specific guideline to be developed, without compromising protection. In addition, information on toxicity of the substance in question to resident species in the area of interest may be lacking in the existing database, and therefore, there may be interest in expanding the database to include site-specific toxicity data. Or, the existing CCME guideline may be dated and hence, application of more advanced protocols and more recently published data can result in a revised guideline, which is more representative of current scientific practice and available toxicity data.

The purpose of this report is to develop SSWQO for arsenic, based on the assessment of toxicity data and the application of more advanced water quality objective protocols for the Fifteen Mile Stream Mine Project. The SSWQO developed in this report will be used to assess surface water arsenic concentrations in the aquatic effects assessment.

2.0   METHODOLOGY

As discussed in CCME (2003), there are typically four possible approaches that can be taken to derive a SSWQO, as follows:

The Background Concentration Approach: This approach can be taken in instances where natural background concentrations exceed the WQGl-FWAL, typically due to natural enrichment (in the case of metals/metalloids). A statistical approach is used to determine the upper limit of natural background, based on available data, which may differ depending upon the number of samples and non-detectable results for a given parameter.

The Recalculation Procedure: This approach could involve the recalculation of the generic FWAL guideline, through removal of data on species that are not relevant to the Fifteen Mile Stream Mine area (such as warm water species, etc.), and more recently published data which has become available since the existing guideline was developed. In addition, this procedure would use more recently developed techniques recommended by the CCME in their 2007 protocol. Minimum data requirements outlined in the protocol (CCME, 2007) must be met, and therefore, literature-based data can be supplemented with additional toxicity testing on resident species, if data are limited.

This approach is particularly of interest where existing guidelines are old, and hence may not include scientific literature published in recent years.   The CCME (2007) protocol prefers that a Species Sensitivity Distribution (SSD) approach be used to calculate the revised guideline, where there are sufficient data.

Water Effect Ratio (WER) Procedure: This approach allows for site-specific toxicity tests using indicator species and/or resident species which are conducted in side-by-side tests with site water and laboratory water. Using this approach, ETMFs inherent in the site water are accounted for in the toxicity tests. By conducting concurrent toxicity tests using two water types, a ratio of effects between laboratory water and site water can be developed, based on the concept that the laboratory water is representative of that typically utilized in studies captured within the WQGl-FWAL. This ratio is subsequently applied to the WQGl-FWAL to derive a SSWQO.

The Resident Species Approach: This approach involves generating a complete set of toxicity data, using resident species and site water. This approach is typically selected when there are limited toxicity data, or where the ETMF associated with a site may have a significant influence on the guideline.

For the purposes of this assessment, the recalculation procedure was used to derive a SSWQO for arsenic using the SSD approach as per guidance from the CCME (2007) protocol.

2.1   **Review of Environmental Fate and Exposure Toxicity Modifying Factors (EMTFs)**

2.1.1   **Environmental Fate**

Arsenic is a ubiquitous metalloid which occurs naturally in the earth's crust (Sharma and Sohn, 2009; HC and EC, 1993). Arsenic exists in four oxidation states: +V (arsenate), +III (arsenite), 0 (arsenic), and –III (arsine). Arsenic compounds can be grouped from a biological and toxicological perspective as inorganic arsenic compounds, organic arsenic compounds and arsine gas (IARC, 2012). In nature, arsenic is most often found in its sulfide form (either alone or with various metals such as silver, lead, copper, nickel, antimony, cobalt and iron), but occasionally occurs as a solid in the elemental state (HC and EC, 1993; IARC, 2012).

Arsenic is mobilized through natural processes such as weathering and erosion of soil and rocks, biological activity and volcanic emissions, and through anthropogenic activities such as smelting of metal ores, coal fired power generation, and use in pesticides and in wood preservers (Smedley and Kinniburgh, 2002; ATSDR, 2007; HC and EC, 1993).

In freshwater, the most prevalent dissolved forms of arsenic are inorganic As V (arsenate) and As III (arsenite). Under aerobic conditions, As V is more stable than As III (WHO, 2001). In lake and river waters, As V is generally the dominant species (e.g., Pettine et al., 1992); however relative portions of As III and As V vary depending upon input sources, redox conditions and biological activity (Smedley and Kinniburgh, 2002). Organic species produced by microbial activity may also be found in freshwater, but to a lesser degree than the inorganic forms. When present in freshwater systems, monomethylarsonic acid (MMA or monomethyl arsenate) and dimethylarsinic acid (DMA or dimethylarsenate), both in the As V state, are the most common forms of dissolved organic arsenic (Braman and Foreback, 1973; Cullen and Reimer, 1989; Markley, 2004; Vukasinovic-Pesic et al., 2005; Smedley and Kinniburgh, 2002). In summer, levels of MMA and DMA have been reported to increase due to increased microbial activity (e.g., Hasegawa, 1997).

The form and concentration of arsenic in water is dependent upon several factors including:

- water oxygen levels (e.g., arsenate predominates under oxidizing / high dissolved O_2 conditions, arsenite predominates under reducing / low dissolved O_2 conditions);

- the degree of biological activity (which is associated with the conversion of inorganic to organic arsenic);

- the type of water source (e.g., freshwater, seawater or groundwater); and,

- how close the water source is to areas naturally enriched in arsenic and / or anthropogenic arsenic sources (Seyler and Martin, 1989; WHO, 2000, 2001).

For the purposes of the assessment, both As V and As III were considered in the development of the arsenic SSWQO as it is possible that both forms exist in the aquatic environment in the area of the Fifteen Mile Stream Mine Project.

Natural concentrations of arsenic can be significantly elevated in areas of arsenic-enriched bedrock (HC and EC, 1993). In surface waters, typical arsenic concentrations are <10 µg/L, and are frequently <1 µg/L. Near anthropogenic sources, concentrations have been reported to be as high as 5 mg/L (IARC, 2012; Smedley and Kinniburgh, 2002). In Canada, arsenic concentrations in uncontaminated surface waters are typically <2 µg/L (CCME, 2001).

Arsenic water concentrations tend to be higher in summer than in winter which is likely due to the release of arsenic by surface sediments that have become anoxic causing a release into the water column of arsenic adsorbed on iron and manganese oxides (Singh et al., 1988; Crecelius et al., 1994).

While arsenic can bioaccumulate in aquatic organisms such as algae, crustaceans and fish, it does not appear to biomagnify in freshwater food chains (Eisler, 1988).

2.1.2   *Exposure Toxicity Modifying Factors*

The toxicity of arsenic is highly dependent on its chemical speciation which influences its mobility in water. The main processes controlling arsenic mobility in water are adsorption (e.g., attachment of arsenic to iron oxide / iron oxyhydroxide surfaces) and desorption reactions and solid-phase precipitation and dissolution reactions (Vukasinovic-Pesic et al., 2005; Senn and Hemond, 2002). Dissolved arsenic can be removed from solution, thereby decreasing bioavailability, through a variety of processes including: biotic uptake, absorption onto iron and manganese hydroxides or clay particles, fixation by organic matter, or to a lesser degree, by precipitation or co-precipitation (Frost and Griffin, 1977; Pierce and Moore, 1982; Thanabalasingam and Pickering, 1986; Korte and Fernando, 1991; Markley, 2004). These processes are, in turn, influenced by pH, redox potential (Eh), organic matter, key inorganic substances such as sulfide and phosphate, and adsorbents (Sharma and Sohn, 2009). The most important factors controlling arsenic speciation have been reported to be Eh and pH (Smedley and Kinniburgh, 2002).

