March 20, 2015

MOUNT POLLEY MINE

Approach for Long-Term Water Management Plan Development

Step A:

- Define study questions;
- Develop process that fits the purpose;
- Consult and involve.

Step B:

- Goldsim® model that reflects current and future water quality and quantity range.

Step C:

- Evaluation of both short and long term options;
- Proven technologies;
- Identify preferred options.

Step D:

- Evaluate risks and benefits of each option;
- High level options assessment (Health and environment);
- Detailed evaluations of options.

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Distribution:

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REPORT

Golder Associates

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List of Abbreviations:

AACE – Association for the Advancement of Cost Engineering

BAT – best achievable technology

BC – British Columbia

BCR – biochemical reactor

COPC – constituents of potential concern

Fe2+ – ferrous iron

$FeCO_3$ – iron carbonate

H3D – three dimensional hydrodynamic model

HDS – high density sludge

HDS Thickener – clarifier/thickener

KCl – potassium chloride

L – litre

m – metres

MAD – mean annual discharge

MEM – Ministry of Energy and Mines

mg – milligrams

MIW – Mine Influenced Water

Mm^3 – million cubic meters

$MnCO_3$ – manganese carbonate

MoE – Ministry of Environment

MPMC – Mount Polley Mining Corporation

Mt – million tonnes

N_2 – nitrogen gas

NaCl – common salt (sodium chloride)

NTU – nephelometric turbidity units

PAG – potentially acid generating

QRRC – Quesnel River Research Centre

RO – reverse osmosis

S – sulphur

SBA – strong base anionic

Se_2O_4 – selenium oxide

SRB – sulfate-reducing bacteria

SRBR – sulfate-reducing bioreactor

TSF – Tailings Storage Facility

TSS – total suspended solids

UM3 – EPA Visual Plumes UM3 model

USBR – The United States Bureau of Reclamation

WBM – water balance model

$ZnCO_3$ – zinc carbonate

1.0 INTRODUCTION

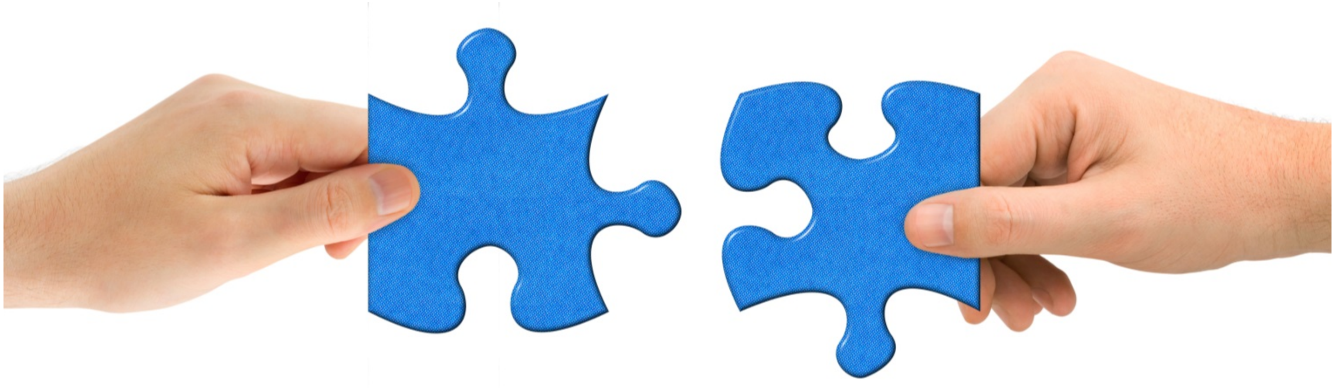
Mount Polley Mining Corporation (MPMC) has a surplus water balance. In its first stage of its development (1997 – 2001), the Mount Polley Mine recycled water from the Tailings Storage Facility (TSF) for re-use in the milling process. Through this period of operation, the mine did not require a discharge to continue operating. When the mine re-opened in 2005, a surplus of water was present and a permit amendment was sought to enable discharge of surplus water into Hazeltine Creek. This permit amendment, issued approximately five years after application for it, imposed certain limits for effluent quality, non-toxicity requirements and target levels for specific analytes in Hazeltine Creek as well as the following volume limits:

- A maximum annual discharge of 1.4 million m^3 (Mm^3) per year could be discharged; and
- A permitted discharge amount was not to exceed 35% of the daily flow of Hazeltine Creek.

The mine expanded its mine life and therefore the footprint of the operation and the contact water that must be managed had also expanded. Because of the need to address water volumes, MPMC proposed an interim measure utilizing a reverse osmosis plant with discharge of treated water to Polley Lake. The reject water from the RO plant was to be directed to the TSF. The proposed application of RO was intended for a short (four year) period of time and was not intended as a suitable technology post-closure.

Since that time, a foundation design flaw and resulting foundation failure of a section of the TSF dam on August 4, 2014 resulted in a breach of the TSF. An expert panel appointed by the Minister of Energy and Mines that investigated the cause of the breach also recommended that tailings impoundments not be used as water storage reservoirs. The annual water volume to be treated is now estimated to be on the order of 5-6 Mm^3; however, in the short term, there are additional water volumes that have accumulated and thus the total volume to discharge will need to be greater.

Following the TSF dam breach on August 4, MPMC is currently pumping contact water from to the Springer pit while the breached TSF dam is being repaired. However, Springer Pit has a finite capacity and it is estimated that that once water in the Springer Pit reaches the 1030 m elevation, the pit water will infiltrate into groundwater that will report to Bootjack Lake. There is therefore some urgency to developing options for treatment and disposal of treated contact water.



2.0 APPROACH TO DEVELOPING A LONG-TERM WATER MANAGEMENT PLAN

The approach proposed takes a long-term perspective to arrive at an effective, long term water management plan for the Mount Polley Mine site that will protect human health and the environment. It also recognizes that in the context of urgency, short term measures may be necessary; however, such measures should fit within the context of a long-term vision.

Golder acknowledges that First Nations and the local community are likely to be concerned with the idea of a discharge to any surface water, regardless of the fact that a discharge is an inevitable reality. A design-and-defend approach, where a plan is assembled, presented and defended against questions lacks the transparency that is necessary to build the trust and confidence in the plan that will build support for it. For this reason, Golder proposes to actively consult while the plan is being developed. This consultation will range across a spectrum from communication through to involvement where appropriate. The depth and breadth of consultation proposed and already underway exceeds the minimum requirements of the *Public Notification Regulation,* which defines the consultation necessary for the processing of an effluent permit. The procedural steps required by that regulation (e.g., publishing in newspapers, posting of signs, etc.) are well defined and will be carried out as the plan and effluent permit application progresses.

Development of the plan will follow the following key steps, depicted graphically on the report cover:

Step A: Establish a project definition incorporating scenarios ranging from existing condition to post closure (Section 2.2)

Step B: Conduct water quantity and quality assessment (Section 3.0)

Step C: Identify, screen and develop water treatment options (Section 4.0)

Step D: Determine treated effluent management options (Section 5.0)

These steps are supported by three key objectives: effectiveness of the solution needed, human health and environmental protection and involvement through open communication and opportunity for involvement by external technical specialists.

2.1 Consultation

The long-term Water Management Plan for Mount Polley will be developed in consultation with regulatory agencies, First Nations, and the local community. MPMC and Golder have already met with the Williams Lake Indian Band and Soda Creek Indian Band and subsequently met with officials of the MoE and the Ministry of Energy and Mines (MEM) to introduce the need for a long-term plan with a long-term solution, regardless of whether or not mining occurs again at Mount Polley and to introduce our initial thoughts on how that plan might look. No analyses or options assessments had yet been carried out. Recognizing that these were early meetings, Golder has attempted to assimilate that feedback and has developed this approach document to outline how we propose to shape the plan development consistent with what we have heard. Initial workshops discussing specific technical aspects have also included technical specialists retained by the First Nation.

MPMC has been regularly meeting with the Likely community, has participated in community meetings in Williams Lake and Soda Creek and recently met with community members from Horsefly. In the next meetings to come, MPMC will present the approach that they plan to follow, listen to feedback and adapt the plan as appropriate. In the interim, MPMC have sent a mail-out to all residents in Likely to advise them of the water management situation and plan, to advise them of the steps that MPMC are taking and to let them know that MPMC will be discussing these plans at the next community meeting.

2.2 Technical Approach

The Water Management Plan will consider four possible mine water scenarios: Existing Conditions, Restricted Start-up, Resumed Operations, and Closure. These scenarios are described below.

2.2.1 Existing Condition

The Existing Conditions scenario reflects the current, post-breach water management. All mine contact water is being directed to Springer Pit either by gravity flow or by pump from the Central Collection Sump. The TSF embankment is currently being repaired to contain runoff from the 2015 freshet, which will be pumped to Springer Pit. Based on the existing Mount Polley water balance model, it is estimated that the average annual contact water volume under existing conditions is approximately 5.4 Mm^3.

The total storage volume in Springer Pit up to the spill-over elevation of 1,050 m is approximately 14.5 Mm^3. However, when the water surface level in Springer Pit rises above approximately 1,030 m, groundwater is predicted to flow out from the pit towards Bootjack Lake (Golder 2014). The total storage volume up to 1,030 m elevation is approximately 10 Mm^3, which is estimated to be approximately two average years of accumulated contact water from Mount Polley. As of March 1, 2015, approximately 4.5 Mm^3 of water was stored in Springer Pit.

2.2.2 Restricted Start-up

Restricted Start-up refers to proposed limited mining of 4 million tonnes (Mt) of higher-grade ore from Cariboo Pit and from underground workings. The ore would be processed in the mill with tailings deposited in Springer Pit. The volume of contact water generated during the Restricted Start-up period would be similar to Existing Conditions.

2.2.3 Resumed Operations

Resumed Operations refers to mining after commissioning of a re-built TSF. For the purposes of the long term water management plan, Golder has taken note of the Minister's panel recommendation that water not be stored in tailings storage facilities and that has been taken to mean that surplus water cannot be stored in the TSF.

2.2.4 Closure

Closure refers to the phase after completion of mining. It is recognized as a distinct phase in a mine life because there are various activities that occur leading up to and following closure and long-term maintenance is necessary. The volume of contact water generated during closure can be reduced through reclamation and rehabilitation of disturbed areas including waste rock dumps, TSF, roads and mill areas.

Potentially acid generating (PAG) waste rock is currently being stockpiled at the Mine, and will be deposited in Springer Pit to be permanently submerged under a water cover to prevent acid generation by reducing exposure to oxygen.

Because the mine is not in active operation and the closure phase extends over a long period of time, solutions that are effective, offer long-term resilience and low maintenance are preferred.

2.3 Water Management Plan: Connection to Permitting Processes

2.3.1 Restricted Restart Permit

MPMC are seeking a permit from MEM to process up to 4Mt of ore. MEM originally tied the processing of the restricted restart permit to having a water management plan in place. Since that time, MEM have advised that they will separate out the two processes but to enable the restricted restart permit to be processed, they would require that MPMC provide a clearly articulated approach towards managing site water balance in the long term that includes consideration of options for treatment and effluent disposal, including obtaining permits from MoE. In addition to the permit from MEM, MoE will need to issue a permit amendment that would allow the deposit of tailings to Springer Pit should the restricted restart permit be granted.

MEM and MoE also required that a contingency measure be identified for water treatment and disposal to address the finite capacity of Springer Pit and the estimated time frame over which discharge would become necessary. This contingency is primarily to address unforeseeable weather patterns where high cumulative rainfall would result in Springer Pit capacity being consumed ahead of schedule. The present document articulates MPMC's approach to water management planning and identifies a contingency (Section 4.3).

Regardless of the status of the restricted restart permit, MPMC are proceeding with the long-term water management plan.

2.3.2 Effluent Permit and Short-Term Contingency

The Mount Polley site has a positive water balance. In order to maintain a neutral balance where water does not accumulate on site, treated water must be discharged. For mine contact water, such discharge requires that an amended permit be issued by the MoE to allow the discharge of treated effluent to a waterbody. For the sake of clarity and because of specific information requirements relating to a major permit amendment, the amendment sought for the long-term effluent permit can be considered to effectively be a separate permit. The MoE have provided their expectations for a permit application in their letter of March 3, 2015. These requirements, with some changes as agreed in a teleconference meeting, are common requirements for studies that are needed to advance an effluent permit for a significant effluent permitting process and these requirements are described in guidance documents and Golder's project team has experience carrying out such studies. Mount Polley has already initiated some of this work, including early consultation; however, normal permitting timelines could be on the order of six months or more though some acceleration would be possible on both the company and government timelines. For the short term contingency, an interim permit amendment will be needed.

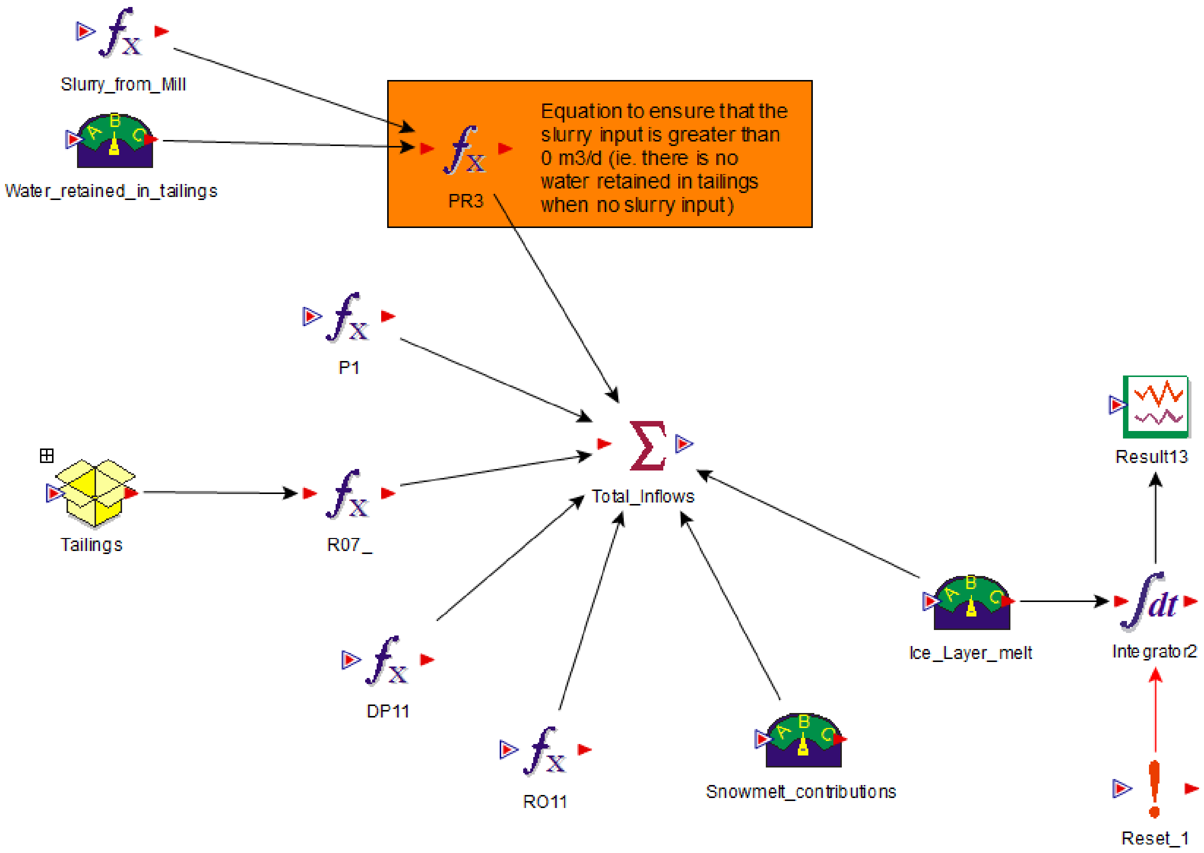
In the event that cumulative climatic conditions are wetter than average, the pit could fill earlier than expected. Therefore MoE and MEM have required that a contingency be developed such that it could be implemented relatively rapidly. A viable contingency that can be implemented is proposed in Section 4.3 of this document. For treatment, existing infrastructure is in place if the restricted restart permit is granted because lime addition at the mill, using existing infrastructure is straightforward. The infrastructure for liming Springer Pit, should the permit not be granted would need to be constructed but could be within the timeframe available.

To implement a contingency, an interim (to differentiate between the contingency and the long-term solution) permit amendment is needed. An evaluation to determine if the treated water will impair the receiving environment uses will have been concluded through modeling and other work that is already underway. MPMC have elected to initiate consultation early in this process.

2.3.3 Federal Requirements

The main federal statutory implications for the water management plan are those contained within the *Fisheries Act* and the *Metal Mining Effluent Regulation* (MMER), a regulation made under that Act. Although a permit is not required under either statute, there are general prohibitions against the deposit of a deleterious substance in the *Fisheries Act* and specific requirements for effluent quality in the MMER. The MMER also has a number of administrative requirements such as advance notification and technical requirements associated with effluent and receiving environment monitoring. MPMC have contacted Environment Canada and these requirements will be addressed in parallel with the provincial process.

The expected effluent quality requirements of any amended permit would also inherently address the federal requirements for effluent quality and the general prohibition against the deposit of a deleterious substance. Similarly, it is expected that there would be harmonization of MMER and permit effluent and receiving environment monitoring.



3.0 WATER QUANTITY AND QUALITY MODELING

Golder will develop a water quality and quantity model and has already started this task. As water management plans are developed and implemented, questions arise and “what if” questions are posed. Such circumstances would necessarily require laborious recalculations if done by hand; however, a computer model allows the exploration of various scenarios with relative speed and efficiency. There is an up-front requirement to build the model. However, Golder feels that this will be time well spent and will be a useful tool to support the consultative approach described above and to accommodate changes to conceptual designs as those designs progress.

The model will also be used to develop inputs for the treatment options analysis. The following inputs will go into that analysis:

- Identification of constituents that may require treatment so that an appropriate technology can be selected;
- The estimated volume of water that is to be treated; and
- The expected chemical profile of the treatment influent water.

Project specific constituents of potential concern (COPC) are initially identified through a screening level comparison of site monitoring results or site-specific geochemical test results to convenient screening criteria (e.g., environmental quality guidelines). Typically, conservative criteria are used so that a constituent is more likely to be identified as a COPC than to not be. The estimated volume and chemical profile of the water to be treated is evaluated through the development of a site model that predicts future changes to treatment influent water quantity and quality. The results of the model can also be used to identify additional COPCs that are not initially screened as COPCs. The following subsections present the initial COPC screening results as well as the path forward for predicting future water quantities and qualities that will be directed to the treatment system and then to discharge.

3.1 Identifying Constituents of Potential Concern

The first stage of the treatment options analysis is to identify COPC that may require treatment. MPMC has a site water quality monitoring program and the data from this program were used to identify COPCs for input into the treatment options analysis. MPMC monitors water quality at the following locations:

- Springer Pit;
- TSF supernatant; and
- The Perimeter Pond of the TSF.

Table 1 presents a summary of the water quality monitoring results from the above locations, and detailed results are provided in Appendix A. To identify COPCs, general parameters (e.g., pH and total suspended solids [TSS]), major ions (e.g., chloride, nitrate and sulphate), total and dissolved metals were compared to the following environmental benchmarks:

- Metal Mining Effluent Regulations (MMER; SOR/2002-222): Schedule 4 maximum authorized concentration in a grab sample. These values are applicable to mine water effluents at the point of discharge.
- BC Approved Water Quality Guidelines (WQG; BC MoE 2006). The BC WQG are inherently conservative concentrations which are intended to be applied to receiving environment water bodies and are not directly applicable to effluents at the end of pipe. They are included here as a first level of screening for the purpose of qualitatively identifying COPCs that require further consideration in the site waste and water management plans. Exceedances of ambient WQG should not be interpreted to mean that concentrations of these parameters will be elevated in the discharge from the Project, or that adverse effects to aquatic receptors will occur.

Table 2 provides a summary of the constituents with reported concentrations greater than the above environmental benchmarks. These constituents are considered COPCs at Mount Polley, and are typical of parameters included in mining assessments.

