Atlantic Gold

Appendix J.4

Fifteen Mile Stream Mine Site Conceptual Minewater Treatment Design, Wood Environment & Infrastructure Americas

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Technical Memo

To: James Millard, Atlantic Gold Corporation

From: Jered Munro, Wood
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Reviewer: Jack De Klerk, Wood

cc: Meghan Milloy, McCallum Environmental

Project No.: TPC182121

Date: 26 September 2019

Re: Fifteen Mile Stream Mine Site Conceptual Minewater Treatment Design

1.0 Introduction

Wood Environment & Infrastructure Solutions (Wood) was retained by Atlantic Mining NS Corp, a wholly owned subsidiary of St. Barbara Ltd. to develop a conceptual treatment process for the Fifteen Mile Stream (FMS) Gold Mine Project. In addition, a list of possible chemical reagents and preliminary predicted annual consumption rates are provided. This information is intended to support the Fifteen Mile Stream Mine Project - Environmental Impact Statement (EIS).

The proposed water treatment plant is a component of the Fifteen Mile Stream Gold Mine Project located near Trafalgar, Halifax County, Nova Scotia. Golder Consultants has prepared a Water Quality Modelling Assessment report[1] and Hydrological Modelling Assessment report[2] for the Fifteen Mile Stream Mine Site to predict the quality and quantity of mine contact water generated from the site and its potential impacts to downsteam receivers. The site water balance referenced in the Golder Hydrological Modelling Assessment report was provided by Knight Piesold Consultants. Modelling was completed for two temporal scenarios: Operations and post-closure stage. The results of the modelling from the report indicate that treatment of the minewater may be required under certain environmental conditions to maintain compliance with the applicable receiving environment criteria at the near-field mixing zone downstream of the point of treated minewater discharge into the river. The Golder report indicates that treatment may be required for the post-closure stage based on upper case (90% percentile) source terms and during low flow periods. . During operations, surface water modelling does not predict water treatment to be necessary, and it is therefore being considered only as a contingency.

2.0 Design Conditions

The basis of design for the Conceptual treatment process is defined by the data provided in the Golder Water Quality and Hydrologic Modelling Assessment reports[1,2,]. The approach for the treatment design is to provide treatment at the source with the highest concentrations to reduce the required volume that needs to be treated and reduce the amount of treatment chemistry required to achieve the effluent requirements. The PAG WRSA

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[1] Fifteen Mile Stream Gold Project Surface Water Quality Modelling Assessment, Prepared by Golder Consultants, August 14, 2019 for Atlantic Mining NS Corp.

[2] Fifteen Mile Stream Gold Project Hydrological Modelling Assessment, Prepared by Golder Consultants, August 16, 2019, for Atlantic Mining NS Corp.

(Potentially Acid Generating Waste Rock Stockpile Area) has been identified as the catchment onsite which has the largest contribution of loadings to the effluent concentrations potentially requiring treatment.

The PAG WRSA has been modelled such that the entire catchment is combined prior to treatment and for the purposes of this report the entire catchment area has been considered for treatment.

The seepage from the capped PAG WRSA is a significantly smaller volume and is the largest impacted source of water onsite. In order to capture this flow independently specific design considerations would have to be included in the design of the underdrain system for the waste rock pile. It may be more cost effective to treat this flow due to the reduced size of the treatment equipment and the treatment efficiencies realized with higher concentrations and lower flowrates.

In the event that Atlantic Gold determined capture of the smaller seepage flow to be feasible the proposed treatment processes could be utilized to realize similar effluent quality but a higher removal efficiency of the contaminants of concern.

2.1 Design Considerations

2.1.1 Minewater Treatment System Requirements

It is expected that the following criteria will inform the design of the minewater treatment process:

- Provide sufficient treatment to meet the effluent criteria summarized in the Golder Reports[1,2,].
- Be sized for the maximum design flow identified in the upper case post closure conditions as presented in the Golder Reports[1,2].
- Include adequate storage capacity in the pit to allow for process downtime and maintenance.
- Automate the main treatment processes to allow un-manned operation during weekends, evenings, and weekdays when an operator is not present.
- Include a centralized control system that can be monitored remotely via an internet connection.
- Provide sufficient chemical storage and containment for at least one week of run time at average conditions.
- Where possible place critical process tanks and equipment indoors to prevent vandalism and alleviate security concerns.
- Comply with applicable, relevant, or appropriate regulations and standards (federal, provincial, and local).
- Comply with appropriate industry, professional engineering, and technical standards.

