AECOM
17007 – 107th Avenue
Edmonton, AB, Canada T5S 1G3
www.aecom.com
780 486 7000 tel
780 486 7070 fax

September 25, 2012

Michael Nahir
Aboriginal Affairs and Northern Development Canada (AANDC)
25 Eddy Street, Room 10D7
Gatineau, CQ K1A 0H4

Dear Mr. Nahir;

Project No: 60225752 (404)
Doc. Control: 001-DISO EA-DISO-LET-0005-Rev1_20120925-FINAL
Regarding: Giant Mine Water Treatment Plant
Approach to Identify Best Available Practical Technology (BAPT)

This document summarizes the general approach taken during the preliminary design phase to identify the best available practical treatment technology for the future year round operation of Giant Mine Water Treatment Plant. Several proven technologies were evaluated and ranked against performance criteria and anticipated target concentrations for plant output. These target concentrations were to meet or exceed the current effluent quality and achieve treatment objectives in conjunction with the diffuser design at the edge of the mixing zone in Yellowknife Bay.

The evaluation takes factors into consideration such as process efficiency, process complexity, and local proven technology, ability to handle raw water variations, building requirements, capital costs and operation costs. The selected technology then becomes the best available practical technology.

1. Alternatives/Options Considered (Technical)

1.1 Criteria for Evaluation of Alternatives

Available pre-treatment and primary treatment technologies were evaluated with respect to their ability to achieve a discharge quality within anticipated effluent requirements. Residual handling methods were also evaluated. A system that is practical, relatively easy to operate and capable of handling variability in influent quality is required for long-term performance. The options identified were evaluated based on these and other requirements (as outlined in Table 1) given the estimated influent quality and the estimated effluent quality at the end of the diffuser mixing zone.

Table 1: Evaluation Criteria for the Giant Mine WTP

Category	Criterion
Oxidative Pre-treatment	• Effectiveness as an oxidant • Dosage requirement • Ability to handle variation in influent quality • Process complexity • Capital cost • Operations and maintenance (O&M) costs • Storage requirement • Health and safety requirements
Primary Treatment	• Process efficiency • Ability to handle variation in influent quality • Process complexity • Capital cost • Operations and maintenance (O&M) costs
Residuals Handling	• Ability to handle variation in influent quality • Sludge cake density • Process complexity • Capital cost • Operating and maintenance cost

An evaluation matrix was developed to help score the options against each of the evaluation criteria listed above in Table 1. Options were assessed by ranking each option from 1 to 4, where 1 is the most qualified option and 4 represents the least qualified option. The overall lowest scoring option represents the best available practical technology (BAPT). If two, or more, options achieved the same score after evaluation, the better technology was chosen based on AECOM's previous experience with the technology.

1.2 Evaluated Options

Oxidative pre-treatment, primary treatment and residuals handling options were evaluated at a high level to determine the BAPT for treatment. This section provides a summary of the evaluated options.

1.2.1 Pre-treatment

Pre-treatment is required in the form of oxidation to optimize arsenic removal efficiency. Arsenic is present in the dissolved arsenite As(III) form and has to be converted to arsenate As (V). Pre-treatment is also required in the form of pH adjustment to increase the pH, as results of recent years have shown, that the mine water can become acidic.

The oxidants evaluated were potassium permanganate, hydrogen peroxide, ozone and chlorine, and the results are shown in Table 2.

Table 2: Evaluation Matrix for Oxidants

	Chlorine	Permanganate	Ozone	Hydrogen Peroxide
Effectiveness as an oxidant	3	2	1	3
Theoretical dosage requirement	4	3	1	2
Process complexity	2	1	3	2
Ability to handle variation in water quality	3	1	2	1
Capital cost	1	2	4	3
O&M cost	2	3	4	1
Storage requirement	3	2	1	3
Health & safety requirements	3	1	3	2
Total	21	**15**	19	17

Note: The lowest scoring option is the BAPT option.

1.2.2 Primary Treatment

Three common primary treatment processes were evaluated for each contaminant of concern at the Giant Mine site. The contaminants present in the mine water could be removed through the following process or process combinations:

- Membrane Filtration
- Ion Exchange (followed by a secondary filtration process)
- Conventional Treatment (followed by a secondary filtration process)

The evaluation matrix is shown in Table 3.

Table 3: Evaluation Matrix for Primary Treatment Processes

Criteria	Membrane Filtration	Conventional Treatment and Filtration	Ion Exchange and Filtration
Process efficiency	3	1	2
Ability to handle variation in influent quality	1	2	3
Process complexity	2	1	3
Capital Cost	2	1	3
O&M Cost	3	1	2
Total	11	**6**	13

Note: The lowest scoring option is the BAPT option.

