

10 Geochemistry

An overview of the geochemical site conditions for the KSM Project (the Project), including characterization data and the development of source terms for the predictive water quality model are provided in this chapter. Prediction and assessment of the potential for metal leaching and acid rock drainage (ML/ARD) is based on the geochemistry of geological materials that will be disturbed by the proposed Project. ML/ARD has the potential to adversely affect surface water and groundwater quality during the construction, operation, closure, and post-closure phases. Extensive geochemical characterization studies from 2008 to 2012 were completed to characterize the potential for ML/ARD from geological materials and wastes that will be exposed and produced during the life of the proposed Project ([Appendix 10-A](#)). The results were used to develop the Metal Leaching and Acid Rock Drainage Management Plan (Section 26.14) and to develop estimates of chemical loadings (i.e., water quality estimates) for contact water for use in the predictions of effluent and receiving environment water quality (see Chapter 14).

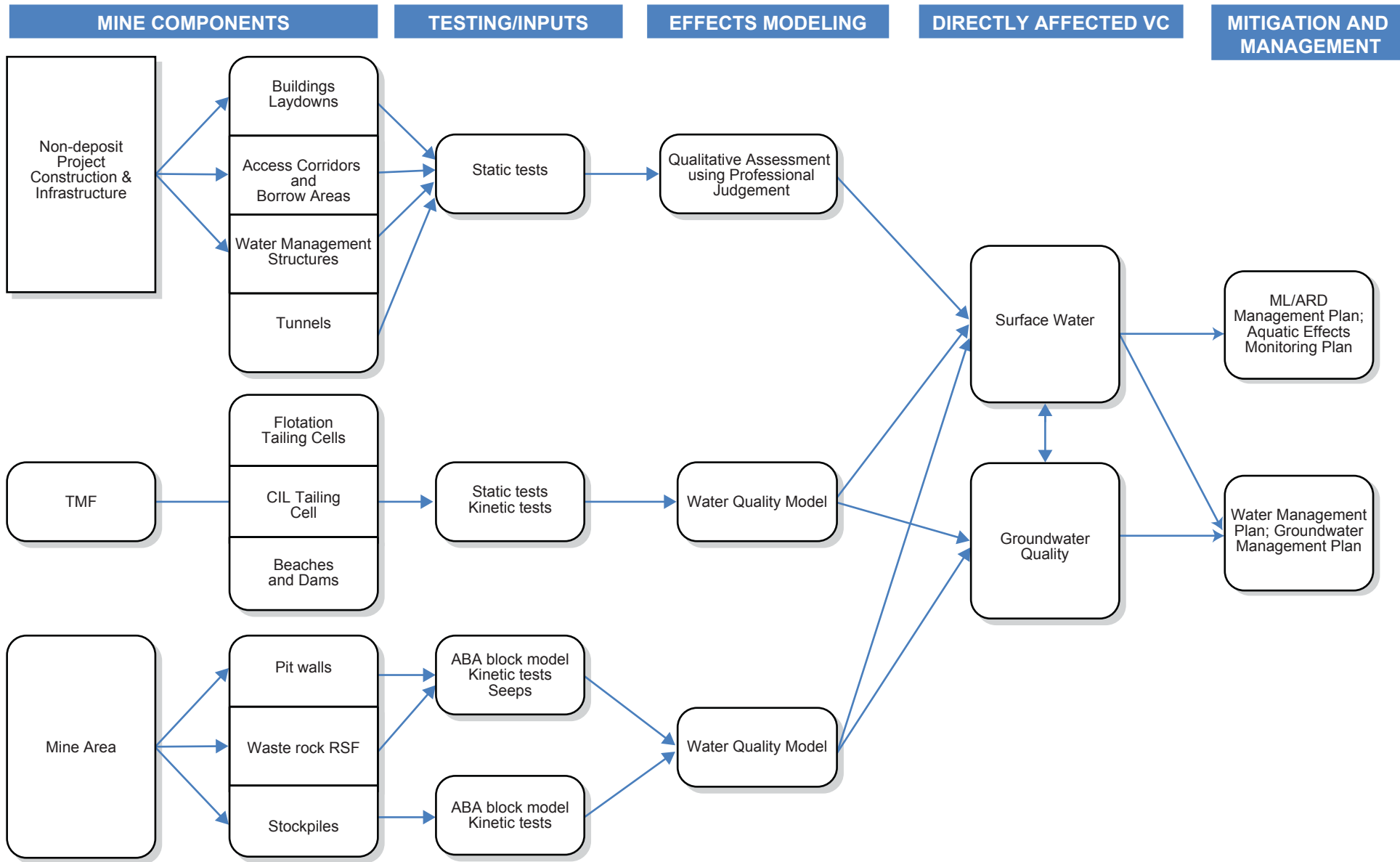
Valued components (VCs) directly affected by ML/ARD are described in the effects assessments of groundwater quality (Chapter 12) and surface water quality (Chapter 14). ML/ARD linkages to surface water and groundwater quality are demonstrated in Figure 10-1.

10.1 Geochemistry Setting

10.1.1 Regional Overview

Exposure of rock or other geologic materials to oxygen and water results in natural weathering processes including chemical oxidation and leaching of solid-phase constituents (e.g., metals). Where sulphide minerals such as pyrite are present, oxidation can create acid rock drainage (ARD), unless sufficient quantities of neutralizing minerals are available. In the event acidic drainage is formed, low pH conditions can lead to higher rates of metal leaching (ML). However, ML can also occur at sites of neutral or alkaline drainage.

The Project is located in an area known as the “Golden Triangle” due to its high mineral potential and the occurrence of a number of high-profile gold projects in the area. Historical mineral exploration and mining activities include the Granduc Mine (1970 to 1978; 1980 to 1984), the Sulphurets Advanced Exploration Project (1986 to 1990), and the Eskay Creek Mine (1995 to 2008). The highly mineralized rock in the region has produced active oxidation and leaching of sulphides, producing prominent and extensive copper sulphate precipitates at the surface, and acidic conditions in groundwater seeps in the deposit areas and the upper reaches of Mitchell Creek. Water and sediment quality baseline studies in the regional study area (RSA) include the cumulative effects of historical mining activities and naturally occurring ML/ARD. Elevated concentrations of metals were observed in the Mitchell, Sulphurets, and Unuk watersheds. Mineralization is also evidenced by mineral exploration in the upper reaches of Treaty Creek and elevated concentrations of some metals were also observed in the Treaty Creek watershed.



10.1.2 Baseline Studies

Effective ML/ARD characterization, prediction, and management of excavated and exposed geological materials are critical in preventing deleterious effects to the receiving environment.

The proposed Project areas of disturbance include the following deposit and non-deposit geological materials and wastes produced during construction and mining:

- Mine Site deposit rock including pit walls, waste rock, and ore;
- tailing material; and
- non-deposit rock including bedrock and overburden excavated or exposed during construction of surface collection and diversion channels, tunnels, access roads, borrow areas, quarries, buildings, and laydown areas.

The objective of the geochemical program was to characterize and predict the potential for ML/ARD due to development of the proposed Project and includes waste rock, ore, pit walls, tailing material, non-deposit material, and groundwater seep geochemistry. The Project components that were characterized in the geochemical program are defined in Table 10.1-1.

Table 10.1-1. Breakdown of Project Components

Project Component	Sub-component	Spatial Boundary	Temporal Boundary
Mine Site	Pit walls	Mine Site	Operation – post-closure
	RSF	Mine Site	Operation – post-closure
	Ore stockpiles	Mine Site	Operation – closure
Tailing		TMF	Operation – post-closure
Non-deposit Rock	Water management structures	Mine Site and TMF	Construction – post-closure
	Access corridors	Entire Project area	Construction – post-closure
	Borrow areas	Entire Project area	Construction - operation
	Quarries	Entire Project area	Construction - operation
	Building and laydown areas	Entire Project area	Construction – post-closure

RSF: Rock Storage Facility

TMF: Tailing Management Facility

10.1.2.1 Characterization Method

The objective of the geochemical program was to characterize and predict the potential for ML/ARD of the proposed Project and includes waste rock, ore, pit walls, tailing, non-deposit material, and groundwater seep geochemistry. A summary of the design basis for characterization of ML/ARD potential is provided in Table 10.1-2.

Table 10.1-2. Metal Leaching/Acid Rock Drainage Characterization Program Design

Mine Component	Geochemical Questions	Data Needed	Methods	
Waste Rock and Ore	ML/ARD potential	ABA	Core sampling, paste pH, acid potential, neutralization potential, solid-phase elemental analysis	
		Mineralogy	Rietveld XRD and petrographic analysis	
		Source of NP	Sobek NP, Rietveld XRD, calcium and magnesium content, total carbon and inorganic carbon content	
	Waste distribution (Project scale)	Spatial variation of ML/ARD characteristics	Sulphur form interpretation	Sulphur species analysis, barium content
				Core sampling, paste pH, acid potential, Sobek NP, solid-phase elemental analysis, ABA block model
	Waste segregation (within a deposit)	Spatial variation of ML/ARD characteristics		Core sampling, composite continuous core samples, paste pH, acid potential, Sobek NP, solid-phase elemental analysis, ABA block model
	Development of site-specific ARD criteria	Rate of depletion of sulphides and acid neutralizing minerals		Humidity cells, field leach barrels
	Variability of characteristics within a deposit and between deposits	Lithological composition of waste rock over mine life		Core sampling, ABA and solid-phase elemental analysis, ABA block model
		Chemical composition of waste rock		Core sampling, ABA and solid-phase elemental analysis, ABA block model
	Onset of acidic conditions	Rate of depletion of sulphides and acid neutralizing minerals		Humidity cells and lag-time calculations
Contact water chemistry	Leaching rates under non-acidic and acidic conditions		Humidity cells	
	Site-specific water quality data		Field leach barrels, groundwater seeps	
Pit Walls	Variability of characteristics within a deposit and between deposits	Lithological composition of pit walls over mine life	ABA block model and mine plan	
	Release of potential parameters of concern	Leaching rates under non-acidic and acidic conditions	Humidity cells	
	Contact water chemistry	See waste rock program	See waste rock program	

(continued)

Table 10.1-2. Metal Leaching/Acid Rock Drainage Characterization Program Design (completed)

Mine Component	Geochemical Questions	Data Needed	Methods
Tailing	ML/ARD potential	ABA	Metallurgical testing, paste pH, acid potential, neutralization potential, solid-phase elemental analysis
		Mineralogy	Rietveld XRD, petrographic and QEMSCAN analyses
		Particle size analysis	Wet sieving and laser diffraction
		Source of NP	Sobek NP, Rietveld XRD, calcium and magnesium content, total carbon and inorganic carbon content
	Variability of characteristics within a deposit and between deposits	Sulphur form interpretation	Sulphur species analysis, barium content
		Source of tailing (deposit)	Metallurgical testing, kinetic testing of composite samples, mine plan
		Onset of acidic conditions	Humidity cells, aging tests, subaqueous columns
Chemistry of TMF ponds and pore water	Leaching rates under non-acidic and acidic conditions	Humidity cells, aging tests, subaqueous columns	
	Leaching rates under sub-aerial and sub-aqueous conditions	Humidity cells, aging tests, subaqueous columns	
Non-deposit Material	ML/ARD potential	ABA	Overburden and outcrop sampling, paste pH, acid potential, Sobek NP, solid-phase elemental analysis
		Surface-soluble leaching from non-deposit or construction materials	Overburden and outcrop sampling, shake-flask extraction of overburden, and meteoric water mobility procedure of non-deposit rock

ABA: acid-base accounting

XRD: X-ray diffraction

NP: neutralization potential

QEMSCAN: quantitative evaluation of minerals by scanning electron microscopy

The ML/ARD prediction program was used for:

- waste and water management planning; and
- the assessment of environmental effects.

Figures 10.1-1 to 10.1-3 show the locations of drill holes, outcrop, and unconsolidated materials that were sampled for the ML/ARD characterization program for three areas of the proposed Project: Coulter Creek Access Corridor (CCAC), Mine Site, and Tailing Management Facility (TMF) including the Treaty Creek access road (TCAR).

10.1.2.2 Mine Site Characterization

10.1.2.2.1 Geology

The Sulphurets District is located along the eastern side of the Coast Mountains (Cretaceous to Early Tertiary intrusions and high grade metamorphics) and the western edge of the Middle Jurassic to Cretaceous Bowser basin. The District is centred over the breached core of the northerly plunging McTagg anticlinorium, which exposes rocks of the Stuhini Group, unconformably overlain by the Hazelton Group rocks. The Upper Triassic Stuhini Group has two main subdivisions: 1) lower dominantly sedimentary units; and 2) upper dominantly volcanic and volcanoclastic units. The Lower Jurassic Hazelton Group is inferred to represent a volcanosedimentary island arc and back arc complex containing basal sediments overlain successively by volcanic/volcanoclastic units, felsic pyroclastic units, and marine sedimentary units.

The northern portions of the Project are dominated by rocks of the Middle Jurassic to Middle Cretaceous Bowser Lake Group, a marine and continental sedimentary succession inferred to have accumulated in a back arc environment. The Hazelton sequence is intruded by Early Jurassic porphyritic intrusions collectively referred to as the Mitchell Intrusion or Texas Creek Plutonic Suite. Regional tectonic events attributed to the accretion of terranes have resulted in thrust faulting and widespread folding in the district. Figures of the regional geology can be found in the Project Description (Chapter 4, Figures 4.4-1 and 4.4-2).

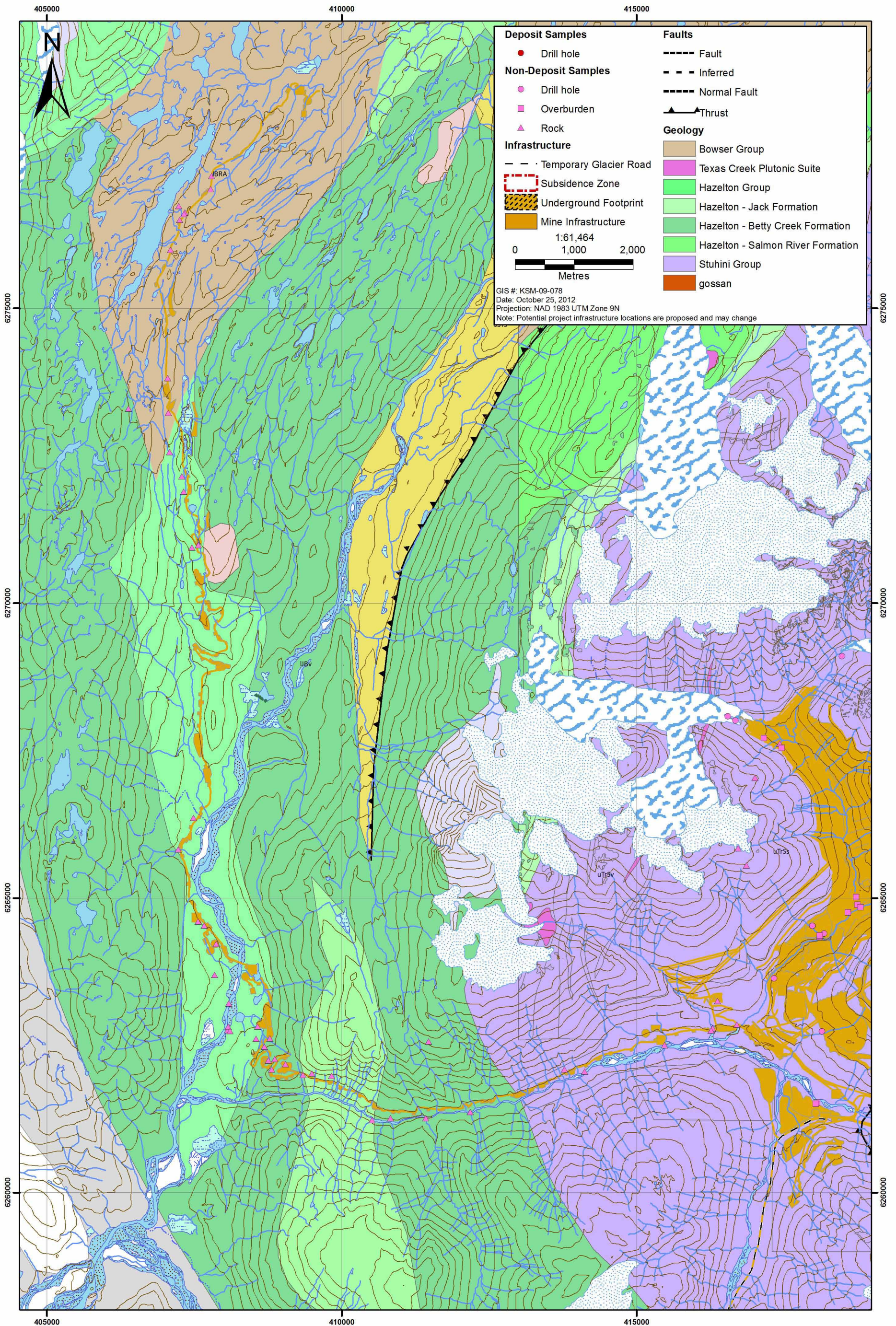
Results from the ML/ARD characterization program were used to develop an acid-base accounting (ABA) block model with a resolution of 25 m × 25 m × 15 m. This spatial scale represents a volume suitable for large excavators to segregate materials on a pit-bench. The geochemical results in the following sections are described for the model codes outlined in Table 10.1-3. The block modelling was undertaken by Mr. Michael Lechner (P.Geo., RPG, CPG and Qualified Person for the Project NI 43-101 resource model). The ABA block model uses three geostatistical methods sequentially from highest confidence to lowest confidence. As a result where there is good control, due to a sample or proximity to samples, the block is assigned the highest confidence value in preference to the lower confidence values.

10.1.2.2.2 Metal Leaching/Acid Rock Drainage Characterization Program

Waste rock, ore, and potential pit wall material were assessed in 2,030 ABA and solid-phase elemental analyses (1,117 waste rock, 911 ore, and 2 unclassified samples), 40 waste rock humidity cells (12 ore and 28 waste rock samples), and 17 field leach barrels from waste rock and ore samples. A detailed presentation of the geochemistry characterization program results is provided in [Appendix 10-A](#). The distribution of ore versus waste chemistries is summarized in [Appendix 10-C](#), which is a supplement to Appendix 5.1-1 of [Appendix 10-A](#).

