APPENDIX K

Best Available Technology Assessment of Closure Water Treatment

17 October 2016

REPORT ON:

Mount Polley Mine Closure Water Treatment BAT Assessment

Submitted to:
Mount Polley Mining Corporation
Box 12
Likely, BC
V0L 1N0

Attention: Mr. Luke Moger

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REPORT

Glossary of Terms

Abbreviation	Definition
BAT	best available technology
BC	British Columbia
BCR	biochemical reactor
COC	constituent of concern
COPC	constituent of potential concern
HDS	high density sludge
LDS	low density sludge
MPMC	Mount Polley Mining Corporation
TAR	Technical Assessment Report
TMT	trimercaptotriazine
TSS	total suspended solids
%	percent
km	kilometre
m^3/d	cubic metres per day
m^3/s	cubic metres per second
mg/L	milligrams per litre
mg/L (as N)	milligrams per litre as nitrogen
mol/m^3-day	moles per cubic metre per day

Executive Summary

The Mount Polley Mine is predicted to produce a surplus volume of mine contact water for the remainder of operations and into closure. The mine currently treats surplus mine contact water as required, using an Actiflo® water treatment plant (Actiflo Plant)—a high-rate coagulation, flocculation, and sedimentation process. A condition of Permit 11678 (an amended effluent discharge permit issued under the *Environmental Management Act*) is the development and implementation of a Long-Term Water Management Plan for the mine. The Long-Term Water Management Plan provides details of the discharge quantity and quality for the operations phase as its main focus, but also addressed closure and post-closure phases of the mine.

This document, the Mount Polley Mine Closure Best Available Technology Assessment, further supports the Long-Term Water Management Plan by providing a preliminary assessment of best available technology (BAT) for treatment of mine contact water during the closure and post-closure phases (closure BAT). The closure BAT assessment was based on the most recent information available for the predicted water qualities and quantities for various mine contact water sources; however, BAT assessments are intended to be revisited based on changing site conditions, and it is anticipated that such reassessment will be made as the mine's reclamation and closure plan and closure water management plan are updated.

This closure BAT assessment considered a predicted surplus volume of mine contact water of 17,000 m^3/d, which would need to be treated to remove three constituents of concern: total suspended solids, total copper, and total selenium. Recognizing that the water management plan and the water quality predictions will be updated as the closure plan is refined, the closure BAT assessment also considered constituents that are predicted to meet the target discharge water quality but that have the potential to be of concern: sulphate, total metals (other than copper), and nutrients (such as nitrate, ammonia, and phosphate).

The closure BAT assessment considered discharge targets that were set using the case where the assimilative capacity of the receiving environment during closure was assumed to be 40:1, the same value as during the operational phase. During the closure planning, the water management strategies will be refined, and the assimilative capacity for the closure water treatment assessment will be revised if needed.

To meet the discharge targets, a number of potential treatment technologies were screened using technology attributes such as complexity, robustness, ease of site implementation, commercially proven track record, waste management, adaptability, energy consumption and physical footprint. From this analysis, four technologies were shortlisted:

- passive pit lake treatment
- decentralized passive biochemical reactor treatment
- hybrid (semi-passive) treatment using a combination of active and passive components
- active optimized high-rate coagulation/flocculation and sedimentation (Actiflo)

The short-listed technologies were considered individually and in combinations to provide a holistic closure water treatment solution. Mine closure brings new opportunities for passive and hybrid treatment systems not afforded during operations due to the nature of the site and the mine plan. Site-wide water treatment strategies are envisioned to take advantage of opportunities to separate flows, treat individual loading sources, seek candidates for passive treatment, and seek opportunities for distributed discharges to pre-mining watersheds. Mount Polley Mining Corporation and stakeholders have expressed interest in fully evaluating passive and hybrid treatment systems, which would require demonstration of feasibility at the pilot scale on site before optimization and implementation at closure. Using a combination of short-listed technologies, two options were developed for closure/post-closure water treatment:

- Option A – Passive and hybrid treatment systems (applied to selected sources).
- Option B – Pit lake treatment followed by optimized Actiflo Plant.

With Option A there is the possibility to discharge directly to pre-development watersheds and waterways. However, this option is subject to refinement of closure water quality predictions and demonstration of certain innovative technologies, which are yet to be proven for the site conditions at the high flow rates considered. The further development of Option A would be dependent on the closure water management plan, which would define discharge locations. Therefore, Option B, with higher certainty for the site conditions at the high flow rates considered, is assessed to be the most viable option at present.

