APPENDIX D
TECHNICAL REPORTS - WATER

APPENDIX D.1
GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELLING TO EVALUATE DISPOSAL OF TAILINGS IN TOUQUOY OPEN PIT

Stantec

Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit

Final Report

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Executive Summary

A three-dimensional steady-state groundwater flow model and solute transport model was constructed using MODFLOW to simulate current groundwater conditions in the Study Area, baseline conditions (i.e., when tailings disposal operations begin at the Touquoy mine site), changes to groundwater inflows during operation (i.e., while tailings are deposited in the Touquoy pit), and to evaluate potential changes to water quality in the receiving environment due to the subaqueous disposal of tailings in the Touquoy pit post-closure (i.e., when the pit is full). The model was prepared using a conceptual model and hydrostratigraphic framework developed from regional and site-specific data, and assumed homogeneous properties within the units. A good calibration of model parameters was obtained, as evaluated by comparing simulated and observed groundwater levels and estimated baseflow. The parameter values for hydraulic conductivity are similar to those obtained from other analyses of field observations. The modelling was also conducted incorporating comments received from NRCan, NS ECC, and DFO on the proposed workplan provided to these agencies prior to completing the model.

At baseline, the Open Pit will be fully dewatered, and is simulated to intercept groundwater seepage at a rate of 768 m^3/d. The extent of the corresponding drawdown cone, as delineated by the 0.5 m drawdown contour, extends approximately 600 m south of the site and about 50 m west of the site toward Moose River. The inflow to the Open Pit decreases as it is filled with tailings and water, until the open pit stage reaches the maximum level of 108 m relative to CGVD2013. At this stage, the groundwater seepage decreases to 373 m^3/d, and the corresponding drawdown cone is comparable to the baseline condition. Groundwater baseflow to Moose River is reduced by less than 1% in all cases.

Upon the filling of the Open Pit to its ultimate lake stage at 108 m CGVD2013, groundwater flow is anticipated to flow from the pit to Moose River through the glacial till and weathered fractured bedrock. Solute transport in this case is dominated by advection (movement with the flow of groundwater). Solute transport modelling using the calibrated model simulates a slow migration of solutes to Moose River, with concentrations approaching a steady state after about 100 years of travel. Mass loadings for various parameters of concern are simulated by the model for inclusion in a surface water mixing model of Moose River (Stantec 2021).

The presence of preferential pathways, such as fractures and faults not characterized in previous field assessment, were assessed with sensitivity analyses in the model to predict the potential migration of solutes from pit into the receiving environment. The results of the sensitivity analyses indicated that should the faults have higher hydraulic conductivity, solute transport to Moose River would occur more quickly. The potential for higher permeability faults should be considered in the development of management, mitigation and contingency plans.

Abbreviations

AMNS	Atlantic Mining NS Inc.
CGVD2013	Canadian Geodetic Vertical Datum 2013
°C	degrees Celsius
cm	centimetres
g/d	grams per day
K_H	horizontal hydraulic conductivity
K_V/K_H	anisotropy ratio
km	kilometres
km^2	square kilometres
M	metres
m/s	metres per second
m^3/d	cubic metres per day
m^3/s	cubic metres per second
mg/L	milligrams per litre
mm	millimetres
mm/yr	millimetres per year

NSDL&F	Nova Scotia Department of Lands and Forestry
RMS	root mean squared
RSS	residual sum of squares

1.0   INTRODUCTION

The Touquoy Gold Project is an operating gold mine located in Mooseland, Nova Scotia. Ore processing at the mine has resulted in higher than anticipated tailings volume than originally scoped in the Environmental Assessment (CRA 2007a,b). The additional tailings volume will exceed the capacity of the design of the current Tailings Management Facility (TMF) at the Touquoy Mine Site. Atlantic Mining NS Inc. (AMNS) retained Stantec Consulting Ltd. (Stantec) to conduct an assessment of the disposal of tailings from the processing of the ore into the Open Pit at Touquoy. Stantec constructed a groundwater flow and solute transport model to assist in the evaluation of the potential changes to water quality in the receiving environment that are likely to result from this activity. The groundwater flow and solute transport model would also allow for the future assessment of potential mitigation measures that could be implemented to reduce the chances of a contaminant release.

1.1   STUDY OBJECTIVES

This study was conducted to assess the environmental effects associated with the disposal of tailings into the open pit developed for the Touquoy Mine Site. A groundwater flow and solute transport model has been developed to:

Evaluate the dewatering rate from the open pit and changes in groundwater flow conditions and discharges when it is fully dewatered which will be used as the baseline conditions to assess impacts

Evaluate the groundwater seepage rates to the open pit as it is filled with tailings

Identify areas where water in contact with the tailings disposed in the open pit is discharged to the receiving environment, and the potential for surface and groundwater interactions

Predict the potential impacts of discharging groundwater from the open pit to the receiving environment

This report forms part of the supporting documentation for the environmental impact study completed for the Touquoy Gold Project modifications. The documentation and modelling were conducted following the guidelines prepared by Wels et al. (2012). The documentation and modelling also incorporates comments received from NRCan, NS ECC , and DFO on the proposed modelling workplan provided to these agencies prior to completing the model. However, some of the comments received are more relevant to a discussion of the effects of dewatering of the Open Pit, and will be addressed under separate cover. A concordance table of the comments received, and the responses is provided in Appendix A of this report.

1.2   STUDY AREA

The study area was defined to incorporate natural hydrogeological boundaries around the Touquoy Mine Site. The subwatershed boundaries for Moose River and Scraggy Lake were selected, as shown on Figure 1.1.

160m

160m

160m

120m

120m

120m

120m

120m

N

Charlottetown

Study Area

Halifax

Study Area

Touquoy Project Features

0   500   1000   1500   2000   2500

metres

121619250

NAD83 UTM Zone 20
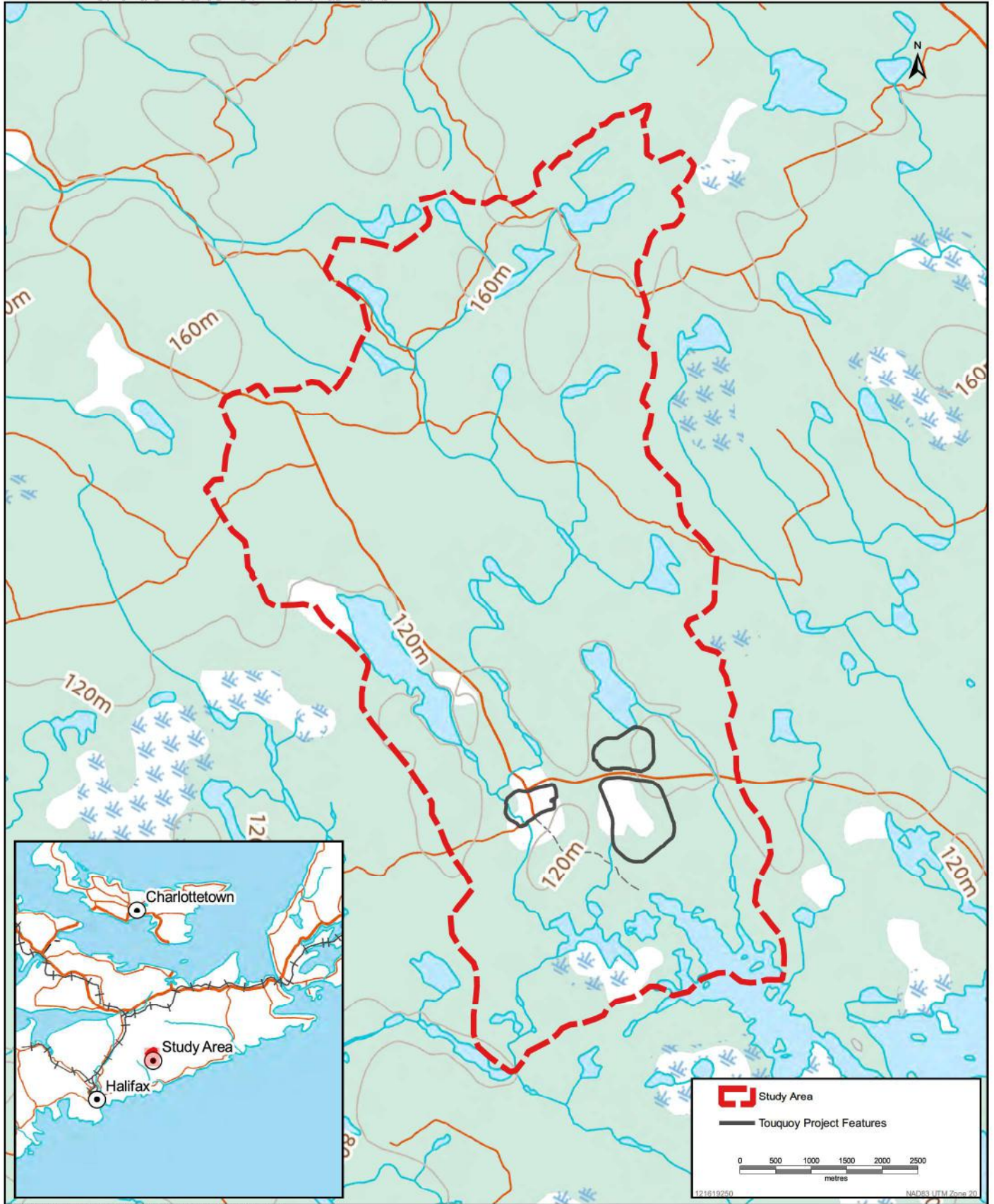
Sources: Base Data - Natural Resources Canada, GeoNova, Atlantic Mining NS Inc.

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TOUQUOY GOLD PROJECT

Study Area

Figure 1.1

2.0   BACKGROUND

2.1   PROJECT AREA DESCRIPTION AND SURROUNDING LAND USES

TheTMF is a fully permitted and approved facility currently operating as part of the approved project in Moose River, Halifax County, Nova Scotia. It is located on land owned by AMNS and Nova Scotia Department of Lands and Forestry (NSDL&F), and centered at 504599 E and 4981255 N (UTM Zone 20 NAD 83 CSRS). Access to Crown land for the construction of the mine site has been granted through a Crown Land Lease Agreement with NSDL&F (Lease No. 2794371 and Petition No. 37668).

The areas surrounding the Touquoy Mine Site is zoned mixed use under the Musquodoboit Valley and Dutch Settlement Land Use By-law. The Touquoy Mine Site location is shown on Figure 2.1.

Groundwater users in the area include Camp Kidston, located 3.5 kilometres (km) northeast of the Touquoy mine site, and permanent residences located approximately 5.8 km to the north of the open pit along Caribou Road.

2.2   CLIMATE

Local area climatic and hydrologic conditions are required for the water balance analysis completed at part of this study. Baseline climate and hydrology conditions at the Touquoy mine site and relevant data required for water balance analysis are presented in this section.

The Middle Musquodoboit climate station operated by Environment and Climate Change Canada (ECCC; Station ID 8203535), was used to characterize the climatic conditions at the mine site. This station is located approximately 20 km northwest of the mine site, and reports data collected between 1961 and 2011.

The climate for the Touquoy Mine Site is characterized as continental with temperature extremes moderated by the ocean. Temperatures typically drop below zero between the months of December through March each year. Precipitation is well distributed throughout the year. July and August are the driest months on average.

As presented in Table 2.1, the climate normal precipitation is approximately 1361.1 millimetres (mm) and the average snowfall of 172.2 centimetres (cm), based on a period of record 1981-2010 (climate normal period, Environment Canada 2015a). The extreme one-day precipitation amount of 173 mm for the period of record of the selected climate station occurred in 1961. Average annual lake evaporation is 515 mm for the mine site area based on average lake evaporation at the Truro climate station (Environment Canada 2015b). Corresponding monthly evaporation rates are presented in Table 2.1.
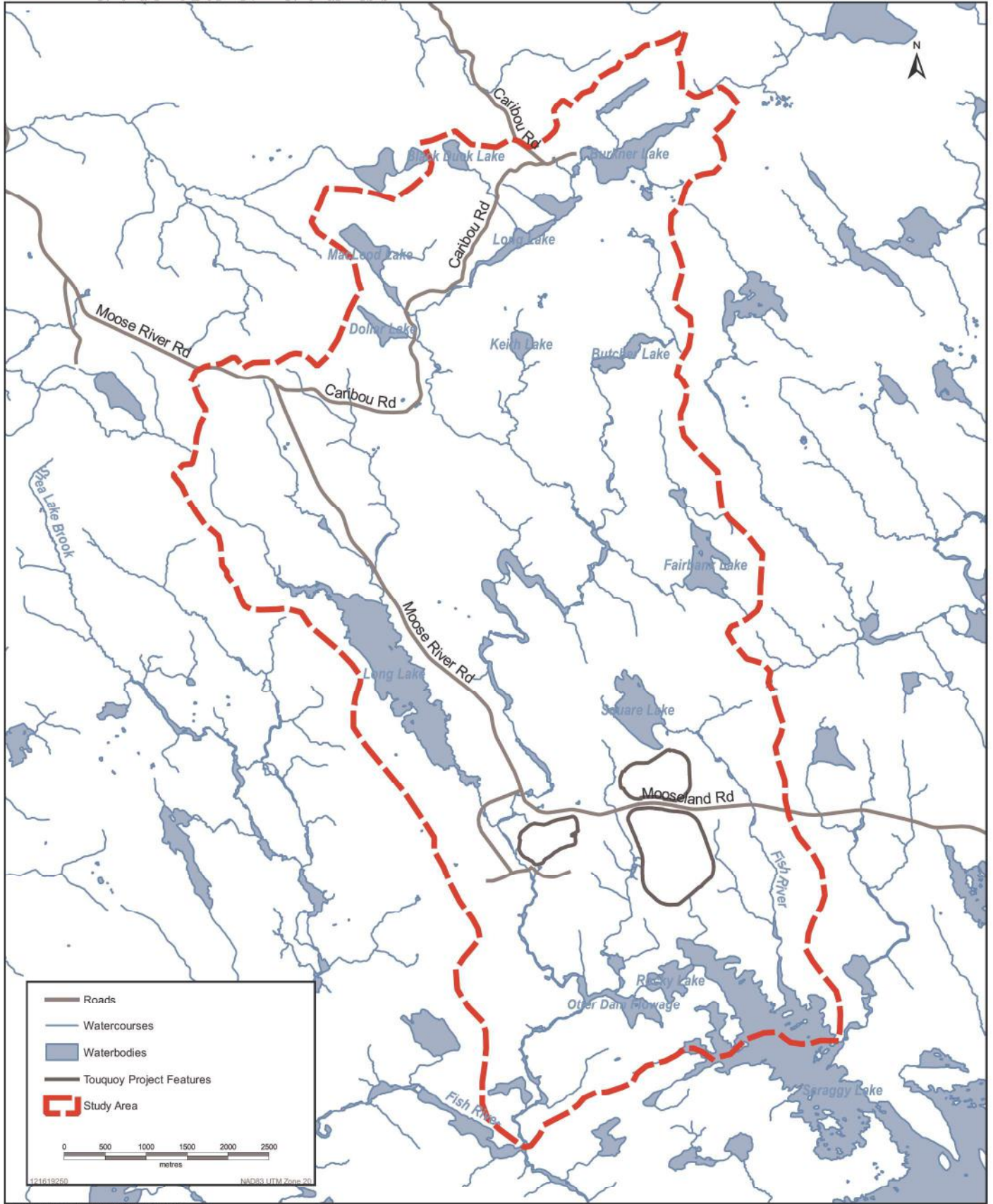
Roads
Watercourses
Waterbodies
Touquoy Project Features
Study Area

0   500   1000   1500   2000   2500
metres

121619250

NAD83 UTM Zone 20

Touquoy Mine Site Location Plan

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TOUQUOY GOLD PROJECT

Figure 2.1

Table 2.1   Representative Climate Values for the Touquoy Mine Site

Climate Normal for the 30-year period (1981-2010) at Middle Musquodoboit Climate Station													
Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (°C)	-6.2	-5.2	-1.3	4.4	9.9	14.8	18.5	18.4	14.2	8.5	3.5	-2.4	6.4
Rainfall (mm)	80.4	62.1	92.8	99.5	104.9	99.8	103.8	91.9	110.7	116.7	128.6	97.2	1188.3
Snowfall (cm)	49.4	41.3	31.4	9.5	0.5	0.0	0.0	0.0	0.0	0.0	8.2	31.9	172.2
Precipitation (mm)	129.8	103.4	124.2	109.0	105.4	99.8	103.8	91.9	110.7	116.7	136.8	129.1	1361.1
Snow Depth (cm)	40	67	64	22	6	1	0	0	0	0	25	28	21.1
Monthly Lake Evaporation at Truro Climate Station for 30 year period (1981-2010)													
Lake Evaporation (mm/day)	0	0	0	0	89.9	102	117.8	96.1	69	40.3	0	0	515.1

2.3   PHYSIOGRAPHY, TOPOGRAPHY, AND DRAINAGE

The Touquoy Mine Site is located within the Atlantic Maritime Ecozone and the South-Central Nova Scotia Uplands Ecoregion (Environment Canada undated). This ecoregion is classified as having an Atlantic high cool temperature ecoclimate. This mixed wood forest region is composed of intermediate to tall, closed stands of red and white spruce, balsam fir, yellow birch, and eastern hemlock. Yellow birch, beech, and red and sugar maple can be found at higher elevations. Eastern white pine is found on sandy areas. The ecoregion has extensive wetland and rock barrens, which support stunted black spruce, larch, and heath.

The topography of the area is presented on Figure 2.2. The elevation varies from a high of about 189.6 metres (m) relative to the Canadian Geodetic Vertical Datum of 2013 (CGVD2013) in the north of the study area, to a low of about 81.6 m CGVD2013 in the southwest of the study area at the outlet of Moose River at Fish River.   The topography in the study area is undulating, with several drumlins covering the land, as discussed in Section 2.4, and shown on Figure 2.3.

Legend:
- Roads
- Watercourses
- Waterbodies
- Touquoy Project Features
- Study Area

Ground Surface Elevation (m)
- 75
- 100
- 125
- 150
- 175

0   500   1000   1500   2000   2500
metres

121619250   NAD83 UTM Zone 20
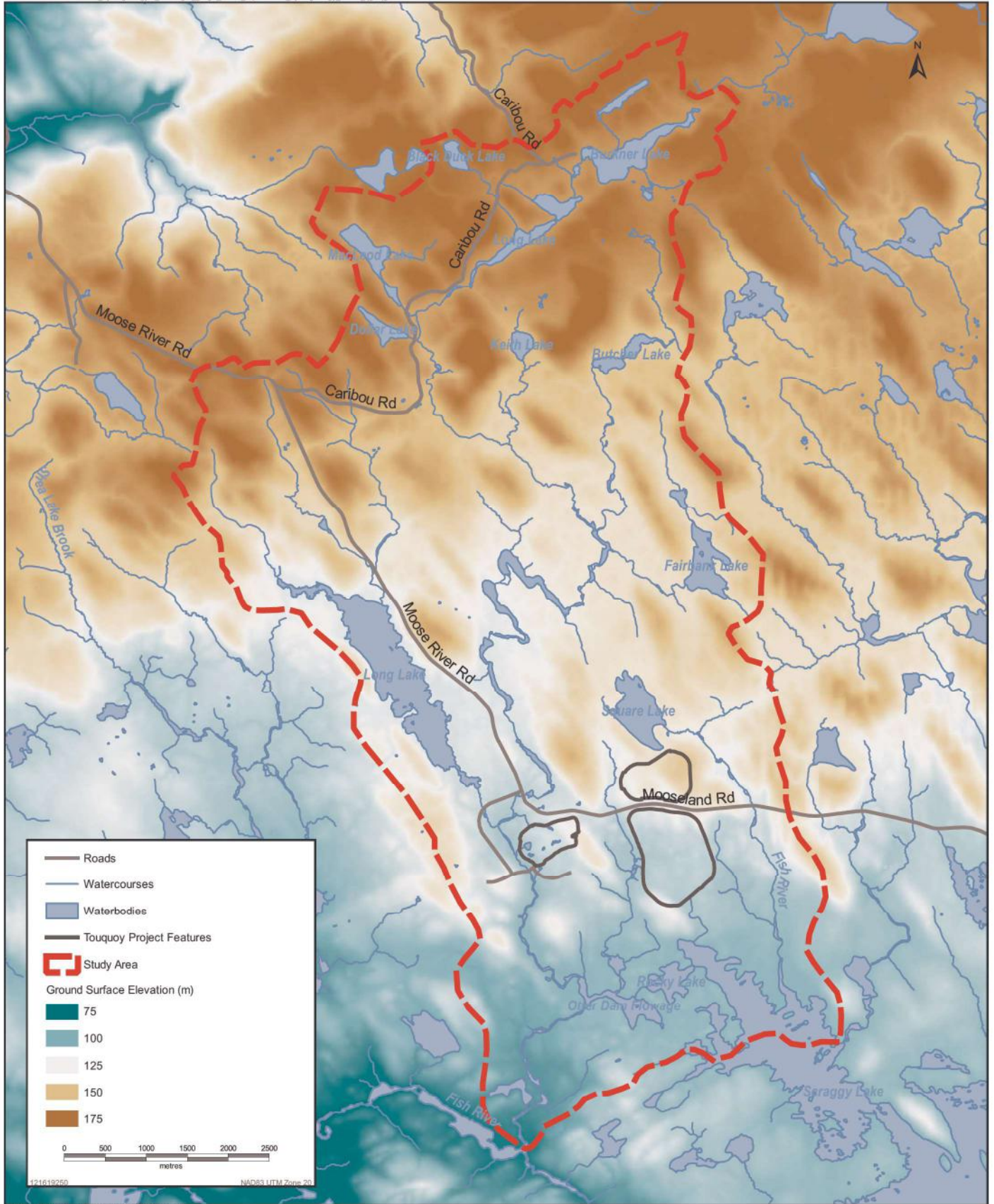
Touquoy Mine Site Topography

Stantec

TOUQUOY GOLD PROJECT

Figure 2.2

2.4   REGIONAL GEOLOGICAL CONTEXT

2.4.1   Overburden Geology

The regional surficial geology of Nova Scotia has been mapped by the Nova Scotia Department of Natural Resources (Stea et al. 1992) and consists of a veneer of stony till overlying bedrock in the south of the study area, or as exposed bedrock in the north of the study area, as shown on Figure 2-3. Organic deposits were observed in low lying areas and areas associated with wetlands. Silty drumlins are noted throughout the study area, as shown on Figure 2.3.

2.4.2   Bedrock Geology

The geology in central Nova Scotia, including the area around the Touquoy Mine Site, is composed dominantly by Cambrian to Ordovician age greywackes and argillites of the Meguma Group, as shown on Figure 2.4 from the geological maps presented in Ausenco (2015). At the Touquoy mine site and the southern portion of the study area, the underlying bedrock is composed of the Moose River, Tangier and Moose River, and Taylor's Head members of the Goldenville Formation. Bedrock in northern portions of the study area consists of the Cunard and Beaverbank members of the Halifax Formation. These formations have undergone significant alteration by a series of northeast-trending, tightly-folded anticlines and synclines, and are further altered by a number of northwest trending faults, as shown on Figure 2.4. The Moose River member is composed dominantly of argillite, while the other members of the Goldenville Formation are dominantly greywacke.

Caribou Rd

Caribou Rd

Black Duck Lake

Gaertner Lake

Long Lake

Caribou Rd

MacLeod Lake

Moose River Rd

Dollar Lake

Keith Lake

Batcher Lake

Caribou Rd

Fairbank Lake

Moose River Rd

Long Lake

Square Lake

Mooseland Rd

Fish River

Ricky Lake

Otter Dam Flowage

Scraggy Lake

Fish River

Legend

— Roads
— Watercourses
▨ Waterbodies
— Touquoy Project Features
▢ Study Area

Surficial Geology
■ Organic Deposits
■ Alluvial Deposits
■ Silty Drumlin
■ Silty Till Plain
■ Stony Till Plain
■ Bedrock

0 500 1000 1500 2000 2500
metres

121619250   NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

Touquoy Mine Site Surficial Geology

◐ **Stantec**

TOUQUOY GOLD PROJECT

Figure 2.3

Caribou Rd

Caribou Rd

Black Duck Lake

Fletcher Lake

Long Lake

Moose River Rd

MacLeod Lake

Dollar Lake

Keith Lake

Butcher Lake

Caribou Rd

Pea Lake Brook

Fairham Lake

Moose River Rd

Long Lake

Square Lake

Mooseland Rd

Fish River

Ricky Lake

Cox Dam Flowage

Scraggy Lake

Fish River

Legend

- Roads
- Watercourses
- Waterbodies
- Touquoy Project Features
- Study Area

Bedrock Geology
- Carboniferous sediments

Meguma Group - Halifax Formation
- Cunard Member
- Beaverbank Member

Meguma Group - Goldenville Fomation
- Taylor's Head Member (greywacke)
- Tangier and Moose River Members (greywacke)
- Moose River Member (argillite)
- Faults

0   500   1000   1500   2000   2500
metres

121619250   NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Inc

N

Touquoy Mine Site Bedrock Geology

Stantec

TOUQUOY GOLD PROJECT

Figure 2.4

3.0   CONCEPTUAL MODEL

3.1   MODELLING APPROACH

The development of a conceptual model is the fundamental first step in the preparation of a numerical groundwater model. The conceptual model combines the available hydrologic and hydrogeologic data from a site, and allows for the interpretation of the hydrostratigraphy and boundary conditions so they can be entered into a numerical groundwater flow model. The general approach used to develop the conceptual and numerical model was to add complexity as warranted by the available data to achieve the objectives of the numerical modelling (see Section 1.1).

3.2   CONCEPTUAL MODEL BOUNDARIES

The conceptual model boundaries were defined to coincide with or extend beyond the proposed limits for the groundwater flow model. Natural hydrologic and hydrogeologic boundaries such as watershed boundaries and surface water bodies were used to define the lateral extent of the conceptual model. The boundaries of the conceptual model correspond with the extent of the study area illustrated on Figure 2.1. The boundaries coincide with watershed boundaries for Moose River, Square Lake and the northern arm of Scraggy Lake. The limits of the conceptual model were constrained vertically by ground surface topography and extended several hundred meters to below the base of the open pit.

3.3   HYDROSTRATIGRAPHY

Previous work by Conestoga-Rovers & Associates (CRA 2007a, 2007b) and Peter Clifton & Associates (PCA 2007) identified three hydrostratigraphic units based on lithology and hydraulic properties: glacial till, weathered fractured bedrock, and competent fractured bedrock. These hydrostratigraphic units were further subdivided into zones based on the surficial geology in the overburden shown on Figure 2.3. The weathered fractured bedrock and competent fractured bedrock were further subdivided to include the bedrock units identified on Figure 2.4.

3.3.1   Overburden Hydrostratigraphic Units

The overburden hydrostratigraphic units include:

- Stony Till
- Silt Till
- Organics
- Silty Drumlin

The stony till is the dominant overburden unit, consisting of cobbly silt-sand grading to sand is assumed to be approximately 4 m thick on average across the study area. The silt till is present in the northwestern portion of the study area, however no specific testing of this unit has been performed, so it is assumed to have similar hydraulic conductivity as the stony till unit. The hydraulic conductivity of the till is estimated to range from 3×10^{-7} to 1×10^{-5} metres per second (m/s), based on estimates from shallow test pits at the western end of the pit (PCA 2007) and slug tests conducted on monitoring wells installed at the Touquoy Mine Site (GHD Limited 2016a,b; Stantec 2019).

3.3.2 Bedrock Hydrostratigraphic Units

Ten bedrock hydrostratigraphic units were identified in the Touquoy Mine Site study area. These are based on the five stratigraphic members (Cunard, Beaverbank, Taylor's Head, Tangier and Moose River, and Moose River) presented on Figure 2.4, each subdivided into a weathered fractured bedrock unit, and a competent fractured bedrock unit.

Weathered fractured bedrock consisting of Meguma Group sandstones and mudstones that has undergone alterations due to weathering and is more permeable than the underlying bedrock. This unit is assumed to be 10 m thick based on the distribution of hydraulic conductivity estimates from packer testing conducted within the footprint of the proposed Touquoy pit.

Competent fractured bedrock consisting of Meguma Group sandstones and mudstones that have not undergone alterations due to weathering. This unit was assumed to extend from the base of the weathered fractured bedrock to below the extent of the open pit.

Hydraulic conductivity testing of greywacke and argillite observed at the Touquoy Mine Site did not identify distinct hydraulic differences between these units, although weathered fractured bedrock was observed to be more permeable than the deeper, more competent bedrock. The variability of hydraulic conductivity estimates in bedrock units is shown on Figure 3.1. Hydraulic conductivity estimates in weathered fractured bedrock range between 4×10^{-9} m/s and 4×10^{-4} m/s. Fewer measurements are available in the competent fractured bedrock, where the hydraulic conductivity ranges between 4×10^{-10} m/s and 1×10^{-7} m/s.

Faults in the bedrock were not specifically tested to assess the hydraulic conductivity at the Touquoy Mine Site. However, regular observations of the faults exposed in the Touquoy open pit have identified some discrete seepage at these faults. The total flow from these exposed faults are generally very low. The faults with seepage were located on pit walls that were generally located away from Moose River, and do not suggest a strong connection with the river.

Conceptual Model
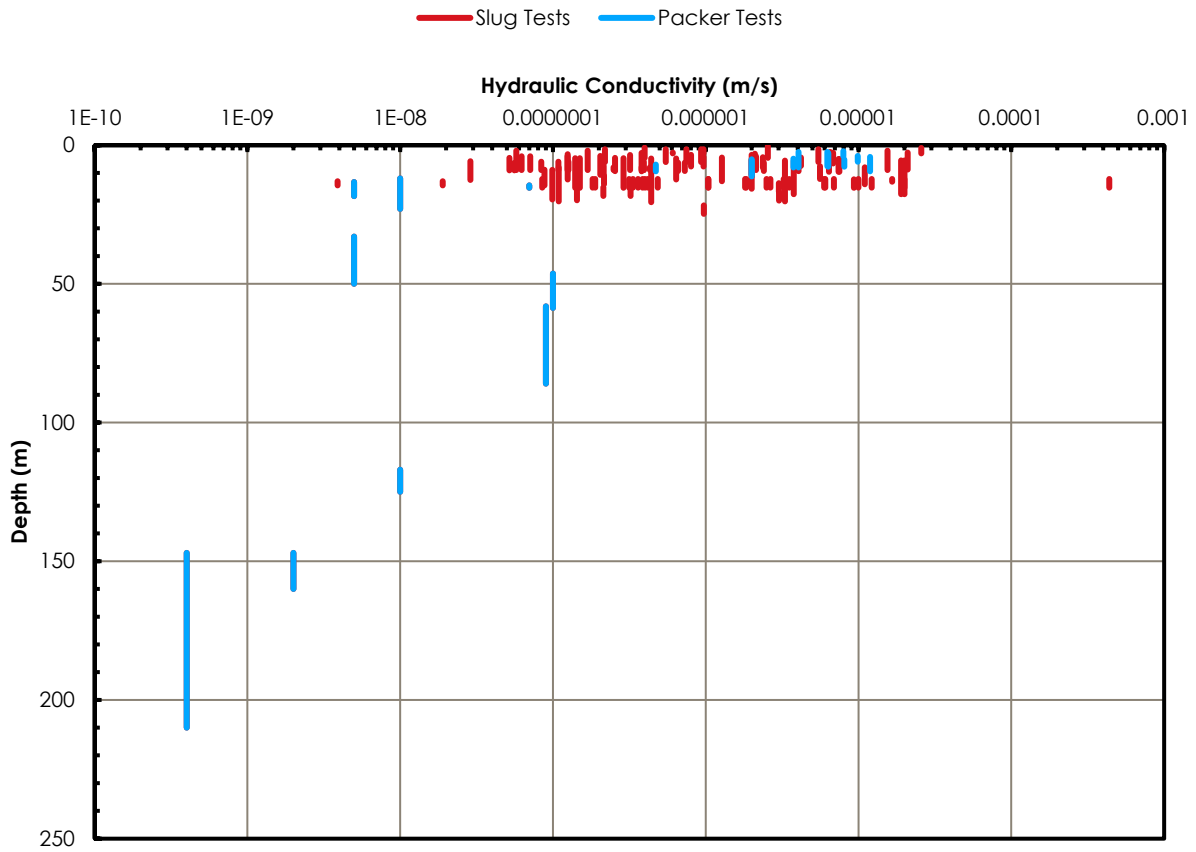
Figure 3.1   Hydraulic Conductivity Estimates in Bedrock

4.0 MODEL CONSTRUCTION AND CALIBRATION

MODFLOW was chosen as the numerical groundwater-software application for this evaluation because it is considered an international standard for simulating and predicting groundwater flow. The MODFLOW-NWT (Niswonger et al. 2012) numerical groundwater flow code was used to simulate the hydrogeologic conditions in the study area. The MODFLOW-NWT code was selected as it is able to efficiently solve the saturated groundwater flow equations under complex hydrogeological conditions without encountering numerical difficulties associated with drying out of model cells that are commonly encountered in dewatering scenarios.

MT3D-USGS (Bedekar et al. 2016) was chosen as the numerical solute transport model. MT3D-USGS is a modular three-dimensional multispecies transport code for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems.

Groundwater Vistas version 7 (Environmental Simulations International 2018) was chosen as the graphical user interface with MODFLOW-NWT and MT3D-USGS. Groundwater Vistas is a pre- and post-processor for MODFLOW-NWT and MT3D-USGS models and other technologies for sensitivity analysis and model calibration.

4.1 MODEL DOMAIN

The model grid was constructed to cover the Study Area, as shown on Figure 4.1. The grid is composed of 624 rows and 562 columns for a total area of 117.6 square kilometres (km^2). Cells outside the Study Area are designated "inactive." The total active area of the model is approximately 58.2 km^2.

A uniform row and column spacing of 50 m was initially applied across the domain. The grid was refined to 5 m spacing (columns and rows) around the Touquoy open pit and Moose River. This refinement extends across the whole model domain and to all layers.

The model was discretized into ten model layers using the hydrostratigraphic units presented in Figure 4.2. Competent fractured bedrock is divided into eight 20-m-thick layers (Layers 3 through 10) based on the pit bench design and two additional layers below the proposed pit floor, as shown on Figure 4.2.

A cross-section showing the conceptual relationship between Moose River, the open pit, and overburden and weathered bedrock thicknesses is shown on Figure 4.3. As shown on Figure 4.3, Moose River is interpreted to occur within the overburden materials, which are 4 to 6 m thick. Moose River is approximately 0.6 m deep, and 13.5 m wide, based on aquatic habitat surveys conducted in this area.
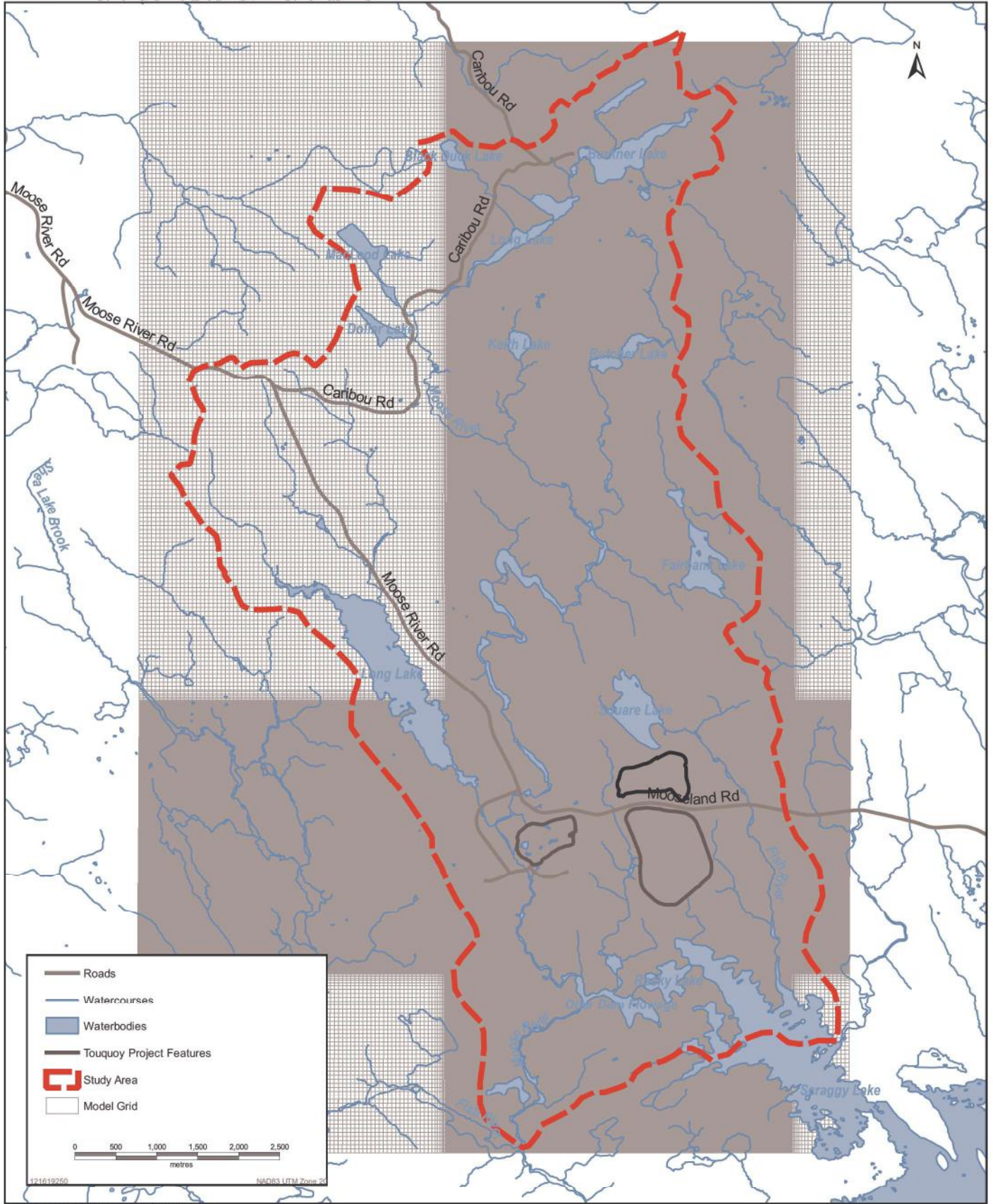
Study Area and Model Grid

Figure 4.1

Stantec

TOUQUOY GOLD PROJECT

Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

Model Construction and Calibration
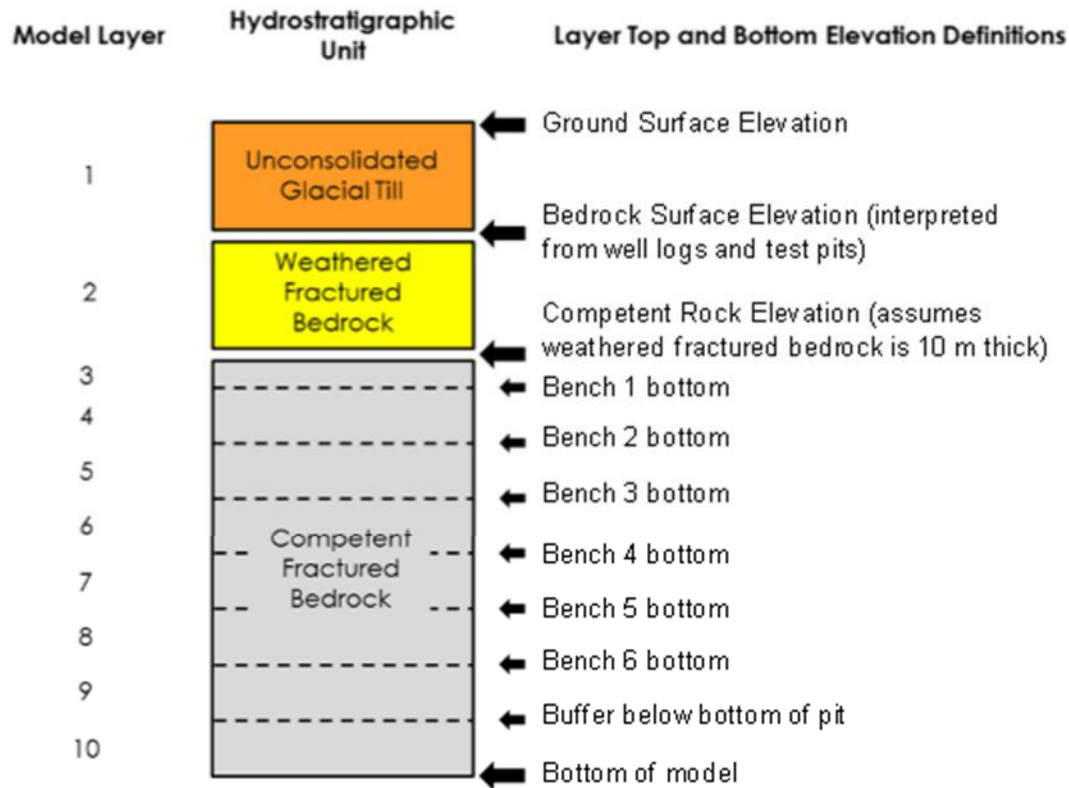
Figure 4.2   Model layer top and bottom elevation definitions and hydrostratigraphy
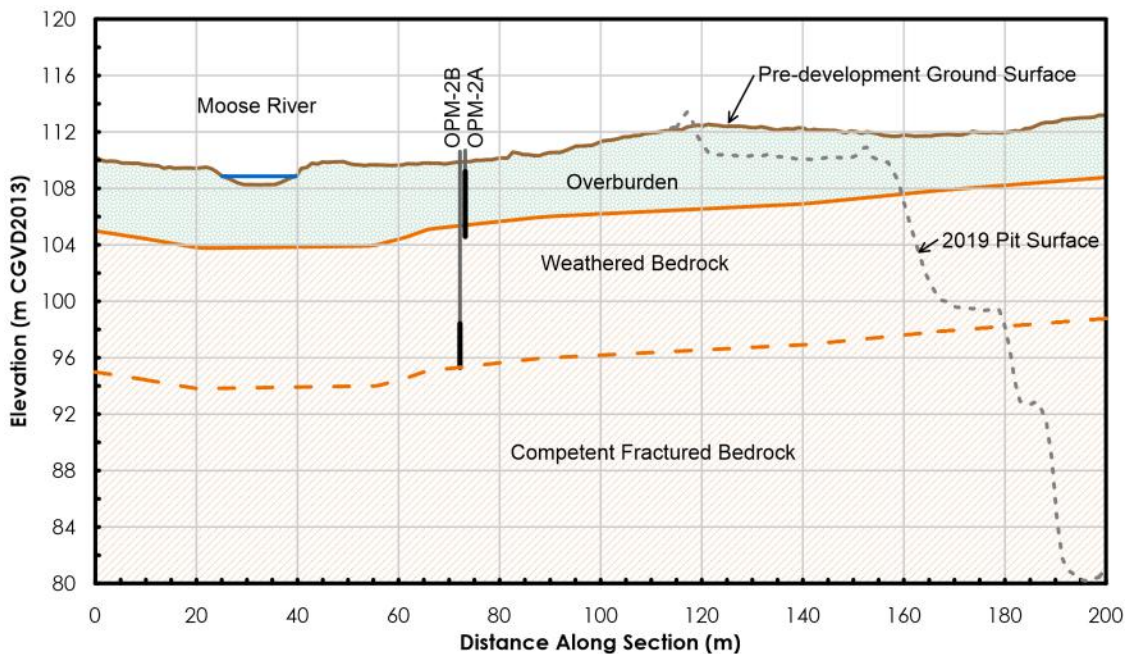
Figure 4.3   Cross-section between Moose River and Open Pit at OPM-2A/B

4.2   DISTRIBUTION OF HYDROGEOLOGICAL PARAMETERS

The hydraulic conductivity, porosity, and recharge rate were assigned in the model based on the hydrostratigraphic units as defined in the conceptual model. The geometric mean hydraulic conductivity values for each unit determined from the field testing programs were used in the initial model set-up, and the hydrostratigraphic units were assumed to be uniform and isotropic. The bulk hydraulic conductivity of the isotropic bedrock hydrostratigraphic units are interpreted to include the fractures and faults described in Section 3.3.2.

4.3   BOUNDARY CONDITIONS

4.3.1   Model Boundary

The model limits were assigned based on local watershed boundaries but were extended into neighbouring watersheds based on anticipated effects from the presence of the Open Pit . The model was extended to natural hydrologic/hydrogeologic boundaries, including watershed boundaries (assumed to be coincident with groundwater flow divides) or surface water features (also assumed to be coincident with groundwater flow divides). The model domain limits are presented on Figure 2.1.

Surface elevations were derived from the LiDAR-derived digital elevation model (DEM) data obtained from GeoNova (2020). The bedrock surface was derived from on-site boreholes and test pits, and from the Nova Scotia drill hole database (Nova Scotia Department of Natural Resources 2016) for off-site exploration boreholes. A minimum overburden thickness of 1 m was assigned in the model.

4.3.2   Recharge and Evapotranspiration

The type of soil and vegetation present at surface is an important factor in determining whether precipitation will become runoff or groundwater recharge. Recharge rates were assigned based on the hydrostratigraphic units exposed at the top of the model domain and consideration of the surficial geology mapping for the area. The groundwater recharge rate was adjusted for each of these major groups during the model calibration process. However, at the end of calibration, the recharge was found to be relatively uniform, so a uniform recharge rate was specified for the entire model domain. Recharge rates were specified for average annual and average summer conditions.

Evapotranspiration was also assigned to the model domain, using a uniform rate representing average annual and average summer conditions. An extinction depth of 1 m was specified for the evapotranspiration rates. Evapotranspiration was adjusted with the recharge rate during the model calibration.

4.3.3   Lakes

Several lakes and watercourses are located within the model domain. Lakes were assigned as boundary conditions in the model using a head-dependent flux boundary (i.e., general head boundary), as shown on Figure 4.4. This type of boundary conditions determines the flow rate between the boundary condition and the aquifer based on the head assigned to the boundary condition. The vertical extent of the lakes was determined using available bathymetric data collected at the lakes, and the reference head for each cell was obtained from the digital elevation model.

Caribou Rd

Caribou Rd

Black Duck Lake

Buckner Lake

Moose River Rd

Long Lake

Moose River Rd

MacLeod Lake

Caribou Rd

Dollar Lake

Keith Lake

Butcher Lake

Caribou Rd

Moose River

Tea Lake Brook

Fairbank Lake

Moose River Rd

Long Lake

Square Lake

Mooseland Rd

Fish River

Legend

- Roads
- Watercourses
- Waterbodies
- Touquoy Project Features
- Study Area
- Model Grid

Surface Water Boundary Conditions

- General Head Boundary
- River Boundary

Rocky Lake

Otter Dam Flowage

Moose River

Fish River

Scraggy Lake

0   500   1,000   1,500   2,000   2,500

metres

121619250

NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

Surface Water Boundary Conditions

Stantec

TOUQUOY GOLD PROJECT

Figure 4.4

The interaction between the surface water in the lakes and the groundwater in the underlying aquifers is defined by a "conductance" term. This term represents the presence of a layer of sediment on the lakebed or streambed that can affect the rate of water transferred between the lake or watercourse and the underlying model layer. The conductance term was used as a calibration parameter.

4.3.4   Watercourses

Watercourses in the groundwater model are assigned to Layer 1 using the River package. The river package allows water to exit the groundwater system when the head in the aquifer is greater than the assigned head (stage) of the river, and allows water to enter the groundwater system with the head in the aquifer is lower than the assigned stage of the river. The rivers were divided into two types within the model, based on river width estimates obtained from satellite imagery. River cells define most stream and river reaches in the domain, and with the exception of Moose River, were assigned an assumed width of up to 3 m and depth of 0.3 m.

Moose River was represented using a combination of river cells and general head boundary cells. The river cells define run and shallow pool reaches of Moose River, and were assigned widths of 8 m and depths of 1 m, except in the area of the Touquoy open pit where additional information on stream width and depth were collected from field observations collected in 2020. Larger and deeper pool areas in Moose River ware represented using a general head boundary condition, based on mapping provided in the Nova Scotia Hydrographic Network (Province of Nova Scotia 2020). The widths for these areas were determined from the mapped extent of the river reaches, and the depths based on a minimum depth of 1 m, or based on field observations of stream depths under average annual or average summer conditions.

The riverbed conductance term was also assigned to the river cells and was used as a calibration parameter. The default conductance term was assigned based on the hydraulic conductivity of the underlying overburden material.

4.3.5   Touquoy Open Pit

The extent of the Open Pit in August 2019 was assigned to the model for the calibration to average annual and average summer conditions observed in 2019. A 3D surface representing the pit shell that was provided by AMNS for inclusion in the model.

Model cells that were intersected by the walls or floor of the open pit were identified and assigned as a seepage face boundary condition in the model using the MODFLOW DRAIN package. The conductance of the DRAIN cells was specified based on the hydraulic conductivity in the cells multiplied by the width, length and thickness of the cell. Blasting effects on the hydraulic conductivity of the bedrock were assumed to be localized to the first 5 m of the exposed bedrock face, coinciding with the width of the drain cells, and were incorporated as part of the conductance value for the drains. The conductance was adjusted during the model calibration to match average summer and average annual pit inflow rates.