The approach to the development of a minewater treatment system includes consideration of the requirements to treat mine drainage through the post-closure phase should this be required.

It is noted that the current process at the Touquoy Mine utilizes Geotubes for the processing of minewater after mixing and co-precipitation. Although this system appears to be operating well under the current effluent quality management strategy, this technology may not be the best suited for the longer term mine drainage requirement after FMS mine closure. It is noted that for each phase, the characteristics of the minewater requiring treatment will be different.

The proposed treatment strategy developed and documented below consists of:

1. A proven conventional physico-chemical treatment approach
2. Continued utilization of the Geotube approach or variant thereof as a stand-alone treatment process and/or in conjunction with components of the conventional physico-chemical treatment method.
3. Additional treatment utilizing ion exchange for low level removal of metals as required.

2.2 Minewater Pumping System Design

2.2.1 Minewater Transmission Piping

During operations at the Fifteen Mile Stream Mine Site, the mine contact water will be directed to the Tailings Management Facility (TMF). During Post-Closure Conditions, the site contact water will be conveyed to the open pit. The collected water from the PAG WRSA will be pumped to a treatment plant on a seasonal basis and discharged to the open pit before being released to the Anti Dam Flowage.

The piping will be run above ground and will not require freeze protection as the intent is to operate on a seasonal basis.

Pipe size will be selected to provide suitably low pressure drop at the maximum flow condition. The layout will be developed to provide reliable flow conditions, with minimal piping lengths.

2.2.2 Pumps, Electrical, and Controls

The PAG WRSA pumps will be selected to provide sufficient head to overcome the static head of the treatment systems and dynamic pressure losses due to friction from piping and fittings.

The pumps will have integral dry-run protection, to prevent damage to the pumps in the event that the sump level drops below the suction of the pumps.

The treatment system feed pumps will have variable speed control, to allow control of the feed rate to the system. The pumps will be controlled by the treatment systems centralized programmable logic controller (PLC) that will utilize a level sensing transmitter to control the operation of the pumps. The run time of each pump will be totalized by the PLC to provide appropriate maintenance intervals.

2.3 Minewater Treatment System Process Design

The minewater treatment system that is being proposed has been selected and is based on the predicted water quantity and quality estimates in the Golder Reports[1,2] and treatment data collected from the Effluent Treatment Plant at the operating Touquoy Mine Site. Due to the variability in the physical characteristics of the environment and its impact on the actual water quality that will be present on-site, Wood has included treatment processes that are not only intended to be required for treatment of the minewater but that can also be employed in order to ensure the required effluent quality is consistently achieved through the post-closure period based on current understanding of the regulations and site-specific effluent criteria. The process flow diagram is presented as Figure 1.

