



MEADOWBANK GOLD PROJECT

Integrated Report on Evaluation of Tailings Management Alternatives

February 2007

INTEGRATED REPORT ON

**EVALUATION OF TAILINGS MANAGEMENT
ALTERNATIVES
MEADOWBANK GOLD PROJECT
NUNAVUT**

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EXECUTIVE SUMMARY

Cumberland Resources Ltd is in the process of permitting the Meadowbank Gold Project, located in Nunavut, some 70 km north of the community of Baker Lake. The project consists of several gold deposits located in close proximity to one another. Much of the project area is covered by lakes, and portions of the deposits are located beneath lakes; as a consequence of this, a series of de-watering dikes will be constructed to allow mining of the deposits once the areas behind the dikes have been de-watered. It is planned to deposit tailings sub-aerially into the northwest arm of the partially de-watered Second Portage Lake.

The inclusion of a proposed tailings disposal site under Schedule 2 of the Metal Mining Effluent Regulations (MMER) requires consultation with the public, as well as approval from a number of regulatory organizations, including Department of Fisheries and Oceans (DFO), Environment Canada (EC), and the Governor-in-Council. Fish-bearing water bodies, such as the northwest arm of Second Portage Lake, are not normally considered for use as tailings disposal sites, unless some type of mitigative measure is implemented such that there is No Net Loss (NNL) of fish habitat. Such measures may include balancing unavoidable habitat losses through habitat compensation, or enhancement of existing habitat.

As part of their submissions for the final public hearings of the Nunavut Impact Review Board (NIRB), DFO and EC indicated that the existing documents relating to the assessment of tailings management alternatives are adequate for the purposes of the Environmental Assessment (EA) process, but that additional information will be needed to meet the requirements for listing the northwest arm of Second Portage Lake under Schedule 2 of the MMER. The additional information requested by EC was:

- a finalized NNL Plan to include details on fish habitat compensation measures to be implemented, monitoring plans for these measures, and compensation structure plans. This was submitted to DFO on 28 November 2006; and,
- the compilation of the existing documentation relating to the assessment of the tailings management alternatives and the tailings site selection process into a single and complete, stand-alone document. Specifically, EC requested that the two following documents be compiled:
 - Golder Associates Ltd., Report on *Evaluation of Tailings Alternatives, Meadowbank Project, Nunavut*, October, 2005.

- Golder Associates Ltd., Technical Memorandum on *Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19*, February 9, 2006.

The document presented herein represents the compilation of the existing documentation relating to the tailings site selection.

Summary of Tailings Site Selection Process

The process by which the selection of the northwest arm of Second Portage Lake as the preferred Tailings Impoundment Area (TIA) is summarized in the following paragraphs, and is presented in detail within the text of this report.

A series of studies to evaluate the possible tailings management options have been undertaken since 1999. The following is a list of the studies that were completed prior to filing of the Draft Environmental Impact Statement (DEIS).

- Golder Associates Ltd., Report on *Tailings and Waste Management Options, Meadowbank Gold Project, Northwest Territories*, March 1999.
- Golder Associates Ltd., Letter on *Revised Tailings and Country Rock Management Concept – Meadowbank Project*, May 11, 1999.
- Golder Associates Ltd., Report on *Mine Waste and Water Management, Meadowbank Gold Project, Nunavut*, March 5, 2004.
- Golder Associates Ltd., Report on *Alternative Waste and Water Management Plan, Meadowbank Gold Project, Nunavut*, March 7, 2005.

Following the submission of the DEIS, a series of Technical Meetings were held in Baker Lake on June 2 and 3, 2005. Following the meetings, a list of commitments by CRL was prepared, which would either be addressed as soon as possible, or to be incorporated into the Final Environmental Impact Statement (FEIS). A series of reports and technical memoranda were issued following the meetings to respond to information requests made by stakeholders, and to commitments made by Cumberland. A report responding specifically to requests for additional information relating to the decision matrix used to evaluate the tailings disposal options was issued:

- Golder Associates Ltd., Report on *Evaluation of Tailings Alternatives, Meadowbank Project, Nunavut*, October, 2005.

This was followed by the issuance of a Technical Memorandum in response to requests by DFO and EC to include additional considerations in the tailings site selection process.

- Golder Associates Ltd., Technical Memorandum on *Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19*, February 9, 2006.

The report and Technical Memorandum presented the basis for the selection of the northwest arm of Second Portage Lake as the TIA, as presented in the Final Environmental Impact Statement (FEIS), submitted in October of 2005 (CRL, 2005a).

The objectives of the previous reports was to identify the most appropriate method for disposal of tailings for the Meadowbank Project based on an evaluation of technical, environmental and economic considerations. The requirements are that the facility have minimal net adverse effects on the environment, now and in the future, be technically sound with the minimal potential for failure and economic.

The process used to select the tailings management system involved:

- Identifying potential tailings storage locations and technologies;
- Developing a list of key site selection criteria that all facilities needed to meet; and
- Developing a site specific, decision matrix model to evaluate, rank, and select the best overall tailings management facility.

Initially, seven potential tailings management areas were identified. Three of these were excluded from further consideration based on a series of pre-screening criteria. Four potential tailings management areas were carried further for analysis using a decision matrix approach.

Location	Disposal Type
Second Portage Arm	Sub-aerial Paste or Dry Stack
Second Portage Arm	Sub-aerial Slurry
North of Second Portage Arm	Sub-aerial Slurry
North of Second Portage Arm	Sub-aerial Paste or Dry Stack

This approach, known as a Multiple Accounts Analysis (MAA), is commonly used as a decision-making tool for the selection of tailings and waste management facilities. An important aspect of the decision matrix methodology is that it requires all factors be weighed in the final outcome, rather than allowing a single factor to dictate the overall outcome.

The decision matrix model considered factors in three primary categories:

- Environmental;
- Operational; and
- Economic.

Each category was subdivided to consider other sub-indicators. Weighting factors were assigned to each sub-indicator and to the overall factors.

Sensitivity Analyses

Four sensitivity analyses were carried out. Firstly, each of the individual weighting factors used in the assessment process was set to 1, assigning equal weighting to each individual sub-indicator. Secondly, only environmental factors and long-term (post-closure) impacts were considered, at the exclusion of operating and economic indicators. Thirdly, environmental factors specifically relating to impacted lakes and fish habitat were weighted as highly as possible within the decision matrix so that the contribution of these sub-indicators towards on-land disposal options ranged between 31% and 35% of the total environmental score, while the contribution to disposal options in Second Portage Lake were reduced to between 13% and 17% of the overall total score. Finally, the amount of fish habitat and number of lakes affected by each option were described by using habitat units (as defined in the No Net Loss report), terrestrial and aquatic wildlife habitat loss and ease of closure. These were then included as sub-indicators, and permanent and temporary aquatic habitat loss were evaluated separately.

Summary of Results

The results of the decision matrix analysis indicate that:

- The most appropriate tailings management option for the Meadowbank Project is the disposal of tailings into the natural rock basin of the northwest arm of Second Portage Lake, followed by permafrost encapsulation. This decision is based on environmental, operational, and economic considerations; and,
- The results of the sensitivity analyses showed that when economic factors were removed from consideration, and the relative importance of operational factors reduced, leaving environmental factors as having the greatest contribution to the overall decision analysis, the preferred option continues to be disposal in the northwest arm of Second Portage Lake, using permafrost encapsulation as the control strategy for acid mine drainage and metal leaching.

It is noteworthy that, regardless of where the tailings will be stored, the northwest arm of Second Portage Lake will be impacted by mine activities due to the construction of a series of de-watering dikes to allow mining of the ore and to ensure structural integrity during construction and operation of the East Dike.

Case Study

A case study of the oxidation of exposed, sub-aerial mine tailings from Rankin Inlet, Nunavut, at sub-zero temperatures is presented. The tailings are acid generating and metal leaching, with saline pore waters. A remediation program begun in 1991 consisted of depositing the tailings into a drained rock basin, with the expectation that permafrost would aggrade into the facility. This is similar to the recommended option for tailings management at the Meadowbank project. A series of thermistors installed in the Rankin Inlet test area indicated that freeze-back of the tailings was occurring more rapidly than predicted. There was no indication of heating by tailings oxidation, despite the reactive nature of the pyrrhotite rich tailings. The results of the laboratory and field investigations indicated that prospective sites for permafrost encapsulation of tailings should have a mean annual air temperature colder than about -6°C. The mean annual air temperature at the Meadowbank Project is -11.3°C. Based on the results presented in the case study, permafrost encapsulation of tailings disposed in a drained rock basin, such as the northwest arm of Second Portage Lake, is a preferred method of disposal in permafrost regions.

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Cumberland Resources Ltd. (CRL) to identify and select an appropriate tailings storage facility for the Meadowbank Gold Project in Nunavut. The project is located approximately 70 km north of Baker Lake, Nunavut (see Figure 1).

A series of studies have been carried out since 1999 to evaluate the most appropriate tailings and waste management strategies for the project. These studies have been presented in a series of reports describing the evaluation process used to select the most appropriate tailings facility:

- Golder Associates Ltd., Report on Tailings and Waste Management Options, Meadowbank Gold Project, Northwest Territories, March 1999.
- Golder Associates Ltd., Letter on Revised Tailings and Country Rock Management Concept – Meadowbank Project, May 11, 1999.
- Golder Associates Ltd., Report on Mine Waste and Water Management, Meadowbank Gold Project, Nunavut, March 5, 2004.
- Golder Associates Ltd., Report on Alternative Waste and Water Management Plan, Meadowbank Gold Project, Nunavut, March 7, 2005.
- Golder Associates Ltd., Report on Evaluation of Tailings Alternatives, Meadowbank Project, Nunavut, October, 2005.
- Golder Associates Ltd., Technical Memorandum on Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19, February 9, 2006.

The objectives of the studies were to identify the most appropriate method for disposal of tailings for the Meadowbank Project based on technical, environmental and economic considerations. The requirements are that the facility have minimal net adverse effects on the environment, now and in the future, be technically sound with the minimal potential for failure and economic. Further clarification of the methodology used to select the tailings facility has been requested, and the objective of this document is to provide this clarification.

A Multiple Accounts Analysis (MAA), or decision matrix method of analysis, was used to evaluate tailings disposal alternatives and to select the best tailings storage facility for the Meadowbank Project.

1.1 Background to the Preparation of an Integrated Report

A series of Technical Meetings were held in Baker Lake on June 2 and 3, 2005 to review the Draft Environmental Impact Statement (DEIS) for Cumberland Resources Limited (CRL), Meadowbank Gold Project. Following the submission of the DEIS, a series of Technical Meetings were held in Baker Lake on June 2 and 3, 2005. Following the meetings, a list of commitments by CRL was prepared, which would either be addressed as soon as possible, or to be incorporated into the Final Environmental Impact Statement (FEIS). A series of reports and technical memoranda were issued following the meetings to respond to information requests made by stakeholders, and to commitments made by Cumberland. A report responding specifically to requests for additional information relating to the decision matrix used to evaluate the tailings disposal options was issued:

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- Golder Associates Ltd., Technical Memorandum on *Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19*, February 9, 2006.

On December 22, 2005, a teleconference was held to discuss certain aspects of the Final Environmental Impact Statement (FEIS) submitted by CRL.

The teleconference focussed on certain aspects of the tailings site selection criteria. Representatives from DFO and Environment Canada (EC) requested additional considerations in evaluating the tailings site selection criteria. The outcome of the meeting resulted in the following eight key points for which further information/clarification was requested:

1. Replace habitat area (ha) of fish habitat and number of lakes affected by each option with true "habitat units" as derived in the No Net Loss report.
2. Consider terrestrial habitat loss and effects on wildlife, as well as loss of aquatic habitat for shorebirds and waterfowl. Include estimates of habitat loss and habitat quality from land-based disposal options for migrating waterfowl,

and songbirds. Estimate the relative loss of habitat associated with the Northwest Arm of Second Portage Lake for migratory birds.

3. Distinguish between permanent and temporary habitat loss, and reflect this in the weightings and scoring of each option.
4. Indicate “Closure” as a distinct subindicator.
5. Provide additional rationale for the categories and their rankings.
6. Provide clarification of cost factors used in the assessment of the different options.
7. Provide clarification regarding the requirement that the northwest arm of Second Portage Lake be dewatered regardless of whether or not the site is used as a tailings disposal facility.
8. Provide clarification of construction and operational challenges associated with the development of on-land disposal system.