4.4   CALIBRATION

4.4.1   Calibration Methodology

The groundwater model was calibrated to known conditions at the Touquoy open pit in 2019. Model calibration was conducted using an iterative approach under steady-state conditions representing average annual and average summer flow conditions. This involved a process where a flow simulation was carried out, the resulting groundwater levels and baseflow rates to watercourses were compared to measured values, and the model input parameters were re-adjusted to achieve better agreement with observed (field measured) conditions and the overall interpreted groundwater flow directions. The process of model calibration involves the adjustment of model parameter values to match field-measured values within a pre-established range of error. A hybrid calibration approach was used that combined automated parameter estimation, facilitated using the Parameter Estimation (PEST) code (Doherty 2018), together with professional judgement and interpretation of the calibration results.

The calibration was completed using the following steps:

1. Prepare model files and input parameters
2. Run PEST to estimate parameter values that provide the best average fit to the observations
3. Review the model results
4. Adjust insensitive parameters from the PEST calibration (if any can be identified)
5. Repeat steps 2 through 4 until the model is determined to be adequately calibrated within acceptable ranges of error

Several parameters were adjusted during the calibration of the model, including:

- Horizontal hydraulic conductivity
- Vertical hydraulic conductivity
- Recharge
- Evapotranspiration
- Riverbed and lake bed conductance

These parameters were adjusted automatically using PEST over the ranges determined from field observations or literature values. A total of 38 parameters were adjusted during the calibration process.

4.4.2   Calibration to Water Levels

Model calibration was assessed by comparing model simulated water levels to observations collected from water level data collected from onsite monitoring wells (Stantec 2020). The water level target at each location was calculated as the average annual and average summer water level observed during 2019 for each location. Water well records had only one water level measurement from the time of completion and were considered the least reliable measurements in the calibration process. Water level observations from onsite wells were considered the most reliable as they have a longer period of record under current land use conditions and varying climatic conditions and provide an average water level appropriate for calibration of a steady state groundwater flow model. The calculated water level targets are presented in Table 4.1 for average annual conditions, and in Table 4.2 for average summer conditions. The locations of the 66 monitoring wells (in 33 well nests) used for water level targets are shown on Figure 4.5.

N

PLM-5A/B

PLM-1A/B

WRW-1A/B
WRW-2A/B
WRW-3A/B

PLM-2A/B
PLM-4A/B

OPM-4A/B
PLM-3A/B

WRW-5A/B
WRW-4A/B

6749
TMW-14A/B

6719
OPM-5A/B
OPM-7A/B
TMW-11A/B

OPM-3A/B
TMW-10A/B
TMW-9A/B
TMW-1A/B

OPM-2A/B
TMW-8A/B
TMW-2A/B

OPM-6A/B
TMW-3A/B

SW-2
TMW-7A/B

TMW-12A/B
TMW-4A/B

TMW-15A/B

TMW-16A/B
TMW-5A/B

TMW-6A/B

TMW-13A/B

Legend

— Roads

— Watercourses

Waterbodies

— Touquoy Project Features

Study Area

Calibration Targets

▽ Surface Water Flow Target

⊕ Groundwater Level Target

0   250   500   750   1,000   1,250
metres

121619250   NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Fairbank Lake

Square Lake

Long Lake

Moose River

Fish River

Fish River

Watercourse #4

Moose River

Rocky Lake

Otter Dam Flowage

Scraggy Lake

Location of Calibration Targets

Stantec

Touquoy Gold Project

Figure 4.5

Model Construction and Calibration

Table 4.1   Water Level Calibration Residuals and Statistics for Average Annual 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
PLM-1A	131.302	132.092	-0.790	Monitoring Well
PLM-1B	128.546	130.726	-2.179	Monitoring Well
PLM-2A	119.447	117.855	1.592	Monitoring Well
PLM-2B	118.791	118.279	0.512	Monitoring Well
PLM-3A	129.148	128.380	0.769	Monitoring Well
PLM-3B	125.498	126.945	-1.447	Monitoring Well
PLM-4A	125.487	124.084	1.403	Monitoring Well
PLM-4B	124.509	124.720	-0.210	Monitoring Well
PLM-5A	126.076	127.842	-1.765	Monitoring Well
PLM-5B	126.098	128.038	-1.940	Monitoring Well
WRW-1A	131.132	129.074	2.058	Monitoring Well
WRW-1B	130.796	129.099	1.698	Monitoring Well
WRW-2A	133.852	129.600	4.253	Monitoring Well
WRW-2B	133.302	130.596	2.706	Monitoring Well
WRW-3A	124.903	128.020	-3.118	Monitoring Well
WRW-3B	125.840	128.407	-2.568	Monitoring Well
WRW-4A	129.504	127.155	2.349	Monitoring Well
WRW-4B	125.834	126.883	-1.050	Monitoring Well
WRW-5A	120.117	119.702	0.415	Monitoring Well
WRW-5B	120.027	119.562	0.465	Monitoring Well
OPM-1A	107.246	107.367	-0.121	Monitoring Well
OPM-1B	106.788	107.338	-0.550	Monitoring Well
OPM-2A	109.074	108.926	0.148	Monitoring Well
OPM-2B	102.597	104.701	-2.103	Monitoring Well
OPM-3A	114.914	114.155	0.759	Monitoring Well
OPM-3B	114.825	114.157	0.668	Monitoring Well
OPM-4A	113.140	113.795	-0.655	Monitoring Well
OPM-4B	113.315	113.800	-0.485	Monitoring Well
OPM-5A	117.556	117.508	0.047	Monitoring Well
OPM-5B	118.055	117.390	0.665	Monitoring Well
OPM-6A	114.514	113.728	0.787	Monitoring Well
OPM-6B	114.678	113.581	1.097	Monitoring Well

Table 4.1   Water Level Calibration Residuals and Statistics for Average Annual 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
OPM-7A	115.464	118.117	-2.653	Monitoring Well
OPM-7B	115.525	118.097	-2.572	Monitoring Well
TMW-1A	115.550	114.455	1.096	Monitoring Well
TMW-1B	115.570	114.517	1.053	Monitoring Well
TMW-2A	113.753	112.612	1.141	Monitoring Well
TMW-2B	113.538	112.687	0.851	Monitoring Well
TMW-3A	108.800	109.862	-1.061	Monitoring Well
TMW-3B	108.707	109.865	-1.158	Monitoring Well
TMW-4A	107.399	108.198	-0.800	Monitoring Well
TMW-4B	107.514	108.199	-0.685	Monitoring Well
TMW-5A	107.346	109.007	-1.661	Monitoring Well
TMW-5B	107.406	108.973	-1.568	Monitoring Well
TMW-6A	105.002	105.721	-0.719	Monitoring Well
TMW-6B	104.849	105.668	-0.819	Monitoring Well
TMW-7A	108.226	109.417	-1.191	Monitoring Well
TMW-7B	107.879	109.475	-1.596	Monitoring Well
TMW-8A	108.472	109.213	-0.741	Monitoring Well
TMW-8B	108.516	109.395	-0.879	Monitoring Well
TMW-9A	110.780	111.951	-1.171	Monitoring Well
TMW-9B	110.881	112.086	-1.205	Monitoring Well
TMW-10A	114.339	113.942	0.397	Monitoring Well
TMW-10B	114.301	114.056	0.245	Monitoring Well
TMW-11A	113.739	115.643	-1.905	Monitoring Well
TMW-11B	112.419	115.785	-3.367	Monitoring Well
TMW-12A	113.809	112.737	1.073	Monitoring Well
TMW-12B	115.664	113.145	2.519	Monitoring Well
TMW-13A	109.399	109.047	0.352	Monitoring Well
TMW-13B	106.698	107.807	-1.109	Monitoring Well
TMW-14A	121.484	118.793	2.691	Monitoring Well
TMW-14B	121.084	118.959	2.125	Monitoring Well
TMW-15A	120.942	118.185	2.757	Monitoring Well
TMW-15B	119.068	117.870	1.198	Monitoring Well

Table 4.1   Water Level Calibration Residuals and Statistics for Average Annual 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
TMW-16A	115.719	116.260	-0.541	Monitoring Well
TMW-16B	115.409	115.211	0.198	Monitoring Well
Residual Statistics				
Number of Wells			66	
Sum of Squared Error (m²)			166	
Mean Error (m)			-0.095	
Absolute Mean Error (m)			1.310	
Root Mean Squared Error (m)			1.584	
Normalized Mean Squared Error (%)			5.1	

Table 4.2   Water Level Calibration Residuals and Statistics for Average Summer 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
PLM-1A	130.521	131.932	-1.410	Monitoring Well
PLM-1B	128.246	130.235	-1.989	Monitoring Well
PLM-2A	119.042	117.036	2.006	Monitoring Well
PLM-2B	118.386	117.634	0.752	Monitoring Well
PLM-3A	128.184	126.478	1.706	Monitoring Well
PLM-3B	124.506	124.605	-0.099	Monitoring Well
PLM-4A	124.427	123.834	0.593	Monitoring Well
PLM-4B	124.089	123.952	0.136	Monitoring Well
PLM-5A	125.976	126.173	-0.197	Monitoring Well
PLM-5B	126.061	126.514	-0.454	Monitoring Well
WRW-1A	130.895	128.802	2.093	Monitoring Well
WRW-1B	130.433	128.850	1.583	Monitoring Well
WRW-2A	133.460	129.100	4.360	Monitoring Well
WRW-2B	132.779	130.212	2.566	Monitoring Well
WRW-3A	124.951	125.874	-0.924	Monitoring Well
WRW-3B	125.735	126.567	-0.831	Monitoring Well

Model Construction and Calibration

Table 4.2   Water Level Calibration Residuals and Statistics for Average Summer 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
WRW-4A	128.501	126.496	2.005	Monitoring Well
WRW-4B	125.349	126.198	-0.849	Monitoring Well
WRW-5A	119.922	119.259	0.662	Monitoring Well
WRW-5B	119.860	119.115	0.745	Monitoring Well
OPM-1A	105.899	107.078	-1.179	Monitoring Well
OPM-1B	105.269	106.758	-1.489	Monitoring Well
OPM-2A	106.478	108.161	-1.684	Monitoring Well
OPM-2B	100.230	103.165	-2.935	Monitoring Well
OPM-3A	113.724	113.148	0.576	Monitoring Well
OPM-3B	113.666	113.151	0.515	Monitoring Well
OPM-4A	112.877	113.303	-0.425	Monitoring Well
OPM-4B	112.909	113.302	-0.393	Monitoring Well
OPM-5A	116.076	116.422	-0.345	Monitoring Well
OPM-5B	117.823	116.399	1.424	Monitoring Well
OPM-6A	113.607	112.119	1.488	Monitoring Well
OPM-6B	113.765	111.932	1.833	Monitoring Well
OPM-7A	114.872	116.288	-1.416	Monitoring Well
OPM-7B	114.939	116.305	-1.366	Monitoring Well
TMW-1A	114.788	113.488	1.300	Monitoring Well
TMW-1B	114.751	113.574	1.177	Monitoring Well
TMW-2A	113.343	112.339	1.003	Monitoring Well
TMW-2B	113.180	112.368	0.812	Monitoring Well
TMW-3A	108.279	109.193	-0.914	Monitoring Well
TMW-3B	108.124	109.207	-1.083	Monitoring Well
TMW-4A	107.157	107.810	-0.653	Monitoring Well
TMW-4B	107.278	107.820	-0.542	Monitoring Well
TMW-5A	107.331	108.224	-0.893	Monitoring Well
TMW-5B	107.343	108.201	-0.858	Monitoring Well
TMW-6A	104.354	105.397	-1.042	Monitoring Well
TMW-6B	104.142	105.367	-1.225	Monitoring Well
TMW-7A	107.961	108.995	-1.035	Monitoring Well
TMW-7B	107.879	109.025	-1.146	Monitoring Well

Model Construction and Calibration

Table 4.2   Water Level Calibration Residuals and Statistics for Average Summer 2019 Conditions

Location	Average Annual Target Water Level (m CGVD2013)	Simulated Average Annual Water Level (m CGVD2013)	Residual (m)	Target Type
TMW-8A	108.415	108.823	-0.407	Monitoring Well
TMW-8B	108.420	108.989	-0.569	Monitoring Well
TMW-9A	110.335	111.594	-1.258	Monitoring Well
TMW-9B	110.659	111.692	-1.032	Monitoring Well
TMW-10A	114.122	113.489	0.634	Monitoring Well
TMW-10B	114.090	113.600	0.490	Monitoring Well
TMW-11A	113.419	115.344	-1.925	Monitoring Well
TMW-11B	112.131	115.479	-3.349	Monitoring Well
TMW-12A	113.345	112.069	1.276	Monitoring Well
TMW-12B	115.664	112.446	3.218	Monitoring Well
TMW-13A	108.720	108.755	-0.035	Monitoring Well
TMW-13B	106.520	107.356	-0.836	Monitoring Well
TMW-14A	120.974	118.035	2.940	Monitoring Well
TMW-14B	120.596	117.797	2.799	Monitoring Well
TMW-15A	120.739	117.870	2.869	Monitoring Well
TMW-15B	118.999	117.324	1.675	Monitoring Well
TMW-16A	115.535	115.904	-0.369	Monitoring Well
TMW-16B	115.272	114.759	0.512	Monitoring Well
Residual Statistics				
Number of Wells			66	
Sum of Squared Error (m²)			155	
Mean Error (m)			0.130	
Absolute Mean Error (m)			1.256	
Root Mean Squared Error (m)			1.531	
Normalized Mean Squared Error (%)			4.6	

A plot of the simulated (modelled) versus observed (measured) groundwater levels is shown in Figure 4.6. A line of best fit (e.g., a line having a slope of 1.0) is shown for comparison. Simulated groundwater levels that match the observed groundwater levels exactly will fall on this line. As shown on Figure 4.6 and in Table 4.1, there is generally good agreement with the automated and manual water level targets.

Model Construction and Calibration
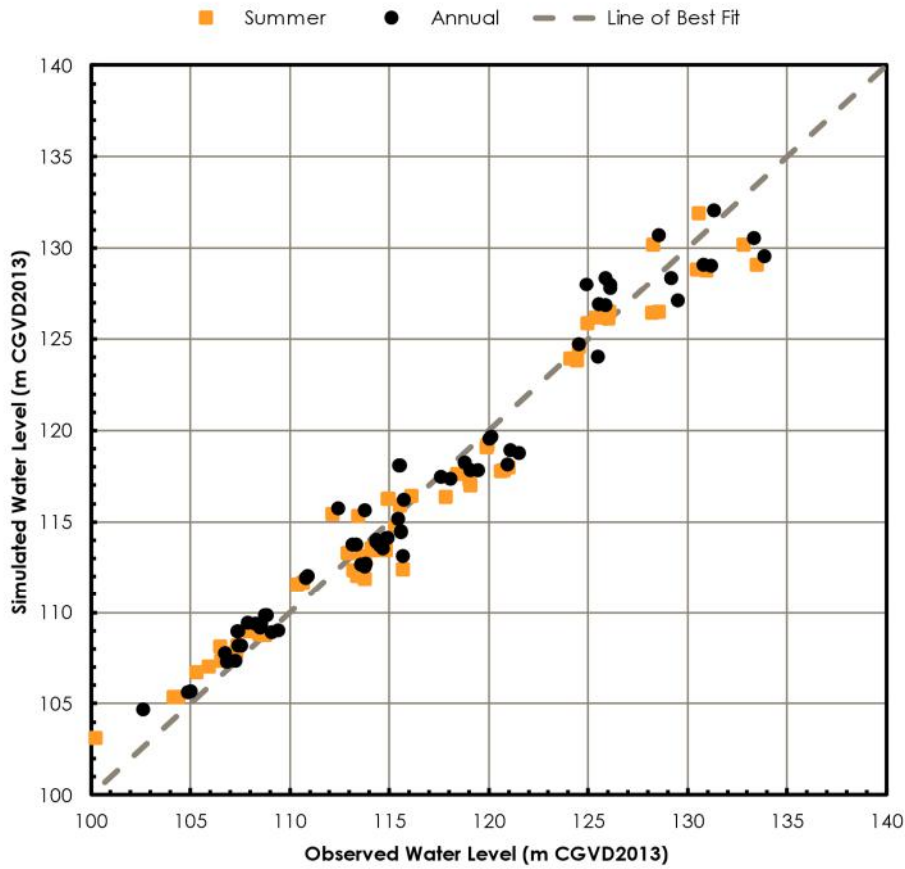
Figure 4.6   Scatterplot Showing the Match of Observed and Simulated Water Levels for Average Annual and Average Summer 2019 Conditions

The statistical measures of the calibration to the water level data are reported in Table 4.1 for average annual conditions, and in Table 4.2 for average summer conditions. These measures include the standard error of the estimate and the root mean squared (RMS) error. In evaluating the fit between the observed and the simulated water levels, the RMS error is usually regarded as the best measure (Anderson and Woessner 1991). The RMS error is essentially a standard deviation calculated as the average of the squared differences between the measured and the simulated water levels. If the ratio of the RMS error to the total water level differential over the model area is small (e.g., less than 10%; Spitz and Moreno 1996), then the errors are only a small part of the overall hydraulic response of the model. In this simulation, the ratio of the RMS errors to the total water level differential (5.2% for average annual and 4.6% for average summer conditions) are less than the recommended 10% threshold.

4.4.3   Calibration to Groundwater Flow Rates

Model calibration was assessed by comparing model simulated groundwater baseflow rates to Moose River, and groundwater inflow rates to the Touquoy open pit for average annual and average summer conditions. Baseflow in Moose River was estimated at SW-2 (see Figure 4.5) using a recursive filtering algorithm (Arnold et al. 1995) to determine baseflow indices for the observed summer and annual river flow rates at SW-2. The baseflow indices and associated baseflow rates are provided on Table 4.3.

Table 4.3   Baseflow Targets in Moose River

Baseflow Period	Baseflow Index	Baseflow Rate (m^3/d)
2019	0.29	28,814
Summer 2019 (July-September)	0.52	9,848

Groundwater inflow rates to the open pits were calculated based on the observed pit dewatering rates at the Open Pit . Groundwater inflow rates for the summer months (i.e., July to September 2019) were estimated based on the dewatering rates, and are presented on Table 4.4. Groundwater inflow rates for the annual conditions were corrected to account for direct precipitation on the open pit.

Table 4.4   Groundwater Inflow Targets to Touquoy Open Pit

Period	Groundwater Inflow Rate (m^3/d)
2019	719
Summer 2019 (July-September)	355

The match of the groundwater flow targets in Moose River and to the Open Pit are presented on Table 4.5. As shown on the table, the groundwater baseflow rates to Moose River are slightly (2%) underpredicted for the average annual condition, but slightly (5%) overpredicted for the summer baseflow period. The average annual pit inflow rates were underpredicted by 3% for the annual conditions, and were overpredicted by 13% for the summer conditions. These are considered good matches the complete set of flow targets and water levels.

Table 4.5   Calibrated Groundwater Inflow Rates

Flow Target	Target Rate (m³/d)	Simulated Rate (m³/d)
Moose River Baseflow 2019 (Annual)	28,814	29,346
Moose River Baseflow Summer 2019 (July-September)	9,848	9,386
Pit Inflow 2019 (Annual)	719	700
Pit Inflow Summer 2019	355	402

4.4.4   Calibrated Model Parameters

The values of the hydrogeologic parameters that were determined from the calibration process are presented in Table 4.6. The hydraulic conductivity values for the various hydrostratigraphic units generated by the model are within the ranges expected for the materials based on measured and literature values.

Table 4.6   Calibrated Model Parameters

Parameter	Value at End of Calibration	Expected Range	
Groundwater Recharge and Evaporatranspiration (mm/yr)			
Annual Recharge	322	135	405
Summer Recharge	123		
Annual Evapotranspiration	85		
Summer Evapotranspiration	97		
Hydraulic Conductivity (m/s)			
Stony Till Plain	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Silt Till Plain	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Organics	1.0×10^{-4}	1.0×10^{-8}	1.0×10^{-4}
Drumlin	4.5×10^{-6}	1.0×10^{-8}	1.0×10^{-4}
Weathered Cunard Member	5.6×10^{-8}	3.9×10^{-9}	4.4×10^{-4}
Weathered Beaverbank Member	3.7×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Taylor's Head Member	3.7×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Tangier & Moose River Members	2.4×10^{-7}	3.9×10^{-9}	4.4×10^{-4}
Weathered Moose River Member	1.3×10^{-8}	3.9×10^{-9}	4.4×10^{-4}
Competent Cunard Member	3.9×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Competent Beaverbank Member	1.1×10^{-8}	3.9×10^{-9}	4.4×10^{-4}
Competent Taylor's Head Member	6.7×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Competent Tangier & Moose River Members	4.9×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Competent Moose River Member	7.4×10^{-9}	3.9×10^{-9}	4.4×10^{-4}
Vertical Anisotropy (K_v/K_h)			
Stony Till Plain	1.0	0.001	5.0
Silt Till Plain	1.0	0.001	5.0

Table 4.6   Calibrated Model Parameters

Parameter	Value at End of Calibration	Expected Range	
Organics	1.0	0.001	5.0
Drumlin	2.0	0.001	5.0
Cunard Member	0.23	0.001	5.0
Beaverbank Member	0.98	0.001	5.0
Taylor's Head Member	4.3	0.001	5.0
Tangier & Moose River Members	0.81	0.001	5.0
Moose River Member	0.30	0.001	5.0
Cunard Member	1.0	0.001	5.0
Beaverbank Member	0.34	0.001	5.0
Taylor's Head Member	1.0	0.001	5.0
Tangier & Moose River Members	0.84	0.001	5.0
Moose River Member	0.53	0.001	5.0

As shown on Table 4.6, the hydraulic conductivity of the overburden units with the exception of the drumlins was at the high-end of the expected range. This may conservatively overestimate the flow into the overburden from groundwater recharge, but provides a reasonable match of water levels in the overburden across the site, and was therefore considered acceptable for this model.

4.4.5   Calibration Uncertainty

An evaluation of the potential uncertainty in the model was conducted by reviewing the relative sensitivity of the parameters adjusted during the calibration to the results of the final calibration. These values were determined using PEST, and are presented on Figure 4.7. The relative sensitivity is provided on a scale from 0 to 1 as a ratio of the sensitivity of the parameter to the calibration of the model, with the sum of the sensitivity values totaling 1. A sensitivity of 0 indicates that varying the parameter does not affect the outcome of the calibration, while a sensitivity approaching 1 indicates that the outcome of the calibration is completely dependent on the value of this parameter.
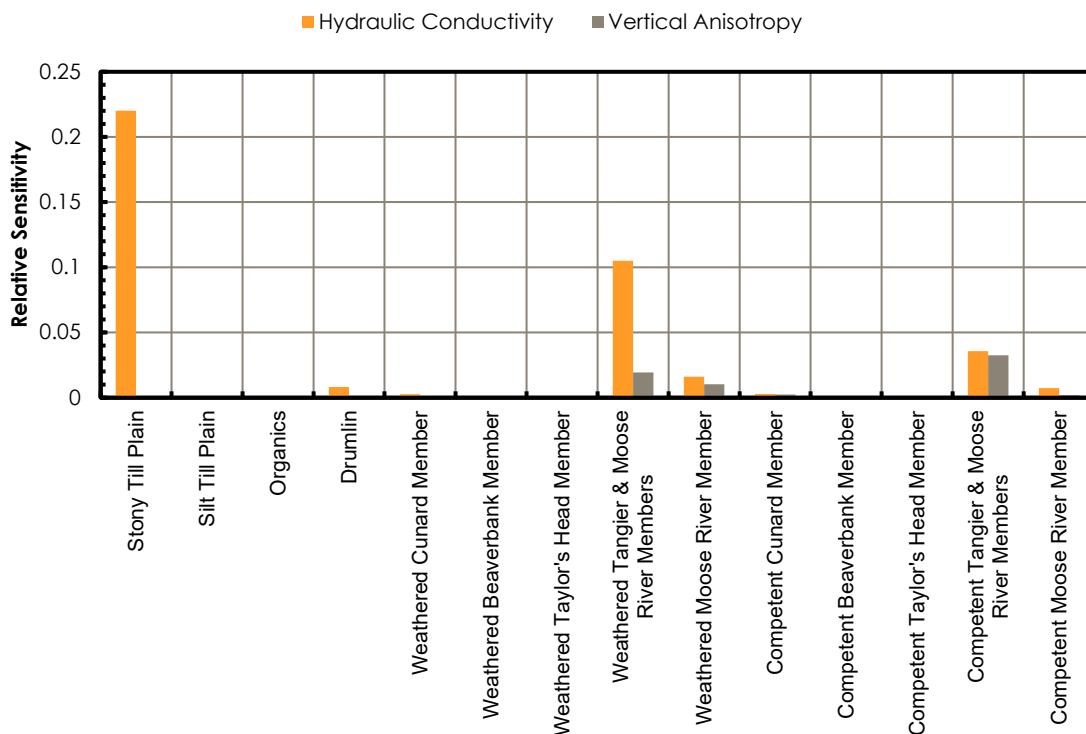
Figure 4.7   Calibration Sensitivity to Parameter Estimates

As shown on Figure 4.7, the model calibration was most sensitive to the hydraulic conductivity within the stony till plain unit (0.23) and the hydraulic conductivity of the weathered Tangier & Moose River Members fractured bedrock units (0.11). While it may be possible to vary the hydraulic conductivity of the shallow bedrock unit, adjusting this parameter away from its calibrated value would also require an alteration to the calibrated recharge rates, which are also sensitive parameters. Therefore, it is not possible to adjust one of these sensitive parameters independently without affecting the calibration of the model. Other parameters varied during the calibration had relatively small effects on the calibration (i.e., the calibration was less sensitive to these parameters over the range adjusted).

4.4.6   Sensitivity to Streambed and Pit Wall Conductance

The sensitivity of the calibrated groundwater baseflow rates to Moose River, and the groundwater inflow rates to the Open Pit to the streambed or pit wall conductance factor were assessed following the calibration. The calibrated conductance factors were multiplied by factors ranging from 0.001 to 10 compared to the baseline conductance rates. The effects of the sensitivities are shown on Figure 4.8. As shown on the figure, the groundwater baseflow rates to Moose River and pit inflow rates do not change significantly from the calibrated rates by increasing the conductance rate by up to a factor of 10, or by decreasing the conductance by a factor of 0.1. Moose River baseflow are observed to decrease when the conductance is decreased by factors below 0.01. This also corresponds to an increase in the pit inflow rates. This is due to the higher groundwater levels that result when the baseflow to Moose River is restricted. The relative stability of the groundwater flow rates when conductance multipliers are greater than 0.1

indicate that the flow to the boundary conditions are controlled more by the hydraulic parameters of the aquifer instead of the conductance assigned to the boundary conditions.
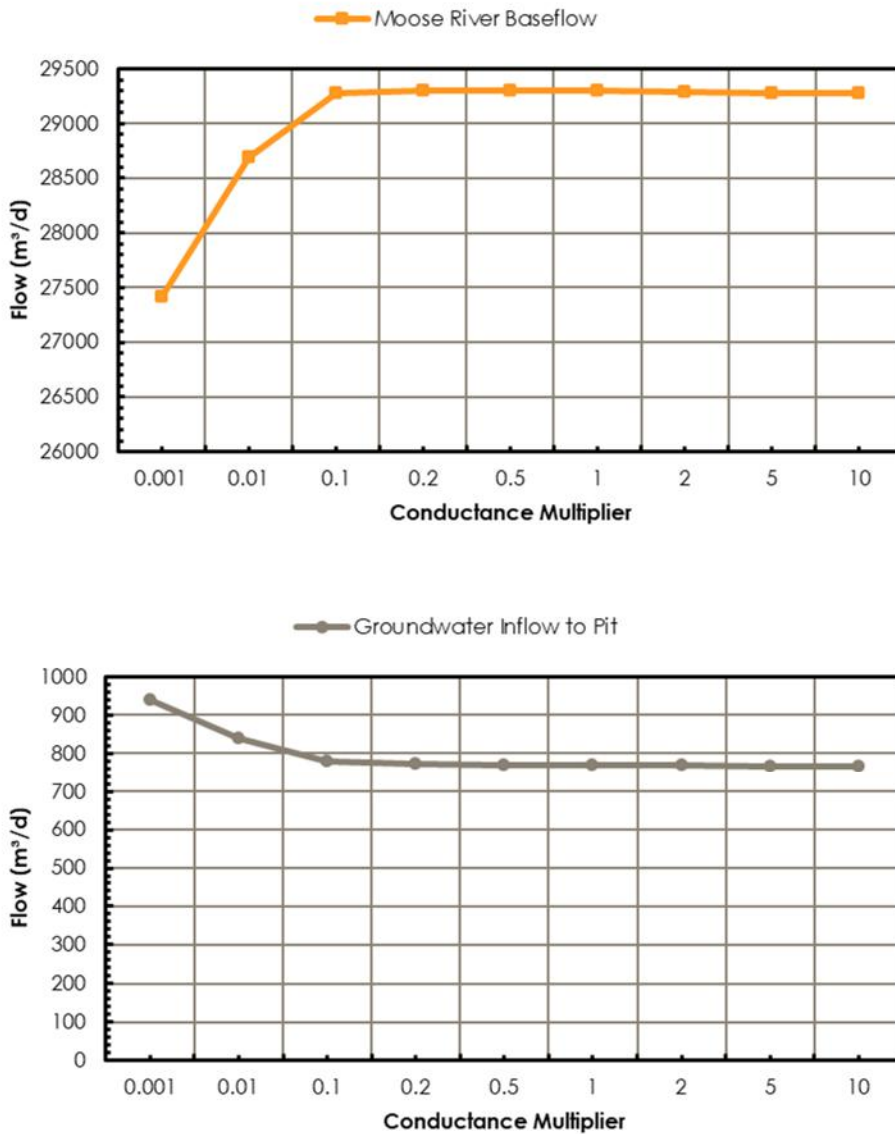
Figure 4.8   Sensitivity of Conductance to Calibrated Groundwater Flow Rates

5.0   MODEL APPLICATIONS

The calibrated groundwater flow model was used to simulate groundwater levels and flow and groundwater discharge to the receiving environment under baseline conditions. The baseline condition is defined as the conditions that will exist prior to disposal of tailings into the Open Pit (i.e., the conditions associated with the fully dewatered Open Pit). The baseline model results were then used to compare model predictions for the end of operation (i.e., the completion of placement of tailings into the Open Pit), during closure (i.e., the filling of the remainder of the open pit with water), and after post-closure (i.e., after the Open Pit is full of water).

Section 5.1 presents the results from the existing conditions simulation using the calibrated model. Model modifications completed to allow simulation baseline conditions, i.e., when the Open Pit is fully dewatered; operating conditions with the deposition of tailings into the open pit; and the post-closure phase following the filling of the open pit are discussed in Sections 5.2 to 5.4.

5.1   PRE-DEVELOPMENT CONDITIONS

5.1.1   Model Setup

The calibrated flow model represents the existing conditions for the Touquoy Mine Site.   This model was adjusted to reflect the pre-development conditions to evaluate the relative changes for drawdown comparisons for the continued operation at the Touquoy Mine site. This was achieved by removing the drain cells boundary condition representing the existing pit conditions used during model calibration. This results in active cells without a specified boundary condition.

5.1.2   Results

The water table elevation under pre-development conditions based on the calibrated groundwater flow model are shown on Figure 5.1. The model provides a good representation of the expected pre-development groundwater flow conditions with groundwater in the area of the Open Pit flowing from the water table high near east of the existing pit toward Moose River.

The model was used to estimate the groundwater discharge to Moose River and its tributaries upstream of surface water monitoring location SW-2. The net baseflow to Moose River at SW-2 is simulated to be 29,845 m^3/d under average annual conditions, and 9,689 under summer conditions. The baseflow rates are used to quantify changes to groundwater discharge during the baseline, operation and closure phases, as presented in Sections 5.2 to 5.4.

Roads

Watercourses

Waterbodies

Touquoy Project Features

Study Area

Water Table Elevation (m)

0   500   1,000   1,500   2,000   2,500
metres
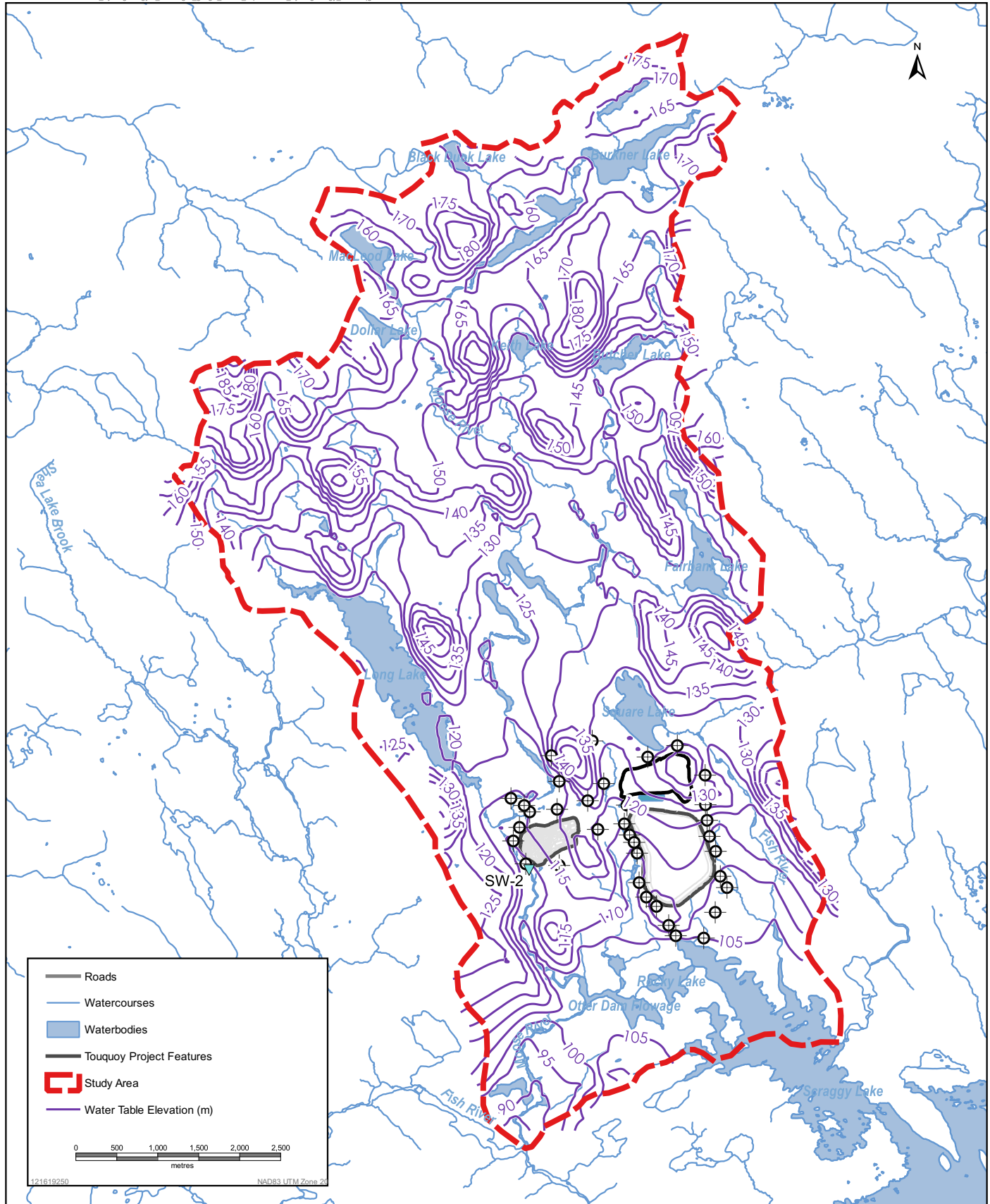
Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Water Table Elevation Contours under Average Annual Pre-Development Conditions

Stantec

TOUQUOY GOLD PROJECT

Figure 5.1

5.2   BASELINE CONDITIONS

5.2.1   Model Setup

Baseline conditions for the operation of the Open Pit as a tailings management area will be the conditions when the Open Pit has been fully excavated and completely dewatered. To simulate these conditions, the model drain cells representing the seepage face boundary condition in the model were adapted to reflect the fully developed open pit, which is approximately 95 m deeper than the existing (i.e., August 2019) pit simulated during calibration. This was run for the average annual conditions to estimate the long-term water table position, and to quantify the baseflow to Moose River and pit inflow rates. The average summer conditions were also run to quantify the baseflow to Moose River and pit inflow rates.

5.2.2   Results

The predicted average annual steady-state groundwater drawdown contours for the average annual baseline conditions are presented on Figure 5.2. The extent of the drawdown cone, as delineated by the 0.5 m drawdown contour, extends approximately 350 m south of the Touquoy pit and about 50 m west of the Touquoy pit toward Moose River.

The pit inflow rates and net baseflow to Moose River at SW-2 are presented on Table 5.1. Compared to the existing conditions, the groundwater inflows to the Open Pit are anticipated to increase by 68 m^3/d (9.5%) on a mean annual basis, and 42 m^3/d (10.4%) on a summer flow basis. The dewatering of the fully-developed open pit is anticipated to reduce the baseflow in Moose River at SW-2 by 49 m^3/d on a mean annual basis, and 29 m^3/d on a summer flow basis.

Table 5.1   Comparison of Baseline to Existing Groundwater Flows (m³/d)

Flow Target	Existing (2019) Conditions	Baseline (Full Depth Pit)
Moose River Annual Baseflow	29,346	29,297
Moose River Summer Baseflow	9,386	9,357
Annual Pit Inflow	700	768
Summer Pit Inflow	402	444

PLM-5A/B

N

PLM-1A/B

Moose River

PLM-2A/B

PLM-4A/B

Watercourse #4

Moose River Rd

PLM-3A/B

OPM-4A/B

6749

OPM-5A/B

Mooseland Rd

6719

OPM-3A/B

OPM-7A/B

10

5

1

0.5

OPM-2A/B

0.5

0.5

OPM-6A/B

OPM-1A/B

SW-2

Moose River

Legend

- Roads
- Watercourses
- Waterbodies
- Touquoy Project Features
- Study Area
- Water Level Drawdown Contours (m)
- ▽ Surface Water Monitor

0 100 200 300 400 500
metres

121619250

NAD83 UTM Zone 20
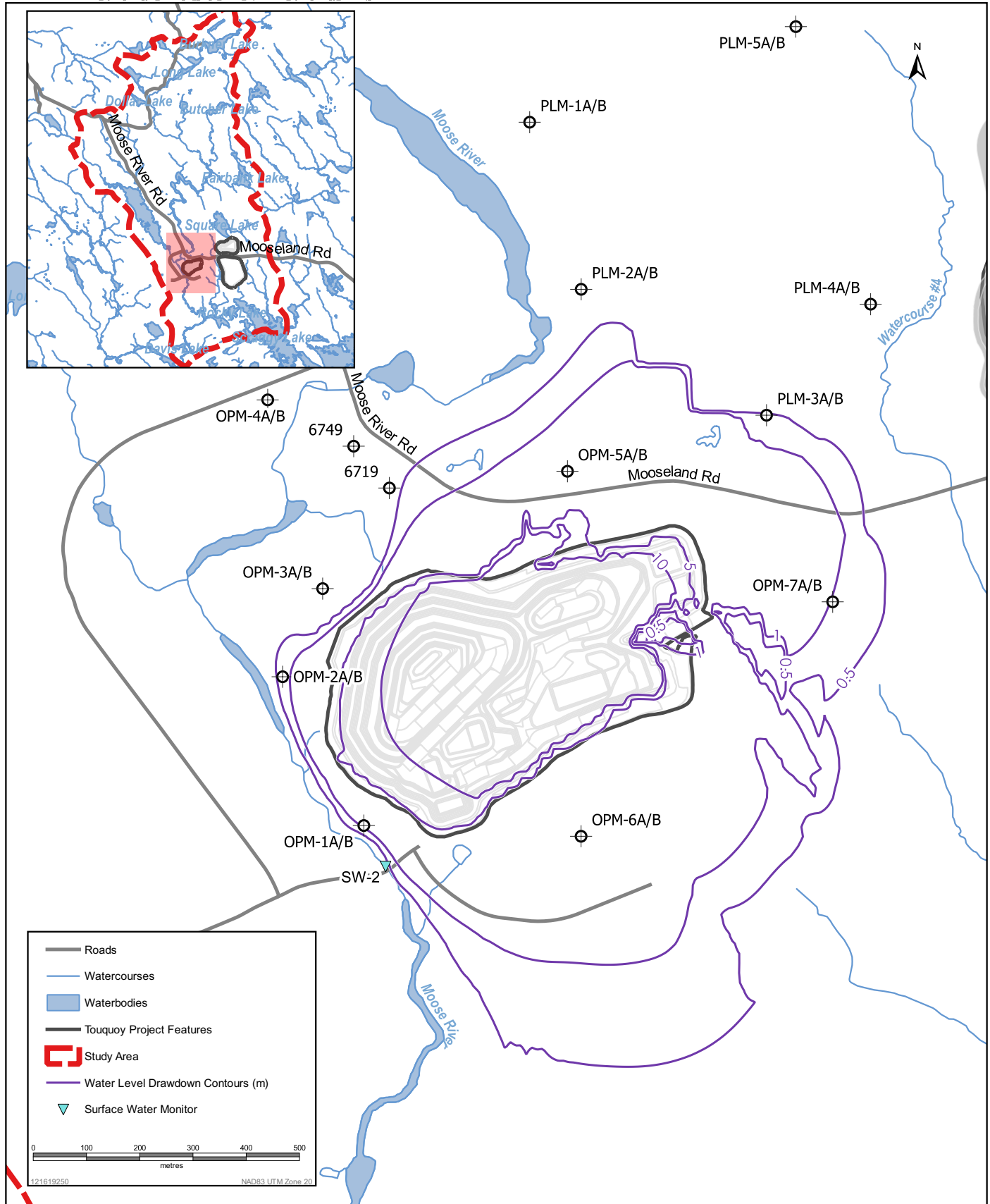
Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

Drawdown at Average Annual Baseline Conditions (Fully Dewatered Pit)

Stantec

TOUQUOY GOLD PROJECT

Figure 5.2

5.3 OPERATION

5.3.1 Model Setup

The operation of the Open Pit as a tailings disposal area will result in the deposition of tailings and associated tailings slurry water to the Open Pit. As the Open Pit fills, the dewatering rate to the Open Pit will decrease. The groundwater inflow to the Open Pit after dewatering is terminated was simulated to provide estimated flow rates for use in the water balance model. Groundwater inflow was simulated by adjusting the stage of the DRAIN cells representing the seepage faces described in Section 5.1, and the addition of tailings to layers below those stages. The stage of the water level forming a pit lake was specified at intervals corresponding to the model layer thicknesses over the entire depth of the open pit by conducting several steady-state runs, one for each model stage, based on the mean annual conditions. The placement of tailings in the Open Pit was assigned using a hydraulic conductivity of 1×10^{-6} m/s. At this value, the flow rates to the Open Pit are governed by the lower pit wall hydraulic conductivity.

5.3.2 Results

The predicted inflow rates to the Open Pit compared to the pit lake stage associated with the deposition of the tailings to the Open Pit are presented on Figure 5.3. As shown on the figure, the inflow rates decrease from 768 m^3/d when the pit stage elevation is at -25 m CGVD2013, to 373 m^3/d at a pit stage of 108 m CGVD2013, at which point the pit lake will overflow to Moose River through an engineered spillway.

The predicted steady-state groundwater drawdown contours for the conditions when the Open Pit is full are presented on Figure 5.4, and the water table contours are presented on Figure 5.5. The extent of the drawdown cone, as delineated by the 0.5 m drawdown contour, extends approximately 350 m south of the site and about 50 m west of the site toward Moose River which is similar to the fully dewatered pit. As presented on Figure 5.3, the groundwater flow to the Open Pit remains at 373 m^3/d because the 108 m CGVD2013 level is below the natural groundwater elevation within the footprint of the Open Pit. However, at this elevation, there are both groundwater inflows to, and outflows from, the Open Pit that are not observed with the fully dewatered Open Pit where no outflows are observed and the inflow condition dominates.