Table 1: Summary of Site Water Quality Monitoring Results

Parameter	Screening Criteria			Springer Pit - Post-TSF Breach				TSF Supernatant				Perimeter Pond			
	British Columbia Water Quality (BCWQ) Guidelines for the Protection of Freshwater Aquatic Life		Metal Mining Effluent Regulations (MMER)												
	30-Day Mean Concentration	Maximum	Maximum Authorized Concentration in a Grab Sample	Average	Minimum	Maximum	95th Percentile	Average	Minimum	Maximum	95th Percentile	Average	Minimum	Maximum	95th Percentile
Specific Conductance (in situ) (µs/cm)	-	-	-	1225	1139	1309	1306	1211	1072	1287	1285	1202	797	1493	1410
pH (in situ) (pH)	-	-	-	8.2	7.8	8.7	8.6	8.8	8.1	9.7	9.4	7.9	7.1	8.4	8.4
Temperature (in situ) (°C)	-	-	-	9.5	3.6	14	13	6.7	1.2	22	18	4.9	0	18	16
Turbidity (in situ) (NTU)	-	-	-	6.4	2.1	14	12	7.5	2.4	12	11	15	4.2	38	33
Alkalinity (mg/L as CaCO3)	-	-	-	92	84	101	100	32	27	38	37	102	72	153	139
Conductivity (µs/cm)	-	-	-	1216	1170	1270	1266	1169	1040	1260	1257	1177	773	1540	1490
Hardness (mg/L as CaCO3)	-	-	-	612	578	668	663	448	393	489	485	615	395	852	757
pH (pH)	6.5-9	6.5-9	-	8.0	7.7	8.2	8.1	7.8	7.6	8.0	8.0	8.0	7.8	8.2	8.1
Total Suspended Solids (mg/L)	-	-	30	8.1	1.5	12	12	16	1.5	55	44	17	1.5	81	32
Chloride (mg/L)	150	600	-	11	9.9	13	13	23	20	26	26	9.9	2.5	16	14
Nitrate (mg/L as N)	3	32.8	-	**8.5**	**7.8**	**9.0**	**9.0**	**7.2**	**6.3**	**7.8**	**7.7**	**7.9**	**5.2**	**11**	**10**
Nitrite (mg/L as N)	0.02-0.2[a]	0.06-0.6[a]	-	0.072	0.043	0.09	0.089	0.12	0.088	0.14	0.14	**0.14**	0.005	**0.48**	**0.28**
Sulphate (mg/L)	128-429[b]	-	-	**558**	**526**	**598**	**595**	**540**	**463**	**583**	**581**	**542**	291	**761**	**731**
Dissolved Metals															
Aluminum (mg/L)	0.023-0.05[c]	0.0068-0.1[c]	-	**0.26**	**0.11**	**0.51**	**0.47**	**0.66**	**0.078**	**2.0**	**1.7**	**1.1**	**0.12**	**4.0**	**3.0**
Cadmium (mg/L)	0.00038-0.00046[b]	0.000038-0.0028[b]	-	0.00011	0.000093	0.00015	0.00014	0.000042	0.000025	0.00012	0.000095	0.000084	0.000035	0.00017	0.00015
Iron (mg/L)	-	0.35	-	0.23	0.093	0.41	0.39	0.4	0.046	1.5	1.2	1.3	0.13	5.7	2.8
Total Metals															
Antimony (mg/L)	-	0.02	-	0.0018	0.0013	0.0021	0.0021	0.002	0.002	0.002	0.002	0.0013	0.00052	0.003	0.0023
Arsenic (mg/L)	-	0.005	1	0.0019	0.0017	0.0022	0.0021	0.0021	0.0021	0.0021	0.0021	0.001	0.00052	0.0018	0.0014
Barium (mg/L)	1	5	-	0.039	0.036	0.045	0.044	0.054	0.054	0.054	0.054	0.044	0.037	0.058	0.051
Beryllium (mg/L)	0.0053	-	-	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Boron (mg/L)	-	1.2	-	0.16	0.14	0.18	0.18	0.12	0.12	0.12	0.12	0.2	0.078	0.3	0.29
Chromium (mg/L)	-	0.001	-	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Cobalt (mg/L)	0.004	0.11	-	0.0012	0.00077	0.0015	0.0015	0.00005	0.00005	0.00005	0.00005	0.00052	0.00005	0.00088	0.00085
Copper (mg/L)	0.002-0.034[b]	0.002-0.082[b]	0.6	**0.045**	**0.039**	**0.049**	**0.048**	0.00093	0.00093	0.00093	0.00093	0.008	0.0036	**0.036**	0.017
Iron (mg/L)	-	1	-	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.016	0.015	0.032	0.018
Lead (mg/L)	0.0034-0.052[b]	0.003-1.25[b]	0.4	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000059	0.000025	0.00028	0.00018

Parameter	Screening Criteria			Springer Pit - Post-TSF Breach				TSF Supernatant				Perimeter Pond			
	British Columbia Water Quality (BCWQ) Guidelines for the Protection of Freshwater Aquatic Life		Metal Mining Effluent Regulations (MMER)												
	30-Day Mean Concentration	Maximum	Maximum Authorized Concentration in a Grab Sample	Average	Minimum	Maximum	95th Percentile	Average	Minimum	Maximum	95th Percentile	Average	Minimum	Maximum	95th Percentile
Lithium (mg/L)	0.096	0.87	-	0.0074	0.0064	0.008	0.008	0.012	0.012	0.012	0.012	0.0064	0.003	0.0088	0.0086
Manganese (mg/L)	0.63-4.35[b]	0.6-9.93[b]	-	0.11	0.094	0.15	0.14	0.012	0.012	0.012	0.012	0.25	0.0009	0.39	0.39
Molybdenum (mg/L)	1	2	-	0.16	0.15	0.17	0.17	0.18	0.18	0.18	0.18	0.14	0.062	0.19	0.19
Nickel (mg/L)	-	0.025-0.15[b]	1	0.00074	0.00066	0.00084	0.00083	0.00025	0.00025	0.00025	0.00025	0.00093	0.00025	0.0052	0.0024
Selenium (mg/L)	-	0.002	-	0.046	0.039	0.054	0.053	0.027	0.027	0.027	0.027	0.025	0.015	0.04	0.039
Silver (mg/L)	0.00005-0.15[b]	0.001-0.003[b]	-	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Thallium (mg/L)	-	0.0003	-	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.0000057	0.000005	0.000012	0.00001
Titanium (mg/L)	-	2	-	0.02	0.019	0.021	0.021	0.013	0.013	0.013	0.013	0.013	0.005	0.024	0.022
Uranium (mg/L)	-	0.3	-	0.0049	0.0039	0.0057	0.0056	0.001	0.001	0.001	0.001	0.0035	0.0013	0.006	0.0052
Vanadium (mg/L)	-	0.006	-	0.0024	0.0018	0.0031	0.003	0.0034	0.0034	0.0034	0.0034	0.00079	0.0005	0.0015	0.0014
Zinc (mg/L)	0.0075-0.58[b]	0.033-0.6[b]	1	0.0023	0.0015	0.0037	0.0036	0.0015	0.0015	0.0015	0.0015	0.006	0.0015	0.022	0.014

Notes:

a) Chloride dependent guideline
b) Hardness dependent guideline
c) pH dependent guideline

123	Denotes a concentration that is greater than the 30-day average BCWQ guideline for freshwater aquatic
123	Denotes a concentration that is greater than the BCWQ maximum guideline for freshwater aquatic life
123	Denotes a concentration that is greater than the MMER maximum authorized concentration in a grab sample

Table 2: Summary of Constituents of Potential Concern

Monitoring Location	British Columbia Water Quality (BCWQ) Guidelines for the Protection of Freshwater Aquatic Life		Metal Mining Effluent Regulations (MMER)
	30-Day Average	**Maximum**	**Maximum Authorized Concentration in a Grab Sample**
Springer Pit	Nitrate[min], sulphate[min], dissolved aluminum[min], and total copper[min]	Dissolved aluminum[min], dissolved iron[95th], and total selenium[min]	-
TSF Supernatant	Nitrate[min], and sulphate[min], and dissolved aluminum[min]	Dissolved aluminum[avg], dissolved iron[avg], and total selenium[min]	Total suspended solids[95th]
Perimeter Pond	Nitrate[min], nitrite[avg], sulphate[avg], dissolved aluminum[min], and total copper[max]	Dissolved aluminum[min], dissolved iron[avg], total antimony[95th], and total selenium[min]	Total suspended solids[95th]

Notes:

[min] - Indicates the minimum reported concentration is greater than the screening criteria

[avg] - Indicates the average reported concentration is greater than the screening criteria

[max] - Indicates the maximum reported concentration is greater than the screening criteria

[95th] - Indicates the 95th percentile reported concentration is greater than the screening criteria

In addition to the above screening approach, constituents that exhibited increasing trends in the TSF over the monitoring period from January 1997 to January 2003 (SRK 2013) were also considered to be COPCs at Mount Polley. The following constituents exhibit increasing trends in the TSF during operation of the Mount Polley Mine: molybdenum, nitrate, selenium, and sulphate.

3.2 Development of the Site Wide Model

As part of the treatment options analysis, a site model will be developed in GoldSim® (GoldSim 2010) to estimate the quantity and quality of the treatment system influent for the scenarios discussed in Section 2.2. GoldSim is a graphical, object-oriented mathematical model in which all input parameters and functions are defined by the user and are built as individual objects or elements linked together by mathematical expressions. The object-based nature of the model is designed to facilitate an understanding of the various factors which control an engineered or natural system and predict the future performance of the system. GoldSim is widely used for mine water quantity and water quality studies.

GoldSim will be used to develop the water model for the following reasons:

- GoldSim model inputs can be entered stochastically allowing statistics and probabilities to be assigned to the model outputs (quantity and quality); and
- The water quantity and quality modules, as well as the proposed options identified in the treatment options analysis can be directly linked allowing all three models to be updated simultaneously when evaluating various sensitivity scenarios or alternate water management strategies.

Golder understands the Springer Pit will be the central water management reservoir that will be the main source of water to the treatment system during Existing Conditions and Restricted Start-up scenarios. Therefore, the site water model will initially be designed to consider all processes in Springer Pit that will materially affect water quantity and quality, as shown in Figure 1. The conceptual model includes the drivers of expected water quality during filling of the pit under the existing water management strategy (Figure 1a) and the influence of storing tailings in the pit during the restricted start-up (Figure 1b). A conceptual water quality model for the restricted start-up and closure phases will be derived once the details of these scenarios are finalized.

Prior to developing the model, a data review and gap analysis will be conducted to confirm the available information is sufficient to provide input into the treatment options analysis. Should data gaps be identified, they will filled through additional study and/or testing as part of the treatment influent water quality modeling exercise.

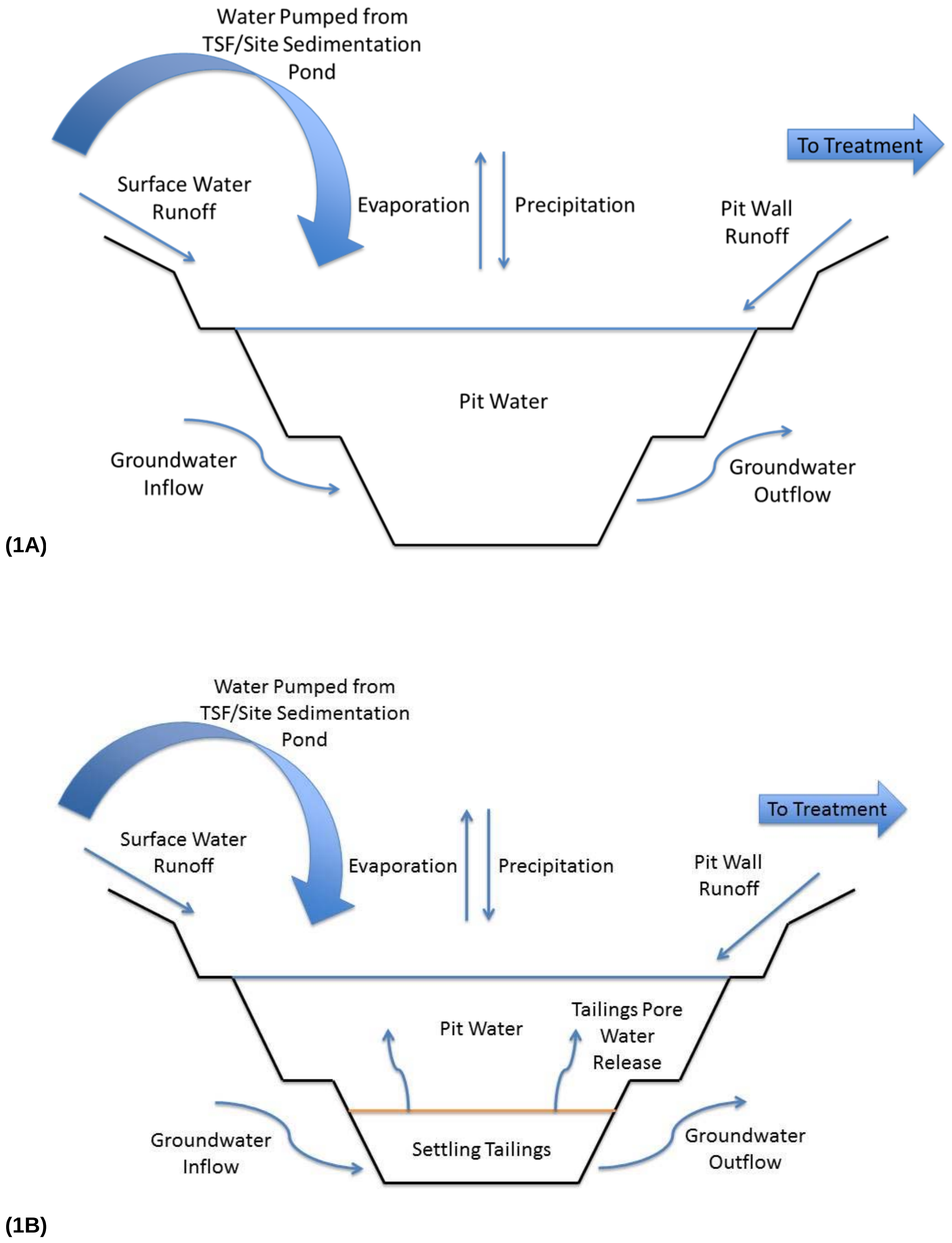


Figure 1: Conceptual Springer Pit Water Quality Model

3.2.1 Water Quantity Module

A site wide water balance module (WBM) will be developed in GoldSim to track flows of minewater across the site. The WBM will include the following inputs:

- precipitation as rain and snow;
- snowpack accumulation and melting;
- evaporation from ponds and enhanced evaporation;
- runoff from mine areas including natural catchments, open pits, waste rock dumps, tailings, roads and other disturbed mine areas;
- inflows and outflows to and from Bootjack and Polley lakes;
- flows in Morehead and Hazeltine creeks;
- groundwater inflow and outflow to and from Springer and Cariboo pits;
- accumulated volumes in ponds and sumps;
- TSF supernatant water;
- pumping; and
- process water flows.

The model will operate on a monthly time step to determine volumes of contact water at the mine, and to assess the required discharge volumes and rates.

Options will be provided to operate the WBM in either: 1) a deterministic mode for average year, and 1-in-10 year through 1-in-200-year precipitation wet and dry scenarios, or 2) using a stochastic monthly precipitation generator to provide probabilistic results.

The deterministic scenarios are useful for providing the average, and upper and lower bounds on water volumes expected over one year. The stochastic scenario can analyse hundreds of years of simulated data to provide a probabilistic result, such as the probability of Springer Pit water level reaching 1030 m elevation in the fall of 2015. Precipitation represents the major input to the water balance and other parameters such as groundwater inflows, while comparatively minor components, can also be represented by stochastic inputs. Furthermore, the stochastic data will be used to assess multiple “realizations” of the mine life to capture multi-year wet and dry periods.

The WBM will be calibrated and verified using historic climate, flow, pumping and accumulated water volume data collected at the mine, and flow data from Hazeltine and Morehead creeks. Simulated flows and volumes from the WBM will be compared to measured values, and model parameters adjusted to optimize model performance.

The WBM will be coupled with the water-quality module (Section 3.2.2) to support the design and assessment of alternate water management and treatment options for different scenarios of mine operation from current conditions through closure.

3.2.2 Water Quality Module

The water quality module will be developed to estimate treatment influent chemistries for all sources requiring treatment. Additionally, the treated effluent can be incorporated into a receiving environment model to predict changes to surface water quality depending on the discharge options selected.

Treatment Influent Water Quality

Treatment influent water qualities will be estimated through the development of a water quality module using the Contaminant Transport component of GoldSim (GoldSim 2010) applying industry best practices (Maest 2005; INAP 2009; MEND 2009) for geochemical models. Within the GoldSim module, water quality monitoring (surface and groundwater) and geochemical data will be used to estimate chemical loadings for each site flow (e.g., TSF runoff water quality, pit wall rock runoff) that could influence treatment influent water quality. SRK Consulting (Canada) Inc. (SRK) will derive geochemical source terms for input into the model using the proposed approach (SRK 2015) presented in Appendix B. The water quality module may include source terms from the following locations:

- Ore stockpiles;
- Ex-pit waste rock dumps;
- Backfilled waste rock;
- Exposed tailings in the impoundment;
- Rock fill and tailings used to construct the impoundment;
- Magnetite stockpiles;
- Sulphur stockpiles;
- Overburden stockpiles;
- Construction fill and roads; and
- Pit walls.

Within the model, the source loadings will be conservatively mixed with surface runoff and groundwater inflows in their relative proportions (as determined based on the water balance) to predict the treatment influent water quality. To predict whether the concentrations of a constituent may be influenced by the solubility of geochemically credible minerals, water qualities produced from the GoldSim model will be evaluated using the geochemical speciation code PHREEQC (Parkhurst and Appelo 1999). PHREEQC is an equilibrium speciation and mass-transfer code that was developed by the United States Geological Survey (USGS). The model has gained widespread use and acceptance by the regulatory and technical community both in North America and abroad. This model has the ability to simulate the pertinent geochemical processes, such as mixing of multiple solutions, precipitation/dissolution of selected solids, redox reactions, evaporation, atmospheric interaction, and adsorption of metals. If mineral phases are identified to have the potential to precipitate from solution, solutions will be equilibrated with these phases to establish solubility limits for mine site effluents that will be incorporated into the GoldSim water quality module.

To evaluate the expected range of conditions in treatment influent chemistry and potential uncertainty in predictions at different points in the mine life, stochastic (probabilistic) input water qualities will be developed for each input. This means the model will randomly select a value for each input, within the statistical range of the input parameters, each time the model is run. Where the data gap analysis identifies a low quantity of input data, sensitivity analyses will be undertaken, expanding the input data set to capture a broader range of variability.

As indicated in Section 4.0, Golder understands the Springer Pit will be the central water management reservoir that will be the main source of water to the treatment system during existing conditions and restricted start-up. Therefore, the model will initially be calibrated to the observed conditions in Springer pit using existing monitoring data (flow and quality) and geochemical source terms provided by SRK.

Receiving Environment Model

Several potential locations may be viable for the treated effluent to be discharged (Figure 2). Following an initial evaluation of the effluent discharge options, a receiving environment component can be added to the GoldSim model and be calibrated for each proposed discharge location. Effluent will be conservatively mixed in GoldSim to predict changes to surface water quality at proposed discharge location. This model will be based on mass balance.

Should the options analysis identify Quesnel Lake as the preferred discharge location, the modeling will be carried out using an existing hydrodynamic model developed for Quesnel Lake's west arm by TetraTech EBA. The EPA Visual Plumes UM3 model will be used for near field (IDZ) plume modeling and will be embedded in the three-dimensional hydrodynamic model H3D, to evaluate the behaviour of an outfall plume proposed to enter Quesnel Lake. H3D is a three-dimensional hydrodynamic model that has been shown to accurately simulate the effects of tide, wind, river flow, density and time variability in receiving water bodies (Stronach et. al. 1993). The Quesnel Lake implementation of the model was developed by TetraTech-EBA to simulate the temperature and sediment regime of the lake after the TSF breach and in subsequent years.

The UM3 and H3D models will be run over multiple years to gauge possible buildup of plume constituent material, and to examine the effects of hydrological and meteorological variability on the plume's fate. The possibility of buildup of effluent constituents in the receiving water can be modeled at different outfall depths. In Quesnel Lake, a water mass consisting of cold water from the spring turnover can be isolated at the bottom of the West Arm, mixing with the main body of the lake during seiche events but otherwise remaining in place until the fall turnover. The modelling will be able to examine such limnological phenomena and determine if there is an optimal depth for effluent dispersal and avoidance of potential buildup of material, if buildup is an issue.

