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:

Permanent Aquatic Habitat Loss

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

Cameron J. Clayton, M.Eng., P.Geo.
Associate, Mining Group

CJC/kt/lba/lw
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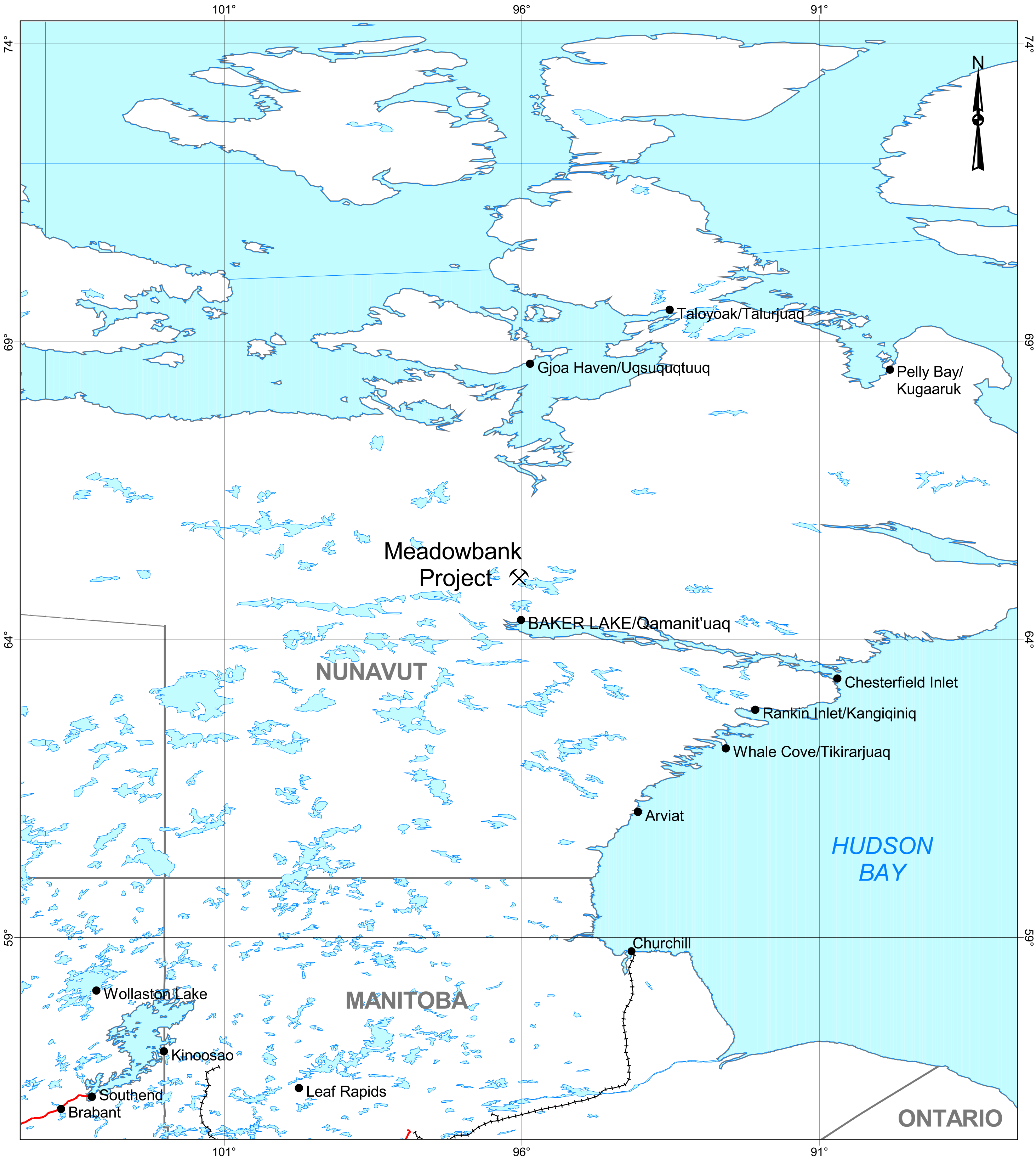

LEGEND

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

200 0 200 Kilometers

Scale - 1:10,000,000

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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REFERENCE