The net baseflow to Moose River at SW-2 under pit full conditions is simulated to be 29,608 m^3/d. Compared to the existing conditions, the groundwater inflows to the Touquoy pit filled to 108 m CGVD2013 is anticipated to increase the baseflow in Moose River at SW-2 by 249 m^3/d.
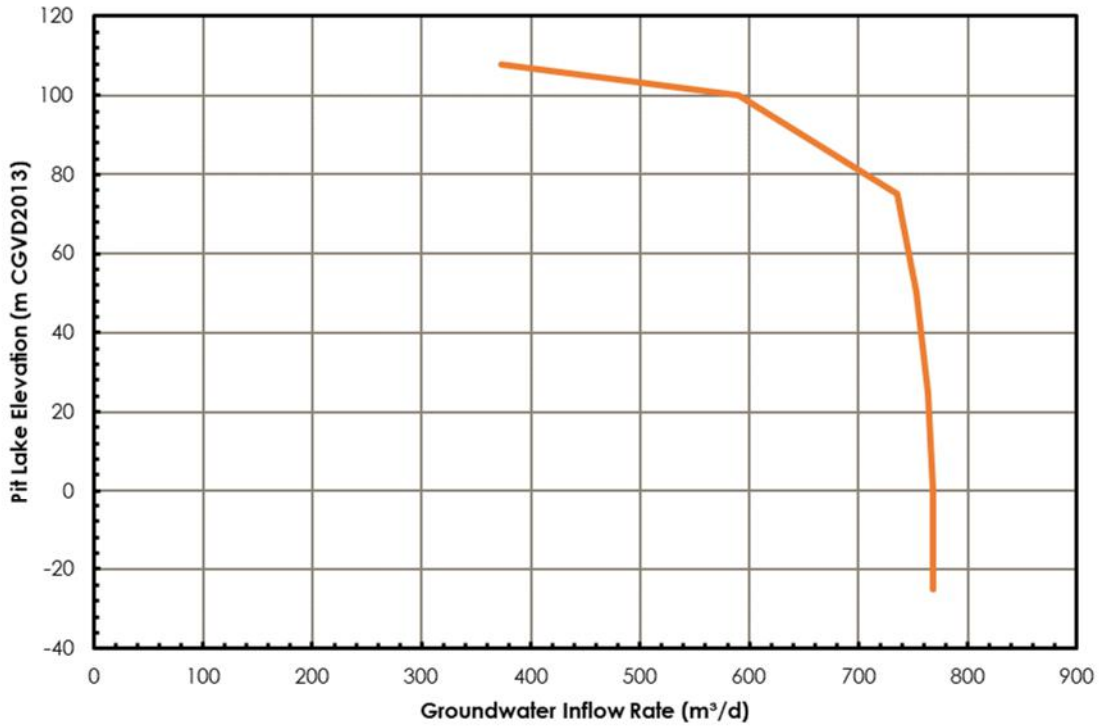
Figure 5.3   Simulated Groundwater Inflow Rates by Pit Lake Stage

N

PLM-5A/B

PLM-1A/B

Moose River

PLM-2A/B

PLM-4A/B

Watercourse #4

PLM-3A/B

OPM-4A/B

Moose River Rd

6749

OPM-5A/B

Mooseland Rd

6719

OPM-7A/B

OPM-3A/B

OPM-2A/B

OPM-1A/B

OPM-6A/B

SW-2

Moose River

Legend

⎯⎯	Roads
⎯⎯	Watercourses
▇	Waterbodies
⎯⎯	Touquoy Project Features
⌐ ⌐	Study Area
⎯⎯	Water Level Drawdown Contours (m)
▽	Surface Water Monitor

0 100 200 300 400 500
metres

121619250

NAD83 UTM Zone 20
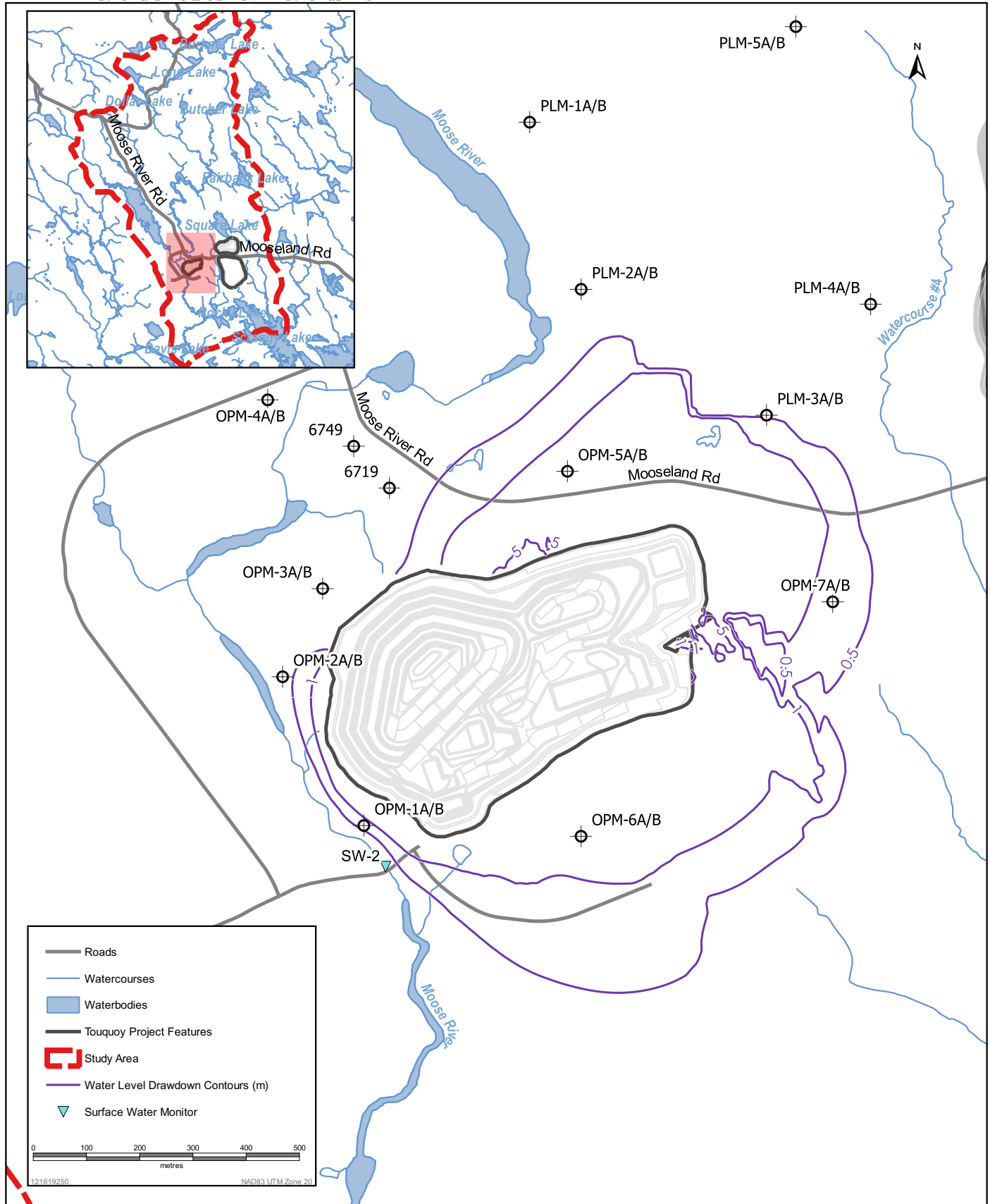
Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

Drawdown Contours with Pit Lake Elevation of 108 m CGVD2013

Stantec

TOUQUOY GOLD PROJECT

Figure 5.4
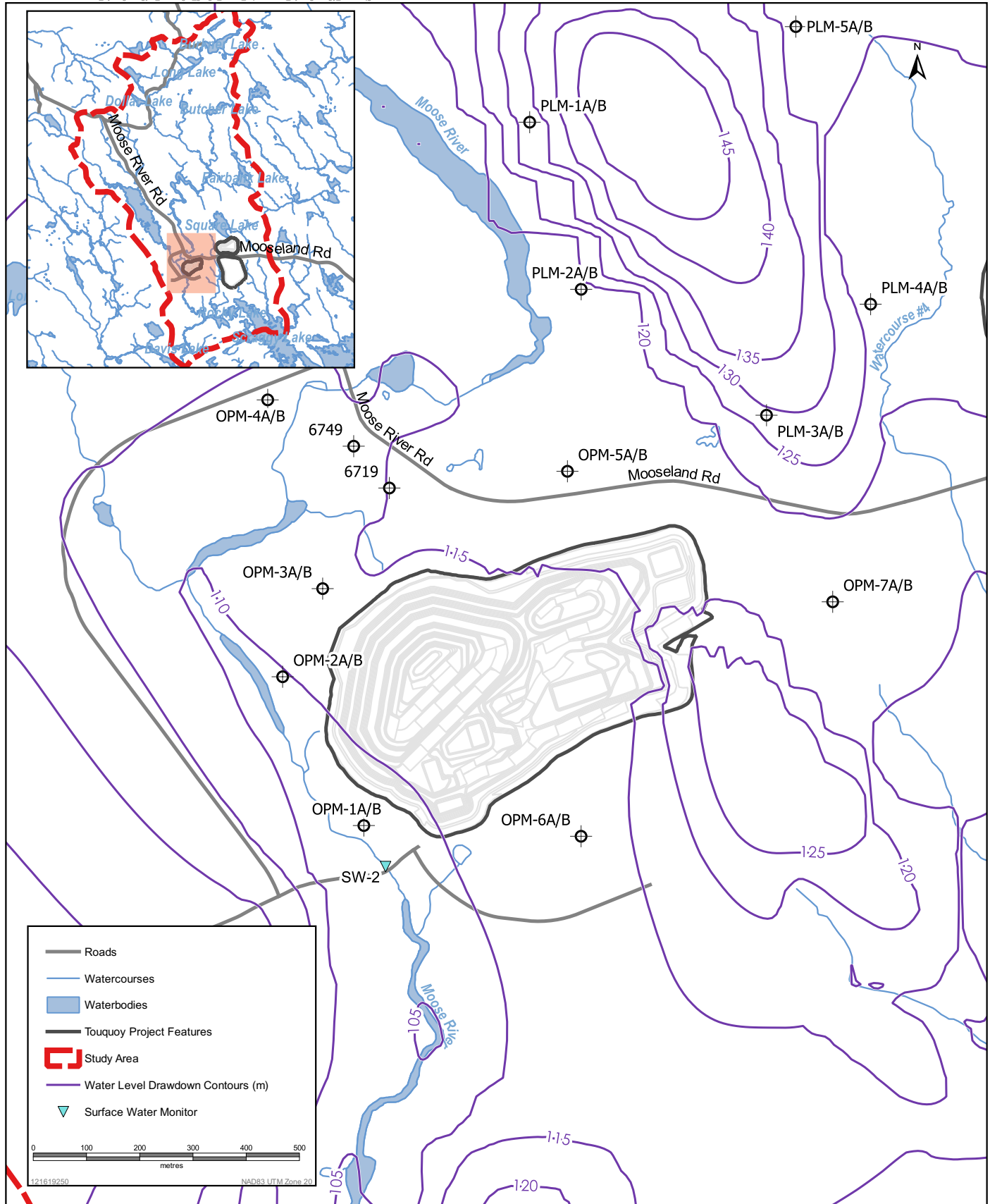
**Water Table Contours with Pit Lake Elevation of
108 m CGVD2013**

Figure 5.5

5.4   POST-CLOSURE

5.4.1   Model Setup

The disposal of tailings in the Open Pit has the potential to degrade the water quality in the Open Pit This water can then migrate from the open pit through groundwater and degrade the water quality in the receiving environments. Therefore, the transport of groundwater from the Touquoy pit to potential receptors was simulated by use of a solute transport model (MT3D-USGS).

The simulation considers the transport of a conservative solute from the water in the Open Pit with a source concentration of 1 mg/L through the groundwater to the receiving environment over time. Solute transport was conducted for a period of 500 years. The solute transport model was set up using the transport parameters shown on Table 5.2. Porosity for each geologic material is based on the mid-range of expected values from the literature. Dispersivity is assumed based on the spatial scale of solute transport. The solute is assumed to have the diffusion coefficient of chloride, a conservative tracer.

Table 5.2   Assigned and calibrated solute transport model parameter values

Parameter	Assigned Value
Porosity	
Overburden Units	0.3
Weathered Bedrock Units	0.1
Competent Bedrock	0.05
Tailings	0.3
Dispersivity (All Geologic Media)	
Longitudinal (m)	5
Transverse and Vertical (m)	1
Solute Species	
Diffusion Coefficient[1] (m^2/s)	1.4×10^{-9}

Notes:

1.   Diffusion coefficient is the product of the free-water diffusion coefficient (2.8×10^{-9} m^2/s for chloride) and an assumed value of tortuosity (0.5).

The water quality associated with the tailings pore water was determined by Lorax Environmental Services (Lorax 2018). The source terms concentrations (mg/L) for various parameters of concern determined by Lorax are presented on Table 5.3. These source terms are multiplied by the relative concentrations generated by the model to estimate the mass loading and average concentrations of groundwater discharging to surface water receptors. The water quality in the Open Pit lake above the tailings were conservatively assumed to have the same quality as the pore water in the tailings.

Model Applications

5.4.1.1   Sensitivity of Solute Transport to Mapped Faults

Several mapped faults were identified on Figure 2.4. As discussed in Section 3.3.2, the hydrogeologic properties of the faults have not been characterized, although water bearing faults in the vicinity of the open pit were identified. As the groundwater flow model was able to calibrate without assigning differing properties in the faults compared to the native bedrock, it is reasonable to expect that the bulk properties of the hydraulic conductivity in the bedrock units from the model are appropriate, as discussed in Section 4.2.

In order to assess the potential impacts from the faults on the predicted water quality loadings to Moose River, the groundwater flow model was modified to include these fault features. The hydraulic conductivity of the fault alignments presented on Figure 2.4 was assigned to be an order of magnitude higher and an order of magnitude lower than the native bedrock, and the flow and transport simulations were re-run to predict the extent of the plume originating from the open pit.

5.4.1.2   Sensitivity of Solute Transport to Bedrock Porosity

The porosity values for bedrock presented on Table 5.2 were adjusted to evaluate the sensitivity of the solute transport results to the porosity in the bedrock. The porosity of the weathered bedrock was assumed to vary from 0.1 to 0.01. The porosity of the competent bedrock was assumed to vary from 0.05 to 0.05 to 0.0001. The average concentrations in Moose River for the various porosity rates used are presented.

5.4.2   Results

The predicted relative concentrations in groundwater originating from the filled open pit are presented on Figures 5.6 to 5.8. The relative concentrations are multiplied by the source term concentrations for the parameters of primary concern in the open pit to predict the concentrations and mass loadings to the receiving environment over time. The distributions of the concentrations after 50 years are shown on Figure 5.6, after 100 years on Figure 5.7, and after 500 years on Figure 5.8. These relative concentrations were multiplied by the source term concentrations for the various parameters of concern provided by Lorax (2018) to estimate the mass loading to, and average concentration in, Moose River over time, as shown on Tables 5.3 and 5.4, respectively.

The average concentrations of arsenic discharged to Moose River over the 500-year simulation period are shown on Figure 5.9. As shown on the figure, the average concentrations of arsenic (and other parameters) in the discharge to the river stabilize after about 150 years.

PLM-5A/B

N

PLM-1A/B

Moose River

PLM-2A/B

PLM-4A/B

Watercourse #4

PLM-3A/B

OPM-4A/B

Moose River Rd

6749

6719

OPM-5A/B

Mooseland Rd

OPM-3A/B

1e-06

0.0001

1e-07

OPM-7A/B

1e-06

1e-05

1e-07

OPM-2A/B

1e-05

1e-05

1e-05

1e-06

OPM-6A/B

OPM-1A/B

1e-05

SW-2

1e-07

Moose River

Legend

- Roads
- Watercourses
- Waterbodies
- Touquoy Project Features
- Study Area
- Surface Water Monitor
- Relative Concentration Contour (mg/L)

0	100	200	300	400	500

metres

121619250

NAD83 UTM Zone 20

Inset map labels:
Long Lake
Dollar Lake
Butcher Lake
Moose River Rd
Fairbank Lake
Square Lake
Mooseland Rd

Relative Concentration Contours in Groundwater 50 Years Following Pit Lake at Stage 108 m
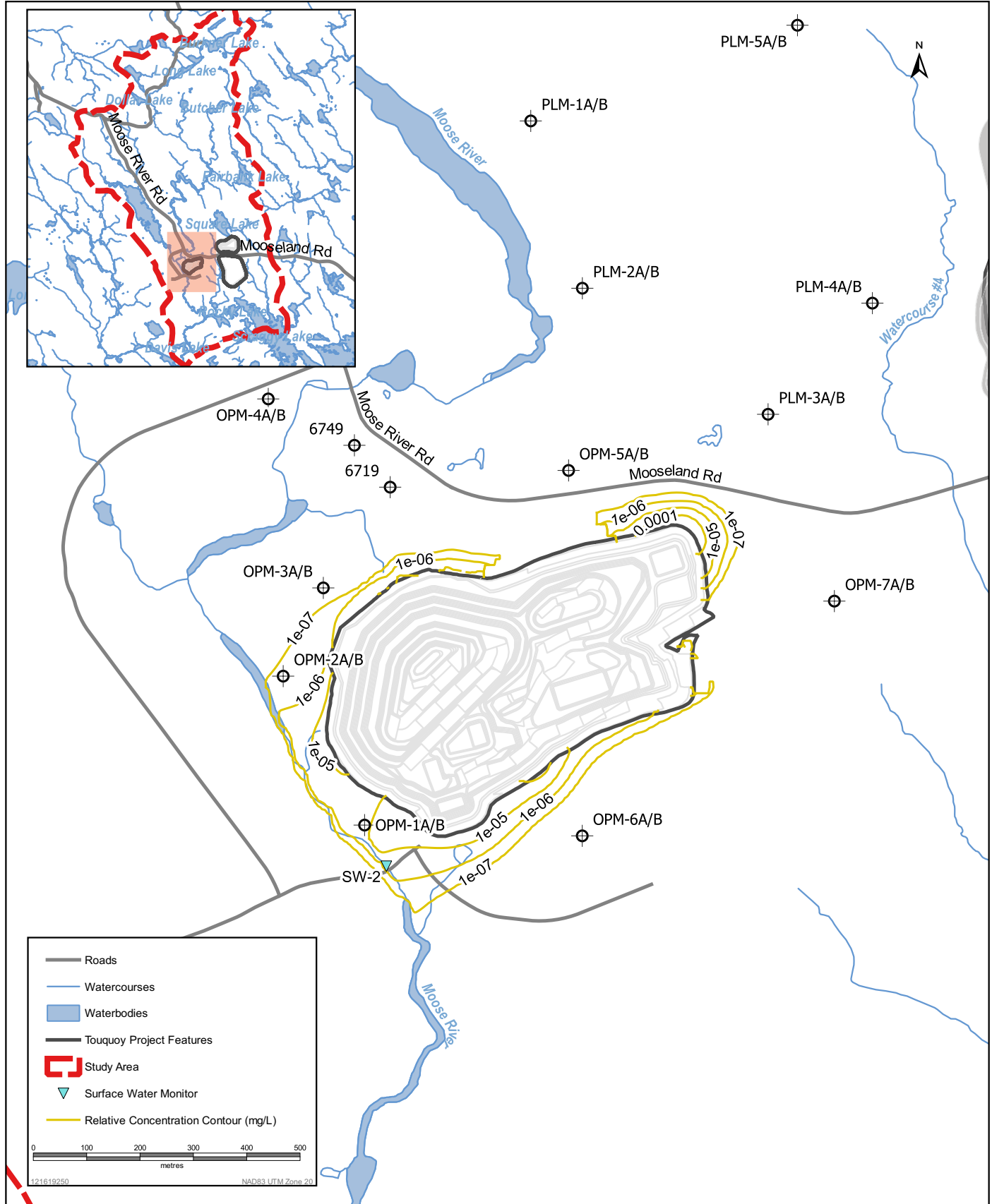
Stantec

TOUQUOY GOLD PROJECT

Figure 5.6

PLM-5A/B

PLM-1A/B

PLM-2A/B

PLM-4A/B

Watercourse #4

PLM-3A/B

OPM-4A/B

6749

Moose River Rd

6719

OPM-5A/B

Mooseland Rd

OPM-3A/B

1e-06

OPM-7A/B

1e-07

1e-06

OPM-2A/B

1e-06

1e-05

1e-06

0.0001

1e-05

1e-07

1e-05

1e-06

OPM-6A/B

OPM-1A/B

SW-2

1e-07

Moose River

Legend

— Roads

— Watercourses

▮ Waterbodies

— Touquoy Project Features

⌐┘ Study Area

▽ Surface Water Monitor

— Relative Concentration Contour (mg/L)

0 100 200 300 400 500
metres

121619250   NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

**Relative Concentration Contours in Groundwater 100
Years Following Pit Lake at Stage 108 m**
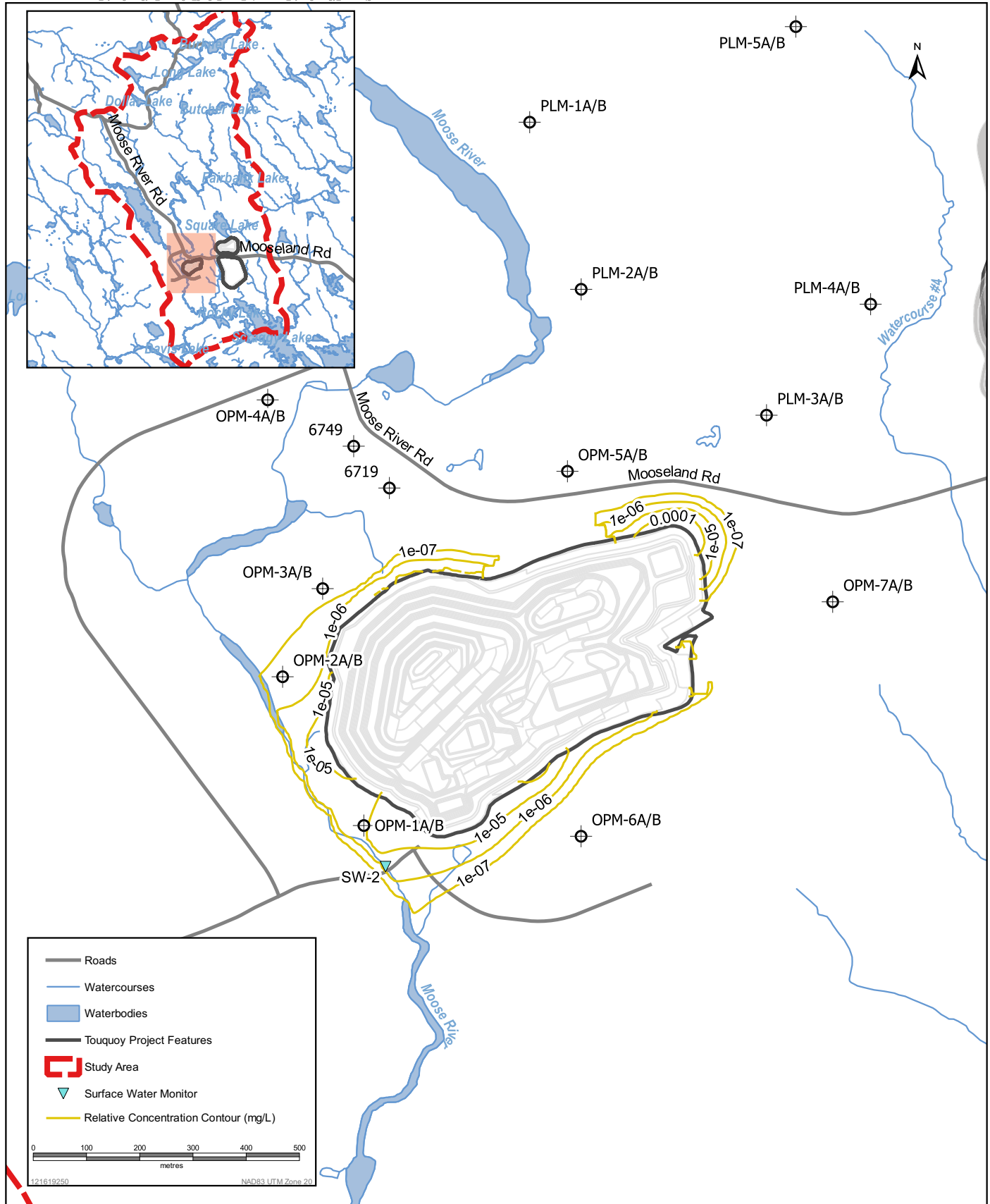
Stantec

TOUQUOY GOLD PROJECT

Figure 5.7

Relative Concentration Contours in Groundwater 500 Years Following Pit Lake at Stage 108 m

Figure 5.8

TOUQUOY GOLD PROJECT

Table 5.3   Predicted Mass Loading to Moose River from Groundwater

Parameter	Source Term Concentration (mg/L)	Mass Loading (g/d)			
Elapsed Time (years)		**10**	**50**	**100**	**500**
Sulphate	897	1.3×10^{-1}	3.3×10^{-1}	3.7×10^{-1}	4.0×10^{-1}
Aluminum	0.0469	6.6×10^{-6}	1.7×10^{-5}	1.9×10^{-5}	2.1×10^{-5}
Silver	0.00001	1.4×10^{-9}	3.7×10^{-9}	4.1×10^{-9}	4.4×10^{-9}
Arsenic	3.07	4.3×10^{-4}	1.1×10^{-3}	1.3×10^{-3}	1.4×10^{-3}
Calcium	86.9	1.2×10^{-2}	3.2×10^{-2}	3.6×10^{-2}	3.8×10^{-2}
Cadmium	0.00002	2.8×10^{-9}	7.3×10^{-9}	8.3×10^{-9}	8.9×10^{-9}
Cobalt	0.0262	3.7×10^{-6}	9.6×10^{-6}	1.1×10^{-5}	1.2×10^{-5}
Chromium	0.0002	2.8×10^{-8}	7.3×10^{-8}	8.3×10^{-8}	8.9×10^{-8}
Copper	0.00937	1.3×10^{-6}	3.4×10^{-6}	3.9×10^{-6}	4.1×10^{-6}
Iron	0.0326	4.6×10^{-6}	1.2×10^{-5}	1.3×10^{-5}	1.4×10^{-5}
Mercury	0.000005	7.0×10^{-10}	1.8×10^{-9}	2.1×10^{-9}	2.2×10^{-9}
Magnesium	14.8	2.1×10^{-3}	5.4×10^{-3}	6.1×10^{-3}	6.6×10^{-3}
Manganese	0.37	5.2×10^{-5}	1.4×10^{-4}	1.5×10^{-4}	1.6×10^{-4}
Molybdenum	0.0603	8.4×10^{-6}	2.2×10^{-5}	2.5×10^{-5}	2.7×10^{-5}
Nickel	0.00685	9.6×10^{-7}	2.5×10^{-6}	2.8×10^{-6}	3.0×10^{-6}
Lead	0.0000248	3.5×10^{-9}	9.1×10^{-9}	1.0×10^{-8}	1.1×10^{-8}
Tin	0.00604	8.4×10^{-7}	2.2×10^{-6}	2.5×10^{-6}	2.7×10^{-6}
Selenium	0.000193	2.7×10^{-8}	7.0×10^{-8}	8.0×10^{-8}	8.5×10^{-8}
Tellurium	0.0000154	2.2×10^{-9}	5.6×10^{-9}	6.4×10^{-9}	6.8×10^{-9}
Uranium	0.00203	2.8×10^{-7}	7.4×10^{-7}	8.4×10^{-7}	9.0×10^{-7}
Zinc	0.0096	1.3×10^{-6}	3.5×10^{-6}	4.0×10^{-6}	4.3×10^{-6}
WAD CN	0.005	7.0×10^{-7}	1.8×10^{-6}	2.1×10^{-6}	2.2×10^{-6}
Total CN	0.087	1.2×10^{-5}	3.2×10^{-5}	3.6×10^{-5}	3.9×10^{-5}
Nitrate (as N)	0.053	7.4×10^{-6}	1.9×10^{-5}	2.2×10^{-5}	2.3×10^{-5}
Nitrite (as N)	0.11	1.5×10^{-5}	4.0×10^{-5}	4.5×10^{-5}	4.9×10^{-5}
Ammonia	34	4.8×10^{-3}	1.2×10^{-2}	1.4×10^{-2}	1.5×10^{-2}

Model Applications

Table 5.4   Predicted Average Groundwater Concentration Discharging to Moose River

Parameter	Source Term Concentration (mg/L)	Average Concentration (mg/L)			
Elapsed Time (years)		**5**	**60**	**150**	**500**
Sulphate	897	4.9×10^{-4}	1.3×10^{-3}	1.4×10^{-3}	1.5×10^{-3}
Aluminum	0.0469	2.5×10^{-8}	6.6×10^{-8}	7.5×10^{-8}	8.0×10^{-8}
Silver	0.00001	5.4×10^{-12}	1.4×10^{-11}	1.6×10^{-11}	1.7×10^{-11}
Arsenic	3.07	1.7×10^{-6}	4.3×10^{-6}	4.9×10^{-6}	5.3×10^{-6}
Calcium	86.9	4.7×10^{-5}	1.2×10^{-4}	1.4×10^{-4}	1.5×10^{-4}
Cadmium	0.00002	1.1×10^{-11}	2.8×10^{-11}	3.2×10^{-11}	3.4×10^{-11}
Cobalt	0.0262	1.4×10^{-8}	3.7×10^{-8}	4.2×10^{-8}	4.5×10^{-8}
Chromium	0.0002	1.1×10^{-10}	2.8×10^{-10}	3.2×10^{-10}	3.4×10^{-10}
Copper	0.00937	5.1×10^{-9}	1.3×10^{-8}	1.5×10^{-8}	1.6×10^{-8}
Iron	0.0326	1.8×10^{-8}	4.6×10^{-8}	5.2×10^{-8}	5.6×10^{-8}
Mercury	0.000005	2.7×10^{-12}	7.1×10^{-12}	8.0×10^{-12}	8.6×10^{-12}
Magnesium	14.8	8.0×10^{-6}	2.1×10^{-5}	2.4×10^{-5}	2.5×10^{-5}
Manganese	0.37	2.0×10^{-7}	5.2×10^{-7}	5.9×10^{-7}	6.4×10^{-7}
Molybdenum	0.0603	3.3×10^{-8}	8.5×10^{-8}	9.6×10^{-8}	1.0×10^{-7}
Nickel	0.00685	3.7×10^{-9}	9.7×10^{-9}	1.1×10^{-8}	1.2×10^{-8}
Lead	0.0000248	1.3×10^{-11}	3.5×10^{-11}	4.0×10^{-11}	4.3×10^{-11}
Tin	0.00604	3.3×10^{-9}	8.5×10^{-9}	9.7×10^{-9}	1.0×10^{-8}
Selenium	0.000193	1.0×10^{-10}	2.7×10^{-10}	3.1×10^{-10}	3.3×10^{-10}
Tellurium	0.0000154	8.4×10^{-12}	2.2×10^{-11}	2.5×10^{-11}	2.6×10^{-11}
Uranium	0.00203	1.1×10^{-9}	2.9×10^{-9}	3.2×10^{-9}	3.5×10^{-9}
Zinc	0.0096	5.2×10^{-9}	1.4×10^{-8}	1.5×10^{-8}	1.6×10^{-8}
Weak Acid Dissociable Cyanide	0.005	2.7×10^{-9}	7.1×10^{-9}	8.0×10^{-9}	8.6×10^{-9}
Total Cyanide	0.087	4.7×10^{-8}	1.2×10^{-7}	1.4×10^{-7}	1.5×10^{-7}
Nitrate (as N)	0.053	2.9×10^{-8}	7.5×10^{-8}	8.5×10^{-8}	9.1×10^{-8}
Nitrite (as N)	0.11	6.0×10^{-8}	1.6×10^{-7}	1.8×10^{-7}	1.9×10^{-7}
Ammonia (as N)	34	1.8×10^{-5}	4.8×10^{-5}	5.4×10^{-5}	5.8×10^{-5}
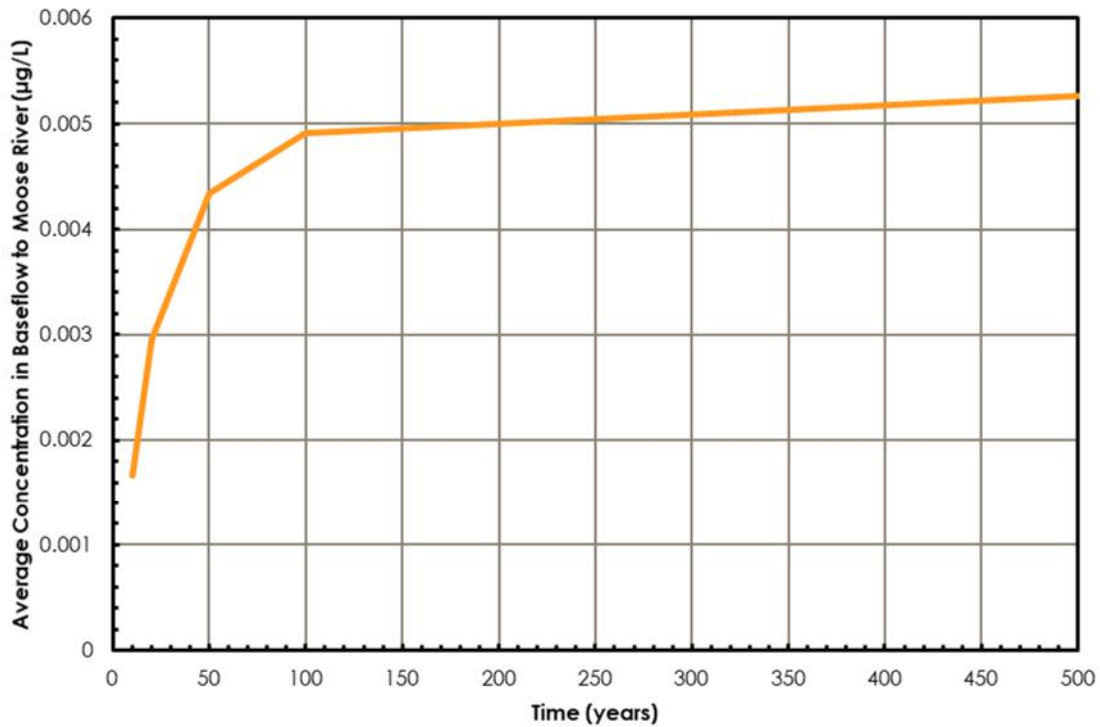
Figure 5.9   Simulated Average Concentrations of Arsenic Discharged to Moose River in Groundwater Seepage

The mass loading and average concentration of the parameters of concern listed in Tables 5.3 and 5.4 are combined with surface water concentrations and discharges from the open pit to predict the water quality in Moose River, as detailed in Stantec (2021).

5.4.2.1   Sensitivity of Solute Transport to Mapped Faults

The sensitivity of the solute transport model to the potential hydraulic conductivity of the mapped faults was assessed by conducting scenarios that considered the faults to be ten times more permeable and ten time less permeable than the calibrated values. The predicted relative concentrations in groundwater originating from the filled Open Pit are presented on Figure 5.10. As shown on Figure 5.10, lowering the permeability of the faults increases the mass loading slightly compared to the values presented in Figure 5.9. This results in more flow (and mass) flowing through the rock matrix than was previously predicted through the faults. However, increasing the hydraulic conductivity of the faults by an order of magnitude significantly increases the predicted concentrations in Moose River. The predicted relative concentrations for the higher permeability faults are presented on Figure 5.11 and Figure 5.12 for 50 and 500 years following the filling of the open pit, respectively. As shown on Figure 5.10, the addition of higher permeability faults indicates that solute transport may proceed more quickly to Moose River than simulated in the case without higher permeability faults (i.e., Figure 5.6).
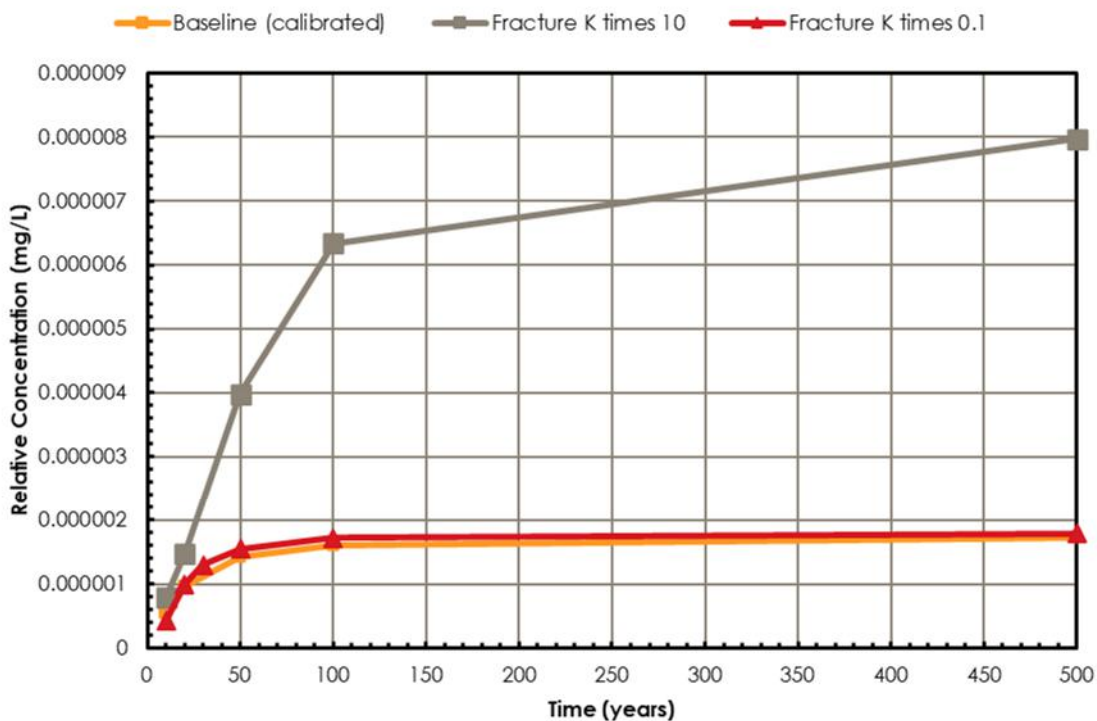
Figure 5.10   Sensitivity of Fracture Hydraulic Conductivity on Relative Concentrations in Moose River
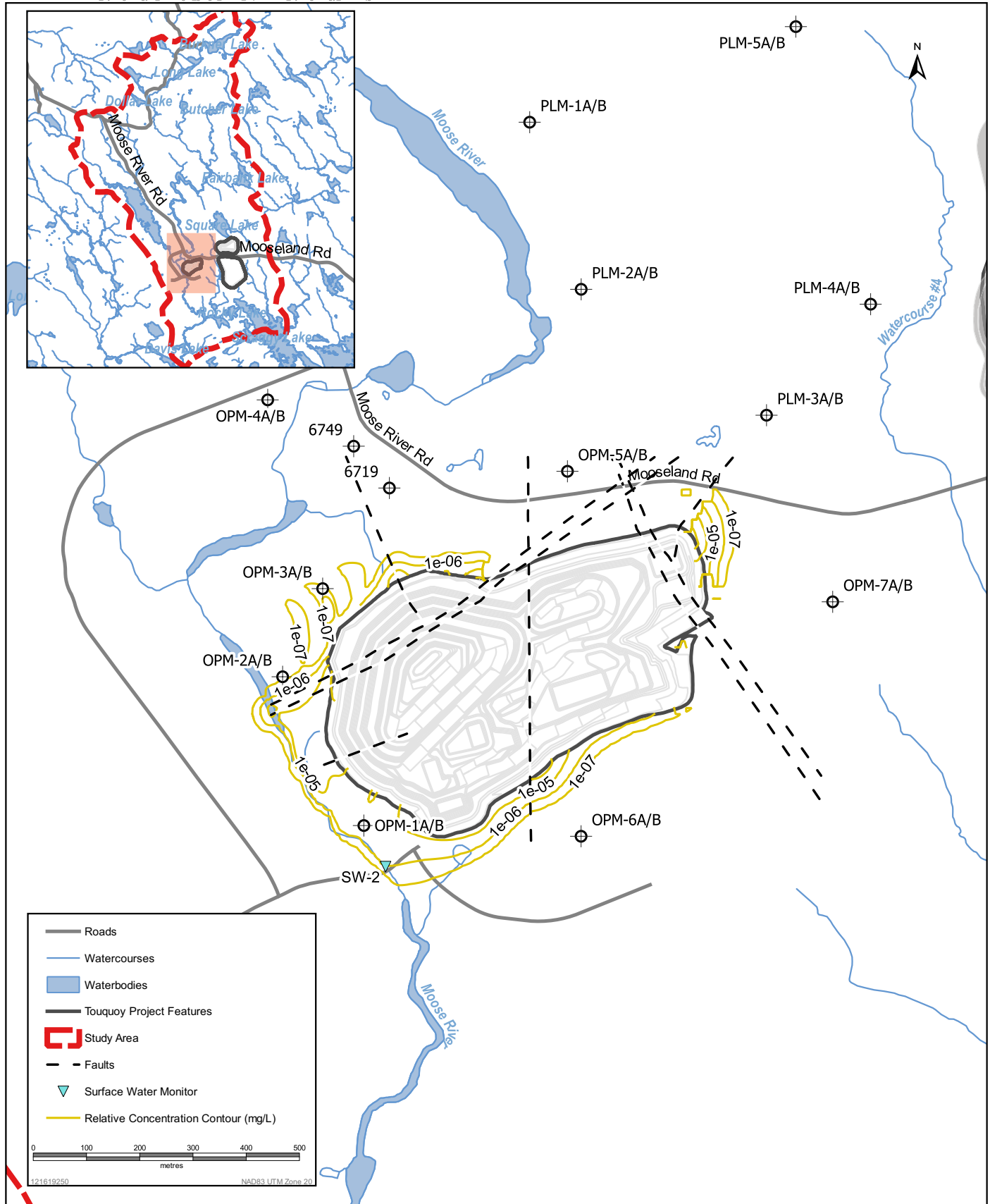
Relative Concentration Contours in Groundwater with High
Permeability Faults 50 Years Following Pit Lake at Stage 108 m
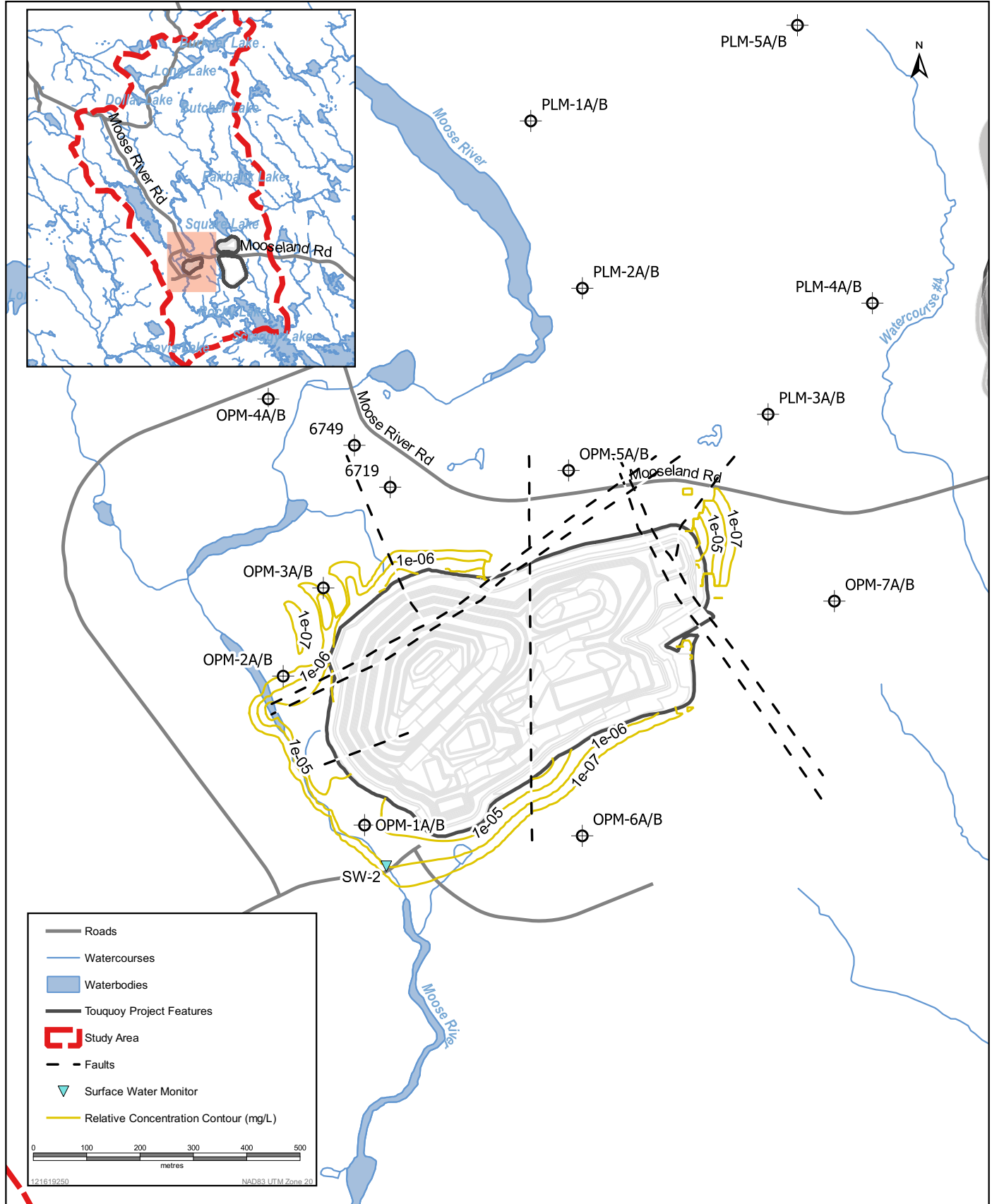
Figure 5.11

TOUQUOY GOLD PROJECT

PLM-5A/B

PLM-1A/B

Moose River

PLM-2A/B

PLM-4A/B

Watercourse #4

PLM-3A/B

OPM-4A/B

6749

Moose River Rd

OPM-5A/B

Mooseland Rd

6719

1e-07

1e-05

OPM-3A/B

1e-06

OPM-7A/B

1e-07

1e-06

OPM-2A/B

1e-06

1e-05

1e-06

1e-07

OPM-1A/B

1e-05

OPM-6A/B

SW-2

Moose River

Legend

———	Roads
———	Watercourses
▨	Waterbodies
———	Touquoy Project Features
▭	Study Area
– – –	Faults
▽	Surface Water Monitor
———	Relative Concentration Contour (mg/L)

0   100   200   300   400   500
metres

121619250   NAD83 UTM Zone 20

Sources: Base Data - GeoNova, Atlantic Mining NS Inc.

**Relative Concentration Contours in Groundwater with High
Permeability Faults 500 Years Following Pit Lake at Stage 108 m**

Stantec

TOUQUOY GOLD PROJECT

Figure 5.12

Model Applications

Based on the sensitivity of the mapped faults to the predicted water quality in Moose River, there is the potential for additional mass to migrate toward Moose River. However, because the predicted concentrations shown on Figures 5.11 and 5.12 remain low (i.e., below detection limits), this transport is not expected to significantly alter the water quality in Moose River. The development of management, mitigation and contingency plans should consider the potential for higher permeability faulting, such as the grouting of high permeability faults, should observed concentrations exceed predictions during the post-closure period.

5.4.2.2 Sensitivity of Solute Transport to Bedrock Porosity

The sensitivity of the solute transport model to the potential porosity of the bedrock was assessed by conducting scenarios as shown on Figure 5.13. The porosity assigned to the shallow bedrock was varied between the baseline value of 10% to 1%, which is a reasonable lower bound to the weathered bedrock observed at the site. The porosity assigned to the deeper, more competent bedrock, was varied from the baseline value of 5% to 0.01%. The transport model was re-run to estimate the mass loading and predicted relative concentrations in groundwater discharge to Moose River.

As shown on Figure 5.13, the timing of the solute transport from the pit to Moose River is sensitivity to the bedrock porosity. However, the magnitude of the final concentrations in Moose River are not significantly different between the scenarios, with slightly lower relative concentrations predicted in the lower porosity scenarios.
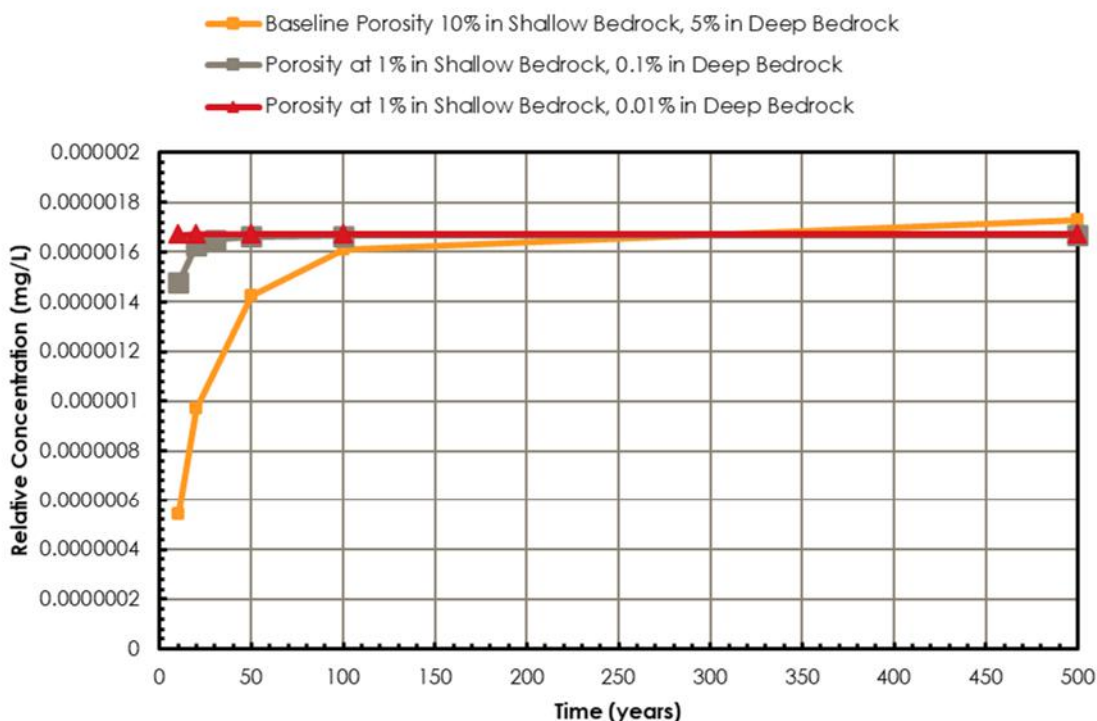
Figure 5.13   Sensitivity of Bedrock Porosity on Relative Concentrations in Moose River

5.5   PREDICTION CONFIDENCE

The approach used in model simulations completed for this Project was to incorporate conservative assumptions for predicting effects that may result from the Project. This report presents the assumptions made in developing these conservative predictions and discusses the high-level confidence of these predictions.

The modelling was conducted using an EPM approach., This is appropriate based on the regional scale of the modelling, and considering that flow was predicted to occur primarily through the shallow weathered bedrock, which is highly fractured, and therefore behaves like a porous medium.

The groundwater flow modelling was conducted using a model calibrated to water levels, and baseflow targets to establish baseline conditions. Predictions made using the model are based on several conservative assumptions to reduce the influence of uncertainty in the predictions. Therefore, the confidence in the predictions made using the model is considered high.

6.0 CONCLUSIONS

A three-dimensional steady-state groundwater flow model and solute transport model was constructed using MODFLOW to simulate groundwater conditions prior to the development of the Open Pit, baseline conditions (i.e., when Open Pit has been fully dewatered), changes to groundwater inflows during operation (i.e., when the tailings are filling the Open Pit), and to evaluate potential changes to water quality in the receiving environment due to the subaqueous disposal of tailings in the Open Pit post-closure (i.e., when the Open Pit is full). The model was prepared using a conceptual model and hydrostratigraphic framework developed from regional and site-specific data, and assumed homogeneous properties within the units. A good calibration of model parameters was obtained, as evaluated by comparing simulated and observed groundwater levels and estimated baseflow. The parameter values for hydraulic conductivity are similar to those obtained from other analyses of field observations.

At baseline, the open pit will be fully dewatered, and is simulated to intercept groundwater seepage at a rate of 768 m^3/d. The extent of the corresponding drawdown cone, as delineated by the 0.5 m drawdown contour, extends approximately 600 m south of the open pit and about 50 m west of the site toward Moose River. The inflow to the open pit decreases as it is filled with tailings and water, until the Open Pit stage reaches the maximum level of 108 m CGVD2013. At this stage, the groundwater seepage decreases to 373 m^3/d, and the corresponding drawdown cone is about the same as the baseline condition. Groundwater baseflow to Moose River is reduced by less than 1% in all cases.

Upon the filling of the Open Pit to its ultimate lake stage at 108 m CGVD2013, groundwater flow is dominated by flow from the Open Pit to Moose River through the glacial till and weathered fractured bedrock. Solute transport in this case is dominated by advection (movement with the flow of groundwater). Solute transport modelling using the calibrated model simulates a slow migration of solutes to Moose River, with concentrations approaching a steady state after about 100 years of travel. Mass loadings for various parameters of concern are simulated by the model for inclusion in a surface water mixing model of Moose River (Stantec 2021). These mass loadings represent the additional contribution from the open pit, and is additive to baseline groundwater quality.

The presence of preferential pathways, such as fractures and faults not characterized in previous field assessment, were assessed with sensitivity analyses in the model to predict the potential migration of solutes from the Open Pit into the receiving environment. The results of the sensitivity analyses indicated that should the faults have higher hydraulic conductivity, solute transport to Moose River would occur more quickly. Therefore, the potential for higher permeability faults should be considered in the development of management, mitigation and contingency plans.

The groundwater flow and solute transport modelling was conducted with the best available information on the hydrogeologic conditions at the Touquoy site. However, it is recommended that the following data gap be addressed to improve the reliability of the predictions made with the model:

Perform geochemical testing of water quality in the Open Pit lake during pit filling to predict the concentrations of potential compounds of concern in the open pit lake. These data could then be simulated to predict actual concentrations to the receiving environment.