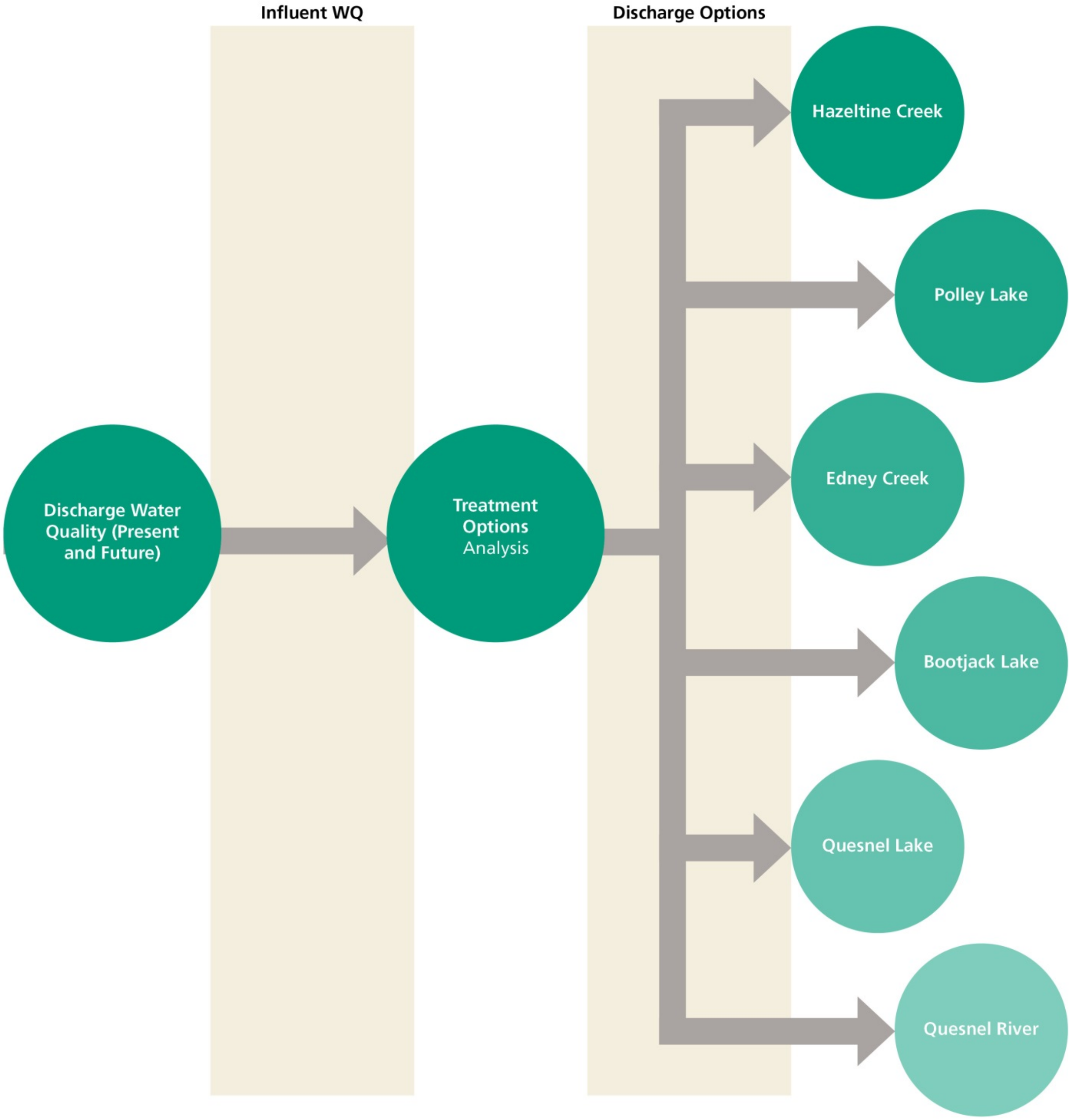


Figure 2: Treated Effluent Discharge Options

The EPCOR mine water treatment at Britannia, BC

4.0 WATER TREATMENT OPTIONS

Although the mine water quality at the Mount Polley Mine is of a considerably higher quality than most mines, treatment is necessary because control at source provides a barrier between site water, the quality of which can vary, and the environment. Additionally, Ministry of Environment (MoE) policy requires the use of Best Available Technology (BAT) prior to utilization of an Initial Dilution Zone (IDZ) to determine whether there is an impact, thus necessitating some form of treatment. The IDZ is an impact *assessment* tool, not a *treatment* zone. Planning for water treatment requires that water conveyance be taken into account; specifically, the various sources of mine waters are collected in one (or a few) places. This feature of water conveyance also provides for the ready implementation of enhanced levels of treatment should geochemical changes result in water quality change in the long term. It also allows the adoption of treatment technologies that rely less on energy inputs and chemical reagents for water treatment as continuous improvements in water management (e.g., capping, diversion, etc.) are pursued over time.

4.1 Best Achievable Technology (BAT)

Water treatment technologies are varied in complexity and capability and modern treatment technology has developed to the point where contaminants can be removed from a water stream. An extreme example would be the use of desalination technology (likely using multiple membrane steps) in combination with evaporative distillation to produce ultra-pure water. It is sometimes assumed that the best technology is one that results in the lowest effluent constituent concentrations; however, these sophisticated technologies come at a very high energy cost, increased emissions, complex operations and maintenance and inherently produce other concentrated waste streams with their own associated risks and management challenges. The best technology therefore needs to be achievable within other constraints and objectives specific to the project site.

The best technology for a site is a function of a number of different considerations. These include an effluent of a quality that does not produce risk to humans or the environment as well as consideration of energy use, reagent use, treatment waste production and handling, operations maintenance and cost. The Water Management Plan necessarily needs to take a long-term view which includes operations of a mine through to closure in a future that may have different operational realities than those at the time of initial planning. High operations cost and complexity, waste generation and energy use are therefore not the hallmarks of a long-term, resilient water management plan and would not represent best technology for this application.

In the context of the present planning exercise, best achievable technology means the technology can achieve the best waste discharge standards and has been shown to economically and operationally feasible. The BAT philosophy encourages the scoping of all technology shown to be economically feasible through successful commercial application in a similar facility in the same industry. However this study will aim to consider the application of technologies that are not yet in commercial operation but that have shown acceptable performance at the demonstration scale. Uncertainty in the absence of commercial operation will be considered in the evaluation.

4.1.1 Process Outline for Defining BAT

The following process describes how the development of this long term water management plan will aim to define BAT for the Mount Polley Mine site.

Step 1: Identify potential technologies or options

In this step the potential technologies or options that could be implemented will be identified. Categories of potential technologies that will be considered are:

- Water diversion practices;
- Water treatment processes;
- Waste handling options;
- Energy-efficient equipment and processes; and
- Engineering practices.

The focus will be on proven technologies because of the need to implement active water treatment and discharge on a short time scale.

Step 2: Eliminate technically infeasible options

From the list of potential technologies, those that do not meet the definition of BAT will be identified and eliminated. Technologies will be eliminated if they are found to be technically infeasible based on physical, chemical, or engineering principles, or where technical difficulties would prevent the successful use of the technology option at the mine site. Examples of what may make an option technically infeasible include: access to inputs (e.g., power or treatment substrates); technologies that are incompatible with other potential options (e.g. aeration and anaerobic treatment) or the receiving environment (e.g., toxic treatment chemicals) and temperature.

Step 3: Consider the reliability of each option

Each technically feasible option will be ranked in terms of the probability that the technology will operate according to its specifications. Reliability, in the case of new technologies will rely on published performance data and case studies as well as Golder's in-house expertise.

Step 4: Rank technically feasible options by control effectiveness

The efficiency of removal of contaminants for each of the technically feasible options from Step 2 will be calculated. This removal efficiency will then be used to rank the options, along with the comparative technologies at other mine sites.

Step 5: Consider the cost-effectiveness of each option

The cost–effectiveness of each option will be determined by conducting cost estimates based on capacity factored methods, parametric models and analogous operations at other mining sites around the world. This will be done as a Class-5 cost estimate as defined by the Association for the Advancement of Cost Engineering (AACE).

Step 6: Select BAT

The removal efficiency, reliability, and cost-effectiveness rankings from Steps 3, 4 and 5, respectively, will be used to make a recommendation on which option is BAT.

The sections below provide an overview of treatment technologies, followed by an approach as to how treatment options will be analyzed, within the context of the water management plan components.

4.2 Overview of Various Treatment Technologies

This technology overview is presented to facilitate discussion during the development of the long-term Water Management Plan. The intent of this section is to provide a basic overview of typical technologies capable of removing the constituents reported to be of interest at Mount Polley (Table 2), grouped by constituent. This overview is not meant to include all the possible solutions that may be available on the market for each target constituent. A wide range of commercial products are normally present for a given technology type.

The overview is organised according to the constituents targeted for removal. The terms active vs. passive treatment are frequently used in this discussion. Hybrid systems that include features of both have recently been recommended at some mine sites. The following clarification is provided as a guide to the reader:

- **Active Treatment Technologies**: Refers to technologies requiring ongoing human operations; maintenance, and monitoring based on external sources of energy (electrical power) using infrastructure and engineered systems. Examples of active treatment technologies include aeration and neutralization, which often include metal precipitation, metals removal, chemical precipitation, membrane processes, ion exchange, and biological sulphate removal.
- **Passive treatment Technologies**: Refers to processes that do not require regular human intervention, operations, or maintenance. They typically employ natural construction materials (e.g., soils, clays, and broken rock), natural materials (e.g., plant residues such as straw, wood chips, manure, and compost) and promote the growth of natural vegetation. Passive treatment systems use gravity flow for water movement. Pulles et al. (2004) defined a passive treatment system as *"A water treatment system that utilizes naturally available energy sources such as topographical gradient, microbial metabolic energy, photosynthesis and chemical energy and requires regular, but infrequent maintenance to operate successfully over its design life"*.
  Gusek (2002) defined passive treatment as: *".... a process of sequentially removing metals and/or acidity in a natural-looking, man-made bio-system that capitalizes on ecological and geochemical reactions. The process does not require power or chemicals after construction, and lasts for decades with minimal human help".*
- **Hybrid Treatment Technologies:** Also known as semi-passive treatment. This is an emerging concept that combines aspects of both active and passive treatment. For example, in the hybrid treatment of a typical mine water, a biological sulphate reduction process takes place in a lined earthen vessel containing inert media and bacteria, fed with a soluble electron donor and nutrients. The use of a soluble electron donor reduces the size of the vessel, and improves control, compared to passive treatment. The result is a process having low complexity, relatively low cost, and less operator input, but without necessarily requiring a large land area.

The overview of treatment technologies outlined below is from the perspective of long term water management planning. However, as noted earlier in this report, a short-term contingency option is required and further information on that option is provided in Section 4.3 of this report.

4.2.1 Total Suspended Solids (TSS)

Passive settling

Passive settling is the removal of TSS without using specific chemical or physical settling aids. This method relies on spontaneous settling of suspended solid particles in a water body as they sink to the bottom under the influence of gravity. Such a water body could be a pit lake or a purpose built settling pond. Passive settling in this context excludes the use of the conventional concrete settling basins, sometimes called clarifiers that are traditionally used in active settling (discussed further below). The efficiency of the system is affected by the size of the water body and the flow rate of the stream flowing through it. Larger particles settle out fast and finer particles require longer settling times. Passive settling typically represents the most economical TSS management option for most sites as operational costs are limited. However, this approach is sometimes not adequate if a settling pond of sufficient size cannot be feasibly constructed.

Chemically assisted settling

The slow settling rates of fine materials constrain the applicability of passive settling. The process may be chemically assisted through the use of coagulants and flocculants. Addition of coagulant/flocculant results in the formation of larger and heavier flocs which settle faster than small particles, and thereby increases the removal efficiency of smaller particles. Flocculants are specifically added to accelerate settling of particles smaller than 0.01 mm by agglomerating them into larger particles with higher settling velocities; however, the flocculation process is effective only when the right types of flocculants (i.e., chemistry) are chosen. In addition, the flocculant dosage and mixing intensity affect the efficiency of the flocculation process and the associated operating costs. Effective type and dosage of flocculants depend on particle characteristics (i.e., size, specific gravity and charge), and water quality (alkalinity, pH, and temperature). Generally, there is no theoretical correlation between the TSS concentration and flocculant dosage that is accurate enough to negate the need for testing. Therefore, optimum flocculation conditions must be found by carefully performing jar tests and verifying treatment performance under different conditions. The jar test is probably the most important routine test carried out for implementing flocculation as part of a treatment process. The aim is to identify potential flocculant products and to determine dosage ranges. The figure below shows the results of a typical jar test after a few minutes of settling. The jar on the left is the untreated sample.

The toxicity of these treatment chemicals must also be evaluated. As observed in Golder's testing of potential flocculent solutions for the settling ponds at the mouth of Hazeltine Creek (report in preparation), manufacturer's toxicity data cannot be relied upon. In addition, it is possible that the effective dose of treatment chemical may be within or near the range of toxicity to aquatic organisms.

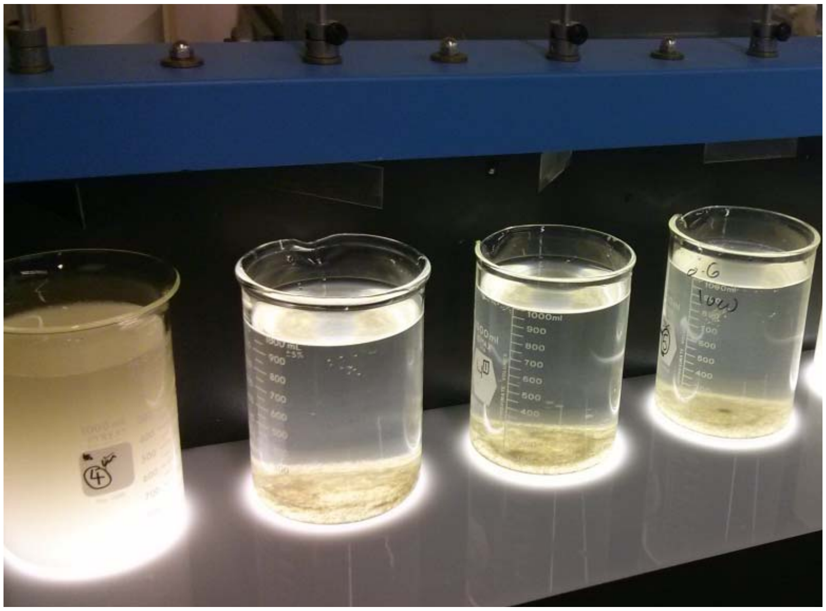


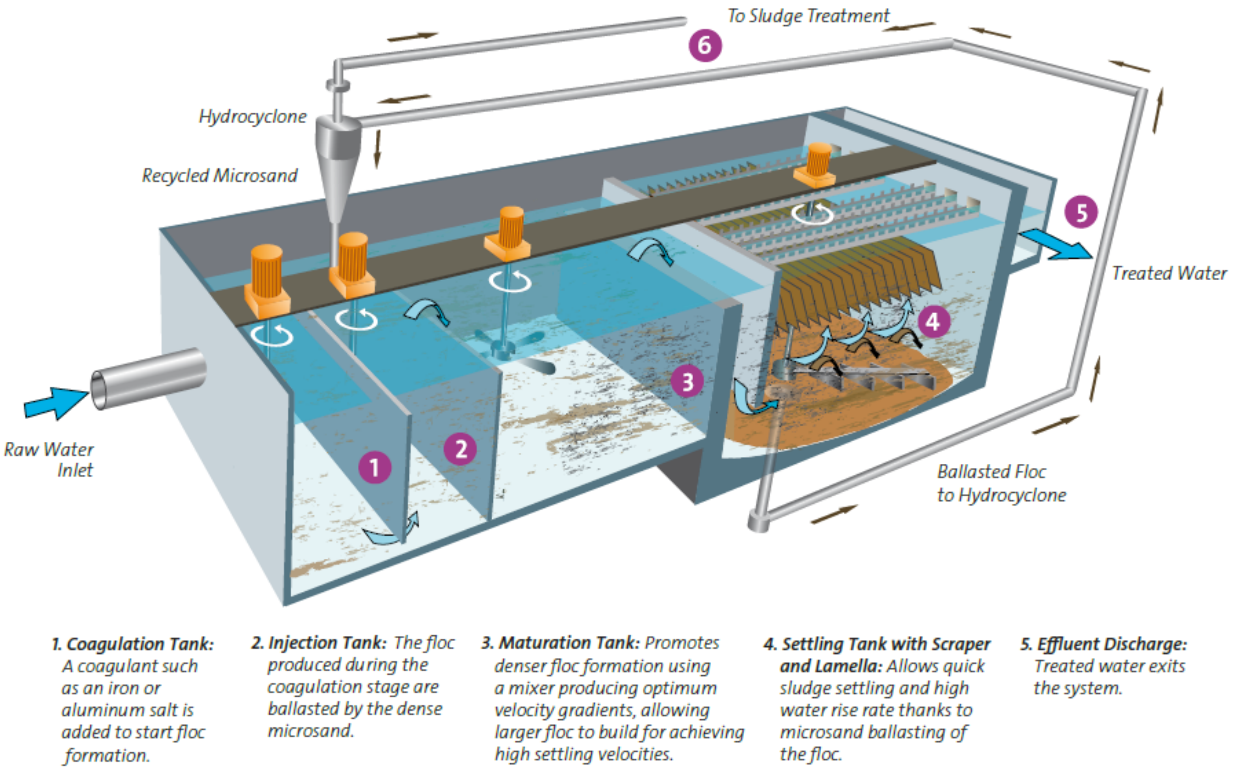
Figure 3: Example: Samples after settling in a jar test with flocculant addition

Active settling

Active settling is defined in the current context as the settling of solids in an engineered vessel under the action of chemical and physical aids. This approach to settling is more sophisticated than the passive settling described above. A typical example of this type of process is the Actiflo® process marketed by Veolia. Veolia describes the system as follows:

> *"A high-rate coagulation/flocculation/sedimentation process that utilizes microsand as a seed for floc formation. The microsand provides a surface area that enhances flocculation and acts as a ballast or weight. The resulting floc settles very fast, allowing for compact clarifier designs with high overflow rates and short detention times. The use of microsand also permits the unit to perform well under dramatically changing flow rates without impacting final effluent quality*".

The microsand is recovered from the settled sludge for re-use in the process. Treated water TSS concentrations well below 40 mg/L can typically be achieved with raw water turbidities up to 5,000 NTU (nephelometric turbidity units) or TSS around 12,000 mg/L. Veolia has existing installations for a variety of industries, including installations at mine sites. A schematic representation of the process is shown in Figure 4.



1. ***Coagulation Tank:*** *A coagulant such as an iron or aluminum salt is added to start floc formation.*
2. ***Injection Tank:*** *The floc produced during the coagulation stage are ballasted by the dense microsand.*
3. ***Maturation Tank:*** *Promotes denser floc formation using a mixer producing optimum velocity gradients, allowing larger floc to build for achieving high settling velocities.*
4. ***Settling Tank with Scraper and Lamella:*** *Allows quick sludge settling and high water rise rate thanks to microsand ballasting of the floc.*
5. ***Effluent Discharge:*** *Treated water exits the system.*

Figure 4: Veolia Actiflo process: An example of an active settling process

Media Filtration

Granular Media Filtration is the process for removal of suspended solids by passing water through a porous medium. Media typically used include sand, anthracite and garnet. Plastic media is also sometimes used. Filtration is commonly the final polishing step in the conventional water treatment process for water treatment plants designed to meet final treated water turbidity limits. Granular media filtration is also often used after gravity separation. It removes additional suspended solids and oils before other treatment processes. It is also a polishing step that lowers the levels of suspended solids and associated contaminants in treated wastes. Particle removal takes place either on the surface of the media (cake filtration) or throughout the depth of the media (depth filtration). A typical application for mine water is the removal of arsenic and antimony after an oxidation step.

Figure 5: Dual media filter in operation at a mine (photo credit Roymec Technologies)

In the granular media filtration process, suspended solid particles typically adsorb or attach to the grains of the filter medium. Solids removed from the water first accumulate at the surface and then penetrate into the filter bed. Water travels through the media, is collected in piping systems downstream of the media, and eventually exits the filter and passes on to a clearwell or before discharge. As particles are removed in the media, loss of pressure occurs in the filter and backwashing is required to renew the filer’s ability to remove solids.

4.2.2 Metals

Precipitation processes

The removal of soluble metals from mine drainage through the use of precipitation is a commonly employed treatment method found at many different mine sites (MEND 2014). Metals are generally precipitated as hydroxides and less frequently, sulphides. Hydroxide precipitation is achieved by increasing the pH of the solution to form an excess of hydroxide ions. The pH increase is typically achieved by the addition of lime. The resulting metal hydroxides are poorly soluble in water and the solid particles that from are separated from the liquid by means of the processes described above for suspended solids removal. These solids are produced in the form of a sludge that often requires further dewatering before disposal. Two typical examples of this process found in the mining industry are: low density lime precipitation process and high density sludge process (HDS) (Kuyacac et. al 1999).

In the low density lime precipitation process lime is added in a simple neutralization system. A typical schematic of the basic technology commonly used in the mineral industry is depicted in Figure 6.

