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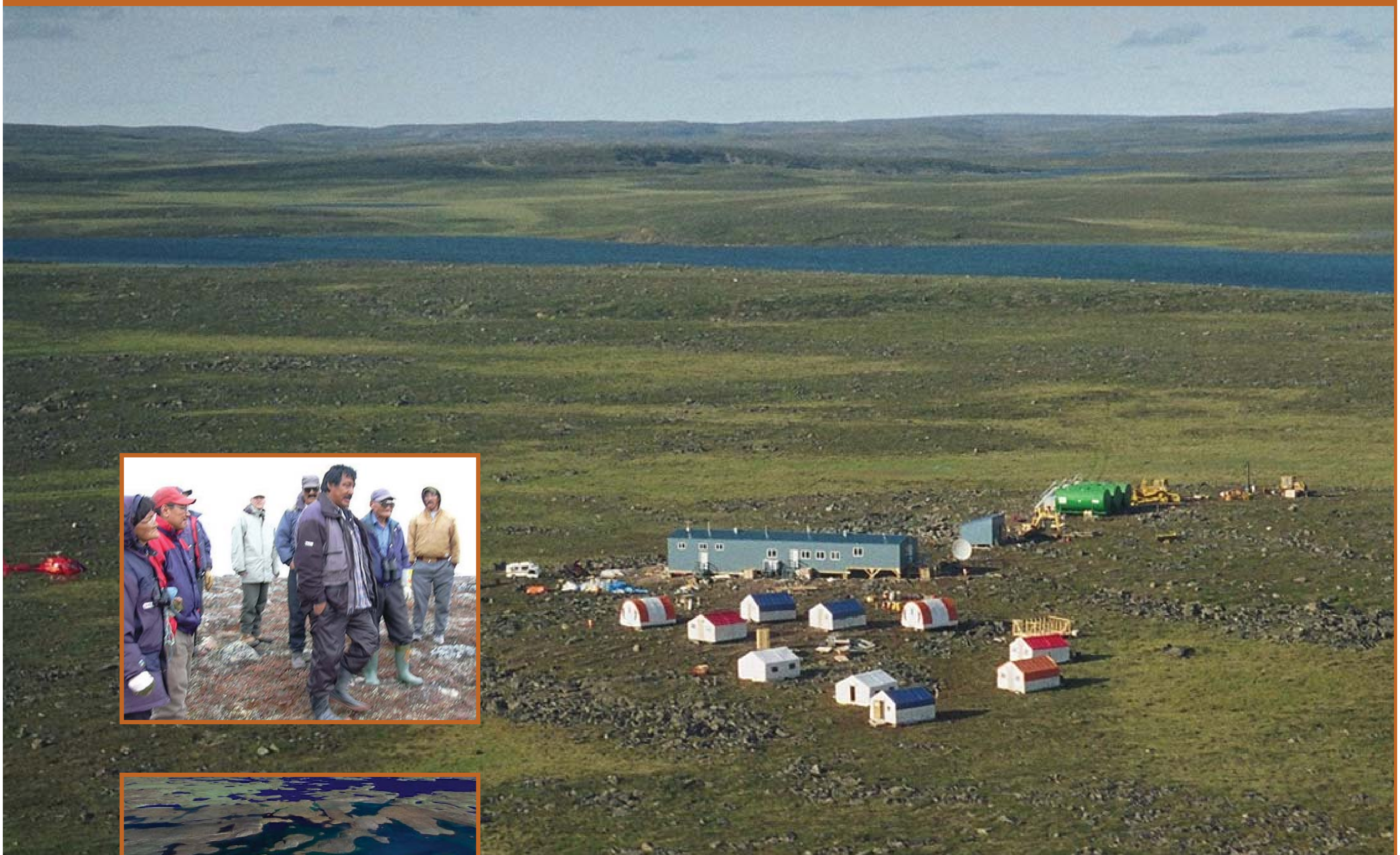

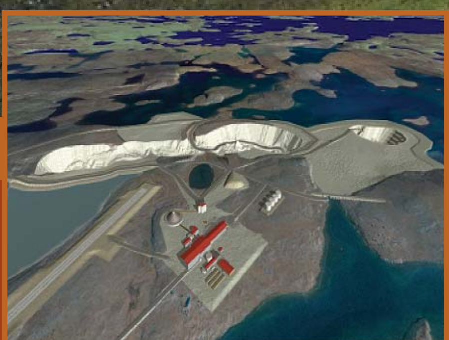

MEADOWBANK GOLD PROJECT

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 -6ºC. The mean annual air temperature at the Meadowbank Project is -11.3ºC. 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:

- 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.

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:

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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 -11.3ºC, 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 -12.8ºC. 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

<table>
<tr><th>Strategy</th><th>Tailings</th><th>Waste Rock</th></tr>
<tr><td>Freeze Controlled</td><td>• 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</td><td>• 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</td></tr>
<tr><td>Climate Controlled</td><td>• May not be a reliable strategy for saturated tailings</td><td>• 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</td></tr>
<tr><td>Engineered Cover</td><td colspan="2">• Special consideration for freeze-thaw effects
• Availability and cost of cover materials are major impediments</td></tr>
<tr><td>Subaqueous Disposal</td><td>• Special considerations for winter ice conditions and pipeline freeze-up</td><td>• Very difficult to dispose of waste rock beneath winter ice</td></tr>
<tr><td>Collection and Treatment</td><td colspan="2">• Costly to maintain at remote locations
• Long term maintenance cost</td></tr>
<tr><td>Segregation and Blending</td><td>• Tailings are normally geochemically homogeneous</td><td>• May be very effective
• Research and development on-going</td></tr>
</table>

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 -11ºC, with monthly temperatures exceeding 0ºC 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 produces 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

Key Indicators	Sub-Indicators	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.

- 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.

- 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 Liner, 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 then 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	
Thompson Mine	Inco	Manitoba	Sub-aqueous slurry	
Nanisivik Mine	Breakwater Resources Ltd	Nunavut	Sub-aqueous slurry	- initial deposition in lake until filled
Red Dog Mine	Teck Cominco	Alaska	Sub-aqueous slurry	
Voisey's Bay	Inco	Newfoundland (Labrador)	Sub-aqueous slurry	- under construction, to be completed in late 2005
Colomac Mine	Comaplex Minerals Corp.	Northwest Territories	Sub-aqueous slurry and sub-aerial slurry	- into a lake with dams
Doris North Project	Miramar Hope Bay Ltd.	Nunavut	Sub-aqueous slurry	- planned
Key Lake	Cameco	Northern Saskatchewan	Sub-aqueous slurry	- initially in on land containment facility now in mined out flodded pit
Rabitt Lake	Cameco	Northern Saskatchewan	Sub-aerial slurry, will be sub-aqueous at closure	- in open pit with a drainage layer surrounding tailings (wall and base)
Copper Cliff Mine	Inco	Sudbury	Sub-aerial slurry	
FlinFlon	Hudson's Bay Mine & Smelting	Northern Manitoba	Sub-aerial slurry	
Kidd Creek Mine	Falconbridge (Falconbridge-Noranda)	Timmins	Sub-aerial slurry	- Thickened to 60-65% deposited from center in a cone
Nanisivik Mine	Breakwater Resources Ltd.	Nunavut	Sub-aerial slurry	- later stage deposition in cells above lake - permafrost encapsulation
Fort Knox and True North	Kinross Gold Corporation	Alaska	Sub-aerial slurry	- in dammed valley, closure will be: sub-aqueous using engineered wetlands
Rankin Inlet	Asamera Minerals Inc.	Nunavut	Sub-aerial slurry in pit	as remediation, permafrost encapsulation
Lupin Mine	Echo Bay Mines Ltd.	Nunavut	Sub-aerial slurry	- deposited in cells, saturated final cover, and paste for underground backfill, permafrost encapsulation
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	
Raglan Mine	Falconbridge (Falconbridge-Noranda)	Quebec	Sub-aerial dry stack	- permafrost encapsulation
La Coipa	Mantos de Oro (Placer Dome)	Chile	Sub-aerial dry stack	- Tailings are filtered to recover excess water as well as residual cyanide and metal credits
Pogo Gold Mine	Teck Cominco and Sumitomo Metal Mining	Alaska	Sub-aerial dry stack in valley impoundment and underground paste backfill	- final permitting and construction
Mineral Hill Mine	Triako Resources Limited	Montana	Sub-aerial dry stack	- in the planning stages
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	
Illinois Creek	Quest Capital Corp.	Alaska	Tailings slurry	final closure
Ryan Lode	Bartholome	Alaska	Lined earthen Dam with reclaimed water system	final closure
Nixon Fork	St. Andrews Goldfields LTD	Alaska	Lined earthen Dam with reclaimed water system	inactive
Julietta	Bema	Russia Far east	Paste tailings 85-90% soilds in to surface facility	
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	- under constrcution

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 $\$1.00/m^3$, while additional haulage costs for till is based on an estimated $\$7.00/m^3$.

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	2nd or 3rd 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 Weighting[1]
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	
	Permanent aquatic habitat loss [3]	10	9	90	
	Temporary aquatic habitat loss [3]	7	9	63	
	Visual impact	2	9	18	
	Terrestrial wildlife habitat loss (song birds, water fowl and terrestrial mammals) [3]	7	9	63	
	Aquatic wildlife habitat loss (water fowl) [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	
	Ease of Closure [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

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				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.								
				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 (m^3)			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)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				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 (m^3)			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 i = 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)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor				Sub-Indicator Weighted Scores			
								B	C	F	G	B	C	F	G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				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.								
				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 (m^3)			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 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 (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%.