1.2.3 Residuals Handling

Dewatering was the preferred residuals handling method, and three dewatering methods were assessed to reduce the volume of solids transferred to the landfill. These methods were:

- Centrifuge
- Belt filter press
- Filter press

Table 4 illustrates the residuals handling evaluation matrix.

Table 4: Precipitation and Filtration Residuals Handling Evaluation Matrix

	Centrifuge	Belt Filter Press	Filter Press
Ability to handle variation in influent quality	2	2	1
Sludge cake density	3	2	1
Process complexity	2	1	2
Capital cost	1	2	3
Operating and maintenance cost	2	1	3
Total	10	**8**	10

Note: The lowest scoring option is the BAPT option.

2. Recommended Option

2.1 Design Criteria Summary

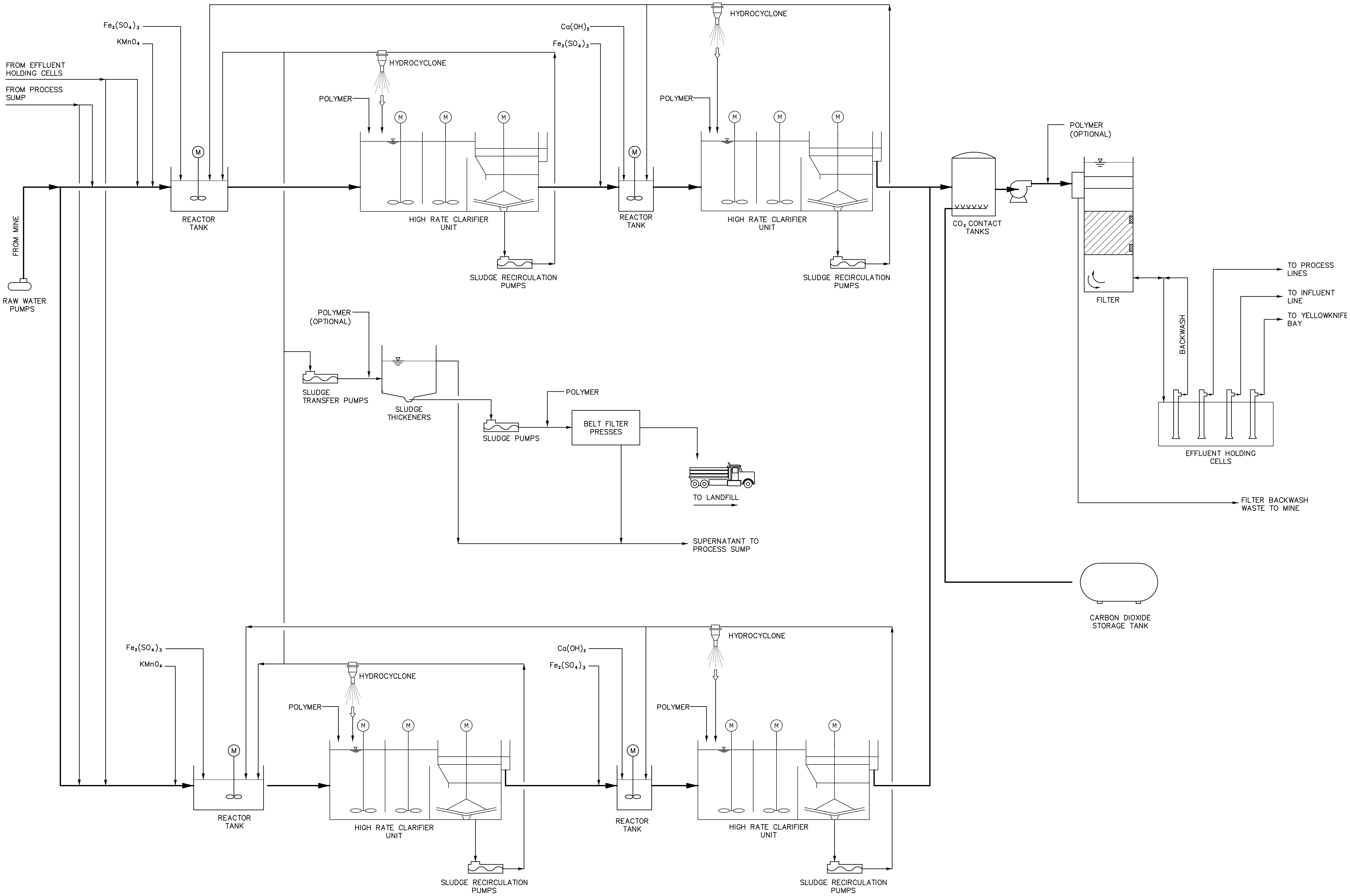
The design criteria for the new WTP are summarized in Table 5. The flows reported include a 20% contingency capacity and 10% downtime.