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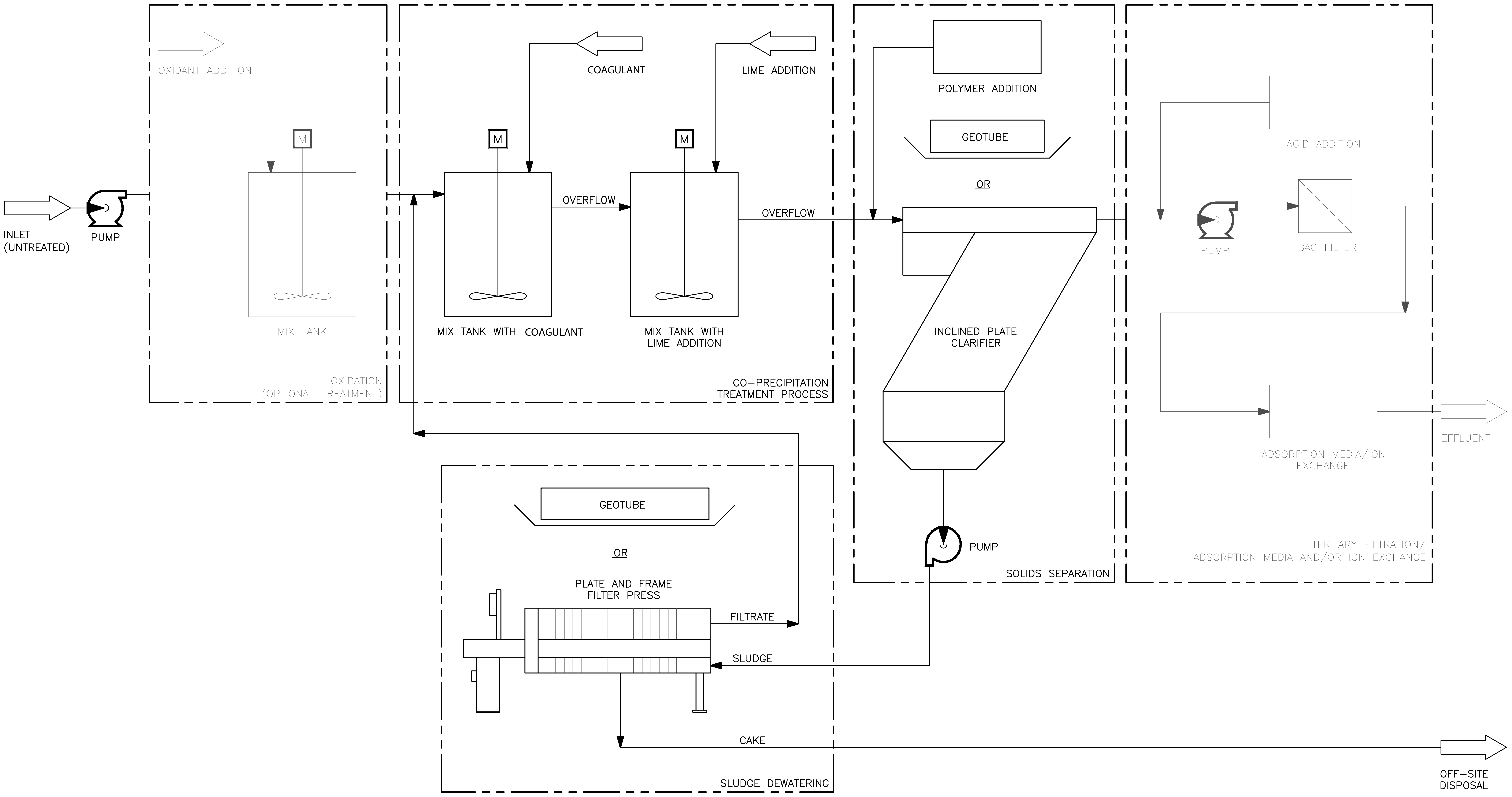

ATLANTIC GOLD
TREATMENT SYSTEM
FIFTEEN MILE STREAM

PROCESS FLOW DIAGRAM

Project No.	-
Date	FEBRUARY 2019
Scale	N.T.S.
Drawing No.	F-01

Plotted By: admin
Last Saved By: admin

Plotted: 2019-05-02
Last Saved: 2019-05-02

2.3.1 Process Design

The mine water treatment system will be designed to provide removal of the contaminants identified in the Water Quality Modelling Assessment report[1] and Hydrological Modelling Assessment[2] The predictions from the modelling in the water quality report indicate that during post-closure, based on upper case source terms and during low flow conditions, there is the potential requirement to treat for cadmium, cobalt, iron and zinc will require treatment for the upper case post-closure stage in order to achieve effluent concentrations that meet the applicable receiving water quality criteria at near field monitoring point in Fifteen Mile Stream downstream from a 100 m mixing zone. The flow rates and parameters required to be treated and removed (kg/yr) for the post closure conditions for the PAG WRSA, as based on the Golder Reports[1,2,] , are provided in Table 1.

Table 1: Treatment System Design Basis

Chemical	PAG Waste Rock Stockpile					
	Influent				Target Effluent	
Annual Flow[2]	375,519	m3/yr	-	-	-	-
			-	-	-	-
Cobalt[1]	0.048	mg/L	18	kg/yr	0.01	mg/L
Cadmium[1]	0.002	mg/L	1	kg/yr	0.002	mg/L
Zinc[1]	0.342	mg/L	128	kg/yr	0.3	mg/L
Iron[1]	6.33	mg/L	2,376	kg/yr	0.3	mg/L

Notes

[illegible]

[illegible]

The conceptual treatment system would consist of a combination of the following treatment processes as required; oxidation (as required), co-precipitation, clarification/filtration, pH adjustment (as required), filtration, and adsorption/ion exchange (as required).

For the purposes of the conceptual treatment design, the solids-laden effluent from the chemical precipitation step could be filtered using the passive Geotube filtration technology or through a clarification step which would produce an underflow at a lower volume and higher concentration of solids. This underflow stream could be dewatered using the Geotube filtration process or a mechanical dewatering process such as a filter press. The dewatered residuals could be stored at a permitted storage location on-site or at permitted off-site approved waste disposal site. The options for treatment are discussed below. A schematic of the proposed process system is included in Figure 1.