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1.0 INTRODUCTION

1.1 Background

The Mount Polley Mine is a copper-gold mine owned and operated by Mount Polley Mining Corporation (MPMC), a subsidiary of Imperial Metals Corporation. The mine site is located 56 km northeast of Williams Lake, British Columbia. Currently, the mine treats surface water using a high-rate coagulation, flocculation and sedimentation process, referred to as the Actiflo® water treatment plant (Actiflo Plant). An amended effluent discharge permit (Permit 11678) issued under the *Environmental Management Act* (EMA) currently allows discharge from the mine; however, the permitted discharge expires on 30 November 2017.

A condition of EMA Permit 11678 is the development and implementation of a Long-Term Water Management Plan for the mine. This Plan is provided as part of the Long-Term Water Management Technical Assessment Report (Long-Term TAR), to which this document is appended. The proposed Long-Term Water Management Plan provides details of the discharge quantity and quality for the operations phase as its main focus, but also discusses the closure and post-closure phases of the mine. It discusses in detail treatment technologies applicable to operations, but discusses only in conceptual terms treatment options related to closure and post-closure.

To further support the Long-Term Water Management Plan, a preliminary best available technology (closure BAT) assessment was prepared for closure/post-closure based on information available for the predicted site conditions, the details of which are provided in this document.

1.2 Supporting Documents

Below is a summary of water treatment work (presented in chronological order) that is related to the closure phase of the mine. Items referenced below are part of the prior work used to support and inform the closure BAT assessment.

- May 2015: Provided a Short-Term Water Treatment Plan (Golder 2015) for the Mount Polley Mine that was submitted in support of the Short-Term TAR, documenting the development of a water treatment option for excess mine contact water in the short-term. It also defined what BAT is in the context of the Short-Term Water Treatment Plan and described the water treatment options that were considered to support the short-term treatment of mine water.
- March 2016: Conducted a water treatment assessment (Golder 2016) during the development of a water treatment plan for the Long-Term TAR. Using a preliminary basis of design, the assessment included a review of active, passive, and semi-passive systems to aid in the preliminary identification of suitable water treatment systems for different mine-impacted water sources from the Mount Polley Mine.
- June 2016:
  - Developed a conceptual water treatment design as part of the Long-Term TAR (Appendix F of the Long-Term TAR). The intent of the design was to support the stated preference of MPMC and some stakeholders for the use of a passive water treatment system with return of water to pre-development watersheds.

- Prepared an operations water treatment plan to support the Long-Term TAR application (Appendix E of the TAR). The operations water treatment plan identified copper as the only parameter predicted to potentially exceed the proposed EMA Permit 11678 water quality limits during the operational phase of the mine. It described bench-scale test work initiated by MPMC to investigate copper removal using different reagents to support optimization of the existing Actiflo Plant to adapt it to seasonally high copper concentrations. The optimization would be achieved by increasing the polyaluminum chloride (PAC) dosages or adding trimercaptotriaine (TMT) reagent in addition to PAC to the feed water. The details of the optimization is described in the plan.
- Prepared the Water Quality Modelling Report to support the Long-Term TAR, from which the water quality data for the closure BAT assessment was extracted (Appendix D of the Long-Term TAR).
- Prepared the Mount Polley Mine Water Balance Report to support the Long-Term TAR, from which the flow rate for the closure BAT assessment was extracted (Appendix B of the Long-Term TAR).

1.3 Objectives

The objective of the closure BAT assessment is to screen technologies to select the best available technologies to apply for closure/post-closure treatment requirements, based on the information available for flow, water quality, and target water quality for discharge.

The assessment was carried out considering the BAT assessment method as outlined in Figure 1 below.