In addition to the teleconference, EC also presented a written request for additional information provided as Information Request (IR) #18 and IR #19 in a letter dated January 20, 2006 and titled “Cumberland Resources Ltd. Meadowland Gold Project – Final Environmental Impact Statement Information Request.” The IRs are summarized as follows:

IR #18: Choice of Environmental Sub-Indicators in Tailings Management Alternatives Assessment

Issue:

The sub-indicators chosen to evaluate the various tailings options under the Environmental Factor are not adequately described and the rationale for choosing some of the sub-indicators is not provided. Further, some of the sub-indicators are duplicative and appear to skew the decision matrix toward considerations of the ease of operation in post-closure scenarios. The sub-indicators should be revised and the rationale for choosing the sub-indicators strengthened.

IR #19: Inclusion of Terrestrial Impacts in Tailings Management Alternatives Assessment

Issue:

The Report on Tailings Management Alternatives, included as Appendix A of the Alternatives Assessment Report, does not include any consideration of the impacts

of the various tailings management options on valued ecosystem components other than fish or on terrestrial habitats. The report should be updated to include these considerations in the environmental analysis.

The requests by DFO and EC were incorporated into a Technical Memorandum issued on February 9, 2006:

- Golder Associates Ltd., Technical Memorandum on *Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19*, February 9, 2006.

The report and Technical Memorandum formed the rationale for the selection of the northwest arm of Second Portage Lake as the TIA, as presented in the Final Environmental Impact Statement (FEIS), submitted in October of 2005 (CRL, 2005a).

As part of their submissions for the final public hearings of the Nunavut Impact Review Board (NIRB), DFO and EC indicated that the existing documents relating to the assessment of tailings management alternatives are adequate for the purposes of the Environmental Assessment (EA) process, but that additional information will be needed to meet the requirements for listing the northwest arm of Second Portage Lake under Schedule 2 of the MMER. The additional information requested by EC was:

- a finalized NNL Plan, which is to include details on fish habitat compensation measures to be implemented, monitoring plans for these measures, and compensation structure plans; and,
- the compilation of the existing documentation relating to the assessment of the tailings management alternatives and the tailings site selection process into a single and complete, stand-alone document. Specifically, EC requested that the two following documents be compiled:
 - Golder Associates Ltd., Report on *Evaluation of Tailings Alternatives, Meadowbank Project, Nunavut*, October, 2005.
 - Golder Associates Ltd., Technical Memorandum on *Additional Clarification on Tailings Alternative Assessment – Environment Canada IR#18 and IR#19*, February 9, 2006.

The finalized NNL Plan was submitted to DFO on 28 November 2006.

The document presented herein represents the compilation of the existing documentation relating to the tailings site selection.

1.2 Physical Setting

The site area consists of low, rolling hills with numerous small lakes. Laterally extensive deposits of glacial till cover the area, with thicknesses typically of 2 m to 4 m. Bedrock consists of a sequence of Archean greenstone (ultramafic and mafic flow sequences) and metasedimentary rocks.

The Meadowbank Project is located in an area of low seismicity (see Figure 2).

Table 1.1: Peak Horizontal Ground Accelerations for Meadowbank Site

Return Period of Seismic Event (years)	Peak Horizontal Ground Acceleration (g)
100	0.018
200	0.025
475	0.034
975	0.044

Source: Seismic Risk Calculation for Meadowbank Project Site, Geological Survey of Canada, Natural Resources Canada, Sidney, B.C., July, 2003.

The site has vegetation cover interspersed with bedrock outcrops and continuously aggrading surfaces. The vegetation includes; lichens, mosses, shrubs, heaths, grasses and sedges (CRL 2003).

No vital caribou areas or protected wildlife areas have been identified in close proximity to the site (CRL 2003). The area is not regularly used for hunting due to its remoteness from Baker Lake and relatively low abundance of wildlife (CRL 2003).

Water quality in the lakes is excellent. However, the lakes are nutrient poor and are classified as ultra-oligotrophic and hence have low fish productivity (CRL 2003).

The annual average temperature is about -11.3°C, based on site data collected between 1997 and 2004 and an annual precipitation of less than 200 mm (AMEC, 2005). Long-term temperature trends collected over 50 years at Baker lake, when applied to the Meadowbank Project site, suggest a mean annual air temperature of -12.8°C. The depth of permafrost is estimated to range from about 450 m to about 550 m, but varies based on proximity to lakes. Taliks typically are located beneath bodies of water that exceed 2 m

to 2.5 m depth of water. The depth of the active layer ranges from about 1.3 m in areas of shallow overburden, up to 4 m adjacent to lakes.

1.3 Planned Mining Operations

The project consists of several gold bearing deposits within reasonable proximity to one another. Mining of the deposits will primarily be performed as a truck and shovel, open pit operation. Ore is to be transported to a central plant site for processing.

A site plan is shown in Figure 3. The mine plan estimates that 22 million tonnes of ore will be processed over the mine life of approximately 8.4 years. The total volume of settled tailings is estimated to be 15 million cubic metres.

2.0 CONTROL STRATEGIES FOR THE MANAGEMENT OF MINE WASTE IN ARCTIC REGIONS

The generation of metal leachate in acidic drainage is a concern for mining projects. In evaluating the potential control strategies for the disposal of the mine waste at the Meadowbank Project, consideration was given to control strategies that are effective in cold regions. Many reports have been prepared that relate to the disposal of mine waste in cold regions. Under the Mine Environment Neutral Drainage (MEND) program some relevant reports are:

Table 2.1: Reports Relating to Disposal of Mine Waste in Arctic

MEND Project	Title	Year
6.1	Preventing AMD by Disposing of Reactive Tailings in Permafrost	1993
1.61.1	Roles of Ice, in the Water Cover Option, and Permafrost in Controlling Acid Generation from Sulphide Tailings	1996
1.61.2	Acid Mine Drainage in Permafrost Regions: Issues, Control Strategies and Research Requirements	1996
1.61.3	Column Leaching Characteristics of Cullaton Lake B and Shear (S) – Zones Tailings Phase 2: Cold Temperature Leaching	1997
1.62.2	Acid Mine Drainage Behaviour in Low Temperature Regimes – Thermal Properties of Tailings	1998
W.014	Managing Mine Wastes in Permafrost Zones, Summary Notes MEND Workshop	1997
5.4.2d	MEND Manual, Volume 4 – Prevention and Control, Chapter 4.8 Permafrost and Freezing	2001
1.61.4	Covers for Reactive Tailings Located in Permafrost	2004

Common control strategies for the prevention or reduction of acid mine drainage are:

1. Control of acid generating reactions;
2. Control of migration of contaminants; and,
3. Collection and treatment.

In assessing the overall control strategies for the Meadowbank Project, an emphasis has been placed on methods that satisfy items 1 and 2 in the above list, which then has an impact on item 3, collection and treatment, by potentially reducing the requirements for these activities.

Dawson and Morin (MEND 1.61.2, 1996) list various acid mine drainage control strategies. Strategies listed below apply to both tailings and waste rock.

Table 2.2: Acid Mine Drainage Control Strategies of the Arctic

Strategy	Tailings	Waste Rock
Freeze Controlled	<ul style="list-style-type: none"> • Total or perimeter freezing options can be considered • Can freeze up to greater than 15 m annually if freezing in thin layers • Process chemicals could cause high unfrozen water contents 	<ul style="list-style-type: none"> • Requires considerable volumes of non-acid waste rock for insulation protection • Better understanding of air and water transport through waste rock required for reliable design
Climate Controlled	<ul style="list-style-type: none"> • May not be a reliable strategy for saturated tailings 	<ul style="list-style-type: none"> • Requires control of convective air flow through waste rock, infiltration control with modest measures and temperature controls • Better understanding of waste rock air, water, and heat transport for reliable design
Engineered Cover	<ul style="list-style-type: none"> • Special consideration for freeze-thaw effects • Availability and cost of cover materials are major impediments 	
Subaqueous Disposal	<ul style="list-style-type: none"> • Special considerations for winter ice conditions and pipeline freeze-up 	<ul style="list-style-type: none"> • Very difficult to dispose of waste rock beneath winter ice
Collection and Treatment	<ul style="list-style-type: none"> • Costly to maintain at remote locations • Long term maintenance cost 	
Segregation and Blending	<ul style="list-style-type: none"> • Tailings are normally geochemically homogeneous 	<ul style="list-style-type: none"> • May be very effective • Research and development on-going

Reference: (MEND 1.61.2, 1996)

The Meadowbank Project is located within the zone of continuous permafrost, and has a mean annual air temperature of about -11.3 degrees C. The project area is underlain by permafrost to depths between 450 m and 550 m based on thermal data collected from the site since 1996.

Freeze Control Strategies: Freeze control strategies rely on the immobilization of pore fluids to control acid mine drainage reactions, and the potential migration of contaminated porewater outside of the impoundment area. The climate conditions at the Meadowbank Project site are amenable to freeze control strategies, and hence should be taken advantage of. In addition to immobilization of pore fluids, permafrost can reduce the hydraulic conductivity of materials by several orders of magnitude. Consequently, freeze control strategies are effective methods for preventing the migration of contaminants through materials. At the Meadowbank Project, the hydraulic conductivity of the bedrock is already low, on the order of 10⁻⁸ m/s. The implementation of a freeze control strategy would result in even lower hydraulic conductivities if tailings were disposed of within a bedrock basin. According to Dawson and Morin, above, freeze control strategies for waste rock dumps can only be effective if sufficient quantities of non-acid generating waste rock are available for use as a cover and insulation protection. Based on the production forecast schedule for the Meadowbank Project, there will be sufficient ultramafic rock, which is not only non-acid generating, but also acid neutralizing with a buffering capacity up to 5 times greater than the other rock types at the project. Consequently, a freeze control strategy for the waste rock dumps in the Portage area, using ultramafic rock as a cover and insulating layer, is a preferred alternative.

Climate Control Strategies: Cold temperatures reduce the rate at which oxidation occurs. The low net precipitation in permafrost regions limits infiltration of water into waste rock and tailings disposal areas. Consequently, the climate of the Meadowbank Project area will act as a natural buffer to the production of acid mine drainage and metal leachate. According to Dawson and Morin (1996) these strategies are best applied to materials placed at a low moisture content to reduce the need for additional controls on seepage and infiltration. Consequently, this strategy is considered to be effective for waste rock, but not tailings. The arid climate at the Meadowbank Project is therefore ideally suited for climate control strategies for use with the waste rock piles.

Engineered Covers: In general, the objectives of engineered covers are to minimize infiltration of water into the disposal facility, and to create a physical barrier to the diffusion of oxygen into the facility, either waste rock or tailings. In temperate climates, dry covers consist of a layer of fine grained material between two coarse grained layers. In permafrost regions, freeze-thaw cracking due to annual freeze-thaw processes is a concern, resulting in damage to the cover layers and a reduction in the effectiveness of

the barrier system. Consequently, materials having a low susceptibility to freeze-thaw damage are desirable. At the Meadowbank Project there is a substantial shortage of thaw-stable soils. Consequently, the development of an appropriate cover design using natural materials available at the site would require significant processing to achieve the requirements for the cover materials. Alternatives to natural materials are manufactured materials, such as geosynthetics or geomembranes. However the costs associated with transporting these materials to site, and the construction of the man-made cover system, are prohibitive.

Subaqueous Disposal Strategies: In temperate regions, the disposal of waste rock and tailings beneath a water cover is a suitable method for disposal as this inhibits the ability of sulphides within the waste materials, either tailings or waste rock, to oxidize. In permafrost regions, additional considerations include the ability to dispose of tailings and waste rock under ice during the ice covered water period of the project. At the Meadowbank Project, ice on the lakes can continue in to July. Consequently, the free-ice period for subaqueous disposal strategies would be limited to a time period of about 3 months. It is notable however, that mines such as Polaris have successfully operated underwater tailings disposal.

Blending and Segregation: Blending and segregation of waste materials consists of combining acidic and alkaline materials to achieve a net neutral waste product producing non-acidic leachate. This approach requires substantial quantities of non-acid generating waste rock to blend with the acid generating rock. At the Meadowbank Project, there are sufficient quantities of non-acid generating waste rock such that this strategy appears desirable. However, in comparison with a total freeze control strategy, there does not appear to be any significant advantage to this method. Furthermore, this type of approach would likely require substantial planning, stockpiling, and re-handling of material; more so than for the freeze control alternative.