Table 5: Design Criteria for Giant Mine WTP

Flows & Storage		
Short-Term		
Average Treatment Flow Rate	26.0	L/s
Peak Wet Year Flow Rate	33.9	L/s
Maximum Equalization Storage Volume Required	177,071	m^3
Long-Term		
Average Treatment Flow Rate	16.7	L/s
Peak Wet Year Flow Rate	21.3	L/s
Maximum Month Storage Volume Required	0	m^3
Parameters of Concern		
Arsenic	Range (min - max): 5 - 280 mg/l	
Total Suspended Solids	Range (min - max): 4.9 - 354 mg/l	
pH	Range (min - max): 2.0 - 8.9	
Zinc	Range (min - max): 0.01 - 2.7 mg/l	
• **Target Effluent Concentration (End of Plant)**		
Arsenic (Normal Plant Operation)	<0.20	mg/l
Arsenic (Maximum Monthly Mean Concentration)	0.50	mg/l
Total Ammonia (if required)	<12	mg/L
Oil & Grease (if required)	<5	mg/L

2.2 Process Design

The following figure illustrates the recommended treatment process for the Giant Mine site. Each process component is described in more detail in the sections to follow.


FROM EFFLUENT HOLDING CELLS
FROM PROCESS SUMP
FROM MINE
RAW WATER PUMPS
$Fe_2(SO_4)_3$
$KMnO_4$
REACTOR TANK
HYDROCYCLONE
POLYMER
HIGH RATE CLARIFIER UNIT
SLUDGE RECIRCULATION PUMPS
$Ca(OH)_2$
$Fe_2(SO_4)_3$
REACTOR TANK
HYDROCYCLONE
POLYMER
HIGH RATE CLARIFIER UNIT
SLUDGE RECIRCULATION PUMPS
POLYMER (OPTIONAL)
CO_2 CONTACT TANKS
FILTER
BACKWASH
TO PROCESS LINES
TO INFLUENT LINE
TO YELLOWKNIFE BAY
EFFLUENT HOLDING CELLS
FILTER BACKWASH WASTE TO MINE
POLYMER (OPTIONAL)
SLUDGE TRANSFER PUMPS
SLUDGE THICKENERS
POLYMER
SLUDGE PUMPS
BELT FILTER PRESSES
TO LANDFILL
SUPERNATANT TO PROCESS SUMP
CARBON DIOXIDE STORAGE TANK
$Fe_2(SO_4)_3$
$KMnO_4$
REACTOR TANK
HYDROCYCLONE
POLYMER
HIGH RATE CLARIFIER UNIT
SLUDGE RECIRCULATION PUMPS
$Ca(OH)_2$
$Fe_2(SO_4)_3$
REACTOR TANK
HYDROCYCLONE
POLYMER
HIGH RATE CLARIFIER UNIT
SLUDGE RECIRCULATION PUMPS

2.2.1 Key Features of the Proposed Process Stages for Giant Mine Waste Water Treatment

The following paragraphs illustrate the advantages of the proposed process configuration which combines a compact treatment system with important elements of the HDS (high density sludge) process.

2.2.1.1 Summary of the High Density Sludge (HDS) Process

In the mining sector the HDS process is generally used to treat acid mine drainage which contains dissolved metals. The process relies on a hydroxide precipitation with an alkaline reagent, often carried out with lime. In the HDS process hydroxides are then transformed to metal oxides thereby increasing the potential to significantly increase the residuals concentration. The alkaline reagent is added here to the recycled sludge underflow of a recycle stream prior to being introduced to the effluent to be treated.

2.2.1.2 Proposed Treatment Configuration

The proposed treatment configuration combines important elements of the HDS process with the important objective of providing a treatment plant with a small footprint and the ability to respond to water matrix and flow fluctuations.

<u>Specific Stage for Arsenic Removal</u>

The proposed treatment system targets the parameter of concern Arsenic specifically with a dedicated treatment stage including oxidation – co-precipitation/adsorption – flocculation and settling by means of a high rate clarification.

