Environment AECOM

Public Works and Government Services Canada

Giant Mine Water Disposal – Information Request Response

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Project Number:

60287818 (400)

Date:

March 14, 2013

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AECOM: 2012-01-06

March 14, 2013

Brad Thompson
Public Works and Government Services Canada
Environmental Services 5th Floor, Telus Plaza North
10025 Jasper Avenue
Edmonton, AB T5J 1S6

Dear Brad:

Project No: **60287818 (400)**

Regarding: Giant Mine Water Disposal – Information Request Response

The MacKenzie Valley Impact Review Board (MVIRB) requested additional information on alternative methods of water treatment and management that do not rely on the diffuser or on Yellowknife Bay. In addition, it was requested to estimate capital and ongoing maintenance costs over a 100 year period and assess the risk of each water treatment alternative.

The following report includes a review of the project, design criteria, development of long term treatment and disposal options and assessment of potential impacts to the environment.

Senes Consultants Ltd. prepared Section 5.0 – Potential Impacts. AECOM Canada Ltd. prepared all other sections of this report.

Should you have any questions please do not hesitate to call.

Sincerely,
AECOM Canada Ltd.

Rudy Schmidtke, M.Sc., P.Eng.
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Revision Log

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Date March 14/13
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1. Introduction

This document is intended to provide factual responses to the specific questions identified in the Review Board Information Request, dated February 2013. In general terms the information request was focused on trying to determine more information about the impacts to fish, aquatic habitat and human health and safety related to the discharge of water that contains arsenic. In addition, there are concerns about the location of the treated water discharge pipe and the potential impact to items such as ice thinning due to the thermal load of the treated water.

The specific questions addressed within this document are:

1. What is the relationship between arsenic levels in the treated water and the associated long term operation cost?
2. What are the options for disposal of the effluent from the water treatment plant ranging from no discharge to a range of alternate discharge points from the currently planned direct deep water submerged discharge into Great Slave Lake?
3. What are the potential impacts on the environment for the options?

The key aspect of the Review Board information request is the need for additional technical information related to further reduction of the arsenic levels within the effluent of the mine site discharge. To further improve the current proposed treatment process train the capital and operating cost impact of the following additional treatment process will be considered:

1. High density sludge
2. Ion exchange
3. Reverse osmosis
4. Mechanical evaporation

This letter report is intended to answer the three key questions identified above and should not be read without the knowledge of the numerous background documents previously prepared for this project. Furthermore, this information is provided for the purpose of comparing various engineering solutions related to water treatment and discharge of the effluent. This document is not intended to provide design criteria and engineering details for the completion of detailed design. It is assumed that any infrastructure decisions made based on the information contained within this report would be augmented with a detailed pre-design prior to embarking on detailed design and construction to verify and develop the current assumptions.

2. Review of the Project Design Criteria

2.1 Design Flows and Raw Water Quality

The two key design criteria for the construction of a water treatment plant are the instantaneous flow that the treatment plant needs to process and the total annual flow for the estimation of the long term annual operating costs. For the total annual flow the long term wet year flow is 520,000 cubic metres per year (m^3/yr) and the typical long term flow is 400,000 m^3/yr. For the basis of the discussion within this report the long term post freeze flow of 400,000 m^3/year is used for all the analysis.

The instantaneous flow that the water treatment plant needs to be able to process is included within **Table 2.1** below. The short term flow rate requirements will be achieved by operating both the parallel process trains. Once the mine is frozen and the reduced long term flow rates are established it is assumed that the both process trains will be retained allowing for a duty-standby configuration. The instantaneous flow rates presented within **Table 2.1** are based on the plant operating for 75% of the year. This leaves 25% of the time on any given year for the plant to be out of service for maintenance and repairs.

Table 2-1 – 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

Provided below in **Table 2.2** is a summary of the expected raw water quality information from the Giant Mine. Some key comments are:

1. The raw water arsenic levels vary significantly, with the majority of the raw water arsenic being dissolved.
2. The pH of the raw water seems to be declining with time within the mine. The low pH impacts the treatment process as coagulation of low pH water is not effective and low pH water tends to be more aggressive typically resulting in the concentration of the total dissolved solids increasing.

Table 2-2 – Expected Raw Water Quality Data for Giant Mine WTP

Parameter	Unit	Minimum	Average	Maximum
Ammonia	mg/L	0.017	1.29	5.30
Dissolved Arsenic (III)	mg/L	1.89	33.6	91.1
Total Arsenic	mg/L	1.99	34.3	123
Copper	mg/L	0.0053	0.0094	0.1030
Cyanide	mg/L	<0.0050	0.0141	0.0280
Lead	mg/L	0.00067	0.0368	0.15
Nickel	mg/L	0.00058	0.051	0.198
Oil & Grease	mg/L	<1.0	3.5	10.0
pH[1]	unitless	2.0	7.45	8.17
Total Dissolved Solids	mg/L	104	1663	2920
Total Suspended Solids	mg/L	<1.0	2.6	20.2
Zinc	mg/L	0.046	0.205	0.559

2.2 Treated Water Quality Standards

There are several pollutants within the water that will be diverted from the Giant Mine, but most of the contaminants are dissolved metals and particulate matter. The target contaminant in the raw water is arsenic. Based on previous assessments of the raw water it is expected that when the arsenic treatment objective is met there will be acceptable reductions on the other dissolved metals and particulate matter. The arsenic removal objectives for the focus of this report are:

1. Base case treatment process train performance 100 micrograms per litre (μg/L)
2. Canadian Drinking Water Guideline of 10μg/L
3. Freshwater aquatic life guideline of 5 μg/L
4. Less than background in the receiving water body. This is assumed to be 0 μg/L

The key exception to the assumptions in the above paragraph is the removal of ammonia. It is documented that there is ammonia present within the raw water; however; the removal of ammonia varies from the treatment process used for the removal of dissolved metals and particulate matter. For the basis of this report it is assumed that ammonia will be reduced to 1.0 milligram per litre (mg/L) in the treated water. This treatment target was established as this is the ammonia level that is generally considered non-toxic by the federal environmental regulators.

The other treatment objective is to achieve drinking water quality effluent as requested by the Yellowknives Dene First Nation.