7.0   REFERENCES

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APPENDIX A

Concordance Table

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
Nova Scotia Environment (Email from Bridget Tutty 9/12/2020)		
NSE-1	Provide representation in the document of the new model discretization. Include a figure showing the overall site modelling grid and domain.	See Section 4.1
NSE-2	Provide information and a cross-section figure from the Moose River to the open pit which shows the hydrogeological conceptual model (including details of actual stratigraphy) for groundwater interactions as well as the model layers and parameters that are representative of this.	See Section 4.1
NSE-3	Update the revised model groundwater calibration analysis based on changes to the model grid, include stream baseflow target for both average annual and yearly minimum flow conditions.	See Section 4.4.3
NSE-4	Update the uncertainty/sensitivity analysis to include the variable effects of streambed conductivity on observed streamflows and groundwater influx to the open pit.	See Section 4.4.6
NSE-5	General question – will long-term ambient hydrogeochemical quality (e.g. observations of elevated pH in the pit water and some monitoring wells) have any effect on the stability and solubility of any parameters found in the proposed tailings? Some parameters such as Arsenic may be more soluble at higher pH levels. If so, are such mixing interaction effects included in the long term transport modelling predictions?	This is beyond the scope of the groundwater flow modelling, and will be addressed under separate cover.
Fisheries and Oceans Canada – Email from Chris Burbidge (11/12/2020)		
DFO-1	DFO needs to understand the plausible worst-case scenario regarding changes in flow in Moose River from the projects and the associated effects to fish and fish habitat to verify compliance with the Fisheries Act. It is not immediately clear how the use of averages in the model will give an indication of the worst-case scenario.	Groundwater fluctuations to baseflow are longer-term processes and vary less frequently than precipitation and runoff processes that are observed in surface water. The groundwater modelling approach can be used to estimate the "worst-case" by reducing the "lowest flows" in the streams by the average summer baseflow reductions calculated using the model.
DFO-2	Actual low flows in Moose River during summer are often much lower than the monthly average. For example, the average flows in the river in August have been estimated to be 0.39 m3/s at SW-2. In August 2019, the lowest flow measured was 0.055 m3/s at SW-2. Flow data from Moose River in summer 2020 have not been provided, but data from a nearby hydrometric station [Middle River of Pictou at	As described in response to DFO-1, groundwater fluctuations in baseflow are longer-term processes that vary less frequently than precipitation and runoff processes. The baseflow reductions for the summer months calculated using this approach are expected to be representative throughout the summer, even if specific

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
	Rocklin (01DP004)] shows that the lowest flow in August 2020 was likely less than 1% of the Mean Annual Discharge.	flows in the stream may be reduced due to lack of precipitation.
DFO-3	It is not clear what is meant by the statement "The average summer conditions will be based on the lowest flows available for the Moose River." on page 1.	This was intended to mean the summer with the lowest flows observed in Moose River (i.e., 2019).
DFO-4	The "lowest observed flow conditions from 2019, and 2020" (page 2) may not represent the potential lowest summer flow conditions (i.e., historical minimum flow).	Our stated goal was to reproduce the lowest <u>observed</u> flows, as we do not have sufficient information to confirm the water levels for potential historical minimum flows in Moose River.
DFO-5	Previous comments: The September 2020 tech memo shows that the measured drawdown at well pairs OPM-1A/B and OPM-2A/B located in between the current open pit and Moose River are 28% to 793% greater than predicted by the groundwater model. The tech memo states that this difference is likely due to local variations in hydraulic connectivity near the wells not represented in the model. The location of these wells mean that they are particularly relevant to the assessment of potential effects to Moose River. Please provide a description of the factors related to hydraulic connectivity at this location that could explain this variation and consider this information in the revised groundwater model.	See Section 4.4.3
DFO-6	The April 2019 groundwater model describes how watercourses are considered in the model using the River package. For Moose River, the model assumed a uniform river width of 8 m and depth of 1 m. A comparison of the estimated mean monthly flows and the stage-discharge curves provided in the tech memo for the water stations in Moose River in the vicinity of the open pit suggest that water depths of 1 m in Moose River in vicinity of the open pit would be relatively rare and would be expected to occur only during temporary high flow events and that an average depth of approximately 0.6 m is more representative of mean annual flows, if only one depth value is to be used in the model. Furthermore, the average channel width estimated in the September 2019 tech memo from the habitat surveys in the vicinity of the open pit was approximately 12 m. Please update the model's river package with the best available information about Moose River.	See Section 4.3.3
DFO-7	The April 2019 groundwater model uses an estimated mean annual discharge (MAD) in Moose River at SW-2 of 1.23 m3/s. The analysis in the 2020 tech memo estimated MAD to be 1.15 m3/s using flow measurements from surface water stations in Moose River in the vicinity of the open pit and a regression analysis of	See Section 4.3.3

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
	long-term data from eight (or possibly ten) WSC stations. Please update the model with the best estimate of MAD for Moose River.	
NRCan – D. Paradis (email from Kathryn MacCarthy 14/12/2020)		
NRCan-1	Given my review of I4, I summarize my main concerns using the scope of work proposed here. I also provide additional concerns reviewing I4. Main points in the Memo (see comments below in the text): 1. Baseflow calibration. 2. Streambed conductance. 3. Numerical dispersion. 4. Effective porosity. 5. Faults impact. Additional points from I4 that need clarifications:	See responses below.
NRCan-2	1. Fig. 4.1: This figure shows the model layer with corresponding stratigraphy. The thickness of each layer and their spatial relations with the pit and the Moose River is however not well illustrated. **Information Request:** A few cross-sections should be presented to better illustrate the conceptual and numerical models. In particular, deep of the pit with respect to the bottom of the numerical model, and the stratigraphy between Moose River and the pit.	See Section 4.1
NRCan-3	2.Table 5.1: Dispersivity is expected to be much higher in the weathered bedrock than competent bedrock. Why is the proponent using the same dispersivity values for weathered and competent bedrock? **Information Request:** Please explain the rationale for using the same dispersivity value for weathered bedrock and the competent bedrock.	As presented by Gelhar (1992), dispersivity is a scale dependent parameter that can be estimated based as 10% of the representative length of the expected plume. The longitudinal dispersivity of 5 m was selected based on the representative distance between the open pit and Moose River (i.e., 50 m).
NRCan-4	3a. Fig 5.4: This figure showing drawdowns may falsely suggest that the pit is gaining water from the Moose River. A map of the hydraulic heads with main groundwater flow direction would be more illustrative of the situation. **Information Request:** Provide a map of the hydraulic heads for comment # 3a above.	See Figure 5.5.
NRCan-5	3b. Fig. 5.5: Also, given the very small relative concentrations predicted away from the pit, and the relatively coarse cells (spatially and vertically) of the model grid with	The grid Peclet number was in the original modelling varied between 5 and 10, and varies between 1 and 10

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
	respect to the distance between Moose River and the pit, has the Peclet number been verified to avoid numerical artifacts (e.g., numerical dispersion and numerical oscillations) to ensure realistic transport simulations? **Information Request:** a clarification is required for comment #3b wrt. Peclet number.	for the current modelling (depending on whether the grid cell is 5 m or 50 m long). Although it is usually suggested to select the grid spacing so that the Peclet number does not exceed 2, in many cases acceptable solutions with mild oscillation are achieved with grid Peclet numbers as high as 10 (Huyakorn and Pinder 1983). The predicted concentration results were reviewed to confirm that oscillatory behaviour did not adversely affect the results (i.e., by checking for negative concentrations in the modelling results).
NRCan-6	3c. Fig. 5.10: This figure seems to show numerical oscillations. To be verified. **Information Request:** confirm whether Figure 5.10 shows numerical oscillations.	The interpreted numerical oscillations are due to flow through the high conductivity faults. The maximum length of timesteps was adjusted in the modelling to avoid numerical oscillations in the updated modelling results. The sensitivity runs presented in Section 5.
NRCan-7	Section 6.0 Conclusions: "Upon the filling of the open pit to its ultimate lake stage at 108 m asl, groundwater flow is anticipated to flow from the pit to Moose River through the glacial till and weathered fractured bedrock.". This is an interesting analysis, but this should be illustrated and discussed in the main body of the report. Should present cross-sections with heads simulated in each layer of the model. **Information Request:** Illustrate and discuss the groundwater flow from the pit to the Moose River, present cross sections with heads simulated in each layer of the model.	The conclusions have been updated based on the updated modelling text.
NRCan-8	Table 5.3: Should tell if those concentrations exceed the authorized concentrations in receiving environments. **Information Request:** confirm whether the concentrations exceed the authorized concentrations in the receiving environments (Table 5.3).	The concentrations in the previous modelling were below the MDMER limits in the receiving environment. The updated modelling results will be compared to MDMER limits in the receiving environment in the updated modelling report.
NRCan-9	Section 1.0: Drawdowns at Moose River are restricted by the modelling approach. In this approach river stage is fixed by the model using constant head boundary condition. This is a limitation of fully-saturated models where rivers cannot be let free. **Baseflow calibration:** However, what matters is the amount of water exchanged between the river and the aquifer. To know the impact of pumping on the river, a	See Section 4.4

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
	mass balance around the river should be done. An important piece of information to get meaningful mass balance is the calibration of the model with baseflow estimated from field measurements. If the model can reproduce field baseflow, we can be more confident in the impact assessment.	
NRCan-10	Section 2.0 Task 1 – re: "streambed sediments": **Streambed conductance**: To be conservative, the streambed conductance should be kept the same as the underlying sediments/bedrock. Using very low conductance value may isolate the river from the main aquifer, and then underestimate the amount of water withdrawn from pumping. Calibration with field-based baseflow estimates will thus be very important to assess the hydraulic connection between Moose River and the aquifer. **Baseflow calibration:** Also, an additional sensitivity analysis showing the sensitivity of baseflow to parameters should be conducted. Parameters of interest are hydraulic conductivity, recharge and streambed conductance. **Effective porosity:** Finally, it would be also useful to see a sensitivity analysis for contaminant concentrations reaching Moose River. In addition to the previous parameters used for baseflow sensitivity analysis, effective porosity should also be tested.	See Section 4.4.6
NRCan-11	Section 2.0 Task 1 – re: "summer low-flow condition.": **Numerical dispersion:** Likely with no recharge?	As indicated in Section 4.3.2, both recharge and evapotranspiration (ET) have be included as separate processes in the modelling update. Therefore recharge will be reduced in the summer, but ET will be increased. The net result is an effective recharge of 22 mm/yr, as calculated using the recharge and ET rates presented in Table 4.6.
NRCan-12	Section 2.0 Task 1 – re: "…flow conditions from 2019 and 2020. These years represent the most complete datasets available…": **Baseflow calibration:** How those 2019 and 2020 year compare to historical conditions. Are they wet, dry or average years ? For annual and low-flow period.	Below average precipitation were observed in the summers of 2019 and 2020.
NRCan-13	Section 2.0 Task 1 – re: "Refining the grid cell size in the existing modell…": **Numerical dispersion:** Refining the grid at the vertical layer should between the Moose River and the pit also be considered. Horizontal and vertical resolutions are particularly important for transport simulations where numerical dispersion (too large Peclet number) seems to be an issue in I4.	The vertical discretization in the vicinity of the open pit was reviewed, and was not updated as part of this update. The relatively fine vertical discretization in the vicinity of the open pit and Moose River does not warrant additional refinement in the shallow model layers.

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
NRCan-14	Section 2.0 Task 2 – re: "transport simulations": **Numerical dispersion:** Appropriate cell size in the region between Moose River and the pit should be used to avoid numerical artifact in the transport simulations. See previous comment. **Effective porosity:** Porosity is also important for transport simulations. Large porosities will accumulate mass in the aquifer and delay migration times. The opposite for low porosity values. What is the supporting information for porosity? Porosity should be also included in the sensitivity simulations. **Effective porosity:** Moreover, porosity values reported in I4 seems to reflect total porosity. For transport simulation, effective porosity should instead be used. Effective porosity is generally much lower than total porosity. Especially in bedrock formations where much of the pores are not interconnected and an important proportion of water is not contributing to flow (stagnant water). To be conservative, without field/lab support, effective porosity values on the lower-end range of reported values in the literature should be used.	A sensitivity analysis for the effects of porosity on transport runs is provided in Section 5.4.2.2.
NRCan-15	Section 2.0 Task 2 – re: "Additional model runs…": **Faults impact:** Given that no field work can support the role of the faults, a conservative scenario with high permeability faults should be used.	This was the approach used in the previous modelling, and has been updated in Section 5.4.2.1 of the current report.

APPENDIX D.2
WASTE ROCK STORAGE AREA GROUNDWATER MODELLING UPDATE, TOUQUOY GOLD MINE

Stantec

July 6, 2021
File: 121619250

Attention: Melissa Nicholson
Atlantic Mining NS Inc.
6749 Moose River Road
Middle Musquodoboit, NS B0N 1X0

Dear Ms. Nicholson,

Reference: Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine

Atlantic Mining NS Inc. (AMNS) is proposing to expand the waste rock storage area (WRSA) approved in the existing Industrial Approval (IA #2012-084244-08). The proposed expansion of the WRSA is required in order to accommodate higher volumes of waste rock from the Open Pit. This modelling update includes the characterization of the effects of seepage from the WRSA on groundwater resources and the potential rate of groundwater flow to surface water features at the site. The groundwater flow model was developed to characterize the effects from the deposition of tailings into the Open Pit (Stantec 2021). The results presented herein provides modifications to the previous models in order to estimate the seepage from the WRSA and discharge to the receiving environment.

SCOPE OF WORK

The following scope of work was completed for this evaluation:

1. Updated the steady-state groundwater flow model to incorporate the seepage from the WRSA at full extent approved in the current IA
2. Updated the steady-state groundwater flow model to incorporate the seepage from the expanded WRSA at full extent
3. Conducted sensitivity analyses of the recharge rate applied to the WRSA on predicted results
4. Prepared this letter report summarizing the simulated effects of the proposed expansion on groundwater seepage downgradient of the WRSA

METHODOLOGY

The groundwater flow modelling considered the following scenarios:

- Scenario 1: WRSA at full extent based on current IA
- Scenario 2: Expanded WRSA at full extent
- Scenario 3: Sensitivity analysis of recharge rate applied to full extent of WRSA based on current IA
  - Scenario 3a: WRSA Recharge = 50% mean net annual precipitation
  - Scenario 3b: WRSA Recharge = 80% mean net annual precipitation

Design with community in mind

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

The model scenarios were simulated using the groundwater flow model prepared for the deposition of tailings in the Open Pit (Stantec 2021). A comparison of the current WRSA footprint included in IA 2012-084244-08 (i.e., used for Scenario 1), and the proposed expanded WRSA footprint (i.e., used for Scenarios 2 and 3) is provided on Figure 1. The original 2016 IA footprint for the WRSA is also provided on Figure 1.

The groundwater flow models were developed using MODFLOW-NWT (Niswonger et al. 2011) and were calibrated to steady-state water levels and baseflow estimates in Moose River. Two additional model layers were added to the top of the model to represent the WRSA that were active only within the footprints of the current and updated WRSAs shown on Figure 1. Waste rock material was assigned within these areas by assigning a hydraulic conductivity of 1×10^{-3} metres per second (m/s), based on ranges published in the literature (Noël and Ritchie 1999, Amos et al. 2015). With the exception of Scenario 4a, the crest elevation of the WRSA (i.e., top of waste rock) was set at 170 metres (m) relative to the Canadian Geodetic Vertical Datum of 2013 (CGVD2013). As indicated above, the WRSA crest elevation for Scenario 4 was set at 190 m CGVD2013.

The WRSA ditches were included in the model using the MODFLOW Drain package. The stage of the drains within the model were assigned assuming 1 m deep ditches around the perimeter of the respective WRSA designs, except for the northwest corner of the WRSA designs, where a surface berm is present and the drain stage was assigned based on ground surface. The conductance of the drains was set based on the assumed hydraulic conductivity of the rip-rap of 1×10^{-3} m/s which will not limit the inflow from the aquifer to the ditch. The clay-lined east and west seepage collection ponds were also simulated using the MODFLOW Drain package, based on the operating stages of 123.5 and 120.0 m, respectively. The conductance of the drain cells representing the ponds was assigned based on the minimum 0.3 m of clay placed beneath the ponds, assuming the hydraulic conductivity of the clay is the same as that used at the TMF at 1×10^{-8} m/s.

Groundwater recharge over the WRSA designs was assigned based on net annual precipitation (total precipitation less evaporation) and runoff. Assuming the runoff coefficient of 30% of the net precipitation, the infiltration rate into the WRSA is estimated to be 70% of net precipitation. The waste rock within the WRSA was assumed to be fully saturated from the start of the simulation, therefore the infiltration rate to the pile also represented the groundwater recharge rate though the base of the pile. The net annual precipitation was estimated to be 843 millimetres per year (mm/yr), resulting in estimated recharge through the WRSA as 591 mm/yr (for Scenarios 1 and 2). The assumption of fully saturated waste rock throughout the simulations conservatively overestimates the loadings from the WRSAs to the receiving environment because there will be an initial wetting period that delays the saturation of the pile as additional waste rock is placed. The sensitivity analyses of recharge presented in Scenario 3 evaluate recharge rates of 50% and 80% of the net annual precipitation rates (i.e., 422 mm/yr for Scenario 3a, and 674 mm/yr for Scenario 3b).

Design with community in mind

Comparison of WRSA Designs Simulated in Groundwater Models

Figure 1
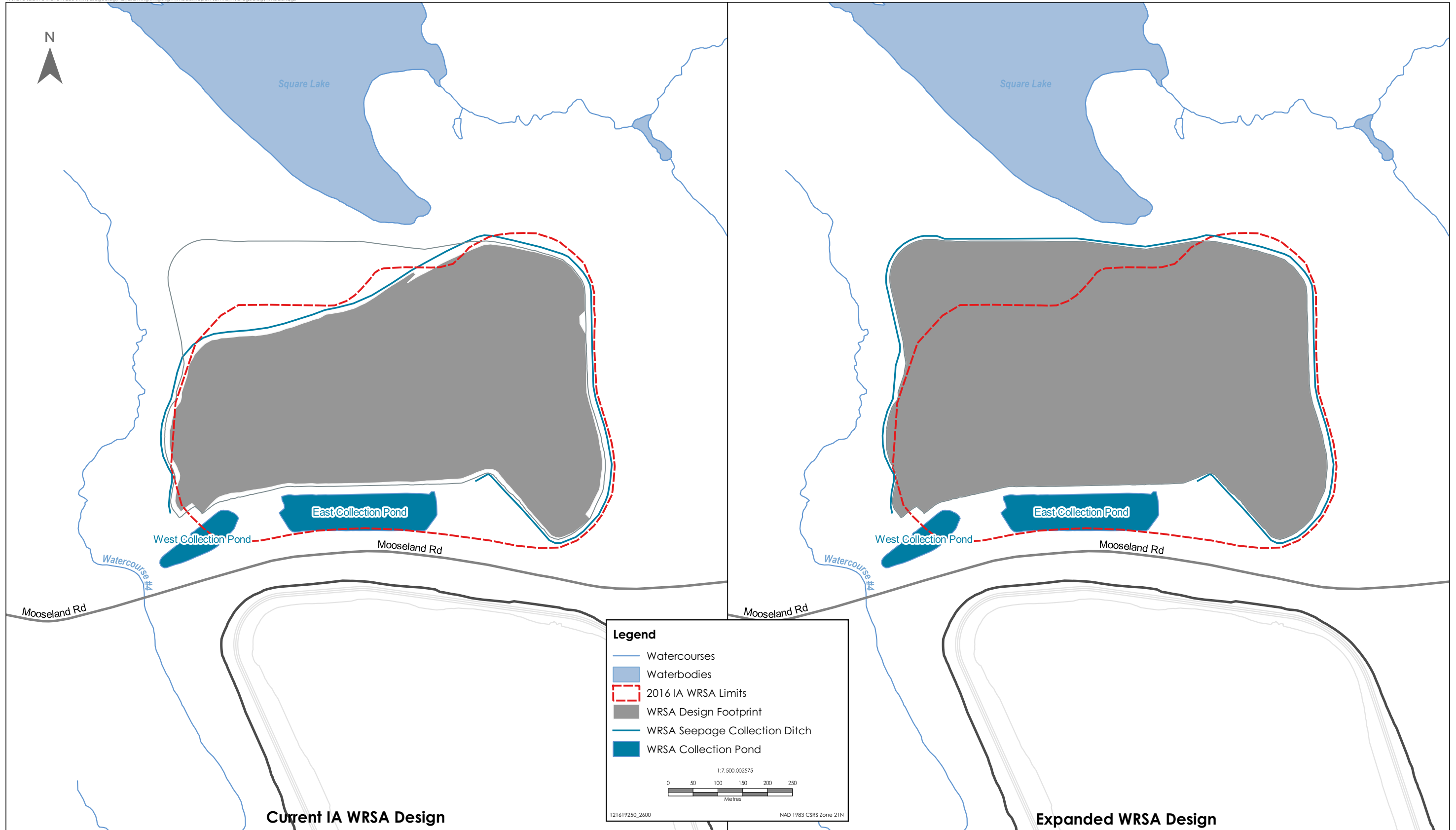
Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

The groundwater recharge from infiltration through the base of the WRSA has the potential to migrate through groundwater to surface water features, including the perimeter ditches for the WRSA and TMF, or to nearby watercourses or lakes. The groundwater flow model was used to better understand the fate of groundwater that originates from the WRSA and to estimate discharge rates to the receiving environment. A forward particle tracking approach was used, where a particle was released from each model node within the WRSA. The travel paths of the particles were simulated through the model domain until they arrived at a receptor, such as a lake or stream.

The groundwater flux associated with each particle track was then determined and used to estimate the total discharge rate for the WRSA to the environment. This is illustrated on the conceptual cross-section shown on Figure 2. A particle trace is shown for a particle that originates in the WRSA and terminates at a lake. The groundwater discharge to the lake that is contributed by the cell in the WRSA is conservatively assumed to be equal to the total average annual recharge rate into that element (e.g., Qin = Qout) during the phase of mine development. It was assumed that the groundwater recharge that enters the WRSA will be carried through to the receptors.
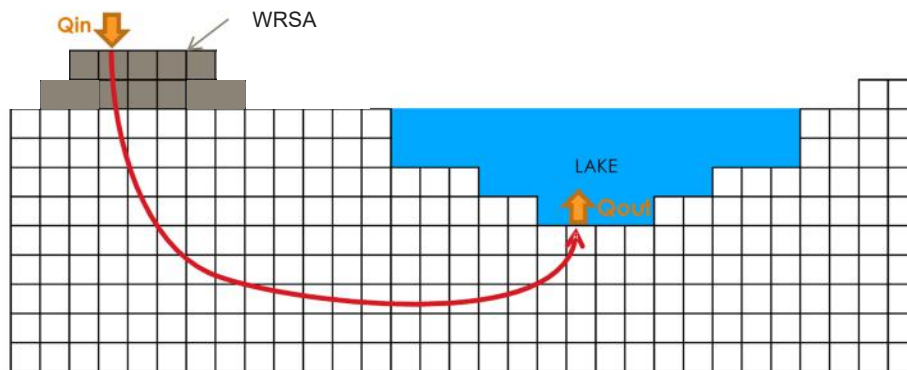
Figure 2 **Conceptual Model Cross-Section Illustrating Particle Traces**

RESULTS

The results of the groundwater modelling conducted for the model scenarios are presented and discussed below.

COMPARISON OF SEEPAGE RATES FROM CURRENT IA AND EXPANDED WRSA

The simulated steady-state particle tracks from the WRSA at full extent based on current IA (Scenario 1) and from the expanded WRSA (Scenario 2) to the final surface water receptors are shown on Figure 3. The groundwater seepage rates from the WRSAs associated with these particle tracks are presented in Table 1.
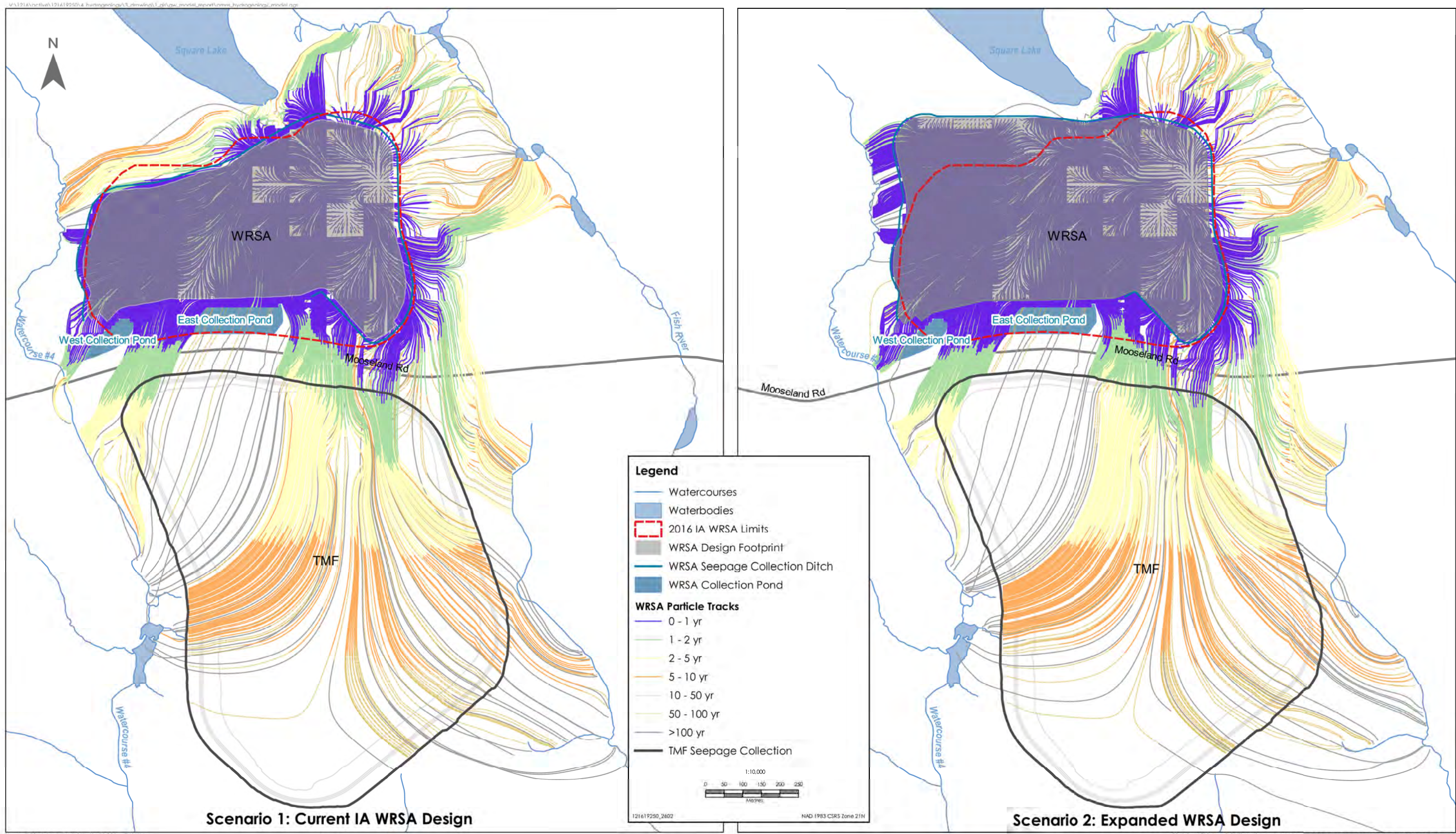
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Legend

Watercourses
Waterbodies
2016 IA WRSA Limits
WRSA Design Footprint
WRSA Seepage Collection Ditch
WRSA Collection Pond

WRSA Particle Tracks
0 - 1 yr
1 - 2 yr
2 - 5 yr
5 - 10 yr
10 - 50 yr
50 - 100 yr
>100 yr
TMF Seepage Collection

1:10,000

0   50   100   150   200   250
Metres

121619250_2802   NAD 1983 CSRS Zone 21N

Scenario 1: Current IA WRSA Design

Scenario 2: Expanded WRSA Design

Sources: All basemap data downloaded from GeoNova.

Disclaimer: This map is for illustrative purposes to support this project; questions can be directed to the issuing agency.

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**Comparison of Predicted Steady-State
Particle Tracks Originating at WRSA**

Figure 3

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

Table 1   Comparison of Predicted Groundwater Seepage Rates (m³/d) to Surface Water Features for Current IA and Expanded WRSA Footprints

Parameter	Scenario 1 Current IA	Scenario 2 Expanded IA	Change (%)
WRSA Seepage Collection	206	270	31%
East Collection Pond	103	126	22%
West Collection Pond	31	33	6%
Watercourse #4	54	126	133%
TMF Seepage Collection	65	70	8%
Square Lake	3	0	-100%
Fish River	44	46	5%
Tributary to Fish River	16	18	13%
Total	**522**	**689**	**32%**

As shown on Figure 3 and in Table 1, the particles released from the WRSA are simulated to migrate toward the WRSA seepage collection ditches and associated collection ponds, Watercourse #4 (to the west), Fish River and its tributary (to the east), the TMF seepage collection ditches, and potentially to Square Lake. The majority of the flow is captured by the WRSA seepage collection ditches and associated collection ponds for both scenarios. The clay-lined East and West Collection Ponds are predicted to intercept some groundwater flow from the WRSA, however the seepage rate is limited by the presence of the clay.

As shown in Table 1, the total groundwater seepage for the expanded WRSA (Scenario 2) is estimated to be 32% greater than that for the current WRSA (Scenario 1). This results in increased flows to the downgradient water features except Square Lake. The expansion of the WRSA to the north results in the movement of the WRSA seepage collection ditch closest to Square Lake at a deeper depth than the current IA design. This deeper ditch is predicted to intercept the small volume of water that was predicted to migrate toward Square Lake under the current IA conditions.

As shown in Table 1, the groundwater seepage for the expanded WRSA (Scenario 2) is estimated to be 133% greater than that for the current WRSA (Scenario 1), based on the current WRSA seepage ditch design which essentially is a berm on grade along the western portion of the expanded WRSA. While the percentage of change appears high, this is mostly because a groundwater flow discharging to Watercourse #4 is small for both scenarios. The mean annual flow in Watercourse #4 is 4,139 m³/d, and the groundwater baseflow contribution from the expanded WRSA is 3.0% of the mean annual flow, versus 1.5% for the current WRSA.

The design of the western portion of the seepage collection ditch for the WRSA expansion limits the amount of groundwater seepage collected on the western portion because the water table is simulated to be below the bottom of the ditch. However, deepening the WRSA seepage collection ditch along the western portion of the WRSA can reduce the seepage to Watercourse #4, should the groundwater seepage need to be mitigated in future.

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

As shown on Figure 3, a portion of the groundwater flow from the WRSA is predicted to travel through the bedrock beneath the TMF, and arrive at the seepage collection ditches around the perimeter of the TMF or to the watercourses downgradient of the TMF. The simulated seepage from the TMF was not included in the scope of this modelling, as it was conducted as part of the slope stability analysis for the TMF, and reported under separate cover. In addition, the presence of the TMF is not accounted for in the groundwater flow model. Therefore, the effects of the TMF on the groundwater flow patterns from the WRSA are not accounted for in this modelling. However, as the presence of the TMF has not significantly altered the distribution of heads observed in the perimeter wells to date (Stantec 2020), this is not anticipated to significantly alter the estimates of seepage from the WRSA to the TMF seepage collection ditches.

The sensitivity analysis of recharge rate applied to the WRSA was conducted on the expanded WRSA footprint only, to evaluate the fate of seepage from the WRSA under other possible recharge scenarios. The recharge associated with 50% of the net precipitation at the WRSA in Scenario 3a was considered to evaluate the effect of enhanced runoff on the WRSA, possibly from the application of a vegetated cover during closure. The recharge associated with 80% of the net precipitation in Scenario 3b was considered to evaluate less runoff from the WRSA.

The results of the particle tracking for the recharge sensitivity analysis are presented on Figure 4. As shown on the figure, the variable recharge affects the timing of the particles slightly, with increased travel times for the lower recharge rate, and decreased travel times for the higher recharge rate. However, the results show only minor changes in the distribution of the particle tracks received at the various receivers.

The corresponding groundwater seepage rates for the recharge rates applied to the expanded WRSA are presented in Table 2. The percentage of the recharge applied to the WRSAs that ultimately arrive at the various receptors are also shown in Table 2. As shown on the table, increasing the recharge rate has the greatest influence on the amount of seepage that is captured in the seepage collection systems. This is due to the position of the water table, which is higher in the vicinity of the seepage collection systems as the recharge rate is increased. This is particularly evident in the ultimate volume of seepage received by Watercourse #4, which is predicted to decrease compared to the baseline scenario (Scenario 2), even though the increase in recharge rate. However, at the lower recharge rates, the overall seepage rates to the receivers are still lower than the baseline scenario (Scenario 2). Therefore, the ultimate seepage rates to the receiving environment (i.e., Watercourse #4 and Fish River and its tributaries) are relatively insensitive to the recharge rate applied to the WRSA based on the capture of the increased recharge rates in the seepage collection systems.

Scenario 3a: Recharge = 50% Mean Net Annual Precipitation

Scenario 2: Recharge = 70% Mean Net Annual Precipitation

Scenario 3b: Recharge = 80% Mean Net Annual Precipitation

Sources: All basemap data downloaded from GeoNova.

Disclaimer: This map is for illustrative purposes to support this project; questions can be directed to the issuing agency.

Legend

—— Watercourses	—— IA Pit Limits	—— WRSA Seepage Collection Ditch
Waterbodies	2016 IA WRSA Limits	WRSA Collection Pond
Open Pit Shell	WRSA Design Footprint	—— TMF Seepage Collection

WRSA Particle Tracks

—— 0 - 1 yr	—— 2 - 5 yr	—— 10 - 50 yr	—— >100 yr
—— 1 - 2 yr	—— 5 - 10 yr	—— 50 - 100 yr	

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Sensitivity of Predicted Steady-State Particle Tracks Originating at WRSA to Recharge

Figure 4

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

Table 2   **Sensitivity Analysis of Predicted Groundwater Seepage Rates (m³/d) [and Percentage of Total] to Surface Water Features for Recharge Applied to WRSA**

Parameter	Scenario 3a: Recharge = 50% Mean Net Annual Precipitation	Scenario 2: Recharge = 70% Mean Net Annual Precipitation	Scenario 3b: Recharge = 80% Mean Net Annual Precipitation
WRSA Seepage Collection	169 [35%]	270 [39%]	321 [41%]
East Collection Pond	78 [16%]	126 [18%]	140 [18%]
West Collection Pond	26 [5%]	33 [5%]	35 [5%]
Watercourse #4	106 [22%]	126 [18%]	117 [15%]
TMF Seepage Collection	55 [12%]	70 [10%]	91 [12%]
Square Lake	0 [0%]	0 [0%]	0 [0%]
Fish River	30 [6%]	46 [7%]	53 [7%]
Tributary to Fish River	13 [3%]	18 [3%]	18 [2%]
Total	**477**	**689**	**775**

CONCLUSIONS

Groundwater flow modelling was previously conducted to support the expansion of the Touquoy TMF. As the seepage from the WRSAs to the downstream environment had not been conducted previously, estimates of the seepage for the WRSA designs for the current WRSA and the expanded WRSA are provided. The groundwater modelling results indicate that the groundwater seepage from the expanded WRSA will increase about 32% from that designed for the current Approved Project and will discharge primarily to the WRSA seepage collection ditches and the associated collection ponds, or to Watercourse #4.

The sensitivity of the predicted seepage from the WRSA to the receiving environment to the recharge rate applied to the WRSA was assessed by varying the recharge rate from 50% to 80% of the net annual precipitation rate. The results show that the ultimate seepage rates to Watercourse #4 and Fish River and its tributaries are relatively insensitive to the recharge rate applied to the WRSA because the increased recharge rates result in an elevated water table in the vicinity of the seepage collection systems, which enhances the interception of the groundwater within the seepage collection systems.

The seepage rates presented above are predicted conservatively high based on the assumption of initially saturated waste rock within the WRSA. The actual waste rock deposition will be at residual saturation and will require the wetting up of the pore space between grains in the waste rock before groundwater flow will occur, thereby delaying the arrival of groundwater to the receiving environment. The implications of the seepage on water quality in the receiving environment are being assessed separately by Minnow Environmental.

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

CLOSURE

This report documents work that was performed in accordance with generally accepted professional standards at the time and location in which the services were provided. No other representations, warranties or guarantees are made concerning the accuracy or completeness of the data or conclusions contained within this report, including no assurance that this work has uncovered all potential liabilities associated with the identified property.

This report provides an evaluation of selected environmental conditions associated with the identified portion of the property that was assessed at the time the work was conducted and is based on information obtained by and/or provided to Stantec at that time. There are no assurances regarding the accuracy and completeness of this information. All information received from the client or third parties in the preparation of this report has been assumed by Stantec to be correct. Stantec assumes no responsibility for any deficiency or inaccuracy in information received from others.

The groundwater flow model is intended to be a tool for the assessment of potential effects of mining operation on groundwater, and groundwater-surface water interactions. It is a theoretical representation of conditions under a specific set of input parameters.

The groundwater flow and water balance models contained herein was designed for the purposes of this study only, and cannot be applied for other purposes without further refinement. Should additional information become available which differs significantly from our understanding of conditions presented in this report, we request that this information be brought to our attention so that we may reassess the conclusions provided herein.

This report has been prepared for the exclusive use of the client identified herein. Stantec assumes no responsibility for losses, damages, liabilities or claims, howsoever arising, from third party use of this report.

Regards,

Stantec Consulting Ltd.

Original signed by

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Design with community in mind

Reference: **Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine**

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Design with community in mind

*APPENDIX D.3
WATER QUALITY PREDICTIONS FOR
SCRAGGY LAKE AND WATERCOURSE
NO.4, TOUQUOY GOLD MINE*

Technical Memo

Date:	July 5, 2021
To:	Craig Hudson (Atlantic Mining NS Inc.)
From:	Mike Gunsinger (Minnow Environmental Inc.)
Cc:	Barb Bryden and Melissa Nicholson (Atlantic Mining NS Inc.)
	Sara Wallace (Stantec)
RE:	**Water Quality Predictions for Scraggy Lake and Watercourse No.4, Touquoy Gold Mine**

1 INTRODUCTION

Atlantic Mining NS Inc. (AMNS) is proposing changes to the operations at the Touquoy Gold Mine (Touquoy), which is located approximately 63 km northeast of Halifax and 19 km southeast of Middle Musquodoboit, Nova Scotia. The operational changes include the expansion of the Waste Rock Storage Area (WRSA) and, once the pit is exhausted of ore and the Tailings Management Facility (TMF) has reached capacity, a transition to in-pit disposal of tailings. Nova Scotia Environment (NSE) has determined that a Class I Environmental Assessment (EA) under the *Environment Act* and Environmental Assessment Regulations is required to evaluate the potential environmental effects of the proposed changes.

AMNS has retained Minnow Environmental Inc. (Minnow) to complete water quality modelling and predict potential effects to surface water quality. The key objective of the water quality modelling is to evaluate potential changes to surface water quality in Scraggy Lake and Watercourse No.4. Scraggy Lake currently receives treated effluent that is discharged from the TMF polishing pond. Watercourse No.4 is located to the east and downgradient of the WRSA and TMF, and is proposed to receive treated effluent from the WRSA pond. Based on the proposed in-pit tailings storage, the final effluent discharge point for tailings-contact water would be relocated to the Moose River; noting that effluent discharge into the Moose River would start during post-closure once the water quality of the pit lake meets regulatory discharge requirements. The potential effects to water quality of the Moose River during post-closure, however, is not assessed in this study and is rather predicted as part of a separate modelling analysis as presented in Stantec (2021a).

The purpose of this technical memo is to provide: an overview of the conceptual water quality model for Scraggy Lake and Watercourse No.4; outline the numerical modelling approach and model inputs; and, present the water quality model results. Further discussion regarding the water quality effects assessment can be found in the main EA document.

2   WATER MANAGEMENT AND TREATMENT

The current water management plan directs the contact water (surface runoff, seepage, and wastewater originating from mine infrastructure) to the TMF for treatment and temporary storage. Water from the open pit dewatering activities is pumped directly into the TMF. Runoff and seepage collection ditches and ponds are located around the perimeter of mine infrastructure, including the WRSA, TMF, mill, and on-site mine roads, to collect site drainage and pump the captured water into the TMF. Through subsurface flow pathways and seepage discharge, a minor percentage of the effluent from the TMF and WRSA bypasses the seepage collection system and reports to the adjacent surface water receivers (Stantec 2020a and 2021b, respectively).

Process water that is discharged from the mill reports to the TMF along with the tailings. The process water is reclaimed from the TMF Pond (also referred to as the Decant Pond), along with lesser amounts of water sourced from the stormwater retention pond and freshwater make-up withdrawn from Scraggy Lake (Stantec 2021c). The process water is treated for some constituents at the mill (primarily cyanide treatment with some metal removal) prior to discharge into the TMF. However, concentrations of some constituents in the TMF Pond remain elevated relative to discharge requirements, such as arsenic and suspended solids. The TMF surplus water, therefore, reports to the Effluent Treatment Plant (ETP) to adjust pH and decrease concentrations of metals (i.e., arsenic) and suspended solids. From the ETP, the treated effluent reports to the polishing pond, where final polishing of the effluent occurs to further decrease concentrations of suspended solids. Treated effluent from the polishing pond discharges to an engineered wetland prior to release to the environment at the northwestern end of Scraggy Lake.

Once the open pit mining at Touquoy is complete, the ore stockpiles will be processed and ore from other AMNS operations (i.e., Beaver Dam and Fifteen Mile Stream) is planned to be transported to site for beneficiation. The deposition of tailings and process water will continue to report to the TMF until it has reached full capacity; after which, tailings deposition is proposed to transition to the open pit. Reclaim water that is required by the process plant will continue to be pumped from the TMF until the pond size has been reduced in accordance with closure plan requirements. After which, the reclaim water will be sourced from the open pit and TMF surplus water. The storage capacity in the open pit is more than sufficient to contain the expected volumes of tailings and process water, and therefore no surface discharge of effluent from the open pit is expected to occur during operations. During closure, the open pit will flood to create

a pit lake, and overflow will be discharged to the Moose River through a spillway. Discharge from the pit lake will only occur when the water quality meets regulatory discharge limits.

The TMF will be progressively reclaimed through dewatering the TMF Pond and construction of a dry-cover system over the tailings surface (Stantec 2020b). The polishing pond will be allowed to drain and reclamation activities will be completed to support establishment of sustainable wetland vegetation. Prior to progressive reclamation, the TMF will continue to be used for water management of tailings-influenced seepage and WRSA runoff/seepage (as required). However, under normal flow conditions, the TMF surplus water will be reclaimed to the mill via pumping to the pit and the TMF will not have a surface discharge to Scraggy Lake during operations (Stantec 2021c). If TMF surplus water needs to be discharged due to unexpected or high-flow events, the ETP will be operated on a temporary basis to treat the TMF surplus water prior to discharge to the environment.

3   DESCRIPTION OF WATER QUALITY MODEL

3.1   Conceptual Model Framework

Source Term Model Components

The water quality model was developed to incorporate the sources of chemical mass load into the surface water receivers, which includes effluent discharges directly from mine infrastructure (TMF, polishing pond, and WRSA), and natural sources of chemical mass load from the surrounding watershed (natural runoff). Specifically, the input components of the water quality model can be summarized as follows (Figure 3.1):

- TMF and polishing pond effluent inputs – discharge of treated effluent from the polishing pond through the final effluent discharge point to Scraggy Lake;

- TMF and polishing pond seepage inputs – passive discharge of tailings-influenced seepage that bypasses the collection system, and also polishing pond seepage, which flows through subsurface pathways into adjacent surface water receivers located downgradient of the TMF;

- WRSA effluent inputs – treated effluent is proposed to be discharged from the WRSA pond at a second (new) final effluent discharge point located near the upstream end of Watercourse No.4 as part of the proposed changes to water management at Touquoy;

- WRSA seepage inputs – waste rock-influenced seepage that bypasses the collection system and flows through subsurface pathways into adjacent surface water receivers located downgradient of the WRSA; and

- Watershed inputs – direct precipitation and natural runoff from the catchment area that feeds the surface water receivers.

The materials underlying the tailings mainly consist of a silty sand and/or gravel till material, with lesser amounts of clay till. The design of the TMF Dam incorporates a clay core and clay blanket under the tailings on the upstream side. The intent of the clay blanket and core is to limit the seepage rate around the perimeter of the TMF. An additional benefit of the upstream clay blanket, clay core, and the natural clay till materials is the chemical mass attenuation properties, whereby some parameters (e.g., arsenic) are sequestered via adsorption as tailings-influenced groundwater flows through these clay materials. Therefore, the water quality model has divided the TMF seepage inputs into two separate geochemical and flow source term components: i) groundwater seepage that passes through the clay materials; and ii) groundwater seepage that flows through the basal silty sand/gravel till materials. These two TMF seepage source terms are conservatively assumed to fully report to the surface water environment.

Surface Water Receivers

The two surface water bodies that are considered in this modelling study are: Scraggy Lake and Watercourse No.4. A natural watercourse flowing through the mine site, Watercourse No.4 flows toward the south through the central portion of the site and along the western perimeters of the WRSA and TMF. Watercourse No.4 connects with the Moose River and ultimately discharges into the Fish River. Watercourse No.4 is proposed to receive treated effluent discharge from the WRSA pond as part of the proposed changes to the water management at Touquoy.

Scraggy Lake is comprised of two main areas that are connected by a narrow channel, with the upper section making up approximately 30% of its total surface area, and the lower section the remaining 70%. The water quality model divides Scraggy Lake into two components to reflect these two separate areas, which are referred to herein as Scraggy Lake Upper and Scraggy Lake Lower. Scraggy Lake Upper receives treated effluent discharge from the polishing pond, which mixes with baseline flows that consists of natural runoff and drainage from Square Lake via the upstream section of the Fish River. The downstream section of the Fish River starts at the outflow of Scraggy Lake Lower and flows into the north end of Lake Charlotte.

Conceptual Model Linkages

The water quality model is set-up as three distinct components to predict the water quality for Scraggy Lake Upper, Scraggy Lake Lower, and Watercourse No.4 (Figure 3.2). The locations simulated in the water quality model for Scraggy Lake Lower and Watercourse No.4 generally align with monitoring stations SW-13 and SW-3, respectively – allowing for comparison between

measured and simulated data. The flow logic for these three components, which forms the framework for the linkages in the water quality model, is summarized as follows (Figure 3.1):

1. <u>Scraggy Lake Upper</u> – Inflows consists of: i) treated effluent discharge from the polishing pond, ii) TMF seepage, iii) WRSA seepage, and iv) natural runoff from the surrounding watershed. Under normal flow conditions, treated effluent discharge to Scraggy Lake Upper is assumed to discontinue when the tailings disposal switches to the open pit. The WRSA seepage is not expected to discharge into Scraggy Lake directly, and rather is conservatively assumed to report to Scraggy Lake Upper via the drainage from Square Lake, Fish River, and a tributary that flows into the Fish River (Stantec 2021b). These flows combine to produce the outflow of Scraggy Lake Upper to Scraggy Lake Lower.

2. <u>Scraggy Lake Lower</u> – Inflows consist of: i) outflow from Scraggy Lake Upper, ii) direct precipitation, and iii) natural runoff from the surrounding watershed. These flows combine to produce the overall outflow from Scraggy Lake to the Fish River.

3. <u>Watercourse No.4</u> – Inflows consist of: i) treated effluent discharge from the WRSA pond (newly proposed second final effluent discharge point), ii) WRSA seepage, iii) TMF seepage, and iv) natural runoff from the upstream area located north of the main site infrastructure. These flows combine to produce the Watercourse No.4 drainage that combines with the Moose River at the downstream confluence.

3.2   Numerical Modelling Approach

A deterministic numerical water quality model was created using GoldSim Version 12.1.4 (GoldSim), which is a dynamic simulation software package that is widely used in the mining industry to complete water balance and water quality modelling. GoldSim is an object-oriented mathematical modelling program, whereby the input parameters and functions are defined by the user and are built into the model as individual elements linked together by mathematical expressions or functions. Because of the flexibility and object-based nature of the program, GoldSim is extensively used as a predictive tool for natural and engineered systems in order to provide a better understanding of the future behaviour of the simulated systems.

The numerical water quality model was set-up using a mass balance approach, which is based on the principle of water and chemical mass continuity. The model incorporates a series of mass-balance mixing cells that consist of several site-specific components, including natural features and processes (e.g., precipitation, lakes, watercourse reaches) and mine-site components (e.g., effluent discharge and seepage). These components are linked together to form a series of mixing cells that reflect the flow logic between the mine operations and the natural environment.

Each of the three components outlined in Section 3.1 exist as separate mixing cells within the GoldSim model to predict a "mixed" or combined water quality. The GoldSim model accounts for flows and chemical loads that enter and exit each of the mixing cells and calculates mixed concentrations through iterations over a specified timestep. Therefore, mixed water quality is calculated for each timestep by integrating specific flow inputs with chemistry inputs to calculate mass loading rates as follows:

$$C_{x+1} = \frac{(C_1 \times Q_1) + (C_2 \times Q_2) \ldots + (C_x \times Q_x)}{(Q1 + Q2 \ldots + Q_x)}$$
[Equation 1]

where:

C_1 = concentration from Input 1;

Q_1 = flow from Input 1;

C_2 = concentration from Input 2;

Q_2 = flow from Input 2;

C_x = concentration from Input X;

Q_x = flow from Input X; and

C_{x+1} = concentration of the combined inflows (mixed water body or watercourse).

Based on this numerical approach, the model assumes fully mixed conditions within Watercourse No. 4 and the two main basins of Scraggy Lake (Scraggy Lake Upper and Scraggy Lake Lower). Therefore, the water quality model does not consider localized hydrodynamics or lake mixing processes on effluent dispersion.