5.2.3 Sensitivity Analysis – Part 3

A third sensitivity analysis was carried out on the baseline case to address specific concerns relating to the effect the proposed methods of disposal may have on fish and fish habitat. For this case, issues relating specifically to impact on fish and fish habitat were adjusted to weight these indicators high in the overall analysis. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 57%
- Operational 31%
- Economic 12%

The relative weighting factor for "number of lakes impacted" and "impact on fish and fish habitat" were adjusted so that these two indicators carried the highest relative weights of all the environmental sub-indicators. The scale factors for the sub-indicator "number of lakes impacted" remained the same as the previous analyses, as the number of lakes impacted by either on-land or in lake disposal is the same regardless of the disposal method selected. The scale factors for the sub-indicator "impacts on fish and fish habitat" however were increased to the maximum possible value of 9 for on-land disposal, representing the 'best' possible case, and were maintained at the least possible value of 1 for disposal in Second Portage Arm, representing the 'worst' possible case. The result of this re-scaling is that "impacts on fish and fish habitat" and "number of lakes impacted" contribute between 31% and 35% to the overall environmental weighting for on-land storage, compared with 13% to 17% contribution for disposal within Second Portage Arm.

Table 5.7 summarizes the results of the analysis.

Table 5.7: Summary of Decision Matrix Results – Sensitivity Analysis (Part 3)

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	468	520	462	522
Operational	263	216	160	256
Economic	60	135	75	60
TOTAL	**791**	**871**	**697**	**838**

The detailed analysis is presented in Table 5.8.

The analysis indicates that when environmental factors are weighted heavily towards impact on lakes and on fish habitat, disposal on-land or in Second Portage Lake carry equivalent total environmental weighting, resulting in a ‘null’ decision based on that category alone. When economic and operational issues are considered in the decision analysis, then Option C, disposal of slurry tailings in the basin of Second Portage Arm, is the preferred option.

TABLE 5.8: SENSITIVITY ANALYSIS RESULTS (PART 3)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				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.								
				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 (m^3)			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 (57% 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	9	9	1 - 2	1	1	1	6	9	9	9	54	81	81	81
	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	9	9	9	9	81	81
	Sum of Environmental Weightings	**72**	**648**									**468**	**520**	**462**	**522**
Operational Factors (31% 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			**1134**	**791**	**871**	**697**	**838**					**791**	**871**	**697**	**838**

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.

5.2.4 Sensitivity Analysis – Part 4

A final sensitivity analysis was conducted to replace absolute habitat areas measured in hectares (ha) with “habitat units” as derived in the No Net Loss report. In addition, 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. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 54%
- Operational 34%
- Economic 11%

Table 5.9 summarizes the results of this additional sensitivity analysis.

Table 5.9: Summary of Decision Matrix Results – Sensitivity Analysis (Part 4)

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	**540**	**581**	**444**	**490**
Operational	**344**	**297**	**214**	**310**
Economic	**60**	**135**	**75**	**60**
TOTAL	**944**	**1013**	**733**	**860**

As with the baseline case, and the previous sensitivity analyses, Option C received the highest overall score.

The full analysis is shown in Table 5.10.

The following sections describe in greater detail the additional sub-indicators considered in this sensitivity analysis as recommended by DFO and EC, and how relative weighting factors and scaling factors have been applied.

TABLE 5.10: SENSITIVITY ANALYSIS RESULTS (PART 4)
Sensitivity to Inclusion of Habitat Units

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				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.								
				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 (m^3)			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
	Permanent aquatic habitat loss (habitat units)	10	9	370	370	0	0	1	1	9	9	10	10	90	90
	Temporary aquatic habitat loss (habitat units)	7	9	919	614	614	799	6	9	9	7	42	63	63	49
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Terrestrial wildlife habitat loss, ha	7	9	15.56	15.56	46.79	46.79	9	9	3	3	63	63	21	21
	Aquatic wildlife habitat loss, ha	5	9	Low	Low	Moderately High	Moderately High	9	9	3	3	45	45	15	15
	Sum of Environmental Weightings	**78**	**702**									**540**	**581**	**444**	**490**
Operational Factors (34% 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
	Ease of Closure	9	9	High	High	Moderate	Moderate	9	9	6	6	81	81	54	54
	Sum of Operational Weightings	**48**	**432**									**344**	**297**	**214**	**310**
Economic Factors[2] (assumes i = 8%) (11% 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			**1269**	**944**	**1013**	**733**	**860**					**944**	**1013**	**733**	**860**

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.

Aquatic Habitat Value

Each of the different tailings management options affect fish habitat to different degrees and for varying purposes and lengths of time. Regardless of the disposal option chosen (i.e., subaerial or within Second Portage north arm), the north arm of Second Portage Lake will be dewatered and isolated from the rest of the system and fish-bearing waters. For those options where mine tailings are proposed to fill the northwest arm of Second Portage Lake (Options A, B and C), this habitat will be permanently lost, although it will be replaced under the terms of the No Net Loss plan (CRL, 2005h). For those options that do not use Second Portage Lake as a repository for mine tailings, this basin will not support fish for some time afterwards, depending on the rate of recovery of water quality after filling of the basin, and before the South Dike is breached.

To determine the relative degree of impact of tailings disposal for each option, loss of habitat was based on the number of habitat units (HUs) permanently affected, as in the case of deposition in Second Portage Lake or temporarily affected, as in the case of disposal on land. Tailings disposal options that affect lesser amounts of habitat, or that affect habitat for shorter durations will be ranked higher than options that affect greater amounts of habitat for longer periods of time.

Aquatic Wildlife Habitat Loss

Aquatic wildlife refers primarily to the Waterfowl VEC whose members utilize lakes, ponds and shorelines for breeding, foraging, rearing of young, and staging during migration. Determination of the relative significance of habitat losses for waterfowl can not be done in a quantitative manner because the Ecological Land Classification does not differentiate between relatively unproductive deep water lakes and more productive wetlands and small ponds. To provide a relative value of each of the impacted wetland areas to waterfowl, each site was rated on a scale ranging from 1 to 6 (compatible with British Columbia Habitat Rating Standards – RIC 1999). In this rating scheme, a ‘1’ or ‘High’ represents habitats that are comparable (i.e., 75-100%) to the best habitats available in Nunavut, and a ‘6’ or ‘Nil’ has no value. Other rating classes are ‘2’ or Moderately High (51-75%), ‘3’ or Moderate (26-50%), ‘4’ or Low (6-25%) and ‘5’ (1-5%). Very Low to Low quality habitats (5 and 4) will include deep water lakes, with an absence of riparian habitats, islands for nesting, and prey species such as fish. Moderately High to High quality habitats (2 and 1) are extensive shallow and productive wetlands with emergent and riparian shoreline habitats with an abundance of prey species.

Options F&G are situated in an area with several shallow, fishless wetlands with relatively extensive sedge communities. Although breeding has not been documented to date, several waterfowl species have been recorded on these wetlands including Canada Goose, Long-tailed Duck, Northern Pintail and Mallard. Relative to other wetland areas in Nunavut, these habitats were rated as Moderately High (2). Options B&C will impact Second Portage Lake, a relatively steep-sided body of water with limited shoreline vegetation. The presence of healthy fish populations occasionally attracts loons and Red-breasted Merganser, but nesting opportunities appear to be very limited. Relative to other waterfowl habitats in Nunavut, these habitats were rated as Low (4). Scale factors were assigned according to the rating given above.

The relative weighting of Aquatic Wildlife Habitat Loss compared to other environmental sub-indicators (see Table 4.1) was set at '5' of a maximum of '9'. A maximum weighting was not given because of the high availability of similar habitats in adjacent areas, and the generally low densities of breeding waterfowl in the Meadowbank area.

5.2.5 Rationale For Relative Weighting Factors and Scaling Factors

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. The rationale for weighting and scaling permanent versus temporary habitat loss for the various tailings disposal options is as follows:

<u>Permanent Aquatic Habitat Loss</u>

The relative weighting factor for permanent aquatic habitat loss was set at a value of 10, which is higher than all other weightings, indicating the importance of this sub-indicator. Tailings disposal Options B and C permanently eliminate fish habitat; hence, these options were given the lowest possible scaling factor of 1. Options B and C propose that the northwest arm of Second Portage Lake be filled with mine tailings and will result in the permanent loss of this habitat behind the Tailings Dike. The total number of habitat units affected is 370. The permanent loss of habitat has been considered within the NNL (CRL, 2005h) plan for the project. The option score, which is the product of the relative weighting and scale factor, for Options B and C are low, having a value of 10, reflecting the permanent habitat loss. The option scores for Options B and C therefore contribute very little to the overall score when all sub-indicators are considered.

Options F and G, on-land disposal, do not result in permanent fish habitat loss in Second Portage Lake. Consequently, these two options represent the 'best' option when this sub-indicator is considered independently, and are therefore assigned the highest possible scale factor of 9 although a small portion of habitat is permanently lost (340 HUs) relative to total number of HUs in Third Portage Lake at the end of mining (11,979 HUs; CRL, 2005h). The option score for Options F and G are high, having values of 90, reflecting no permanent loss of fish habitat in Second Portage Lake. Tailings options F and G would eliminate several small, non fish-bearing ponds. These ponds are shallow and freeze to the bottom during winter and thus have no value as fish habitat.

Tailings Option E would result in the permanent loss of 101 HUs as Dogleg Lake would be filled and permanently eliminated as habitat.

Temporary Aquatic Habitat Loss

The relative weighting factor of temporary habitat loss was assigned a value of 9, indicating it to be of slightly less relative important than permanent habitat loss. All tailings disposal options will result in the temporary loss of habitat within the open pit area east of the Tailings Dike and west of the East Dike. Temporary habitat loss in Second Portage Pit, prior to enhancement at closure, is approximately 244 HUs. Additional temporary habitat loss in Third Portage Lake arm will occur if Option B is pursued. This habitat (305 HUs) would be lost during mine operations and for several years beyond closure, until such time as water quality improves to the extent that the dikes could be breached and allow water from Third Portage Lake to mix with the (treated) reclaim water. Option G may result in a longer-term temporary habitat loss (185 HUs) in Second Portage north arm.