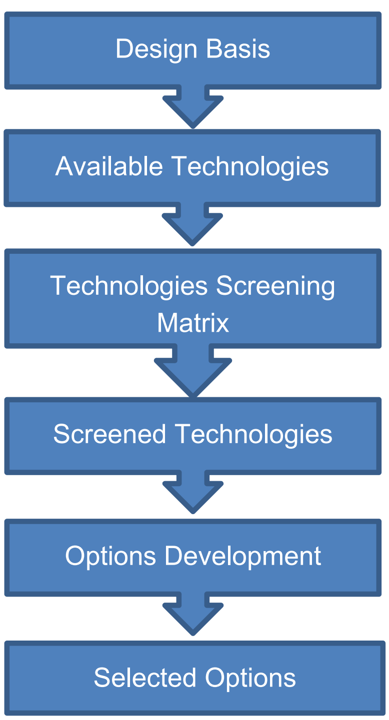

Figure 1: BAT Assessment Process Flow Diagram

2.0 DESIGN BASIS

2.1 Flow

The stochastic site water balance model (Appendix B of the Long-Term TAR) was used to predict post-closure flows for the period of July 2020 to 2100. The maximum of the 90th percentile monthly flows were modelled for closure/post-closure, and the average of these maximum monthly flows (i.e., 17,000 m^3/d) was selected as the design basis.

Typical mine closure activities are designed to reduce the volumes of water that require treatment. For example, waste materials may be covered or moved to mined-out pits, and a greater proportion of non-contact water may be diverted. Reclamation and closure planning research and updates provide an opportunity to revisit the design basis for the closure BAT. The next update to the Reclamation and Closure Plan is required to be submitted to the Ministry of Energy and Mines by 15 January 2017.

During closure, the mine will have the benefit of different water management opportunities such as:

- use of in-pit treatment after the pits are converted to end-pit-lake landforms
- use of decentralized treatment systems
- improved systems (i.e., landform design and covers) to reduce contact of water with mineralized materials, and thus, improved opportunities to divert clean water and provide distributed discharges to pre-mining watersheds

2.2 Water Quality and Targets

2.2.1 Constituents of Concern

As part of the closure/post-closure conceptual water treatment assessment, modelled discharge water qualities (Appendix D of the Long-Term TAR) for the Springer Pit and Perimeter Embankment Till borrow Pond for closure/post-closure were compared to the proposed effluent limits assuming a dilution ratio of 40:1 to identify constituents that may require treatment. The predicted concentrations and targets are presented in Table 1.

Table 1: Closure/Post-closure Predicted Concentrations and Proposed Limits

Parameter	Units	Proposed Effluent Discharge Limit	Closure		Post-closure	
			Springer Pit	Perimeter Embankment Till Borrow Pond	Springer Pit	Perimeter Embankment Till Borrow Pond
Major Ions						
Sulphate	mg/L	1,100	547	906	561	531
Nutrients						
Ammonia	mg/L (as N)	1.3	0.44	0.25	0.55	0.18
Nitrate	mg/L (as N)	34	17	25	17	17
Total phosphorus	mg/L	0.09	0.031	0.037	0.032	0.034
Total Metals						
Arsenic	mg/L	0.028	0.0018	0.0011	0.0021	0.0014
Chromium	mg/L	0.004	0.00092	0.0014	0.001	0.0016
Copper	mg/L	0.033	**0.047**	**0.072**	**0.061**	**0.053**
Iron	mg/L	1	0.71	0.78	0.71	0.77
Lead	mg/L	0.00082	0.00019	0.0002	0.0002	0.00021
Molybdenum	mg/L	0.36	0.16	0.22	0.16	0.12
Nickel	mg/L	0.0051	0.0018	0.0027	0.0019	0.002
Selenium	mg/L	0.075	**0.087**	**0.14**	**0.088**	0.069
Zinc	mg/L	0.059	0.0092	0.017	0.011	0.011

Notes:

Maximum 95th percentile predicted concentrations for Springer Pit and Perimeter Embankment Till Borrow Pond closure/post-closure water quality (refer to the TAR).

Values in red denote concentrations that exceed the proposed effluent discharge limit.

The proposed effluent discharge limits are based on the assimilative capacity of the receiving environment that are demonstrated in the operational phase.

For the closure/post-closure phase, total copper and selenium (in addition to suspended solids) were the only parameters expected to require treatment, and are thus identified as “constituents of concern” (COCs). The modelled values, however, may be conservative; but for the purpose of the closure BAT assessment, both constituents will be considered to require treatment. In making this consideration, is noted that the maximum of the 95th percentile modelled selenium concentration (0.088 mg/L) was only marginally higher than the proposed EMA Permit 11678 effluent limit of 0.075 mg/L.

Typical mine closure activities are designed to reduce the loads of COCs that require treatment. The design basis for the closure BAT is planned to be re-evaluated following the 15 January 2017 Reclamation and Closure Plan update.