3.3 Model Time Series and Scenarios

The water quality model was set-up to simulate past years (2018, 2019, and 2020) for the purposes of calibrating the model relative to observed conditions. The ultimate objective of the water quality modelling exercise is to evaluate potential changes to surface water quality under a scenario that considers the proposed changes to the operations. As such, the water quality model was run to predict future conditions during 2021 through 2023 to simulate the period that captures the WRSA expansion and the transition to in-pit disposal. Based on this, the two scenarios presented in this study are as follows:

- **Scenario 1: Base Case Conditions** – Model simulations were completed under base case conditions to predict water quality in Scraggy Lake and Watercourse No.4 during past operating years at Touquoy (2018, 2018, and 2020). The existing operational conditions and water management logic at Touquoy were applied along with the base case geochemical source terms to simulate the past operating years. The objective of the

base case condition was to compare the model results to measured data, and therefore allow for model calibration and validation.

- **Scenario 2: Proposed New Case Conditions** – Model simulations of future years (2021, 2022, and 2023) were completed to capture the potential changes to water quality based on the proposed operational changes. Scenario 2 demonstrates the net effect on surface water quality due to the proposed expansion of the WRSA and the proposed discharge of treated effluent from the WRSA pond into Watercourse No.4. These proposed changes associated with the WRSA were simulated in combination with a switch to in-pit tailings disposal, which is assumed to occur during mid-2022. Accordingly, the model applies effluent discharge rates, seepage rates, and geochemical source terms that consider the proposed changes; this includes capturing the changes to the geochemical source terms (based on expected increase of rock tonnage in the WRSA) and increase in seepage rates due to changes to the WRSA footprint. Scenario 2 also considered base case and upper case geochemical source terms to provide predictions that are based on the most likely concentrations (base case) and potential worst-case concentrations (upper case).

3.4   Model Inputs

A summary of the water quality model input data, including a description of the approach and the data source, is provided in Table 3.1. The water quality model inputs are discussed in more detail in the following sections.

3.4.1 Flow Inputs

Daily measurements of flow are recorded at the outflow from the ETP. Average monthly flow rates of effluent discharge into Scraggy Lake Upper were calculated for January through December based on the daily effluent flow measurements during 2018, 2019, and 2020 (Table 3.2). For effluent discharge rates during 2021, the effluent discharge schedule is based on the rates predicted in the TMF water balance (Stantec 2020c). After the disposal of tailings switches to the open pit, the TMF surplus will be reclaimed to the process plant and effluent discharge rates are assumed to be zero under normal flow conditions.

The watershed baseline flows into Scraggy Lake (Table 3.2) were based on a regional water balance (CRA 2007; Golder 2007). The average monthly baseline flows account for water gains through natural runoff and direct precipitation, and also water losses via evaporation – these flows were applied as the "natural runoff" flow component of the model, as described in the conceptual model (Section 3.1). The average monthly baseline flows were split to reflect two subwatersheds, whereby 46% of the baseline flows are assumed to report to Scraggy Lake Upper and 54% of the

baseline flows are assumed to report to Scraggy Lake Lower. Average monthly baseline flow data for Watercourse No.4 were derived based on estimated average watershed flows (Stantec 2021d; Table 3.2).

Groundwater seepage rates from the TMF into Scraggy Lake and Watercourse No.4 (Table 3.3) were derived from predictions by Stantec (2020a). Conservatively, all seepage from the TMF that bypasses the seepage collection system is assumed to fully daylight to surface and report to the surface water environment with no seepage remaining in the subsurface. Since the TMF seepage is not expected to change relative to base case conditions, a single set of seepage rates were derived and applied to both Base Case Conditions (Scenario 1) and Proposed New Case Conditions (Scenario 2). The TMF seepage rates have been divided into seepage that flows through the clay materials (clay blanket/clay core/clay till) and the basal materials (silty sand and gravel till) that are more broadly present under the tailings.

The WRSA pond effluent discharge rate and WRSA seepage rates were estimated by Stantec (2021b,d). The WRSA pond discharge was only applied under Scenario 2 because this effluent discharge into Watercourse No.4 is a newly proposed final effluent discharge point. The WRSA pond discharge is treated prior to discharge. The treatment is assumed to decrease the nitrate concentrations by 60% prior to discharge into Watercourse No.4. The WRSA seepage rates include separate rates that were derived for both Scenario 1 and Scenario 2 to reflect expected differences in seepage rates under the existing WRSA configuration relative to the expanded WRSA configuration (Table 3.4). The WRSA seepage that is predicted to bypass the seepage collection system is assumed to report to Square Lake, Fish River, the "Tributary to Fish River", and Watercourse No.4. For the purposes of the water quality predictions, the combined seepage rates reported for Square Lake, Fish River, and the Tributary to Fish River are conservatively assumed to represent the WRSA seepage that ultimately reports to Scraggy Lake.

3.4.2 Geochemical Source Term and Water Chemistry Inputs

Modelled Parameters

The water quality model predicts concentrations of the following parameters for Scraggy Lake Upper, Scraggy Lake Lower, and Watercourse No.4: aluminum, ammonia (total), antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chloride, chromium, cobalt, copper, cyanate, cyanide (total), fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, nitrate, nitrite, phosphorus, potassium, selenium, silver, sodium, strontium, sulphate, thallium, tin, titanium, uranium, vanadium, and zinc.

Some parameters were not included as part of the water quality model and predictions were not completed as follows:

- pH and alkalinity – the waste rock, ore, and tailings are expected to be non-acid generating, and the drainage from the mine site facilities and all geochemical source term components have neutral pH. Therefore, the pH and alkalinity in Scraggy Lake and Watercourse No.4 are not expected to substantially change from baseline conditions.

- Dissolved oxygen and temperature – the effluent discharge from the polishing pond is not expected to have redox characteristics that are reducing in nature, or temperatures that vary significantly from the natural conditions in the local surface water receiving environment. Therefore, the effluent discharge into the surface water receivers is not expected to alter the physical mixing behaviour.

- Total suspended solids (TSS) – the transport of TSS is highly influenced by site-specific hydrological conditions, particularly with respect to the design of the water management systems at the site. Engineered control structures have been incorporated into the design of the water management system to allow for settlement of suspended solids and manage the sediment load from the site. Loading rates of suspended solids are anticipated to be similar to current conditions.

Geochemical Source Terms

The water quality of the treated effluent discharge from the TMF and polishing pond has been monitored at station SW-14 (Figure 3.2) – this data was used to derive the effluent quality inputs for the water quality model (Table 3.5). Average monthly concentrations for each month during 2018, 2019, and for March 2020 were calculated using data collected during specific months – noting that effluent was not discharged during some months in 2018 (January through June), 2019 (August through December), and 2020 (January, February, July, and August); therefore, average monthly concentrations were not calculated for those months. For future years, average annual concentrations were used for the effluent quality inputs, which were derived based on data collected at SW-14 during 2018, 2019, and 2020.

Baseline water quality was sampled at the monitoring stations SW-13 and SW-3 located at the downstream end of Scraggy Lake and Watercourse No.4, respectively (Figure 3.2). Surface water samples representing baseline (pre-mining) conditions were taken monthly from March 2016 until October 2017. The monitoring data collected at SW-13 and SW-3 during these periods was used to calculate average concentrations for the chemistry input that reflects the water quality of the baseline watershed flows, including natural runoff (Table 3.6).

Seepage chemistry for the TMF was estimated by Lorax (2020) and is summarized in Table 3.7a. Predictions of TMF seepage quality are reported as "attenuated" and "unattenuated" to reflect seepage flow through geologically distinct materials. The TMF seepage chemistry referred to as

"attenuated" reflects the tailings-influenced groundwater that flows through the clay materials (clay blanket, clay core, and clay till). The TMF seepage chemistry that is referred to as "unattenuated" reflects the tailings-influenced groundwater that flows through the main basal layer under the tailings (silty sand and gravel till). The clay materials have been demonstrated to attenuate some parameters through adsorption mechanisms (Lorax 2020), which validates incorporating the two different input chemistries within the water quality model. In addition, a base case and an upper case were applied in the water quality model to assess average (or most likely) seepage chemistry and the potential worst-case TMF seepage chemistry, respectively.

Effluent chemistry for the WRSA was estimated by Lorax (2020) and is summarized in Table 3.7b. The WRSA effluent chemistry is expected to be dependent on the quantities of waste rock, with greater quantities of waste rock increasing the water-rock interactions that alters the drainage chemistry. As with the geochemical source terms for the TMF seepage, a base case and an upper case were applied in the water quality model to assess the average (or most likely) chemistry and the potential worst-case chemistry, respectively.

3.5   Model Validation and Verification

The water quality model underwent a validation and verification process by comparing the simulated concentrations generated by the water quality model relative to the measured water quality data. For the comparison process, the water quality data collected at monitoring station SW-13 were applied to verify the results for Scraggy Lake, and water quality data collected at monitoring station SW-3 were applied to verify the results for Watercourse No.4.

Subsequent to the start of effluent discharge into Scraggy Lake in July 2018, several months were required to observe a chemical breakthrough at the outlet of Scraggy Lake for specific parameters. A chemical breakthrough refers to the changes to concentration of a known chemical species as the concentrations transition from baseline values to steady-state conditions. In the measured data at monitoring stations SW-13, chemical breakthrough started during late-summer 2018 and carried through to the end of 2019 (Figure 3.3) – this timing of the chemical breakthrough reflects a combination of the residence time and assimilative capacity of the lake. During the second half of 2019, the concentrations have levelled off with only seasonal fluctuations, which signals the onset of steady state conditions.

To further validate the water quality model results, the observed chemical breakthrough was compared to the simulated concentrations generated by the water quality model (Figure 3.3). The simulated concentrations show an excellent fit with respect to the observed trend of the chemical breakthrough at the outlet of Scraggy Lake. The excellent model fit provides a relatively high degree of certainty with respect to the model inputs applied (geochemical source terms and flow

inputs) and that the mixing processes being simulated by the model align well with the actual processes in Scraggy Lake. Therefore, the validated base case model provides confidence that the model can be applied as a tool to provide reasonable estimates of water quality under various scenarios.

4   RESULTS

The water quality model results of the Base Case Conditions (Scenario 1) and Proposed New Case Conditions (Scenario 2) for Scraggy Lake Upper, Scraggy Lake Lower, and Watercourse No.4 are presented in Tables 4.1, 4.2, and 4.3, respectively. Predicted concentrations have been compared against: i) Nova Scotia Environmental Quality Standards (NS EQS); ii) the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of freshwater aquatic life; iii) IA Site Water Monitoring Criteria for surface water monitoring locations (as per Appendix K of the IA Amendment, effective date: April 9, 2020), hereafter referred to as IA Water Quality Criteria/Criterion; and iv) average baseline concentrations (pre-mining operations).

4.1   Scraggy Lake

Generally, the predicted concentrations in Scraggy Lake (Upper and Lower) under Scenarios 1 and 2 are less than the NS EQS, CCME CWQG and IA Water Quality Criteria concentrations (Tables 4.1 and 4.2). A comparison of the water quality predictions for Scraggy Lake under Scenario 1 versus Scenario 2 indicates that the proposed changes to the Touquoy operations is predicted to result in concentrations that are similar to and/or improved relative to those predicted for existing conditions (Base Case). The stable to improving water quality in Scraggy Lake is largely due to the cessation of process water deposition into the TMF and reclaim of TMF drainage to the process plant (i.e., zero release of TMF surplus through a surface discharge under normal flow conditions). Because treated effluent will no longer be discharged to Scraggy Lake once the operations switch to in-pit tailings disposal, the mass loading rates to Scraggy Lake will decrease and the water quality will be stable to improved relative to existing conditions.

The results of the water quality predictions for Scraggy Lake Upper and Lower for Scenario 2 (Proposed New Case Conditions) indicate that the aluminum concentrations are expected to range from 141 to 144 µg/L, which are greater than the NS EQS of 5 µg/L and the CCME CWQG and IA Water Quality Criterion of 100 µg/L. However, the predicted concentrations of aluminum are within the range of baseline (pre-mining) concentrations (Figure 4.1), which is evident by comparing the predicted concentrations to the average baseline concentration of 145 µg/L (Tables 4.1 and 4.2) and baseline concentrations were measured to be as high as 310 µg/L. The average baseline concentration of aluminum is above the NS EQS of 5 µg/L and the CCME

CWQG and the IA Water Quality Criterion of 100 µg/L (Figure 4.1), and therefore aluminum concentrations greater than water quality guidelines are naturally occurring.

Similarly, the results of the water quality predictions for Scraggy Lake Upper and Lower indicate that the cadmium concentrations are expected to range from 0.0148 to 0.0151 µg/L, which is greater than the NS EQS of 0.01 µg/L, but less than the CCME CWQG and IA Water Quality Criterion of 0.04 µg/L. The average baseline concentration of cadmium in Scraggy Lake is 0.015 µg/L; noting further that baseline concentrations were commonly above 0.015 µg/L and measured to be as high as 0.071 µg/L (Figure 4.1). Therefore, the predicted cadmium concentrations are within the range of baseline concentrations, and values above the NS EQS of 0.01 µg/L are naturally occurring.

4.2   Watercourse No.4

A comparison of the water quality predictions for Scenario 1 versus Scenario 2 (Table 4.3) indicates that the proposed changes to the Touquoy operations are predicted to result in higher concentrations of some major ion parameters, but metals concentrations are predicted to be similar to existing conditions (base case). For example, concentrations of sulphate, calcium, magnesium, and nitrogen species are expected to increase, while concentrations of metals, such as aluminum, iron, arsenic, cobalt, and copper, are expected to be similar to existing or current conditions. Generally, the predicted concentrations in Watercourse No.4 under both Base Case Conditions (Scenario 1) and Proposed New Case Conditions (Scenario 2) are less than the NS EQS, CCME CWQG, and IA Water Quality Criteria concentrations (Table 4.3), with a few exceptions as noted below.

The predicted water quality for Watercourse No.4 suggests that concentrations of arsenic will range from about 9 to 16 µg/L, which are greater than the NS EQS, CCME CWQG, and IA Water Quality Criterion of 5 µg/L. The average arsenic concentration under the Proposed New Case Conditions (Scenario 2), and using the base case geochemical source terms, was predicted to be 8.8 µg/L; this predicted average concentration is the most likely condition that will persist under the Proposed New Case Condition (Scenario 2) and it is closely aligned with the average baseline (pre-mining) concentrations of arsenic in Watercourse No.4 (10.9 µg/L). Furthermore, the baseline concentrations of arsenic have been measured as high as 38 µg/L (Figure 4.2). Therefore, the range of baseline concentrations encompasses the full range of predicted concentrations (even using the upper case geochemical source terms, which are considered to be more representative of worst case conditions).

Aluminum concentrations are predicted to range from 94 to 112 µg/L, which are greater than the NS EQS of 5 µg/L and mostly greater than the CCME CWQG and IA Water Quality Criterion of

100 µg/L. The average baseline (pre-mining) concentration of aluminum in Watercourse No.4 is 425 µg/L, with two maximum baseline peaks measured at 2,500 and 1,100 µg/L (Figure 4.2). The predicted aluminum concentrations are therefore within the range of baseline concentrations, and concentrations greater than water quality guidelines are naturally occurring.

Cadmium concentrations are predicted to range from 0.013 to 0.020 µg/L, which is greater than the NS EQS of 0.01 µg/L, but less than the CCME CWQG and IA Water Quality Criterion of 0.16 µg/L. The average baseline concentration of cadmium in Watercourse No.4 is 0.013 µg/L, and baseline concentrations were measured as high as 0.057 µg/L (Figure 4.2). Therefore, the predicted cadmium concentrations are within the range of baseline concentrations, and values above the NS EQS of 0.01 µg/L are naturally occurring.

5   CLOSURE CONSIDERATIONS

The conceptual reclamation plan for Touquoy is presented in Stantec (2020b). The slopes of the WRSF will be graded to allow for the construction of a revegetated soil cover. The TMF will be progressively reclaimed through dewatering the TMF Pond and construction of a dry-cover system over the tailings surface. The dewatering of the TMF Pond and draining of the upper tailings will result in a drop of the water table to a lower equilibrium condition, which will decrease the hydraulic gradient (and seepage flow rates) between the TMF and surface water receivers. The polishing pond will be allowed to drain and reclamation activities will be completed to support establishment of wetland vegetation. Therefore, the polishing pond and engineered wetland will be developed to provide sustainable wetland features that will assist with further improvements to water quality of the surface drainage from the reclaimed TMF.

The implementation of these closure measures will improve chemical stability and decrease mass loading rates from the WRSF and TMF source terms relative to current conditions.   The reclamation of the WRSF will reduce infiltration rates and water-rock interactions by construction of a vegetated cover. Similarly, the TMF cover system will reduce water-tailings interactions and infiltration rates within the TMF. Therefore, the closure measures will promote the runoff of non-contact water and there will be a reduction in the quantities of contact water that report from the reclaimed WRSF and TMF to the environment via seepage. Based on the decreases to mass loading rates, the water quality in Scraggy Lake and Watercourse No.4 is expected to improve and have stable and/or decreasing trends during the post-closure period.

6   SUMMARY AND CONCLUSIONS

A water quality model was developed to predict the water quality in the surface water environments located downstream of the TMF, specifically the model simulates the water quality

of Scraggy Lake and Watercourse No.4. The modelling was completed for AMNS as part of the Class I EA that was determined to be required to evaluate the proposed changes to site operations at Touquoy. Water quality predictions were completed for Base Case Conditions (Scenario 1) and Proposed New Case Conditions (Scenario 2), and the results were compared to water quality guidelines and baseline water quality data.

A summary of the findings are as follows:

- Predicted water quality in Scraggy Lake indicates that the concentrations under the Proposed New Case Conditions (Scenario 2) are similar to and/or improved relative to those predicted for the Base Case Conditions (Scenario 1). Concentrations of all modelled parameters are less than water quality guidelines, except for parameters that naturally occur at levels greater than the water quality criteria (i.e., aluminum and cadmium). Therefore, based on the water quality modelling, there are no substantial changes to the water quality of Scraggy Lake that are associated with the proposed operational changes at Touquoy.

- Predicted water quality in Watercourse No.4 suggests that the concentrations under the Proposed New Case Conditions (Scenario 2) are expected to be higher for some major ions relative to those predicted for the Base Case Conditions (Scenario 1). However, the predicted increase in the major ions concentrations at the assessment location does not result in exceedances water quality guidelines, and therefore are expected to be protective of aquatic life and not affect the natural function of the watercourse. Metal concentrations for Proposed New Case Conditions (Scenario 2) are predicted to be similar to those for Base Case Conditions (Scenario 1). Concentrations of all modelled parameters are less than water quality guidelines, except for parameters that naturally occur at levels greater than the water quality criteria (i.e., aluminum, arsenic, and cadmium). Therefore, based on the water quality modelling, there are no substantial changes to the water quality of Watercourse No.4 that are associated with the proposed operational changes at Touquoy.

- Although closure was not numerically assessed using the water quality model, a qualitative assessment infers that the implementation of the proposed closure measures will improve chemical stability and decrease mass loading rates from the WRSF and TMF source terms relative to current conditions. Therefore, the water quality in Scraggy Lake and Watercourse No.4 is expected to improve relative to the predicted concentrations for the operational period, and the concentration trends will be stable to decreasing over the long-term during the post-closure.

6   CLOSURE

We trust that this technical memo meets your needs at this time. Should you have any questions with respect to the content of the memo, please do not hesitate to contact us.

Yours truly,

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Hydrogeochemist   Senior Hydrogeochemist

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FIGURES
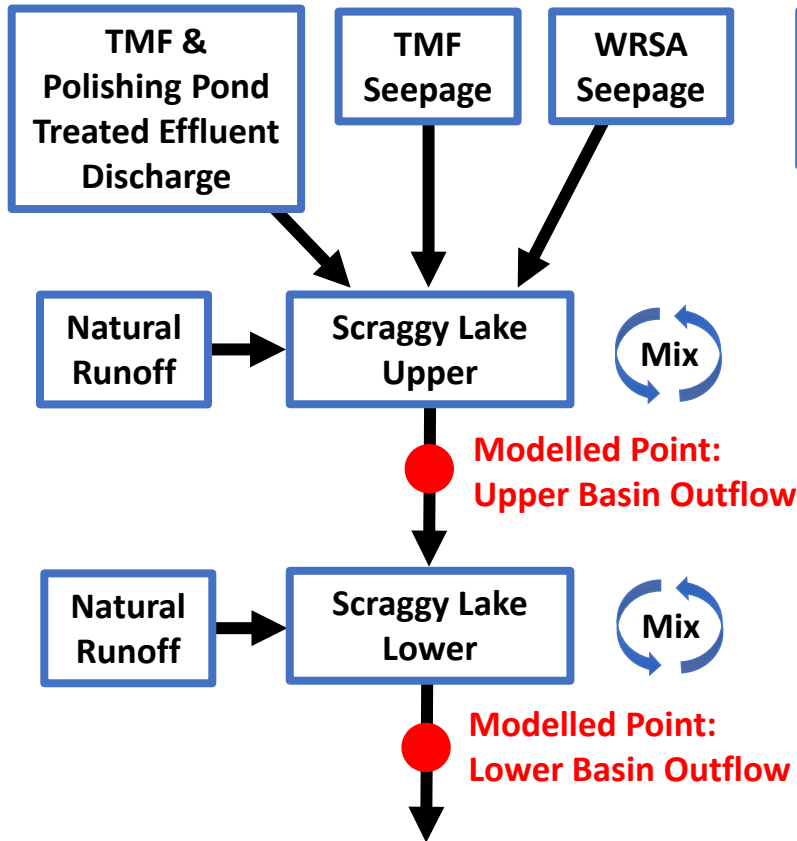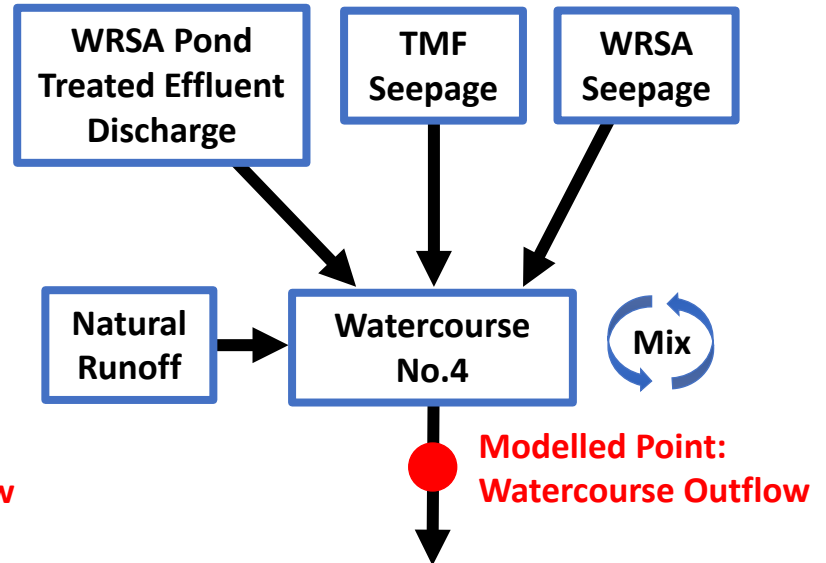
Figure 3.1: Conceptual Water Quality Model

Water Quality Monitoring and Model Output Locations, Touquoy Gold Project
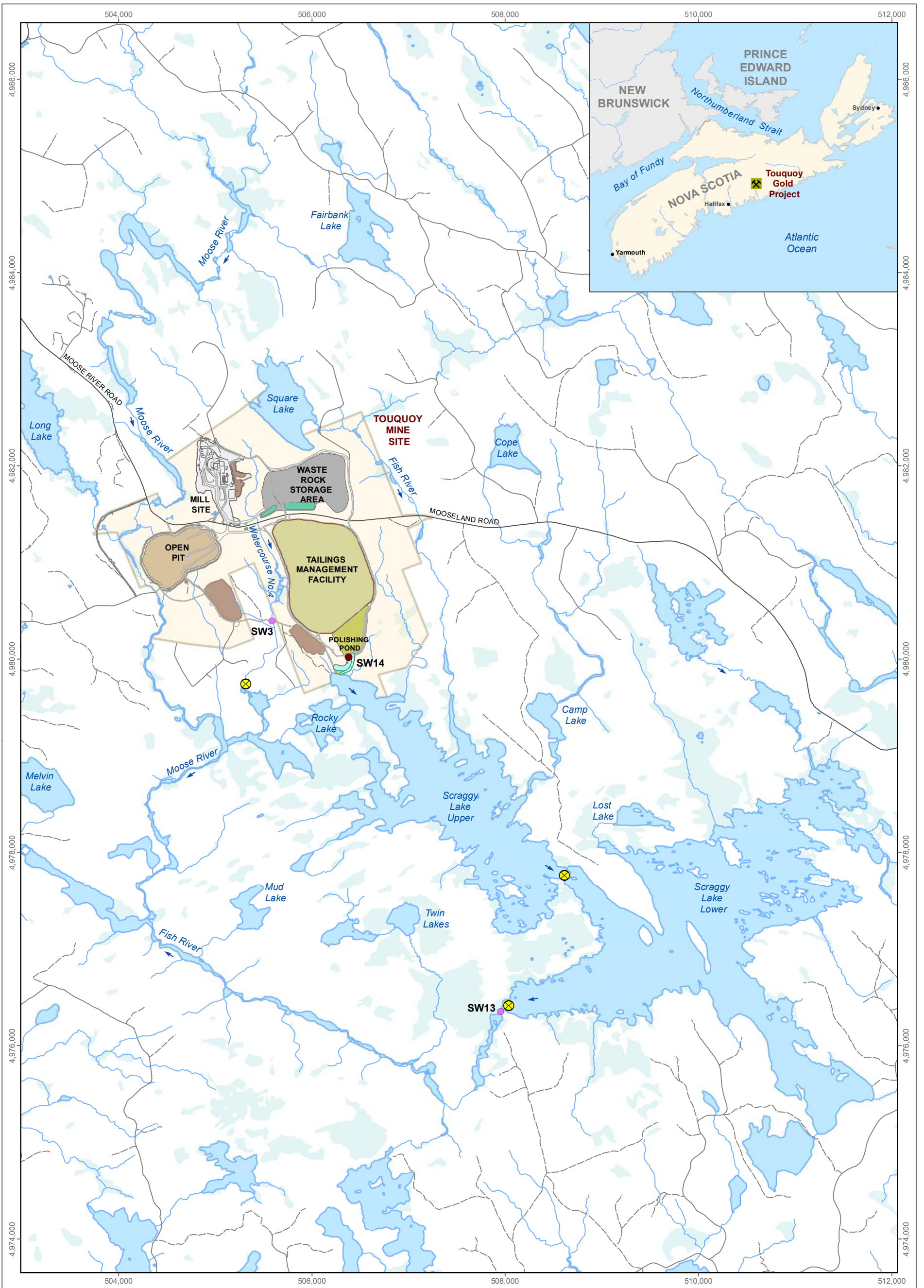
LEGEND

- Final Effluent Discharge Location
- Surface Water Monitoring Location
- Water Quality Model Output Location

Mine Infrastructure

- Waste Rock Storage Area
- Stockpile
- Tailings Management Facility
- Wetland
- Seepage Collection Pond
- Polishing Pond
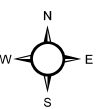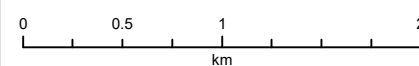
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Reproduced under licence from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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Figure 3.2

Document Path: C:\Users\MLaPalme\Trinity Consultants, Inc\St Barbara - 217202.0048 - Touquoy Class 1 EA Support\D - GIS\Report\21-48 Figure 3.2 WQ and Model Output Locations.mxd
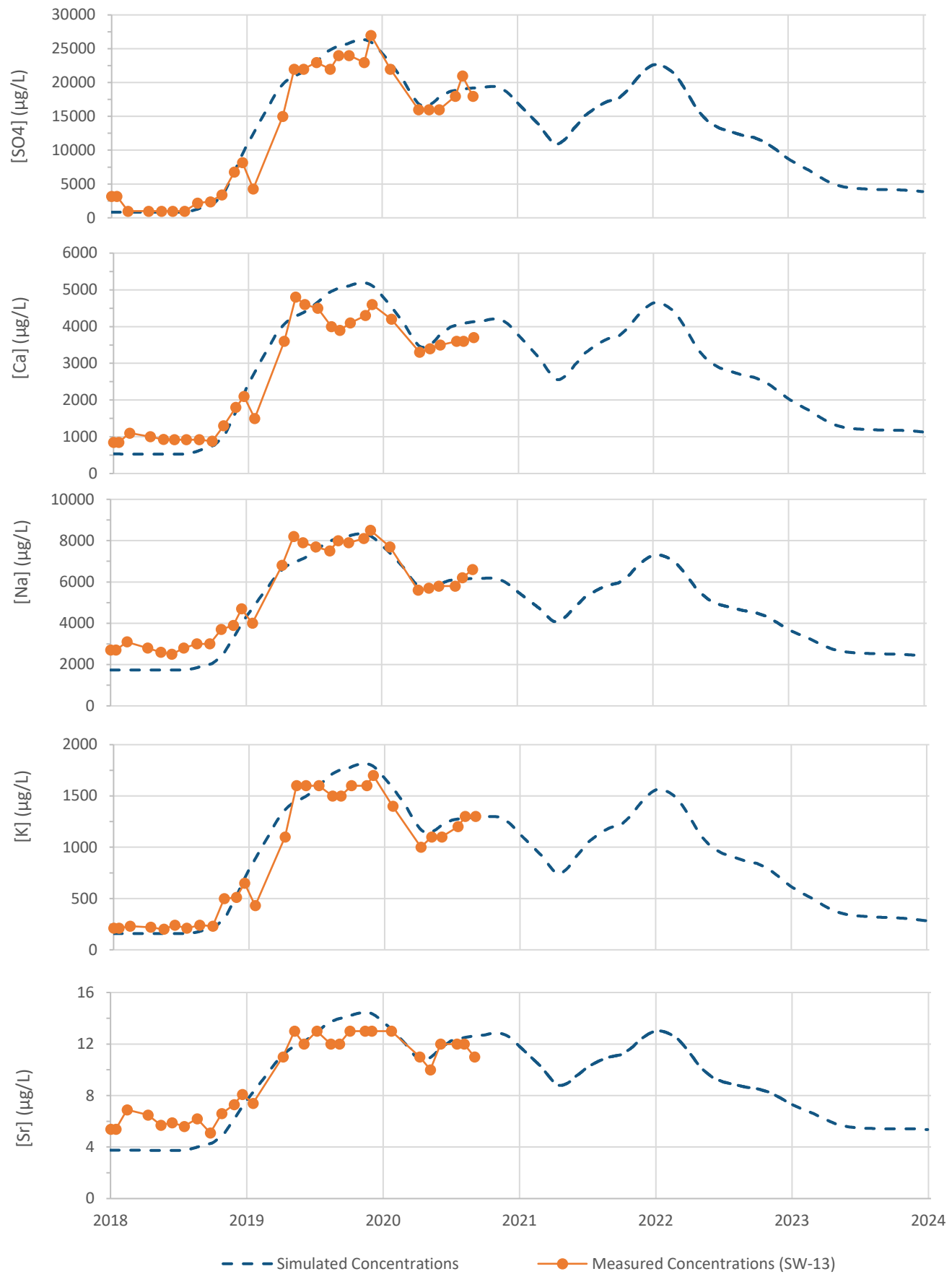
Figure 3.3: Comparison of Simulated and Measured Concentrations at the Scraggy Lake Outlet (SW-13)
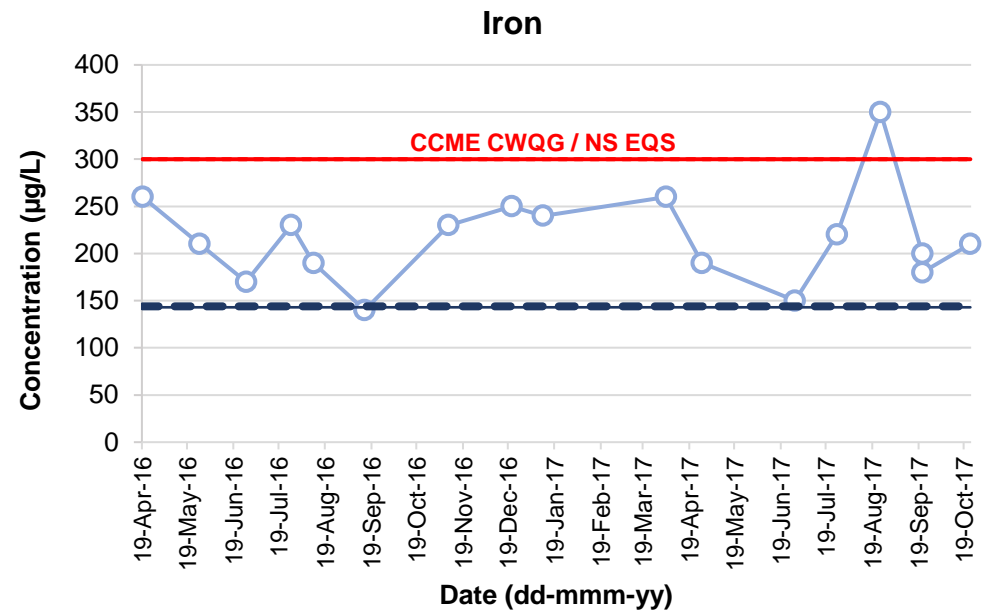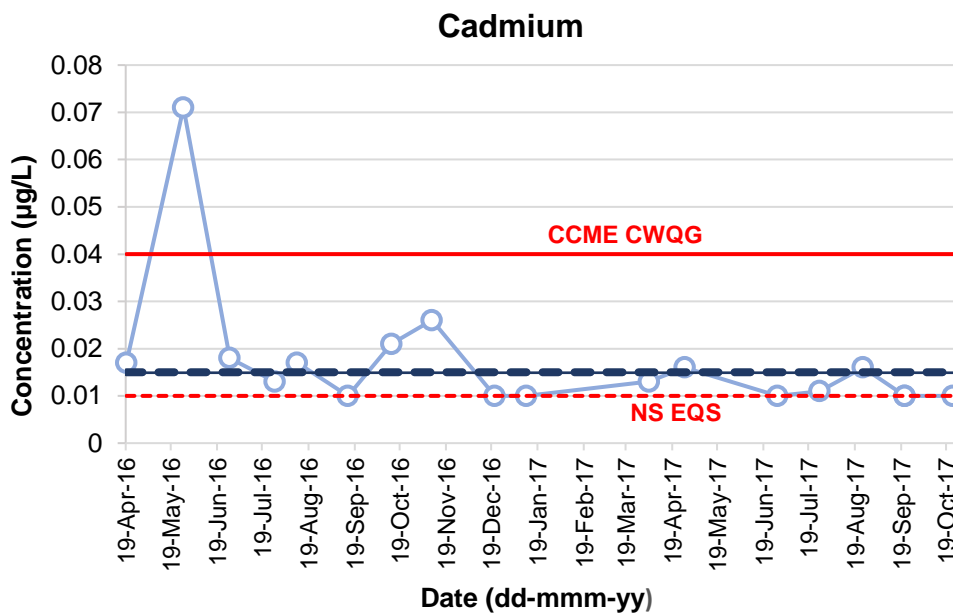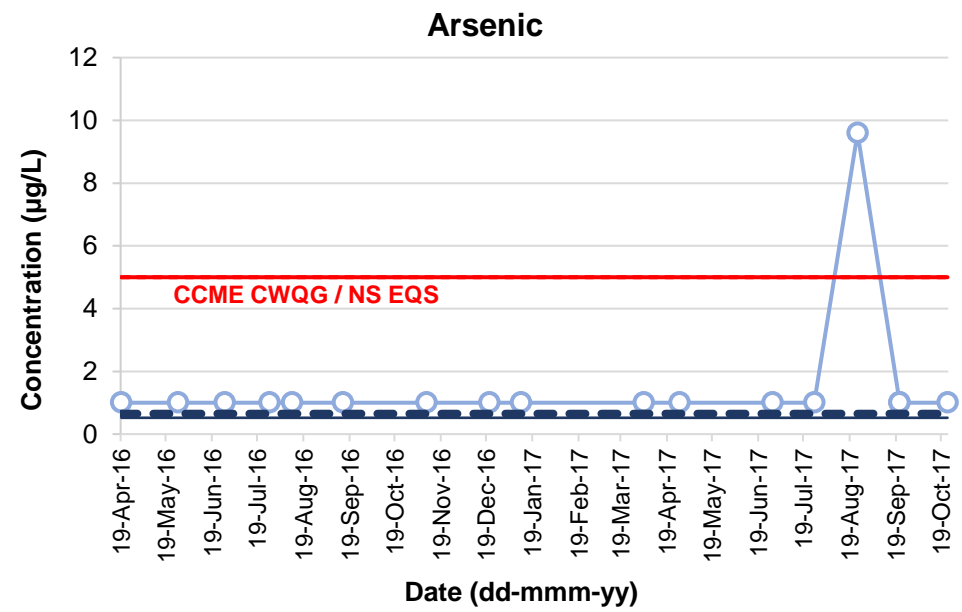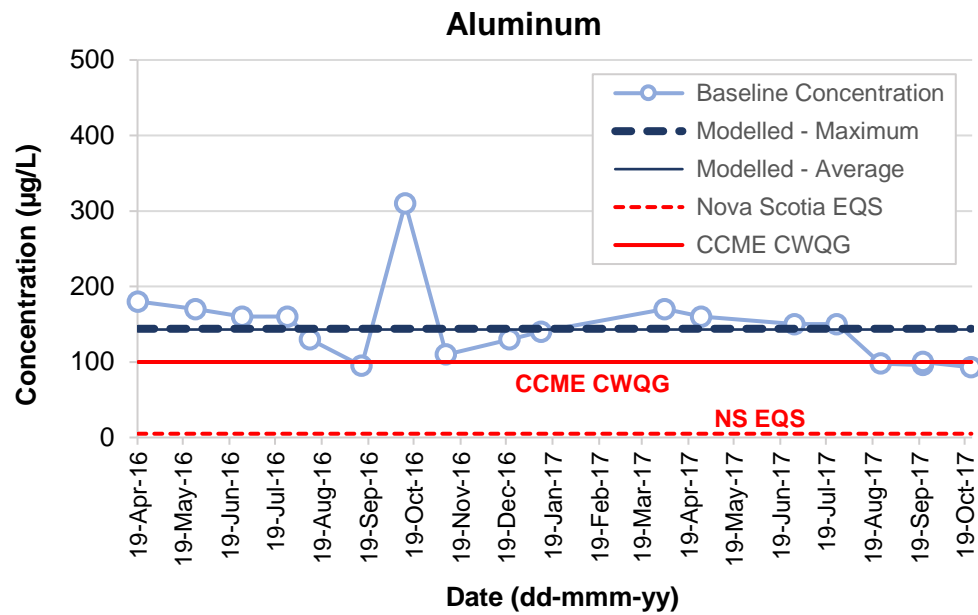
Figure 4.1: Baseline Concentrations of Aluminum, Arsenic, Cadmium, and Iron in Scraggy Lake Lower (Station SW-13) Compared to Water Quality Guidelines and Modelled Concentrations
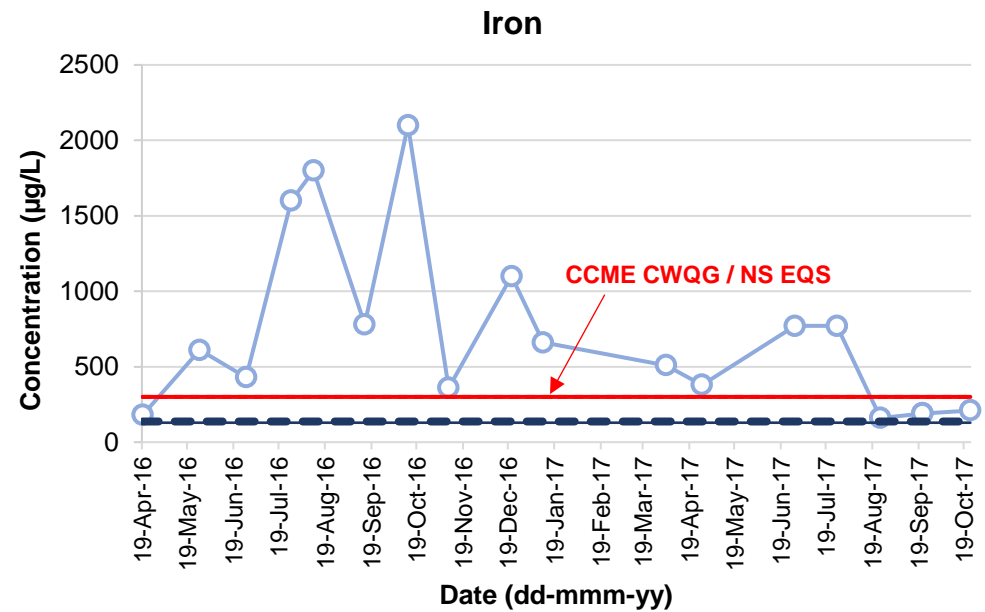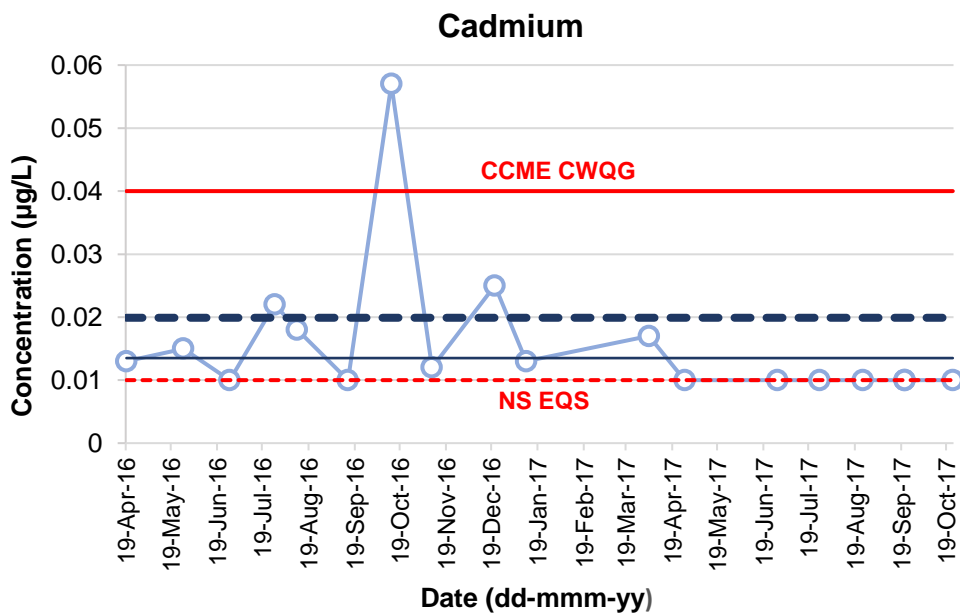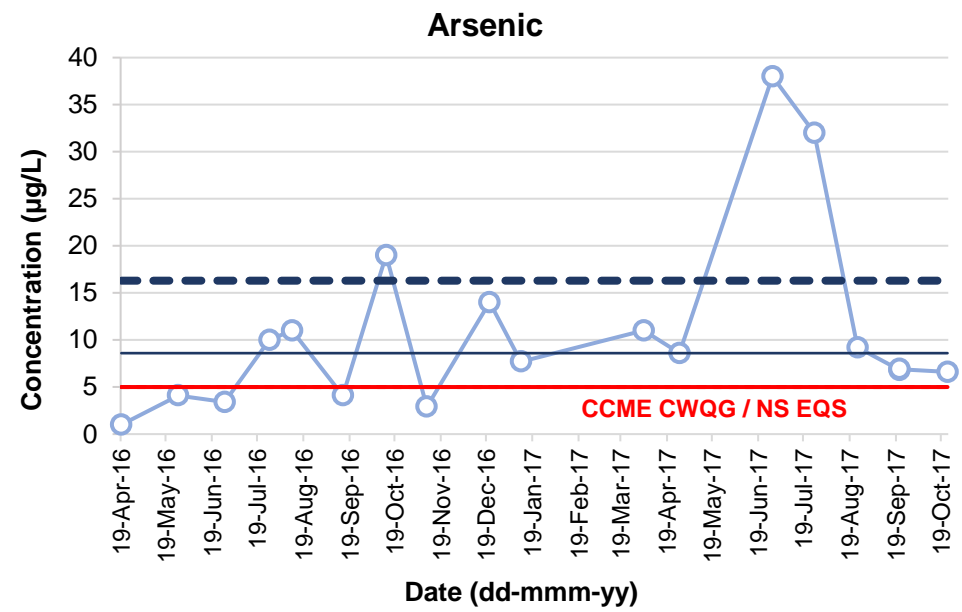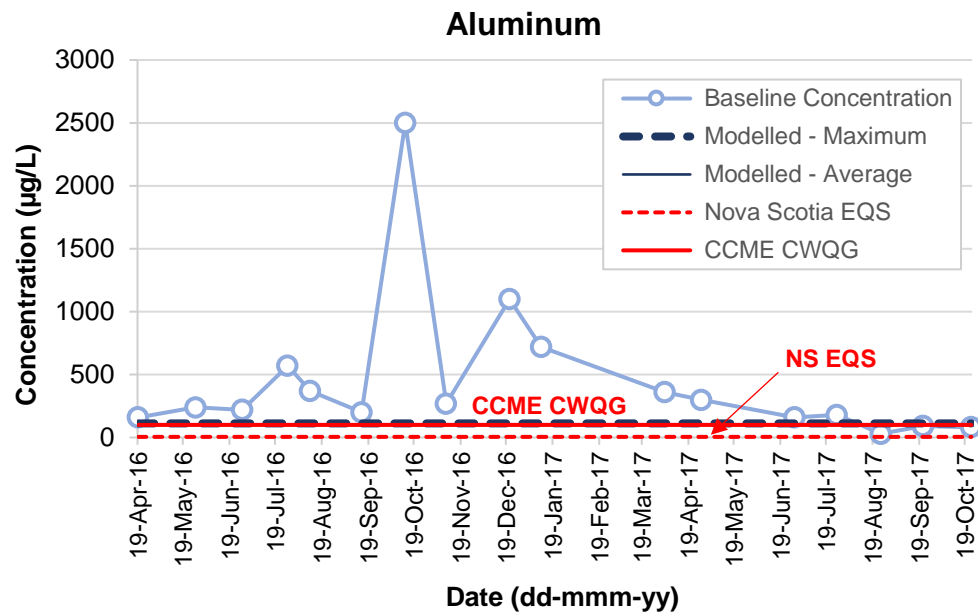
Figure 4.2: Baseline Concentrations of Aluminum, Arsenic, Cadmium, and Iron in Watercourse No.4 (Station SW-3) Compared to Water Quality Guidelines and Modelled Concentrations

TABLES

Table 3.1: Summary of Water Quality Model Inputs

Model Input	Data Approach	Source
Flow Source Terms		
Treated effluent discharge rates from polishing pond	Monthly average effluent discharge rates for 2018, 2019, and 2020 were calculated from daily flow measurements of effluent discharge.	AMNS
	Monthly average effluent discharge rates for 2021 are based on the TMF water balance (rev 14).	Stantec (2020c)
	After tailings disposal transitions to the open pit, the monthly average effluent discharge rates for 2022 and 2023 are assumed to be zero under normal flow conditions.	Stantec (2021c)
TMF seepage rates	Average annual seepage rates were estimated using seepage modelling. The proportion of seepage that flows through the clay materials (clay core, clay blanket, and in-situ clay till) relative to the seepage that flows through the silty sand and gravelly till materials was also estimated using seepage modelling.	Stantec (2020a)
WRSA seepage rates	Average annual seepage rates were estimated using seepage modelling. Seepage from the WRSA reports to Square Lake, the Fish River, and the Tributary to Fish River, which is assumed to ultimately report to Scraggy Lake.	Stantec (2021b)
Treated effluent discharge rates from WRSA pond	Monthly average effluent discharge rates from the WRSA pond are based on expected discharge requirements and assumed to be the same for all years.	Stantec (2021d)
Baseline flow into Scraggy Lake	Monthly average flows are based on a water balance for the Scraggy Lake watershed under average flow conditions. The baseline flows consider input from direct precipitation and natural runoff, and losses from evaporation.	CRA (2007) & Golder (2007)
Baseline flow into Watercourse No.4	Monthly average flow data based on estimated average watershed flows, which consider direct precipitation and natural runoff.	Stantec (2021d)
Geochemical Source Terms		
Treated effluent water chemistry from polishing pond	Monthly average effluent concentrations were calculated from measured data collected at monitoring station SW-14 during 2018, 2019, and 2020.	AMNS
TMF seepage chemistry	Average annual base case and upper case geochemical source terms were derived for TMF seepage flowing through the clay materials ("attenuated") and silty sand/gravel till ("unattenuated").	Lorax (2020)
WRSF effluent chemistry	Average annual base case and upper case geochemical source terms were derived for WRSA effluent.	Lorax (2020)
Watercourse No.4 baseline water chemistry	Monthly average concentrations were derived from data collected at monitoring station SW-3 between March 14, 2016 to October 25, 2017.	AMNS
Scraggy Lake baseline water chemistry	Monthly average concentrations were derived from data collected at monitoring station SW-13 between March 14, 2016 to October 25, 2017.	AMNS

Note: AMNS - Atlantic Mining NS Inc.