Differing major and minor species of As III, As V, MMA and DMA will be present depending upon pH (Sharma and Sohn, 2009). In natural waters, as the pH increases, arsenate (As V) tends to become less strongly sorbed. When pH increases above 8.5, the concentration of arsenic in solution increases as a result of either i) the adsorbed arsenic desorbing from the surfaces of mineral oxides (especially iron oxides) or ii) the increased pH prevents these anions from being adsorbed (Vukasinovic-Pesic et al., 2005; Smedley and Kinniburgh, 2002). At near neutral pH levels, arsenic can stay in solution at relatively high concentrations (Smedley and Kinniburgh, 2002). Under strongly reducing conditions and at near neutral pH, As desorbs from mineral oxides (Smedley and Kinniburghm 2002). At low to near-neutral pH and under oxidizing conditions, arsenic is strongly adsorbed by oxide minerals as the arsenate ion (As V). Arsenic

behaves differently from most metals, which occur in solution as cations, where an increase in pH decreases solubility (Smedley and Kinniburgh, 2002; Vukasinovic-Pesic et al., 2005).

Arsenic, similar to other heavy metalloids (e.g., selenium, antimony, molybdenum, vanadium, chromium) is an oxyanion-forming element (i.e., compound with generic chemical formula $A_xO_y^{z-}$ where A represents an element and O represents oxygen) (Smedley and Kinnburgh, 2002). Arsenic is however, relatively mobile under a wide range of redox conditions (both oxidizing and reducing). This differs from other heavy metalloids (e.g., Se, Cr) which become immobilized under reducing environments (Smedley and Kinnburgh, 2002).

The distribution of arsenic species as a function of pH and Eh were illustrated in Smedley and Kinnburgh (2002) and copied below (Figure A-1). At low pH (<6.9) and under oxidizing conditions (high Eh values) inorganic arsenic occurs mainly as $H_2AsO_4^-$ and as pH increases, $HAsO_4^{-2}$ becomes dominant. Under reducing conditions (low Eh) and at pH <9.2, $H_3AsO_3^0$ predominates (Smedley and Kinnburgh, 2002).
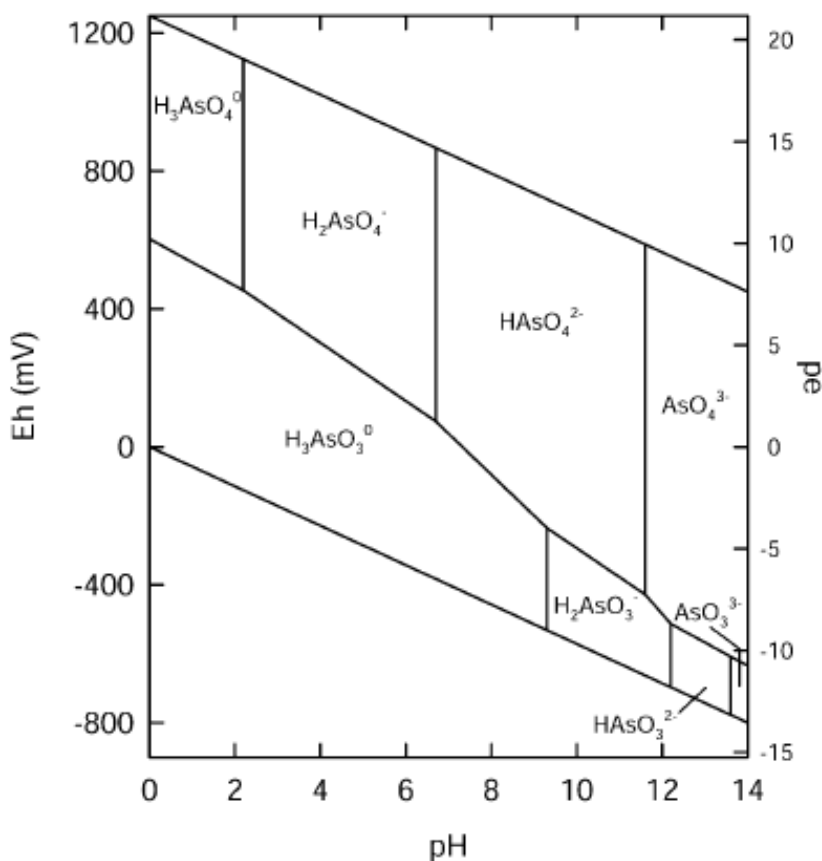

Figure A-1   Eh-pH Diagram for Aqueous Species in the System As-O$_2$-H$_2$O at 25ºC and 1 Bar Total Pressure (as presented in Smedley and Kinnburgh, 2002)

Anions such as phosphate, carbonate, bicarbonate, silicate and possibly dissolved organic matter (DOM) can outcompete arsenic for sorption sites which can inhibit arsenic adsorption or increase

arsenic leaching from mineral surfaces (Sharma and Sohn, 2009; Campos, 2002; Vukasinovic-Pesic et al., 2005, Smedley and Kinnburgh, 2002). This will result in higher concentrations of dissolved arsenic in surface waters.

In summary, arsenic toxicity in surface water is influenced primarily by pH, Eh, and the presence of other anions.

2.2 Data Considered in the Derivation of the Existing CCME Arsenic Guideline

The CCME WQGl was developed following a review of toxicity data from 21 different species of fish, 14 species of invertebrates and 14 species of plants (CCME, 2001). Toxicity endpoints upon which the chronic CCME (2001) WQGl-FW was developed are provided in Table A-1, where available. Note that chronic data for *Anabus testudineus* (climbing perch) and *Clarius batrachus* (walking catfish) are not included in Table A-1, as these species are not relevant to Canadian waters. The final guideline derived by the CCME was based on the 14-day EC50 (growth) for the algae *Scenedesmus obliquus* (Vocke et al., 1980), which was the most sensitive freshwater organism to arsenic identified. The 50 µg/L EC50 was multiplied by a safety factor of 0.1, to obtain the current guideline value of 5 µg/L (CCME, 1991).