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

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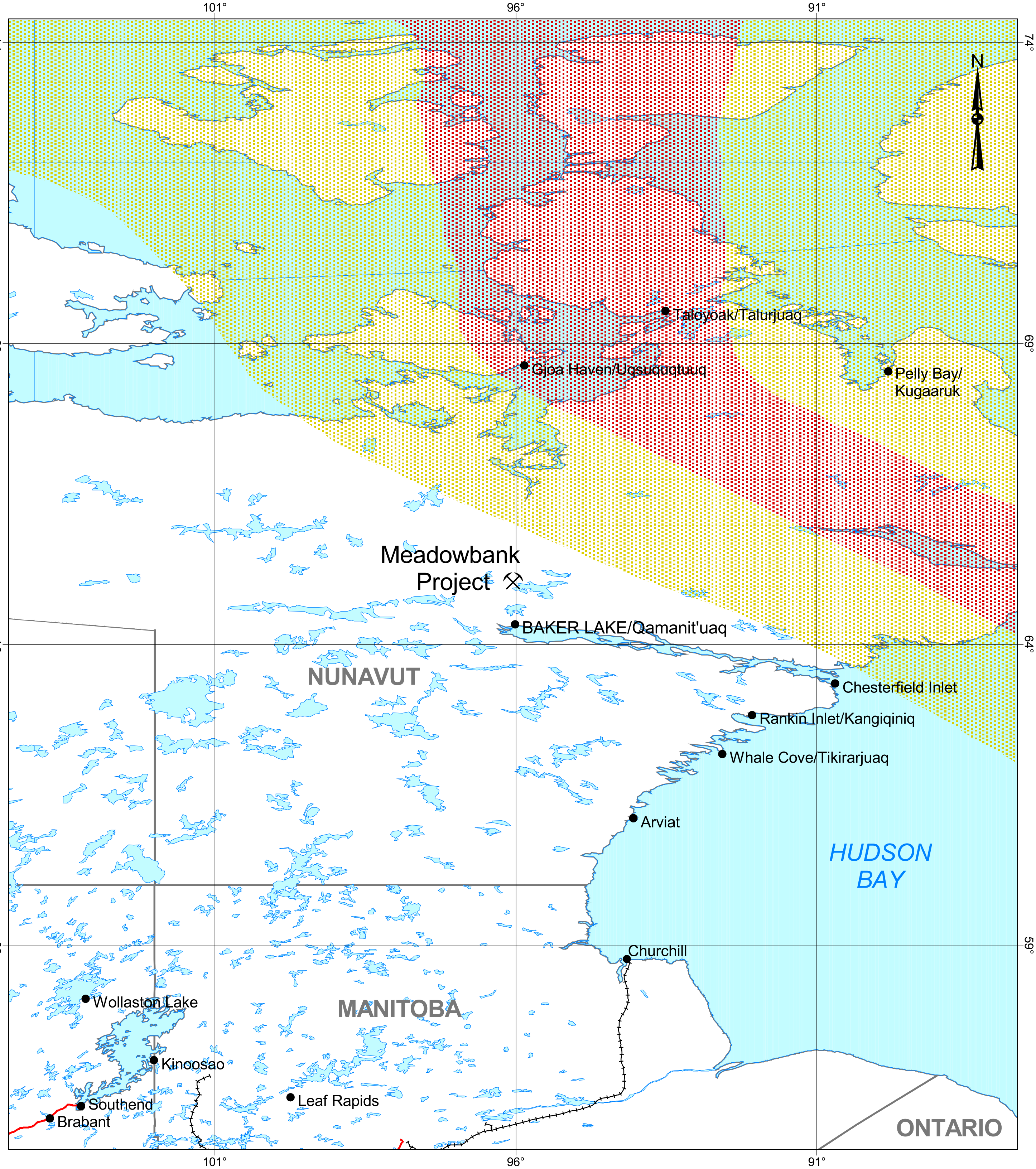

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LEGEND

- 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

Golder Associates

PROJECT No. 06-1413-089			SCALE AS SHOWN	REV. 0
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GIS	CDB	01 Feb. 2007		
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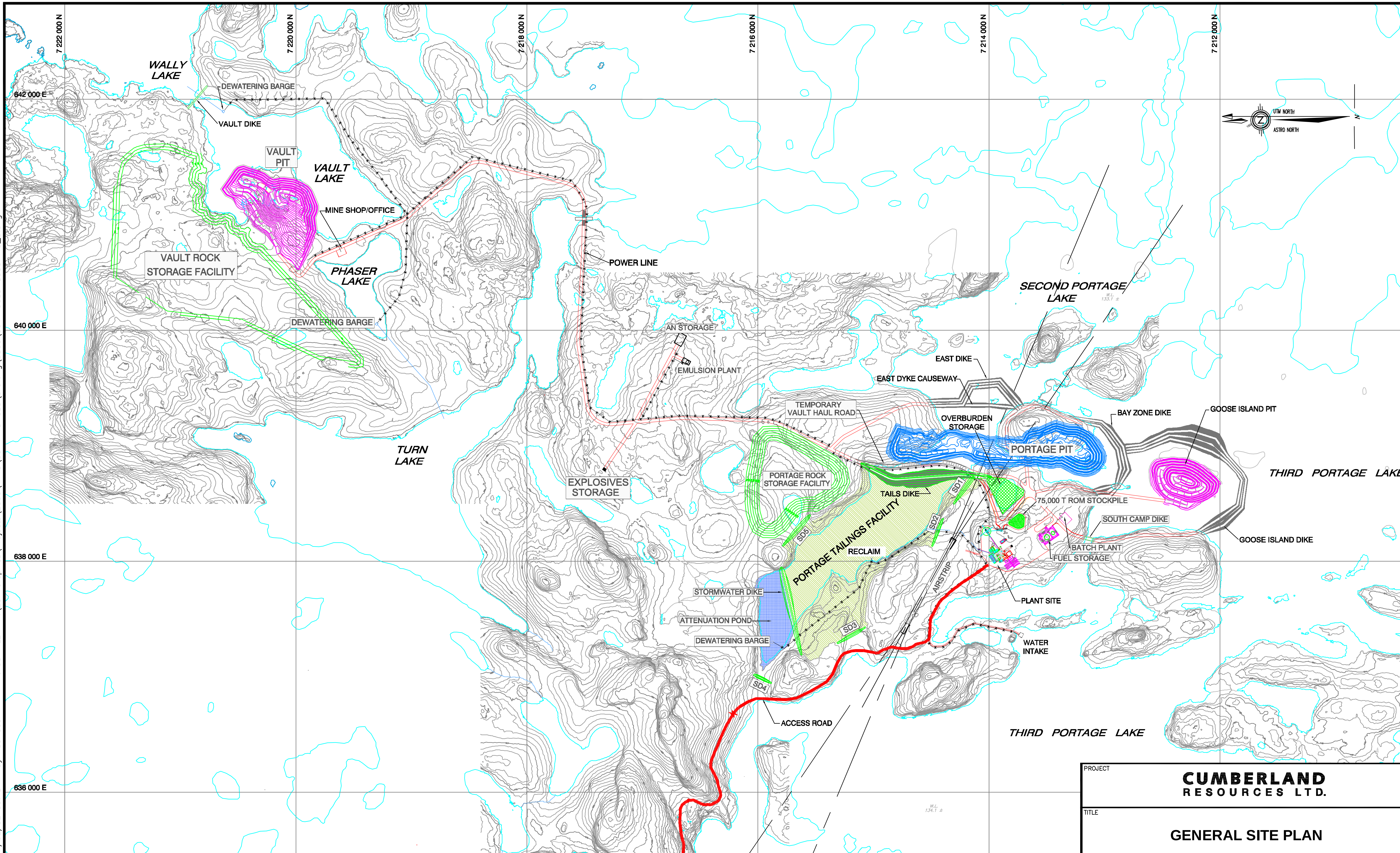