2.3.1.1 Chemical Oxidation (as Required)

It is not expected that oxidation will be required but may be dependent on the form of the dissolved metals species that are present. In the event that oxidation is required, minewater from the PAG WRSA will be pumped to an oxidation tank. The flow will be measured by an influent flow meter before it enters the oxidation tank. The oxidation tank and downstream co-precipitation system consisting of a mix tank for primary coagulant addition followed by a second mix tank for lime addition will be completely-mixed to provide load equalization which will help to dampen changes in influent concentration of the various parameters.

The purpose of the oxidation tank is to provide mixing time for the addition of a chemical oxidant such as potassium permanganate ($KMnO_4$), Hydrogen Peroxide, Fenton's Reagent prior to Physico-chemical treatment. The addition of an oxidant will cause ferrous iron to be oxidized to ferric.

The oxidation tank working volume should be sized to provide approximately 10 to 30 minutes of residence time at the average treatment flow rate depending on the water matrix and chemistry that is selected. Mixing may be provided by a top-mounted mixer. The tank will be completely mixed to ensure sufficient distribution of the oxidant and reduce the likelihood of short-circuiting.

During the filling stage of the Fifteen Mile Stream Pit, treatability testing will be required to confirm the PAG WRSA water quality and to determine the recommended dosage for the treatment system. The oxidant handling system should be designed to provide a range of dosages to provide the required flexibility for changes in the minewater quality, and to service the full range of minewater flows that are realized.

Due to the flows required for seasonal treatment, a bulk handling system is typically employed for make down of the required chemistry. It is expected that if required, flexible intermediate bulk containers (FIBC) of oxidant would be purchased from a local chemical supplier and delivered to the FMS site as-needed. The system will incorporate instrumentation to allow a known mass/volume of oxidant to be incorporated in a make-up tank. The make-up tank will have a volume which will allow approximately 7 days of run time before becoming empty.

The solution will be fed to the oxidation tank via a vendor-supplied dosing skid including two diaphragm metering pumps to ensure accurate dosing. The solution will be fed to the system at a rate that is proportional to the influent minewater flow.

An oxidation-reduction potential (ORP) meter will be installed in the oxidation tank to ensure oxidative conditions are maintained. A warning alarm will be initiated if the ORP is outside of the expected range to alert the operator that there is a potential problem with the oxidant dosing system.

2.3.1.2 Co-Precipitation

After the oxidation step, the minewater will be pumped to the two (2) tank co-precipitation system. Lime will be added to the tank to raise the pH to a target value. The co-precipitation tank should have a working volume to provide approximately 10 to 30 minutes of retention time. The tank will be completely mixed. Elements of concern will be controlled via mechanisms that include: a) precipitation as hydroxides and, b) adsorption onto metal hydroxides. It is expected that a weight ratio of between 15:1 and 55:1 of coagulant to the metals requiring treatment will be needed depending on the water matrix and the removal efficiency that is required to achieve the effluent criteria. The water will provide a natural supply of iron to support coprecipitation, and supplemental iron will be added as needed using a ratio controlled coagulant dosing system. The two-tank system is the preferred co-precipitation method to be implemented if multiple pH ranges or better pH control are needed. These precipitates that form will remain suspended in the agitated tanks and will settle out and be removed from the minewater stream in subsequent treatment processes.

2.3.1.3 Solids Separation

Following precipitation of metals, the resulting suspended solids will be removed by a solids separation process. The clarified effluent will be discharged to the pit. Additional treatment processes downstream of the clarification step will be employed if further treatment is required. It is expected that one of two processes would be considered for solids separation if required.

Clarifier Option

The minewater could be conveyed by gravity from the co-precipitation tank to an inclined plate clarifier. The clarifier system will be provided with integral flash mix and flocculation tanks. A polymer flocculant will be added directly to the flash mix tank at a rate proportional to the influent minewater flow rate. The polymer will further agglomerate the pre-treated minewater from the co-precipitation process resulting in the production of large flocs of bridged particulates and promoting sweep floc, resulting in uniform rapid settling through the clarification step.

The polymer will be purchased as neat liquid and will be diluted to a concentration of between 0.1 and 0.5% (wt/wt) in batches with a vendor-supplied make down system designed especially for effective wetting of the polymer for optimum effectiveness.