All disposal options, including on-land disposal options, also require at least the temporary loss of habitat within Second Portage Lake, including the proposed tailings disposal area considered as part of Options A, B and C, because of the requirement to dewater the lake. In addition, disposal Option B requires that a portion of Third Portage Lake be used as a reclaim water reservoir. This area, located north of Camp Island within a small basin called Third Portage arm, has a relatively large amount of high value habitat and will be lost for the duration of mining as well as some years after closure, depending on recovery of water quality. Various numbers of HUs will be temporarily lost according to disposal option. In this case, the habitat unit values were used to determine the scale factors for each option, according to the methodology described above. Options C and F are indicated to have the lowest temporary habitat loss of 614 HUs each. Consequently, Options C and F were both assigned a scale factor of 9 representing the ‘best’ option for this sub-indicator. Option B will result in the greatest temporary loss of habitat units (919 HUs) because of the need to use Third Portage Lake arm, while Option G may cause greater residual habitat loss (799 HUs) in Second Portage Lake northwest arm because of potentially greater impacts to sediment quality. The scale factors for Options B and G were determined according to the number of HUs temporarily lost relative to Options C and F. For example, Option C has 614 HUs of temporary loss, while Option B has 919 HUs. Option C has a scale factor of 9 as it affects the least HUs. Therefore the scale factor assigned to Option B is determined as (614 HUs x 9)/919 HUs, or a scale factor of 6. Similarly, Option G has a scale factor determined by (614 HUs x 9)/799 HUs, or a scale factor of 7.

Terrestrial Wildlife Habitat Loss

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.

Each of the different tailings management options affect wildlife and wildlife habitat in different ways. To determine potential impacts of the various tailings options on terrestrial wildlife, the projected footprint area losses of high suitability habitats were determined for each of the VECs (Note: Ecological Land Classification units and wildlife VEC habitat suitability analyses are presented in the Baseline Terrestrial Ecosystem Report and Terrestrial Ecosystem Impact Assessment – CRL, 2005d and CRL, 2005e, respectively). For ungulates, the footprint area loss of high suitability habitat was determined for both the growing and winter seasons.

To determine a High Suitability Habitat Loss (HSHL) value that reflects all VECs, the average of high suitability habitat losses for each of Ungulates – growing, ungulates – winter, small mammals, waterfowl and other breeding birds, was calculated. This HSHL value allows comparisons of the relative magnitude of high value terrestrial habitat losses for each of the four tailings options. Therefore, tailings disposal options that affect lesser amounts of terrestrial habitat will be ranked higher than options that affect greater amounts of terrestrial habitat. Of the four tailings disposal options, Options B and C (HSHL = 15.56 ha), which require draining and filling of Second Portage Lake, impact relatively little (i.e., one-third) high suitability terrestrial habitat compared to Options F and G (HSHL = 46.79 ha). Consequently, Options B and C are given a scale factor of 9. When all terrestrial habitats are assessed (i.e., those of High, Moderate and Low value to wildlife VECs), a similar difference is noted. Area losses for Options B and C are 34.07 ha compared to 111.14 ha for Options F and G. Scale factors were assigned according to the relative value of HSHL described above.

The relative weighting of Terrestrial Wildlife Habitat Loss compared to other environmental sub-indicators (see Table 4.1) was set at '7' of a maximum of '9'. A maximum weighting was not given because of the high availability of similar habitats in adjacent areas, and the creation of terrestrial habitats, albeit low suitability habitats, after mine closure.

5.3 Discussion

The result of the initial base case decision matrix analysis, and the subsequent sensitivity analyses are similar. The best disposal option for tailings management at the Meadowbank Project is disposal of tailings into the natural rock basin of the northwest arm of Second Portage Lake. Permafrost encapsulation of the tailings will form the control strategy for acid mine drainage and metal leaching. The primary advantages provided by Option C are as follows:

- Lowest potential for the generation of acidic drainage and the release of metal constituents to the environment;
- Lowest potential for the generation of dust from the facility during operations and closure, and consequently the lowest potential for the migration of contaminants beyond the limits of the storage facility and the mine site. Facilities exposed to wind erosion will have a greater risk of release of wind-blown contaminants to the environment by deposition on-land or into lakes;
- Simplest construction methodology requiring construction materials from the mining activities;
- Simplest closure methodology, requiring least amount of borrow materials;
- Low risk of instability of tailings facility, and hence lower risk of potential release of tailings to the environment;
- Ease of operation in harsh Arctic climates;
- Lowest relative capital cost; and
- Precedence in Arctic climate.

Regardless of the tailings disposal option chosen, the northwest arm of Second Portage Lake will necessarily be dewatered to allow mining of the Portage Deposit, and to ensure structural integrity during construction and operation of the East Dike.

6.0 CASE STUDY – NORTH RANKIN INLET NICKEL MINE

The North Rankin Inlet Nickel Mine presents a case study that is directly comparable to the conditions at the Meadowbank Project and to the recommended tailings management plan. Rankin Inlet is a community located approximately 250 km south, and 430 km east of the Meadowbank Project site (see Figure 1). The community is located on Hudson Bay. The similarities between the Meadowbank Project site and Rankin Inlet are: the sites are in the zone of continuous permafrost; the mean annual air temperature at both sites is approximately -11ºC; remedial measures to manage the reactive and acid generating tailings at Rankin Inlet have included the disposal of the tailings by permafrost encapsulation in a drained bedrock basin to maintain the tailings and their saline pore water in a chemically inert state. Thermal instrumentation at the Rankin Inlet site has shown the tailings to be frozen or freezing, and that freeze-back is occurring more rapidly than predicted. There is no evidence of thermal heating due to oxidation of tailings. The results of the field and laboratory investigations of the tailings at Rankin Inlet are presented by Meldrum, et. al. (2001) and are summarized in the following sections.

6.1 Summary of Rankin Inlet Remediation Project

The North Rankin Inlet Nickel Mine was operated for five years from 1957 to 1962 and produced 297,000 tonnes of tailings. Prior to remediation the acid-generating sulphide rich tailings were exposed on the shores of Hudson Bay for 30 years, releasing acidic, metal-rich water. In addition to release of the contaminated pore water into Hudson Bay, oxidized tailings dust was wind blown through the town of Rankin Inlet, and deposited on the tundra as well as further out on to the sea ice covering the bay during the winter months, and on to the water surface during the summer months. In 1991 a remedial program was initiated which involved the burial of the tailings in a drained bedrock basin, relying on eventual permafrost encapsulation to limit the tendency of contaminated pore water to migrate further from the site. The remediation involved the *in-situ* treatment of 100,000 m^3 of contaminated water, the draining of a bedrock basin, and the subsequent filling of the basin with 48,000 m^3 of tailings to a maximum depth of 16 m with the intention of encapsulating the tailings in permafrost rendering them chemically inert (Erickson, 1995). The tailings were covered with 1 m of gravel fill from a nearby esker to host the active layer, thus keeping the tailings in a frozen state as permafrost was expected to grow downward over time through the tailings.

Pyrrhotite is estimated to comprise between 5% and 20% by volume of the tailings at Rankin Inlet. Pyrrhotite is the most rapidly oxidizing sulphide commonly found in mine waste. In addition to the rapidly oxidizing sulphides, the tailings exhibited freezing point depression due to the high salinity of the porewater resulting from inundation with seawater. By comparison, the tailings at the Meadowbank Project are estimated to contain between 4% and 5% sulphides, primarily pyrite.

Three years after burial a series of field investigations and instrumentation was undertaken at the site. The field investigations involved the drilling of boreholes, the collection of a frozen core sample of tailings using a Cold Regions Research and Engineering Laboratory (CRREL) core barrel, and the installation of a series of thermistor cables to monitor the thermal conditions within the tailings. Additional laboratory experimentation was carried out to determine the effect of freezing point depression on sulphide oxidation rates and whether or not this will affect the local thermal regime.

6.2 Thermal Regime in the Tailings at Rankin Inlet

A map showing the locations of the thermistor installations, as well as the results of the monitoring program between March 29, 1997 and February 4, 1998 are shown on Figure 10. The figures indicate that the tailings at the time the data were collected were freezing or were frozen. A thermistor installed outside of Deep Pond but adjacent to the reclamation site shows the permafrost thermal regime to a depth of 16 m, with a mean annual ground temperature of about -7ºC (see Thermistor Cable 8 on Figure 10). By comparison, the mean annual ground temperature at the Meadowbank Project is expected to be on the order of -8ºC to -10ºC, based on site specific data collected from thermistors.

Figure 11 shows the predicted mean annual ground temperature in the reclaimed tailings for a range of time intervals after burial, with the data for borehole six plotted for comparison. The results indicate that the freezing of the tailings occurs more rapidly than predicted, and that the entire tailings thickness will be at least partly ice-bonded 15 years after burial (Meldrum et. al., 2001). Meldrum suggests this may be a result of lower volumetric moisture content than assumed by the modeling. However, an alternative explanation could be that the two-dimensional model used to predict ground freezing does not take into account the three-dimensional effect of perimeter freezing.

6.3 Key Conclusions of the Rankin Inlet Studies and Implications for the Meadowbank Project Site

The following key conclusions were drawn from the laboratory testing and field instrumentation measurements at the Rankin Inlet site and are compared with the expected site conditions at the Meadowbank Project.

- A significantly reduced but measurable oxidation takes place at -2ºC, augmented by freezing point depression due to saline pore waters. There is no measurable oxidation at -10ºC.

- The reactivity and oxidation of the tailings at Rankin Inlet below a mean annual ground temperature of -2ºC is expected to be very low. It is expected that the reactivity and oxidation of the tailings at the Meadowbank Project will be similar, provided that similar disposal philosophies are adopted.