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REFERENCES

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
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CADD	WLI/AS	01FEB07	
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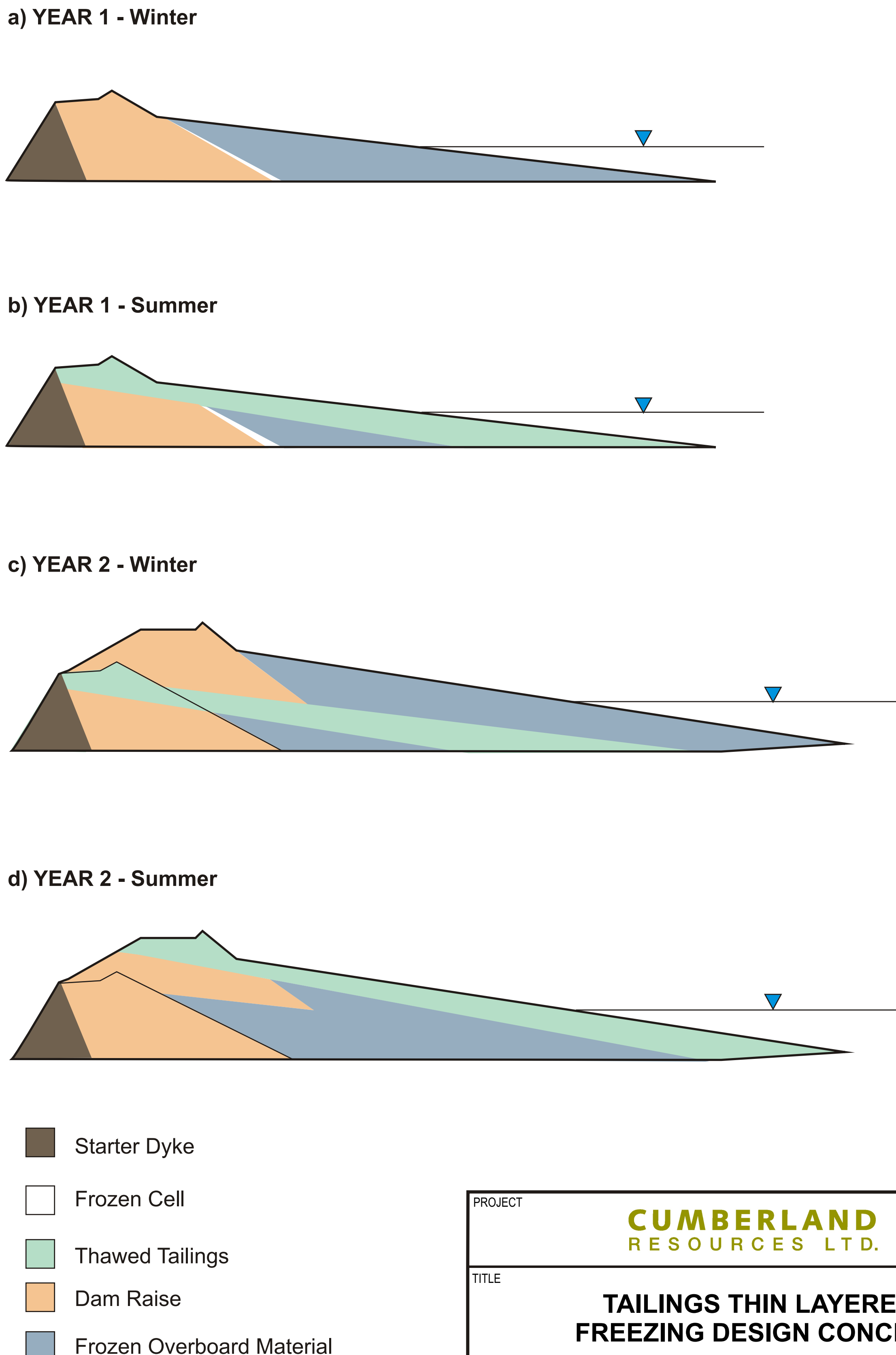
REVIEW			