Table A-1   Chronic Toxicity Data for Species Used by CCME for Arsenic WQGl-FW Derivation [1]

Species Used in Toxicity Study	Toxicity Endpoint	Metric	Value (µg/L)	Chemical Form	Reference
Bosmina longirostris	Immobility	96-hour EC50	850	Sodium arsenate	Passino and Novak, 1984
Oncorhynchus mykiss	Lethality	28 day LC50	550	NA	Birge et al., 1978
Cyclops vernalis	Reduced growth (20%)	14 day EC20	320	NA	Borgmann et al., 1980
Daphnia magna	Reproduction (16% ↓ in reproduction)	21 day EC16	520	Sodium arsenate	Biesinger and Christensen, 1972
Gammarus pseudolimnaeus	Lethality	7 day LC80	960	NA	Spehar et al., 1980
Ceriodaphnia dubia	Immobilization	7 day LOEC	1000	NA	Spehar and Fiant, 1986
Scenedesmus obliquus	Growth	14 day EC50	50	Inorganic AsV	Vocke et al., 1980
Melosira granulata	Growth	14 day EC50	75	NA	Planas and Healey, 1978
Ochromonas vallesiaca	Growth	14 day EC50	75	NA	Planas and Healey, 1978

Notes:
NA = not available
1. Data obtained from CCME (2001).

2.3 Review of Available Arsenic Toxicity Data

Toxicity data for use in the derivation of the arsenic SSWQO were compiled from a number of sources, including the following:

- CCME, 2001 Water quality guideline document for arsenic
- US EPA ECOTOX database (www.epa.gov/ecotox/); all forms of arsenic were searched
- Literature searches for arsenic toxicity review papers

A summary of the identified toxicity data for arsenic is provided in Table A-2. Toxicity data for tropical species were excluded as they do not inhabit waterbodies in the region of the Fifteen Mile Stream Mine Project. It should also be noted that this is not a comprehensive arsenic review, however, this review is considered to capture most relevant toxicity studies. It was assumed that the CCME conducted a thorough literature search in the derivation of the guideline, and hence the starting point for the literature search was literature commencing following that point. In addition, not all studies were reviewed in detail. The focus of this research was to identify chronic studies, using standardized accepted protocols, on relevant species to Canadian waters.

Chronic test durations are discussed in CCME (2007) and include tests for non-lethal endpoints with durations greater than or equal to 21 days for fish (juveniles or adults), or greater than or equal to 7 days for egg and larval studies. For aquatic invertebrates, chronic test durations are considered to be greater than or equal to 96-h for non-lethal endpoints for shorter-lived invertebrates (e.g., *D. magna),* for nonlethal endpoints of ≥ 7 days duration for longer-lived invertebrates (e.g., crayfish), and lethal endpoints from tests of ≥ 21 days duration for longer-lived invertebrates. Lethal endpoints from shorter-lived invertebrates from tests with <21-day exposure periods are considered on a case-by-case basis. For algal species, all toxicity tests with algae with exposure durations of longer than 24 hours are considered long-term exposure tests because of the length of the algal life cycle compared to the duration of the exposure.

Only those studies of acceptable quality were included in Table A-2. See Attachment 1 for summaries of acceptability rankings.

2.4.1 *Identifying Relevant Chronic Toxicity Data*

To calculate a chronic SSD, the CCME (2007) has set out the following minimum data requirements which must be met for a Type A guideline:

- Fish: Three studies on freshwater fish species, including one salmonid and one non-salmonid.
- Invertebrates: Three studies on freshwater aquatic / semi-aquatic invertebrate species, at least one of which is a planktonic crustacean species. For semi-aquatic species, life stage tested must be aquatic.
- Plants / Algae: At least one study on freshwater vascular plant or freshwater algal species. Where plants or algae are identified as being among the most sensitive species, the chemical of interest is classified as phytotoxic and three studies on freshwater plant or algal species are then required to derive a long term SSD.

Freshwater toxicity data for arsenic was summarized in Table A-2. Each of these toxicity studies were evaluated for quality and categorized as Primary, Secondary or Unacceptable (see Attachment 1). Toxicity data from Primary and Secondary studies are considered acceptable for use in the derivation of a SSWQO, however unacceptable data are not. Note that studies by Birge were considered suspect based on a review of the U.S. EPA's water quality criteria for aluminum and arsenic, which revealed that the corresponding data from these studies were listed as 'other data' but were not included in the datasets used for criteria derivation; no reason was given for this exclusion. The Birge (1978) and Birge et al. (1978) data have been found to yield anomalously low toxic concentrations for numerous microelements and were excluded from the SSD. Therefore, the results from these experiments were considered questionable and were not included.

Briefly, for Primary studies, toxicity test must have used currently acceptable standard methods and measured concentrations must be reported. Studies must have sensitive test endpoints with preferred test endpoints for Primary studies including effects on embryonic development, hatching, or germination success; survival of juvenile stages, growth, reproduction; and survival of adults. Other effects such as behavioural or endocrine-disrupting effects can be used if it can be demonstrated these effects are a result of the exposure, they result in an adverse ecological effect and the studies are scientifically sound. For secondary studies, the requirements for standard test methods and measured concentrations are less stringent. The same preferred test endpoints exist for Secondary studies in addition to pathological and behavioural effects (if ecological relevance can be shown, but the requirement for this is not a stringent as it is for primary data) and physiological effects. Toxicity data that do not meet the criteria for either Primary or Secondary studies are considered to be Unacceptable. Additional clarification of Primary, Secondary and Unacceptable studies is provided in CCME (2007).

From the compiled freshwater arsenic toxicity data (Table A-2), those studies designated as Primary or Secondary were considered for use in deriving the SSD.

Table A-2   Arsenic Chronic Toxicity Data

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Reference
		pH	T (ºC)	Alkalinity / Hardness (mg/L; CaCO₃)			
Aquatic Invertebrate							
Daphnia magna (Water flea)	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction NOEC	633	Lima et al., 1984
Daphnia magna	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction LOEC	1320	Lima et al., 1984
Daphnia magna	Arsenite (As III)	7.4	21.5 +/-3	45.5/47.2	28 day (growth and reproduction) NOEC	630	Call et al, 1983
Daphnia magna	Arsenite (As III)	7.4	21.5 +/-3	45.5/47.2	28 day (growth and reproduction) LOEC	1320	Call et al, 1983
Daphnia magna	Sodium arsenate (Na₂HAsO₄)	7.4 – 8.2	NR	42.3 / 45.3	21 day EC16 (16% ↓ in reproduction)	520	Biesinger and Christensen, 1972
Daphnia magna	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day Survival and Reproduction; NOEC	955	Spehar et al, 1980
Daphnia magna	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day Survival and Reproduction; NOEC	932	Spehar et al, 1980
Daphnia magna	Arsenic trioxide (As₂O₃)	Measured but NR	21+1	NR	21 day IC10 (reproduction)	1300	Tisler and Zagorc-Koncan, 2002
Cyclops vernalis; C. bicuspidatusthomasi (Copepod)	Sodium arsenite (As III)	7.6 - 8.8	15	88 / 139	14 day EC20	320	Borgmann et al., 1980
Hyallela azteca (Amphipod)	Sodium arsenate (Na₂HAsO₄)	7.23 – 8.83	25	84 / 124	7 day LC50	483	Borgmann et al., 2005
Ceriodaphnia dubia (Water flea)	Sodium Arsenate (As V)	7.9	25.8	50.5/119.4	8 day survival (IC 12.5)	1020	Naddy et al, 1995
Ceriodaphnia dubia	Specific form NR; data for low UV radiation	7.29 – 9.27	25	NR	24 day to 3rd generation NOEC brood size	1000	Hansen et al, 2002
Ceriodaphnia dubia	Specific form NR; data for low UV radiation	7.29 – 9.27	25	NR	24 day to 3rd generation survival NOEC	1500	Hansen et al, 2002