3. Development of the Long Term Treatment Options

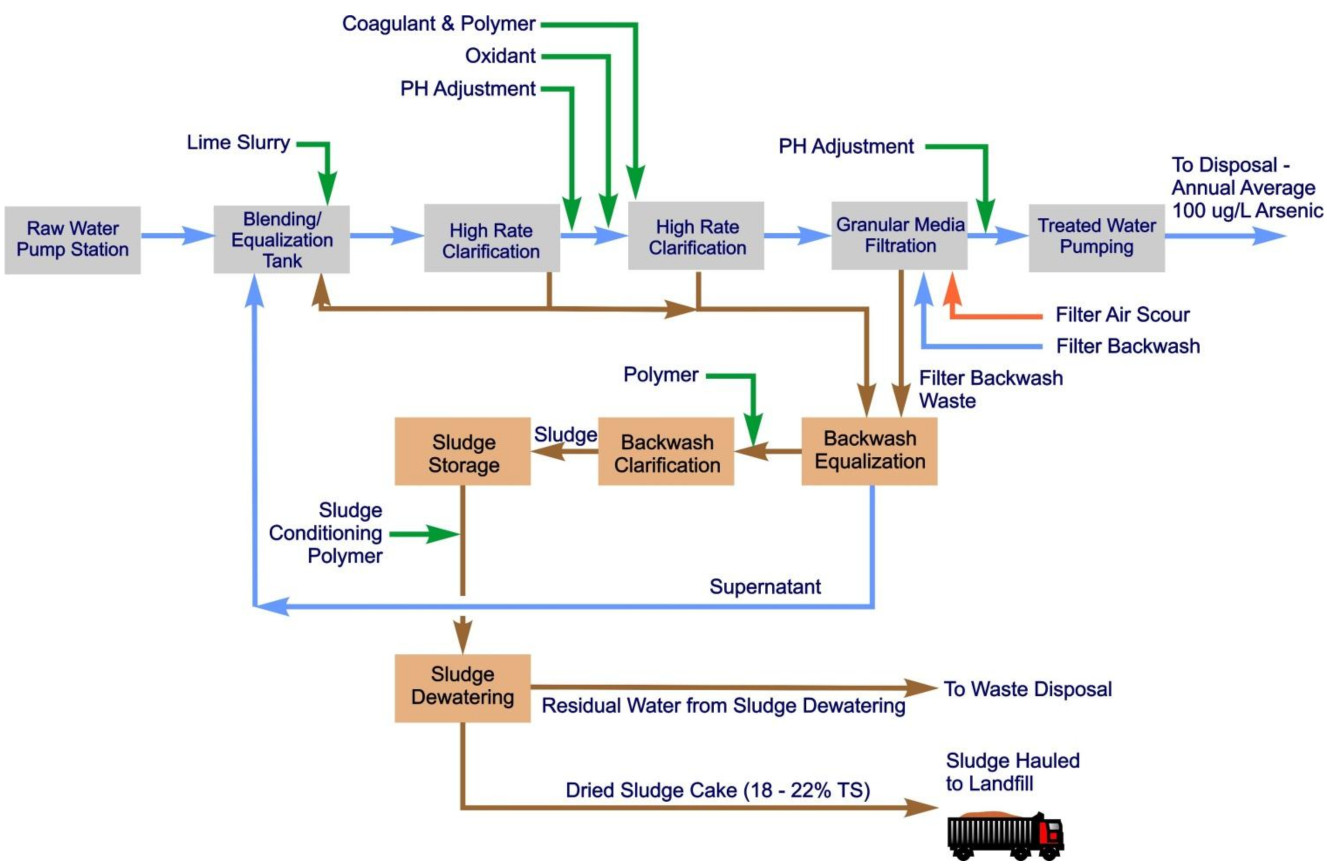
In response to the information request alternate treatment process trains that achieve different levels of treated water quality have been developed. Presented below is the existing process treatment process train from the Developer Assessment Report (DAR) with a targeted arsenic effluent level of 100 μg/L. This treatment process is used as the baseline treatment process as a point of comparison for other treatment process trains that offer a higher level of treatment. The key measure used for the comparison of the treatment process trains is the expected arsenic concentration of the treated water.

3.1 Option 1 – Current DAR Treatment Process Train

This option is the existing treatment process train as presented in the DAR. This option provides a treatment process that can achieve an arsenic level of 100 μg/L in the treated water. The benefits and challenges associated with this option is documented in the DAR and not repeated in this report.

Figure 3.1 provides a schematic showing the key process elements associated with this option.

Figure 3.1 – Option 1 Existing DAR Treatment Process



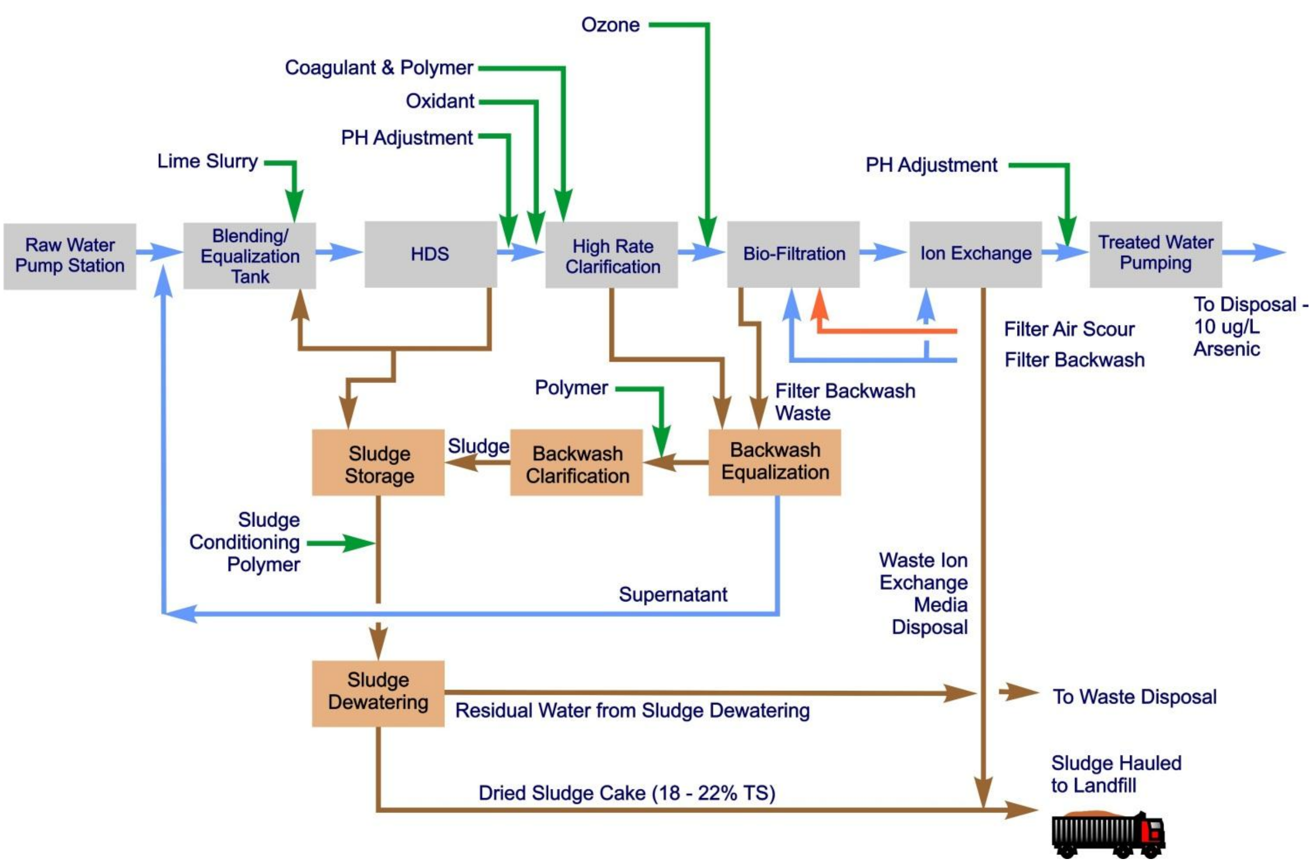
3.2 Option 2 – Achieve Drinking Water Standards with Ion Exchange

This treatment process train is similar to Option 1 with the following changes:

1. Clarification and neutralization of the raw water will be completed using a high density sludge process followed by a high rate clarification process. To achieve the higher quality treated water that this option offers a more conservative approach is being suggested for the pre-treatment processes.
2. Following clarification the plan is to ozonate and filter the water. The addition of the ozone is for biological filtration to support the reduction of ammonia to a level of 1.0 mg/L. Biological filtration is an effective method used to remove ammonia from a raw water source; however, to support biological activity on the filters a phosphorus source may need to be added. Also, biological filtration typically struggles to perform at raw water temperatures less than 5 degrees Celsius (°C).
3. Once the water stream is filtered the final step would be an ion exchange filter designed to target the removal of arsenic. The targeted arsenic effluent concentration will be 10 μg/L.
4. More residuals flow and load will be produced with this option than Option 1, but the management of the residuals will be very similar with the change being that the process elements are larger.