2.2.2 Constituents of Potential Concern

During operations, the water quality model will need to be validated, and decentralized treatment options along with flow diversion will need to be assessed. Therefore, there is a potential that treatment for other constituents may be required during closure/post-closure. The following have been identified as being “constituents of potential concern” (COPCs):

- sulphate
- total metals (other than copper)
- nutrients (nitrate, ammonia, phosphate)

3.0 TREATMENT TECHNOLOGY ALTERNATIVES

3.1 Types of Treatment Systems

Water treatment systems can be classified as active or passive, with a combination of these two systems being referred to as semi-passive or hybrid systems.

Conventional active treatment systems require control systems, regular reagent and labour inputs, and typically rely on electrical and mechanical processes for routine operation, all of which contribute to the operating costs. Although not limited by narrow operational parameters (as may be the case of passive systems), sustainability considerations may determine the viability of active treatment systems.

Passive treatment systems harness naturally available means such as microbial activity and topography to treat mine contact water, and may require regular but infrequent maintenance to operate successfully over the system life. Passive systems, by their nature, are more suited to continuous flows and loadings, because they do not feature internal process control mechanisms to react to changes in the feed water. By the same token, passive systems typically operate at a lower treatment efficiency than active systems. Relative to active treatment systems, conventional passive treatment systems often require a large land area for large flows (such as the combined site-wide flow at the mine), making conventional passive treatment impractical for such cases (or more suited to treatment of multiple, smaller, streams of flow).

Hybrid systems have been developed for three major purposes: to mitigate the large land area of passive systems, to provide a basic level of process control and thus improve efficiency, and to introduce active treatment unit processes to the treatment train to allow for the treatment of a wider range of COCs. Hybrid systems, however, have only been demonstrated in selected situations at a small number of commercial installations, and therefore require a higher level of effort, and a longer schedule, to demonstrate and optimize the systems.

3.2 Treatment Technologies Matrix

An assessment was carried to identify technologies capable of removing the COCs and COPCs. The qualified technologies are listed in Table 2. They were compared using the following treatment attributes:

- commercially proven
- system complexity
- system robustness
- ease of site implementation
- waste management requirements
- footprint

Table 2: Active and Passive Treatment Technologies Matrix

Type of Treatment	Technologies	Examples/Processes	Attribute Ratings						Score	COCs			COPCs		
			Commercially Proven	Complexity	Robustness	Ease of Site Implementation	Waste Management	Footprint		TSS	Copper	Selenate	Sulphate	Metals	Nutrients (nitrate, ammonia, phosphate)
Active Treatment	High-rate coagulation/flocculation and sedimentation	Actiflo (including optimization) [(a)]	3	2	3	3	2	3	16	●	●			●	
Active Treatment	pH adjustment – metal removal processes	HDS, LDS	3	2	3	1	2	2	13	●	●		○	●	
Active Treatment	Sulphide precipitation – metals removal	Sulphide reagents	3	2	3	2	2	3	15	○	●			●	
Active Treatment	Metal co-precipitation processes	Iron/aluminum co-precipitation	3	2	3	2	2	3	15	○	●	○		●	
Active Treatment	Membrane processes	Nano filtration / reverse osmosis (HiPro)	3	1	1	1	1	2	9	●	●	○	●	●	○
Active Treatment	Selenium removal processes	Biological processes: - ABMET (GE) - FBR (Envirogen) - SeHAWK (Frontier)	3 2 2	1 1 1	2 2 2	1 1 1	1 1 1	3 3 3	11 10 10	●	○	●			●
Active Treatment	Selenium removal processes	Physical/chemical processes: - SeleniumZero® (Veolia) - SelenIX (BioteQ)	2 1	1 1	2 3	1 1	1 2	3 3	10 11	●	○	●		○	
Passive Treatment	Pit lake treatment	Combination of biochemical, co-precipitation, and/or sedimentation processes. Also applicable to saturated granular fills	2	3	2	3	3	2	15	●	●	●	○	○	○
Passive Treatment	Biochemical reactor (BCR)	Metals, selenium removal	1	3	2	1	2	2	11	●	●	●	○	●	●
Passive Treatment	Aerobic wetlands	Free water surface constructed wetlands	2	3	2	1	2	1	11	○	○			○	●
Passive Treatment	Hybrid treatment	A hybrid or semi-passive treatment technology that combines active and passive components	1	3	3	2	2	2	13	●	●	●	○	●	○

Notes:

Rating scores of 1, 2, and 3 denotes the relative performance scores of a specific technology based on certain water treatment attributes, with "3" being most favourable and "1" least favourable.