2.1.1 Summary

A review of control strategies for mine waste disposal, both waste rock and tailings, in cold regions has been presented. The following lists aspects of the project that must be considered in selecting an overall waste management philosophy:

- The Meadowbank Project site is located in the zone of continuous ‘dry’ permafrost;
- The permafrost is classified as ‘dry’, having ice content of less than 10% based on regional permafrost classification maps;
- The permafrost is continuous, with permafrost up to 450 m to 550 m deep based on thermal data collected from the site;

-
- The mean annual air temperature at the site is about -11.3 degrees C;
 - The project site is considered to be arid and dry, with mean annual precipitation on the order of about 290 mm (rainfall and estimated snowfall);
 - There is a shortage of naturally occurring thaw-stable materials at the site;
 - Most of the waste rock that will be produced during mining is potentially acid generating;
 - However, there are sufficient quantities of acid-neutralizing ultramafic waste rock material at the site for use as a cover of waste rock piles and tailings; and
 - All of the tailings are acid generating and metal leaching.

Based on the summary of conditions at the site, the following strategies for tailings management are appropriate from a technical perspective.

Tailings Disposal Alternatives

Due to the arid climate and permafrost environment, tailings should be disposed of in a manner that encourages total freezing as a control strategy. Subaerial disposal is preferred, given the length of time that water at the site is ice covered, allowing the tailings to be frozen in thin layers rather than one thick layer in order to maximize the total frozen thickness. This can be accomplished through the use of slurry pipelines. The tailings will eventually become encapsulated by permafrost, thus limiting oxygen diffusion and water infiltration into the pile, thereby limiting the generation of acid mine drainage. This is shown conceptually on Figure 4.

If disposed of on-land, a system of containment dikes would need to be constructed. The dike system would contribute to perimeter freezing of the tailings pile. However, there are insufficient quantities of natural materials available to construct such a dike system. Ideally, disposal of the tailings into a rock basin within permafrost would be the most suitable control strategy. Freezing of the tailings pile would then occur during deposition of the thin layers into the basin, and from the perimeter of the basin which would already be frozen. The hydraulic conductivity of the thawed bedrock at the site is on the order of 10⁻⁸ m/s. Permafrost can reduce the hydraulic conductivity of a material by as much as several orders of magnitude. Consequently, an additional advantage to disposal within a naturally occurring bedrock basin followed by total freezing is that the ability for constituents to migrate out of the facility is substantially restricted. The use of the naturally occurring bedrock and permafrost as the control mechanism to inhibit the onset of acid mine drainage, to restrict the potential release of constituents to the environment,

and to restrict infiltration into the pile is preferred over other alternatives that rely on the construction of kilometres of engineered dikes constructed with man made and processed materials, such as clay liner systems, which have hydraulic conductivities that are higher than the bedrock in the Meadowbank Project area. Furthermore, the use of engineered structures carries with it an inherent risk of failure. It is therefore desirable to minimize the reliance on engineered structures.

In considering an on-land disposal facility, there are also certain operational issues that must be taken into consideration in evaluating this alternative. Typical operational considerations include the following:

- Milling process;
- Distance to mill;
- Line and grade;
- Water management; and
- Constructability.

In a temperate climate, such operational considerations are managed relatively easily. However, under the specific climate conditions at the Meadowbank Project, these operational considerations become far more important. One of the most important aspects of the Meadowbank Project is the temperature regime. The mean annual air temperature at the site is on the order of -11°C , with monthly temperatures exceeding 0°C for only three to four months of the year. This extremely cold climate presents operational challenges to processes that require the use of water. Consequently, all of the waste management operational considerations are affected by the cold temperatures

Capping of the tailings storage facility would consist of the placement of a coarse convective insulating layer of ultramafic rock over the facility to a minimum depth of about 2 m. This thickness is consistent with other cover designs over reactive tailings in the north. During winter convective heat transfer developed within the coarse cover material will transfer heat out of the tailings pile; during the summer trapped air within the voids will act as insulation. This will limit the depth of annual thaw penetration to within the acid-neutralizing ultramafic waste rock. During detailed design, a detailed cover design will be developed that will consider the addition of a fine grained layer of soil material as a base layer to the coarse rock cover. This layer would retain moisture within it resulting in a reduction in the thickness of the active layer. It is possible that this layer could consist of till material dozed in a thin layer over the tailings facility. There are sufficient quantities of till material that will be produced during pre-mining and pre-stripping that could be stockpiled and used for this purpose.

3.0 MEADOWBANK TAILINGS SITE SELECTION PROCESS

The tailings selection process for the Meadowbank project involved three main steps:

- developing a list of key site selection criterion;
- identifying potential tailing storage facilities and deposition methods; and
- developing a decision matrix model to evaluate potential storage facilities.

The site selection process was based on a decision matrix model to assess alternatives.

3.1 Initial Site Selection Criterion

Initially seven potential tailings storage sites were identified. These are listed in Table 3.1 along with the disposal methodology for each site, and are shown on Figure 5.

Table 3.1: Summary of Potential Tailing Storage Options

Option	Location	Disposal Type
A	Second Portage Arm and North Portage Pit	Sub-aqueous Slurry
B	Second Portage Arm	Sub-aerial Paste or Dry Stack
C	Second Portage Arm	Sub-aerial Slurry
D	Third Portage Lake	Sub-aqueous Slurry
E	East from Vault Haul Road	Sub-aerial Slurry
F	North of Second Portage Arm	Sub-aerial Slurry
G	North of Second Portage Arm	Sub-aerial Paste or Dry Stack

A list of initial site selection criterion that any tailings storage facility for the Meadowbank mine site must meet was developed. This list was used as an initial screening tool, and any locations that did not meet these criteria were eliminated from further analysis. The following key site selection criteria were utilized:

- The site was required to have sufficient volume to store planned volume of tailings;
- The site required the potential to provide additional capacity for tailings storage;
- The location would accommodate mine expansion;
- The location is within catchments of the open pits; and

- The site allows control and collection of the tailings supernatant.
- Low potential for failure of the containment facility

Based on the pre-screening assessment, only four of the initial seven options met the site selection criteria, as indicated in Table 3.2. Table 3.3 presents the results of the pre-screening process for the initial seven options.

Table 3.2: Options Evaluated Using the Decision Matrix

Option	Location	Disposal Type
B	Second Portage Arm	Sub-aerial Paste or Dry Stack
C	Second Portage Arm	Sub-aerial Slurry
F	North of Second Portage Arm	Sub-aerial Slurry
G	North of Second Portage Arm	Sub-aerial Paste or Dry Stack

Options B and C require draining of the northwest arm of Second Portage Lake. Options F and G are on land. All options require that the northwest arm of Second Portage Lake be diked and nearly completely drained.

Table 3.3: Tailings Site Selection Pre-Screening

		Option A	Option B	Option C	Option D	Option E	Option F	Option G
		2nd Portage Arm and North Portage Pit	Second Portage Arm	Second Portage Arm	Third Portage Lake	East of Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm
		Sub-aqueous slurry	Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack
		Construction – Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	Construction - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	Construction – Place silt curtain to control sediment dispersion or other sediment control and install and maintain pipeline.	Construction – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	Construction – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	Construction – build minor containment berms on frozen ground; install and maintain pipeline.
		Operation - Place tailings in Second Portage Arm until Year 6, then North Portage Pit. Use water above tailings for reclaim. Transport tailings by pipeline.	Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	Operation - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	Operation – deposit tailings into 3rd Portage Lake. Reclaim from Second Portage Arm (water management pond) and 3rd Portage Lake. Transport tailings by pipeline.	Operation - Place tailings slurry on surface. Use Second Portage Arm for water management, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	Operation - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	Operation - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.
Key Indicators	Sub-Indicators	Closure – Submerged tailings: Tailings remain submerged and thawed. Long term metal leaching potential.	Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure – Submerged tailings: Tailings remain submerged and thawed. Long term metal leaching potential.	Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.
Site Selection Criteria	Sufficient volume to store planned volume of tailings	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Potential for increased capacity	No	Yes	Yes	Yes	Yes	Yes	Yes
	Location enables mine expansion	No	Yes	Yes	Yes	Yes	Yes	Yes
	Impoundment is within catchment of open pits	Yes	Yes	Yes	No	No	Yes	Yes
	Allows control/collection of supernatant	Yes	Yes	Yes	No	Yes	Yes	Yes
	Potential candidate for tailings storage facility	No	Yes	Yes	No	No	Yes	Yes

3.2 Description of Possible Tailings Deposition Methods

The tailings deposition methods considered for use at the Meadowbank Project are:

- Sub-aqueous Slurry;
- Sub-aerial Slurry;
- Sub-aerial Dry Stack; and
- Sub-aerial Paste.

The following subsections provide a brief summary of each of these technologies.

3.2.1 Sub-Aqueous Slurry

This method of tailings deposition, involves the direct placement of tailings slurry into a body of water. The water body may consist of a natural lake, river, or other body of water, within an on-land flooded containment facility, or within a flooded pit. This type of tailings deposition method is commonly used in combination with wet ore mineral processing techniques. Slurries typically have solids contents between 20% and 40%, but may range between 5% and 50%. Tailings slurries are typically transported in pipelines or open channels to the containment area. Slurries may be deposited from a single point or multiple locations.

Sub-aqueous deposition implies that all tailings are deposited under water. This is primarily used when tailings have a high potential to produce ARD or severe dust problems. After slurry deposition, solids settle out and the supernatant water can then be decanted and recycled for use within the plant.

Engineered containment structures are built to control the area over which tailings are placed. These structures may consist of dykes or dams, and may be constructed using upstream, downstream or center line construction methods (Figure 6). Figure 7 shows a typical tailings dam structure and the associated water cycle (European Commission, 2004).

As part of this type of tailings management facility, diversion structures are commonly constructed to redirect natural surface water away from the tailings storage facility.

The following are examples of mines that use this type of tailings deposition: Hudson's Bay Ruttan Mine, Manitoba; Inco's Thompson Mine, Manitoba; Nanisivik Mine (initial deposition), Nunavut; Polaris Mine Nunavut ; and the Red Dog Mine, Alaska.

3.2.2 Sub-Aerial Slurry

Sub-aerial slurry deposition is generally the same as the sub-aqueous method of tailings deposition, but in this case the tailings are not all deposited under water. In general, the resulting density of the tailings when a sub-aerial method of deposition is used is greater than when sub-aqueous methods are used as settlement of the deposit is promoted through drainage and evaporation from the tailings beach.

Additional thickening techniques, often using chemical additives, may be employed to increase the solids content above 50% (typically 50% – 60%), thus improving storage efficiency.

Water within this type of facility may also be decanted and recycled for use within the plant.

As part of this type of tailings management facility, diversion structures are commonly constructed to redirect natural surface water away from the tailings storage facility.

The following are examples of mines that use this type of tailings deposition: Inco's Copper Cliff Mine, Ontario; Hudson's Bay Flin Flon, Manitoba; Kidd Creek Mine, Ontario; and Nanisivik Mine (later stage), Nunavut.

3.2.3 Sub-Aerial Dry Stack

An alternative to slurry type tailings deposition systems is called "dry stack". This method uses mechanical devices, such as high capacity vacuum and pressure belt filters, to dewater the tailings. The resulting tailings have about 50% to 70% solids, and are not able to be pumped. Instead they are transported by truck or conveyor system. It is important to note that these tailings are not truly "dry", but rather have moisture contents several percentage points below saturation.

Typically, these tailings are then placed, spread, and compacted to form an unsaturated, dense and stable mound. No additional containment structures are required such as dykes or dams.

This type of facility may be advantageous if the mine is:

- Located in an arid regions, where water conservation is a driving factor, and where subsequent saturation by precipitation is not an issue;
- Located in a high seismic area;

- In a region where water handling is difficult; and
- Limited by available space for disposal of tailings.

These facilities may result in a smaller footprint area due to their increased density; however, a secondary facility for re-circulation of water may still be required.

The nature of the tailings produced, both the grain size and mineralogy, can play an important role in determining the effectiveness of filter processing. Tailings with a high percentage of clay-sized particles and also clay mineralogy may negate the effectiveness of a filtering system.

These facilities still may require surface water runoff and seepage management systems. Ditches to redirect non-contact water away from the facility and ditches to collect runoff from the stack are utilized. Additionally, methods to collect seepage and prevent groundwater contamination may be required. A series of under drains, groundwater cut-off walls, or liners may be used. A closure cover is required to prevent erosion, prevent dust generation, and to provide an appropriate media for re-vegetation. Potentially acid generating tailings may require an infiltration barrier to reduce ARD generation.

Examples of dry stack tailings facilities are: Greens Creek Mine, Alaska; Raglan, Quebec; and La Coipa, Chile (Davies and Rice, 2001; Brown, 2002). Additional facilities are being considered or planned at: Pogo Gold Mine, Alaska; Las Cruces, Spain; and Mineral Hill, Montana.