The key benefits of this treatment process train is higher quality treated water including the reduction of ammonia to less than 1.0 mg/L and an arsenic concentration of less than 10 μg/L. Theoretically, both the bio-filtration and ion exchange process proposed for this option should work successfully, but this needs to be verified with pilot testing prior to design and construction. **Figure 3.2** provides a schematic showing the key process elements associated with this option.

Figure 3.2 – Option 2 Treatment Process Train



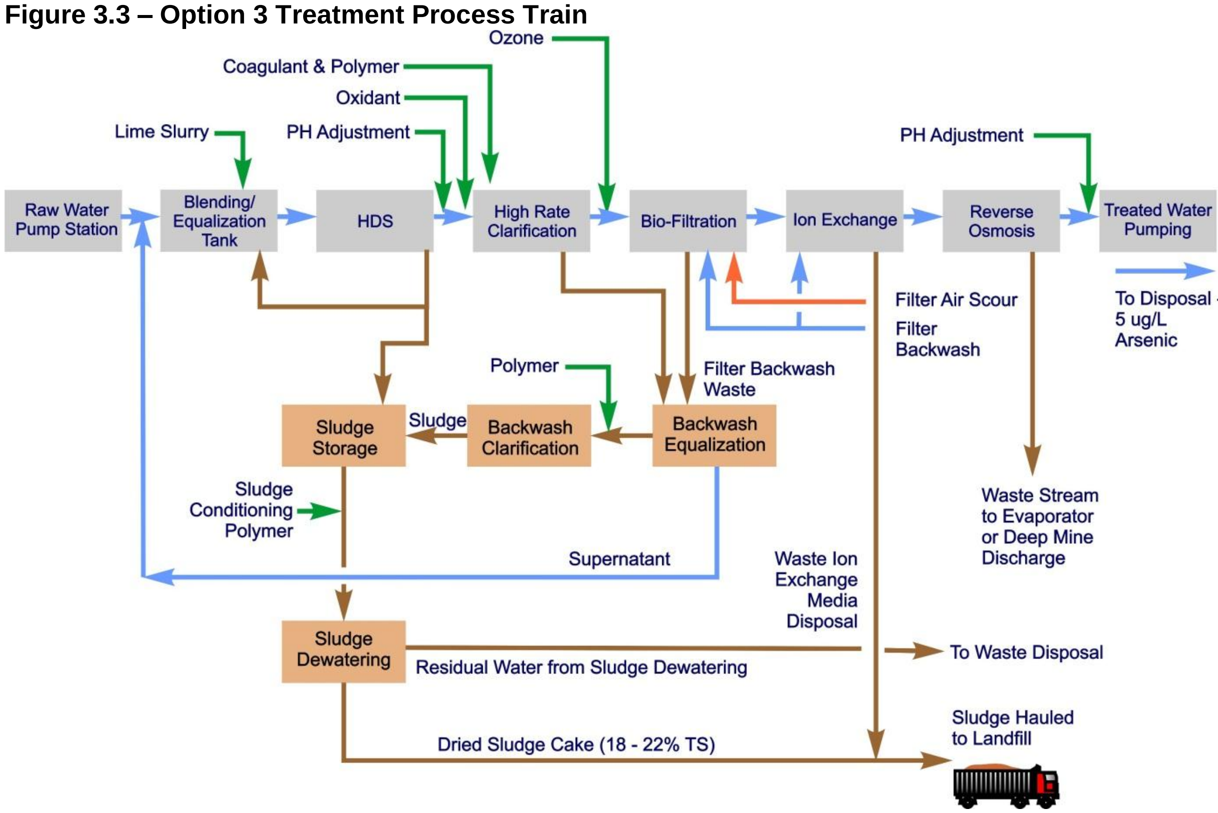
3.3 Option 3 - Achieve Aquatic Standards with Reverse Osmosis

This option also focuses on the production of treated water with an arsenic level of 5 μg/L, but the final process is reverse osmosis. To achieve the treated water quality expected and to ensure the reverse osmosis process sustains the upstream treatment process to sufficiently pre-treat the water.

The key issue with the use of reverse osmosis is the generation of the waste stream. For the purpose of process option review it is assumed that the reject stream from reverse osmosis will be 30% of the treated water flow. This results in a measurable volume of brine produced by the reverse osmosis process that needs to be managed.

The options considered for the disposal of the reverse osmosis is a deep discharge within the mine or evaporation for the disposal of the reverse osmosis reject stream. The life cycle cost implications of these two brine management solutions are significantly different, as an evaporator adds a measurable increase in the operating cost. The estimated diesel fuel required to operate the evaporator for the disposal of the reverse osmosis brine is 9,800 m^3/yr, producing a carbon footprint. This volume could be reduced by concentrating the brine prior to evaporation, but for the point of comparison it is assumed that the evaporator processes the entire brine flow. The benefit of this significant operating cost increase is the elimination of the potential risk of contaminant concentration associated with re-cycling of the reverse osmosis flow to the bottom of the mine. **Figure 3.3** provides a schematic showing the key process elements associated with this option.