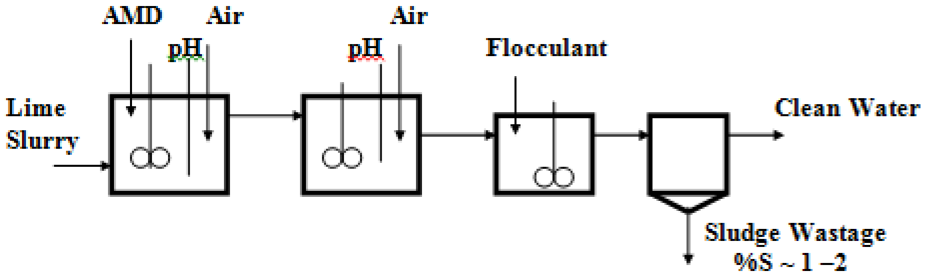


Figure 6: Low density lime precipitation

The mine water is first mixed with lime slurry directly in a pond or in a mechanically agitated and aerated reaction tank (US EPA 1983; MEND/CANMET 1994). In tank application, single stage or two-stage reaction may be employed depending on the characteristics of the acid water and the neutralization chemicals. Then, if necessary, a flocculant may be added to the neutralized water to promote settling. A clarifier or a settling pond is used for solid-liquid (i.e., sludge, separation). The overflow (i.e., treated water) is discharged to the environment or is recycled back to the process.

In the HDS process a mechanical technique is used to improve the physical properties of the sludge. As shown in Figure 7, a portion of the underflow sludge is recycled back to the treatment process (Knocke and Kelley 1987; Yamabe 1990; Kuyucak 1998). The recycled sludge is used in the process along with lime as in dry or slurry form. The neutralization of the water and oxidation of Fe^{2+} take place in the chemical oxidation reactors (or neutralization tanks). Flocculant is added to the neutralization tank overflow to enhance the settling. The flocculated slurry flows into a clarifier/thickener (“HDS Thickener”). The overflow from the clarifier is discharged to the environment or is reclaimed. Excess underflow sludge is disposed of, as sludge wastage. The process can be adapted to conventional equipment.

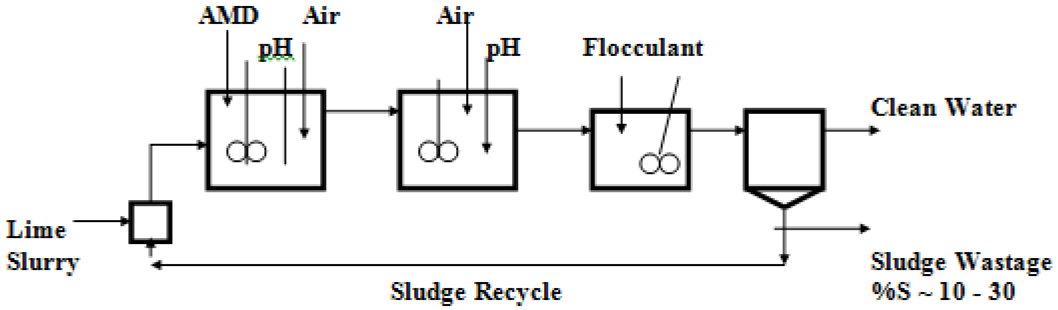


Figure 7: The High Density Sludge Process

The HDS process is considered as the state-of–the-art lime neutralization method which offers attractive potential for minimizing waste sludge volumes. In North America, it has been proven successful (MEND/CANMET 1994) for generating a denser sludge that contains >10% solids, yet flows by gravity due to its low viscosity. The particles are more granular and hydrophobic in nature, tending to attract metals and repel water, settle rapidly and drain readily to achieve high solids content (~30 to 40% solids) during their disposal. The need for a large clarifier is reduced. Due to small sludge volume, the cost of waste sludge pumping and treatment per volume of treated water (i.e., more water is recovered for the same quantity of lime consumed) is reduced. Scaling in the process equipment is eliminated or minimized. The sludge is chemically and physically more stable (i.e., less metal leachability and less disturbance by wind) during its disposal/storage in an impoundment.

Biological treatment

Biological removal of metals is used both in active and passive treatment systems. Two important biological mechanisms for the removal of metals relevant to this project are the following:

- **Sulphide precipitation**: This mechanism is most typically utilized in passive bioreactors (BCRs: discussed below). The sulphate ions present in the mine effluent are converted to sulphide by bacteria in a biological reduction process. The sulphides combine with the dissolved metals to form an insoluble precipitate which is retained in the BCR. This mechanism allows for the removal of iron, aluminum, copper and antimony (Refer Table 2).
- **Reduction of oxy-anions to insoluble metals**: This mechanism is at the heart of biological selenium removal in both active and passive treatment systems. The oxy-anions of selenium (selenate and selenite) are soluble. A bacterial process that utilizes an electron donor reduces the oxy-anions to elemental selenium which is insoluble and is removed from the liquid through a solid separation process (active treatment) or retained in the BCR (passive treatment).

ITRC (2013) defines BCRs as *"...engineered treatment systems that use an organic substrate to drive microbial and chemical reactions to reduce concentrations of metals, acidity, and sulfate in Mine Influenced Waters (MIWs)"*. The chemistry is fairly well understood and research and development over the last 20 years have improved the effectiveness, hydraulic permeability, and longevity of these systems. Multiple examples exist around the world today. This technology can address a wide range of flows, acidity, and metals loading. The figure below shows a cross section of a standard BCR. To accommodate larger flows, multiple cells may be constructed.

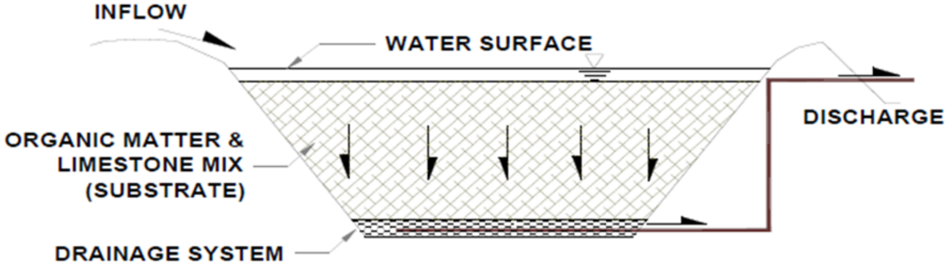


Figure 8: Profile view of a BCR

A BCR can be designed to operate in gravity flow or pumped flow. BCRs operate with or without external energy and chemical input and can often be sustained for months at a time without human intervention. Where external energy and/or chemical are used the system would more accurately be described as a hybrid treatment technology as depicted in Figure 9.

BCR systems can also be engineered to incorporate the bioprocesses, chemical reactions, and the bulk of solids separation within an organic substrate bed. The organic substrate used is generally a mixture of locally available organic materials (such as wood chips or manure) and often contains limestone to provide additional neutralizing capacity and to increase substrate permeability. The optimum substrate design is ideally achieved through extensive preliminary field and laboratory testing using various substrates with site-specific MIW. Regardless of the design, BCR systems require monitoring and operation and maintenance attention to sustain the longevity of the entire system.

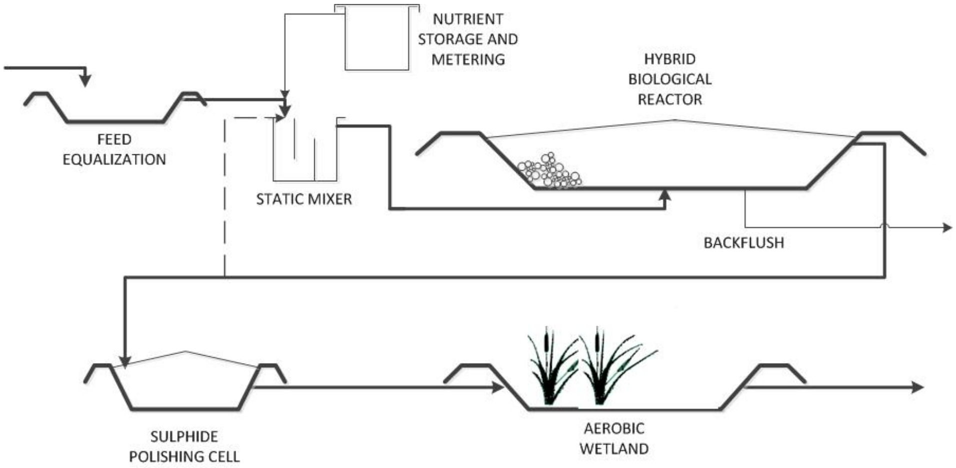


Figure 9: Example Hybrid System Process Flow Diagram

Figure 10: A passive BCR cell under construction (Golder Associates 2014)

BCRs treat MIW by using microorganisms to transform contaminants and to increase pH in the treated water. Anaerobic BCRs, also called “sulfate-reducing” bioreactors (SRBRs, SRBs), are most commonly used. The microbial process of sulfate reduction produces sulfide and bicarbonate within the reactor, allowing the target metals such as cadmium, copper, nickel, lead, and zinc in MIW to precipitate as metal sulfides at pH values above 5.0. The bicarbonate promotes an increase in pH and will promote the removal of some metals as carbonates such as $FeCO_3$, $MnCO_3$ and $ZnCO_3$ under the appropriate conditions. Conditions may include a specific pH and carbonate concentration.

Ion exchange

Ion exchange is a process in which ions of a given species are displaced from a solid insoluble exchange material (usually a resin) by ions of a different species in solution (e.g., Se_2O_4 in the case of selenium). It may be operated in either batch or continuous mode (Metcalf and Eddy, 1991). The key disadvantage of the ion exchange process is the requirement for frequent regeneration of the resin as the material becomes saturated with the removal of target contaminants. This leads to cost in the form of chemical consumption and a concentrated saline waste stream requiring further treatment and disposal. An example relevant to this project is the recent development of a process for removal of selenium from mine water.

BioteQ has developed a system based on ion exchange coupled with the redox reactions between ferrous ion and selenate. A chemical process for the reduction of selenate by ferrous hydroxide was developed by The United States Bureau of Reclamation (USBR) in the 1980s, producing elemental selenium and magnetite (Murphy 1988). However, the process was not efficient. The BioteQ process uses an innovative approach based on ion exchange to concentrate the selenate ions upstream of a similar iron redox process. The key to the IX stage is the use of a strong base anionic (SBA) resin in the sulphate form, rather than the conventional approach of ion exchange in the chloride form. With the resin in the sulphate form, it is able to selectively adsorb selenate ions from a mining effluent in the presence of sulfate. In the past, selectivity has been the limitation of ion exchange for trace selenium removal in a sulphate matrix. The resin is regenerated with a strong sodium sulphate solution, and the desorbed selenium is sequestered by iron to produce a dense, inorganic selenium-magnetite solid sludge. The low volume of the solid waste product is a key benefit.

4.2.3 Nitrate

Biological denitrification

Denitrification is a microbially facilitated process of nitrate reduction that ultimately produces molecular nitrogen gas (N_2) through a series of intermediate gaseous nitrogen oxide products. This process is performed by a large group of bacteria that occur in abundance in the natural environment. These bacteria belong to a group known as heterotrophic facultative anaerobic organisms. The process requires the availability of easily biodegradable carbon to drive the bacterial metabolism responsible for the conversion of nitrate to nitrogen gas. This reaction can be implemented as either and active process (used in domestic wastewater treatment) or in a passive BCR or wetland.

Ion exchange

Nitrates can be removed from a water stream using ion exchange resins. Ion exchange resins have long been used for nitrate removal. There are generally two types of resin used: “nitrate-selective” and “standard”. The primary difference between them is the relative affinity of multivalent ions like sulfate and arsenate. Nitrate-selective resins are de-selective for multivalent ions, like sulfate and arsenate. These resins have higher affinities for nitrates than most other common ions found in mine water, including sulfates. A fair number of nitrate-selective resins have been synthesized. A drawback of the process is that some pre-treatment is typically required to protect the resin bed from oxidation and physical fouling by other constituents in the mine water. The process uses a strong-base anion exchange resin, which is regenerated with common salt (NaCl) or potassium chloride (KCl). Regenerant[1] levels must be high enough in nitrate removal to ensure that nitrate leakages are kept to acceptably low levels. In certain cases, extended rinses may be required after regeneration before nitrate levels reach acceptable levels. Techniques such as counter-current regeneration or re-mixing after regeneration can reduce and even eliminate high initial leakages. The same drawbacks exit for this ion exchange process as described for metal removal by ion exchange described above.

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[1] A regenarant is a concentrated chemical solution used to regenerate the adsorptive capacity of an ion exchange column once it becomes exhausted

4.2.4 Sulphate

Active Treatment

In the last decade, a number of operators have successfully demonstrated advanced sulphate removal using membrane processes (such as Reverse Osmosis), at large flow rates, to achieve sulphate levels in product water of 100 mg/L or below (Hutton 2009). Examples include the 25,000 m^3/day eMalahleni water treatment plant (started 2005) and the Optimum Coal mine water treatment plant (2009) in South Africa, a facility at Kennecott Mine for treatment of impacted groundwater (2006) and the Northern West Virginia Water Treatment Plant (2013) in the USA. The product water from the eMalahleni and Kennecott plants is sent directly to local municipalities to provide drinking water. The cost of treatment to moderate sulphate levels should be significantly lower than the cost to meet strict levels. One option is to bypass part of the flow, allowing for a smaller capacity membrane plant, so the mixture of treated water and bypass water meets the objectives. Another option is to select membrane types which are semi-permeable to the target ions, thereby increasing the sulphate level in the effluent, and hopefully, decreasing costs. All the active treatment options, however, require a fully-staffed mechanical treatment plant with appropriate skills and training and attention to process control, to prevent costly problems such as scaling.

Figure 11: The eMalahleni Mine Water Reclamation Plant: South Africa (photo credit Anglo American)

Passive Treatment

Alternatives to large-scale active treatment processes are available which are less costly for applications where the discharge limits are not lower than 100 mg/L, for example, in cases where only 30-50% removal is desired (Bratty et al. 2015).

Passive treatment can offer sulphate removal with a greatly reduced level of complexity, greatly reduced staffing levels and skills, and as a result, potentially offers cost savings. Passive treatment research and development has been carried out over a period of decades. A large number of facilities have been constructed, but a relatively small subset of these projects involve designs specifically targeting sulphate removal. Passive treatment for advanced sulphate removal has met with mixed success; however the limitations of the process are beginning to be well understood and companies can now evaluate the passive treatment option with greater confidence. In general, passive treatment requires a much larger land area than active treatment, and as a result the process has not been frequently applied to large flow rates.

4.3 Short Term Water Treatment Options

Based on the current understanding of the water quality at Mount Polley and in view of the water balance conditions (sections 2.2.1 and 2.3.2) the restricted start-up may require water treatment to allow excess water to be discharged from the mine site. The options for treating this excess water are therefore need to consider a shorter timeframe than options that may found to be BAT for the longer term (i.e., future operations and post-closure). These options also require consideration of contingencies for how water (treated or otherwise) may be discharged to the environment. This contingency is discussed in Section 4.3.3. The following options are proposed for treating water in the short term. These options are based on achieving acceptable parameter concentrations at the edge of the IDZ in the receiving water nobody and are described below. Figure 13 is presented below to aid the discussion of the short term treatment options.

4.3.1 Short Term Option 1: Liming and passive settling in Springer pit

The increase in pH required to precipitate metals in solution as described in 4.2.2 is routinely achieved by the addition of lime. The milling and metals extraction process at Mount Polley includes lime addition as a standard process step with lime slaking equipment currently installed on site. This creates the opportunity to utilize installed equipment to safely and effectively increase the pH of the Springer pit water to a level that will favour precipitation of a portion of the metals identified as COPC's in section 3.1. A keay advantage of thid approach is that it avoids the longer lead times associated with the long term options. The retention time and large surface area of Springer pit creates conditions favourable to the removal of solids through passive settling. This solid material is expected to include both precipitates as well as tailings produced as part of the restricted start-up condition. An analysis of in-pit TSS behaviour will be conducted to assess the effectiveness of this option will be sufficient to achieve the desired solids removal. The treated water in the pit will be re-used in the mill for normal operations while the excess will be discharged by pipeline (Section 4.3.3). This will require the construction of additional piping and valve(s).

4.3.2 Short Term Option 2: Active TSS removal with pH correction

This option will be required if the analysis of in-pit TSS behaviour shows that passive settling alone will not achieve the desired water quality. In this case the deployment of an active settling process will be required to lower TSS concentrations sufficiently. This option is therefore similar to short term option 1 with the following additional components:

- An active high rate settling process with possible flocculent addition such as described in section 4.2.1and Figure 4. The resulting waste from this process will be the underflow from the thickening step. This waste will be routed back to Springer pit where it will form part of the deposited tailings.
- A pH correction step may be required and could use either CO_2 or a mineral acid to bring the pH into an acceptable range within MMER or as stipulated in the ministry approval.
- A limnocorral may be recommended. This serves the purpose of restricting a portion of the TSS and thus increasing the efficacy of the active TSS removal.

4.3.3 Effluent Conveyancing and Discharge (Short Term)

The same options that are under consideration for effluent discharge points for long-term water management are also being considered. However, given that the short - term (contingency) option may require early implementation, the options that are relatively easy to implement and capable of accepting the flow volume represent the preferred options. All options would require a permit amendment to be issued.

Hazeltine Creek Discharge

The reconstructed Hazeltine Creek channel has been designed to contain the mean annual flood (MAF) within the armored channel. Additional vegetated floodplain area has been designed to carry flows with return periods of up to 200 years. For Reach 2 of Hazeltine Creek, which is above Gavin Bridge, the capacity of the armored MAF channel is 1.6 m^3/s. The armored MAF channel in Reach 3 below Gavin Bridge has a capacity of 1.8 m^3/s.

A maximum effluent discharge rate of 0.3 m^3/s (9.5 Mm^3/y) is proposed, subject to a limit of 0.8 m^3/s (effluent discharge + natural flows) at the Gavin Bridge, which represents 50% of the MAF. This would allow Hazeltine Creek to carry the flows without causing erosion or overtopping of the armored channel. The armoured channel should provide primary protection against channel erosion upon placement; however, the floodplain area should not be used to convey flows because its stability against erosion requires the formation of a vegetated community. It is expected that this will take several years to develop and thus would not be suitable for effluent conveyance in the short-term.

In most years, effluent discharge would be limited during May, and part of April and June when the natural flows exceed 0.5 m^3/s. No effluent discharge would occur when the natural flow at Gavin Bridge exceeds 0.8 m^3/s.

At present, Hazeltine Creek does not have fish in it. Therefore, if used as a conveyance structure, Hazeltine Creek would not be required to meet ambient water quality guidelines. However, BAT would remain a pre-requisite to discharge and water quality guidelines would need to be met within an initial dilution zone in Quesnel Lake. This will need to be modeled before accepting this option.