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PROJECT	CUMBERLAND RESOURCES LTD.
TITLE	TAILINGS THIN LAYERED FREEZING DESIGN CONCEPT

Golder Associates

PROJECT No.	06-1413-089		FILE No. FIGURE 2	
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REFERENCES

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PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

TAILINGS STORAGE OPTIONS

Golder Associates

PROJECT No.		06-1413-089	FILE No.	1050-FIG_4
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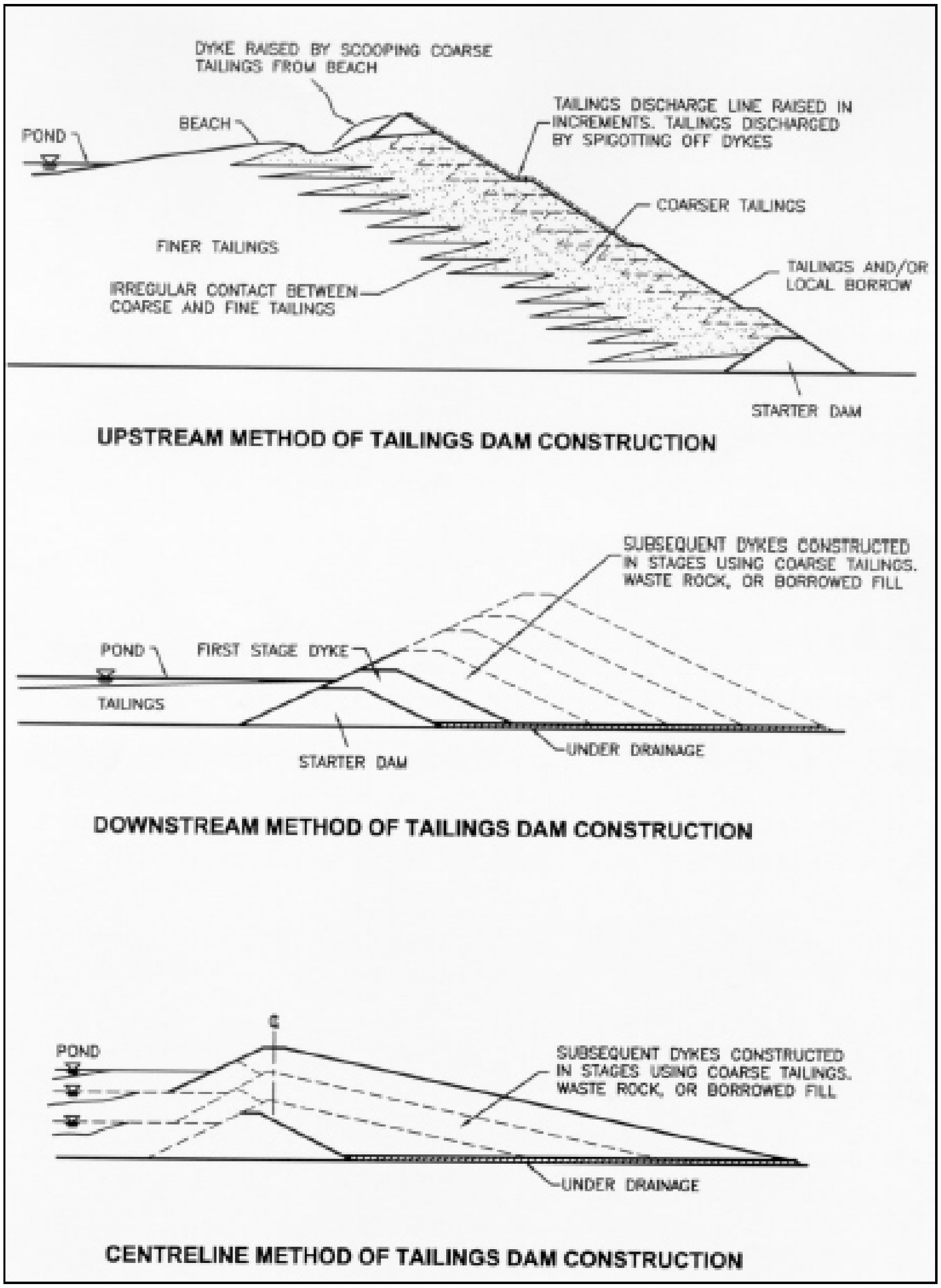
REVIEW				



Source: Martin, 2002.