Figure 3.3 – Option 3 Treatment Process Train



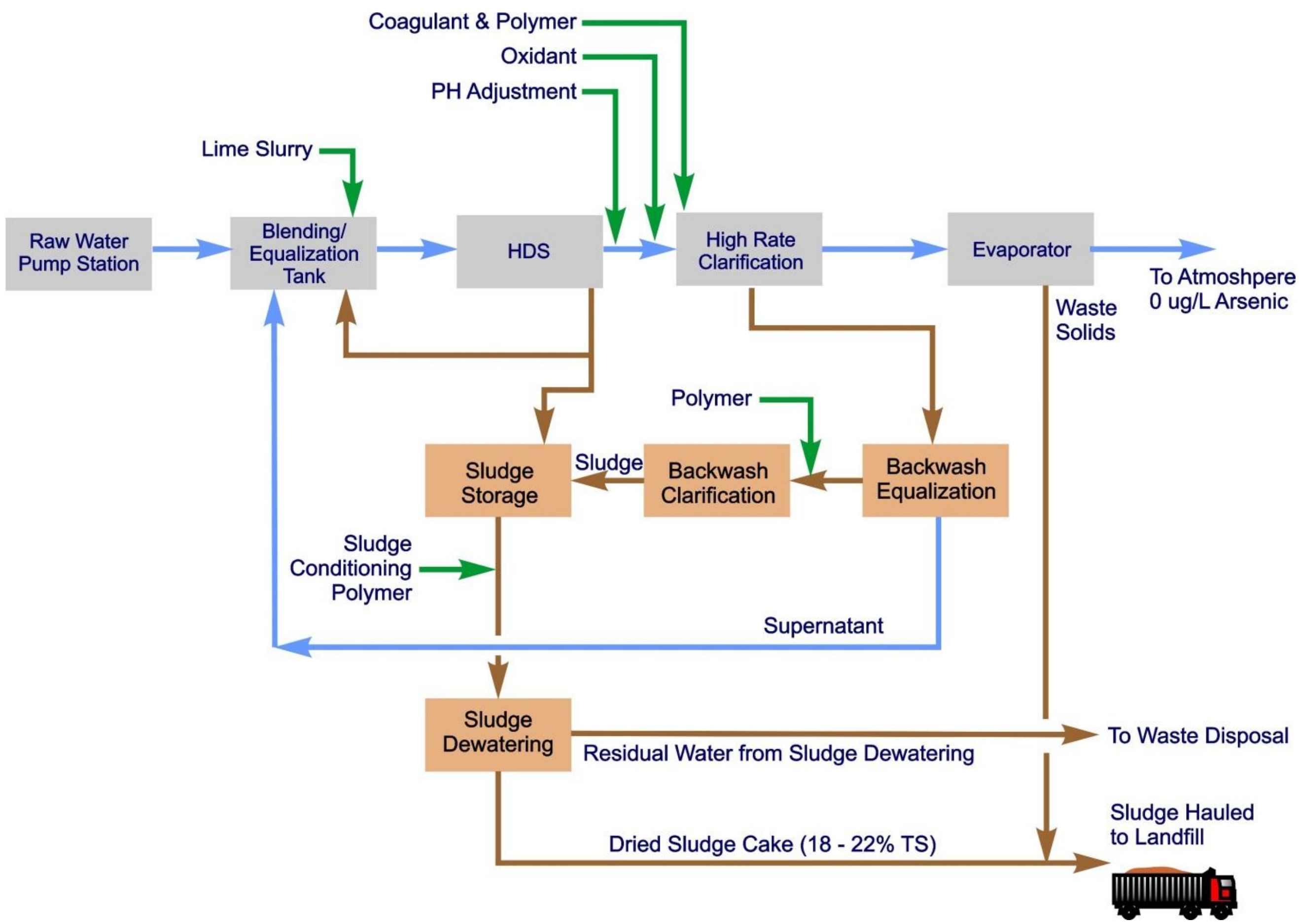
3.4 Option 4 – Zero Discharge Treatment

This option is markedly different from all the other options as there is no liquid discharge associated with Option 4. For this option the raw water from the mine site will be pre-treated with clarification followed with evaporation of the flow. This results in all the water being discharged to the atmosphere and the solids from the clarification process and the evaporator being collected for disposal at the landfill.

To evaporate 400,000 m^3/yr it is estimated that 33,000 m^3/yr of diesel fuel will be required resulting in a very large carbon footprint. This equates to roughly two tanker trucks of fuel per day for every day of the year. It is acknowledged that this option offers essentially no direct impact to surrounding surface water bodies; however, the overall environmental impact associated with consuming 33,000 m^3/yr of diesel fuel offers a significant operating cost and environment impact that does not justify the benefits of this option.

Figure 3.4 provides a schematic showing the key process elements associated with this option.

Figure 3.4 – Option 4 Treatment Process Train



3.5 Technical Summary of the Options

Provided below in **Table 3.1** is a comparison of the various treatment process trains to achieve the different arsenic treated water levels being considered.

The proposed water treatment options are all slightly different and result in different treated water quality, but generally consist of similar components from an operation and maintenance perspective. This means there is not expected to be a marked difference in the number of or the credentials of the operational staff for each treatment option presented within this report. All the treatment processes require a high level of water treatment process understanding and chemistry knowledge. This means skilled and experienced operational staff are critical to ensure the ultimate selected treatment process functions as designed.

Table 3-1 – Summary of the Treatment Options

Potential Primary Treatment Process Trains	Residual Management Considers	Treatment Objective	Comments (highlight the pros and cons)
1. Raw water pumping, chemical addition (oxidation, coagulation, pH adjustment), clarification (HDS), granular media, pH adjustment, treated water pumping to diffuser.	Sludge will be equalized and de-watered. Centrate disposal from the sludge de-watering process will need to be considered. This will be common to all the options that include sludge de-watering.	100 µg/L	This is option is the basis of design for the treatment facility and this option will consistently meet the objectives of the DAR. This option does not provide any measurable treatment for ammonia.
2. Raw water pumping, chemical addition (oxidation, coagulation, pH adjustment), clarification (HDS), granular media (bio-filter), ion exchange or absorptive media, pH adjustment, treated water pumping.	In addition to Option 1 there will be more filter backwash to manage on-site and the disposal of the exhausted ion exchange media.	10 µg/L	This option offers a treatment process capable of achieving the treatment objectives. The raw water temperature is expected to be about 8 °C, which is the border line temperature for bio-filtration. Also, the ion exchange process needs to be closely monitored to minimize arsenic break through.
3. Raw water pumping, chemical addition (oxidation, coagulation, pH adjustment), clarification (HDS), granular media, ion exchange or absorptive media, reverse osmosis, pH adjustment, treated water pumping.	Brine disposal from reverse osmosis options range from discharging at the bottom of the mine versus evaporation.	5 µg/L	This option will be able to consistently achieve high quality treated water. However, the disposal of the brine from the reverse osmosis process needs to be addressed. Other key considerations that need to be properly quantified are the long term operating costs.
4. Raw water pumping, chemical addition (oxidation, coagulation, pH adjustment), clarification (HDS), granular media and evaporation.	Solids that accumulate on the evaporator will be collected and hauled to the landfill. Solids from the clarification process will be de-watered for landfill disposal.	0 µg/L	The key benefit of this option is no discharge. However, the benefit of no discharge to a surrounding surface water body needs to be reviewed compared to the impact of operating an evaporator.

3.6 Financial Assessment of the Treatment Options

Estimates of indicative capital costs have been developed for the four water treatment process options. The estimates of probable costs have been developed from prices obtained from major suppliers and from data from recent projects of similar nature and scope. However, a number of factors may significantly affect the actual cost and the cost implications of these cannot be readily forecast. These include factors such as the volume of work in hand or in prospect for contractors and suppliers at the time of tender calls, future labour contract settlements, inflation and market escalation. The following notes are relevant to the estimates presented:

- Costs are estimated based on current (2012) price levels. Inflation and escalation to account for actual expected prices at the time of tendering are not included.
- Outfall costs are not included (See Table 4.2 for indicative outfall costs)
- A geotechnical investigation was not completed prior to the preparation of the estimate. The actual surface conditions may dramatically impact the capital estimate.
- All building super-structures are assumed to be simple pre-engineered metal facilities with utilitarian finishes.

The estimate for the Water Treatment Plant Operating and Maintenance costs are based on the following assumptions:

1. Energy cost assumptions:
   a. The cost of electrical power is $0.23/kWh
   b. Building heat is provided with electrical furnaces
   c. The pressure loss across the reverse osmosis membrane is assumed to be 2070 kPa
   d. Evaporators are assumed to operate using diesel fuel as the energy source at a cost of $1.36 / L
2. Chemical cost assumptions:
   a. Potassium permanganate oxidation – 3.4 to 669 kg/day
   b. Ferric Sulfate – $0.90/kg – 0.88 to 17.4 L/min
   c. Hydrated Lime -$0.50/kg - 0.084kg/m^3 = 84mg/L
   d. Residual sludge can be disposed at the local landfill at no cost
   e. The membrane filtration options assume that the coagulation system functions 10% of the year
3. Labour cost is estimated assuming the number of full time operators at a total cost of $60/hr based on a 40 hour work week
4. The discount rate is 3%
5. All operating costs assume continuous 12 month facility operation
6. Net Present Value of the operating costs is based on a 100 year life cycle
7. Capital replacement of the assets is not included within the 100 year life cycle cost estimate

The capital and operating cost presented should not be viewed as absolute values, but rather indicative cost estimates suitable for the cost comparison of options. The absolute capital cost estimates need to be determined during the completion of additional engineering for the selected option.

Table 3.2 presents a summary of the estimated capital cost, net present value (NPV) of the operating costs and the total net present value for each option. The net present value is estimated based on 100 years of operation of the water treatment plant. In addition, environmental risk is illustrated in the table and on Figures 3.6 and 3.7 for each treatment option based on the assessment completed in Section 5.0 of this report. The environmental risk for all treatment objectives is low.