The rapid mix tank will provide complete mixing of the minewater and the dilute polymer solution. The flocculation tank will provide a period of slow mixing to allow proper floc formation. The flocculated minewater will flow into the inclined plate area, allowing the solids to settle to the sludge hopper, and with the clarified minewater discharged as overflow from the effluent weir.

Geotube Option

As an alternative to the Clarifier Option, the minewater could be conveyed by gravity from the co-precipitation process to a Geotube array. The pre-treated minewater from oxidation (if required) and co-precipitation would flow by gravity into the Geotubes with the precipitated solids retained inside the Geotube and with the clarified effluent passing through the permeable fabric into a collection point for discharge via gravity or through a pumped pressure system to a permitted discharge location/structure.

2.3.1.4 pH adjustment

The treatment process may require operation of the process at elevated pH to achieve the optimum precipitation of metals. The pH adjustment will first be achieved in the co-precipitation process through the controlled dosage with lime and as required to best co-precipitate metals, including zinc, cadmium and iron in the effective pH range for these materials. This may require operating the co-precipitation process at a pH range above the acceptable upper limit required for effluent discharge.

Once the co-precipitated materials are removed by clarification (conventional physico-chemical treatment) or by the usage of Geotubes for liquid/solids phase separation, further pH adjustment may be required on the clarified effluent to meet discharge criteria. The pH would be lowered by the addition of 93-97% sulfuric acid (H_2SO_4). It is recommended that the pH tank would have a working volume that provides suitable residence time to achieve pH neutralization and stabilization. The pH tank would be completely mixed with a top mounted mixer.

Acid would be added to the pH adjust tank via a vendor-supplied dosing skid, utilizing diaphragm metering pumps. The wetted parts of the pumps, and the acid tubing will be Teflon® or other material selected to ensure compatibility with concentrated sulfuric acid. The rate of acid addition will be controlled by a pH control loop in the PLC.

Concentrated acid would be delivered in 1 m3 chemical totes (assuming minor pH adjustment is required). The totes will be placed on pre-fabricated spill-containment platforms as soon as they are delivered to provide secondary containment in the event of a leak. Two totes will be on site at any given time, to allow one to be in use while the second is being replaced.

2.3.1.5 Filtration and Adsorption (as Required)

Depending on the effectiveness of the upstream treatment processes, the actual water matrix concentrations and the permitted effluent concentrations to meet discharge criteria, additional effluent polishing steps may be required to achieve low levels of zinc and cobalt. These effluent polishing steps may include conventional filtration followed by adsorption on a media such as activated alumina, titanium-based media, bentonite, zeolite or synthetic ion exchange media. Multiple adsorption steps may be required if one media type is not effective for all contaminants.

After pH neutralization (where required), the minewater will be transferred from the pH tank to the downstream effluent polishing system. The transfer system will include pumps to operate the filters and the adsorption process including backwashing provisions.

The conventional filters will remove any remaining particulate to prevent potential clogging and fouling of the downstream adsorption process.

For the adsorption process, an empty bed contact time used will be used as recommended by the media manufacturer sufficient to size the full-scale equipment. The equipment will be verified through treatability testing. The adsorption system will consist of a two-tank configuration operated in series. Once the target bed volumes of minewater have been treated, or breakthrough of the contaminant is detected in samples collected after the first tank, the media in the first tank would be replaced, and the second tank would become the primary tank. The spent media will either be returned to the vendor to be recycled or will be transported to an appropriate waste facility.

2.3.1.6 Sludge Management

Precipitated solids can be managed using several treatment techniques and will dependent on the level of treatment required. For the conventional physico-chemical treatment system, solids management consists of collecting underflow solids from the clarification processes and thickening of these solids before dewatering. The thickened sludge would then be dewatered through a filter press or comparable equipment.

It is expected that thickening would provide lower volume of sludge storage volume due to increased solids concentration but will require a more complex process to achieve. The underflow from a clarification step would be pumped to a sludge storage /thickening tank with an air-diaphragm pump. The sludge storage tank will have a working volume adequate to accommodate three days of production. The sludge would be treated in batches through a dewatering process such as a filter press. The filter press requires operator attention, so the sludge dewatering process is typically manually initiated when an operator is on site.

Alternatively, and through using the Geotube option, the sludge underflow from clarification could be transferred to geotubes for thickening and dewatering. The geotubes would then be disposed of when filled and once thickening and in-situ dewatering is accomplished.