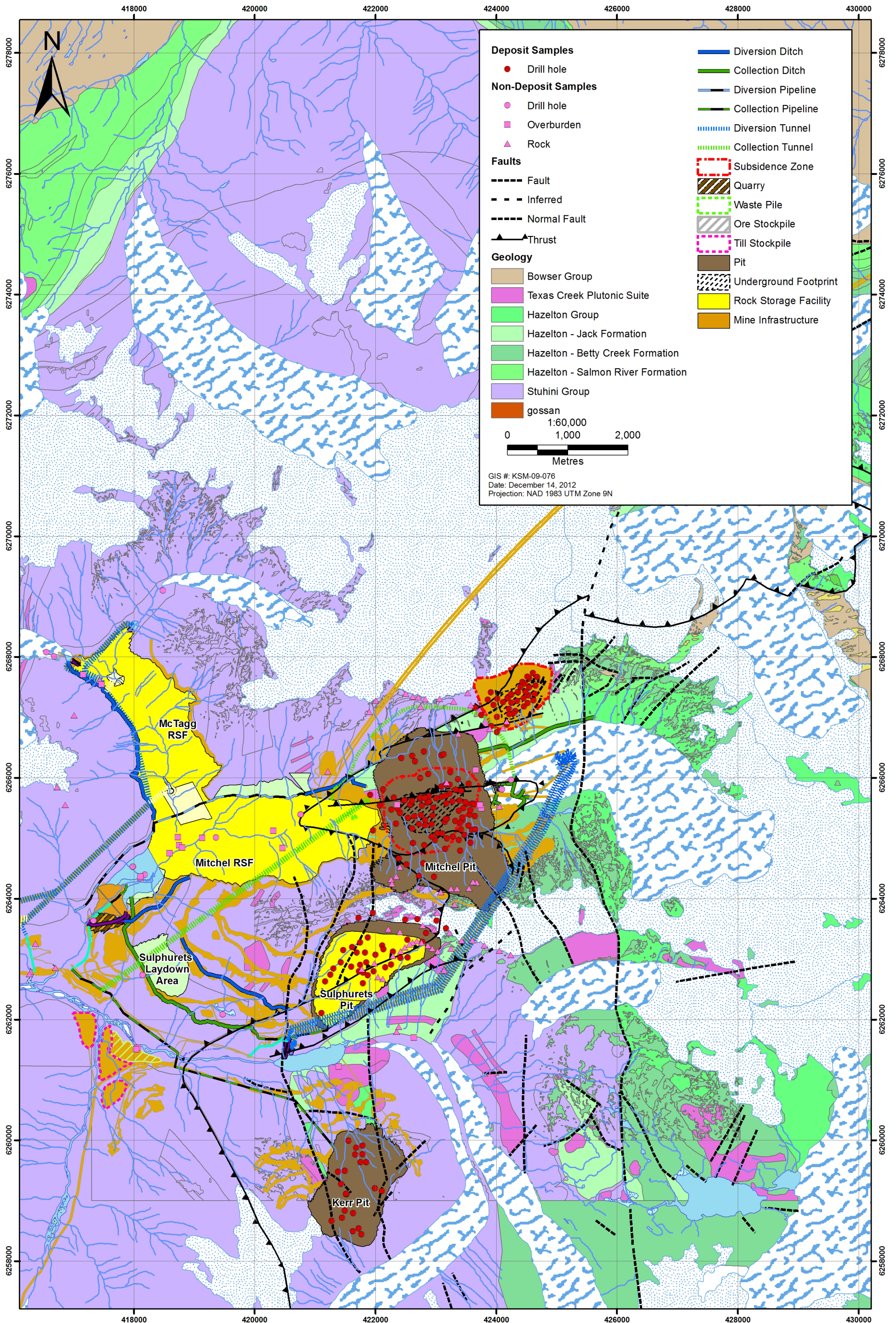
Static Testing

ABA test results of the 2,030 waste rock, pit wall, and low-/high-grade ore material samples are summarized, by deposit, in Table 10.1-4.



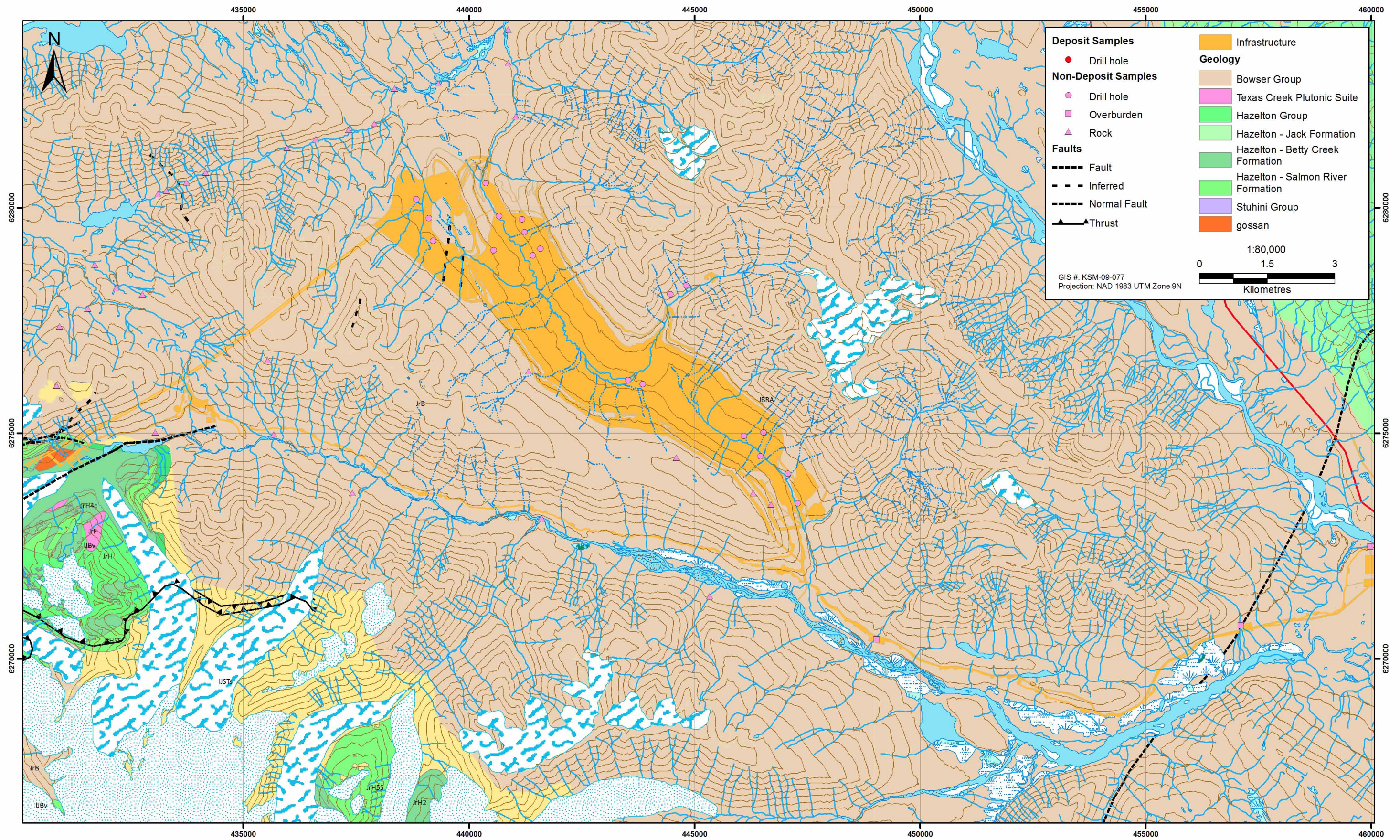
Goechemistry Sample Locations:
Coulter Creek Access Corridor

Figure 10.1-1



Locations of Geochemistry Samples in Relation to Mine Site Infrastructure

Figure 10.1-2



Deposit Samples

- Drill hole

Non-Deposit Samples

- Drill hole
- Overburden
- ▲ Rock

Faults

- Fault
- - - Inferred
- Normal Fault
- ▲ Thrust

Geology

- Infrastructure
- Bowser Group
- Texas Creek Plutonic Suite
- Hazelton Group
- Hazelton - Jack Formation
- Hazelton - Betty Creek Formation
- Hazelton - Salmon River Formation
- Stuhini Group
- gossan

1:80,000

0 1.5 3

Kilometres

GIS #: KSM-09-077
Projection: NAD 1983 UTM Zone 9N

Figure 10.1-3

Table 10.1-3. Acid Base Accounting Block Model Codes and Associated Descriptions

Block Model Codes	Description
Kerr	
KERR	All of the Kerr deposit
Sulphurets	
Overburden	> 50% soil or glaciofluvial material
UP Hazelton	Default for Sulphurets material above STF
Monzonite	Monzonite intrusion
LP Hazelton	Default for Sulphurets below STF
Lower Au zone	Sulphurets low grade ore zone
Au, leach, Raewyn zones	Default for Sulphurets ore zones
Undefined	Default for edge effects or minor units
Mitchell	
Overburden	> 50% soil or glaciofluvial material
Monzonite	Monzonite intrusion
UP Hazelton	Default material above MTF on north or south side of Mitchell Creek
Leach breccia/bornite breccia	Mitchell ore zone
LP Hazelton	Default material below MTF on north or south side of Mitchell Creek
Undefined	Default for edge effects or minor units
Iron Cap	
IRON CAP	All of the Iron Cap deposit

LP = lower panel

UP = upper panel

MTF – Mitchell Thrust Fault

STF = Sulphurets Thrust Fault

Stored acidity (paste pH < 6) was observed in samples from Mitchell LP Hazelton, Mitchell Leach breccia/bornite breccia, Iron Cap deposit, and Kerr deposit, indicating the presence of stored residual oxidation products. Stored acidity was not observed in Sulphurets deposit samples.

Concentrations of sulphur ranged from 0.01 to 19.05% with, sulphide-sulphur being the dominant sulphur species. Rietveld X-ray diffraction (XRD) analysis indicated that the most common sulphide mineral was pyrite (FeS₂) with lesser amounts of chalcopyrite (CuFeS₂), chalcocite (Cu₂S), sphalerite ((Zn,Fe)S), galena (PbS), and molybdenite (MoS₂), and trace amounts of bornite (Cu₄FeS₄), enargite (Cu₃AsS₄), and tennantite (Cu₁₂As₄S₁₃). Gypsum (CaSO₄.2H₂O) and anhydrite (CaSO₄) were identified in some samples from the Kerr and Sulphurets deposits.

Bulk Sobek neutralization potential (NP) values showed strong correlation with the NP calculated from calcium and inorganic carbon values across a wide range of NP values. The strong correlation between bulk Sobek NP and calculated NP indicates that most of the NP of the deposits is provided by calcium carbonate minerals. The most common carbonate minerals identified by mineralogical analysis were calcite, dolomite/ankerite, and lesser amounts of siderite.

Table 10.1-4. Summary of Acid Base Accounting Test Results for Waste Rock and Potential Pit Wall Material

Deposit	Model Code	% Samples with Paste pH < 6.0	Total-Sulphur (%)	Total-Sulphur and Sulphide-Sulphur Relationship	Sobek NP (kg CaCO ₃ /t)	Sobek NP Correlation	% Samples with Adjusted SNPR < 2.0	% Waste Rock with Adjusted SNPR < 2.0
Kerr	Kerr	18	0.01 to 13.81	Strong	0 to 482	Strong Ca CaNP	82.0	99
Sulphurets	S Overburden	0	0.06 to 3.47	Strong	7 to 183	Strong Ca CaNP	55.6	0.1
	S Au, Leach, Raewyn	0	0.2 to 6.62	Strong	5 to 142	Strong Ca CaNP	90.2	4.6
	S Lower Au	0	0.8 to 6.23	Strong	26 to 177	Strong Ca CaNP	87.1	9.5
	S LP Hazelton	0	0.43 to 7.01	Strong	29 to 350	Strong Ca CaNP	65.0	5.2
	S UP Hazelton	0	0.01 to 6.62	Strong	8 to 266	Strong Ca CaNP	33.3	5.4
	S Monzonite	0	0.03 to 2.2	Strong	9 to 253	Strong Ca CaNP	9.4	1.5
	S Undefined	0	0.07 to 7.5	Strong	12 to 306	Strong Ca CaNP	38.8	6.6
Mitchell	M Overburden	0	0.5 to 2.71	Strong	8 to 125	Strong Ca CaNP	71.4	1.5
	M UP Hazelton	0	0.02 to 12.75	Strong	7 to 241	Strong Ca CaNP	87.2	59.0
	M LP Hazelton	7.4	0.07 to 8.97	Moderate	0 to 263	Moderate Inorg NP	92.0	15.8
	M Monzonite	0	0.03 to 4.43	Strong	7 to 342	Strong Ca CaNP	35.0	2.4
	M Leach breccia/bornite breccia	30.4	1.96 to 19.05	Strong	0 to 57	Moderate Inorg NP	100.0	0.4
Iron Cap	Iron Cap	7.6	0.11 to 11.86	Strong	0 to 258	Strong Ca CaNP	92.0	100

NP = neutralization potential

SNPR = sulphide net potential ratio

Ca CaNP = calcium calculated neutralization potential

Inorg NP = inorganic neutralization potential

UP = upper panel

LP = lower panel

Waste rock with adjusted SNPR data were provided in the ABA block model

The estimation of unavailable NP, i.e., the maximum NP that corresponds to a paste pH below 6.0, was used as a standard practice (Price 2009). Based on the relationship between paste pH and bulk Sobek NP values, up to 15 kg CaCO₃/t of measured NP could be associated with acidic paste pH values. This value was derived from the complete 2008, 2009, and 2010 KSM Project static test database. The data indicate that the unavailable NP of 15 kg CaCO₃/t is valid for the Kerr, Mitchell, and Iron Cap deposits. An unavailable NP of 8 kg CaCO₃/t is valid for the Sulphurets deposit.

The neutralization potential was assessed using the bulk Sobek method for the majority of samples. Six samples collected along the TCAR alignment were analyzed using the modified Sobek method. The bulk Sobek method may overestimate NP due to the subjective nature of acid addition during the test (Price 2009). A conservative unavailable NP number was applied as a correction to the bulk Sobek results. Following this correction, good correlation was observed between measured carbonate NP values and bulk Sobek NP values indicating that NP has been appropriately assessed. If required, additional analyses can be completed; however, based on the above discussion, it is considered unnecessary. Figure 10.1-4 displays the relationship between Total Carbon NP and Sobek NP. There is good agreement between the two parameters indicating that Total Carbon by Leco can be used to calculate NP as outlined in the management plans in Sections 26.14.4.1.1 and 26.14.4.2.1.

Each Rock Storage Facility (RSF) will be composed of a mix of alteration types and rocks from several deposits and therefore the conservative estimate of unavailable NP is applied across all deposits model codes. The neutralization potential was adjusted by this estimate of unavailable NP to calculate an adjusted NP.

Potential waste rock, ore, and pit wall materials collected from Kerr deposit (82%), Sulphurets deposit (44%), Mitchell deposit (86%), and Iron Cap deposit (92%) were classified as potentially acid generating (PAG) based on static ABA tests (adjusted sulphide net potential ratio [SNPR] < 2) with the exception of materials designated by model codes Sulphurets UP Hazelton, Sulphurets Monzonite, and Mitchell Monzonite.

The solid-phase element concentrations of waste rock, pit wall, and low-/high-grade ore material were measured by inductively coupled plasma mass spectrometry (ICP-MS) analysis after strong four-acid (hydrofluoric, hydrochloric, nitric, and perchloric acids) digestion and by X-ray fluorescence whole-rock analysis. The solid-phase multi-element analysis results can be used as a screening tool to determine elements that occur in anomalously high concentrations in the solid-phase that may be of concern in drainage chemistry. The presence of the elements identified as anomalous do not provide information about the mineral source, potential leaching rates, or environmental significance. Some of these elements could be inert or sparingly soluble within silicates. Leaching rates were determined by kinetic tests results.

The results showed that the elements with contents frequently higher than three times the average basalt crustal abundance were silver, arsenic, barium, bismuth, cadmium, cesium, copper, mercury, potassium, molybdenum, lead, rubidium, sulphur, antimony, selenium, thallium, tungsten, and zinc. Elements with contents frequently higher than three times the average shale crustal abundance were silver, arsenic, barium, cadmium, copper, mercury, molybdenum, lead, sulphur, antimony, selenium, tungsten, and zinc. These results are further detailed in [Appendix 10-A](#).

