APPENDIX 3.0-A

WATER MANAGEMENT OPTIONS

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1.0 INTRODUCTION

Shore Gold Inc. (‘Shore’) submitted a draft Environmental Impact Statement (‘EIS’) in December 2010 to support the potential development of the Star-Orion South Diamond Project which consists of a proposed open pit diamond mining operation approximately 40 km east of Prince Albert, Saskatchewan. A key feature of the project water management strategy contained in the EIS was the use of the Duke Ravine as a water reservoir/polishing pond for the deposit of process water and water from the pit dewatering program (including surficial and Mannville Formation groundwater) that would be managed through a pipeline and diffuser to the Saskatchewan River (SKR).

Following a preliminary review, Environment Canada and other reviewers raised questions about the suitability of the proposed water management strategy, and requested investigations into alternate strategies to manage the water that will be generated as a result of this project. As a result, separation of process water and Mannville water was selected in order to manage metal concentrations in the process water separately from the pit-dewatering water. This aspect of the water management plan is described in Section 2.

This report provides a list of the alternative water management strategies identified and the details of the consideration each option was given in arriving at the most appropriate water management strategy for Mannville formation dewatering water for the Star-Orion South Diamond Project.

2.0 METHODOLOGY

2.1 OVERVIEW OF WATER MANAGEMENT ALTERNATIVES ASSESSMENT

This water management alternatives assessment closely followed Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* (The 'Guideline'). The Guideline outlines the process in which to identify the best option for managing tailings disposal from environmental, technical and socio-economic perspectives. In this instance, the process as outlined in the guideline was utilized to identify the best option for disposing of the Mannville Formation groundwater that will be generated from Shore Gold's Star-Orion South Diamond Project.

The Guideline outlines a seven step process that initially identifies the various options for water management. These steps are as follows:

1. Identify Candidate Alternatives;
2. Pre-Screening Assessment;
3. Alternative Characterization;
4. Multiple Accounts Ledger;
5. Value-Based Decision Process;
6. Sensitivity Analysis; and
7. Document Results.

The options that were identified for this assessment are described in section 3.0 including environmental and approval implications, requirements for further study, source references and conceptual design graphics. This is followed by a pre-screening assessment in section 4.0 which entails the screening or exclusion of alternatives that do not meet minimum specifications. In this case those minimum specifications include environmental, technical, economic and socio-economic issues such as:

- Ability to achieve target water quality parameters;
- Water storage and retention requirements;
- Impact of construction on the project schedule;
- Impact of water management option on mine operations;
- Relative possibility of achieving regulatory approval;
- Impact on capital and operational expenditure requirements; and
- Relative possibility of acceptance by stakeholders and general public.

The pre-screening assessment includes a qualitative narrative and rationale for each option and a determination of whether it will be carried forward for further assessment.

The third step in the process is the characterization of each of the alternatives which is outlined in section 5.0. This includes further assessment of the environmental, technical, economic and socio-economic issues of each of the options carried forward.

This information is summarized in the multiple accounts ledger in section 6.0 and the sub-accounts are assigned sensitivity and risk weightings which are multiplied to arrive at a relative rating for each option. Sub-accounts are assigned a relative sensitivity rating of 1 for low sensitivity ascending to 5 for high. Low sensitivity is defined as having a lower priority in relation to other sub-accounts and low significance to project activity. Conversely, high sensitivity has a higher priority in relation to other sub-accounts and is significant to project activity. Furthermore, each of the sub-accounts for each of the options is assigned risk ranging from low to high risk based on the criteria and rationale provided. Low risk is defined as having a minimal to negligible impact on the overall project while high risk is the converse. The relative risk assigned to each sub-account for each option is summed together to arrive at the overall risk for the option.

Following this is the final assessment in section 7.0 which documents the results of the value-based decision process and sensitivity analysis of the short listed options that have been carried forward. The assessment leads to a determination of the best option for the management of the Mannville Formation groundwater.

2.2 WATER QUALITY PARAMETERS CONSIDERED

HCI (2005) indicated that the chemistry of the Mannville Formation groundwater will have a total dissolved solids ('TDS') concentration of about 4,000 mg/L, a sodium concentration of about 1,200 mg/L, and a chloride concentration of about 1,600 to 1,700 mg/L. These key parameters are the primary focus of consideration for this assessment. Other environmental receptors factored into the process include aquatic biota and noise.

Tables 2-1 and 2-2 below outline the Mannville formation water quality measured in 2010 during the 20 day prototype dewatering well pump test. These results generally agree with values in HCI (2005).

Table 2-1: Mannville Formation Water Quality

2010 Orion South Pumptest			Mannville Formation Groundwater Quality										Surface Water Quality Objectives for the Protection of Aquatic Life (modified from CCME 1999)		SMOE *Mineral Industry Environmental Protection Regulations, 1996*	
Group #			**OSPT**	**OSPT**	**OSPT**	**OSPT**	**OSPT**	**OSPT**	**OSPT**	**OSPT**	**OSPT**					
Sample #			**#10064**	**#10065**	**#10066**	**#10067**	**#10068**	**#10071**	**#10072**	**#10073**	**#10074**				**Maximum Monthly Arithmetic Mean Concentration (Bq/L)**	**Maximum Grab Sample Concentration (Bq/L)**
Date			**26-Oct-10**	**29-Oct-10**	**2-Nov-10**	**4-Nov-10**	**7-Nov-10**	**11-Nov-10**	**12-Nov-10**	**14-Nov-10**	**14-Nov-10**					
Analyte	**Units**	**MIEPR**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**		**Objective***	**Comments**		
Aluminum	mg/L		0.021				0.005		0.0021		0.0024		5 - 100	See Note 1	0.5 mg/L	1.0 mg/L
Ammonia (in mg/L)													--	See Table 4.1.1		
Antimony	mg/L		<0.002				<0.002		<0.0002		<0.0002					
Arsenic	ug/L	500	<1				<1		0.3		0.2	--	5			
Barium	mg/L		0.013				0.011		0.010		0.010					
Beryllium	mg/L		<0.001				<0.001		<0.0001		<0.0001					
Bicarbonate	mg/L		473	476	477	477	474	474		474						
Boron	mg/L		2.1				2.0		2.0		1.9					
Bromoxynil													5			
Cadmium	mg/L		<0.0001				<0.0001		0.00001		0.00001		0.017 – 0.10			
Calcium	mg/L		138	136	133	133	136	134		134						
Carbonate	mg/L		<1	<1	<1	<1	<1	<1		<1						
Chloride	mg/L		1600	1600	1600	1560	1600	1700		1700						
Chlorine													0.5			
Chlorpyrifos													0.0035			
Chromium	mg/L		<0.005				<0.005		<0.0005		<0.0005					
Chromium VI													1			
Cobalt	mg/L		0.001				<0.001		0.0001		0.0001		4-Feb	See Note 3		
Copper	mg/L	0.3	0.010				0.005		0.0032		0.0024	--			0.3 mg/L	0.6 mg/L
Cyanide												--	5		1.0 mg/L	2.0 mg/L
Dicamba													10			
Diclofop-methyl													6.1			
Dimethoate													6.2			
Fluoride	mg/L		2.2	2.2	2.3	2.2	2.2	2.3		2.5						
Glyphosate													65			
Hydroxide	mg/L		<1	<1	<1	<1	<1	<1		<1						
Iron	mg/L		0.36				0.29		0.24		0.23		300			
Lead	mg/L	0.2	<0.001				<0.001		0.0005		0.0003	--	1 – 7	See Note 4	0.2 mg/L	0.4 mg/L
Lead-210												<0.02			0.92	1.84
Lindane													0.01			
Magnesium	mg/L		47	46	45	45	46	45		45						
Manganese	mg/L		0.099				0.092		0.087		0.086					
Mercury (inorganic)													0.026			
Molybdenum	mg/L		<0.001				<0.001		0.0002		0.0001					
Nickel	mg/L	0.5	0.002				<0.001		0.0005		0.0005	--	25 – 150	See Note 5	0.5 mg/L	1.0 mg/L
Nitrate	mg/L		<0.04	<0.04	<0.04	<0.04	<0.04	<0.04		<0.04						
Oxygen, Dissolved (in mg/L)													5.5 – 9.5	See Note 6		
P. Alkalinity			<1	<1	<1	<1	<1	<1		<1						
Pentachlorophenol													0.5			
pH	pH units		7.82	7.82	7.82	7.88	7.79	7.74		7.73						
Phosphorus	mg/L		0.06				0.06		0.05		0.05					
Phenols (mono- and dihydric)													4			
Phenoxy Herbicides (2,4-D)													4			
Picloram													29			
Polonium-210												0.01			--	--
Potassium	mg/L		57	57	58	58	57	56		56						
Radium-226												0.04			0.37	1.11
Radium-228												0.07			--	--
Radon-222												7			--	--
Selenium	mg/L		<0.001				<0.001		0.0003		0.0002		1			
Silver	mg/L		<0.0001				<0.0001		<0.00001		<0.00001		0.1			
Sodium	mg/L		1190	1210	1270	1250	1210	1210		1220						
Specific conductivity	µS/cm		6420	6530	6470	6530	6450	6160		6180						
Strontium	mg/L		2.6				2.5		2.50		2.48					
Sulfate	mg/L		740	750	740	750	750	740		740						
Sum of ions	mg/L		4240	4280	4320	4270	4270	4360		4370						
Temperature													Narrative Statement	See Note 7		
Thallium	mg/L		<0.002				<0.002		<0.0002		<0.0002					
Thorium-228												<0.01			--	--
Thorium-230												<0.01			1.85	3.7
Thorium-232												<0.01			--	--
Tin	mg/L		<0.001				<0.001		<0.0001		<0.0001					
Titanium	mg/L		<0.002				<0.002		0.0002		<0.0002					
Total alkalinity	mg/L		388	390	391	391	389	389		389						
Total dissolved solids	mg/L		3960	3960	3970	3960	3950	3950		3950						
Total hardness	mg/L		537	528	517	517	528	519		519						
Triallate													0.24			
Trifluralin													0.2			
Un-ionized Ammonia**												--			0.5 mg/L	1.0 mg/L
Uranium	ug/L	2500	<1				<1		<0.1		<0.1		15	See Note 8		
Uranium-234												<0.001			--	--
Uranium-235												<0.0001			--	--
Uranium-238												<0.001			--	--
Uranium												<0.1 ug/L			2.5 mg/L	5.0 mg/L
Vanadium	mg/L		<0.001				<0.001		0.0002		0.0002					
Zinc	mg/L	0.5	0.16				0.021		0.014		0.011	--	30		0.5 mg/L	1.0 mg/L

*All values in micrograms per litre (ug/L) unless otherwise indicated

** Un-ionized ammonia is the portion of total ammonia nitrogen that is in the form NH3. The pH and temperature to be used in calculating un-ionized ammonia are to be those of the approved receiving water at the time of the sampling.

Note 1: Aluminum Objective: 5 ug/L at pH <6.5, Ca <4 mg/L and DOC <2 mg/L; 100 ug/L at pH ≥ 6.5, Ca ≥ 4 mg/L and DOC ≥ 2 mg/L.

Note 2: Cadmium Objective: 0.017 ug/L where hardness is 0 - 48.5 mg/L; 0.032 ug/L where hardness is 48.5 - 97; 0.058 where hardness is 97 - 194; 0.10 ug/L where hardness is >194.

Note 3: Copper Objective: 2 ug/L where hardness is 0 - 120 mg/L; 3 ug/L where hardness is 120 - 180 mg/L; 4 ug/L where hardness is >180 mg/L.

Note 4: Lead Objective: 1 ug/L where hardness is 0 - 60 mg/L; 2 ug/L where hardness is 60 - 120 mg/L; 4 ug/L where hardness is 120 - 180 mg/L; 7 ug/L where hardness is >180 mg/L.

Note 5: Nickel Objective: 25 ug/L where hardness is 0 - 60 mg/L; 65 ug/L where hardness is 60 - 120 mg/L; 110 ug/L where hardness is 120 - 180 mg/L; 150 ug/L where hardness is >180 mg/L.

Note 6: Dissolved Oxygen Objective: 6.0 mg/L for warm-water biota in early life stages; 5.5 mg/L for warm-water biota in other life stages; 9.5 mg/L for cold-water biota in early life stages; 6.5 mg/L for cold-water biota in other life stages.

Note 7: Temperature Objective: Thermal additions should not alter thermal stratification or turnover dates, exceed maximum weekly average temperatures, nor exceed maximum short-term temperatures.

Note 8: The objective was developed by the Industrial, Uranium and Hardrock Mining Unit of Saskatchewan Environment.

Table 2-2: Effluent Water Quality

Pollutant	Estimated Concentration (mg/L)	Regulatory Effluent Criteria		
		SMOE Surface Water Quality Objectives for Agriculture Uses (mg/L)	CCME Water Quality Guidelines for Protection of Agriculture (mg/L)	Manitoba (mg/L)
Total Dissolved Solids	4,000	500 – 3,500 (Irrigation) 3,000 (Livestock)	500 – 3,500 (Irrigation) 3,000 (Livestock)	500 (Drinking) 700 (Irrigation)
Sodium	1,200	n/a	n/a	200 (Drinking)
Chloride	1,600 – 1,700	100 – 700 (Irrigation)	100 – 900 (Irrigation)	250 (Drinking) 100 – 900 (Irrigation)
Sodium Absorption Ratio (SAR)	--	--	--	4.0 SAR (Irrigation)

3.0 WATER MANAGEMENT CANDIDATE ALTERNATIVE OPTIONS

The following options were identified as possible water management alternatives to handle the Mannville Formation groundwater:

A) Spray Evaporation;

B) Diffuser System;

C) Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR;

D) Orion North/South, Mannville Formation groundwater injected into infiltration gallery;

E) Exfiltration/evaporation of Mannville Formation groundwater with use of pond;

F) Irrigate Fort a la Corne Forest with Mannville Formation groundwater;

G) Deep well injection of Mannville Formation groundwater;

H) Reverse osmosis treatment; and

I) Reverse osmosis treatment with deep well injection of solute.

Each of the alternative options is described below according to the following attributes:

- General description;
- Constructability;
- Ease of Operation;
- Potential for Malfunction/Issues During Operation;
- Impact of approach on operation of the mine;
- Environmental Impact of Approach;
- Regulatory Approval;
- Public Approval; and
- Need for further study.

3.1.1 Option A: Spray Evaporation

General Description

- The discharge of Mannville Formation groundwater generally during high temperature months through the use of spraying equipment;

- One or more spray evaporators connected with hoses and/or piping are erected at a specific location or locations and spray a mist into the atmosphere thereby increasing evaporation potential; and
- Typical volume reduction is greater than 50%.

Constructability

- Spray evaporation has been investigated or used by other mining companies as an option to handle water disposal;
- There is potential for sharing of spray evaporation system design but modification will likely be required;
- At the Rock Creek Project in Alaska (Rock Creek and Hurrah mines) spray evaporators were used during Aug-Sep 2010 to dispose of non-domestic wastewater in conjunction with planned groundwater recharge, transpiration and soil containment; and
- Design will primarily depend on water quality, water volume, weather indicators such as temperature and rainfall, and the available area for airborne water and particulate matter to drift once released into the atmosphere.