- Freeze-back of the reclaimed tailings at Rankin Inlet is underway. Eventually a pocket of unfrozen brine may remain, enclosed between the overlying ice-bonded tailings and the refrozen bedrock beneath the former Deep Pond. Although the salinity of the tailings pore water results in considerable freezing-point depression, the effect of this on oxidation rate is low.

- Heating by tailings oxidation has not been noticeable at Rankin Inlet.

- Based on the field studies and laboratory testing of tailings at the Rankin Inlet site, encapsulating tailings in permafrost should minimize oxidation where the tailings temperature is maintained below -2ºC. At Rankin Inlet, a mean annual air temperature of about -11ºC produces a mean annual ground temperature of about -7ºC. Consequently, Meldrum et. al. (2001) suggest that any prospective site for tailings disposal by permafrost encapsulation should have a mean annual air temperature of less than -6ºC, as the field studies at the Rankin Inlet site indicated that ice bonding of the tailings begins at about -4ºC. At the Meadowbank Project, the mean annual air temperature of the site is estimated to be about -11.3ºC, and the mean annual ground temperature is estimated to range from about -8ºC to about -10ºC, based on site specific measurements. Long-term temperature trends based on monitoring data collected over a period of 50 years at Baker Lake, when applied to the Meadowbank Project site, suggest a mean annual air temperature of -12.8ºC. Consequently, the encapsulation of tailings in permafrost is a preferred control strategy for the Meadowbank Project site.

- The tailings at the Rankin Inlet site are expected to be fully ice-bonded approximately 15 years after burial. This is consistent with predicted thermal modeling of the Meadowbank Tailings Facility in the northwest arm of Second Portage Lake.

- Freezing of the tailings at Rankin Inlet is occurring at a faster rate than predicted. Meldrum et. al. (2001) attributes this to a lower volumetric moisture content than assumed in the modeling. However, an alternative explanation is that the two-dimensional modeling does not account for the three-dimensional effect of perimeter freezing of the tailings, or the advancement of the freezing front from the permafrost surrounding the drained rock basin into which the tailings were deposited. A similar situation, more rapid freezing than predicted, may occur at the Meadowbank Project with the permafrost freezing front advancing into the tailings deposited into the drained rock basin of the northwest arm of Second Portage Lake.

- The precipitation of secondary minerals due to progressive freezing of the tailings may locally inhibit fluid migration by cementation.

7.0 SUMMARY AND CONCLUSIONS

This report has presented a compilation of 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. The documents that have been compiled into this single document at the request and direction of Environment Canada (EC) are:

- 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.

This report has presented the decision making process used to select a tailings management system (location and technology) for the Meadowbank Gold Project. A decision matrix approach was utilized. 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.

Three primary categories were considered:

- Environmental;
- Operational; and
- Economic.

Sub-indicators within each category were identified, and weighting factors were assigned based on the relative importance of sub-indicators to each other. A scale, or scoring factor was applied to help separate ‘best’ options from ‘worst’ options. In the evaluation of all options, environmental factors contributed the most significantly to the outcome of the decision analysis.

Seven potential tailings management facilities were identified. These facilities were screened to determine if they met the basic site selection criteria:

- 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 permit mine expansion;

- The location is within catchments of the open pits; and
- The site allows control and collection of supernatant.

Only four of the options met these criteria, as listed below.

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

A decision matrix analysis was carried out for these four options. 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, for which 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. The results of the decision matrix analysis indicate that the preferred tailings management option for the Meadowbank Project, based on environmental, operational, (including engineering and technical) and economic considerations, is the disposal of tailings into the natural basin of the northwest arm of Second Portage Lake, followed by permafrost encapsulation. The sensitivity analyses showed that even when economic factors were removed from consideration, and operational factors were reduced in terms of relative importance leaving environmental factors as having the greatest importance, the preferred option is still indicated to be disposal in the northwest arm of Second Portage Lake followed by permafrost encapsulation as a control strategy for acid mine drainage.

Regardless of the tailings disposal option chosen, the northwest arm of Second Portage Lake will necessarily be dewatered to allow mining of the Portage Deposit, and to ensure structural integrity during construction and operation of the East Dike.

A case study of the oxidation of mine tailings from Ranking Inlet, Nunavut, at sub-zero temperatures was 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 preferred option for tailings management at the Meadowbank project. A series of thermistors installed in the 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 highly 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 -6ºC. The Meadowbank Project site has a mean annual air temperature of about -11.3ºC and mean annual ground temperature of -8ºC to -10ºC Based on long-term temperature trends at Baker Lake, applied to the Meadowbank Project site, a mean annual air temperature of -12.8ºC is indicated. 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 the preferred method of disposal of tailings at the Meadowbank Project.

8.0 CLOSURE

We trust that this report meets your requirements at this time. If you have any additional questions, please do not hesitate to contact the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.

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Principal

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Associate, Mining Group

CJC/kt/lba/lw
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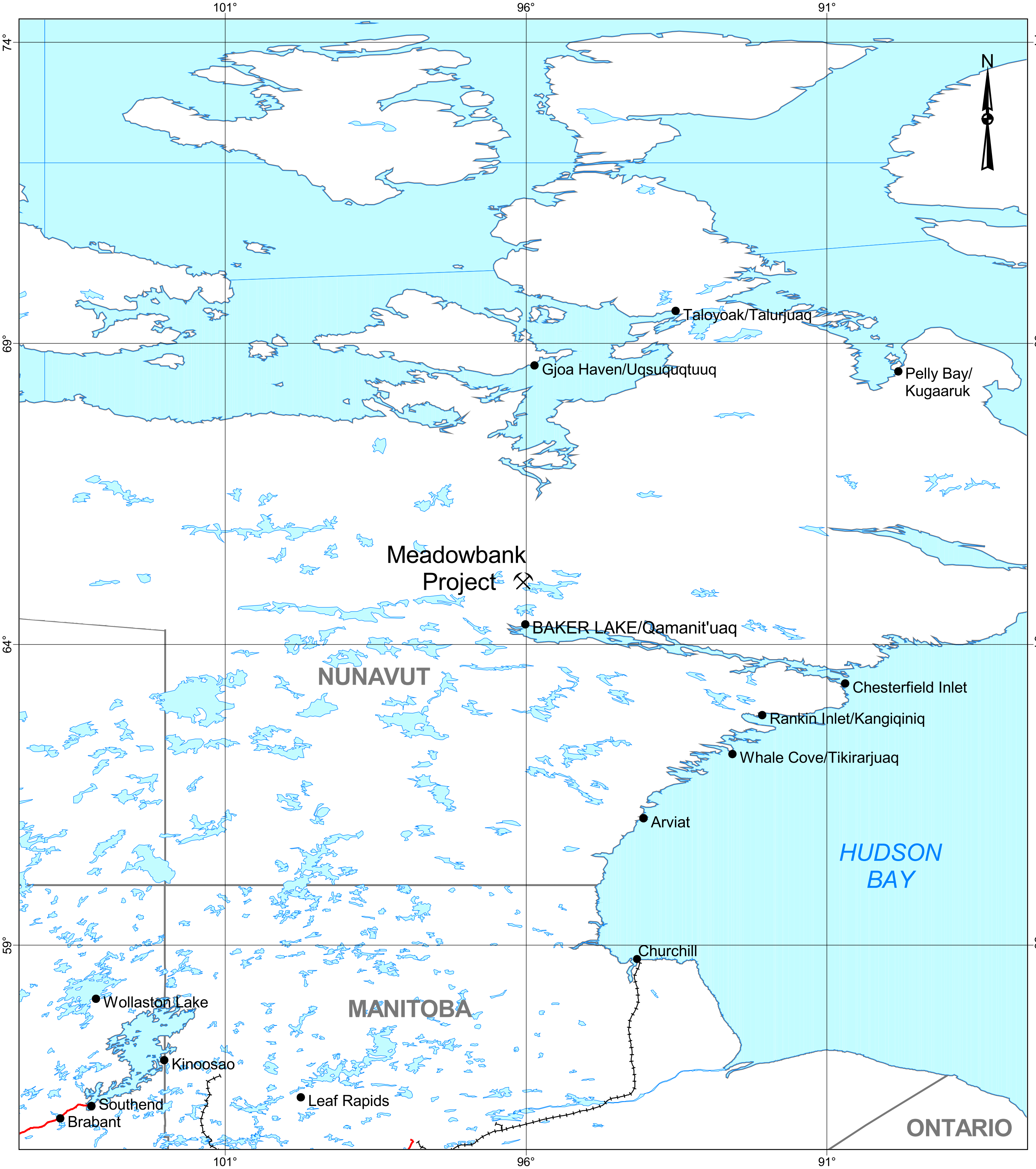

LEGEND

- Meadowbank Project
- Town/Village
- Provincial Border
- Water
- Primary Highway
- Railroad

200 0 200 Kilometers

Scale - 1:10,000,000

REFERENCE

Base digital data obtained from ESRI Inc.,
DATUM: WGS84 PROJECTION: Geographic

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

LOCATION PLAN
MEADOWBANK PROJECT

Golder Associates

PROJECT No. 06-1413-089			SCALE AS SHOWN	REV. 0
DESIGN	CJC	01 Feb. 2007	FIGURE 1	
GIS	CDB	01 Feb. 2007		
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REVIEW				