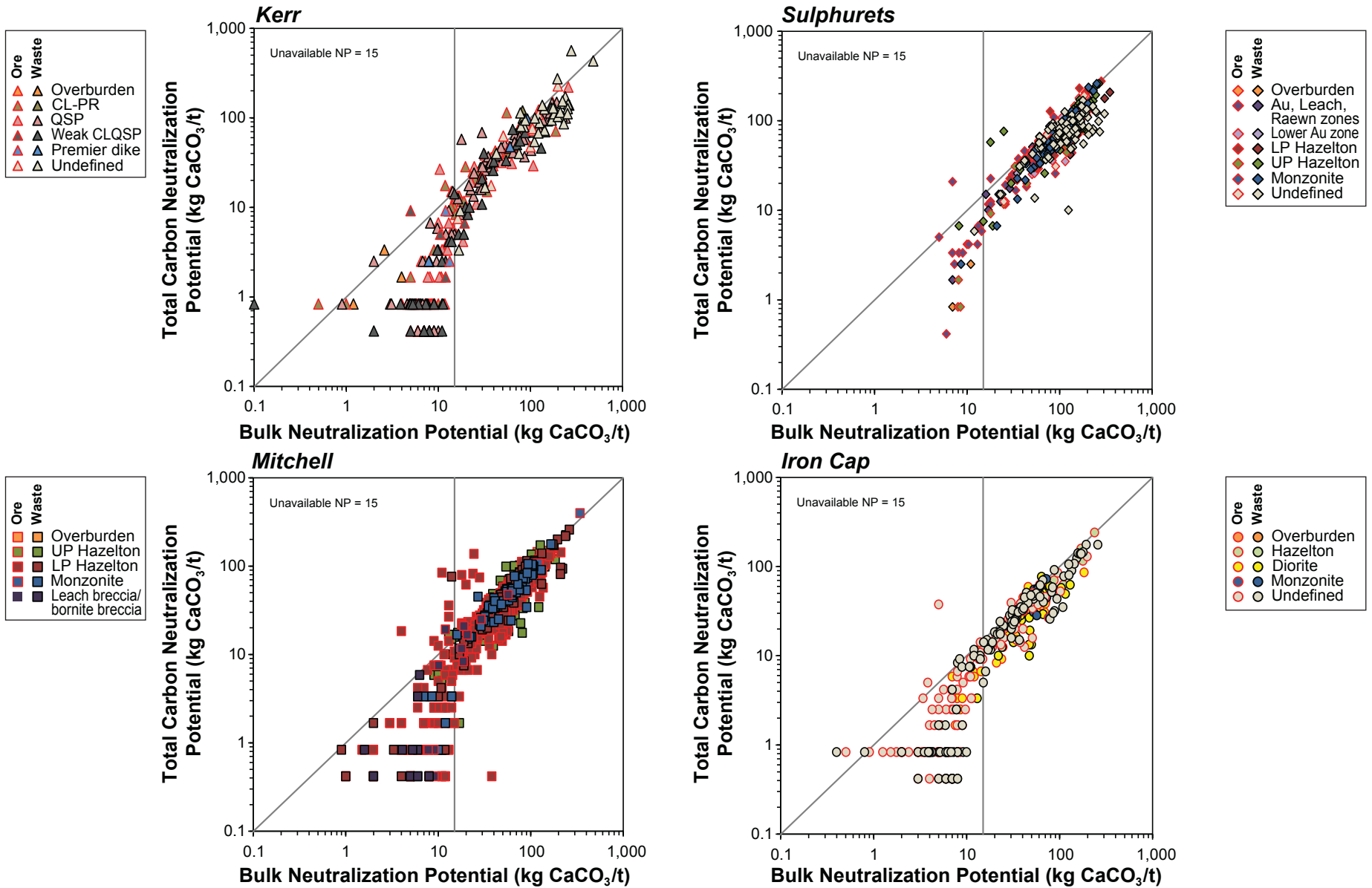


Figure 10.1-4

Kinetic Testing

ABA testing of humidity cell and field leach barrel material was completed prior to initializing the kinetic testing. The adjusted SNPR from these ABA results was compared to the results of all static tests for the relevant model code. The results showed that samples used for kinetic testing had adjusted SNPR values within the interquartile range (between the 25th and 75th percentiles) of all static results for most model codes, indicating that the samples selected for kinetic testing are representative of the static database and proposed waste rock and pit walls.

Humidity cells used in this assessment have been operating for more than 40 weekly cycles and in some instances more than 100 weekly cycles, and most have reached a steady state. Humidity cells with less than 20 weeks of data were not included in the assessment; however, the data are available in [Appendix 10-C](#). Waste rock and ore humidity cell leachate data were used as estimates of chemical loadings (i.e., water quality estimates) for seepage and runoff from the RSFs, pit walls, and low-grade ore stockpiles for use in the predictions of effluent and receiving environment water quality.

The humidity cell leach rates represent the majority of the 2012 ABA block model codes (Table 10.1-5). In the cases where a block model code was not represented by an existing humidity cell, chemical loadings were taken from a proxy for use in the water quality model as outlined in Table 10.1-6 and subsequent text.

Table 10.1-5. Humidity Cell Representivity

	Percent of Total Waste Rock		Number of Humidity Cells		% Proposed Waste Rock Represented	
	PAG	NPAG	PAG	NPAG	PAG	NPAG
Kerr						
K Overburden	3.0%	0.0%	0	0	0.0%	0.0%
K CP-PR	3.1%	0.0%	2	0	3.1%	0.0%
K QSP	31.2%	0.2%	1	0	31.2%	0.0%
K Weak CLQSP	16.6%	0.0%	1	0	16.6%	0.0%
K Premier Dike	2.1%	0.0%	0	0	0.0%	0.0%
K Undefined	43.1%	0.6%	0	0	0.0%	0.0%
Total					50.9%	0.0%
Sulphurets						
S Overburden	0.1%	2.1%	1	0	0.1%	0.0%
S Au, Leach, Raewyn zones	4.6%	0.1%	0	0	0.0%	0.0%
S Lower Au zone	9.5%	0.0%	2	0	9.5%	0.0%
S LP Hazelton	5.2%	0.3%	0	0	0.0%	0.0%
S UP Hazelton	5.5%	14.0%	1	1	5.5%	14.0%
S Monzonite	1.5%	18.1%	0	0	0.0%	0.0%
S Undefined	6.6%	32.4%	2	0	6.6%	0.0%
Total					21.7%	14.0%
Mitchell						
M Overburden	1.5%	0.0%	0	0	0.0%	0.0%
M UP Hazelton	58.9%	1.2%	8	0	59.0%	0.0%
M LP Hazelton	15.8%	0.4%	12	0	15.8%	0.0%

(continued)

Table 10.1-5. Humidity Cell Representivity (completed)

	Percent of Total Waste Rock		Number of Humidity Cells		% Proposed Waste Rock Represented	
	PAG	NPAG	PAG	NPAG	PAG	NPAG
Mitchell (cont'd)						
M Monzonite	2.4%	19.1%	0	1	0.0%	19.1%
M Leach breccia/ bornite breccia	0.4%	0.0%	1	0	0.4%	0.0%
M Undefined	0.0%	0.0%	0	0	0.0%	0.0%
Total					75.1%	19.1%
Iron Cap						
IC Overburden	0.0%	0.0%	0	0	0.0%	0.0%
IC Hazelton	68.2%	0.0%	0	0	0.0%	0.0%
IC Diorite	0.0%	0.0%	2	0	0.0%	0.0%
IC Monzonite	29.1%	0.0%	0	0	0.0%	0.0%
IC Undefined	2.6%	0.0%	4	0	2.6%	0.0%
Total	100.0%	0.0%	6	0	2.6%	0.0%

SNPR: Sulphide Net Potential Ratio

Table 10.1-6. Waste Rock Humidity Cells Representing Mine Site Waste Rock in the Water Quality Model

Water Quality Model Code	Method
KN Kerr neutral	All weeks HC 20 Cycle 1-28 HC 22
KA Kerr acidic	All weeks HC 21 All weeks after cycle 28 HC 22 All weeks HC 23
SON S Overburden neutral	Proxy: S Undefined neutral
SOA S Overburden acidic	All weeks HC S-06-05
SAUN S Au, leach, Raewn neutral	Proxy: S Lower Au neutral
SAUA S Au, leach, Raewn acidic	Proxy: S Overburden acidic
SLAN S Lower Au neutral	All weeks HC 24 All weeks HC 25
SLAA S Lower Au acidic	Proxy: S Overburden acidic
SLPN S LP Hazelton neutral	Proxy: S Undefined neutral
SLPA S LP Hazelton acidic	Proxy: S Overburden acidic
SUPN S UP Hazelton neutral	All weeks HC S-06-04 All weeks HC 17
SUPA S UP Hazelton acidic	Proxy: S Overburden acidic
SMON S Monzonite neutral	Proxy: HC S-06-04
SMOA S Monzonite acidic	Proxy: S Overburden acidic
SUNN S Undefined neutral	All weeks HC 18 All weeks HC 19
SUNA S Undefined acidic	Proxy: S Overburden acidic
MUPN M UP Hazelton neutral	All weeks HC M-07-33 All weeks HC M-07-44 All weeks HC 3 All weeks HC 10 All weeks HC 13 All weeks HC 14

(continued)

Table 10.1-6. Waste Rock Humidity Cells Representing Mine Site Waste Rock in the Water Quality Model (completed)

Water Quality Model Code	Method
MUPA M UP Hazelton acidic	All weeks HC 2
MLPN M LP Hazelton neutral	All weeks HC 5
	All weeks HC 6
	All weeks HC 7
	All weeks HC 8
	All weeks HC 9
	All weeks HC 11
	All weeks HC 12
	All weeks HC 16
	All weeks HC 26
MLPA M LP Hazelton acidic	All weeks HC M-06-14
	All weeks HC M-07-43
	All weeks HC 1
MMON M Monzonite neutral	All weeks HC M-07-30
	All weeks HC NM-05-03
MMOA M Monzonite acidic	Proxy: M UP Hazelton acidic
MBBN M Leach breccia/bornite breccia neutral	No material of this type in waste rock schedule
MBBA M Leach breccia/bornite breccia acidic	All weeks HC 15
MUNN M Undefined neutral	No material of this type in waste rock schedule
MUNA M Undefined acidic	No material of this type in waste rock schedule
ICN Iron Cap neutral	All weeks HC IC1
	All weeks HC IC2
	Cycles 0-9 HC IC4
	All weeks HC IC5
	Cycles 0-6 HC IC6
ICA Iron Cap acidic	All weeks HC IC3
	All weeks after cycle 9 HC IC4
	All weeks after cycle 6 HC IC6

The following rationale was used to determine the proxies outlined in Table 10.1-6:

- Humidity cell HC 2 was used as a proxy for M Monzonite acidic because the material in this test was classified a porphyry monzonite in the original drill log.
- S Undefined neutral was used for S Overburden neutral and S LP Hazelton neutral because undefined material incorporates some overburden and LP Hazelton and the range of values in S Overburden neutral data spans most other model codes.
- S Lower Au neutral was used for S Au, leach Raewyn neutral because both model codes are ore material.
- S Overburden acidic was used to represent all acidic Sulphurets model codes because this was the only humidity cell that produced acidic leachate.
- Humidity cell SS-06-04 was used as a proxy for S Monzonite neutral because the sample was classified as monzonite based on the drill log, even though the ABA block model classified the block that the sample occupies as S Undefined.

Leachate predictions from PAG material were developed using the results following the generation of acidic leachate in humidity cells (pH < 6.0). Leachate predictions from not potentially acid generating (NPAG) material were developed using the results with neutral leachate (pH greater than 6.0). This approach results in neutral pH leachate from humidity cells that are classified as PAG being used to predict neutral pH leachate from NPAG material.

Tables 10.1-7, 10.1-8, and 10.1-9 present the leachate results for each model code. Individual humidity cell results are documented in [Appendix 10-A](#). The average leachate rates and the 95th percentile leachate rates were used as source terms in the water quality model (see Section 10.2).

The average neutral leach rates were generated by calculating the mean of neutral weeks from each humidity cell and then taking the mean of all cells of a specific model code (as outlined in Tables 10.1-7, 10.1-8, and 10.1-9). The process was repeated for average acidic leach rates using only acidic weeks as outlined in Tables 10.1-7, 10.1-8, and 10.1-9. Ninety-fifth percentile leach rates were generated by calculating the 95th percentile of all available results for humidity cells of a specific model code.

Based on rates of sulphate, calcium, and magnesium release, a predicted time to the depletion of bulk Sobek NP and the onset of ARD was calculated. When a humidity cell was predicted to never become acid generating, the lag time was arbitrarily set to a default of 1,000 years. The lag time for model codes that are predicted to become acid generating based on static test results range from 0 to 1,000 years (Table 10.1-10).

Metal leaching typically reflected drainage pH with leach rates in acidic drainage often two to three orders of magnitude higher than in neutral drainage from the same model code. Sulphate, aluminum, arsenic, cadmium, copper, iron, lead, and zinc leach rates were higher in the acidic humidity cells relative to the near-neutral humidity cells across various model codes.

The uncertainty associated with using many humidity cells to represent various block mode codes was assessed using either the relative percent differences (RPD) or the relative standard deviation (RSD; Table 10.1-11). RPD were calculated to determine the difference between two humidity cells used in model codes when only two representative humidity cells were used:

$$\text{where: } RPD = 100|rep1 - rep2| / [(rep1 + rep2) / 2]$$

The RSD was calculated to show the variability of humidity cells used for model codes with more than two humidity cells:

$$\text{where: } RSD = 100 \times [StDev / mean]$$

The RPD and RSD quantify the inherent variability and uncertainty due to the laboratory protocol, environmental heterogeneity, and/or sampler handling.

Table 10.1-7. pH and Leaching Rates (mg/kg/week) from Kerr and Iron Cap Humidity Cells

ABA Block Model Codes	KN Kerr Neutral		KA Kerr Acidic		ICN Iron Cap Neutral		ICA Iron Cap Acidic	
	Mean	p95	Mean	p95	Mean	p95	Mean	p95
pH	6.91	6.36	4.37	3.32	7.18	6.81	3.72	2.81
Ag	0.00001	0.00003	0.00015	0.00022	0.00001	0.00002	0.00030	0.00081
Al	0.02	0.10	4.68	18.77	0.17	0.37	11.09	22.07
As	0.00058	0.00142	0.02223	0.08622	0.00367	0.00817	0.02312	0.07934
B	0.0103	0.0147	0.0118	0.0188	0.0695	0.0794	0.0659	0.0806
Ba	0.0288	0.0524	0.0540	0.1515	0.1150	0.1383	0.0884	0.2005
Be	0.00002	0.00002	0.00290	0.00297	0.00018	0.00014	0.00742	0.01882
Ca	37.8	51.3	43.3	28.6	48.6	72.3	37.1	74.4
Cd	0.00021	0.00031	0.00207	0.00660	0.00121	0.00095	0.03337	0.13624
Cl	0.45	0.43	0.62	0.65	3.13	10.68	0.97	1.99
Co	0.0017	0.0039	0.0378	0.0560	0.0070	0.0045	0.1133	0.2511
Cr	0.0008	0.0018	0.0029	0.0039	0.0002	0.0003	0.0067	0.0231
Cu	0.1269	0.3509	28.6522	49.7143	0.0168	0.0351	11.5893	26.7299
F	0.11	0.27	0.33	0.81	1.29	2.12	13.79	40.74
Fe	0.046	0.052	36.958	60.681	0.016	0.072	47.509	135.622
Hg	0.0000057	0.0000421	0.0000222	0.0000440	0.0000049	0.0000063	0.0000109	0.0000304
K	2.96	8.72	2.95	3.73	15.27	34.39	6.30	15.42
Li	0.0022	0.0060	0.0031	0.0012	0.0052	0.0146	0.0029	0.0059
Mg	5.38	10.74	5.09	12.96	3.66	7.55	1.42	5.82
Mn	1.061	2.114	0.925	2.391	1.093	0.623	1.199	4.231
Mo	0.0122	0.0431	0.0009	0.0031	0.0090	0.0246	0.0008	0.0028
Na	0.69	1.18	2.32	0.33	5.25	8.85	1.71	3.06
Ni	0.0006	0.0012	0.0149	0.0173	0.0013	0.0013	0.0151	0.0363
Pb	0.0007	0.0019	0.0065	0.0138	0.0034	0.0035	0.2670	1.2950
Sb	0.0012	0.0032	0.0052	0.0186	0.0227	0.0238	0.0127	0.0440
Se	0.0081	0.0111	0.0267	0.0539	0.0166	0.0275	0.0182	0.0606
Si	1.05	2.17	3.93	8.04	4.33	5.85	13.74	21.37

(continued)

Table 10.1-7. pH and Leaching Rates (mg/kg/week) from Kerr and Iron Cap Humidity Cells (completed)

ABA Block Model Codes	KN Kerr Neutral		KA Kerr Acidic		ICN Iron Cap Neutral		ICA Iron Cap Acidic	
	Mean	p95	Mean	p95	Mean	p95	Mean	p95
Sn	0.00037	0.00093	0.00055	0.00146	0.00057	0.00135	0.00116	0.00313
SO ₄	102	129	330	326	128	239	314	571
Sr	0.301	0.428	0.586	0.968	0.873	1.306	0.407	1.341
Tl	0.00003	0.00002	0.00007	0.00002	0.00018	0.00026	0.00051	0.00130
U	0.00003	0.00009	0.00174	0.00331	0.00418	0.01505	0.09472	0.29961
V	0.00016	0.00062	0.00054	0.00140	0.00103	0.00355	0.00148	0.00315
Zn	0.006	0.012	0.395	1.466	0.038	0.051	3.143	12.246
Acidity	9.63	13.49	192.91	325.96	3.87	9.26	288.35	684.45
Alkalinity as HCO ₃	18.1	36.4	0.0	6.2	28.6	75.0	0.0	0.8

Chloride set to the detection limit when not analyzed

Values of pH and alkalinity are set to the 5th percentiles of data in the cases where the 95th percentile (p95) is used as the conservative case

K = Kerr deposit

S = Sulphurets deposit

Table 10.1-8. pH and Leaching Rates (mg/kg/week) from Sulphurets Humidity Cells

ABA Block Model Codes	SOA S Overburden Acidic		SLAN S lower Au Neutral		SUPN S UP Hazelton Neutral		SUNN S Undefined Neutral	
	Mean	p95	Mean	p95	Mean	p95	Mean	p95
pH	2.98	2.57	7.28	6.87	7.85	7.52	7.39	7.59
Ag	0.00002	0.00006	0.00002	0.00004	0.00001	0.00002	0.00002	0.00007
Al	6.02	10.61	0.10	0.17	0.27	0.46	0.10	0.18
As	0.13471	0.40880	0.00098	0.00272	0.00132	0.00206	0.00093	0.00231
B	0.0111	0.0115	0.0136	0.0393	0.0075	0.0114	0.0046	0.0095
Ba	0.0029	0.0152	0.0226	0.0294	0.2668	0.4327	0.0500	0.0914
Be	0.00209	0.01571	0.00003	0.00002	0.00028	0.00056	0.00002	0.00002
Ca	23.5	67.9	22.9	33.5	21.9	27.6	33.0	42.7
Cd	0.01641	0.03077	0.00013	0.00030	0.00011	0.00052	0.00409	0.01642

(continued)

Table 10.1-8. pH and Leaching Rates (mg/kg/week) from Sulphurets Humidity Cells (completed)