Table 3.2: Effluent Discharge and Watershed Baseline Flow Inputs

Month	Treated Effluent Discharge						Baseline Flows		
	TMF & Polishing Pond				Proposed New Case Conditions (Scenario 2)	WRSA Pond Effluent Discharge (Scenario 2 only)	Scraggy Lake (Scenarios 1 & 2) [e]	Watercourse No.4 [f]	
	Base Case Conditions (Scenario 1)							Base Case Conditions (Scenario 1)	Proposed New Case Conditions: (Scenario 2)
	2018 [a]	2019 [a]	2020 [a]	2021 [b]	2022 & beyond [c]	2022 & beyond [d]			
January	0	7,623	0	0	0	338	123,552	4707	4402
February	0	7,291	0	0	0	308	127,008	4709	4011
March	0	7,721	3,562	0	0	459	177,984	6209	5970
April	0	8,885	12,738	11,607	0	615	185,760	8462	8003
May	0	7,582	12,117	11,240	0	357	118,368	4922	4640
June	0	10,400	5,537	8,630	0	188	68,256	2572	2450
July	517	8,622	0	3,533	0	112	39,744	1507	1451
August	3,746	0	0	0	0	105	44,064	1449	1360
September	2,637	0	276	0	0	127	28,512	1709	1655
October	6,209	0	5,774	6,803	0	264	65,664	3583	3441
November	6,402	0	7,465	5,407	0	471	123,552	6439	6134
December	6,982	0	6,730	5,442	0	473	145,152	6506	6153

Notes:

Flow rates are in m^3/day.

(a) Average monthly discharge rates for 2018, 2019, and 2020 were calculated from measured daily flow volumes.

(b) Average monthly discharge rates for 2021 are predictions based on the TMF water balance (rev 14; Stantec 2020c).

(c) Once the transition is made to in-pit tailings disposal, TMF surplus water will be reclaimed to the mill and the average monthly effluent discharge rates for 2022 and beyond are assumed to be zero under normal flow conditions.

(d) Average monthly effluent discharge rates from the WRSA pond to Watercourse No.4 were provided by Stantec (2021d). These effluent discharge rates were only applied for Scenario 2, and were assumed to be 0 m^3/day for Scenario 1.

(e) Baseline flow rates for Scraggy Lake are taken from CRA (2007) and Golder (2007).

(f) Baseline flow rates for Watercourse No.4 change provided by Stantec (2021d).

Table 3.3: TMF Seepage Flow Inputs

TMF Dam Section	Length (m)	Seepage Rates (m³/d)		
		Base Case Conditions (Scenario 1) & Proposed New Case Conditions (Scenario 2)		
		Total [a]	Clay Blanket, Core, or In-situ Clay Till [b]	Silty Sand & Gravel Till [b]
Seepage Reporting to Watercourse No.4				
A	725	92	19	73
B	250	49	11	38
C [c]	239	68	26	41
Total		**209**	**56**	**152**
Seepage Reporting to Scraggy Lake				
C [c]	239	68	26	41
D	650	1	0	1
E	572	212	49	163
F	925	60	17	43
Total		**341**	**93**	**248**

Notes:

(a) Total seepage rates for each TMF Dam section reporting to the environment are taken from Table 4.1 of Stantec (2020a).

(b) The total seepage rate reporting to the surface water environment is split into two seepage rates that flow through geologically distinct material groups: i) clay blanket, core, or in-situ clay till, and ii) silty sand and gravel till. This seepage rate split is based on the percent seepage through the "clay blanket, core or in-situ till" as presented in Table 2 in Stantec (2020a), with the remaining seepage assumed to flow through the silty sand and/or gravel till.

(c) For TMF Dam Section C (Stantec 2020a), the seepage was assumed to report to both Watercourse No.4 and Scraggy Lake, and accordingly the total seepage rate was split 50/50.

Table 3.4: **WRSA Seepage Rate Inputs**

Surface Water Feature	Seepage Rates (m^3/d) [a]	
	Base Case Conditions (Scenario 1)	**Proposed New Case Conditions (Scenario 2)**
Watercourse No.4	54	126
Scraggy Lake [b]	63	64

Notes:

(a) Seepage rates are taken from Table 1 in Stantec (2021b). The Proposed New Case Condition (Scenario 2) considers the increase in the size of the WRSA and associated increases in seepage rates that may bypass the seepage collection system.

(b) Seepage reporting to Square Lake, the Fish River, and the Tributary to Fish River are conservatively assumed to ultimately report to Scraggy Lake. Therefore, the seepage rates for Scraggy Lake are the sum of the seepage rates predicted to report to Square Lake, the Fish River, and the Tributary to Fish River.

Table 3.5: Polishing Pond Effluent Discharge Chemistry Inputs

	Parameters	2018 [a]						2019 [a]							2020 [a]	Post March 2020
	Units - µg/L	July	August	September	October	November	December	January	February	March	April	May	June	July	March	Annual Average [b]
Major Ions	Chloride (Cl)	16,000	17,500	18,333	18,200	16,400	17,571	21,000	22,000	25,250	21,750	23,500	25,400	27,600	19,667	21,090
	Fluoride (F)	-	180	180	170	190	190	190	150	130	-	155	32	42	-	146
	Sulphate (SO$_4$)	470,000	495,000	576,667	682,000	634,000	618,571	674,000	627,500	592,500	475,000	480,000	596,000	692,000	496,667	587,685
	Calcium (Ca)	-	115,000	117,500	130,000	128,000	135,714	130,000	122,500	111,750	100,500	102,500	106,000	128,000	113,333	118,523
	Magnesium (Mg)	-	6,400	7,250	7,667	6,720	6,671	6,420	6,450	6,475	6,950	7,150	6,920	6,760	9,100	6,995
	Potassium (K)	-	48,000	48,500	50,000	46,200	47,286	49,200	47,000	44,750	36,750	40,000	43,400	54,000	35,333	45,417
	Sodium (Na)	-	165,000	165,000	176,667	160,000	160,000	170,000	165,000	162,500	132,500	137,500	150,000	178,000	116,667	156,833
Nutrients & Cyanide Species	Nitrate (NO$_3$-N)	700	1,160	950	4,120	5,840	5,743	862	850	723	5,150	8,350	5,560	2,542	647	3,269
	Nitrite (NO$_2$-N)	2,000	1,750	1,157	1,228	1,288	1,186	1,380	1,325	1,400	1,350	810	966	796	85	1,132
	Total Ammonia (NH$_3$+NH$_4$)	5,900	3,950	3,200	2,745	4,520	8,629	13,000	13,750	13,750	7,000	5,300	8,800	15,800	5,673	8,163
	Phosphorus (P)	-	50	68	50	50	50	50	50	50	50	50	50	50	50	51
	Total Cyanide (CN$_T$)	110	126	125	143	148	32	29	23	31	15	13	12	15	11	56
	Cyanate (OCN)	-	1,600	351	528	4,360	8,043	14,000	12,667	10,600	1,425	1,060	1,138	10,334	3.1	5,085
Metals	Mercury (Hg)	-	0.0108	0.0103	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0071
	Aluminum (Al)	-	9.8	9.4	5.8	3.0	3.1	4.0	8.7	5.5	2.5	2.5	3.6	7.5	2.5	5.2
	Antimony (Sb)	-	1.7	1.6	1.7	2.1	2.3	2.3	3.1	2.7	1.9	2.1	2.4	3.4	0.70	2.2
	Arsenic (As)	-	27	26	8.8	3.2	2.5	3.1	5.0	3.4	3.4	4.1	7.6	27	6.0	10
	Barium (Ba)	-	42	49	50	33	25	22	17	21	22	22	21	23	26	29
	Beryllium (Be)	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Bismuth (Bi)	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Boron (B)	-	25	25	25	25	25	30	25	25	25	25	25	25	25	25
	Cadmium (Cd)	-	0.010	0.008	0.006	0.007	0.009	0.010	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.007
	Chromium (Cr)	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Cobalt (Co)	-	87	85	101	105	99	99	93	84	53	49	54	67	21	77
	Copper (Cu)	-	1.1	1.0	0.75	1.0	1.0	1.0	1.2	1.4	0.70	0.60	0.76	2.7	1.2	1.1
	Iron (Fe)	-	86	138	110	39	25	36	36	49	53	39	33	53	83	60
	Lead (Pb)	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Manganese (Mn)	-	360	373	398	300	243	180	104	130	102	51	32	15	407	207
	Molybdenum (Mo)	-	4.9	4.3	4.6	5.5	8.4	9.2	14	13	7.8	8.0	11	16	6.3	8.6
	Nickel (Ni)	-	3.7	3.1	3.0	5.2	5.4	7.3	5.7	6.3	3.9	3.7	2.8	4.4	4.5	4.5
	Selenium (Se)	-	0.50	0.50	1.4	2.4	3.2	5.3	5.4	4.5	2.9	2.6	2.5	2.7	0.35	2.6
	Silver (Ag)	-	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	Strontium (Sr)	-	195	203	227	222	237	252	253	253	223	243	246	282	263	238
	Thallium (Tl)	-	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	Tin (Sn)	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Titanium (Ti)	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Uranium (U)	-	0.61	0.63	0.58	0.49	1.2	1.0	1.9	1.9	0.88	0.64	0.85	1.3	0.63	1.0
	Vanadium (V)	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Zinc (Zn)	-	7.8	10.0	2.9	5.0	6.9	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.4	4.1

Notes:

Units are in µg/L; concentrations below the Laboratory Detection Limit (LDL) were assigned a value at half the LDL concentration.

(a) Monthly average concentrations calculated from water quality data collected at monitoring station SW-14.

(b) Average concentrations (calculated from monthly averages from August 2018 to March 2020, inclusive) at monitoring station SW-14 were used as the model input for the effluent chemistry during post-March 2020.

Table 3.6: Baseline Water Chemistry Inputs

Parameters		Baseline Chemistry	
		Scraggy Lake[a]	Watercourse No.4[b]
	Units - µg/L		
Major Ions	Chloride (Cl)	3,539	9,150
	Fluoride (F)	50	50
	Sulphate (SO_4)	1,000	13,167
	Calcium (Ca)	691	7,494
	Magnesium (Mg)	339	1,611
	Potassium (K)	214	1,122
	Sodium (Na)	2,083	5,856
Nutrients & Cyanide Species	Nitrate (NO_3-N)	35	218
	Nitrite (NO_2-N)	5.0	5.0
	Total Ammonia (NH_3+NH_4)	48	76
	Phosphorus (P)	50	50
	Total Cyanide (CN_T)	0.57	0.87
	Cyanate (OCN)	13	14
Metals	Mercury (Hg)	0.014	0.0072
	Aluminum (Al)	145	425
	Antimony (Sb)	0.50	0.50
	Arsenic (As)	1.0	11
	Barium (Ba)	2.6	7.9
	Beryllium (Be)	0.50	0.50
	Bismuth (Bi)	1.0	1.0
	Boron (B)	25	25
	Cadmium (Cd)	0.015	0.013
	Chromium (Cr)	0.50	0.5
	Cobalt (Co)	0.42	0.95
	Copper (Cu)	1.0	1.0
	Iron (Fe)	216	711
	Lead (Pb)	0.31	0.70
	Manganese (Mn)	31	173
	Molybdenum (Mo)	1.0	1.0
	Nickel (Ni)	1.0	1.0
	Selenium (Se)	0.50	0.50
	Silver (Ag)	0.050	0.050
	Strontium (Sr)	4.5	22
	Thallium (Tl)	0.050	0.050
	Tin (Sn)	1.0	1.0
	Titanium (Ti)	1.9	11
	Uranium (U)	0.050	0.050
	Vanadium (V)	1.0	1.0
	Zinc (Zn)	2.7	2.7

Notes:

Units are in µg/L; concentrations below the Laboratory Detection Limit (LDL) were assigned a value at half the LDL concentration.

(a) Concentration inputs are the averages calculated from data collected at monitoring station SW-13 between March 14, 2016 and October 25, 2017.

(b) Concentration inputs are the averages calculated from data collected at monitoring station SW-3 between March 14, 2016 and October 25, 2017.

Table 3.7a: TMF Seepage Chemistry Inputs

Parameters		TMF Seepage Chemistry [a]					
		Base Case Conditions (Scenario 1)		Proposed New Case Conditions (Scenario 2)			
		Attenuated	Unattenuated	Attenuated		Unattenuated	
Units - µg/L		Base Case	Base Case	Base Case	Upper Case	Base Case	Upper Case
Major Ions	Chloride (Cl)	23,700	24,600	23,700	26,040	24,600	25,000
	Fluoride (F)	340	250	340	377	250	357
	Sulphate (SO_4)	582,000	594,000	582,000	598,000	594,000	604,100
	Calcium (Ca)	143,000	91,550	143,000	153,700	91,550	98,080
	Magnesium (Mg)	29,400	9,950	29,400	31,620	9,950	10,540
	Potassium (K)	3,510	35,100	3,510	4,033	35,100	64,710
	Sodium (Na)	144,500	169,000	144,500	160,400	169,000	181,200
Nutrients & Cyanide Species	Nitrate (NO_3-N)	25	250	25	60	250	636
	Nitrite (NO_2-N)	5.0	50	5.0	10	50	500
	Total Ammonia (NH_3+NH_4)	164	1,640	164	232	1,640	16,400
	Phosphorus (P)	11	73	11	13	73	100
	Total Cyanide (CN_T)	5.0	12	5.0	8.5	12	14
	Cyanate (OCN)	-	-	-	-	-	-
Metals	Mercury (Hg)	0.0025	0.0025	0.0025	0.0050	0.0025	0.0050
	Aluminum (Al)	1.5	15	1.5	2.3	15	23
	Antimony (Sb)	0.11	1.1	0.11	0.14	1.1	3.7
	Arsenic (As)	0.89	8.9	0.89	1.0	8.9	89
	Barium (Ba)	64	15	64	80	15	16
	Beryllium (Be)	0.0050	0.0050	0.0050	0.010	0.0050	0.010
	Bismuth (Bi)	-	-	-	-	-	-
	Boron (B)	39	46	39	46	46	54
	Cadmium (Cd)	0.0080	0.010	0.0080	0.016	0.010	0.015
	Chromium (Cr)	0.10	0.13	0.10	0.20	0.13	0.26
	Cobalt (Co)	3.7	9.0	3.7	4.2	9.0	11
	Copper (Cu)	0.40	2.5	0.40	0.48	2.5	3.4
	Iron (Fe)	1.0	4.1	1.0	1.2	4.1	5.0
	Lead (Pb)	0.010	0.010	0.010	0.014	0.010	0.011
	Manganese (Mn)	6.3	63	6.3	56	63	121
	Molybdenum (Mo)	2.6	18	2.6	3.3	18	19
	Nickel (Ni)	0.19	1.0	0.19	0.30	1.0	1.2
	Selenium (Se)	0.38	1.7	0.38	1.2	1.7	2.4
	Silver (Ag)	0.0050	0.0025	0.0050	0.010	0.0025	0.0050
	Strontium (Sr)	207	244	207	226	244	254
	Thallium (Tl)	0.0050	0.0091	0.0050	0.0053	0.0091	0.0098
	Tin (Sn)	0.020	0.020	0.020	0.032	0.020	0.020
	Titanium (Ti)	-	-	-	-	-	-
	Uranium (U)	3.0	1.5	3.0	3.7	1.5	2.0
	Vanadium (V)	0.20	0.41	0.20	0.22	0.41	0.44
	Zinc (Zn)	1.0	0.50	1.0	1.6	0.50	1.0

Notes:

Units are in µg/L; concentrations below the Laboratory Detection Limit (LDL) were assigned a value at half the LDL concentration.

(a) Seepage chemistry data provided by Lorax (2020). TMF seepage geochemical source terms (attenuated and unattenuated) were applied for both Scenarios 1 and 2.

Table 3.7b: WRSA Effluent Chemistry Inputs

Parameters		WRSA Effluent Chemistry [a]		
		Base Case Conditions (Scenario 1)	Proposed New Case Conditions (Scenario 2)	
	Units - µg/L	Base Case	Base Case	Upper Case
Major Ions	Chloride (Cl)	-	-	-
	Fluoride (F)	-	-	-
	Sulphate (SO$_4$)	1,028,640	1,113,792	1,311,648
	Calcium (Ca)	353,564	357,127	335,493
	Magnesium (Mg)	55,075	71,573	119,872
	Potassium (K)	11,145	14,296	29,148
	Sodium (Na)	34,375	38,127	55,084
Nutrients & Cyanide Species	Nitrate (NO$_3$-N)	25,000	25,000	44,000
	Nitrite (NO$_2$-N)	200	200	360
	Total Ammonia (NH$_3$+NH$_4$)	430	430	760
	Phosphorus (P)	-	-	-
	Total Cyanide (CN$_T$)	-	-	-
	Cyanate (OCN)	-	-	-
Metals	Mercury (Hg)	0.0070	0.0070	0.013
	Aluminum (Al)	8.7	8.7	8.7
	Antimony (Sb)	0.85	1.1	1.1
	Arsenic (As)	27	32	60
	Barium (Ba)	49	61	90
	Beryllium (Be)	0.85	1.1	1.1
	Bismuth (Bi)	-	-	-
	Boron (B)	25	25	50
	Cadmium (Cd)	0.018	0.023	0.075
	Chromium (Cr)	0.50	0.50	1.0
	Cobalt (Co)	3.8	5.2	9.1
	Copper (Cu)	1.6	2.1	2.8
	Iron (Fe)	1.5	1.5	1.5
	Lead (Pb)	0.25	0.25	0.50
	Manganese (Mn)	202	256	3,802
	Molybdenum (Mo)	1.6	2.0	2.2
	Nickel (Ni)	12	15	48
	Selenium (Se)	1.1	1.4	1.9
	Silver (Ag)	0.050	0.050	0.10
	Strontium (Sr)	1,156	1,449	2,065
	Thallium (Tl)	0.085	0.11	0.11
	Tin (Sn)	1.7	2.2	2.2
	Titanium (Ti)	-	-	-
	Uranium (U)	9.9	11	20
	Vanadium (V)	1.0	1.0	2.0
	Zinc (Zn)	4.2	5.2	5.4

Notes:

Units are in µg/L; concentrations below the Laboratory Detection Limit (LDL) were assigned a value at half the LDL concentration.

(a) Effluent chemistry data based on geochemical source terms developed by Lorax (2020).

Table 4.1: Water Quality Predictions for Scraggy Lake Upper

Parameters		Comparison Criteria — Water Quality Guidelines — Nova Scotia EQS [a]	CCME CWQG [b],[c]	IA Water Quality Criteria [d]	Average Baseline Conditions [e]	Scraggy Lake (Upper Basin) — Base Case Conditions (Scenario 1) — Base Case Geochemical Source Terms Min	Average	Max	Proposed New Case Conditions (Scenario 2) — Base Case Geochemical Source Terms Min	Average	Max	Upper Case Geochemical Source Terms Min	Average	Max
Units - µg/L						Min	Average	Max	Min	Average	Max	Min	Average	Max
Major Ions	Chloride (Cl)	-	120,000	120,000	3,539	4,129	5,288	6,654	3,681	3,788	3,982	3,686	3,795	3,988
	Fluoride (F)	-	120	120	<100	47	52	61	51	52	53	52	53	54
	Sulphate (SO$_4$)	-	-	-	1,000	21,921	44,984	75,898	5,375	8,573	13,970	5,601	8,879	14,329
	Calcium (Ca)	-	-	-	691	4,677	8,906	13,888	1,422	2,033	3,047	1,438	2,054	3,072
	Magnesium (Mg)	-	-	-	339	753	1,146	1,434	506	589	688	560	665	778
	Potassium (K)	-	-	-	214	1,352	2,930	5,112	335	506	886	436	643	1,014
	Sodium (Na)	-	-	-	2,083	6,498	12,635	21,083	2,731	3,502	4,934	2,807	3,604	5,031
Nutrients & Cyanide Species	Nitrate (NO$_3$-N)	-	2,935	2,935	35	105	325	688	68	90	125	89	119	159
	Nitrite (NO$_2$-N)	-	60	60	<10	2.4	13	31	1.2	2.3	4.9	1.8	2.9	5.4
	Total Ammonia (NH$_3$+NH$_4$)	-	8,471	-	48	16	41	81	3	5	10	7	10	14
	Phosphorus (P)	-	-	-	<100	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Total Cyanide (CN$_T$)	-	-	-	0.57	1.0	2.1	3.7	0.68	0.94	1.6	0.70	1.0	1.6
	Cyanate (OCN)	-	-	-	13	3.0	26	71	1.4	3.6	8.9	1.4	3.6	8.9
Metals	Mercury (Hg)	0.026	0.026	0.026	<0.013	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066
	Aluminum (Al)	5	100	100	145	124	131	138	141	143	143	141	143	143
	Antimony (Sb)	20	-	20	<1	0.49	0.61	0.80	0.50	0.51	0.53	0.52	0.53	0.54
	Arsenic (As)	5	5	5	1.04	0.57	0.79	1.1	0.51	0.53	0.58	0.66	0.75	0.83
	Barium (Ba)	1,000	-	1000	2.6	4.0	5.2	6.3	3.2	3.4	3.7	3.2	3.4	3.8
	Beryllium (Be)	5.3	-	5.3	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Bismuth (Bi)	-	-	-	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Boron (B)	1,200	1,500	1,200	<50	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Cadmium (Cd)	0.01	0.04	0.04	0.015	0.0136	0.0141	0.0146	0.0148	0.0149	0.0150	0.0149	0.0150	0.0151
	Chromium (Cr)	-	-	-	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Cobalt (Co)	10	-	10	0.42	0.89	2.9	6.1	0.33	0.56	1.1	0.34	0.58	1.1
	Copper (Cu)	2	2	2	<2	0.96	1.02	1.05	1.01	1.01	1.01	1.01	1.02	1.02
	Iron (Fe)	300	300	300	216	127	133	139	141	142	143	141	142	143
	Lead (Pb)	1	1	1	<0.5	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
	Manganese (Mn)	820	250	820	31	33	46	68	32	33	35	36	38	41
	Molybdenum (Mo)	73	73	73	<2	1.26	1.79	2.56	1.08	1.14	1.22	1.09	1.14	1.23
	Nickel (Ni)	25	25	25	<2	0.94	1.1	1.3	0.88	0.89	0.93	0.91	0.94	1.0
	Selenium (Se)	1	1	1	<1	0.57	0.82	1.0	0.51	0.52	0.55	0.51	0.53	0.56
	Silver (Ag)	0.1	0.25	0.1	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Strontium (Sr)	21,000	-	21,000	4.5	14	24	36	6.4	8.0	10	7.0	8.8	11
	Thallium (Tl)	0.8	0.8	0.8	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Tin (Sn)	-	-	-	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Titanium (Ti)	-	-	-	1.9	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Uranium (U)	300	15	15	<0.1	0.10	0.15	0.22	0.07	0.08	0.10	0.09	0.10	0.12
	Vanadium (V)	6	-	6	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Zinc (Zn)	30	- [b]	- [b]	2.7	2.56	2.71	2.76	2.69	2.70	2.72	2.70	2.71	2.72

Concentration greater than the Nova Scotia EQS, CCME CWQG, and IA Water Quality Criteria.

Concentration greater than the Nova Scotia EQS.

Notes: "<" indicates concentrations were below the laboratory detection limit; units are in µg/L.

(a) Nova Scotia EQS reported are taken from Table A2 - References for Pathway Specific Standards for Surface Water.

(b) Average total hardness value of 6 mg/L as CaCO$_3$ (from SW13) was used to derive hardness dependant CCME CWQGs (Cd, Cu, Pb, Mn, and Ni). Hardness is below the applicable range (23.4 to 399 mg/L as CaCO3) to apply the CCME CWQG and IA Water Quality Criteria equation to calculate a zinc guideline.

(c) All pH and temperature dependent CCME CWQG were derived assuming a pH of 7.0 and temperature of 10°C.

(d) Surface water quality monitoring criteria as per the Industrial Approval (IA) [Approval No. 2012-084244-06], see Table 6 in Appendix K. The units for the nitrate and nitrite criteria are incorrect in the IA, and are corrected herein to be consistent with CCME CWQG.

(e) Baseline values represent the average concentrations monitored at SW-13 between March 14, 2016 and October 25, 2017.

Table 4.2: Water Quality Predictions for Scraggy Lake Lower

	Parameters	Comparison Criteria				Scraggy Lake (Lower Basin)								
		Water Quality Guidelines		IA Water Quality Criteria (d)	Average Baseline Conditions (e)	Base Case Conditions (Scenario 1)			Proposed New Case Conditions (Scenario 2)					
						Base Case Geochemical Source Terms			Base Case Geochemical Source Terms			Upper Case Geochemical Source Terms		
	Units - µg/L	Nova Scotia EQS (a)	CCME CWQG (b),(c)			Min	Average	Max	Min	Average	Max	Min	Average	Max
Major Ions	Chloride (Cl)	-	120,000	120,000	3,539	4,127	4,318	4,520	3,636	3,746	3,953	3,640	3,749	3,956
	Fluoride (F)	-	120	120	<100	49	52	55	51	51	52	51	52	53
	Sulphate (SO$_4$)	-	-	-	1,000	16,532	21,182	26,364	3,917	6,970	12,755	4,059	7,098	12,870
	Calcium (Ca)	-	-	-	691	3,433	4,355	5,196	1,134	1,700	2,776	1,144	1,709	2,784
	Magnesium (Mg)	-	-	-	339	609	687	729	443	484	558	472	516	587
	Potassium (K)	-	-	-	214	1,131	1,450	1,816	285	502	904	348	559	955
	Sodium (Na)	-	-	-	2,083	5,551	6,864	8,343	2,422	3,235	4,761	2,469	3,278	4,800
Nutrients & Cyanide Species	Nitrate (NO$_3$-N)	-	2,935	2,935	35	101	173	238	57	77	113	70	89	124
	Nitrite (NO$_2$-N)	-	60	60	<10	3.2	8.1	12	1.4	2.8	5.5	1.6	3.1	5.7
	Total Ammonia (NH$_3$+NH$_4$)	-	8,471	-	48	14	20	27	3.4	6.2	11	5.4	8.0	13
	Phosphorus (P)	-	-	-	<100	<50	<50	<50	<50	<50	<50	<50	<50	<50
	Total Cyanide (CN$_T$)	-	-	-	0.57	1.0	1.7	2.6	0.69	1.0	1.7	0.70	1.0	1.7
	Cyanate (OCN)	-	-	-	13	5.2	17	27	1.8	4.8	10	1.8	4.8	10
Metals	Mercury (Hg)	0.026	0.026	0.026	<0.013	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066	<0.0066
	Aluminum (Al)	5	100	100	145	137	139	140	141	143	144	141	143	144
	Antimony (Sb)	20	-	20	<1	0.52	0.56	0.59	0.50	0.51	0.53	0.51	0.52	0.54
	Arsenic (As)	5	5	5	1.04	0.57	0.60	0.64	0.49	0.52	0.56	0.58	0.61	0.65
	Barium (Ba)	1,000	-	1000	2.6	3.7	4.0	4.2	3.1	3.3	3.6	3.1	3.3	3.6
	Beryllium (Be)	5.3	-	5.3	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Bismuth (Bi)	-	-	-	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Boron (B)	1,200	1,500	1,200	<50	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Cadmium (Cd)	0.01	0.04	0.04	0.015	0.0145	0.0146	0.0147	0.0148	0.0149	0.0150	0.0148	0.0150	0.0150
	Chromium (Cr)	-	-	-	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Cobalt (Co)	10	-	10	0.42	0.93	1.8	2.5	0.35	0.66	1.2	0.36	0.67	1.2
	Copper (Cu)	2	2	2	<2	1.00	1.01	1.01	1.00	1.00	1.00	1.01	1.01	1.01
	Iron (Fe)	300	300	300	216	138	140	141	141	143	144	141	143	144
	Lead (Pb)	1	1	1	<0.5	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
	Manganese (Mn)	820	250	820	31	34	38	42	32	33	35	34	35	37
	Molybdenum (Mo)	73	73	73	<2	1.24	1.36	1.48	1.06	1.10	1.19	1.06	1.11	1.19
	Nickel (Ni)	25	25	25	<2	0.95	0.99	1.0	0.87	0.89	0.93	0.89	0.91	0.94
	Selenium (Se)	1	1	1	<1	0.57	0.62	0.67	0.51	0.52	0.56	0.51	0.53	0.56
	Silver (Ag)	0.1	0.25	0.1	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Strontium (Sr)	21,000	-	21,000	4.5	11	13	14	5.5	6.7	9.0	5.9	7.0	9.3
	Thallium (Tl)	0.8	0.8	0.8	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Tin (Sn)	-	-	-	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Titanium (Ti)	-	-	-	1.9	<2	<2	<2	<2	<2	<2	<2	<2	<2
	Uranium (U)	300	15	15	<0.1	0.085	0.098	0.112	0.064	0.070	0.080	0.071	0.077	0.086
	Vanadium (V)	6	-	6	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Zinc (Zn)	30	- [b]	- [b]	2.7	2.69	2.72	2.74	2.70	2.71	2.73	2.70	2.71	2.73

▮ Concentration greater than the Nova Scotia EQS, CCME CWQG, and IA Water Quality Criteria.

▮ Concentration greater than the Nova Scotia EQS.

Notes: "<" indicates concentrations were below the laboratory detection limit; units are in µg/L.

(a) Nova Scotia EQS reported are taken from Table A2 - References for Pathway Specific Standards for Surface Water.

(b) Average total hardness value of 6 mg/L as CaCO$_3$ (from SW13) was used to derive hardness dependant CCME CWQGs (Cd, Cu, Pb, Mn, and Ni). Hardness is below the applicable range (23.4 to 399 mg/L as CaCO3) to apply the CCME CWQG and IA Water Quality Criteria equation to calculate a zinc guideline.

(c) All pH and temperature dependent CCME CWQG were derived assuming a pH of 7.0 and temperature of 10°C.

(d) Surface water quality monitoring criteria as per the Industrial Approval (IA) [Approval No. 2012-084244-06], see Table 6 in Appendix K. The units for the nitrate and nitrite criteria are incorrect in the IA, and are corrected herein to be consistent with CCME CWQG.

(e) Baseline values represent the average concentrations monitored at SW-13 between March 14, 2016 and October 25, 2017.

Table 4.3: Water Quality Predictions for Watercourse No.4

Parameters		Comparison Criteria				Watercourse No.4								
		Water Quality Guidelines		IA Water Quality Criteria (d)	Average Baseline Conditions (e)	Base Case Conditions (Scenario 1)			Proposed New Case Conditions (Scenario 2)					
						Base Case Geochemical Source Terms			Base Case Geochemical Source Terms			Upper Case Geochemical Source Terms		
		Nova Scotia EQS (a)	CCME CWQG (b),(c)			Min	Average	Max	Min	Average	Max	Min	Average	Max
Units - µg/L														
Major Ions	Chloride (Cl)	-	120,000	120,000	9,150	12,608	13,325	14,280	12,017	12,571	13,427	12,049	12,651	13,582
	Fluoride (F)	-	120	120	<100	55	64	76	53	61	73	55	66	84
	Sulphate (SO$_4$)	-	-	-	13,167	73,830	152,225	256,517	201,375	299,411	450,895	227,131	334,788	501,142
	Calcium (Ca)	-	-	-	7,494	29,927	49,611	75,797	74,849	101,556	142,826	72,249	98,648	139,442
	Magnesium (Mg)	-	-	-	1,611	5,664	8,543	12,372	14,879	19,641	27,000	21,836	29,063	40,230
	Potassium (K)	-	-	-	1,122	1,792	2,969	4,535	2,514	3,760	5,684	3,909	6,289	9,965
	Sodium (Na)	-	-	-	5,856	5,425	9,244	14,326	6,478	10,226	16,016	7,202	11,421	17,940
Nutrients & Cyanide Species	Nitrate (NO$_3$-N)	-	2,935	2,935	218	265	456	712	709	1,083	1,662	1,141	1,812	2,848
	Nitrite (NO$_2$-N)	-	60	60	<10	2.9	4.3	6.0	6.7	8.7	12	13	22	34
	Total Ammonia (NH$_3$+NH$_4$)	-	8,471	-	76	25	37	53	29	41	60	97	208	379
	Phosphorus (P)	-	-	-	<100	52	52	53	48	49	50	50	50	50
	Total Cyanide (CN$_T$)	-	-	-	0.87	1.1	1.5	2.0	1.0	1.4	1.9	1.1	1.6	2.2
	Cyanate (OCN)	-	-	-	14	12	13	13	11	12	13	11	12	13
Metals	Mercury (Hg)	0.026	0.026	0.026	0.007	0.0065	0.0067	0.0069	0.0064	0.0067	0.0069	0.0073	0.0073	0.0074
	Aluminum (Al)	5	100	100	425	103	112	118	94	105	112	94	105	112
	Antimony (Sb)	20	-	20	<1	0.51	0.53	0.55	0.54	0.57	0.60	0.59	0.69	0.84
	Arsenic (As)	5	5	5	10.9	7.8	7.8	7.8	8.6	8.8	9.0	10.7	12.9	16.3
	Barium (Ba)	1,000	-	1,000	7.9	12	14	17	16	19	23	19	23	29
	Beryllium (Be)	5.3	-	5.3	<1	0.47	0.50	0.52	0.53	0.54	0.55	0.53	0.54	0.55
	Bismuth (Bi)	-	-	-	<2	0.85	0.92	0.97	0.77	0.86	0.92	0.77	0.86	0.92
	Boron (B)	1,200	1,500	1,200	<50	25	26	27	25	26	27	27	29	31
	Cadmium (Cd)	0.01	0.16	0.16	0.013	0.0127	0.0129	0.0129	0.0135	0.0135	0.0136	0.0166	0.0179	0.0199
	Chromium (Cr)	-	-	-	<1	0.79	0.84	0.88	0.76	0.82	0.86	0.83	0.87	0.89
	Cobalt (Co)	10	-	10	0.95	0.75	1.0	1.2	0.91	1.1	1.5	1.1	1.4	1.9
	Copper (Cu)	2	2.3	2.3	<2	0.65	0.67	0.69	0.67	0.69	0.72	0.70	0.74	0.81
	Iron (Fe)	300	300	300	711	127	137	145	115	129	137	115	129	137
	Lead (Pb)	1	3.1	3.1	0.70	0.44	0.48	0.50	0.42	0.46	0.48	0.44	0.47	0.49
	Manganese (Mn)	820	590	820	173	132	138	142	138	143	145	315	372	460
	Molybdenum (Mo)	73	73	73	<2	0.81	1.1	1.6	0.86	1.2	1.7	0.88	1.2	1.7
	Nickel (Ni)	25	94	94	<2	1.1	1.2	1.3	1.7	1.9	2.3	3.3	4.1	5.2
	Selenium (Se)	1	1	1	<1	0.37	0.41	0.45	0.41	0.45	0.50	0.44	0.51	0.60
	Silver (Ag)	0.1	0.25	0.1	<0.1	0.044	0.047	0.049	0.044	0.047	0.049	0.050	0.051	0.052
	Strontium (Sr)	21,000	-	21,000	22	76	123	186	242	322	447	321	429	596
	Thallium (Tl)	0.8	0.8	0.8	<0.1	0.046	0.048	0.049	0.051	0.052	0.052	0.051	0.052	0.052
	Tin (Sn)	-	-	-	<2	0.90	0.95	0.98	1.01	1.03	1.04	1.01	1.03	1.04
	Titanium (Ti)	-	-	-	10.7	9.0	10	10	8.2	9.1	9.8	8.2	9.1	9.8
	Uranium (U)	300	15	15	<0.1	0.17	0.36	0.60	0.73	1.0	1.5	1.3	1.7	2.5
	Vanadium (V)	6	-	6	<2	0.92	0.96	0.98	0.92	0.96	0.98	1.03	1.04	1.04
	Zinc (Zn)	30	16	16	2.7	2.46	2.55	2.62	2.68	2.72	2.75	2.77	2.77	2.78

Concentration greater than the Nova Scotia EQS, CCME CWQG, and IA Water Quality Criteria.

Concentration greater than the Nova Scotia EQS.

Notes: "<" indicates concentrations were below the laboratory detection limit; units are in µg/L.

(a) Nova Scotia EQS reported are taken from Table A2 - References for Pathway Specific Standards for Surface Water.

(b) An average total hardness value of 98 mg/L as CaCO$_3$ (calculated from data collected at SW3) was used to derive hardness dependant CCME CWQG (Cd, Cu, Pb, Mn, Ni, and Zn).

(c) All pH and temperature dependent CCME CWQG were derived assuming a pH of 7.0 and temperature of 10°C.

(d) Surface water quality monitoring criteria as per the Industrial Approval (IA) [Approval No. 2012-084244-06], see Table 6 in Appendix K. The units for the nitrate and nitrite criteria are incorrect in the IA, and are corrected herein to be consistent with CCME CWQG.

(e) Baseline values represent the average concentrations monitored at SW-3 between March 14, 2016 and October 25, 2017.

APPENDIX D.4
TOUQUOY GOLD MINE – WRSA GEOCHEMICAL SOURCE TERMS

TECHNICAL MEMORANDUM

To:	**Melissa Nicholson, Ryan Keating (AMNS)**	**Date: Dec. 14, 2020**
From:	**Timo Kirchner, Patrick Mueller**	**Project #: A563-4**
Subject:	**Touquoy Gold Mine – WRSA Geochemical Source Terms**	

1. Introduction

The Touquoy Gold Mine, owned by Atlantic Mining Nova Scotia Inc. (AMNS), is located approximately 60 km northeast of Halifax, Nova Scotia, where mining operations commenced in September 2017. As part of ongoing mine planning, AMNS has identified a need to expand the waste rock storage area (WRSA) to meet operational requirements. Lorax Environmental Services Ltd. (Lorax) was retained to model geochemical source term predictions for seepage from this facility in consideration of the currently permitted footprint as well as for the WRSA expansion. Along with water balance modelling results, these predictions are then incorporated into the site-wide water quality model (prepared by others) which will inform the project effect on water quality and site's aquatic effects assessment. This memorandum discusses the model approach and results for WRSA drainage predictions.

WRSA source term predictions were generally derived using kinetic test results conducted on waste rock and ore. Nitrogen concentration predictions reflecting the rinsing of blast-residue from particle surfaces in WRSA drainage are an exception as these were calculated using site water quality data. Base and Upper Case drainage chemistry predictions were modelled for an operational scenario for both the waste rock tonnage assumed in the current footprint as well as for the expanded WRSA. The following chapter gives an overview of the approach chosen and assumptions made in the derivation of the WRSA geochemical source terms. Model results are subsequently presented in Chapter 3.

2. Approach

2.1 General Chemistry

A flow chart illustrating the work stages comprising the scale-up of kinetic tests results, which was applied to model the contact water chemistry for the WRSA, is given in Figure 2-1. Each of these work stages is described in more detail below. Importantly, scaling factors used in this exercise were derived via inverse modelling of available Touquoy site monitoring data.
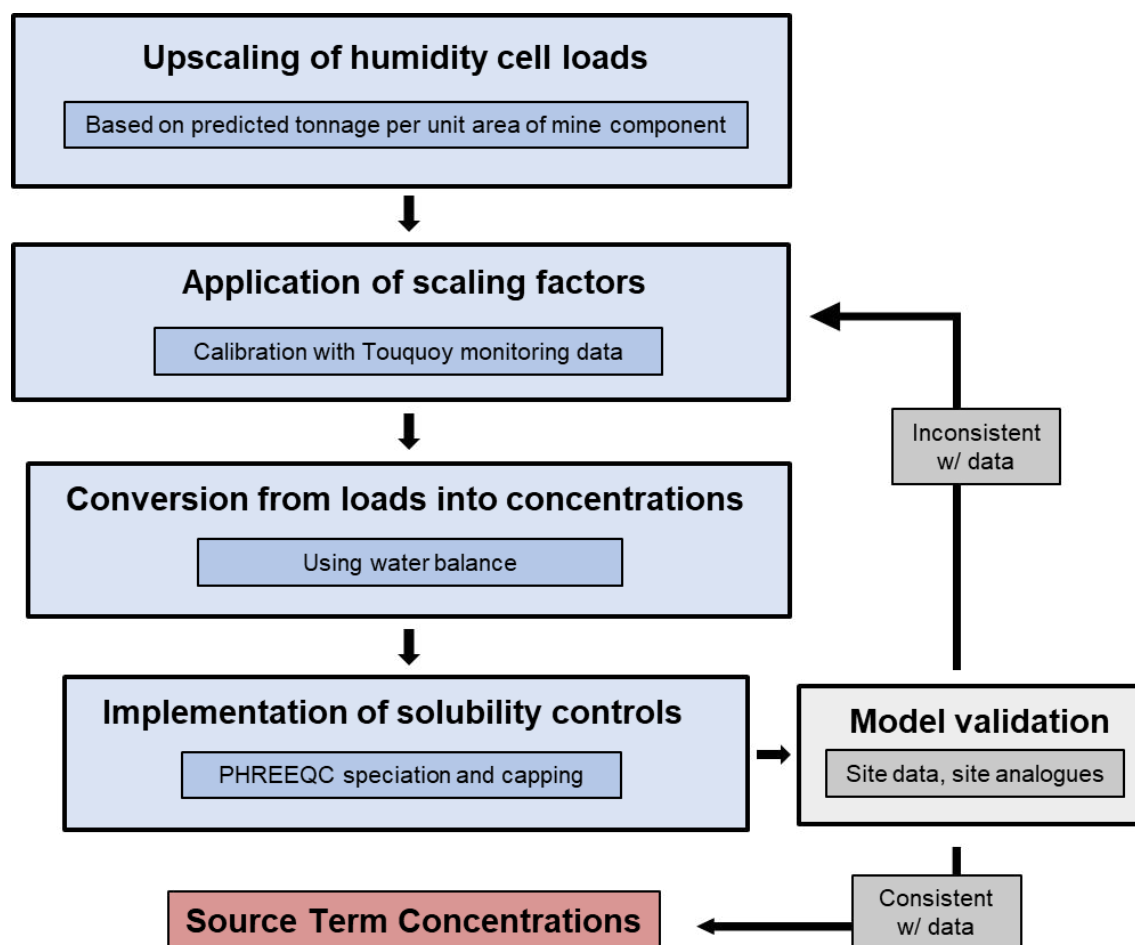
Figure 2-1: **Work stages involved in the scaling of WRSA geochemical source terms**

2.1.1　Derivation of Humidity Cell Loading Rates

Aqueous geochemical signatures produced by water in contact with mine wastes are predominately controlled by the mineralogical make-up of the materials as well as mining-related processes (*e.g.*, ore processing, blasting, *etc.*), with sulphide mineral oxidation and carbonate dissolution generally dictating pH. Trace element leaching signatures are typically governed by the sulphide mineral reactivity, abundance and type, although other phases can also have an effect on drainage chemistry. Based on these considerations, humidity cell tests used for the calculation of loading rates were selected to capture representative lithological and mineralogical variables.

Loading rates are herein defined as the mass of a solute released per kg of rock material over one week of humidity cell testing (mg/kg/wk). For this source term iteration, only an operational scenario was modelled. To maintain conservatism, this operational source term assumes the maximum WRSA capacity at the End of Mining (EOM) considering both the current footprint and the WRSA expansion footprint. Conceptually, it is assumed that potentially acid-generating (PAG)

materials will remain neutral during operations up until the end of mining. This assumption is supported by current operational ML/ARD monitoring data (Lorax, 2020) as well as site water quality monitoring records.

Input loading rates were derived from seven site-specific humidity cell tests, the results of which are discussed in Golder (2007). These experiments represent all major waste rock types to be stored on site as well as one low-grade ore humidity cell. The waste rock loading rates were grouped into the following categories to allow for the reconciliation with the units presented in the waste rock production schedule:

- *Argillite* (HC 1 = **AR** = Argillite w/ <5% Greywacke interbeds and HC 2 = **AG** = Argillite w/ 5- 49% Greywacke interbeds) and

- *Greywacke* (HC 3 = **GA** = Greywacke w/ 20-50% Argillite interbeds and HC 4 = **GW** = Greywacke w/ < 20% Argillite interbeds)**.**

Humidity cell data were proportioned to be representative of the static test populations' sulphide sulphur content. The weighting of the two humidity cells to derive the loading rate for each unit was then determined based on this statistical value. An overview of how the different tests were accounted for is given in Table 2-1. In order to simulate operational leaching rates, humidity cell cycles 5-15 were used to calculate the input loading rates for the source term model. An overview of these input loading rates is given in Table 2-2. Base and Upper Case predictions were generated by varying the scaling factors rather than a range of humidity cell input values as described further below. As such, only the median humidity cell loading rates are presented in Table 2-2.

Table 2-1:
Weighting of Humidity Cells to Derive Neutral Input Loading Rates

Sample ID	Lithology Code	Sulphide S (%)	Weighting
Argillite			
06-017	AR	0.03	8%
06-012	AG	0.08	33%
06-006	AR	0.18	28%
06-049	AR	0.22	13%
06-079	AR	0.51	18%
Greywacke			
06-039	GA	0.49	67%
06-068	GW	0.08	33%

Table 2-2:
Median Humidity Cell Loading Rates (Cycles 5-15) Used as Input for the Touquoy Source Term Model

Parameter	Unit	Argillite	Greywacke
Sulphate	mg/kg/wk	0.56	0.43
Al	mg/kg/wk	0.015	0.0071
Sb	mg/kg/wk	0.00067	0.00034
As	mg/kg/wk	0.0066	0.0098
Ba	mg/kg/wk	0.000077	0.000059
Be	mg/kg/wk	0.0000037	0.0000019
B	mg/kg/wk	0.00023	0.000096
Cd	mg/kg/wk	0.0000055	0.0000029
Ca	mg/kg/wk	0.83	0.58
Cr	mg/kg/wk	0.000028	0.000014
Co	mg/kg/wk	0.0000024	0.00000034
Cu	mg/kg/wk	0.000031	0.000013
Fe	mg/kg/wk	0.00090	0.00048
Pb	mg/kg/wk	0.0000019	0.00000097
Li	mg/kg/wk	0.00018	0.000096
Mg	mg/kg/wk	0.15	0.058
Mn	mg/kg/wk	0.0037	0.0023
Hg	mg/kg/wk	0.0000092	0.0000048
Mo	mg/kg/wk	0.000034	0.000031
Ni	mg/kg/wk	0.000064	0.000034
P	mg/kg/wk	0.00092	0.00049
K	mg/kg/wk	0.38	0.19
Se	mg/kg/wk	0.000092	0.000048
Ag	mg/kg/wk	0.0000028	0.0000014
Na	mg/kg/wk	0.051	0.035
Sr	mg/kg/wk	0.0020	0.0014
Tl	mg/kg/wk	0.0000092	0.0000048
Sn	mg/kg/wk	0.000047	0.000019
U	mg/kg/wk	0.000012	0.000054
V	mg/kg/wk	0.000039	0.000032
Zn	mg/kg/wk	0.000086	0.000060

2.1.2 Scaling of Geochemical Loads

One of the most critical steps in the development of geochemical source terms is the scaling of geochemical loads from small-scale laboratory experiments to mine-site dimensions. In theory, if the entire modelled facility was contacted by water under conditions similar to those seen in humidity cell experiments, the upscaled leachable load L (in mg) would be written as:

$$L_i = r_i * m * t$$

where r_i is the geochemical loading rate for species I, m is the mass (in kg) of the material contained in the facility of interest, and t (in wk) is the time interval of interest.

Through empirical and theoretical studies (*e.g.,* Malmström *et al.*, 2000; Kempton, 2012; Andrina *et al.*, 2012; Sapsford *et al.*, 2009; Kirchner & Mattson, 2015; Bornhorst & Logsdon, 2016), it is now well-established that this approach will generally strongly overestimate the geochemical load that is expected to drain from mine facilities due to the marked differences between laboratory and field conditions. To account for these differences, "scaling factors" are applied in the development of geochemical source terms. These scaling factors are implemented into the source term model simply by multiplication with the humidity cell loading rate calculated above as follows:

$$SL_i = L_i * SF_a * SF_b * ... * SF_x$$

where SL_i is the scaled load for species i (in mg) and SF is the scaling factor for a given parameter to be scaled (a, b, x). In the absence of site monitoring data, such parameters typically include grain size, water/rock ratio, and temperature. The following describes the derivation of the individual scaling factors employed in the Touquoy source terms model.

2.1.3   Particle Size

Before representative material is placed into laboratory kinetic test cells, rock samples are crushed to a nominal grain size of <1/4" to allow for better comparability of reaction rates across different experiments containing different geological materials. The particle size distribution of the mine rock stockpiles, and other facilities influences the degree of water-rock interaction by controlling the exposed surface area; surface area increases exponentially as the particle size decreases. Various studies have examined the role of particle size on waste rock drainage chemistry and found that generally only the fine fraction, contributing a relatively small percentage of the overall waste rock inventory, is responsible for most for the geochemical loads released during water-rock contact (*e.g.*, Fines *et al.* 2003; Neuner *et al.*, 2009; Strömberg and Banwart1999). In consideration of this phenomenon, it can be assumed that only a fraction of material contained in the Touquoy WRSA is reactive. Observations made at the Touquoy site suggest that the argillite end-member is generally more fissile and friable than greywacke waste rock. As such, particle size scaling factors of 10% and 20% were assigned to greywacke and argillite, respectively. These percentages reflect the assumed proportion of the humidity cell grain size fraction (<1/4") within the Touquoy WRSA.

2.1.4   Contact Water

Laboratory experiments are conducted using high water-rock ratios (0.5L:1kg) that allow for the flushing of virtually all material surfaces placed into the reactor cell. The hydrogeology of unsaturated waste rock facilities has been researched intensively and most studies suggest that only

a portion of the rock mass contained in these facilities is contacted by infiltrating water (Marcoline *et al.*, 2006; Andrina *et al.*, 2009, Neuner *et al.*, 2009). The larger the mine storage facility for a given infiltration rate, the more rock material will be physically shielded from water contact as preferential flow paths develop and water is diverted along higher permeability layers. Furthermore, low water/rock ratios within a mine rock are more likely to result in the development of geochemical equilibrium conditions (Morin, 2013). Therefore, after a certain mass of rock material has been flushed, further physical contact may not necessarily lead to an increase in concentrations as kinetic or thermodynamic limitations are reached (Kirchner & Mattson, 2015).