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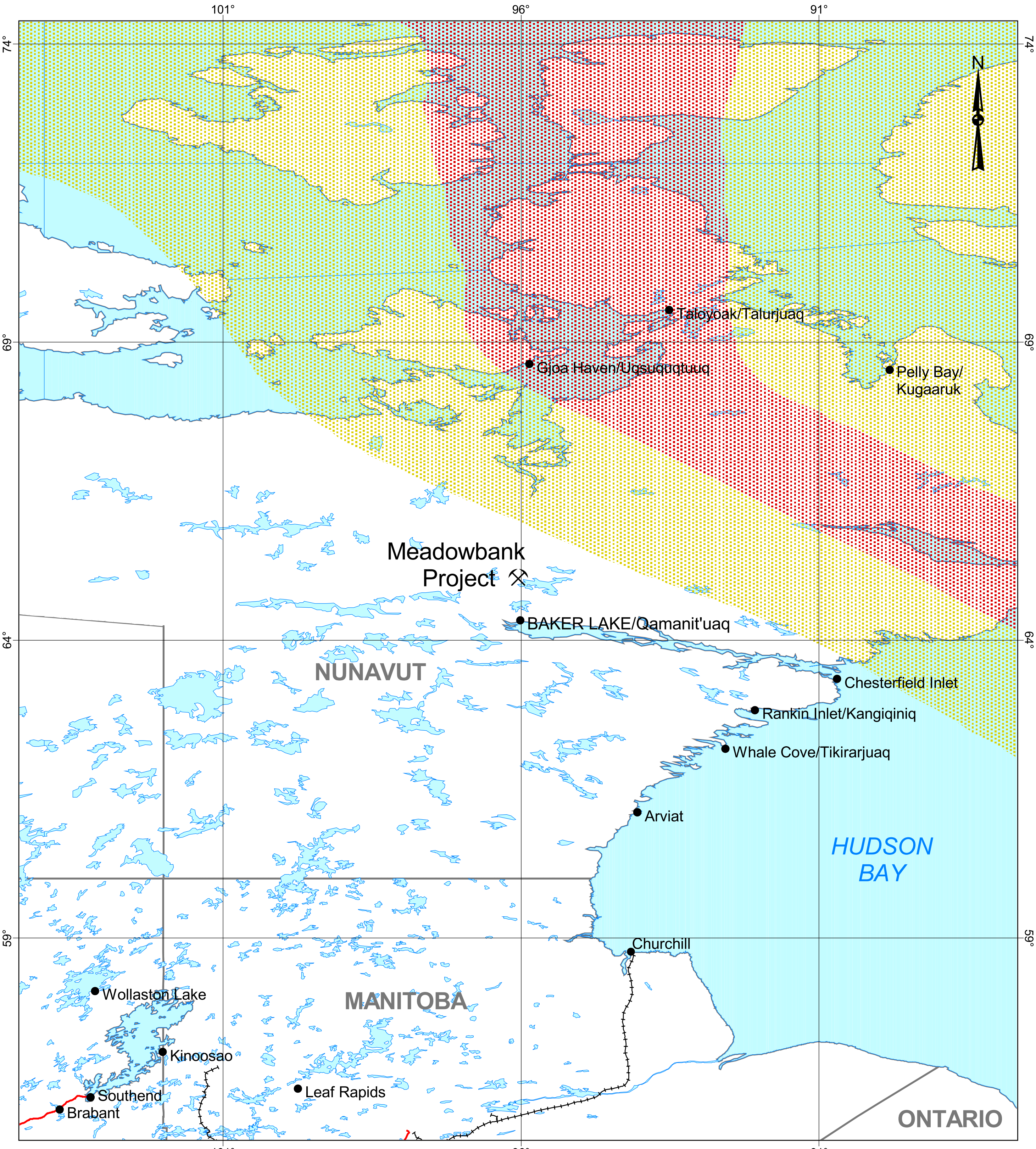

LEGEND

- Meadowbank Project
- Town/Village

Peak Horizontal Ground Acceleration (g), for 10% probability of exceedance in 50 Year Event

- 0 - 0.039
- 0.04 - 0.079
- 0.08 - 0.109
- Provincial Border
- Water
- Primary Highway
- Railroad

200 0 200 Kilometers

Scale - 1:10,000,000

REFERENCE

Base digital data obtained from ESRI Inc.,
DATUM: WGS84 PROJECTION: Geographic

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

SEISMIC ZONING MAP
MEADOWBANK PROJECT

PROJECT No. 06-1413-089			SCALE AS SHOWN	REV. 0
DESIGN	CJC	01 Feb. 2007	FIGURE 2	
GIS	CDB	01 Feb. 2007		
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Golder Associates

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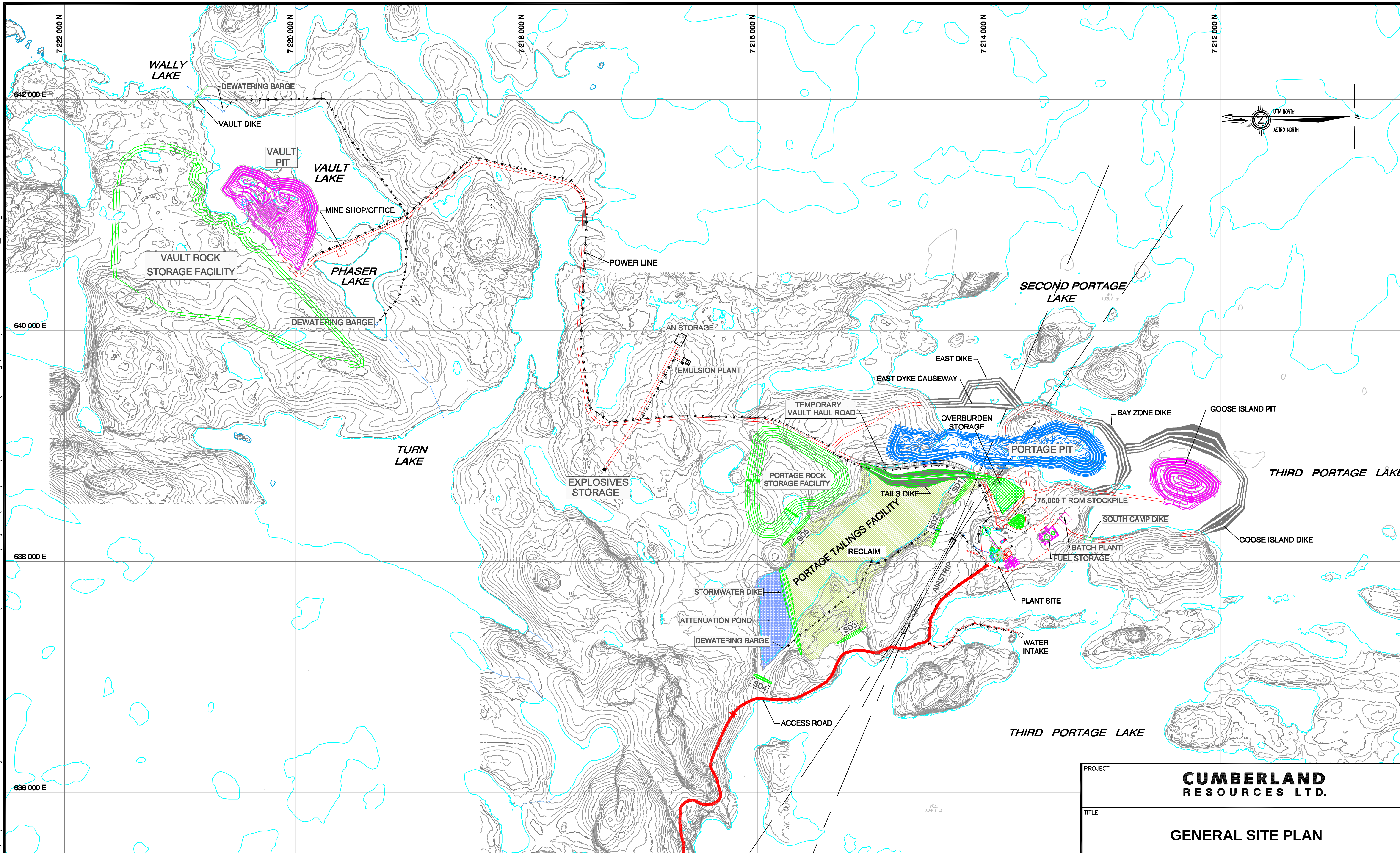

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1) Drawing taken from AMEC, Drawing # A1-131395-100-C-0001.

LEGEND

SD: SADDLE DAM

PROJECT	CUMBERLAND RESOURCES LTD.
TITLE	GENERAL SITE PLAN

Golder Associates

PROJECT No.	06-1413-089	FILE No.	1050-FIG_3
DESIGN	CJC	01FEB07	SCALE AS SHOWN REV. –
CADD	WLI/AS	01FEB07	
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REVIEW			