Ease of Operation

- Will require periodic oversight and maintenance of blower fans, pumps, sprayers, etc., by a staff member; and
- Periodic daily visual inspection to monitor wind speed and direction so that excess deposition does not occur.

Potential for Malfunction/Issues During Operation

- Leaks and breaks in equipment;
- Changing and varying wind speeds and direction; and
- Excess land deposition.

Impact of Approach on Operation of Mine

- Additional capital and operational expenditures will be required. This will include but not be limited to; design of the spray evaporation system; construction of spray evaporation system; operational inspections; and periodic maintenance including corrosion protection.

Environmental Impact of Approach

- Possible impacts to the environment include changes in the soil moisture regime (more water in the summer), groundwater recharge potentially leading to excessive subsurface flow and seepage, excess runoff, water quality impacts to surface and groundwater.

Regulatory Approval

- Spray evaporator equipment has been approved by regulators for other mining projects; and
- Water quality of Mannville Formation groundwater will be a factor in gaining regulatory approval.

Public Approval

- If no additional impact to the environment and little to no additional site disturbance then no change in potential public approval; and
- Conversely, if the public perception of water quality is poor, objections may be raised.

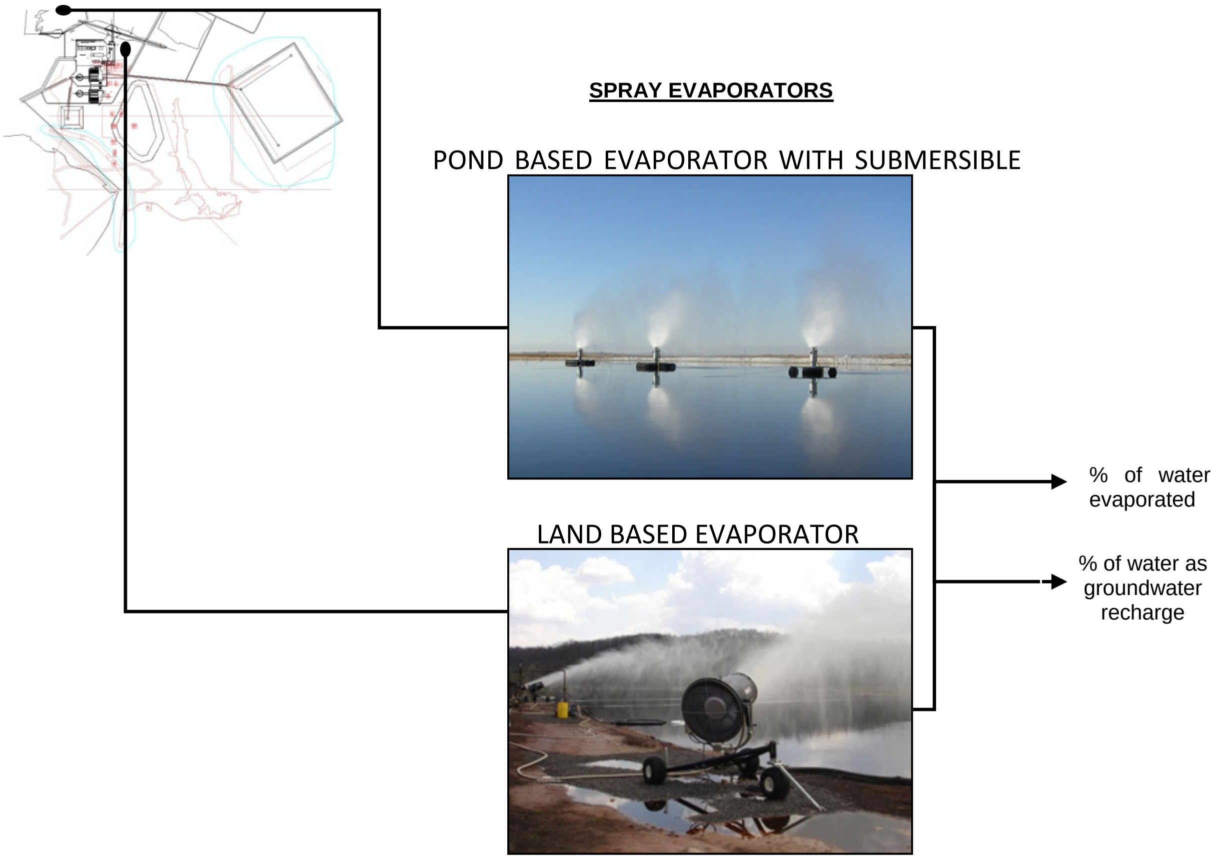
Need for Further Study

- Assessment of environmental impact due to water quality after evaporation;
- Experience with previous spray evaporator equipment approval processes could be drawn on to develop regulatory applications and provide a starting point for environmental and/or impact assessments; and
- Assessment of wind speed and direction across the site; an environmental assessment of the spray evaporation system; completion of application amendments; and ongoing environmental monitoring and controls as determined through the EA process.

References

- Response to Comments Document Land Application Permit No. 010DB0011, Rock Creek Project, 2010. http://dnr.alaska.gov/mlw/mining/largemine/rockcreek/index.htm; and
- Rock Creek Mine and Big Hurrah Project, 2010 Annual Report. http://dnr.alaska.gov/mlw/mining/largemine/rockcreek/index.htm.

Conceptual Drawing / Process Flow



3.1.2 Option B: Diffuser System

General Description

- The diffuse release of separated Mannville Formation groundwater and other surficial aquifer waters through a diffuser pipe system built into or on top of the SKR bed; and
- The purpose of the diffuser option is to promote rapid mixing of released Mannville Formation groundwater with the river water to reduce impacts to water quality.

Constructability

- A diffuser design has already been incorporated into the current design of the project but may require design modification to allow for additional capacity;
- Straight forward construction with known technology; and
- In 2006, a diffuser system was proposed by Rescan to Novagold Canada Inc. for release of treated supernatant of concentrate slurry into the Iskut River in British Columbia; the system was approved and permitted.

Ease of Operation

- Periodic visual inspection and maintenance of ports and piping is required, which would be triggered by an inspection cycle, adverse monitoring data outside of cycle time, or unexpected back pressure from the diffuser; and
- No moving parts to maintain.

Potential for Malfunction/Issues During Operation

- Periodic coverage of the fluid release ports by sediment is possible.

Impact of Approach on Mine Operations

- Capital and operational expenditures will be required; installation of pipeline; installation of pumps; and siting of the diffuser; and
- Expenditures for environmental assessment and regulatory application amendments will be required. This will include the environmental assessment of the farfield impacts outlined in the technical memorandum (AMEC 2011); completion of application amendments; and ongoing environmental monitoring and controls as determined through the EA process.

Environmental Impact of Approach

- It is expected that the diffuser will lead to an increase in concentration of major ions and metals in the immediate vicinity (near field) of the diffuser system;
- Potential for fish habitat to be affected; and
- Potential substantial release of sediment downstream during construction.

Regulatory Approval

- In-stream construction to install the diffuser will require DFO and SMOE approvals; and
- Water quality and quantity impacts will require assessment with implementation of monitoring and control programs to mitigate and/or curtail potential environmental impacts.

Public Approval

- Downstream or far field environmental impacts seen or perceived could lead to stakeholder impediment to approval of approach.

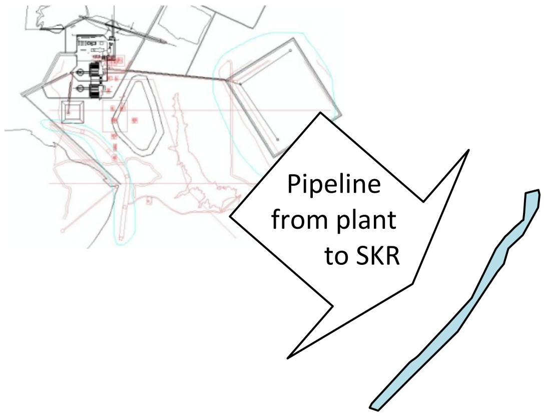
Need for Further Study

- Environmental assessment is required to fully understand potential impacts near and far field and eventual control and monitoring requirements; and
- Diffuser design engineering and modelling.

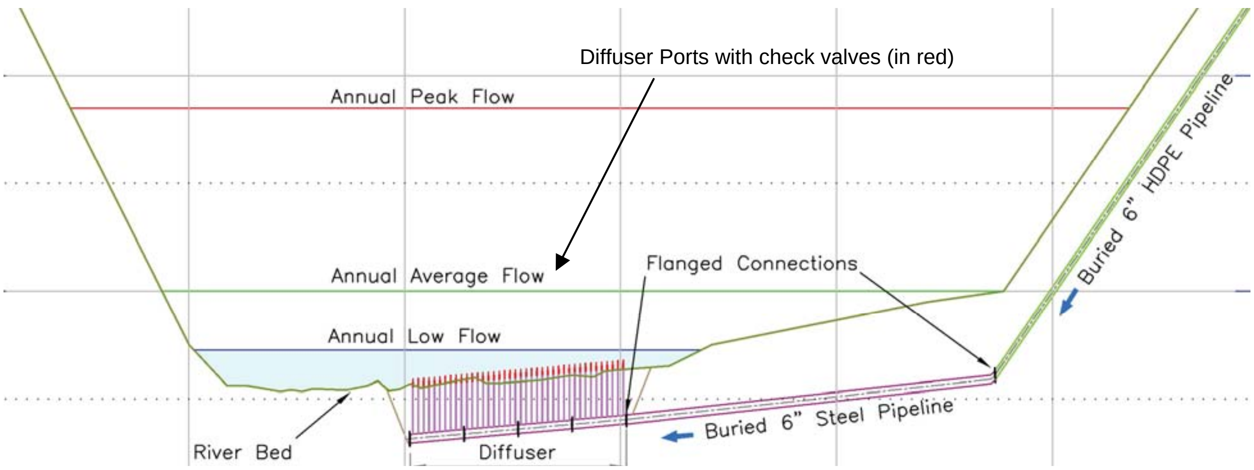
References

- Hydrology Handbook (on Google books), Second Edition, ASCE Manuals and Reports on Engineering Practice No. 28, ©1996;
- Installation of the Diffuser in the Iskut River for Discharge of Treated Concentrate Water. http://a100.gov.bc.ca/appsdata/epic/documents/p239/1166472672387_d5c68167761c454ab7bfb9547d26c260.pdf; and
- http://www.environmental-engineer.com/lea_projects.html.
- Saskatchewan River Dispersion Modeling – Diffuser Plume Estimate, Technical Memorandum, AMEC, Sumer, Sucra, July 20, 2011.

Conceptual Drawing / Process Flow



Cross Sectional View of SKR and Diffuser System



3.1.3 Option C: Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR

General Description

- The intake of SKR water followed by mixing with Mannville Formation groundwater immediately prior to discharge back into the SKR (i.e. mixing occurs at or near river); and
- The intent of this approach is the management of Mannville Formation groundwater so that near field water quality effects are minimized in the SKR.

Constructability

- Water intake and discharge is well known technology and is simple in terms of construction; and
- The water intake and discharge points will be in the SKR and will be required to meet DFO design guidelines, which will likely involve a standpipe in bank gravel (if available) with suitable screening of sediment and engineered limits of intake velocity.

Ease of Operation

- Straight forward operation once mixing facility is built;
- Requires periodic maintenance and inspection; and
- Probable requirement for standby pump(s) and generator supply if electric pumps are utilized.

Potential for Malfunction/Issues During Operation

- Potential clogging and obstruction of intake and discharge piping and at mixing facility.

Impact of Approach on Mine Operations

- Capital and operational expenditures will be required for mixing facility.

Environmental Impact of Approach

- Water withdrawal from the SKR would be required;
- Water quality of discharge water could affect ecosystems downstream;
- Navigability of the river could be affected by the intake pipe; and
- Decrease in aesthetics of the river bank because of visibility of the intake and discharge structures.

Regulatory Approval

- DFO, SMOE and others may need to approve water withdrawal from the SKR and discharge of Mannville Formation groundwater to SKE; a high volume of SKR water intake poses risk to approval; and

- Intake configuration may be problematic.

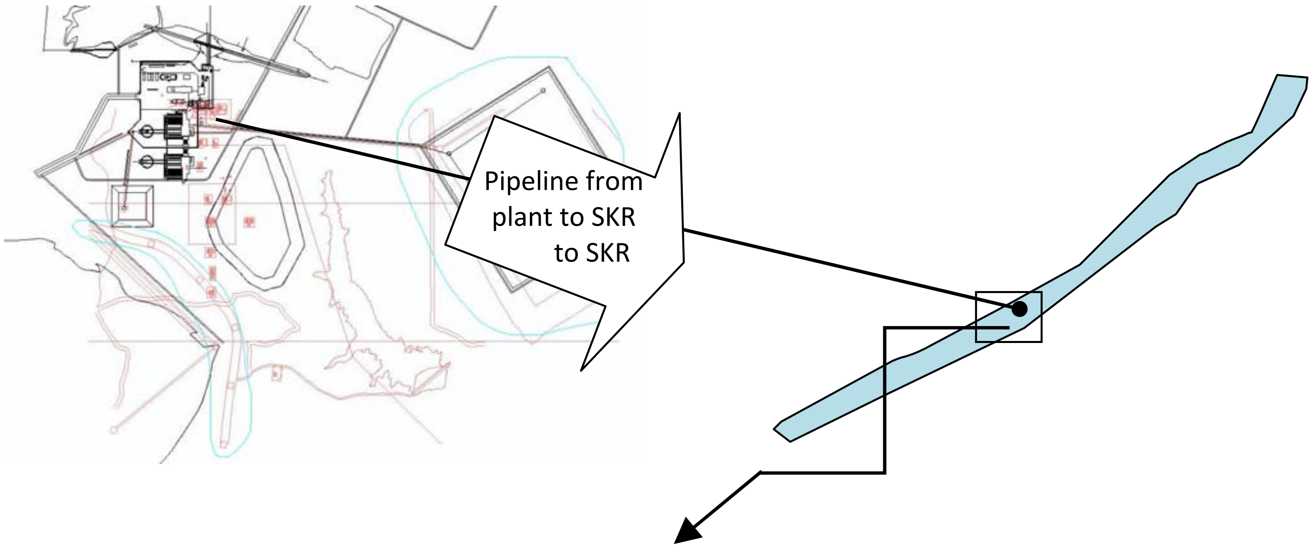
Public Approval

- Downstream or far field environmental impacts seen or perceived will lead to heightened awareness;
- Both withdrawal from and discharge of water to the SKR are likely to raise public concerns; and
- Engineered structure near the SKR will heighten visibility and decrease aesthetic/wilderness appeal for river recreationists/users.

Need for Further Study

- Environmental assessment is required to fully understand potential impacts near and far field and eventual control and monitoring requirements; and
- Engineering design of the intake to manage water quality and modelling of the discharge water quality required.