3.2.4 Sub-Aerial Paste

Paste tailings have to be thickened using chemical additives, or a combination of mechanical devices and chemical additives, such as hydrating agents (i.e., Portland cement, fly ash), creating a slurry that will not separate. Pastes typically consist of approximately 60% solids for fine grained tailings and up to 80% solids for coarse tailings.

Paste tailings are frequently used for backfilling underground mines; however, surface disposal of paste tailings is also possible. Above ground use of paste technology, still requires the use of containment facilities, although due to the increased density of the tailings and lower moisture content, the size and/or height of the facilities may be reduced compared to other slurry type methods of disposal. Paste tailings can be transported using high pressure pipelines to the storage area. Two methods for deposition of paste tailings are shown in Figure 8.

These facilities require surface water runoff and seepage management systems. Ditches to redirect non-contact water way from the facility and ditches to collect runoff from the stack are utilized.

A secondary facility for re-circulation of water may still be required.

The following are examples of mines that use the paste method technology for tailings deposition: Bulyanhulu, Tanzania; Myra Falls, on Vancouver Island; and Kidd Creek Mine, Timmons, Ontario. The Colstrip power plant in Montana also utilizes this technology for fly ash disposal.

3.3 Description of the Potential Tailings Storage Areas

Based on the initial screening criteria, two potential tailings storage areas were identified:

- Storage within Second Portage Arm (Option B and Option C); and
- On land storage north of Second Portage Arm (Option F and Option G).

The following sections briefly describe these two areas and the ancillary components and structures for each of the Options that were evaluated.

3.3.1 Storage Within Second Portage Arm (Option B and Option C)

Option B

Option B is to dispose of the tailings as a Sub-aerial Paste or Dry Stack in the natural rock basin of the northwest arm of Second Portage Lake. This will require dewatering of this portion of the lake. As part of mine construction, a dike and haul road will be constructed across the east end of this portion of the lake to facilitate dewatering and mining of the Portage Deposit. The dike will isolate the northwest arm of Second Portage Lake from the remaining portion. The water level within the arm of Second Portage Lake would be lowered by 38 m (elevation 95 m asl). Once de-watered, the rock basin would freeze. Once the base was frozen, then thickened tailings (“dry stack”) or paste tailings would be transported, by truck (if dry stack method was selected) or by pipeline (if paste technology was utilized), and placed in lifts, such that each lift would freeze. The tailings stack at closure would be frozen and permafrost would eventually penetrate further into the base of the storage facility.

A separate water reclaim pond would be required, and would likely be constructed just to the west of the proposed plant site in a small basin of Third Portage Lake (sometimes referred to as Third Portage Arm). This small basin of Third Portage Lake would be isolated from the remaining portion of the lake by constructing small dikes. At the end of the mine life, the water quality within this basin would be monitored, and if it met water quality guidelines, the basin would be re-connected to the remainder of Third Portage Lake by removal of the dike system.

Using Third Portage Arm as a separate water reclaim pond will result in the temporary loss (at least 20 years) of approximately 305 habitat units (CRL, 2005h). This loss will persist during mine life and for some years beyond, while water quality improves after closure. The amount of habitat loss in this basin (305 habitat units) is nearly equivalent to the total number of habitat units permanently lost (370) from tailings disposal in the northwest arm of Second Portage Lake, despite the large difference in area between the two basins. This is because much of the northwest basin of Second Portage Lake consists of steep sloping, deep, low value habitat that contributes relatively little to overall habitat value. Third Portage Arm contains a greater amount of high value habitat (16.3 ha) than the northwest arm of Second Portage Lake (12.7 ha), explaining this apparent discrepancy.

The tailings facility within the northwest arm of Second Portage Lake would be progressively reclaimed during operations by covering with a layer of relatively inert capping material. The cover would be designed to contain the depth of annual thaw within the relatively benign capping material so that the entire tailings mass would remain encapsulated by permafrost. Advantages to the Option B method of tailings storage include the following:

- The option is inherently more stable than the other alternatives that place tailings on land, or at a higher 'potential energy'. Option B utilizes a natural depression with the tailings placed in a "dry" form.
- Regardless of where tailings are stored, the northwest arm of Second Portage Lake will be impacted by mine activities due to the construction of a series of de-watering dikes to allow mining of the ore. Consequently, this option takes advantage of a necessary requirement for the mining process to proceed, avoiding the need to construct a specific on-land disposal area which would result in a greater area of impact by the mine.
- The option is located immediately downstream from the proposed Portage Waste Rock Storage Facility. Runoff from the waste rock can be collected and managed within the facility if necessary.

-
- Freezing of the tailings and the talik beneath Second Portage Lake will limit the potential for ARD and ML generation and migration of contaminants into the surrounding environment (groundwater and surface water).
 - Second Portage Lake is currently a regional discharge point for deep groundwater flow. The hydraulic gradient will continue to be towards the lake once the lake level has been drawn down to allow mining. This will reduce the potential for contaminant migration into the surrounding environment. The potential for contaminant release is further reduced by the low hydraulic conductivity of the surrounding bedrock.
 - The surface of the facility is low relative to the surrounding topography, and relative to an equivalent facility that might be constructed on land. Consequently, the potential for the generation of dust from the tailings during operations and closure is less than for an equivalent on-land facility. Furthermore, capping of the tailings will reduce the potential for post-closure dust generation and also help ensure that tailings remain in a frozen state, year round.
 - The facility will be located close to the plant site and other mine facilities, which will make it easier to operate and will reduce the risk of operational problems.
 - The facility avoids significant losses of high suitability terrestrial wildlife habitats (i.e., 15.56 ha for Option B compared to 46.79 ha for Options F and G).
 - The option avoids wetland breeding habitats of Moderately High value in Options F and G.

Disadvantages to Option B method of tailings storage include the following:

- Temporary loss of 305 HUs in the Third Portage Lake if a reclaim pond is created within Third Portage arm.
- There is a greater potential for ARD generation during operation as tailings will be exposed to oxygen and therefore have the potential for sulfide oxidation.
- The northwest arm of Second Portage Lake will permanently contain tailings.

Option C

Option C is to dispose of tailings by sub-aerial deposition in the natural rock basin of the northwest arm of Second Portage Lake, and would involve partial dewatering. The East Dike and haul road that will be constructed across the east end of this portion of the lake to permit dewatering and mining of the Portage Deposit and to provide road access to the

plant site, as previously discussed, will isolate the northwest arm from the remaining portion of the lake. For Option C, the water level upstream will be lowered by 28 m (elevation 105 m asl) to permit tailings dike construction. Once the tailings dike has been constructed, slurried tailings would be transported by a pipeline and deposited within the tailings facility. The tailings and talik beneath the northwest arm of the lake will eventually freeze. The facility would be progressively reclaimed during operations by covering with a layer of relatively inert capping material. The cover would be designed to contain the depth of annual thaw within the relatively benign capping material so that the entire tailings mass would remain encapsulated by permafrost.

Advantages to the Option C method of tailings storage include:

- No additional temporary loss of fish habitat within Third Portage is necessary as reclaim water can be managed within the northwest arm of Second Portage Lake and then later within Goose Pit.
- The option is inherently more stable than other alternatives that place tailings on land, or at a higher 'potential energy' as it utilizes the natural depression of Second Portage Lake.
- Regardless of where tailings are stored, the northwest arm of Second Portage Lake will be impacted by mine activities due to the construction of a series of de-watering dikes to allow mining of the ore. Consequently, this option takes advantage of a necessary requirement for the mining process to proceed, avoiding the need to construct a specific on-land disposal area, which would result in a greater area of impact by the mine.
- The option is located immediately downstream from the proposed Portage Waste Rock Storage Facility. Runoff from the waste rock can be collected and managed within the facility.
- Freezing of the tailings and the talik beneath Second Portage Lake will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment (groundwater and surface water).
- Second Portage Lake is currently a regional discharge point for deep groundwater flow. The hydraulic gradient will continue to be towards the lake once the lake level has been drawn down to allow mining. This will reduce the potential for contaminant migration into the surrounding environment.
- The surface of the facility is low relative to the surrounding topography, and relative to an equivalent facility that might be constructed on land. Consequently, the

potential for the generation of dust from the tailings during operations and closure is less than for an equivalent on-land facility. Furthermore, capping of the tailings will reduce the potential for post-closure dust generation and also help ensure that tailings remain in a frozen state, year round.

- The facility will be located close to the plant site and other mine facilities, which will make it easier to operate and will reduce the risk of operational problems.
- This method of tailings management has been used at numerous locations, both in temperate and cold climates.

Disadvantages to the Option C method of tailings storage include:

- Higher potential for ML during operation, as tailings will be submerged and therefore have the potential for leaching and release of metals. However, leaching and release of metals will be contained within the storage facility.
- The northwest arm of Second Portage Lake will permanently contain tailings.

3.3.2 Storage North of Second Portage Arm (Option F and Option G)

Option F

Option F is to dispose of tailings slurry sub-aerially on land, north of Second Portage Lake. There are several small ponds and drainage channels in this area. However, these ponds are very shallow and freeze to the bottom during winter. Because of shallow depth, isolation and absence of fish, these ponds are not recognized as having productive fish habitat.

Option F would require the construction of conventional tailings containment berms on frozen ground in a permafrost region that contains soft compressible soils including peat and an active layer that is variable, all of which provide challenges to designing and constructing a geotechnically stable containment system. A geomembrane liner system would likely need to be installed on the tailings (upstream) side of the containment berms, and keyed into the permafrost. There are insufficient natural materials suitable for use as a liner. The berms would require additional quarrying of rock material which would create greater land disturbance. It is likely that the additional rock material for construction of the embankment berms would require the development of a separate quarry from the mining activities. Material from mining operations has been identified as potentially acid-generating, and the current mine plan takes this into consideration when defining where the material will be stored in specific waste storage facilities, and how the waste will be managed in the long term to minimize impacts on the environment.

Furthermore, the current plan optimizes the use of waste from pre-mining activities in the construction of the de-watering dikes, and specifically places potentially acid-generating material under water where possible. There would be insufficient quantities of material produced during pre-mining activities to be used for the construction of the extensive embankment system that would be required for on-land storage. In addition to this, based on the current understanding of the geochemistry of the materials produced from pre-mining activities, these would not be suitable for construction of the berms, as they would be continually exposed to an oxidizing environment in the thaw layer, and would be flushed annually during spring freshet, and during rain storm events. The run-off from the embankment system would need to be collected, managed, and treated unless an alternative quarry site of geochemically benign material could be identified and exploited for the construction of the berms.

Once the embankments were constructed, slurried tailings would be transported in a pipeline and deposited within the berms. Eventually, the tailings would freeze and the tailings would be encapsulated by permafrost. A capping system consisting of geochemically benign materials would need to be designed to limit infiltration of water into the tailings, and to restrict the annual thaw depth within this layer.

The dike and haul road that will be constructed across the east end of the northwest arm of Second Portage Lake to permit dewatering and mining of the Portage Deposit, will isolate the northwest arm from the remaining portion of the lake. For Option F, the northwest arm of Second Portage Lake would be used for water management and tailings reclaim water, and this basin would likely be permanently lost for fish habitat. A dike would need to be constructed in the area of the currently proposed tailings dike for water management purposes. Tailings reclaim water would also be stored and re-circulated from the tailings facility. Once mine operations were finished, the water contained within the northwest arm of Second Portage Lake would need to be treated. Once the treated water meets guideline requirements, the dike would be removed, reconnecting the northwest arm of Second Portage Lake with the rest of the lake.

Advantages to Option F method of tailings storage include:

- The northwest arm of Second Portage Lake may only be isolated from the remaining portion of the lake during the operational phase of the mine. Depending on the water quality at the completion of mine operation, it may be possible for the northwest arm to be re-connected with the remainder of the lake.
- Freezing of the tailings and the underlying soil layer will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment.

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- Capping of the tailings will reduce the potential for post-closure dust generation and will shed water, thus limiting infiltration into the facility.
 - This method of tailings management has been used in both temperate and cold climates.