● Denotes technologies that will certainly remove the constituents of concern.

○ Denotes technologies that may remove the constituents of concern.

a) A high rate coagulation/flocculation and sedimentation process optimized to allow further removal of copper concentrations through the addition of a trimercaptotriazine (TMT) dosing system or higher PAC dosages.

COCs = constituents of concern; COPCs = constituents of potential concern; TSS = total suspended solids; HDS = high density sludge process; LDS = low density sludge process.

3.3 Treatment Technologies Descriptions

3.3.1 High-Rate Coagulation/Flocculation and Sedimentation

Veolia's Actiflo clarifier model ACP-650 is currently in operation at the mine. The Actiflo clarifier system consists of a high-rate coagulation, flocculation, and sedimentation process that uses microsand as ballast during floc formation to accelerate settling. The process can be optimized to remove metal constituents.

The system installed at the mine has a design treatment capacity rate of 0.23 m^3/s, and it currently removes a portion of the total suspended solids and metal constituents. Extending the operation of the existing unit can be considered for closure and post-closure scenarios, taking advantage of the optimizations that will be made during operations to allow further removal of trace copper through the addition of organosulphides such as TMT or higher dosages of PAC. For more information on the optimized Actiflo Plant, refer to Appendix E of the Long-Term TAR. The Actiflo system, optimized to remove metals using organosulphides, is referred to as the "optimized Actiflo" system.

3.3.2 pH Adjustment Metal Removal Processes

The low density sludge (LDS) process is one of the most commonly used active treatment processes for mine water treatment. Through the addition of a neutralizing reagent (usually lime), the pH is increased to facilitate metal hydroxide precipitation. The system consists of a reagent mixing and dosing stage, a reaction stage with mechanical mixing and aeration if necessary, followed by a flocculation and clarification stage. Low density, high volume sludge is produced, which is usually disposed of on site.

The high density sludge (HDS) process employs the same treatment principles and components as the LDS process, but has the added feature that a portion of the sludge is recycled back to the first stage of neutralization. The recycled sludge is mixed with the added lime to increase the sludge density (hence the name of the process). This feature allows more efficient reagent use, as well as progressively increasing the sludge density to limit the volume and cost of sludge handling required.

3.3.3 Sulphide Precipitation

Dissolved metals can be treated through sulphide precipitation, where the precipitate can either form as a metal sulphide or as an organosulphide complex, depending on the added reagent. In some cases, the feed metals can be recovered in a saleable form to help offset the costs of the reagent. Depending on the target metal, the pH is adjusted and sulphide reagent dosed as a solution (as sodium hydrosulphide or organic sulphide) with or without iron or aluminum salts. The system consists of reagent dosing stage, followed by a flocculation and clarification stage. More complete removal of some metals can be achieved than through the conventional lime-based LDS or HDS processes due to the low solubility of many metal sulphide precipitates.

3.3.4 Metal Co-precipitation

Due to their capacity to adsorb some metals as well as oxyanions (e.g., arsenic and molybdenum), iron oxyhydroxides can be used to co-precipitate with dissolved metals. Fine or colloidal solids are also efficiently removed. The process uses pH adjustment and specific iron dosages to achieve metal removal through process units similar to those used in lime and sulphide removal processes.

3.3.5 Membrane Processes

The membrane provides an electro-physical barrier and allows the separation of ionic species from a fluid. In a membrane process, feed water is separated into a product water stream and a concentrate or brine stream. The selected species are removed from the feed and concentrated in the brine stream. The process recovery, defined as the ratio of product water flow to brine flow, varies depending on the water chemistry, subject to constraints of scaling and the osmotic gradient across the membrane. Membrane processes are limited by colloidal, organic, or biological fouling of membranes, as well as chemical precipitation (scaling). To prevent fouling, the feed to reverse osmosis membrane systems usually requires pre-treatment in the form of chemical addition and filtration. Although recoveries of up to 99% can be achieved in multi-stage reverse osmosis systems with inter-stage precipitation (e.g., the HiPRO process), the brine retentate and sludge produced require appropriate disposal.

3.3.6 Selenium Removal Processes

The soluble oxyanions selenate and selenite are the most common forms of selenium in mine waters. These more soluble selenium forms have high mobility rates. Because selenite is more reactive than selenate, some treatment processes involve the reduction of selenate to selenite as part of the treatment process.