Ceriodaphnia dubia	Sodium arsenite (As III)	8.1 – 8.2	25 +/- 2	97 – 112/100 – 165	7 day MATC (immobilization)	1140	Spehar and Fiandt, 1986
Pteronarcys dorstata (Stonefly)	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961	Spehar et al, 1980
Pteronarcys dorstata	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	973	Spehar et al, 1980
G. fossarum (Amphipod)	As^{3+} (sodium arsenite)	8	12 +/- 2	NR	10-day LC50	200	Canivet et al, 2001
G. pseudolimnaeus (amphipod)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	7 day LC80 14 day LC15	960 88	Spehar et al, 1980
G. pseudolimnaeus (amphipod)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day LC20	973	Spehar et al, 1980
H. campanulate (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC5 (LOEC)	960	Spehar et al, 1980
H. campanulate (snail)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC10 (LOEC)	973	Spehar et al, 1980
S. emarginata (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC0 (NOEC)	960	Spehar et al, 1980
S. emarginata (snail)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC10 (LOEC)	973	Spehar et al, 1980
H. sulfurea (Ephemeroptera)	As^{3+}	8	12 +/- 2	NR	10-day LC50	1650	Canivet et al, 2001[a]
A. aquaticus (Isopod)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2300	Canivet et al, 2001
N. rhenorhodanensis (Amphipod)	As^{3+}	8	12 +/- 2	NR	10-day LC50	3900	Canivet et al, 2001
H. pellucidula (Trichoptera)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2400	Canivet et al, 2001
Physa fontinalis (Snail)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2200	Canivet et al, 2001
G. pulex (amphipod)	Arsenic acid (H_3AsO_4)	NR	10.0	NR	10 day Survival; LC10	376.5	Vellinger et al. 2013[a]
Aquatic Plant / Algae							
Melosira granulata (Diatom)	Na_3AsO_4 (arsenate)	NR	20	NR	IC20/ LOEC (growth) (8 – 24 days)	75	Planas and Healey, 1978
Ochromonas vallesiaca (Algae)	Na_3AsO_4 (arsenate)	NR	20	NR	IC35/ LOEC (growth) (8 – 24 days)	75	Planas and Healey, 1978
Ankistrodesmus falcatus (Algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	256	Vocke et al, 1980
Scenedesmus obliquus (Green algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	48	Vocke et al, 1980

Scenedesmus subspicatus (Green algae)	Arsenic trioxide (As$_2$O$_3$)	NR	21+1	NR	72 hour EC10 (growth – biomass)	9400	Tisler and Zagorc-Koncan, 2002
Chlorella sp. (Algae)	As (III)	7.6	27	NR	72 IC50 growth	25,200	Levy et al, 2005
Chlorella sp. (Algae)	As (V)	7.6	27	NR	LOEC/72 h IC50 growth	1930/ 25400	Levy et al, 2005
Monoraphidium arcuatum (Algae)	As (III)	7.6	27	NR	LOEC/ 72 h IC50 growth	3750/ 14600	Levy et al, 2005
Monoraphidium arcuatum (Algae)	As(V)	7.6	27	NR	LOEC/ 72 h IC50 growth	81/254	Levy et al, 2005
Freshwater Fish and Amphibians							
Pimephales promelas (Fathead minnow)	Sodium arsenite (As III)	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight, length) NOEC	2130	Lima et al., 1984
Pimephales promelas	Sodium arsenite (As III)	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight, length) LOEC	4300	Lima et al., 1984
Pimephales promelas	Sodium arsenite (As III)	7.4	25 +/- 3	42.4/43.9	32 day (growth) MATC	3330	Spehar and Fiandt, 1986
Pimephales promelas	Arsenite (As III)	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) NOEC	2130	Call et al, 1983
Pimephales promelas	Arsenite (As III)	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) LOEC	4300	Call et al, 1983
Pimephales promelas	Sodium arsenate (As V)	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; NOEC	530	DeFoe, 1982
Pimephales promelas	Sodium arsenate (As V)	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; LOEC	1500	DeFoe, 1982
Rana pipiens (Northern leopard frog)	Arsenic V	7.9	22 - 23	170	113-day survival, growth, and metamorphosis NOEC	1000	Chen et al. 2009
Micropterus salmoides (Largemouth bass)	NaAsO$_2$	NR	NR	NR	28-day LC1	4601	Birge et al, 1978
Oncorhynchus kisutch (Coho salmon)	As$_2$O$_3$	8.2	3.8 – 13.8	88/ 69	6 month LOEC (juvenile migration)	300	Nichols et al, 1984
Oncorhynchus kisutch	As$_2$O$_3$	8.2	3.8 – 13.8	88/ 69	6 month NOEC (juvenile survival, growth)	300	Nichols et al, 1984
Oncorhynchus mykiss (Rainbow trout)	NaAsO$_2$	NR	NR	NR	28-day LC1	40	Birge et al, 1978
Oncorhynchus mykiss	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961	Spehar et al, 1980

Oncorhynchus mykiss	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	973	Spehar et al, 1980
Oncorhynchus mykiss	NaAsO$_2$	7.4	13 +/- 0.5	-/104	28 day LC1	39.7	Birge, 1978
Oncorhynchus mykiss	NaAsO$_2$	7.4	13 +/- 0.5	-/104	28 day LC50	540	Birge, 1978
Oncorhynchus mykiss	Arsenic III (As$_2$O$_3$)	7.8	13.4	282/380	181-d growth LOEC 181-d growth NOEC 181-d threshold of chronic toxicity	9640 2480 4900	Rankin and Dixon, 1994

Notes:

T = temperature; NR = not reported

A Data generated by Canivet et al, 2001 and Vellinger et al, 2013 are included in Table A-2 for completeness, but are not considered for the SSD as a 10-day LC50 is not considered long enough to be classified as a chronic study

2.4 Arsenic SSD

Consistent with CCME (2007) guidance, a species sensitivity distribution (SSD) approach was used to derive a Type A guideline. The SSD approach was comprised of identifying chronic toxicity data for species relevant to the Fifteen Mile Stream Mine area, analyzing the data using a regression approach and selecting the final chronic effects benchmark. The HC5 (*i.e.*, the concentration that is hazardous to no more than 5% of a species in the community) was selected as the final chronic effects benchmark as per CCME (2007) guidance.

Further details of the approach are provided in the following sections.