Figure 3.6 graphically shows the net present value of each treated process train relative to the arsenic removal target. Also, provided on this graph is the total arsenic load expected from each treatment process train assuming that the long term annual treated water flow is 400,000 m^3/yr. Also provided is **Figure 3.7** with Option 3 and 4 removed. Given the scale of this graph, the marked increase in cost that occurs to reduce the arsenic levels to 5 μg/L from 10 μg/L is clearly shown. Based on the estimated cost information and the associated arsenic levels some comments are:

1. Option 1 is the existing treatment process train and is the benchmark that the other options are compared against. The other treatment options should be viewed as additional costs relative to Option 1, not absolute capital and operating costs.
2. The life cycle cost premium to reduce the arsenic levels to 10 μg/L from 100 μg/L is in the order of $16.1 M.
3. Option 3 is presented and discussed to further reduce the treated water arsenic levels to 5 μg/L from 10 μg/L. Option 3 relies on reverse osmosis for final polishing of the water stream and removal of arsenic to a level of 5 μg/L. The primary treatment process is expected to function reliably; however, the challenge with this option is disposal of the reject stream from the reverse osmosis membrane. The rejected stream is expected to be in the order of 30% of the treated water flow and contain elevated levels of arsenic and total dissolved solids. The options for the disposal of the reserve osmosis process stream are to the atmosphere using an evaporator or discharging the flow to the bottom of the mine. Neglecting the practical challenges associated with piping the flow to the bottom of the mine it is questionable if this is a sustainable long term approach given the operating life of this facility. This means the estimated life cycle cost premium to reduce the treated water arsenic levels to 5 μg/L from the current design proposal is estimated to be in the order of $154 M to $ 500 M depending on the water waste stream disposal method used.
4. Option 4 results in no arsenic being discharged to the environment as all the water will be discharged to the atmosphere through the use of an evaporator. The residual sludge produced from the clarification process to pre-treat the water prior to the evaporator and the solids from the evaporator will be collected and discharged at the landfill. The option will essentially have no impact to the environment associated with a liquid discharge, but the carbon footprint associated with evaporating 400,000 m^3/yr of water is measurable. The estimated life cycle cost premium associated with this option is in the order of $ 1.5 B.

Based on the cost information and the associated potential operational pitfalls with the treatment process trains, Option 2 provides the most reduction in the treated water arsenic levels for the smallest proportional increase in both the capital and net present value cost. If this option is selected pilot testing should be completed to verify the arsenic removal efficiency and the process design parameters. Based on the results of the pilot testing, pre-design engineering should be completed to confirm the assumptions made during the completion of this report.

Table 3-2 - Summary of Estimated Capital and Operating Cost and Environmental Risk

Net Present Value Summary	Total NPV	NPV Capital	NPV O&M	Risk
Option 1	$87,800,000	$38,900,000	$48,900,000	Low
Option 2	$103,900,000	$42,000,000	$61,900,000	Low
Option 3 - Residuals to Mine Waste	$154,300,000	$56,700,000	$97,600,000	Low
Option 3 - Residuals Evaporated	$583,700,000	$56,700,000	$527,000,000	Low
Option 4	$1,541,900,000	$49,700,000	$1,492,200,000	Low

Figure 3.3 – Annual Arsenic Loading and NPV of the Water Treatment Options

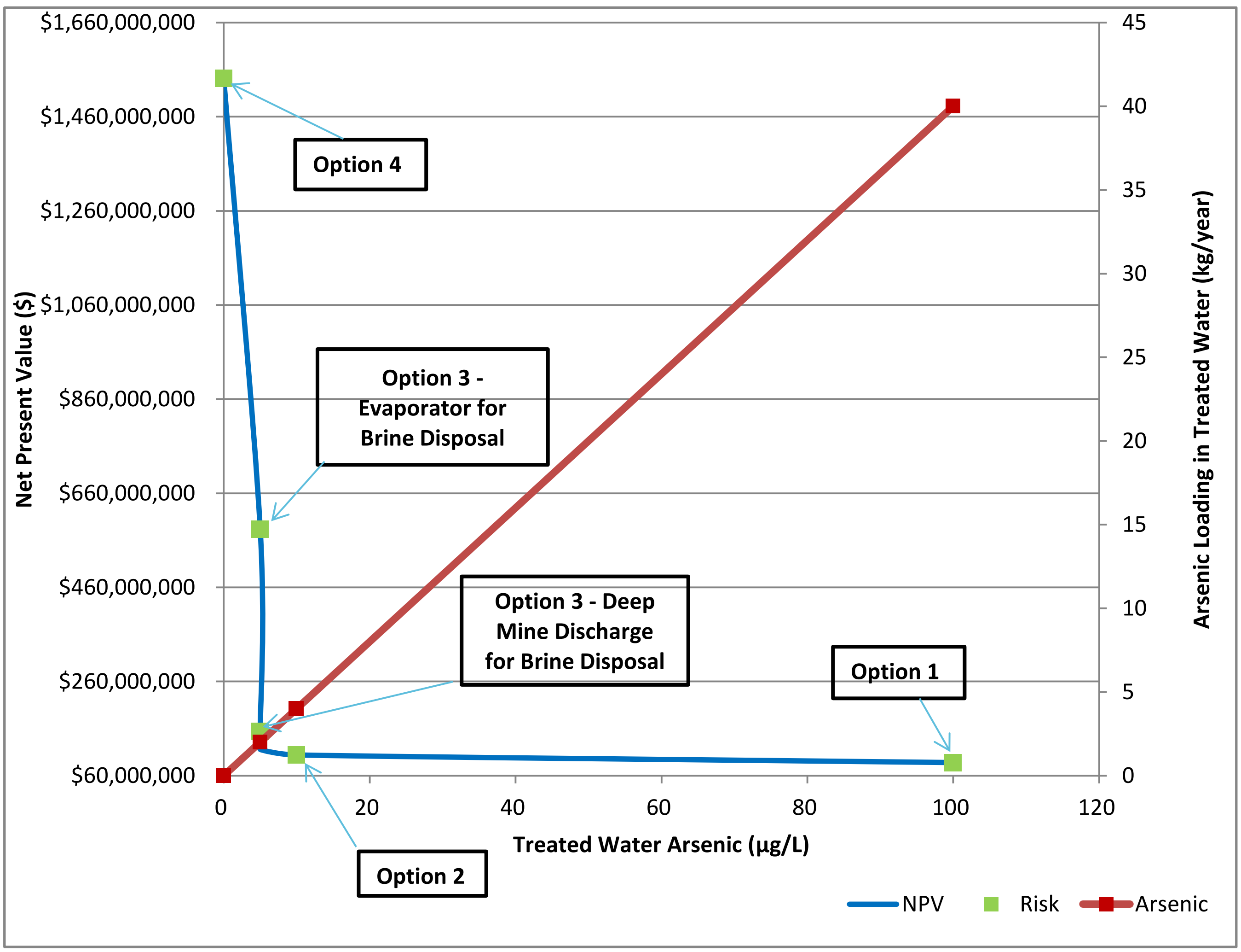
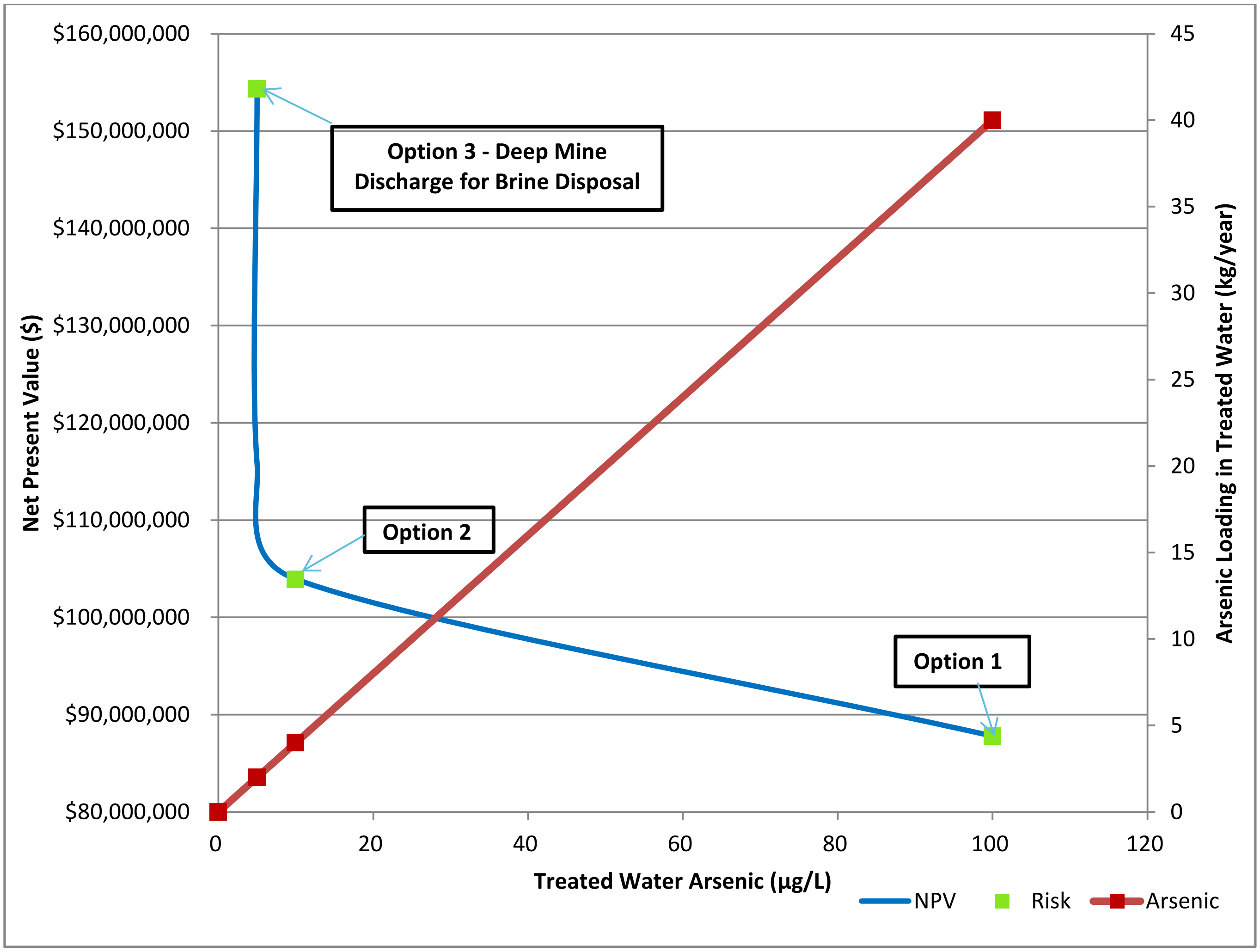