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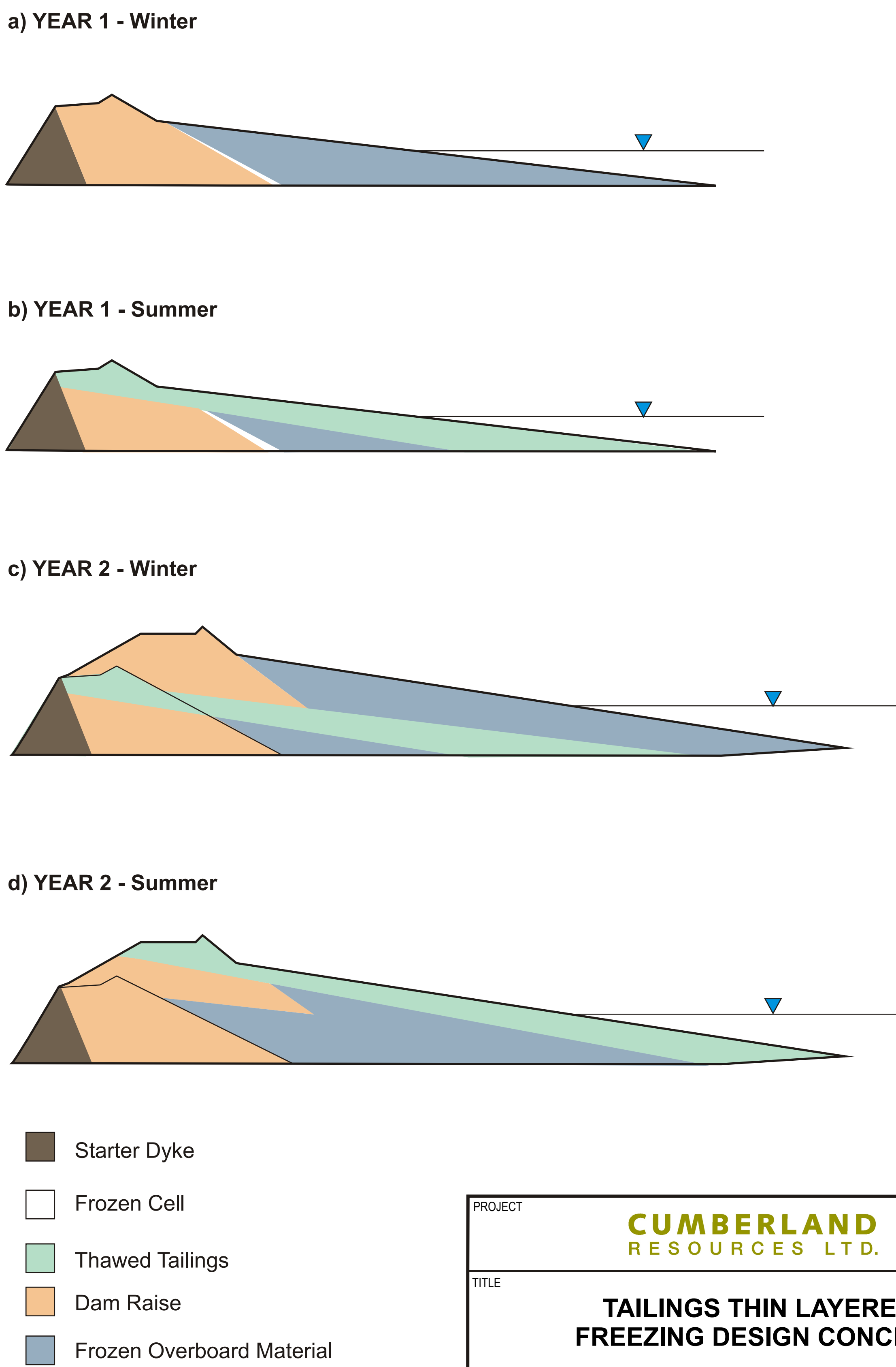

Reference: MEND 1.61.2, 1996

PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

TAILINGS THIN LAYERED FREEZING DESIGN CONCEPT

Golder Associates

PROJECT No.	06-1413-089		FILE No.	FIGURE 2
DESIGN	CC	01FEB07	SCALE NTS	REV.
CADD	SS/AS	01FEB07		
CHECK			**FIGURE 4**	
REVIEW				

DRAWING DATE: 01-Feb-07 COREL FILE: N:\Bur-Graphics\Projects\2006\1413\06-1413-089\Drafting\8500\Figure 2.cdr

REFERENCES

1) AMEC AMERICAS LTD., Drawing # A1-131395-100-C-0001 (100-C-0001.DWG), Meadowbank Feasibility Study, April 2005

0 200 400 600 800 1000

Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

TAILINGS STORAGE OPTIONS

Golder Associates

PROJECT No.	06-1413-089		FILE No. 1050-FIG_4
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CADD	NV/AS	01FEB07	
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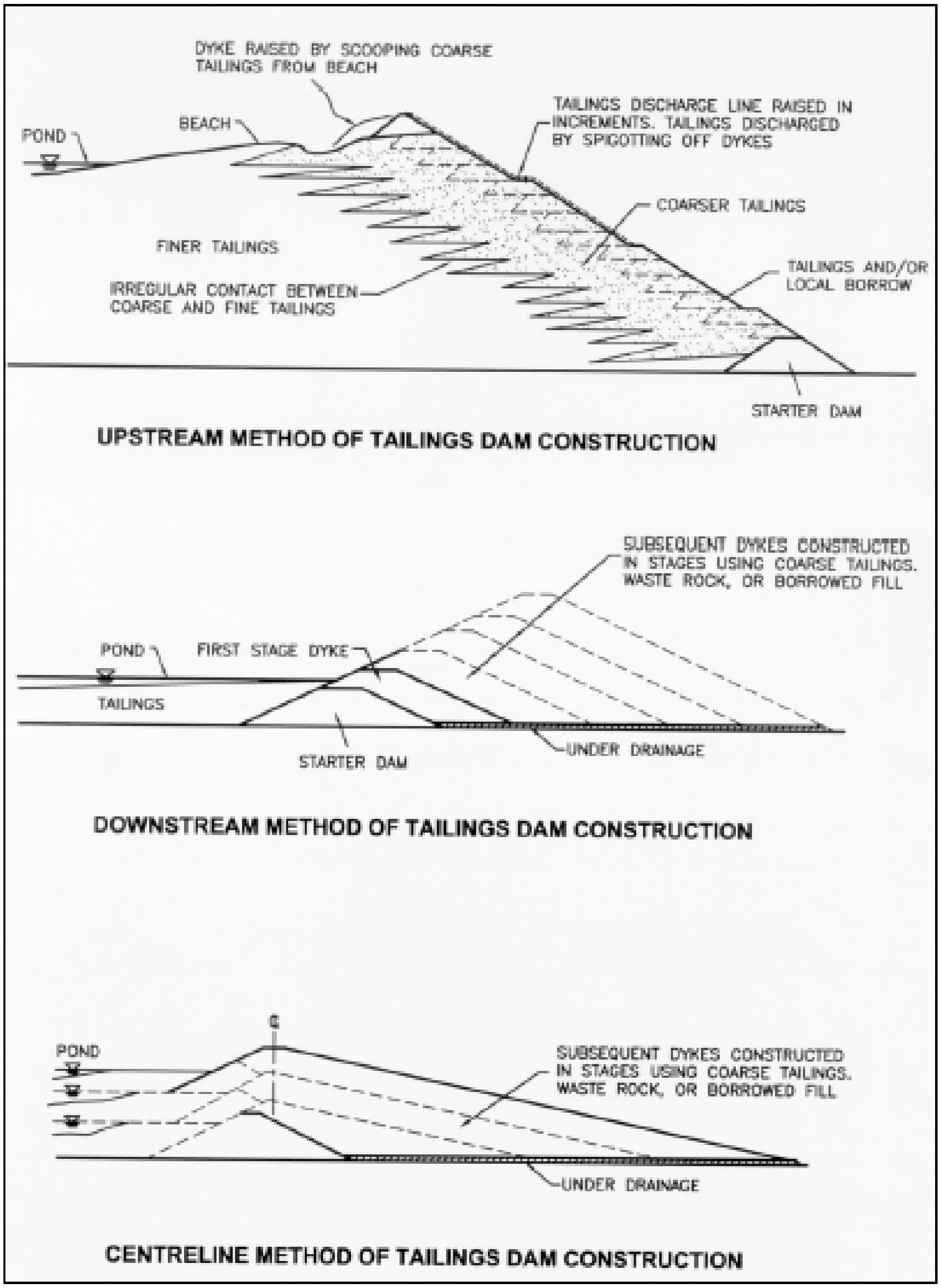
REVIEW			



Source: Martin, 2002.

PROJECT	CUMBERLAND RESOURCES LTD.			
TITLE	TAILING DAM CONSTRUCTION METHODS			
Golder Associates	PROJECT No. 06-1413-089			FILE No. FIGURES 4
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	CADD	VEE	01FEB07	FIGURE 6
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	REVIEW			

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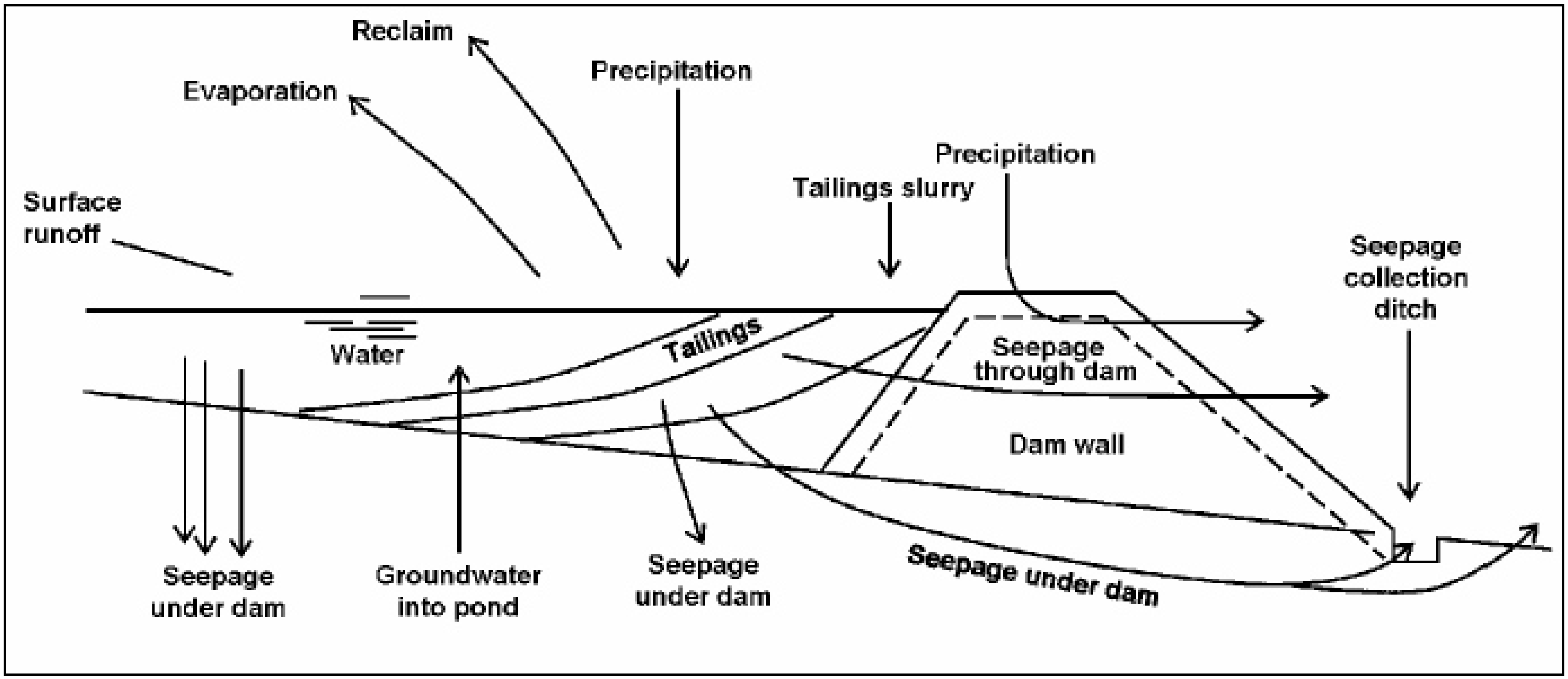