2.4.2 SSD Modelling

Data for the aquatic community including freshwater fish, invertebrates, and aquatic vascular and non-vascular plants were used to develop a species sensitivity distribution for arsenic. SSD Master v3 (CCME, 2007) was used to fit four sigmoid-shaped (cumulative distribution function – CDF) models to the chronic toxicity values for freshwater species. SSD Master v3 was designed to facilitate the derivation and selection of appropriate SSD models for use in benchmark setting and risk assessment. The CCME currently uses this application in the development of Type A water quality guidelines for the protection of aquatic life. SSD Master v3 evaluates the data using four models including the Normal, Logistic, Extreme Value (Gompertz) and Gumbel (Fisher-Tippett) models (CCME, 2007). In arithmetic space the Weibull model is also available. The application is fully automated and Excel-based. SSD Master v3 uses the standard Excel Solver add-in to fit the CDF models. Solver proceeds through different combinations of model parameter values until the sum of square error term cannot be further minimized. The application automatically generates residual plots and goodness-of-fit, probability-probability (p-p) and quantile-quantile (q-q) plots, as well as plots of the SSDs and associated approximate confidence intervals.

As is evident in Table A-2, there were a number of test durations, endpoints, and effects reported in the arsenic freshwater toxicity studies. Based on guidance for a CCME WQGl - FWAL (CCME, 2007), the most sensitive endpoint (i.e., growth, reproduction, and mortality) based on appropriate standard test durations are preferred. For the development of a long-term WQGl - FWAL, growth and reproduction endpoints (non-lethal) are preferred. Ideally, the data used to generate the SSD would be regression based (ECx/LCx) for no to low toxic effects (e.g., EC<25). The preferred order of endpoints is: ECx/ICx representing a no-effects threshold >EC10/IC10 > EC11-25/IC11-25 > MATC > NOEC > LOEC> nonlethal EC26-49/IC26-49 > nonlethal EC50/IC50 (CCME, 2007).

In the case of arsenic, there is a varied dataset available with many endpoints and durations for numerous species (Table A-2). The most common endpoint available for most taxa is the no observed effect concentration (NOEC). This is not the preferred endpoint for WQGl - FWAL development as it typically has a significant amount of uncertainty associated with it. NOECs and LOECs are generally poor predictors of low toxic effects (Moore and Caux, 1997). However, there are sufficient NOECs to derive an SSD for the aquatic community using the

CCME WQGl Type A approach, based on the data available. The one exception is for aquatic plants. There are few aquatic plant studies available that are relevant and of acceptable quality. The available data report only LOECs, EC50 and EC10 data for growth (Table A-2), but all of these studies are of an acceptable duration to represent chronic exposures. While only LOECs, EC50 and EC10 data were available for use in the SSD modeling, the effects reported occurred at much lower concentration than were associated with no-effects in other studies, with the exception of the EC10 (growth – biomass) for *Scenedesmus subspicatus* of 9400µg/L (Tisler and Zagorc-Koncan, 2002). As such, all of these data with alternative endpoints (non – NOEC studies) were considered appropriate for use in the SSD modeling.

When deriving an SSD for an aquatic community, it is important to ensure that no one species over-weights the SSD due to its relative sensitivity/tolerance. In many datasets, standard test organisms (e.g., fathead minnow, *Daphna magna*) can bias the results due to the abundance of data for those species. Therefore, when multiple data were available for the same species, the geometric mean of these values was used to represent that species in the SSD. This calculation was required for *Daphnia magna, Pimphales promelas,* and *Ceriodaphnia dubia*.

Also, when arsenic III and V data were present for a single species, only the most sensitive dataset was entered into the SSD.

Table A-3 presents the dataset used in the generation of the SSD.

Certain studies had to be excluded, despite being of adequate quality, due to their duration, relative to chronic exposures. These include Canivet et al (2001) and Vellinger et al (2013), which only involved 10 day study durations. Due to the survival endpoint in these studies, and the species tested, a duration of > 21 days would be required for these data to be included in a chronic SSD (as per CCME protocols). Similarly, some of Spehar et al (1980) data for amphipods was of shorter duration (7 day to 14 day) and therefore had to be excluded.

Table A-3   Data Selected and Geometric Means for the same Species for the Species Sensitivity Distribution for Arsenic

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	T (°C)	Alkalinity / Hardness (mg/L; CaCO₃)						
Aquatic Invertebrates										
Daphnia magna	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction NOEC	633		NOEC	Lima et al., 1984	P
Daphnia magna	Arsenite (As III)	7.4	21.5 +/- 3	45.5/47.2	28 day (growth and reproduction) NOEC	630	631.5	NOEC	Call et al, 1983	P
Ceriodaphnia dubia	Specific form not stated; low UV radiation only reported	7.29 – 9.27	25	NR	24 day to 3rd generation NOEC brood size	1000		NOEC	Hansen et al, 2002	S
Ceriodaphnia dubia	Specific form not stated; low UV radiation only reported	7.29 – 9.27	25	NR	24 day to 3rd generation survival NOEC	1500	1224.7	NOEC	Hansen et al, 2002	S
Cyclops vernalis; C. bicuspidatus thomasi (Copepod)	Sodium arsenite (As III)	7.6 - 8.8	15	88 / 139	14 day EC20	320		EC20	Borgmann et al., 1980	S
H. campanulate (snail)	As³⁺	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC5 (LOEC)	960		LOEC	Spehar et al, 1980	P
S. emarginata (snail)	As³⁺	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC0 (NOEC)	960		LOEC	Spehar et al, 1980	P
Pteronarcys dorstata	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961		NOEC	Spehar et al, 1980	P
Aquatic Plants										
Ankistrodesmus falcatus (Algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	256		EC50	Vocke et al, 1980	P

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	T (°C)	Alkalinity / Hardness (mg/L; CaCO$_3$)						
Chlorella sp. (Algae)	As (V)	7.6	27	NR	LOEC/72 h IC50 growth	1930		LOEC	Levy et al, 2005	S
Monoraphidium Arcuatum (Algae)	As(V)	7.6	27	NR	LOEC/ 72 h IC50 growth	81		LOEC	Levy et al, 2005	S
Scenedesmus obliquus (Green algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	48		EC50	Vocke et al, 1980	P
Scenedesmus subspicatus (Green algae)	Arsenic trioxide (As$_2$O$_3$)	NR	21+1	NR	72 hour EC10 (growth – biomass)	9400	9400	EC10	Tisler and Zagorc-Koncan, 2002	P
Melosira granulata	Na$_3$AsO$_4$ (arsenate)	NR	20	NR	LOEC (growth) (8 – 24 days)	75	75	LOEC	Planas and Healey, 1978	S
Ochromonas vallesiaca	Na$_3$AsO$_4$ (arsenate)	NR	20	NR	LOEC (growth) (8 – 24 days)	75	75	LOEC	Planas and Healey, 1978	S
Freshwater Fish and Amphibians										
Pimephales promelas	Sodium arsenite	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight and length) NOEC	2130		NOEC	Lima et al., 1984	P
Pimephales promelas	Arsenite	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) NOEC	2130	1339.7	NOEC	Call et al, 1983	P
Pimephales promelas	Sodium arsenate	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; NOEC	530		NOEC	DeFoe, 1982	S
Oncorhynchus kisutch	As$_2$O$_3$	8.2	3.8 – 13.8	88/ 69	6 month survival and growth (juvenile): NOEC	300		NOEC	Nichols et al, 1984	P
Oncorhynchus mykiss	Arsenic III	7.8	13.4	282/380	181-d growth NOEC	2480		NOEC	Rankin and Dixon, 1994	P

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	T (°C)	Alkalinity / Hardness (mg/L; CaCO₃)						
Rana pipiens (Northern leopard frog)	Arsenic V	7.9	22 - 23	170	113-day survival, growth, and metamorphosis NOEC	1000		NOEC	Chen et al. 2009	S

2.4.3 SSD Results

Table A-4 presents the data selected to model the SSD and the associated plotting positions in the graph.