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	CADD	VEE	01FEB07	FIGURE 6
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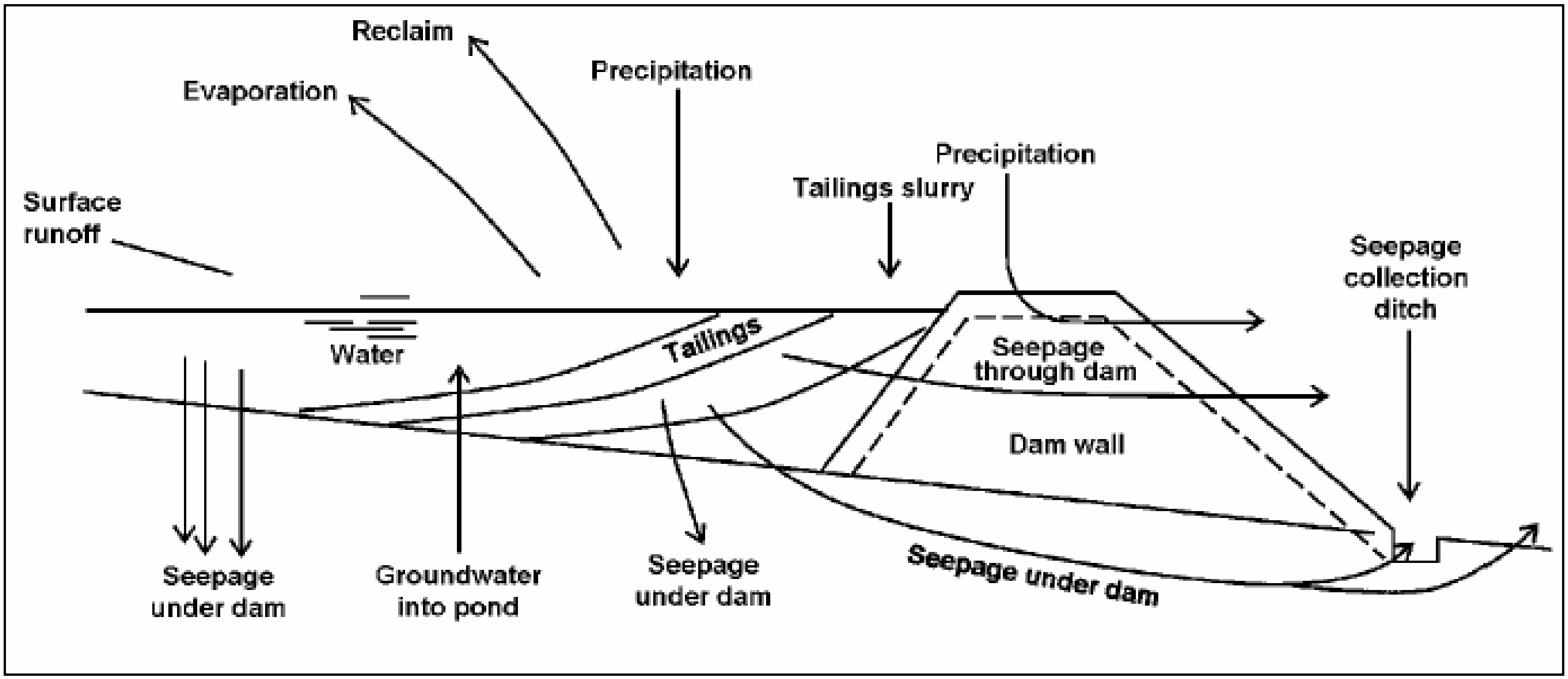

Source: European Commission, 2003.

PROJECT CUMBERLAND RESOURCES LTD.