Conceptual Drawing / Process Flow



Examples of intake and mixing near a river, generally low tech

3.1.4 Option D: Orion North/South, Mannville H_2O injected into infiltration gallery

General Description

- The construction of an infiltration gallery to inject Mannville Formation groundwater into the shallow subsurface in a diffuse manner over the paleochannel such that the downward natural gradient of the groundwater naturally recharges the Mannville Formation, over time.

Constructability

- Straight forward construction with known technology.
- The siting of the infiltration gallery has not yet been identified; a suitable location with good soil hydraulic conductivity and groundwater elevations is required.

Ease of Operation

- Requires periodic inspection and maintenance of injection pumps; additional energy and maintenance costs to run injection pumps.

Potential for Malfunction/Issues During Operation

- Injector ports are very susceptible to clogging and obstruction; Pretreatment of influent is often required; and
- Potential malfunctioning of pumps.

Impact of Approach on Mine Operations

- Additional capital and operational expenditures will be required for siting and construction of gallery.

Environmental Impact of Approach

- Uncertainty as to fate of Mannville Formation groundwater in the paleo-channel; water may just resurface, resulting in water quality impacts to the shallow flow system and SKR.

Regulatory Approval

- Use of this option will require demonstration that the option is feasible, and a description of the potential environmental effects will likely require transport modelling of the parameters of concern.

Public Approval

- Construction of gallery in the middle of FalC could lead to increased public concern; and

- Deep groundwater released to the surface terrestrial environment could raise public concern.

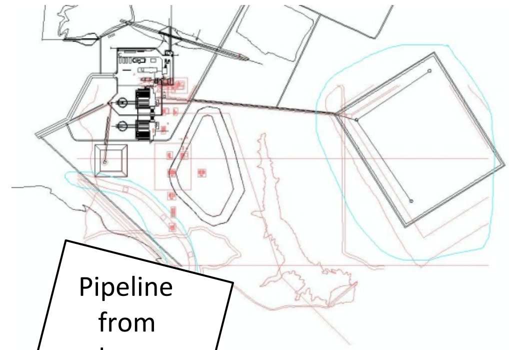
Need for Further Study

- Detailed GW modelling; and
- Transport modelling of parameters of concern.

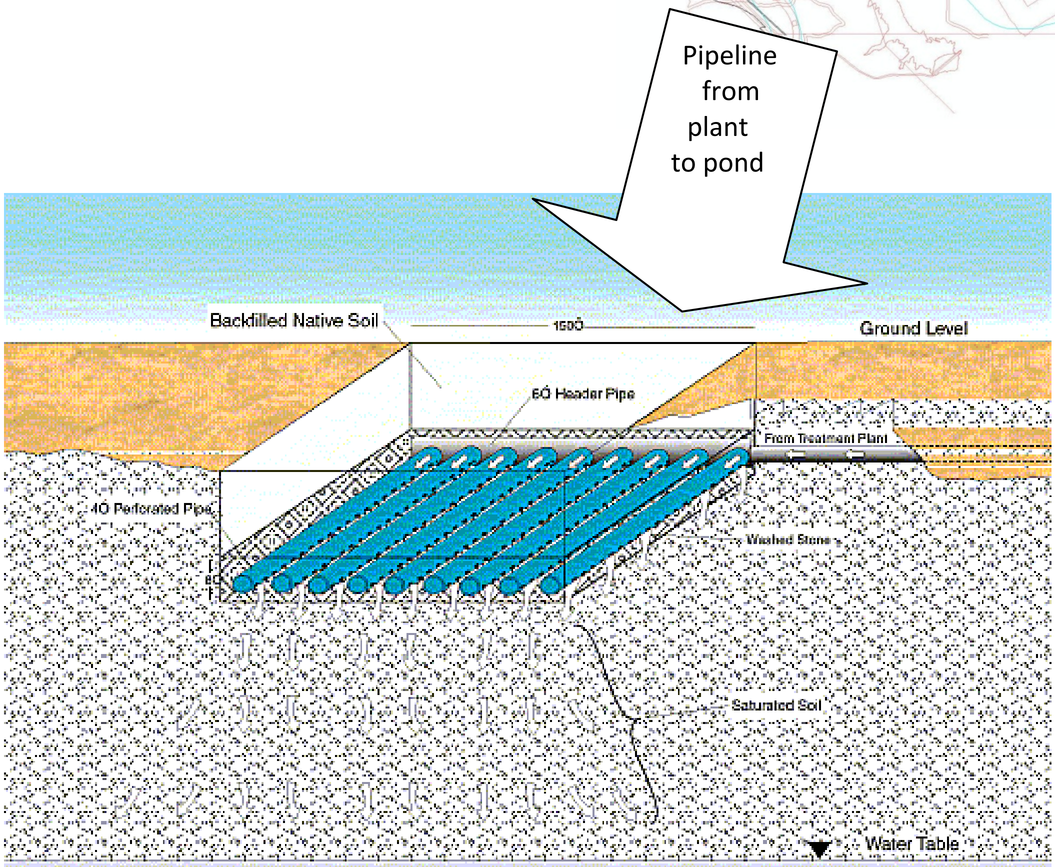
References

- http://www.verdexchange.org/node/278;
- http://www.pioneer-inc.biz/LSR_Preserve.htm; and
- http://www.mmr.org/cleanup/plumes/lf1/images/Lf1trnch.gif.

Conceptual Drawing / Process Flow



Conceptual drawing of infiltration gallery



Examples of infiltration gallery installations

3.1.5 Option E: Exfiltration/evaporation of Mannville Formation groundwater with use of pond

General Description

- The construction of an exfiltration/evaporation pond for Mannville Formation groundwater; and
- The intent of this approach is to allow for evaporation of Mannville Formation groundwater in an unlined pond while also allowing for exfiltration of Mannville Formation groundwater through the pond bottom at an engineered rate, potentially allowing for natural filtration.

Constructability

- Straight forward construction with known technology.

Ease of Operation

- Will require minimal inspection and maintenance once constructed; and
- If the pond is gravity fed, periodic maintenance of pumping equipment will not be required.

Potential for Malfunction/Issues during Operation

- Potential for release of Mannville Formation groundwater from over-topping;
- Potential for leakage/seepage long term;
- Evaporation is almost exclusively limited to unfrozen conditions.; and
- Wetter than usual summers could mean target evaporation volumes would not be reached.

Impact of Approach on Mine Operations

- Additional capital and operational expenditures will be required for siting, construction, and operation of pond.

Environmental Impact of Approach

- Potential water quality impacts to shallow flow system and surface flows and water bodies from seepage.

Regulatory Approval

- Feasibility and robustness of approach would need to be demonstrated to handle natural variability (i.e., longer winters or wetter summers).

Public Approval

- Construction of pond will lead to increased project footprint and could lead to increased public concern; and

- Deep groundwater released to the surface terrestrial environment could raise public concern

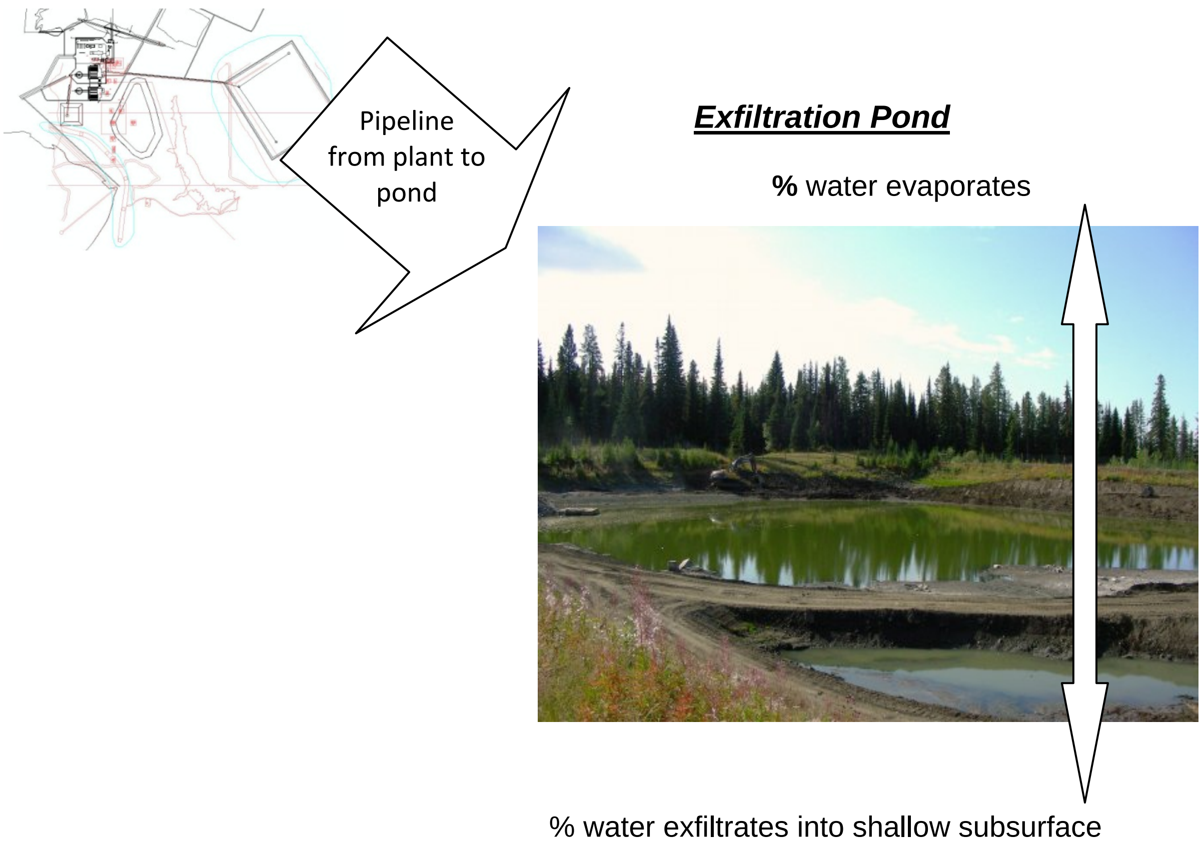
Need for Further Study

- Detailed design; and
- Impact assessment.

References

- http://savesilverstarpark.org/Sewage-Treatment-Plant/248/.

Conceptual Drawing / Process Flow



3.1.6 Option F: Irrigate Fort a la Corne Forest with Mannville Formation groundwater

General Description

- Setting up a spray irrigation system for forest irrigation.

Constructability

- Known technology but typically with sewage effluent; and
- Construction of required infrastructure in the FalC may require clearing.

Ease of Operation

- Water volumes applied to any given area would require careful management according to water quality, soil characteristics and shallow geology;
- Sprinklers would need to be moved on a regular cycle to prevent impacts to soil from saturation and erosion depending on water volumes.
- Periodic maintenance and inspection of spray equipment, pumps and lines.

Potential for Malfunction / Issues During Operation

- Potential for saturation and over-watering; and
- Potential malfunction or breakage of spray equipment, pumps and lines.

Impact of Approach on Mine Operations

- Capital and operational expenditures will be required for construction and siting; and
- Also ongoing operational costs when spray system needs to be moved or modified.

Environmental Impact of Approach

- Potential water quality impacts to shallow flow system and surface flows and water bodies in the event of over watering; and
- Potential effects on soil quality, although coarse textured soils are less susceptible to salinization.

Regulatory Approval

- A large scale irrigation scheme may require a separate, robust assessment on its' own and approval timelines may be impacted.

Public Approval

- Installation of a sprinkler system in the forest will lead to increased public awareness and potential for loss of use of part of the forest where spraying occurs; and
- Perception of converting the forest into managed tree farming may create opposition.

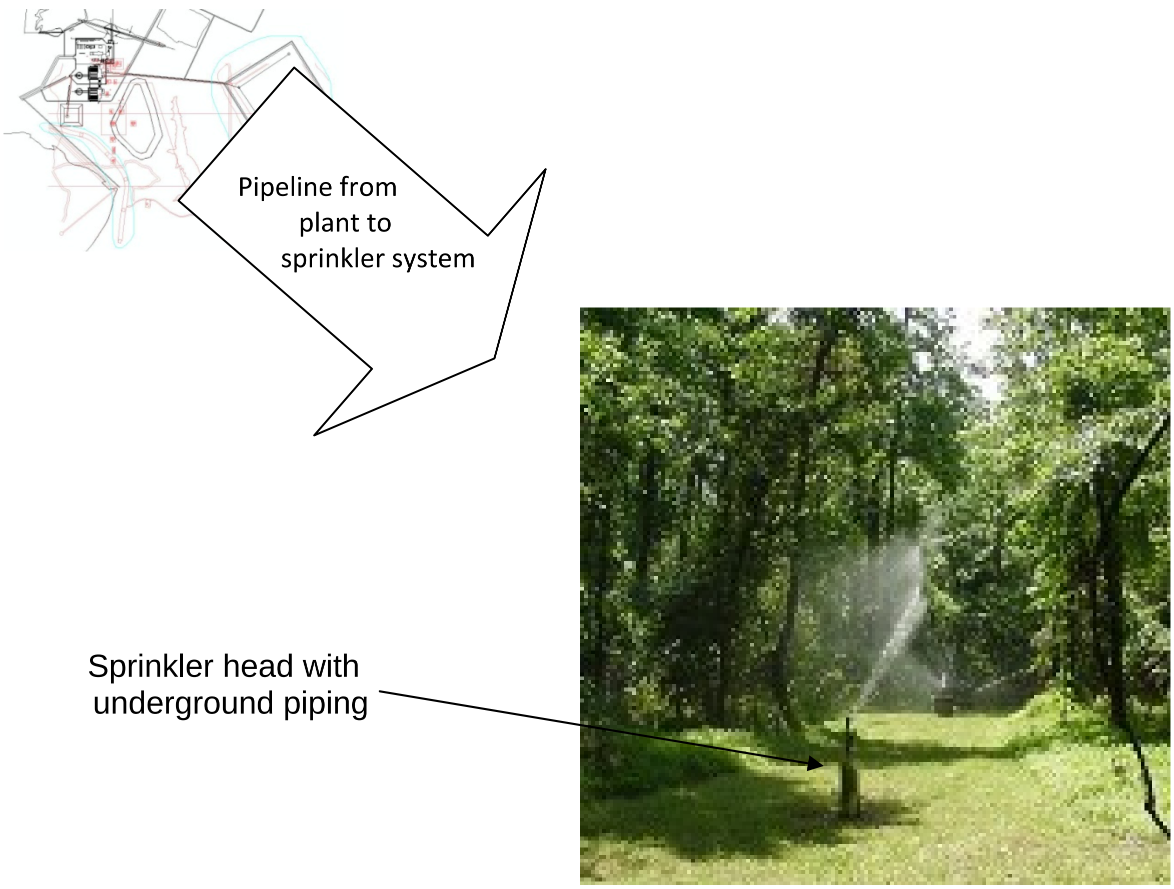
Need for Further Study

- Detailed design; and
- Impact assessment (and collection of additional baseline date) to soils from excess irrigation and potential for migration into and through the shallow groundwater aquifer.

References

- http://www.wakegov.com/water/wastewater/assistance/npdes.htm.