Table A-4   Data Selected for the Species Sensitivity Distribution and Associated Plotting Positions

Taxon Grouping	Species	Concentration (µg/L)	Log Concentration	Plotting Position	Species Number
Plant	*Scenedesmus obliquus*	48	1.681241237	0.03	1
Plant	*Melosira granulata*	75	1.875061263	0.08	2
Plant	*Ochromonas vallesiaca*	75	1.875061263	0.14	3
Plant	*M.arcuatum*	81	1.908485019	0.19	4
Plant	*Ankistrodesmus falcatus*	256	2.408239965	0.25	5
Fish	*Oncorhynchus kisutch*	300	2.477121255	0.31	6
Invertebrate	*Cyclops vernalis; C. bicuspidatusthomasi*	320	2.505149978	0.36	7
Invertebrate	*Gammarus pulex*	376.5	2.575764981	0.42	8
Invertebrate	*Daphnia magna*	631.5	2.800373355	0.47	9
Invertebrate	*H. campanulate*	960	2.982271233	0.53	10
Invertebrate	*S. emarginata*	960	2.982271233	0.58	11
Invertebrate	*Pteronarcys dorstata*	961	2.982723388	0.64	12
Amphibian_Reptile	*rana pipens*	1000	3	0.69	13
Invertebrate	*Ceriodaphnia dubia*	1224.7	3.088029718	0.75	14
Fish	*Pimephales promelas*	1339.7	3.127007557	0.81	15
Plant	*Chlorella*	1930	3.285557309	0.86	16
Fish	*Oncorhynchus mykiss*	2480	3.394451681	0.92	17
Plant	*Scenedesmus subspicatus*	9400	3.973127854	0.97	18

Overall, the extreme value distribution provided the best overall fit for the generation of an SSD for the aquatic community according to the Anderson-Darling (AD) goodness-of-fit test statistic (AD statistic = 0.440, p > 0.05) and the Mean Square Error in the Lower Tail (MSE lower tail: 0.0286). However, for the purposes of the SSWQO, the fit of the distribution around the HC5 value in the lower tail is of greater importance. Visual inspection of the curve (Figure A-1) indicates that the extreme value model does not represent the data in the lower tail as well as the normal model, which comes much closer to the lowest value in the dataset (48 µg/L for *Scenedesmus obliquus*) (Figure A-2). Comparison of the confidence limits around the HC5 values for the extreme value and normal distributions indicates that the confidence limits around the HC5 of the extreme value distribution (lower confidence limit = 17.56 µg/L; upper confidence limit = 48.87 µg/L; HC5 = 29.29 µg/L) is also wider than that for the normal distribution (lower confidence limit = 41.94 µg/L; upper confidence limit = 68.38 µg/L; HC5 = 53.55 µg/L). A summary of the model results is presented in Table A-5 for comparison purposes. Therefore, based on overall fit, the extreme value distribution provides a better fitting model; however, based on the fit at the lower tail of the distribution, the normal distribution provides a better fitting model and as such, likely provides a more realistic prediction of the HC5. To be

conservative however, the HC5 from the extreme value model was selected for use as it provides a lower HC5 (selected extreme value model HC5 is 29.29 µg/L; rounded to 30 µg/L).
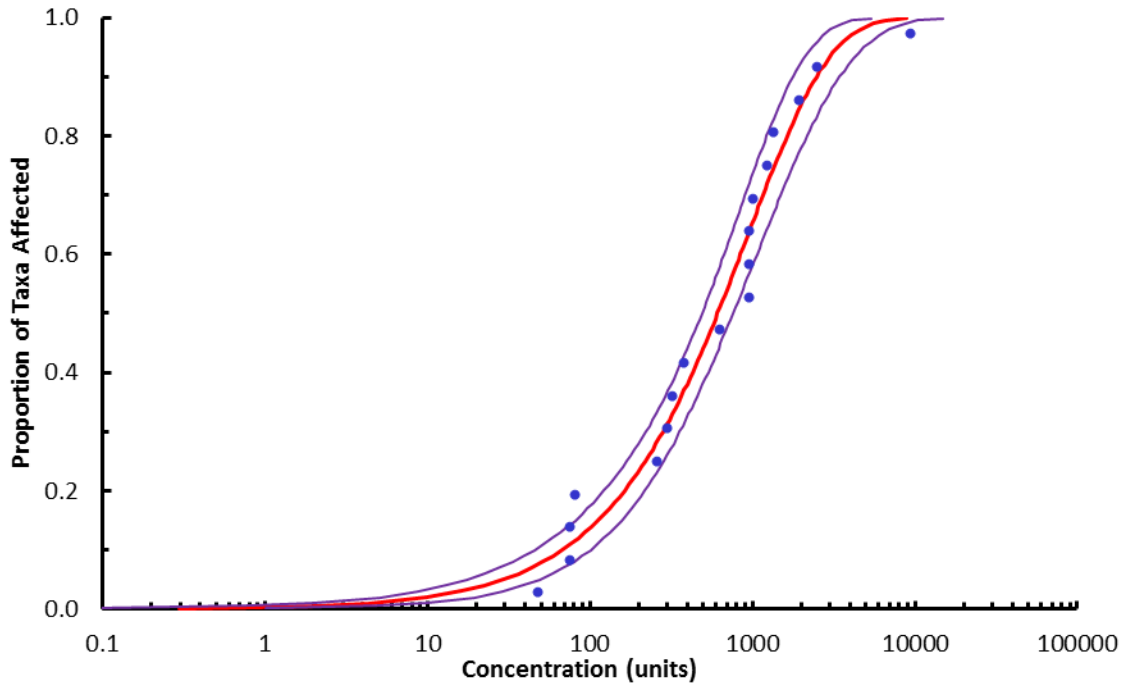