Disadvantages to Option F method of tailings storage include:

- A substantial system of containment berms will need to be constructed on poor soil foundation conditions. Consequently, there is an elevated risk of failure of the foundations, and hence the containment berms. The containment facility would be constructed immediately up-slope of the northwest arm of Second Portage Lake. A failure of the containment berms could potentially result in the introduction of tailings into Second Portage Lake. The introduction of tailings into the lake could result in the development of a silt plume, which could conceivably impact the entire lake, although this would be a relatively short-term impact.
- There is a higher potential for dust generation during operation and closure, due to the higher relief. Wind erosion of the tailings surface during operations and during closure could result in the transportation and deposition of tailings over considerable distances down-wind of the facility.
- It is likely that a separate quarry source of non-potentially acid-generating (NPAG) rock will need to be developed to produce the materials required to construct the embankment berms. There are insufficient quantities of rock available from pre-mining activities to construct the perimeter de-watering dikes as well as embankment berms. The rock from the pre-mining activities is unsuitable for use as construction material for the scale of facility that would be required to enclose the tailings due to its potential for acid generation. If there were sufficient material available from pre-mining activities for this use, then a substantial water collection and treatment system would need to be constructed to collect run-off from the embankment berms.
- There is a higher potential for generating acidic drainage and leaching metals during operation as the tailings will be in a partially saturated state, and exposed to oxygen.
- The tailings facility will have greater visibility.
- The system would require a geomembrane liner or similar seepage cutoff system on the upstream face of the embankment berms, keyed into the permafrost.
- The mine footprint (area of disturbance) would be increased substantially.

- Native sediments in the northwest basin of Second Portage Lake may become metals contaminated due to prolonged contact with mine tailings reclaim water, which could pose a source of metals to the receiving environment for a prolonged period after re-flooding.
- The facility results in significant losses of high suitability terrestrial wildlife habitats (i.e., 46.79 ha for Option F compared to 15.56 ha for Options B and C).
- The option impacts wetland breeding habitats of Moderately High value.

Option G

Option G is to dispose of thickened (“dry”) or paste tailings sub-aerially on land, north of Second Portage Lake. There are several small non-fish-bearing ponds that are not considered suitable fish habitat due to their shallow depth and the typical thickness of ice that forms on their surfaces during the winter months.

The development of the site would involve constructing minor embankment berms and diversion ditches on frozen ground. Once the berms were constructed, tailings would be transported by truck (if dry stack method was selected) or by pipeline (if paste technology was utilized), and placed or deposited in lifts within the berms. Tailings would eventually freeze. A capping system, consisting of geochemically benign materials, would need to be designed to limit infiltration of water into the tailings, and to restrict the annual thaw depth within this layer.

As with Option F, the northwest arm of Second Portage Lake would be de-watered, and a water containment dike would be constructed along the western edge of the proposed Portage Pit. The purpose of the dike would be to allow the management of site water and tailings reclaim water within the arm of Second Portage Lake. As an alternative to the use of the arm of Second Portage Lake for water management, the arm of Third Portage Lake, immediately to the west of the mill and mine site process plant, could be isolated by the construction of dikes, and then used to manage site and tailings reclaim water.

Advantages to Option G method of tailings storage include:

- The northwest arm of Second Portage Lake may only be isolated from the remaining portion of the lake during the operational phase of the mine. Depending on the water quality at the completion of mine operation, it may be possible for the northwest arm to be re-connected with the remainder of the lake.
- The height of containment dikes will be less than for Option F.

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- Freezing of the tailings and the underlying soil layer will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment.
 - Capping of the tailings will reduce the potential for post-closure dust generation and will shed water, thus limiting infiltration into the facility.

Disadvantages to Option G method of tailings storage include:

- There is a higher potential for dust generation during operation and closure, due to the higher relief. Wind erosion of the tailings surface during operations and during closure could result in the transportation and deposition of tailings over considerable distances down-wind of the facility.
- There is a high potential for the generation of acidic run-off during operation, as tailings will be only partially saturated, thus exposed to oxygen enabling sulfide oxidation to occur.
- The tailings facility will be more readily visible.
- Long containment berms will need to be constructed on poor soil foundation conditions. These berms will be less than those required for Option F; however, an inherent risk of failure remains and therefore, a risk of releasing tailings to the environment.
- Native sediments in the northwest basin of Second Portage Lake may become metals-contaminated due to prolonged contact with mine tailings reclaim water, which could pose a source of metals to the receiving environment for a prolonged period after re-flooding.
- The facility results in significant losses of high suitability terrestrial wildlife habitats (i.e., 46.79 ha for Option G compared to 15.56 ha for Options B and C).
- The option impacts wetland breeding habitats of Moderately High value.

4.0 MEADOWBANK DECISION MATRIX MODEL

4.1 Decision Matrix Models

Decision matrix types of analyses are also sometimes referred to as Multiple Accounts Analyses (MAA) or alternatives analyses. These types of analyses have been used as site selection tools for tailings facilities and other mining related decision processes including

at: Zortman and Landusky Mine Sites, Montana (Shaw *et.al.*, 2001), Red Dog Mine, Alaska (Northern Miner, 2005), and Questa Molybdenum Mine, New Mexico (MolyCorp Watch Project). Numerous papers have been published on the subject of Multiple Accounts Analyses such as: Robertson and Shaw (1998 and 1999); Caldwell and Robertson (1983); Vick (1990); Brown (2002); and the Decision Makers Field Guide (2005).

Similar types of analyses are also used in the fields of risk assessment, risk management, selection of the best available technologies or options for environmental remediation projects, resource planning, and sustainable development (Canter, 1985; International Atomic Energy Agency, 2000; CH2MHill, 2004, Robson Valley Land and Resource Management Plan, 1999).

4.2 Site Selection Factors

The development of the decision matrix model for the Meadowbank Project first involved developing a site specific list of criteria that would be utilized to evaluate and rank the facilities. The criteria covered three main areas:

- environmental factors;
- operational factors; and
- economic factors.

This section will explain in greater detail the decision matrix methodology and each of the sub-indicators used in the site selection process within the three primary categories of environmental, operational, and economic factors. Sub-indicators were chosen to evaluate a wide spectrum of potential impacts, without double counting impacts.

Each of the factors was further subdivided into sub-indicators, in order to evaluate specific aspects. Weightings were assigned to each factor and sub-indicator.

Each tailings facility option was then evaluated based on the sub-indicator and a relative score was assigned. These scores were then multiplied by the weighting factors and summed to give the overall score. The options were then ranked according to the overall score, with the highest score indicating the preferred option.

Quantitative methods were utilized to assign the relative scores where possible, however some sub-indicators necessitated the use of qualitative assessment. Judgement and perception of the individual conducting the analyses is inevitably a part of any such decision making system, both in the assignment of qualitative scores and of weighting factors.

The weighting factors were specifically designed to place a higher significance on the environmental factors, and less on the operational and economic factors.

Some sub-indicators, such as the potential for the tailings facility to generate acid rock drainage (ARD), were divided into two components: the potential for impact during mine construction and operation, and the potential for long-term impact, after mine closure. In these cases the long-term sub-indicator was generally assigned a higher weighting than the short term operation sub-indicator.

4.3 Environmental Factors

The European Commission published a Report on Best Available Techniques (BAT) reference document for Management of Tailings and Waste-Rock in Mining Activities (2004). This document was developed in response to a Communication from the European Commission COM(2000) 664 [COM(2003) 319 final, 2.6.2003] on the 'Safe Operation of Mining Activities' that was a follow-up action to tailings dam bursts that occurred in Aznalcollar and Baia Mare. The follow-up measures included an elaboration of the BAT Reference Document based on an exchange of information between European Union's Member States and the mining industry. The document was developed in response to the Commission's initiative and in anticipation of the proposed Directive on the management of waste from extractive industries (European Commission, 2004). The following key environmental issues or impacts associated with tailings facilities were listed in this document:

- Site specific issues relating to facility location and relative land take;
- Potential emissions of dust and effluents during operation (to air, land and water) and their impact;
- Potential emissions of dust and effluents after closure (to air, land and water) and their impact;
- ARD and metal leaching generation, release and impact;
- Potential releases due to failures of facilities (i.e., burst or collapses of tailing management facilities); and
- Site rehabilitation and aftercare to minimize environmental impacts.

In accordance with the intention to utilize Best Available Techniques to respect environmental considerations, a list of sub-indicators was developed and used to evaluate

the various tailings options. These sub-indicators are presented in the following table and are described briefly in subsequent sections.

Table 4.1: Environmental Sub-Indicators

	Sub-Indicators
Environmental Factors	Sub-catchment area
	Footprint area
	Potential for generating dust during operation
	Potential for generating dust after closure
	Potential for Acid Rock Drainage (ARD) generation during operation
	Potential for ARD generation after closure
	Potential for metal leaching (ML) during operation
	Potential for ML after closure
	Potential for seepage to impact groundwater during operation
	Potential for seepage to impact groundwater after closure
	Potential for geotechnical hazards ¹
	Permanent aquatic habitat loss [Lake area impacted] ²
	Temporary aquatic habitat loss [Number of lakes impacted] ²
	Visual impact
	Terrestrial wildlife habitat loss (song birds, water fowl and terrestrial mammals) ²
	Aquatic wildlife habitat loss (water fowl) [Impact on fish and fish habitat] ²

Note:

- 1 Includes consideration of foundation conditions, impact of seismicity, and height of structure.
- 2 Categories added at request of DFO and EC (i.e., new and additional sub-indicators to original study). Square brackets indicate sub-indicators in original tailings site selection document (Golder, October 2005), and modified for Technical Memorandum (Golder, February 2006).

4.3.1 Sub-Catchment Area

A catchment is an area of land bounded by natural high points (hills, ridges and mountains). Surface water (rainfall and runoff) flows down through the catchment area and into one low point (a creek, river or bay). Catchment areas may be further divided into sub-catchments; typically each sub-catchment area will have homogeneous physical characteristics.

Sub-catchment area for the purpose of this evaluation was defined as the primary portion of the watershed that would be impacted by the deposited tailings. The total

sub-catchment area (hectares) was used to assign the relative scores and determine the impact of each option. Options having lower sub-catchment areas are preferable to those with greater areas, and hence were assigned a relatively higher score.

4.3.2 Footprint Area

The footprint area of the tailings storage facility is defined as the area covered by the deposited tailings both on land and in water. The total footprint area, in hectares, was used to assign the relative scores and judge the impact of each facility location. The site having the smallest footprint area was given the highest relative score, and the other options were assigned a lower score, relative to their footprint area.

4.3.3 Potential for Generating Dust During Operations

The relative potential for each facility and tailings deposition method to generate dust during mine operation was qualitatively judged and a value of low, moderate, or high was assigned. This factor is dependent on the method of tailings deposition selected and the relative exposure of the site to wind. In assessing this indicator, a tailings site having the lowest topographic profile, or within an area of low topographic relief, would have a high relative value assigned representing a more desirable site. A site having high topographic profile, and located in an area exposed to wind, would be assigned a low relative value, representing a less desirable site.

At the Meadowbank Project site, the prevailing wind direction is from the northwest, averaging about 20 km/h to 30 km/h. The maximum daily wind gust recorded at the Meadowbank climate station was 83 km/h. A tailings facility located on-land and substantially exposed above ground would have the potential for on-going dust generation during operations and during closure. The dispersion of dust could potentially result in deposition in lakes and on land down wind of the source. A facility located topographically as low as possible would be preferable in that the potential for on-going dust generation and down-wind dispersion over water and land would be reduced.

4.3.4 Potential for Generating Dust After Closure

The relative potential for each facility to generate dust after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is dependent on the planned method for closure, grain size of cover material, including methods of erosion protection, topographic profile, and exposure of the site to wind. A facility that as part of the closure plan is to be covered, thus reducing or eliminating the potential for dust, either by a rock, soil or vegetative cap, or underwater, would have a high relative value assigned. A facility that remained exposed after mine closure would have a low value assigned.

4.3.5 Potential for Acid Rock Drainage (ARD) Generation During Operation

Geochemical testing has shown that tailings at Meadowbank contain metal sulphides and will have the potential to generate ARD. The relative potential for each facility to generate ARD during mine operation was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition and the planned method of operation that may minimize the generation of ARD.

Sulphides oxidize when exposed to oxygen and air, which in turn creates an acidic metal-laden leachate and can be generated over a prolonged period of time if acid buffering minerals are not present. The rate of generation of ARD is accelerated with fine particles as the surface area potentially exposed to oxygen is much greater, which is typically the case when dealing with tailings and processed mine waste. Other factors that may increase the rate of ARD generation are: high oxygen concentration, high temperature, low pH, and bacterial activity (European Commission, 2004).

Tailings deposition methods that reduce or prevent the generation of ARD would receive a higher score. For example, methods that reduce or eliminate exposure to oxygen, such as through the use of submerged tailings facilities, or permafrost encapsulation would receive a higher relative score, in comparison to facilities where tailings are exposed to oxygen (i.e., aerial). Alternatively, facilities that mix acid generating tailings with buffering agents would receive a higher score in comparison to the same facility with insufficient buffering agents. Facilities that maintain tailings at low temperatures and in a frozen state through permafrost encapsulation would receive a high score.