ABA Block Model Codes	SOA		SLAN		SUPN		SUNN	
	S Overburden Acidic		S Lower Au Neutral		S UP Hazelton Neutral		S Undefined Neutral	
List of Parameters	Mean	p95	Mean	p95	Mean	p95	Mean	p95
Cl	9.36	21.94	0.42	0.75	0.28	0.40	0.26	0.22
Co	0.1582	0.2773	0.0002	0.0004	0.0001	0.0002	0.0006	0.0014
Cr	0.0046	0.0083	0.0008	0.0017	0.0006	0.0015	0.0008	0.0016
Cu	7.8732	10.1324	0.0072	0.0155	0.0048	0.0104	0.0018	0.0038
F	0.57	1.29	0.78	1.50	0.10	0.43	0.08	0.22
Fe	132.168	288.423	0.079	0.116	0.023	0.116	0.013	0.042
Hg	0.00000001	0.00000002	0.0000103	0.0000410	0.0000031	0.0000211	0.0000055	0.0000210
K	1.08	3.50	3.91	9.90	1.22	3.52	1.39	4.31
Li	0.0006	0.0008	0.0065	0.0145	0.0036	0.0058	0.0030	0.0095
Mg	0.38	0.76	2.82	6.41	0.69	2.38	1.79	5.07
Mn	0.737	2.716	0.126	0.159	0.035	0.066	0.178	0.765
Mo	0.0021	0.0055	0.0304	0.0414	0.2787	0.9369	0.0093	0.0187
Na	0.41	0.56	1.73	5.05	0.86	1.69	0.42	0.87
Ni	0.0825	0.1428	0.0006	0.0014	0.0005	0.0008	0.0006	0.0014
Pb	0.0007	0.0023	0.0006	0.0026	0.0002	0.0008	0.0315	0.0982
Sb	0.0179	0.0326	0.0081	0.0194	0.0036	0.0118	0.0035	0.0150
Se	0.0099	0.0126	0.0028	0.0063	0.0053	0.0114	0.0050	0.0156
Si	8.48	12.37	1.36	2.32	2.00	3.18	1.30	2.17
Sn	0.00011	0.00011	0.00074	0.00182	0.00035	0.00115	0.00043	0.00107
SO ₄	587	1125	41	79	14	34	56	87
Sr	0.138	0.443	0.689	1.596	0.568	2.406	0.719	2.156
Tl	0.00073	0.00111	0.00001	0.00002	0.00006	0.00011	0.00002	0.00002
U	0.01407	0.07097	0.00147	0.00462	0.00137	0.00601	0.00120	0.00308
V	0.00224	0.00713	0.00104	0.00252	0.00489	0.01124	0.00359	0.00832
Zn	5.916	11.535	0.005	0.011	0.004	0.010	0.101	0.405
Acidity	552.88	1094.27	9.33	13.81	7.19	12.51	7.94	13.29
Alkalinity as HCO ₃	0.0	2.3	39.2	55.6	52.2	61.2	43.1	54.3

Chloride set to the detection limit when not analyzed

Values of pH and alkalinity are set to the 5th percentiles of data in the cases where the 95th percentile (p95) is used as the conservative case

S = Sulphurets deposit

Table 10.1-9. pH and Leaching Rates (mg/kg/week) from Mitchell Humidity Cells

ABA Block Model Codes	MUPN		MUPA		MLPN		MLPA		MMON		MBBA	
	M UP Hazelton Neutral		M UP Hazelton Acidic		M LP Hazelton Neutral		M LP Hazelton Neutral		M Monzonite Neutral		M Leach breccia/bornite breccia Acidic	
List of Parameters	Mean	p95	Mean	p95	Mean	p95	Mean	p95	Mean	p95	Mean	p95
pH	7.54	7.21	4.93	4.41	7.32	6.95	3.35	2.84	7.90	7.75	2.58	2.19
Ag	0.00003	0.00011	0.00006	0.00015	0.00003	0.00009	0.00011	0.00027	0.00001	0.00001	0.00137	0.00253
Al	0.13	0.33	1.18	3.14	0.08	0.30	9.63	20.95	0.35	0.54	17.01	26.93
As	0.00300	0.01574	0.00102	0.00275	0.00176	0.00592	0.00317	0.00489	0.00099	0.00118	0.20297	0.37197
B	0.0067	0.0119	0.0100	0.0559	0.0056	0.0114	0.0104	0.0122	0.0107	0.0116	0.0060	0.0094
Ba	0.0704	0.1547	0.0332	0.0574	0.0618	0.1500	0.0376	0.0746	0.3430	0.8220	0.0155	0.0310
Be	0.00011	0.00053	0.00078	0.00163	0.00002	0.00053	0.00498	0.02031	0.00053	0.00058	0.00197	0.00854
Ca	27.8	73.0	6.1	16.6	61.3	376.2	12.1	31.3	19.9	27.3	93.3	211.8
Cd	0.00087	0.00430	0.00200	0.00328	0.00010	0.00053	0.01614	0.04267	0.00075	0.00529	0.00101	0.00142
Cl	0.34	0.60	0.28	0.65	0.34	0.81	0.00	2.10	0.00	0.00	7.55	21.00
Co	0.0023	0.0020	0.1430	0.2324	0.0003	0.0019	0.0427	0.0759	0.0001	0.0001	0.2170	0.3875
Cr	0.0008	0.0017	0.0010	0.0020	0.0008	0.0016	0.0043	0.0111	0.0006	0.0006	0.0346	0.1563
Cu	0.0105	0.0236	18.6699	26.1798	0.0050	0.0149	8.0555	17.3443	0.0041	0.0092	1.1004	3.2172
F	0.48	1.68	0.93	1.17	0.31	1.71	1.09	2.96	0.24	1.32	1.63	3.32
Fe	0.020	0.047	0.077	0.314	0.116	0.066	72.403	234.409	0.077	0.212	1055.252	1859.399
Hg	0.0000160	0.0000426	0.0000185	0.0000425	0.0000229	0.0000421	0.0000053	0.0000111	0.00000003	0.00000001	0.0000314	0.0001343
K	1.85	5.02	2.37	6.09	2.01	7.03	2.45	9.38	1.60	3.31	1.96	5.51
Li	0.0028	0.0057	0.0049	0.0076	0.0019	0.0056	0.0196	0.0547	0.0053	0.0058	0.0278	0.0534
Mg	1.22	5.01	0.70	1.98	1.94	5.17	9.28	17.67	0.52	1.15	12.28	21.99
Mn	0.227	0.856	10.895	19.214	0.232	0.502	4.024	17.239	0.046	0.114	2.052	3.628
Mo	0.0202	0.0940	0.0029	0.0111	0.0277	0.0918	0.0008	0.0012	0.0101	0.0441	0.0116	0.0276
Na	0.49	0.91	0.78	1.44	0.74	1.16	4.10	2.15	0.34	0.59	6.72	8.31
Ni	0.0006	0.0013	0.0294	0.0411	0.0008	0.0029	0.0100	0.0212	0.0005	0.0006	0.0266	0.0439
Pb	0.0016	0.0086	0.0061	0.0220	0.0005	0.0018	0.3157	1.4539	0.0001	0.0001	0.0355	0.0726
Sb	0.0569	0.4429	0.0011	0.0054	0.0070	0.0246	0.0005	0.0011	0.0009	0.0012	0.0011	0.0022
Se	0.0081	0.0270	0.0101	0.0138	0.0066	0.0206	0.0154	0.0480	0.0043	0.0112	0.2604	0.4925
Si	1.58	2.66	3.65	5.00	1.08	2.38	9.96	18.04	2.43	3.37	40.11	78.10

(continued)

Table 10.1-9. pH and Leaching Rates (mg/kg/week) from Mitchell Humidity Cells (completed)

ABA Block Model Codes	MUPN		MUPA		MLPN		MLPA		MMON		MBBA M Leach breccia/bornite breccia Acidic	
	M UP Hazelton Neutral	M UP Hazelton Acidic	M UP Hazelton Acidic	M UP Hazelton Acidic	M LP Hazelton Neutral	M LP Hazelton Neutral	M LP Hazelton Neutral	M LP Hazelton Neutral	M Monzonite Neutral	M Monzonite Neutral	Mean	p95
Sn	0.00051	0.00113	0.00107	0.00247	0.00058	0.00151	0.00049	0.00112	0.00012	0.00012	0.00097	0.00219
SO ₄	37	129	77	100	137	884	376	823	4	9	3,539	6479
Sr	0.190	0.485	0.063	0.163	0.588	3.608	0.433	2.225	0.111	0.320	0.170	0.304
Tl	0.00003	0.00011	0.00010	0.00055	0.00002	0.00011	0.00016	0.00012	0.00011	0.00012	0.00028	0.00083
U	0.00694	0.02566	0.00358	0.00946	0.00613	0.02181	0.01389	0.04628	0.00153	0.00492	0.01787	0.04390
V	0.00574	0.01763	0.00023	0.00076	0.00060	0.00148	0.00842	0.03778	0.00503	0.01118	0.01832	0.02885
Zn	0.010	0.037	0.086	0.185	0.005	0.012	1.395	3.624	0.001	0.001	0.202	0.372
Acidity	8.14	14.09	49.76	77.28	9.20	14.06	323.04	790.94	5.92	10.48	3,345.11	5,555.56
Alkalinity as HCO ₃	42.5	58.3	1.1	3.8	32.7	48.9	0.0	2.3	50.3	64.2	0.2	0.2

Chloride set to detection limit when not analyzed

Values of pH and alkalinity are set to the 5th percentiles of data in the cases where the 95th percentile is used as the conservative case

M = Mitchell deposit

IC = Iron Cap deposit

Table 10.1-10. Calculated Lag Times for Mine Site Waste Rock by Model Code

Model Code	Lag Time (year)			
	Min	25th	Median	Mean
Kerr	0	14	28	28
SAU			541	
S Overburden			0	
S Lower Au	81	311	541	541
S LP Hazelton			124	
S UP Hazelton	1,000	1,000	1,000	1,000
S Monzonite			176	
S Undefined	71	97	124	124
M Leach breccia/bornite breccia			0	
M LP Hazelton	0	0	43	214
M UP Hazelton	61	144	217	320
Iron Cap	0	0	126	253

Table 10.1-11. Relative Percent Differences or Relative Standard Deviation between Humidity Cells Used in Model Input Codes

	KA RSD	KN RPD	SLAN RPD	SUPN RPD	SUNN RPD	MUPN RSD	MLPN RSD	MLPA RSD	MMON RPD	ICN RSD	ICA RSD
pH	42	13	11	5.8	3.4	3.1	1.3	6.0	1.3	3.8	10
Acidity, Total (as CaCO ₃)	117	18	2.5	92	58	34	17	78	13	15	35
Alkalinity, Total (as CaCO ₃)	162	101	89	4.8	33	22	22	80	6.8	42	20
Ammonia as N											
Bromide (Br)											
Chloride (Cl)	122	102	4.1	200	0.3		15			82	12
Fluoride (F)	154	40	174	97	0.3	188	223	53	118	35	110
Nitrate (as N)											
Sulphate (SO ₄)	129	113	45	43	2.6	115	212	70	17	22	38
Aluminum (Al)-Dissolved	145	166	71	80	80	82	30	64	9.1	48	33
Antimony (Sb)-Dissolved	164	151	39	52	47	241	147	74	42	46	83
Arsenic (As)-Dissolved	102	109	26	53	82	187	59	60	27	42	35
Barium (Ba)-Dissolved	72	86	29	77	84	86	62	87	172	65	49
Beryllium (Be)-Dissolved	109	21	4.1	185	0.3	168	4.1	56	0.5	19	8.3
Boron (B)-Dissolved	14	126	22	92	22	66	23	54	0.5	8.4	19
Cadmium (Cd)-Dissolved	110	97	159	149	200	184	78	96	70	96	111
Calcium (Ca)-Dissolved	83	67	68	27	19	79	177	59	1.3	27	60
Chromium (Cr)-Dissolved	151	39	19	4	0	47	15	74	28	8.9	24
Cobalt (Co)-Dissolved	123	171	126	61	158	235	165	49	0.5	55	39
Copper (Cu)-Dissolved	76	175	33	102	61	57	101	56	145	26	41
Iron (Fe)-Dissolved	145	186	198	92	169	68	31	126	105	37	51
Iron (Fe)-Dissolved	19	126	143	128	196	176	92	123	0.2	70	79
Lead (Pb)-Dissolved	115	56	43	136	0.3	105	2.5	78	0.5	53	39
Lithium (Li)-Dissolved	112	191	79	45	47	176	116	75	173	62	96

(continued)

Table 10.1-11. Relative Percent Differences or Relative Standard Deviation between Humidity Cells Used in Model Input Codes (completed)

	KA	KN	SLAN	SUPN	SUNN	MUPN	MLPN	MLPA	MMON	ICN	ICA
	RSD	RPD	RPD	RPD	RPD	RSD	RSD	RSD	RPD	RSD	RSD
Magnesium (Mg)-Dissolved	102	177	33	120	3.9	127	66	62	181	32	80
Manganese (Mn)-Dissolved	22	191	200	200	16	108	32	173	0.5	7.4	25
Mercury (Hg)-Dissolved	80	152	32	197	69	167	77	119	185	55	46
Molybdenum (Mo)-Dissolved	144	98	4.5	76	7.0	39	113	100	12	9.4	61
Nickel (Ni)-Dissolved	54	164	61	93	67	36	22	79	104	24	18
Potassium (K)-Dissolved	34	148	0.7	10	147	80	117	86	176	49	36
Selenium (Se)-Dissolved	133	61	84	64	32	31	28	63	9.1	27	36
Silicon (Si)-Dissolved	128	49	4	51	145	106	77	118	0.5	19	52
Silver (Ag)-Dissolved	47	154	78	57	34	58	29	5	107	41	40
Sodium (Na)-Dissolved	48	118	75	77	55	77	190	68	93	16	48
Strontium (Sr)-Dissolved	3.3	57	162	136	0.3	105	2.5	63	0.5	28	73
Thallium (Tl)-Dissolved	8.7	51	37	135	9.2	75	49	56	56	79	18
Tin (Sn)-Dissolved	111	114	132	81	194	126	126	83	183	22	39
Uranium (U)-Dissolved	137	161	107	23	160	126	35	163	114	70	32
Vanadium (V)-Dissolved	160	71	93	32	197	115	39	123	0.5	77	100
Zinc (Zn)-Dissolved	42	13	11	5.8	3.4	3.1	1.3	6.0	1.3	3.8	10

10.1.2.2.3 Groundwater Seep Characterization

Naturally occurring groundwater seeps were sampled at the Kerr deposit (5 seeps), Sulphurets deposit (1 seep), Mitchell deposit (23 seeps), McTagg Creek Valley (3 seeps), and Ted Morris Creek Valley (5 seeps). The Mitchell deposit seeps were classified according to the proximal model code: LP Hazelton or UP Hazelton volcanics.

The pH values of the Kerr, Sulphurets, and Mitchell seeps were acidic. Sulphate concentrations at the Kerr and Mitchell seeps frequently exceeded the British Columbia Ministry of Environment freshwater aquatic life guideline, with values as high as 7,400 mg/L. In general, the trace metal concentrations were very high. Seep flow rates varied greatly between seeps, e.g., K-3 at 0.03 L/s and MS-G at 77.01 L/s. Baseline monitoring of groundwater seeps indicate that seep flow rates are usually within an order of magnitude at repeat sampling events.

A statistical summary of the elements with elevated concentrations at the deposit seeps is presented in Table 10.1-12. Full details are presented in [Appendix 10-A](#), Section 8.

10.1.2.3 Tailing Characterization

A multi-year (2007 to 2012) comprehensive metallurgical program has been completed on the Kerr, Sulphurets, Mitchell, and Iron Cap deposits. The full details of this metallurgical program are discussed in the Preliminary Feasibility Study ([Appendix 4-C](#); Wardrop 2012).

10.1.2.3.1 Metal Leaching/Acid Rock Drainage Characterization Program

Tailing material was assessed in 33 static tailing samples, eight humidity cells, six subaqueous columns (SAC), and three aging tests.

Static Testing

ABA test results of the 33 tailing material samples are summarized by deposit in Table 10.1-13.

Paste pH values of rougher tailing material from the Kerr, Sulphurets, Mitchell, and Iron Cap deposits exhibited values above 6, indicating the absence of stored acidity.

The Mitchell sulphide tailing indicated stored acidity from oxidized rocks (paste pH < 6). Concentrations of total-sulphur ranged from 0.21 to 0.38% in Mitchell rougher samples. Mitchell sulphide and a Mitchell 90:10 rougher/sulphide composite tailing showed the highest total-sulphur concentrations (22.4 and 3.13%, respectively). Total-sulphur concentrations range from 0.19 to 0.5% in a composite of Mitchell/Kerr rougher tailing, and from 0.05 to 0.19% in Mitchell/Sulphurets rougher composite and Iron Cap rougher tailing.

A strong correlation between total-sulphur and sulphide-sulphur concentrations is only evident for Mitchell rougher/sulphide tailing. Rietveld XRD analysis indicated that the most common sulphide mineral was pyrite with lesser amounts of chalcopyrite in Mitchell rougher/sulphide tailing. The primary mineral identified in Mitchell sulphide tailing was pyrite with lesser amounts of chalcopyrite and molybdenite. Minor amounts of gypsum were identified in tailing as another sulphur-bearing mineral.