TITLE

TAILINGS DAM AND WATER CYCLE

Golder Associates

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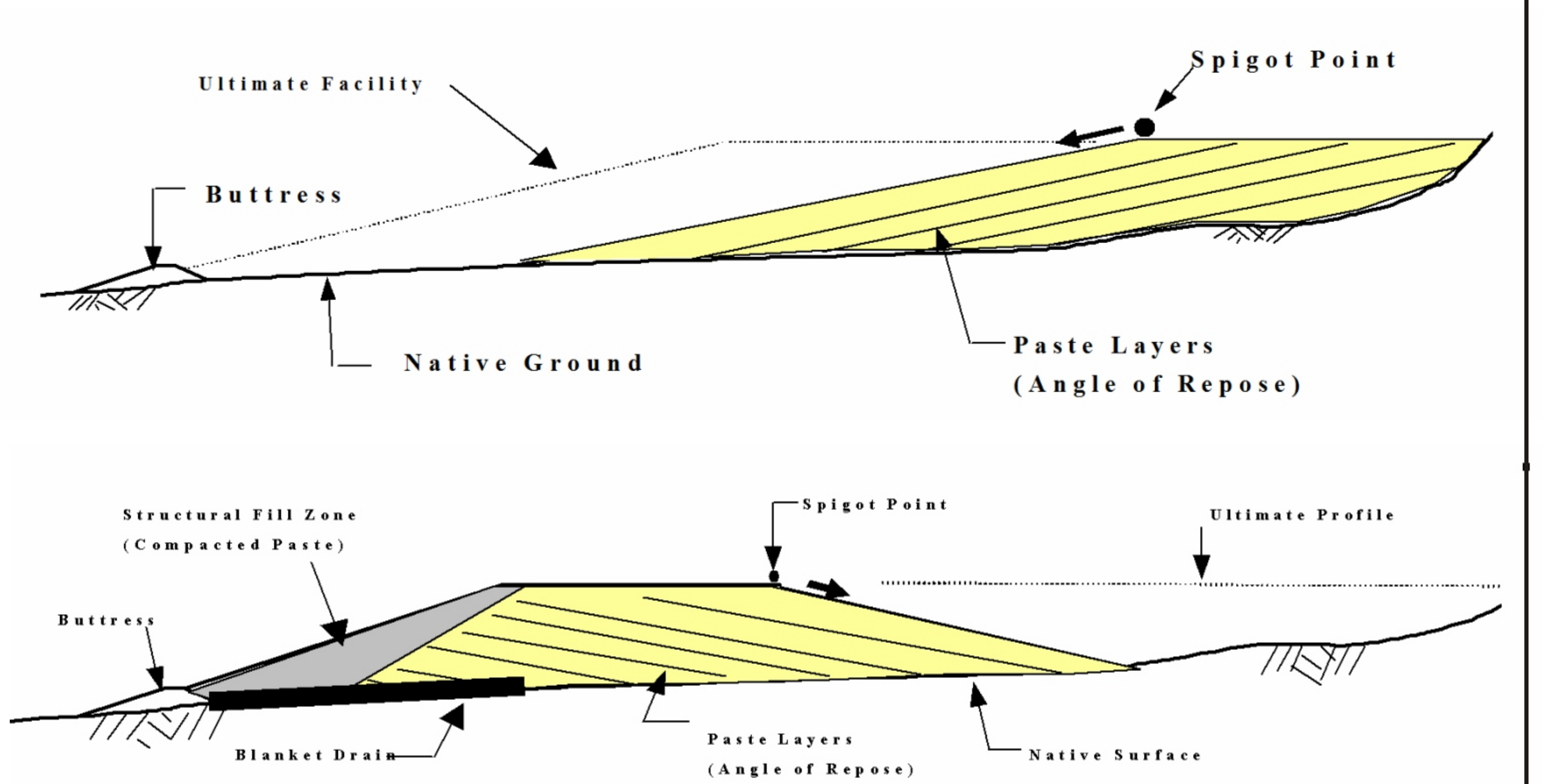

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PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

ABOVE GROUND PASTE TAILINGS DEPOSITION METHODS

Golder Associates

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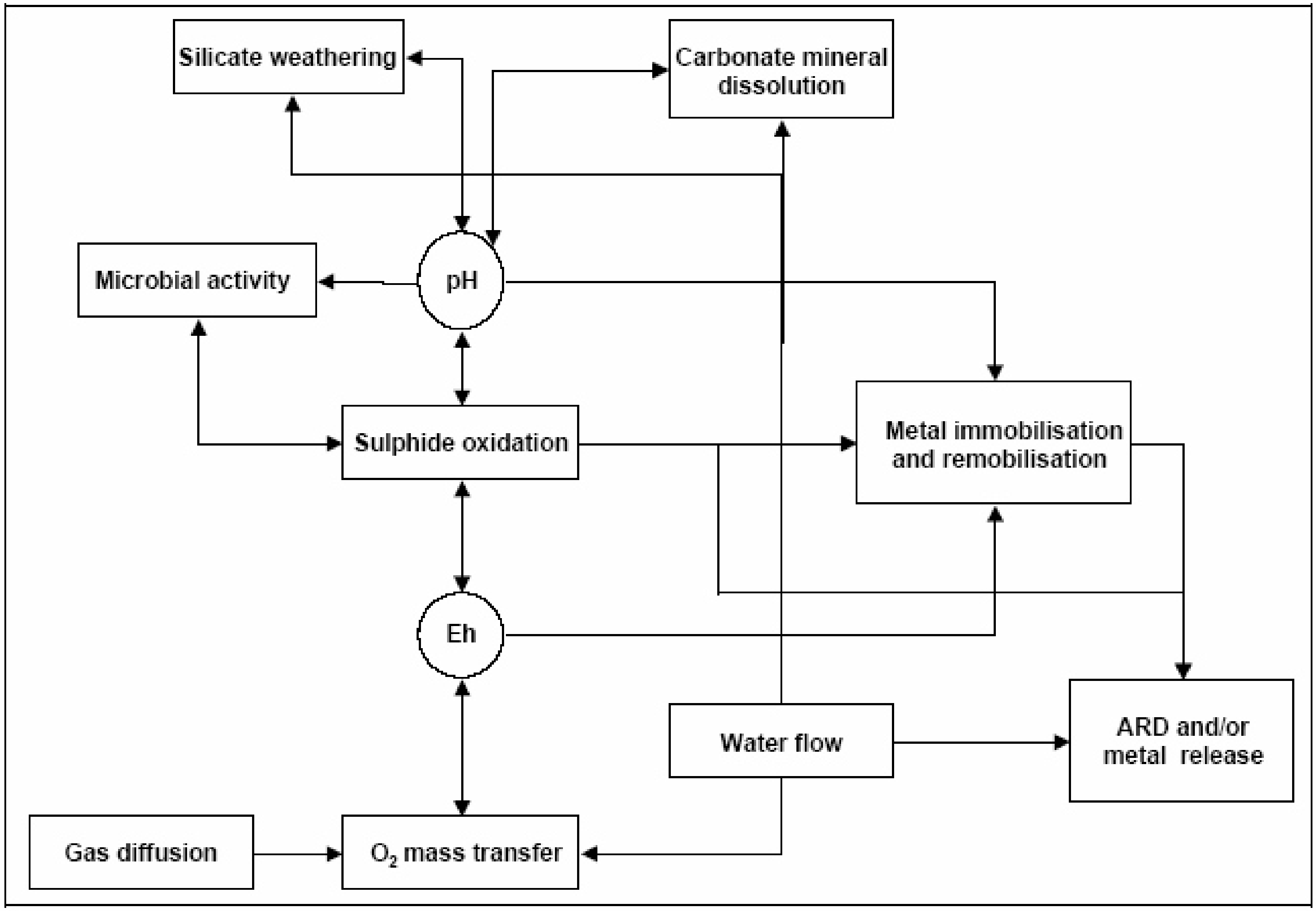