4.3.6 Potential for ARD Generation After Closure

The relative potential for each facility to generate ARD after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition, and the planned method for closure which may reduce or control generation of ARD. As discussed in the previous subsection, facilities that in the long term control factors that lead to acid generation, would receive a relatively higher score in comparison to facilities that do not control these factors. Deposition and maintenance of a submerged facility, a lined and dry facility, or a permafrost encapsulated facility would receive higher scores, in comparison to above ground facilities exposed to air and precipitation.

4.3.7 Potential for Metal Leaching (ML) Generation During Operation

Geochemical testing has shown that tailings generated at Meadowbank will have the potential to generate ML (Golder, 2005b). The impact of metals released into the

environment may be toxic, but depends on many factors including: concentration, pH, temperature, and water hardness (European Commission, 2004). Figure 9 schematically shows some of the primary geochemical and physical processes and their interaction that may lead to the generation of ARD and the potential release of metals (ML).

The relative potential for each facility to generate ML during mine operation was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition and the planned method of operation that may minimize the generation of ML. Facilities that reduce or eliminate the generation and/or transmission of soluble metals to the environment (i.e., hydraulic containment) would receive a high relative score, in comparison to facilities that do not control metal leaching.

Metals may leach from tailings irrespective of the pH, therefore controlling the flux of water through and out of the tailings facility may have the most significant impact on reducing the release of constituents. Consequently, management strategies that limit infiltration of water into the tailings facility, and limit the ability for tailings to come into contact with natural water sources such as groundwater, surface water, and precipitation, through the use of permafrost encapsulation, low permeability cover systems, containment berms and diversion ditches, are preferable.

4.3.8 Potential for ML Generation After Closure

The relative potential for each facility to generate ML after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition, and the planned method for closure which may reduce or control generation and migration of ML. The evaluation of this sub-indicator is the same as discussed in the previous subsection.

4.3.9 Potential for Seepage to Impact Groundwater During Operation

The relative potential for seepage from each facility to impact groundwater resources during operation was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition, the planned method of operation, including any steps that will be taken to control groundwater discharges, and groundwater flow paths and flow rates of the site (i.e., groundwater discharge or recharge area). Facilities that produce low rates of seepage and seepage with low levels of contamination would receive a high relative score in comparison to facilities that are expected to generate high quantities of seepage with a high concentration of contaminants (including metals and low pH).

One method of reducing the potential for groundwater impact may be achieved by controlling the flux of water through the facility. During operation flow through the facility may be controlled by the surrounding berms and liner or low permeability boundary. Facility liners may be man-made or natural, such as low permeability rock, till, clay, permafrost, or synthetic materials (i.e., high density polyethylene). Materials such as sands and gravels, or highly fractured rock are highly conductive and would not reduce the flux through the facility.

At the Meadowbank Project site, the hydraulic conductivity of the bedrock is on the order of 10^{-8} m/s, while that of the overburden materials is on the order of 10^{-6} to 10^{-5} m/s. Consequently, a naturally contained basin facility underlain by bedrock would be preferable to an engineered facility underlain by till.

4.3.10 Potential for Seepage to Impact Groundwater After Closure

The relative potential for seepage from each facility to impact groundwater resources after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of tailings deposition, planned methods to control groundwater discharges, and the planned closure method, as discussed in the previous section. Facilities that generate low rates of seepage and seepage with low levels of contamination would receive a high relative score in comparison to facilities that are expected to generate high quantities of seepage with higher concentration of contaminants.

4.3.11 Potential for Geotechnical Hazards

The relative potential for geotechnical hazards to exist at each facility was qualitatively judged and a value of low, moderate or high was assigned. The assessment considered foundation conditions, seismic activity, and height and type of structure. Tailings facilities may be constructed using very high dams, and very long perimeter dykes. These may contain large quantities of mobile tailings that can be released to the environment if the retaining structures fail either through the man-made perimeter dikes and dams, or failure through the foundation materials due to low strength.

If the tailings are deposited on-land, within a storage facility, the facility will require the construction of several kilometers of dikes. The dikes will be engineered structures constructed with processed materials. The performance and stability of these structures will depend on the foundation conditions, foundation preparation, fill materials, and quality of the construction. Experience at the site has shown that the till materials can be problematic to construct with, having high moisture content and low strength. Consequently, there is a higher inherent risk associated with failure of an engineered structure constructed on weak soils. This risk increases with the length of the structure.

It is desirable from an environmental perspective to minimize the reliance on engineered structures.

Facilities constructed at higher relative elevations will have a greater relative potential energy compared with facilities constructed at lower elevations. Consequently, there is a greater risk associated with facilities at higher elevations as a breach and release of tailings from these facilities will move to an elevation having a lower potential energy. Such a failure could result in the release of tailings to the environment. If the site was located directly upslope of a fish bearing lake then there is the potential for damage to fish stocks not only in that lake but also to downstream habitat and fish stocks. The use of natural depressions at lower relative elevations considerably reduces the reliance on engineered structures, and hence the geotechnical and environmental risks associated with these structures.

4.3.12 Permanent and Temporary Aquatic Habitat Loss

The expected quality (i.e., low, medium, high) of and quantity of lake area (i.e. aquatic habitat) impacted by each of the tailings facilities (tailings deposition and reclaim water) was determined and was used to assign the relative scores and judge the impact of each facility location. The facility with the lowest relative quantity of high quality habitat area impacted would receive a higher score, relative to a facility that impacts a greater amount of high value habitat area. Furthermore, habitat loss was divided into permanent and temporary categories, as each option has the potential to affect different amounts of habitat units in different lakes for varying lengths of time.

4.3.13 Visual Impact

The relative visual impact for each facility was qualitatively judged and a value of low, moderate, or high was assigned. This factor considered such items as height, shape, and contrast with the surrounding terrain. A facility with a low profile and that would blend in with the surrounding area would receive a higher relative score than a facility with a high topographic relief, that did not blend into the surrounding terrain.

4.3.14 Terrestrial Wildlife Habitat Loss

The projected footprint area losses of high suitability terrestrial wildlife habitats was determined for each of the different tailings management options. In this context, terrestrial wildlife includes wildlife Valued Ecosystem Components (VECs) that could be significantly impacted by terrestrial habitat losses. These VECs include ungulates, small mammals, waterfowl, and other breeding birds. For the purposes of this alternatives analysis, uncommon and wide-ranging wildlife species, including predatory mammals

and raptors, were not included. For ungulates, the footprint area loss of high suitability habitat was determined for both the growing and winter seasons.

4.3.15 Aquatic Wildlife Habitat Loss

A value representing the relative loss of aquatic wildlife habitat resulting from each option was evaluated by comparing the habitats that would be lost to the best available habitats in Nunavut, such that the best habitats were assigned the highest values. Examples of such valuable habitats include extensive, shallow and productive wetlands with emergent and riparian shoreline and an abundance of prey species. In contrast, deep water lakes, with an absence of riparian habitats, islands for nesting, and prey species such as fish, were assigned the lowest values. Aquatic wildlife in this context refers primarily to the Waterfowl VEC whose members utilize lakes, ponds and shorelines for breeding, foraging, rearing of young, and staging during migration.

4.4 Operational Factors

Table 4.2 presents a list of the sub-indicators that were used to evaluate the operational factors for the tailings options under consideration. The following subsections briefly describe each of these sub-indicators and how they were evaluated.

Table 4.2: Operational Sub-Indicators

	Sub-Indicators
Operational Factors	Ease of operation
	Distance from mill
	Potential for delays due to freezing
	Construction risk
	Disposal system has precedent in arctic environment
	Ease of closure ¹

¹ Categories added at request of DFO and EC (i.e., new and additional sub-indicators to original study). Square brackets indicate sub-indicators in original tailings site selection document (Golder, October 2005), and modified for Technical Memorandum (Golder, February 2006).

4.4.1 Ease of Operation

The relative ease of operation of each facility was qualitatively judged and a value of low, moderate, or high was assigned. Various factors were considered including such items as: number of personnel, energy requirements, and mechanical components. For example, a gravity drain system may be judged as being easier to operate than a system that required three pumping stations. In this case the gravity system would receive a

relatively higher score than the alternative system. Another example would be a facility that requires multiple tailings discharge locations may be less desirable than a facility with a single discharge point, especially considering the Arctic climate.

4.4.2 Distance from Mill

The nominal distance from the mill to the proposed tailings discharge location was determined. This value was used to assign a relative score for each tailings facility based on the proximity to the mill. The facility closest to the mill would receive the highest relative score, and the facility located furthest from the mill would receive the lowest relative score. Increased distance results in higher pumping power requirements, higher risk of pipe blockage either due to freezing or sanding, and increased pipe maintenance. It is also recognized that reduced distance from the mill allows more frequent inspections and facilitates maintenance.

4.4.3 Potential for Delays due to Freezing

The relative potential for delays to be caused due to freezing that would impact mining processing operations was qualitatively judged and a value of low, moderate, or high was assigned. This considered various factors including; deposition method, tailings transport method, and ability to operate a reclaim pond. Facilities that were judged as being more susceptible to freezing that could then cause delays within other portions of the plant received a relatively low score, whereas facilities that were less subject to freezing received a relatively high score.

For example a facility that required multiple pumping stations or a longer pipeline for transport of tailings and reclaim water would likely be more susceptible to freezing and therefore cause delays than a system that required only one pump, and transport length was shorter.

4.4.4 Construction Risk

The relative potential for delays or problems to occur during construction was qualitatively judged and a value of low, moderate, or high was assigned. Various factors including: type of construction, likely construction schedule, and site conditions, were taken into account. Facilities that utilized local materials that can be placed on a year round basis received a higher score. In comparison, facilities that required a large number of components to be imported, and that could only be delivered by ship and during summer months when the port is open and free of ice, received a lower score.

4.4.5 Disposal System has Precedent in Arctic Environment

The relative precedent for use of each of the proposed tailings deposition methods was qualitatively judged based on the evaluators' experience and published literature, and a value of low, moderate, or high was assigned. Facilities that have been successfully built and operated in arctic climates received relatively higher scores than facilities that have not been built or rarely built in arctic climates. A list of various tailings management systems used in Arctic or cold climate regions are shown in Table 4.3. The list is not comprehensive but is intended to provide the reader with additional background as to which management strategies are commonly used in the north.

4.4.6 Ease of Closure

The relative ease of closure of each facility was qualitatively judged and a value of low, moderate, or high was assigned. Various factors were considered including such items as: number of personnel requirements, energy requirements, material requirements, equipment requirements, and economic factors. For the cases considered, the distance from the plant facility, open pit, and accessibility to waste is an important criterion from a decision making perspective. For example, suitable waste rock material will be used to progressively reclaim the facility, starting during operations, and completing during the closure stage. A facility that is further away from the available material will be judged to have a lower ease of closure than one that is located close, or adjacent to the required materials. In the case of the facilities considered, there was very little difference with respect to the subjective rankings used to assess them. The on-land facilities that were considered were judged to be slightly more difficult to close than would be a facility located in the northwest arm of Second Portage Lake.