Table 10.1-12. Statistical Summary of Selected Elements in Groundwater Seeps

Parameter (mg/L)	Kerr Deposit			Mitchell Valley North			Mitchell Valley South			Ted Morris and McTagg Valleys		
	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min
pH	7.29	3.46	1.25	7.52	6.24	2.79	9.54	4.30	2.02	7.74	7.02	5.25
Total Fluoride	1.00	0.50	0.050	2.05	0.836	0.063	18.05	1.88	0.299	4.79	0.893	0.040
Total Aluminum	8.79	5.36	0.0053	3.905	0.639	0.0033	195	7.14	<i>0.0015</i>	67.8	0.0757	<i>0.0015</i>
Total Arsenic	0.0273	0.0009	<i>0.00005</i>	0.00462	0.000165	<i>0.00005</i>	1.19	0.00311	<i>0.00005</i>	0.023	0.00025	<i>0.00005</i>
Total Cadmium	0.00324	0.00189	<i>0.000005</i>	0.00727	0.00224	<i>0.000005</i>	0.2335	0.0191	0.000088	0.177	0.04	0.000016
Total Chromium	0.0042	0.00131	<i>0.00005</i>	0.0005	0.0001	<i>0.00005</i>	0.0404	0.000403	<i>0.00005</i>	0.0165	0.0005	<i>0.00005</i>
Total Cobalt	0.0391	0.0229	<i>0.00005</i>	0.0117	0.00197	<i>0.00005</i>	0.562	0.02625	0.00036	0.281	0.0306	<i>0.00005</i>
Total Copper	4.23	1.81	0.00088	2.15	0.348	0.00077	91	3.66	0.00081	1.74	0.0063	0.00016
Total Iron	77.5	19.4	<i>0.015</i>	23.6	0.015	<i>0.015</i>	2430	23.5	<i>0.015</i>	32.0	3.19	<i>0.015</i>
Total Lead	0.0048	0.000605	0.000025	0.00688	0.00106	0.000025	0.579	0.0199	<i>0.000025</i>	0.00219	0.00010	<i>0.000025</i>
Total Manganese	4.13	2.43	0.00118	0.889	0.207	0.000707	32.85	2.33	0.0132	11	2.36	0.000182
Total Mercury	0.000059	<i>0.000005</i>	<i>0.000005</i>	<i>0.00001</i>	<i>0.000005</i>	<i>0.000005</i>	0.000015	0.000005	<i>0.000005</i>	<i>0.00001</i>	0.000005	<i>0.000005</i>
Total Selenium	0.00108	0.00039	<i>0.00005</i>	0.00495	0.00188	<i>0.00005</i>	0.238	0.00139	<i>0.00005</i>	0.016	0.0043	<i>0.00015</i>
Total Silver	0.00005	0.000011	<i>0.000005</i>	0.000111	0.00002	<i>0.000005</i>	0.00269	0.0000615	<i>0.000005</i>	0.000413	0.000022	<i>0.000005</i>
Total Vanadium	0.0138	0.001	<i>0.0001</i>	0.00155	0.0005	<i>0.0001</i>	0.289	0.00205	<i>0.0005</i>	0.0065	0.001	<i>0.0005</i>
Total Zinc	0.522	0.28	0.0002	0.474	0.136	0.0015	15	1.17	0.0202	10.4	2.45	0.001

Italicized values are below the detection limit

Table 10.1-13. Summary of Acid Base Accounting Test Results for Tailing Material

Tailing	Number of Samples	Samples with Paste pH < 6.0	Total-Sulphur (%)	Total-Sulphur and Sulphide-Sulphur Relationship	Sobek NP (kg CaCO ₃ /t)	Sobek NP Correlation	Samples with Adjusted SNPR < 2.0
Mitchell rougher	1	0	0.38	Weak	28	Strong Inorg NP	0
Mitchell sulphide	1	1	22.4	Strong	6	Strong Ca NP	1
Mitchell rougher/sulphide 90:10	1	0	3.13	Strong	22	Strong Inorg NP	1
Mitchell rougher-fine	1	0	0.38	Weak	31	Strong Inorg NP	0
Mitchell rougher-coarse	1	0	0.21	Weak	31	Strong Inorg NP	0
Mitchell/Kerr rougher	16	0	0.19-0.5	Weak	12-26	Strong Inorg NP	0
Mitchell/Sulphurets rougher	4	0	0.11-0.19	Weak	41-46	Strong Inorg NP	0
Iron Cap rougher	8	0	0.05-0.08	Weak	24-28	Strong Inorg NP	0

NP = neutralization potential; SNPR = sulphide net potential ratio; Ca NP = calcium calculated neutralization potential; Inorg NP = inorganic neutralization potential

Bulk Sobek NP values showed strong correlation with the NP calculated from calcium and inorganic carbon values across a wide range of NP values. The strong correlation between Sobek NP and calculated NP indicates that most of the NP of the deposits is provided by calcium carbonate minerals. The most common carbonate minerals were calcite, dolomite, and lesser amounts of siderite. The estimation of unavailable NP was used as a standard practice (Price 2009). A value of 15 kg CaCO₃/t of unavailable NP was derived from the complete 2008 to 2012 KSM Project static test database. The NP was adjusted by this estimate of unavailable NP to calculate an adjusted NP.

All tailing samples were classified as NPAG based on static ABA tests (adjusted SNPR > 2) with the exception of Mitchell sulphide and Mitchell rougher/sulphide tailing (adjusted SNPR < 2).

The solid-phase element concentrations of tailing samples were measured by ICP-MS analysis after strong four-acid digestion and by X-ray fluorescence whole-rock analysis.

Mitchell sulphide and Mitchell rougher/sulphide tailing material typically had silver, arsenic, cadmium, copper, iron, molybdenum, sulphur, antimony, and selenium concentrations that were greater than three times the shale crustal abundance. The rougher tailing material typically had silver, copper, molybdenum, antimony, and selenium concentrations that were greater than three times the shale crustal abundance.

The particle size distribution of the tailing samples submitted for humidity cell tests was analyzed by the wet sieving method (Mitchell rougher tailing) and by laser diffraction method (Mitchell/Kerr rougher and Mitchell/Sulphurets rougher tailing). [Appendix 10-A](#) presents the particle size analyses results.

Analysis of the Mitchell rougher tailing analysis showed that 80% by weight was finer than 75 microns. The Mitchell rougher-fine tailing analysis showed that 80% by weight was finer than 12 microns. The Mitchell rougher-coarse tailing analysis showed that approximately 80% by weight was finer than 150 microns. Mitchell/Kerr rougher tailing and Mitchell/Sulphurets rougher tailing analyses showed that 80% by volume was finer than 84 microns and 89 microns, respectively.

Kinetic Testing

Tailing humidity cells leachate test results were used as estimates of source concentrations (i.e., water quality estimates) for seepage and runoff from dams and beaches in the TMF for use in the predictions of effluent and receiving environment water quality. Pilot plant supernatant chemistry was used to predict the chemical loading from the mill to the TMF. The tailing material leach rates are presented in Tables 10.1-14 and 10.1-15.

Based on rates of sulphate, calcium, and magnesium release, a predicted time to the depletion of NP and the onset of ARD was calculated and used to estimate the time to the onset of ARD for sub-aerial deposition of tailing. The rougher tailing is predicted to never become acidic. The sulphide tailing is predicted to have a very short time to the onset of ARD (less than five years).

Table 10.1-14. pH and Leaching Rates from Tailing Kinetic Tests Representing Source Terms for Tailing Management Facility Tailing Material

List of Parameters (mg/kg/week)	M Rougher Coarse Cyclone Dams		M Rougher Beaches		M/K Rougher Beaches		M/S Rougher Beaches		IC Rougher Beaches	
	HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all
pH	8.0	7.7	8.0	7.7	8.0	7.8	8.3	8.1	8.2	8.1
Silver Ag	0.0000024	0.0000025	0.0000060	0.0000025	0.0000023	0.0000025	0.0000023	0.0000025	0.0000026	0.0000025
Aluminum Al	0.02	0.03	0.01	0.01	0.02	0.04	0.05	0.09	0.03	0.05
Arsenic As	0.0002	0.0002	0.0001	0.0001	0.0007	0.0006	0.0008	0.0014	0.0005	0.0006
Boron B	0.002	0.002	0.002	0.002	0.011	0.025	0.004	0.013	0.003	0.006
Barium Ba	0.10	0.20	0.09	0.20	0.06	0.13	0.11	0.16	0.09	0.15
Beryllium Be	0.00012	0.00012	0.00012	0.00012	0.00011	0.00012	0.000022	0.000025	0.000022	0.000025
Bromide Br							0.01	0.01	0.01	0.01
Calcium Ca	33	151	73	283	62	199	12	16	11	15
Cadmium Cd	0.00008	0.00012	0.0000024	0.000002	0.0000025	0.000002	0.0000061	0.000014	0.0000103	0.000017
Chloride Cl							0.1	0.1	0.4	0.4
Cobalt Co	0.0000239	0.0000248	0.0000235	0.0000248	0.0000229	0.0000245	0.0000226	0.0000248	0.0000224	0.0000245
Chromium Cr	0.0001	0.0001	0.0001	0.0001	0.0005	0.0012	0.0004	0.0001	0.0001	0.0001
Copper Cu	0.0012	0.0013	0.0005	0.0011	0.0007	0.0010	0.0010	0.0016	0.0005	0.0007
Fluoride F	0.03	0.10	0.05	0.13	0.05	0.09	0.04	0.12	0.31	0.37
Iron Fe	0.0071	0.0074	0.0076	0.011	0.0080	0.0074	0.010	0.021	0.0083	0.016
Mercury Hg	0.000002	0.000002	0.000002	0.000002	0.000002	0.000002	0.000002	0.000003	0.000002	0.000002
Potassium K	1.18	3.44	1.71	6.38	1.35	3.01	1.19	2.36	1.73	4.26
Lithium Li	0.002	0.001	0.002	0.006	0.002	0.010	0.001	0.002	0.001	0.001
Magnesium Mg	1.09	1.33	2.07	4.23	0.763	1.54	1.06	1.34	0.829	0.979
Manganese Mn	0.036	0.13	0.063	0.26	0.025	0.046	0.0074	0.017	0.024	0.040
Molybdenum Mo	0.007	0.016	0.003	0.005	0.003	0.009	0.021	0.041	0.006	0.012
Sodium Na	0.24	0.38	0.32	0.93	0.20	0.52	0.20	0.41	0.19	0.51

(continued)

Table 10.1-14. pH and Leaching Rates from Tailing Kinetic Tests Representing Source Terms for Tailing Management Facility Tailing Material (completed)

List of Parameters (mg/kg/week)		M Rougher Coarse Cyclone Dams		M Rougher Beaches		M/K Rougher Beaches		M/S Rougher Beaches		IC Rougher Beaches	
		HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all	HC av all	HC 95th all
Nickel	Ni	0.000603	0.00330	0.000433	0.00227	0.000114	0.00012	0.000115	0.00013	0.000112	0.00012
Lead	Pb	0.000012	0.00001	0.000012	0.00001	0.000021	0.00004	0.000068	0.00016	0.000096	0.00024
Antimony	Sb	0.000875	0.00125	0.000227	0.00025	0.000644	0.00084	0.001341	0.00356	0.002817	0.00412
Selenium	Se	0.001636	0.00245	0.001522	0.00247	0.001275	0.00245	0.000600	0.00170	0.000951	0.00168
Silicon	Si	0.5	0.9	0.6	0.7	0.6	0.7	1.0	1.5	0.9	1.1
Tin	Sn	0.00002	0.00002	0.00003	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
Sulphate	SO ₄	64	337	161	683	133	476	12	58	9	21
Strontium	Sr	0.3	1.2	0.8	2.4	0.7	1.9	0.2	0.3	0.2	0.3
Thallium	Tl	0.000024	0.000025	0.000024	0.000025	0.000023	0.000025	0.000002	0.000002	0.000013	0.000024
Uranium	U	0.00013	0.00063	0.00035	0.0013	0.000224	0.00064	0.00026	0.00043	0.00077	0.0011
Vanadium	V	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0005	0.0014	0.0002	0.0002
Zinc	Zn	0.00072	0.00074	0.00071	0.00074	0.00114	0.00123	0.00113	0.00125	0.00067	0.00074
Acidity		1	2	2	3	1	3	1	2	1	2
Alkalinity as HCO ₃		20	22	23	28	19	25	24	28	23	29

Values of pH and alkalinity are set to the 5th percentiles of data in the cases where the 95th percentile is used as the conservative case

M = Mitchell tailing; M/S = Mitchell-Sulphurets tailing; M/K = Mitchell-Kerr tailing; IC = Iron Cap tailing

Table 10.1-15. pH and Concentrations (mg/L) from Pilot Plant Tests Representing Source Terms for the Ore Process Complex

List of Parameters	Rougher Process (including sludge)		Carbon-in-Leach (CIL) Process	
		Plant Supernatant		Plant Supernatant
pH		9.5*		8.42
Silver	Ag	0.00001		0.000084
Aluminum	Al	0.07015		0.0075
Arsenic	As	0.004275		0.0114
Boron	B	0.025		0.025
Barium	Ba	0.0378		0.0329
Beryllium	Be	0.00005		0.00025
Bromide	Br	0.1115		0.5
Calcium	Ca	66.9		555
Cadmium	Cd	0.000005		0.000141
Chloride	Cl	15		13
Cobalt	Co	0.00025		0.0127
Chromium	Cr	0.0005		0.00025
Copper	Cu	0.0001		0.0674
Fluoride	F	0.885		0.2
Iron	Fe	0.0025		0.015
Mercury	Hg	0.000025		0.000005
Potassium	K	32.3		88.4
Lithium	Li	0.0025		0.0174
Magnesium	Mg	1.58		8.64
Manganese	Mn	0.01525		0.0398
Molybdenum	Mo	0.0224		0.211
Sodium	Na	19		429
Nickel	Ni	0.0005		0.0037
Lead	Pb	0.0001		0.000125
Antimony	Sb	0.00025		0.018
Selenium	Se	0.004875		0.0543
Silicon	Si	0.429		3.2
Tin	Sn	0.0025		0.00025
Sulphate	SO ₄	207		1620
Strontium	Sr	0.486		1.62
Thallium	Tl	0.000025		0.000025
Uranium	U	0.00005		0.000025
Vanadium	V	0.0025		0.0025
Zinc	Zn	0.0025		0.026
Acidity		0.25		0.5
Alkalinity as HCO ₃		11.15		235

Elements with values below the method detection limit in all the sources: Br, Cr, Be, B, Pb, Tl, Sn, and V

* Estimated pH of Treaty Process Plant effluent

Metal leaching in humidity cells typically reflected drainage pH with concentrations in acidic drainage often two to three orders of magnitude higher than in neutral drainage. Sulphate, aluminum, arsenic, cadmium, copper, iron, lead, selenium, and zinc were high in the acidic humidity cell relative to the near-neutral humidity cells.

SAC results were used to assess the stability of tailing material stored under a water cover. SAC kinetic tests performed on tailing material imply that leach rates slowly decline in the pore water if the test never becomes acidic.

10.1.2.4 Non-deposit Material Characterization

10.1.2.4.1 Metal Leaching/Acid Rock Drainage Characterization Program

Non-deposit samples were collected from overburden and rock in the proposed Project area for the assessment of ML/ARD potential in areas that may be disturbed, exposed, or excavated during proposed mining activities such as infrastructure development. Non-deposit material assessed for this characterization includes overburden samples collected from drill holes and grab samples from hand-dug test pits, and rock samples collected from drill holes and grab samples hammered from outcrops. A detailed presentation of the non-deposit samples characterization is provided in [Appendix 10-A](#).

Non-deposit overburden material is likely to be used for reclamation and as fill material for construction of buildings and roads. As such it will likely be moved during the life of the operation and remain exposed to physical and chemical weathering and erosion conditions similar to current conditions. Overburden material had significant variability based on the sampling site, from organic silts to well-graded fine to coarse gravels.

Non-deposit rock material is likely to be exposed during road construction or in locations where bedrock will be blasted to make level surfaces (e.g., building or dam foundations), or used as fill material during construction of buildings and potentially in roads. As such, it will likely be moved during the life of the operation and remain exposed to physical and chemical weathering and erosion. The non-deposit rock samples vary between sedimentary and volcanic rock types and come from the Stuhini, Hazelton, Bowser Lake groups, and one sample from the Zippa Mountain Plutonic Complex.

Non-deposit material was assessed in 238 ABA tests, four shake flask extraction leachate tests on overburden material, and three meteoric water mobility protocol leachate extractions on composites of material from above the Mitchell Pit walls.

The sampling locations of the Mine Site and Processing and Tailing Management Area (PTMA), including the TCAR and CCAC non-deposit ML/ARD samples are presented in Figures 10.1-1 to 10.1-3.

10.1.2.4.2 Overburden Static Testing

ABA test results of the non-deposit overburden material samples are summarized in Table 10.1-16.

Paste pH values in non-deposit overburden material were above 6, with the exception of Mitchell material. The Mitchell non-deposit overburden presented stored acidity from oxidized rocks (paste pH < 6) in 25% of the samples. Concentrations of total-sulphur ranged from below the detection limit (0.01%) to 6.78%. A strong correlation between total-sulphur and sulphide-sulphur concentrations was evident in all samples.

NP values ranged from 6 to 304 kg CaCO₃/t. Mitchell samples had slightly lower NP values than other locations. The Sobek NP correlated reasonably well with NP calculated from calcium and inorganic carbon, but not with NP calculated from calcium and magnesium, indicating that most of the NP is from calcium-bearing carbonates. Mean and median unadjusted SNPR values were consistently above 2.0 for non-deposit overburden located outside the Mitchell Pit, indicating that the majority of overburden material is NPAG.

The extraction from four overburden shake flask extractions had elevated concentrations for sulphate, aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, and zinc above receiving environment water quality guidelines indicating the potential for ML from non-deposit overburden.

10.1.2.4.3 Non-deposit Rock Static Testing

ABA test results of the non-deposit rock material samples are summarized in Table 10.1-17.

Paste pH values were typically above 6.0 with the exception of 26% of the Mitchell and 29% of proposed Sulphurets Pit samples.

Concentrations of total-sulphur ranged from below the detection limit (0.01%) to 13.07%. The proposed Mitchell Diversion Tunnels (MDT), near Mitchell Pit, near Sulphurets Pit, and Sulphurets laydown area locations had the highest total-sulphur concentrations. A strong correlation between total-sulphur and sulphide-sulphur concentrations was evident in all samples.

Bulk Sobek NP values varied among sample locations. The CCAC, MDT, Mitchell Pit, and Sulphurets Pit had paste pH values < 6.0, indicating some unavailable NP. Based on adjusted SNPR values, samples from the proposed TCAR, McTagg Twinned Diversion Tunnels, and Sulphurets laydown area demonstrated a low potential for acid generation. Material from Water Storage dam quarries with adjusted SNPR values greater than 3.0 will be used during initial construction of the Water Storage dam prior to the excavation of the Sulphurets quarry.

Three Mitchell highwall composites were subjected to a meteoric water mobility protocol leachate extraction. The concentrations of sulphate, aluminum, arsenic, boron, chromium, copper, phosphorus, selenium, vanadium, and zinc in the extraction reflected acidic extraction conditions. This result indicates that the Mitchell highwall material would be unsuitable as construction material outside of the Water Storage Facility (WSF) catchment.