Biological treatment technology relies on biological reduction of the dissolved form (selenate/selenite) to the stable particulate elemental selenium form, which can be removed through a filtration step. This can be achieved in a fixed bed bioreactor (ABMet by GE), a fluidized bed (FBR by Envirogen), or a combination of the two (SeHAWK by Frontier).

Chemical/physical treatment approaches include making use of an ion exchange process with electrochemical reduction and precipitation (used in the SelenIX process by BioteQ), or using zero valent iron to enable sorption/co-precipitation of dissolved selenium (SeleniumZero by Veolia). Reduced iron salts (ferrous chloride or sulphate) have also been shown to reduce selenate to selenite and coprecipitate selenite.

More information on these selenium removal processes can be obtained directly from the vendors' websites:

- ABMet (GE): http://www.gewater.com/products/abmet-selenium-removal.html
- FBR (Envirogen): http://www.envirogen.com/pages/contaminants/selenium-2/
- SeHAWK (Frontier): http://frontierwater.com/
- Selen-IX (BioteQ): http://www.bioteq.ca/technology-solutions/selenium/
- SeleniumZero (Veolia): http://www.veoliawatertech.com/news-resources/datasheets/selenium-removal-veolia.htm

3.3.7 Pit Lake Treatment

In situ pit lake treatment is a process that promotes water treatment through biological and sedimentation processes. The biological treatment process involves amending surface water with the required nutrients, including organic carbon and phosphorus, to promote anaerobic treatment. The goal of in situ treatment is to create and maintain reducing conditions in the deeper portions of the water column to sequester constituents of concern, such as selenium and metals, within the lake sediments. The sedimentation process allows constituents associated with settleable solids to be removed by gravity.

The biological process relies on the same anaerobic microbial selenate and selenite-reduction processes as active and passive biological treatment. Nitrate is removed by the process of denitrification, wherein microbes facilitate the reduction of nitrate to nitrogen gas. The nitrate is reduced prior to selenium reduction due to the thermodynamics of the reactions. Therefore, the effectiveness and cost of selenium treatment depends on the presence of nitrate. Similarly, sulphate reduction also occurs with pit lake treatment which leads to dissolved metal removal via metal sulphide precipitation. Divalent metals including copper can be removed via this mechanism.

A similar anaerobic process has been postulated for saturated granular fills. Such zones are made up of pits and other mine cavities that are backfilled with waste rock material and allowed to be saturated with water, where anaerobic conditions may be encouraged, and where the mine water may be allowed to pass through.

3.3.8 Biochemical Reactor

A biochemical reactor (BCR) is an engineered passive treatment system that uses an organic substrate to optimize microbial and chemical reactions, thus removing metals and sulphate and increasing the pH of the water. The organic substrate is made up of wood chips, manure, and straw, and is normally mixed in varying ratios with limestone sand.

A BCR can be effective in removing copper, selenium, and sulphate from water. Metals precipitate as metal-sulphide or carbonates. In cold climates, the BCR could be covered with an insulating layer. The design (and footprint) of the BCR is driven by the loading rates of the targeted constituents: nitrate, selenium, metals, and sulphate.

A BCR can introduce new contaminants, such as increased sulphide concentrations, nutrients, and biochemical oxygen demand. Therefore, downstream polishing is normally required, which can consist of sulphide removal, aerobic ponds and wetlands, or sedimentation.

3.3.9 Constructed Aerobic Wetlands

Constructed aerobic wetlands are manmade structures designed to mimic processes occurring in natural wetlands in removing pollutants from the water. In wetlands, there are high degrees of interaction between soil chemistry, nutrient cycles, and habitat, among others. An aerobic constructed wetland consists of a shallow, lined basin filled with substrate, covered by open water, and often with aquatic plants. Although both anaerobic and aerobic bacteria can exist in aerobic wetlands, aerobic conditions tend to prevail because of the open water surface. An aerobic constructed wetland is typically provided as a polishing step following biological treatment of wastewater, such as a BCR or a hybrid system.

3.3.10 Semi-passive (Hybrid) Treatment

Active and passive systems may be used in conjunction to improve treatment efficiency and minimize footprint and costs, while giving flexibility to treat a variety of flows and loads. Under these conditions, they are called "hybrid" or "semi-passive" treatment systems. For instance, in a semi-passive treatment system, nutrients or chemicals may be added using metered pumps (active components) upstream of passive components (e.g., pit lake, BCR, or wetland), or active treatment technologies (e.g., Actiflo or active selenium treatment) may be used as a polishing process or "fail-safe" system downstream of a passive system to comply with receiving environment water quality limits.