Correcting for different water/rock ratios (*i.e.,* contact water) in humidity cells with respect to full-scale mine facilities may be one of the largest uncertainties associated with a source term model if not calibrated adequately. The operational Touquoy mine with its comprehensive water quality monitoring network presents a unique opportunity to use site-specific data for the derivation of scaling factors. Specifically, loading rates from argillite and greywacke humidity cells were upscaled to the current tonnage stored in the WRSA and, under consideration of the known water balance, compared to the corresponding site monitoring data. Since the humidity cell data were already grain-size corrected (Section 2.1.3), and monitoring data were preferentially collected during months in which a temperature correction may not be necessary, the calculated difference between the upscaled chemical loads and the observed loads from water monitoring effectively represents the empirical contact water factor. This approach also has the advantage of generating element-specific scaling factors. This is important as it has been shown that major and minor/trace metals cannot generally be predicted accurately using the same assumptions (*e.g.,* Kirchner & Mattson, 2015).

Scaling factors were calculated using site data available at the end of 2019. Table 2-3 provides the 2019 and projected (EOM) waste rock tonnages and lithological proportions in the WRSA. The latter were used for the source term predictions for the two model scenarios with and without consideration of the WRSA expansion. Corresponding water balance assumptions made in the calculation of scaling factors and geochemical source terms were provided by Jones (pers. comm., 2020) and are listed in Table 2-4. Additional qualifiers regarding the back-calculation of scaling factors can be summarized as follows:

o Scaling factors were back-calculated using the 2019 water quality database available for the WRSA collection ponds (WRSP).

o Statistical concentration values from these stations were calculated and implemented as follows:

➢ Base Case: Median and 75th percentile concentrations for major and minor/trace elements, respectively;

> ➢ Upper Case: 90th percentile and maximum concentrations for major and minor/trace elements, respectively.

Using different statistical concentrations for major versus minor/trace elements relies on the assumption that the latter behave less conservatively and may have been attenuated between WRSA toe and the WRSP monitoring sites.

o Flows considered in the derivation of the scaling factors include:

> ➢ WRSA seepage (ultimately used for the calculation of scaling factors);
>
> ➢ Runoff from prepared ground and seepage collection ditches;
>
> ➢ Direct precipitation on ponds; and
>
> ➢ Evaporation from pond surface.

Since there is no water monitoring station specifically capturing the water chemistry of prepared and natural ground runoff, the 25th percentile concentrations of the first two sampling events at WRSP-1 and WRSP-2 were chosen for this purpose. This is considered appropriate since in the early stages (2018) of WRSA runoff monitoring, prepared ground runoff would have controlled the WRSP chemistry before waste rock piles reached a certain capacity. Using the 25th percentile also conservatively affects the back-calculation of geochemical loads from WRSA toe seepage itself.

Empirical contact water scaling factors back-calculated for the Touquoy project are listed in Table 2-5. The considerable range in scaling factor values across the presented parameters is evidence of the difference in geochemical mobility, where species with a lower scaling factors are attenuated more strongly within the WRSA or leached at lower rates relative to the loading rates seen in humidity cells.

Average annual drainage and runoff concentrations for a given species i (ST_{Ci}) were calculated by dividing the annual scaled geochemical loads (SL_i) by the annual predicted WRSA seepage volume (V_{WRSA}) at EOM (Table 2-4). The following equation describes this model step:

$$ST_{Ci} = (SL_i) / V_{WRSA}$$

Table 2-3:
Current (2019) and Predicted WRSA Tonnages and Proportions Assumed for the Derivation of Geochemical Source Terms

Unit	2019		EOM: Current WRSA		EOM: WRSA Expansion	
	Proportion	**Tonnage (kt)**	**Proportion**	**Tonnage (kt)**	**Proportion**	**Tonnage (kt)**
Argillite	50%	4,292	55%	9,219	63%	13,893
Greywacke	50%	4,292	45%	7,543	38%	8,336
Total	100%	8,585	100%	16,763	100%	22,228

Table 2-4:
Water Balance Assumptions Made for the Development of WRSA Source Terms

Water Source	Volume (L)		
	2019	**EOM: Current WRSA**	**EOM: WRSA Expansion**
WRSA Seepage/Runoff	102,212,146	291,802,824	316,726,716
Prepared Ground Runoff	188,993,424	-	-
Evaporation	-19,753,414	-19,793,928	-21,484,596
Precipitation on ponds	40,107,844	40,190,103	43,622,880

Notes: Total volumes reporting to the WRSP are from Jones (pers. comm., 2020). Proportioning of flows contributing to these volumes are based on the site water balance.

Table 2-5:
Scaling Factors Derived for the Touquoy WRSA

Parameter	Base Case	Upper Case
Sulphate	0.83	1.3
Al	0.00043	0.00091
Sb	0.00072	0.00072
As	0.0015	0.0027
Ba	0.31	0.46
Be	0.13	0.13
B	0.11	0.11
Cd	0.0018	0.0059
Ca	0.22	0.33
Cr	0.017	0.017
Co	1.2	2.0
Cu	0.031	0.041
Fe	0.026	0.026
Pb	0.13	0.13
Mg	0.22	0.37
Mn	0.029	0.43
Hg	0.00067	0.00067
Mo	0.022	0.024
Ni	0.10	0.33
P	0.051	0.051
K	0.017	0.034
Se	0.0068	0.0091
Ag	0.017	0.017
Na	0.13	0.26
Sr	0.29	0.41
Tl	0.0051	0.0051
Sn	0.022	0.022
U	0.14	0.26
V	0.020	0.020
Zn	0.025	0.026

2.2 Model Validation and Capping

As a final step, the model output was compared to water quality results from other data sources, specifically field-scale kinetic testing (field bins) conducted on site-specific waste rock materials. These data sources are valuable in re-assessing solubility limits and provide an opportunity to validate scaling factors used for the geochemical source term model. It should be noted that a total of four field bins are currently operational. Of these, two field experiments were initiated in 2017 and contain the Touquoy waste rock end-members argillite and greywacke. Samples in these bins were sourced from blast rock after Touquoy operations had commenced. Two additional field bins were constructed with Fifteen Mile Stream and Cochrane Hill drill core material in 2018. These sites are prospect deposits owned by AMNS and fall into the same geological terrane as the Touquoy deposit. Since the Cochrane Hill material is more strongly metamorphosed and has begun to release leachate with a pH of < 7, this sample was excluded from the source term validation step as operational Touquoy waste rock drainage is expected to remain circum-neutral during operations.

During the scaling exercise it was noted that concentrations of several species (Ag, B, Cr, Hg, P, Pb, V) commonly fall below the detection limit in humidity cell and field bin leachates as well as site monitoring data. Therefore, these elements not expected to pose a concern under neutral conditions due to their low solubility. In these cases, the respective detection limit and half the detection limit value were chosen as the solubility caps for the Upper Case and Base Case scenarios, respectively.

Due to the relatively well-constrained mineralogical fate of Fe, Al, and sulphate in mining environments, caps for these species were derived using the geochemical speciation code PHREEQC, which contains an extensive thermodynamic database (Parkhurst and Appelo, 1999). Table 2-6 provides an overview of the caps implemented and the concentration-limiting mineral phase for PHREEQC-modelled species.

Table 2-6:
Solubility Constraints Considered in the Touquoy WRSA Source Term Model

Parameter	Unit	Source Term Cap		Data Source
		Base Case	Upper Case	
SO_4	mg/L	Gypsum equilibrium		PHREEQC-Gypsum
Ag	mg/L	0.00005	0.0001	Field and HC Data
B	mg/L	0.025	0.05	Field and HC Data
Al	mg/L	Gibbsite equilibrium		PHREEQC-Gibbsite
Cr	mg/L	0.0005	0.001	Field and HC Data
Fe	mg/L	$Fe(OH)_3$ equilibrium		PHREEQC-$Fe(OH)_3$
Hg	mg/L	0.0000065	0.000013	Field and HC Data
P	mg/L	0.05	0.1	Field and HC Data
Pb	mg/L	0.00025	0.0005	Field and HC Data
V	mg/L	0.001	0.002	Field and HC Data

2.3   Nitrogen Species

Nitrogen residues from explosives are water soluble and are readily mobilized by contact water from mine waste (Ferguson and Leask, 1988; Baily *et al.*, 2013; Mueller *et al.*, 2015). The accumulation and depletion of nitrogen compounds from detonated mine rock has been observed at other surface mines (Lorax, 2017) and N loads exported into sediment pond water are typically correlated with the quantity of blasted material placed in the pond catchment. The release of N from mine rock stockpiles is influenced by site specific conditions including, but not limited to, precipitation quantity, runoff infiltration rates, blasting methods, blasting conditions, explosives type and stockpile size.

Nitrogen source terms for predicted WRSA drainage chemistry were derived empirically from site-specific, operational data using the Touquoy WRSP water quality database, waste rock placement records, and explosives use records. The source terms were then scaled to reflect the same model scenarios as described above, namely the currently approved WRSA design and the WRSA expansion.

For the 2019 hydrological year, all runoff reporting to the sediment pond percolated through mine rock material (Keating, pers. comm., 2020) with the exception of direct precipitation on the water management pond. The N source term derivation assumes all prepared ground was covered with blasted mine rock. The water balance models an evaporation-corrected 326,291 m^3 annual accumulation in the WRSA for 2019 (Table 2-7). Direct precipitation on the pond over this time period is approximately 52,703 m^3, which accounts for a dilution factor of approximately 1.19.

Water quality monitoring results from April 2019 through January 2020 were used to calculate average and maximum annual WRSP concentrations for total nitrogen (the sum of ammonia, nitrate and nitrite) for 2019; these were 9.54 and 17.1 mg N/L, respectively (Table 2-8). The highest concentration of total nitrogen was observed in January 2020 (17.1 mg N/L) and therefore this month was also included with the 2019 dataset to add conservatism to the calculated average and maximum values assigned to 2019.

For the purpose of N source term derivation, the 2019 total nitrogen concentrations are attributed entirely to the 2.46 Mt waste placed in 2018 (Table 2-9 and Table 2-12). This is a conservative assumption since the total nitrogen concentrations observed in 2019 were likely influenced by rock placed prior to 2018 and through 2019.

Ferguson and Leask (1988) developed methods for predicting N loads to waste rock based on the explosives type and quantities used for blasting at large surface coal mines in southeastern British Columbia. The Ferguson and Leask (1988) methods were applied to the Touquoy 2018 mining records for waste yielding a calculated N load of 6,386 kg N. For comparison, the WRSP water

quality observed April 2019 through January 2020 was assumed to be entirely influenced by waste mined and deposited in 2018. The WRSP annual average total nitrogen concentration derived for 2019 (9.54 mg N/L) and the corresponding WRSP pumping volume extrapolated to a full year (299,377 m^3) were used to estimate that a total of 2,855 kg N were released from the WRSP in 2019, which equates to approximately 45% of the Ferguson and Leask predicted loads for the 2018 waste tonnage (Table 2-9 and Table 2-10). Due to preferential flow paths within waste stockpiles, it is reasonable to expect that a portion of the total nitrogen may remain sequestered in the waste and may also infiltrate directly to groundwater. It has been observed at other mines that N export from mine rock stockpiles lags waste placement by up to three years (Baily *et al.*, 2013; Lorax, 2017). Comparison of the observed and theoretical N loads attributed to 2018 waste tonnage, as well as observations of WRSP water quality through July 2020 suggest a significant proportion of the stored N is flushed in the year following waste placement. Therefore, a one-year lag time for N release was used to predict N species concentrations in WRSA drainage.

Scaling factors for total nitrogen were derived by applying the 2019 annual average and maximum total nitrogen concentrations observed in the WRSP (Table 2-8) to the 2018 waste deposition record (Table 2-9) with a correction for the estimated dilution from non-contact precipitation (Table 2-7). The 2019 average and maximum total nitrogen values were used to model the Base Case and Upper Case values, respectively, for both scenarios. Based on the water quality, rock placement records and estimated dilution from direct precipitation on the WRSA, scaling factors of 4.61 mg N/L/Mt and 8.23 mg N/L/Mt were derived (Table 2-11). The scaling factors were applied to the previous year's waste deposition (Table 2-12) to estimate annual average total nitrogen concentrations in the WRSP for the current year (Table 2-13). The highest total nitrogen concentrations were predicted to occur in 2021 (21.2 and 37.9 mg N/L, Base Case and Upper Case, respectively) and these were used to derive the N species concentrations in WRSA drainage for both the tonnage under the current footprint and the expanded WRSA.

The concentration and relative distribution of the N species (ammonia, nitrate and nitrite) that were measured in the WRSP may be influenced by microbial and ion-exchange processes within the waste stockpile. The water quality observed in WRSP2 from April 2019 through July 2020 is considered to represent steady state conditions for any of these processes that may be active in the Touquoy WRSA. Therefore, the WRSA drainage chemistry for N species was derived by converting the highest predicted total nitrogen concentrations (Table 2-13) to ammonia, nitrate and nitrite based on the average relative distributions observed April 2019 through July 2020 (Table 2-8).

The main assumptions underpinning the total nitrogen prediction methodology are:

- The predicted Base Case and Upper Case EOM ammonia, nitrite and nitrate predictions are annual average concentrations. Monthly meaurements of WRSA toe seepage and WRSP water may occasionally exceed estimates of the annual average values;
- Explosives management and blasting practices and blast pattern conditions thoughout the period of record (April 2017 through July 2020) are representative of practices and conditions through to EOM;
- Bulk Titan XL 1000 emulsion explosive will be used for all blasting to EOM. Based on the N content of a similar explosive product it is assumed Titan XL 1000 is 25% total nitrogen (as N);
- The WRSP2 collection pond water is representative of toe seepage from the WRSA (i.e., there is neglible dilution from non-contact surface runoff). This asumption should be verfied on an ongoing basis by monitoring of WRSA toe seeps, as well as WRSP water quality and flows; and
- The waste rock placement, infiltration and WRSP pumping rates will remain similar to the modelled annual values through EOM.

Table 2-7:
Observed and Modelled WRSP Flows for 2019

	Units	2019
WRSP to TMF, measured (April – December)	m^3	224,553
WRSP to TMF, extrapolated annual total	m^3	299,377
WRSP annual flows corrected for evaporation, modelled[1]	m^3	326,291
WRSP direct precipitation, modelled[1]	m^3	52,703
WRSP dilution factor[1]	-	1.19

[1]Derived from Water Balance Revision v.13 Touquoy Gold Project (Keating, pers. comm., 2020)

Table 2-8:
Average and Maximum Nitrogen Species Concentrations and Species Relative Distributions

	Units	Value
2019 annual average concentration, total nitrogen[1]	mg N/L	9.54
2019 annual maximum concentration, total nitrogen[1]	mg N/L	17.1
NH_3 / $\sum$ N species (average)[2]	%	1.7%
NO_2 / $\sum$ N species (average)[2]	%	0.8%
NO_3 / $\sum$ N species (average)[2]	%	97.5%

[1]WRSP2 monitoring data, April 2019 – January 2020, average or maximum value for the period of record.
[2]WRSP2 monitoring data, April 2019 – July 2020, average value for the period of record.

Table 2-9:
Waste Deposition and Explosives Use in 2018 and Ferguson and Leask (1988) Estimated N Load on Waste Rock

	Units	2018
2018 waste deposition to WRSA	Mt	2.46
2018 annual powder factor	kg/t	0.2
Proportion of emulsion used for blasting	%	100%
Explosives used for blasting 2018 waste	kg	500,854
N in explosives	%	25%
Estimated N load in explosives used for blasting 2018 waste	kg N	125,214
F&L estimated N load (residues) in 2018 waste rock (> 20% emulsion)[1]	kg N	6,386

[1]The F&L N load was derived using methods described by Ferguson and Leask (1988).

Table 2-10:
2019 Observed Nitrogen Export from the WRSP to the TMF Compared to the Ferguson and Leask (1988) Estimate.

	Units	Value
Observed export, 2019[1]	kg N	2,855
Observed exported / theoretical (Ferguson and Leask, 1988) load	%	45%

[1]The observed N export calculated for the April – December 2019 period was extrapolated to an annual amount and is attributed entirely to waste deposited in 2018.

Table 2-11:
Base Case and Upper Case Scaling Factors for Total Nitrogen Concentrations

	Units	Value
Base Case Scale Factor	mg N/L / Mt	4.61
Upper Case Scale Factor	mg N/L / Mt	8.23

Table 2-12:
Observed and Projected Annual Waste Deposition to the WRSA from 2017 to EOM in 2023.

Year of Waste Placement	Total Waste Placed in WRSA (Mt) [1]
2017	0.46
2018	2.46
2019	4.71
2020	5.48
2021	5.37
2022	3.74
2023	0.29

[1]The 2017, 2018 and 2019 quantities are from site records. 2020 is a combination of observed (January to July) and scheduled (August to December) tonnages. Scheduled quantities extrapolated from both EOM scenarios amounts are presented for 2021, 2022 and 2023.

Table 2-13:
Annual Average Total Nitrogen Concentrations Derived Using the Touquoy Site Specific Scaling Factors for Each Year from 2018 to 2023.

Year	Total Nitrogen Concentration (Annual Average) Derived from Touquoy Scaling Factors (mg N/L)	
	Base Case	Upper Case
2018	1.8	3.2
2019	9.5	17.1
2020	18.2	32.6
2021	21.2	37.9
2022	20.8	37.2
2023	14.5	25.9

3. Results

The Touquoy WRSA drainage chemistry predictions derived by upscaling of humidity cell loading rates as well as using site monitoring data are presented in Table 3-1. As noted previously, it is expected that WRSA contact water will maintain a circum-neutral pH throughout operations. The predicted values are annual average concentrations, it is expected that monitoring data will fluctuate and individual samples may be higher or lower than the predicted drainage chemistry.

Table 3-1:
Operational WRSA Drainage Chemistry Predictions at EOM for General Parameters
Derived via Humidity Cell Upscaling and from Monitoring Records

Parameter	Units	EOM: Current WRSA		EOM: WRSA Expansion	
		Base Case	Upper Case	Base Case	Upper Case
pH	-	8.0	8.0	8.0	8.0
Alkalinity (as CaCO$_3$)	mg/L	128	129	129	130
Ammonia (as N)	mg/L	0.43	0.76	0.43	0.76
Nitrite (as N)	mg/L	0.20	0.36	0.20	0.36
Nitrate (as N)	mg/L	25	44	25	44
Sulphate	mg/L	1029	1204	1114	1312
Al	mg/L	0.0087	0.0087	0.0087	0.0087
Sb	mg/L	0.00085	0.00085	0.0011	0.0011
As	mg/L	0.027	0.050	0.032	0.060
Ba	mg/L	0.049	0.072	0.061	0.090
Be	mg/L	0.00085	0.00085	0.0011	0.0011
B	mg/L	0.025	0.043	0.025	0.050
Cd	mg/L	0.000018	0.000058	0.000023	0.000075
Ca	mg/L	354	346	357	335
Cr	mg/L	0.00050	0.00085	0.00050	0.0010
Co	mg/L	0.0038	0.0068	0.0052	0.0091
Cu	mg/L	0.0016	0.0022	0.0021	0.0028
Fe	mg/L	0.0015	0.0015	0.0015	0.0015
Pb	mg/L	0.00025	0.00042	0.00025	0.00050
Mg	mg/L	55	92	72	120
Mn	mg/L	0.20	3.0	0.26	3.8
Hg	mg/L	0.0000070	0.000011	0.0000070	0.000013
Mo	mg/L	0.0016	0.0018	0.0020	0.0022
Ni	mg/L	0.012	0.038	0.015	0.048
P	mg/L	0.050	0.085	0.050	0.10
K	mg/L	11	23	14	29
Se	mg/L	0.0011	0.0015	0.0014	0.0019
Ag	mg/L	0.000050	0.000085	0.000050	0.00010
Na	mg/L	34	48	38	55
Sr	mg/L	1.2	1.6	1.4	2.1
Tl	mg/L	0.000085	0.000085	0.00011	0.00011
Sn	mg/L	0.0017	0.0017	0.0022	0.0022
U	mg/L	0.0099	0.018	0.011	0.020
V	mg/L	0.0010	0.0017	0.0010	0.0020
Zn	mg/L	0.0042	0.0043	0.0052	0.0054

4. Closure

This technical memorandum is for the exclusive use of Atlantic Mining Nova Scotia Inc. The preparation and review of this document was completed by the Lorax staff identified below.

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TECHNICAL MEMORANDUM

To:	**Melissa Nicholson, Ryan Keating (AMNS)**	**Date: July 13, 2020**
From:	**Timo Kirchner, Bruce Mattson**	**Project #: A563-4**
Subject:	**Touquoy Gold Mine – TMF Geochemical Source Term Update (2020)**	

1. Introduction

The Touquoy Gold Mine, owned by Atlantic Mining Nova Scotia (AMNS), is located approximately 60 km northeast of Halifax, Nova Scotia, where mining operations commenced in September 2017. AMNS is preparing an application for an Industrial Approval (IA) amendment to permit the expansion of the Touquoy pit. This project is estimated to produce an additional 8.5 Mt of waste rock and 2 Mt of ore. Accordingly, a larger volume of tailings than previously predicted is expected to be discharged into the tailings management facility (TMF). As part of this permit application, Lorax Environmental Services Ltd. (Lorax) was retained to provide an update to the geochemical source term predictions for seepage from the Touquoy TMF. Along with water balance modelling results, these predictions are incorporated into the site water quality model which will ultimately inform the site's aquatic effects assessment.

The most recent geochemical TMF seepage source terms were generated by Stantec (2016a) as part of the 2016 IA-amendment application. At that time, seepage chemistry predictions were approximated by supernatant produced during bench-scale metallurgical testing. While this is adequate given the lack of tailings-specific kinetic test data at the time, tailings supernatant chemistry does not account for the interaction of sedimented tailings with pore water under low liquid/solid ratios and oxygen-deplete conditions. In the updated model iteration discussed herein, the TMF seepage quality is predicted using saturated kinetic experiments (columns) initiated in 2018 and conducted on a run-of-mine (ROM) tailings sample. Base and Upper Case predictions were developed for implementation into the site water quality model. Two separate source terms were derived for the following water types:

1. Seepage through the engineered upstream clay blanket and core;
2. Seepage through the native (sandy) till layer underlying the TMF

The following section gives an overview of the approach chosen and assumptions made in the derivation of the TMF seepage chemistry predictions. Model results are subsequently presented in Section 3.

2. Approach & Assumptions

2.1 Seepage Through Upstream Clay Blanket and Core

Water quality predictions for seepage exiting the TMF through the upstream clay blanket and core were derived directly (*i.e.,* not via upscaling) from saturated column experiments conducted on the fine fraction of ROM tailings material. The fine fraction was isolated from a ROM tailings sample slurry by letting the tailings solids settle naturally within the sample container followed by the removal of the top layer of solids to produce a ~7 kg fine tailings sample. Initially, tailings supernatant was routed through these materials at a flow rate of 7 mL/hr over a 24 hour period. In 2019, the kinetic experimental scope was expanded to add a saturated column containing a compacted till layer downgradient of the tailings column in order to quantify the attenuation potential of the clay core and blanket underlying parts of the TMF. The inflow solution was switched to site TMF pond water at that time and leachate analysis was thereafter conducted on effluent from both the tailings and till column. This test was complemented by batch adsorption experiments using the same material and tailings leachate. A detailed discussion of the geochemical trends observed during these kinetic and batch experiments is provided in Lorax (2019).

One of the key assumptions made in the development of the source terms presented herein is that liquid/solid ratios imposed in the kinetic test program are sufficiently low, and pore water residence times sufficiently high, to promote geochemical equilibrium conditions on the tested scale. In other words, the leachate collected from the tailings and till columns is thought to be representative of seepage contacting similar solid materials on a field-scale. As such, saturated column leachate concentrations were used directly to predict the operational TMF seepage quality. This is in contrast to humidity cell based upscaling exercises typically used for unsaturated waste rock piles (e.g., Kempton, 2012, Kirchner & Mattson, 2015). As noted above, saturated column data from the fine tailings fraction was used in this exercise. Due to the increased surface area of this material in comparison to an "average" ROM tailings sample and the elevated content of secondary reaction products, such as ferric As-bearing phases precipitated in response to in-line ferric sulphate addition before tailings discharge, presents a further layer of conservatism with respect to this model approach. An overview of the different source term cases and data sources used is provided in Table 2-1

2.2 Seepage Through Native Till

The upstream clay blanket and core capture only a peripheral portion of the seepage leaving the TMF. Seepage losses to groundwater bypassing these engineered features are expected for the central portion of the TMF and will have an impact on the geochemical loads reporting to the receiving environment. However, the TMF is underlain by native, sandy till material in these areas

which, at least operationally, is expected to provide some attenuation for As and other dissolved species. This is supported by groundwater monitoring results at various stations between the TMF and Watercourse 4 showing the breakthrough of TMF seepage for conservative tracers (*e.g.,* sulphate), but not As. Specifically, As concentrations generally remain below or close to the analytical detection limit (1 µg/L = 0.001 mg/L) and below 0.01 mg/L for all samples (Figure 2-1). Note that the relatively higher concentrations in TMW-11A cannot be conclusively attributed to TMF seepage but may also represent natural groundwater contributions as well as TMF embankment runoff.

To date, no saturated kinetic or batch adsorption testing has been conducted on the sandy native till material, however limited solid-phase characterization results are available from various studies (Lorax, 2019; Stantec, 2016a). These results include acid-base accounting (ABA), aqua regia digestible metals, shake flask extractions (SFE), and particle size analysis. All of these static tests were also performed on the clay till used for the construction of the clay blanket and core and therefore allow for a comparison of these materials.
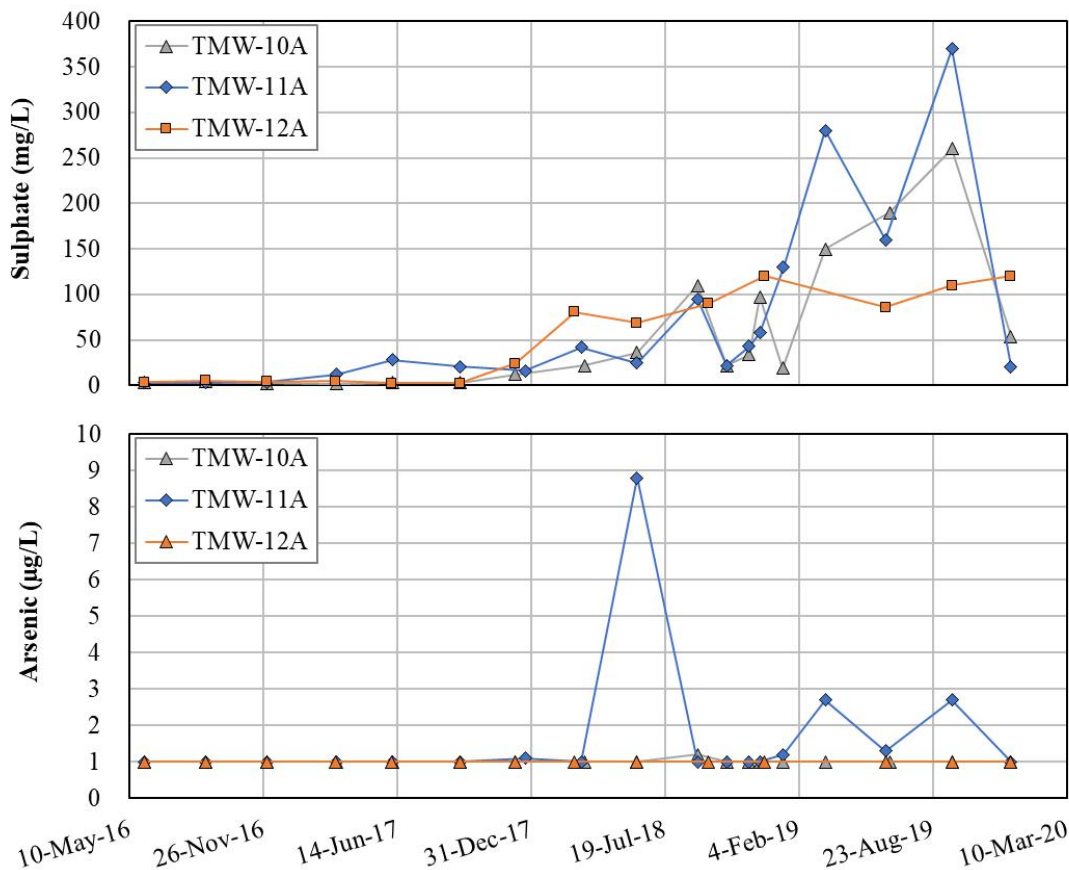
Figure 2-1: **Comparison of sulphate and Arsenic concentrations in groundwater monitoring wells located downgradient of the TMF and upgradient of Watercourse 4.**

Samples of the two material types (clay and sandy till) received by Lorax showed remarkably similar particle size distribution with ~50% of both the till types made up of the <2 mm size fraction which was used for the As adsorption experiments (Lorax, 2019). A geotechnical investigation conducted by Stantec (2016b) provides the results of particle size analyses on various overburden samples collected from boreholes along the perimeter of the TMF before the facility was constructed. This study revealed that the overburden thickness and clay contents are variable throughout the study area. Nevertheless, the majority of samples revealed particle size distributions similar to those measured in the samples submitted to Lorax with ≥50% representing the <2mm size fraction in most samples. Clay contents most commonly fall between 20% and 50% with few values below or above this range. Solid-phase and SFE leaching characteristics indicate that the two samples received by Lorax are relatively similar geochemically and display a low As leaching potential (0.0013 mg/L in clay till and 0.0004 mg/L in sandy till).

Despite the overall similarities across the different till materials studied, it cannot be said with certainty that the clay content in areas outside of the clay blanket cover is sufficiently high to afford the same attenuation capacity as the material utilized for the engineered clay blanket. Therefore, to maintain conservatism and to account for the uncertainty around the mineral and reactive surface area of the two till types, it was herein assumed that the attenuation capacity of the sandy native till material is only a fraction of that quantified through column and batch adsorption experiments (Lorax, 2019). The following assumptions were consequently made to predict the chemistry of seepage in contact with native till:

- <u>Base Case:</u> The concentrations of dissolved species subject to attenuation is one order of magnitude (10x) higher than those measured for clay till leachates;
- <u>Upper Case:</u> The concentrations of dissolved species subject to attenuation is two orders of magnitude (100x) higher than those measured for clay till leachates.

According to this approach, species considered "subject to attenuation" are those that show a reduction in concentration of > 90% (Base Case) or > 99% (Upper Case) between the tailings and clay till effluent as presented in Lorax (2019). For dissolved species with ≤ 90% or ≤ 99% attenuation, Base and Upper Case source terms were derived simply by adopting the median and 90th percentile tailings column effluent concentrations, respectively. By using this approach, the applied factors are effectively capped with measured data from un-attenuated tailings contact water.

Note that species consistently falling below the analytical detection limit in both saturated column leachates were set to half the detection limit in the Base Case scenario and to the detection limit value in the Upper Case scenario. This concerns the following species: Br, Ag, Be, Cr, Hg.

Table 2-1:
Overview of TMF Source Term Assumptions Utilized

Source term	Data Source(s)	Case	Statistical Value
TMF Seepage through Clay Till	Clay column effluent concentrations	Base Case	Median
		Upper Case	90th Percentile
TMF Seepage through Native Sandy Till	1. Multiple of median clay column effluent concentrations	Base Case	10 x
		Upper Case	100 x
	2. Tailings column effluent concentrations	Base Case	Median
		Upper Case	90th Percentile

Notes: pH and alkalinity values in the Upper Case predictions were calculated using the 10th percentile value.

3. Model Results

Geochemical source term predictions for TMF seepage to be used as input for the site-wide water quality model are provided in Table 3-1. Concentrations in seepage in contact with the engineered clay blanket and core are lower for most minor and trace elements, although the opposite is true for some species. This is generally due to these species leaching at higher concentrations from the saturated clay column compared to the tailings column (*e.g.,* Ca, Li, U) or variable detection limits (*e.g.,* Ag, Sn). Importantly, supported by static and kinetic test results, it is assumed that TMF seepage will remain circum-neutral for the time period modelled herein.

Table 3-1:
Geochemical Source Term Predictions for Touquoy TMF Seepage

Parameter	Unit	TMF Seepage (Clay Till)		TMF Seepage (Sandy Till)	
		Base Case	Upper Case	Base Case	Upper Case
pH	-	7.8	7.8	8.1	8.0
Alkalinity (as CaCO$_3$)	mg/L	203	188	151	129
Ammonia (as N)	mg/L	0.16	0.23	1.6	16
Nitrite (as N)	mg/L	0.0050	0.010	0.050	0.50
Nitrate (as N)	mg/L	0.025	0.060	0.25	0.64
Dissolved P	mg/L	0.011	0.013	0.073	0.10
Total Cyanide	mg/L	0.0050	0.0085	0.012	0.014
Sulphate	mg/L	582	598	594	604
Br	mg/L	0.25	0.50	0.25	0.50
Cl	mg/L	24	26	25	25
F	mg/L	0.34	0.38	0.25	0.36
Ag	mg/L	0.0000050	0.000010	0.0000025	0.0000050
Al	mg/L	0.0015	0.0023	0.015	0.023
As	mg/L	0.00089	0.0010	0.0089	0.089
B	mg/L	0.039	0.046	0.046	0.054
Ba	mg/L	0.064	0.080	0.015	0.016
Be	mg/L	0.0000050	0.000010	0.0000050	0.000010
Ca	mg/L	143	154	92	98
Cd	mg/L	0.0000080	0.000016	0.000010	0.000015
Co	mg/L	0.0037	0.0042	0.0090	0.011
Cr	mg/L	0.00010	0.00020	0.00013	0.00026
Cu	mg/L	0.00040	0.00048	0.0025	0.0034
Fe	mg/L	0.0010	0.0012	0.0041	0.0050
Hg	mg/L	0.0000025	0.0000050	0.0000025	0.0000050
K	mg/L	3.5	4.0	35	65
Li	mg/L	0.017	0.019	0.0049	0.0053
Mg	mg/L	29	32	10.0	11
Mn	mg/L	0.0063	0.056	0.063	0.12
Mo	mg/L	0.0026	0.0033	0.018	0.019
Na	mg/L	145	160	169	181
Ni	mg/L	0.00019	0.00030	0.0010	0.0012
Pb	mg/L	0.000010	0.000014	0.000010	0.000011
Sb	mg/L	0.00011	0.00014	0.0011	0.0037
Se	mg/L	0.00038	0.0012	0.0017	0.0024
Si	mg/L	8.0	8.5	4.6	5.3
Sn	mg/L	0.000020	0.000032	0.000020	0.000020
Sr	mg/L	0.21	0.23	0.24	0.25
Tl	mg/L	0.0000050	0.0000053	0.0000091	0.0000098
U	mg/L	0.0030	0.0037	0.0015	0.0020
V	mg/L	0.00020	0.00022	0.00041	0.00044
Zn	mg/L	0.0010	0.0016	0.00050	0.0010

4. Closure

This technical memorandum is for the exclusive use of Atlantic Mining NS Corp. The preparation and review of this document was completed by the Lorax staff identified below.

Lorax Environmental Services Ltd.

Prepared by: Reviewed by:

- Original signed and sealed by -   *- Original signed by -*

Timo Kirchner, M.Sc., P.Geo.   **Bruce Mattson, M.Sc., P.Geo.**
Environmental Geoscientist   Principal, Senior Environmental Geoscientist

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APPENDIX D.5
TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT DISCHARGE

Stantec

Touquoy Gold Project Assimilative Capacity Study of Moose River – Touquoy Pit Discharge

FINAL REPORT

June 30, 2021

File: 121619250

Prepared for:

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Sign-off Sheet

This document entitled Touquoy Gold Project Assimilative Capacity Study of Moose River – Touquoy Pit Discharge was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Atlantic Mining NS Inc. (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document. originally signed by

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Reviewed by _____ originally signed by _____
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Igor Iskra, Ph.D., P.Eng.

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LIST OF APPENDICES

APPENDIX A   WATER QUALITY PARAMETERS AND STATISTICS

June 30, 2021

1.0   INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Atlantic Mining NS Inc. (AMNS) to conduct an assimilative capacity study of Moose River for effluent discharge and seepage from the in-pit disposal of tailings as part of the Touquoy Gold Project. The Touquoy Gold Mine is located in Halifax County, Nova Scotia, approximately 60 kilometres northeast of Halifax. The study is focused on the water surplus in the exhausted Touquoy pit (Open Pit) during reclamation/closure phase discharged via a proposed spillway to Moose River at the final discharge point.

The objective of the assimilative capacity study is to define parameters of potential concern for the effluent, characterize the mixing zone for the Touquoy pit effluent and propose the maximum effluent limits for the parameters of potential concern.

2.0   BACKGROUND

The Touquoy Mine Site in Halifax County, Nova Scotia comprises an area approximately 271 hectares (ha). Site areas associated with major project components include the Mill Facility, Open Pit, Tailings Management Facility (TMF), Waste Rock Storage Area (WRSA), Clay Borrow Area, and ancillary facilities. The Open Pit is located between Moose River on the west and Watercourse # 4 on the east that each flow north to south adjacent to the limits of the Open Pit.

The existing Open Pit is actively dewatered and pumped to the TMF. Water in the TMF is decanted to the effluent treatment plant for treatment.

Over several years, the Open Pit will be allowed to fill through natural runoff, direct precipitation, and groundwater inflow, as well as flows from the deposition of the tailings slurry from the mill, supplemental flows from the WRSA ponds, and periodic flows from the polishing pond downstream of the existing TMF. This will result in a water cover over the tailings surface. Once water quality in the pit lake meets the MDMER discharge criteria, water surplus from natural processing (e.g., snowmelt or rainfall events) will be released to Moose River via an engineered spillway.

Figure 1 presents the study area including the Open Pit, surface water monitoring station SW-2 and proposed spillway to convey overflow from the pit to Moose River. The engineered spillway is 110 m long with an invert elevation of 108.0 metres (m) at the Open Pit and elevation of 107.5 m at the outlet to Moose River at the bank. The channel will have an approximate slope of 0.45% (Figure 2).

GRID NORTH

SW-11

MOOSE RIVER ROAD

MOOSE RIVER

LONG LAKE

SW-1

MILL SITE

RE-ALIGNED INTERSECTION
AT MOOSELAND / MOOSE
RIVER ROAD

HAUL
ROAD

MOOSE RIVER

OPEN PIT

WESTERN
DIVERSION
ROAD

SW-2

PROPOSED
SPILLWAY

END OF MIXING
ZONE - 100 m

TOPSOIL
STOCKPILE

0   100   300   500m

1:10 000

V:\1216\active\121619250\1_geotechnical\3_drawings_logs\4000_BEAVER-DAM\4_Sheet_Files\121619250.4000_LOC_FIG-1.dwg
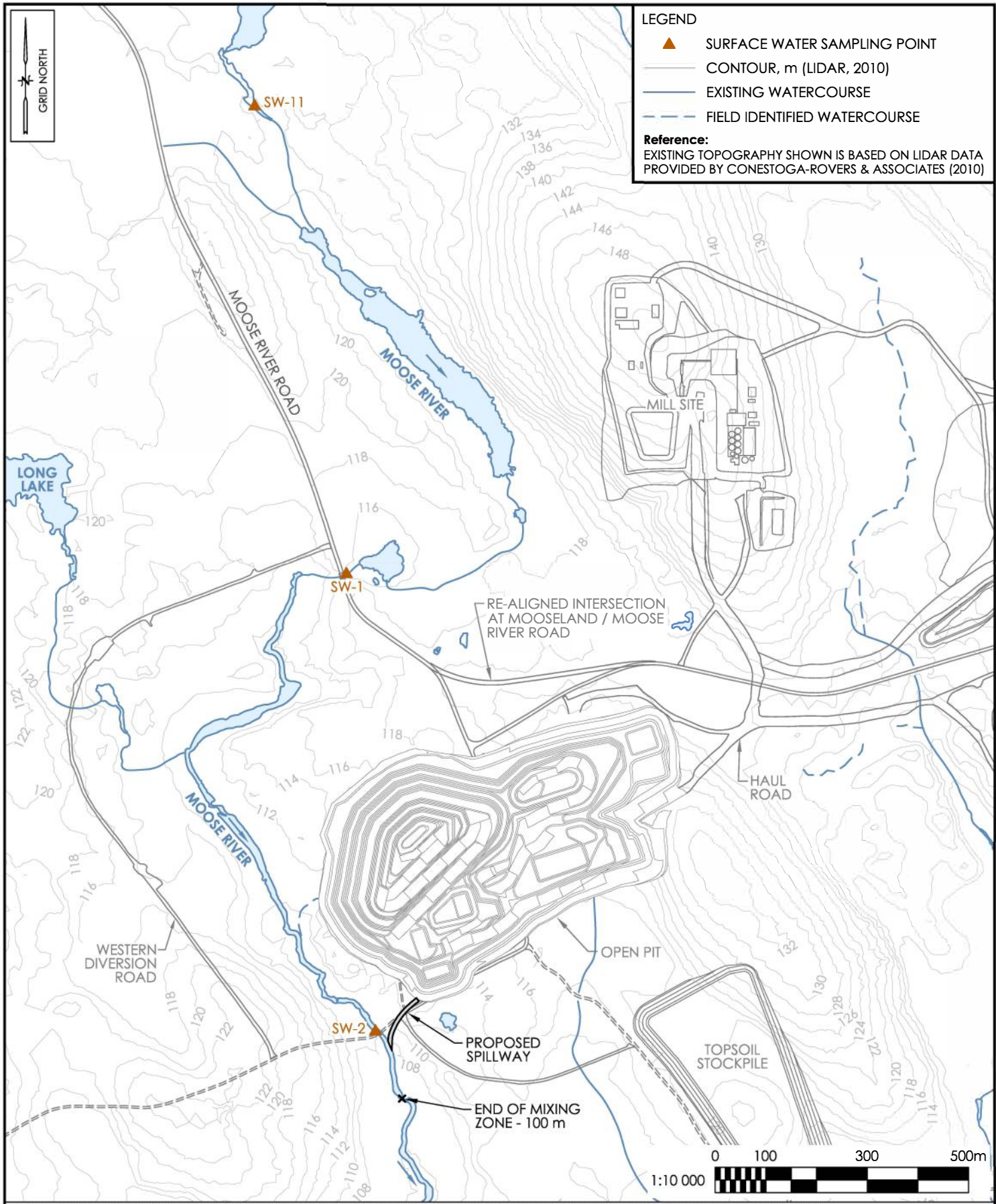
SITE MAP
TOUQUOY GOLD PROJECT
NOVA SCOTIA

Client: ATLANTIC MINING NS INC

Job No.:	121619250	Fig. No.:
Scale:	1 : 10 000	1
Date:	11-JUN-2021	
Dwn. By:	JL	**Stantec**
App'd By:	ll	

LEGEND

▲ SURFACE WATER SAMPLING POINT

0+025 RIVER CENTERLINE AND STATIONING (m) FROM SW2

CONTOUR, m (LIDAR, 2010)

EXISTING WATERCOURSE

FIELD IDENTIFIED WATERCOURSE
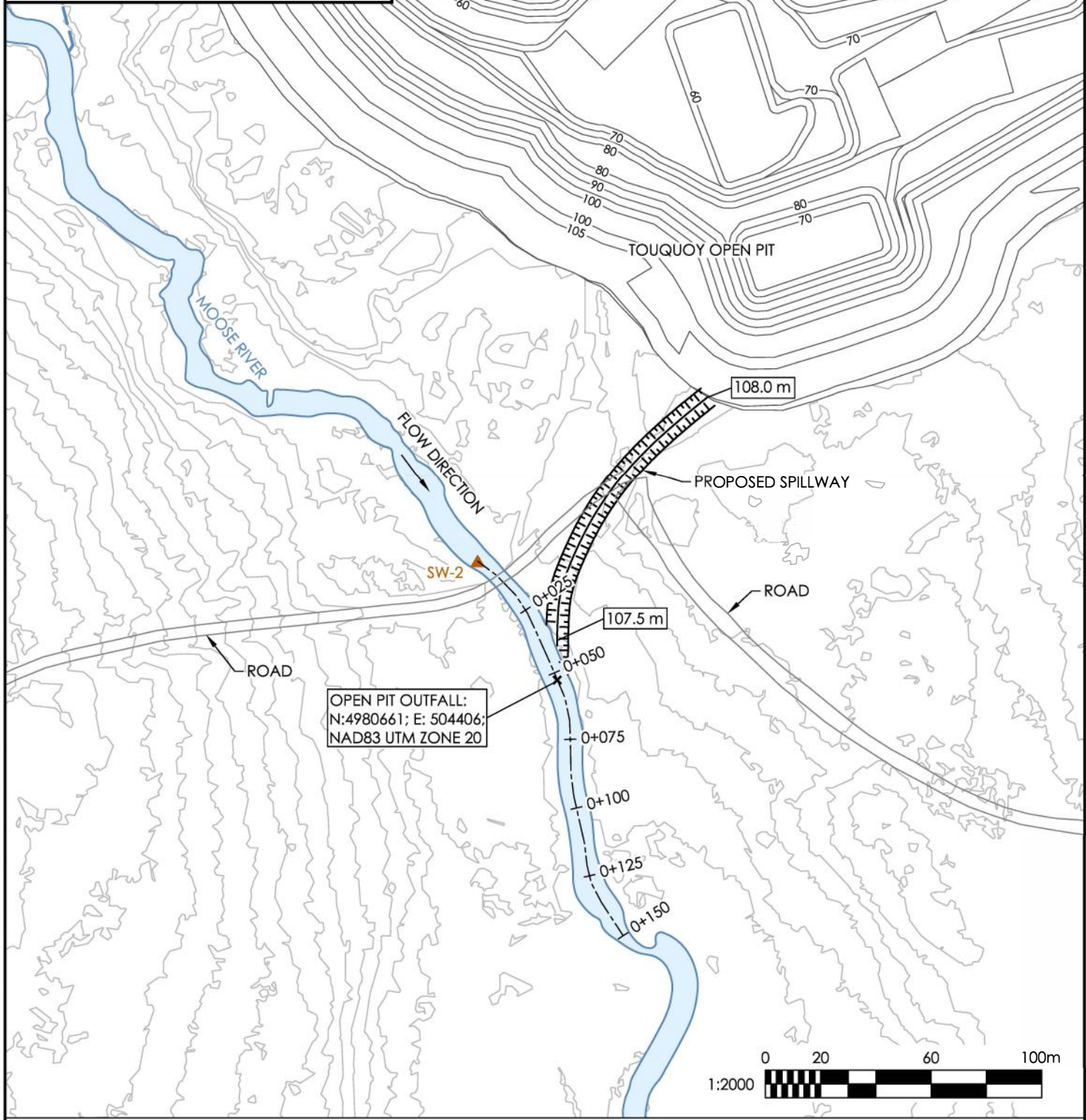
GRID NORTH

TOUQUOY OPEN PIT

108.0 m

PROPOSED SPILLWAY

ROAD

107.5 m

MOOSE RIVER

FLOW DIRECTION

SW-2

ROAD

OPEN PIT OUTFALL:
N:4980661; E: 504406;
NAD83 UTM ZONE 20

0+025
0+050
0+075
0+100
0+125
0+150

0   20   60   100m

1:2000

V:\1216\active\121619250\1_geotechnical\3_drawings_logs\4000_BEAVER-DAM\4_Sheet_Files\121619250.4000_LOC_FIG-2.dwg

LOCATION OF OPEN PIT OUTFALL	Job No.:	121619250	Fig. No.:
TOUQUOY GOLD PROJECT	Scale:	1 : 2000	2
NOVA SCOTIA	Date:	11-JUN-2021	
	Dwn. By:	JL	Stantec
Client: ATLANTIC MINING NS INC	App'd By:	RJ	

3.0   REGULATORY FRAMEWORK

Effluent discharge from the Open Pit is regulated by the *Metal and Diamond Mining Effluent Regulation* (MDMER). The maximum authorized monthly mean concentrations for effluent water quality for existing mines effective June 1, 2021 are presented in Table 1, and are based on those presented in Schedule 4 - Table 2 of the MDMER regulation. Wastewater treatment will be required for parameters that are predicted to exceed the MDMER limits in the effluent.

Table 1:   MDMER Limits for Mine Effluent after June 1, 2021

Parameter	MDMER, Table 2, Schedule 4
Arsenic	0.3 mg/L
Copper	0.3 mg/L
Cyanide	0.5 mg/L
Lead	0.1 mg/L
Nickel	0.5 mg/L
Zinc	0.5 mg/L
Suspended Solids	15.00 mg/L
Radium 226	0.37 Bq/L
Un-ionized ammonia (as N)	0.5 mg/L
Note: The concentrations for metals and cyanide are total values.	

The Canadian Council Ministers of the Environment (CCME) framework for assessing assimilative capacity of the receiver (CCME 2003) was used in this study. The key steps outlined in the CCME guidance are as follows:

1. Identifying physical/chemical and/or biological parameters of potential concern (PoPC) for the proposed discharge. Parameters of potential concern are defined as those which exceed the applicable regulatory limits in the Open Pit overflow effluent.

1. Establishing appropriate (i.e., freshwater) ambient Water Quality Objectives (WQOs) for receiving waters. The WQOs for this study were based on the Nova Scotia Environment and Climate Change (NSECC) criteria provided in Table 6 of Appendix K of the Industrial Approval for the site (Approval 2012-084244-08), which are largely derived from the Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CCME 2021).