Table 10.1-16. Summary of Acid Base Accounting Test Results for Non-deposit Overburden Material

Non-deposit Overburden Material	Number of Samples	% Samples with Paste pH < 6.0	Range of Total-Sulphur (%)	Total-Sulphur and Sulphide-Sulphur Relationship	Range of Sobek NP (kg CaCO ₃ /t)	Sobek NP Correlation	% Samples with Adjusted SNPR < 2.0
TMF	2	0	0.17-0.22	Strong	11-47	Strong Inorg, Ca NP	0
McTagg RSF	2	0	0.03-0.04	Strong	54-72	Strong Inorg, Ca NP	0
Mitchell RSF	25	0	0.005-4.59	Strong	12-304	Strong Inorg, Ca NP	24
Near Mitchell Pit	4	25	0.05-6.78	Strong	9-17	Strong Inorg, Ca NP	75
Sulphurets laydown area	1	0	0.05	Strong	11	Strong Inorg, Ca NP	0
Ted Morris Valley	5	0	0.02-0.17	Strong	9-18	Strong Inorg, Ca NP	0
WSF	10	0	0.06-1.47	Strong	9-242	Strong Inorg, Ca NP	10

NP = neutralization potential

SNPR = sulphide net potential ratio

Ca NP = calcium calculated neutralization potential

Inorg NP = inorganic neutralization potential

Table 10.1-17. Summary of Acid Base Accounting Test Results for Non-deposit Rock Material

Non-deposit Rock Material	Number of Samples	% Samples with Paste pH < 6.0	Range of Total-Sulphur (%)	Total-Sulphur and Sulphide-Sulphur Relationship	Range of Sobek NP (kg CaCO ₃ /t)	Sobek NP Correlation	% Samples with Adjusted SNPR < 2.0
TMF	24	0	0.02-1.02	Strong	4-261	Strong Inorg, Ca NP	33
Near Mitchell Pit	27	26	0.01-6.61	Strong	0.4-335	Moderate Inorg, Ca NP	48
Near Sulphurets Pit	14	29	0.01-3.2	Strong	0-134	Strong Inorg, Ca NP	43
Sulphurets laydown area	3	0	0.3-0.75	Strong	84-125	Strong Inorg, Ca NP	0
WSF	2	0	0.02-1.68	Strong	193-415	Strong Ca NP	0

NP = neutralization potential

SNPR = sulphide net potential ratio

Inorg NP = inorganic neutralization potential

10.1.2.4.4 Access Corridors

Access to the Mine Site is proposed via the CCAR. The TCAR is proposed to access the tunnel portals, with a junction to the North Treaty Creek access road (NTCAR) near the North Treaty tributary to access the TMF and Treaty Process Plant. The CCAR, TCAR, and NTCAR alignments have been designed by McElhanney Consulting Services for the Seabridge KSM Prefeasibility Study (Wardrop 2012). A detailed ML/ARD potential assessment of the CCAR and TCAR is included in [Appendix 10-B](#).

Topographical base maps are overlain with the ML/ARD potentials and the access road alignment sections in 200 m intervals for the CCAR (Figure 10.1-5), TCAR, and NTCAR (Figure 10.1-6). These figures include simplified local geology and locations of ML/ARD fieldwork bedrock and colluvium samples.

Coulter Creek Access Road

The distribution of ML/ARD classification for each 200 m segment of the proposed CCAR is provided in Table 10.1-18. Thirty-two percent or 10.6 km of the CCAR alignment has an ML/ARD potential of “possible” or “high” (Figure 10.1-5).

Table 10.1-18. Distribution of Coulter Creek Access Road Metal Leaching/Acid Rock Drainage Classification

ML/ARD Ranking	Number of Segments	% of Total
High	5	3%
Possible	48	29%
Low	49	30%
None	62	38%
Total	164	100%

Treaty Creek Access Road

The distribution of ML/ARD classification for each 200 m segment of the proposed TCAR and NTCAR are provided in Table 10.1-19 and shown on Figure 10.1-6. No segments of the TCAR or NTCAR alignments were classified as having a high ML/ARD potential.

Table 10.1-19. Distribution of the Treaty Creek Access Road Metal Leaching/Acid Rock Drainage Classification

ML/ARD Ranking	Number of Segments	% of Total
High	0	0%
Possible	50	23%
Low	5	2%
None	163	75%
Total	218	100%

The ML/ARD potential rankings of the CCAR are relatively evenly distributed among “possible,” “low,” and “none.” Road segments of the CCAR with a high ML/ARD potential (3% of the alignment) are frequently associated with fault zones and geological contacts, as well as those sections where cut dominates fill. The ML/ARD potential of the northern 20 km of the CCAR alignment along Coulter Creek is possible to high and the majority of the southeastern sections along Sulphurets Creek have an ML/ARD potential of none.

The ML/ARD potential ranking of the TCAR is predominantly low to none with few segments of high or possible ML/ARD potential. This ranking reflects the alignment on alluvial and colluvial sediments.

10.1.2.4.5 Tunnels

The proposed KSM Project will require the construction of permanent access tunnels between the different components within the Mine Site and between the Mine Site and the PTMA. The following tunnels will be completed during the construction phase:

- East Catchment Diversion Tunnel, phase 1;
- McTagg Twinned Diversion Tunnels, phase 1;
- Mitchell Diversion Tunnels, phase 1;
- Mitchell-Treaty Twinned Tunnels;
- Sulphurets-Mitchell Conveyor Tunnel; and
- WSF diversion tunnel.

The following tunnels will be completed during the operation phase:

- East Catchment Diversion Tunnel, phase 2;
- Mitchell Diversion Tunnels, phase 2;
- McTagg Twinned Diversion Tunnels, phases 2 and 3;
- Mitchell underground drainage tunnels;
- Mitchell underground drainage tunnels; and
- Mitchell Pit north wall dewatering adit.

A preliminary assessment was performed to calculate an approximate volume of PAG material to be excavated from each tunnel (Table 10.1-20). The assessment subdivided each tunnel alignment based on the stratigraphic unit of the bedrock along the tunnel alignment. Where samples existed, the percentage of the tunnel segment classified as PAG (adj SNPR < 2) was based on all samples within 2 km of the tunnel alignment and within the same stratigraphic unit. This result was compared to the percentage of all non-deposit samples collected from the same stratigraphic unit with an adjusted SNPR less than two. The greater of the two percentages was used to calculate the volume of PAG material (Table 10.1-20).

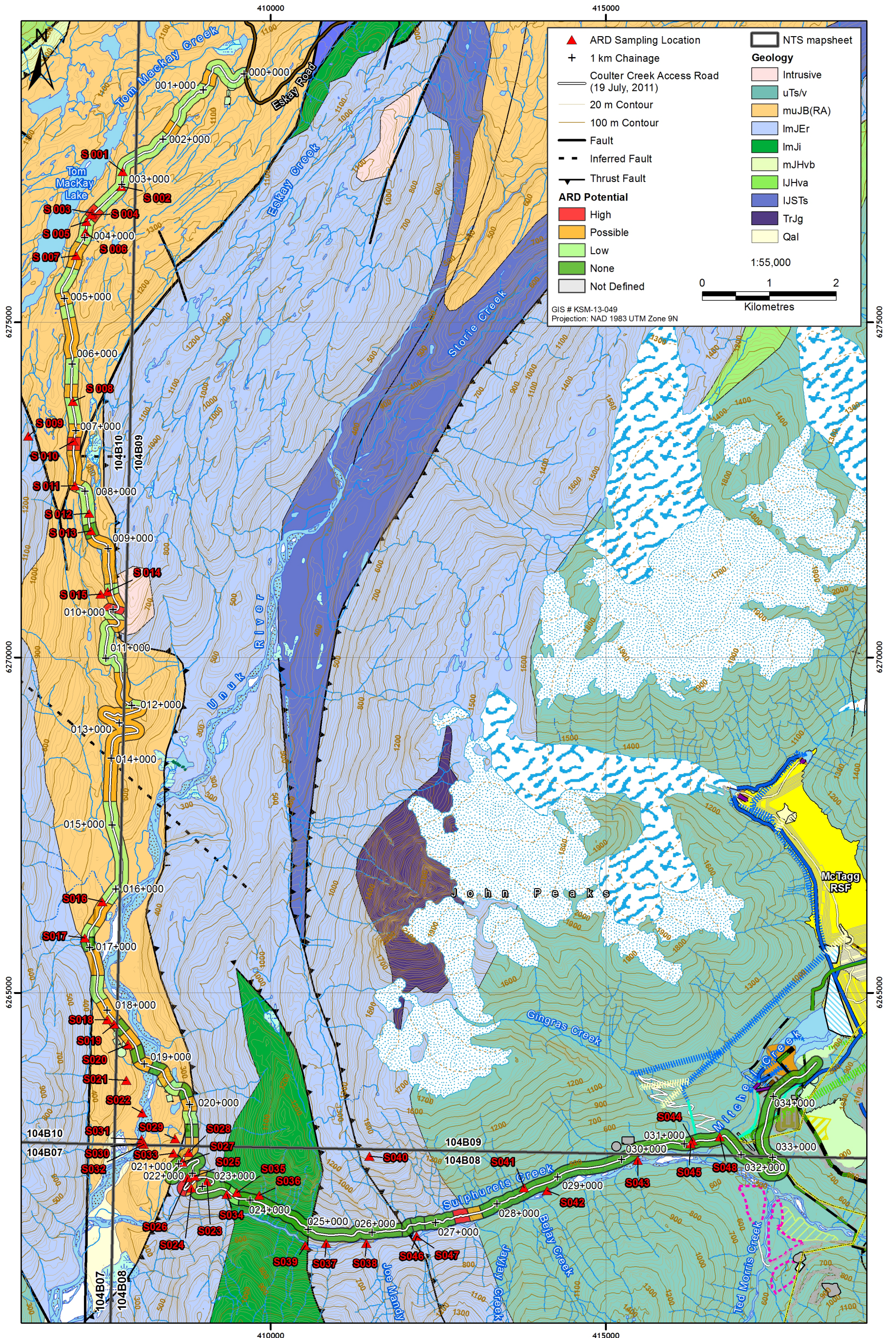


Figure 10.1-5

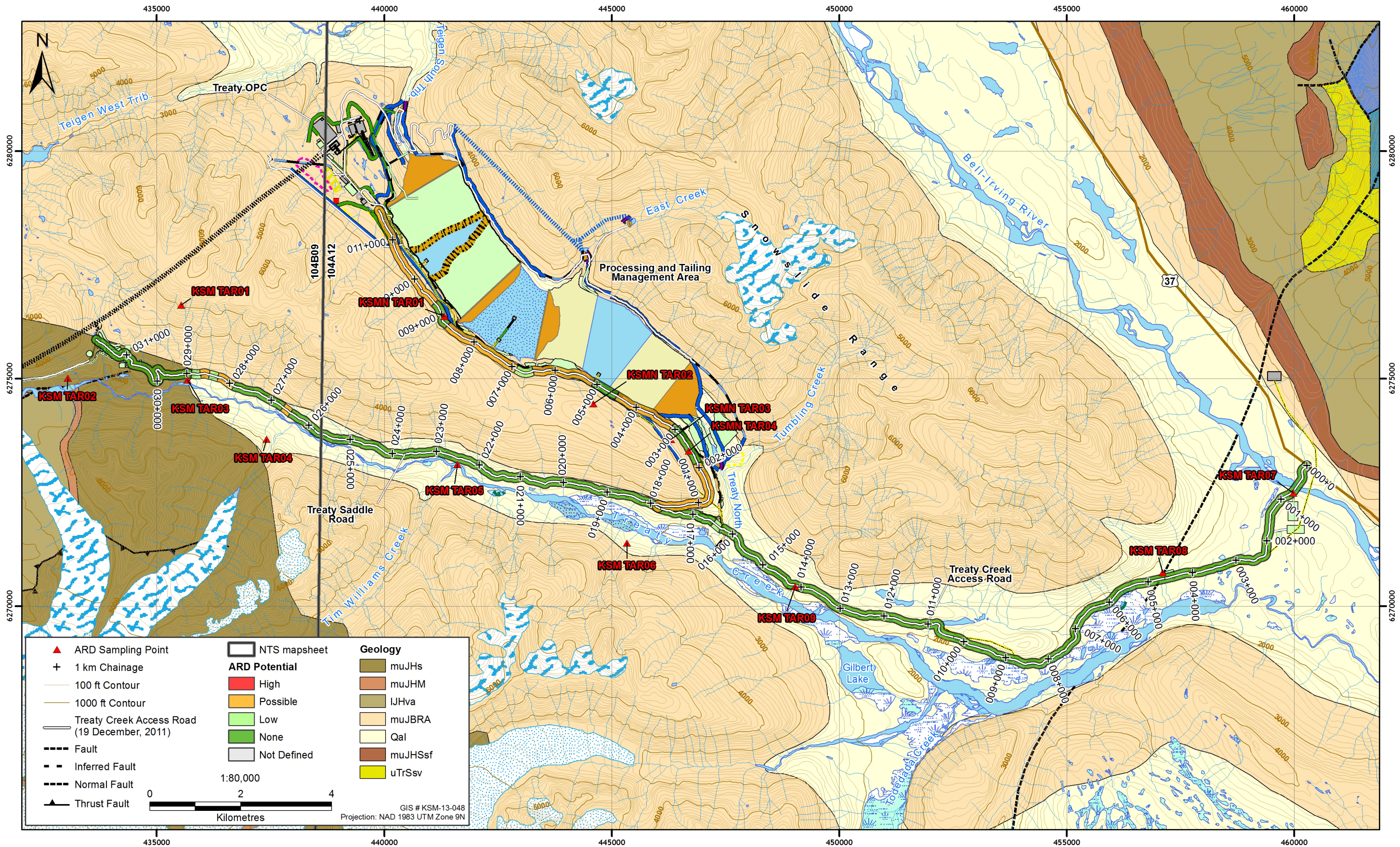


Figure 10.1-6

Table 10.1-20. Summary of Acid Base Accounting Test Results for Non-deposit Rock Material

Tunnel	Volume Extracted (m ³)	% PAG (based on samples within 2 km of alignment)	% PAG (based on stratigraphy)	Volume PAG Material (m ³)
East Catchment diversion tunnel	99,500	50	29	49,800
McTagg Twinned Diversion Tunnels	573,100	18	20	117,000
Mitchell Diversion Tunnels	942,900	52	31	489,400
Mitchell underground drainage tunnels	371,900	28	20	103,300
Mitchell-Treaty Twinned Tunnels	958,700	24	29	274,500
Mitchell Pit north wall dewatering adit	65,000	52	26	33,700
Sulphurets-Mitchell Conveyor Tunnel	186,000	0	26	47,600
WSF diversion tunnel	26,100	0	20	5,300

10.2 Source Terms for Water Quality Modelling

This section provides the source terms that were used in the water quality prediction model that was developed to predict water quality and inform water management planning. The model inputs discussed in this section include: mined ore and waste rock, tailing, and chemical loading contributions from the Treaty Process Plant supernatant and high density sludge. Surface water quality prediction results are presented in Chapter 14.

10.2.1 Source Term Methodology

10.2.1.1 Data Sources

Source terms were developed using expected characteristics of each Project component including rock type, grain size distribution, predicted release rates, mine plan, and Project schedule. Water chemistry source terms were developed from humidity cell release rates that are presented in tables in Section 10.1 and are fully documented in [Appendix 10-A](#). Rock types were defined based on the ABA block model in [Appendix 10-A](#). The mine plan and schedule were obtained from the Preliminary Feasibility Study (Wardrop 2012).

10.2.1.2 Chemical Loading Calculations

To calculate the load or mass flux moving from the solid material into the aqueous phase, the rate of release was scaled and multiplied by the mass of solid material available for reaction as follows:

$$L = R \times M$$

where:

L = Load or mass flux (mg/week)

R = Rate of release (mg/[kg × week])

M = Mass of material (kg)

10.2.1.3 Detection Limits

The detection limits of the kinetic tests varied over time as analytical methods improved, which resulted in a decrease in reported detection limits of one to two orders of magnitude for some parameters. Frequently, the concentration of a given parameter in the leachate was below the initial (higher) and second (lower) detection limits. Occasionally the parameter would have values between the initial and secondary detection limits and these in-between values could occur either as the detection limit changed or after the limit was decreased. In order to reduce the effect of higher detection limits artificially raising the calculated mean leach rates, the following methodology was used:

- in the case where results were reported above both the initial (higher) and secondary (lower) detection limit, half of the reported detection limit was used;
- when results were reported between the two detection limits and in the weeks during or prior to the decrease in detection limit, half of the reported detection limit was used;
- when results were reported between the two detection limits and only after the second (lower) detection limit has been reported, half of the lower detection limit was used for all values that were reported as below either of the reported detection limits; and
- when results were reported as constantly below detection limit for all weeks, half of the second detection limit was used for all values.

10.2.2 Mine Site

10.2.2.1 Scaling Factor

Release rates observed for laboratory waste rock and ore humidity cells were adjusted for grain size effects, temperature effects, and the degree of flushing or water contact using a bulk scaling factor.