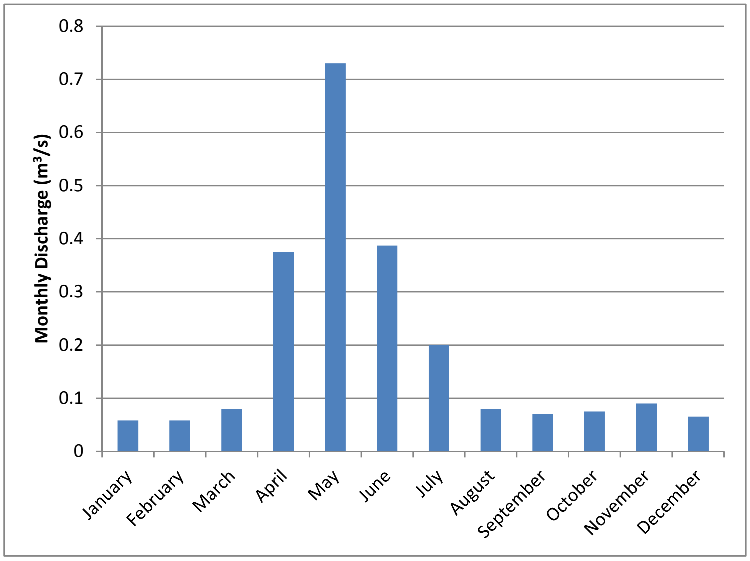
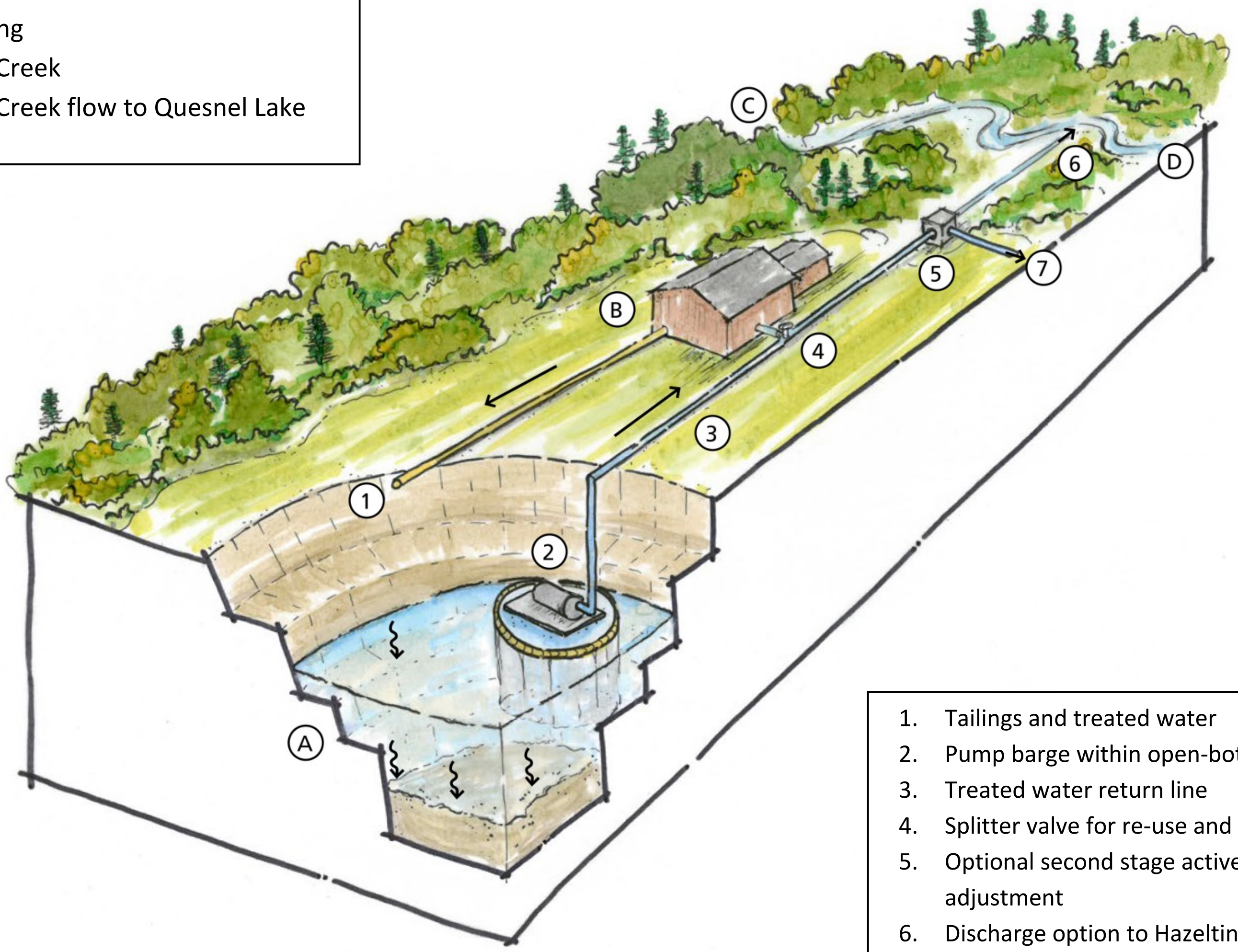


Figure 12: Average Monthly Flows on Hazeltine Creek at Gavin Bridge

Quesnel Lake

Discharge to Quesnel Lake would be conveyed from the treatment facility via pipe to a submerged diffuser. The main constraints associated with this option would be sourcing sufficient pipe, fabrication of the diffuser and welding together the section of the pipe. Mount Polley's existing staff are skilled at welding pipe and have the necessary equipment on site. Quesnel Lake would not be limited by flow conditions.

A. Springer Pit
B. Mill Building
C. Hazeltine Creek
D. Hazeltine Creek flow to Quesnel Lake



1. Tailings and treated water
2. Pump barge within open-bottom limnocorral
3. Treated water return line
4. Splitter valve for re-use and discharge
5. Optional second stage active TSS removal and pH adjustment
6. Discharge option to Hazeltine Creek
7. Discharge option to Quesnel Lake

Figure 13: Conceptual illustration of short-term water treatment schematic.

4.4 Long Term Treatment Options Evaluation

The options presented here are preliminary options intended as a starting point for discussion as well as to demonstrate how technologies may be deployed to achieve the desired effluent quality in the long term. This evaluation will be carried out using the steps described in section 4.1. It is likely that additional options may be identified during the course of this study. The evaluation will be done through developing a comprehensive list of options followed by a pre-screening exercise to arrive at a short list of at least four options that will be carried forward for detailed analysis. It is also likely that as a more detailed understanding is developed during the water quantity and quality predictions, options that combine technologies in different ways than initially envisaged may become attractive. The approach of distributed treatment as opposed to a centrally located treatment system to treat a combined mine effluent stream will also rely on this improved understanding of the site. The following sections described the preliminary options based on the information available at this time.

4.4.1 Long Term Option 1: No treatment

This option will be used as the base case for comparison of all other treatment options. This is a “null” option for evaluation. It would not fit the provincial policy with respect to BAT.

4.4.2 Long Term Option 2: Passive settling

This option is already being implemented at MPMC in the Hazeltine Creek area but wider application as part of the long term water management planning will be assessed. Feasible options may include the use of constructed sedimentation ponds or utilizing mine pits (e.g., Springer Pit). This could serve either as the most suitable option for a localized stream or as a pre-treatment step upstream of further treatment. A basic understanding of suspended solids from the Mount Polley Mine is being developed based on a combination of laboratory tests of samples from Hazeltine Creek and modeling currently under way. These insights will support the further development of this option.

4.4.3 Long Term Option 3: Chemically assisted settling

The option of using coagulant and flocculent chemicals will be assessed as part of this option and may be considered as an enhancement of Option 2. The advantage obtained from increased settling velocities and lower sedimentation pond footprint will be weighed up against the risk of adverse effects in the receiving aquatic environment. Tests are already underway at Golder to investigate numerous commercially available products for removing fine sediments in the lower Hazeltine sediment control ponds in terms of efficiency and toxicological risk with preliminary results available. Dosing and control equipment requirements would need to be analysed as part of this option.

4.4.4 Long Term Option 4: Passive BCR with sulphide removal cell

Lowering the concentrations of all the COPCs identified in Section 3.1 to the relevant environmental benchmarks is possible through the passive treatment technology. It is envisaged that passive BCRs in combination with sulphide removal cells could be constructed in various locations around the Mount Polley Mine site. Feasibility will be assessed based on experience at other sites in BC and beyond. The analysis will include the availability of construction materials and potential BCR substrate media in reasonable proximity to the mine. The addition of the sulphide removal cell may be required due to the fact that there are inadequate concentrations of metals in the mine water to precipitate sulphides in the BCR effluents sufficiently to ensure sulphate concentrations remain below target values.

4.4.5 Long Term Option 5: Hybrid-passive system

An enhancement to Option 4 is to assess the use of the hybrid-passive concept to reduce the size of the passive BCRs. The addition of an amendment in the form of a soluble carbon source may be required to overcome site constraints at Mount Polley. This amendment would be used to reduce the required footprint and to increase reactor performance in colder months. Depending on the specific feed water, part of the hybrid reactor overflow may be recycled to provide a ligand for specific influent metals. The hybrid treatment option may include a system to sequester sulphide, usually based on contact of the water with iron compounds. Lessons from the design of passive bioreactors inform the detailed design of hybrid reactors, such as: sizing, hydraulics, packing, flow distribution, and prevention of clogging and short-circuiting.

4.4.6 Long Term Option 6: Active settling with pre-treatment and precipitation

This option includes the use of a sedimentation pond to remove the bulk of the suspended solids in the mine water upstream of an active settling process. An active enhanced settling process (like the Actiflo system, Section 4.2.1) may be enhanced by the incorporation of lime for metal precipitation. This option will likely be limited to a subset of the sources of MIW at the site due to the fact that sulphate will not be removed by this process. The feasibility of this option will therefore rely on the development of a more detailed understanding of the source terms and the projected future water quality expected at various location on the mine site. This will be done through the modelling techniques described in Section 3.2.

4.4.7 Long Term Option 7: High density sludge with post-treatment

This option is similar to Option 6 but will rely on the use of conventional clarifiers for solid liquid separation instead of enhanced settling. The advantage of this approach is that one plant may be used to treat the combined effluent of the entire site as opposed to distributed treatment at various locations. Post-treatment for the removal of selenium may be required and the same limitations related to sulphate removal as described in Option 6 apply to this option.

4.4.8 Long Term Option 8: Reverse Osmosis

The limitations of this option are well understood. High energy consumption and a lack of suitable brine disposal options constrain the deployment of reverse osmosis in this case. It is also an unattractive option for a post closure scenario due the high level of operator attendance required. However, the considerable amount of work already conducted before the TSF breach occurred will make it relatively easy to include this option in the development of the long term planning of water management at his site. It is also possible that mobile RO systems may be considered as a short term intervention option while more permanent solutions are developed and implemented.

5.0 EVALUATION OF EFFLUENT MANAGEMENT OPTIONS

The preceding sections presented the approach to quantifying the mine water quality and quantity and to evaluating water treatment options. For all treatment options, the treated water must then be discharged. The selection of an appropriate discharge location and method for discharge must be based on long-term considerations.

In its first stage of its development (1997 to 2001), the Mount Polley Mine recycled water from the TSF for re-use in the milling process. Through this period of operation, the mine did not require a discharge to continue operating. When the mine re-opened in 2005, a surplus of water was present and a permit amendment was sought to enable discharge of surplus water into Hazeltine Creek. This permit amendment, issued approximately 5 years after application for it, imposed certain limits for effluent quality, non-toxicity requirements and target levels for specific analytes in Hazeltine Creek as well as the following volume limits:

- A maximum annual discharge of 1.4 Mm^3 per year could be discharged; and
- A permitted discharge amount was not to exceed 35% of the daily flow of Hazeltine Creek.

The mine has continued to expand its mine life and therefore the footprint of contact water that must be managed. Because of urgency in the water volumes, MPMC proposed a reverse osmosis plant with discharge to

Polley Lake. The reject water from the RO plant was to be directed to the TSF. The proposed application of RO was for a short (four year) period of time and was not intended to be a suitable technology post-closure.

Since that time, a foundation design flaw resulted in a breach of the TSF on August 4, 2014. An expert panel appointed by the Minister of Energy and Mines also recommended that tailings impoundments not be used as water storage reservoirs. The water volume to be treated is now estimated to be on the order of 5 to 6 Mm^3.

A water treatment option capable of meeting the demands of the full water balance, together with a water discharge option that is capable of receiving that full volume is a requirement of any long-term view option. The discussion below develops proposed criteria for effluent disposal options.

5.1 Criteria for Discharge Options

The following criteria are proposed for evaluating the discharge options:

- Implementation of the first components of the plan before Springer Pit reaches the 1030 level;
- Capacity of the receiving water bodies to accommodate the flow and quality of the discharge;
- Sustainability of the longer term components of the plan up to closure and beyond;
- Receiving environment resilience (i.e., the potential for treated effluent constituents to accumulate in the vicinity of the point of discharge); and
- Protection of receiving environment uses (e.g., aquatic life, drinking water, recreational contact).

Table 3 summarizes the rational for selection of the criteria and the approach that will be used to assess the options for discharge.

A consideration of the merits between the most ideal discharge option and realistic timelines will be included in this portion of the study. Development of the Water Management Plan and treatment and disposal options is an iterative process. It may be necessary to revisit the initial treatment and discharge recommendations if it is subsequently demonstrated that the effect on the receiving water exceeds provincial water quality guidelines, or is not acceptable for other reasons.

Table 3: Summary of criteria for evaluating discharge options

Criteria	Considerations	Assessment Approach / Methodology
Implementation	The discharge option must be operational before Springer Pit water levels rise to the 1030 m elevation, to avoid emergency overflow / bypass of the TSF.	A Gantt chart tool will be developed and the schedule will be analyzed to determine if the design, construction, and implementation phases can be accommodated in the required time frame.
	Data gaps that may require filling to support the technical assessment required for permitting.	The available receiving environment information will be reviewed for suitability to support permitting for each discharge option. If insufficient data are available, the schedule to collect such data will be assessed against the need to have the discharge option operational before Springer Pit water levels rise to the 1030 m elevation. Data collection may be initiated if feasible.
Capacity	The effluent volume (approximately 5 to 6 M m^3) must be accommodated by the option without adverse effects (e.g., scouring, erosion, flooding).	*For creeks:* Provincial in-stream flow guidance will generally be followed to develop a historic hydrograph, if sufficient data are available, and the stream channel characteristics will be reviewed to evaluate the volume of additional water that can be accommodated by the channel. This evaluation will incorporate information from the site water balance model. *For lakes:* Realistic discharge rates would not affect lake capacity. However, resilience (see below) and capacity of outflow creeks will be evaluated per in-stream flow guidance.
Receiving environment resilience	Effluent constituents should not accumulate (build up) in the receiving environment, in particular for the lake options.	*For creeks:* The behaviour of the effluent plume in creeks will be evaluated using hydrological and mass balance models. This will incorporate information from the site water quality and water balance models. *For lakes:* Detailed 3D hydrodynamic modelling will be used for Quesnel Lake to evaluate the behaviour of the effluent plume in the lake. In Bootjack and Polley Lakes the evaluation will be undertaken with a hydrological assessment and mass balance model. This will incorporate information from the site water quality and water balance models.

Criteria	Considerations	Assessment Approach / Methodology
Protection of receiving environment uses	Proposed effluent quality will be evaluated according to the following hierarchy of preferences: ■ Attainment of drinking water, recreation, aquatic life, agriculture and other user quality guidelines ■ Risk-based tools are an option accepted by MoE where WQG may not exist or may need to be modified.	*For creeks:* Water quality in the receiving environment will be predicted using hydrologic and mass balance models and the resulting concentrations compared to applicable WQG. This will incorporate information from the site water quality and water balance models. *For lakes:* Near field: A nearfield model will be used to identify concentrations within and at the edge of the IDZ. Detailed 3D hydrodynamic modelling will be used for Quesnel Lake to predict far field and future water quality in the lake. In Bootjack and Polley Lakes the "far field" evaluation will be undertaken with a hydrological assessment and mass balance model to evaluate the capability for flushing of these systems. The predicted water quality will be compared to applicable WQG. This will incorporate information from the site water quality and water balance models.
Sustainability	Factors will include energy use, gravity, infrastructure, secondary waste processes and reagents consumed	Conceptual level estimates will be made for each option and compared on a relative basis.

Notes:
MoE – BC Ministry of Environment; TSF – tailings storage facility; WQG – water quality guidelines

5.2 Potential Options to be Considered

The range of potential options for consideration is dictated to a considerable extent by the surrounding landform, terrain and water bodies. The water body must be sufficiently large so that it can accommodate the increased flow without erosion or flooding of downstream areas and needs to consider water uses such that it does not interfere with those uses. The available water bodies are:

- Hazeltine Creek;
- Polley Lake;
- Edney Creek;
- Bootjack Lake;
- Quesnel River; and
- Quesnel Lake.

5.2.1 Hazeltine Creek

Discharge to Hazeltine Creek cannot exceed 35% of the natural flow at the W7 gauge at the time of discharge (SRK 2013). Based on the discharge limit of 35% of the mean annual discharge (MAD), Hazeltine Creek could potentially receive 2.1 Mm^3 of treated effluent in an average year.

Because of the daily variability in Hazeltine Creek flows (KP 2004), the flows would have to be closely monitored and frequent adjustments made to the discharge rate. Furthermore, because the effluent would comprise up to 26% of the total flow, the effluent could potentially have a significant effect on Hazeltine Creek water quality.

As result of the TSF dam breach and resulting debris flow, Hazeltine Creek was scoured. The now-exposed sediments are susceptible to erosion; erosion control and creek restoration efforts are underway. However, at this time, the ability for Hazeltine Creek to accommodate additional flows, within the timing horizon necessary is limited and in conflict with rehabilitation efforts. Over the long term, Hazeltine Creek may be able to accommodate additional flow once it has been physically and biologically (vegetation) stabilized.

5.2.2 Polley Lake

Discharge to Polley Lake would face similar constraints as a direct discharge to Hazeltine Creek. The Polley Lake water body would attenuate the daily flows so that less frequent adjustment of the discharge rate may be required, and would provide limited opportunity for a mixing prior to the flow entering the Hazeltine Creek channel. Based on the discharge limit of 35% of the mean annual discharge (MAD), Polley Lake could potentially receive 1.9 Mm^3 of effluent in an average year. Diffuser design options will be developed based on the initial dilution zone for the discharge plume, and a mass balance water quality model will be developed to assess the effect of discharge options to Polley Lake.

As part of response efforts to the TSF dam breach, a flow control structure is being constructed on Polley Lake. Under these new conditions and in the short term, a Polley Lake discharge may conflict with those objectives.

5.2.3 Edney Creek

Edney Creek is largely unaffected by development at the mine, and provides important spawning habitat. The catchment area of Edney Creek is larger than Hazeltine Creek, and would potentially have capacity to accept greater volumes of discharge from the mine. However, Edney Creek also supports spawning and rearing for the listed Interior Coho. Additionally, while Polley Lake elevation pump down was being carried out, Edney Creek was evaluated for the potential to accommodate the Polley Lake pumping flows. It was determined that only a minor fraction of those flows could be accommodated. Further assessment, including other options for conveyancing in Edney Creek will be carried out.

5.2.4 Bootjack Lake

Discharge to Bootjack Lake would face similar constraints as a discharge to Polley Lake with the exception of constraints related to the TSF dam breach response; however, Bootjack is a smaller water body, with a catchment area approximately half that of Polley lake, and therefore may have less resilience to receive discharge.

5.2.5 Quesnel Lake

Quesnel Lake is a large and deep water body. In the West arm of the lake, which would be the most probably location of an outfall if this option were pursued, water depths are in excess of 100 m providing opportunity for a well-submerged engineered diffuser. The lake has considerable volume and flushing potential, as was observed with the flushing of turbid waters from the lake over the winter months. Considerable data are available for Quesnel Lake and a hydrodynamic model has been constructed, allowing a higher level of pre-discharge impact analysis than the other water bodies. The hydrodynamic model will allow consideration of contaminant build up over many years.

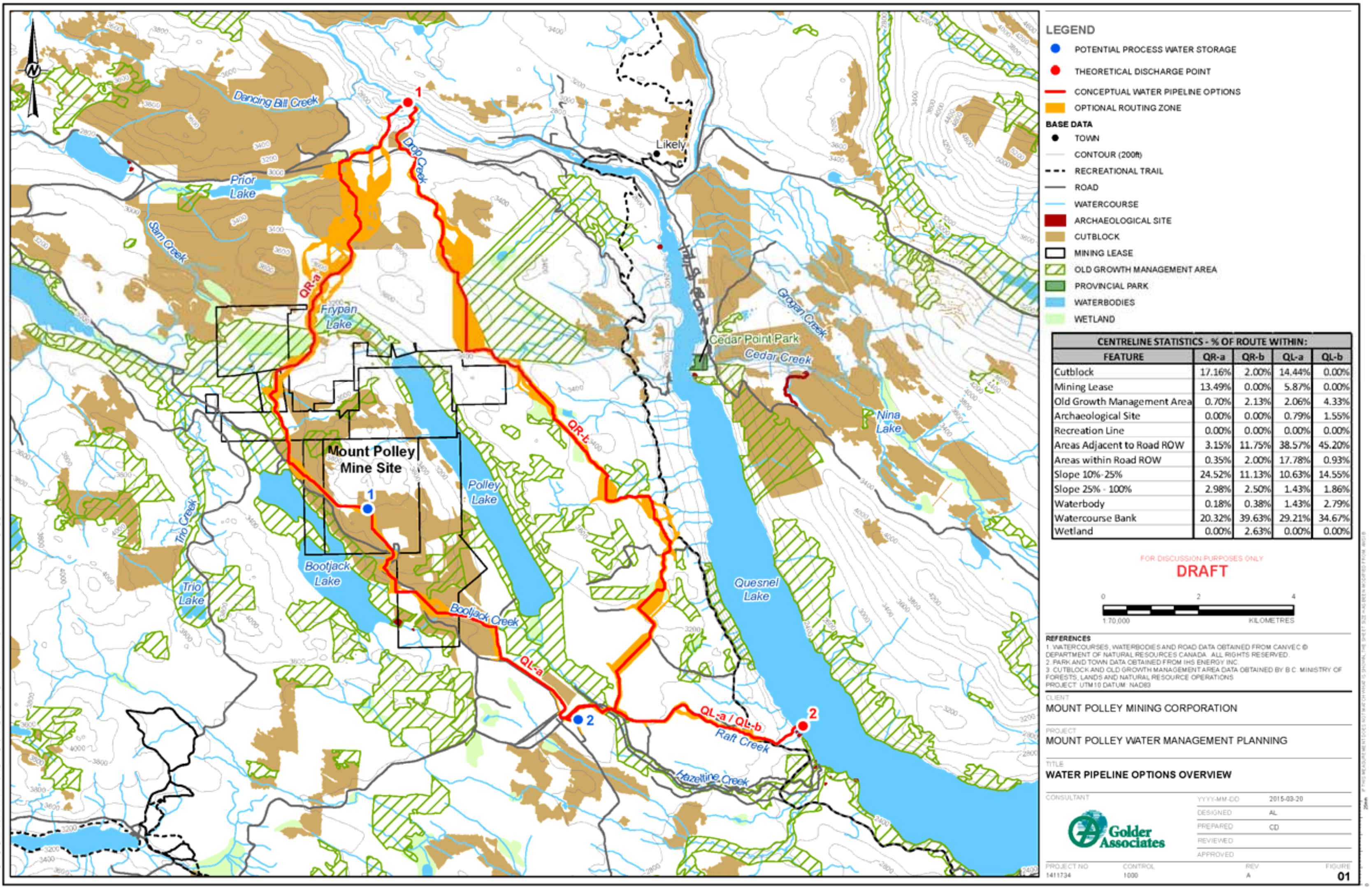
The Quesnel Lake option would involve a pipe routing approximately along the Gavin Lake FSR.