Figure A-1   SSD Based on the Sensitivity of the Freshwater Aquatic Community to Arsenic using the Extreme Value Model
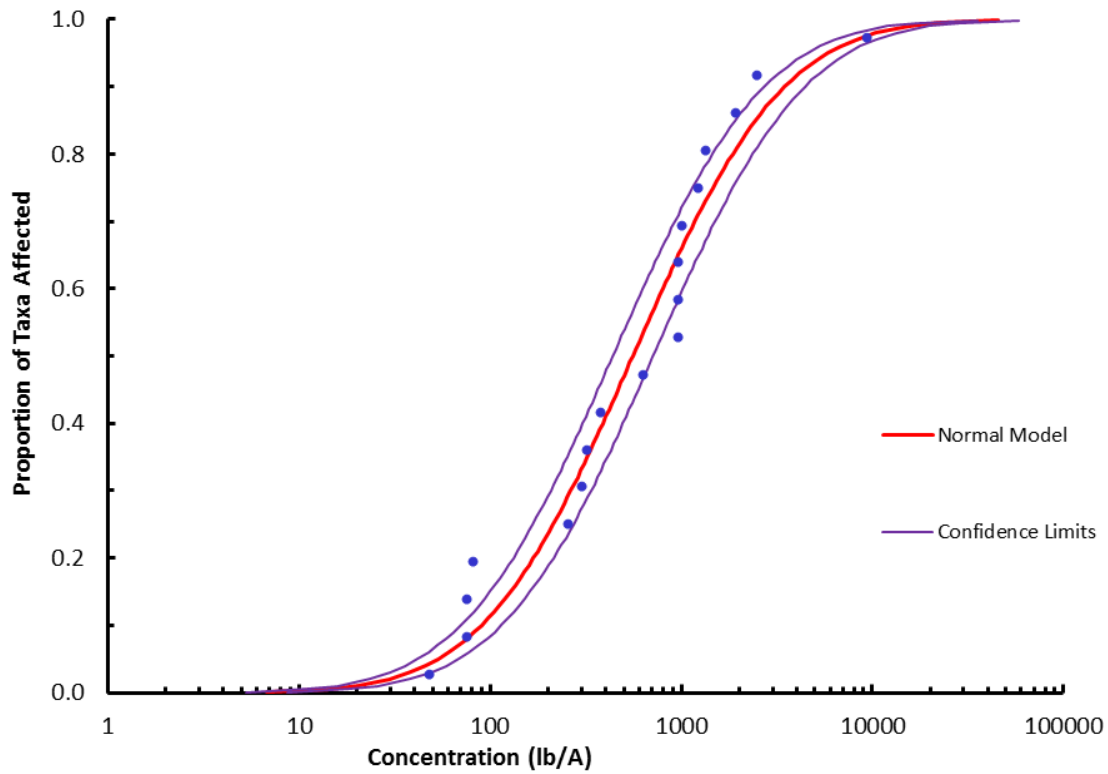
Figure A-2   SSD Based on the Sensitivity of the Freshwater Aquatic Community to Arsenic using the Normal Model

Table A-5   Comparison of Goodness of Fit Statistics and Model Results (HC5 in µg/L) based on the results from SSD Master v3

Result	Normal	Logistic	Extreme Value	Gumbel
MSE	0.0035	0.0034	0.0025	0.0057
MSE Lower Tail	0.0368	0.0353	0.0286	0.0554
Data from specified distribution? Anderson-Darling (n>5)	Yes	Yes	Yes	Yes
Anderson-Darling Statistic (A^2)	0.417	0.404	0.440	0.789
HC50 (µg/L)	558.376	565.929	610.058	514.600
HC5 (µg/L)	53.55	45.93	29.29	76.32
Lower confidence limit on the mean (expected HC5)	41.94	31.86	17.56	46.50
Upper confidence limit on the mean (expected HC5)	68.38	66.22	48.87	125.27

The equation for the extreme value model is:

$$f(x) = 1 - e^{-e^{(X-\mu)/S}}$$

Where, *f(x)* = proportion of taxa affected;

> *x* = concentration metameter;

> *μ* = location parameter; and

> *s* = scale parameter (always positive).

The fitted model parameters were: *μ* = 2.97 and *s* = 0.506 for the toxicity dataset used in µg/L. The HC5 (concentration that will affect 5% of species in the SSD) was 29.29 µg/L with an approximate lower confidence limit (LCL) of 17.56 µg/L and upper confidence limit (UCL) of 48.87 µg/L.

2.4.4 *Proposed SSWQO for Arsenic*

The HC5 value of **30 µg/L** (29.29 µg/L rounded upwards) is proposed as the SSWQO for arsenic at the Fifteen Mile Stream Mine Area.

While this HC5 value is above the CCME WQGl-FWAL of 5 µg/L (2001), it is more conservative than the toxicity endpoint upon which the CCME WQGl-FWAL is based (i.e., 14-day EC50 (growth) of 48 µg/L for the algae *Scenedesmus obliquus* (Vocke et al., 1980), which was the most sensitive freshwater organism to arsenic identified).

This proposed SSWQO for arsenic is less than the U.S. EPA (1995) CCC for arsenic of 150 µg/L based on dissolved concentrations.

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Appendix B   Baseline Surface Water Concentrations

Table B-1   Baseline Surface Water Concentrations Collected from SW5 (Total Metals mg/L; N = 8)[a]

Parameter	Min	Max	Mean	75th percentile	95th percentile	# of Non-Detects	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
Aluminum	0.087	0.32	0.179	0.2	0.288	0/9	0.005	0.005
Antimony	<0.001	<0.001	0.0005	0.0005	0.0005	9/9	NV	0.02
Arsenic	0.0034	0.077	0.0252	0.037	0.0658	0/9	0.005	0.005
Boron	<0.05	<0.05	0.025	0.025	0.025	9/9	1.5	1.2
Cadmium	<0.00001	0.00002	0.0000121	0.000014	0.0000184	2/9	0.00004	0.00001
Chromium	<0.001	0.001	0.000556	0.0005	0.0008	8/9	0.0089	0.001
Cobalt	<0.0004	0.00051	0.000262	0.0002	0.000486	7/9	NV	0.01
Copper	<0.0005	0.001	0.000864	0.001	0.001	8/9	0.002	0.002
Iron	0.13	0.89	0.394	0.59	0.778	0/9	0.3	0.3
Lead	<0.0005	0.00025	0.00025	0.00025	0.00025	9/9	0.001	0.001
Manganese	0.041	0.11	0.0731	0.082	0.11	0/9	NV	0.82
Mercury	<0.000013	0.00002	0.0000101	0.000015	0.0000188	6/9	0.000026	0.000026
Molybdenum	<0.002	<0.002	0.001	0.001	0.001	9/9	0.073	0.073
Nickel	<0.002	<0.002	0.001	0.001	0.001	9/9	0.025	0.025
Selenium	<0.001	<0.001	0.0005	0.0005	0.0005	9/9	0.001	0.001
Silver	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.00025	0.0001
Thallium	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.0008	0.0008
Uranium	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.015	0.3
Zinc	<0.005	<0.005	0.0025	0.0025	0.0025	9/9	0.007	0.03

Notes:

[a] Summary statistics were calculated using half the detection limit value when a chemical was not detected in a sample.