2.3.1.7 Chemical Reagents and Consumables

The estimated preliminary chemical consumption rates are outlined in Table 2. The estimates are based on the post-closure stage flows and quantities estimated by Golder[1,2]. Reagents will be stored in accordance with applicable regulatory requirements. Proper containment and separation of chemicals will be provided.

Table 2: Reagent Consumption Estimate

Chemical	Estimated Minimum		Estimated Maximum	
	Dose (kg/m3)	Annual Quantity (kg/yr)	Dose (kg/m3)	Annual Quantity (kg/yr)
Potassium Permanganate (98%)	0.009	4,000	0.018	7,000
Lime Slurry (10%)	0.016	6,000	0.093	36,000
Sulphuric Acid (98%)	0.0021	800	0.013	4,800
Adsorption Media[1]	0.045	17,000	0.237	89,000

Notes

1. Specialty titanium oxide and/or sodium titanate based media from Graver Technologies.

2.3.1.8 Instrumentation and Control

The system will be designed to be automated to the extent practical. It is estimated the system will require two visits to the site per week by a qualified operator. The frequency may be higher during periods of high minewater flow.

The treatment system will include instrumentation for control and monitoring purposes. The primary treatment equipment and instrumentation will be automated with a single, centralized programmable logic controller (PLC). The system will be operated through a human machine interface (HMI) located in the treatment building. The system will also have remote monitoring and data collection capabilities through an internet interface, to allow the operator to view the status of the system at any time from an alternate location. The control system will also have dial-out functionality so that critical alarms can trigger an automated call to the operator's mobile phone.

The control system will include data logging and tracking of all process inputs.

2.3.2 Treatment System Pad and Building

The treatment system will require a building structure to house the proposed equipment, process pumping systems and tankage.

2.3.2.1 Building Pad

The surface of the building pad will be predominantly 3/4-inch crushed rock; however, a sloped concrete pad should be considered for offloading of chemicals to provide a location for collection if a spill were to occur during unloading.

2.3.2.2 Treatment Building

A treatment building will be considered for housing the treatment system and would consist of a pre-fabricated or pre-engineered structure. The building would contain the treatment equipment, chemical storage tanks, a washroom, an electrical room, and a combined office and lab area for bench scale testing and process monitoring.

Pre-engineered metal clad buildings are typically cost-effective and have a long lifespan with relatively low maintenance.

The building would include two man-doors: one for everyday access and the second for emergency egress. The building will also include a 12-foot roll-up door to allow access for bulk chemical deliveries and to move equipment in and out of the building for maintenance purposes.

If year-round treatment was employed the building would be heated to maintain the interior temperature above a minimum of 10˚C. The building would need to be insulated with a minimum of R20 insulation for the walls and R30 for the roof. An exhaust fan will be utilized to prevent excess heat build-up in the summer.

2.3.2.3 Layout

The building layout will incorporate the following considerations when determining the layout for the design.

- If required, adsorption tanks or columns should be positioned close to the roll-up door since the media will need to be removed and replaced periodically.
- Coagulant and acid storage and dosing areas should be separated from the lime storage and dosing areas due to chemical compatibility.
- If employed, the dewatering process should be positioned near the outside wall to allow easy transportation of the solids.

2.3.2.4 Utilities

Power for the building, including three-phase power for large motors, and single-phase power for small motors, lighting, and instrumentation, will be required from either a fixed transmission system or on-site generator.

Power will be supplied to each of the pit through buried utility trenches, from a distribution panel in the electrical room.

Potable water will be required for chemical make down and general cleaning and housekeeping operations. A storage tank and pressurized supply system will be required as part of the design considerations.

An internet connection for the remote monitoring of the control system, as well as for alarm call-outs to the operator's mobile phone will be required.

2.3.2.5 Security

Due to concerns over potential property damage or malicious interference, all critical process equipment and chemical storage tanks should be housed inside the treatment building. The treatment building doors will remain locked at all times. The building will have no windows to minimize the potential for vandalism damage.

The roll-off containers for the solids storage will be stored outside in a fenced area with a locked gate.

3.0 Closure

The conceptual process design has been provided based on the information available at the time. Changes to the water quality, quantity, process, environmental conditions etc. will have an impact on the requirements of the design and should be verified through additional data gathering, testing and verification as it becomes available. The process that has been proposed follows typical treatment techniques for the predicted water quality. The cost effectiveness and feasibility of the proposed process will need to be confirmed prior to implementation as this was not a consideration in the develop of the approach.

Sincerely,

Wood Environment & Infrastructure Solutions
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