Conceptual Drawing / Process Flow



3.1.7 Option G: Deep well injection of Mannville Formation groundwater

General Description

- Injection of Mannville Formation groundwater into a well with an injection zone that contains water with water chemistry similar to that of the Mannville Formation groundwater; and
- Often termed "deep" as water quality typically degrades with depth; suitable water quality for injection is often on the order of 300 m or deeper.

Constructability

- Known technology with straightforward construction in other areas of the Province. Construction in the FalC to an appropriate depth is unknown;
- Highly regulated; will be required to adhere to strict construction and testing protocol; and
- If a suitable geological formation can be located in the FalC, minimal disturbance would be required.

Ease of Operation

- Straight forward operation; will require management of injection pressures and injectate water quality;
- Will require construction of monitor wells to safeguard against upwelling and monitor water quality in injection zone; and
- Probable requirement for standby pump(s) and generator supply.

Potential for Malfunction / Issues During Operation

- Potential malfunction or breakage of pumps and lines;
- Potential clogging as evidenced by increasing injection pressures and requiring rehabilitation;
- Potential for upwelling/migration of poor quality water; and
- Potential for surface spills and/or breakage in casing resulting in releases to environment.

Impact of Approach on Mine Operations

- Additional capital and operational expenditures will be required for construction, siting and testing; and
- Also ongoing operational costs for injection, monitoring and maintenance.

Environmental Impact of Approach

- Potential water quality impacts to overlying aquifers.

Regulatory Approval

- Injection facilities have been permitted for other operations in the Province.

Public Approval

- Potential for public to question "out of site-out of mind" management method and long term ramifications.

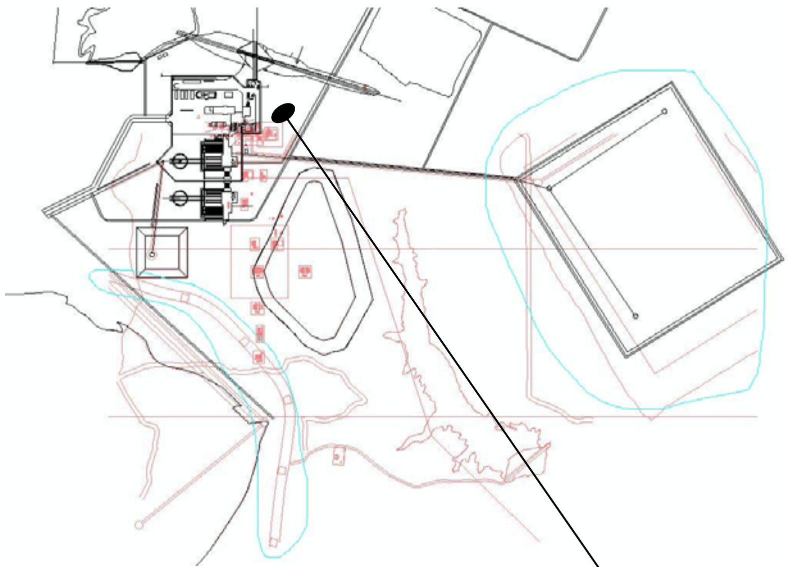
Need for Further Study

- Requires identification of a suitable geologic formation for injection. Current data suggests that no suitable formation exists, however further pilot testing in the form of drilling, packer testing and hydrogeological analysis may be required.

References

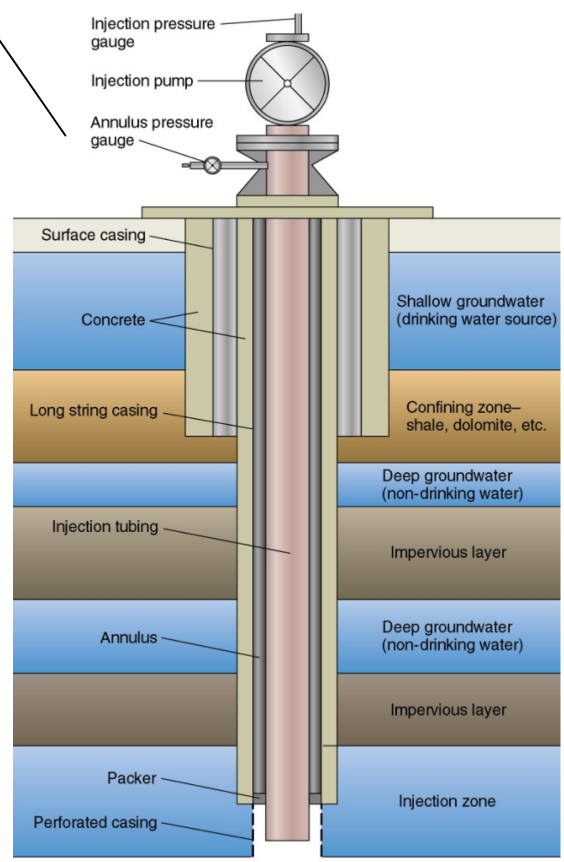
- http://teacher2.smithtown.k12.ny.us/sgessler/toxic%20waste.htm; and
- http://www.waterandwastewater.com/blog/archives/wastewater/.

Conceptual Drawing / Process Flow



Typical injection well wellhead

Injection well located at plant site



3.1.8 Option H: Reverse osmosis treatment

General Description

- Use of Reverse Osmosis (RO) water treatment technology to create 'clean water' for release to the environment and concentration of parameters into 'brine';
- RO technology utilizes selective membrane filtration that traps larger molecules in the solute while pure solute is allowed, under pressure, to pass to the other side of the membrane where it is collected; and
- Most of the treated volume is high quality water, while a portion of the treated water (in which ions and dissolved metals are concentrated) becomes very poor quality water. The treated volume could be discharged to the environment, while the concentrate would require further treatment and/or disposal off site, likely transported by road.

- Evaporation of the water in the concentrate leaving a solid that would be then landfilled is another option in place of trucking off site.

Constructability

- RO and river water discharge is known technology with straightforward construction;
- Trucking of sludge off site is the most straightforward management option; and

- Potentially waste water treatment facilities within the region would handle disposal of solute (with associated approvals). However, the salts would still be discharged into the SKR from the waste water treatment facilities. Surcharges would also apply based on volume and water quality of the concentrate.

- Evaporation of the water in the concentrate is known technology with straightforward construction, but would require additional footprint.

Ease of Operation

- RO requires regular monitoring to ensure proper functioning and periodic maintenance to clean RO membranes; and
- Transportation would likely involve contracted trucking company and the handling of approximately 36,000 m^3/day of concentrate. This volume is likely not feasible for off-site transport.

- The concentrate would be evaporated to yield a sludge / solid that would require solidification and landfilling. This has the potential to reduce the concentrate volume by up to 90%, leading to off site disposal of approximately 3,600 m^3/day, which would still be excessive.

- Evaporation technology is expensive and requires fuel consumption to remove the water. Rough estimates of additional operating costs due to evaporation alone range from between $9.6 to $19.3 million per year to operate.

Potential for Malfunction/Issues During Operation

- Potential clogging of RO membranes reducing efficiency; and
- Potential malfunction or breakage of RO membranes and pumps contaminating pure solute.
- The evaporator plates require frequent cleaning to maintain adequate operational efficiency. Pretreatment of the concentrate may be required to reduce fouling in the evaporator which is a significant factor in operational efficiency. Further solidification of the sludge may be required to meet minimum landfill requirements.

Impact of Approach on Mine Operations

- Additional capital and operational expenditures will be required for water treatment equipment, waste water storage and construction;
- RO membranes are sensitive and prone to malfunction. Standby unit will be required to avoid operational delays; and
- Ongoing operational costs for RO monitoring and maintenance.
- Evaporation technology consumes relatively large amounts of energy and is typically only feasible when the dried sludge can be sold.

Environmental Impact of Approach

- Additional vehicle movement and energy consumption will increase greenhouse gas related emissions and the possibility of wildlife contact/impact.
- A landfill approval and permit would be required for the solidified brine residue.

Regulatory Approval

- RO treatment facilities and evaporators have been approved for other projects.

Public Approval

- Addition of a landfill may increase public concern.

Need for Further Study

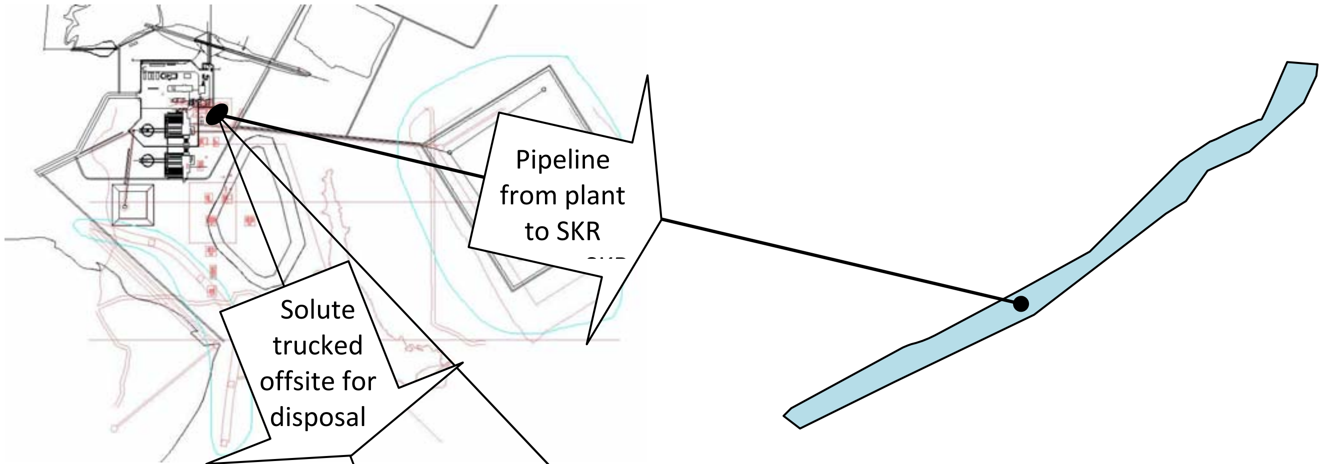
- Need to complete an engineering study on what type and size of evaporator is required and the associated energy consumption.

- Need to identify suitable location and prepare designs for a suitable landfill for the dried sludge.

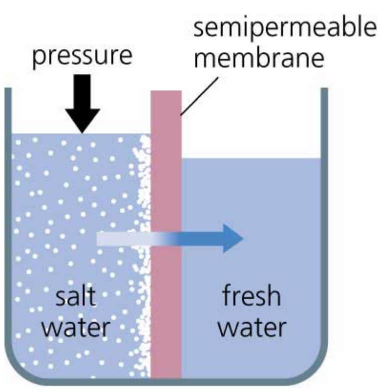
References

- http://www.ecosafeusa.com/FDAReverseOsmosis.pdf
- Handbook of Environmental Engineering, Volume 6: Biosolids Treatment Processes, Edited by: L. K. Wang et al. © The Humana Press Inc., Totowa, NJ
- http://www.evaporator.com/

- Conceptual Drawing / Process Flow



Visual conception of reverse osmosis technology



Typical Reverse Osmosis equipment

3.1.9 Option I: Reverse osmosis treatment with deep well injection of solute

General Description

- Use of Reverse Osmosis (RO) water treatment technology to treat the Mannville water yielding ‘clean water’, approximately 70% of the original volume and concentrate or brine consisting of the remaining 30%;
- RO technology utilizes selective membrane filtration that traps larger molecules in the solute while pure solute is allowed, under pressure, to pass to the other side of the membrane where it is collected;
- Injection of concentrate into a well with an injection zone with suitable hydrogeological parameters. It is likely that treatment of all Mannville Formation groundwater is not required. In this case approximately half of the Mannville Formation groundwater would be treated and the ‘clean water’ would be used to blend the remaining half of the groundwater; and
- Often termed “deep” as water quality typically degrades with depth; suitable water quality for injection is often on the order of 300 m or deeper.

Constructability

- RO is known technology with straightforward construction and deep well injection is used in other parts of the Province; and
- Construction of injection wells would require adaptation to local conditions and identification of a suitable injection zone capable of accepting the required volumes.

Potential for Malfunction / Issues During Operation

- Potential clogging of RO membranes reducing efficiency;
- Potential malfunction or breakage of RO membranes and pumps contaminating pure solute;
- Potential malfunction or breakage of injection pumps and lines;
- Potential clogging of injection lines as evidenced by increasing injection pressures and requiring rehabilitation;
- Potential for upwelling/migration of poor quality water; and
- Potential for surface spills and/or breakage in casing resulting in releases to environment.

Impact of Approach on Mine Operations

- Additional capital and operational expenditures will be required for water treatment equipment, water storage, construction, siting and testing;
- RO membranes are sensitive and prone to malfunction. Standby unit will be required to avoid operational delays; and

- Also ongoing operational costs for RO monitoring, RO maintenance and injection monitoring and maintenance.

Environmental Impact of Approach

- Potential water quality impacts to overlying aquifers.
- Increased energy consumption and greenhouse gas emissions.

Regulatory Approval

- RO and deep well injection facilities are permitted within the Province.

Public Approval

- Potential for public to question "out of site-out of mind" management method and long term ramifications; and
- Similar operations currently exist in the Province.

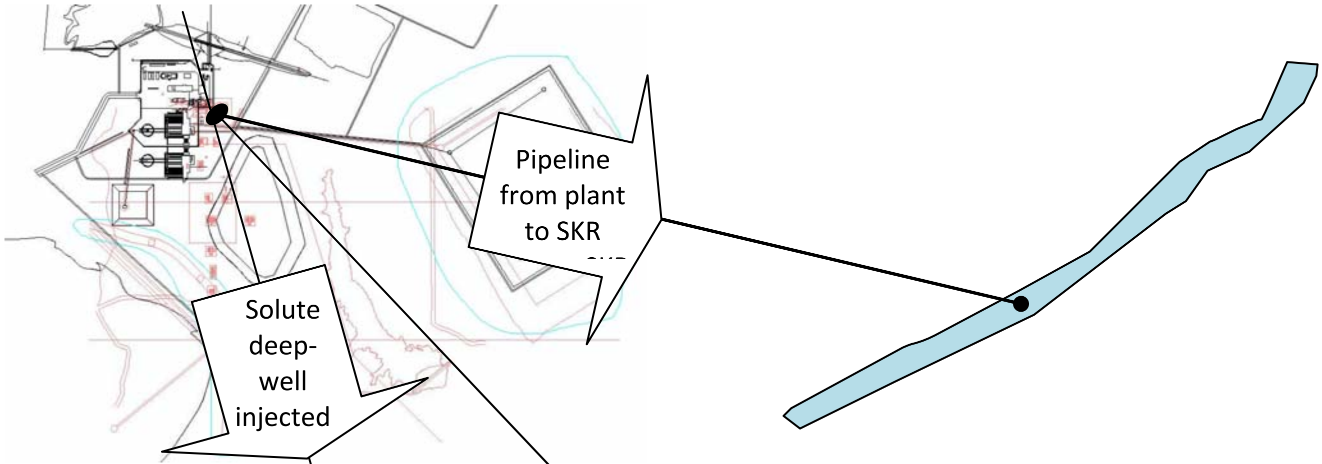
Need for Further Study

- Identification of a suitable geological formation for injection. This may require substantial drilling and modeling, if feasible; and
- Detailed design

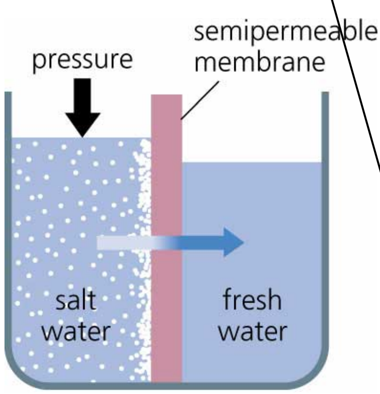
References

- http://teacher2.smithtown.k12.ny.us/sgessler/toxic%20waste.htm; and
- http://www.waterandwastewater.com/blog/archives/wastewater/.