Source: European Commission, 2002.

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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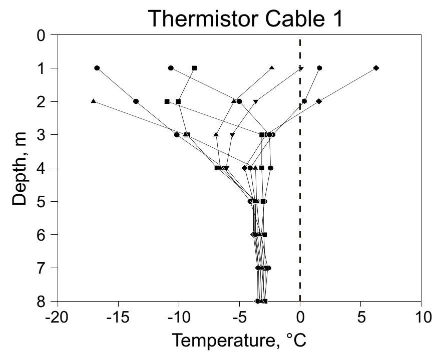
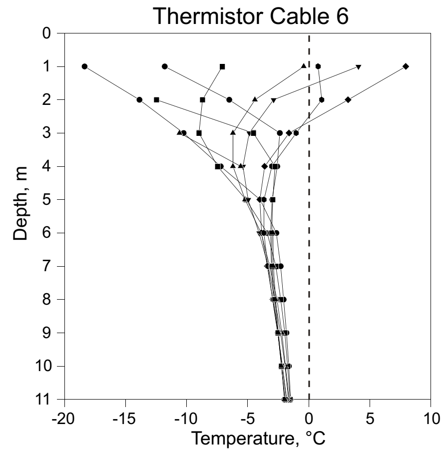
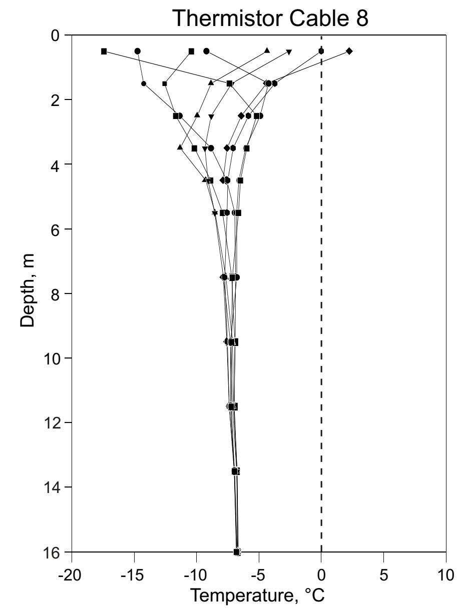
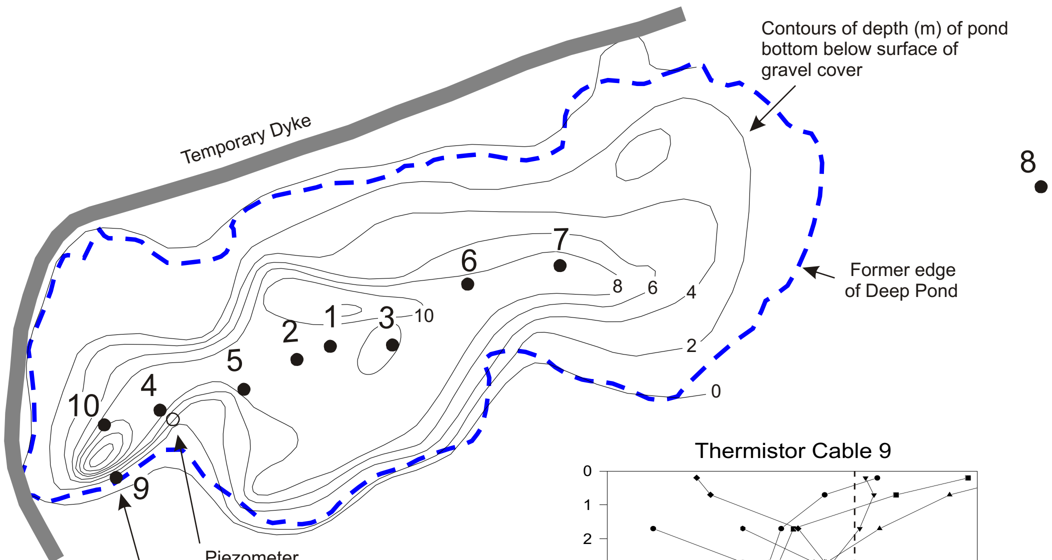
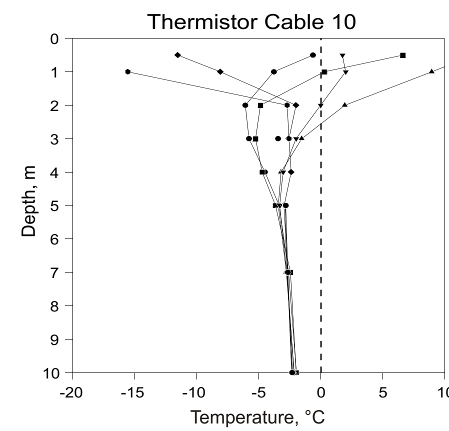
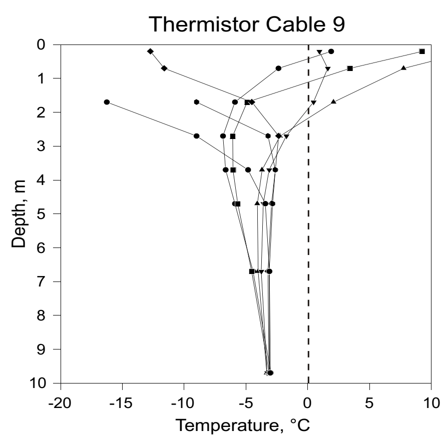