Figure 3.4 – Annual Arsenic Loading and NPV of the Water Treatment Options



4. Development of the Long Term Water Disposal Options

4.1 Background

It is apparent the public has concerns regarding arsenic release in Yellowknife Bay and the reliance on mixing in the bay to ensure that there is no adverse effect on water quality, aquatic biota and people. This report is an overview of potential outfall locations, other than the diffuser in the Bay, and potential issues with each.

Table 4-1 – Giant Mine Developers Assessment Report Table ES.2.1 (October 2010)

Component	Proposed Remediation Activity	Benefits
Site Water Management	- Construct new water treatment plant - Direct all contaminated water to the mine for treatment - Treat contaminated water and discharge to Great Slave Lake - Manage treatment byproducts on site	- Eliminates off-site migration of contaminants in groundwater - Storage of contaminated water on surface no longer required - Eliminates treated water to Baker Creek - Reduces the amount of arsenic discharged to Great Slave Lake.

4.2 Objectives

The outfall must discharge the treated water to the receiving environment in a manner that safeguards the environment, complies with licensing restrictions and which safeguards people/animals/aquatic life that are in the vicinity of the outfall.

Three major items of concern are:

1. Quality of the treated water at the end of pipe
2. The temperature of the water at the end of pipe and its effect on ice cover particularly in the shoulder seasons
3. Disturbance of the water body bottom sediment, both during construction and during operation

The first objective will be met by the treatment process selected. The outfall location must satisfy objectives 2 and 3.

4.3 Outfall Types

There are numerous locations where an outfall could discharge the treated water. These are broadly classified as outfalls that:

- Neither directly nor indirectly impact Great Slave Lake
- Do not thermally impact the receiving lake
- May thermally impact the receiving lake

4.4 Outfalls that Do Not Directly or Indirectly Impact Great Slave Lake.

The watershed of Great Slave Lake extends for many kilometers from the shoreline, therefore any discharge that does not directly or indirectly impact Great Slave Lake must either be directed to the atmosphere, such as an evaporation process, or directed to a deep subsurface zone.

1. The issue of evaporative treatment is discussed under plant options.
2. A deep injection system would consist of several pipes likely greater than 1000 m drilled into a permeable zone that is confined or capped by impermeable rock. At the Giant Mine, the nature of the Precambrian shield rock is such that a highly permeable deep zone that can accept sustained injection is very unlikely. The bedrock fracture system in Precambrian bedrock generally has very little volume available in joints and fractures and is not confined by impermeable rock. Injection into the bedrock is not feasible.

4.5 Outfalls that Do Not Thermally Impact the Receiving Water Body.

Three potential options were considered to satisfy this criteria.

1. The treated water could be piped to Jackfish Lake, a distance of 4 kilometres (km), and discharged adjacent to the Northwest Territories Power Corporation power plant. Since open water is already maintained at this location by the cooling water discharge from the power generators the thermal effect of the water from Giant Mine would be minimal. This option is however, discarded as the affect of the additional water into this lake, and its long term effect on the lake level, is unknown. Further, if the additional water does not affect the lake level, the flow and icing in the ravine between Jackfish Lake and Back Bay would increase with the increased flow.
2. The treated water could be discharged to Baker Creek on a year round basis. Flow in Baker Creek would effectively minimize any thermal impact before the water reaches Back Bay. This option is discarded as the creek flow is known to cease in winter and substantial icing/glaciations would occur with only the plant flow in the creek during the winter months.
3. Treated water discharge could be stored on site in a lined engineered containment cell and then discharged to Baker Creek during the summer months. To store two thirds of the years plant production would require a holding cell approximately 400 metres (m) square with a working depth of 6 m. A very large footprint is required to construct this cell and will require additional disturbance to the land. The large open water will attract waterfowl to the Giant Mine site and be in conflict with remedial activities. Dam safety reviews and annual maintenance will be required to maintain

the performance of the system. This option is discarded as storage of the mine water underground mitigates additional land disturbance and long term maintenance.