2. If the background concentration of a POPC in the receiving environment is higher than the WQO on which the discharge limit is established, the discharge limit should not be more stringent than the natural background concentration.

3. Determining the areal extent of the initial mixing zone (IMZ) in the area of the outfall in the receiving water. CCME (2003) defines the mixing zone as, "*an area contiguous with a point source (effluent)*

> *where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives*".

4. Developing use-protection-based effluent discharge limits at the end-of-pipe which will meet ambient WQOs at the edge of the mixing zone (through modelling and other methods).

As per Chapter 6 of CCME (2003) the conditions within a mixing zone should not result in the bioaccumulation of chemicals (e.g., metals) to levels that are harmful or toxic.

4.0   RECEIVING WATER HYDROLOGY

The Open Pit effluent will reach Moose River in close proximity to SW-2. The upstream Moose River catchment area at SW-2 is 39.03 square kilometres (km^2). No long-term hydrometric stations exist on Moose River around the Touquoy Mine Site.

In the absence of long-term local hydrologic records, regional relationships were developed using selected Water Survey of Canada (WSC) stations to transpose flow data to the Touquoy Mine Site. The WSC stations were selected based on criteria including catchment area, station location, and period of record. Transpositional scaling is based on the assumption of homogeneity (due to their proximity and similar climate and land use conditions) between the selected regional WSC stations.

There are limited gauging station datasets available in Nova Scotia near the site that meet the primary selection criteria (e.g., catchment area, distance to Touquoy Mine Site). The WSC stations selected for the regional hydrology assessment are summarized in Table 2.

Table 2:   WSC Regional Hydrology Stations

Station ID	Station Name	Drainage Area (km^2)	Years of Record	Record Period	Distance to Site (km)
01DH003	FRASER BROOK NEAR ARCHIBALD	10.1	26	1965-1990	45
01EJ004	LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE	13.1	39	1980-2018	65
01FG001	RIVER DENYS AT BIG MARSH	14.0	14	2005-2018	167
01EE005	MOOSE PIT BROOK AT TUPPER LAKE	17.7	38	1981-2018	192
01EH006	CANAAN RIVER AT OUTLET OF CONNAUGHT LAKE	65.4	11	1986-1996	107
01DP004	MIDDLE RIVER OF PICTOU AT ROCKLIN	92.2	54	1965-2018	58
01DG003	BEAVERBANK RIVER NEAR KINSAC	96.9	98	1921-2018	60
01FA001	RIVER INHABITANTS AT GLENORA	193	54	1965-2018	150
01ED013	SHELBURNE RIVER AT POLLARD'S FALLS BRIDGE	268	20	1999-2018	202

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01EO003	EAST RIVER ST. MARYS AT NEWTOWN	282	15	1965-1979	75
01EK001	MUSQUODOBOIT RIVER AT CRAWFORD FALLS	650	82	1915-1996	27

Average monthly flows for Moose River at SW-2 were derived using the regional relationships. Figure 3 presents the regression analysis completed to determine the relationship between catchment areas and average flow in April, August, and June-July-August for the selected WSC stations. April was selected as this month corresponds to the highest flows in the region and summer months typically correspond to the lowest flows.

Figure 3:   Regional Regression Analysis
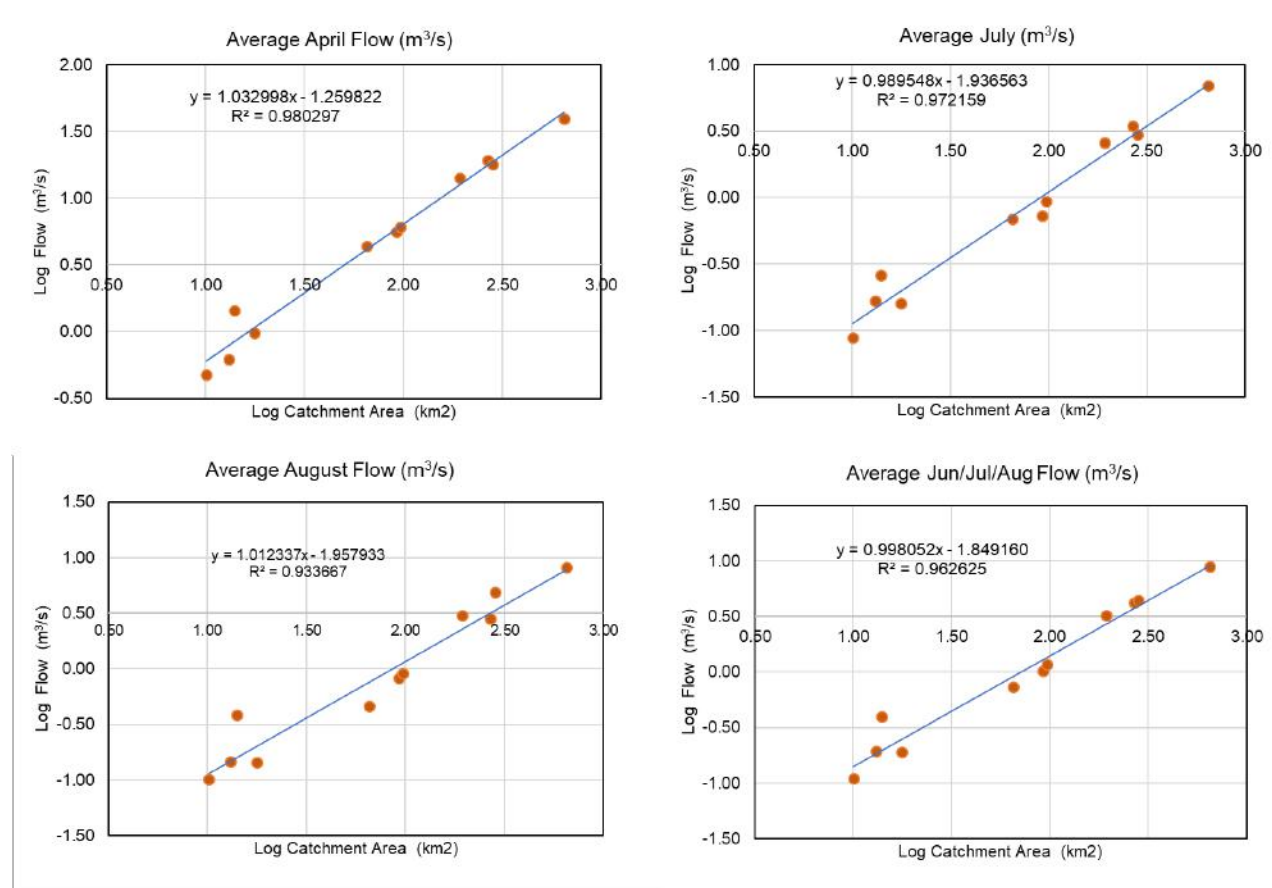
As presented on Figure 3, strong linear trends exist between the average monthly flow rates of the selected monitoring stations and drainage area for April, August, and June to August with correlation coefficients (R^2) of 0.98, 0.93, and 0.96, respectively. From these regional relationships, the average April and August flows for SW-2 in Moose River are estimated to be 2.42 cubic metres per second (m^3/s) and 0.45 m^3/s, respectively. Results of the statistical analysis on the regional flow records indicated that generally the peak and low flow events occur in April and August, respectively.

5.0   RECEIVING WATER QUALITY

The effluent will be discharged to Moose River via an engineered spillway as presented on Figure 2. A monitoring program has been ongoing since 2016 to monitor background water quality in Moose River at three monitoring stations SW-1, SW-2, and SW-11. Table 3 summarizes the location of each monitoring station.

Table 3:   Water Quality Monitoring Stations on Moose River

Site	Location	Rationale	Location Description
SW-1	504325E, 4981604N	Background	Moose River – adjacent to site and upstream of Moose River road culvert and Open Pit
SW-2	504378E, 4980703N	Downstream – Near-field	Moose River – downstream of Facility and upstream of Bridge, just below the Open Pit
SW-11	504140E, 4982529N	Background	Moose River – upstream of the Site to represent relatively un-impacted conditions upstream of the facility

Surface water monitoring station SW-2 is located immediately upstream of the proposed effluent location (Figure 1) and therefore was used to characterize ambient water quality.

Table 4 summarizes the 2016 and 2017 water quality data at SW-2 for total metals, cyanides. The table also presents the Water Quality Objectives provided in Appendix K, Table 6 of the Industrial Approval. The background water quality for Moose River at SW-2 has four parameters which exceed the WQOs: aluminum, arsenic, cadmium and iron. Tables A-1 to A-3 in Appendix A present a complete list of monitored water quality parameters and statistics.

Table 4:   Background Water Quality at SW-2

Water Quality Parameter	Average Concentration mg/L	75th Percentile Concentration mg/L	Water Quality Objective mg/L
Aluminum	**0.169**	**0.187**	0.005 (if pH is <6.5); 0.100 (if pH is ≥6.5)
Arsenic	**0.012**	**0.018**	0.005
Calcium	1.2	1.3	-
Cadmium	**0.000014**	**0.000019**	0.00004 (if Hardness is <17 mg/L); $10^{\{0.83(log[hardness])-5.46\}}$ (if Hardness is ≥17 mg/L to ≤280 mg/L); 0.37 (if Hardness is >280 mg/L)
Cobalt	<0.0004	<0.0004	0.010
Chromium	<0.001	<0.001	-
Copper	<0.002	<0.002	2 (if Hardness is <82 mg/L); $0.2*e^{\{0.8545(ln[hardness])-8.373\}}$ (if Hardness is ≥82 mg/L to ≤180 mg/L); 4 (if Hardness is >180 mg/L)
Iron	**0.48**	**0.62**	0.3

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Table 4: Background Water Quality at SW-2

Water Quality Parameter	Average Concentration mg/L	75th Percentile Concentration mg/L	Water Quality Objective mg/L
Lead	<0.0005	<0.0005	1 (if Hardness is ≤60 mg/L); $e^{\{1.783(ln[hardness])-11.613\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 7 (if Hardness is >180 mg/L)
Mercury	<0.000013	<0.000013	0.000026
Magnesium	0.488	0.52	-
Manganese	0.06	0.07	0.82
Molybdenum	<0.002	<0.002	0.073
Nickel	<0.002	<0.002	25 (if Hardness is ≤60 mg/L); $e^{\{0.76(ln[hardness])-2.06\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 150 (if Hardness is >180 mg/L)
Tin	<0.001	<0.001	-
Selenium	<0.001	<0.001	0.001
Silver	<0.0001	<0.0001	0.0001
Sulphate	<2	<2	-
Thallium	<0.0001	<0.0001	0.0008
Uranium	<0.0001	<0.0001	0.015
Zinc	<0.005	<0.005	$e^{\{0.947(ln[hardness])-0.815(pH)+0.398(ln[DOC]+1.625\}}$ (if Hardness is 23.4 to 399 mg/L, pH is 6.5 to 8.13, and DOC is 0.3 to 22.9 mg/L)
WAD Cyanide	<0.003	<0.003	0.005*
Total Cyanide	<0.005	<0.005	-
Nitrate (as N)	<0.05	0.054	13
Nitrite (as N)	<0.01	<0.01	60
Ammonia (as N)	<0.05	0.062	

Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.
* Free form of cyanide

6.0   EFFLUENT WATER QUANTITY AND QUALITY

An environmental water balance was used to predict the Open Pit effluent overflow to Moose River at mine closure (Stantec 2021b). Figure 4 shows the average predicted monthly Open Pit overflow under climate normal conditions. As shown in the figure, average monthly effluent flow will vary seasonally from 0.9 litres per second (L/s) in July to 48.3 L/s in April. The average monthly effluent flow rate to Moose River will be 16.9 L/s.

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The Open Pit seepage rate to the river was simulated using a groundwater flow model (Stantec 2021a). Average daily seepage rate to Moose River was estimated at 258 cubic metres per day, or 3.0 L/s.

Figure 4:   Monthly Effluent Flow Rates
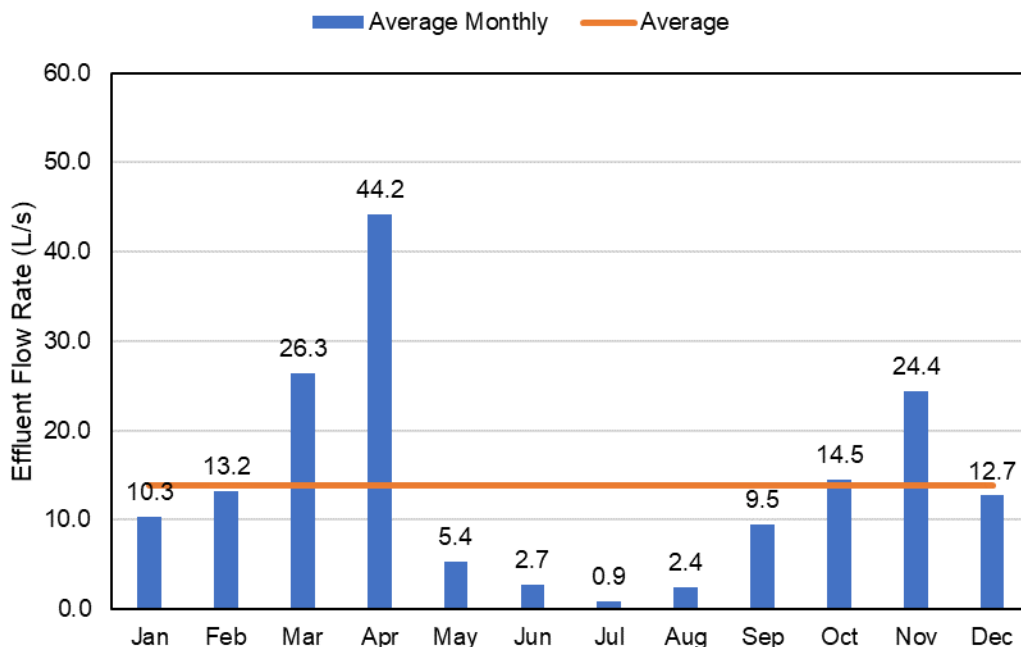
Effluent water quality was predicted using the water quality and quantity model and groundwater flow model (Stantec 2021a and Stantec 2021b). Water quality modelling considered the pore water quality in the tailings and the groundwater inflow quality in the pit floor and walls, dilution from surface runoff, direct precipitation, and process water surplus, and the geochemistry of the individual water quality parameters. Table 5 presents a list of predictions of the average and maximum concentrations in the effluent for metal parameters and nitrogen species. Concentrations of aluminum, arsenic, cobalt, copper, WAD cyanide, and nitrite in the effluent water quality have exceedance of the WQOs. In addition, the effluent concentrations of arsenic and ammonia are predicted to slightly exceed the 2021 MDMER discharge limit, therefore, arsenic and ammonia treatment will be required prior to release of the effluent to environment.

Total cyanide and weak acid-dissociable (WAD) cyanide concentrations in the effluent are below the MDMER discharge limit for cyanide (i.e., 0.5 milligrams per litre (mg/L) for total cyanide). There are no WQOs guidelines for these forms of cyanide. Further discussion about cyanide is presented in Section 10.0.

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Table 5: Predicted Effluent Water Quality Parameters and Limits

Water Quality Parameter	Average Concentration in Touquoy Pit Discharge mg/L	Maximum Concentration in Touquoy Pit Discharge mg/L	MDMER Discharge Limit[1] mg/L	Water Quality Objective mg/L
Aluminum	**0.015**	**0.033**		0.005 (if pH is <6.5); 0.100 (if pH is ≥6.5)
Arsenic	**0.178**	**0.616**	**0.3**	0.005
Calcium	24.5	49.4		-
Cadmium	0.000005	0.000008		0.00004 (if Hardness is <17 mg/L); $10^{\{0.83(\log[\text{hardness}])-5.46\}}$ (if Hardness is ≥17 mg/L to ≤280 mg/L); 0.37 (if Hardness is >280 mg/L)
Cobalt	0.009	**0.046**		0.010
Chromium	0.00015	0.00031		-
Copper	**0.005**	**0.026**	0.3	2 (if Hardness is <82 mg/L); $0.2*e^{\{0.8545(\ln[\text{hardness}])-8.373\}}$ (if Hardness is ≥82 mg/L to ≤180 mg/L); 4 (if Hardness is >180 mg/L)
Iron	0.012	0.029		0.3
Lead	0.00008	0.00020	0.1	1 (if Hardness is ≤60 mg/L); $e^{\{1.783(\ln[\text{hardness}])-11.613\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 7 (if Hardness is >180 mg/L)
Mercury	0.000012	0.000016		0.000026
Magnesium	3.24	4.89		-
Manganese	0.062	0.102		0.82
Molybdenum	0.003	0.007		0.073
Nickel	0.006	0.013	0.5	25 (if Hardness is ≤60 mg/L); $e^{\{0.76(\ln[\text{hardness}])-2.06\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 150 (if Hardness is >180 mg/L)
Tin	0.001	0.003		-
Selenium	0.00020	0.00056		0.001
Silver	0.00001	0.00003		0.0001
Sulphate	69.0	166		-
Thallium	0.00001	0.00003		0.0008
Uranium	0.0028	0.0032		0.015

Table 5:   Predicted Effluent Water Quality Parameters and Limits

Water Quality Parameter	Average Concentration in Touquoy Pit Discharge mg/L	Maximum Concentration in Touquoy Pit Discharge mg/L	MDMER Discharge Limit[1] mg/L	Water Quality Objective mg/L
Zinc	0.0009	0.0019	0.5	$e^{\{0.947(\ln[hardness])-0.815(pH)+0.398(\ln[DOC]+1.625\}}$ (if Hardness is 23.4 to 399 mg/L, pH is 6.5 to 8.13, and DOC is 0.3 to 22.9 mg/L)
WAD Cyanide	**0.016**	**0.087**		0.005*
Total Cyanide	0.048	0.249	0.5	-
Nitrate (as N)	1.36	3.98		13
Nitrite (as N)	**0.144**	**0.693**		60
Ammonia (as N)	0.070	0.721		
Unionized Ammonia (as N)	0.002	0.011	0.5	0.019

Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.
* Free form of cyanide
** Unionized ammonia estimated using maximum summer temperature and pH observed at SW-2

7.0 GROUNDWATER SEEPAGE FROM TOUQUOY PIT TO MOOSE RIVER

Groundwater seepage from the Open Pit discharging directly to Moose River was predicted using a groundwater model (Stantec 2021a). The groundwater seepage from the Open Pit to Moose River is estimated to be 5.5 L/s, based on climate normal conditions. Table 6 presents a list of average water quality concentrations in the groundwater seepage based on the water quality source terms predicted for the tailings. As shown on Table 6, no parameters in the seepage are predicted to exceed the MDMER or WQOs.

Table 6: Predicted Water Quality of Seepage from Touquoy Pit

Water Quality Parameter	Average Concentration in Seepage mg/L	MDMER (after 2021) mg/L	Water Quality Objective mg/L
Aluminum	6.6×10^{-8}		0.005 (if pH is <6.5); 0.100 (if pH is ≥6.5)
Arsenic	4.3×10^{-6}	0.3	0.005
Calcium	1.2×10^{-4}		-
Cadmium	2.8×10^{-11}		0.00004 (if Hardness is <17 mg/L); $10^{\{0.83(\log[\text{hardness}])-5.46\}}$ (if Hardness is ≥17 mg/L to ≤280 mg/L); 0.37 (if Hardness is >280 mg/L)
Cobalt	3.7×10^{-8}		0.010
Chromium	2.8×10^{-10}		-
Copper	1.3×10^{-8}	0.3	2 (if Hardness is <82 mg/L); $0.2*e^{\{0.8545(\ln[\text{hardness}])-8.373\}}$ (if Hardness is ≥82 mg/L to ≤180 mg/L); 4 (if Hardness is >180 mg/L)
Iron	4.6×10^{-8}		0.3
Lead	3.5×10^{-11}	0.1	1 (if Hardness is ≤60 mg/L); $e^{\{1.783(\ln[\text{hardness}])-11.613\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 7 (if Hardness is >180 mg/L)
Mercury	7.1×10^{-12}		0.000026
Magnesium	2.1×10^{-5}		-
Manganese	5.2×10^{-7}		0.82
Molybdenum	8.5×10^{-8}		0.073
Nickel	9.7×10^{-9}	0.5	25 (if Hardness is ≤60 mg/L); $e^{\{0.76(\ln[\text{hardness}])-2.06\}}$ (if Hardness is >60 mg/L to ≤180 mg/L); 150 (if Hardness is >180 mg/L)
Tin	8.5×10^{-9}		-
Selenium	2.7×10^{-10}		0.001

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Table 6:   Predicted Water Quality of Seepage from Touquoy Pit

Water Quality Parameter	Average Concentration in Seepage mg/L	MDMER (after 2021) mg/L	Water Quality Objective mg/L
Silver	1.4×10^{-11}		0.0001
Sulphate	1.3×10^{-3}		-
Thallium	2.2×10^{-11}		0.0008
Uranium	2.9×10^{-9}		0.015
Zinc	1.4×10^{-8}	0.5	$e^{\{0.947(\ln[hardness])-0.815(pH)+0.398(\ln[DOC]+1.625\}}$ (if Hardness is 23.4 to 399 mg/L, pH is 6.5 to 8.13, and DOC is 0.3 to 22.9 mg/L)
WAD Cyanide	7.1×10^{-9}		0.005*
Total Cyanide	1.2×10^{-7}	0.5	-
Nitrate (as N)	7.5×10^{-8}		13
Nitrite (as N)	1.6×10^{-7}		60
Total Ammonia (as N)	4.8×10^{-5}		

* Free form of cyanide

8.0   ASSIMILATION RATIOS

Assimilation or dilution ratio analysis was conducted to find the worst-case month for dilution and mixing, i.e., the month with the lowest assimilative capacity. The Open Pit effluent post-mine closure will be driven by the same metrological factors (precipitation, evaporation, snowmelt) as the whole Moose River catchment. A very low flow in the river will correspond to a very low effluent flow from the Open Pit. The same relationship will exist with high flows.

Table 7 presents the dilution ratios of the effluent with the receiver water assuming full mixing. The dilution ratios were calculated as a ratio of flow in the receiver to the effluent flow for the same month. A ratio between the catchment area of Moose River at SW-2 (39.03 km²) and catchment area of the Open Pit (0.41 km²) is 95 to 1.

Table 7:   Dilution Ratio in the Receiver at Full Mixing

Month	Receiver Flow (L/s)	Effluent Flow (L/s)	Dilution Ratio
June/July/August	548	4.6	119
July	435	3.6	121
August	450	5.0	90
April	2,420	48.3	50

The minimum dilution ratio of 50 is observed in April when Moose River and effluent have high flows. This occurs because the Open Pit effluent and river flow are driven by the same meteorological factors.

9.0   MIXING ZONE STUDY

The approach to modelling the areal extent of the initial mixing zone involved the application of an effluent plume model. The Cornell Mixing Zone Expert System (CORMIX), version 12.0 (Doneker and Jirka 2017) was used in this study. CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system also predicts the behaviour of the discharge plume at larger distances. The basic CORMIX methodology relies on the assumption of steady ambient conditions. Background information regarding the physical characteristics of the receiving waters was used as input to the model, which is provided below.

9.1   CORMIX MODEL INPUTS

The required model inputs for the ambient conditions include flows, water density, wind, and depth of water in Moose River. Ambient flow affects the near-field transport and shape of the resulting plume from the effluent. Boundary ambient conditions are defined by average river depth at the outfall and in the mixing zone. Model inputs are summarized below:

- The average flow in Moose river in April is 2,420 L/s and the climate normal effluent flow is 48.3 L/s in April.

- The Moose River channel geometry at the outfall was estimated based on river bathymetry data measured at SW-2 as part of the on-going hydrometric monitoring program for Touquoy operation. Channel width with active flow at the discharge point is 8 m. The average water depth used in the model is 1.5 m for high water conditions.

- The horizontal angle (sigma) of spillway channel to the bank was assumed 45˚ based on proposed spillway design. The spillway was assumed to have a trapezoidal shape with a bottom width of 3 m and side slopes of 2:1. Longitudinal slope of the spillway is 0.45%.

- Both the effluent and receiver were assumed to have the same temperature of 10°C and same density of 1,000.5 kg/m^3.

- The Manning's roughness coefficient used in the model, which represents the roughness or friction applied to the flow by the channel and based on the bottom substrate, was assumed to be 0.035 for low flow conditions and 0.04 for high flow conditions.

- Winds in CORMIX can affect the circulation, mixing, and plume movement in the river channel. The mean wind speed of 4.2 m/s from at the Halifax Stanfield International Airport was used in the model.

9.2   ASSUMPTIONS

The following assumptions of the modelling investigation were made in the assimilative capacity study:

- Steady ambient and effluent conditions were assumed in CORMIX
- Outfall configuration (spillway size and slope) was based on available preliminary design
- CORMIX parameters were derived based on available field data and literature
- Bathymetry information in the mixing zone was based on cross-section information at SW-2
- Modelling was conservatively focused on dilution and mixing ratios and decay and bioaccumulation were not simulated.

10.0   RESULTS AND DILUTION RATIOS

The distance from the effluent discharge location to the boundary of the mixing zone applied in this study is limited to 100 m as per guidance from NSECC (Environment Canada 2006).

The CORMIX model showed that a full-mixing dilution ratio of 46 is achieved within 120 m from the outfall. A dilution ratio of 51 is achieved at the end of the mixing zone, i.e., 100 m from the outfall.

Concentrations of the parameters of potential concern at the end of the mixing zone were calculated conservatively. The maximum Open Pit concentrations were used to define the effluent and the 75th percentile was used to define the ambient water quality conditions. The seepage load (concentration times seepage rate) was excluded to be conservative, due to the low predicted groundwater quality which would dilute the effluent.

The focus of assessment was on six parameters of potential concern with concentrations predicted to exceed the WQOs presented by NSECC: aluminum, arsenic, cobalt, copper, nitrite, and cyanide. Concentrations of the parameters of potential concern at the end of the mixing zone are presented in Table 8.

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Table 8:   Water Quality Modelling Results, mg/L

WQ Parameter	Effluent Max, mg/L	Receiver, 75th Percentile	Water Quality Objectives	MDMER	Concentration at End of 100 m Mixing Zone	Concentration at 120 m. Fully Mixed
Aluminum	0.03	0.187	5 (if pH is <6.5); 100 (if pH is ≥6.5)		0.1837	0.1840
Arsenic	0.3	0.018	0.005	0.3	0.0233	0.0228
WAD Cyanide	0.087	<0.003	0.005*		0.0032	0.0030
Total Cyanide	0.249	<0.003	-	0.5	0.0074	0.0069
Cobalt	0.046	<0.0004	0.010		0.00110	0.00102
Copper	0.026	<0.002	2 (if Hardness is <82 mg/L); $0.2 \cdot e^{\{0.8545(\ln[hardness])-1.465\}}$ (if Hardness is ≥82 mg/L to ≤180 mg/L); 4 (if Hardness is >180 mg/L)	0.3	0.00148	0.00144
Nitrite (as N)	0.693	<0.01	0.06		0.019	0.017

* Free form of cyanide

Aluminum is predicted to have lower concentration in the effluent in comparison with the ambient background. Therefore, the predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but still above the WQOs, resulting in a slight improvement in ambient aluminum concentrations.

Predicted maximum concentration of arsenic in the effluent is 0.616 mg/L. The MDMER limit is 0.30 mg/L, therefore, arsenic will require treatment prior to discharge. After arsenic treatment to the MDMER limit of 0.30 mg/L, its concentration at the end of the mixing zone is predicted at 0.023 mg/L. High arsenic background concentration limits mixing potential of this parameter. The arsenic concentration at the 100 m mixing zone boundary is above the WQOs. A site-specific water quality objective of 0.030 mg/L was developed for the Touquoy Mine Site (Intrinsik 201X) based on the CCME guideline (2001). The predicted arsenic concentrations are below the reported lowest toxic levels for fish, algae and aquatic plants.

Cyanide is presented in water in three forms: total, WAD, and free. There are no provincial or federal limits for total and WAD cyanide, however, there is a limit of 0.005 mg/L for free cyanide. The maximum WAD concentration in the effluent is 0.087 mg/L. Conservatively assuming that WAD is equal to the free form, the resulting concentration of free cyanide at the end of the mixing zone will be 0.0030 mg/L, which is less than the WQOs for free cyanide.

Predicted maximum total cyanide concentration in the effluent is 0.249 mg/L. These effluent concentrations are below the MDMER limit of 0.5 mg/L for total cyanide.

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11.0 CONCLUSIONS

It was determined that a 100-m mixing zone would be appropriate for the Touquoy pit effluent on the basis of requirements of NSECC

Ambient water quality was characterized using the 2016 and 2017 water quality data at SW-2. Background water quality in Moose River at SW-2 has four parameters which exceed the WQOs specified in the existing Industrial Approval: total aluminum, arsenic, cadmium and iron.

The concentrations of total aluminum, arsenic, cobalt, copper, and nitrite were identified to potentially exceed the WQOs in the Open Pit effluent. Arsenic concentrations in the effluent exceed the MDMER limits. Therefore, arsenic treatment will be required prior to release of the effluent to environment.

The CORMIX (version 12.0) three-dimensional model was used to derive the effluent criteria for the Touquoy pit effluent discharge to Moose River. The outfall configuration, bathymetry and flows were modeled conservatively based on available information.

Concentrations of the parameters of potential concern at the end of the mixing zone are presented in Table 11. The predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but above the WQOs. The predicted arsenic concentration is above the WQOs but below the site specific water quality objective (Intrinsik 201X). Conservatively assuming that WAD cyanide is equal to the free form, the resulting concentration of free cyanide at the end of the mixing zone will be 0.0030 mg/L, which is less than applicable provincial and federal limits for free cyanide. Concentrations of cobalt, copper, and nitrite at the end of the mixing zone are predicted to be below the WQOs.

12.0 CLOSURE

This report has been prepared for the sole benefit of the Atlantic Mining NS Inc. (AMNS). This report may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and AMNS.

Any use that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgment of Stantec Consulting Ltd. based on the data obtained from the work. If any conditions become apparent that differ from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

13.0 REFERENCES

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APPENDIX A
Water Quality Parameters and Statistics

Stantec

Table A.1   Surface Water Analytical Data - SW-2

Parameter	Units	2016-2017 Statistics						2016 Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Anion Sum	me/L	0.10	0.14	0.21	0.14	0.165	22	0.12	0.149	0.21	0.1	0.14	0.17	-
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Calculated TDS	mg/L	8.00	11.25	14.00	11.00	13	12	-	-	-	8	11.3	14	-
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Cation Sum	me/L	0.18	0.25	0.31	0.26	0.28	22	0.18	0.256	0.31	0.18	0.239	0.3	-
Colour	TCU	23.00	66.27	140.00	60.00	74	22	23	62.6	140	44	69.3	110	-
Conductivity	µS/cm	21.00	26.00	35.00	24.50	28	22	22	26.2	35	21	25.8	33	-
Dissolved Chloride (Cl)	mg/L	3.60	4.80	5.90	4.75	5.275	22	4.2	4.84	5.3	3.6	4.77	5.9	-
Dissolved Fluoride (F-)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Dissolved Sulphate (SO4)	mg/L	<2.0	<2.0	2.6	<2.0	<2.0	22	<2	<2	2.6	<2	<2	2	-
Hardness (CaCO3)	mg/L	3.50	5.00	7.30	4.85	5.25	22	3.5	5.14	7.3	3.8	4.89	6.7	-
Ion Balance (% Difference)	%	10.50	26.35	40.90	27.55	30.15	22	14.3	26.4	40.9	10.5	26.3	40.5	-
Langelier Index (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrate + Nitrite (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrite (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	<0.050	0.14	<0.050	0.062	21	<0.05	<0.05	0.095	<0.05	<0.05	0.14	-
Orthophosphate (P)	mg/L	<0.010	<0.010	0.011	<0.010	<0.010	22	<0.01	<0.01	0.011	<0.01	<0.01	0.011	-
pH	pH	4.90	6.05	6.89	6.05	6.2375	22	4.9	6.03	6.89	5.63	6.07	6.47	-
Reactive Silica (SiO2)	mg/L	<0.50	1.16	2.50	1.090	1.875	22	<0.5	1.02	2.5	<0.5	1.27	2.2	-
Saturation pH (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	22	<5	<5	<5	<5	<5	<5	-
Total Chemical Oxygen Demand	mg/L	14.00	27.36	67.00	24.50	27.75	22	14	27.8	67	20	27	43	-
Total Mercury (Hg)	µg/L	<0.013	<0.013	0.02	<0.013	<0.013	22	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	0.026
Total Organic Carbon (C)	mg/L	3.90	7.90	19.00	6.95	9.375	22	3.9	7.49	19	4.4	8.25	13	-
Total Suspended Solids	mg/L	<1.0	2.68	32	<1.0	1.2	22	<1	4.86	32	<1	<1	<2	-
Total Dissolved Solids	mg/L	9.00	11.90	15.00	11.00	13.5	10	9	11.9	15	-	-	-	-
Turbidity	NTU	0.43	1.17	3.30	1.10	1.375	22	0.58	1.34	3.3	0.43	1.02	1.8	-
Dissolved Aluminum (Al)	mg/L	70.00	176.00	270.00	170.00	220	5	-	-	-	70	176	270	10
Dissolved Antimony (Sb)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	20
Dissolved Arsenic (As)	mg/L	5.10	8.64	13.00	6.90	13	5	-	-	-	5.1	8.64	13	5
Dissolved Barium (Ba)	mg/L	2.80	4.58	6.50	4.70	5.2	5	-	-	-	2.8	4.58	6.5	1000
Dissolved Beryllium (Be)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	5.3
Dissolved Bismuth (Bi)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Boron (B)	mg/L	<50	<50	<50	<50	<50	5	-	-	-	<50	<50	<50	1200
Dissolved Cadmium (Cd)	mg/L	<0.010	0.014	0.027	0.017	0.018	5	-	-	-	<0.01	0.0144	0.027	0.01
Dissolved Calcium (Ca)	mg/L	1100.00	1340.00	1700.00	1300.00	1500	5	-	-	-	1100	1340	1700	-
Dissolved Chromium (Cr)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	-
Dissolved Cobalt (Co)	mg/L	<0.40	<0.40	<0.40	<0.40	<0.40	5	-	-	-	<0.4	<0.4	<0.4	10
Dissolved Copper (Cu)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	2
Dissolved Iron (Fe)	mg/L	310.00	438.00	660.00	450.00	450	5	-	-	-	310	438	660	300
Dissolved Lead (Pb)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	5	-	-	-	<0.5	<0.5	<0.5	1
Dissolved Magnesium (Mg)	mg/L	450.00	538.00	620.00	510.00	620	5	-	-	-	450	538	620	-
Dissolved Manganese (Mn)	mg/L	20.00	51.60	84.00	57.00	66	5	-	-	-	20	51.6	84	820
Dissolved Molybdenum (Mo)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	73
Dissolved Nickel (Ni)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	25
Dissolved Phosphorus (P)	mg/L	<100	<100	<100	<100	<100	5	-	-	-	<100	<100	<100	-

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Dissolved Potassium (K)	mg/L	180.00	220.00	320.00	210.00	210	5	-	-	-	180	220	320	-
Dissolved Selenium (Se)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	1
Dissolved Silver (Ag)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.1
Dissolved Sodium (Na)	mg/L	2600.00	2860.00	3100.00	3000.00	3000	5	-	-	-	2600	2860	3100	-
Dissolved Strontium (Sr)	mg/L	5.40	6.88	8.80	6.40	7.9	5	-	-	-	5.4	6.88	8.8	21000
Dissolved Thallium (Tl)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.8
Dissolved Tin (Sn)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Titanium (Ti)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Uranium (U)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	300
Dissolved Vanadium (V)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	6
Dissolved Zinc (Zn)	mg/L	<5.0	<5.0	5.60	<5.0	<5.0	5	-	-	-	<5	<5	5.6	30
Cyanate	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	22	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05	-
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.0010	<0.0010	0.002	<0.0010	<0.0010	22	<0.001	<0.001	0.0012	<0.001	<0.001	0.0018	0.005
Thiocyanate	mg/L	<0.17	<0.17	<0.17	<0.17	<0.17	22	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	-
Weak Acid Dissociable Cyanide (CN-)	mg/L	<0.003	<0.003	0.004	<0.003	<0.003	22	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	-
Benzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	2100
Toluene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	700
Ethylbenzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	320
Total Xylenes	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	22	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0026	330
>C10-C16 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.01	<0.01	<0.013	-
C6 - C10 (less BTEX)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	-
>C16-C21 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-
>C21-<C32 Hydrocarbons	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Modified TPH (Tier1)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.15
Hydrocarbon Resemblance	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Radium-226		<0.050	<0.050	<0.050	<0.050	<0.050	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0
Total Aluminum (Al)	µg/L	73.00	169.23	350.00	165.00	187.5	22	73	171	350	100	168	260	10
Total Antimony (Sb)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	20
Total Arsenic (As)	µg/L	4.00	12.25	30.00	7.85	17.75	22	4	14.7	30	4.6	10.2	19	5
Total Barium (Ba)	µg/L	2.50	4.11	8.60	3.80	4.375	22	2.5	4.3	8.6	3	3.96	5.8	1000
Total Beryllium (Be)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	5.3
Total Bismuth (Bi)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Boron (B)	µg/L	<50	<50	<50	<50	<50	22	<50	<50	<50	<50	<50	<50	1200
Total Cadmium (Cd)	µg/L	<0.010	0.014	0.04	0.014	0.019	22	<0.01	0.0162	0.04	0.01	0.0128	0.022	0.01
Total Calcium (Ca)	µg/L	840.00	1198.18	1700.00	1200.00	1300	22	840	1230	1700	920	1170	1600	-
Total Chromium (Cr)	µg/L	<1.0	<1.0	1.7	<1.0	<1.0	22	<1	<1	1.7	<1	<1	<1	-
Total Cobalt (Co)	µg/L	<0.40	<0.40	0.71	<0.40	<0.40	22	<0.4	<0.4	0.71	<0.4	<0.4	<0.4	10
Total Copper (Cu)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	2
Total Iron (Fe)	µg/L	190.00	483.18	850.00	485.00	617.5	22	190	481	810	200	485	850	300
Total Lead (Pb)	µg/L	<0.50	<0.50	0.86	<0.50	<0.50	22	<0.5	<0.5	0.86	<0.5	<0.5	<0.5	1
Total Magnesium (Mg)	µg/L	350.00	488.18	750.00	460.00	520	22	350	503	750	370	476	630	-
Total Manganese (Mn)	µg/L	29.00	60.00	180.00	54.00	68.5	22	35	70.1	180	29	51.6	88	820
Total Molybdenum (Mo)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	73
Total Nickel (Ni)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	25
Total Phosphorus (P)	µg/L	<100	<100	<100	<100	<100	22	<100	<100	<100	<100	<100	<100	-
Total Potassium (K)	µg/L	130.00	215.91	530.00	190.00	240	22	150	256	530	130	183	310	-
Total Selenium (Se)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	1
Total Silver (Ag)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Sodium (Na)	µg/L	2100.00	2772.73	3500.00	2800.00	3000	22	2200	2850	3500	2100	2710	3400	-
Total Strontium (Sr)	µg/L	4.50	6.30	11.00	5.85	6.65	22	4.5	6.39	11	4.6	6.22	8.8	21000

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Total Thallium (Tl)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8
Total Tin (Sn)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Titanium (Ti)	µg/L	<2.0	<2.0	3.70	2.15	2.5	22	2	<2	3.5	<2	2.07	3.7	-
Total Uranium (U)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	300
Total Vanadium (V)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	6
Total Zinc (Zn)	µg/L	<5.0	<5.0	6.1	<5.0	<5.0	22	<5	<5	6.1	<5	<5	6	30

Table A.2 2016 Surface Water Monitoring - SW-2

Parameter	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.15	0.12	0.14	0.14	0.13	0.15	0.21	0.13	0.19	0.13
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	-	-	-	-	-	-	-	-	-	-
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.21	0.18	0.26	0.25	0.28	0.28	0.28	0.31	0.28	0.23
Colour	49	57	52	68	53	33	23	140	74	77
Conductivity	22	22	23	23	24	28	31	35	27	27
Dissolved Chloride (Cl)	5.3	4.2	5	4.8	4.5	5.3	5.1	4.7	5	4.5
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.6	<2.0	2.2	<2.0
Hardness (CaCO3)	4.4	3.5	4.6	5	5.5	5.1	4.9	7.3	6	5.1
Ion Balance (% Difference)	16.7	20	30	28.2	36.6	30.2	14.3	40.9	19.2	27.8
Langelier Index (@ 20C)	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrate + Nitrite (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	<0.050	<0.050	0.062	<0.050	0.095	<0.050	0.062	<0.050	0.091	<0.050
Orthophosphate (P)	0.01	<0.010	<0.010	0.011	0.01	0.011	<0.010	<0.010	<0.010	0.011
pH	6.17	5.62	6.24	5.93	6.66	6.16	6.89	4.9	5.86	5.82
Reactive Silica (SiO2)	1.3	0.88	<0.50	<0.50	0.52	<0.50	<0.50	2.5	1.8	2.2
Saturation pH (@ 20C)	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	21	17	22	23	24	27	14	67	38	25
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	5	4.9	5.5	6.2	7.1	4.6	3.9	19	9.4	9.3
Total Suspended Solids	<1.0	<1.0	<1.0	2.4	<1.0	<1.0	32	1.2	<1.0	10
Total Dissolved Solids	11	9	11	10	11	11	15	14	15	12
Turbidity	1.4	1.3	1.1	1	1.4	1	0.58	3.3	1.4	0.91
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	-	-	-
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	-	-	-
Dissolved Arsenic (As)	-	-	-	-	-	-	-	-	-	-
Dissolved Barium (Ba)	-	-	-	-	-	-	-	-	-	-
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	-	-	-
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-
Dissolved Boron (B)	-	-	-	-	-	-	-	-	-	-
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	-	-	-
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	-	-	-
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	-	-	-
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	-	-	-
Dissolved Copper (Cu)	-	-	-	-	-	-	-	-	-	-
Dissolved Iron (Fe)	-	-	-	-	-	-	-	-	-	-
Dissolved Lead (Pb)	-	-	-	-	-	-	-	-	-	-
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-

Parameter	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	-	-	-
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	-	-	-
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	-	-	-
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	-	-	-
Dissolved Potassium (K)	-	-	-	-	-	-	-	-	-	-
Dissolved Selenium (Se)	-	-	-	-	-	-	-	-	-	-
Dissolved Silver (Ag)	-	-	-	-	-	-	-	-	-	-
Dissolved Sodium (Na)	-	-	-	-	-	-	-	-	-	-
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	-	-	-
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	-	-	-
Dissolved Tin (Sn)	-	-	-	-	-	-	-	-	-	-
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	-	-	-
Dissolved Uranium (U)	-	-	-	-	-	-	-	-	-	-
Dissolved Vanadium (V)	-	-	-	-	-	-	-	-	-	-
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	-	-	-
Cyanate	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Benzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
C6 - C10 (less BTEX)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	-	-	-	-	-	-	-	-	-	-
Radium-226	-	-	-	-	-	<0.050	-	-	-	-
Total Aluminum (Al)	150	140	170	140	170	100	73	350	210	210
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	5.2	4	30	23	29	20	17	8	5.7	4.9
Total Barium (Ba)	3.6	3.9	3.9	3.6	3.2	3	2.5	8.6	5.8	4.9
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.015	0.016	0.025	<0.010	<0.010	<0.010	<0.010	0.04	0.024	0.022
Total Calcium (Ca)	1000	840	1200	1200	1400	1200	1200	1700	1400	1200
Total Chromium (Cr)	<1.0	<1.0	1.6	<1.0	<1.0	<1.0	1.7	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	0.71	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	240	190	580	530	810	480	490	690	430	370
Total Lead (Pb)	<0.50	<0.50	0.86	<0.50	<0.50	<0.50	<0.50	0.52	<0.50	<0.50
Total Magnesium (Mg)	430	350	420	470	520	500	450	750	590	550
Total Manganese (Mn)	43.00	35.00	89.00	55.00	64.00	37.00	53.00	180.00	75.00	70.00

Parameter	March	April	May	June	July	August	September	October	November	December
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	240	210	300	180	150	160	240	530	310	240
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	2400	2200	3100	2800	3000	3500	3500	2700	2900	2400
Total Strontium (Sr)	5.1	4.5	5.2	5.6	6.7	5.9	5.4	11	7.8	6.7
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	2.1	<2.0	2.8	<2.0	2.5	<2.0	<2.0	3.5	<2.0	2
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	6.1	<5.0	<5.0	<5.0	<5.0	6.1	<5.0	<5.0

Table A.3   2017 Surface Water Monitoring - SW-2

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.17	0.12	0.17	0.1	0.12	0.12	0.11	0.13	0.15	0.15	0.17	0.17
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	13	10	12	8	10	9	10	10	14	12	14	13
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.26	0.21	0.21	0.18	0.21	0.24	0.26	0.23	0.3	0.26	0.28	0.23
Colour	61	55	44	52	74	63	59	48	110	72	110	84
Conductivity	29	24	25	21	22	24	24	24	29	27	33	28
Dissolved Chloride (Cl)	5.8	4.3	4.6	3.6	4	4.3	3.9	4.3	5.4	5.2	5.9	5.9
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Hardness (CaCO3)	4.7	4.5	4.3	3.8	4.3	4.4	5	4.7	6.7	5.3	6.2	4.8
Ion Balance (% Difference)	20.9	27.3	10.5	28.6	27.3	33.3	40.5	27.8	33.3	26.8	24.4	15
Langelier Index (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Langelier Index (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrate (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrate + Nitrite (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	0.082	<0.050	<0.050	-	0.14	0.05	<0.050	0.062	<0.050	<0.050	<0.050	<0.050
Orthophosphate (P)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010
pH	5.63	6.03	5.96	5.92	6.28	6.33	6.47	6.23	6.18	6.06	5.84	5.97
Reactive Silica (SiO2)	1.9	1.8	1.3	0.74	0.71	<0.50	0.51	0.52	2.1	1.3	2.2	1.9
Saturation pH (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Saturation pH (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	27	23	21	24	20	27	22	26	35	28	43	28
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	<0.013	<0.013	0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	6.5	5.7	4.4	4.7	6.9	7.2	7.6	7	13	10	13	13
Total Suspended Solids	<1.0	<1.0	<1.0	1.6	<2.0	1.4	<2.0	<1.0	1.2	<1.0	1.2	<1.0
Total Dissolved Solids	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	1.2	1.1	0.96	1.2	1.4	1.1	0.66	0.43	0.7	0.71	1.8	1
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	70	220	150	270	170
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Arsenic (As)	-	-	-	-	-	-	-	13	13	6.9	5.2	5.1
Dissolved Barium (Ba)	-	-	-	-	-	-	-	2.8	5.2	3.7	6.5	4.7
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Boron (B)	-	-	-	-	-	-	-	<50	<50	<50	<50	<50
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	<0.010	0.018	<0.010	0.027	**0.017**
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	1100	1700	1300	1500	1100
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	<0.40	<0.40	<0.40	<0.40	<0.40
Dissolved Copper (Cu)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Iron (Fe)	-	-	-	-	-	-	-	320	660	450	450	310
Dissolved Lead (Pb)	-	-	-	-	-	-	-	<0.50	<0.50	<0.50	<0.50	<0.50
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	450	620	490	620	510

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	20	66	31	84	57
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	<100	<100	<100	<100	<100
Dissolved Potassium (K)	-	-	-	-	-	-	-	180	210	180	320	210
Dissolved Selenium (Se)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Silver (Ag)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sodium (Na)	-	-	-	-	-	-	-	2600	3100	3000	3000	2600
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	5.4	8.8	6.4	7.9	5.9
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Tin (Sn)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Uranium (U)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Vanadium (V)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	<5.0	<5.0	<5.0	5.6	<5.0
Cyanate	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0018	<0.0010	0.001	0.0013	<0.0010	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Benzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0026	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.010	<0.010	<0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
C6 - C10 (less BTEX)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	-	-	-	<0.050	-	-	-	-	-	-	-	-
Total Aluminum (Al)	190	150	140	130	170	160	140	100	220	170	260	180
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	4.6	4.7	6.9	6.2	11	18	19	17	16	7.7	6.1	5.5
Total Barium (Ba)	4.3	3.9	3.7	3.2	3.9	3.4	3.4	3	5.1	3.4	5.8	4.4
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.018	0.012	0.016	0.018	0.013	<0.010	<0.010	<0.010	0.01	**0.011**	**0.022**	**0.019**
Total Calcium (Ca)	1100	1100	1000	920	1000	1100	1300	1200	1600	1300	1400	1000
Total Chromium (Cr)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	320	290	250	200	340	630	750	610	850	590	620	370
Total Lead (Pb)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Total Magnesium (Mg)	490	460	420	370	430	420	460	460	600	520	630	450
Total Manganese (Mn)	61	51	42	35	58	52	41	29	71	35	88	56

Parameter	61	51	42	35	58	52	41	29	71	35	88	56
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	150	150	170	200	170	170	130	150	220	160	310	210
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	3200	2400	2500	2100	2300	2800	2900	2600	3400	3000	3000	2300
Total Strontium (Sr)	6.1	5.8	5.6	4.6	5.6	5.6	6.5	5.7	8.8	6.4	7.5	6.4
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	<2.0	<2.0	<2.0	<2.0	2.2	2.4	2.7	2.2	3.7	3	2.2	2.5
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	<5.0	<5.0	6	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0