Map of Deep Pond showing borehole locations and depth of bottom below surface of gravel cover (2 m contour interval). Insets show ground temperature records between March 29, 1997 and Feb. 4, 1998

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

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

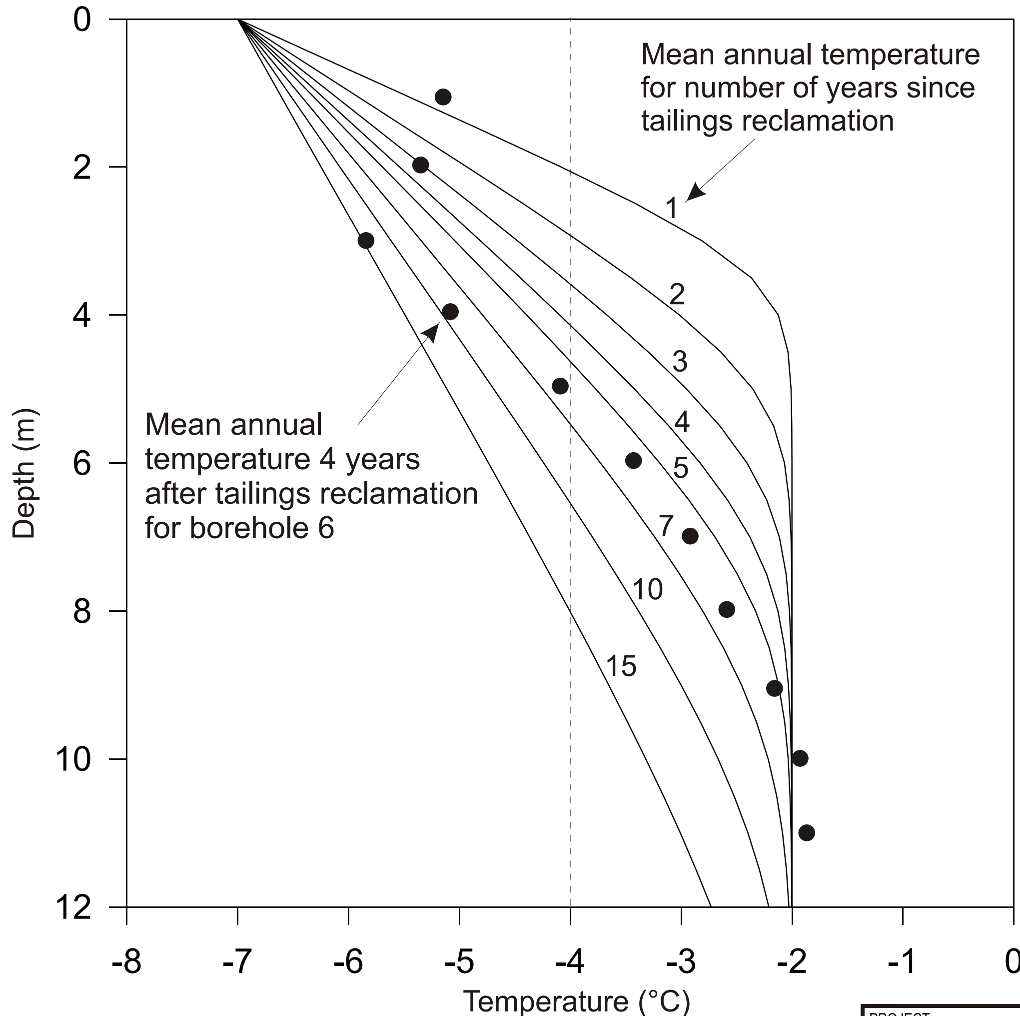
RANKIN INLET TAILINGS STUDY
THERMAL MONITORING

Golder Associates

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

FIGURE 10

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				