The scaling factor is calculated as follows:

$$SF = K_t \times K_f \times K_c$$

where:

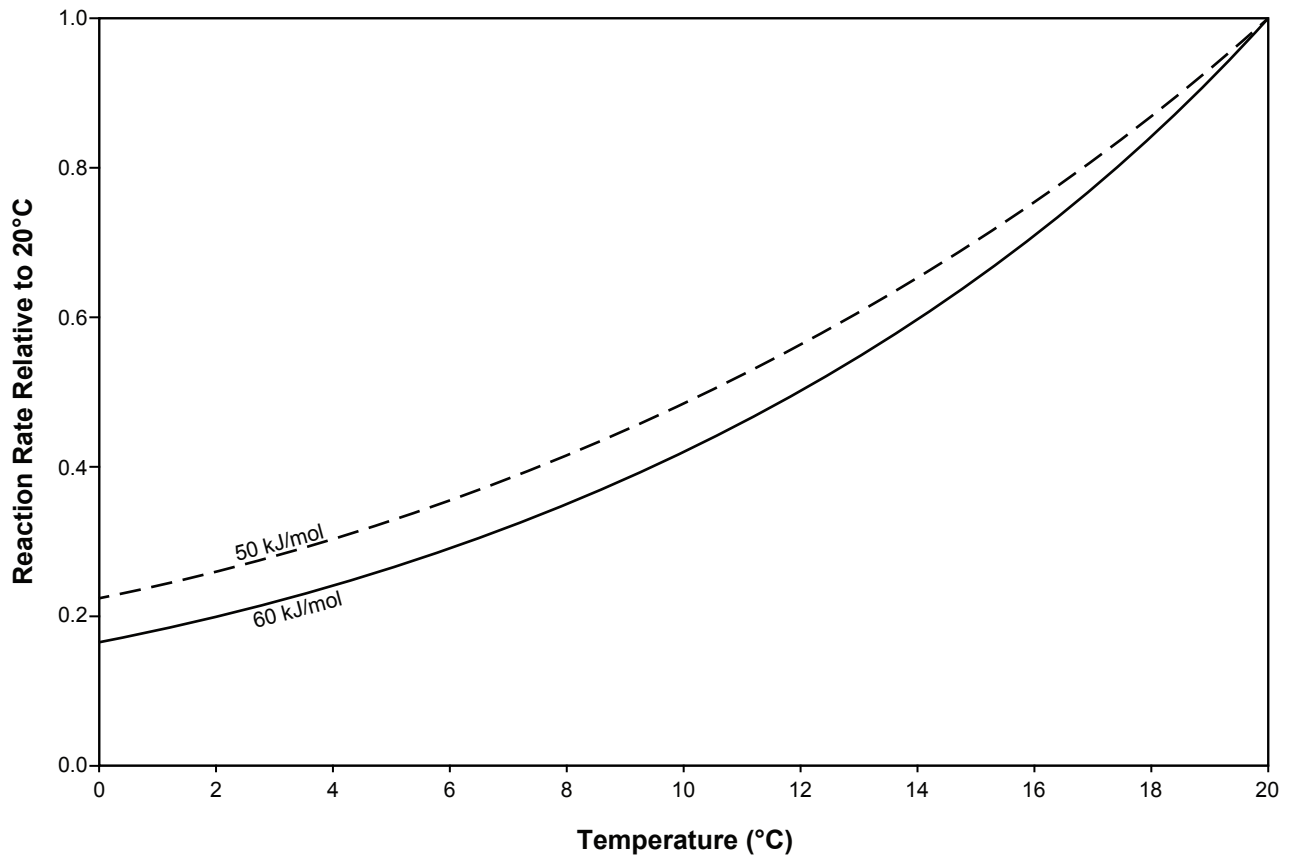
SF = scaling factor;

K_t = adjustment factor to correct for temperature effects (unitless);

K_f = adjustment factor to correct for grain size fraction effects (unitless); and

K_c = adjustment factor to correct for the proportion of material that is in contact with liquid water (unitless).

The grain size fraction effect was determined based on the proportion of the reactive fraction present in the Mine Site component. The reactive fraction is represented by the percent of material < 6 mm (the size fraction of a standard humidity cell). The effects of temperature were adjusted based on the Arrhenius equation for pyrite activation energies of 50 and 60 kJ/mol, as described in MEND (2006; Figure 10.2-1); a scaling factor was applied to each Mine Site component based on the estimated temperatures. The adjustment factor for the degree of flushing was determined based on the estimated portion of material in contact with water at any given time.



Source: MEND (2006).

Figure 10.2-1

10.2.2.2 McTagg and Mitchell Rock Storage Facilities

The water chemistry from the RSFs was predicted for the operation phase and closure/post-closure phases.

10.2.2.2.1 Operation

The waste rock and ore production schedule is identified in the mine plan, as defined in Table 10.2-1.

Table 10.2-1. Mine Schedule

Deposit	Year	Mining Method
Mitchell	-2 to 23	open pit
Sulphurets	-2 to 6	open pit
Sulphurets	23 to 27	open pit
Kerr	27 to 50	open pit
Mitchell	26 to 51.5	block cave
Iron Cap	32 to 51	block cave

Waste rock disposal schedules for the Mitchell RSF and McTagg RSF were prepared by Moose Mountain Technical Services. The waste rock disposal schedules were developed based on the ABA block model and are presented in Table 10.2-2 for the Mitchell RSF and Table 10.2-3 for the McTagg RSF. Waste rock generated during the construction phase was included in Year 1. The humidity cells for each model code used in the water quality prediction model are defined in Section 10.1.2.2, Table 10.1-6. The water chemistry model inputs combined humidity cell results from both ore and waste rock as this approach captured more potential variability within the waste rock, particularly as the definition of ore is not a fixed value. As described in Section 10.1.2.2, leachate was modelled based on neutral and acidic rates. Leachate from PAG material was modelled using the results following the generation of acidic leachate in humidity cells (pH < 6.0). Leachate from NPAG material was modelled using the results with neutral leachate (pH > 6.0).

The scaling factors for the RSFs are summarized in Table 10.2-4. The reactive fraction in the Mitchell and Sulphurets waste rock is estimated to be 10% of the total mass based on computer blasting simulation software (SABREX) modeling completed by Moose Mountain Technical Services (2011). The scaling factor for the internal temperature of the RSFs considers the mean annual ambient temperature and the possibility of hot spots in the RSF. A scaling factor of 0.5 was used, which corresponds to an internal temperature of 15°C. Approximately 20% of the waste rock in the reactive grain size fraction will be in contact with water at any given time, therefore a scaling factor of 0.2 was used (Elboushi 1975). The bulk scaling factor for the RSFs was determined to be 0.01.

10.2.2.2.2 Closure

The source terms developed for water quality predictions during the operation phase apply to the closure phase of the proposed Project.

Table 10.2-2. Waste Schedule by Model Code to Mitchell Rock Storage Facility (in kt)

Year	Sulphurets - Overburden	Sulphurets - Au, Leach & Raewyn Zones	Sulphurets - Lower Au Zone	Sulphurets - Lower Plate Hazelton	Sulphurets - Upper Plate Hazelton	Sulphurets - Monzonite	Sulphurets - Undefined	Sulphurets - Overburden	Sulphurets - Au, Leach & Raewyn Zones	Sulphurets - Lower Au Zone	Sulphurets - Lower Plate Hazelton	Sulphurets - Upper Plate Hazelton	Sulphurets - Monzonite	Sulphurets - Undefined
	SNPRA<2							SNPRA≥2						
Year -3	5.7	0	0	39.3	852.6	0	54.6	700	0	0	0	1,886	0	873
Year -2	19	0	0	131	2,842	0	182	1,675	0	0	0	4,402	0	2,039
Year -1	302	70	423	1,515	5,562	1,970	2,520	1,318	0	0	1,267	8,660	8,460.2	8,287
Year 1	138	328	401	1,070	3,381	3	2,803	769	0	0	281	5,635	8,410	14,556
Year 2	0	1,440	219	1,099	1,570	0	2,321	755	49	0	170	3,780	2,606	7,690
Year 3	122	2,314	1,456	838	114	0	4,214	894	0	0	183	4,119	471	5,921
Year 4	137	2,175	952	12	0	0	1,905	575	0	0	40	11	0	4,027
Year 5	0	2,663	2,730	1	0	0	50	397	6	105	0	0	0	2,180
Year 6 to 10	0	1,505	1,072	1	0	0	0	74	0	90	0	0	0	65
Year 11 to 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 21 to 30	0.00	18,985.20	48,460.10	25,996.75	21,554.65	6,897.80	27,768.65	6,880.25	631.80	73.45	670.15	59,874.75	74,310.60	151,840.65
Year 31 to 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 41 to 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total by model code	718.00	29,480.20	55,713.10	30,663.75	35,023.65	8,870.80	41,763.65	13,337.25	686.80	268.45	2,611.15	86,481.75	94,257.80	196,605.65

Year	Mitchell - Overburden	Mitchell - Glacial Ice	Mitchell - Upper Plate Hazelton	Mitchell - Lower Plate Hazelton	Mitchell - Monzonite	Mitchell - Bornite/Leach Breccia	Mitchell - Overburden	Mitchell - Glacial Ice	Mitchell - Upper Plate Hazelton	Mitchell - Lower Plate Hazelton	Mitchell - Monzonite	Mitchell - Bornite/Leach Breccia	IC	
	SNPRA<2						SNPRA≥2						SNPRA<2	SNPRA≥2
Year -3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year -2	2,270	0	9,855	0	0	0	0	0	0	0	0	0	0	0
Year -1	4,557	0	23,513	27	1,262	0	0	0	3,467	63	6,627	0	0	0
Year 1	6,207	0	74,000	699	1,920	0	0	0	2,188	240	2,913	0	0	0
Year 2	2,724	0	109,481	851	2,255	0	0	0	0	5	3,080	0	0	0
Year 3	1,689	0	113,333	521	0	0	0	0	327	0	1,375	0	0	0
Year 4	1,129	0	74,597	20,027	495	0	0	0	2,136	2,168	3,840	0	177	0
Year 5	543	0	39,241	1,684	6,603	0	0	0	0	72	1,982	0	891	0
Year 6 to 10	2,442	0	228,394	83,392	13,431	2,054	566	452	7,262	2,231	111,461	0	0	0
Year 11 to 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 21 to 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 31 to 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 41 to 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total by model code	21,561	0	672,414	107,201	25,966	2,054	566	452	15,380	4,779	131,278	0	1,068*	0

* During Iron Cap development some waste rock will be placed in the Mitchell RSF

Table 10.2-3. Waste Schedule by Model Code to McTagg Rock Storage Facility (in kt)

Year	Sulphurets - Overburden	Sulphurets - Au, Leach & Raewyn Zones	Sulphurets - Lower Au Zone	Sulphurets - Lower Plate Hazelton	Sulphurets - Upper Plate Hazelton	Sulphurets - Monzonite	Sulphurets - Undefined	Sulphurets - Overburden	Sulphurets - Au, Leach & Raewyn Zones	Sulphurets - Lower Au Zone	Sulphurets - Lower Plate Hazelton	Sulphurets - Upper Plate Hazelton	Sulphurets - Monzonite	Sulphurets - Undefined
	SNPRA<2							SNPRA≥2						
Year -2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year -1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 6 to 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 11 to 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 21 to 30	0	10,222.80	26,093.90	13,998.25	11,606.35	3,714.20	14,952.35	3,704.75	340.20	39.55	360.85	32,240.25	40,013.40	81,760.35
Year 31 to 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 41 to 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total by model code	0	10,222.80	26,093.90	13,998.25	11,606.35	3,714.20	14,952.35	3,704.75	340.20	39.55	360.85	32,240.25	40,013.40	81,760.35

Year	Mitchell - Overburden	Mitchell - Glacial Ice	Mitchell - Upper Plate Hazelton	Mitchell - Lower Plate Hazelton	Mitchell - Monzonite	Mitchell - Bornite/Leach Breccia	Mitchell - Overburden	Mitchell - Glacial Ice	Mitchell - Upper Plate Hazelton	Mitchell - Lower Plate Hazelton	Mitchell - Monzonite	Mitchell - Bornite/Leach Breccia	IC	
	SNPRA<2						SNPRA≥2						SNPRA<2	2<=SNPRA
Year -2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year -1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 6 to 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 11 to 20	1,206	0	202,860	127,307	9,623	3,771	25	2,467	2,448	1,790	152,792	0	15,724	0
Year 21 to 30	0	0	0	593	0	33	0	0	0	0	0	0	0	0
Year 31 to 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Year 41 to 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total by model code	1,206	0	202,860	127,900	9,623	3,804	25	2,467	2,448	1,790	152,792	0	15,724	0

Table 10.2-4. Summary of Scaling Factors Used for the Rock Storage Facilities

Scaling Factor	Selected Scaling Factor
Grain Size Effect (K_r)	0.1
Temperature (K_t)	0.5
Water contact (K_c)	0.2
Bulk scaling factor	0.01

10.2.2.2.3 Post-closure

The source terms developed for water quality predictions during the operation phase apply to the post-closure phase of the proposed Project.

10.2.2.3 Sulphurets Pit Backfill

10.2.2.3.1 Operation

Only Kerr waste rock will be backfilled into the Sulphurets Pit. The waste rock placement schedule is summarized in Table 10.2-5.

Table 10.2-5. Waste Schedule by Model Code for Sulphurets Pit Backfill (in kt)

Year	Kerr	
	SNPRA<2	SNPRA≥2
Year -2	0	0
Year -1	0	0
Year 1	0	0
Year 2	0	0
Year 3	0	0
Year 4	0	0
Year 5	0	0
Year 6 to 10	0	0
Year 11 to 20	0	0
Year 21 to 30	103,715	1,677
Year 31 to 40	358,984	1
Year 41 to 50	196,795	3,821
Total by model code	659,494	5,499

The scaling factor for Sulphurets Pit is summarized in Table 10.2-6. Kerr waste rock has a higher percentage of fines than the Mitchell and Sulphurets waste rock because it will be crushed for transport on a conveyor; therefore, the reactive fraction of Kerr waste rock is estimated to be 20% of the total mass. The oxidation of sulphide minerals is an exothermic reaction that is anticipated to elevate the internal temperatures of backfilled waste rock above ambient temperatures and is assumed to be 25°C. Therefore, no temperature adjustment was applied. It is

estimated that 20% of the waste rock in the Sulphurets Pit backfill will be in contact with water at any given time.

Table 10.2-6. Summary of Scaling Factors Used for the Sulphurets Pit Backfill

Scaling Factor	Selected Scaling Factor
Grain Size Effect (K_r)	0.2
Temperature (K_t)	--
Water contact (K_c)	0.2
Bulk scaling factor	0.04

During the operation phase, the mass of reactive rock was adjusted to account for the ongoing placement of the high-density polyethylene cover (see Chapter 4 Project Description, Section 4.5.1.5, and Chapter 27 Reclamation and Closure, Section 27.4.2.2 for a description of the construction, operation, and closure of the mined-out Sulphurets Pit backfilled with Kerr waste rock). For the first three years of waste rock placement, it is assumed that 0% of the waste rock is covered. In subsequent years, the amount of waste rock covered increases incrementally from 0% up to 95% by Year 51.5. Linear interpolation was used to determine the proportion of waste rock that was covered each year. The scaling factor in years 30 to 51.5 were adjusted accordingly.

The humidity cells for the Kerr waste rock model code used in the water quality prediction model for Sulphurets Pit are defined in Section 10.1.3.2, Table 10.1-6.

10.2.2.3.2 Closure

After the placement of the high-density polyethylene cover on the final bench of the Sulphurets Pit backfill, it is assumed that 95% of the waste rock will be encapsulated under the cover. The water quality for the closure phase was predicted using the same approach as the final year of waste rock placement during the operation phase.

10.2.2.3.3 Post-closure

The post-closure phase was considered using the same approach as for the closure phase.

10.2.2.4 Pit Wall Runoff

The pit wall runoff water quality was predicted for the operation phase and closure/post-closure phases.

10.2.2.4.1 Operation

The area of exposed pit wall by pit, model code, and year for the water quality prediction model are defined in Tables 10.2-7, 10.2-8, and 10.2-9.

For the water quality prediction model, the mass of exposed and reactive pit walls was calculated based on the exposed surface area, an estimated reactive depth of 0.5 m for inter-bench areas, and a reactive depth of 1 m for benches.

Table 10.2-7. Area of Exposed Pit Wall in Sulphurets Pit by Model Code

Year	SAUA	SLAA	SLPA	SUPA	SMOA	SUNA	SON	SAUN	SLAN	SLPN	SUPN	SMON	SUNN	Total Area
-2	18.078	0	22.095	68.294	9.039	6.026	15.065	0	0	0.000	130.562	194.839	42.182	506.179
-1	51.092	1.004	40.874	114.447	20.437	60.289	16.350	0	0	15.328	164.517	259.548	220.718	964.603
1	106.683	19.415	46.296	134.863	20.129	57.367	17.110	0	0	8.052	167.070	247.585	342.191	1,166.761
2	195.740	38.245	71.904	119.841	19.973	46.938	17.976	0.999	0	12.983	197.737	225.700	304.595	1,252.630
3	310.263	73.902	64.680	116.222	20.213	83.882	20.213	0	0	13.138	164.732	226.380	281.965	1,375.589
4	348.693	127.339	67.455	119.344	20.756	58.115	18.680	5.189	0	11.416	167.082	232.462	306.144	1,482.675
5	339.860	208.593	65.278	119.158	20.723	55.953	22.796	2.072	4.145	12.434	166.822	232.100	283.908	1,533.841
10	327.551	313.956	69.016	125.981	21.910	59.156	23.005	2.191	7.668	13.146	176.374	245.390	301.260	1,686.604
20	337.136	379.039	71.035	129.668	22.551	60.888	23.678	2.255	7.893	13.531	181.535	252.570	310.075	1,791.855
30	343.321	390.131	159.841	59.659	36.021	87.800	24.764	1.126	22.513	0	260.023	490.780	1,384.540	3,260.520
40	340.402	1,303.494	158.482	59.152	35.714	87.054	24.554	1.116	22.321	0	257.813	486.608	1,372.769	4,149.479
50	344.675	1,292.412	160.472	59.894	36.163	88.147	24.862	1.130	22.602	0	261.049	492.716	1,390.003	4,174.125
51.5	344.675	1,308.637	160.472	59.894	36.163	88.147	24.862	1.130	22.602	0	261.049	492.716	1,390.003	4,190.350

Table 10.2-8. Area of Exposed Pit Wall in Mitchell Pit by Model Code

Year	MOA	MUPA	MLPA	MMOA	MBBA	MON	MGN	MUPN	MLPN	MMON	Total Area
-2	26.112	220.951	0	0	0	0	0	0	0	0	247.064
-1	37.808	440.415	7.153	27.590	0	0	0	57.223	7.153	75.616	652.958
1	58.374	1,433.176	410.629	12.077	0	0	0	22.142	46.296	67.432	2,050.126
2	36.951	2,067.252	631.161	2.996	0	0	0	21.971	57.923	106.858	2,925.111
3	29.308	2,386.091	863.076	2.021	0	0	0	23.244	61.648	119.254	3,484.642
4	15.567	2,336.035	1,383.356	30.096	0	0	0	16.604	132.835	152.553	4,067.046
5	12.434	2,811.101	1,551.131	40.410	0	0	0	16.579	131.592	170.966	4,734.213
10	25.196	3,030.123	2,777.065	87.639	61.347	1.095	4.382	41.629	272.777	710.973	7,012.227
20	16.913	3,407.445	3,593.490	36.081	99.224	0	3.383	28.189	392.386	826.491	8,403.603
30	16.885	3,401.692	3,588.549	36.021	97.931	0	3.377	28.141	391.724	825.096	8,389.415
40	16.741	3,372.771	3,558.039	35.714	97.098	0	3.348	27.902	388.393	818.081	8,318.088
50	16.951	3,415.112	3,602.706	36.163	98.317	0	3.390	28.252	393.269	828.351	8,422.513
51.5	16.951	3,415.112	3,602.706	36.163	98.317	0	3.390	28.252	393.269	828.351	8,422.513

Table 10.2-9. Area of Exposed Pit Wall in Kerr Pit by Model Code

Year	KA	KN	Sum
-2	0	0	0
-1	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
10	0	0	0
20	0	0	0
30	945.540	0	945.540
40	2,658.484	1.116	2,659.601
50	3,633.219	42.943	3,676.162
51.5	3,633.219	42.943	3,676.162

The scaling factors used in the pit wall water quality predictions are summarized in Table 10.2-10. The grain size and temperature effects for the pit walls were assumed to be the same as in the RSF, with the reactive fraction of the total mass estimated to be 10% (scaling factor of 0.1). The pit wall surfaces will be exposed to precipitation and 100% of the pit walls will be in contact with runoff mobilizing all sulphide mineral oxidation products; therefore, no water contact adjustment was applied. The bulk scaling factor for the pit wall was determined to be 0.05.