Table B-2   Baseline Surface Water Concentrations Collected from SW6 (Total Metals mg/L; N = 9)[a]

Parameter	Min	Max	Mean	75th percentile	95th percentile	# of Non-Detects	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
Aluminum	0.17	0.3	0.22	0.25	0.29	0/9	0.005	0.005
Antimony	<0.001	<0.001	0.0005	0.0005	0.0005	9/9	NV	0.02
Arsenic	<0.002	0.021	0.0044	0.0045	0.015	1/9	0.005	0.005
Boron	<0.05	<0.05	0.025	0.025	0.025	9/9	1.5	1.2
Cadmium	0.000011	0.000026	0.000017	0.00002	0.000024	0/9	0.00004	0.00001
Chromium	<0.001	<0.001	0.0005	0.0005	0.0005	9/9	0.0089	0.001
Cobalt	<0.0004	<0.0004	0.0002	0.0002	0.0002	9/9	NV	0.01
Copper	<0.0005	<0.002	0.00083	0.001	0.001	9/9	0.002	0.002
Iron	0.15	1.3	0.40	0.33	1.0	0/9	0.3	0.3
Lead	<0.0005	0.00075	0.00031	0.00025	0.00055	8/9	0.001	0.001
Manganese	0.054	0.079	0.065	0.068	0.076	0/9	NV	0.82
Mercury	<0.000013	<0.000013	0.0000065	0.0000065	0.0000065	9/9	0.000026	0.000026
Molybdenum	<0.002	<0.002	0.001	0.001	0.001	9/9	0.073	0.073
Nickel	<0.002	<0.002	0.001	0.001	0.001	9/9	0.025	0.025
Selenium	<0.001	<0.001	0.0005	0.0005	0.0005	9/9	0.001	0.001
Silver	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.00025	0.0001
Thallium	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.0008	0.0008
Uranium	<0.0001	<0.0001	0.00005	0.00005	0.00005	9/9	0.015	0.3
Zinc	<0.005	<0.005	0.0025	0.0025	0.0025	9/9	0.007	0.03

Notes:

[a] Summary statistics were calculated using half the detection limit value when a chemical was not detected in a sample.

Table B-3   Baseline Surface Water Concentrations Collected from EMZ-2 (Total Metals mg/L; N = 13)[a]

Parameter	Min	Max	Mean	75th percentile	95th percentile	# of Non-Detects	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
Aluminum	0.1	0.3	0.21	0.25	0.29	0/13	0.005	0.005
Antimony	<0.001	<0.001	0.0005	0.00050	0.0005	13/13	NV	0.02
Arsenic	<0.002	0.033	0.0062	0.0048	0.026	1/13	0.005	0.005
Boron	<0.05	<0.05	0.025	0.025	0.025	13/13	1.5	1.2
Cadmium	<0.00001	0.000026	0.000017	0.000022	0.000024	1/13	0.00004	0.00001
Chromium	<0.001	0.0012	0.00055	0.00050	0.00078	12/13	0.0089	0.001
Cobalt	<0.0004	<0.0004	0.0002	0.00020	0.00020	13/13	NV	0.01
Copper	<0.0005	<0.002	0.00077	0.0010	0.0010	13/13	0.002	0.002
Iron	0.15	1.3	0.36	0.33	0.87	0/13	0.3	0.3
Lead	<0.0005	0.00075	0.00029	0.00025	0.00045	12/13	0.001	0.001
Manganese	0.054	0.095	0.067	0.072	0.085	0/13	NV	0.82
Mercury	<0.000013	<0.000013	0.0000065	0.0000065	0.0000065	13/13	0.000026	0.000026
Molybdenum	<0.002	<0.002	0.001	0.001	0.001	13/13	0.073	0.073
Nickel	<0.002	<0.002	0.001	0.001	0.001	13/13	0.025	0.025
Selenium	<0.001	<0.001	0.0005	0.0005	0.0005	13/13	0.001	0.001
Silver	<0.0001	<0.0001	0.00005	0.00005	0.00005	13/13	0.00025	0.0001
Thallium	<0.0001	<0.0001	0.00005	0.00005	0.00005	13/13	0.0008	0.0008
Uranium	<0.0001	<0.0001	0.00005	0.00005	0.00005	13/13	0.015	0.3
Zinc	<0.005	<0.005	0.0025	0.0025	0.0025	13/13	0.007	0.03

Notes:

[a] Summary statistics were calculated using half the detection limit value when a chemical was not detected in a sample.

Table B-4   Baseline Surface Water Concentrations for SW15 (Based on results from SW12; Total Metals mg/L; N = 8)[a, b]

Parameter	Min	Max	Average	75th percentile	95th percentile	# of Non-Detects	CCME (mg/L)	Nova Scotia Tier 1 (mg/L)
Aluminum	0.053	0.38	0.237	0.323	0.363	0/8	0.005	0.005
Antimony	<0.001	<0.001	0.0005	0.0005	0.0005	8/8	NV	0.02
Arsenic	<0.001	0.0015	0.000625	0.0005	0.00115	7/8	0.005	0.005
Boron	<0.05	<0.05	0.025	0.025	0.025	8/8	1.5	1.2
Cadmium	<0.00001	0.000035	0.0000174	0.0000205	0.0000305	2/8	0.00004	0.00001
Chromium	<0.001	<0.001	0.0005	0.0005	0.0005	8/8	0.0089	0.001
Cobalt	<0.0004	0.00054	0.000338	0.00046	0.000512	4/8	NV	0.01
Copper	<0.0005	0.001	0.000844	0.001	0.001	7/8	0.002	0.002
Iron	0.053	1.2	0.588	0.855	1.2	0/8	0.3	0.3
Lead	<0.0005	0.00059	0.000373	0.00057	0.000583	5/8	0.001	0.001
Manganese	0.026	0.091	0.0568	0.0775	0.0868	0/8	NV	0.82
Mercury	<0.000013	<0.000013	0.0000065	0.0000065	0.0000065	8/8	0.000026	0.000026
Molybdenum	<0.002	<0.002	0.001	0.001	0.001	8/8	0.073	0.073
Nickel	<0.002	<0.002	0.001	0.001	0.001	8/8	0.025	0.025
Selenium	<0.001	<0.001	0.0005	0.0005	0.0005	8/8	0.001	0.001
Silver	<0.0001	<0.0001	0.00005	0.00005	0.00005	8/8	0.00025	0.0001
Thallium	<0.0001	<0.0001	0.00005	0.00005	0.00005	8/8	0.0008	0.0008
Uranium	<0.0001	<0.0001	0.00005	0.00005	0.00005	8/8	0.015	0.3
Zinc	<0.005	0.0062	0.00296	0.0025	0.00491	7/8	0.007	0.03

Notes:

[a] Summary statistics were calculated using half the detection limit value when a chemical was not detected in a sample.

[b] Surface water concentrations are not available for SW15; therefore, surface water concentrations from SW12 (upstream of SW15) were used as a surrogate