5.2.6 Quesnel River

Quesnel River is used by salmonids for spawning near Likely, BC. Based on local information, which will be confirmed and expanded should this option be selected, the Quesnel River downstream of the Quesnel River Research Centre (QRCC) is used primarily as a migration corridor for transiting salmon. Presumably, it would also be used for rearing. The Quesnel River is a large river and there is a reasonable likelihood that scouring/flooding considerations may not be a concern as it is for other water bodies. However, low flow events may not provide the necessary dilution/dispersion to meet requirements for a provincial permit. In addition, there may be constraints associated with topography and property ownership.

To evaluate the feasibility of a pipeline route, Golder has carried out an initial geospatial impedance analysis for pipeline routing that uses topography and other data (e.g., location of old growth management areas) to select an optimized pipeline routing and to calculate factors such as elevation differences which would affect long-term desirability of this option. An initial modeling exercise is also underway. It will collect existing flow data and evaluate the available dilution and resulting exposure concentrations in the receiving environment. To evaluate erosion potential, the range of flow conditions will be examined.

An initial routing option has been produced using impedance analysis and is provided in Figure 14. This routing option will require further detailed evaluation including, among other factors, an evaluation of property ownership issues along the corridor, constructability and long term operating considerations should the Quesnel River option be identified as feasible.



CENTRELINE STATISTICS - % OF ROUTE WITHIN:				
FEATURE	QR-a	QR-b	QL-a	QL-b
Cutblock	17.16%	2.00%	14.44%	0.00%
Mining Lease	13.49%	0.00%	5.87%	0.00%
Old Growth Management Area	0.70%	2.13%	2.06%	4.33%
Archaeological Site	0.00%	0.00%	0.79%	1.55%
Recreation Line	0.00%	0.00%	0.00%	0.00%
Areas Adjacent to Road ROW	3.15%	11.75%	38.57%	45.20%
Areas within Road ROW	0.35%	2.00%	17.78%	0.93%
Slope 10%-25%	24.52%	11.13%	10.63%	14.55%
Slope 25% - 100%	2.98%	2.50%	1.43%	1.86%
Waterbody	0.18%	0.38%	1.43%	2.79%
Watercourse Bank	20.32%	39.63%	29.21%	34.67%
Wetland	0.00%	2.63%	0.00%	0.00%

REFERENCES
1. WATERCOURSES, WATERBODIES AND ROAD DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. PARK AND TOWN DATA OBTAINED FROM IHS ENERGY INC.
3. CUTBLOCK AND OLD GROWTH MANAGEMENT AREA DATA OBTAINED BY B.C. MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS
PROJECT: UTM 10 DATUM: NAD83

CLIENT
MOUNT POLLEY MINING CORPORATION

PROJECT
MOUNT POLLEY WATER MANAGEMENT PLANNING

TITLE
WATER PIPELINE OPTIONS OVERVIEW

CONSULTANT

YYYY-MM-DD	2015-03-20
DESIGNED	AL
PREPARED	CD
REVIEWED	
APPROVED	

PROJECT NO	CONTROL	REV	FIGURE
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Figure 14: Estimated alignment options of a pipe routing to Quesnel Lake using impedance analysis.

6.0 OPTIONS ANALYSIS

Section 4 presents a number of options for water treatment and Section 5 presents options for managing treated effluent volumes. Each of these sections provides criteria for screening and short-listing options. If either of these short lists fails to identify a clear “winning” option, an options analysis may be a viable approach to do so. A Kepner-Tregoe (KT) Analysis is a potential tool that could be used to weigh competing criteria to further reduce a short list to one or two options.

A KT Analysis is a matrix of options and decision criteria. Each criterion is assigned a numerical weighting that indicates its overall importance. Criteria are typically organized according to economic, technological, environmental and social factors. Each category can include a single criterion or multiple criteria. For example, economic factors can be represented as net present value or broken down into capital and operating expenses. Likewise, environmental factors often include multiple types of biological receptors as well as competing criteria such as the generation of by-products. After criteria have been established, the options are then compared on a criterion-by-criterion basis, and ranked according to each criterion (ignoring all other factors). Once each option is ranked within each category, the applied weightings are used to generate an overall numerical score that indicates which option is preferred.

The process of populating the matrix, including assigning weightings and ranking options, is often held in a workshop setting with interested parties as well as internal and external experts in the fields of each category in the matrix. This approach can lose its effectiveness if the number of participants becomes large, particularly if their technical background is poor. However, feedback can be incorporated into the analysis by assigning weightings to criteria which have identified through previous consultation efforts. In either case, the matrix can be documented to present a transparent and traceable decision to support the final option that is selected.

Additionally, if the final outcome of the decision analysis is not clear (i.e., two options have similar overall scores), a sensitivity analysis can be conducted by simply changing the weightings of criteria that are uncertain or flexible. This allows a number of “what if” scenarios to be evaluated to determine whether a single option emerges as a winner under various circumstances. There is also the option to over-ride the decision arrived at by scoring if the various parties can’t accept the outcome or it the matrix selects a decision that incompatible with law or policy.

The contingency option will be developed under the auspices of a long-term water management plan. However, there are different factors driving the contingency, not the least of which is the possible urgency. Therefore, it would not be amenable to an options analysis together with long term options. The contingency option will be considered separately.

7.0 MONITORING PLAN

Water balance and water quality models will be developed based on water quality data collected to date and based on climate and hydrology parameters developed for the site. A water quantity and quality monitoring plan will be developed to confirm the assumptions made in the water models, verify predicted water quantity and quality trends, and trigger planned discharge management strategies (treatment) and/or adaptive management strategies, should these trends be different than predicted.

The monitoring plan will include monitoring of water quality and quantity at key locations during the various Project stages discussed above. The following preliminary locations for water quality and quantity monitoring are identified:

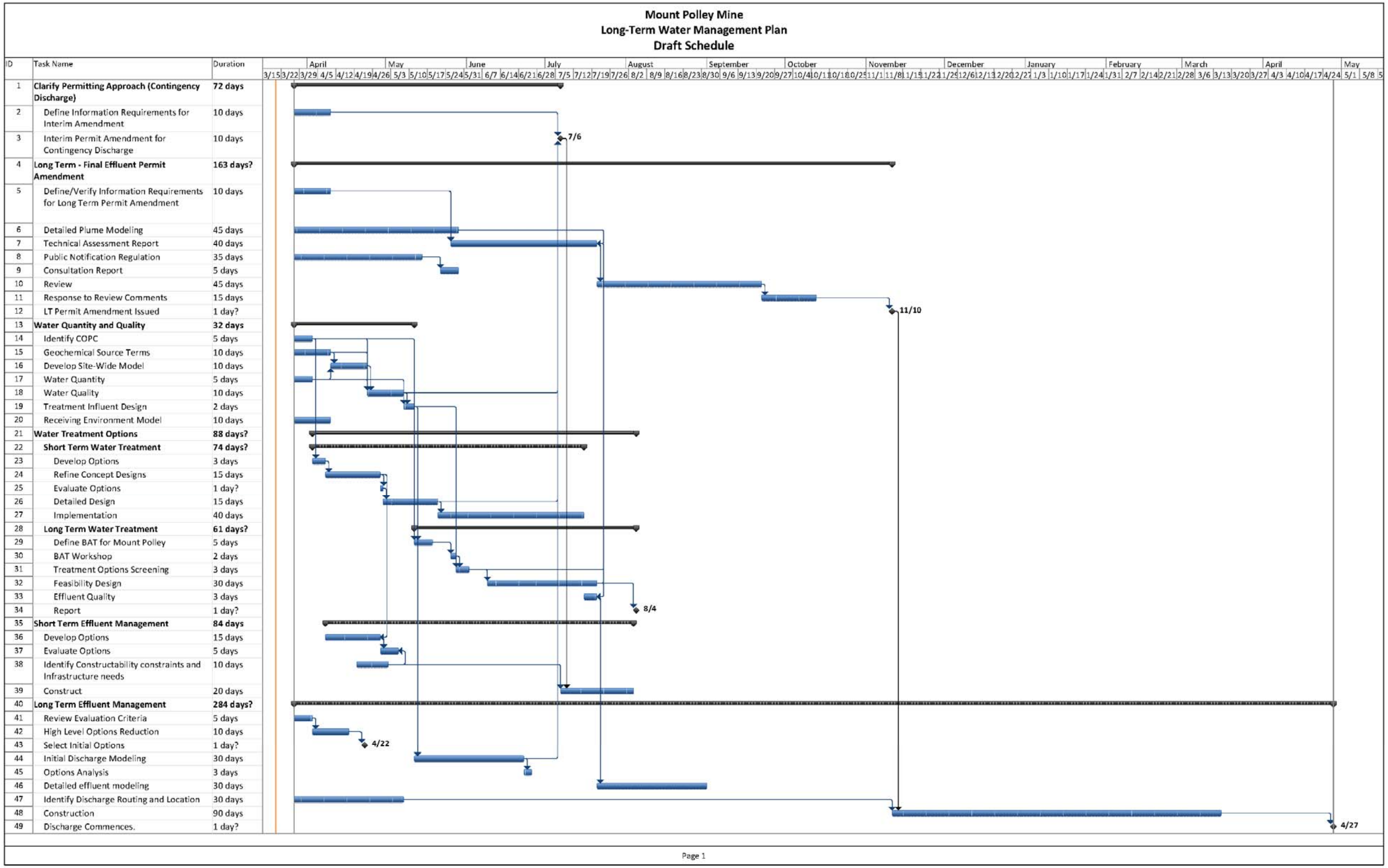
- Central Collection Pond
  - inflows quantity
  - water quality
- TSF seepage pond(s)
  - inflows quantity
  - water quality
- Springer Pit, including
  - water quality of top water layer in the pit
  - water quality at depth (optional)
  - water quantity and quality at discharge of the pit (when would start)
- Treatment plant
  - water quality and quantity at the plant inlet and outlet

Additional monitoring stations may be established at select locations to further monitor or qualify water quality and quantity trends as considered appropriate during the development of the water models. Water quality parameters to be monitored will be defined based on the identified COPC. Monitoring frequency at the different locations will be defined as part of the development of the monitoring plan and based on specific requirements included in the existing water license for the mine. Data from the monitoring program will be collected, compiled, and managed internally by MPMC.

8.0 SCHEDULE

A draft project schedule is provided in Figure 15. It is anticipated that this schedule will be updated as additional information becomes available and as both the short and long-term water management plans develop. In particular, the choice of options will affect construction schedules which require details to confirm the construction program and to source materials. The urgency of the schedule may also change as the coming seasonal conditions become known and monitoring of the pit level and other factors provide important information. Even with those seasonal conditions, MPMC believe that contingency measures are available, subject to agency approval.

The schedule is also subject to change as consultation with agencies, First Nations and the local community becomes advanced.



Mount Polley Mine
Long-Term Water Management Plan
Draft Schedule

ID	Task Name	Duration
1	**Clarify Permitting Approach (Contingency Discharge)**	**72 days**
2	Define Information Requirements for Interim Amendment	10 days
3	Interim Permit Amendment for Contingency Discharge	10 days
4	**Long Term - Final Effluent Permit Amendment**	**163 days?**
5	Define/Verify Information Requirements for Long Term Permit Amendment	10 days
6	Detailed Plume Modeling	45 days
7	Technical Assessment Report	40 days
8	Public Notification Regulation	35 days
9	Consultation Report	5 days
10	Review	45 days
11	Response to Review Comments	15 days
12	LT Permit Amendment Issued	1 day?
13	**Water Quantity and Quality**	**32 days**
14	Identify COPC	5 days
15	Geochemical Source Terms	10 days
16	Develop Site-Wide Model	10 days
17	Water Quantity	5 days
18	Water Quality	10 days
19	Treatment Influent Design	2 days
20	Receiving Environment Model	10 days
21	**Water Treatment Options**	**88 days?**
22	**Short Term Water Treatment**	**74 days?**
23	Develop Options	3 days
24	Refine Concept Designs	15 days
25	Evaluate Options	1 day?
26	Detailed Design	15 days
27	Implementation	40 days
28	**Long Term Water Treatment**	**61 days?**
29	Define BAT for Mount Polley	5 days
30	BAT Workshop	2 days
31	Treatment Options Screening	3 days
32	Feasibility Design	30 days
33	Effluent Quality	3 days
34	Report	1 day?
35	**Short Term Effluent Management**	**84 days**
36	Develop Options	15 days
37	Evaluate Options	5 days
38	Identify Constructability constraints and Infrastructure needs	10 days
39	Construct	20 days
40	**Long Term Effluent Management**	**284 days?**
41	Review Evaluation Criteria	5 days
42	High Level Options Reduction	10 days
43	Select Initial Options	1 day?
44	Initial Discharge Modeling	30 days
45	Options Analysis	3 days
46	Detailed effluent modeling	30 days
47	Identify Discharge Routing and Location	30 days
48	Construction	90 days
49	Discharge Commences.	1 day?

Figure 15: Draft Water Management Plan Schedule.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Lee Nikl, M.Sc., R.P.Bio.
Principal, Senior Environmental Scientist

ORIGINAL SIGNED

Corne Pretorius, M.Sc.
Group Manager; Mine Water Management Group

ORIGINAL SIGNED

Mike Herrel, M.Sc. P.Geo.
Senior Geochemist

ORIGINAL SIGNED

Robert Millar Ph.D., P.Eng., P.Geo.
Associate, Senior Hydrotechnical/Water Resources Engineer

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APPENDIX A

Water Quality Data for Springer Beach (Post-TMF Breach), TSF Supernatant, and Perimeter Pond

APPENDIX A

Water Quality Data for Springer Beach (Post-TMF Breach), TSF Supernatant, and Perimeter Pond