Source: European Commission, 2003.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

TAILINGS DAM AND WATER CYCLE

Golder Associates

PROJECT No.	06-1413-089		FILE No.	FIGURES 3
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REVIEW				

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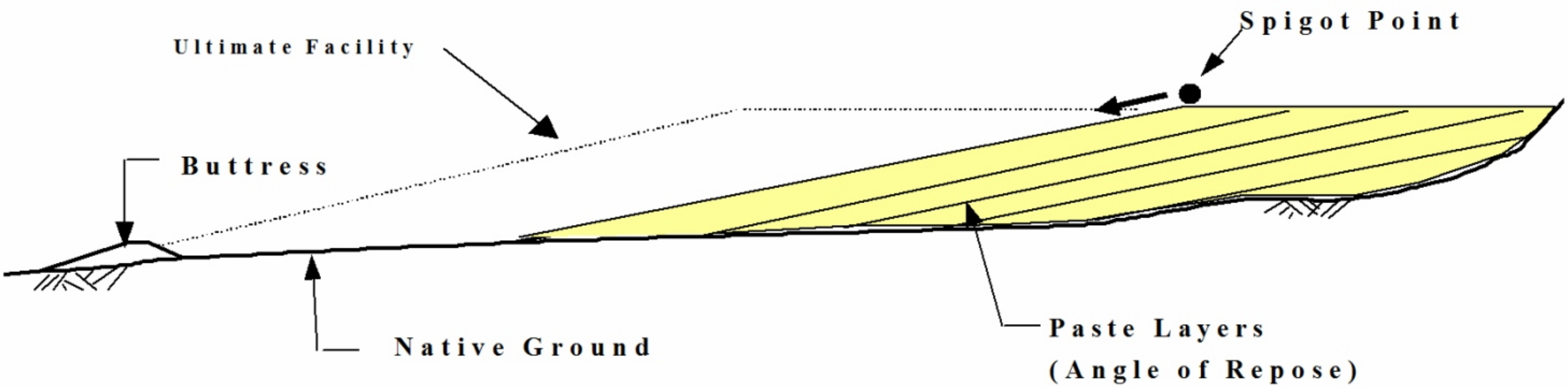

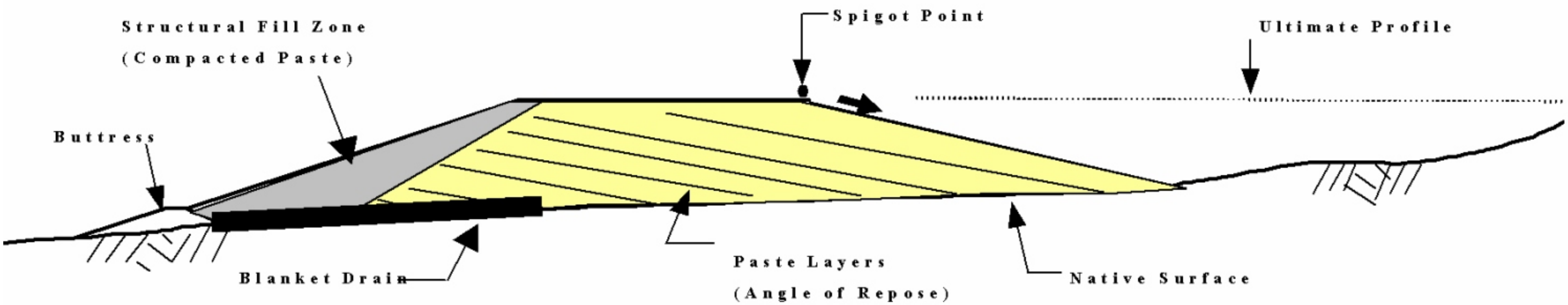

Source: European Commission, 2002.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

ABOVE GROUND PASTE TAILINGS DEPOSITION METHODS

Golder Associates

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CADD	VEE/AS	01FEB07	FIGURE 8	
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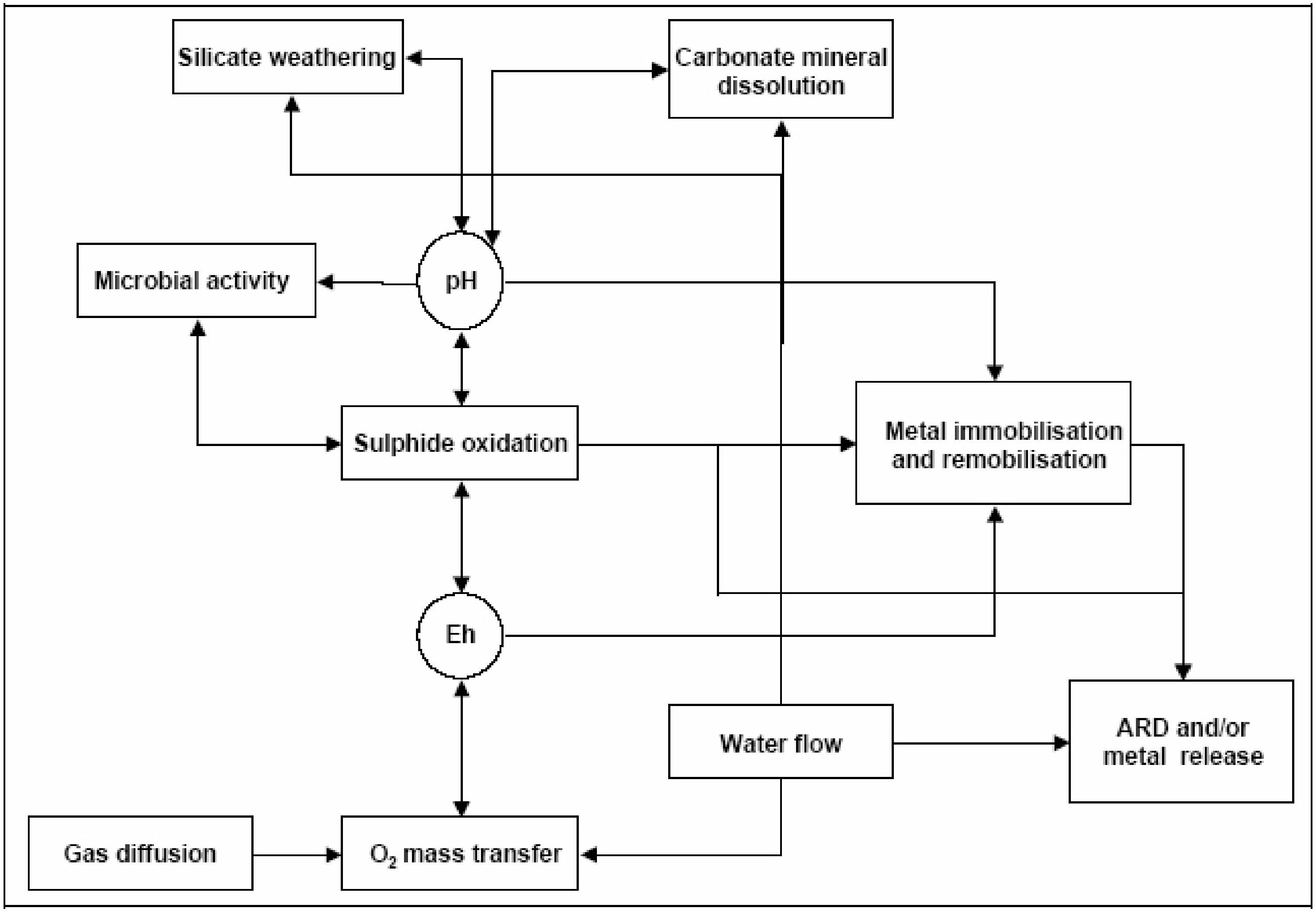

Source: European Commission, 2002.

PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
GEOCHEMICAL AND PHYSICAL PROCESSES POTENTIALLY RESULTING IN ARD AND ML

Golder Associates

PROJECT No. 06-1413-089			FILE No. FIGURES 3	
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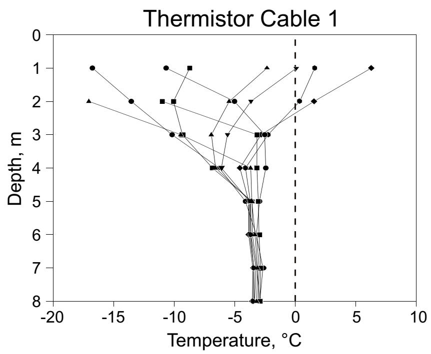
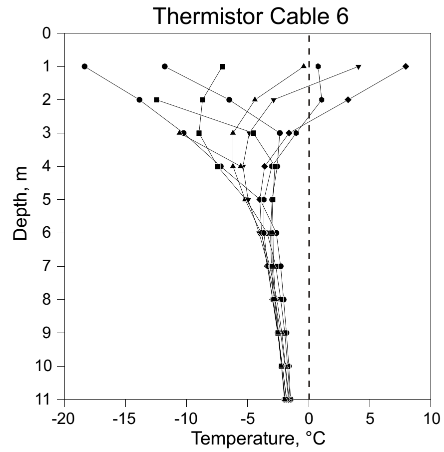
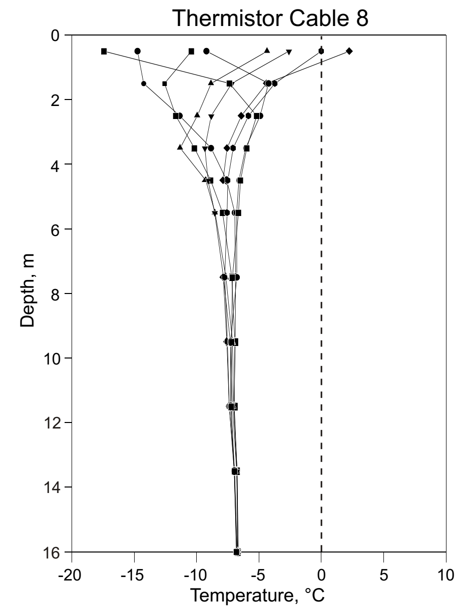
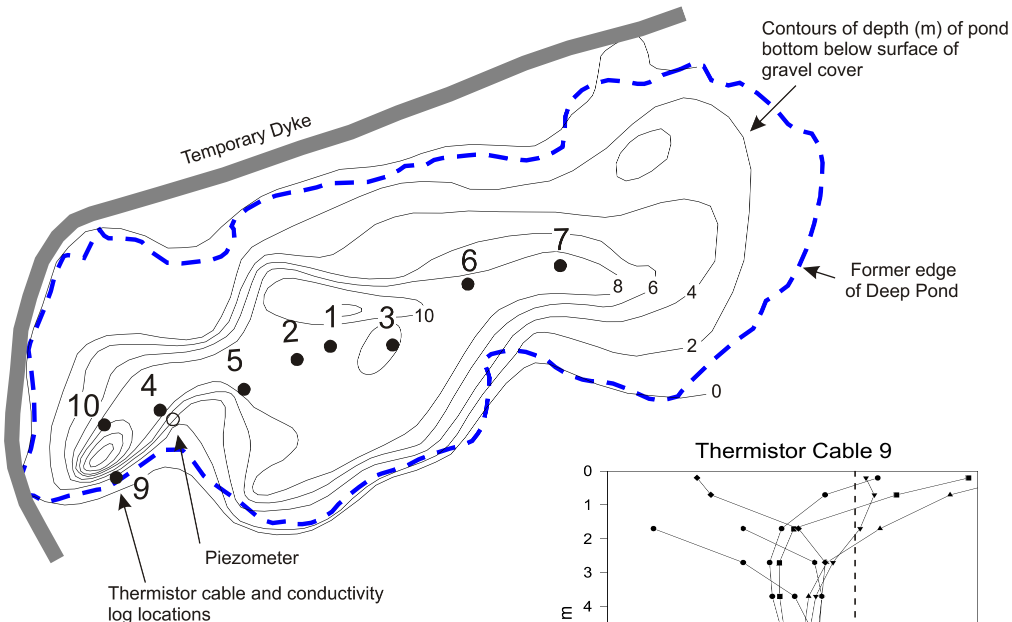
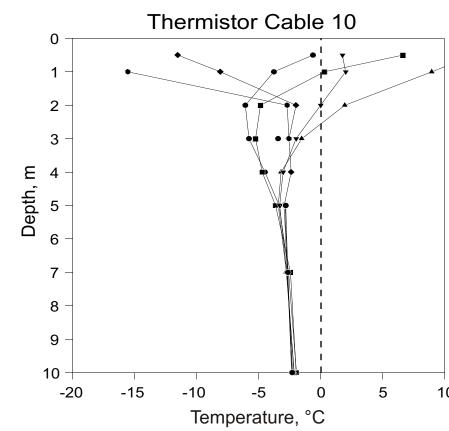
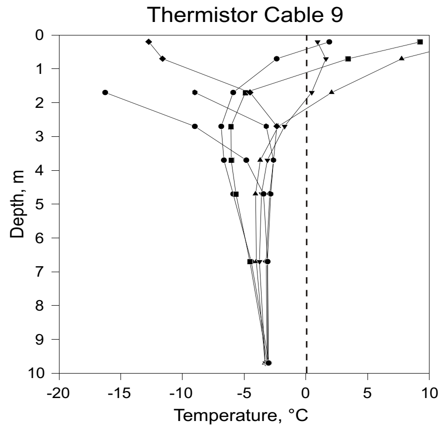












Map of Deep Pond showing borehole locations and depth of bottom below surface of gravel cover (2 m contour interval). Insets show ground temperature records between March 29, 1997 and Feb. 4, 1998

Reference: Oxidation of Mine Tailings from Rankin Inlet, Nunavut, at Subzero Temperatures. Meldrum, et.al., 2001.

PROJECT

CUMBERLAND RESOURCES LTD.

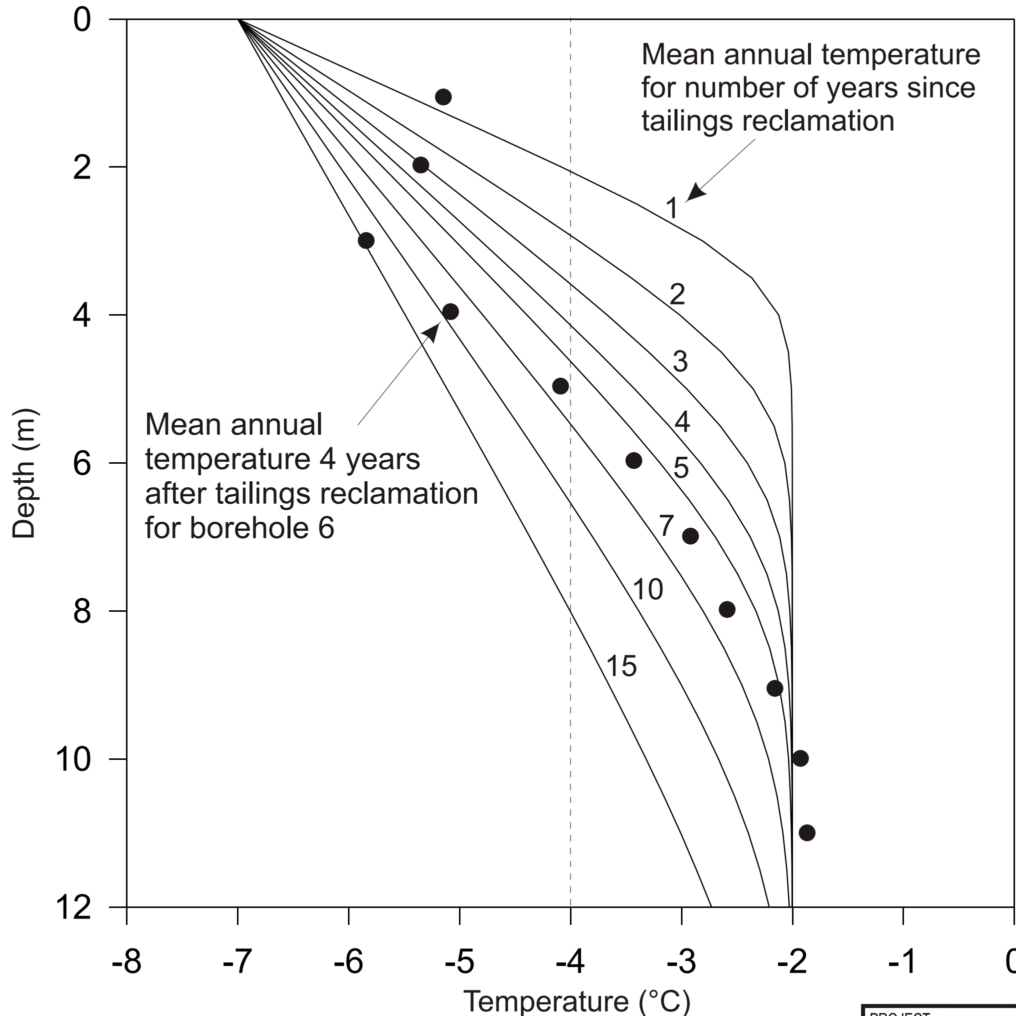
TITLE

RANKIN INLET TAILINGS STUDY
THERMAL MONITORING

Golder Associates

PROJECT No.	06-1413-089		FILE No. FIGURES 2	
DESIGN	CC	01FEB07	SCALE NTS	REV.
CADD	SS/AS	01FEB07	FIGURE 10	
CHECK				
REVIEW				

DRAWING DATE: 01-Feb-07 COREL FILE: N:\Bur-Graphics\Projects\2006\1413\06-1413-089\Drafting\8500\Figures 2.cdr



Prediction of mean annual ground temperature in reclaimed tailings for a range of time intervals after burial in late 1993. Dashed line at -4°C shows temperature at which tailings become noticeably ice-bonded. Dots show mean annual ground temperatures for borehole 6, 4 years after burial. Temperature reversal for uppermost 2 m is due to annual variation of thermal properties in the active layer.

Reference: Oxidation of Mine Tailings from Rankin Inlet, Nunavut, at Subzero Temperatures.
Meldrum, et.al., 2001.

PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

RANKIN INLET TAILINGS STUDY
PREDICTED FREEZE-BACK TIME

Golder Associates

PROJECT No.	06-1413-089		FILE No. FIGURES 2	
DESIGN	CC	01FEB07	SCALE NTS	REV.
CADD	SS/AS	01FEB07	**FIGURE 11**	
CHECK				
REVIEW				