4.6 Outfalls that Have Potential Thermal Effects on the Receiving Water Body.

Any outfall to a lake has the potential to have thermal impact. Four examples are as follows:

1. The currently contemplated outfall and diffuser in Great Slave Lake is some 1500 m offshore in an area that is some 10 m deep and is influenced by the Yellowknife River current. This current, together with the diffuser arrangement, promotes rapid mixing of the discharge with the lake water, lowering the discharge water temperature to the lake temperature. It is anticipated that the discharge will be 4 to 6^{o}C with the under ice lake temperature being 0.5^{o}C.
2. A near shore outfall in Great Slave Lake could be constructed immediately offshore of the old Giant town site where a 4 to 6 m depth of water is available. Alternatively the discharge could be in a rock cut, on shore, that is deep enough to place the discharge below winter ice level. This arrangement minimizes the potential disturbance of bottom sediment during construction. The lack of current in this area will increase any thermal impact however, as it is near shore, it is much simpler to describe as an area to avoid and simpler to install warning markers if such prove warranted.
3. An on-shore outfall adjacent to Great Slave Lake could be constructed such that plant discharge is directed to the water surface in summer and to ice surface in winter. This would avoid work in the lake but could thermally impact near shore ice or cause extensive icing overflow conditions on the lake surface. As with 2 above it is near shore, it is much simpler to describe as an area to avoid and simpler to install warning markers if such prove warranted.
4. An adjacent lake could be considered however the effects noted in 2 and 3 above would be similar and winter lake outflow may be induced where there is no current winter flow. Since all lakes near Yellowknife see substantial snow machine traffic this option would not mitigate the thermal loading and ice safety concerns.

Potential outfalls are shown in the following figure:
Figure 4.1 - Potential Outfalls

Table 4.2 – Summarizes the feasible outfalls and provides indicative capital costs and 100 year NPV assuming 3% discount rate and 1% operation and maintenance per year on outfall works.

Public Works and Government Services Canada

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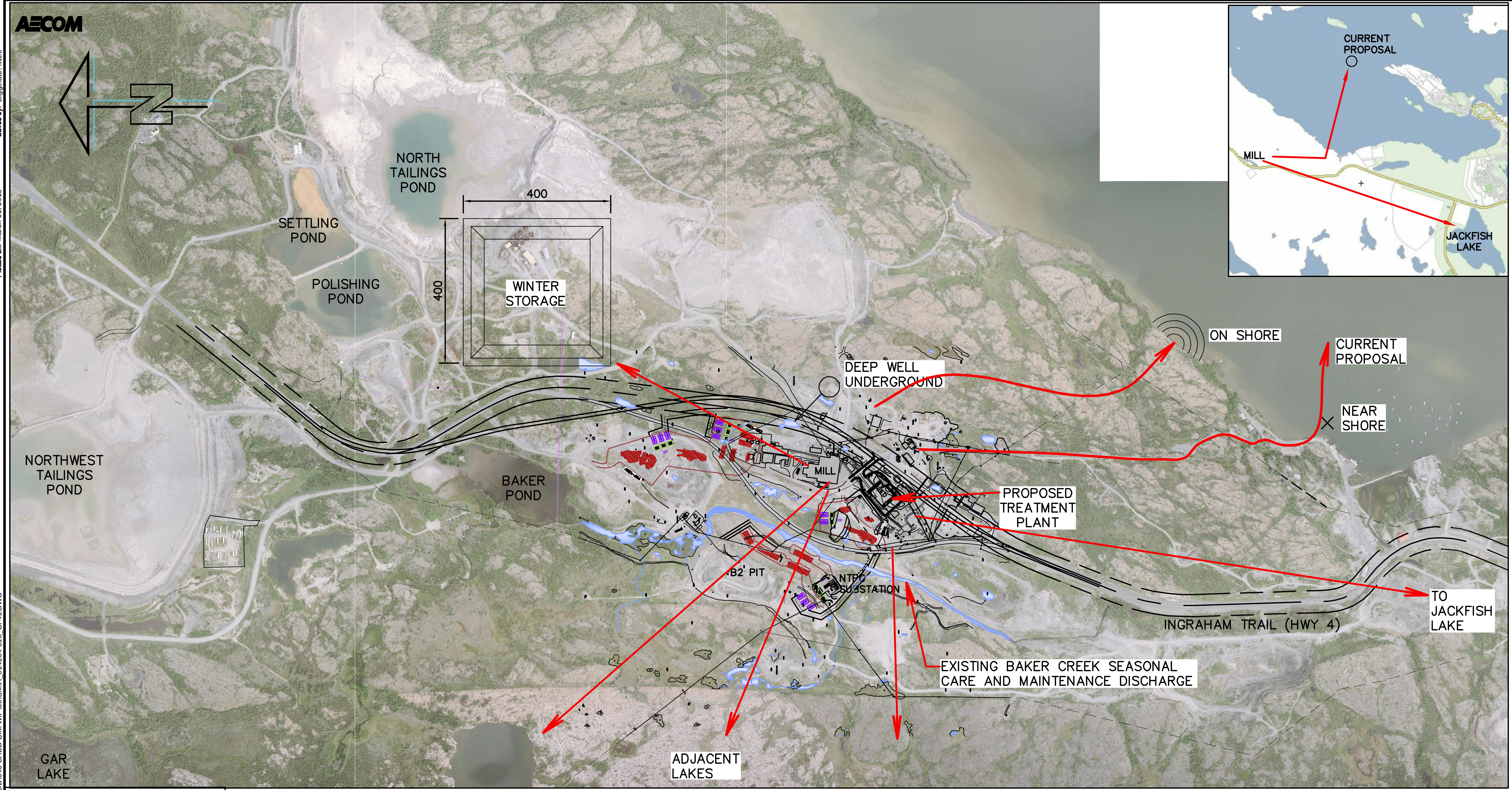

Saved by: Biggelaar, Marc

Plotted on: March 11, 2013

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DO NOT SCALE DRAWINGS

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PRELIMINARY
NOT FOR CONSTRUCTION

Client/client	Project title/Titre du projet	Drawing title/Titre du dessin	Approved by/Approuve par	PWGSC Project Manager/Administrateur de Projets TPSGC	Project No./No. du projet
PUBLIC WORKS GOVERNMENT SERVICES CANADA	EFFLUENT TREATMENT PLANT INFORMATION RESPONSE	POTENTIAL OUTFALLS STORAGE OPTIONS		Brad Thompson	R.014204-318
			Designed by/Concept par	PWGSC, Architectural and Engineering Resources Manager/ Ressources Architectural et de Directeur d'Ingénierie, TPSGC	Sheet/Feuille: FIGURE 4.1
			Drawn by/Dessine par	Date/Date: March 11/2013	Revision/Revision: A