Table 4.3
Tailings Deposition Methods in Arctic or Cold Climates

Mine Name	Owner	Location	Tailings Disposal Method	Notes
Ruttan Mine	Hudson's Bay Mine & Smelting	Northern Manitoba	Sub-aqueous slurry	- initial deposition in lake until filled - under construction, to be completed in late 2005 - into a lake with dams - planned - initially in on land containment facility now in mined out flooded pit - in open pit with a drainage layer surrounding tailings (wall and base)
Thompson Mine	Inco	Manitoba	Sub-aqueous slurry	
Nanisivik Mine	Breakwater Resources Ltd	Nunavut	Sub-aqueous slurry	
Red Dog Mine	Teck Cominco	Alaska	Sub-aqueous slurry	
Voisey's Bay	Inco	Newfoundland (Labrador)	Sub-aqueous slurry	
Colomac Mine	Comaplex Minerals Corp.	Northwest Territories	Sub-aqueous slurry and sub-aerial slurry	
Doris North Project	Miramar Hope Bay Ltd.	Nunavut	Sub-aqueous slurry	
Key Lake	Cameco	Northern Saskatchewan	Sub-aqueous slurry	
Rabitt Lake	Cameco	Northern Saskatchewan	Sub-aerial slurry, will be sub-aqueous at closure	
Copper Cliff Mine	Inco	Sudbury	Sub-aerial slurry	- Thickened to 60-65% deposited from center in a cone - later stage deposition in cells above lake - permafrost encapsulation - in dammed valley, closure will be: sub-aqueous using engineered wetlands as remediation, permafrost encapsulation - deposited in cells, saturated final cover, and paste for underground backfill, permafrost encapsulation
FlinFlon	Hudson's Bay Mine & Smelting	Northern Manitoba	Sub-aerial slurry	
Kidd Creek Mine	Falconbridge (Falconbridge-Noranda)	Timmins	Sub-aerial slurry	
Nanisivik Mine	Breakwater Resources Ltd.	Nunavut	Sub-aerial slurry	
Fort Knox and True North	Kinross Gold Corporation	Alaska	Sub-aerial slurry	
Rankin Inlet	Asamera Minerals Inc.	Nunavut	Sub-aerial slurry in pit	
Lupin Mine	Echo Bay Mines Ltd.	Nunavut	Sub-aerial slurry	
Ekati Mine	BHP	Northwest Territories	Thickened tailings (50%) - sub aerial and sub-aqueous	- in dammed lake with lake level raised - non acidic generating
Polaris Mine	Teck Cominco (formerly Cominco)	Cornwallis Island, Nunavut	Thickened tailings	- deposition in lake
Greens Creek Mine	Hecla Mining Company	Alaska	Sub-aerial dry stack	- permafrost encapsulation - Tailings are filtered to recover excess water as well as residual cyanide and metal credits - final permitting and construction - in the planning stages
Raglan Mine	Falconbridge (Falconbridge-Noranda)	Quebec	Sub-aerial dry stack	
La Coipa	Mantos de Oro (Placer Dome)	Chile	Sub-aerial dry stack	
Pogo Gold Mine	Teck Cominco and Sumitomo Metal Mining	Alaska	Sub-aerial dry stack in valley impoundment and underground paste backfill	
Mineral Hill Mine	Triako Resources Limited	Montana	Sub-aerial dry stack	
Met Site, Kidd Creek Mine	Falconbridge (Falconbridge-Noranda)	Timmins	Sub-aerial paste (thickened)	- radius of the conical pile is 1.2km and the height of the cone is 25m. The height of the cone increases by 0.2m/y and by closure the height is expected to be 29m
Colstrip power plant	LLC, Portland General Electric Company, Puget Sound Energy, PacifiCorp, AVISTA Corporation and NorthWestern Energy LLC	Montana	Sub-aerial paste	- for fly ash disposal
Snap Lake	De Beers Canada	Northwest Territories	Sub-aerial paste and paste backfill underground	- non acidic generating are placed on land
Kubaka Mine	Omolon Mining Company (operators facility is a joint venture)	Russia	Tailings facility as consisting of two levels; Partially dry tailings in the upper level, and lower level holding the liquid tailings	- permafrost as containment
Colomac Mine	N.W.T.	Northwest Territories	Sub-aqueous slurry	final closure final closure inactive
Illinois Creek	Quest Capital Corp.	Alaska	Tailings slurry	
Ryan Lode	Bartholome	Alaska	Lined earthen Dam with reclaimed water system	
Nixon Fork	St. Andrews Goldfields LTD	Alaska	Lined earthen Dam with reclaimed water system	
Julietta	Bema	Russia Far east	Paste tailings 85-90% solids in to surface facility	- under constrction
Kumtor	Cameco, Kyrgyz Govt	Kyrgyzstan	Sub- aerial	
Con	Miramar	Yellowkife	Sub aerial	
Giant	Diand (formerly Royal Oak)	Yellowkife	Sub aerial	
Pogo	Teck Cominco (formerly Cominco)	Alaska	Dry Stack	
Kemess	Northgate	BC	De-watered slurry	
Huckleberry	Imperial Metals Corporation	BC	De-watered slurry	
Mount Polley	Imperial Metals Corp.	BC	Tailings slurry	
Diavik	DDMI, Rio Tino	NWT	Fine Pk as sub-aerial slurry into HDPE and coletanche bitumenous lined containment, coarse pk trucked moist and dumped (stacked) in till lined containment	
Snap lake	Debeers	NWT	Paste tailings on surface into cells	

4.5 Economic Factors

The economic factors influencing each of the tailings options were considered. The following table presents the sub-indicators that were used to evaluate the economic factors for the tailings options under consideration based on an assessment of the present value of costs.

Table 4.4: Economic Sub-Indicators

	Sub-Indicator
Economic Factors	Total present value of costs (initial costs + delayed costs)

The total present value costs for each facility were estimated and used to rank the facilities. This value includes initial construction costs, facility operational costs over the ten-year mine life, and closure costs. An 8% interest rate was used for these calculations. The resulting total costs were then ranked and scored, with the lowest cost allocated the highest score.

4.5.1 Assumptions

Initial Capital Cost Estimates

The capital cost factors presented in the base case and subsequent decision matrices are based on general assumptions of unit costs for construction of the related facilities. The cost factors that are presented are intended as ‘order-of-magnitude’ estimates of the actual costs to allow a relative comparison of the cost impact on the project of the various options that have been considered. The costs are not intended to represent the detailed project costs, but the relative impact on the equivalent project cost components.

The following is a list of items considered in the costs that were developed to compare economic factors:

- Tailings dike construction – rockfill;
- Tailings dike construction – till;
- Pipeline (mill to tailings impoundment);
- Pipeline (to reclaim pond);
- Pipeline (reclaim to mill);
- Reclaim barge, including pump;

- Additional pumps;
- Tailings thickener;
- Water pond construction costs; and
- Tailings pumps (relative to disposal into the northwest arm of Second Portage Lake), lowest cost).

Rockfill and Till Relative Costs

The tailings dike construction costs for disposal into the northwest arm of Second Portage Lake (defined later in this report as tailings disposal Options B and C), were considered to represent the base case cost whereby haulage of material from the open pits to the location of the tailings dike is the shortest possible distance from the active mining location. Any distance beyond this base case represents additional haulage costs to the project. Consequently, the construction of an on-land facility north of Second Portage Lake would require additional haulage costs for rockfill and till in excess of the costs required to build a tailings dike at the closest point to the active mining area, which would be required for disposal into the northwest arm of Second Portage Lake. Additional haulage costs for rockfill are based on an estimated cost of \$1.00/m³, while additional haulage costs for till is based on an estimated \$7.00/m³.

Tailings Impoundment and Water Reclaim System Components

Pipeline costs for all alternatives were estimated based on \$350 per lineal metre of piping. The quantities estimated for the main components of a tailings impoundment and reclaim system, and on which the initial capital cost comparison in the decision matrix are based, are summarized in the following table. The unit costs used in the evaluation are considered to be reasonable approximations for relative cost comparison purposes, which was the intention of the cost evaluation.

Table 4.5: Quantities Estimated for the Main Components of Tailings Impound and Reclaim System

Item	Unit cost	Units	Quantity			
			B	C	F	G
Pipeline (Mill to Tailings Impoundment)	\$350	m	2,600	2,800	4,100	4,100
Pipeline (to Reclaim Pond)	\$350	m	800	0	1,600	1,000
Pipeline (Reclaim to Mill)	\$350	m	800	2,800	1,200	1,000
Reclaim barge including pump	\$800,000	each	1	1	1	1
Additional pumps	\$100,000	each	0	1	1	0
Tailings thickener	\$9,000,000	each	1	0	0	1
Water pond construction costs	\$5	m3	92,000	Internal	Internal	2 nd or 3 rd Portage Lake
Tailings pumps (relative to Option C)	\$200,000	each	0	1	2	0

Net Present Value of Delayed Cost

In addition to the estimates of initial capital costs for comparison purposes, the net present value of the deferred costs are estimated and included in the assessment of the economic factors. As with the initial capital costs, the assessment is not intended to be a rigorous detailed economic evaluation of the overall project, but is intended to allow a relative comparison of the discounted costs for the main components comprising the tailings storage options that are considered. The costs used in the evaluation are considered to be reasonable for relative comparison purposes, and exact costs are not necessary.

In assessing the net present value (NPV) of the delayed costs, the following cost components are considered:

- Tailings dike raise construction – rockfill;
- Tailings dike raise construction – till;
- Water pond dike construction; and
- Reclamation costs associated with capping of the tailings facility at closure.

The estimates of reclamation costs associated with the capping of the facilities are based on \$0.50/m³. Capping volumes are estimated assuming a final thickness of 2 m spread

over the footprint area of the tailings impoundment facilities evaluated in the decision matrix.

4.6 Weighting Factors and Scoring

The contributions of the three primary categories were assigned weightings so that the overall contribution of the primary categories to the outcome of the decision matrix was as follows.

**Table 4.6: Contribution of the Primary Categories to Weighting Factors
Used in the Decision Matrix**

Primary Category	Contribution to Overall Weighting¹
Environmental	54%
Operational	34%
Economic	11%

4.6.1 Scale Factor

In order to separate the best alternatives from the worst, a scaling, or scoring factor was applied (S_{IND}). Each sub-indicator was assigned a score between 1 and 9 points, similar to the system described by Robertson and Shaw (1999). The scores provide a relative ranking between the options with the 'best' option receiving a score of 9, and the 'worst' a score of 1. All subsequent options were then compared to the 'best' option and assigned a lower relative score.

An example of the scoring method is presented in Table 4.7.

Table 4.7: Example of Scoring System used in the Decision Matrix

Option	Distance to Mill	Points	Notes
A	1 km	9	9 points awarded for the facility located closest to the mill (BEST)
		8	
		7	
		6	
C	2 km	5	9 points x 1 km (BEST)/2 km = 5 points
		4	
B	3 km	3	9 points x 1 km (BEST)/3 km = 3 points
		2	
		1	

4.6.2 Relative Weighting Factor

Each sub-indicator of the primary categories was assigned a relative weighting factor (W_{IND}), ranging from one to ten, to introduce a value bias between the individual sub-indicators, based on the relative subjective importance of one indicator versus another. A higher weighting factor indicates a perceived greater relative value or importance between sub-indicators. For example, the relative importance of the impact of a disposal on fish and fish habitat is considered greater than the visual impact of the facility. Consequently, the sub-indicator of fish and fish habitat has been given a relative weighting factor that is four-and-a-half times greater than the weighting factor for visual impact.

Table 4.8 presents the weighting factors for the sub-indicators in each of the primary categories, as well as the maximum possible value and maximum possible score that could potentially be achieved.

Table 4.8: Weighting Factors for Sub-Indicators

Factor	Sub-Indicator	Relative Weighting	Max, Possible Score	Max. Possible Weighted Score ¹	Max. Possible Category Score ¹
Environmental	Sub-catchment area	1	9	9	603
	Footprint area	1	9	9	
	Potential for generating dust during operation	6	9	54	
	Potential for generating dust after closure	4	9	36	
	Potential for Acid Rock Drainage (ARD) generation during operation	5	9	45	
	Potential for ARD generation after closure	7	9	63	
	Potential for metal leaching (ML) during operation	2	9	18	
	Potential for ML after closure	5	9	45	
	Potential for seepage to impact groundwater during operation	5	9	45	
	Potential for seepage to impact groundwater after closure	6	9	54	
	Potential for geotechnical hazards ²	5	9	45	
	<u>Permanent aquatic habitat loss</u> ³	10	9	90	
	<u>Temporary aquatic habitat loss</u> ³	7	9	63	
	Visual impact	2	9	18	
	<u>Terrestrial wildlife habitat loss (song birds, water fowl and terrestrial mammals)</u> ³	7	9	63	
	<u>Aquatic wildlife habitat loss (water fowl)</u> ³	5	9	45	
Operational	Ease of operation	9	9	81	351
	Distance from mill	8	9	72	
	Potential for delays due to freezing	10	9	90	
	Construction risk	4	9	36	
	Disposal system has precedent in arctic environment	8	9	72	
	<u>Ease of Closure</u> ³	9	9	81	
Economic	Total present value of costs (initial cost + delayed costs)	15	9	135	135
TOTAL					1269

Notes:

- ¹ Values represent the maximum score, if each sub-indicator assigned a maximum scoring factor of 9 points.
- ² Includes consideration of foundation conditions, impact of seismicity, and height of structure.
- ³ Categories added at request of DFO and EC (i.e., new and additional sub-indicators to original study).

Calculations

The cumulative score for each of the primary categories was determined as the sum of the products of the sub-indicator weightings and relative scores.

$$OptionScore = \sum (W_{IND} \times S_{IND})_{Environment} + \sum (W_{IND} \times S_{IND})_{Operations+} + \sum (W_{IND} \times S_{IND})_{Economic}$$

The resulting option score based on qualitative and quantitative inputs provides a means to evaluate the relative ranking of the various options considered. The method is transparent, and allows stakeholders the opportunity to assess the relative weightings and scaling factors based on personal preference. A significant aspect of the decision matrix methodology is that it requires all factors be weighed in the final decision, rather than allowing a single factor to dictate the overall outcome.