<u>Dedicated Metal Removing Stage (Lime Precipitation)</u>

Metals which are not, or insufficiently, removed by the Arsenic removal stage are treated in a separate treatment stage for metals, by applying a conventional lime precipitation coagulation – flocculation and settling by means of a high rate clarification.

<u>Sludge Recycle</u>

Both the Arsenic and the metal removal units can be operated with a sludge underflow recycle which is directed back to the reactor tank upstream of the coagulation/flocculation process thereby increasing sludge seed concentration, optimizing reagent usage and increasing the sludge solids content. The sludge recycle line of the metal removal stage (alkaline) can also be recycled upstream of the Arsenic removal stage in case acidic mine effluent has to be treated.

<u>Residuals Concentration</u>

The proposed treatment configuration creates solids with a lower concentration compared to an effective HDS process. A dedicated thickening, storage and dewatering unit is therefore included in the design to achieve comparable final solids concentration of approximately 20% dry solids.

Small Footprint

The proposed process configuration employs a high rate clarification system with a design rise rate of 40 m/h, which is significantly higher than the rise rate of conventional clarification systems, thereby reducing the required footprint of the plant significantly. This has several advantages:

- The reduced footprint allows a smaller building thereby saving construction costs.
- The reduced footprint requirement allows two independent identical treatment trains which significantly improves operational flexibility to respond to flow and load fluctuations and will provide essentially 100% redundancy in the long term.
- The reduced footprint allows space for a third process train thereby providing flexibility to respond to potential future water treatment requirements.
- A smaller building requires less HVAC equipment and reduces the operating costs such as heating, which is significant in northern climates.
- The reduced footprint of the technology allows a two stage treatment system with higher treatment reliability than a single stage system.

Non-technical Benefits

The selected process configuration has important similarities with the existing treatment process at Giant Mine. Oxidation, coagulation, flocculation and settling are common features, which will facilitate operator training and may shorten the learning curve.

2.2.2 Oxidation

Several potential oxidants (chlorine, Ozone, hydrogen peroxide and potassium permanganate) were evaluated in the design basis memorandum. Although the evaluation matrix did not produce a clear preferred option, Permanganate is a rapid and effective oxidant of arsenite As(III). Potassium Permanganate was selected for simple preparation process with available pre-engineered dry feed systems and the available high grade (granular form) of the chemical.

Potassium permanganate ($KMnO_4$) is sold as a granular solid, and dissolved in water prior to addition. The available high grade means smaller transport volumes, higher storage capacity resulting in longer intervals between deliveries and thereby reducing operational complexity.

2.2.3 Primary Treatment

The conventional precipitation and filtration treatment processes consist of chemical addition, settling, filtration and sludge return. Conventional treatment is advantageous as it is an energy efficient established technology with low operating and maintenance costs that requires little operator involvement.

2.2.3.1 Clarification

A clarifier removes particles suspended in water through gravity settling. Conventional clarifiers have a large footprint and slow reaction times compared to other treatment options, but are capable of handling large quantities of water and are relatively simple to operate and maintain. High rate clarifiers can be loaded at higher rates than is typical for conventional clarifiers resulting in a smaller footprint requirement and an increased ability to handle variability in water quality. High rate clarifier units are recommended for solids reduction at Giant Mine.

Two high rate clarifier units are proposed for each train, each designed with a settling area for a rise rate of 40 m/h. The first unit in each train will be used for the removal of arsenic precipitates formed from the first stage of chemical addition (ferric sulphate and potassium permanganate). The second unit will reduce both arsenic and metal precipitates from the second chemical addition stage (ferric sulphate, polymer and lime).

2.2.3.2 Chemical Addition

Reactor Tanks

The chemicals are added on the influent line to each train. Two reactor tanks in series configuration are included on each train to improve mixing.

Ferric Sulphate Addition (first high rate clarifier unit)

Coagulants artificially increase the attractive forces between particles in water and enable the flocculation process. The resulting larger particles or flocs are easier to remove through settling and filtration. The coagulation / flocculation process is used to reduce total suspended solids concentrations.

Iron based (ferric) coagulants are the most effective for arsenic removal, and ferric sulphate ($Fe_2(SO_4)_3$) is the preferred option as it is less aggressive, less expensive and forms sludge that is easier to dewater than competing ferric coagulants. Ferric sulphate is most effective in moderately acidic water (pH of 4 to 6), and its addition results in the removal of arsenic through a combination of three processes.