- Conceptual Drawing / Process Flow



Visual conception of reverse osmosis technology



Typical Reverse Osmosis equipment

Injection well located at plant site

4.0 PRE-SCREENING ASSESSMENT

The pre-screening assessment is the first step in focusing the assessment on options that are not considered feasible or contain a “fatal flaw”. This pre-screening assessment includes a qualitative, high-level assessment based on the following:

- Sufficient capacity to manage expected volumes;
- Practical distance from mine / mill;
- Availability of land for water management option;
- Technically feasible; and
- Project economic viability.

4.1 PRE-SCREENING LEVEL ASSESSMENT RATIONALE

An overview of the pre-screening level assessment is presented in Table 4-1.

Table 4-1: Pre-Screening Level Assessment

Account	Pre-Screening Criteria	Rationale	A - Spray Evaporation	B - Diffuser System	C - Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR	D - Mannville Water injected into infiltration gallery	E - Exfiltration/evaporation of Mannville Formation groundwater with use of pond	F - Irrigate Fort a la Corne Forest with Mannville Formation groundwater	G - Deep well injection of Mannville Formation groundwater	H - Reverse osmosis treatment	I - Reve osmos treament deep w injection solut
Environmental Issues	Does the management option have the potential to lead to adverse residual potential effects on the environment?	Water management should mitigate or reduce potential effects of the discharge on the environment.	Yes - residual accumulation of salts in the soil.	No	No	Unknown - if Mannville water is accomodated by the paleochannel, no further effects are expected, however, water quality may be affected in ravines if sufficient volume reaches ravines	No	Yes - changes in vegetation, plant growth, and wildlife habitat are expected on irrigated portions of the FalC; possible accumulation of salts on irrigated soils.	No	Yes- creation and disposal of concentrate may impact the environment	No
	Does the option require large amounts of energy?	Options to reduce energy consumption and release of carbon dioxide are preferred	Yes - Additional pumping required	No	No	Yes - Additional pumping required	No	Yes - Additional pumping required	Yes - Additional pumping for injector wells required	Yes - Reverse osmosis is an energy intensive operation; removal of concentrate from site requires fuel	Yes - Re osmosis i energ intensi operatio Additio pumping injector v require
	Area disturbed - Does the option require significant additional area ?	Increases to the Project footprint would increase potential environmental effects.	No	No	No	No	Yes - Pond required to store water	Yes- a very large network of infrastructure would be required for water distribution and delivery	No	No - Concentrate	No
Technical Issues	Constructability – Based on existing information, is there a risk that design and construction is not possible or unachievable?	Well known design and construction reduces operational risks. Only options that are Likely achievable should be considered.	Yes- scale of operations would require a massive system	No	No	Yes- connection between the surficial aquifer and the Mannville through the paleochannel and the corresponding flows may not accomodate the required volume	No- design would need to consider reduced evaporation during winter months	No	Yes – the availability of a suitable injection zone is unknown but unlikely based on extensive local drilling	No	Yes – t availability suitab injection is unknow unlikely b on exten local dril

Account	Pre-Screening Criteria	Rationale	A - Spray Evaporation	B - Diffuser System	C - Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR	D - Mannville Water injected into infiltration gallery	E - Exfiltration/evaporation of Mannville Formation groundwater with use of pond	F - Irrigate Fort a la Corne Forest with Mannville Formation groundwater	G - Deep well injection of Mannville Formation groundwater	H - Reverse osmosis treatment	I - Reve osmos treament deep w injection solut
	Potential for Malfunction/Issues During Operation - Does the option introduce technology that requires field trials or has anticipated operational risks?	Low risk technology increases control of potential environmental impacts and eliminates operational interruption.	Yes – wet or humid weather will reduce target evaporation volumes.	No	No	Yes - infiltration gallery highly susceptible to clogging and obstruction of injector ports.	No – however capacity would require careful monitoring	Yes – management of a complex distribution network increases the possibility of over-watering and saturation of terrain and other malfunctions.	Yes- field trials needed to identify suitable geology for injection, if it exists	No	Yes- fi trials nee to ident suitabl geology injection, exists
	Impact of Approach on Mine Operations - Does the option significantly disrupt mine operations?	Disruption of mine operations leads to reduced productivity affecting project economics.	No	No	No	No	No	No	No	No	No
Project Economic Issues	Capital Expenditure Requirements - Does the option significantly increase capital expenditure requirements?	Options that significantly alter project economics are not financially viable.	No	No	No	Yes - infiltration gallery installation is costly	Yes- construction of the pond requires significant earth work	Yes- irrigation equipment is costly	Yes - significant capital is required to construct the injection wells	Yes- Significant capital is required to build the RO plant	Yes - Significa capital required build the plant ar construct injection w
	Operational Expenditure Requirements - Does the option significantly increase operational expenditure requirements?	Options that significantly alter project economics are not financially viable.	No	No	No	No	No	No	Yes - high operational costs are expected to inject.	Yes- cost of hauling over 30,000 m3 of concentrate daily are prohibitive, as well as operating costs for the RO plant	Yes - Operatio costs wil high due operatio the RO p and injec wells

Account	Pre-Screening Criteria	Rationale	A - Spray Evaporation	B - Diffuser System	C - Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR	D - Mannville Water injected into infiltration gallery	E - Exfiltration/evaporation of Mannville Formation groundwater with use of pond	F - Irrigate Fort a la Corne Forest with Mannville Formation groundwater	G - Deep well injection of Mannville Formation groundwater	H - Reverse osmosis treatment	I - Reve osmos treament deep w injectio solut
Socio-economic Issues	Public Approval - Does the option present an alternate that stakeholders and the general public will oppose?	Options with which stakeholders and/or the general public have concern will increase opposition to the proposed solution.	Unknown - general public may have concern to potential changes to air and soil.	No-significant public concern was not expressed during engagement for the EIS (see Chapter 4)	No	Unknown	Unknown	Likley opposition to converting the FalC to a managed wood lot	No	Yes - may be opposition to an increase in truck traffic required for concentrate disposal; option also creates potential significant off site impacts due to concentrate disposal.	No
Potential candidate for Water Management			No	Yes	Yes	No	No	No	No	No	Yes
Summary of reasons for exclusion			Evaporation is reduced during winter months and will lead to additional snow accumulation and excess spring runoff. Volume of water to be managed likely makes this option unfeasible.	Not excluded at this stage	Not excluded at this stage	The water is unlikely to flow entirely into the Mannville formation through the paleochannel. Surface volumes may affect water quality in ravines and creeks. Massive infrastructure required	Large footprint required and uncertainties regarding capacity.	Summer evapotranspiration only. Water would need to be stored over the winter, or ice will form on the surface, build during the winter and thaw in the spring leading to super saturated soil. Massive infrastructure required. High operational complexity. Potential effects on plant growth and soil structure. Conversion of the FalC to a woodlot.	This alternative would make the mining project uneconomic due to the high cost of development and operation of multiple wells necessitated by the volume of water from pit-dewatering and makes this unfeasible. Removes a significant volume of water from the hydrological cycle.	The costs, increase in truck traffic and off site disposal are not feasible.	Not exclu at this st

The final assessment inclusive of this overview and a determination of ability of each option to fulfil minimum project criteria is provided below.

Option A: Spray Evaporation

Spray evaporation (option A) can be constructed in a manner to have sufficient capacity to manage expected volumes. However, this option requires the use of significant areas of land that would likely be rendered unusable for any other purpose making this option unfavourable due to low availability of suitable land at site. Public concern about the effects to soils and increased moisture in the selected areas may increase. Weather may also hinder the technical feasibility at various points of the year requiring large storage capacities as a contingency. This option is not likely to negatively affect project economic viability.

This option has not been included in further evaluations as it is not likely that a suitable area of land will be available, and uncertainties regarding the ability of this option to be scaled up enough to be feasible,. Furthermore, evaporation will be severely reduced during winter months and will lead to additional snow accumulation and excess spring runoff containing high TDS and sodium concentrations further reducing evaporation. Plant growth and soil structure will also be negatively affected.

Option B: Diffuser System

A diffuser system (option B) can be constructed with enough capacity to manage the expected volumes and would be locally situated at the SKR, a reasonable distance from the mine. There is enough land available riverside to construct a diffuser system and the diffuser system is also technically feasible to release the Mannville Formation water to the river at a predetermined rate to minimize environmental effects. This option is not likely to negatively affect project economic viability.

This option has been included in further evaluations.

Option C: Mixing SKR and Mannville Formation groundwater immediately before discharge back into SKR

The mixing of the Mannville Formation water with SKR water immediately prior to discharge to the SKR has enough capacity to manage expected volumes and would be located directly adjacent to the river, a short distance from the plant site. This option is also technically feasible as SKR water would be used in sufficient volumes to minimize environmental effects. This option is not likely to negatively affect project economic viability and water withdrawal / sequestration will not alter river flow dynamics.

This option has been included in further evaluations.

Option D: Orion North / South, Mannville H2O injected into infiltration gallery

An infiltration gallery (option E) can be constructed with enough capacity to manage the expected volumes and would be situated north of the mine site over the paleochannel to take advantage of the natural downward groundwater gradient to move water back into the Mannville formation. A large area and surface disturbance would be required. The infiltration gallery would likely incur much higher construction and operations costs than the other options considered.

This option has not been included in further evaluations as it is unlikely that sufficient volumes of water can be managed without risk that water quality in the ravines and surficial groundwater are affected. In addition, recycling of the Mannville water in this fashion is likely to continually increase the volume of water pumped from the pits, creating a positive feedback loop.

Option E: Exfiltration/evaporation of Mannville Formation groundwater with use of pond

The use of an exfiltration / evaporation pond is an effective method with sufficient capacity to manage expected volumes of the Mannville Formation groundwater. This option requires a very large parcel of land and corresponding terrestrial disturbance leading to additional environmental impact. This option is likely to moderately negatively affect project economic viability.

This option has not been included in further evaluations as it is not likely that impacts associated with disturbance of large additional areas of land will be justified and it is anticipated that project stakeholders will view this option negatively. Also, there is reasonable potential for the pond to overfill in the winter and spring months due to reduced evaporation and freezing thus rendering this option ineffective in controlling the environmental impact.

Option F: Irrigate Fort a la Corne Forest with Mannville Formation groundwater

The Irrigation of Fort a la Corne Forest (option G) requires the use of significant areas of land, a conversion of this area to a managed woodlot, and further potential effects on land use. Increased moisture in the selected irrigation area may also lead to additional environmental changes. This option is likely to moderately negatively affect project economic viability.

This option has not been included in further evaluations due to the large area required and changes to land use.

Option G: Deep well injection of Mannville Formation groundwater

Deep injection at the project site requires wells into the deeper formations, potentially the Cambrian Deadwood formation. Injecting into the Mannville formation or the Dolomite limestones (which are thought to be hydraulically connected to the Mannville) will be ineffective as the water will recirculate into the dewatering cone of depression. The most likely deep layer potentially present at site is the Cambrian Deadwood formation, at a likely depth of about 1,000 m. It is unknown if this layer is present on site, and if so, what the thickness of the unit would be. The hydraulic charecteristics of this formation are unknown and therefore it is not known if this formation would accept the required volumes. Injection wells in Saskatchewan are typically into the Mannville; therefore, the feasibility and practicality of injection into the Deadwood is unknown. Further, it is possible that an Ordovician sandstone (Winnipeg Formation) may exist at depth but it's mapped thickness is 6 m at approximately 645 m depth based on information from a drill data point 15 km to the east of the site. As such, the thickness may actually be much less than 6 m (TGI Williston Basin Working Group, 2008).

At present, it is unknown but considered extremely unlikely that a suitable location for deep well injection (option H) can be found at the site or at a reasonable distance to the site that can accept up to 120,000 m3 per day. Injection into the Mannville Formation, outside of the cone of depression, would require a pipeline and pumping up to 45 km in distance. Deep well injection is unlikely to be feasible, even if a suitable formation can be found, due to very high feasibility, construction and operational costs.

This option has not been included in further evaluations as it will significantly and negatively affect project economic viability through increased financial capital and operational requirements.

Option H: Reverse Osmosis Treatment

This option, on its own, does not adequately address management of the RO concentrate. Removal of the concentrate from site, and off site treatment by a third party is not feasible due to the high volumes of concentrate produced. Treatment of all the volume of Mannville water would create 30,000 to 40,000 m^3 of concentrate per day which would require evaporation or removal from site. Based on rough estimates, 2 tanker trucks would be required to remove the approximately 30,000 m^3 of solute from the mine site every 3 minutes while the mine is being dewatered if the concentrate is to be trucked off site. This is not feasible. Evaporation is also prohibitively expensive.

This option has not been included in further evaluations as it will significantly and negatively affect project economic viability through increased financial capital and operational requirements.

Option I: Reverse osmosis treatment with deep well injection of solute

As explained in Option G it is unlikely that a suitable location for deep well injection can be located at the site or at a reasonable distance to the site. However, using injection for the concentrate only decreases the volume, and increases the possibility that a geological formation can be used. Partial treatment of the Mannville, in combination with discharge to the SKR may also improve the economics of this option. However, there is high likelihood that these options will significantly and negatively impact project economics. Additional information about the feasibility (or lack of feasibility) of this option was requested by technical reviewers.

As such, this option has been included in further evaluations.

5.0 ALTERNATIVE CHARACTERIZATION

Options B (diffuser system), C (mixing with SKR immediately prior to discharge) and I (Reverse osmosis with deep well injection of concentrate) have been included for further characterization. Categories for alternative characterization have been defined as follows:

- *Environmental Characterization*: includes an assessment of the impact on SKR water quality and aquatic biota, both near and far-field effects, the effect of the water discharge quantity, terrestrial effects, resource use and availability and the generation of noise;
- *Technical Characterization*: includes an assessment of installation requirements, detailed design considerations, feasibility of construction and installation, regulatory requirements and the impact on river navigability;
- *Project Economic Characterization*: includes an assessment of the financial implications to the project and of detailed design; and
- *Socio-economic Characterization*: includes an assessment of each option on potable water quantity and quality, consumption of fish that may be impacted by water quality effects, land and water uses such as boating and fishing, cultural or archaeological values; local employment or contracting opportunities; aesthetic values such as visibility / noise.