5.0 RESULTS OF DECISION MATRIX METHOD

5.1 Base Line Analysis

Tailings facility Options B, C, F, and G for the proposed Meadowbank Project were analyzed using the decision matrix method of analysis described above. The following table summarizes the results.

Table 5.1: Summary of Baseline Analysis Decision Matrix Results

Factor	Options			
	B	C	F	G
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	438	475	372	432
Operational	263	216	160	256
Economic	60	135	75	60
TOTAL	761	826	607	748

Table 5.2 presents the full results of the decision matrix for the tailings storage options. The individual scores for each sub-indicator are shown along with the summed scores for environmental factors, operational factors, and economic factors.

Based on the decision matrix method Option C tailings slurry disposal in the northwest arm of Second Portage Lake, is the most appropriate tailings management strategy for the Meadowbank Project site based on an evaluation that included environmental, operational, and economic considerations.

5.2 Sensitivity Analyses

The relative sensitivity of the decision matrix system and resulting selection to changes in the weighting factors was evaluated with four sensitivity analyses. Firstly, each of the individual weighting factors was set to 1. This assigns an equal weighting to each individual sub-indicator. The results of this analysis are presented and described in the following section. Secondly, only environmental factors and long term (post-closure) impacts were considered. This analysis excluded the influence of operating and economic impacts from the decision matrix. Thirdly, environmental factors specifically relating to lake and fish habitat impacts were weighted as highly as possible within the decision matrix so that the contribution of these sub-indicators towards on-land disposal options ranged between 31% and 35% of the total score, while the contribution to disposal options in Second Portage Lake were reduced to between 13% and 17% of the overall total. Finally, a fourth sensitivity analysis was performed, whereby the amount of fish habitat and number of lakes affected by each option were described by using habitat units (as defined in the No Net Loss report), permanent and temporary aquatic habitat loss were evaluated as separate sub-indicators, and terrestrial and aquatic wildlife habitat loss and ease of closure were included as new sub-indicators.

TABLE 5.2: TAILINGS STORAGE OPTIONS DECISION MATRIX RESULTS				Option B	Option C	Option F	Option G	Scale Factor				Sub-Indicator Weighted Scores			
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm	B	C	F	G	B	C	F	G
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	Construction - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	Construction - build conventional tailings containment berms on frozen ground; install and maintain pipeline.	Construction - build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	Operation - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	Operation - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	Operation - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m³)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (55% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	6	9	Moderate	Moderate	High	High	7	9	1	4	42	54	6	24
	Potential for dust generation after closure	4	9	Low	Low	Moderate	Moderate	9	9	6	6	36	36	24	24
	Potential for ARD generation during operation	5	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	35	45	15	25
	Potential for ARD generation after closure	7	9	Low	Low	Moderate	Moderate	7	7	5	5	49	49	35	35
	Potential for ML during operation	2	9	Low	Moderate	Moderate	Low	8	7	7	9	16	14	14	18
	Potential for ML after closure	5	9	Moderate	Moderate	Low	Low	7	7	9	9	35	35	45	45
	Potential for seepage to groundwater during operation	5	9	Low	Low	Low	Low	9	9	9	9	45	45	45	45
	Potential for geotechnical hazards ¹	6	9	Low	Low	High	Moderate	9	9	1	5	54	54	6	30
	Potential for seepage to groundwater after closure	5	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	35	35	45	45
	Area of lakes impacted (ha)	5	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	25	30	45	45
	Number of lakes impacted	4	9	1 - 2	1	1	1	6	9	9	9	24	36	36	36
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Impact on Fish and Fish Habitat	9	9	High	High	Moderate	Moderate	1	1	4	4	9	9	36	36
Sum of Environmental Weightings		67	603									438	475	372	432
Operational Factors (33% of Weighted Total)	Ease of operation	9	9	High	Moderate	Low	Moderate	9	4	2	6	81	36	18	54
	Distance from mill	8	9	1200 m	1200 m	2800 m	2800 m	9	9	4	4	72	72	32	32
	Potential for delays due to freezing	10	9	Low	Moderate	High	Moderate	9	6	1	7	90	60	10	70
	Construction Risk	4	9	Moderate	Moderate	Low	Low	3	2	7	9	12	8	28	36
	Disposal system has precedent in arctic environment	8	9	No	Yes	Yes	Yes	1	5	9	8	8	40	72	64
	Sum of Operational Weightings	39	351									263	216	160	256
Economic Factors ² (assumes i = 8%) (12% of Weighted Total)	Initial Capital Cost (\$CDN) (Approximate) ³			\$11,800,000	\$2,860,000	\$5,955,000	\$14,675,000					0	0	0	0
	Net Present Value of Delayed Costs ³			\$2,986,613	\$3,428,432	\$5,955,892	\$528,041					0	0	0	0
	Total Present Value of costs	15	9	\$14,786,613	\$6,288,432	\$11,910,892	\$15,203,041	4	9	5	4	60	135	75	60
	Sum of Economic Weightings	15	135									60	135	75	60
TOTAL SCORE			1089	761	826	607	748					761	826	607	748

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Relative capital cost for comparison only. Interest rate assumed as 8%.
3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.

5.2.1 Sensitivity Analysis – Part 1

To consider the impact of the weighting factors used in the decision matrix, a sensitivity analysis was conducted with all sub-indicator weightings set equal to one. This results in each of the sub-indicators having equal importance in the decision process and removes any value bias between the sub-indicators that might be imposed by personal preferences. The greatest numbers of sub-indicators were associated with the environmental category, while the lowest numbers of sub-indicators were associated with the economic category. Consequently, the relative importance of each category is determined by the number of sub-indicators representing that category. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 71%
- Operational 24 %
- Economic 5%

The results of this analysis are summarized in Table 5.3.

Table 5.3: Summary of Decision Matrix Results – Sensitivity Analysis (Part 1)

Factor	Options			
	B	C	F	G
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	106	113	91	104
Operational	31	26	23	34
Economic	4	9	5	4
TOTAL	141	148	119	142

The detailed analysis is shown in Table 5.4.

As with the baseline case, Option C received the highest overall score although only marginally greater than Options B and G.

TABLE 5.4: SENSITIVITY ANALYSIS RESULTS (PART 1)				Option B	Option C	Option F	Option G	Scale Factor				Sub-Indicator Weighted Scores			
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm	B	C	F	G	B	C	F	G
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	Construction - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	Construction - build conventional tailings containment berms on frozen ground; install and maintain pipeline.	Construction - build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	Operation - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	Operation - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	Operation - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation. Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m³)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (71% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	1	9	Moderate	Moderate	High	High	7	9	1	4	7	9	1	4
	Potential for dust generation after closure	1	9	Low	Low	Moderate	Moderate	9	9	6	6	9	9	6	6
	Potential for ARD generation during operation	1	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	7	9	3	5
	Potential for ARD generation after closure	1	9	Low	Low	Moderate	Moderate	7	7	5	5	7	7	5	5
	Potential for ML during operation	1	9	Low	Moderate	Moderate	Low	8	7	7	9	8	7	7	9
	Potential for ML after closure	1	9	Moderate	Moderate	Low	Low	7	7	9	9	7	7	9	9
	Potential for seepage to groundwater during operation	1	9	Low	Low	Low	Low	9	9	9	9	9	9	9	9
	Potential for geotechnical hazards ¹	1	9	Low	Low	High	Moderate	9	9	1	5	9	9	1	5
	Potential for seepage to groundwater after closure	1	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	7	7	9	9
	Area of lakes impacted (ha)	1	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	5	6	9	9
	Number of lakes impacted	1	9	1 - 2	1	1	1	6	9	9	9	6	9	9	9
	Visual Impact	1	9	Low	Low	High	Moderate	9	9	1	3	9	9	1	3
	Impact on Fish and Fish Habitat	1	9	High	High	Moderate	Moderate	1	1	4	4	1	1	4	4
	Sum of Environmental Weightings	15	135									106	113	91	104
Operational Factors (24% of Weighted Total)	Ease of operation	1	9	High	Moderate	Low	Moderate	9	4	2	6	9	4	2	6
	Distance from mill	1	9	1200 m	1200 m	2800 m	2800 m	9	9	4	4	9	9	4	4
	Potential for delays due to freezing	1	9	Low	Moderate	High	Moderate	9	6	1	7	9	6	1	7
	Construction Risk	1	9	Moderate	Moderate	Low	Low	3	2	7	9	3	2	7	9
	Disposal system has precedent in arctic environment	1	9	No	Yes	Yes	Yes	1	5	9	8	1	5	9	8
	Sum of Operational Weightings	5	45									31	26	23	34
Economic Factors ² (assumes 1 = 8%) (5% of Weighted Total)	Initial Capital Cost (\$CDN) (Approximate) ³			\$11,800,000	\$2,860,000	\$5,955,000	\$14,675,000								
	Net Present Value of Delayed Costs ³			\$2,986,613	\$3,428,432	\$5,955,892	\$528,041								
	Total Present Value of costs	1	9	\$14,786,613	\$6,288,432	\$11,910,892	\$15,203,041	4	9	5	4	4	9	5	4
	Sum of Economic Weightings	1	9									4	9	5	4
TOTAL SCORE			189	141	148	119	142					141	148	119	142

Notes

1. Includes consideration of foundation conditions, impact of seismicity, and height of structure

2. Relative capital cost for comparison only. Interest rate assumed as 8%.

3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.

4. Note the relative distribution of scores between the three primary factors has changed, due to the weightings allocated. The new distribution is Environmental = 71%, Operational = 24%, and Economic = 5%.

5.2.2 Sensitivity Analysis – Part 2

An additional sensitivity analysis was carried out by excluding economic factors, and by reducing the effect of operational factors. The resulting decision matrix was weighted strongly towards the influence of environmental factors. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 89%
- Operational 11%
- Economic 0%

Table 5.5 summarizes the results of the analysis.

Table 5.5: Summary of Decision Matrix Results – Sensitivity Analysis (Part 2)

Factor	Options			
	B	C	F	G
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	438	475	372	432
Operational	8	40	72	64
Economic	0	0	0	0
TOTAL	446	515	444	496

The detailed analysis is presented in Table 5.6.

The analysis indicates that when the decision matrix is heavily weighted towards the consideration of environmental factors Option C (tailings slurry disposal in Second Portage Lake) is the preferred option.

TABLE 5.6: SENSITIVITY ANALYSIS RESULTS (PART 2)				Option B	Option C	Option F	Option G	Scale Factor				Sub-Indicator Weighted Scores			
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm	B	C	F	G	B	C	F	G
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	Construction - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	Construction - build conventional tailings containment berms on frozen ground; install and maintain pipeline.	Construction - build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	Operation - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	Operation - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	Operation - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Closure - Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	Closure - Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m³)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (89% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	6	9	Moderate	Moderate	High	High	7	9	1	4	42	54	6	24
	Potential for dust generation after closure	4	9	Low	Low	Moderate	Moderate	9	9	6	6	36	36	24	24
	Potential for ARD generation during operation	5	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	35	45	15	25
	Potential for ARD generation after closure	7	9	Low	Low	Moderate	Moderate	7	7	5	5	49	49	35	35
	Potential for ML during operation	2	9	Low	Moderate	Moderate	Low	8	7	7	9	16	14	14	18
	Potential for ML after closure	5	9	Moderate	Moderate	Low	Low	7	7	9	9	35	35	45	45
	Potential for seepage to groundwater during operation	5	9	Low	Low	Low	Low	9	9	9	9	45	45	45	45
	Potential for geotechnical hazards¹	6	9	Low	Low	High	Moderate	9	9	1	5	54	54	6	30
	Potential for seepage to groundwater after closure	5	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	35	35	45	45
	Area of lakes impacted (ha)	5	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	25	30	45	45
	Number of lakes impacted	4	9	1 - 2	1	1	1	6	9	9	9	24	36	36	36
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Impact on Fish and Fish Habitat	9	9	High	High	Moderate	Moderate	1	1	4	4	9	9	36	36
	Sum of Environmental Weightings	67	603									438	475	372	432
Operational Factors (11% of Weighted Total)															
	Disposal system has precedent in arctic environment	8	9	No	Yes	Yes	Yes	1	5	9	8	8	40	72	64
	Sum of Operational Weightings	8	72									8	40	72	64
Economic Factors (0% of Weighted Total)															
	Sum of Economic Weightings	0	0									0	0	0	0
TOTAL SCORE			675	446	515	444	496					446	515	444	496

Notes

1. Includes consideration of foundation conditions, impact of seismicity, and height of structure

2. Note the relative distribution of scores between the three primary factors has changed, due to the revised number of sub-indicators. The new distribution is Environmental = 89%, Operational = 11%, and Economic = 0%.