3.4 Technology Screening

When comparing the different treatment technologies provided in Table 2, key water treatment attributes and the effectiveness of treatment (i.e., removal efficiency) were considered. Based on the attribute ratings scores, the top three active and passive technologies were shortlisted as closure BAT:

- high-rate coagulation/flocculation and sedimentation (optimized Actiflo Plant)
- sulphide precipitation – metals removal
- metal co-precipitation processes
- pit lake treatment
- BCR
- hybrid (semi-passive) treatment

While some technologies score high on key attributes, they do not provide adequate COC removal. Others (e.g., membrane processes) provide adequate COC and COPC removal, but score low on key attributes, such as system complexity. Similarly, even though aerobic wetlands has the same attributes score as BCR, it is not shortlisted as it does not provide adequate COC removal.

Selenium removal technologies are distinct; therefore, selenium removal was a key determinant in the selection of technology. The active biological or physical/chemical selenium removal processes are capable of meeting selenium targets, but the technologies typically rated lower than passive or hybrid systems on complexity, ease of implementation and/or waste management. Currently, during the operations phase, selenium removal is not required and not practised. Planned work to update the reclamation and closure plan and closure water management plan will elucidate the issue of future selenium management requirements.

Several other active treatment technologies were considered, but these rated lower from the point of view of complexity, ease of implementation, sustainability, and waste management. Conventional active treatment technologies such as lime treatment do not meet the requirements to remove all the anticipated COCs. When considering the COPCs, the complexity of the active systems becomes even greater.

The passive and hybrid systems rated well for simplicity and sustainability, but the performance of the systems needs to be verified through further work on site. The passive and hybrid systems under consideration include a biological treatment element, which is well suited to the list of COCs and COPCs.

Most of the technologies shortlisted above likely cannot be implemented as standalone solutions, but require further optimization and site integration to meet the discharge criteria. These modified concepts are presented as treatment options in the next section.

4.0 TREATMENT OPTIONS

Based on the shortlisted closure BAT treatment technologies identified above, treatment options that would be suited for closure/post-closure water treatment were developed. The holistic or site-wide water treatment BAT assessment needs to take advantage of opportunities to separate flows, treat individual loading sources, seek candidates for passive treatment, and seek opportunities for distributed discharges to pre-mining watersheds, through the closure planning process.

Two options were selected for further consideration and are listed below and followed by more detailed descriptions:

- Option A – Decentralized passive and hybrid treatment systems (applied to selected sources).
- Option B – Passive or hybrid pit lake treatment followed by optimized Actiflo Plant.

In Option A, a set of decentralized treatment systems is expected to be built upon closure. The closure BAT is designed to take advantages of the features, such as the pit lake treatment, that are not possible during operations.

In Option B, the passive and hybrid systems would act as pre-treatment, then the effluent and diversions would be combined or centralized and passed through the Actiflo Plant in the current location.

A conventional centralized passive system, for which a conceptual design was developed, was seriously considered as an option. However, upon further review, which included a benchmarking analysis where the conceptual design was compared with projects of similar design basis and scale, it was deemed to be impractical at the mine site and was dismissed. One of the determining factors in the dismissal was that the land area (i.e., footprint) would have been prohibitively large for the given (centralized) flows and loads. Another factor is the performance limitations, and in particular the treatment efficiency, of such systems as demonstrated in benchmark cases for the flows and corresponding configurations considered. Elements of this option have been retained as an alternative passive approach, tailored to the most suitable flows and loads. Updates to the closure water management plan would feed into the selection of specific streams suitable for passive treatment. A hybrid passive system also has potential for application in this system, although it is not commercially proven.

4.1 Option A – Decentralized Passive and Hybrid Treatment Systems

Decentralized passive or hybrid treatment systems utilize the main strengths of passive systems, while avoiding some weaknesses through selective application of the technologies. A system could be tailored as modular units at specific water sources. The net effect is intended to reduce the loadings of the COCs in the overall water management systems. The pit lake treatment system could become a part of the decentralized treatment system, designed to handle some of the highly variable flows.

The concept of decentralized passive or hybrid systems is therefore dependent on the updates to the closure water management plan and the updates to the closure water quality plan. The application of the technology will necessarily be developed in conjunction with water management systems in order to predict the assimilative capacity of the combined flows and the receiving bodies. The concept also depends on planned pilot work specific to the Mount Polley mine site to demonstrate some of the innovative, but not commercially proven, concepts.