5.1 OPTION B: DIFFUSER SYSTEM

5.1.1 Environmental Characterization

Water Quality – Effects on Aquatic Biota

A draft impact assessment (AMEC, 2010) of use of a multiport diffuser located in the SKR was completed for the December 2010 EIS (Section 6.2.7.5). The report indicated the chloride concentration in the effluent drops to between 18 and 40 mg/L above a SKR background concentration of 10 mg/L within 40 m of discharge from the multi-port diffuser. Further dispersion modelling (AMEC 2011) completed following the submission of the December 2010 EIS indicated that chloride concentrations in the river are reduced to 21 to 26 mg/L above background at 40 m downstream of the source. Both predicted concentrations are well below CCME's CWQG for the Protection of Aquatic Life guidelines.

Water Discharge Quantity

Mannville water produced from pit dewatering averages about 100,000 m^3/day (or 1.16 m^3/s) and peaks at 120,000 m^3/day (or 1.39 m^3/s). The Water Survey of Canada recorded maximum and minimum daily discharges of the Saskatchewan River at the nearest hydrometric station to the project, which is located on the Saskatchewan River below Tobin Lake (Station No. 05KD003). The period of data analysis commenced in January 1962 and concluded in December 2010. Over this time period, minimum discharge during the lowest average per-month flow period (November) has averaged approximately 128 m^3/s (7Q10 low flow), and maximum discharge during the highest average per-month flow period (July) has averaged approximately 702 m^3/s (http://www.wsc.ec.gc.ca/applications/H2O/report-eng.cfm?station=05KD003&report=monthly&year=2010). The proposed discharge rate represents a 0.41 to 0.49 % increase in river flow rate during the low flow period and 0.17 to 0.20 % increase during the high flow period. Furthermore, the proposed discharge rate is below the daily natural variability in flow rate in the SKR in 2010 (http://www.wsc.ec.gc.ca/applications/H2O/report-eng.cfm?station=05KD003&report=daily&year=2010). Therefore, the proposed discharge rate is unlikely to have an adverse impact on SKR flow.

Terrestrial effects

The diffuser system would require a pipeline to the River, a small retention pond to provide sufficient pressure head for consistent operation. The overall terrestrial footprint is small.

Resource use and availability

The diffuser option uses little additional energy, as the water will be pumped directly from the Mannville formation to the diffuser, and the diffuser itself is a passive, gravity driven process. Water placed into the River is available for environmental processes and continues to function in the hydrological cycle.

Noise

Noise will be generated during construction. However, noise will not be generated by the diffuser once it is in operation.

5.1.2 Technical Characterization

Water Storage / Retention Requirements

Diffuser systems are designed and installed in a manner that does not require water storage. However, retention in some form is required to maintain a constant positive pressure on the diffuser heads in relation to the negative pressure exerted by the hydrodynamic force of the river. The amount of retention will be included into the engineering design following an assessment of the hydrodynamic pressure of the river.

Dilution Requirements

Diffuser systems are engineered, designed and installed in a manner that does not require dilution. Diffusers discharge effluent across a wide swath of the river through multiple ports. Dilution will occur unaided as effluent is released and mixes with SKR water. The appropriate dilution factor will be maintained by strictly controlling the release rate of the effluent.

Installation Requirements

The primary method of installation for diffusers is to install it in a trench cut into the stream bed and backfilled with gravel. They are then armoured with covering stone appropriate sized that eliminates their washing away due to the force of the rivers flow. This technique requires work in the river bed and can be disruptive to the aquatic environment during the construction phase.

An alternate installation method involves the stabilization of the diffuser pipe on the surface on the river bed. This method is less disruptive to the aquatic environment during the construction period. However, navigability may be disrupted during low flow periods as the pipe extends approximately 350 mm from the bottom of the river bed. Also, the area in the riverbed underlying the diffuser pipe is a mat that is constructed with concrete and can be considered to pose a larger impact on potential fish habitat than just the protrusion of the diffuser ports. As such the buried diffuser pipe is the preferred installation method and would enter the river channel from the northern shore of the river.

All construction will be completed during the low flow period to allow easier access to the river. However, further study including river levels and bank stability will be required to establish the best period to construct the in-river portion of the diffuser system and installation location to support heavy equipment and closeness to the point of generation.

Detailed Design Considerations

Detailed design would need to consider river characteristics, design and contingency volumes, port spacing and modeling. These considerations are known, as diffuser design methodology is well understood from design and installation of many installations for a number of specific applications.

Feasibility of Construction and Installation

Construction and installation is known to be possible. A similar installation was constructed on the North Saskatchewan River for a pulp mill effluent. No technical issues are expected to reduce or eliminate the feasibility of the diffuser.

Regulatory

Water quality near the diffuser would be changed as a result of Mannville water discharge. The magnitude of the change depends upon the distance from the diffuser, with larger short term changes occurring near the diffuser. Based on modeling AMEC (2011) showed that near field effects would be limited to 40 m from the discharge.

Acute toxicity testing was conducted on Mannville formation water obtained from the 2010 prototype dewatering well. This testing showed no acute effects (i.e., greater than 90% survival) on rainbow trout and *Daphnia* Manga. Therefore, no near field effects are expected on aquatic biota.

SMOE has enacted the Mineral Industry Environmental Protection Regulations, 1996 (Chapter E-10.2 Reg 7) pursuant to the *Environmental Management and Protection Act* (Chapter E-10.22) which provides a list of general criteria of water discharges from the mineral industry. TDS, sodium and chloride are not listed in this regulation. However, SMOE has published Surface Water Quality Objectives for the Protection of Aquatic Life which is based on CCME's Canadian Water Quality Guidelines for the Protection of Aquatic Life. CCME's Canadian Water Quality Guidelines ('CWQG') for the Protection of Aquatic Life lists the maximum short term concentration for chloride as 640 mg/L and the maximum long term concentration as 120 mg/L for the protection of freshwater aquatic environments. CCME's CWQG for the Protection of Aquatic Life does not list a guideline concentration for TDS or sodium.

Federally, the *Fisheries Act* prohibits deposition of 'deleterious substances' into Canadian fisheries waters. As discussed further in Section 6.2.8 Environmental Health in the revised EIS, the Mannville water passes acute toxicity testing, but shows chronic effects on *Ceriodaphnia* at full concentration. Based on historic precedent, discussions held during the development of the Metal Mining Effluent Regulations and supported by the results obtained through the Environmental Effects Monitoring programs, the discharge would be considered non-deleterious and therefore be permitted by the *Fisheries Act.*

Chronic toxicity testing was conducted on Mannville water obtained from the prototype dewatering well. No chronic effects were found on fathead minnow, while 100% mortality was found in 100% concentration Mannville water on *Ceriodaphnia* after 7 days. Since it would not be possible for aquatic organisms to be exposed to 100% concentration Mannville water for more than a few seconds, no chronic or long term effects are expected on aquatic biota in the far field.

The diffuser will be installed in river which will affect the river flow during construction, and require the successful application of a harmful alteration, disruption or destruction of fish habitat (HADD) permit from the Department of Fisheries and Oceans Canada (DFO) prior to construction.

Navigability

SKR navigability will be minimally affected by the diffuser infrastructure during construction and residual effects of the diffuser after construction are not envisioned. During construction a portion of the river may require a coffer dam or similar water retaining structure to install piping and associated infrastructure in dry conditions. Post construction, ample area for vessel navigation is anticipated as the diffuser ports will extend along a pipe 60 m into the SKR at a depth of 3.5 m while the width of the SKR in this area is 260 m.

5.1.3 Project Economic Characterization

Financial Requirements

The diffuser will require minimal capital and operating expenditures. This includes the construction of the diffuser and the installation of all piping to transfer the Mannville water to the discharge area at the river. A reservoir with a small holding capacity will be required to control and moderate the discharge rate and to maintain a positive pressure in relation to the hydrodynamic force of the river.

Detailed Design

Cost overruns are not envisioned as a result of technical considerations related to diffuser design and modeling of the release behaviour of Mannville water due to the various precedent designs and available knowledge concerning diffusers. The diffuser design will result in less design and infrastructure requirements compared to option D and much less as compared to option J.

5.1.4 Socio-economic Characterization

Potable Water Quantity and Quality

No effect on potable water quantity or quality is expected as potable water in adjacent residences is from groundwater sources rather than surface water from the SKR. SKR water quality is not significantly changed 40 m from the discharge point, therefore; communities or residences using SKR water for potable water further downstream should not see a difference in river water quality.

Land and Water Uses

Land uses are primarily outdoor recreation including hunting, gathering, camping, trail use as well as Traditional Land Uses. Activities within the SKR are potentially affected by the construction of the above ground pipeline and on shore facilities.

Water uses include boating and fishing by Aboriginal and non-Aboriginal people. Access to the SKR for boating is not in the vicinity of where the diffuser would be installed and therefore there would not be an effect on boating access to the SKR. However, there would be a localized effect to boat navigability as outlined in the sections above.

Cultural or Archaeological Values

The general locations of the facilities have been screened for heritage resources. Prior to construction, the specific pipeline alignment and any on shore disturbances will be screened via a pre-disturbance heritage resource survey, and facilities would be sited to avoid impacts.

Local Employment and Contracting Opportunities

There are employment and contracting benefits from designing, building and to a lesser extent maintaining / monitoring the diffuser system. Diffusers can be installed by a contractor specializing in coffer dams, pipelines and general water infrastructure. Saskatchewan has a number of these contractors, however it is not known if local (i.e., Prince Albert, Melfort, Nipawin) contractors have these capabilities. It is more likely that these contractors are based in Saskatoon or Regina.

Overall the construction phase of the project is expected to employ an average of 669 workers and nearly half of the $1.9 million construction expenditures (44%) are expected to be within Saskatchewan. A small proportion of these construction employment and expenditure estimates include construction of this water management system.

Aesthetic Values

The location of the diffuser within the SKR would be virtually undetectable, however the pipeline and on shore facilities would be visible.

5.2 GROUNDWATEROPTION C: MIXING SKR AND MANNVILLE FORMATION GROUNDWATER IMMEDIATELY BEFORE DISCHARGE BACK INTO SKR

5.2.1 Environmental Characterization

Water Quality – Effects on Aquatic Biota

Mixing River water with the Mannville groundwater prior to discharge into the Saskatchewan River reduces near field effects compared with Option B. Mixing would be conducted such that the point discharge water quality would be the same as the far-field water quality in Option B. For example, the predicted chloride concentrations in the discharge would be reduced to 21 to 26 mg/L above baseline. These changes in water quality are not expected to affect aquatic biota.

As there are no anticipated near field effects, far field effects are not expected.

Water Discharge Quantity

Changes to flows in the Saskatchewan River are identical to those predicted in Section 5.1.1.

Terrestrial Effects

Impacts to the terrestrial environment are limited to the footprint of the pipeline and the on-shore mixing facility.

Resource use and availability

The mixing option uses some additional energy as compared to Option B, as the water intake will require pumping to ensure an appropriate flow. Water placed into the river is available for environmental processes and continues to function in the hydrological cycle.

Noise

Noise will be generated during construction from the heavy equipment and during the operating phase by the pumping system used for the river water intake. Noise generation will be mitigated through suitable housing.

5.2.2 Technical Characterization

Water Storage / Retention Requirements

The intake and discharge system will require water storage. Presumably, design considerations should account for additional water storage near the intake/discharge area to account for unforeseen issues that could negatively affect or shut down physical processes related to SKR intake, the mixing area and associated infrastructure at the river, and further discharge of effluent back to the SKR.

Dilution Requirements

Water will be diluted during the mixing at the mixing facility near the intake and discharge structures. The appropriate dilution factor will be maintained by strictly controlling the release rate of the effluent.

Installation Requirements

For this option, a river water intake (RWI) including all associated infrastructure would be constructed in the SKR. There are many different types of RWI designs ranging from direct pumping systems to gravity flow systems to infiltration galleries. Of these three methods the infiltration gallery presents the least disturbance to navigability but will require a larger area of disturbance during construction. Conversely, direct pumping and gravity flow systems present the largest interference with river navigability but have a considerably smaller footprint during the construction phase. All of these options will provide sufficient quantity to provide adequate mixing to reduce near field effects.

The riverside at the outfall will be encased with rip-rap for erosion control and will be installed at a suitable location downstream from the RWI.

As with the diffuser, construction will be completed during the low flow period to allow easier access to the river. Further study of the river is required to identify the proper locations for the RWI and the outfall as well as to determine the appropriate size of the mixing tank that will allow for the proper dilution and mixing but also for operational interruptions.

Detailed Design Considerations

Detailed design would need to consider river characteristics, location, design and contingency volumes, and modeling. These considerations are known, as intake and mixing facility design methodology is well understood from design and installation of many similar installations for a number of specific applications.

Feasibility of Construction and Installation

Construction and installation is known to be possible. No technical issues are expected to reduce or eliminate the feasibility of this option.

Regulatory

Limited in-stream works may be permitted by issuance of a letter of advice if either is not deemed to harmfully affect fish habitat. Should construction cause a harmful affect to occur, the successful authorization of a harmful alteration, disruption or destruction of fish habitat (HADD) from the Department of Fisheries and Oceans Canada (DFO) will be needed prior to construction.

Federally, the *Fisheries Act* prohibits deposition of ‘deleterious substances’ into Canadian fisheries waters. As discussed further in Section 6.2.8 Environmental Health in the revised EIS, the Mannville water passes acute toxicity testing, but shows chronic effects on *Ceriodaphnia* at full concentration. Based on historic precedent, discussions held during the development of the Metal Mining Effluent Regulations and supported by the results obtained through the Environmental Effects Monitoring programs, the discharge would be considered non-deleterious and therefore be permitted by the *Fisheries Act.*

Navigability

Similar to the construction of the diffuser, SKR navigability will be minimally affected by the diffuser infrastructure during construction and residual effects of the diffuser after construction are not envisioned. During construction, a portion of the river may require a coffer dam or similar water retaining structure to install piping and associated infrastructure in dry conditions. Post construction, navigability will be reduced at the in-stream portion of the RWI.

5.2.3 Project Economic Characterization

Financial Requirements

The river water intake will require minimal capital expense. The mixing facility will have to be designed along with water storage to allow for additional water handling capacity. Operating costs are not expected to significantly increase.

Detailed Design

Cost overruns are not envisioned as a result of technical considerations related to intake and discharge due to the various precedent designs and available knowledge concerning this type of water sequestration and release. This option will result in incrementally more design requirements and thus slightly greater cost compared to the diffuser option (option B) as more piping and reservoir infrastructure will be required.

5.2.4 Socio-economic Characterization

Potable Water Quantity and Quality

Like the diffuser option, there are no effects anticipated on potable water quantity or quality as potable water in adjacent residences is from groundwater sources rather than surface water from the SKR. SKR water quality at the discharge point is not significantly changed, therefore, communities or residences using SKR water for potable water further downstream will not see a difference in river water quality.