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Table 4-2 – Outfall Summary

Discharge Point	Advantages	Disadvantages	Capital Cost ($1,000)	Recommendation
Great Slave Lake, in a location influenced by Yellowknife River currents.	An outfall diffuser and current rapidly disperse the treated water to background temperature levels.	Long in lake pipeline will disturb bottom sediments during construction. Distance from shore makes locating and signing difficult.	$5,500 ($7,250 NPV)	Recommended for 100 µg Arsenic content at end of pipe
Great Slave Lake near shore	Less length reduces disruption of bottom sediments during construction. Known location more readily defined and signed. Less length reduces capital cost.	Lack of current in still areas near shore increases the impact of treated water temperature.	$3,300 ($4,400 NPV)	Recommended for 5 or 10 µg Arsenic at end of Pipe
Great Slave Lake On-Shore	No disruption of bottom sediments.	Potential overflow/icing conditions in winter.	$3,300 ($4,400 NPV)	Not recommended due to potential icing on or near shore.
Baker Creek (year round)	No direct impact on Great Slave Lake. Baker Creek on mine property not commonly visited by people or snow machines. Least capital cost outfall.	Baker Creek is prone to icing in the winter and often requires machine intervention to clear the channel. Additional flow in Baker Creek may result in additional bottom sediment disturbance. Surface discharge route through impacted mine lease.	$500 ($665 NPV)	Not Recommended due to potential icing.
Baker Creek (Summer Only)	No thermal impact	Requires open storage for winter water plant production.	$7,000 ($9,200 NPV)	Not recommended due to open water storage on site will attract waterfowl and be in conflict with remedial activities. A very large footprint will disturb additional land.
Jackfish Lake	Lake already used for cooling for NWTPC power plant.	Additional winter input may cause lake level rise or additional icing in ravine to Back Bay.	$6,300 ($8,300 NPV)	Not recommended due to uncertainties of impact on Jackfish Lake and outlet ravine.
Nearby Lakes	No direct thermal impact on Great Slave Lake. Flow can mix with natural winter outflow if such exists.	People and snow machines heavily use all lakes near Yellowknife. Continuous input of treated water may cause outlet flow where naturally there is no winter flow.	Not Estimated	Not recommended due to potential impacts

4.7 Discharge to Solar Evaporation Pond

One of the options considered for the disposal of the water treatment plant discharge is an evaporation pond. This process has the tremendous advantages of low operational input and with negligible carbon footprint impacts. The key challenge with this option is the location of the project. The evaporative losses in Yellowknife are low and are estimated to be 133 mm / year meaning the calculated pond surface area required to evaporate an annual volume of 520,000 m^3/y is roughly 400 hectares. The footprint is equivalent to 2 km x 2 km (i.e., about 8 times larger than the current tailings areas) and is shown graphically in **Figure 4.2** below. All the assumptions associated with the calculations are provided below in **Table 4.3**.

Given the size of the pond required to support evaporation we assume that this option is not feasible.

Table 4-3 – Assumption Associated with an Evaporation Pond

Parameter	Measurement	Units	Notes / Source
Mean annual rainfall	165	mm/yr	Canadian Climate Normals, Yellowknife Station 'A', 1971 to 2000
Mean annual snowfall	116	mm/yr	Ibid.
Mean annual precipitation	281	mm/yr	Sum of rainfall and snowfall
Average lake evaporation	415	mm/yr	Evaporation studies at Pocket Lake by AANDC Waters Division (per Bob Reid via personal communication)
Water balance	-134	mm/yr	Negative balance therefore evaporation is theoretically feasible
Evaporative rate	0.134	m3/m2/yr	
Volume to evaporate	520,000	m3/yr	Wet year post freeze volume requiring treatment (per AECOM)
Area required to evaporate	3,880,597	m2	equivalent to roughly 2 km x 2 km

Figure 4.2 - Aerial Photograph Showing the Estimated Solar Evaporation Pond Footprint Required

5. Potential Impacts

5.1 Environmental Risk

With regards to the evaluation of treatment and disposal options, the Review Board asked for "2 d) a description of the potential impacts on the environment, including an assessment of risks, and the developer's view of the significance of those impacts." For context, the Base Case scenario presented in the DAR used a conservative estimate of 400 µg/L arsenic in the treated effluent (i.e. the maximum expected concentration during upset conditions) and a flow rate of 350,000 m^3/yr for an annual load of 140 kg/yr total arsenic. On average, the conventional chemical-physical water treatment system is expected to achieve an effluent arsenic level of 100 µg/L or better. Using the current long-term mine water flow estimate of 400,000 m^3/yr the equivalent arsenic load for the Base Case scenario therefore equals 40 kg/yr. The equivalent annual arsenic loads for the various treatment scenarios considered in this review of treatment options, including the Base Case scenario, are summarized in Table 5.1. The arsenic loads range from 4 kg/yr for a treatment train that includes conventional chemical precipitation and effluent polishing using ion exchange (or an alternative adsorption media) to 0 kg/yr for the option entailing mine water evaporation (i.e. assumes no release of effluent to the environment).

While the assessment of treatment alternatives demonstrates that the arsenic loadings associated with treated effluent can be reduced compared to the proposed conventional treatment system, the overall contribution of the mine water discharge to Yellowknife Bay is small compared to the baseline arsenic load deriving from other sources in the vicinity of the Giant Mine site. For context, these sources and their loadings post-remediation are as follows:

- Baker Creek upstream of Giant Mine = 220 kg/yr
- Tributaries from west of Giant Mine = 67 kg/yr
- Runoff from Giant Mine surface facilities to Baker Creek = 190 kg /yr
- Direct runoff from Giant Mine to Yellowknife Bay = 69 kg/yr
- Total of all sources (excluding treated effluent) = 546 kg/yr

Based on the above, the projected loadings of the proposed conventional water treatment system (40 kg/yr) represent less than 7.5% of the total post-remediation arsenic loadings entering Great Slave Lake from the Giant Mine site or via Baker Creek. For additional context, the baseline arsenic load in the Yellowknife River equals approximately 200 kg/yr (i.e., five times greater than the proposed conventional water treatment system).

The findings from ecological and human health risk assessments undertaken with reference to the direct discharge of treated effluent to Yellowknife Bay have shown that there is no significant residual risks for the Base Case scenario (i.e. the option presented in the DAR). These findings are consistent with the fact that the predicted arsenic concentration in the mixing zone is expected to fall below the lowest toxicity reference value for aquatic species (i.e., EC_{20} of 120 µg/L for fish) and below the Canadian Water Quality Objective for protection of Freshwater Aquatic Life of 5 µg/L within a short distance of the diffuser. Our conclusions regarding the residual risks associated with other options considered in this assessment are summarized in **Table 5.1**. Considerations of note in determining residual risks include:

- Option 2 - there would be no need to design for effluent dilution as the quality of the effluent at the "end of pipe" would be non-toxic to even the most sensitive species. Furthermore, the discharge meets Health Canada's drinking water quality guidance of 10 µg/L for arsenic and hence, would pose low risk of adverse health effects to people who might come in contact with the effluent, drink the treated water or catch and consume fish that come in contact with the effluent.
- Option 3 – like Option 2 there would be no need to design for effluent dilution for either of these options. The arsenic level in the effluent is below the Canadian Water Quality Guideline of 5 µg/L for protection of freshwater aquatic life and also below Health Canada's drinking water guideline.
- Option 4 – would reduce arsenic risks associated with the treated effluent to zero in the aquatic environment but would result in the release of green house gas and other combustion pollutants to the atmospheric environment.

In summary, none of the potential water treatment and disposal options, including the current proposal, pose a risk of significant adverse effect to ecological species or to people now and into the future.

Table 5-1 – Treated Mine Water Arsenic Concentrations and Loads

Treatment Option	Effluent Arsenic Concentration (µg/L)	Effluent Arsenic Load (kg/yr) [a)]	Residual Risks in Near Field
1. Conventional Chemical Precipitation, Clarification and Filtration System (Base Case Option)	100	40	Minimal residual ecological or human health provided effective dilution of the treated effuent is achieved.
2. As per Option 1 plus Ion Exchange	10	4	Minimal residual ecological or human health risks. Not dependent on effluent dilution.
3. As per Option 1 plus Reverse Osmosis	5	2	No residual ecological or human health risks. Not dependent on effluent dilution.
4. As Option 1 plus Evaporation of Treated Mine Water [b)]	0	0	No residual ecological or human health risks. Not dependent on effluent dilution.

Notes: a) Arsenic load calculated based on long-term effluent flow of 400,000 m^3/yr
b) Treatment of mine water prior to evaporation is recommended to reduce scaling problems with the evaporator