Parameter	Screening Criteria			Springer Pit - Post-TMF Breach											TSF Supernatant												
	British Columbia Water Quality (BCWQ) Guidelines for the Protections of Freshwater Aquatic Life		Metal Mining Effluent Regulations (MMER)																								
Date	30-Day Mean Concentration	Maximum	Maximum Authorized Concentration in a Grab Sample	17/09/2014	07/10/2014	21/10/2014	06/11/2014	19/11/2014	Samples >MDL	Samples (n)	Average	Minimum	Maximum	95th Percentile	02/01/2013	06/02/2013	01/05/2013	08/08/2013	05/11/2013	11/02/2014	01/05/2014	Samples >MDL	Samples (n)	Average	Minimum	Maximum	95th Percentile
Specific Conductance (in situ) (µs/cm)	-	-	-	1180	1295	1309	1139	1203	5	5	1225	1139	1309	1306	1273	1273	1072	1193	1281	1287	1099	7	7	1211	1072	1287	1285
pH (in situ) (pH)	-	-	-	8.1	7.8	8.2	8.2	8.7	5	5	8.2	7.8	8.7	8.6	8.9	8.9	9.7	8.1	8.4	8.8	8.6	7	7	8.8	8.1	9.7	9.4
Temperature (in situ) (°C)	-	-	-	14	13	10	7.3	3.6	5	5	9.5	3.6	14	13	3.4	3.5	8.4	22	1.2	2.9	5.4	7	7	6.7	1.2	22	18
Turbidity (in situ) (NTU)	-	-	-	4.8	2.1		14	5.1	4	4	6.4	2.1	14	12			8.4			2.4	12	3	3	7.5	2.4	12	11
Alkalinity (mg/L as CaCO3)	-	-	-	90	101	98	88	84	5	5	92	84	101	100	29	27	31	36	38	31	34	7	7	32	27	38	37
Conductivity (µs/cm)	-	-	-	1170	1250	1270	1210	1180	5	5	1216	1170	1270	1266	1200	1180	1060	1190	1250	1260	1040	7	7	1169	1040	1260	1257
Hardness (mg/L as CaCO3)	-	-	-	585	644	668	578	583	5	5	612	578	668	663	460	489	403	440	474	475	393	7	7	448	393	489	485
pH (pH)	6.5-9	6.5-9	-	8.1	7.7	8.1	8.2	8.1	5	5	8.0	7.7	8.2	8.1	7.7	7.9	7.6	7.8	7.9	7.8	8.0	7	7	7.8	7.6	8.0	8.0
Total Dissolved Solids (mg/L)	-	-	-	965	998	988	971	950	5	5	974	950	998	996	969	939	783	918	945	946	786	7	7	898	783	969	962
Total Suspended Solids (mg/L)	-	-	30	5.4	<3.0	12	12	9.7	4	5	8.1	<3.0	12	12	5.6	<3.0	11	20	55	<3.0	19	5	7	16	<3.0	55	44
Turbidity (NTU)	-	-	-	4.4	1.3	4.2	7.6	6.2	5	5	4.7	1.3	7.6	7.3	3.3	2.8	3.6	10	45	1.9	13	7	7	12	1.9	45	36
Ammonia (mg/L as N)	-	-	-	0.14	0.12	0.12	0.11	0.091	5	5	0.11	0.091	0.14	0.13	0.35	0.4	0.25	0.22	0.17	0.3	0.33	7	7	0.29	0.17	0.4	0.38
Chloride (mg/L)	150	600	-	11	9.9	13	11	10	5	5	11	9.9	13	13	23	24	20	21	26	26	23	7	7	23	20	26	26
Nitrate (mg/L as N)	3	32.8	-	**7.8**	**8.5**	**9.0**	**8.7**	**8.4**	5	5	**8.5**	**7.8**	**9.0**	**9.0**	**7.4**	**7.7**	**6.3**	**7.3**	**7.5**	**7.8**	**6.8**	7	7	**7.2**	**6.3**	**7.8**	**7.7**
Nitrate and Nitrite (mg/L as N)	-	-	-	7.8	8.6	9.1	8.8	8.4	5	5	8.5	7.8	9.1	9.0	7.6		6.4	7.4	7.6	7.9	6.9	6	6	7.3	6.4	7.9	7.8
Nitrite (mg/L as N)	0.02-0.2[a]	0.06-0.6[a]	-	0.09	0.085	0.08	0.061	0.043	5	5	0.072	0.043	0.09	0.089	0.13	0.14	0.13	0.091	0.088	0.14	0.13	7	7	0.12	0.088	0.14	0.14
Orthophosphate-Dissolved (mg/L as P)	-	-	-	<0.0010	<0.0010	<0.0010	0.0043	0.0079	2	5	0.0027	<0.0010	0.0079	0.0072	<0.0010	0.0017	<0.0010	<0.0010	<0.0010	0.0023	0.0058	3	7	0.0017	<0.0010	0.0058	0.0048
Phosphorus Total Dissolved (mg/L)	-	-	-	0.0038	0.0028	0.0023	0.0076	0.012	5	5	0.0057	0.0023	0.012	0.011	<0.0020	0.0044	0.0023	<0.0020	<0.0020	0.005	0.013	4	7	0.0039	<0.0020	0.013	0.01
Phosphorus Total (mg/L)	-	-	-	0.011	0.0057	0.0083	0.014	0.016	5	5	0.011	0.0057	0.016	0.016	0.0079	0.0067	0.015	0.015	0.06	0.0077	0.031	7	7	0.02	0.0067	0.06	0.051
Sulphate (mg/L)	128-429[b]	-	-	**537**	**581**	**598**	**550**	**526**	5	5	**558**	**526**	**598**	**595**	**563**	**575**	**477**	**540**	**576**	**583**	**463**	7	7	**540**	**463**	**583**	**581**
Total Nitrogen (mg/L)	-	-	-	7.3	8.1	8.4	8.4	8.0	5	5	8.0	7.3	8.4	8.4	7.2	7.2	6.6	7.8	7.5	7.7	7.1	7	7	7.3	6.6	7.8	7.8
Dissolved Organic Carbon (mg/L)	-	-	-	3.1	2.4	2.7	4.4	4.5	5	5	3.4	2.4	4.5	4.5	5.4	6.0	7.3	4.2	3.6	5.3	5.0	7	7	5.3	3.6	7.3	6.9
Dissolved Metals																											
Aluminum (mg/L)	0.023-0.05[c]	0.0068-0.1[c]	-	**0.25**	**0.11**	**0.15**	**0.51**	**0.3**	5	5	**0.26**	**0.11**	**0.51**	**0.47**	**0.2**	**0.078**	**0.52**	**0.88**	**2.1**	**0.082**	**0.84**	7	7	**0.66**	**0.078**	**2.1**	**1.7**
Antimony (mg/L)	-	-	-	0.002	0.0021	0.002	0.0017	0.0012	5	5	0.0018	0.0012	0.0021	0.0021	0.0021	0.0019	0.0018	0.0021	0.0022	0.002	0.0015	7	7	0.0019	0.0015	0.0022	0.0021
Arsenic (mg/L)	-	-	-	0.0023	0.0021	0.002	0.0021	0.0017	5	5	0.002	0.0017	0.0023	0.0022	0.002	0.0021	0.0018	0.0024	0.003	0.0021	0.0019	7	7	0.0022	0.0018	0.003	0.0028
Barium (mg/L)	-	-	-	0.039	0.037	0.04	0.048	0.047	5	5	0.042	0.037	0.048	0.048	0.053	0.056	0.055	0.088	0.075	0.039	0.045	7	7	0.059	0.039	0.088	0.084
Beryllium (mg/L)	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	5	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	7	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (mg/L)	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	5	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	7	<0.00050	<0.00050	<0.00050	<0.00050
Boron (mg/L)	-	-	-	0.17	0.18	0.19	0.19	0.15	5	5	0.17	0.15	0.19	0.19	0.12	0.12	0.099	0.1	0.096	0.12	0.095	7	7	0.11	0.095	0.12	0.12
Cadmium (mg/L)	0.00038-0.00046[b]	0.000038-0.0028[b]	-	0.00015	0.00011	0.000098	0.00012	0.000093	5	5	0.00011	0.000093	0.00015	0.00014	<0.000050	<0.000050	<0.000050	<0.000060	<0.00010	<0.000050	<0.00023	0	7	0.000042	<0.000050	0.00012	0.000096
Calcium (mg/L)	-	-	-	180	195	202	186	177	5	5	188	177	202	201	153	163	133	145	158	155	127	7	7	148	127	163	162
Chromium (mg/L)	-	-	-	<0.00050	<0.00050	<0.00050	0.00062	<0.00050	1	5	0.00032	<0.00050	0.00062	0.00055	<0.00050	<0.00050	<0.00050	<0.00050	0.00068	<0.00050	<0.00050	1	7	0.00031	<0.00050	0.00068	0.00055
Cobalt (mg/L)	-	-	-	0.0017	0.0016	0.0016	0.0016	0.001	5	5	0.0015	0.001	0.0017	0.0017	0.00014	0.00011	0.0003	0.00051	0.0017	<0.00010	0.0005	6	7	0.00047	<0.00010	0.0017	0.0013
Copper (mg/L)	-	-	-	0.06	0.052	0.059	0.08	0.057	5	5	0.062	0.052	0.08	0.076	0.0048	0.0031	0.0083	0.015	0.041	0.002	0.016	7	7	0.013	0.002	0.041	0.033
Iron (mg/L)	-	0.35	-	0.22	0.093	0.13	0.41	0.3	5	5	0.23	0.093	0.41	0.39	0.096	0.047	0.33	0.46	1.5	0.046	0.36	7	7	0.4	0.046	1.5	1.2
Lead (mg/L)	-	-	-	0.00014	0.000063	0.00014	0.00016	0.00013	5	5	0.00013	0.000063	0.00016	0.00016	0.000052	<0.000050	0.00012	0.000078	0.00054	<0.000050	0.00009	5	7	0.00013	<0.000050	0.00054	0.00041
Lithium (mg/L)	-	-	-	0.0075	0.0076	0.0078	0.008	0.0068	5	5	0.0075	0.0068	0.008	0.0079	0.013	0.012	0.0085	0.011	0.012	0.011	0.0091	7	7	0.011	0.0085	0.013	0.012
Magnesium (mg/L)	-	-	-	31	34	36	32	30	5	5	33	30	36	36	18	20	17	19	19	21	19	7	7	19	17	21	21
Manganese (mg/L)	-	-	-	0.1	0.11	0.11	0.13	0.16	5	5	0.12	0.1	0.16	0.15	0.015	0.015	0.024	0.023	0.064	0.02	0.035	7	7	0.028	0.015	0.064	0.055
Mercury (mg/L)	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	<0.000010	<0.000010	<0.000010	-	-	0	3	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (mg/L)	-	-	-	0.18	0.17	0.18	0.18	0.15	5	5	0.17	0.15	0.18	0.18	0.19	0.2	0.16	0.18	0.2	0.2	0.15	7	7	0.18	0.15	0.2	0.2
Nickel (mg/L)	-	-	-	0.00084	0.00084	0.00092	0.0012	0.0011	5	5	0.00097	0.00084	0.0012	0.0011	<0.00050	<0.00050	0.00057	0.00081	0.00085	<0.00050	0.00062	4	7	0.00051	<0.00050	0.00085	0.00084
Selenium (mg/L)	-	-	-	0.055	0.05	0.047	0.044	0.037	5	5	0.047	0.037	0.055	0.054	0.029	0.028	0.027	0.03	0.031	0.035	0.028	7	7	0.03	0.027	0.035	0.034
Silicon (mg/L)	-	-	-	6.8	6.7	6.6	7.2	6.2	5	5	6.7	6.2	7.2	7.1	6.0	5.6	6.3	8.4	10	5.5	6.1	7	7	6.9	5.5	10	9.7
Silver (mg/L)	-	-	-	0.000016	<0.000010	0.000011	0.000018	0.000012	4	5	0.000012	<0.000010	0.000018	0.000018	<0.000010	<0.000010	0.000024	<0.000010	0.000022	<0.000010	<0.000010	2	7	0.00001	<0.000010	0.000024	0.000023
Sodium (mg/L)	-	-	-	43	37	38	39	38	5	5	39	37	43	42	83	89	67	76	82	91	73	7	7	80	67	91	90
Strontium (mg/L)	-	-	-	1.8	2.0	2.2	2.2	1.9	5	5	2.0	1.8	2.2	2.2	1.4	1.6	1.4	1.5	1.6	1.5	1.4	7	7	1.5	1.4	1.6	1.6
Thallium (mg/L)	-	-	-	<0.000010	<0.000010	0.000011	<0.000010	<0.000010	1	5	0.0000062	<0.000010	0.000011	0.0000098	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0	7	0.000005	<0.000010	0.000005	0.000005
Tin (mg/L)	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	5	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	<0.00010	1	7	0.00006	<0.00010	0.00012	0.000099
Titanium (mg/L)	-	-	-	0.033	0.025	0.028	0.046	0.035	5	5	0.033	0.025	0.046	0.044	0.02	<0.010	0.028	0.055	0.13	0.014	0.051	6	7	0.043	<0.010	0.13	0.11
Uranium (mg/L)	-	-	-	0.0052	0.0057	0.0057	0.005	0.0038	5	5	0.0051	0.0038	0.0057	0.0057	0.001	0.00088	0.00066	0.0011	0.0011	0.0014	0.0013	7	7	0.0011	0.00066	0.0014	0.0014
Vanadium (mg/L)	-	-	-	0.004	0.003	0.0029	0.0038	0.0028	5	5	0.0033	0.0028	0.004	0.004	0.0038	0.0032	0.0044	0.0046	0.0087	0.0024	0.0033	7	7	0.0043	0.0024	0.0087	0.0075
Zinc (mg/L)	-	-	-	0.005	0.0041	0.0039	0.0052	0.0053	5	5	0.0047	0.0039	0.0053	0.0053	<0.0030	<0.0030	<0.0030	0.0031	0.0059	<0.0030	<0.0030	2	7	0.0024	<0.0030	0.0059	0.0051
Total Metals																											
Aluminum (mg/L)	-	-	-	0.0038	0.0033	<0.0030	<0.0050	0.0048	3	5	0.0032	<0.0030	0.0048	0.0046	0.011	-	-	-	-	-	-	1	1	0.011	0.011	0.011	0.011
Antimony (mg/L)	-	0.02	-	0.0018	0.0021	0.002	0.0016	0.0013	5	5	0.0018	0.0013	0.0021	0.0021	0.002	-	-	-	-	-	-	1	1	0.002	0.002	0.002	0.002
Arsenic (mg/L)	-	0.005	1	0.0022	0.0019	0.0019	0.0019	0.0017	5	5	0.0019	0.0017	0.0022	0.0021	0.0021	-	-	-	-	-	-	1	1	0.0021	0.0021	0.0021	0.0021
Barium (mg/L)	1	5	-	0.036	0.036	0.039	0.041	0.045	5	5	0.039	0.036	0.045	0.044	0.054	-	-	-	-	-	-	1	1	0.054	0.054	0.054	0.054
Beryllium (mg/L)	0.0053	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	5	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-	-	-	-	-	-	0	1	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (mg/L)	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	5	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	-	-	-	-	-	0	1	<0.00050	<0.00050	<0.00050	<0.00050
Boron (mg/L)	-	1.2	-	0.15	0.17	0.19	0.17	0.14	5	5	0.16	0.14	0.19	0.18	0.12	-	-	-	-	-	-	1	1	0.12	0.12	0.12	0.12
Cadmium (mg/L)	-	-	-	0.0001	0.00011	0.000096	0.000094	0.000074	5	5	0.000096	0.000074	0.00011	0.00011	<0.000050	-	-	-	-	-	-	0	1	<0.000050	<0.000050	<0.000050	<0.000050
Calcium (mg/L)	-	-	-	182	201	206	180	183	5	5	190	180	206	205	154	-	-	-	-	-	-	1	1	154	154	154	154
Chromium (mg/L)	-	0.001	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	5	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	-	-	-	-	-	0	1	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (mg/L)	0.004	0.11	-	0.0014	0.0015	0.0015	0.001	0.00077	5	5	0.0012	0.00077	0.0015	0.0015	<0.00010	-	-	-	-	-	-	0	1	<0.00010	<0.00010	<0.00010	<0.00010
Copper (mg/L)	0.00038-0.00046[b]	0.000038-0.0028[b]	0.6	**0.046**	**0.044**	**0.049**	**0.046**	**0.039**	5	5	**0.045**	**0.039**	**0.049**	**0.048**	0.00093	-	-	-	-	-	-	1	1	0.00093	0.00093	0.00093	0.00093
Iron (mg/L)	-	1	-	<0.030	<0.030	<0.030	<0.030	<0.030	0	5	<0.030	<0.030	<0.030	<0.030	<0.030	-	-	-	-	-	-	0	1	<0.030	<0.030	<0.030	<0.030
Lead (mg/L)	0.0034-0.052[b]	0.003-1.25[b]	0.4	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0	5	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	-	-	-	-	-	-	0	1	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (mg/L)	0.096	0.87	-	0.008	0.0078	0.0079	0.0072	0.0064	5	5	0.0074	0.0064	0.008	0.008	0.013	-	-	-	-	-	-	1	1	0.013	0.013	0.013	0.013
Magnesium (mg/L)	-	-	-	32	34	37	31	31	5	5	33	31	37	37	18	-	-	-	-	-	-	1	1	18	18	18	18
Manganese (mg/L)	0.63-4.35[b]	0.6-9.93[b]	-	0.094	0.1	0.11	0.11	0.15	5	5	0.11	0.094	0.15	0.14	0.012	-	-	-	-	-	-	1	1	0.012	0.012	0.012	0.012
Mercury (mg/L)	-	-	-	-	-	-	-	-	0	0	-	-	-	-		-	-	-	-	-	-	0	0				
Molybdenum (mg/L)	1	2	-	0.16	0.17	0.17	0.17	0.15	5	5	0.16	0.15	0.17	0.17	0.18	-	-	-	-	-	-	1	1	0.18	0.18	0.18	0.18
Nickel (mg/L)	-	0.025-0.15[b]	1	0.00066	0.00075	0.00067	0.00077	0.00084	5	5	0.00074	0.00066	0.00084	0.00083	<0.00050	-	-	-	-	-	-	0	1	<0.00050	<0.00050	<0.00050	<0.00050
Potassium (mg/L)	-	-	-	3.2	2.6	2.6	2.9	3.6	5	5	3.0	2.6	3.6	3.5	14	-	-	-	-	-	-	1	1	14	14	14	14
Selenium (mg/L)	-	0.002	-	0.054	0.048	0.047	0.042	0.039	5	5	0.046	0.039	0.054	0.053	0.027	-	-	-	-	-	-	1	1	0.027	0.027	0.027	0.027
Silicon (mg/L)	-	-	-	6.4	6.5	6.5	5.9	5.8	5	5	6.2	5.8	6.5	6.5	5.5	-	-	-	-	-	-	1	1	5.5	5.5	5.5	5.5
Silver (mg/L)	0.00005-0.15[b]	0.001-0.003[b]	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0	5	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	-	-	-	-	-	-	0	1	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (mg/L)	-	-	-	42	37	38	37	38	5	5	39	37	42	41	86	-	-	-	-	-	-	1	1	86	86	86	86
Strontium (mg/L)	-	-	-	1.5	2.0	2.1	2.2	1.9	5	5	1.9	1.5	2.2	2.1	1.4	-	-	-	-	-	-	1	1	1.4	1.4	1.4	1.4
Thallium (mg/L)	-	0.0003	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0	5	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	-	-	-	-	-	-	0	1	<0.000010	<0.000010	<0.000010	<0.000010
Tin (mg/L)	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	5	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-	-	-	-	-	-	0	1	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (mg/L)	-	2	-	0.02	0.019	0.021	0.019	0.02	5	5	0.02	0.019	0.021	0.021	0.013	-	-	-	-	-	-	1	1	0.013	0.013	0.013	0.013
Uranium (mg/L)	-	0.3	-	0.0046	0.0055	0.0057	0.0048	0.0039	5	5	0.0049	0.0039	0.0057	0.0056	0.001	-	-	-	-	-	-	1	1	0.001	0.001	0.001	0.001
Vanadium (mg/L)	-	0.006	-	0.0031	0.0025	0.0024	0.002	0.0018	5	5	0.0024	0.0018	0.0031	0.003	0.0034	-	-	-	-	-	-	1	1	0.0034	0.0034	0.0034	0.0034
Zinc (mg/L)	0.0075-0.58[b]	0.033-0.6[b]	1	0.0032	<0.0030	<0.0030	<0.0030	0.0037	2	5	0.0023	<0.0030	0.0037	0.0036	<0.0030	-	-	-	-	-	-	0	1	<0.0030	<0.0030	<0.0030	<0.0030

Notes:

a) Chloride dependent guideline

b) Hardness dependent guideline

c) pH dependent guideline

MDL - Method detection limit

123	Denotes a concentration that is greater than the BCWQ guideline for freshwater aquatic life 30-day average
123	Denotes a concentration that is greater than the BCWQ guideline for freshwater aquatic life maximum
123	Denotes a concentration that is greater than the MMER maximum authorized concentration in a grab sample

APPENDIX A

Water Quality Data for Springer Beach (Post-TMF Breach), TSF Supernatant, and Perimeter Pond