Land and Water Uses

Land uses are primarily outdoor recreation including hunting, gathering, camping, trail use as well as Traditional Land Uses. Activities within the SKR are potentially affected by the construction of the above ground pipeline and on shore facilities.

Water uses include boating and fishing by Aboriginal and non-Aboriginal people. Access to the SKR for boating is not in the vicinity of where the RWI or outfall would be installed and therefore there would not have an effect on boating access to the SKR. However, there would be a localized effect to boat navigability during construction as outlined in the sections above.

Cultural or Archaeological Values

The general locations of the facilities have been screened for heritage resources. Prior to construction, the specific pipeline alignment and any on shore disturbances will be screened via a pre-disturbance heritage resource survey, and facilities would sited to avoid impacts.

Local Employment and Contracting Opportunities

Like the diffuser option, there are employment and contracting benefits from designing, building and to a lesser extent maintaining / monitoring this water management system. This system can also be installed by a contractor specializing in coffer dams, pipelines and general water infrastructure. Saskatchewan has a number of these contractors, however it is not known if local (i.e., Prince Albert, Melfort, Nipawin) contractors have these capabilities. It is more likely that these contractors are based in Saskatoon or Regina. Shore may require that the contractor demonstrate local employment content to increase local participation and benefits.

Overall the construction phase of the project is expected to employ an average of 669 workers and nearly half of the $1.9 million construction expenditures (44%) are expected to be within Saskatchewan. Current construction employment and expenditure estimates do not include construction of this water management system, but it is expected to be similar in cost to the diffuser system (Option B).

Aesthetic Values

The location of the RWI, mixing tank and outfall structures within the SKR valley means that they are more detectable / visible by river recreationists compared to option B and may detract from the current aesthetics and wilderness use of the river valley.

5.3 OPTION I: REVERSE OSMOSIS TREATMENT WITH DEEP WELL INJECTION OF SOLUTE

Two sub-options are considered for reverse osmosis treatment with deep well injection. The first sub option, full treatment, is treatment of the entire volume of Mannville water (100,000 m^3/day), with discharge of the treated water to the SKR, and deep well disposal of the concentrate. The second option, partial treatment, is treatment of 50,000 m^3/day, with blending of the treated water with the remainder of the Mannville, discharge of the blended water to the SKR, and deep well disposal of the concentrate. Each option will be discussed in the following sections.

5.3.1 Environmental Characterization

Water Quality – Effects on Aquatic Biota

For the full treatment option, the treated water discharged to the SKR is expected to have less dissolved parameters than the current river water, and as such, is not expected to have any effect on aquatic biota.

For the partial treatment option, water quality parameters will be reduced by approximately 40% compared to the Mannville water. Treatment of 50,000 m3/day will result in 35,000 m3/day of treated water, 15,000 m3/day of concentrate, and 50,000 m3/day of Mannville water. Discharge of the blended water (85,000 m3/ day consisting of 50,000 m3/day

Mannville and 35,000 m3/day treated water) is not expected to change water chemistry significantly in the near field, and therefore not expected to affect aquatic biota. In either case, the concentrate (solute) will be piped to a suitable location for deep well injection as discussed below.

In both cases, no far field effects are anticipated. The concentrate would need to be injected into an appropriate geologic formation that would eliminate the potential for the concentrate to reach any surface water body or aquifer used for any purpose.

Water Discharge Quantity

This option would add from 70,000 m3/day to 85,000 m3/day of water to the Saskatchewan River. As these volumes are less than those for option B, no effect is predicted.

Terrestrial Effects

Additional terrestrial footprint would be required for the injection wells, pumping stations and pipelines to the injection sites. It is assumed that the RO plant would be located within the existing plant site. As with Options B and C, a pipeline and discharge to the Saskatchewan River is needed.

Resource use and availability

RO and deep well injection is the most energy intensive option and therefore has the largest potential carbon emissions. RO requires pressure to force water through the membranes, and energy is needed to pump concentrate into an appropriate geological formation.

Water injected deep into geological formations is permanently removed from biological functioning and permanently removed from the hydrological cycle. Over the life of the mine, this could permanently remove up to 291 million m3 of water.

Noise

Noise will be generated during construction as is the case with all of the options presented and during the operating phase by the pumping system used for the RO and injection equipment. Noise generation will be mitigated through suitable housing.

5.3.2 Technical Characterization

Installation Requirements

The RO unit would be housed within the processing plant, modified to include the additional infrastructure, and a pipeline would be constructed from the process plant to the SKR for discharge of the clean water and another to convey the solute to each of the injection well sites for final disposal. An outfall would be constructed on the bank of the SKR for discharge of the clean water which would require work in-stream during the construction period. Pumps scaled to the size of the intended injection flow rate would be mounted and boreholes suitable for injection would need to be constructed at each of the injection well sites. The depth of the injection wells would depend on the location of a suitable geologic layer, with sufficient storage, permeability and thickness to accept the required volumes.

At present it is expected that the solute will need to be piped a minimum distance of 45 km from the mine site to be outside the cone of depression. If injection will occur at the site it will likely require wells into the deeper formations, potentially the Cambrian Deadwood formation, as injection into the Mannville formation (typical injection layer in Saskatchewan) or the Dolomite limestones (which are thought to be hydraulically connected to the Mannville) will be ineffective as the water will recirculate into the dewatering cone of depression. Currently, it is unknown whether the Deadwood formation is present but would be at a depth of at least 1000 m. Further investigation into whether the layer (if present) can accept the proposed volume would be required in addition to feasibility and practicality.

Detailed Design Considerations

The RO, pipelines, river outfall and injection wells are all with precedent and have all been designed many times for multiple applications. However, a suitable location for deep well injection has not been identified. Injection into the Mannville formation or the Dolomite limestones (thought to be connected to the Mannville) at the project site is not feasible as it would interfere with the Mannville cone of depression during mine operations. Potentially, the solute can be pumped into the Cambrian Deadwood formation but the injection well would likely require a depth of at least 1000 m. It is unknown whether this formation is present on site, and it is possible that this formation lacks sufficient thickness and permeability to accept the required volumes. Another option may be an Ordovician sandstone (Winnipeg Formation) at approximately 645 m, however the unit thickness is mapped as 6 m at the nearest drill data point 15 km to the east of site (TGI Williston Basin Working Group, 2008). As such, it is unlikely to be a good candidate for injection. If no suitable formation is present at site, concentrate would need to be conveyed via pipeline to injection sites into the Mannville formation at a minimum distance of 45 km from the mine site to make this option possible.

Feasibility of Construction and Installation

Based on current information about the geology of the site, it is considered unlikely that an appropriate geological formation will be found at site to accept the volume of concentrate. This is a major limitation for this option. Even if a suitable site is located, the feasibility of constructing multiple wells to great depth (a minimum of about 645 m) is unknown. If on site injection is not possible, then additional cost, disturbance and energy would be required to pipe the concentrate outside of the Mannville cone of depression.

Regulatory

The river outfall may require the successful application of a HADD authorization from the DFO prior to construction. The injection wells may require separate approvals from the SMOE provided a suitable location(s) can be identified.

Federally, the *Fisheries Act* prohibits deposition of 'deleterious substances' into Canadian fisheries waters. As discussed further in Section 6.2.8 Environmental Health in the revised EIS, the Mannville water passes acute toxicity testing, but shows chronic effects on *Ceriodaphnia* at full concentration. Based on historic precedent, discussions held during the development of the Metal Mining Effluent Regulations and supported by the results obtained through the Environmental Effects Monitoring programs, the discharge would be considered non-deleterious and therefore be permitted by the *Fisheries Act.* Since RO discharges have lower TDS and chloride concentrations that the Mannville, it is reasonable to assume that the discharges would be permitted under the *Fisheries Act*.

Navigability

During the construction period of the outfall, a water-retaining structure will be used which will interfere with surface navigability. SKR navigability will be only marginally affected at the location of the river outfall post-construction. None of the other infrastructure proposed with this option will be installed at or near a river.

5.3.3 Project Economic Characterization

Financial Requirements

Based on Unit capital costs, reverse osmosis treatment ranges from $1.18 to $5.00 per gallon treatment capacity and operation and maintenance of an RO system are estimated to cost between $0.676 and $1.00 per 1,000 gallons treated. Injection well disposal costs are approximately $1.10 per 1000 gallons treated based on an injection well depth of 600 metres. These initial estimates of capital and operational financial commitments are outlined in Table 5-1 (FDEP 2010 and HDR 2010).

Table 5-1: Estimated Reverse Osmosis and Deep-well Injection Capital and Operating Costs

Rate (m3/d)	Plant Capital (Million $)	Disposal Capital (Million$)	Plant Operations (Million$/yr)	Disposal Operations (Million$/yr)
100,000	$31 – 132	$19.8 – 29	$6.6 – 9.6	$10.6
50,000	$20 – 66	$9.9 – 15.5	$3.4 – 4.8	$5.3

Source; FDEP 2010 and HDR 2010

Construction costs of wells at a depth of 350 ms to dewater the Mannville formation are estimated to cost $1.4 million per well. Assuming that the Deadwood formation has suitable characteristics to be an injection site, the cost to construct an injection well at nearly 3 times the depth would be approximately $4.2 million per injection well. In general, two injection wells are needs for every production well. Each pit dewatering well in the Mannville is expected to produce about 4,545 m^3/day. Since approximately 30% of the water removed from the Mannville formation (15,000 to 30,000 m^3/day) would require injection, 8 to 16 injection boreholes plus contingency would be required. Based on treatment costs presented above with injection wells as per current feasibility cost estimates, the capital and operating costs are shown in Table 5.2 below, including the impact on NPV and IRR for the project.

Table 5-2: Estimated Impact on the Star-Orion South Diamond Project NPV and IRR

Rate	Capital Costs with disposal wells	Operating costs Per year	Impact on Project NPV	Impact On Project IRR
100,000 m3/ day	$106-$207 million	$20.2 million	- $202 million to -$299 million	- 1.3% to -2%
50,000 m3/day	$60-$104 million	$10.1 million	- 165 million to -202 million	-1% to -1.3%

The current project economics of an NPV of $1,272 million and an IRR of 13.7% indicate a project with moderate economics that barely achieve the threshold of investment required by the financial community. Decreasing the economics of the project (i.e., from an IRR of 13.7% to a range of 11.7% to 12.7% as per the above table) results in lower economic feasibility, severely limiting the ability of the project to proceed. The cost for a 45 km pipeline has not been considered but is anticipated to substantially degrade project economics and viability as all costs previously described would still be required.

Detailed Design

Substantial additional cost would be required to identify if a suitable geological formation is present at site. Additional pilot well drilling and hydrogeological testing would be required, costing approximately $8 to $15 million.

5.3.4 Socio-economic Characterization

Potable Water Quantity and Quality

Since it is not currently known the exact location of the final disposal of the solute it cannot be established whether potable water in the vicinity of the injections wells will be affected. However, it is intended that the solute be injected into a deep geological formation that will not allow the solute to affect potable water. As with the previous options there are no effects anticipated from the treated water discharged from the RO unit to the SKR as potable water in adjacent residences is from groundwater sources rather than surface water from the SKR.

Land and Water Uses

Land uses are primarily outdoor recreation including hunting, gathering, camping, trail use and Traditional Land Use. The pipelines for transporting the solute may be within the mine site or may need to be within a 45 km radius of the mine site. If the solute pipelines are on the mine site there would be no additional effects to land users; if the pipelines run off site and are above ground then they could create barriers to or otherwise limit/impact land use.

The outfall for RO water to the river will have a relatively small footprint within the river valley, and therefore should have no effect on land uses. During construction there would be a short period of disruption in the immediate vicinity of the construction activities for land and water uses.

Cultural or Archaeological Values

The general locations of the facilities, if located at the site, have been screened for heritage resources. Prior to construction, the specific pipeline alignment and any on shore disturbances will be screened via a pre-disturbance heritage resource survey, and facilities would sited to avoid impacts.

Local Employment and Contracting Opportunities

Like the other options, there are employment and contracting benefits from designing, building and to a lesser extent maintaining/monitoring this water management system. It is unknown whether regional contractors are able to install these systems and Shore may require that the contractor demonstrate local employment content to increase local participation and benefits.

Overall the construction phase of the project is expected to employ an average of 669 workers and nearly half of the $1.9 million construction expenditures (44%) are expected to be within Saskatchewan. Current construction employment and expenditure estimates do not include construction of this water management system, but given financial estimates above, there would be significant costs for construction that would be considered positive to regional/provincial contractors.

Aesthetic Values

The location of the solute pipeline is unknown and if it is routed off site may have an impact on the aesthetic values of the areas through which it may run. The outfall structure within the SKR valley may be detectable by river recreationists and detract from the current aesthetics and wilderness use of the river valley.

6.0 MULTIPLE ACCOUNTS LEDGER VALUE-BASED DECISION PROCESS

Each option that met the pre-screening criteria has been characterized and assessed for risk pertaining to the identified sub-accounts. Risk for each of the subaccounts has been assigned a ranking from low risk to high risk and a score of 1 for low risk items ascending to 5 for to high risk items. The characterization of each option that met the pre-screening criteria has been summarized and provided in the table below.