- ***precipitation***: the formation of the insoluble compounds Al(AsO4) or Fe(AsO4)
- ***co-precipitation***: the incorporation of soluble arsenic species into a growing metal hydroxide phase
- ***adsorption***: the electrostatic binding of soluble arsenic to the external surfaces of the insoluble metal hydroxide

All three of these mechanisms can independently contribute towards contaminant removal. Solids produced in the above process are removed from the first high rate clarifier unit and further treated in the residuals handling stages.

Lime Addition (second high rate clarifier unit)

Given historical data, heavy metals may be present in concentrations above the potential water license limits. As a result, lime ($Ca(OH)_2$) is added in the second high rate clarifier unit to increase the pH, which shifts the equilibrium of carbonate and hydroxides in solution causing the heavy metals to precipitate out of solution and form insoluble compounds. Lime addition will also cause sulphate in solution to precipitate. These compounds can then be removed through clarification and filtration.

<u>Polymer Addition</u>

Polymers are added to the treatment process to improve the floc characteristics, which enables better solids separation from the treated effluent, and acts as a filter aid, which improves filter run times and higher filtered effluent quality.

2.2.4 Post-treatment

2.2.4.1 pH

A pH adjustement step is included as the addition of lime to the treatment process may raise the pH above the potential water license limit (maximum pH limit of 9.5). Carbon dioxide (CO_2) will be used to adjust the pH to neutral (around 7) of the clarifier effluent prior to filtration and discharge to the environment.

2.2.4.2 Filtration

A filtration step is included as part of the multi-barrier approach to treatment. Filtration will be used as a polishing step to remove flocs that failed to settle in the clarifier, and to reduce the total suspended solids concentration.

The filtered effluent is also used as service water (e.g. water for the makeup of chemical solutions such like potassium permanganate) thereby reducing the amount of potable water for the process.

2.2.5 Residuals Handling

The process produces concentrated sludge; however, as microsand is removed in the hydrocyclone, the excess sludge sent to the residual handling area is usually between 1% and 5% wt. As a result, a thickening process is included to reduce the volume to be dewatered. Dewatering equipment will be operated 8 hours per day, 5 days per week.

2.2.5.1 Thickening

Gravity thickeners are commonly used for water treatment residual thickening, and are recommended for use at the Giant Mine site. The solids thicken via gravity induced settling and compaction, and a sloped floor allows the thickened solids to be collected and pumped.

The thickener will be used also be used for storage of thickened sludge during periods when the dewatering equipment is offline.

2.2.5.2 Dewatering

Our high level evaluation indicated that a belt filter press is suited to this application. Belt filter presses are continuous-feed dewatering devices that may apply chemical conditioning, gravity drainage and mechanically applied pressure to dewater sludge.

Dewatered solids will be stored in an engineered waste landfill, while the filtrate would be sent to the mine or returned to the start of the treatment process.

2.2.6 Effluent Storage

Two underground cells, each capable of storing approximately 800 m^3 of effluent, are used to monitor the effluent and equalize variations in effluent quality prior to discharge. Should the effluent not meet discharge limits, the contents of the tank would be recycled back into the treatment system. Monitoring will include both on-site analysis of grab samples and, where appropriate, on-line monitoring.

Table 6 lists the range of expected storage time over the range of expected treatment plant flow rates, valid for two available effluent storage cells.

Table 6: Estimate of Storage Time in Underground Cell

	Treatment Plant Flow	Available Storage
	l/s	h
Short term average flow (630,000 m^3/a)	26	15.4
Short term wet year peak flow (822,200 m^3/a)	34	11.8
Long term average flow (404,290 m^3/a)	12.8	31.3
Long term wet year peak flow (517,491 m^3/a)	16.4	24.4

Note: *The treatment flows identified in Table 6 take into account 10% plant downtime and an additional 20% contingency. For the available storage calculation we assumed that the operating level of the effluent storage cells is at about 10% (i.e., 160 m^3), which allows an effective storage volume of 1440 m^3.*

Sincerely,
AECOM Canada Ltd.

for Robert H. Boon, P.Eng.
Senior Water Engineer
Robert.Boon@aecom.com

RB:mw
Encl. Statement of Qualifications and Limitations
cc:

Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("Consultant") for the benefit of the client ("Client") in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents Consultant's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to Consultant which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

Consultant shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. Consultant accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

Consultant agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but Consultant makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by Consultant represent Consultant's professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since Consultant has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, Consultant, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by Consultant and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

Consultant accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of Consultant to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

AECOM: 2012-01-06