Table 10.2-10. Summary of Scaling Factors Used for the Pit Walls

Scaling Factor	Selected Scaling Factor
Grain Size Effect (K_r)	0.1
Temperature (K_t)	0.5
Water contact (K_c)	1
Bulk scaling factor	0.05

The humidity cells used to predict the water quality from the pit walls are defined in Section 10.1.2.2, Table 10.1-6. The water chemistry representing each model code is defined in Table 10.2-7 for Sulphurets Pit, Table 10.2-8 for Mitchell Pit, and Table 10.2-9 for Kerr Pit.

10.2.2.4.2 Closure

At closure, the full extent of the Kerr Pit and the extent of the Sulphurets Pit that is not covered by Kerr waste rock backfill will be exposed; therefore, pit wall runoff was modelled using the same method as during the operation phase. The Mitchell Pit will be flooded at the end of the operation phase; therefore runoff is not included in the water quality model.

10.2.2.4.3 Post-closure

The post-closure phase was considered using the same approach as the closure phase.

10.2.2.5 Mitchell Pit Lake

10.2.2.5.1 Operation

The Mitchell Pit Lake does not exist during the operation phase of the proposed Project.

10.2.2.5.2 Closure

The Mitchell Pit will begin to fill with water after the completion of block caving in Year 51.5. The Mitchell Pit Lake will develop over five years, with water inputs from the MDT, precipitation, and catchment surface water runoff. The MDT sub-glacial water was estimated based on stream water from the north and south slopes of the Mitchell Valley and glacial melt water.

10.2.2.5.3 Post-closure

The post-closure phase was considered using the same approach as closure.

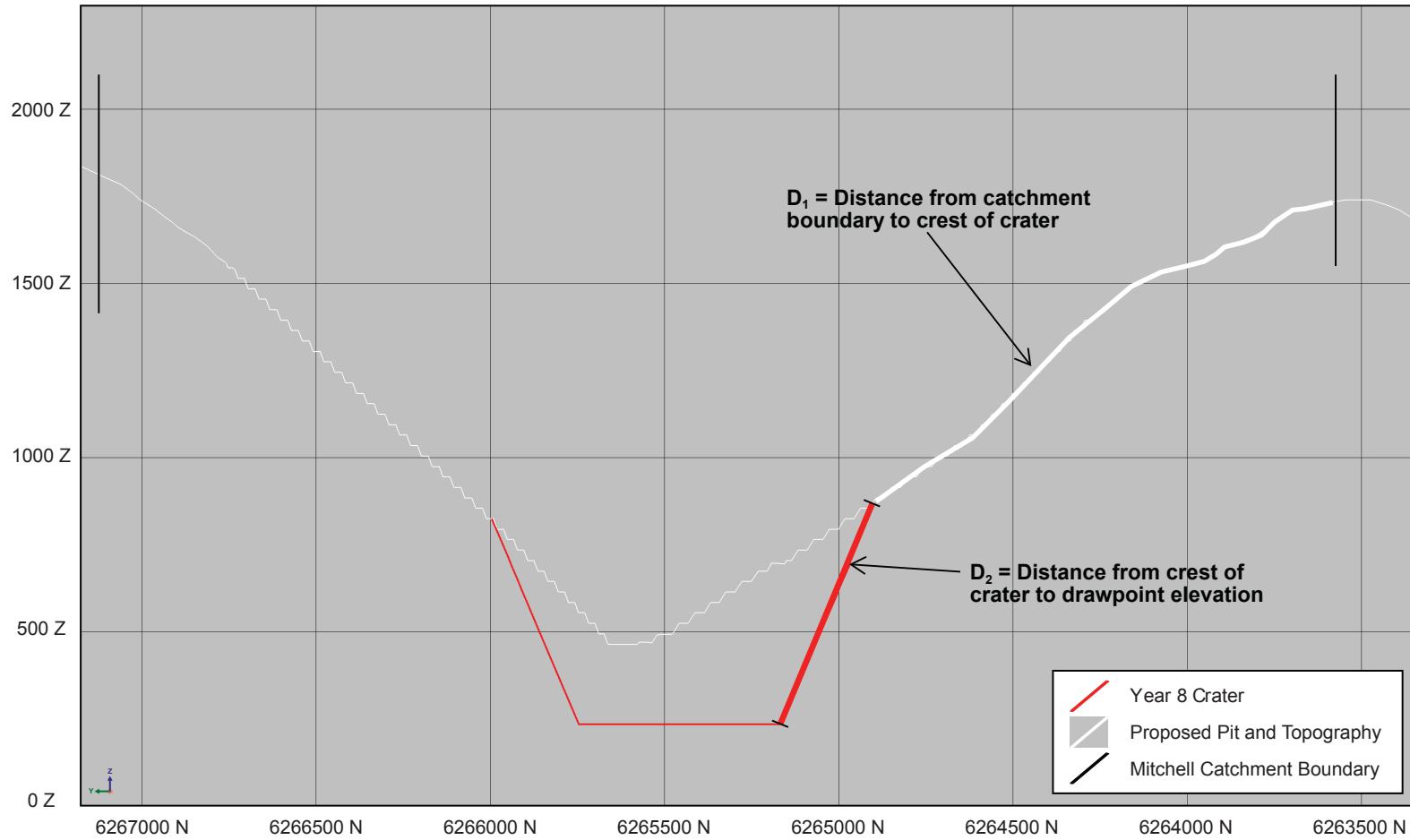
10.2.2.6 Block Caving

10.2.2.6.1 Operation

Block caving of the Mitchell and Iron Cap deposits begins in Year 26 and 32, respectively. Block caving generates a volume of disturbed material that subsides into the block cave as ore material is extracted from the cave underground. This area is called the “subsidence zone” and is expressed at the surface as a crater. In order to predict the quality of the water in the underground workings, the flow path of water through the block cave subsidence zone must be defined. Precipitation that falls within the Mitchell and Iron Cap crater areas flows directly down through the disturbed material. Precipitation that falls on the Mitchell Pit walls and runoff that bypasses surface diversions flows along the exposed rock of the pit walls, represented by line D1 in Figure 10.2-2. Runoff then preferentially flows through a very narrow zone of disturbed material within the subsidence zone and fractured rock at the outer edge of the subsidence zone, represented by line D2 in Figure 10.2-2.

The scaling factor for the subsidence zone was determined using the same temperature and water contact as the RSFs. Because the subsidence zone is not blasted rock, the proportion of fines is lower than the RSFs and is estimated to be 1%. Therefore, a bulk scaling factor of 0.001 was used for the subsidence zone. The crater surface area is presented in Table 10.2-11 and was used to determine the mass loading due to water flow from direct precipitation. The mass of disturbed material in the subsidence zone was used to determine the mass loading contribution from within the subsidence zone. The mass of material in contact with water each year for the Mitchell and Iron Cap deposits is presented in Table 10.2-12.

The water chemistry used in the model to predict drainage water quality through the Mitchell Block Cave Mine included the Mitchell bornite breccia/leach breccia acidic, lower panel Hazelton acidic, and neutral (model codes MBBA, MLPA and MLPN, respectively) humidity cells (Table 10.1-9). The Iron Cap water chemistry was predicted using the Iron Cap neutral and acidic humidity cells, and model codes ICN and ICA, respectively (Table 10.1-7).



**Cross Section of Pit and Block Cave
Indicating the Surface Areas for Model Inputs**

Figure 10.2-2

Table 10.2-11. 2D Areas Associated with Block Caving of the Mitchell and Iron Cap Deposit

Year	Mitchell		Iron Cap	
	Footprint Surface Disturbance (m ²)	Undisturbed Surface Area (m ²)	Footprint Surface Disturbance (m ²)	Undisturbed Surface Area (m ²)
26	31,515	5,766,115	--	--
27	68,595	5,729,035	--	--
28	221,135	5,576,495	--	--
29	420,738	5,376,892	--	--
30	706,427	5,091,203	--	--
31	706,427	5,091,203	--	--
32	972,927	4,824,703	44,868	1,860,216
33	972,927	4,824,703	100,019	1,805,065
34	1,104,626	4,693,004	184,564	1,720,520
35	1,192,964	4,604,666	221,135	1,683,949
36	1,258,444	4,539,186	331,624	1,573,460
37	1,322,205	4,475,425	463,424	1,441,660
38	1,396,935	4,400,695	520,666	1,384,418
39	1,431,955	4,365,675	569,752	1,335,332
40	--	--	599,491	1,305,593

Table 10.2-12. Volumes of Disturbed Material within the Mitchell and Iron Cap Subsidence Zones

Year	Mitchell	Iron Cap	Mitchell	Iron Cap
	Mass In-situ Material (Mt)		Mass of Material in Contact (Mt)	
26	16	--	18	--
27	37	--	18	--
28	120	--	18	--
29	231	--	17	--
30	373	--	16	--
31	355	--	16	--
32	477	30.40	15	4.86
33	457	64.85	15	4.72
34	535	108.73	15	4.50
35	590	127.77	14	4.40
36	607	174.41	14	4.10
37	634	235.75	14	3.75
38	667	262.28	13	3.58
39	670	284.27	13	3.44
40	649	291.06	13	3.36
41	627	276.34	13	3.36

(continued)

Table 10.2-12. Volumes of Disturbed Material within the Mitchell and Iron Cap Subsidence Zones (completed)

Year	Mitchell	Iron Cap	Mitchell	Iron Cap
	Mass In-situ Material (Mt)		Mass of Material in Contact (Mt)	
42	606	261.61	13	3.36
43	584	246.88	13	3.36
44	562	232.15	13	3.36
45	541	219.43	13	3.36
46	519	209.50	13	3.36
47	497	202.66	13	3.36
48	476	198.22	13	3.36
49	465	196.02	13	3.36
50	459	195.14	13	3.36
51	458	195.01	13	3.36

10.2.2.6.2 Closure

At closure, the Mitchell underground drainage tunnels will be plugged and the underground workings and Mitchell Pit will be flooded. Water will continue to migrate through the Iron Cap Block Cave Mine during the closure phase. The source terms used during the operation phase were applied to the water quality prediction model for closure phase.

10.2.2.6.3 Post-closure

The source terms used during the closure phase were applied to the water quality prediction model for the post-closure phase.

10.2.3 Processing and Tailing Management Area

Water and tailing management of the PTMA is structured in five stages: Stage 1 – years 0 to 25; Stage 2 – years 26 to 30; Stage 3 – years 31 to 51.5; Stage 4 – years 51.5 to 56.5; and Stage 5 – post-closure. Water quality predictions were developed for the North Cell TMF, Centre Cell TMF, and South Cell TMF. Project components contributing geochemical source terms to the water quality model include exposed tailing beaches, cycloned tailing dams, supernatant from the Treaty Process Plant, and high density sludge from the Mine Site Water Treatment Plant.

10.2.3.1 Operation

As described in Section 10.1.2.3, results from humidity cells, SACs, and pilot plant supernatant were used to estimate the water quality in the TMF. The tailing and plant supernatant source terms are presented in Tables 10.1-14 and 10.1-15. There are five stages in the development of the PTMA and the total areas representing each stage for the calculation of mass loadings is presented in Table 10.2-13. The source terms for each stage are defined below. Tailing will be deposited in the North Cell TMF from Year 1 until it reaches its maximum capacity in approximately Year 26. The ore production schedule is presented in Table 10.2-14.

Table 10.2-13. Tailing Management Facility Component Areas (in m²)

Stage	North Dam	North Cell Pond	North Cell Tailing Beaches	Splitter Dam	Centre Cell Pond
1	660,235	1,885,998	2,914,849	355,430	1,588,755
2	660,235	768,625	4,032,547	346,213	1,619,254
3	660,235	768,625	4,032,547	79,572	2,247,051
4	660,235	768,625	4,032,547	79,572	2,247,051
5	660,235	910,887	3,875,560	54,810	1,395,819
Stage	Saddle Dam	South Cell Pond	South Cell Tailing Beaches	Southeast Dam	
1	376,975				
2	378,359	1,282,497	420,471		229,515
3	32,312	1,756,693	3,357,532		699,047
4	32,312	508,035	4,606,203		699,047
5	46,561	706,251	4,441,313		699,047

Table 10.2-14. Ore Production Schedule (in kt)

Year	Mitchell Pit	Mitchell Block Cave Mine	Sulphurets Pit	Kerr Pit	Iron Cap Block Cave Mine	Total
1	27,850		1			27,851
2	26,780		17,830			44,610
3	28,520		19,030			47,550
4	28,520		19,030			47,550
5	28,520		19,030			47,550
6	31,350		16,150			47,550
7 to 10	47,450		4			189,804
11 to 20	474,500		10			474,510
21 to 23	137,092		56,701			193,793
24			56,701			56,701
25			56,701			56,701
26		6,639	56,701			63,340
27 to 30		26,554		18,100		44,654
31		19,883		9,810		29,693
32 to 40		178,944		88,290	95,530	362,764
41 to 50		189,467		126,083	97,695	413,245
51		16,480			135	16,615

The water chemistry from the north and south ponds is modelled based on the chemical contributions from the exposed beaches, and the cyclone sand dams. The water chemistry for the Centre Cell is estimated based on the contributions from the cyanide detoxification water treatment process ([Appendix 4-X](#)) and from runoff.

10.2.3.1.1 Process Plant

The water chemistry used in the water quality prediction model to represent the contribution from the Process Plant to the North Cell and South Cell (based on the mine plan) is the pilot plant supernatant from the Mitchell rougher tailing including 0.15% High Density Sludge (Table 10.1-15). Water from the Treaty Process Plant that is directed to the Centre Cell is post-cyanide detoxification and activated carbon water treatment (Table 10.1-15).

10.2.3.1.2 Cycloned Tailing Dams

The source term used to estimate the water quality from the North Cell and South Cell dams included the average release rate for the Mitchell rougher-course humidity cell for all weeks (M rougher dams). The surface area of dams in each stage of development was estimated for each stage of the TMF operation (Table 10.2-13). It is assumed that the top 0.5 m of the dams contributes to the chemical loading.

10.2.3.1.3 Exposed Tailing Beaches

The source terms used to estimate the water quality for the exposed tailing beaches included the overall average leaching rate from humidity cells for Mitchell rougher tailing (M rougher Beaches), Mitchell/Kerr rougher tailing (M/K rougher beaches), Mitchell/Sulphurets rougher tailing (M/S rougher beaches), and Iron Cap rougher tailing (IC rougher beaches). The mass of exposed tailing in the North Cell is estimated based on the assumption that 0.5 m of tailing contributes to the mass loading. The surface area of the exposed tailing for each stage is presented in Table 10.2-13.

10.2.3.2 Closure

The Treaty Process Plant will be decommissioned at the end of the operation phase; therefore, no contribution from the Treaty Process Plant is included in the water quality prediction model for closure. The source terms used during the operation phase for the cyclone tailing dams and exposed tailing beaches in the north and south cells were applied to the water quality prediction model for the closure phase.

Mitchell and Iron Cap ore will be the last ore deposits mined and processed. Therefore, at closure the exposed material in the dams will consist predominantly of Mitchell and Iron Cap tailing. The total load off the dams into the North Cell and South Cell was determined based on the steady state rates from the average between the Mitchell rougher humidity cell and the Iron Cap humidity cell. The mass of material was determined based on the exposed area of the dams with a reactive depth of 0.5 m contributing to the load.

The only water chemistry source term for the Centre Cell at closure is runoff, as the tailing remains flooded.

10.2.3.3 Post-closure

The source terms used during the closure phase were applied to the water quality prediction model for the post-closure phase.

10.3 Geochemistry Conclusions

A five-year ML/ARD characterization program resulted in the analysis of over 2,000 waste rock, ore, tailing, and non-deposit material ABA tests; 48 waste rock humidity cells (12 ore, 28 waste rock, and 8 tailing samples); 17 field leach barrels from waste rock and ore samples; six SACs; and three aging tests. The laboratory and field results were used to develop source terms (e.g., water quality estimates) for the predictive water quality model. Source terms were developed for RSFs; Sulphurets Pit backfill; pit wall run-off; the Mitchell Pit Lake; block cave mines; and the ponds, beaches, and dams of the TMF.

The Mine Site, PTMA, and non-deposit components of the proposed Project have the potential to adversely affect surface water and groundwater quality. Chapters 12, 14, and 26 provide further details on valued component selection, scoping, mitigation, the significance of residual and cumulative effects, and proposed management plans.

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