Table 6-1: Alternative Characterization and Risk Assignment Table

Alternative Characterization													
Account	**Sub-account**	**Sensitivity Weighting**	**Rationale**	**B - Diffuser System**			**C - Mixing SKR and Mannville Formation ground water immediately before discharge back into SKR**			**I - Reverse Osmosis treatment with deep well injection of solute**		
				Commentary	**Risk**	**Relative Risk**	**Commentary**	**Risk**	**Relative Risk**	**Commentary**	**Risk**	**Relative Risk**
Environmental Issues	Water Quality - Near Field Effects	5	Alternatives that pose the greatest control of effluent quality provide a lower degree of risk of regulatory non-compliance.	**Low risk;** Release rate is designed for maximum concentration at low flow periods; A diffuser enlarges the dilution zone and mixes the effluent rapidly with the receiving water body.	1	5	**Low risk**; Decreased low flow periods reduces intake and risks ability to meet discharge criteria; The existence of bed load or suspended load sediment affects the design concept and the suitability of the site for locating an intake.	1	5	**Low risk**; Water quality at point of discharge will meet all regulatory criteria.	1	5
	Water Quality - Far Field Effects	5	Alternatives that pose the greatest control of effluent quality provides a lower degree of risk of regulatory non-compliance.	**Low risk;** Release rate is designed for maximum concentration at low flow periods.	1	5	**Low risk**; Decreased low flow periods reduces intake and risks ability to meet discharge criteria.	1	5	**Low risk**; Water quality at point of discharge will meet all regulatory criteria.	1	5
	Water Discharge Quantity	1	Alternatives that have the least volume of discharge and the greatest control of the discharge provide a lower impact to the environment.	**Low risk;** This option produces the least possible discharge volume and is designed to have minimal to no impact due to erosion.	1	1	**Low to medium risk**; The intake structures require minimal maintenance but increase the discharge quantity by a factor of eight (8).	2	2	**Low risk;** This option produces the least possible quantify of discharge and is designed to have minimal to no impact due to erosion.	1	1
	Aquatic Biota	4	Alternatives that effect aquatic biota more significantly poses a greater risk of regulatory non-compliance.	**Low risk**; This option is predicted to have no significant effect on the aquatic biota	1	4	**Low risk**; This option is predicted to have no significant effect on the aquatic biota	1	4	**Low risk**; This option is predicted to have no significant effect on the aquatic biota	1	4
	Noise	3	Alternatives that generate higher levels of noise poses a greater risk of regulatory non-compliance and stakeholder impact.	**Low risk**; This option will not generate noise during operation. Construction will generate short term noise with negligible effects.	1	3	**Low to medium risk**; The noise generated from the pumping infrastructure will be easily managed through the housing of the noise generating parts. Construction will generate short term noise effects.	2	6	**Low to medium risk**; The noise generated from the pumping infrastructure will be easily managed through the housing of the noise generating parts. Construction will generate short term noise effects.	2	6
Technical Issues	Water Storage / Retention Requirements	3	Alternatives that have high storage / retention requirements pose a greater degree of risk of operational malfunction.	**Low risk**; A diffuser requires only requires minimal water sequestration in order to maintain positive pressure across the diffuser columns in relation to the hydrodynamic force of the river.	1	3	**Low to medium risk;** Moderate water storage / retention is required to attain constancy in effluent parameter concentration. Low flow periods reduce intake increasing retention quantity.	2	6	**Low risk**; RO and deep well injection requires only requires minimal water storage in order for maintaining equipment functionality.	1	3

Alternative Characterization													
Account	Sub-account	Sensitivity Weighting	Rationale	B - Diffuser System			C - Mixing SKR and Mannville Formation ground water immediately before discharge back into SKR			I - Reverse Osmosis treatment with deep well injection of solute		
				Commentary	Risk	Relative Risk	Commentary	Risk	Relative Risk	Commentary	Risk	Relative Risk
	Dilution Requirements	5	Alternatives that require dilution introduce additional infrastructure and increase the risk of operational malfunction and impact on the environment.	**Low risk**; A diffuser does not require dilution. Diffuser installation discharges are hydraulically optimized to allow for highly turbulent discharges resulting in strong initial mixing and effluent distribution.	1	5	**Medium risk**; Mannville Formation groundwater will be diluted with water from the SKR prior to discharge requiring the installation of a River Water Intake (RWI).	3	15	**Low risk**; Reverse Osmosis and deep well injection does not require dilution.	1	5
	Installation Requirements	3	Alternatives that have many components have an increased risk of operational malfunction and have a greater risk of permanent impact on the environment.	**Low to medium risk**; Construction will require the temporary installation of a coffer dam or similar water retaining structure to install piping and associated infrastructure. However, contruction plans will include the necessary rehabilitation of the river bed as will closure plans. Once installed minimal environmental impacts expected.	2	6	**Medium risk**; Construction of the river water intake (RWI) will also require the temporary installation of a coffer dam or similar water retaining structure. Installation of the pipeline between the RWI and the mixing installation will be below grade and will involve land disturbance. Ongoing impact from the RWI will require ongoing maintenance to minimize environmental impact.	3	9	**Low to medium risk**; Construction of RO and deep well injection is known technology with straightforward construction; Deep well injection is highly regulated and will be required to adhere to strict construction and testing protocol; However, it is currently unknown whether an on-site location is available.	2	6
	Detailed Design	4	Alternatives that have many components require additional design and have an increased risk of operational malfunction and have a greater risk of impact on the environment.	**Low risk**; Periods of low flow, hydraulic transients (Surges), riverbed movement and physical damage contribute to minimized effectiveness of the diffuser. However, current diffuser port design minimizes backflow of sand, silt and debris which reduces the hydraulic capacity of the outfall and compromises the initial dilution.	1	4	**Low to medium risk**; A river water intake (RWI) located in below freezing air temperature requires protection for screens against the formation of anchor and/or frazil ice. Anchor ice in rivers can significantly reduce flow into RWIs.	2	8	**Medium to high risk**; RO and deep well injection is known technology with straight forward construction; However, a suitable location for deep well injection has not been identified and it is currently thought that a location outside the Mannville cone of depresssion a minimum of 45km is required along with a pipeline, route identification and design.	4	16
	Regulatory	5	Alternatives which require regulatory interaction pose a greater risk of not receiving approval.	**Medium risk**; Diffuser ports are installed in or at the river bed and involve the disruption of aquatic habitat. However, effluent concentration of some parameters will likely require DFO approval.	3	15	**Low to medium risk**; The discharge may not require additional permit approvals from the DFO; However, the RWI will require initial design review and ongoing maintenance to ensure fish are adequately protected.	2	10	**Medium risk**; The river outfall may not require additional permit approvals from the DFO; However, deep well injection is highly regulated and proposed injection sites have not been identified requiring additional investigative work.	3	15

Alternative Characterization													
Account	**Sub-account**	**Sensitivity Weighting**	**Rationale**	**B - Diffuser System**			**C - Mixing SKR and Mannville Formation ground water immediately before discharge back into SKR**			**I - Reverse Osmosis treatment with deep well injection of solute**		
				Commentary	**Risk**	**Relative Risk**	**Commentary**	**Risk**	**Relative Risk**	**Commentary**	**Risk**	**Relative Risk**
	Navigability	2	Alternatives that interfere with navigability pose a greater risk of damage from surface travel or vandalization and introduce visible items into the river which risk raising objection from stakeholders.	**Low risk**; Diffuser has minimal interference with surface navigability.	1	2	**Low to medium risk**; A river water intake (RWI) located in below freezing air temperature requires protection for screens against the formation of anchor and/or frazil ice. Anchor ice in rivers can significantly reduce flow into RWIs.	2	4	**Low risk**; River outfall from RO has minimal interference with surface navigability.	1	2
	Operation and Maintenance	2	Alternatives that have significant operational or maintenance requirements pose a greater risk of malfunction.	**Low risk;** Diffuser has minimal operational and / or maintenance requirements.	1	2	**Low to medium risk**; A river water intake (RWI) has operation and maintenance requirements to avoid fish entrainment in pumping devices and other associated infrastructure.	2	4	**Medium risk**; RO is relatively easy to maintain; However, the maintanance of RO along with a pipeline and deep well injection adds to the comlexity of maintenance activities required.	3	6
Economic Implications	Financial Requirements	5	Alternatives that have a high capital and / or operating and maintenance costs pose a greater risk of affecting overall project economics.	**Low risk;** The addition of the diffuser will have a minimal effect on overall project economics. Financial requirement will mostly include captial expenditures with negligible expenditures for operational and maintenance requirements.	1	5	**Low risk;** The addition of the RWI and effluent outfall will have a minimal effect on overall project economics. Financial requirement will mostly include captial expenditures with negligible expenditures for operational and maintenance requirements.	1	5	**High risk**; Decreasing the IRR from 13.7% to a range of 11.7% to 12.7% result in lower economic feasibility that severely limits the ability of the project to proceed	5	25
	Detailed Design	1	Alternatives that require significant engineering, significant site customization or are being designed for the first time pose a greater risk of increased financial outlay due to failure than pre-engineered solutions.	**Low risk;** Diffuser technology is well known and easily transfers to many different applications. Success of detailed design will be contigent of finding a suitable location for installation and quality of installation.	1	1	**Low risk;** RWI and outfall designs are well established and will have a minimal effect on overall project economics. Financial requirement will mostly include captial expenditures associated with installation and minimal expenditures for operational and maintenance requirements.	1	1	**Medium to high risk;** RO design is standardized and straight forward; However, on-site injection locations have not been identified and it is currently assumed that the solute will require conveyance by pipeline a distance outside the Mannville cone of depression.	4	4
Socio-Economic Indicators	Potable Water Quantity and Quality	5	Alternatives that have effects on potable water sources pose greater risk for human health effects and are costly to the proponent to mitigate.	**Low risk:** Diffuser has no effect on ground water sources used for potable water in the region.	1	5	**Low risk**: This option has no effect on ground water sources used for potable water in the region.	1	5	**Low risk:** Clean water discharge has no effect on ground water sources used for potable water in the region. Deep injection of solute should not impact acquifers used for domestic water.	1	5

Account	Sub-account	Sensitivity Weighting	Rationale	B - Diffuser System: Commentary	B: Risk	B: Relative Risk	C - Mixing SKR and Mannville Formation ground water immediately before discharge back into SKR: Commentary	C: Risk	C: Relative Risk	I - Reverse Osmosis treatment with deep well injection of solute: Commentary	I: Risk	I: Relative Risk
	Fish Consumption	2	Alternatives that increase contaminants in fish that are consumed pose greater risk for human health effects and ability to exercise Treaty or Aboriginal Rights and are costly to the proponent to mitigate.	**Low to medium risk:** Fish consumption is already diminished due to presence of fish contaminants; increased loadings could further diminish real or perceived risk of human health effects of fish consumption.	2	4	**Low to medium risk**: Fish consumption is already diminished due to presence of fish contaminants; increased loadings could further diminish real or perceived risk of human health effects of fish consumption.	2	4	**Low risk:** No loadings of contaminants to the SKR that could impact of fish and fish consumption.	1	2
	Land and Water Use	1	Alternatives that negatively impact or impede land and water uses will be less likely to be acceptable to the public, stakeholders and Aboriginal groups.	**Low risk:** Diffuser has buried or in-stream infrastructure that is virtually undectable at the ground and water surface. Localized navigability effect at the diffuser structure. No effect on access to river or river valley.	1	1	**Medium risk**: Mixing tank is located close to RWI and outfall within the river valley and have greatest footprint of the 3 options. No effect on access to river; could impede some use of the river valley.	3	3	**Low to medium risk**: Effects of injection of solute and discharge may be percieved negatively; above ground concentrate pipeline may affect land uses.	2	2
	Cultural or Archaeological Values	5	Alternatives that destroy or limit access to areas of cultural or archaeological value without acceptable mitigation or accommodation will be less likely to be acceptable to the public, stakeholders and Aboriginal groups.	**Low risk:** Diffuser system infrastructure is buried. Assuming no cultural or archaeological values are destroyed during construction this option poses least risk to cultural or archeaological values.	1	5	**Medium risk:** Mixing tank is located close to RWI and outfall within the river valley and have greatest footprint of the 3 options and thus more potential to impact cultural values within the river valley. Presence of archaeological values is unknown.	3	15	**Medium risk**: Requires more infrastructure development in the river valley and potentially could impact a transect of wilderness up to 45 km linear direction from the project site which could affect cultural values located in the river valley as well as 45 km away. Presence of archaeological values is unknown.	3	15
	Local Employment and Contracting Opportunities	2	Alternatives that provide local employment and contracting opportunities are more cost effective than bringing in labour and/or contractors from outside of the region and are more acceptable to the public, stakeholders and Aboriginal groups who are receiving these benefits.	**Low risk:** Diffuser system provides employment and contracting opportunities during construction for local/regional/provincial workers and companies.	1	2	**Low risk**: Diffuser system provides employment and contracting opportunities during construction for local/regional/provincial workers and companies.	1	2	**Low risk**: RO and deep well injection system provides employment and contracting opportunities during construction for local/regional/provincial workers and companies.	1	2

Alternative Characterization													
Account	Sub-account	Sensitivity Weighting	Rationale	B - Diffuser System			C - Mixing SKR and Mannville Formation ground water immediately before discharge back into SKR			I - Reverse Osmosis treatment with deep well injection of solute		
				Commentary	Risk	Relative Risk	Commentary	Risk	Relative Risk	Commentary	Risk	Relative Risk
	Aesthetic Values	1	Alternatives that detract from the wilderness aesthetic of the river valley will be less acceptable to those using/recreating in the river valley or in the river.	**Low Risk:** Diffuser system, once in place, is less visible than the other 2 options.	1	1	**Medium risk**: RWI, mixing tank and outfall structure are visible to river and river valley users and detract from the wilderness aesthetic.	3	3	**Low to medium risk:** Outfall structure is visible to river and river valley users and detract from the wilderness aesthetic. Concentrate pipeline, if constructed above ground, may negatively impact aesthetic values.	2	2
			Overall Risk		24	79		38	116		40	131

7.0 CONCLUSIONS

A multi-port diffuser (Option B) is the preferred management option for the Mannville Formation groundwater. It has a less complex design than the other options evaluated and it proposes only one additional in-river disruption as opposed to two for each of the other options or a pipeline of significant length. The overall risk rating for this option scores lower than the other two options.

The multi-port diffuser (option B) will require lower capital expenditure than the other preferred options as well as fewer resources for design. Mixing the Mannville Formation groundwater with SKR at the river (option C) requires the installation of a river water intake, an effluent outfall to the river and the installation of a mixing apparatus on or near the shore of the SKR. RO treatment with deep well injection of the solute (option I) has not been established as a viable option, as there is considerable uncertainty about the feasibility of this option, which would require considerable further study. Even if proven feasible, large additional costs are required greatly impacting Project economics.

Considering that the near and far field effects on water quality and aquatic biota are nearly identical between the 3 options, the considerable additional cost of RO and injection, if even feasible, is not justified.

While all options will require some surge capacity and associated terrestrial effects, option B requires only the addition of the multi-port diffuser apparatus. Option B requires the least amount of construction and physical works and is thus the preferred option.

Mixing the Mannville Formation groundwater with SKR at the river (option C) requires a water license which will limit the amount of withdrawal so as not to negatively affect downstream users. There is a potential that insufficient water for dilution may be available to reduce Mannville Formation groundwater sufficiently to meet receiving water guidelines without a diffuser (minimum would be 7:1). The requirement for a diffuser with option C would result in an incremental expense over option B with a less favourable cost-benefit ratio. While this option presents the lowest concentration of the target parameters of concern it creates another and potentially larger impact through the water withdrawal and sequestration of SKR. Water withdrawal and sequestration can be viewed negatively by stakeholders and introduce a much more complex regulatory approval structure. It also introduces the possibility of fish destruction from the RWI that must be vigorously managed.

Reverse osmosis (RO) is an established water treatment technology and can be utilized for a variety of applications. However, the concentrate (solute) that is generated presents a significant problem for this project as it cannot be injected in the Mannville formation on site, as is typical in Saskatchewan. When pumped into the Mannville formation or the Dolomite limestones (thought to be hydraulically connected to the Mannville) it will interfere with dewatering and create a positive feedback loop of ever increasing dewatering volumes. If the Deadwood formation is present at site and is not hydraulically connected to the Mannville formation injection wells could be drilled to a depth of at least 1000 m for on-site injection. However, if this layer does not exist or if it is not hydraulically segregated from the Mannville layer the solute must be conveyed via pipeline outside the cone of depression (at least 45 km away). Since no additional environmental projection is achieved by this option, the great additional cost is not justified, even if a suitable injection site can be found. If a 45 km pipeline is required project economics become even less desirable. This option is unlikely to be technically feasible.

The diffuser (option B) is the most viable option. It mitigates any potential effects caused by the Mannville formation groundwater using passive methods that do not require large energy inputs or careful management. The diffuser is economically viable and does not present an option with which stakeholders or the general public have expressed significant concern about.

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