4.2 Option B – Pit Lake Treatment System followed by Actiflo

This option would use the existing active treatment system in conjunction with the passive treatment capabilities of pit lake treatment. Currently, sedimentation is taking place in Springer Pit. The Springer Pit and Wight Pit have potential for in situ pit lake treatment for passive selenium removal, and could also serve as sedimentation basins with partial solids and metals removal in closure.

In the current water management infrastructure arrangement, water from the Springer Pit is conveyed to the optimized Actiflo Plant. The Actiflo Plant uses chemical addition to achieve further metal precipitation and solids removal. Since both the Springer Pit and the optimized Actiflo Plant would be existing features at closure, a limited amount of new operational components is required to implement this portion of the semi-passive treatment system.

One of the disadvantages of this option is that it is tied to a central treatment facility that relies on sufficient dilution in the receiving waterbody. Due to the sulphate concentration in the mine water, this treatment system is likely not suitable for direct discharge to all receiving waterbodies without dilution. Another constraint is that this system, under the current water management infrastructure arrangement, requires site water with elevated selenium to be routed via Springer Pit, which implies a central collection system. Incorporation of the Wight Pit as another location for in situ pit treatment and piloting of pit lake treatment on site is required.

5.0 SELECTED OPTION

As previously identified by MPMC, Option A would be, if practical, preferred for its advantages, including the possibility to discharge directly to pre-development watersheds and waterways. Option A, however, is subject to important constraints, including the performance limits of such systems, and the available land area. Therefore, the preference for Option A is subject to updates to closure water management systems, and subject to further work to refine the performance criteria at the bench and pilot scale. The system also has the advantage of requiring low long-term maintenance.

A conceptual design for a pilot passive and semi-passive treatment systems is provided in Appendix F of the Long-Term TAR. As part of future studies, MPMC may also consider other types of active systems if use of hybrid or passive treatment systems are not proven to be feasible through future research or piloting studies.

Due to the uncertainties associated with Option A, Option B is selected as the most viable option at present, and is considered BAT for the Mount Polley Mine at closure.

6.0 CONCLUSION

Mine closure brings new opportunities for passive and hybrid treatment systems not afforded during operations due to the nature of the site and the mine plan. To meet the treatment requirements for the predicted surplus volume of mine contact water at closure, a number of potential treatment technologies were screened and evaluated. From these, four technologies were shortlisted as closure BAT:

- pit lake treatment
- decentralized BCR
- hybrid (semi-passive) treatment
- high rate coagulation/flocculation and sedimentation (optimized Actiflo Plant)

Several active treatment technologies were considered, but these rated lower from the point of view of complexity, ease of implementation, sustainability, and waste management. Conventional active treatment technologies such as lime treatment do not meet the requirements to remove all the anticipated COCs.

The technologies shortlisted above likely cannot be implemented as standalone solutions, but require further optimization (or combination) and site integration to meet discharge criteria. Using these BAT, two treatment options were developed that would be best suited for closure/post-closure water treatment:

- Option A – Decentralized passive and hybrid treatment systems (applied to selected sources).
- Option B – Passive or hybrid pit lake treatment followed by optimized Actiflo Plant.

Although Option A is preferred, the uncertainties that remain around this passive treatment option need to be addressed and the system needs to be optimized through pilot testing, which makes Option B the most viable option at this stage, and is currently considered BAT for the Mount Polley Mine at closure.

The closure BAT assessment was based on the most recent information available for the predicted water qualities and quantities for various mine contact water sources; however, BAT assessments are intended to be revisited based on changing site conditions, and it is anticipated that such reassessment will be made as the mine's reclamation and closure plan and closure water management plan are updated. The next update to the Reclamation and Closure Plan is required to be submitted to the Ministry of Energy and Mines by 15 January 2017.

7.0 CLOSURE

We trust the above meets your present requirements. If you have questions or additional requirements, please contact the undersigned.

GOLDER ASSOCIATES LTD.

Thalita da Silva Sympovsky, MEng, PEng
Environmental/Process Engineer

Henlo du Preez, BEng
Water Treatment Specialist

Michael Bratty, MSc, PEng
Associate, Senior Water Treatment Engineer

TdSS/HDP/MB/cf/it/kp

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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

Golder Associates