Parameter	Screening Criteria			Perimeter Pond																										
	British Columbia Water Quality (BCWQ) Guidelines for the Protections of Freshwater Aquatic Life		Metal Mining Effluent Regulations (MMER)																											
Date	30-Day Mean Concentration	Maximum	Maximum Authorized Concentration in a Grab Sample	02/01/2013	06/02/2013	01/05/2013	08/08/2013	05/11/2013	05/12/2013	10/12/2013	12/12/2013	16/12/2013	19/12/2013	07/01/2014	27/01/2014	28/01/2014	29/01/2014	30/01/2014	11/02/2014	04/03/2014	01/04/2014	01/05/2014	03/06/2014	03/07/2014	Samples >MDL	Samples (n)	Average	Minimum	Maximum	95th Percentile
Specific Conductance (in situ) (µs/cm)	-	-	-	1239	1112	1250	1493	1316	1251	1162	1147	1050	1347	1010	1211	1270	1258	1205	1185	1390	797	960	1186	1410	21	21	1202	797	1493	1410
pH (in situ) (pH)	-	-	-	8.2	8.0	7.8	8.2	8.2	8.4	7.7	7.3	7.6	8.1	7.8	7.1	7.9	8.1	8.1	7.6	8.4	8.0	7.9	8.1	8.2	21	21	7.9	7.1	8.4	8.4
Temperature (in situ) (°C)	-	-	-	0	0.1	5.9	19	2.2	1.6		3.3	2.0	3.7	1.6	5.3	5.3	5.5	3.2	0.1	0.5	1.9	7.8	14	16	20	20	4.9	0	19	16
Turbidity (in situ) (NTU)	-	-	-			5.9			15										6.7	16	38	21	4.2		7	7	15	4.2	38	33
Alkalinity (mg/L as CaCO3)	-	-	-	139	109	74	72	121	153	106	109	107	113	91	105	109	108	105	88	102	89	76	86	83	21	21	102	72	153	139
Conductivity (µs/cm)	-	-	-	1170	1040	1240	1490	1250	1540	1130	1140	1040	1270	985	1160	1200	1190	1160	1170	1300	773	890	1170	1400	21	21	1177	773	1540	1490
Hardness (mg/L as CaCO3)	-	-	-	675	622	679	757	659	852	579	597	512	663	494	589	622	626	606	557	602	395	485	582	754	21	21	615	395	852	757
pH (pH)	6.5-9	6.5-9	-	8.1	8.0	7.9	8.0	7.9	8.1	7.8	8.0	8.0	8.1	8.0	8.2	8.1	8.1	8.1	8.1	8.1	8.0	7.9	8.1	8.1	21	21	8.0	7.8	8.2	8.1
Total Dissolved Solids (mg/L)	-	-	-	976	851	979	1230	1050	1230	892	900	806	1000	743	678	977	945	703	891	850	576	739	927	1150	21	21	909	576	1230	1230
Total Suspended Solids (mg/L)	-	-	30	3.9	<3.0	11	9.7	<3.0	12	20	27	21	5.7	81	22	21	20	28	<3.0	6.9	28	33	3.4	6.8	18	21	17	<3.0	81	33
Turbidity (NTU)	-	-	-	3.8	3.0	3.9	2.7	5.3	16	39	28	30	6.1	92	31	20	20	29	7.8	7.8	31	29	3.9	6.2	21	21	20	2.7	92	39
Ammonia (mg/L as N)	-	-	-	<0.0050	0.0071	<0.0050	0.0065	0.079	0.28	0.31	0.21	0.33	0.085	0.56	0.18	0.097	0.12	0.21	0.23	0.81	0.73	0.066	<0.0050	0.024	18	21	0.21	<0.0050	0.81	0.73
Chloride (mg/L)	150	600	-	<5.0	<5.0	5.5	14	11	13	7.6	8.1	11	12	11	11	12	10	12	11	17	7.1	5.3	12	12	19	21	9.9	<5.0	17	14
Nitrate (mg/L as N)	3	32.8	-	**7.7**	**8.9**	**10**	**6.9**	**6.9**	**11**	**9.4**	**8.7**	**8.7**	**6.5**	**8.1**	**5.2**	**5.3**	**5.4**	**6.4**	**6.5**	**9.4**	**9.1**	**6.9**	**9.4**	**9.4**	21	21	**7.9**	**5.2**	**11**	**10**
Nitrate and Nitrite (mg/L as N)	-	-	-	7.7	8.9	10	6.9	7.0	11	9.5	8.9	8.9	6.6	8.3	5.3	5.4	5.6	6.5	6.6	9.9	9.4	7.0	9.4	9.4	21	21	8.0	5.3	11	10
Nitrite (mg/L as N)	0.02-0.2[a]	0.06-0.6[a]	-	0.011	<0.010	<0.010	0.028	0.06	0.18	**0.18**	**0.17**	**0.26**	0.14	**0.23**	0.14	0.13	0.13	0.17	0.19	**0.48**	**0.28**	0.049	0.027	0.034	19	21	**0.14**	<0.010	**0.48**	**0.28**
Orthophosphate-Dissolved (mg/L as P)	-	-	-	0.0026	0.0028	0.003	<0.0010	0.0022	0.0036	0.0025	0.0029	<0.0010	0.0038	<0.0010	0.0041	0.005	0.0061	0.0046	0.0063	0.0036	0.0014	0.0037	<0.0010	<0.0010	16	21	0.0029	<0.0010	0.0063	0.0061
Phosphorus Total Dissolved (mg/L)	-	-	-	0.0049	0.0047	0.0058	0.0041	0.0041	0.0072	0.0065	0.007	0.0057	0.0065	0.0073	0.0078	0.0083	0.0096	0.0081	0.01	0.0078	0.0048	0.0091	0.0033	0.0036	21	21	0.0065	0.0033	0.01	0.0096
Phosphorus Total (mg/L)	-	-	-	0.0099	0.0084	0.015	0.013	0.011	0.031	0.051	0.044	0.056	0.017	0.11	0.049	0.039	0.043	0.046	0.024	0.02	0.044	0.05	0.017	0.017	21	21	0.034	0.0084	0.11	0.056
Sulphate (mg/L)	128-429[b]	-	-	**531**	**479**	**595**	**761**	**595**	**731**	**493**	**514**	**448**	**585**	407	**526**	**572**	**571**	**522**	**518**	**581**	291	429	**525**	**709**	21	21	**542**	291	**761**	**731**
Total Nitrogen (mg/L)	-	-	-	7.2	8.2	9.9	6.7	6.6	10	9.7	8.9	8.8	6.5		5.5	5.3	5.6	6.5	6.7	11	9.4	6.6	8.9	8.5	20	20	7.8	5.3	11	10
Dissolved Organic Carbon (mg/L)	-	-	-	3.1	4.3	5.3	3.3	2.9	4.8	3.1	3.1	4.1	2.9	3.4	3.5	3.1	3.4	2.6	4.0	4.1	5.0	5.3	4.7	3.8	21	21	3.8	2.6	5.3	5.3
Dissolved Metals																														
Aluminum (mg/L)	0.023-0.05[c]	0.0068-0.1[c]	-	**0.12**	**0.13**	**0.47**	**0.18**	**0.33**	**1.0**	**3.0**	**1.5**	**2.0**	**0.46**	**4.0**	**1.4**	**1.0**	**1.2**	**1.3**	**0.43**	**0.38**	**1.7**	**1.5**	**0.26**	**0.39**	21	21	**1.1**	**0.12**	**4.0**	**3.0**
Antimony (mg/L)	-	-	-	0.00081	0.00047	0.00042	0.00062	0.00088	0.0014	0.0018	0.0013	0.0014	0.00084	0.0023	0.0011	0.00087	0.00095	0.0014	0.0015	0.0022	0.0029	0.00065	0.00053	0.00063	21	21	0.0012	0.00042	0.0029	0.0023
Arsenic (mg/L)	-	-	-	0.00077	0.00059	0.00067	0.00088	0.0013	0.0015	0.0017	0.0015	0.0016	0.0013	0.0031	0.0017	0.0016	0.0015	0.0016	0.0016	0.002	0.0019	0.0011	0.00087	0.0011	21	21	0.0014	0.00059	0.0031	0.002
Barium (mg/L)	-	-	-	0.037	0.042	0.048	0.047	0.065	0.063	0.06	0.055	0.061	0.042	0.076	0.051	0.048	0.049	0.047	0.043	0.053	0.059	0.048	0.051	0.054	21	21	0.052	0.037	0.076	0.065
Beryllium (mg/L)	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0	21	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (mg/L)	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	21	<0.00050	<0.00050	<0.00050	<0.00050
Boron (mg/L)	-	-	-	0.26	0.12	0.078	0.12	0.23	0.3	0.28	0.25	0.19	0.26	0.14	0.27	0.3	0.28	0.25	0.22	0.16	0.11	0.083	0.082	0.11	21	21	0.2	0.078	0.3	0.3
Cadmium (mg/L)	0.00038-0.00046[b]	0.000038-0.0028[b]	-	<0.00025	<0.00010	<0.00020	<0.00011	<0.00030	<0.00027	<0.00021	<0.00018	<0.00012	<0.00024	<0.00011	<0.00020	<0.00025	<0.00022	<0.00019	<0.00012	<0.00011	<0.000070	<0.00017	<0.00010	<0.00010	0	21	0.000084	<0.000070	0.00017	0.00015
Calcium (mg/L)	-	-	-	220	188	207	236	217	256	178	178	161	211	158	190	194	189	189	169	189	119	148	181	226	21	21	191	119	256	236
Chromium (mg/L)	-	-	-	<0.00050	<0.00050	0.00062	<0.00050	0.00064	0.0014	0.0037	0.0023	0.0027	0.00074	0.0065	0.0022	0.0018	0.0019	0.0022	0.00072	0.0006	0.0025	0.0022	<0.00050	0.00051	17	21	0.0016	<0.00050	0.0065	0.0037
Cobalt (mg/L)	-	-	-	0.00095	0.00019	0.00047	0.00016	0.00094	0.0014	0.0018	0.0013	0.002	0.0011	0.0027	0.0015	0.0013	0.0013	0.0014	0.00075	0.0008	0.0012	0.0014	0.00035	0.00038	21	21	0.0011	0.00016	0.0027	0.002
Copper (mg/L)	-	-	-	0.011	0.0076	0.036	0.0095	0.0097	0.018	0.028	0.024	0.021	0.0099	0.04	0.023	0.017	0.018	0.022	0.04	0.014	0.028	0.072	0.021	0.02	21	21	0.023	0.0076	0.072	0.04
Iron (mg/L)	-	0.35	-	0.31	0.13	0.39	0.17	0.28	1.0	2.8	1.7	1.9	0.44	5.7	1.9	1.3	1.5	1.7	0.54	0.47	2.2	1.4	0.27	0.39	21	21	1.3	0.13	5.7	2.8
Lead (mg/L)	-	-	-	0.000054	0.00008	0.00011	0.000058	0.00011	0.00027	0.002	0.001	0.0009	0.00023	0.0014	0.0012	0.00069	0.00059	0.002	0.00024	0.00014	0.00057	0.00042	0.00078	0.00013	21	21	0.00061	0.000054	0.002	0.002
Lithium (mg/L)	-	-	-	0.0049	0.0031	0.0033	0.0071	0.0078	0.0089	0.0089	0.0079	0.0081	0.0074	0.0085	0.0077	0.0082	0.0084	0.0086	0.0072	0.0096	0.006	0.0038	0.0054	0.0075	21	21	0.0071	0.0031	0.0096	0.0089
Magnesium (mg/L)	-	-	-	34	37	40	41	33	40	31	30	28	30	29	26	27	27	28	28	34	25	28	33	41	21	21	32	25	41	41
Manganese (mg/L)	-	-	-	0.23	0.045	0.068	0.026	0.25	0.4	0.32	0.28	0.32	0.38	0.42	0.38	0.38	0.36	0.34	0.32	0.4	0.2	0.15	0.069	0.065	21	21	0.26	0.026	0.42	0.4
Mercury (mg/L)	-	-	-	-	-	-	<0.000010	-	-	-	-	-	-	-	-	-	-	-	<0.000010	-	-	-	-	-	0	2.0	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (mg/L)	-	-	-	0.13	0.077	0.15	0.28	0.17	0.18	0.14	0.12	0.13	0.15	0.11	0.14	0.16	0.14	0.14	0.13	0.18	0.063	0.12	0.14	0.19	21	21	0.14	0.063	0.28	0.19
Nickel (mg/L)	-	-	-	0.00086	0.00063	0.0013	0.0006	0.0011	0.0017	0.0034	0.0022	0.0023	0.0011	0.0053	0.0037	0.0025	0.0023	0.0074	0.00097	0.00092	0.0025	0.0026	0.00093	0.001	21	21	0.0022	0.0006	0.0074	0.0053
Selenium (mg/L)	-	-	-	0.018	0.022	0.052	0.031	0.017	0.028	0.03	0.026	0.026	0.016	0.025	0.016	0.014	0.015	0.017	0.021	0.028	0.036	0.038	0.041	0.041	21	21	0.026	0.014	0.052	0.041
Silicon (mg/L)	-	-	-	7.9	6.7	5.7	4.6	7.7	12	15	10	13	8.1	20	9.7	8.6	8.9	10.0	7.5	8.3	10	8.0	5.6	5.6	21	21	9.1	4.6	20	15
Silver (mg/L)	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	0.000012	0.00002	0.000022	0.000018	0.000034	<0.000010	0.000034	0.000016	0.000018	0.000012	0.000012	0.000028	0.000011	0.000019	0.000017	0.000037	<0.000010	15	21	0.000016	<0.000010	0.000037	0.000034
Sodium (mg/L)	-	-	-	24	20	25	55	51	48	36	38	42	42	40	39	44	37	40	44	64	19	15	37	45	21	21	38	15	64	55
Strontium (mg/L)	-	-	-	4.9	3.1	2.9	4.4	5.1	4.7	3.3	3.3	2.4	4.4	1.8	3.7	4.2	4.0	3.7	2.7	2.8	0.72	2.5	2.5	3.5	21	21	3.4	0.72	5.1	4.9
Thallium (mg/L)	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000015	0.000018	0.000015	0.00002	0.000017	0.00003	0.000015	0.000013	0.000014	0.000015	<0.000010	<0.000010	0.000014	0.000011	<0.000010	<0.000010	12	21	0.000012	<0.000010	0.00003	0.00002
Tin (mg/L)	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	1	21	0.000053	<0.00010	0.00011	0.00005
Titanium (mg/L)	-	-	-	0.022	<0.010	0.025	0.016	0.022	0.075	0.18	0.08	0.14	0.036	0.28	0.084	0.059	0.069	0.078	0.031	0.035	0.11	0.074	0.018	0.037	20	21	0.07	<0.010	0.28	0.18
Uranium (mg/L)	-	-	-	0.0036	0.0014	0.0011	0.0019	0.0029	0.0049	0.005	0.0037	0.0043	0.0033	0.004	0.0034	0.0029	0.003	0.0043	0.0037	0.0048	0.006	0.0017	0.0013	0.0018	21	21	0.0033	0.0011	0.006	0.005
Vanadium (mg/L)	-	-	-	0.0011	<0.0010	0.0014	0.0012	0.002	0.0038	0.0069	0.005	0.0059	0.0021	0.012	0.0052	0.0038	0.0041	0.0046	0.0023	0.0025	0.006	0.0042	0.0014	0.002	20	21	0.0037	<0.0010	0.012	0.0069
Zinc (mg/L)	-	-	-	0.0084	0.0038	0.0077	<0.0030	0.009	0.01	0.015	0.018	0.014	0.0081	0.027	0.012	0.012	0.011	0.027	0.0076	0.0032	0.0077	0.011	0.0044	0.0039	20	21	0.011	0.0015	0.027	0.027
Total Metals																														
Aluminum (mg/L)	-	-	-	0.0015	-	-	-	0.003	0.0047	0.0035	0.0015	0.0015	0.0015	0.022	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.036	0.05	0.016	0.0069	8	18	0.0087	0.0015	0.05	0.038
Antimony (mg/L)	-	0.02	-	0.00077	-	-	-	0.00076	0.0014	0.0017	0.0013	0.0014	0.00084	0.0022	0.0011	0.00087	0.00092	0.0015	0.0015	0.0021	0.003	0.00061	0.00052	0.00063	18	18	0.0013	0.00052	0.003	0.0023
Arsenic (mg/L)	-	0.005	1	0.0007	-	-	-	0.00075	0.0011	0.00093	0.0009	0.001	0.0011	0.0012	0.0011	0.0011	0.001	0.001	0.0013	0.0018	0.0011	0.00052	0.00076	0.00085	18	18	0.001	0.00052	0.0018	0.0014
Barium (mg/L)	1	5	-	0.038	-	-	-	0.049	0.058	0.044	0.044	0.044	0.04	0.044	0.039	0.04	0.039	0.037	0.04	0.05	0.043	0.037	0.048	0.05	18	18	0.044	0.037	0.058	0.051
Beryllium (mg/L)	0.0053	-	-	0.00005	-	-	-	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0	18	0.00005	0.00005	0.00005	0.00005
Bismuth (mg/L)	-	-	-	0.00025	-	-	-	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0	18	0.00025	0.00025	0.00025	0.00025
Boron (mg/L)	-	1.2	-	0.25	-	-	-	0.22	0.31	0.25	0.24	0.17	0.25	0.14	0.26	0.29	0.26	0.24	0.21	0.17	0.11	0.081	0.078	0.12	18	18	0.2	0.078	0.31	0.29
Cadmium (mg/L)	-	-	-	0.00013	-	-	-	0.00015	0.00017	0.000056	0.000057	0.00005	0.00012	0.000035	0.0001	0.00013	0.00011	0.000057	0.000052	0.00005	0.00003	0.000054	0.00005	0.00005	0	18	0.00008	0.00003	0.00017	0.00015
Calcium (mg/L)	-	-	-	216	-	-	-	211	272	181	188	159	216	153	193	202	204	194	175	185	118	149	179	233	18	18	190	118	272	239
Chromium (mg/L)	-	0.001	-	0.00025	-	-	-	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0	18	0.00025	0.00025	0.00025	0.00025
Cobalt (mg/L)	0.004	0.11	-	0.00084	-	-	-	0.00056	0.00088	0.0006	0.00054	0.00041	0.0008	0.00031	0.00064	0.00072	0.0007	0.00059	0.00014	0.00056	0.00025	0.00064	0.00021	0.00005	17	18	0.00052	0.00005	0.00088	0.00085
Copper (mg/L)	0.00038-0.00046[b]	0.000038-0.0028[b]	0.6	0.0072	-	-	-	0.0044	0.0071	0.0056	0.0073	0.006	0.0058	0.0036	0.0052	0.0078	0.0052	0.0046	0.0043	0.006	0.0073	**0.036**	0.014	0.0074	18	18	0.008	0.0036	**0.036**	0.017
Iron (mg/L)	-	1	-	0.015	-	-	-	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.032	0.015	0.015	0.015	1.0	18	0.016	0.015	0.032	0.018
Lead (mg/L)	0.0034-0.052[b]	0.003-1.25[b]	0.4	0.000025	-	-	-	0.000025	0.000025	0.00011	0.000098	0.000025	0.000058	0.000025	0.00028	0.00016	0.000051	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	6.0	18	0.000059	0.000025	0.00028	0.00018
Lithium (mg/L)	0.096	0.87	-	0.0042	-	-	-	0.007	0.0086	0.0066	0.0062	0.0064	0.007	0.0051	0.0066	0.0072	0.007	0.0073	0.0071	0.0088	0.0046	0.003	0.0049	0.0082	18	18	0.0064	0.003	0.0088	0.0086
Magnesium (mg/L)	-	-	-	33	-	-	-	32	42	31	31	28	30	27	26	29	28	30	29	34	24	27	33	42	18	18	31	24	42	42
Manganese (mg/L)	0.63-4.35[b]	0.6-9.93[b]	-	0.22	-	-	-	0.19	0.39	0.27	0.24	0.27	0.36	0.28	0.36	0.37	0.34	0.31	0.21	0.39	0.16	0.11	0.057	0.0009	18	18	0.25	0.0009	0.39	0.39
Mercury (mg/L)	-	-	-	-	-	-	-	-	-	0.000005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	0.000005	0.000005	0.000005	0.000005
Molybdenum (mg/L)	1	2	-	0.13	-	-	-	0.16	0.19	0.12	0.12	0.12	0.14	0.11	0.13	0.15	0.15	0.14	0.13	0.18	0.062	0.12	0.13	0.19	18	18	0.14	0.062	0.19	0.19
Nickel (mg/L)	-	0.025-0.15[b]	1	0.00066	-	-	-	0.00069	0.00086	0.00057	0.00051	0.00051	0.0007	0.00025	0.0019	0.0052	0.00062	0.00095	0.00025	0.00058	0.00025	0.0011	0.00075	0.00056	15	18	0.00093	0.00025	0.0052	0.0024
Potassium (mg/L)	-	-	-	2.1	-	-	-	5.7	7.1	4.3	4.7	5.5	5.9	6.0	5.5	6.3	5.8	4.5	6.6	9.2	1.9	2.0	6.4	7.2	18	18	5.4	1.9	9.2	7.5
Selenium (mg/L)	-	0.002	-	0.018	-	-	-	0.016	0.029	0.031	0.029	0.025	0.017	0.024	0.017	0.015	0.016	0.018	0.022	0.028	0.037	0.038	0.039	0.04	18	18	0.025	0.015	0.04	0.039
Silicon (mg/L)	-	-	-	7.5	-	-	-	6.8	10.0	7.1	7.2	6.9	7.2	7.0	6.8	6.9	7.0	7.5	6.8	7.3	6.6	5.0	5.0	4.9	18	18	6.8	4.9	10.0	7.8
Silver (mg/L)	0.00005-0.15[b]	0.001-0.003[b]	-	0.000005	-	-	-	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0	18	0.000005	0.000005	0.000005	0.000005
Sodium (mg/L)	-	-	-	24	-	-	-	43	51	35	36	38	41	38	40	45	39	39	45	64	18	15	36	44	18	18	38	15	64	53
Strontium (mg/L)	-	-	-	4.6	-	-	-	4.8	5.0	3.1	3.2	2.3	4.2	1.7	3.7	4.2	4.1	3.6	2.8	2.7	0.71	2.4	2.4	3.6	18	18	3.3	0.71	5.0	4.9
Thallium (mg/L)	-	0.0003	-	0.000005	-	-	-	0.000005	0.000005	0.000005	0.000005	0.000005	0.00001	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000012	0.000005	0.000005	0.000005	2	18	0.0000057	0.000005	0.000012	0.00001
Tin (mg/L)	-	-	-	0.00005	-	-	-	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0	18	0.00005	0.00005	0.00005	0.00005
Titanium (mg/L)	-	2	-	0.015	-	-	-	0.005	0.022	0.017	0.005	0.016	0.012	0.005	0.01	0.013	0.011	0.011	0.011	0.014	0.024	0.014	0.005	0.017	14	18	0.013	0.005	0.024	0.022
Uranium (mg/L)	-	0.3	-	0.0035	-	-	-	0.0028	0.005	0.0048	0.0037	0.004	0.0031	0.0037	0.0033	0.0028	0.0031	0.0043	0.0037	0.0046	0.0061	0.0017	0.0013	0.0018	18	18	0.0035	0.0013	0.0061	0.0052
Vanadium (mg/L)	-	0.006	-	0.0005	-	-	-	0.0005	0.0012	0.0005	0.0005	0.0011	0.0005	0.0013	0.0005	0.0005	0.0005	0.0011	0.0011	0.0014	0.0015	0.0005	0.0005	0.0005	7	18	0.00079	0.0005	0.0015	0.0014
Zinc (mg/L)	0.0075-0.58[b]	0.033-0.6[b]	1	0.007	-	-	-	0.0048	0.0056	0.007	0.0054	0.0062	0.0072	0.0041	0.012	0.022	0.0048	0.006	0.005	0.0015	0.0015	0.004	0.0015	0.0015	14	18	0.006	0.0015	0.022	0.014

Notes:

a) Chloride dependent guideline

b) Hardness dependent guideline

c) pH dependent guideline

MDL - Method detection limit

123	Denotes a concentration that is greater than the BCWQ guideline for freshwater aquatic life 30-day average
123	Denotes a concentration that is greater than the BCWQ guideline for freshwater aquatic life maximum
123	Denotes a concentration that is greater than the MMER maximum authorized concentration in a grab sample

APPENDIX B

Plan for Development of Source Terms for Input into Site Load Balance, Mount Polley Mine

SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2

T: +1.604.681.4196
F: +1.604.687.5532

vancouver@srk.com
www.srk.com

Memo

To:	Lee Nikl, Golder Associates	**Client:**	Mount Polley Mining Corporation
From:	Stephen Day	**Project No:**	1CI008.003
Cc:	Chris Kennedy, SRK	**Date:**	March 5, 2015
Subject:	Plan for Development of Source Terms for Input into Site Load Balance, Mount Polley Mine – DRAFT		

1 Background

As requested, this memorandum provides a plan for development of geochemical source terms which will be used as inputs into Golder Associates' load balance for the Mount Polley Mine.

2 Approach

Due to the long operating history, extensive geochemical testing and monitoring database, and similarity to some types of porphyry copper deposits elsewhere in BC, source terms will be developed empirically rather than theoretically by reference to site and analog datasets.

Uncertainty in predictions will be represented by developing two sources described as "expected case" and "reasonable worst case".

3 Method

Development of source terms will include the following steps:

- Identification for all sources for which terms are required. Based on understanding of the site, it is expected that sources could include ore stockpiles, ex-pit waste rock dumps, backfilled waste rock, exposed tailings in the impoundment, rock fill and tailings used to construct the impoundment, magnetite stockpiles, sulphur stockpiles, overburden stockpiles, construction fill, roads and pit walls.
- For each source, a conceptual geochemical model (CGM) will be described, including lithological and geochemical characteristics, geochemical processes and expected long term performance (for example, transition to acidic conditions for potentially acid rock drainage (ARD) generating (PAG) materials).
- Based on the CGMs, base data needed to develop the source terms will be compiled. Any data gaps needed to be filled to develop the source terms will be identified.

- Using source configurations (volume, dimensions), geochemical characteristics and water balance, source terms will be developed. Source terms may be provided as concentrations or loadings and as annual or monthly predictions that are fixed or varying depending on changes in the facilities (such as waste addition) and geochemical evolution.

4 Geochemical Inputs

Geochemical inputs may include the following:

- Results of static geochemical testing including acid-base accounting and element analyses;
- Waste material mineralogy;
- Results of kinetic geochemical testing using humidity cells; and
- Near source site monitoring data such as seeps.

SRK Consulting (Canada) Inc.

Stephen Day, PGeo
Corporate Consultant (Geochemistry)

Reviewed by:

Chris Kennedy, PGeo
Principal Consultant (Geochemistry)

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For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
Suite 200 - 2920 Virtual Way
Vancouver, BC, V5M 0C4
Canada
T: +1 (604) 296 4200